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BROOKHAVEN NATIONAL LABORATORY
Operated by
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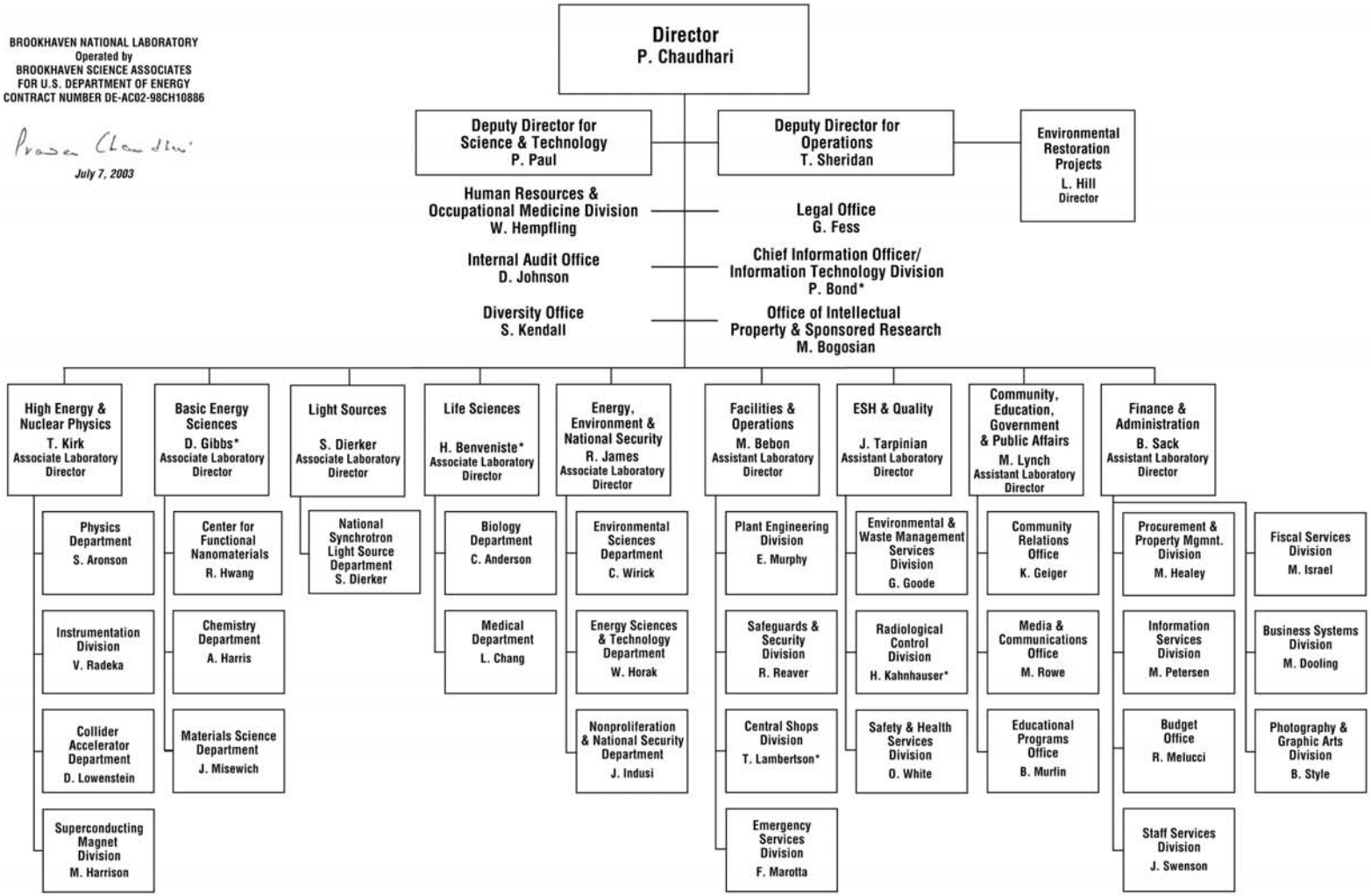
BROOKHAVEN NATIONAL LABORATORY
Departments, Divisions and Offices



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1.0 Director's Message

It has been only a few months since I joined the Brookhaven National Laboratory. In this short period, I am impressed by the quality of our scientists and our operations staff. There is breadth and depth of scientific activity at the laboratory. We have a history of running facilities very well. Given this positive background, it is my goal to enhance the scientific, technological, and operations of the Laboratory such that the Brookhaven National Laboratory becomes known as the best science laboratory in the world.

For an institution to flourish in science, it requires outstanding scientists and an environment that generates ideas, nurtures creativity, and provides a setting to succeed.

The first and foremost requirement to be the best is to have the best scientific and engineering talent in the world. The proud historical record of excellence and achievements that Brookhaven established over its more than fifty year's history and the five Nobel Prizes that it has garnered provide an excellent basis. We will search for the best and attract them to join our current distinguished staff.

My predecessors have already put much in place. New chairs have been brought into the Laboratory for the Chemistry, Materials Science, and the Nanoscience Departments. Brookhaven's new Goldhaber Fellowship program for outstanding young scientists has now a class of ten. A new center in nanoscience, the Center for Functional Nanomaterials (CFN) is moving to construction. Nanoscience represents not only science of the nanoscale, but a fundamental shift in the philosophy of science based on reductionism to one of synthesis and emergence.

The year 2003 has been one of great successes and rewards for our scientists: Dr. Ray Davis, BNL chemist now retired, received the Nobel Prize in physics for his seminal work on solar neutrinos. That this work was carried out in the Chemistry department of BNL, using techniques from chemistry, nuclear physics and high-energy physics, illuminates one of the defining characteristics of Brookhaven: its great scientific breadth and willingness to undertake interdisciplinary research. Dr. Joanna Fowler, from the Chemistry Department and a leader of BNL's distinguished Imaging Group was elected member of the National Academy of Science.

The relativistic Heavy Ion Collider (RHIC) had its third successful year of data taking. This year was dedicated to colliding deuterons with gold nuclei. This run was vital as a background check for Au on Au collisions done earlier. The latter would produce quark-gluon matter, the former not. On the basis of these data, the RHIC community was able to state publicly that a new form of matter, consisting of a very dense assembly of quarks and gluons, has been discovered. This announcement marks the first major scientific milestone of the RHIC program, and an impressive discovery indeed.

The Laboratory has extensive facility plans that will allow the Laboratory to stay at the cutting edge of its mission to supply the scientists of the nation, the Northeast and the Laboratory with the most advanced experimental instruments. These plans are summarized in the pages following this message

Brookhaven's infrastructure dates back many decades, some to the first and second world wars. This provides not only poor working conditions for our laboratory scientists, but also for the 4,500 users and visitors that come to the lab each year. Just like the research facilities, the research space has to be brought into the 21st century. The coming year starts the construction of the Research Support Center, a 50,000 sqft building. It is my hope that we will be able to build the User Science Center about a year later. Plans for an Energy Science Building, funded by non-government sources are advancing. For our users and visitors we hope to have modern apartments available in the next two years.

In summary, the next five years will be an exciting and rewarding period for Brookhaven, and for science at the Department of Energy. I am happy to be a part of it.

2.0 Laboratory Mission

Brookhaven National Laboratory (http://www.bnl.gov/), a large multidisciplinary research institution on Long Island, New York, is operated by Brookhaven Science Associates (BSA) under contract with the US Department of Energy. With about 2800 employees and an annual budget of more than $460 million, the Laboratory is one of the largest employers in Eastern Long Island. Its 350 buildings occupy about 5,300-acres on the western edge of Suffolk County's environmentally important Pine Barrens.

Since its founding in 1947 by the distinguished research universities of the Northeast, the Laboratory's primary mission has been to pursue scientific research requiring unique, complex, and often large facilities, and to design, construct, and operate those facilities for its scientists and external users. BNL's eleven departments are grouped in five directorates: Nuclear and High-Energy Physics, Basic Energy Sciences, Light Sources, Life Sciences, and Energy/Environment/National Security Two large facilities dominate the research capabilities and the interest of the users: The AGS-RHIC (Relativistic Heavy Ion Collider) complex and the National Synchrotron Light Source. More than 4100 scientists from the US and abroad use our facilities and participate in joint scientific ventures with our staff.

2.1 Compelling Vision

Brookhaven National Laboratory's (BNL) vision is to bring the power of science and technology to bear on compelling questions such as: What is the origin of the universe and what is it made of? What are the natural laws governing physical behavior? How does life arise and interact with its environment? How can we use our understanding to improve our lives, our public health, and advance our national, economic and energy security?

We provide answers through our many-faceted programs. Our scientists and engineers mobilize cross-disciplinary teams and utilize our world-class facilities. As a national institution, we carry out our work in partnership with universities, other national and industrial laboratories and industry, consistent with the overarching mission of the Department of Energy.

BNL creates and operates unique scientific user facilities that provide tools to answer questions ranging from the origin and evolution of the universe to the behavior of complex physical systems and materials. We ask how elementary particles and forces have shaped the cosmos, how they evolved into atoms, molecules and living cells, and how these constituents interact to create the fascinating phenomena we observe around us. Each year, these powerful tools allow BNL scientists with our partners to explore the deepest scientific questions and advance the frontiers of knowledge in the physical, biological, environmental, and medical sciences.

We will address the need for imaging tools with higher spatial resolution capable of visualizing materials at the nanoscale, for creating functional materials formed from nanostructures, for increased computational capabilities, and for providing new methods for non-invasively tracking biological and dynamic processes in the human body in real time. We will explore the interface between the life and physical sciences, both to understand the basic science, and to stimulate new technologies and materials that serve the national interest.

BNL's scientists are dedicated to advancing our knowledge of the fundamental, life-sustaining processes that are imperative for human health and for improving the quality of life. We will develop new technologies and capabilities to characterize, model and predict behaviors of diverse cellular systems with complex infrastructures.

No part of our program is more important than the investigation of current science and technology questions that bear on important societal needs of Americans. These questions range in subject from abstract physics and chemistry issues to the most practical of applications to immediate issues about our national quality of life. They include the nation's need for clean and reliable energy, for the remediation and preservation of our natural environment, and for the development of advanced technologies to improve our national security.

The final element of our vision is to be a responsible neighbor and valued resource to the people of New York and the Northeast, especially those who live with us on Long Island. We will conduct all of our operations in an environmentally friendly manner, offer educational and community outreach, and provide the stimulation of a lively and accessible center for those who wish to learn more about science and technology.

2.2 Goals

To act upon our vision, BNL will continue its historic mission as a world-leading research laboratory by applying our talents and resources to drive forward the cutting edge of the physical, life, and accelerator-based sciences and by contributing strategic program efforts to advance the environmental, energy, and national security missions of the Department of Energy. As a basis for this mission, BNL will recruit and retain a cadre of outstanding scientists and engineers.

The Laboratory will design, build and operate, on its own or in collaboration with others, important new scientific instrumentation and accelerator facilities and will continue to operate these large and complex scientific user facilities to support the research needs of the nation's and the world's academic and industrial scientists.

BNL will actively participate in national activities assuring homeland security, as well as the safety of New York City and its larger region.

The research focus of the Laboratory will be on leading-edge, long-lead time and interdisciplinary topics in nuclear and high energy physics, basic energy sciences, life sciences, environmental sciences, and energy sciences to support the mission of the Department of Energy. In more specific terms, BNL will pursue the following goals:

1. BNL will be the lead laboratory in the world in high-energy nuclear physics.

Brookhaven's Relativistic Heavy Ion Collider (RHIC) will be used to explore the fundamental theory of strong interactions, Quantum Chromodynamics (QCD). The focus for the next five-years will be on the study of deconfined quark-gluon plasma, a form of matter that is believed to have dominated the early universe. RHIC will also explore the quark-gluon phase transition to baryonic matter, during which all of the present nuclear mass was created. RHIC's unique polarized proton beams will elucidate how quarks and gluons interact to produce the spin of nucleons, the building blocks of all matter in the universe.

The RHIC-II luminosity upgrade will allow us to study the roles of five quark species in quark-gluon plasma. Finally, by bringing an energetic electron beam into collision with existing RHIC ion beams, a search for a saturated gluon condensate, the fundamental ground state of strongly interacting matter predicted by QCD, is enabled. BNL will accomplish this frontier research goal via the future eRHIC Project.

2. BNL will be in the top tier group of high-energy physics laboratories, worldwide.

BNL will perform particle physics research at the energy frontier using the D0 detector at the Fermilab Tevatron and the ATLAS detector at CERN's Large Hadron Collider (LHC). BNL will also operate a Tier-1 Computing Center and a Physics Analysis Center for U.S. members of the ATLAS Collaboration. In the next two years, BNL will begin to build and carry out two forefront particle physics experiments, KOPIO and MECO, that test the Standard Model using rare, symmetry-violating processes to mass scales beyond the reach of the LHC. BNL also plans to build and operate a dedicated 10 Teraflops (sustained) QCDOC super computer to perform lattice-gauge theory predictions for important questions in particle and nuclear physics. Over the next decade, BNL will develop a very compelling, long-baseline neutrino physics program based on a high-intensity, few-GeV neutrino beam produced by AGS protons and a mega-ton scale experimental detector located more than 2,000 km from BNL.

3. BNL will lead in the development, construction, operation and scientific use of advanced Synchrotron Radiation facilities.

In the near term BNL will continue to operate the National Synchrotron Light Source (NSLS) Complex as the most widely used user facility in the nation offering X-ray, UV and Infrared radiation beams for research in materials and structural biology. It is BNL's highest priority that by the end of this decade, NSLS will be upgraded to NSLS-II, the world's most intense and brightest third-generation electron storage ring. The upgraded new facility will allow determination of the structure of molecular machines, probe the structure and properties of individual nanometer sized objects, and provide the data that solves the correlated electron problem of magnetic and superconducting materials.

4. BNL will be a leader in the fabrication, characterization and study of multi-functional nanomaterials.

Immediately, BNL will jumpstart operation of the Center for Functional Nanomaterials (CFN) for the fabrication and characterization of nanoparticles and nanoparticle arrays at the atomic scale. To be completed in 2008, the CFN will be a major User Facility for scientists from the Laboratory, universities and industry. Over the next five years, using the CFN as a base, we will grow programs at the interface between the physical and life sciences, and between nanoscience and a variety of energy and environmental related sciences and technologies. Initial emphasis will be on the basic science of nanocatalysis, electronic materials and advanced electron microscopy.

5. BNL will be a leader in the synthesis and characterization of materials for studying fundamental phenomena and applications.

The Laboratory will grow new materials with controlled microstructures to investigate the electronic, optical, magnetic, and time-dependent properties of thin films, interfaces, and bulk materials, including nano- and bio-materials, and organic/inorganic hybrids. BNL will develop the needed synthesis and fabrication capabilities and use its large array of advanced instrumentation in x-ray scattering (NSLS at BNL), neutron scattering (HYSPEC to be built at SNS), UV and IR spectroscopy (NSLS and DUV-FEL at BNL), and electron microscopy (CFN at BNL) for the pursuit of this program.

6. BNL will expand its PET and MRI imaging research programs and advance human neuroscience by adding new directions and imaging instrumentation for a world-leading imaging laboratory in the study of psychiatric disorders of major public importance.

Our overarching vision in the imaging programs is (1) to develop new radiotracers and imaging instruments to rapidly advance our knowledge of how brain function and behavior are shaped by gender, genetics, age, environment, drugs and disease and (2) to apply these tools to diseases which have a major impact on society including addictive disorders, obesity and violence. The program will provide rich data input to build and rapidly grow computational neuroscience at Brookhaven. Over the next 3 to 5 years BNL will have developed the technology for imaging the brains of awake animals. The MR instrumentation will be expanded with a 9.4Tesla animal MRI and a 7T whole-body human system. A totally new initiative directed at society's growing obesity epidemic will be to develop high-field MR instruments to accommodate morbidly obese human subjects both for cognitive imaging research and to fill a growing need in hospital settings. Lastly, to advance the original vision of the Atomic Energy Commission set out 5 decades ago, Brookhaven will build and operate a novel 70-MeV high-current cyclotron as a national facility dedicated to medical radiopharmaceutical research and development and to the training of the next generation of radioisotope scientists and technicians.

7. BNL will develop new scientific tools to advance the national Genome-to-Life program of the DOE focusing on understanding microbial communities.

BNL will be a strong partner in the national Genome-to-Life program of the DOE through development of innovative DNA and RNA expression, protein purification and characterization processes for high-throughput facilities to identify and characterize microbial proteins. The scientific focus will be on understanding the changing impact of the environment on complex microbial communities.

8. BNL will spearhead an advanced center for Computational Biology operating a multi-hundred-teraflop computer as a national user facility.

BNL will become the leading center for computational biology and build up a core group of first-rate computational biologists, chemists, physicists, applied mathematicians and software experts that will use and operate a multi-hundred-teraflop computer as a national user facility.

9. BNL will unite its instrumentation, bioengineering, materials science and medical programs in an effort to develop artificial sensors capable of functioning as real-time signal processing units in the central nervous system.

BNL will draw on its expertise in the fields of instrumentation, bioengineering, biology, material sciences, chemistry, nanosciences, and medical technologies to develop a new program focused on developing bioengineering devices for coupling central nervous system cells to artificial sensors. The sensors will enable transmission of conduction in real-time and function as an integral part of the central nervous system cell. This unit will be a revolutionary development for advancing central nervous system repair technology and communication.

10. BNL will be a leader in the understanding of global change and environmental sciences.

BNL will study the radiation balance of the earth focusing on the properties and effects of aerosols and airborne pollution in the atmosphere. BNL will study the effects of elevated carbon dioxide levels, elevated temperature, moisture content and chemical pollutants on the plant environment using the Free-Air Carbon-Dioxide Enrichment (FACE) facilities and provide technical support and management at national FACE facilities for research by university and national laboratory scientists. BNL will use its unique facilities to discover the molecular basis and kinetics of environmental contaminants at DOE sites.

11. BNL will be the leading technical asset to the Midatlantic and Northeast regions in reducing energy consumption through efficiency and renewables initiatives.

This includes development of cleaner liquid fuels and more efficient combustion processes, as well as studies of chemical transformations that enhance energy conversion, storage and utilization. BNL will contribute to the science and technology of a hydrogen-based economy with emphasis on metal hydrides for hydrogen storage and methane hydrates as a viable energy source. BNL will be a national leader in next-generation nuclear power reactors, including the safe and efficient operation of existing facilities and development of proliferation resistant nuclear fuel cycles and reactor concepts optimized for hydrogen production.

12. BNL will be the leading provider of technical support for homeland security in the Northeast corridor and will continue to assist the DOE's mission in nonproliferation and national security.

BNL will apply its scientific, engineering and instrumentation capability to develop and install advanced sensor systems to stem the proliferation of weapons of mass destruction. It will bring critical

technical expertise to DOE's nonproliferation mission and assist with the safeguarding of weapons-grade nuclear materials in Russia and elsewhere.

BNL will provide in-depth technical and scientific support to the Department of Homeland Security and other authorities having responsibility to detect and counter terrorism, focusing on the security of the New York Metropolitan area, its infrastructure and ports. BNL will be the leading research and development organization for the development of advanced sensors and networks for standoff detection of nuclear, chemical and biological agents within urban environments.

2.3 Laboratory Profile within the DOE Context

The four key missions of the Department of Energy are Energy Resources, Science and Technology, Environmental Quality, and National Security. Brookhaven National Laboratory has been for over fifty years, and continues to be, a leader in the DOE's mission in Science and Technology while 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 solving 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. Because of its expertise in accelerator-based facilities and detectors BNL is increasingly providing research facilities for other agencies, such as the NASA Space Radiation Facility and NSF funded AGS based high-energy physics experiments.

2.4 Core Competencies

Brookhaven National Laboratory is recognized for excellence in

- Experimental and theoretical high-energy, nuclear, condensed matter physics, chemistry, and materials science.
- Surface science
- Biochemistry and gene technology.
- Imaging concepts and applications to animal and human brains.
- Environmental science and airborne pollution.
- Improved and emerging energy technologies.
- Accelerator physics and technology, including superconducting magnets.
- Detector technology for national security and homeland protection applications needs.
- Operation of large and small user facilities. Among them are:
    - For High Energy and Nuclear Physics: The Relativistic Heavy Ion Collider (RHIC), Alternating Gradient Synchrotron Complex (AGS), Accelerator Test Facility (ATF), and the Superconducting Magnet Development and Construction Facility (for international laboratory collaborations).
    - 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), NASA Space Radiation Facility (NSRF), and the Clinical Research Center and Animal Facility.

- For Data and Computation: The RHIC Computing Facility (RCF), RIKEN Teraflop Computer, National Nuclear Data Center (NNDC), Center for Data Intensive Computing (CDIC), Visualization Center, and the Atmospheric Radiation Measurement (ARM) External Data Center.
- For radioactive isotope production: The Brookhaven Linac Isotope Producer (BLIP), Target Processing Laboratory (TLP) for producing radiopharmaceuticals, PET Isotope Production Cyclotrons, and the Tandem Van de Graaff Facility.

3.0 Laboratory Strategic Plan

Science-based multidisciplinary 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 who develop a strategic plan for the department. These plans and the DOE's planning initiatives and priorities provide the initiatives for the near term (2 years and 5 years) and the far horizon (10 to 15 years). In the following section we give the Laboratory Initiatives. They represent BNL's plans for science and facilities that will assure the continuing health and mission capability of the Laboratory from the present to the next two decades. They were developed in annual Strategic Planning Meetings that involved all senior science managers, augmented by selected group leaders from science and technology.

3.1 Laboratory Initiatives

The Laboratory Initiatives presented here in some detail flow from the Laboratories planning efforts and are centers of internal investment. They are updated every year as circumstances change, but represent a long-term plan. The time scale of the selected initiatives ranges from three years to ten years. Some initiatives have obtained project support by DOE or other agencies and are in early stages of realization. Others are provided to the Department of Energy for its consideration. *Their inclusion in this plan does not imply the DOE's approval of or intent to implement an initiative.* Table 1 provides a summary of those facilities, projects, and buildings that we envision will take us into the future.

Additional programmatic initiatives are extensions of ongoing efforts that are pursued by the respective research groups. These are described in the relevant programmatic chapters.

Table 1 - Laboratory Initiatives

Facility/Project/Building	Description in Section
Next Generation RHIC RHIC Luminosity Growth "RHIC II" eRHIC	3.1.1 3.1.1.1 3.1.1.2
RSVP	3.1.2
Very Long Baseline Super Neutrino Beam	3.1.3
New Storage Ring Light Source (NSLS-II)	3.1.4
BNL Center for Functional Nanomaterials	3.1.5
Materials Synthesis	3.1.6
Multimodality Imaging in Small Animals	3.1.7
Cyclotron Isotope Research Center	3.1.8
Genomes to Life Initiative	3.1.9
Computational Biology	3.1.10
Advanced Sensors and Urban Atmospheric Observatory	3.1.11
Large Synoptic Survey Telescope (LSST)	3.1.12
Research Support Building	3.1.13
Energy Sciences Building	3.1.14
User Research Center	3.1.15

3.1.1 Next Generation RHIC (NP)

Frontier accelerator and collider facilities for experimental high energy and nuclear physics evolve as scientific discoveries reshape subsequent investigations. The RHIC complex is no exception. Possible directions are: 1) expand the heavy ion species to include ions up to uranium; 2) increase the luminosities of the heavy-ion and polarized-proton interaction points; 3) add the capability for electron-ion collisions; 4) upgrade the detectors to match the evolution of the collider. The scientific needs will determine which of these options must be implemented. Several studies have mapped out the scientific directions for this facility. Key to fully characterizing the properties of the quark-gluon plasma (QGP), and study the QCD vacuum through the heavy-ion program are the following:

- Measuring the gluon density of the plasma through high transverse momentum studies of jet quenching, using jets tagged in coincidence with high transverse momentum photons (effectively producing "beams" of high energy partons to probe the plasma), and flavor-tagged jets to study the quark mass dependence of energy loss,
- Complete mapping of the quarkonium states (J/psi, Upsilon, and their excited states) to measure the thermodynamics of de-confinement through varying quarkonium dissociation temperatures. Studying the effects of chiral symmetry restoration in the dense medium via electron pair spectra,
- Making large statistics measurements of partonic collectivity through correlations among light-strange-, and charmed-quark states,
- Obtaining direct photon spectra using the Hanbury-Brown-Twiss (HBT) interference phenomenon to provide a direct measurement of QGP temperature, size, and lifetime,
- Producing high transverse momentum direct photons to study the saturated gluon phase at very early times.

Additional work will search for new phenomena in bulk QCD matter, such as strong CP violation associated with the de-confinement phase transition. All of these require very large samples of unbiased data ($>10^8$ events), motivating the need for a major luminosity upgrade of the RHIC's heavy ion capability, i.e., "RHIC II" (Section 3.1.1.1)

The physics program of eRHIC builds on results from fixed-target muon and electron beam experiments at DESY and CERN. Colliding electrons with the stored heavy ion beams of RHIC provides important experimental advantages over fixed target experiments. The goals of eRHIC are:

- *Quark and gluon distributions in the nucleon* - offer a unique capability for measuring `flavor tagged' structure functions by providing access to a wide range of final states allowing us to map quark and gluon distributions in nucleons, nuclei, and possibly even mesons,
- *Spin structure of the nucleon* -- operating at the highest center-of-mass energy, provide crucial data on the proton's spin-dependent structure functions at lower *x,* and precisely measure the polarization of sea quarks,
- *Correlations between partons* - completely characterize the partonic substructure of the nucleon describing the correlation among parton densities, utilizing a new class of 'Generalized Parton Distributions', for which eRHIC kinematics are optimal,
- *Hadronization in nucleons and nuclei* –study how the colored quarks and gluons in the nuclear medium that are struck by the virtual photon in deep inelastic scattering evolve into the colorless hadrons that are observed in nature,
- *Partonic matter under extreme conditions* -- enable a search for the fundamental ground state of partonic matter predicted by QCD: saturated gluonic matter, the 'Color Glass Condensate'.

3.1.1.1 RHIC Luminosity Growth "RHIC II"

The goal of the RHIC luminosity upgrade is to increase the luminosity of the machine tenfold-fold, in addition to a factor four obtained by increasing the number of circulating bunches, making necessary improvements to the existing RHIC detectors in order to exploit it.

Presently, RHIC luminosity is limited by intra-beam scattering (IBS) that is particularly severe with the high charge of the gold ions. The growth of the beams' size due to IBS can be overcome by cooling them with a high intensity cold electron beam; for the 100 GeV/n gold beam with 10^9 ions per bunch, a 54-MeV electron beam with an average current of about 100 mA is required. In this case, the charge of each electron bunch is about equal to that of the ion bunch and the two beams co-move at the same velocity. The "cold" electron beam cools the "hot" ion beam. The high electron beam power approximating 5 MW necessitates recovering the beam's energy by decelerating it in the superconducting linac, as was successfully demonstrated at JLab with a 50 MeV, 5 mA electron beam.

Electron cooling of the high energy, heavy ion beams in RHIC is a challenging project that extends beyond established technology. It requires a bunched electron beam accelerated by a linear accelerator, beam cooling during collider operation, and a precise magnetic channel to spiral the electron beam through the gold beam, to avoid recombination of e^- and Au^{79+}. We began an R&D program in FY 2003 to develop these critical items. Electron cooling improves the luminosity of gold collisions in RHIC by a factor of 10. It also improves operation with polarized protons by a factor of about four.

The RHIC II luminosity upgrade for the heavy ion and spin program also entails substantial upgrades to the PHENIX and STAR detectors. The necessary R&D will be completed and the project will be positioned for construction starting as early as FY 2008 if funding can be made available. RHIC II could be ready for long-lead procurements in FY 2007, if the Nuclear Physics Program can provide appropriate resources. The RHIC II luminosity upgrade for the accelerator and detectors can be completed in 3 years. Table 2 shows the estimated cost.

Table 2 - Schedule and Cost of RHIC II	**Estimated Cost ($M)**
Electron beam cooling at full RHIC energy	34
Detector upgrades for rare processes	60
Total estimated direct costs (FY03$M)	94
EDIA@15%;Contingency@25%;ProjectG&A@13%	59
Total Estimated Costs (FY03 $M w/o escalation)	153

3.1.1.2 eRHIC

Over the last five years, there has been substantial international interest in a high luminosity ($\sim 10^{33}$ $cm^{-2}s^{-1}$) polarized electron-ion collider covering a CM energy range from about 30 to 100 GeV, primarily to better probe the fundamental quark and gluon structure of strongly interacting matter. The advancement of this research area will require the new eRHIC facility, especially since the DESY electron proton collider HERA will be decommissioned in 2007. A large international collaboration has been formed and is actively base lining the accelerator facility as well as appropriate detectors. The recent NSAC evaluation of proposed facilities gave the highest rating to the science of eRHIC.

The design of an optimized accelerator, collision region, and detector for eRHIC is underway. It will require iteration between the machine design and simulation of the physics measurements because the detailed design of the electron-ion interaction region is closely coupled to that of the eRHIC detector elements. At least one central detector element will be required that will track the scattered electron and hadronic final state, calorimetry to determine the final state energies, particle identification for both electron and hadrons, and jet reconstruction.

The present design for eRHIC envisions building an electron accelerator ring with 5-10 GeV energy, 1/4 of the RHIC's circumference, that collides with the ion beam in one of the existing RHIC

experimental areas. The injector into the ring is either a 2 GeV linac or a 2 GeV Booster ring. The electron beam then is accelerated to collision energies and becomes polarized through the synchrotron radiation process. Special electron ring bending magnets, "super-bends", with relatively high field (2 T) in the short central part of the magnet, will decrease the polarization time to only 5-16 minutes, depending on the electron beam energy. A pair of solenoidal spins rotators around the interaction region produces longitudinal polarization. This design of eRHIC with a self-polarizing electron ring offers a cost-effective solution for an electron-ion collider that can be realized using today's level of accelerator technology. The electron-beam cooling of the Au beams that are obtained as part of the RHIC-II upgrade are key to achieving the high luminosity. The electron-gold and electron/proton collisions can be implemented such that they are transparent to RHIC's ongoing heavy ion program.

The R&D for the eRHIC component will be finished by FY 2007; its construction could start as early as FY 2010, and is projected to take 4 years to complete. Table 3 gives the costs.

Table 3 - Schedule and Cost of eRHIC	**Estimated Cost ($M)**
10 GeV electron accelerator & storage ring	200
Detector for e-p/Au collisions	100
Intersection region	15
Total estimated direct costs (FY03$M)	315
EDIA@15%;Contingency@25%;ProjectG&A@13%	196
Total Estimated Costs (FY03 $M w/o escalation)	511

3.1.2 Rare Symmetry Violating Processes (NSF)

The Rare Symmetry Violating Processes (RSVP) experiments will use the intense AGS proton beam to produce powerful secondary beams for two experiments called MECO and KOPIO that probe two fundamental symmetries of nature. The NSF Major Equipment Research Program will fund the building of the experiments; the NSF Division of Physics would sponsor the incremental facility operation cost.

The KOPIO experiment will study very rare decays (a kaon decaying into a neutral pion, a neutrino, and an antineutrino). The observation of these rare reactions will probe charge-parity symmetry violation, fundamental evidence that a mirror-image anti-universe would look slightly different from our own. This is important because the laws of physics must explain the observed and manifest large-scale matter-antimatter asymmetry of the universe. The second experiment, "Muon to Electron Conversion", MECO, measures a process forbidden in the Standard Model (SM), but allowed under many non-SM alternatives. Its objective is to detect cleanly an extremely rare event, a muon decaying into an electron. Such a finding would signal the existence of a fifth unseen force in the Universe, and entire families of new particles now predicted by theory alone. The experiments are led and managed by scientists from U.S. universities, and national and international laboratories. Table 4 provides a time line for the project.

Table 4 - RSVP Funding Profile (NSF) in the FY-04 President's budget

	FY 01	**FY 02**	**FY 03**	**FY 04**	**FY 05**	**FY 06**	**FY 07**	**FY 08**
R&D	0.9	1.2	1.2	1.5	2.0	2.0		
Construction						30.0	42.66	20.25
Pre-Operation & Operation.						5.3	8.5	8.5

3.1.3 Very Long Baseline Super Neutrino Beam (KA)

The discovery of neutrino masses and their manifestation as neutrino oscillations, along with the consequences from observed solar and atmospheric neutrino fluxes on earth, revolutionized neutrino physics and resulted in a shared 2002 Nobel Prize in Physics for Dr. Raymond Davis, retired from BNL, and Prof. Masatoshi Koshiba. A 2003 BNL White Paper proposed a program of decisive measurements determining the complete set of parameters that describe the neutrino mass and oscillation system. In March 2003 a special HEPAP facility panel judged that a BNL developed concept, the 'Very Long Baseline Neutrino Oscillations Experiment' was "central to the future of the field".

The new facilities required for the VLB Neutrino program are: 1) a 1 MW, wide-band, few-GeV "Super Neutrino Beam", of a kind well-documented in previous experiments and which is provided by a modestly upgraded AGS proton driver accelerator; 2) a half-megaton water Cerenkov detector (such as the UNO detector) located deep underground in the former Homestake Mine in Lead, South Dakota (or in a comparable location). The wide-band neutrino beam allows direct visual observation of neutrino oscillations. A companion paper to the BNL White paper, "Proton Decay Detector", relates the astrophysics and nucleon decay discovery potential of the half-megaton UNO Detector. The influential 2003 National Research Council report, "Connecting Quarks with the Cosmos", confirmed the importance of neutrino oscillations and their full description.

The proposed *Very Long Baseline Super Neutrino Beam* (VLBSNB) will measure (or set definitive upper limits for) the complete set of neutrino oscillation parameters. They are:

- precise determination of the oscillation parameters Δm_{32}^2 and $sin^2 2\theta_{23}$;
- detection of the oscillation of $\nu_\mu \rightarrow \nu_e$ and measurement of $sin^2 2\theta_{13}$;
- measurement of $\Delta m_{21}^2\ sin^2 2\theta_{12}$ in a $\nu_\mu \rightarrow \nu_e$ appearance mode, independent of the value of θ_{13};
- verification of matter enhancement and the sign of Δm_{32}^2 (i.e., which neutrino is heavier);
- determination of the CP-violation parameter δ_{CP} in the neutrino sector.

Two key conditions are essential: 1) the very long baseline (over 2500 km) that is possible in the U.S. and naturally realized in the BNL-Homestake venue discussed in the white papers; 2) the specific few-GeV energy band of the neutrino beam in which the cross sections and background parameters are critical to success. No other neutrino oscillation program, worldwide, has put forward a practical plan for achieving these critical geographical baseline and beam energy conditions.

All the enabling technologies for this program were demonstrated in existing facilities, and both projects are ready for the engineering design phase, as soon as funds are available. BNL will pursue this project as a future DOE HEP construction project. Table 5 gives the estimated costs.

Table 5 - Estimated AGS Upgrade Cost/Neutrino Beam Cost

AGS Upgrade Cost		**Neutrino Beam Cost**		
1.2 GeV SC Linac:	**COST**	**Item**	**Basis**	**Cost**
Front End	$ 2.2 M	Proton Transport	RHIC Injector	$14.8 M
LE SC Linac	$ 38.3 M	Target/Horn	E889	$ 5.5 M
ME SC Linac	$ 30.7 M	Shielding/Dump	New	$ 5.8 M
HE SC Linac	$ 28.1 M	Decay Tunnel	E889	$ 0.4 M
AGS Upgrades:		Hill. Const.	New	$ 8.0 M
AGS Power Supply	$ 32.0 M	Near Detector Vault	E889	$ 8.5 M
AGS RF Upgrade	$ 8.6 M	Conventional Facility	RHIC	$ 7.5 M
AGS Injection Channel	$ 3.7 M	Other Const.	E889	$ 6.0 M

Full Turn Extraction	$ 5.5 M	Installation		$ 5.2 M
Shielding	$ 3.5 M	**Total Direct Cost**		**$ 61.7M**
Installation	$ 4.2 M			
Total Direct Cost	**156.8 M**			

3.1.4 New Storage Ring Light Source (NSLS-II) (KC)

Synchrotron radiation research has grown rapidly over the last decade, playing an important role in materials, chemical, life and environmental sciences and technologies. As the quality of synchrotron radiation sources improve, new research techniques become feasible.

An extensible design is under development to upgrade and modernize the National Synchrotron Light Source (NSLS). It ensures that the new facility will provide cutting edge performance while maintaining the extremely high degree of reliability and beam stability that are the cornerstones of our commitment to users. The NSLS serves a large community of scientific, medical, and industrial R&D activities, and is especially vital for the large research community in the eastern US. A new light source with high-brightness will provide the opportunity for groundbreaking research for US science. With the outstanding track record of the NSLS, the strength of its user community, and its scientific infrastructure, BNL is the ideal place for this source.

The NSLS-II will involve constructing a 3- to 4-GeV-electron storage ring with a full-energy injector designed to meet the following goals:

- Reduce the horizontal electron beam emittance by nearly two orders of magnitude from 60 nm to 1-2 nm. This requirement goes well beyond the current state of the art.
- Increase the brightness of the insertion devices by four orders of magnitude to 10^{21} photons/sec/0.1% BW/mm^2/mrad^2 in the 5-20 keV range.
- More than quadruple the insertion device capacity from 5 to 21 devices.
- Provide full tunability of insertion device output in the range of 5-20 keV by developing small gap superconducting insertion devices.
- Incorporate "top off" injection capability to maintain a constant current to better than a 1% fluctuation over several weeks to yield a fixed heat load on the beam line optics.
- Design storage ring lattice to be compatible with future operation in Energy Recovering Mode (ERL).

Although the new storage ring envisioned for NSLS-II will allow a subsequent upgrade to an ERL, presently, there are numerous severe technological challenges to realizing an ERL as an x-ray user facility. The need for enhanced source capabilities at NSLS is far too urgent to await the maturity of ERL technology. Our design strategy will ensure that the NSLS continues to push the frontier of new source development, while providing the user community with the brightest and most reliable source of photons well into the 21st century. In particular, the four orders of magnitude increase in brightness provided by the NSLS-II will create many exciting scientific opportunities, such as x-ray imaging with a spatial resolution approaching 10 nm, studying atomic scale dynamics down to sub-microsecond time scale, and structurally characterizing proteins with very large unit cells or those available only as very small crystals. The enhanced spatial and temporal resolutions that can be probed by NSLS-II will be crucial to characterizing the new nanoscale structures fabricated in the CFN. Table 6 gives a preliminary cost estimate.

Table 6 - NSLS-II Preliminary Project Cost

	FY 06	FY 07	FY 08	FY 09	FY 10	FY 11	FY 12
FY03 $M	13.5	14.2	41.6	85.7	88.5	69.6	37.2

3.1.5 BNL Center for Functional Nanomaterials (KC)

The CFN is a User Facility broadly dedicated to tailoring materials' properties at the nanoscale in order to achieve a specific function. The CFN will integrate Brookhaven's capabilities in synchrotron characterization techniques with new ones in nanomaterials synthesis and nanofabrication. It complements other planned national centers and capitalizes on the NSLS's leadership in materials probes and on BNL's BES programs in strongly correlated electron systems, catalysis, molecular materials, electro-chemistry, and nanostructures in complex functional materials. It will use major existing facilities: the LEAF, ultra-fast lasers and scanning probes, and the BNL Transmission Electron Microscopy facility.

The centerpiece of the CFN is a new building contiguous with the NSLS. It will house clean rooms, general laboratories, wet and dry laboratories, office space, and rooms for seminars and conferences. The CFN will have seven major laboratory facilities: nanopatterning, proximal probes, electron microscopy, materials synthesis, ultrafast optical sources, and theory and computation. The seventh takes advantage of dedicated beam lines at the NSLS, including the soft and hard microprobes, UV soft and spectroscopy, soft and scattering, near field IR, and *in situ* characterization.

The CFN will draw interdisciplinary researchers, from within BNL and outside. It is a separate department whose organizational structure closely parallels that of the NSLS. A new director (chair), Bob Hwang, joined BNL coming from Sandia. A senior scientist will head each laboratory facility bearing responsibility for the user interface, developing new scientific techniques, and supervising user scientific and technical staff. Two senior scientists already brought their programs to the CFN: Yimei Zhu (electron microscopy) and Tom Vogt (materials synthesis and characterization). Together with the CFN Director, they will comprise the core scientific leadership. A Science Advisory Committee will guide the overall science direction. The CFN will be a focal point for collaborations with nearby universities, NSF nanocenters, and industry in the Northeast. We already have close relationships with the USB, Columbia University, and Princeton University, and we are developing relationships with Lucent, IBM, Rutgers, and RPI. We expect the design and construction to take four years with completion in FY-07. CFN has recently passed CD-1 with a total expected cost of $80.9M (see Table 7).

Table 7 - Schedule and Cost (in Millions) of the CFN Construction

		Funded		Budgeted		Proposed		
	TEC	FY02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
CFN	80.9			3.0	22.90	35.00	20.00	

3.1.6 Materials Synthesis (KC)

The design, discovery and growth of novel bulk materials, often in single-crystal form, is one of the primary driving forces in materials science/condensed matter physics. The goal of this Initiative is to establish a materials synthesis capability in the Laboratory. It involves the condensed matter physics (CMP) group, the materials science (MS) department and the CFN. Four staff hires specialize in Nanomaterial synthesis, single crystal intermetallics, single crystal oxide growth, and pulsed laser deposition. Two additional hires are planned for FY-04.The common goal is to understand the science of synthesis and to develop on-site synthesis capabilities that enhance and extend ongoing research. Materials synthesis capabilities now include Pulsed Laser Deposition, fabrication of thin films, rational functionalization of carbon nanotubes, synthesis of superconducting materials, large inorganic molecules, and single crystal oxides. A recently formed group synthesizes and characterizes intermetallics, powdered oxides and Silar-grown thin films. These developments were funded by programmatic funding in consultation with BES program managers.

These efforts form the core of a new interdepartmental Center for Materials Synthesis to be established at BNL, which will have a designated director. For FY-04 we are searching for a complex oxide molecular beam epitaxy scientist to synthesize the highest quality oxide material thin films; such a hire will complement and strengthen existing programs in superconductivity (MSD), correlated electron systems (CMP), and in spin-polarized electron systems (MSD,CMP). With these efforts BNL will be well positioned in FY 05 to address the need for more core capability in materials synthesis at National Laboratories.

3.1.7 Multimodality Imaging in Small Animals (KP)

The objective of this initiative is to achieve breakthroughs that would ultimately lead to improvements in human health. The new pre-clinical small animal imaging initiative at Brookhaven National Laboratory soon will include access to (a) wide-bore microPET, (b) multiple short-lived radiotracers, (c) high field microMRI/MRS, (d) optical imaging, (e) microCT, (f) complex physiological monitoring equipment and (e) bio-computational analysis tools. The future scientific need to combine imaging methodologies, chemistry and biocomputing in small animal studies is clear. The BNL Life Sciences small animal initiative will be focusing on (1) imaging gene expression; (2) drug design and tracking of therapy; (3) guided therapy (high resolution or high targeting); (3) correlating virtual 3D fMRI maps and complex behavior and (4) new CNS biosensors and targets. In addition to equipment operation and maintenance, this coupling of imaging and genetics will involve three to five PIs and five postdoctoral fellows and would require support/collaborations with the NIH, USB, and DOE at a funding level in the $5-6 million per year range.

3.1.8 Cyclotron Isotope Research Center-CIRC (NE)

The nation's requirements for a stable, domestic source of medical isotopes and for isotope R&D for diagnosis and therapy are currently unmet. The proposed Center will fulfill the scientific need for future human clinical research. Its goals are the following:

- Produce present and future radioisotopes for the biomedical, scientific, and industrial communities;
- Conduct research into radionuclide production;
- Develop and evaluate next-generation radiopharmaceuticals for imaging and therapy;
- Provide education and training in nuclear and radiochemical techniques;
- Serve as a source of very intense positrons for positron physics and material science research;
- Provide simultaneous multi-user capability for research, production, and (in the future) for commercial users.

To minimize costs, the cyclotron will be built adjacent to BNL's existing radioisotope processing facilities and will utilize target transfer equipment and hot cell designs used at the BLIP. Construction and installation is projected to cost $37.5 million (Table 8). The overall project is considered low risk because the cyclotron and the separator are straightforward extrapolations of existing technology and would be purchased competitively. This proposal is an effort of the Collider Accelerator, Medical, and Chemistry Departments; we seek funding from the DOE/NE.

Table 8 - Schedule and Cost (in Millions) of the CIRC Construction

		Funded		Budgeted		Proposed		
	TEC	FY02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
CIRC	37.5				9.88	13.40	11.87	2.35

3.1.9 Genomes to Life Initiative (KP)

One of the major goals of the DOE's "Genomes To Life" (GTL) program is to characterize the function of complex microbial communities in their natural environment at the molecular level. BNL has developed a GTL core plan that maximizes the expertise and facility capabilities at BNL to provide cutting-edge, high-throughput molecular methods to expand scientific and technical understanding of the genetic diversity of microbial communities in the environment. A systems biology approach has been proposed that will form the core support to develop the tools to understand the genetic basis of microbial community functional, stability and adaptation to environments important to the DOE. In parallel, computational biology workshops and infrastructure are being developed to address the computational modeling component of the GTL program.

A base program plan funded at approximately $3M per year in FY 04 dollars would create a unique opportunity to implement a multi-departmental, multi expertise research initiative that supports the DOE's efforts in biological sciences (plant research, microbiology and computational biology), medical sciences (imaging), environmental sciences (environmental chemistry, FACE experiments), and energy sciences (hydrogen producing bacteria). This program will require support for a staff of about 20, consisting of 5 scientists, 10 technicians and 4 postdocs. Table 9 shows a projected cost estimate.

Table 9 - Projected GTL Project Costs

	FY04	FY05	FY 06	FY 07	FY 08
FY03 ($M)	4.3	4.5	4.8	5.0	5.4

3.1.10 Computational Biology (KP/OSCR)

For FY-04 BNL is initiating a major new imitative in Computational Biology. It takes account of the fact that computational biology is manifestly one, perhaps the, major thrust of the biological sciences and industry in the future. Recent substantial advances in high-speed computer technology provide the means to achieve major advances in *biomolecular dynamics simulations*, in *data mining for high-throughput biology* and *simulation of biological processes*. All of these three fields are computational underpinnings of the Genome-To-Life goals of the DOE. The Grand challenge for the future is solving the protein-folding problem. BNL brings great assets to this task: The National Synchrotron Light Source has a vibrant program in protein structure determinations, including the first determination of the most important molecular machine which produces proteins, the Ribosome. BNL also hosts the only Scanning Transmission microscope used for non-crystalline biological structures and is now installing a Cryo-Electron Microscope. The national Protein Databank for the registration of protein structure data was invented and located for many decades at BNL. Our biologists are also collaborating in the DOE GTL program. The present initiative aims to add the crucial support element of computational biology to the Laboratory.

BNL is planning this initiative as a collaborative effort with its six core Northeastern research universities, all with powerful research efforts in advanced biology, and with the Northeastern pharmaceutical industry. A symposium held at BNL on July 31, co-sponsored by IBM, (http://www.bnl.gov/Compbio/) will define the scientific questions that are the near term targets of computational biology. It is anticipated that a defining White Paper will be developed shortly thereafter.

The core of any computational biology initiative must be a high-scale computer, with a capability in the *hundreds of teraflops*, and optimized for the algorithms applied in computational biology. BNL is proposing to house this uniquely powerful computer and make it available to computational biologists in the lab the Northeast and indeed the Nation.

BNL views the Blue-gene-L architecture produced by IBM as the most promising and cost-effective choice for such a high-end computer. Its architecture evolved from the QCDOC chip architecture that has been developed by a Columbia University-BNL consortium, initially for use in

lattice gauge calculations. Two 10-teraflop QCDOC computers are now being built (one for great Britain, the other for the Japanese-funded RIKEN-BNL Institute). This architecture is scalable and highly parallel. It promises to be very effective for Molecular Dynamics, the backbone of computational biology. BNL computer scientists are very involved with this architecture and in fact the construction of the two QCDOC machines.

A BlueGene-L computer of 360 to 500 teraflops is estimated to cost between $70 Million and $100 Million. With time steps of 10^{-15} s it can simulate the evolution of about 100,000 particles for about 10 microseconds, comparable to the fastest protein folding times.

3.1.11 Advanced Sensors and Urban Atmospheric Observatory (DHS)

At the nation's seaports, airports and border crossings, security is focused increasingly on the possibility that terrorists may illegally smuggle radioactive material into the country for use as an improvised nuclear weapon or a radiological dispersal device. In response, BNL constructed the Radiation Detector Testing and Evaluation Facility, RADTEC (Section 4.4.4) for commercial and government off-the-shelf detectors. BNL is also developing its own advanced sensors and technologies for detecting nuclear weapons, dirty bombs, toxic chemicals, biological pathogens and conventional explosives. Among the most promising are:

- *Cadmium-Zinc-Telluride-Based Detectors:* A new class of solid-state radiation sensors to detect and image gamma rays emitted by radionuclides of interest to terrorists, including isotopes of plutonium, uranium, cobalt and cesium. Unlike most detectors capable of identifying isotopes, which must be kept chilled to liquid nitrogen temperatures to function effectively, these sensors work at room temperature, and are compact, light-weight, and low maintenance.
- *Large-Volume Xenon-Based Detectors*: Can be used to locate radioactive materials at transportation choke points, such as bridges, tunnels and tollbooths. These detectors also operate at room temperature, and provide better energy resolution than scintillators, which are widely used for locating and safeguarding radioactive sources.
- *Highly Sensitive Neutron Detector*: Can measure neutrons using large, high-efficiency helium-3 detectors sensitive only to thermal neutrons, and not to natural gamma radiation. This type of sensor triggers very few false alarms.
- *Thermal Neutron Camera*: Can detect the presence of fissile material, such as plutonium, from up to 200 feet away and locate the source's position. BNL developed a thermal neutron imaging device, which uses a special coded aperture and a position-sensitive neutron detector.
- *Accelerator-Based Cargo-Scanning Technology:* Can detect the nitrogen found in many explosives and fissile material within large shipping containers. The technique uses a gamma-ray resonance method to quantify and produce a map of nitrogen-containing chemicals, such as explosives. This map, with a standard radiographic image revealing density fluctuations, produces a very powerful picture of the presence of most explosives.

Brookhaven's most ambitious sensor initiative is the urban Atmospheric Observatory (UAO). It aims to understand and monitor the flow of air and radioactive particles in an urban environment. With the Environmental Measurements Lab in New York City (NYC), two monitoring stations were deployed in NYC during FY03. The UAO will provide an operational hands-off system for improved assessment of a terrorist incident or attack within New York. It will also create a world-class scientific resource for urban meteorology measurements. Fast and accurate, this system will provide information on the transport of dangerous agents across NYC; it is designed to automate emergency management procedures, couple into command and control centers, and provide first responders with precise, real-time information. A projected cost estimate is given in Table 10.

Table 10 - Projected Costs and (Number of FTEs) for the Advanced Sensor Initiative						
	FY03	**FY04**	**FY 05**	**FY 06**	**FY 07**	**FY08**
FY03 ($M)	2.3(9.2)	3.2(12.8)	4.8(19.2)	5.0(20)	5.0(20)	5.0(20)

3.1.12 Large Synoptic Survey Telescope (LSST) (KA)

Recent advances in understanding the unfolding cosmology of the universe were driven by the rapid transition from classical astronomy methods to powerful new scanning-mode observation instruments that greatly expand the data available. They reveal that the universe is composed of a majority of matter that is not baryonic in nature (dark matter), and that its energy density is large and growing, giving rise to an accelerating rate of expansion on the largest scales (dark energy). Our core capabilities in high energy nuclear and particle physics are well suited to including experimental astrophysics and cosmology in the Laboratory's research portfolio. The science complements BNL's interest in electroweak physics at the energy frontier, and in phase transitions of hadronic matter in the early universe. Further, the technology overlaps with our technological expertise in high energy and nuclear physics.

Hence, BNL is seeking a collaborative role in one or more of the larger astronomical initiatives resulting in our developing a relationship with a collaboration fleshing out a proposal to build the 'Large Synoptic Survey Telescope' (LSST), a visible and near infra-red optical telescope with a 50 cm x 50 cm, 1-Gigapixel detector at its focal plane. This instrument (http://www.lssto.org/lsst_home.html) is ground-based with a wide field of view, able to repeatedly measure down to 24th magnitude, objects over large areas of the sky in a relatively short time. It can explore the nature of the 'dark energy' and the distribution of 'dark matter' that dominates the cosmic environment.

BNL intends to join the LSST collaboration. The initiative to pursue this work began in FY 2003 and we expect to propose it to the DOE as a HEP-funded activity at BNL starting in FY 2005. Table 11 gives a preliminary cost estimate in the time frame FY 05-08.

Table 11 - Preliminary Cost Estimate for LSST						
	FY03	**FY04**	**FY 05**	**FY 06**	**FY 07**	**FY08**
FY03 ($M)			2	5	10	10

3.1.13 Research Support Building (SLI)

Progress toward consolidating staff into permanent buildings and demolishing sixty-year-old wood buildings has been on-going for the past five years and will accelerate with the construction of the Research Support Building; its design began in FY03 with construction slated to start in FY04. This project will eliminate more than 50,000 square feet (SF) of old buildings and construct a new 55,000 SF two-story office and support services structure. The Research Support Building Phase I will combine the services needed by resident staff and the 4,100 annual visitors into one easily accessible building in the core of the BNL site. They will include Human Resources, Staff Services, Post Office, Credit Union, Fiscal, and Training. Proposed future projects in Phase II and Phase III will consolidate the balance of administrative and support functions from the inefficient and dispersed wood frame buildings into modern, efficient buildings located in the core of the BNL site.

This building has passed CD-1 in 2003 and is beginning actual construction in FY-04 Its cost and construction schedule is given in Table 12.

Table 12 - Schedule and Cost (in Millions) of Construction Initiatives								
		Funded		Budgeted		Proposed		
	TEC	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
Research Support Bldg.	18.2		3.3	5.15	9.8			
Energy Sciences Bldg.	18.3			1.8	7.5	9.0		
User Research Center	15.4			1.6	6.8	7.0		

3.1.14 Energy Sciences Building (SLI or Alternative Financing)

BNL is committed to strengthening its programs in applied sciences in the Departments of Environmental Sciences, Energy Sciences and Technology, and Nonproliferation and National Security, and the Office of Technology Transfer. The Energy Sciences Building Project is a key element in BNL's plan to upgrade facilities essential to the DOE's applied sciences' missions. BNL is making strategic investment in interdisciplinary programs in hydrogen-based energy programs. We must construct laboratory and office facilities to replace outdated, inefficient buildings that cannot meet mission needs and are not acceptable to the top-level labor force that we must attract.

The affected departments are dispersed among 24 buildings, only two of which are suitable for continued use. For example, the Environmental Sciences Department occupies 14 buildings where over 65% of the 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 science facilities. BNL cannot attract first-rate scientists to work in these undesirable conditions. The existing wood frame structures are costly to operate and maintain, and many systems fail to meet current code design; they require continued investment just to maintain minimum functional capability. Energy costs of $1.60/SF are double the amount for a similar sized modern office building.

As submitted to the DOE budget for FY-04 the two-story energy science building structure will provide ~ 40,000 SF of laboratory, office, and support space. It will be constructed in the core area of the site, providing maximum flexibility for collaborative teams from various departments to use the building fro their research. However, this building also offers opportunities for alternative financing of the construction cost. The legal procedures are presently being worked out. We hope that construction can start in FY-04. The total cost under DOE funding rules is estimated at $18.2 Million (see Table 12). Under the third-party approach we would construct 60,000 SF for a total cost of $19.5 Million.

3.1.15 User Research Center (SLI)

The RHIC program consists of large international collaboration and many of these collaborators need to be present at the during the RHIC runs, and during off-times to retrieve and analyze that data. When RHIC is down for longer periods, like the summers, the experiments need to be repaired and improved, and much of this work is done by University faculty, postdocs and students. Some 1,100 visiting scientists work at RHIC every year and that number is expected to grow. At any given time, hundreds of visiting scientists work alongside our staff. At the same time the U.S. effort for the large ATLAS detector of the LHC will build up, as the LHC starts its research program in FY 08. BNL will host a Tier-1 data and analysis center for ATLAS. This will draw additional guest scientists to the Laboratory.

BNL does not have enough space to accommodate them. Moreover, since Brookhaven is the focal point of a worldwide effort to carry out and analyze these experiments, we require areas where large groups can work together, close to each other, the experimental equipment. Proximity to the existing computing facility, which is essential for analyzing data, as well as the BNL research staff there, is essential. At present, there is no central facility that allows this kind of consolidation of the RHIC

research. This is particularly painful when compared to the facilities available at other major accelerator-based research centers, such as CERN and Fermilab.

The User Research Center will be a permanent facility for the on-site and the visiting scientific community. For this project, BNL will construct a 54,500 SF office building next to the Physics Department, located at the core of the site and directly adjacent to the RHIC Computing Facility. The building will include individual and multi-person offices, a large seminar room, two conference areas, space for transient users with access to computer terminals, and a lobby for public displays and visitor orientation. The building has been submitted for the FY-04 budget with a total cost of $15.4 Million. The construction profile is given in Table 12.

4.0 Department of Energy Programs

4.1 Science and Technology Facilities

The following sections describe our major user facilities and evolutionary upgrade plans for the future. In conjunction with our proposed initiatives, described in section 3, these plans will assure our continued success in meeting the DOE's Science and Technology mission well into the future.

4.1.1 Relativistic Heavy Ion Collider (KB)

Present Program: The Relativistic Heavy Ion Collider (RHIC) is the largest facility for nuclear physics and the most energetic source of heavy ion and polarized proton collisions in the world. RHIC offers the potential for new discoveries about the most fundamental forms of matter. Its construction was completed in FY 1999 and it has operated as a national user facility in Nuclear Physics since FY 2000, serving a user community of nearly 1400 scientists and graduate students. It just completed its third annual data-taking cycle.

The core of the RHIC experimental research program includes the following:

- the experimental demonstration of the existence of quark gluon plasma, a new state of matter, and the exploration of its properties,
- the detailed study of the origin of nucleon spin and its connection to the gluon.

Near-term Program: In the President's Budget for FY2004, RHIC will run 25 weeks of beam operations for heavy ion and polarized proton physics. The FY2003 run consisted of deuteron-gold and polarized proton – polarized proton collisions. We expect that the FY2004 run will emphasize gold – gold collisions. The final decision will be made after considering the experimenters' requests and the Program Advisory Committee's advice.

Long-term Program: It will take at least ten years to fully explore the prospective richness of RHIC phenomena and, if they are as rich as anticipated, the program could stretch beyond twenty years. The four existing RHIC detectors (BRAHMS, PHENIX, PHOBOS, and STAR) represent an optimum diversity and complement each other. These detectors and the accelerator facilities that produce the colliding beams will evolve with time, following the unfolding directions in science. The RHIC program will accommodate this through a program of systematic upgrades that assures that RHIC science is at the forefront of discovery. There will be major improvements, such as constructing major new detectors or significantly modifying existing ones, significantly improving the accelerator to enhance beam parameters, such as luminosity, and new capabilities, such as electron collisions in the RHIC ring that can qualitatively expand its exploratory horizon. The program will benefit from a fourfold increase in average luminosity during this programmatic evolution and, by means of full-energy electron cooling, realize an additional factor of ten in average luminosity growth by about 2010, as an early goal of the RHIC II/eRHIC Project. The RHIC II/eRHIC Project will advance the program greatly (Sections 3.1.1.1 and 3.1.1.2)

All the research groups 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. The RCF began operations in FY 2000 and will grow as the research needs mature. We developed, and are implementing, a detailed plan for maintaining the RCF over the next decade of RHIC operations.

4.1.2 Alternating Gradient Synchrotron (KB/KA)

Present Program: The AGS is the world's highest intensity, high-energy proton beam accelerator. It serves mainly as the injector accelerator for RHIC, providing beams of heavy ions and polarized protons. At the lower energy end, short-lived isotopes for medical research are produced using the proton linac, and various industrial items are tested with ion beams at the Tandem van de Graaff.

Since 1999, the AGS's prime mission has been to inject heavy ions into RHIC, on an as-needed basis. Through FY 2002, the AGS also provided 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. As a result of the FY 2003 Presidential Budget, BNL was instructed to cease AGS operations for the user community because of the DOE's severe budget constraints in the U.S. High Energy Physics program. The AGS capabilities will remain available to other agencies, provided that such work does not interfere with its prime mission. At present, NASA supports a radiobiology research program using heavy ion beams (Section 5.1.1) and the new NASA Space radiation facility was successfully completed on time and on budget on June 30, 2003. It is a national user facility for research in space radiation biology. DOE-NNSA supports a proton radiography experiment. The DOE's Nuclear Physics Division authorized this compatible use under the Work for Others (WFO) Program.

Long-term Program: The AGS provides the world's best venue for exploring very rare phenomena in particle physics because of the exceptional intensity of the high-energy proton beams. In FY 2005, the AGS is expected to embark on the RSVP project (Section 3.1.2). In addition, several important experiments using pion, kaon, and muon beams were planned at the AGS for particle and nuclear physicists. Three of them were approved, initially funded, and started by the DOE; others were undergoing approval, before the decision to cease the HENP operations of the AGS. NASA expects to continue and expand the radiobiology program at the AGS with the new NASA Space Radiation Laboratory (NSRL) that was completed and commissioned in FY 2003, specifically for this program.

BNL plans to propose a high-intensity neutrino beam facility based on upgrading the AGS (see Section 3.1.3). Discussions were held with members of the particle and nuclear physics communities and with potential agency sponsors of a BNL neutrino program. It is highly likely that BNL and USB will develop a full collaboration to accomplish neutrino physics with the VLB beam and the UNO detector combining to carry out the neutrino oscillations physics program.

4.1.3 National Synchrotron Light Source (KC)

Present Program: The National Synchrotron Light Source (NSLS) is one of the principal DOE synchrotron sources. Light sources are essential tools for research in many disciplines. Initially, research focused mainly on material problems and chemical processes, but expanded more recently to include large biological systems and environmental problems. The NSLS is devoted to producing synchrotron radiation, developing new radiation sources, and developing new applications of this radiation. Currently, it provides high-intensity infrared, ultraviolet, and x-ray radiation to approximately 70 user beamlines. In 2002, more than 2400 users from over 400 national and international institutions came to the NSLS.

Near-term Program: To enhance the NSLS's capability to meet increasing and changing user demands, major upgrades were completed recently or are in progress. Two new RF cavities are being installed in the x-ray ring. A new digital orbit feedback system, which significantly improved orbit stability on the VUV ring, is being implemented on the x-ray ring. A new NIH-funded beamline, X6A, for structural biology was completed by the NSLS, and is ready for user operation. A major initiative is underway to upgrade all the insertion device beamlines on the x-ray ring to meet the demand of new scientific programs: (1) a new high-resolution monochromator was installed and commissioned for the soft x-ray undulator beamline X1B; (2) the superconducting wiggler beamlines at X17 are being reconfigured to increase experimental throughput; (3) on X21, photon beam transport is being provided to establish two new end-stations for materials science research; (4) on X25, a state-of-the-art 9-cell CCD detector was installed; (5) a new in-vacuum undulator, with better energy tunability, was installed in X13

for microbeam applications; (6) a new in-vacuum undulator beamline, X29, is being constructed to provide higher brightness radiation for structural biology, (7) an in-vacuum undulator beamline, X9, will be developed to provide higher brightness radiation for nanoscience users; and, (8) development was started on in-vacuum superconducting undulators. The higher field provided by the superconducting magnet will eliminate the tuning gaps of current in-vacuum undulators.

As the synchrotron radiation users community expands, most new users will not be experts in synchrotron instrumentation and techniques, so the NSLS will need to increase its role in all aspects of the user program; we face a growing need to support and operate more beamlines. Accordingly, a new user science division was created to better communicate with existing and potential users, increase user support at NSLS and Participating Research Team (PRT) beamlines, identify and coordinate new scientific opportunities, and develop optics and detectors. Several major initiatives were undertaken or funded in collaboration with the user community that require significant involvement by the NSLS:

- Consortium for Materials Properties Research in Earth Science: NSF in FY 2002 funded a new national resource for high-pressure research based at USB. The program's centerpiece is high-energy x-ray diffraction and infrared study of materials under high pressure at the NSLS.
- Powder Diffraction Center: The NSLS is organizing a center for x-ray powder diffraction, with four dedicated instruments: a high resolution instrument, a high throughput instrument, an instrument optimized for high pressure and pair-distribution function, and one with combined capability for powder diffraction and x-ray spectroscopy.
- Center for Environmental Molecular Science: Funding was approved to establish a Center for Environmental Molecular Science, proposed by a USB-BNL collaboration, to address the molecular-scale reaction mechanisms governing the interactions of selected environmental contaminants with mineral and mineral-like phases. The experiments will rely heavily on a suite of synchrotron techniques at the NSLS.
- Nanoscience users program: The NSLS is working closely with the CFN to structure the general user program, and to meet the demand for synchrotron techniques by nanoscience users. New synchrotron tools will be developed specifically for their programs.
- Catalysis beamlines consortium: The NSLS has many catalysis researchers from universities, government laboratories, and industry. It plans to upgrade and optimize a suite of beamlines, ranging from infrared to x-ray, for this research.

Long-term Program: Extensive development programs within the existing NSLS accelerator complex will improve the stability, reliability, and lifetime of electron beams, and develop new insertion devices to modulate polarization state and produce even brighter photon beams. Equally important are programs to develop new beamline instrumentation, including beamline optics, monochromators, and especially detectors that will let users take full advantage of the NSLS's unique research capabilities. However, since more of the users require higher brightness, a combination of a higher brightness source and many more insertion device beamlines will be needed to meet these demands. Accordingly, the NSLS is aggressively pursuing a major upgrade of the facility (Section 3.1.4).

4.1.4 Accelerator Test Facility (KA)

Present Program: The mission of the Accelerator Test Facility (ATF) is to serve as a user's facility for accelerator scientists, educate graduate student in physics of beams, and pursue basic research in accelerator physics. An important component of the success of the DOE is innovative accelerator R&D. Exploring the physics of beams requires experimental facilities where scientists from universities, national laboratories, and small businesses can experiment with new ideas and techniques. Existing facilities, such as high-energy colliders and synchrotron light sources, serve thousands of users and are

unsuitable for accelerator development. Accelerator and beam scientists need their own user facility. The ATF is such a resource that is dedicated to long-term R&D on the Physics of Beams

We provide the electron beam and infrastructure for supporting many experiments and continuously characterizing the electron beam, and for developing manipulation tools. Our core capabilities include a high-brightness photo-injector electron gun, a 70 MeV linac, high power lasers synchronized to the electron beam to the picosecond level, four beam lines (most with energy spectrometers), and a sophisticated computer control system. We are preeminent in developing RF photocathode electron gun technology, laser acceleration of electrons, and we made a significant impact on electron beam development for advanced accelerator concepts, including the Free Electron Laser (FEL).

The number of experiments grew rapidly and reached a steady state, with experiments being completed at about the same rate as new ones are approved.

We significantly contribute to educating graduate and postdoctoral students for careers in accelerator physics. Between 1992 and 2002, we graduated eighteen students from nine domestic and international institutions (SUSB, MIT, UCLA, Princeton, Dartmouth, New Mexico, Columbia, Stanford, and Lund).

Seventy researchers used the ATF in FY 02 to conduct R&D on Advanced Accelerator Physics and to study the interactions of high power electromagnetic radiation and high-brightness electron beams, including laser acceleration of electrons and FELs. Other areas included developing electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics, and computer controls. The ATF hosted two important proof-of-principle FEL experiments. The BNL High-Gain Harmonic-Generation (HGHG) experiment, in collaboration with ANL, demonstrated this unique approach to highly coherent FEL radiation. The VISA experiment, in collaboration with SLAC, LBNL, LLNL, and UCLA, tests and characterizes SASE FEL operation in the visible region, where high quality optical diagnostics are readily available. The VISA FEL exhibited a very high gain and saturation, and provided unique measurements of micro-bunching and non-linear harmonic generation.

Notable recent results include the staging of laser accelerators in the Staged Electron Laser Accelerator (STELLA) experiment, and achieving a record hard photon flux in picosecond pulses from the Compton Scattering experiment. The STELLA experiment now pursues another milestone: the generation of mono-energetic laser-accelerated electrons. The Compton experiment, in collaboration with Japanese scientists under the US/Japan collaboration in High-Energy Physics, demonstrated channeling of the CO_2 laser using a plasma lens in a capillary tube. Next year, we expect to enter the plasma acceleration field using the new terawatt picosecond CO_2 laser that operates with a long pulse mode.

We improved the facility's infrastructure. We measured the phase space distribution of a picosecond slice of an electron beam in transverse and longitudinal tomography, improved the photocathode drive laser, enhanced the beam's brightness, improved the beam's phase and amplitude stability, 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 CO_2 laser.

Near-term Program: Next year we hope to complete upgrading the computer control system, with improvements in the electron beam brightness and associated beam diagnostics, install a bunch compressor, upgrade the high-energy beam transport system, and begin operations with the CO_2 laser.

Long-term Program: In the next five years, we expect to increase the facility's energy to 120 MeV, construct a new Experimental Hall for more beam lines and a strong laser field experimental station for experiments that do not require the electron beam (such as generating GeV ion beams, plasmas). We intend to increase beam time to users and add new user experiments. Work will continue to get ever-higher beam brightness from our photoinjector. The Thomson x-ray source will be extended to sub-picosecond pulse length. The new bunch compressor will open up research in femtosecond electron bunches. New experiments will include plasma and laser wake-field acceleration, optical stochastic cooling and studies of magnetized electron beams.

4.1.5 Laser Electron Accelerator Facility (KC)

The Laser Electron Accelerator Facility (LEAF) performs research in radiation chemistry and photochemistry that delivers synchronized picosecond electron and photon pulses for ultrafast studies of ionization in condensed media. LEAF is opening a new window on the ultrafast dynamics of electron attachment, transfer, and mobility in condensed phase systems, and elucidating the dynamics of highly energetic molecules, such as radical ions, that are candidates for new energy storage and solar energy conversion systems.

Present Program: We studied the thermodynamics of electron attachment and mobility in supercritical fluids, made the first measurements of the spectrum and reactivity of the solvated electron in ionic liquids, and investigated rapid electron tunneling in organic molecules. Our LEAF priorities are to develop powerful, unique instrumentation that will allow us to carry out outstanding science.

Near-term Program: In 2003, we will continue groundbreaking investigations of electron reactivity and dynamics in condensed media. We are initiating two upgrades to establish unique new scientific capabilities, aimed for initial experiments in FY05 and FY06. These are:

- *Ultrafast Single Shot (UFSS) system* will obtain kinetic traces with ~10ps resolution from single electron pulses. This will allow studies of fast charge transfer in small samples of custom-synthesized molecules to explore new concepts in molecular electron coupling.
- *Pulse pump probe (PPP) system* will generate radical ions with an electron pulse, and then examine excitation dynamics with laser pump-probe experiments at 0.1ps resolution. Experiments will enable investigations of ultrafast short-distance charge transfer under distance-independent energetics obtained in electron pulse experiments.

We are also increasing user access. Our current studies are collaborative ones that provide a strong basis for developing a user program. We prepared a user plan that will start in FY04, linking LEAF to the CFN.

Future Program: The UFSS will make LEAF a world center for studying fast electron transfer reactions, and will include both collaborative and General User Access. The new UFSS and PPP capabilities will enable studies of radiation-induced chemistry relevant to electron transport in solar energy conversion and energy storage, as well as molecular charge transport in nanoscale materials, with the CFN. We will assess the feasibility of adding capability for transient vibrational spectra to enhance structural understanding in ultrafast measurements.

4.1.6 Deep Ultra Violet Free Electron Laser

The Deep Ultra Violet Free Electron Laser (DUV-FEL) is a dedicated experiment for developing advanced FEL sources and science that delivers excellent temporal coherence and ultra-short (femtosecond) output pulses through chirped pulse amplification or cascading multiple High-Gain Harmonic Generation (HGHG) stages. This principle had been proposed at BNL about a decade ago and is now being successfully demonstrated.

The accelerator consists of a BNL photocathode gun driven by a solid-state laser system scaled from the LEAF gun driver. A four-tank S-band SLAC linac was fitted with an electron bunch compression chicane developed in collaboration with LANL and SLAC. The accelerator provides beam energies above 200 MeV, with pulses potentially as short as 100 femtoseconds and charges on the order of 1 nC. The 10m long NISUS undulator, used for the FEL experiments, will range into the deep ultraviolet region (<100 nm). The DUV-FEL offers a flexible yet economical platform for a host of accelerator and applications experiments. Thus far, we conducted a series of FEL experiments including Self Amplified Spontaneous Emission lasing at 400 nm, direct laser seeding of the electron beam at 266 nm, and HGHG from 800nm laser seed light to 266 nm FEL light.

An experimental user program has begun using the DUV-FEL's unique light beam, including the 88 nm third harmonic of the FEL fundamental. The first experiments, based on ion imaging techniques

developed in the BNL Chemistry department, examine problems in chemical physics that require higher intensity VUV light than is readily available in laboratory lasers. These experiments have shown the remarkable pulse-to-pulse amplitude stability that results from the laser seeding of the FEL light. The DUV-FEL was developed with AFSOR funds.

4.1.7 Transmission Electron Microscopy Facility (KC)

Present Program: The Transmission Electron Microscopy (TEM) facility has a unique, 300kV field-emission microscope. It is capable of high-resolution transmission and scanning atomic and magnetic imaging, spectroscopy, energy filtered electron diffraction, and electron holography. Our research focuses on understanding nanoscale crystal structure and defects, and their role in determining the physical properties of advanced materials. Recently, this group moved to the Nanoscience Department.

This year, we developed a novel interferometric technique based on coherent electron diffraction, coupled with imaging, to measure lattice displacements in crystal defects with accuracy down to 1 picometer, a tenfold improvement over existing techniques. We also developed and implemented phase retrieval methods, including electron holography, to map the valence electron distribution and interfacial charge variation in superconductors. Using advanced magnetic imaging methods, we studied the *in-situ* magnetic behavior and local induction distribution as a function of temperature and field in hard magnets, and in magnetic nanoassemblies fabricated in-house. We will become an important contributor to the TEAM Project.

Near-term Program: Besides the continued study of the electronic and magnetic structure of functional materials, we will explore new approaches to the phase problem for non-periodic objects. We will continue to develop TEM based electron lithography to fabricate tailored structures exhibiting novel magnetic properties, and to understand their exchange coupling and switching behavior. A state-of-the-art omega filter microscope with a monochromator (funded by NYSTAR and DOE) providing < 0.2eV energy resolution, will boost our research on nanoprobe electron energy-loss spectroscopy.

Long-term Program: The TEM facility complements the capabilities in Physics, NSLS, Chemistry, Biology, and is a central component of the CFN. A user program is being developed through the CFN's Jumpstart Program. Key areas of investigation will be:

- Atomic structure, bonding, and charge variation at nanostructured interfaces with unprecedented spatial resolution using quantitative electron diffraction, imaging, electron energy-loss spectroscopy, Z-contrast, and structural modeling techniques.
- Magnetic and ferroelectric behavior, and shape-memory effects of functional materials and devices, including p-n junctions, under controlled stress, magnetic, and electric fields.
- Nanoscience and technology, including fabricating quantum-structure using electron lithography with spatial resolution (line width) below 5nm.
- Single atom imaging and imaging analysis with BNL biologists for biological and materials research.
- Development of a new generation achromatic microscope (<0.07nm spatial resolution and <0.1eV energy resolution) with aberration correctors and a built-in scanning tunneling microscope (or magnetic force microscope) to build a true nano-lab inside the microscope for manipulating structures and measuring properties.

The Laboratory is a partner in the TEAM (Transmission Electron Aberration-corrected Microscope) project, involving collaborative R&D among five BES-sponsored electron beam microcharacterization centers; Frederick Seitz Materials Research Laboratory; the National Center for Electron Microscopy at LBNL; ORNL; and, ANL. Parallel R&D activities focus on designing UHV experimental modules and microelectromechanical system stage, sub-Angstrom Z-contrast imaging and atomic resolution electron energy loss spectroscopy, and modeling electron optics. BNL's emphasis is on

developing detectors, monochromators, and techniques, such as position sensitive coherent electron detection. The program interfaces with its partners through quarterly meetings of the directors and exchange visits among researchers at the institutions.

4.1.8 Center for Data Intensive Computing (KJ)

The CDIC plays a role in the SciDAC (Scientific Discovery through Advanced Computing) program through Terascale Simulation Tools and Technologies (TSTT). TSTT is a multi institutional effort to develop interoperable adaptive grid and meshing tools for a variety of scientific problems. Applications specific to BNL include RHIC; US-ATLAS, climate modeling and simulation; nanoscience; computational biology; brain imaging; protein structure and function; and, computational fluid dynamics. This data must be processed, visualized, analyzed, understood, and stored. Ultimately, data achieves value by influencing human decisions; increasingly, such decisions will be computer-assisted. Hence, the modern theory of data management goes beyond sheer volume to data intelligence.

The CDIC's research program in computational science will develop new approaches to managing large-scale, highly complex data and to assessing their inherent uncertainties. The CDIC has close links with the Department of Applied Mathematics and Statistics and the Computer Science Department at USB, and with BNL's Information Technology Division. The Center will promote excellence in scientific computing at BNL.

4.2 Scientific Programs

These sections describe the ongoing research programs with plans for the next 5 years. Programmatic initiatives that are being planned by research groups are included with the relevant programs.

4.2.1 Nuclear and High Energy Physics (KA/KB)

The DOE/SC High Energy and Nuclear Physics program sponsor experimental and theoretical Nuclear and High Energy Physics. Scientists in the Physics Department conduct most of the research, while solar neutrino research is managed by the Chemistry Department.

4.2.1.1 Nuclear Physics -Quark Gluon Plasma, Solar Neutrinos, and Spin Physics (KB)

Present Program: BNL has a large, strong research program in nuclear physics, supported by the DOE's Nuclear Physics Division, that complements the Laboratory's user facilities. BNL is responsible for maintaining RHIC's five experimental detectors as fully functional forefront instruments and for providing leadership in experimental nuclear physics, through our five RHIC research groups. They are the Heavy Ion Research Group (BRAHMS), PHENIX, PHOBOS, STAR and the RHIC Spin Group (leading the RHIC spin program and the pp2pp experiment). During FY 2003, they will operate and maintain all detectors and participate in the third RHIC data taking run using full-energy (100 GeV/amu) deuteron on gold colliding beams and the first run with polarized proton beams.

Nuclear physics staff also supported a limited set of fixed-target medium-energy user experiments with secondary kaons and pions beams from the AGS that focused on important special topics, particularly hypernuclei. The DOE terminated the operation of the AGS for such experiments in FY 2003 and phased out the hypernuclear program; staff scientists will be reassigned to areas, such as the RHIC spin program; analysis and publication of data already collected will be completed.

Another nuclear science area is the search for solar neutrino flavor oscillations and mass. BNL has actively participated 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. Published SNO results confirm that the model of the sun predicts the number of electron-type neutrinos

that the sun produces, and that they are transformed to other neutrino types as they travel to the earth. This research will continue in FY 2003 and 2004.

A world-class nuclear theory group is working on QCD, including phenomenological models of matter at high energy density, the high-energy limit of hadronic interactions and nuclear structure, spin physics and hypernuclei. We collaborate closely with nuclear theorists in the RIKEN BNL Research Center (RBRC), and at Columbia, SUSB, and Yale. The RBRC, located at BNL, is a complementary theory and experimental physics institute. RBRC scientists are an integral part of the nuclear physics research at BNL and are funded primarily by the RIKEN Institute of Wako, Japan.

Nuclear Physics research at BNL includes the polarized-beam/polarized-target Laser Electron Gamma Source (LEGS) Experiment at the NSLS that probes the electromagnetic structure of the nucleon, including the nuclear structure around the delta resonance region. These studies will provide unique data for polarized photons interacting with polarized hydrogen and deuterium (frozen spin) targets and will be used to measure the spin-polarizability and Gerasimov-Drell-Hearn spin-sum rules. Future work will elucidate B^0 production from polarized neutrons from the same targets. We expect that it will continue through 2006.

Future Program: The RHIC-based experimental groups will be further strengthened, and the experimental and theoretical nuclear physics supporting the evolving RHIC, RHIC Spin and LEGS programs will continue. During FY 2003, BNL made progress in consolidating a strong RHIC Spin experimental group in the Physics Department to provide intellectual strength to the spin physics program, comparable to the existing relativistic heavy-ion program. The BNL RHIC groups have started planning the evolution of detectors as new results and research directions appear. R&D proposals for detector upgrades were presented to the newly impaneled Detector Advisory Committee who endorsed them and recommended R&D funding priorities. They are awaiting DOE funding. BNL's research groups will be foremost in defining and accomplishing the work with the RHIC community.

The two real-time operating solar neutrino detectors, Super Kamiokande and SNO, have thresholds of ~ 5 MeV, and are sensitive only to ^{8}B neutrinos. Only GALLEX and SAGE, the radiochemical solar neutrino detectors, had thresholds below 1 MeV and could observe ^{7}B (Homestake) neutrinos and pp. A concept is under study at BNL for a neutrino detector, the Low Energy Neutrino Spectrometer (LENS), with a very low threshold, ~0.25 MeV, to measure the energy spectra and fluxes of pp and ^{7}B neutrinos in real time. BNL joined the new international LENS collaboration. R&D on LENS will continue through 2003, with the goal to design and build a LENS prototype in mid 2003. If this proof-of-principle test is successful, a proposal will be made to the DOE in 2004-2005 for a ~100 ton LENS detector.

4.2.1.2 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. Presently, BNL groups lead and support precision experiments at the AGS and participate in experiments at other facilities, such as the D0 Experiment at Fermilab and the ATLAS Experiment at the LHC.

To accomplish this research mission, the DOE's Division of High Energy Physics supports two experimental groups (Electronic Detector and Omega), and a particle theory group. They are expected to continue their current mission at least for the next decade. BNL also supports a small experimental group for advanced accelerator physics in the Center for Accelerator Physics (CAP). CAP scientists are engaged in a program of accelerator R&D to explore the technical feasibility of muon colliders, muon storage rings, and high-power conventional sources (horn-focused) of neutrino beams.

Future Programs: The Electronic Detector Group (EDG) will continue to study rare kaon decays to uncover experimental manifestations of CP-violation. Such decays represent an important experimental window into the nature of CP-violation, and a tool for exploring physics beyond the Standard Model (SM). The latter will continue to be an important topic for many years, and BNL's experimental group will continue to be a leader in this field. The current experiment in this program,

E949, should make the first definitive measurement of the very rare Kaon decay, $K^+ \rightarrow \pi^+ \upsilon\bar{\upsilon}$. The next experiment will be the companion neutral decay KOPIO, approved with MECO for funding by NSF (Section 3.1.2). The EDG also participates to a smaller extent in the MINOS neutrino experiment under construction at Fermilab; it will confirm the neutrino oscillations observed in the Super Kamiokande experiment underway in Japan and provide better statistics on the ν_μ to ν_τ oscillation channel.

The Omega group engages in experiments at the energy frontier of particle physics, the D0 Experiment at Fermilab, and the ATLAS Experiment at the LHC. The BNL group contributes intellectual leadership, and important hardware and software. BNL is the host Laboratory for the U.S. ATLAS Construction Project and the U.S. ATLAS Research Program that includes computing, detector maintenance and operations, and R&D upgrades. Its cost is expected to rise to about $35 M/year by 2007. The Research Program will support all U.S. scientists participating in the ATLAS experiment once it becomes operational and serves as a source of data on high energy physics.

The Omega Group takes part in the muon (g-2) experiment at the AGS, producing a new precision measurement that constitutes one of the best near-term probes for revealing evidence for physics beyond the SM. Published results in FY 2002 upheld findings from FY 01; there could be additional data runs in future years. It could be succeeded by a new experiment using the muon (g-2) ring to provide new upper limits on the muon neutrino mass. The Omega Group's plan for the next 20 years is to explore particle physics in D0 and ATLAS.

The BNL High Energy Theory group will continue to pursue a wide range of theoretical studies in particle physics, including electro-weak studies, collider phenomenology, perturbative Quantum Chromodynamics, lattice gauge theory, and field theory with emphasis on finite temperature effects. This work supports BNL's experimental program, as well as advancing the forefront experimental program worldwide. Recent examples are detailed calculations of next to leading order and next to next to leading order Higgs production at hadron colliders.

4.2.1.3 Program Initiative ATLAS Physics Analysis Center

The U.S. investment in the European Large Hadron Collider, i.e., about 20% of the detectors' and a significant part of the collider's costs, will be optimized if U.S. scientists take a leading role in analyzing the experimental data and are seen at the vanguard of the program's frontier discoveries. Accordingly, the U.S. partners in ATLAS and CMS are pursuing two strategies during its construction: 1) supplying much of the expertise for developing the computing and software to acquire and analyze the data from the detectors once they begin operating; and, 2) planning analysis centers in the U.S. where groups of physicists can lead the data reduction and analysis. Since BNL is the host laboratory for the U.S. ATLAS Collaboration, it is natural to establish a Physics Analysis Center here. The Laboratory already houses the ATLAS Tier-1 Computing Center. We expect that BNL will provide space for members of the Collaboration to interact with colleagues, learn the most effective analysis techniques, and develop new approaches for analyzing the experimental data as it is prepared for analysis in the CERN Tier-0 and BNL Tier-1 Computing Centers. A core group of BNL researchers, probably ten, will oversee the operations of the Physics Analysis Center and ensure its effective leadership and program opportunities for group research initiatives, develop and offer tutorials and seminars, and maintain and improve the technical software and analysis tools for the visitors. Staff size will be determined as the concept is developed and formally proposed to the DOE HEP's Division. It will be optimum for the Center to start as early as FY 2005, so that the core analysts can develop and tune up for data using simulated data already created by the Collaboration.

4.2.2 Advanced Facilities-Concepts, Designs and Instrumentation (KA/KB/KC)

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

4.2.2.1 Accelerator Physics

BNL, with its suite of diverse accelerators (such as the AGS, RHIC, NSLS, Tandem, and ATF) has one of the largest concentrations of innovative accelerator scientists in the U.S. In addition to improving and upgrading BNL's accelerators, we pursue a program of continuing accelerator physics research. In particular, the development of RHIC to a high luminosity collider (Section 3.1.1.1) requires exploring concepts at the forefront of accelerator physics that are applicable to future RHIC upgrades and other high luminosity colliders, such as the LHC. Experiments to study advanced concepts are performed at the ATF (Section 4.1.4). BNL also maintains a modest graduate program in accelerator physics that we are seeking to expand in collaboration with SUSB.

The development of electron cooling of RHIC beams requires a very intense and bright electron beam exceeding present performance parameters significantly. R & D has started in this area (Section 3.1.1.1).

BNL provides accelerator design and components to outside clients, including the complete design and construction of the Accumulator Ring and Beam Transport for the DOE's SNS construction project that will be active through 2006. BNL completed construction of the NSRL (Section 5.1.1) for NASA and the design of CIRC (Section 3.1.8) for a potential DOE-NE construction project. We are designing a 250 MeV rapid cycling medical synchrotron for a next generation proton cancer therapy facility.

We participate in the international "Neutrino Factory and Muon Collider Collaboration," that pursues R&D on capturing an intense beam of muons in an accelerator/storage ring complex. A successful muon storage ring design could facilitate precise characterization of neutrinos or later, provide a basis for a muon-muon collider to extend the frontier of particle physics beyond the era of the LHC. The BNL Center for Accelerator Physics provides a focus for this work. Its goal is to explore the feasibility of a multi-TeV (Trillion electron volts) collider. The national program includes computer simulations 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 beam's emittance, and acceleration to a high energy for injection into a storage ring. These studies will resolve the technical impediments to a research facility where muons could be stored in a racetrack ring to create an intense beam of high energy neutrinos for neutrino physics, or circulated in a collider where muon-muon collisions could be used for investigating TeV scale high energy physics. In addition to simulations and other design studies, BNL's specific mission is to conduct an experimental targeting study, E951, using high-intensity proton beams from the AGS. The AGS 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.

Within the Neutrino Working Group, we developed a proposal to produce a neutrino super-beam at BNL (Section 3.1.3). A new superconducting 1.2 GeV linac would be used for low-loss injection of H^- into the AGS and a new AGS main power supply would allow for a 2.5 Hz repetition rate. Further upgrades to 4 MW beam power are being examined.

These activities, plus the exploration of concepts for the future evolution of BNL accelerator facilities, complete the spectrum of accelerator physics activities at BNL. All are expected to continue, supporting the needs of the Laboratory, and responding to opportunities to contribute to the national program of accelerator R&D, design, and improvement.

4.2.2.2 Superconducting Magnet Research and Development

Present Program: Since the 1980s, a primary BNL core competency is designing, constructing, and testing substantial numbers of large, superconducting magnets, especially for accelerators. As it was fully institutionalized during the development of the RHIC and SSC accelerators, this capability matured into a leading source of U.S. expertise. In parallel, we began a vigorous program in designing and applying high temperature superconductors (HTS) to innovative magnet designs. Current R&D focuses on the magnet requirements of future accelerators and on novel designs to upgrade existing ones.

Near-term Program: Work centers on building and testing a limited number of superconducting dipoles for the LHC Accelerator Project, testing all the superconductor cables for the CERN-based LHC accelerators, and building spare superconducting helical dipoles for RHIC, as required. The Superconducting Magnet Division is engaged is designing and fabricating mini-beta quadrupoles for the BEPC II machine upgrade at IHEP in Beijing, based on similar items we produced for upgrading the HERA machine at DESY in Germany.

BNL entered a collaboration several years ago with the GSI Laboratory in Germany to develop rapid-cycling superconducting magnets. It involved changes to the superconducting cable and the method of its manufacture into a coil, and specialized cooling and mechanical modifications. The first results were very successful with a demonstrated sustained ramping at 3KA/sec to beyond 4T (the cable's limit) with a short, 1m, RHIC style dipole magnet. This phase of the R&D program will conclude with field quality measurements at these high ramp rates. While the GSI-proposed in-house program determines the initial requirements, other applications interest BNL, such as injectors to future very high-energy hadron colliders.

The recent HEPAP 20 year plan gave its highest priority rating to an LHC luminosity upgrade and a 1 Tev Linear Electron-Positron Collider (LC). The BNL Superconducting Magnet Division is active in both areas. The LHC luminosity upgrade calls for next generation high field/gradient dipoles and quadrupoles that can operate reliably in a high radiation environment; this can only be achieved with Nb3Sn or HTS. In collaboration with Fermilab and LBNL, BNL is starting R&D towards developing this technology.

It is generally accepted that the next major international HEP facility will be a linear collider (LC). The Magnet Division produced an accelerator design for the final focus region based on compact superconducting quadrupoles using BNL's unique direct wind construction that permits much greater operational flexibility than an alternative based on a permanent magnet. It has sufficient technical advantages that the US Linear Collider Steering Committee adopted it as the baseline. The technical requirements are especially demanding due to space constraints and vibration, with additional challenges imposed by the 22 MW beam in a 20mm aperture. The first phase of this program involves producing and testing a prototype

The RHIC luminosity upgrade will include a solenoid magnet with tight tolerances on alignment and field uniformity. A measuring system with the 10^{-6} precision needed to verify these requirements is itself a formidable proposition. The Magnet Division started the conceptual design of a prototype. We also are investigating the possibility of using HTS for very high field (25T) NMR. Only HTS can reach the 25T field level needed for a next generation device, but issues related to stability and field quality need to be demonstrated. Small test coils will be used to develop power supplies with the necessary stability.

Long-term Program: A long-term goal is to develop HTS magnets for high field and hostile environment situations. The Magnet Division works with other national laboratories and industrial partners on these. We are investigating the potential application of HTS to an ultra-high field NMR solenoid. Our R&D and production work are expected to continue, supporting BNL's long-range accelerator programs. In this work, we also collaborate with the Superconducting Materials Group in the Materials Science Department.

4.2.2.3 Advanced Instrumentation

Present Program: BNL's Instrumentation Division offers strong core competencies in advanced detector, instrumentation, and source development related to our main user facilities and to other DOE facilities. It is a research division that develops state-of-the-art instrumentation for BNL's scientific and technical research organizations, providing them with expertise in detectors, microelectronics, micro-fabrication, lasers, and optics; it offers specialized laboratories and development areas. The current focus includes the following:

- Semiconductor detectors, Gas and noble liquid detectors,

- Lasers and optics,
- Monolithic circuits, Micro- and nano-fabrication

In many technical areas, the instrumentation developed at BNL was first-of-a kind, enabling scientists to pursue experiments that could not have been attempted without it. Examples are liquid argon calorimetry, silicon drift detectors, cathode pad chambers, low noise electronics, and optics metrology. The Division's size and mission is expected to remain stable to preserve and encourage continued innovation of instrumentation concepts that look to future capabilities for BNL's scientific and technology applications.

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 U.S. ATLAS Project and RHIC detectors, direct our intensive R&D to upgrading them, and also to the new detector envisioned for the eRHIC facility, and detectors for the future linear accelerator. We will undertake various projects for the Medical Research Program, new detectors for protein crystallography, and neutron detectors for the SNS. We expect several new projects that will support the applied science programs and the new fixed-target experiments, MECO and KOPIO. New efforts will center on improving the electronic systems, especially their radiation hardness. Participation in astrophysics programs, such as the LSST will be pursued. In the immediate future we intend to upgrade and enhance BNL's capability in nanoscale patterning for basic science studies and for sensors.

4.2.3 Nanoscale Science (KC)

Many physical and chemical properties of a material change dramatically as the object reaches a size of about 30 nanometers, or less. 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, led to a major national and DOE program in nanoscience and technology. BNL aligned its interdisciplinary nanoscience plan with the DOE's goals.

BNL's nanoscience research, a collaboration among six internal departments and divisions, will establish an understanding of the chemical and physical responses of *functional nanomaterials* and develop *new nanoscale materials probes*. At its center is the CFN (Section 3.1.5). In progress at BNL are six nanoscience research areas that are shared with the CFN:

- Functional nanoscale strongly correlated oxides
- Magnetic nanoassemblies
- Nanocatalyst materials
- Charge transfer in molecular nanosystems
- Functional thin organic films
- Applications in nanoscience

The Laboratory invested $6 million through LDRD in nanoscience projects to hire postdoctoral fellows and staff in specific areas, such as nanotube imaging. The projects include nanomagnetism, and charge transfer in molecular materials and catalytic materials; other BNL funds enhanced instrumentation for nanofabrication and nanomaterials synthesis.

Three Nanoscale Science Engineering and Technology proposals were funded: Catalytic Nanomaterials, Charge Transfer at the Nanoscale, and Nanotemplate Directed Assembly of Soft Matter and Biomaterials. Essential components of nanoscience research at BNL are our growing program in TEM and a Materials Synthesis effort in the Physics Department, both of which received a major boost in funding.

BNL's long-term goal is to become a regional leader in the fundamental physics, materials science, and chemistry of nanoscience, while building on past successes in bulk functional materials, such as piezoelectrics, and to forge permanent links to nearby universities and industry.

4.2.4 Condensed Matter Physics, Materials and Engineering Sciences (KC)

Brookhaven's condensed matter physics, materials science, and nanoscience programs explore magnetism, superconductivity, and phase transitions in bulk materials, at surfaces, and in the self-assembly of soft-materials. Much of the experimental work requires instruments developed at our major user facilities and fosters continuing interactions of the facility and BNL staff. Our projects are interdisciplinary and collaborative with other scientists at Brookhaven, universities, other national laboratories, and industry.

4.2.4.1 Neutron Scattering

Present Program: The neutron scattering program aims at understanding the physical principles underlying cooperative phenomena in complex solids by elastic and inelastic neutron scattering, including structural and magnetic phase transformations, magnetic structure, and elementary excitations, such as spin waves and phonons. A major theme concerns strongly correlated electron phenomena in transition-metal-oxide compounds, such as high-temperature superconductivity in the layered cuprates and charge-stripe order in nickelates. The interplay between electronic, magnetic, and structural degrees of freedom is of particular interest, and also the nanoscale spatial inhomogeneity resulting from competing interactions. We explore dimensional cross-over in systems of weakly coupled spin-chains, quantum critical phenomena, the effects of nanodomains in relaxor ferroelectrics, and shape-memory alloys exhibiting Martensitic phase transformations. These phenomena are studied by neutron scattering at US facilities and abroad, often complemented by parallel x-ray scattering or electron spectroscopy studies at the NSLS. Crystal growth and bulk sample characterization are new components, in response to the DOE's initiatives in Complex Materials and in Nanoscience.

Researchers detected phase separation between commensurate and incommensurate magnetism in lightly-doped $La_{2-x}Sr_xCuO_4$, reported the first measurement of the full spin-wave dispersion in a stripe-ordered nickelate, and discovered a surprising ground-state structure in an important piezoelectric material. Through the Center for Neutron Science (CNS), we established a cooperative program with the NIST Center for Neutron Research, stationing a junior level researcher there.

Future Program: We will continue to study quantum phase transitions in low dimensions, especially spin chains, nanoproperties of ferroelectrics, and the origins of high T_c superconductivity in complex materials. Large crystals of a stripe-ordered cuprate will be grown to study high-energy spin dynamics at ISIS. We will obtain a second furnace for crystal growth, and a magnetometer for sample characterization. The SNS approved a joint proposal with the CNS for designing and constructing HYSPEC (vide infra). The CNS will hire a project scientist through the SNS to oversee construction. BNL scientists are also involved with other instruments that will be built for the SNS.

4.2.4.2 Center for Neutron Science

The CNS seeks to develop and maintain world-class neutron science capabilities at BNL and continues to support neutron facilities and research at other DOE facilities. Research focuses on activities at NIST, HFIR, and ISIS. BNL's CNS neutron program, includes:

- In a major new initiative for the Center for Neutron Science, an instrument development team, led by Brookhaven, is designing a novel neutron instrument for the SNS, a hybrid spectrometer (HYSPEC) that uses conventional choppers for defining the incident beam wavelength, and a focusing crystal to optimize the flux on the sample. It is being built at ORNL.The condensed matter physics community will use it to study small single crystals of new materials. In addition to having the highest flux on

sample of any spallation source inelastic instrument, it will be the only one capable of full polarization analysis inelastic studies. The SNS advisory committee approved this concept, CD-0 was formally approved, and a proposal for funding was sent to the DOE.

- Relocating a US-Japan instrument from the HFBR to the cold neutron source at HFIR. Operated under the US-Japan Cooperative Program on Neutron Scattering, it will provide preferred access to US and Japanese collaborations.
- Planning another cold source instrument for the HFIR, particularly through instrument design.
- Refurbishing instruments located in NIST's reactor hall for which we will receive preferred access to use them.
- Developing novel large area detectors with good spatial and excellent temporal resolution for neutron applications, in collaboration with BNL's Instrumentation Division, supporting instrument development at BNL and for the SNS.
- Developing a regional education and training program at BNL to train graduate and postdoctoral fellows by interacting with scientists doing neutron-science measurements and instrumentation design. A regional short course, in collaboration with NIST, is planned for young researchers to gain hands-on experience in neutron and x-ray diffraction at the NIST reactor and the NSLS.

4.2.4.3 X-ray Scattering

Present Program: The program's central objective is to investigate the structural, electronic, and magnetic properties of condensed matter systems using synchrotron-based x-ray scattering techniques, particularly surface and interfacial phenomena, including thin films, electronic ordering in transition metal oxides, and electronic excitations in solids. Much of it is collaborative with other BNL departments, universities, industry, and other national laboratories. This work, primarily at NSLS and APS beamlines, supports the DOE's initiatives in Complex Materials and in Nanoscience. A successful NSET proposal on nanotemplate directed assembly of soft matter and biomaterials allowed us to jointly hire, with the new soft matter group, a leader for x-ray scattering studies of thin organic films on nano-templated surfaces, and a second scientist. This year, we observed excitations consistent with spin-charge separation in $SrCuO_2$, and discovered large vesicle-like structures formed by polyoxomolybdates in solution, a possible new solute state.

Future Program: Researchers will extend their studies of charge and orbital ordering by utilizing soft x-ray resonances to directly probe the relevant 3d electrons for the first time, continue to explore the wetting of nano-landscaped surfaces, extend the inelastic x-ray scattering program to include electronic excitations in manganites, and expand the in-house synthesis and characterization of polyoxomolybdates with a new hire in synthesis. These studies will benefit from the construction of the BNL CFN. The BNL-led Inelastic X-ray Scattering project at the APS will start constructing their hutches by the end of the year. Commissioning experiments are planned for three years from now. Its order of magnitude improvement over existing facilities will enable new classes of experiments, from polymer dynamics in the meV range, to electron dynamics in strongly correlated electron systems.

4.2.4.4 Soft-Matter

Present Program: This program investigates the fundamental interactions in soft matter and biomaterials that give rise to their nano scale structural properties in the bulk, including how their structure and growth can be modified at nanotemplated surfaces. We also develop novel methods to process these materials into technologically important nanostructured assemblies. The Soft Matter and Biomaterials Group is a collaboration of the Physics Department, the NSLS, and universities; it directly meshes into the CFN.

This year, researchers investigated the phase behavior of alkanes, alcohols, fatty acids, and thiols (Fig. 8a) on liquid mercury surfaces, the self-assembly of surfactant templated thin-film silica mesophases, the wetting of organic liquids on nano-landscaped surfaces, and the kinetics of self-assembly in thin block-copolymer films and in solution processible organic transistors. Studies of phase transitions between liquid crystal phases with nanoscale interlayer orientational order, using resonant x-ray diffraction, yielded evidence for intra-layer nanoscale orientational order

Future Program: Nano-templates, prepared by a variety of methods, will be used to probe nanoscale interactions, and direct the assembly of liquids, smectic liquid crystals, membrane proteins, and biominerals. Researchers will extend their studies of wetting of nano-landscaped surfaces by varying the pore spacings and creating nanogrooved surfaces using e-beam lithography. Nanoscale chemically patterned surfaces will be developed, and the formation of nanodroplets studied as a function of the chemical potential. We will order a specially designed AFM to explore lipid-protein complexes in controlled humidity/vapor conditions. Our collaborators are preparing substrates with AFM-scribed nanopatterned polymer alignment layers and with AFM dip-pen lithographed chemically patterned surfaces; we will study their effect on liquid crystal ordering and phase transitions.

4.2.4.5 Electron Spectroscopy

Present Program: The Electron Spectroscopy Program relates the electronic structure and dynamics of materials to their conductivity and physical properties, in support of the DOE's initiatives in Complex Materials and Nanoscience. It includes:

- 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,
- Spin-polarized valence-band photoemission studies of magnetic films and surfaces.

This year, researchers carried out high-resolution photoemission studies to explore the correlation between effective dimensionality in layered strongly correlated systems and the character of their excitation spectra, to characterize the infrared spectrum of calcium copper titanate, and the optical and electronic properties of MgB_2. The Pulsed Laser Deposition (PLD) facility was commissioned and a range of thin films was grown, including the high dielectric constant material calcium copper titanate, $NdNiO_3$, $LaCuO_4$ and $LaNiO_4$.

Future Program: We will continue high-resolution photoemission studies of other two-dimensional charge-density-wave systems and high T_c materials. Work will proceed on the optical properties of ultra-thin metallic films, emphasizing the adsorption of organic and insulating layers. The PLD facility will be upgraded to include laser assisted molecular beam epitaxial growth, together with in situ photoemission studies. We will explore using time-dependent photoemission for studying quasi-particle self-energies. A new facility for infrared studies of materials under pressure is being commissioned.

4.2.4.6 Condensed Matter Theory

Present Program: In response to the DOE's initiatives in Complex Materials, Nanoscience, and Scientific Computing, the theory group continues collaborations with neutron scattering scientists on quantum magnetism and high temperature superconductivity, and with electron spectroscopists on charge transport in insulators and "bad metals". We also address aspects of the electronic structure of solids. This year, BNL developed theoretical techniques to distinguish evolved and random features in a complex network, such as interacting proteins in yeast, discovered a non-perturbative description of the Mott-insulator metal transition for weakly coupled chains, and calculated the dependence of the lattice constant on crystallite size for $BaTiO_3$ nanocrystals, as determined from powder diffraction. A particularly

important theoretical achievement was the formulation and solution of a model of frustrated magnets that allows fractional quantum number excitations (spinons) to propagate beyond one dimension by building dimer 'bridges' between different ground states. It is a novel, highly original mechanism inherently based on strong correlations.

We established The Institute for Strongly Correlated and Complex System. By hosting visitors, arranging workshops, and organizing coherent approaches to outstanding problems, BNL became a leader in this evolving area. In less than a year, the Institute generated 7 publications.

Future Program: Researchers will use non-perturbative techniques to study spin and charge transport in nanowires, Josephson junction arrays and quantum dots; investigate various phases of strongly correlated electrons in nanotubes; explore experimentally determined optical conductivities of "bad metals" using approaches beyond Fermi liquid theory; carry out first- principles studies of the electronic and magnetic properties of complex materials including bulk and nanopatterned thin films of transition metal oxides; and apply statistical methods related to economics, biology, and soft matter. The relationship between the models of frustrated magnets and models of Quantum Computation will also be explored.

4.2.4.7 Materials Chemistry and Electrochemical Sciences

Present Program: Materials chemistry research involves the synthesis and structure of conducting polymers, while electrochemical research investigates the mechanisms of metal-environment interactions and new materials for fuel cells and batteries.

We take an interdisciplinary approach to synthesizing and characterizing ion conducting polymers. The goal is to design and synthesize new functional groups and ionic conducting polymers based on ion-ion and ion-polymer interactions in non-aqueous electrolytes. Absorption and Raman spectroscopy studies indicate that ion pairing and cluster formation occur in the latter. All conventional non-aqueous electrolyte solvents are Lewis bases that interact strongly with cations. Our new approach is to modify the solvent to enhance anion-solvent interactions by adding to it new Lewis acids synthesized at BNL. The compounds form complexes with the anions, dissociate the ion pairs, and free the cations, thereby significantly increasing the number of charge carriers, the conductivity, and the Li^+ ion transference number. Researchers use electrochemical and conductivity studies and a wide array of spectroscopic techniques, such as x-ray absorption spectroscopy, to elucidate ion-ion and ion-solvent interactions.

Our program on the mechanisms of metal-environment interactions studies beneficial and destructive reactions that occur on metal surfaces, resulting in the formation of protective coatings or products of corrosion. It focuses on the processes by which these reactions take place, and characterizes the physics and chemistry of the products, and their dependence on the nature of the metal or alloy. The research emphasizes in situ methods and takes advantage of the TEM and NSLS.

Future Program: We will continue work in key areas, and initiate research as outlined below:

- Design, synthesis, and characterization of polymer and gelled electrolytes with Lewis acid centers, emphasizing cation-conducting polymers with conductivities $>10^{-4}$ S/cm at 25°C.
- Raman studies of polymer electrolytes.
- Development of functional nanomaterials for batteries and fuel cells (with SUSB), and other novel nanomaterials
- Study of oxide layers formed in organic media.
- Study of localized corrosion of active metals, including aluminum and magnesium.
- Chemical and physical properties of oxide films formed on transition metal surfaces.
- Development of new soft x-ray techniques for *in situ* studies.

4.2.4.8 Superconductivity and Magnetic Materials

Present Program: Elucidating the physical and chemical factors underlying the structure-sensitive properties of superconductors and advanced magnetic materials is key to implementing them in high-efficiency power distribution systems and energy-efficient motors, actuators, and sensors. Our program investigates the properties of superconducting materials with high critical temperatures, fields, and current densities, and of high energy-product advanced permanent magnets, methods of characterizing and fabricating superconductors and magnets, as well as exploring new materials. The primary goal is to understand the nanoscopic, microscopic and microstructural factors influencing the materials' properties.

The superconductivity research program focuses on high-temperature superconducting cuprates, particularly $YBa_2Cu_3O_7$ (YBCO), and the recently discovered superconducting compound MgB_2. Fabrication of superconductors is done primarily in the MSD, but collaborations within and outside of BNL were established to investigate the properties of materials synthesized by a wide variety of methods. This research utilizes our advanced TEM capabilities and the NSLS. Recent accomplishments include the following:

- Fabrication of fine-grained bulk MgB_2 with a critical current density J_c of ~ 1 MA/cm^2 at 5 K, the highest critical current density ever achieved in the bulk form.
- Clarification with advanced TEM methods of the nucleation and growth mechanisms of epitaxial YBCO occurring in the BaF_2 process.
- Development of systematic theoretical models to understand chemical bonding, crystal lattice defects, and the physical properties of rare-earth cuprates.

Advanced magnetic materials research aims to understand and manipulate materials factors that control their collective magnetic responses. Our research focuses on nanostructured rare earth transition-metal-based magnetic (RE/TM) intermetallic compounds, such as $Nd_2Fe_{14}B$ and $PrCo_5$, and model systems of nanocomposites, such as thin-film bilayers of CoPt-Co. Theoretical models of magnetoelasticity and of cohesion and magnetic order in RE/TM-based compounds were developed. The research features both theory and experiment, and uses the facilities at the NSLS and the APS. Other experimental probes include atomic and magnetic force microscopies, and TEM. We collaborate with researchers from industry, national laboratories, and universities. The following are some recent accomplishments:

- Identified the role of crystallographic texture in controlling the size of multi-grain interaction domains in nanocrystalline $Nd_2Fe_{14}B$ using magnetic force microscopy;
- Developed processing principles to control interfacial exchange interactions in composite Co/CoPt magnets, thereby improving their exchange-spring magnetic properties;
- Developed a Landau-theory based model combining magnetism, elasticity and martensitic phase transitions to describe magnetic shape-memory alloys and giant magnetocaloric effects.

Future Program: We will investigate the nanoscale structure of superconducting and advanced magnetic materials and the effect of this structure on material properties. We will complete the development of electron holography techniques to investigate mechanisms of the effects of grain boundary misorientations on J_c in YBCO, develop theoretical models to describe the interactions of crystal lattice defects with electronic stripe structure formation in cuprate superconductors, and determine defect-superconductivity interactions in MgB_2. A recent strategic hire will investigate novel synthetic methods to produce controlled defect structures in MgB_2 that enhance its critical current density at high magnetic fields. The fabrication methods developed for cuprates will be used to generate nanoscale structures of novel transition-metal oxides, including single nanoparticles, to study their size-dependent

structure and properties. Future research on advanced permanent magnets include understanding the role of the matrix, and the shape of nucleated grains in mediating interparticulate interactions in ferromagnetic nanocomposites, and clarifying the role of interfacial quality on exchange coupling and reversal behavior in CoPt/Co model bilayers and oxide/metal nanocomposites. Determination of the influence of melt-quenching conditions on the microstructure and magnetic domain structure in advanced magnetic alloys will continue.

4.2.4.9 Materials Synthesis and Characterization

Present Program: Our focus is on the fundamental knowledge of structure-property relationships of inorganic materials consistent with the DOE's initiative in Nanoscience. Researchers use x-ray and neutron powder diffraction to study zeolites and other framework structures, rare earth doped manganates and cobaltates, metal alloys, and oxides used as battery electrodes, and magnetically ordered alloys and compounds. One goal is to elucidate phase transitions, particularly those involving charge and spin ordering, using Rietveld refinement techniques and *ab initio* structure solution. Another goal is exploratory materials synthesis (sol-gel and other soft chemistry techniques) for bulk materials, thin films, and nanoparticles. This research group, and a PRT from industry and academia, stewards the NSLS X7A beam line and will provide synthetic capabilities to the CFN User Program.

We also provided the first high-pressure crystallographic studies of a superhydrated zeolite. This demonstrates how hydrostatic pressure in the presence of water can be used to control water content and assemble unique water nanostructures within the channels created by an aluminosilicate framework. A US patent application based on the results is pending.

Future Program: BNL's pioneering work on pressure-induced hydration of zeolites will be expanded and a new hydrothermal sample environment developed to allow exploration of structural chemistry under extreme conditions. We will enter the area of functional oxide heterostructures using BNL's PLD capability, while continuing to develop pair-distribution-function techniques to analyze crystallographic data from nanosystems. The NSLS formed a consortium to upgrade and operate X7A and two other powder diffraction beamlines that will play a significant role in the NSLS/CFN.

4.2.4.10 Advanced Electron Microscopy Study of Nanostructured Materials

Present Program: This program investigates structural defects in superconductors, magnets, and other functional materials at the nanoscale, and the correlation of the structural defects with material properties. It develops and employs advanced quantitative electron microscopy techniques, such as coherent diffraction, atomic imaging, spectroscopy, and phase retrieval methods, including electron holography. Computer simulations and theoretical modeling are developed to interpret experimental data. We also fabricate thin films with tailored microstructure and nanoassemblies using TEM based electron lithography to understand their electronic and magnetic behaviors. Recent progress includes the following:

- Understanding structural defects, charge distribution and hole symmetry in MgB_2
- Developing a unique symmetrization method based on the transport-of-intensity equation for nanoscale magnetization mapping of various magnetic materials
- Developing quantitative algorithms and procedures for measuring interfacial potential using electron holography to study charge distribution across Bi-2212 and Ca-doped YBCO superconductor grain boundaries
- Fabricating Co nanoparticles via *in-situ* TEM manipulation of CoF_2 films.

Future Program: Electron microscopy (EM) has been foundational to materials research at BNL and will play an increasingly important role in the CFN. Through the CFN, quantitative EM techniques

will be developed that will focus on magnetic phenomena, chemical composition, *in-situ* materials synthesis, catalytic properties of nanoscale materials, and high resolution imaging of soft and bio-materials. These capabilities will be developed in coordination with the Transmission Electron Aberration-corrected Microscope (TEAM) initiative. These long-term efforts will constitute the heart of our growing interdisciplinary materials research.

4.2.5 Energy Sciences (KC)

BNL's Energy Science R&D emphasizes energy conversion, energy use, and alternate sources of energy, coupling it to our competencies in advanced experimental techniques, and our unique facilities and capabilities. We concentrate on basic research in combustion, catalysis, bio-fuels, batteries, bioenergetics, and solar energy conversion and storage, sponsored by BES.

4.2.5.1 Catalysis and Interfacial Chemistry

Present Program: The primary goal of the Catalysis and Surface Chemistry research is to understand at the molecular level chemical reactions that occur at the surface/interface of solids. This knowledge is gained by examining how chemical reactivity responds to the interplay of a material's physical and electronic structure, morphology, and dynamic properties. BNL's research includes the fundamental aspects of sulfur interaction with model catalysts, the synthesis and reactivity of doped metal oxide powders, the preparation, characterization, and reactivity of nanoparticles, the selective oxidation of small hydrocarbons, and the dynamics of desorption and activated adsorption. We identify and characterize reactive surface species over a wide range of time and length scales under a variety of conditions by combining spectroscopic and structural tools, often using two Chemistry Department-supported NSLS beam lines (X7B, U7A).

Near-term Program: New studies of the role of nanoscale features in catalyis exploit our growing capabilities in atomically resolved Scanning Tunneling Microscopy to characterize surface structure of model metal catalysts whose reactivity is probed by high-resolution photoemission at U7A. This work emphasizes metal-on-metal and metal-cluster on oxide growth, aimed at controlling the dispersion and density of clusters, and understanding the parameters controlling the stability of their morphology. A new molecular beam scattering apparatus will soon provide information about barriers and the role of internal energy in activated gas-surface reactions, and will connect the UHV reactivity studies to higher pressure behavior typical of catalyst application.

Future Program: The program will focus on the reactivity and structure correlations of nanoscale materials holding promise as chemical- and photo-catalysts with properties that can be controlled by particle size, particle density, and chemical environment. Such studies will require new expertise in materials synthesis, and new characterization tools that can index chemical activity with the spatial resolution of proximity probes, such as near-field optical IR and UV spectromicroscopy. Novel synchrotron-based electron microscopes offer promise for catalysis because they will probe the sub micron structure and reactivity of surfaces in the sub-second time domain. High pressure synchrotron-based soft x-ray photoelectron spectroscopy will help close the existing "pressure gap" between catalysis and surface science, affording new insights into the fundamental details of surface catalytic reactions under realistic conditions (~10 torr).

4.2.5.2 Photo and Radiation Induced Chemistry

Present Program: This program applies the complementary techniques of excitation by photons and fast electrons to understand the basis of capturing and storing light energy in useful chemical forms. We investigate electron transfer reactions, motions of charges in condensed media, 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 (Section 4.1.5) adds a new dimension. Theoretical and experimental research on donor/acceptor systems elucidates the factors controlling excited-state lifetimes and electron transfer rates. The long-term storage of solar energy as fuels or valuable chemicals requires efficient coupling of light absorption and chemical transformations. One major effort centers on mechanistic studies of systems that couple photo-induced electron-transfer processes to the bond-forming reactions required for photo-generating dihydrogen and photo-reducing carbon dioxide to carbon monoxide or methanol. Kinetic and mechanistic studies of transition metal hydride complexes unravel the factors governing the rates and mechanisms of M-H bond cleavage and guide the development of new homogeneously catalyzed reactions.

Future Program: As our focus shifts to the nanoscale, we will study electron and photon injection into metal nanoparticles, molecular wires, and nanotube assemblies by a combination of theory and experiment. Studies at LEAF will characterize fast reactive events, such as ion recombination reactions, the lifetimes of excited ions that could function as energy-storage intermediates, and "dry-electron" capture. Efforts will continue on methods to photoreduce energy-poor substances. Transient optical absorption, transient FTIR, and structural techniques at the NSLS will be used to investigate energy storage by metal complexes and macrocycles.

4.2.5.3 Gas Phase Reaction Dynamics and Combustion

Present Program: Improving the efficiency and control of emissions from burning fuels for energy depends on a more accurate understanding of the complex chemistry of combustion. The chemistry of free radicals is central to the chain reactions of fuel oxidation, and predicting the results of the reactive combination of pairs of free radicals is a preeminent challenge. BNL's chemists apply experiment and theory to answer fundamental questions about free radical chemistry. State-of-the-art calculations explore the pathways, energetics, and structures of free radicals and their reactions. A unique flow-tube laser photolysis mass spectrometer is optimized for studying reactions between different free radicals. High-resolution laser spectroscopy monitors the energy flow within excited molecules, and during chemical reactions or molecular collisions. Laser spectroscopy of reactive intermediates provides benchmark structural and energetic information to validate calculations, and for kinetic studies. Crossed-molecular beam ion imaging studies interrogate the details of molecular collisions that underlie our understanding of chemical transformations.

Future Program: Targeting common problems with complementary tools takes advantage of the collaboration between experimentalists and theorists, such as addressing different aspects of the molecular interactions in a network of combustion reactions related by a common transient, highly excited CH_3OH. Predictions made from the computed potential energy surface are being tested by ion imaging measurements of the crossed beam reaction of $O + CH_4$, flow tube mass spectrometric studies of the $OH + CH_3$ reaction, and high-resolution laser spectroscopic measurements of electronic and rotational energy transfer in $CH_2 + H_2O$ collisions. The DUV-FEL (Section 4.1.6) opens new opportunities in frontier areas in chemical dynamics and enables physics in extraordinary regimes of optical power and wavelength. A new emphasis on experimental and theoretical studies of the electronic structure of metal-containing radicals and cluster compounds cuts across gas phase chemical dynamics, surface chemistry, and catalysis programs.

4.2.5.4 Electrochemistry and Electrocatalysis

Present Program: Research in electrochemistry and electrocatalysis centers on understanding the relationship between the crystallographic and electronic structure of an electrode's surface, and its atomic electrochemical and electrocatalytic properties. We study structure, ordering, surface interactions, and phase behavior of metals, anions, and molecular and mixed monolayers on electrode surfaces to obtain a true microscopic description of electrochemical interfaces. We probe adsorption processes and electrocatalytic reactions by investigating structural and electronic properties, and structure–activity

relationships. The results will enhance our understanding of the properties of important catalytic materials and offer guidelines for improving and synthesizing new ones; the findings also may be applicable to electrochemical energy conversion in fuel cells and lithium batteries.

Specific research includes structural and spectroscopic characterization of Pt surfaces with mixed metal-anion, and anion-CO ad-layers, time-resolved structural studies of metal monolayer formation and ordering on foreign substrates, and structural characterization of oxide formation on catalytically important metal electrodes. Our special spectroelectrochemical "drop cell" permits *in situ* structural studies with sub-angstrom resolution without the mass transport limitations of thin layer cells. Spontaneous deposition of noble metals and induced layer-by-layer growth facilitate a new approach to nanoparticle engineering for synthesizing electrocatalysts, where a core nanoparticle is used as a reducing agent for depositing a sub-monolayer shell of catalytic metal. Highlights include the development of new fuel cell catalysts with lowered Pt loading and enhanced tolerance to CO.

Future Program: Electrocatalysis studies will include work related to hydrogen production and use in fuel cells, and electrochemistry studies will include work on fundamental processes occurring in lithium batteries. They will span fundamental studies on well-defined crystal surfaces and on nanoparticle electrocatalysts, including correlations between nanoparticle activity and size/structure. Our methods of spontaneous deposition of noble metal on noble metal and induced layer-by-layer growth of thin films of catalytic metals will be used to form bimetallic surfaces and for "fine tuning" electronic and catalytic properties. Active sites will be identified, and the synthesis of active atomic ensembles for O_2 reduction and oxidation of H_2, CO, and methanol will be investigated. The mechanism of oxygen activation during CO oxidation on these surfaces will be investigated. We will continue to expand our work on *in-situ* structural measurements during electrocatalytic and electrochemical processes.

4.2.6 Environmental Sciences (KP and KC)

Present Program: The DOE/OBER supports BNL's environmental science programs, the centerpiece of which is Climate change. With partner national laboratories, we can assist the DOE in implementing the President's Climate Change Initiative. BNL's environmental remediation science and technology programs are aligned with the DOE's focus to implement environmental cleanup faster and cheaper.

The OBER-sponsored Atmospheric Science program explores the atmospheric processes controlling the transport, transformation, and fate of energy-related chemicals and particulate matter. We emphasize processes and models related to new air-quality standards for tropospheric ozone and particulate matter, and the relationships between air quality and climate change. BNL is a partner in the DOE/OBER's Atmospheric Radiation Measurement (ARM) program, comparing modeled and measured short-wave forcing on tropospheric aerosols, and examining the sensitivity of modeled aerosol forcing to input parameters. Collaborating with modelers, we are incorporating humidity-dependent effective radius treatment of aerosol forcing into general circulation models. We maintain the ARM External Data Center that assembles and distributes data to the ARM and atmospheric science communities.

The DOE/OBER funds BNL's Terrestrial Carbon Cycle program that investigates the natural carbon cycle, including quantifying the role of the terrestrial biosphere as a sink or source of carbon dioxide. In North Carolina's Duke Forest, BNL established and operates the Forest Atmosphere-Carbon Transfer and Storage Experiment (FACTS-1) to study the processes regulating forest carbon balance. BNL also supports the development of FACE facilities (section 4.2.6.1). We are applying new molecular biology tools to determine how plants adjust carbon uptake to increases in atmospheric CO_2, and are developing a novel system for field use to measure soil carbon non-destructively using inelastic neutron scattering.

The DOE/OBER's Natural and Accelerated Bioremediation Research Program (NABIR) aims to understand complex phenomena to reduce or prevent pollution to protect human health and the environment. We provide the knowledge to make bioremediation a viable option for DOE's most

challenging clean-up problems. In anaerobic systems, researchers are exploring the transformations of heavy metal ions undergoing bacterial sulfate reduction to elucidate the processes for reducing and precipitating heavy metals as sulfides in subsurface environments. They explore fundamental mechanisms by which natural microbial communities stabilize soluble organic and inorganic plutonium complexes. Their results will lead to (1) a better understanding of environmental conditions likely to retard plutonium mobility and transport, and (2) strategies for engineering the long-term immobilization of plutonium in soils and sediments.

Near-term Program: In summer 2004, we will participate in the Northeast Aerosol Climate Study, using new and improved instruments for field studies. Depending on future field programs, this includes instrumentation onboard aircrafts for rapid *in situ* measurements of the size distribution of ambient aerosols and the chemical composition of individual particles. We will continue defining the mechanistic role of multiphase chemical processes in generating tropospheric photooxidants and aerosols, including developing analytical methods to characterize aerosol organic constituents, measure the gas phase concentration of nitrous acid, and improve capabilities to acquire size-related composition of organic and inorganic components in aerosols.

To accurately represent the impact of exogenous aerosols, researchers will develop methods to use BNL's aerosol model to designate the boundary and initial conditions for higher resolution models. Our sulfate model will be converted into an operational one by automatically acquiring and reducing meteorological data from the U.S. National Centers for Environmental Prediction for the necessary input.

We will develop models and parameters for short wave radiative forcing by aerosols, gauging their accuracy and uncertainty with ARM data, and develop and code models to evaluate aerosol short wave forcing from vertical profiles and for down-welling radiation. We will improve the cloud microphysics of liquid water clouds in general circulation models, focusing on the relationships between the concentrations of cloud condensation nuclei, cloud turbulence, and cloud microphysics. Our approach is to develop and test parameterizations using measurements from the ARM cloud and radiation test bed. We will continue investigating solutions under extreme conditions, particularly the dynamics of nucleation, develop new systems to investigate nanoparticles, and begin studies on ice nucleation under upper tropospheric conditions.

BNL will continue to operate the FACTS-1 facility, measuring canopy photosynthesis, conductance, and leaf area index. Laboratory and field investigations will continue to improve, refine, elucidate, and validate mechanisms that control how plants adjust their uptake of carbon and nitrogen to increases in carbon dioxide. Understanding the relationship between carbon and nitrogen metabolism is essential in predicting the response of terrestrial ecosystems to global change, particularly its long-term effects; our goal is to be able to scale our findings to the ecosystem level by improving our mechanistic knowledge of biological processes.

We will continue work for the OBER/NABIR and explore the interactions between humates and uranium-organic complexes at the NABIR Field Research Site. As part of the OBER Environmental Management Science Program, we intend to investigate the mechanisms of microbial dissolution and stabilization of transuranics, to pave the way for understanding the chemical redistribution of actinides in transuranic wastes after microbial action. We expect to continue our role in the NSF/DOE Center for Environmental Molecular Science.

Future Program: BNL plans to grow the environmental science program in four areas. NSLS accelerator physicists and environmental scientists are developing synchrotron applications for molecular environmental science, environmental cleanup, and geosciences. Additional staff will implement them at the NSLS, and offer scientific and technical support to new users. Modelers and visualization experts will complement our strong experimental programs in Atmospheric Science and Terrestrial Carbon Cycle research. BNL's perfluorocarbon tracer technology was used in the DOE Terrestrial Carbon Cycle and Atmospheric Science programs and several DOE/EM projects. The tracer group will make available more types of tracers and expand their analytical capabilities. In addition, the Biology Department's basic research will be closely connected to the Environmental Sciences Department's applied research.

4.2.6.1 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 recently recognized FACE, free-air CO2 enrichment experimental sites, as a distributed facility for studying the effects of enhanced carbon dioxide on a range of terrestrial ecosystems, and led the development of the North American Carbon Program, largely based on the AmeriFlux facilities that use eddy flux covariance to measure carbon dioxide flux. We are developing the ability to couple measurements from FACE and other sites to guarantee that the effects of artificially enhanced carbon dioxide can be compared directly with natural fluxes at the same site. The acquisition and management of such data, in near-real time, from widely distributed facilities is crucial to success; hence, we are developing software, and Internet-based tools to accomplish this, for a growing user community. Since the terrestrial biosphere is the primary driver for the annual variability in atmospheric carbon dioxide, we 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 likely in the next century.

New long-term research capabilities are needed to understand how terrestrial ecosystems respond to rapid environmental change, which are the most vulnerable and the most severely impacted, and how future ecosystems will look. BNL's ecologists in collaboration with other national laboratories are addressing these challenges. Existing facilities are unable to conduct the crucial multi-factor ecosystem experiments because they cannot realistically manipulate temperature. Our Environmental Facility Initiative and those at other national laboratories are contributing to the conceptual design of a new distributed facility for these needs. It probably will operate for about 10-30 years, include multiple replicated plots of hundreds of square meters, and be able to manipulate CO_2, temperature, water, nutrients, and other parameters.

The next generation of distributed facilities is being built on existing DOE capabilities, specifically the FACE and AmeriFlux programs. With the advancement of the North American Carbon Program, these facilities offer unprecedented scope for monitoring and probing how terrestrial ecosystems respond to human perturbations that cause rapid environmental change. Our overall goal is to provide the DOE with capabilities to help shape the overall roadmap for such facilities, and to position the Laboratory as a significant partner as they are further defined.

4.2.7 Life Sciences

BNL combines multi-disciplinary scientific talent and facilities for world-class research in the Life Sciences. Current programs use our unique facilities and imaging instruments, including the BLIP, NSRL, AGS, NSLS, PET, and magnetic resonance (MR) facilities. New and upcoming initiatives in the Life Sciences will introduce state-of-the-art instrumentation for translational genomics and phenotyping, and new infrastructure for high throughput structural microbiology. The Life Sciences programs continue to break scientific frontiers and are highly competitive. The programs/projects are jointly funded by DOE/(OBER, BES, NE), the Office of National Drug Control Policy, and NIH institutes, including the National Institute on Drug Abuse (NIDA), National Institute for Mental Health (NIMH), National Institute on Alcoholism and Alcohol Abuse (NIAAA), National Institute on Neurological Disorders and Stroke, National Institute for General Medical Sciences, National Multiple Sclerosis Society, NASA, industry, BNL-SUSB seed grants, and the National Alliance for Research on Schizophrenia And Depression. Additionally, we have clinical collaborations with SUSB, Mount Sinai Medical School, New York University, University of Southern California, University of Rochester, Tufts University, etc.

4.2.7.1 Imaging & Radiotracer Sciences

Present Program: Brookhaven is at the forefront in developing medical isotopes, radiotracers, and imaging instruments to diagnose disease and to visualize and quantify biochemical processes in the

human brain, thereby broadening our knowledge of diverse diseases, such as Parkinson's, Alzheimer's, schizophrenia, and drug addiction. The program is moving in new directions to develop tools for understanding the relationship between genes, protein products, diseases, and behavior with a current focus on addictive disorders (drug abuse, obesity), behavioral disorders (impulsivity and violence) and neurodegenerative and psychiatric disorders (AIDS, multiple sclerosis, schizophrenia). A multi-disciplinary group of scientists leads the program that includes a PET Imaging Laboratory (with two high-resolution human PET scanners; a microPET); three cyclotrons including a newly commissioned medical cyclotron; a radiotracer laboratory; a neuroscience laboratory (microdialysis; behavior; electro-physiology); and a high field (4 Tesla) MRI Laboratory for spectroscopic and functional imaging studies in humans.

Most clinical research programs at our PET and MR facilities are collaborative with research hospitals in the NY area and clinics on LI. For example, we study schizophrenia with NYU and Pilgrim State, cocaine abuse with Columbia, and endocrine tumors with North Shore/LIJ. Clinical work on HIV and drug abuse is done with clinics on LI. Several collaborations are fully funded by the pharmaceutical industry. We intend to establish more such collaborations.

Future Program: For BNL's long-term program in imaging sciences, we are proposing several initiatives:

Biomedical Engineering Laboratory: A new project to develop specialized PET and MRI instruments to image the Awake Animal Brain is well underway and promises to revolutionize animal imaging by designing and fabricating instruments which can image the brain of the awake rat or mouse in real-time, under natural physiological conditions. It will advance our ability to relate biochemistry and behavior in transgenic animals, and promises applications beyond animal imaging, such as compensation for motion and correction in human PET and MRI studies. We have a strong multidisciplinary team from five BNL department/divisions, Lawrence Berkeley National Laboratory, and the USB Medical Center and Biomedical Engineering Department. This collaboration resulted in several independent projects in biomedical engineering and imaging that will seek funding from sources, such as the National Institute for Biomedical Imaging and Bioengineering (NIBIB).

Clinical Research, Cognitive and Behavioral Neurosciences: PET and MRI techniques can evaluate the brain's physiology and pathology. Past and ongoing research at BNL added to our understanding of how the brain is affected in various disorders, including addiction to cocaine, methamphetamine, alcoholism, attention-deficit-hyperactivity disorder, HIV, multiple sclerosis, Alzheimer's disease, schizophrenia, obesity, and normal aging. Advanced physiological MRI techniques, including MR spectroscopy, perfusion MRI and T1-relaxometry, provide non-radioactive and complementary approaches to evaluating brain pathophysiology in different disease states. Functional MRI significantly extended our knowledge of human brain systems that are involved in emotion, motivation, and higher-order cognition by recording brain activity while these states are elicited, and has been transforming cognitive-behavioral neuroscience research for the past 10 years. We are combining sophisticated theoretical approaches to the brain's operation (e.g., neuronal network computational theory) with complex statistical models on human cognition and emotion to provide the nexus for brain imaging evidence to reveal how the brain actually works.

PET and Plant Science: We developed an integrated plant metabolism chamber to investigate plants' synthetic capacities as a function of environmental stressors. This system exploits short-lived positron emitting isotopes, including carbon-11 (half-life: 20.4 min) and nitrogen-13 (half-life: 9.97 min) that can be detected externally with coincidence counting and visualized by a combination of PET and Direct Positron Imaging. Unlike existing destructive techniques, we can make repeated measurements on the same plant through its development. This project, part of the Chemistry and Biology Departments' collaboration with Harvard University, was launched within the PET Program through LDRD funding, with graduate student support for SUSB. Stable funding for BNL's Plant Science is being sought from the USDA and the DOE.

4.2.7.2 Isotope Research and Production Program

Present Program: The Isotope Research and Production Program's goals are to develop, produce, evaluate, and distribute new radionuclides (or those not produced elsewhere) and radiopharmaceuticals that would lead to improved diagnostic and therapeutic procedures in nuclear medicine, particularly for oncology, cardiology, and neurosciences. The program encompasses BLIP, cyclotrons, high-level radiation processing facilities, radiochemical laboratories, as well as protocols for animal testing and clinical studies.

We continue to explore using radioisotopes, such as Sn-117m, for cancer therapy and for treating painful bone metastases in patients with advanced breast, prostate, and lung cancer. We use other isotopes produced at the BLIP for labeling monoclonal antibodies directed against antigens expressed in breast, colon and other cancers. Another new approach at BNL for tumor ablation or imaging is to fuse viral proteins to antibodies to increase the uptake of the labeled conjugate into tumor cells.

Future Program: We will continue to focus on the following:

- Develop new isotopes (e.g., Si-32, Ge-68/Ga-68 generator), and associated radiolabeling methodology.
- Synthesize new ligands containing radiolabelled Sn-117m that attach to bioengineered molecular antibodies, specific to estrogen receptors for imaging/radioisotopic therapy of breast cancer.

4.2.7.3 Cancer Research

Present Program: Our goals are to develop Microbeam Radiation Treatment (MRT) at the NSLS for treating brain cancer. Conventional radiation is thought to damage the normal Central Nervous System (CNS). MRT, an innovative method of irradiation, has been shown to preferentially kill intracranial gliomas in rats at doses that are tolerated by normal brain tissue. Studies at the NSLS show that normal tissues, including the CNS, tolerate single exposures to microbeam irradiation at in-beam doses at least ten times higher than single-fraction conventional broad beams.

Future Program: Our long-term goal is to extend these studies to large animals to examine damage to the normal tissue in irradiating deeply seated tumors, and to evaluate MRT for clinical use.

4.2.8 NIH Intramural Program

A new NIH intramural program for PET imaging in drug abuse research was established at BNL to support research by NIDA investigators, notably Dr. Nora Volkow, while she is Director of NIDA. It supports 6 FTEs to continue to develop and apply imaging technologies to understand brain reward mechanisms and the brain circuits disrupted during addiction. Administered through the NIAAA, it strengthens the concept of enhanced efficiency through interagency agreements and further solidifies Brookhaven's leadership role in addiction research.

4.2.9 Molecular and Structural Biology (KP)

The Biology Department's technical infrastructure supports research in cell, molecular, and structural biology. The department houses unique instrumentation for STEM and maintains five beam lines at the NSLS for structural characterization of biomolecules at moderate to high resolution.

Present Program: Most established research programs were begun in response to DOE initiatives, for example, to study health effects of ionizing radiation, or to develop countermeasures against biological warfare agents. The DOE still supports several with additional funding from NASA, NIH, and DOD. This research led to key advances in characterizing radiation-induced DNA damage, and the enzymology of DNA double strand break repair, and in determining structure-activity relationships in microbial enterotoxins and neurotoxins.

Much effort focused on developing new core capabilities and on enhancing existing ones in response to the DOE's "Genomes to Life" (GTL) initiative. Its overall goal is to exploit genome sequence information to understand microbial "systems biology", e.g., how protein functional elements of cells cooperate to generate and sustain microbial systems, and how individual microbial cells cooperate in communities to effect environmental changes that may enhance bioremediation of contaminated soils or carbon sequestration.

Future directions: Related to the GTL program, we are developing sample sequencing methods to characterize species composition and gene expression profiles in complex microbial communities; optimizing the highly successful T7 phage-based protein expression system and adapting it for high throughput (robotic) protein production; developing fusion protein technology to facilitate proper folding, performing affinity purification and imaging of expressed proteins. A cryoEM instrument is being installed for structural characterization of protein complexes at moderate resolution. Ultimately, we will require support from the GTL program for strategic hires and purchasing critical instrumentation. The department plans to collaborate with the Medical Imaging group to develop an initiative in biomaterials.

4.2.10 Space Radiation Biology and Neuroscience Programs

Space travel beyond the Earth's protective magnetic field will expose astronauts to galactic cosmic radiation (GCR) such as high energy (1 GeV/nucleon) $^{56}Fe^{26+}$ particles, which cannot be effectively shielded in currently envisaged spacecraft, and may irreversibly damage many of the cells they traverse. NASA funded construction of the NSRL, (Section 5.1.1), and, with the DOE and NIH maintains the Medical Department's laboratories. NASA and/or the National Space Biomedical Research Institute (NSBRI) support several scientists at the NSRL. The next 10 years' life sciences research at NSRL will be highly relevant to NASA's development of advanced space propulsion systems that could shorten interplanetary travel times.

4.2.11 Plant System Sciences (KC)

Present Program: BNL's plant program uses the most advanced biochemical-genetic techniques to develop a conceptual framework to unravel the factors contributing to the complexity of plant traits. In the short term, we are doing basic research on plant traits and on developing analytical tools to aid breeding. Our long-term goal is to understand specific plant processes so that crop plants can be rationally and systematically improved. For example, by understanding how crop plants synthesize fatty acids, their genes can be modified to produce oils with desired properties that can be transferred to crop plants. A major goal is to understand the principles of how agriculturally important plant products accumulate (e.g., plant oils and cotton fiber). We are developing better methods to map and identify genes that affect plant traits.

Future Program: We expect that our present work will provide a context for generally improving corn and cotton crops by understanding their genome structure and mapping the quantitative trait loci for agronomic traits.

4.2.12 Educational Programs (KX)

Present Program: The DOE's Office of Science, with other agencies, supports BNL's educational mission. Its goals include the following:

- To enrich the training of future teachers, scientists, and engineers by
    - developing excellent educational programs, resources, and activities that take advantage of BNL's world-class, cutting-edge and unique scientific research,
    - offering research internships for undergraduates to support the DOE's scientific mission,

- providing enriching educational experiences and career pathways in science, technology, engineering, and mathematics (STEM) for diverse groups of pre-college and undergraduate students.

- To increase scientific literacy in schools by
  - enhancing the preparation of pre-service STEM teachers,
  - offering in-service STEM teachers opportunities for professional development.
- To form a community of students, teachers, and scientists, who share a passion for science and science education. We will offer resources and activities that support the Laboratory's efforts in Community Involvement and Public Outreach, and contribute to its role as an invaluable educational asset for the local and national community.

Undergraduate Internship Programs: Each year, approximately 100 students participate in educational programs and collaborate with mentors on research projects. Many students in the Science Undergraduate Laboratory Internship (SULI) Program co-author scientific papers that are later published in scientific journals and presented at conferences. The Community College Institute (CCI) helps to increase the diversity of the student population at the Laboratory and contributes to building the future technical workforce. In the Pre-Service Teacher Program (PST), undergraduates who are committed to STEM teaching careers, participate in research. They also work with Master Science teachers who help them apply what they learn at the Laboratory to the classroom. The Faculty and Student Teams (FaST) program brings teams of faculty and undergraduates to BNL to work with scientists. The U.S. Support Group, ISPO, offers undergraduate internships with mentors from the International Atomic Energy Agency.

Conferences, Workshops, or Summer School: These educational enrichment programs include a Nuclear Chemistry Summer School, Undergraduate Mini-semesters, and two summer programs for high school students, (the Minority High School Apprenticeship Program for 9th and 10th graders, and the Community Summer Science Program for high school juniors and seniors). In 2003, the Laboratory hosted a conference for approximately 240 undergraduates and faculty from historically black colleges and universities. Our staff developed resources related to Ray Davis' Nobel Prize-winning work with solar neutrinos and exhibited them at the National Science Teachers Association's (NSTA) convention. We also launched an Online Science Classroom and demonstrated an interactive online physics learning resource, the "RHIC Adventure", at the NSTA convention and at the National Association for Research in Science Teaching conference.

Informal Education Programs: BNL's Science museum offers elementary and middle school students a variety of hands-on, minds-on, inquiry science experiences related to BNL's research. The museum's staff conducts outreach programs for elementary schools, such as "Magnets to Go" and hold professional development workshops for elementary and middle school teachers at the museum. In 2002, the PST program and staff evaluated these educational programs.

Teacher Professional Development Programs: We offer a variety of programs and resources for STEM teachers. Local physics teachers participate in Quarknet, and a Cosmic Ray Project. We submitted two Math and Science Partnership grant proposals to the NSF; one is a partnership with SUSB and Hofstra University, for grades 5-8 math and science teachers, and the other is with Southampton College and other institutions. Another proposal to the NSF was for the Information Technology Experiences for Students and Teachers Program to bring high school science teachers and students to the Laboratory to learn how information technology is used in scientific research. We will continue to develop the Online Classroom and distance education courses for teachers, in collaboration with local universities, such as SUSB and Southampton College.

BNL's Educational Outreach and Resource Programs: The Laboratory collaborates with many local pre-college educational organizations, conducts workshops for teachers, offers special student events and tours, and provides technical assistance to school districts, largely through voluntary efforts,

and cooperation among BNL organizations. These include an Elementary School Science Fair, a Middle School Magnetic Levitation Contest, a High School Bridge Building Contest, a High School Science and Society Essay Contest, Science Fair help days held at local libraries, assistance for schools participating in a national robotics contest, museum programs, and, an Energy and Environmental Science Summer Camp for elementary school students. In 2003, BNL held its first regional High School Science Bowl. The Office of Educational Programs (OEP) started conducting educational tours for high school students that include hands-on, inquiry science learning experiences and visits to BNL facilities. OEP staff also began regularly visiting the science departments at local high schools.

We continually update the OEP's web site with new information and resources. Online databases and forms, created in 2002, allow registration for events, and programs. In 2003, an online OEP Program database was developed to collect detailed information on all BNL's educational programs. A team of scientists, high school science teachers, and graduate students is developing the Online Classroom Project in collaboration with the Joint Institute for Nuclear Research in Russia. In 2003, the focus was on developing educational resources related to the science of the RHIC. These included a teachers' guide and lesson plans related to particle and nuclear physics. The OEP launched an interactive physics game, the "RHIC Adventure" at two national science education conferences during 2003. Over the next two years, we will assess its effectiveness as a teaching tool. These outreach efforts reach hundreds of teachers and parents and thousands of students annually.

Undergraduate and Teacher Programs will remain the principal foci of the DOE-supported education activities. Additional funding will be needed for the larger numbers of pre-service teachers participating in our programs. The DOE already supports FaST, and a major effort will be made to enroll participants from the historically black colleges and universities. In FY 2003, BNL will have one FaST team comprised of a faculty member and two undergraduates. There is great demand for undergraduate interns at the Laboratory and any increase will necessitate additional administrative help and facilities.

We hope to expand our Teacher Professional Development Programs with support from the DOE and other agencies, such as the NSF Math and Science Partnership grants. The DOE may soon fund the Laboratory Science Teachers Professional Development Program (LSTPD). (This is a new program and past in-service teacher programs at the DOE's labs were extremely successful). Preparations are underway for the creation of a Teacher Resource Center in the BNL Science Education Center.

Similarly, with DOE's support, programs for grades K-12 will grow. Presently these programs, e.g., Science Museum programs, outreach to schools and libraries, and tours of BNL facilities by high school students, are supported by overhead funds.

Future Program: The Laboratory will continue to align its educational programs to support the Laboratory's objectives in the following ways:

- Establish an advisory council consisting of BNL's senior scientific management and external educators.
- In 2004, hold joint events and attend key conferences with the Diversity Office to increase the diversity of the Laboratory's workforce, and participants in the educational programs
- Develop an online tracking database to follow the careers of former participants in educational programs.
- Continue to improve the primary undergraduate programs, CCI, FaST, PST, and SULI.
- Develop flexible strategies for extending the SULI model to continue building collaborations with partnership organizations including opportunities for part-time semester co-op students, cost-sharing arrangements with NSF programs, FaST projects, and joint appointments through local industry.
- Prepare for the future LSTPD program where in-service teachers come to the Laboratory during the summer to do research with mentors.
- Develop courses and workshops for teachers, in collaboration with USB, related to the scientific research at the Laboratory.

- Develop an online database to measure the effects of teacher professional development programs on student achievement in science, and attitude towards science and vocational interest.
- Raise the local and national profile of the OEP through a focused program of science education research. The Laboratory's educational programs will be evaluated systematically, and the findings published and presented at conferences. Collaborations with science departments will take place more frequently.
- Maintain and enhance the many successful pre-college science education programs, such as the Minority High School Apprenticeship Program, the Community Summer Science Program, the Bridge Building Contest, the Magnetic Levitation Contest, the Elementary School Science Fair, the Science and Society Essay Contest, and the Science Bowl. In 2004, if funding is available, we hope to hold a Junior Science Bowl and Solar Car Race.
- Continue the Online Classroom Project, focusing on a different area of scientific research each year, such as the new Nanoscience Center and the Genomes to Life Initiative.
- Hold an Online Science Expo for secondary school students to exhibit science research projects online.
- Enhance the Academic Year High School Research Program by establishing an online database that will match secondary students with BNL mentors for science research projects (i.e., Intel) and science fair projects.
- Expand the Secondary School Outreach Program to local middle and high schools. In 2004, we will add visits to middle schools. We plan to submit an Informal Science Education grant proposal to the NSF to develop programs and resources for middle school students and teachers.
- Hold annual Crystal Growing Contests for local students with the NSLS.
- Expand informal opportunities in science education through BNL's Science Museum, and explore possibilities for external funding, and a new location to accommodate the return of science exhibits on loan, as well as new exhibits. New technology, such as wireless networks, will be introduced into the museum exhibits for optimizing learning opportunities.
- Create an outdoor educational science park to display the bubble chambers and other large historical scientific apparatus.
- Enhance the facilities of the Science Education Center by improving the computer facilities, the library, and classrooms.
- Help scientific staff add educational components to grant proposals. Since many of our scientists hold adjunct appointments at USB, more graduate students are doing their thesis research at BNL, and several of our Life Sciences programs have ongoing training programs through the NIH and other agencies, a practical goal is to attract students to USB for careers in scientific research.

Eventually, the OEP will become the focus and clearinghouse for all educational activity at BNL. Although this will require additional resources, it will bring savings by reducing duplication of effort, and offering greater opportunities for securing external funding for educational programs.

4.3 Energy Resource Mission (EE/FE/NE) Energy Technologies

BNL performs R&D for the DOE's Energy Resource Mission to provide clean, sustainable energy, focusing on basic and applied research, systems analysis, technology development, and transfer to industry of technologies that offer innovative solutions to important energy challenges. On-going projects include proliferation resistant nuclear reactor designs, energy/economic modeling, energy

infrastructure reliability, and energy production, transmission, and storage, including fuel cells and batteries.

The DOE's Offices of Energy Efficiency and Renewable Energy (EERE), Fossil Energy (FE), and Nuclear Energy Science and Technology (NEST) support the Laboratory's role in this mission with some funding from other DOE offices, such as the Office of Policy. The DOE/BES sponsors much of the basic research. BNL's local, national, and international energy partnerships support continued U.S. leadership in the energy field for sponsors in the DOE, NRC, EPA, NYS, and private industry.

4.3.1 Energy Efficiency and Renewable Energy (EE)

Present Program: BNL research supports the strategic objective to reduce oil and energy use by developing more efficient, nonpolluting heating systems, including advanced low NO_x oil burner technologies, and improving the distribution and use of energy in homes and buildings. BNL's flame quality indicators are licensed and are becoming available commercially. We are pursuing large-scale field tests of this technology, named by the DOE as an Energy 100 technology.

BNL is developing standards for ultra-low sulfur fuel for home heating that will significantly reduce emissions from heating systems and increase efficiency by reducing fouling in boilers. A large-scale field test of this work is in progress. Such fuels enable the use of very high-efficiency condensing boilers; BNL is testing concept systems. We also conduct programs with the NYS Energy Research and Development Agency.

BNL continues research on corrosion resistant materials and cements for reducing geothermal energy costs. Last year with NREL, we focused on corrosion testing of NiCrMo alloys, evaluating coatings and mortars for resistance to sulfur oxidizing bacteria, numerical modeling of remediated wells, non-destructive test methods, and field testing. This work will continue into next fiscal year. BNL researchers received an R&D 100 Award and also the Federal Laboratory Consortium Technology Transfer Award for developing a high performance polyphenylenesulfide coating system that is highly effective in hostile corrosive environments, such as geothermal power plants and chemical processing facilities.

BNL's programs on Natural Gas Storage Systems for EERE work with U.S. industry to demonstrate systems that will significantly reduce costs for producing and storing liquefied natural gas. We assess its production from landfills, develop state-of-the-art storage tanks and refueling facilities, design novel cryogenic fuel delivery systems, propose market end-uses, and work on hydrogen storage technologies.

Scientists are developing battery materials for hybrid and electric vehicles, focusing on cathodes for high-rate lithium ion batteries. Work continues on novel methods to make fuel cell electrocatalysts with substantially reduced platinum requirements. These programs use the NSLS for material characterization. BNL will continue research on the material properties of high temperature superconductors that focuses on their manufacture and application; it uses our TEM facility extensively.

In support of the strategic objective to provide national and international energy data and analysis, BNL continues to develop and apply the MARKAL-MACRO computer code, a technology specific, data-rich optimization model that gives least-cost energy system solutions under specified constraints to support policy and planning decisions. It evaluates energy source uses on environmental and micro/macro economic scales and can answer specific questions in conjunction with other models, such as air quality dispersion models and Geographic Information Systems representations. We work with Hong Kong, and on a new initiative for the Central American States and Taiwan that will evaluate Clean Development Mechanisms in support of the Kyoto Protocols. EPA Region 2 co-sponsors some of this research. We are collaborating with the Energy Information Agency who selected MARKAL-MACRO as the modeling tool for the next world energy outlook report, and are developing hemispheric models for the DOE and EPA.

Future Program: BNL will further emphasize combined cooling, heating, and power (CHP) technologies that substantially improve efficiency. Presently, we participate in testing the performance of a gas-fired microturbine power generator, fuel cells, and an oil-fired microturbine.

BNL and the oil heat industry prepared a comprehensive five-year plan that would offer homeowners clear benefits from burning better quality petroleum fuels and bio-fuels. Coordinated by BNL, it proposes to commercialize low NO_x heating burners and very high efficiency heating systems.

BNL will continue a program with Consolidated Edison of New York to examine critical infrastructure issues in the electric grid. In parallel, an LDRD will develop new probabilistic based techniques to analyze electrical failures.

4.3.1.1 Energy Efficiency and Renewable Energy Initiatives

The Laboratory supports the strategic goal of reducing energy use, specifically through expanded programs in renewable energy and energy efficiency:

Wind Power: Interest in wind energy is escalating with the urgency for alternative energy resources that include installing large-scale land and offshore wind turbines. Implementing them poses unique problems of system dynamics and foundations. An LDRD project proposes to evaluate the dynamic response of large wind turbine systems and assess alternative foundation materials. The key element is computationally treating turbine-tower-foundation systems as a whole, rather than as separate components. The computational methodology will represent a significant technical advance, and may lead to a commercial software package. Alternative foundation materials investigated will include high fly ash content concrete and fiber reinforced concrete, a new approach with great potential for improving the economics of wind energy.

Distributed Power: Distributed power may increase reliability and efficiency by reducing transmission power losses, and offering the possibility of using waste heat. Although numerous research challenges must be overcome, it offers an avenue for the practical use of renewable technologies, such as photovoltaics and geothermal energy. BNL is testing microturbines for micro-CHP applications.

4.3.2 Fossil Energy (FE)

Present Program: Several programs explore the next generation options for producing, transmitting, storing, and using fossil fuels that significantly reduce greenhouse gas emissions. Key projects include fuel cells, thermophotovoltaic (TPV) power generation, and distributed energy systems. We are developing advanced materials to take full advantage of domestic energy supplies, sulfur removal technologies, biochemical upgrades to increase available fossil fuels, and natural gas storage systems.

In FY 2001, DOE began an initiative to harvest the vast quantities of methane hydrates from the ocean floor and permafrost. The first phase concentrated on establishing their fundamental properties to ensure the safe production of methane by 2015. BNL has expertise in structural studies of clathrate hydrates and has teamed with other national laboratories in applying it. An LDRD project is pursuing research in the kinetics of their transformation.

TPV technology generates electric power from a hot surface using photocells. As part of an industrial team, we are developing a 500-Watt, oil-fired portable generator for the U.S. Army. We are working with another industry team on civilian applications, such as hybrid solar/gas-fired TPV cogeneration, and self-powered residential heating appliances.

Future Program: The DOE's goal is to ensure reliable, clean, and diverse supplies of domestic fuels. Our program on deep sulfur removal for liquid fuels will continue, including biochemically upgrading oils and other petroleum products; we selected several bacteria strains to test for desulfurization, denitrification, and hydrocarbon redistribution.

We will expand work on micro-scale conversion of liquid fuels, and extend our small-scale burner technology to microcombustion. We will begin research on advanced gasifier technology for distributed power sources.

4.3.2.1 Fossil Energy Initiatives

The Laboratory developed an advanced fuels initiative, in collaboration with USB, to support the DOE's objectives in energy resources; it will have two main thrusts initially:

Natural Gas to Liquids: Vast natural gas reserves remain, due to the high cost of market access. Catalytic and chemical processing of this gas to liquid fuel offers the potential for a large resource of ultra-clean liquid fuels for diesel applications. BNL has an international reputation in Liquid Phase Low Temperature methane conversions; we will focus on advanced nanoscale 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 removing sulfur, building on our ongoing work in bioprocesses for upgrading crude oil.

4.3.3 Nuclear Energy (NE)

Present Program: BNL's core competencies are fully aligned with the DOE's Office of Nuclear Energy, Science and Technology's (NE) four major initiatives: the Advanced Fuel Cycle Initiative (AFCI) program; the Nuclear Energy Research Initiative (NERI); the Generation-IV Advanced Reactors; and the Nuclear Energy Plant Optimization (NEPO).

Research in the AFCI program is carried out at BNL, Los Alamos, Argonne, Oak Ridge, other national labs, several major universities, and in industry. BNL continues to support spallation target development and sub-critical multiplier design and analyses. We are examining reactor-based options for transmutation.

BNL continues to participate in several NERI programs to develop advanced reactor concepts and proliferation resistant reactors, one of which is in partnership with Argonne National Laboratory.

The DOE/NE recently completed a Generation IV Nuclear Energy System Roadmap study; BNL was a member of the Technical Working Group considering options for water-cooled reactors. BNL participated in three Generation IV workshops this fiscal year, hosting the one on nuclear data needs.

The DOE and the Electric Power Research Institute established joint NEPO programs to pursue technologies that foster life-extension and optimize electrical generation from existing power plants. This could reduce global carbon emissions by extending the operation of existing light water reactors beyond their license period. With industry, BNL is examining advanced designs for the control rooms of nuclear power plants.

Future Program: BNL will expand its work on proliferation resistant reactors in collaboration with Russian research institutions and U.S. industry. We will continue to support the DOE's accelerator applications research, and will work with the CDIC to expand its capabilities in computational fluid dynamics for all energy resource applications.

4.3.3.1 Nuclear Energy Initiatives

The Laboratory continues to develop programs supporting the DOE's strategic objective to expand the capability of nuclear energy to contribute to the Nation's energy needs. We are expanding our research programs in accelerator applications, human factors, and the disposition of plutonium.

4.4 National Security Mission (NN)

BNL does not have a weapons development mission; rather, we work on domestic and international programs in nonproliferation and national security seeking to prevent their unauthorized use and spread, focusing on the following:

- nuclear materials safeguards and chemical/biological/nuclear arms control verification and transparency,
- security-related environmental threat reduction,
- Russian fissile materials protection, control, and accounting,
- technical support to the International Atomic Energy Agency (IAEA) on nuclear materials safeguards (WFO, section 5.1), technology development and deployment for Homeland Security initiatives.

4.4.1 Safeguards and Arms Control Verification and Transparency

Present Program: BNL performs analyses and R&D, provides technical support to U.S. programs and policymakers, and builds prototype instruments and systems to further U.S. interests in nuclear materials safeguards and security, verification and transparency, nonproliferation of weapons of mass destruction, and nuclear security-related infrastructure protection. We support the DOE and the IAEA in implementing "integrated safeguards systems" incorporating traditional Non-Proliferation Treaty safeguards with the new Strengthened Safeguards System, especially the provisions of the Additional Protocol.

For domestic safeguards, the DOE accepted the methodology developed by BNL to confirm the presence of highly enriched uranium (HEU) in warheads returned from the DOD. A member of our technical staff serves as a "transparency monitor" under the US/Russian Federation Highly-Enriched Uranium Purchase Agreement. In cooperation with Russia in arms reduction and transparency, BNL determined the radiation signatures of U.S. nuclear weapons and components with high-resolution gamma ray spectroscopy. We participate in the Integrated Technology Development Plan that coordinates the work of the DOE and DOD in designing, testing, and authenticating instruments for monitoring international arms control treaties.

Future Program: During the next two years, BNL will collaborate with Russian scientists in designing, developing, and testing nuclear warhead dismantlement transparency systems. We expect to participate in developing advanced nuclear detectors and measurement systems for U.S. safeguards and arms control and homeland security requirements, including

- γ-ray spectroscopy at room temperature with sufficient resolution to distinguish between plutonium and highly enriched uranium and other non-strategic radioactive materials,
- 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,
- advanced sensor designs using CZT detectors.

We will work to reconstitute our R&D capabilities in advanced radiation detectors through new hires and increased collaboration with BNL's Instrumentation Division.

4.4.2 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 refocus the expertise of former Russian weapons scientists to environmental projects.

In FY 01, under the Arctic Military Environmental Cooperation Program funded by the DOE, DOD, and EPA, and the EPA's Murmansk Initiative, BNL helped the Russian Ministries of Defense and Atomic Energy install technologies and processes to more safely manage nuclear wastes produced from dismantling Russian nuclear-powered ballistic missile launching submarines. We installed 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 three Russian Closed Cities. BNL also supports the U.S. Delegation to the IAEA's Contact Expert Group in focusing international efforts on Russian radioactive waste management. =

Future Program: We hope to expand the Nuclear Cities concept to regions where the Russian Northern and Pacific nuclear naval fleets operate to lower the proliferation threat from underemployed or unemployed Russian naval shipyard personnel.

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

Present Program: Since 1994, Brookhaven has been involved in the following non-proliferation MPC&A Programs at Russian facilities:

- Introducing technologies to precisely measure bulk liquid and solid nuclear materials during storage and processing,
- Developing and implementing comprehensive plans for physical inventory, statistical sampling, measurement requirements and control techniques, and performance procedures,
- Supporting Minatom and Gosatomnadzor in generating regulatory documents for protecting, controlling, and accounting for nuclear materials,
- Upgrading physical security and MPC&A systems.

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

Under the Material Consolidation and Conversion Project our main objective is to consolidate HEU into fewer buildings and sites in Russia, and, when possible, eliminate HEU as a proliferation concern by converting it to low-enriched uranium; we collaborate with two nuclear facilities in Russia to have them do the latter.

As MCP&A upgrades funded by the DOE were completed, the Program examined the need for operational inspection and verification of them. In February 2001, the General Accounting Office (GAO) recommended this to the National Nuclear Security Administration. In May 2001, Brookhaven was asked, in a small pilot project, to install an MPC&A operations monitoring system at a Russian nuclear site to evaluate the feasibility of the GAO recommendation. After successful completion, similar systems were installed in as many sites as possible during FY 2002.These MPC&A projects are expected to continue beyond FY 2003. A BNL scientist leads the Technical Survey Team (TST) that provides top-level technical review, strategic and program-related advice, and recommendations to the DOE/HQ on all aspects under the MPC&A Program. We anticipate that TST will expand its influence on the future direction of the MPC&A Program in Russia. BNL is developing an analytical model that will estimate the reduction in relative risk associated with implementing MPC&A upgrades.

Future Program: BNL will continue to support all aspects of the MPC&A Program. We will assume the leadership of the MPC&A Awareness Project to ensure that it is fully integrated into the institutional mission of the Russian sites, government ministries, and public awareness. BNL expects to assist the Russians in conducting initial comprehensive physical inventories and material balances in very large uranium and plutonium processing operations, thereby providing a good quantitative assessment of the improvements in accounting for nuclear materials. Once completed, the program's emphasis will be directed toward gaining assurances that the Russians continue to implement, and can sustain, the

upgrades. A new activity for FY2003 is support for security of radiological sources in Russia and other FSU states.

4.4.4 Department of Homeland Security (DHS) Direct Funded Work

Present Program: The DHS supported BNL in establishing a new facility for evaluating available state-of-the-art radiation detection equipment. This "test-bed" facility, called the Radiation Detector Testing and Evaluation Center (RADTEC), is assembling, operating, and testing detectors for various homeland security applications. After our evaluations, the radiation detectors will undergo field trials at key locations in the New York metropolitan area.

The Center is expected to become an important resource for local, county, state, and federal officials, allowing researchers to define the strengths and limitations of various detectors, providing a quantitative (detector performance) and a qualitative (ease of use) method to compare them. Such comparison is necessary to provide the most comprehensive security screening deploy ment for the busy ports and access points in the New York metropolitan area.

Future Programs: Our homeland security programs focus on developing advanced, science-based solutions for the challenges faced by those protecting U.S. national security interests at home and abroad. Brookhaven recently was designated as an official DHS contributing laboratory. We expect to expand significantly our work for them over the next several years based on the extensive portfolio of counterterrorism and nonproliferation technologies developed at BNL that include safeguarding fissile materials; developing sensors to detect nuclear weapons, dirty bombs, toxic chemicals, biological pathogens, and explosives; and designing tools and approaches for identifying, characterizing, and managing risk in various environments.

4.5 Environmental Quality Mission (EM, NP, KP)

Present Program: The predominant work of Brookhaven's Environmental Quality Mission is to remediate the site, decontaminate and decommission the BGRR, and support Waste Management Operations. The DOE/EM funds the remediation programs. We implemented an innovative, near real-time characterization program to reliably determine the proper disposal path for over 5000 cubic yards of contaminated soils removed from former disposal pits.

The DOE/BER funds research related to their Environmental Quality Mission. Researchers investigate the biochemical mechanisms underlying 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 these contaminants. Phytoremediation, using plants to sorb pollutants from the ground, is a promising inexpensive technology for environmental restoration. BNL scientists are exploring both the basic mechanisms of contaminant uptake and applied techniques to enhance its effectiveness.

Newmont Mining Corp. licensed BNL's patented Sulfur Polymer Stabilization/Solidfication process; we are providing technical assistance for its scale-up and commercialization.

Future Program: We envision advances leading to technologies that will further environmental restoration and long-term management of the DOE's contaminated sites. Brookhaven has expertise 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 the sponsors' needs. We are developing a technology for the *in situ* treatment of mercury-contaminated soils; it could be effective at several DOE sites. We began a broad research effort (Center for Environmental Molecular Science/EnviroSuite) with USB and the NSLS to investigate fundamental mechanisms of environmental remediation. The findings will support DOE's cleanup and long-term stewardship missions.

4.6 Major DOE Partnerships

Relativistic Heavy Ion Collider (RHIC): RHIC represents a major collaborative effort among the U.S. DOE Laboratories, U.S. universities, and worldwide scientific communities. The four RHIC detectors, BRAHMS, PHENIX, PHOBOS, and STAR, involve more than 1100 scientists from five DOE National Laboratories, 40 U.S. universities, and 50 non-US institutions from 19 different countries. Each collaborating DOE Laboratory, as well as many of the U.S. 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 U.S. in the LHC Project and its subsequent scientific program. BNL is the host laboratory for U.S. participation in the ATLAS detector (Sections 4.2.1.2 and 4.2.1.3). BNL collaborates with two other DOE laboratories (ANL and LBNL) and with research teams from about 29 universities in the U.S., and is a member of a three-laboratory team (with Fermilab and LBNL) that manages the U.S. contributions to the accelerator part of the LHC Project. BNL will test all the LHC's superconducting cable and produce a set of RHIC-type superconducting magnets for the machine lattice. BNL also contributes important expertise to the accelerator physics effort for the LHC.

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 each 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. Its goals 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 nine 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 (with Argonne National Laboratory, Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and Thomas Jefferson National Accelerator Facility) that will construct the world's most powerful accelerator-based neutron source for the DOE's Basic Energy Sciences program. BNL's responsibility is to design, construct, and commission 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 there. This very productive research continues. The announcement of the discovery of the top quark by the D0 Collaboration, several years ago, demonstrates this productivity; BNL's physicists played a leading role in that very important successful search. BNL 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 the DOE. Participating institutions represent Canada, the U.S., 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, along with institutions from the U.S., 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 be in future years. BNL's nuclear chemists have contributed significantly to solar-neutrino experiments and will continue to do so 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 the DOE's climate change response, and to link with other agency participants from the National Oceanographic and Atmospheric Agency and the National Space and Aeronautics Agency. National coordination and integration is essential for developing a unified research program on climate change.

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 States' reactors. The team corrects major safety deficiencies and establishes nuclear safety infrastructures that will be self-sustaining. More than 150 joint projects were begun at nuclear installations. BNL's focus will continue to be on training, simulator development, safety system upgrades, fire hazard analysis, and technology transfer.

Initiatives for Proliferation Prevention: BNL is an active participant with other multi-program laboratories and the Kansas City Plant in the Initiatives for Proliferation Prevention Program (IPP). The program's goal 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 U.S. businesses in non-weapons related research and commercial activities. BNL initiated over fifty individual projects that reflect our overall research portfolio. The projects span 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 U.S. 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 former weapons scientists in the ten closed cities of the Russian Federation.

4.7 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. It focuses on early exploration and exploitation of creative and innovative concepts that enhance the Laboratory's ability to carry out its current and future mission objectives in line with the DOE's goals. This discretionary tool is an important way of maintaining our scientific excellence. It stimulates the scientific-technological community by fostering new ideas, maintaining staff excellence, and focusing on advancing the national agenda within the overall DOE mission. Projects normally ranging from $50,000 to $200,000 per year are appropriate, with a preference for the smaller ones. They generally are funded for two years with the possibility for a third. Typically, they include but are not limited to:

- New or unexplored directions at the forefront of basic and applied science and technology to enrich the Laboratory's capabilities.
- Advanced exploration of new hypotheses, concepts, or innovative approaches to scientific or technical problems.
- Experiments and analyses directed toward "proof of principle" or early determination of the value of new scientific ideas.
- Conceptual and preliminary technical analysis of experimental facilities or devices.

The LDRD's Scientific Program Director, who reports to the Deputy Director for Science and Technology, coordinates, oversees, and administers the program. A Committee, consisting of the Deputy Director, the Scientific Program Director, all Associate Laboratory Directors, and four scientists from the Brookhaven Council, review all proposals, select the projects to be funded, and determine the amount of each award.

The LDRD program is a crucial and indispensable ingredient in promoting BNL's multidisciplinary mission; it also fosters the advancement and full utilization of user facilities. The noteworthy research accomplished under the Program has resulted in numerous publications, presentations at professional meetings, and patent applications and patents. The program also supports several post-doctoral fellows, the nation's future scientists. Accordingly, BNL will increase its relatively modest expenditures for the Program from less than two percent of its budget to about four percent (Table 13), still below the DOE-mandated cap of six percent.

Table 13 - Proposed LDRD Funding Levels (In Millions)

Fiscal Year	2003	2004	2005	2006	2007	2008
Budget	8.5	9.0*	9.5*	10.0*	11.0*	12.0*

* Projected

5.0 Work For Others (WFO) and Technology Transfer

5.1 WFO Federal Sponsors

We are consolidating our entire WFO program, which includes work for other federal agencies and non-federal sponsors, in our Office of Intellectual Property and Sponsored Research (OIP). The primary goal is to increase the research funding BNL receives from other federal agencies. Both the Office of Science and OMB have encouraged the SC laboratories to be research resources for the other federal agencies, where appropriate, and consolidating WFO will address this issue. The OIP, supported by a WFO Planning Task Force composed of senior staff, is formulating a Strategic Plan For Work For Other Federal Agencies to present to the Laboratory Director before September 30, 2003.

For each WFO sponsor listed below, the Supplementary Information contains a complete tabulation of the programs it currently supports.

5.1.1 National Aeronautics and Space Administration (NASA)

The construction and operation of the NSRL, formerly the Booster Applications Facility, represents the DOE's ongoing partnership with NASA to provide extraordinary facilities and capabilities for radiobiological and materials research related to NASA's mission. This is consistent with BNL's goal to undertake innovative science, our strategic objective to apply our unique research facilities to problems of human health, and to provide our capabilities to assist other national programs. The following are the goals of NASA and the DOE:

- use BNL's accelerator facilities to simulate aspects of the space radiation environment,
- support investigations of the responses of living systems to radiation exposure in space,
- promote science and technology that meets NASA's requirements for radiation protection in space.

The NSRL, a new experimental facility and accelerator, uses the Booster's heavy-ion beams to explore radiation effects related to the space program. It provides protons and heavy ions (such as Fe, Si, C, Ni, Ar, Au) for radiobiology studies and evaluations of radiation on microelectronics, delivering a complete range of high-atomic number, high-energy (HZE) heavy ion beams with energies from 40 MeV/A to 1500 MeV/A, depending on the particular ion species.

To meet the specific needs of NASA's Space Radiation Health Program and the NSBRI, the facility maintains laboratories for *in vitro*, *in vivo*, and physics experiments. The experimental facility resides in a well-shielded irradiation area, and in a support building containing ready-rooms, laboratories, and offices. Other existing on-site facilities are used, such as tissue culture laboratories and animal handling installations. Dosimetry and local access control is provided through a local facility control room.

BNL's scientists are involved in two areas: 1) The Space Biomedical Research program that focuses on understanding the biological consequences of long-term space flight is a collaboration between BNL's Medical, Collider-Accelerator, and Biology Departments, Instrumentation Division, and SUSB. 2) The NSBRI is a consortium of twelve institutions, including BNL, working to prevent or solve health problems related to prolonged space travel and exposure to microgravity. BNL's current NSBRI programs are listed in Table S7 under Private Entities.

Since 1995, NASA has supported research at the AGS by BNL and users on the radiobiological effects of high-energy heavy ions during future long-term deep space flights. The principal objective is to improve our understanding of the biological effects of low fluences of charged particles on living cells and tissues. These experiments will continue at the NSRL, beginning in July 2003, in collaboration with universities, national laboratories, and research institutes from the U.S. and abroad. Our space neuroscience projects will be expanded to include state-of-the-art neuroimaging techniques to explore the

neurochemical and functional alterations induced by long-term space flight, particularly sleep disorders and psychosocial problems.

Since BNL has this state-of-the-art space radiobiology facility, NASA expressed interest in developing 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 NASA's manned space program. This will enhance and align our current programs with NASA's strategic plan.

5.1.2 Department of Health and Human Services/National Institutes of Health (NIH)

Our Imaging and Neuroscience Center, the STEM, and the NSLS's Structural Biology program operate through partnerships between DOE and NIH and receive funding from both agencies.

More than 800 biologists from BNL, other national laboratories, universities, and pharmaceutical companies use nine of the NSLS experimental stations for macromolecular crystallography. Four beamlines are involved in a cooperative effort, funded by the DOE/OBER and NIH's National Center for Research Resources (NCRR). This consortium, in which some NSLS staff participates, is the PX Research Resource (PXRR). The approximately $4M annual budget supports twenty workers who provide support to users, maintain the facilities, engage in R&D to improve them, and conduct research in experimental methods for structural biology. The fifth beamline, administered by LANL, is developing new standardized methods, equipment, and software in structural biology for macromolecular crystallography. The NCRR funding covered important innovations: an on-site technical specialist to support users for 20 hours per day; personnel and facilities for a mail-in data collection service ("FedEx Data"); and, web-based observation of experiments with the possibility for remote control.
The five structural biology beamlines are:

- X8-C - Operated by a PRT from LANL, NRC Canada, UCLA, Hoffman-La Roche, and BNL's Biology Department.
- X12-B - BNL Biology Department PRT.
- X12-C - BNL Biology Department PRT.
- X25 - Operated cooperatively by a BNL NSLS PRT and the Biology Department.
- X26-C - Operated by a PRT from Cold Spring Harbor Laboratory, USB, the Georgia Research Alliance, and the BNL Biology Department.

With The Albert Einstein College of Medicine, the PXRR will construct a new NSLS beamline at position X29, based on a small-gap in-vacuum undulator. The NIH National Institute of General Medical Sciences (NIGMS) provided the initial construction funds for most components within the synchrotron wall; the NCRR will pay for the experimental station. It is anticipated that the NSLS will provide the balance of funding, thereby directly supporting PX research.

To improve the efficiency of the "FedEx" service and other work, we will construct a robotic specimen changer at X12-B and replicate it at X25. This work is a direct collaboration between the NIH and DOE/OBER-funded development work at LBL.

Along with other centers, BNL is piloting procedures for cost-effective large-scale protein crystallography. In partnership with Structural Genomics, Inc., The Albert Einstein College of Medicine, Cornell Medical School, and Mt. Sinai School of Medicine, BNL participates in an NIH funded program to further advance structural genomics and to establish a pilot structure-production center.

NIH also substantially supports individual biomedical investigators.

5.1.3 Department of Defense (DOD)

Several key projects are underway for the Army to develop coatings and materials that better resist corrosion. We support the Navy in the Artic Military Environmental Cooperation Program, and the Office of Naval Research in developing the next generation free electron laser, and in acquiring shipboard acoustic Doppler profiles in the Arabian Sea. The Medical Department undertakes drug abuse imaging studies for the Army to develop a new test bed that involves MRI and molecular modeling.

5.1.4 Environmental Protection Agency (EPA)

Authorities face an operational crisis in New York Harbor in removing sediments and soils contaminated with anthropogenic toxic materials. In collaboration with the U.S. Army Corps of Engineers, we are producing economical, environmentally effective treatment technologies for the dredged material.

International cooperation is critical to the EPA's mission. Its Office of International Activities (OIA) cooperates with other nations in solving environmental problems of concern to the US. BNL's staff assists in designing and overseeing the construction of a waste processing facility in Murmansk, Russia and provides technical support in evaluating Russian technologies for waste treatment. Through the OIA, BNL is fostering environmentally sound, sustainable development initiatives in Kazakstan.

With the EPA, we are establishing a mobile treatment facility for radioactive wastes. Our environmental chemistry group is conducting a southern oxidants study. The MARKAL MACRO program developed at BNL is still used abroad in energy planning; the EPA is funding us to work with representatives from Central America and Puerto Rico to utilize it.

5.1.5 National Science Foundation (NSF)

Our Physics and Collider Accelerator Departments are beginning collaborations with the University of California at Irvine and Yale on research components of RSVP. We expect that this program will result in construction to upgrade the AGS in future years. Through Woods Hole Laboratory and university collaborators, we conduct many NSF funded oceanography studies.

5.1.6 Nuclear Regulatory Commission (NRC)

Following several years of decline, the work supported by the NRC at BNL stabilized. We expect funding at the same level or higher in the future, as new reactor concepts, such as the pebble bed modular reactor, and new fuel concepts, such as high burn-up mixed-oxide fuel, are opened to regulatory review. The introduction of risk informed regulation and the submission of license renewal applications will continue to require BNL's efforts.

BNL provides technical support to the NRC and performs safety related research for them. This work includes risk assessment, reliability analysis, thermal-hydraulic and neutronic-analyses evaluations for 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. We support the licensing of the ESBWR and ACR-700 designs.

The Laboratory provides environmental qualification data on aged electrical cables using experimental condition-monitoring resources housed in our Electric Cable Test Facility. BNL is heavily involved in training regulatory staff in this country and the FSU. We also collaborate in seismic research with NUPEC of Japan.

5.1.7 Department of State (DOS)

The Department of State funds Brookhaven's International Safeguards Project Office (ISPO), which supports the IAEA in nuclear safeguards. The ISPO provides ongoing technical review and management of the U.S. Program of Technical Assistance to IAEA Standards, and offers advice on new initiatives to enhance the effectiveness and efficiency of IAEA safeguards. Currently, ISPO tracks nearly 100 active projects. We may secure additional funds for initiatives on managing Russian radioactive waste.

We continue to offer technical support and programs on simulators, provide training to enhance the safe operation of nuclear power plants, decommissioning and decontamination, and waste management, and to support work in Eastern Europe and the FSU.

5.1.8 Other Federal Work

BNL assists the FAA and DOT with risk- and reliability-analyses and assessments of threats by insiders and outsiders to ensure aircraft system reliability, availability, maintainability, and airport security. We use probabilistic-risk analysis techniques, developed and proven for 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.

5.2 WFO Non-Federal Sponsors

Recently, work for non-federal sponsors has increased considerably, presenting opportunities for future growth. BNL will seek to expand its sponsored research with non-federal entities in areas relevant to the DOE's research missions. BNL offers the private sector varied opportunities for sponsored research in environmental sciences, energy technologies, materials sciences, and biotechnology.

5.2.1 Private Firms

BNL scientists perform research for several private firms, often using our unique facilities. Most of this work is in energy sciences for the local electric utilities.

5.2.2 Non-Profit Organizations/Institutions

The largest segment of our work for non-profit organizations/institutions is with hospitals and medical foundations in the field of biomedical research using Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI). We continue to perform work for the Electric Power Research Institute (EPRI) related to nuclear power plant operations.

5.2.3 Educational Institutions

BNL's atmospheric chemistry and oceanography programs carry out extensive sponsored research for educational institutions; several leverage the DOE's investments in atmospheric chemistry. Educational institutions also extensively use our capabilities in biomedical research. Our MRI group receives funding for work in addiction, HIV, and fMRI applications and the PET group is funded for work in monitoring the brain's metabolic functions and providing new insight into treating schizophrenia and Alzheimer's disease.

5.2.4 State Agencies

Most of our funding from state agencies came from the New York State Energy Research and Development Authority (NYSERDA). Our Combustion Equipment Technology (Oil Heat) Research Program conducted important research in advanced oil heat technologies for NYSERDA for several years. When this direct funding ended, NYSERDA began funding work at small NYS companies and BNL continues its involvement through funding received from these companies.

5.2.5 Foreign Sponsors

BNL's expertise in risk-assessment studies for the NRC generated a significant amount of foreign sponsored research for similar work at foreign nuclear power plants. BNL receives funding to help nations utilize our MARKAL-MACRO computer code for designing energy-efficient infrastructures.

5.3 Technology Transfer

One objective of the Laboratory's Basic Science and Technology Critical Outcome is to be effective in "…developing, managing, and transferring to industry intellectual property and technical know-how associated with research discoveries." Our technology transfer program, for which the OIP is responsible, addresses this objective through two primary goals: to complement the DOE's research mission through involvement in technology transfer projects that enhance our research capabilities; and, to be a resource to U.S. companies, enhancing their domestic and international competitiveness. We use the following mechanisms in our technology transfer program:

- Industry's use of designated facilities for proprietary or non-proprietary research;
- Work for non-federal sponsors (universities, utilities, hospitals, non-profit institutions, and state and local governments);
- Work for other federal agencies;
- Collaborative research under Cooperative Research and Development Agreements (CRADAs);
- Intellectual property protection and licensing.

Under its Prime Contract with the DOE, BSA has the right to take title to technologies invented by Brookhaven employees and the patents covering them, and to license these patent rights to industry. The following are some of our 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 materials for diagnostics and therapeutics;
- advanced electrochemical materials for battery components;
- electrocatalysts for fuel cells.

Industry is especially interested in inventions from our biotechnology research programs. 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 the Biology Department's T-7 gene expression system continues to evolve, with over 200 licenses in place with industry. We have over 160 technologies in the BSA Patent Licensing Portfolio; almost half of them are already licensed to industry; and almost one in every ten of these technologies is already commercialized, with new products based on them on the market. The net

revenue generated by the licensing program, which is shared with the inventors and re-invested in the Laboratory's research programs, has increased the last several years. The licensing program is very cost effective, with the costs of patent prosecution, maintenance, and licensing being 29% of the gross revenue in FY 00, 27% in FY 01, and 23% in FY 02 (Licensing Information is provided in Tables S9-S11).

We will continue to expand the Patent Licensing Program to effectively foster the marketing of our new technologies and explore the possibilities that BNL's computer software may have marketable, applications and be appropriate for copyrighting and licensing.

Over the past several years, CRADA projects have proven to be a valuable component of our research portfolio, enhancing BNL's research capabilities and providing researchers with access to industrial expertise. They generated new technologies and numerous patents, created new commercial products and processes, and demonstrated the societal relevance and public benefit of the DOE/SC research program (Table S8 is a comprehensive list of CRADAs.)

Our CRADA projects are funded primarily from the following sources:

- DOE's/SC Laboratory Technology Research (LTR) Program that in the mid-90s supported most of BNL's CRADA programs; it apparently will be terminated in FY04;
- DOE's Initiative for Proliferation Prevention Program for the Newly Independent States of the FSU (IPP-NIS); and,
- industrial partners who fully fund BNL's CRADAs.

The LTR program continues to fund a few multi-year CRADA projects. BNL's instrumentation capabilities are used in two LTR CRADAs with LI companies. The first, with Advanced Energy Systems, involves designing, fabricating, and testing a high duty factor, high brightness, all niobium superconducting RF gun. In the second, we are working with Brookhaven Technology Group 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. The final one involves our biotechnology research capabilities with Miravant Medical Technologies for synchrotron-based structural studies of hydroporphyrin sensitizers for photodynamic therapy of cancer.

The IPP-NIS program supports research partnerships that take advantage of the research capabilities of established scientific institutions in the NIS, and the commercialization expertise of U.S. industry. The DOE supports the research by BNL and the NIS institute, while our industrial partner supports its own work through a CRADA. BNL participates in fifteen IPP-NIS CRADAs, including the BNL/Canberra Aquila, Inc. project, under which we are working with the Russian General Physics Institute to develop remote detectors for breath alcohol, and the BNL/MIT CRADA wherein we collaborate with GE's Global Nuclear Fuels and Kaz Atom to develop fuel-processing technologies.

We continue to attract funding from industry to support CRADAs. Our Biology Department and Dow Chemical Company are working to create environmentally beneficial agricultural plants with novel applications for human health and nutrition. Our Medical Department with Psimei Pharmaceuticals is developing new boron containing drugs for neutron capture therapy of malignant tumors and for photosensitization. Our Chemistry Department works with Johnson and Johnson on radiotracer development.

Technology transfer, especially the work for other federal agencies, is a potential growth area in our overall R&D portfolio. We will vigorously pursue opportunities to expand research partnerships to support the Laboratory's overall strategic plan.

6.0 Management and Operations Systems

Brookhaven National Laboratory's strategic planning processes align our management and operating systems with the DOE's national missions and strategic plans. Several systems, central to BNL's ability to meet these challenges, include an integrated set of non-overlapping management systems that set forth the requirements defined by the DOE. They collectively form the Standards-Based Management System (SBMS), our 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 Laboratory-wide procedures and guidelines that fulfill the requirements of each system.

The Laboratory enhanced the line ownership and accountability of managers for performance. BNL's contract with the DOE is founded on Performance-Based Management principles and practices. We are making a concerted, focused effort to plan our future and manage our assets. We will accomplish our goals by continually aligning our missions with those of the DOE, as stated in the President's Management Agenda and the DOE's Annual Performance Plan.

6.1 Human Capital

Our Human Resource goal is to continually improve our personnel programs, processes, and policies so the Laboratory can attract, retain, and reward a highly qualified, diverse workforce. We will maintain an environment of opportunity and empowerment, increasing employee and leadership effectiveness, and improving the staff's diversity.

Training is targeted to current and anticipated Laboratory needs. Career development will be expanded, and the scientific career advisory program strengthened. Employee's performance appraisals and annual goals are emphasized with Lab managers; succession planning and 360º feedback programs develop more effective future managers. Brookhaven values its diverse staff and their rich cultural and ethnic backgrounds; our Diversity Office partners with employees to provide programs and celebrations that recognize these heritages.

6.2 Information Technology Management

The Information Technology (IT) program supports the Laboratory's scientific research and business processes by directing IT resources to realize our mission and goals. The following are the major strategic objectives for IT:

- Support Advanced Computation Research and provide an effective computing infrastructure,
- Enhance network capabilities to meet the growing needs of research,
- Provide effective computers and network security,
- Implement a communications infrastructure and standardization program,
- Improve the usability and integrate the applications of PeopleSoft and related business tools,
- Sustain a program of IT training and professional development for IT staff and users,
- Implement an IT benchmarking and metrics program.

BNL is revitalizing the Laboratory's major computational centers, the CDIC, the RCF, the BNL RIKEN, QCDOC, and QCDSP facilities. Simultaneously, we are broadening the client base of the general-purpose Brookhaven Computing Facility by better understanding the users' scientific objectives, and providing more relevant and attractive systems and services. This includes enhancing the Linux Cluster, Silicon Graphics Onyx, and Sun Solaris platforms, and introducing modern software products, such as Java, XML, and the Globus grid suite. In the well-established Visualization program, we

emphasize providing hyper-resolution facilities and extending high quality visualization to the researchers' desktops, as funding permits.

Local and wide-area network capabilities are, perhaps, our most strategic asset. Effective, secure networking is vital to the highly collaborative research environment of the Laboratory's major programs and infuses every area of our business. Wide area network bandwidth must increase within five years to 2500 Mb/sec to meet estimated research requirements, especially those of RHIC and ATLAS. The local area backbones must increase commensurately, extending a high quality gigabit network to most of the site, and providing three to five times that bandwidth.

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 will encourage the use of common software tools and reduce costs.

The Cyber Security initiative is particularly important. BNL's Unclassified Cyber Security Program Plan is being implemented with help from our Computer Security Advisory Council. A complete Perimeter Defense Network, and host-based security and authentication services will be in place; however, the dynamic nature of ensuring cyber security demands a constant reassessment 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. Recently, the Laboratory implemented several major new administrative information systems; first, integrated financial management programs, then human resource management programs, all purchased from PeopleSoft, Inc. All existing applications were moved from the legacy systems to Windows NT operating environment, except Travel and Labor Cost Distribution that will do so in FY'03 and '04, respectively.

Our Benchmarking and Metrics program monitors efficiency, quality, and customer satisfaction. Key IT service categories and associated metrics were defined in FY 01, the baseline year. Some IT Metrics are being collected, reported, and published; others are constantly being developed

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

6.3 Communications Management

Brookhaven is successfully promoting the value of its science programs, and those of the DOE, to targeted audiences, including decision makers, science policy leaders, science-attentive and science-interested publics, and the general public. This year, the Laboratory proudly shared the news that Raymond Davis Jr. won the 2002 Nobel Prize in physics. Brookhaven managed all media relations activities related to the DOE's Nanoscale Science Research Centers Workshop, which included Brookhaven's own CFN. RHIC was featured in The NY Times Science Times, triggering other media interest worldwide. Other research, such as homeland security, addiction, nanoscience, and environmental research, received attention in all media. At the same time, the Laboratory continues its ongoing dialogue with the community and a broad spectrum of stakeholders about legacy environmental issues and our commitment to protect the environment and minimize waste.

Our two- to five-year goal is to generate community understanding for our research programs and new initiatives, and to increase confidence and trust in our cleanup efforts. To meet these goals, the Laboratory will

- Continue to familiarize the community with our scientific research,

- Generate regional pride in Brookhaven as a community asset, internationally renowned and contributing to the educational and economic benefit of LI and NYS,
- Involve stakeholders and the general public through tours, student visits and similar activities that make our science and people familiar, friendly, and accessible,
- Position Brookhaven as a preferred location to do science by making it attractive to users and potential employees,
- Work with our DOE colleagues to foster multi-laboratory initiatives and promote the DOE,
- Seek input from internal and external stakeholders on issues of importance to them.

The Laboratory will continue to support programs that engage the community, including the Envoy Program, Speakers Bureau, and Summer Sunday Tours.

The Community Advisory Council (CAC) advises the Brookhaven Director on issues of importance to the community at large and to the organizations represented on the CAC. The Laboratory has an ongoing dialogue with the CAC on programs of interest, supplying data as requested, facilitation services, and administrative support.

The World Wide Web is an increasingly important vehicle for communicating the mission and achievements of the Laboratory to all stakeholders. Information on Brookhaven's web site, will be timely, accurate, interesting, and useful.

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

Protecting the environment, the safety and health of workers and others, and the quality with which all work is done, are integrated into work from its planning stages to completion. Managers responsible for the work understand the hazards, establish appropriate controls before authorizing work to begin, and ensure appropriate control of all workplace risks.

New initiatives, including eRHIC, the CFN, NSLS-II, revitalization of site infrastructure, and the completion of the environmental restoration program will require the continuous involvement of ESH&Q disciplines to maintain work planning and control processes consistent with our commitment to safe workplaces and environmental stewardship.

Operational excellence is our goal, i.e., all operations will be safe, environmentally responsible, and cost-effective. We make every effort to reduce indirect costs by eliminating redundancy and non-value-added work. We will consider new approaches to achieving efficient support, including sharing resources between support units; purchasing services from the Lab's support organizations and from elsewhere; and, enhancing resource sharing and integration with corporate partners /sister laboratories. Our objective is to reprogram savings into investments in our core capabilities to support business development while maintaining competitive rates.

6.4.1 Environmental Management

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

BNL minimizes environmental impacts by implementing our ISO 14001 certified Environmental Management System for all facilities and operations. We stress dedicated planning for avoiding waste at the earliest stages, continually looking for ways to lower the cost of managing wastes, and minimizing waste-related risks to the environment.

Concurrent with preventing pollution, our waste management program's goals are to minimize waste generation, use recycling and reduction instead of treatment and disposal, and manage wastes off

site to prevent stockpiling. The transition of Waste Management funding from the DOE/EM to the DOE/SC forced a more thoughtful assessment by waste generators and further examination of alternate strategies for collection and disposal. Right sizing the Waste Management function will continue for another year or so.

BNL is committed to accelerating the completion of its environmental restoration mission. Our restoration program is fully engaged in cleanup projects involving contaminated soils, groundwater, the Peconic River, and BGRR decommissioning. BSA intends to manage this effort until the EM program is completed. Final end-state decisions and the supporting Record Of Decisions are important next steps toward finishing the EM projects.

6.4.2 Safety and Health

Continued emphasis on the Integrated Safety Management Core Functions and Guiding Principles will help BNL enforce work planning and control as the fundamental building block of our ESH&Q program. We continue to improve workers' Roles, Responsibilities, Accountabilities and Authorities (R2A2), and the depth and effectiveness of self-assessments. We will increase the field presence of safety and health professionals by supplementing existing field staff with backup from other members of the Safety Evaluation Group.

6.4.3 Quality Management

Quality requirements from the DOE Order 414.1A and 10CFR830.120 are incorporated directly into the Management Systems and Subject Areas, where applicable. This approach assures incorporation of quality activities into the Laboratory's everyday operations, and reinforces the understanding that quality is each employee's responsibility.

The Baldrige-Based methodology previously used to assess the maturity of Quality Management is being employed for "Maturity Evaluations" of four additional management processes. Evaluation focuses in three areas: "Approach/Definition," "Deployment/ Implementation," and "Assessment/Improvement." The results will help BNL's Management Systems Stewards to prioritize issues and take appropriate actions for improvement. The maturity evaluation process was endorsed throughout the DOE complex.

The DOE and the Laboratory place increasing emphasis on our self-assessment and improvement program, including being reflected in annual Performance Measures, as directed in the "Card Principles." In addition, third-party assessments of the Lab's self-assessments of our Management Systems offer further data on performance-based management contracts in a DOE laboratory construct. However, the ability to objectively measure the adequacy and effectiveness of a self-assessment and improvement program presents many challenges. Accordingly, we are piloting/using a Baldrige-Based methodology for this purpose.

6.5 Safeguards and Security Management

The Safeguards and Security (SS) organization supports the basic scientific mission of DOE and BNL 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,
- preventing radiological or toxicological sabotage that would endanger employees, the public, or the environment.

It establishes guidelines, plans, and strategies to protect sensitive or classified information, export information, CRADAs, protocol visits, and WFO.

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 implement preventive programs, such as property-protection access controls, site surveillance, community crime prevention, and Security Education and Awareness.

The Counterintelligence program includes protecting information, conducting foreign travel briefings and debriefings and host debriefings, and interacting with the foreign visits and assignments office. BNL's Senior Counterintelligence Officer works closely with SS personnel, the Operations Security Working Group, and Federal agencies and leads the Laboratory's efforts to maintain a current list of sensitive technologies.

The SS Enhancements Plan is long-range to ensure that security is continuously improved efficiently and cost-effectively. Subject-matter experts review it annually to ensure that the necessary protective measures are planned systematically to identify and prioritize vulnerabilities. BNL is pursuing an action plan for implementing DOE's Integrated SS Management policy.

The continuing security need for, and importance of, a Visitor Reception Center was heightened after the World Trade Center bombings. BNL has no facility for visitors, vendors, or contractors to obtain necessary information about programs, regulations, restrictions, or to fulfill training requirements before entering the site. Such a 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 (e.g., job postings), and parking and vehicle inspection areas. It would result in better access control, better informed and trained employees, guests, and contractors, and enhanced community relations.

7.0 Site, Facilities and Infrastructure Management

7.1 Description of Laboratory Site and Facilities

Thirty percent of BNL's 5,320 acres site is developed. Many buildings date back to World War II, some earlier. Most major permanent facilities are the DOE/SC facilities built in the 1950's and 1960s, excluding those constructed for RHIC. The remainder are wells and treatment facilities supporting the DOE/EM environmental remediation programs. Their long-term stewardship will move from EM to SC in several years. BNL's site-wide utilities include electrical-, steam-, sanitary sewer-, storm sewer-, and potable-water systems, with limited distribution systems for chilled-water and compressed air. Tables 14 and 15 show the Laboratory's space distribution, and replacement plant value, respectively.

Table 14 - Laboratory Space Distribution

LABORATORY SPACE DISTRIBUTION

	SC		EM	
	Sq. Ft.	#	Sq. Ft.	#
Facility Type				
Total Buildings	4,028,494	365	188,877	21
Active Buildings	3,415,146	257	17,749	7
Operational Excess Buildings	540,123	98	0	0
Non-operational Excess	73,225	10	171,128	14
Portable Structures [1]	93,486	294	10,854	30
Leased Off-site	1,000	1	0	0

1. Portable structures: Facilities not meeting the criteria for real property buildings. They include trailers, sheds, containers, railroad cars, and HAZMAT storage units.
Source: DOE FIMS Database 04/18/03

Table 15 - Laboratory Replacement Plant Value

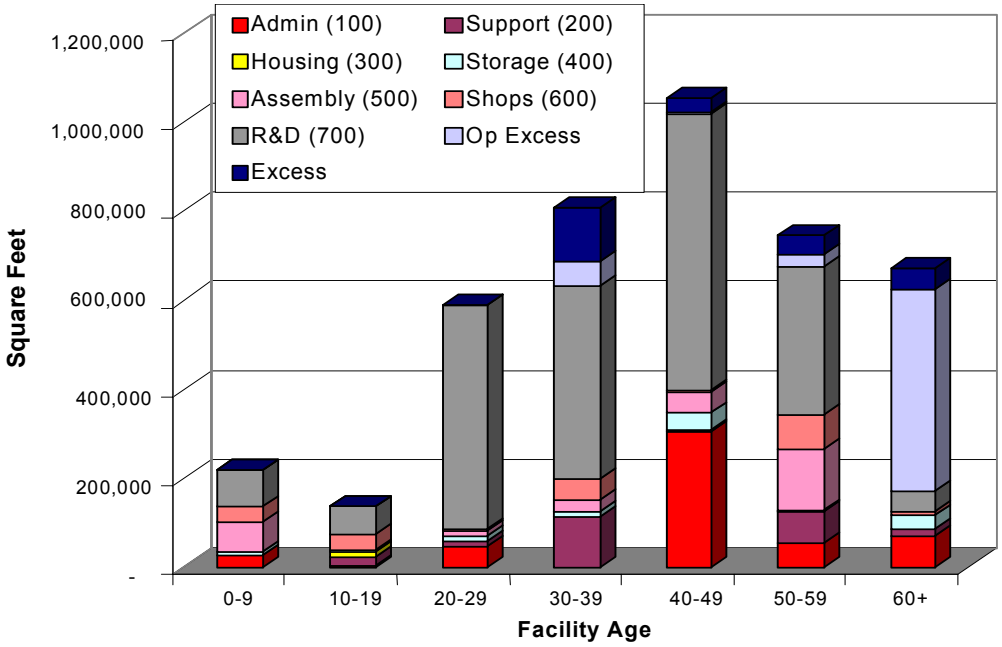
REPLACEMENT PLANT VALUE ($)

Asset Type	SC	EM
Active Buildings	1,033,943,584	1,550,768
Operational Excess Buildings	158,445,007	0
Non-operational Excess Buildings	19,482,474	59,311,258
Active Utilities (BNL Type 2-7)	179,346,637	0
Active Programmatic (BNL Type 10-18, 40)	937,751,308	29,063,008
Active Other OSF (BNL Type 1, 30-34) [1]	31,983,732	0
Excess Other Structures & Facilities (OSF)	6,681,643	62,368,511

ad, walks, parking, railroad, and non-utility OSF
Source: DOE FIMS Database 04/18/03.

Figure 1 shows the amount of operational excess space in the 60+ years old bracket that BNL plans to demolish when replacement facilities are constructed. Much of BNL's R&D space is between 30-49 years old; most of it is major laboratory/office buildings that need rehabilitation.

Figure 1 - Age Distribution of Buildings by Facility Use Code – Source:FIMS data 4/18/03
(Average Age, Weighted by Square Footage = 41.6)



USE CODE	FACILITY AGE						
	0-9	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60+**
100	26,823	4,106	44,453	-	302,592	54,143	69,393
200	-	18,650	11,715	112,579	6,084	70,778	14,295
300	-	9,034	-	-	-	-	-
400	4,811	6,385	11,080	11,020	38,394	1,982	32,768
500	69,772	-	12,524	25,976	46,026	135,745	-
600	31,924	34,298	5,953	46,740	2,458	77,700	5,408
700	84,244	61,569	502,188	436,568	621,151	334,441	47,125
Op Excess	-	-	-	52,912	5,750	26,344	455,117
Excess	-	-	208	122,242	32,285	41,697	47,921

Figure 2 - Use and Condition of Non-surplus Space – Source: FIMS Data 4/18/03

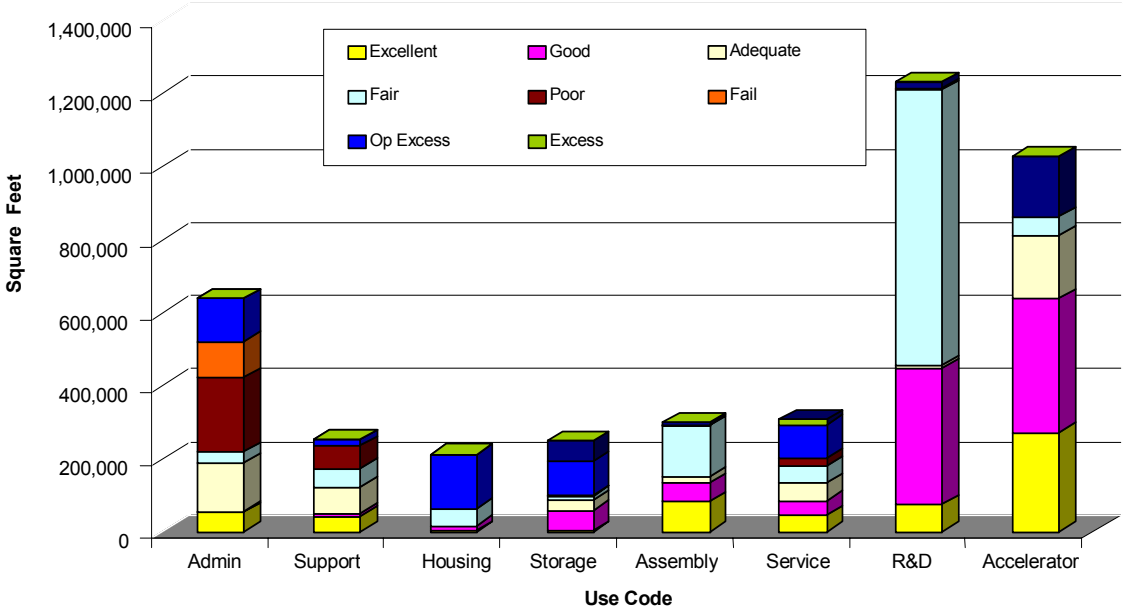
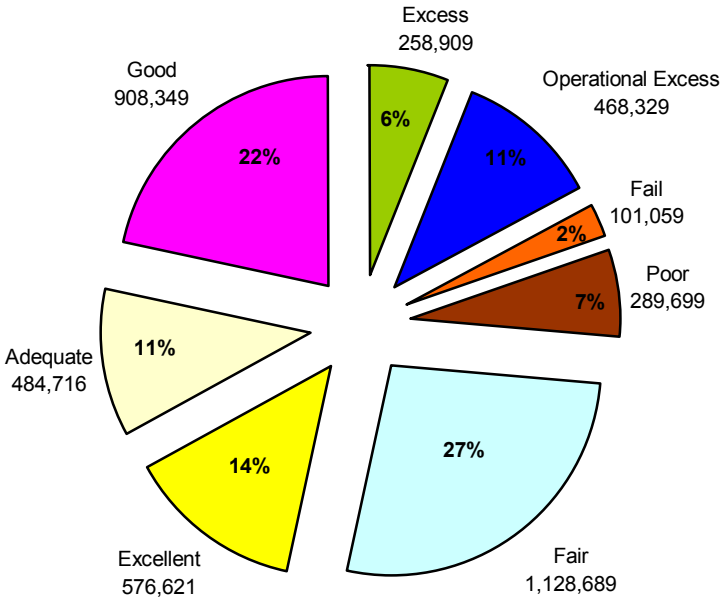


Figure 3 - Condition of Laboratory Space – Based on FIMS Data dated 4/18/03



Figures 2 and 3 illustrate the condition and use of existing Laboratory space. Over 25% of BNL's space is poor or worse, requiring major rehabilitation or replacement. A further 27% is classified as "Fair", also indicating a significant need for rehabilitation funds. Figures 2 & 3 break out the Operational Excess category to show those facilities for which reinvestment does not seem the economic solution; the Site Master Plan identifies projects to replace them. Maintenance and capital investment for them will be restricted to immediate operational needs.

Table 16 - Infrastructure Measures by Facility Use Code Type

Use Code Group	Deferred Maintenance (DM) ($M)	DM Condition Index	Rehab & Modernization Costs ($M)	DM + RMC Condition Index	Utilization Index*
100-Admin	**49.9**	**32%**	**0.7**	**33%**	**1.00**
200-Support	**9.7**	**14%**	**1.9**	**16%**	**1.00**
300-Housing	**0.1**	**8%**	**0**	**8%**	**1.00**
400 -Storage	**1.1**	**5%**	**0.7**	**8%**	**1.01**
500-Assembly	**10.6**	**16%**	**0**	**16%**	**1.01**
600-Shops	**5.3**	**7%**	**3.2**	**12%**	**1.05**
700-R&D	**94.1**	**15%**	**8.9**	**16%**	**1.08**
OperationalExcess	**0.8**	**1%**	**0**	**1%**	**N/A**
Excess Facilities	**9.1**	**6%**	**0**	**6%**	**N/A**

* For the utilization index, excess space is calculated with the current (for operational excess) or last (for current excess) use code.

7.2 Strategies: General Purpose/Conventional Facilities

7.2.1 Strategies

BNL developed several strategies to help address its major issues:

- *Operating Funds*: Several years of static and declining budgets strained BNL's ability to provide adequate operating funds for general maintenance and maintenance projects. Our overall strategy is to disproportionately increase maintenance budgets when operating funds rise (in real dollars), so that maintenance budgets see true growth. However, it is uncertain when and if this will occur. Hence, BNL prioritizes projects to ensure selected capital and operating projects are closely coupled to our Critical Outcomes.
- *Capital Projects:* BNL's capital construction strategy is to propose projects to replace outdated structures and modernize permanent ones. Selectively proposed new footprints only provide capability that does not exist now, such as the clean rooms for the CFN.
- *Alternately Funded Investment:* To supplement the projected capital shortfall, BNL will seek external investment to replace its aged accommodations, and is also pursuing alternately funded laboratory/office space.
- *Energy Supply:* BNL is exploring various ways to obtain the cheapest energy, including co-generation, merchant power plants located on our site, bilateral contracts with local merchant plants, an extension of the NYPA contract, and a power contract with the local Long Island Power Authority (LIPA). However, completing any power plant option, will take several years, and require interim arrangements. The least costly option would probably be to extend the NYPA contract. All options, including a NYPA renewal, are likely to raise electric costs after 2005 It should be noted, however, that the current rate is at a historical 20 year low due to special provisions negotiated into the current NYPA contract. NYPA is unlikely to agree to these provisions in a renewal.

7.3 Maintenance Investment Plan

For FY03, BNL will spend $13M from indirect and direct funds on maintenance for active conventional buildings and other structures and facilities (OSF). These assets have an RPV of approximately $1,045M, representing a Maintenance Investment Index (MII) of 1.25%. In the Integrated Facilities & Infrastructure (IFI) Crosscut, submitted with the FY05 Budget Call, BNL forecasted an increase in maintenance funding only paralleling inflation. As RPV would rise at approximately the same rate, BNL's MII would remain the same.

7.4 Institutional General Plant Projects (IGPP)

BNL has no plans to fund projects with IGPP. If BNL's operating budget were to significantly increase, part of the additional G&A would likely be used fund capital backlog projects with IGPP.

7.5 SC Direct Capital Investment Needs

Inadequate funding for the General Purpose Facilities program is extending the cycle of high operating and maintenance costs, rather than securing reductions through greater investment in new facilities. The Laboratory is concerned about the inability of the SLI Program to meet the needs identified in the Site Master Plan.

Within the planning period, BNL proposes new programmatic facilities (Table 17), including the CFN, described in Section 3.1.5 ($80.9M), and the CIRC, outlined in Section 3.1.8 ($37.50M).

Table 17 - Laboratory Major Programmatic Construction Projects
($ In Millions In Budget Authority)

		Funded		Budgeted		Proposed		
	TEC	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**FY08**
Program Related[a] – SC								
Accelerator Improvement Projects (KB)		2.5	2.90	2.90	3.30	1.40	6.00	6.00
Accelerator Improvement Projects (KC)		1.4	1.39	1.51	1.61	1.70	1.80	1.91
General Plant Projects (KB)		6.1	6.06	6.18	6.50	6.80	7.10	7.50
Total								
Program Related - WFO - NASA								
Booster Applications Facility (BAF)	35.40	9.5	3.9					
Proposed Construction – NE								
Cyclotron Isotope Research Center	37.50				9.88	13.40	11.87	2.35
Proposed Construction – SC								
Center for Funct. Nanomaterials (KC)(AA1D0005)	80.90		0	3.00	22.90	35.00	20.00	
Total								
Under Evaluation								
RHIC II/eRHIC								
Electron Bean Injection System								
NSLS II								
Superbeam								
eRHIC								
Total Funded Program Construction		**19.50**	**14.25**					
Total Budgeted Program				**13.59**	**44.19**			

Construction								
Total Proposed Program Construction						**58.30**	**46.77**	**17.76**
a) as submitted to the FY-04 DOE budget.								

In addition, several proposed SLI projects (Table 18) for new buildings, including a User Research Building ($15.4M), Energy Sciences Building ($18.3M), and additional phases of the Research Support Building would enable consolidating support functions and demolishing the old wood buildings. The Research Support Buildings also will reduce backlogs in Life Safety compliance, roofing, and duct cleaning, and replacing mechanical equipment.

Table 18 - Laboratory Major SLI Construction Projects
($ In Millions In Budget Authority)

			Funded		**Budgeted**		**Proposed**		
SLI Projects[a]	**Project Type**	**TEC**	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**FY08**
Funded/Budgeted									
Electrical System Mods Ph. II (N98D0022)	1	6.73	3.30	2.88					
Ground & Surface Water (A93D0340)	1	6.03	2.76	1.38					
Research Support Building-Ph I (AA0D0030)	5	18.20		3.30	5.15	9.80			
Total									
Proposed - KG01									
User Research Building (N98D0015)	5	15.40			1.6	6.8	7.00		
Energy Science Building (N98D0015	5	18.30			1.8	7.5	9.0		
Chilled Water Facility – Ph II (AA3D0002)	3,5	8.50				1.5	8.50		
Multi-Program Science Lab Renovation (AA3D0002)	2	15.00					1.60	7.50	5.90
Research Support Cnter–Ph II (AA1D0006)	5	18.20							1.60
Total									
Proposed - KG02									
None									
Total GPF Funded Construction			**6.06**	**7.56**					
Total GPF Budgeted Construction					**8.55**	**25.6**			
Total GPF Proposed Construction							**26.1**	**7.50**	**7.50**
SLI Project Types: 1. ES&H Support, 2. Building Rehabilitation/Upgrades, 3. Utility System Rehabilitation/Upgrades, 4. Roads and OSF Rehabilitation/Upgrades, 5. New Building. a) as submitted to the FY-04 DOE budget									

During the same planning period, BNL also proposes to renovate the interiors and mechanical systems of its major 40-year-old laboratory/office buildings. Many other projects identified in the Site Master Plan 2000 are not listed due to the funding target limitations imposed in the IFI Cross-cut. The GPP has a backlog of $60M. Previously, BNL averaged appropriations of ~$11M/year in combined GPP

and Science Laboratories Infrastructure funds. With a GPP budget averaging slightly over $6.0M annually, larger building projects were sidelined because a single one could consume up to 90% of a fiscal year's GPP budget. This backlog is expected to increase faster as existing facilities age. The Strategic Facilities Plan proposes an increase to fund one major GPP project over the current funding level.

7.6 Funding Impacts on Facilities

Figure 3 shows that 27% of the space on site is "Fair". These assets have an RPV of $423M, using a midpoint Facility Condition Index of 17.5%; this translates into a deferred maintenance of $75M. With capital investments and maintenance projects averaging, respectively, about $12M (GPP & SLI) and $2M per year, under the current trend, more facilities will go from Good to Fair and some from Fair to Poor. This trend will be reversed only by the requested increases in capital funding for rehabilitation of major lab/office buildings and new construction described in our Strategic Facilities Plan. It will begin to reverse if the proposed alternative financing projects for Housing and the Energy Sciences Building are approved.

7.7 Excess Facilities Program

BNL received more than $2M in FY02 and FY03 to demolish more than 100,000 square feet of excess space, and anticipates funding to raze 22,000 square feet in FY04. Planned consolidation will release up to 20,000 square feet in FY05 for demolition. The SLI program does not cover demolition of contaminated space, although the DOE/SC is considering its inclusion. If the DOE funded demolition of contaminated space, more than 25,000 square feet of additional excess space would be available.

7.8 Alternatively Funded Projects

BNL identified a housing replacement project as an excellent candidate for alternative funding and monitored ORNL's attempts to allow state and corporate backed development. We met with the Long Island Housing Partnership (LIHP) which, with state and local officials, acts as facilitators in developing legislative and financial support for housing projects. Housing rented at market rates (verified by GSA) should provide an attractive cash flow to a developer. The concept is similar to the successful third party Military Family Housing. The DOE would provide a land lease to an offeror via a competitive Request for Proposal (RFP). Once the apartments were built and BNL accepted occupancy, they would be leased back to BNL for a five-year term with an option for a second five years. The rents would repay the lease. An Expression of Interest document was published and, based on the favorable response to a meeting held in May 2002 to gauge investors' interest, a draft RFP and financial analysis were prepared. The DOE is reviewing the RFP and applicability of OMB A-11 requirements. Upon approval, BNL will solicit proposals with the intent of entering into a construction contract, with occupancy beginning in early FY05.

Preparation of a Request for Proposals and supporting documentation for constructing an alternatively funded laboratory/office building for Energy Sciences Building is underway. A developer workshop has been held which indicated substantial interest in the project. Delivery of the project documents to DOE is anticipated in late August 2003.

7.9 Assets Management

Our comprehensive and cost effective Assets Management Program encompasses the use, control, and disposal of assets. Our "Walk-Through" Program ensures that all equipment is properly controlled, and identifies idle or surplus materials. The site inspection program monitors the

accumulation of materials. Together with the Waste Minimization Program, the Laboratory quickly and efficiently disposes of surplus assets, consistent with Federal and DOE Property Management Regulations.

7.10 Energy Management and Sustainable Design

7.10.1 Energy Management

BNL's Energy Management Group works to reduce BNL's energy use and costs by identifying cost effective energy efficiency projects, monitoring energy use and utility bills, and assisting in obtaining the cheapest energy sources. It develops, implements, and coordinates BNL's Energy Management Plan. Its initiatives were very successful; building energy use per square foot for FY 02 was 28% less than in FY 85, saving over $2 million. In FY02, BNL participated in the LIPA Load Reduction Programs agreeing to reduce electrical demand during the peak summer period. The benefit to BNL was a reduction in energy costs of nearly $1.3 million.

In 2002, we completed several projects, including eliminating once-through cooling in Building 902 substantially saving potable water, using fuel purchasing strategies that saved nearly $600,000, and connecting Building 911A to the central chilled water, removing two large, outdated chlorofluorocarbon chillers. We installed a solar cover for BNL's swimming pool that is expected to reduce operating costs by $15,000. BNL received $235,000 for new energy conservation projects and studies, including a new compressed air drying system at the Central Chilled Water Facility that will use nearly 30% less energy than the current one. We recently evaluated the requirements for the Energy Star Label and found only one eligible building. However, in a cold winter it probably would not meet the minimum benchmark score. Despite the costs in verifying the nonenergy use criteria, we will continue to pursue the Label.

7.10.2 Sustainable Design

DOE Order 413.3 Program and Project Management for the Acquisition of Capital Assets requires that all new BNL buildings include sustainable features, following the recommendations of the Green Building Council, and, where appropriate to program mission and budget requirements, building certification under LEEDs (Leadership in Energy and Environmental Design). Sustainable features are the use of sustainable materials, sustainable practices during construction, energy analysis for lowest life cycle cost, selection of Energy Star appliances and equipment, reduced water-consumption devices, energy efficient building materials, passive solar heating, daylighting, and use of storm water for irrigation. Experts in environmental engineering will assure that we incorporate sustainable design and pollution prevention principles.

8.0 Resource Projections

Table 19 - Laboratory Funding Summary							
($ In Millions In Budget Authority)							
	FY 02	**FY 03**	**FY 04***	**FY 05***	**FY 06****	**FY 07****	**FY 08****
DOE Effort	328.0	307.0	318.6	395.8	393.9	393.9	393.9
Work For Other Than DOE	44.2	51.1	49.1	48.4	48.4	48.4	48.4
Total Operating	**372.2**	**358.1**	**367.7**	**444.2**	**442.3**	**442.3**	**442.3**
Capital Equipment	29.3	18.9	18.5	24.8	24.8	24.8	24.8
Program Construction	49.0	48.5	34.9	70.8	83.1	47.2	17.8
General Purpose Equipment (GPE)	5.5	4.5	4.4	10.8	10.8	10.8	10.8
General Plant Projects (GPP)	6.1	6.0	6.2	6.5	6.8	7.1	7.5
TOTAL FUNDING	**462.1**	**436.0**	**431.7**	**557.1**	**567.8**	**532.2**	**503.2**
* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY							
** CONSTANT FY2005 DOLLARS							

Table 20 - Laboratory Personnel Summary							
(Personnel In FTE)							
	FY 02	**FY 03**	**FY 04**	**FY 05**	**FY 06**	**FY 07**	**FY 08**
Direct							
DOE Effort	1176	1163	1126	1259	1259	1259	1259
Work For Other Than DOE	302	297	263	211	211	211	211
Total Direct	**1478**	**1460**	**1389**	**1470**	**1470**	**1470**	**1470**
Indirect							
Total Organizational Burden	163	170	165	167	167	167	167
LDRD and Program Development	57	66	57	21	21	21	21
Total Material Burden	72	78	77	77	77	77	77
Distributed/Allocated Services	606	622	76	626	626	626	626
IIDirect (G&A)	479	476	484	501	501	501	501
Total Indirect (G&A)	**1377**	**1412**	**859**	**1392**	**1392**	**1392**	**1392**
Total Laboratory Personnel	**2855**	**2872**	**2798**	**2862**	**2862**	**2862**	**2862**

Table 21 - Funding Summary By Assistant Secretarial Office							
($ In Millions in Budget Authority)							
	FY 02	FY 03	FY 04	FY 05*	FY 06**	FY 07**	FY 08**
Director, Office Of Science							
Operating	232.0	230.1	230.5	297.6	295.7	295.7	295.7
Inventories	-1.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	28.7	18.9	18.5	24.8	24.8	24.8	24.8
GPE	5.5	4.5	4.4	10.8	10.8	10.8	10.8
GPP	6.1	6.0	6.2	6.5	6.8	7.1	7.5
Construction	10.0	11.8	16.0	51.9	69.7	35.3	15.4
TOTAL	**280.7**	**271.3**	**275.6**	**391.4**	**407.8**	**373.7**	**354.2**
A/S Conservation & Renewable Energy							
Operating	6.6	5.7	5.3	7.0	7.0	7.0	7.0
Construction	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL (Operating)	**6.7**	**5.7**	**5.3**	**7.0**	**7.0**	**7.0**	**7.0**
A/S Office of Energy Assurance							
Operating	**0.4**	**0.3**	**1.0**	**1.2**	**1.2**	**1.2**	**1.2**
A/S Environment, Safety & Health							
TOTAL (Operating)	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
A/S Nonprofit. &National Security							
TOTAL (Operating)	**51.6**	**29.0**	**37.5**	**36.7**	**36.7**	**36.7**	**36.7**
A/S, Environ. Restoration & Waste Mgmt.							
Operating	32.5	37.5	38.8	46.3	46.3	46.3	46.3
Capital Equipment	0.6	0.6	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	**33.1**	**37.5**	**38.8**	**46.3**	**46.3**	**46.3**	**46.3**
A/S Fossil Energy							
Operating	0.7	0.4	0.6	0.5	0.5	0.5	0.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**0.7**	**0.4**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
Office of Nuclear Energy							
Operating	3.7	3.1	3.8	5.3	5.3	5.3	5.3
Construction	0.0	0.0	0.0	9.9	13.4	11.9	2.4
TOTAL	**3.7**	**3.1**	**3.8**	**15.2**	**18.7**	**17.2**	**7.7**
Energy Information Administration							
TOTAL (Operating)	**1.0**	**0.0**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**

Office Of Counter Intelligence							
TOTAL (Operating)	**0.8**	**0.7**	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**
TOTALS-DOE PROGRAMS							
Operating	329.6	307.0	318.6	395.8	393.9	393.9	393.9
Inventories	-1.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	29.3	18.9	18.5	24.8	24.8	24.8	24.8
Program Construction	10.1	11.8	16.0	61.8	83.1	47.2	17.8
GPE	5.5	4.5	4.4	10.8	10.8	10.8	10.8
GPP	6.1	6.0	6.2	6.5	6.8	7.1	7.5
TOTAL	**379.0**	**348.2**	**363.7**	**499.7**	**519.4**	**483.8**	**454.8**

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3% ,RESPECTIVELY
** CONSTANT FY2005 DOLLARS

Table 22 - Funding Summary – Work for Others and Laboratory Totals

($ In Millions In Budget Authority)

	FY 02	**FY 03**	**FY 04***	**FY 05***	**FY 06****	**FY 07****	**FY 08****
Nuclear Regulatory Commission							
TOTAL (Operating)	**8.6**	**9.8**	**10.1**	**10.2**	**10.2**	**10.2**	**10.2**
Department Of Defense							
TOTAL (Operating)	**0.3**	**1.3**	**1.5**	**0.9**	**0.9**	**0.9**	**0.9**
National Aeronautics and Space Administration							
Operating	2.1	2.4	6.4	7.5	7.5	7.5	7.5
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[(a)]Construction - Booster Appl. Facility	9.5	3.9	0.0	0.0	0.0	0.0	0.0
FUNDING TOTAL	**11.6**	**6.3**	**6.4**	**7.5**	**7.5**	**7.5**	**7.5**
Department Of State							
TOTAL (Operating)	**4.7**	**4.3**	**3.3**	**3.1**	**3.1**	**3.1**	**3.1**
National Science Foundation							
TOTAL (Operating)	**0.0**	**0.0**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
Department Of Health And Human Services							
TOTAL (Operating)	**11.1**	**14.1**	**12.6**	**12.5**	**12.5**	**12.5**	**12.5**
Environmental Protection Agency							
TOTAL (Operating)	**1.8**	**2.6**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
Other Federal Agencies							
TOTAL (Operating)	**0.6**	**0.9**	**1.1**	**0.5**	**0.5**	**0.5**	**0.5**

Table 22 - Funding Summary – Work for Others and Laboratory Totals							
($ In Millions In Budget Authority)							
	FY 02	FY 03	FY 04*	FY 05*	FY 06**	FY 07**	FY 08**
Other DOE Labs							
Operating	5.5	4.4	2.8	3.5	3.5	3.5	3.5
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction - SNS	29.4	32.8	18.9	9.0	0.0	0.0	0.0
TOTAL (Operating)	**34.9**	**37.2**	**21.7**	**12.5**	**3.5**	**3.5**	**3.5**
All Others							
TOTAL (Operating)	**9.5**	**10.9**	**8.4**	**7.3**	**7.3**	**7.3**	**7.3**
Home Land Security							
TOTAL (Operating)	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Totals-Work For Other Than DOE							
Operating	44.2	51.1	49.1	48.4	48.4	48.4	48.4
Construction	38.9	36.7	18.9	9.0	0.0	0.0	0.0
TOTAL (Operating)	**83.1**	**87.8**	**68.0**	**57.4**	**48.4**	**48.4**	**48.4**
Laboratory Totals							
Operating	373.8	358.1	367.7	444.2	442.3	442.3	442.3
Inventories	-1.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	29.3	18.9	18.5	24.8	24.8	24.8	24.8
Program Construction	49.0	48.5	34.9	70.8	83.1	47.2	17.8
GPE	5.5	4.5	4.4	10.8	10.8	10.8	10.8
GPP	6.1	6.0	6.2	6.5	6.8	7.1	7.5
TOTAL	**462.1**	**436.0**	**431.7**	**557.1**	**567.8**	**532.2**	**503.2**

(a) Funded
* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY
** CONSTANT FY2005 DOLLARS

Table 23 - Personnel By Assistant Secretarial Office (Personnel In FTE)	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
Department Of Energy Programs (FTEs)							
Director, Office Of Science	1041	1029	985	1112	1112	1112	1112
A/S Conservation & Renewable Energy	19	17	21	23	23	23	23
A/S Office Of Energy Assurance	0	1	3	3	3	3	3
A/S Environment, Safety & Health	2	1	2	2	2	2	2
A/S, Nuclear Energy	10	10	9	13	13	13	13
A/S, Nonproliferation And National Security	30	34	36	36	36	36	36
A/S, Office Of Counter Intelligence	4	4	4	4	4	4	4
A/S, Defense Programs	0	0	0	0	0	0	0
A/S Environmental Restoration & Waste Management	68	65	64	64	64	64	64
A/S, Fossil Energy	2	2	2	2	2	2	2
Energy Information Administration	0	0	0	0	0	0	0
Office Of Chief Financial Officer	0	0	0	0	0	0	0
TOTAL: DOE Programs	**1176**	**1163**	**1126**	**1259**	**1259**	**1259**	**1259**

Table 24 - Personnel-Work for Others and Laboratory Totals (Personnel In FTE)	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
Work For Other Than DOE (FTEs)							
Nuclear Regulatory Commission	25	27	31	30	30	30	30
Department Of Defense	2	1	3	4	4	4	4
Department Of State	7	9	8	8	8	8	8
Nat'l Aeronautics And Space Administration	38	24	23	27	27	27	27
Department Of Health And Human Services	40	47	43	49	49	49	49
National Science Foundation	0	0	0	1	1	1	1
Environmental Protection Agency	3	3	3	3	3	3	3
Other Federal Agencies	4	3	2	1	1	1	1
Other DOE Labs	121	114	80	29	29	29	29
Home Land Security	0	0	0	0	0	0	0
All Others	62	69	70	59	59	59	59
TOTAL: Work For Other Than DOE	**302**	**297**	**263**	**211**	**211**	**211**	**211**
Total Laboratory-Direct	**1478**	**1460**	**1389**	**1470**	**1470**	**1470**	**1470**
Total Organizational Burden	163	170	165	167	167	167	167
Laboratory Directed R&D	57	66	57	21	21	21	21
Total Material Burden	72	78	77	77	77	77	77
Distributed/Allocated Services	606	622	626	626	626	626	626
Indirect(G&A)	479	476	484	501	501	501	501
TOTAL INDIRECT	**1377**	**1412**	**1409**	**1392**	**1392**	**1392**	**1392**
TOTAL: Laboratory-Personnel	**2855**	**2872**	**2798**	**2862**	**2862**	**2862**	**2862**

Table 25 - Funding By Assistant Secretarial Level Office – DOE Office of Science							
(In Millions In Budget Authority)							
	FY 02	FY 03	FY 04*	FY 05*	FY 06**	FY 07**	FY 08**
DEPARTMENT OF ENERGY PROGRAMS							
KA-14 Theoretical Physics							
OPERATING	2.4	2.3	2.4	2.9	2.9	2.9	2.9
DIRECT PERSONNEL	9	10	9	11	11	11	11
KA-15 Advanced Technology R&D							
Operating	9.9	4.8	4.9	9.0	9.0	9.0	9.0
Changes In Inventories							
Capital Equipment	10.9	0.3	0.2	0.3	0.3	0.3	0.3
TOTAL FUNDING	**20.8**	**5.1**	**5.1**	**9.3**	**9.3**	**9.3**	**9.3**
DIRECT PERSONNEL	84	21	21	39	39	39	39
KA-11 Proton Accel. Physics							
Operating	14.2	13.7	10.0	31.3	31.3	31.3	31.3
Capital Equipment	1.7	5.9	3.8	3.4	3.4	3.4	3.4
TOTAL FUNDING	15.9	19.6	13.8	34.7	34.7	34.7	34.7
KA High Energy Physics							
Operating	26.5	20.8	17.3	43.2	43.2	43.2	43.2
Changes In Inventories	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	12.6	6.2	4.0	3.7	3.7	3.7	3.7
TOTAL FUNDING	**39.1**	**27.0**	**21.3**	**46.9**	**46.9**	**46.9**	**46.9**
DIRECT PERSONNEL	**168**	**132**	**95**	**141**	**141**	**141**	**141**
KB-01 Medium Energy Physics							
Operating	4.2	3.2	3.5	4.2	4.2	4.2	4.2
Capital Equipment	0.2	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL FUNDING	**4.4**	**3.3**	**3.6**	**4.3**	**4.3**	**4.3**	**4.3**
DIRECT PERSONNEL	18	16	16	18	18	18	18
KB-02 Heavy Ion Physics							
Physics Research	6.0	6.0	6.4	7.4	7.4	7.4	7.4
Facility Operations	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AGS/TVDG Operations	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RHIC Operation	72.2	91.9	93.4	111.2	111.2	111.2	111.2
RHIC Expt'l Support	23.9	18.1	19.1	22.3	22.3	22.3	22.3
Other Operation	5.9	0.0	0.0	0.0	0.0	0.0	0.0
Total Facility Operations	102.0	110.0	112.5	133.5	133.5	133.5	133.5
Total Operating	108.0	116.0	118.9	140.9	140.9	140.9	140.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Add. Exp. Equip.	3.1	2.5	2.3	6.1	6.1	6.1	6.1
RHIC Oper. Equip.	1.1	1.1	1.2	2.2	2.2	2.2	2.2
RHIC Exp. Support-Equipment	3.7	4.0	4.4	4.7	4.7	4.7	4.7

Table 25 - Funding By Assistant Secretarial Level Office – DOE Office of Science (In Millions In Budget Authority)							
	FY 02	**FY 03**	**FY 04***	**FY 05***	**FY 06****	**FY 07****	**FY 08****
GPE	5.5	4.5	4.4	10.8	10.8	10.8	10.8
Other Programmatic	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Capital	13.4	12.1	12.3	23.8	23.8	23.8	23.8
(GPP)	6.1	6.0	6.2	6.5	6.8	7.1	7.5
Construction (AIP)	2.5	2.9	2.9	3.3	1.4	6.0	6.0
User Research Center (b)	0.0	0.0	1.6	6.8	7.0	0.0	0.0
Total Construction	8.6	8.9	10.7	16.6	15.2	13.1	13.5
TOTAL FUNDING	**130.0**	**137.0**	**141.9**	**181.3**	**179.9**	**177.8**	**178.2**
DIRECT PERSONNEL	456	477	461	492	492	492	492
KB-03 Nuclear Theory							
TOTAL (Operating)	**5.0**	**4.7**	**4.8**	**5.6**	**5.6**	**5.6**	**5.6**
DIRECT PERSONNEL	22	22	21	26	26	26	26
KB-04 Low Energy Physics							
Operating	0.7	0.7	0.7	0.8	0.8	0.8	0.8
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL FUNDING	**0.8**	**0.8**	**0.8**	**0.9**	**0.9**	**0.9**	**0.9**
DIRECT PERSONNEL	2	3	4	4	4	4	4
KB Nuclear Physics							
Operating	117.9	124.6	127.9	151.5	151.5	151.5	151.5
Capital Equipment	13.7	12.3	12.5	24.0	24.0	24.0	24.0
Construction							
GPP	6.1	6.0	6.2	6.5	6.8	7.1	7.5
Construction (AIP)	2.5	2.9	2.9	3.3	1.4	6.0	6.0
User Research Center (b)	0.0	0.0	1.6	6.8	7.0	0.0	0.0
Total Construction	8.6	8.9	10.7	16.6	15.2	13.1	13.5
TOTAL FUNDING	**140.2**	**145.8**	**151.1**	**192.1**	**190.7**	**188.6**	**189.0**
DIRECT PERSONNEL	498	518	502	540	540	540	540
KC-02 Materials Sciences							
Operating (Research)	11.5	11.4	11.3	12.6	12.6	12.6	12.6
NSLS Operations	23.2	31.4	32.5	39.4	39.4	39.4	39.4
HFBR Operations	1.3	0.3	0.0	0.0	0.0	0.0	0.0
Cntr. For Func. Nanomaterials Jump Start	0.0	1.7	1.7	1.9	0.0	0.0	0.0
Total Operating	36.0	44.8	45.5	53.9	52.0	52.0	52.0
Changes In Inventories	-1.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	3.6	3.8	5.0	5.3	5.3	5.3	5.3
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[(b)] Cntr. For Functional Nanomaterials	0.0	0.0	3.0	22.9	35.0	20.0	0.0
Construction (AIP)	1.4	1.4	1.5	1.6	1.7	1.8	1.9

Table 25 - Funding By Assistant Secretarial Level Office – DOE Office of Science (In Millions In Budget Authority)							
	FY 02	**FY 03**	**FY 04***	**FY 05***	**FY 06****	**FY 07****	**FY 08****
Total Construction	1.4	1.4	4.5	24.5	36.7	21.8	1.9
TOTAL FUNDING	**39.4**	**50.0**	**55.0**	**83.7**	**94.0**	**79.1**	**59.2**
DIRECT PERSONNEL	184	199	214	239	239	239	239
KC-03 Chemical Sciences							
Research (Operating)	9.9	10.5	10.2	13.0	13.0	13.0	13.0
NSLS Operations	7.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Operating	17.1	10.5	10.2	13.0	13.0	13.0	13.0
Capital Equipment	1.3	1.0	1.2	1.8	1.8	1.8	1.8
TOTAL FUNDING	**18.4**	**11.5**	**11.4**	**14.8**	**14.8**	**14.8**	**14.8**
DIRECT PERSONNEL	34	43	43	49	49	49	49
KC-06 Energy Biosciences							
Operating	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
TOTAL FUNDING	**1.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	4	0.0	0.0	0.0	0.0	0.0	0.0
KC - Basic Energy Sciences							
Research (Operating)	22.5	21.9	21.5	25.6	25.6	25.6	25.6
NSLS Operations	30.4	31.4	32.5	39.4	39.4	39.4	39.4
HFBR Operations	1.3	0.3	0.0	0.0	0.0	0.0	0.0
Cntr. For Func. Nanomaterials Jump Start	0.0	1.7	1.7	1.9	0.0	0.0	0.0
Total Operating	**54.2**	**55.3**	**55.7**	**66.9**	**65.0**	**65.0**	**65.0**
Changes In Inventories	-1.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	5.0	4.8	6.2	7.1	7.1	7.1	7.1
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[(a)]Cntr. For Functional Nanomaterials (B)	0.0	0.0	3.0	22.9	35.0	20.0	0.0
Construction (ARAM)	1.4	1.4	1.5	1.6	1.7	1.8	1.9
Total Construction	1.4	1.4	4.5	24.5	36.7	21.8	1.9
TOTAL FUNDING	59.0	61.5	66.4	98.5	108.8	93.9	74.0
DIRECT PERSONNEL	**222**	**242**	**257**	**288**	**288**	**288**	**288**
KG - Multiprogram Energy Labs							
Operating	0.0	0.8	0.8	0.8	0.8	0.8	0.8
Construction	**6.1**	**7.5**	**7.0**	**17.3**	**24.6**	**7.5**	**7.5**
TOTAL FUNDING	6.1	8.3	7.8	18.1	25.4	8.3	8.3

Table 25 – Funding By Assistant Secretarial Level Office – DOE Office of Science (In Millions In Budget Authority)							
	FY 02	**FY 03**	**FY 04***	**FY 05**	**FY 06***	**FY 07***	**FY 08****
KP - Biological & Environmental Research – TOTALS							
Research (Operating)	20.1	16.2	16.1	19.7	19.7	19.7	19.7
Capital Equipment	2.9	0.1	0.2	0.1	0.1	0.1	0.1
TOTAL FUNDING	**23.0**	**16.3**	**16.3**	**19.8**	**19.8**	**19.8**	**19.8**
DIRECT PERSONNEL	76	68	59	71	71	71	71
KJ - Computation and Technology Research - TOTALS							
TOTAL (Operating)	**1.4**	**1.2**	**1.2**	**1.0**	**1.0**	**1.0**	**1.0**
DIRECT PERSONNEL	7	7	6	4	4	4	4
KL- Workforce Dev. For Teacher and Scientists							
TOTAL (Operating)	**0.4**	**0.5**	**0.5**	**1.7**	**1.7**	**1.7**	**1.7**
DIRECT PERSONNEL	0	0	0	0	0	0	0
KH - Facilities & Infrastructure - TOTALS							
TOTAL (Operating)	**1.4**	**0.0**	**00**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
FS - Safeguards & Security Science - TOTALS							
Operating	10.1	10.7	11.0	12.8	12.8	12.8	12.8
Capital Equipment	0.0	0.0	0.0	0.7	0.7	0.7	0.7
TOTAL FUNDING	**10.1**	**10.7**	**11.0**	**13.5**	**13.5**	**13.5**	**13.5**
DIRECT PERSONNEL	70	62	66	68	68	68	68
TOTALS – DOE OFFICE OF SCIENCE							
Totals-Energy Science							
Total Operating	232.0	230.1	230.5	297.6	295.7	295.7	295.7
Change In Inventories	-1.6	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	28.7	18.9	18.5	24.8	24.8	24.8	24.8
GPE	5.5	4.5	4.4	10.8	10.8	10.8	10.8
GPP	6.1	6.0	6.2	6.5	6.8	7.1	7.5
Construction	10.0	11.8	16.0	51.9	69.7	35.3	15.4
TOTAL FUNDING	**280.7**	**271.3**	**275.6**	**391.6**	**407.8**	**373.7**	**354.2**
DIRECT PERSONNEL	**1041**	**1029**	**985**	**1112**	**1112**	**1112**	**1112**

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY
** CONSTANT FY2005 DOLLARS; [(a)] PROPOSED

Table 26 - Funding By Assistant Secretarial Level Office – Other DOE Programs							
(In Millions In Budget Authority)							
	FY 02	FY 03	FY 04*	FY 05*	FY 06**	FY 07**	FY 08**
A/S Conservation & Renewable Energy							
EB - Solar and Renewable Research Technologies							
TOTAL (Operating)	**1.8**	**1.7**	**2.3**	**2.5**	**2.5**	**2.5**	**2.5**
DIRECT PERSONNEL	8	7	7	8	8	8	8
EC - Buildings and Community Systems							
Operating	0.5	0.2	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**0.5**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
DIRECT PERSONNEL	1	1	1	1	1	1	1
EE – Transportation							
TOTAL (Operating)	**3.4**	**2.9**	**1.4**	**1.5**	**1.5**	**1.5**	**1.5**
DIRECT PERSONNEL	6	6	7	7	7	7	7
EH - Policy And Management (EERE)							
TOTAL (Operating)	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
DIRECT PERSONNEL	1	1	1	1	1	1	1
EO - Power Technology							
TOTAL (Operating)	**0.6**	**0.7**	**1.0**	**2.4**	**2.4**	**2.4**	**2.4**
DIRECT PERSONNEL	3	2	5	6	6	6	6
WB - In-House Energy Management							
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.1	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
Conservation & Renewable Energy - TOTALS							
Operating	6.6	5.7	5.3	7.0	7.0	7.0	7.0
Construction	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**6.7**	**5.7**	**5.3**	**7.0**	**7.0**	**7.0**	**7.0**
DIRECT PERSONNEL	19	17	21	23	23	23	23
A/S Office Of Energy Assurance							
ES – Office Of Energy Assurance							
Operating	0.4	0.3	1.0	1.2	1.2	1.2	1.2
DIRECT PERSONNEL	0.0	1	3	3	3	3	3
A/S Environment, Safety & Health							
HC – Environment, Safety And Health (Non-Defense)							
TOTAL (Operating)	**0.2**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**
DIRECT PERSONNEL	1	0.0	1	1	1	1	1

Table 26 - Funding By Assistant Secretarial Level Office – Other DOE Programs							
(In Millions In Budget Authority)							
	FY 02	FY 03	FY 04*	FY 05*	FY 06**	FY 07**	FY 08**
HD - Environment, Safety And Health (Defense)							
TOTAL (Operating)	**0.1**	**0.1**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	1	1	1	1	1	1	1
Environment, Safety and Health - TOTALS							
TOTAL (Operating)	**0.3**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**	**0.3**
DIRECT PERSONNEL	2	1	2	2	2	2	2
A/S Nonproliferation and National Security							
PS Program Direction –Nat'nl Nuc. Sec. Admin.							
TOTAL (Operating)	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
NN - Nonproliferation and National Security Program Direction							
TOTAL (Operating)	**50.0**	**28.1**	**36.3**	**35.3**	**35.3**	**35.3**	**35.3**
DIRECT PERSONNEL	26	29	31	31	31	31	31
A/S Nonproliferation and National Security -TOTALS							
TOTAL (Operating)	**51.6**	**29.0**	**37.5**	**36.7**	**36.7**	**36.7**	**36.7**
DIRECT PERSONNEL	30	34	36	36	36	36	36
A/S Office Of Counter Intelligence - TOTAL							
CN - Counter Intelligence							
TOTAL (Operating)	**0.8**	**0.7**	**0.6**	**0.7**	**0.7**	**0.7**	**0.7**
DIRECT PERSONNEL	4	4	4	4	4	4	4
A/S Defense Programs - TOTAL							
DP - Other Weapons Activities							
TOTAL (Operating)	1.5	0.9	1.2	1.4	1.4	1.4	1.4
PERSONNEL	4	5	5	5	5	5	5
A/S Environmental Restoration And Waste Management - TOTALS							
EW Environ. Restoration And Waste Mgmt.							
Operating	32.5	37.5	38.8	46.3	46.3	46.3	46.3
Capital Equipment	0.6	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**33.1**	**37.5**	**38.8**	**46.3**	**46.3**	**46.3**	**46.3**
DIRECT PERSONNEL	68	65	64	64	64	64	64
A/S Fossil Energy							
AA Coal							
TOTAL (Operating)	**0.3**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
DIRECT PERSONNEL	1	1	1	1	1	1	1
AB GAS	0.2	0.0	0.3	0.3	0.3	0.3	0.3
TOTAL (Operating)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIRECT PERSONNEL	1	1	1	1	1	1	1

Table 26 - Funding By Assistant Secretarial Level Office – Other DOE Programs							
(In Millions In Budget Authority)							
	FY 02	**FY 03**	**FY 04***	**FY 05***	**FY 06****	**FY 07****	**FY 08****
AC – Petroleum							
TOTAL (Operating)	**0.2**	**0.2**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	1	1	0	0	0	0	0
Fossil Energy – TOTALS							
TOTAL (Operating)	**0.7**	**0.4**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
DIRECT PERSONNEL	2	2	2	2	2	2	2
Office of Nuclear Energy							
ST Isotope Prod. And Distribution Program							
Operating	2.8	2.3	3.0	3.5	3.5	3.5	3.5
[(b)] Cyclotron Isotope Research Center	0.0	0.0	0.0	9.9	13.4	11.9	2.4
TOTAL FUNDING	**2.8**	**2.3**	**3.0**	**13.4**	**16.9**	**15.4**	**5.9**
DIRECT PERSONNEL	7	7	7	8	8	8	8
AF - Nuclear Energy Research & Development							
TOTAL (Operating)	**0.9**	**0.8**	**0.8**	**1.8**	**1.8**	**1.8**	**1.8**
DIRECT PERSONNEL	3	3	2	5	5	5	5
Office Of Nuclear Energy – TOTAL							
Operating	3.7	3.1	3.8	5.3	5.3	5.3	5.3
Construction	0.0	0.0	0.0	9.9	13.4	11.9	2.4
TOTAL FUNDING	**3.7**	**3.1**	**3.8**	**15.2**	**18.7**	**17.2**	**7.7**
PERSONNEL	10	10	9	13	13	13	13
Energy Information Administration – TOTAL							
TA - National Energy Information System							
TOTAL (Operating)	**1.0**	**0.0**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
DIRECT PERSONNEL	0	0	0	0	0	0	0

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY
** CONSTANT FY2005 DOLLARS

Table 27 - Work For Others Programs							
($In Millions In Budget Authority)							
	FY 02	FY 03	FY 04*	FY 05*	FY 06**	FY 07**	FY 08**
Nuclear Regulatory Commission							
Nuclear Reactor Regulation							
Operating	**2.1**	**2.1**	**2.6**	**2.5**	**2.5**	**2.5**	**2.5**
DIRECT PERSONNEL	8	7	9	8	8	8	8
Nuclear Regulatory Research							
Operating	**4.6**	**5.6**	**5.7**	**5.9**	**5.9**	**5.9**	**5.9**
DIRECT PERSONNEL	14	17	19	18	18	18	18
Commission And Staff Offices							
Operating	**1.9**	**2.1**	**1.8**	**1.8**	**1.8**	**1.8**	**1.8**
DIRECT PERSONNEL	3	3	3	4	4	4	4
TOTAL (Operating)	**8.6**	**9.8**	**10.1**	**10.2**	**10.2**	**10.2**	**10.2**
DIRECT PERSONNEL	25	27	31	30	30	30	30
Department Of State							
TOTAL (Operating)	**4.7**	**4.3**	**3.3**	**3.1**	**3.1**	**3.1**	**3.1**
DIRECT PERSONNEL	7	9	8	8	8	8	8
Department Of Defense							
TOTAL (Operating)	**0.3**	**1.3**	**1.5**	**0.9**	**0.9**	**0.9**	**0.9**
DIRECT PERSONNEL	2	1	3	4	4	4	4
National Aeronautics and Space Administration							
Operating	2.1	2.4	6.4	7.5	7.5	7.5	7.5
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
[(a)] Construction – Booster Application Facility	9.5	3.9	0.0	0.0	0.0	0.0	0.0
TOTAL FUNDING	**11.6**	**6.3**	**6.4**	**7.5**	**7.5**	**7.5**	**7.5**
DIRECT PERSONNEL	38	24	23	27	27	27	27
Department Of Health & Human Services							
TOTAL (Operating)	**11.1**	**14.1**	**12.6**	**12.5**	**12.5**	**12.5**	**12.5**
DIRECT PERSONNEL	40	47	43	49	49	49	49
National Science Foundation							
TOTAL (Operating)	**0.0**	**0.0**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
DIRECT PERSONNEL	0	0	0	1	1	1	1
Environmental Protection Agency							
TOTAL (Operating)	**1.8**	**2.6**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
DIRECT PERSONNEL	3	3	3	3	3	3	3

Table 27 - Work For Others Programs							
($In Millions In Budget Authority)							
	FY 02	FY 03	FY 04*	FY 05*	FY 06**	FY 07**	FY 08**
Other Federal Agencies							
TOTAL (Operating)	**0.6**	**0.9**	**1.1**	**0.5**	**0.5**	**0.5**	**0.5**
DIRECT PERSONNEL	4	3	2	1	1	1	1
Other DOE Laboratories							
Operating	5.5	4.4	2.8	3.5	3.5	3.5	3.5
Capital	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction - SNS.	29.4	32.8	18.9	9.0	0.0	0.0	0.0
TOTAL FUNDING	**34.9**	**37.2**	**21.7**	**12.5**	**3.5**	**3.5**	**3.5**
DIRECT PERSONNEL	121	114	80	29	29	29	29
All Others							
TOTAL (Operating)	**9.5**	**10.9**	**8.4**	**7.3**	**7.3**	**7.3**	**7.3**
DIRECT PERSONNEL ***	**62**	**69**	**70**	**59**	**59**	**59**	**59**
HOME LAND SECURITY							
TOTAL (Operating)	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Direct Personnel							

* ESCALATION FACTORS: FY2003 AND FY2004 AT 3.8% AND 3.3%, RESPECTIVELY
** CONSTANT FY2005 DOLLARS - Note: (1)Dept of State amt corrected from $5M to $4.7M. (2) State agency $.5M moved from other Federal agency to All other category.
*** Includes FTE's from Non-Reportable Programs, (a) Funded.

Supplemental Tables

Equal Employment Opportunity

Laboratory Staff Composition

Subcontracting and Procurement

Small and Disadvantaged Business

Experimenters at Designated User Facilities 2002

University and Science Education

Work for Others by Project

Active CRADA Projects

BSA Patent Portfolio

Examples of Products Marketed Under License from BNL

BSA Licensing Revenue

Table S1 - Brookhaven National Laboratory Equal Employment Opportunity

OCCUPATIONAL CODES	TOTAL		WHITE		MINORITY									
					TOTAL		BLACK		HISPANIC		NATIVE AMERICAN		ASIAN/PACIFIC ISLANDER	
GENDER	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Officials & Managers														
	311	74	288	66	23	8	7	3	4	2	0	0	12	3
	80.8%	19.2%	74.8%	17.1%	6.0%	2.1%	1.8%	0.8%	1.0%	0.5%	0.0%	0.0%	3.1%	0.8%
Professional Staff														
Scientists & Engineers	926	175	711	112	215	63	15	10	25	9	0	0	175	44
	84.1%	15.9%	64.6%	10.2%	19.5%	5.7%	1.4%	0.9%	2.3%	0.8%	0.0%	0.0%	15.9%	4.0%
Management & Administrative	57	171	50	148	7	23	4	13	0	5	1	0	2	5
	25.0%	75.0%	21.9%	64.9%	3.1%	10.1%	1.8%	5.7%	0.0%	2.2%	0.4%	0.0%	0.4%	2.2%
	463	41	413	37	50	4	23	2	16	0	2	0	9	2
Technicians	91.9%	8.1%	81.9%	7.3%	9.9%	0.8%	4.6%	0.4%	3.2%	0.0%	0.4%	0.0%	1.8%	0.4%
All Other														
	397	279	305	189	92	90	61	62	23	21	5	1	3	6
	58.7%	41.3%	45.1%	28.0%	13.6%	13.3%	9.0%	9.2%	3.4%	3.1%	0.7%	0.1%	0.4%	0.9%
	2154	**740**	**1767**	**552**	**387**	**188**	**110**	**90**	**68**	**37**	**8**	**1**	**201**	**60**
Totals	**74.4%**	**25.6%**	**61.1%**	**19.1%**	**13.4%**	**6.5%**	**3.8%**	**3.1%**	**2.3%**	**1.3%**	**0.3%**	**0.03%**	**6.9%**	**2.1%**

Table S2 - Brookhaven National Laboratory Staff Composition										
	PHD		MS/MA		BS/BA		OTHER		TOTAL	
	#	%	#	%	#	%	#	%	#	%
PROFESSIONAL STAFF										
Scientists	476	80.5	45	7.6	40	6.8	30	5.1	591	20.4
Engineers	98	19.2	177	34.7	151	29.6	84	16.5	510	17.6
Management & Administrative	63	10.4	148	24.4	153	25.2	242	39.9	606	20.9
Other Professional	4	50.0	1	12.5	2	25.0	1	12.5	8	0.3
SUPPORT STAFF										
Technicians	0	0.0	17	3.4	66	13.1	421	83.5	504	17.4
All Others	0	0.0	11	1.6	49	7.2	616	91.1	676	23.4
LABORATORY TOTAL	**641**	**22.1**	**399**	**13.8**	**461**	**15.9**	**1394**	**48.2**	**2895**	**100.0**

Table S3 - Subcontracting And Procurement			
Dollars in Millions-Obligated (1)	**FY 2002**	**Estimated FY 2003**	**Estimated FY2004**
Subcontracting and Procurement from:			
Universities	8.8	7.5	7.5
All Others	166.4	146.4	147.5
Transfers to other DOE Facilities	1.9	2.0	2.0
Total External Subcontracts and Procurement	**177.1**	**155.9**	**157.0**
(1)Show total dollars obligated within each fiscal year.			

Table S4 - Small And Disadvantaged Business Procurement		
Dollars in Millions – Budget Authority (1)	**FY 2002**	**Estimated FY 2003**
Procurement from S&DB	9.6	5.5
Percent of Annual Procurement	7.6	5.0
(1) Show total dollars obligated within each fiscal year.		

Table S5 - Experimenters At User Facilities (12/31/02)			
Facility	**Number of Experimenters**	**Number of Organizations**	**Percentage of Use**
RELATIVISTIC HEAVY ION COLLIDER			
Laboratory	108	1	10%
Other DOE Laboratory	100	9	9.2%
Non-DOE U.S. Government	2	2	0.2%
U.S. Universities	382	49	35.2%
U.S. Industry	0	0	0%
Foreign Government Labs[a]	282	38	26 %
Foreign Universities	205	45	18.9%
Foreign Industry	0	0	0.0%
Other	5	4	0.5%
Total	1084	148	100%
ALTERNATING GRADIENT SYNCHROTRON			
Laboratory	17	1	4 %
Other DOE Laboratory	67	11	15.8%
Non-DOE U.S. Government	14	9	3.3%
U.S. Universities	162	46	38.4%
U.S. Industry	8	3	1.9%
Foreign Government Labs[a]	88	20	20.9%
Foreign Universities	61	26	14.5%
Foreign Industry	1	1	0.2%
Other	4	1	0.9%
Total	422	118	100.1%
TANDEM VAN DE GRAAFF COMPLEX			
Laboratory	5	1	3.5%
Other DOE Laboratory	6	1	4.2%
Non-DOE U.S. Government	20	3	14%
U.S. Universities	10	5	7.0%
U.S. Industry	59	26	41.3%
Foreign Government Labs[a]	1	1	0.7%
Foreign Universities	0	0	0%
Foreign Industry	40	15	28%
Other	2	2	1.4%
Total	143	54	100%
ACCELERATOR TEST FACILITY			
Laboratory	9	1	26.5%
Other DOE Laboratory	2	2	5.9%
Non-DOE U.S. Government	0	0	0.0%
U.S. Universities	7	5	20.6%
U.S. Industry	2	1	5.9%
Foreign Government Labs[a]	5	1	14.7%
Foreign Universities	6	4	17.6%
Foreign Industry	0	0	0.0%
Other	3	3	8.8%
Total	34	17	100%

SCANNING TRANSMISSION ELECTRON MICROSCOPE			
Laboratory	8	N.A	15%
Other DOE Laboratory	2	1	3.7%
Non-DOE U.S. Government	11	7	20.7%
U.S. Universities	21	13	39.6%
U.S. Industry			
Foreign Government Labs[a]			19%
Foreign Universities	10	6	
Foreign Industry			
Other	1	1	2%
Total	53	28	100%
NATIONAL SYNCHROTRON LIGHT SOURCES			
Laboratory	250	1	10.36%
Other DOE Laboratory	80	12	3.32%
Non-DOE U.S. Government	121	19	5.01%
U.S. Universities	1379	162	57.15%
U.S. Industry	161	63	6.67%
Foreign Government Labs[a]	25	16	1.04%
Foreign Universities	207	93	8.58%
Foreign Industry	12	6	0.50%
Other	178	44	7.37%
Total	2413	416	100%
GRAND TOTAL			
Laboratory	397	5	9.6%
Other DOE Laboratory	257	36	6.2%
Non-DOE U.S. Government	168	40	4%
U.S. Universities	1961	280	47.3%
U.S. Industry	230	93	5.5%
Foreign Government Labs[a]	401	76	9.7%
Foreign Universities	489	174	11.8%
Foreign Industry	53	22	1.3%
Other	193	55	4.6%
Total	4149	781	100%

[a] Users from an organization located in the United States may be counted as US even if the parent company is headquartered abroad.

Table S6 - Education Program Participation						
		FY2001			FY 2002	
	Total	Minority	Women	Total	Minority	Women
PRE-COLLEGE PROGRAMS						
Student Programs						
Community Summer Science Program CSSP	34	2	15	27	0	8
Minority High School Apprenticeship Program MHSAP	23	23	15	25	25	
Women in Science and Engineering WISE	31	4	31	31	0	31
Elementary Science Fair	500			510	na	na
Science and Society Essay Contest	0			8	0	3
Maglev Train Contest	200			166	na	na
Bridge Building Contest	300			322	na	na
Robotics Contest				20	na	na
Discovery Tours Grades 1-3	9,079			5367	na	na
Investigations in Science Grades 4-6	5,170			5857	na	na
Inquiries	1,021			741		
Magnets to Go Grades 4-6	7,496			6402	na	na
Museum Summer Camp	na			132	na	na
High School Tours	863			949	na	na
Teacher Programs						
MSTe	215			0		
Quarknet	15			15		
Cosmic Ray Project	15			15		
Discoveries to Go	1,333			0		
Teacher Training	350			20		
Special Programs						
Online Classroom	2			2		
Museum On-Site Programs	401			396		

Table S6 - Education Program Participation						
		FY2001			FY 2002	
	Total	Minority	Women	Total	Minority	Women
Student Programs						
Community College Institute CCI	16	5	8	19	6	9
College Mini-Semester	14	12	8	20	5	13
Energy Research Laboratory Fellowship ERULF	59	7	24	69	24	27
Semester ERULF	5	3	3	14	1	6
Nuclear Chemistry Summer School	12			14	0	6
Pre-Service Teacher PST	6	5	4	11	9	9
Suffolk Comm. College SCCC CO-OP	0	2	2	2	1	1
USSP to the IAEA				6	0	1
BNL-SCCC Environmental Field Program	4			0		
Academic Year Research Interns	1	0	1	1	0	1
Longwood Girls-in-Science Club	40	12	28	0		
Special Programs						
Faculty and Student Teams FaST	0			0		
College Tours	1851					
Faculty Programs						
FaST	0			0		

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	DEPARTMENT OF COMMERCE	
DOC/NIST	NIST Research Reactor Control Room Upgrade Plan	EENS
NOAA	G-1 Measurements for Summer 2002 New England Air Quality Study	EENS
	Reactor Analysis in Support of the NIST Research Reactor	EENS
	Support Services for the National Weather NEXRAD	EENS
	DEPARTMENT OF DEFENSE	
ARMY	A Field Program to Identify TRI Chemicals and Determine Emission Factors	EENS
	Alternative SNM Signatures methodology Study	EENS
	AMEC Radiation Protection: Arctic Military Environmental Cooperation	EENS
	Design, Development & Fabrication of a Breadboard Prototype 500W TPV Power Source PH I	EENS
	Development of Superconducting High Current RF Cavities at 700MHz	AD
	Imaging Illicit Drug Abuse: Development of a New Test-Bed Using MRI Microscopy and Molecular Modeling	MO
	Laser Seeded Free Electron Lasers and High Gain Harmonic Generation Experiments at the Source Development Laboratory of the NSLS	NSLS
	Morphology Study of UDF CoPolymer & Terpolymer Relaxors by Simultaneous Time Resolved SAXS/WAXS	NSLS
	Nondestructive Evaluation of Corrosion Under Coatings	EENS
	DEPARTMENT OF HEALTH AND HUMAN SERVICES (DHHS) - PROGRAM 40	
NIH	Rapid Detection and Identification of Zoonotic Pathogens	BO
NIH/NCRR	Development for Macromolecular Crystallography at the NSLS	BO
NIH/NCRR	STEM Mass Mapping & Heavy Atom Labeling of Biomolecules	BO
NIH/NIAAA	Dopaminergic Brain Function in Alcoholics	CO
NIH/NIAAA	NIH/NIAA Intramural Research Program at BNL	MO
NIH/NIAID	Adenovirus Protease Regulation and Antiviral Development	BO
NIH/NIAID	Adenovirus Receptor Interaction Structure Function	BO
NIH/NIBIB	Microbeam Radiation Therapy for Gliomas	MO
NIH/NCI	Ceramid and Radiation Induced Apoptosis in CNS Glia	MO
NIH/NCI	DNA Damage Clusters: Repair in Mammalian Cells	BO
NIH/NCI	DNA Damage Quantitation by Single Molecule Laser Sizing	BO
NIH/NCI	Genetic Variation in Human NHEJ DNA Repair Genes	BO
NIH/NIAID	Vaccine Intervention for Lyme Borreliosis	BO
NIH/NIDA	Brain Imaging and Drug Abuse	MO

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NIH/NIDA	CLP: An Archetypal ATP-Dependent Protease	NSLS
NIH/NIDA	Feto-Maternal Pharmacokinetics of abused Inhalants	MO
NIH/NIDA	Human Brain Pharmacokinetics of (-) Delta 9 Thc	MO
NIH/NIDA	Modulation of Neutrons Matter Release by Cannabinoids	BO
NIH/NIDA	Monitoring Methamphetamine Abuse Treatment with 1H MRS	MO
NIH/NIDA	Neuroimaging and Mentoring in Drug Abuse Research	MO
NIH/NIDA	Operating Funds for Regional NIDA Neuroimaging Center	MO
NIH/NIDA	Optimizing Intensity and Duration of GVG Pharmacotherapy	CO
NIH/NIDA	PET in Cocaine Abuse	MO
NIH/NIDA	PET Investigations of Abused Inhalants	CO
NIH/NIDA	PET Studies of Brain Dopamine in Cocaine Abusers	MO
NIH/NIDA	PET Studies of Brain Dopamine in Cocaine Abusers	MO
NIH/NIDA	Pharmacokinetics of Psychostimulants & Reinforcement	MO
NIH/NIDA	Radiotracer R&D in Nuclear Medicine and Neurosciences	MO
NIH/NIGM NIH/NIBIB	Nondiamagnetic Agents in In-Vivo 23NA & 1H20 MR	CO
NIH/NIGMS	Metals & Protein Structure in Protein Folding Diseases	NSLS
NIH/NIGMS	The Structural Basis of Selective Permeability in Aquaporins	BO
NIH/NIGMS	X6A Protein Crystallography Beamline	NSLS
NIH/NIMH	Activation Studies in Early HIV Dementia	MO
NIH/NIMH	Behavioral Correlates of FMRI Response in Cocaine Users	MO
NIH/NIMH	Brain Dopamine Function in Adults with ADHD	MO
NIH/NINDS	4 Tesla MRI Bolus CR Studies of Human Brain BBB Permeability	CO
	DEPARTMENT OF STATE	
AID	BNL Advisors to the Intentional Science and Technology Center	EENS
	International Safeguards Project Office POTAS	EENS
	MARKAL Workshop at BNL	EENS
	Support the International Atomic Energy Agency (IAEA) in the area of the effectiveness of international safeguards.	EENS
	ENVIRONMENTAL PROTECTION AGENCY	
EPA	Development a Decision Support Technology Matrix and Reference Guide	EENS
	Development of a Mobile Modular Treatment Facility for Liquid Radioactive Waste Associated with the Decommissioning of Russian Nuclear Submarines	EENS
	Development of the MARKAL-MACRO Model for Puerto Rico	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	NY/NJ Harbor Sediment Decontamination Tech. Demonstration: Phase II Pilot Scale	EENS
	Southern Oxidants Study Research Program at BNL	EENS
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	
NASA	An Advanced Gamma-Ray Spectrometer for Determining Geological Activity & Composition of Planetary Bodies	EENS
	Booster Applications Facility	AD
	Germ Cell Mutagenesis in Medaka Fish Following Exposure to Heavy, High Energy Cosmic Ray Nuclei	BO
	Heavy Ion Beam for Single Event Upset studies.	AD
	Radiobiological research with high-energy ions.	MO, BO, AD
	Reaction Pathways & Thermodynamic Studies of Atmospheric Reactions	EENS
	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
	NUCLEAR REGULATORY COMMISSION (NRC)	
NRC	Advance Alarm System Review Criteria	EENS
	Advanced Reactor Regulatory Framework Development	EENS
	Analysis of Reactivity Transients	EENS
	Analysis of Standby and Demand Stresses on NPP Safety System	EENS
	Application of Risk Information & insights in Regulatory A.	EENS
	Armenian Nuclear Regulatory Authority - Development of a Safety Analysis Review Capability	EENS
	Armenian Nuclear Regulatory Authority - Development of a Safety Analysis Review Capability	EENS
	Armenian Nuclear Regulatory Authority - Development of a Safety Analysis Review Capability	EENS
	Armenian Nuclear Regulatory Authority - Development of a Safety Analysis Review Capability	EENS
	Armenian Nuclear Regulatory Authority - Development of a Safety Analysis Review Capability	EENS
	Armenian Nuclear Regulatory Authority-Development of a Safety Analysis Review Capability	EENS
	Armenian Nuclear Regulatory Authority-Development of a Safety Analysis Review Capability	EENS
	Boiling Water Reactor Fluence	EENS
	Collaborative Research on Wire System Aging	EENS
	Coop-Switz-PRA Supports Y-6547	EENS
	Coop-Taiwan-PRA Supports Y-6547	EENS
	Credit for Operator Action	EENS
	DCS Specific Activities	EENS
	Detailed Accident Frequency Analyses	EENS
	Digital Instrumentation and Control System	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NRC	Digital Systems PRA	EENS
	Displacement Based Seismic Design	EENS
	Dry Cask PRA	EENS
	EQ/Aging Power Cables and Electrical Penetration	EENS
	Estimate for Construction of PPS Drop Test Facility	EENS
	FY 1998 IPP Management	NN
	General Reactor Analysis	EENS
	High Temperature Combustion Program	EENS
	HRA By- Product Material	EENS
	Improved Methods for Performing Importance Analysis	EENS
	Japanese Collaboration on Seismic Issues	EENS
	LOCA Testing of Safety-Related Cables	EENS
	Low Power and Shutdown Risk Study-Level 2	EENS
	MELCOR Benchmarking, Verification & Applications – Korean Funds	NN
	MELCOR Verification & Benchmarking	EENS
	Nuclear Safety Research Information Meeting	EENS
	NUREG-0700- Rev. 2	EENS
	OECD Workshop	EENS
	Peer Review BWR Internals	EENS
	Program Plan Development	EENS
	Radiological Emergency On-Shift and Augmentation Staffing Levels for Nuclear Power Plants	EENS
	Reactor Analysis for High-Burnup Fuel	EENS
	Reactor Core Analysis	EENS
	Reactor Dosimety and RPV Benchmark Problems	EENS
	Reactor Oversight Program Support	EENS
	Reeval. Of Reg. Guidance for Modal Combinations	EENS
	Risk Associated with Cable Aging	EENS
	Risk Comp Scheduling Preventive Maintenance for PWRs	EENS
	Risk Informed Initiatives for Nuclear Materials	EENS
	Risk-Informing Part 50	EENS
	Role of Human Performance in Advanced Reactors	EENS
	Russia Priority 1 -Licensing Basis and Safety Analysis - Russian Regulatory Authority	EENS
	Russian Regulatory Training	EENS
	Safety & Regulatory issues Related to Permanent Shutdown of NPPs Awaiting…(C1. Status-Activities)	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NRC	Screening Reviews of Seismic - IPEEE (C1. Status - Activities)	EENS
	Seismic Response of Degraded Structures and Components	EENS
	Soil-Structure Interaction for Buried Structures	EENS
	SPAR Model Development Level 2/LERF	EENS
	Specialist Support for NPP Inspections	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Strengthening Kazak Regulatory Authority	EENS
	Subtask 2.10	EENS
	Subtask 2.9- Assist. Dept. Of Plan of Risk Informing 10 CFR Part 50	EENS
	Support for Inspection and Assessment Program Development and Oversight	EENS
	Support for OECD Workshop on Seismic Input	EENS
	Support for Review of ACR-700 Design	EENS
	Support for Review of ESBWR Advanced BWR Design	EENS
	Support in Development of Consensus PRA	EENS
	Support to Russian Federal Nuclear and Radiation Safety Authority	EENS
	Support to State Nuclear Regulatory Committee of Ukraine	EENS
	Support to State Nuclear Regulatory Committee of Ukraine	EENS
	Support to State Nuclear Regulatory Committee of Ukraine	EENS
	Support to State Nuclear Regulatory committee of Ukraine -U-9450	EENS
	Support to State Nuclear Regulatory committee of Ukraine -U-9450	EENS
	Support to State Nuclear Regulatory committee of Ukraine -U-9450	EENS
	Take 1: Cable Acquisition	EENS
	Task 03: Balance of Projects	EENS
	Task 1 Neutronic Codes for ACR-700	EENS
	Task 1.2 Administration of IMUG	EENS
	Task 1: Assistance to NRC for Participation in CSNI Activities	EENS
	Task 1: Case Study in Site Decommissioning	EENS
	Task 1: Containment Analysis	EENS
	Task 1: International MACCS Users Group	EENS
	Task 1: Literature Review	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NRC	Task 1: Plan for Risk Informing Part 50 Recommendations	EENS
	Task 1: Power Cables	EENS
	Task 1: Project Management	EENS
	Task 1: Project Management	EENS
	Task 1: Select Dry Cask System	NN
	Task 1: Technical Support for Review of TRACG Realistic Large LOCA Code for ESBWR	EENS
	Task 1: Test Plans	EENS
	Task 1:Technical Support and Training	EENS
	Task 10: Dissemination Phase II	EENS
	Task 10: REA Design Acceptance Criteria	EENS
	Task 11: Generic Issue 185	EENS
	Task 11: Peach Bottom Fire Protection Baseline Inspection - Electrical Assistance	EENS
	Task 12 Analysis of MOX Fuel	EENS
	Task 12: St. Lucie Fire Protection Inspection	EENS
	Task 13: McGuire Fire Protection Inspection	EENS
	Task 14: North Anna Fire Protection Inspection	EENS
	Task 14: Reactor System/Mechanical Systems in Support of the Brown's Ferry Fire Protection Baseline Inspection	EENS
	Task 15: Davis Besse Fire Protection Inspection	EENS
	Task 15: Reactor System/Mechanical Systems in Support of the Brown's Ferry Fire Protection	EENS
	Task 1D: Spent Fuel Heat up Code Development	EENS
	Task 2.11: Modify Draft Letter Report and Submit Final Report	EENS
	Task 2: Case Study of Uranium Recovery Facilities	EENS
	Task 2: Condition Monitoring Tests	EENS
	Task 2: Containment Training	EENS
	Task 2: Identify Initiators/Failures	NN
	Task 2: License Renewal Training	EENS
	Task 2: On-Call Assistance	EENS
	Task 2: Plan for Risk Informing Part 50 Charges	EENS
	Task 2: Plan for Risk Informing Part 50 Charges	EENS
	Task 2: Senior Review Board	EENS
	Task 2: Splices	EENS
	Task 2: Technical Meetings	EENS
	Task 2: Technical Support for Review of Topical Report: NEDC-3306P,"General Electric Boiling Water Reactor Maximum Extended Load Line Limit Analysis Plus	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NRC	Task 3: Artificial Again of Cables	EENS
	Task 3: Case Study of 10 CFR Part 76, Gaseous Diffusion Plant	EENS
	Task 3: Development of Supplementary Guidance on External Events Risk Characterization for NRC Significance Determination Process	EENS
	Task 3: Fuses	EENS
	Task 3: HVAC Training	EENS
	Task 3: Meetings	EENS
	Task 3: Review of Westinghouse AP1000 Design Control Document Sections 3.8.2, 3.8.3, 3.8.4, and 3.8.5 Pertaining to the Design of Nuclear Island Structures	EENS
	Task 3: Seismic Insights	EENS
	Task 3: Workshop	EENS
	Task 4 Integration of Case Studies	EENS
	Task 4 LOCA Testing	EENS
	Task 4: Added Review Plans	EENS
	Task 4: Dissemination	EENS
	Task 4: Finalizing the ASME Standard Appendix	EENS
	Task 4: Igniter Cost Benefit	EENS
	Task 4: Licensee Corrective Action Program	EENS
	Task 4: On-Call Assistance	EENS
	Task 4: PRA Workshop	EENS
	Task 4: Research Coordination	EENS
	Task 4: TA for Ukraine Task 3.1.1-96#2 Continuation of How To Apply New Standards-Ukraine regulator Training	EENS
	Task 5, Rev. 1, Mod 1: Benchmarking and Revision of NRC Significance Determination Process (SDP) Notebooks	EENS
	Task 5: Application for Risk-Informed approaches to NMSS Regulatory Activities and Initiatives	EENS
	Task 5: Benchmarking and Revision of NRC Significance Determination Process) Notebooks	EENS
	Task 5: dissemination	EENS
	Task 5: Human Performance in the Reactor Oversight Program	EENS
	Task 5: Training on Pressure Vessel Fluents	EENS
	Task 6: Procedure Guide	EENS
	Task 6: Risk Scoping Study on Cable Aging	
	Task 7: User of Arrhenius	EENS
	Task 8: Review of the VCSNS License Renewal Application in Areas Relating to the Contaminants, Structures and Component Support	EENS
	Task 8: Testing of IAEA cables	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NRC	Task 9: Post LOCA Testing	EENS
	Technical Assistance	EENS
	Technical Assistance for Risk Assessment of Nuclear Materials and Waste	EENS
	Technical Assistance for Safety Analysis and Licensing Procedures - Ukrainian Regulatory Training	EENS
	Technical Assistance in Support of DSSA Reactor System Issues	EENS
	Technical Assistance in Support of DSSA Regulatory Licensing Improvements	EENS
	Technical Assistance in Support of Technical Evaluation of Non-Power Reactors-University of Maryland License Renewal	EENS
	Technical Assistance in Support of the Division of Engineering Review of Inservice Inspection Relief Request Licensing Actions	EENS
	Technical Assistance in Support of the Division of Engineering Regulatory Licensing Improvement Activities	EENS
	Technical Assistance in Support of the Division of Engineering Review of Design Certification Applications	EENS
	Technical Support for Kalininskaya VVER-1000 Probabilities Risk Assessment	EENS
	Technical Support for the Russian Kalininskaya	EENS
	Technical Support for the Russian Kalininskaya VVER-1000 Probabilistic Risk Assessment	EENS
	Technical Support for the Russian Kalininskaya VVER-1000 Probabilistic Risk Assessment	EENS
	Technical Support for the Russian Kalininskaya VVER-1000 Probabilistic Risk Assessment	EENS
	Technical Support for the Russian Kalininskaya VVER-1000 Probabilistic Risk Assessment	EENS
	Technical Support in Risk Assessment	EENS
	Ukraine Priority 3.1 -Safety Analysis and Licensing Procedures - Ukrainian Regular Training	EENS
	Ukraine Priority 3.1 -Safety Analysis and Licensing Procedures - Ukrainian Regular Training	EENS
	NATIONAL SCIENCE FOUNDATION PROGRAM 40	
NSF	Enhancing Science Project Research with Information Technology ESPIRIT	
	OTHER FEDERAL AGENCIES - PROGRAM 40	
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
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
PETC	Clean Coal Fossil Fuels and Energy Efficiency	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	PRIVATE ENTITIES	
Aerodyne Research, Inc	Development of a Versatile Aerosol Mass Spectrometer for Organic Aerosol Analysis	EENS
Airborne Containment Systems	Testing of Filtration Efficiency on Device for Removal of Biological Radiological Hazards Injected into Commercial Air Handling Systems	EENS
Ariadne Genomics, Inc	System Analysis of Molecular Networks	PO
Battelle Memorial Institute	Technical Support for BMI Technology Platforms	BO
Cooley's Anemia Foundation	A Novel Method to Measure Iron In Vivo in the liver and Heart of Thalassemia	EENS
Cornell Univ.	Tort Law Database	EENS
EC2000, LC.	Evaluation of EC2000 Devices for Oil-Fired Residential Heating Systems	EENS
Emory Univ.	AIDS and Opiates : A Monkey Model	MO
Enconet Consulting	Risk Informed Applications for Nuclear Power Plants	EENS
Energy Research Center, Inc.	New York State Premium Low-Sulfur Fuel Marketplace Demonstration	EENS
EPRI	Development of Design Process Guidance for Digital Control Room Technologies	EENS
EPRI	Development of Technical Bases for Guidance for Digital Control Room Technologies	EENS
EPRI	Providing Human Factors Technical Support for Digital I&C Modernization	EENS
Fermionics Corparation	Fabricate CZT Detectors from Crystals.	DA
General Electric Corporation	Next Generation EB-PVD Apparatus	EENS
Georgia Institute of Technology	Measurement of Particle Chemical composition During NARE-TRACE-P	EENS
Houston Advanced Research Center	Quantification of Fugitive Reactive Alkene Emissions From Photochemical Plants with Perfluocarbon Tracers	EENS
Insight Tech. Inc.	Two-stage oil burner with load tracking control	EENS
ITT Industries	Development of an Enhanced Bio-Aerosol Trigger Sensor Using Raman Signatures	EENS
ITT Industries	Ultraviolet Raman Spectral Signature Acquisition and Short-Range Raman Lidar Optical Physics	EENS
KeySpan	Alternative Repair materials for Restoring Damaged 16 Year-old Insulating Polymer Concrete Dike Overlay	EENS
KeySpan	CBC Filled Wire Mesh Composite Capping for Retaining, Berm Foundation	EENS
KeySpan	Determination of Gas Flow Rates at Gas-Fired Power Stations	EENS
KeySpan	Polymer Grouts & Polymer Composite Liners for Retaining Excavated Wall	EENS
MY Medical Center	Clinical Correlates of Longitudinal PET Changes in Alzheimer's Disease.	CO
New England Medical Center	In Vivo Proton MRS Studies of Cerebral Injury in HIV Infection	MO
New England Medical Center	Selegiline Oxidative Stress & HIV Dementia	MO

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NOCO Energy Corp.	Low Cost Bioheating Oil Applications	EENS
NSBRI	Effect of Deep Space Radiation on Human Hematopoietic Stem Cells	BO
NSBRI	CNS Damage & Counter Measures	MO
NSBRI	Heavy Ion Microbeam & Micron Resolution Detector	EENS
NSBRI	Risk Assessment & chemoprevention of HZE Induced CNS Damage	EENS
NYSERDA	High Efficiency condensing Heating Appliance Firing Low Sulfur Oil	EENS
NYSERDA	High Efficiency condensing Heating Appliance Firing Low Sulfur Oil	EENS
NYSERDA	Improved Electric Power Efficiency in Heating Equipment - Phase II	EENS
NYSERDA	Variable Firing Rate Oil Burner using Pulsed Fuel Flow control	EENS
Oilheat Research Alliance	Maximizing Fuel Performance in Residential Heating Systems	EENS
Penn State Univ.	Development of Cloud Property Retrieval Algorithms at Boundary Facilities	EENS
Raytheon	Technical Support for the FAA Aircraft Wire Degradation Study	EENS
Scripps Research Inst.	Methamphetamine and Aids Toxic Interactions in Animals	MO
Soluziona Ingeneieria	Review of CNJC Design Documentation for Proposed Control Room Modifications	EENS
St. Lukes	Medical Applications Accuracy Neutron Activation	EENS
Strutural Genomix, Inc.	Center for Strutural Genomics	BO
Suny Albany	New York Super Site Experiment	EENS
SUNY SB	A Study of the Outer Shelf Shelfbreak Front and Slope from long-term ADCP and Hydrographic Observations from the MV Oleander	EENS
SUNY- SB	New Approaches for Assessing Mutagenic Risk of Contaminants in L.I. Sound Environment	BO
SUNY- SB	Regulation of Tissue Repair	BO
Sweedish Nuclear Power Inspectorate	Adapt NRC guidance for control room design reviews to be suitable for review of the Swedish Oskarsham NPP.	EENS
Texas National Resource Conservation	Analysis of TexAWS 2000 Data	EENS
Univ. Connecticut	Project 2: PETA & SPEC Radiotracers for Brain Cannabinoid System	MOc
Univ. Rhode Island	The Oleander Project: Long-term Velocity Measurements of the Shelf, Slope, Gulf Stream and Sargasoo Sea.	EENS
Univ. Southern Calif.	Attentional Modulation in Early Sensory Processing	MO
Univ. Southern Calif.	The Collection of Shipboard Acoustic Doppler Current Profiler Data During the Shelf Basin Interaction Program	EENS
Univ. Tokyo	US/Japan Cooperative Program on Neutron Scattering.	EENS
University of Miami	Univ. Miami) A Set of high-accuracy infrared radiometers, and supporting sensors, will be installed on a series of ships undertaking long-duration cruises to demonstrate the ability of VOS vessels to make accurate skin sea-surface temperature measurements.	EENS
Unv. California at Irvine	Conceptual Design of the MECO Vacuum Window	EENS
Unv. Florida	Catalytic Mechanism of Human MN Superoxide Dismutase	CO

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
Unv. Rochester	US ATLAS Barrel Cryostat Design & Procurement	PO
Woods Hole Oceanographic Inst.	GLOBEC 01: The Physical Oceanography of Georges Bank and its Impact on Biology	EENS
	STATE AGENCIES & LOCAL GOVERNMENTS	
NYSERDA	Improved Electric Power Efficiency in Heating Equipment	BO
	The Use of Biodiesel Fuel Blends in Space Heating Equipment	BO
	High Efficiency, Condensing Heating Appliance Firing Low Sulfur Oil	BO
	Variable Firing Rate Oil Burner Using Pulsed Fuel Flow Control	BO
Texas Natural Resources Conservation Commission	Analysis of TexAWS 2000 Data	CO
	OTHER DOE CONTRACTORS	
Albuquerque Office	Proton Radiography Experiment	EENS
	FY2000 Joint DOE Integrated Technology Implementation Plan	EENS
	Support U.S. Efforts Directed Toward Current and Potential Arms Control and Nonproliferations Agreements	EENS
Argonne	Criticality and Security of Spent Removable Blocks from Heavy Liquid Metal Cooled Reactors at Sosnovny Bohr, Russia	PO
	Support the Decommissioning Planning Meeting held at Argonne National Laboratory East	EENS
	Atmospheric Radiation Measurement Program	MO
	SNS Neutron Detectors-BNL Refurbishment	CO
	CSP Nanocomposite Magnets Annual Workshop	MO
Battelle-PNNL	Provide Support to PNNL in assisting INEEI SBMS Development	BO
	Aircraft Measurements PNL 2001 Field Experiment	CO
	Participation and Scientific Management of ARM Program	CA
	Various Battelle - PNL Work Orders for Continuation of LISBON Project	PO
	Dismantling, Packing and Transport Services from BNL for Use of Battelle	MO
	Electroactive Materials for Anion Separation-Technetium from Nitrate	PO
	Foreign Visits and Assignments Database	EENS
Chicago Ops. Office	EPA/DOE Environment Management System Audit Review	EENS
EML	Optimization of Heterogeneous Use of Th in PWRs to Enhance Proliferation Resistance	BO
	Samples Project Support	CA
FERMI	Design, Construction and Installation of the Forward Pre-shower Detector for the D Zero Upgrade Project	
Idaho Operations Office	Amorphous Silica	EENS
	Develop Generation IV Technology Roadmap	EENS

Table S7 - FY 02 Work For Others by Project (6/27/03)		
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	Silica Precipitation by Thermophilic Bacteria in Hot Springs	EENS
LANL	Planning & Design of Superconducting Quadrupoles for the Advanced Hydrotest Facility Lenses	EENS
	HMS Modeling Code	EENS
	Design and Produce Twelve Silicon Pixel Detectors	
LLNL	Nuclear Closed Cities Initiative	CA
	Engineer & Construct Beamline Stands for the Calorimeter Detector at BNL for Data Taking in the PHENIX Experiment	AGS
M2AL68120	Current & Potential Arms Control/Warhead Dismantlement & Nonproliferation Transparency Regimes in Support of DTRA	EENS
NERI	Particle Bed Gas-Cooled Fast Reactor Design	EENS
ORNL	Spallation Neutron Project	EENS
	Provide Support to ORNL Office of Independent Oversight	EENS
	Assistant to the ORNL SNS Project	IO
	Mercury Waste Profiling	IO
PPP Lab.	National Spherical Torus Experiment NSTX Specification for 2D Position-Sensitive X-Ray Detector	MA
Richland Ops. Office	Generation IV Nuclear Energy Systems	DH
Rocky Flats Ops. Office	Biomobility of Actinides	EENS
	SEU Testing	EENS
	Dedicated Beamline for Accelerating Heavy Ions	EENS
	Provide Collection & Analysis of Material Control and Accounting Information Special Nuclear Materials	EP
	Provide V-Copy System Descriptions, System Operations, and Location-Related Documentation for NUREG/CR-6144 Plant	MA
	Source-Term Calculations for WIPP Performance Assessment	SE
	Dynamics of Dislocations Near Interfaces in Thin Metal Films	SE
	Assessment Review Team Services at Sandia National Labs.	EENS
Savannah River	PUREX Alternative Treatment Review	ER
UT-Battelle ORNL	Project Assistance for Deploying SBMS at the DOE Oak Ridge Ops.	PHY

Table S8 - Active CRADA Projects (6/30/03)		
ACCEL Instruments	Accelerator Design of Proton Therapy Facility Based On A Superconducting Cyclotron	AD
Acceleron	Non-Vacuum Electron Beam Welding	AD
Advanced Energy Systems, Inc.	Development of High Average Current, High Brightness, All Niobium, Superconducting RF Injector	IO
Applicable Electronics, Inc.	Non-Invasive Techniques to Study Local Passivity Breakdown of Metal Alloys in Aqueous Media	MA
Aquila Technilogies Group, Inc.	Development of an Unattended Multi-Object Recognition System for Remote Surveillance "MORS"	EENS
Battelle Memorial Institute	Design of Novel Antimicrobial Drugs: Determination of Structures in the Lysine Biosynthesis Pathway	BO
BioSet, Inc.	Peptide Analogs	MO
Brookhaven Technology Group, Inc.	Development of a High Current, High Gradient, Laser Excited, Pulsed Powered Electron Gun	IO
Burle Industries, Inc.	Project to Develop a Red Side Window Photomultiplier Tube and a Mesh Dynode Proximity Focusing Photomultiplier Tube	PO
Canberra-Aquila, Inc.	Development of Remote Detectors of Breath Alcohol in Moving Vehicles	EENS
Dow Chemical Company	Directed Genetic Engineering of Lipid Metabolism in Plants	BO
DuPont	Combustion Code for the Chemical Industry	EENS
Excom, Inc.	Development of Application of Pattern Recognition System	EENS
Excom, Inc.	Development of a Multi-Facet Pattern Recognition System	EENS
Fenix Technology International, Inc.	UPEC Heavy Metals Technology Development and Validation	EENS
Glaxo Smith Kline	Characterization of Dopamine Transporter Blockade by GW353162 in Human Brain	MO
Heat Wise Inc.	Low Nox Commercial Burner	EENS
Honeywell Consumer Products Group	Inhibition of Magnesium Corrosion for Automobile Coolant Application	MA
Ion Focus Technology	Miniature Neutron Generator For Brachytherapy Tumor Treatment	EENS

Table S8 - Active CRADA Projects (6/30/03)		
Johnson & Johnson Pharmaceutical R&D, LLC	Radiotracer Synthesis and PET Imaging Evaluations for Brain Histamine Receptors	CO
Lakrom Ltd.	Development of 3-D Thermal Hydraulic Capabilities for Nuclear Power Plant Simulators	EENS
Miravant Medical Technologies	Synchrotron-Based Structural Studies of Hydroporphyrin Sensitizers for Photodynamic Therapy	MA
MIT	MIT/Global Nuclear Fuels – KazAtom Prom/ULBA Project	EENS
Ocean Optics, Inc.	Metrology Tools for Surface Profile Measurement	IO
Psimei Pharmaceuticals PLC	Development of Porphyrins for BNCT	MO
PVI Vacuum System Technology	Highly Stripped Ion Sources for MeV Ion Implanters	AD
Radiation Monitoring Devices	Development of Field-Portable CdZnTe (CZT) Radiation Detectors to Monitor and Localize Special Nuclear Materials	EENS
Sub-Terra Sensors, LLC	Terrestrial Magnetic Surveyor (TEMASU)	EENS
Symbol Technologies, Inc.	CMOS Imaging Arrays with Integrated Signal Processing	IO
Technology Commercialization International	Co-production of Pd-103, Sr-82 and Ge-68 for Commercial Distribution and Medical Applications	MO
Technology Commercialization International	Development of High Specific Activity And No-Carrier-Added Tin 117-m For Radionuclide Therapy of Cancer	MO
Thorium Power, Inc.	Radkowsky Thorium Fuel Project	NE

Table S9 - BSA Patent Portfolio (6/30/03)			
Technology Field	**Inventions in Portfolio**	**Inventions Licensed**	**Inventions Commercialized**
Molecular Biology	33	13	4
Optics	30	30	0
Pharmaceuticals	25	12	2
Instrumentation	21	13	4
Materials	14	4	0
Environmental Remediation	14	5	4
Catalyst	9	0	0
Medical Devices	7	0	0
Electronics	7	1	1
Energy Production	2	0	0
Nanofabrication	2	0	0
Total	**164**	**78**	**15**

Table S10 - Examples of Products Marketed Under License From BSA (6/30/03)	
PRODUCT	**DEPARTMENT**
Appartatus for Purification of Food Wastes	EENS
Asbestos Remediation	NE
Cytoplasmic Bacteriophage Display System	BO
Fast Repetition Rate Fluorometers for Measuring Fluorescence	EENS
Growth Media For Expression Systems	BO
Metal Chelating Agents For Antibody Delivery Systems	MO
Monolithic Amplifier	IO
Polyethylene Encapsulation of Radioactive and Mixed Wastes	EENS
Recombinant Plasmids for Encoding Restriction Enzymes Dpn I and Dpn II	BO
Red Blood Cell Labeling Kit for Labeling Whole Blood with Tc-99m	MO
Surface Profiling Interferometers	IO
T7 Gene Expression System, Vectors and Protein Products	BO

Table S11 - BSA Licensing Revenue ($1000)				
	FY 00	**FY 01**	**FY 02**	**FY 03 (Thru 5/30/03)**
Gross Revenue	2068	2439	2603	1365
Net Revenue	1463	1777	1996	1068