Brookhaven National Laboratory Economic Impact Report

Meeting National Needs, Creating Opportunities for Growth

BROOKHAVEN
NATIONAL LABORATORY

This report was prepared by Appleseed, a New York City-based economic development consulting firm that works with government, corporations, and nonprofit institutions to promote economic growth and opportunity.

80 Broad Street
13th Floor
New York, NY 10004

www.appleseedinc.com

Fiscal Year 2009 Highlights

By the numbers...

State & Local Impacts
National Influence
Global Reach

$704 Million in economic output generated by Brookhaven Lab and its visitors

$573 Million in total funding

5,400 jobs created throughout New York State

3,000 employees, **98%** living on Long Island

3,000+ visiting researchers from university, corporate and government institutions, nearly **700** from New York State

12% growth in employment from 2006 to 2009

$75.2 Million in goods and services purchased from New York State companies, including **$62.7 Million** from Long Island companies

295 full-time equivalent jobs directly supported throughout New York State, including **255** on Long Island

$74.7 Million invested in new facilities and renovations

$45.1 Million paid to New York State contractors, including **$34.9 Million** to Long Island-based contractors

314 jobs directly supported in construction and related industries in New York State including **238** with Long Island contractors

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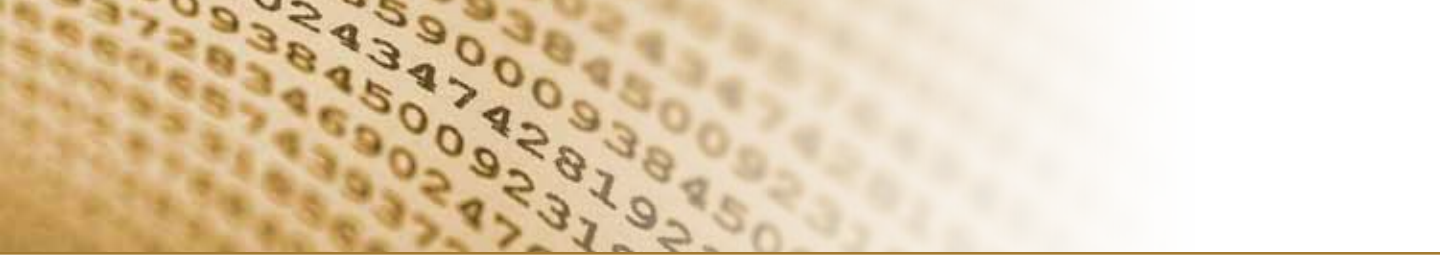
Executive Summary

Over the past 60 years, research, development, and innovation – on university campuses, in corporate research centers and small business ventures, and at national laboratories – have been among the most significant drivers of economic growth in the United States. Today, as the U.S. looks for new sources of growth while facing major challenges in areas as diverse as health, energy efficiency, climate change, and national security, research and innovation are as vital as ever.

Located in Upton, New York, the U.S. Department of Energy's (DOE) Brookhaven National Laboratory is one of just six multi-program national labs funded by DOE's Office of Science. Established in 1947, Brookhaven Lab is the only national lab located in the Northeast. It is also one of New York State's largest centers of scientific research and a major contributor to the growth of Long Island's[1] technology-based economy. At a time when the recovery of the State's economy depends (perhaps more than ever) on its capacity for innovation, Brookhaven Lab represents a uniquely valuable resource – both as a major science-based enterprise in its own right, and as a source of the scientific discovery and technological innovation on which growth depends.



This report examines Brookhaven Lab's significant impact on the economy of Long Island and New York State as a whole, both as a major science-based enterprise in its own right and through its mission of research, technology development and deployment and education.

Brookhaven National Laboratory as an Enterprise – Fiscal Year 2009

- Brookhaven National Laboratory is managed by Brookhaven Science Associates – a limited-liability company founded by the Research Foundation of the State University of New York on behalf of Stony Brook University, the largest academic user of Lab facilities, and Battelle Memorial Institute, a nonprofit, applied science and technology organization – under a contract with DOE.

- Brookhaven Lab's funding in fiscal year 2009 totaled $573 million – about 96 percent of which came from the Department of Energy and other federal agencies.

- As of September 2009, Brookhaven Lab employed 2,893 people – 94 percent of whom worked full time, and more than 98 percent of whom live on Long Island. The Lab's payroll for FY 2009 totaled $250 million.

- Between September 2006 and September 2009 – a period during which payroll employment declined both on Long Island and in New York State – employment at Brookhaven Lab grew by 12 percent.

- In FY 2009, Brookhaven Lab spent $212 million on purchases of goods and services (other than construction). Of this total, $75.2 million was spent on purchases of goods and services from New York State companies, including $62.7 million in purchasing from Long Island companies. This spending directly supported about 295 full-time-equivalent jobs throughout New York State – including about 255 FTE jobs with vendors and contractors on Long Island.

- In FY 2009, Brookhaven Lab invested $74.7 million in construction of new facilities and renovation of existing ones. Of this total, $45.1 million was paid to New York State contractors, including $34.9 million paid to contractors based on Long Island. We estimate that this spending directly supported 314 FTE jobs in construction and related industries throughout New York State, including 238 FTE jobs with Long Island contractors.

- Through the "multiplier effect," Brookhaven Lab's spending on payroll, purchasing, and construction in FY 2009 indirectly generated $324 million in additional economic output and approximately 1,822 FTE jobs throughout New York State – including $290 million in output and 1,660 FTE jobs on Long Island.

- In fiscal year 2009, state and local personal income taxes withheld from the salaries of Lab employees, along with unemployment insurance taxes, totaled more than $13.5 million. The Laboratory also distributed more than $1 million in payments in lieu of taxes and other fees to local governments.

- Appleseed estimates that off-site spending by visitors to Brookhaven Lab in 2009 directly and indirectly accounted for about $9.5 million in economic output and 97 FTE jobs on Long Island.

- Appleseed estimates that, in total, the direct, indirect, and induced impact of spending by Brookhaven Lab and by its visitors in FY 2009 generated approximately:

  - $647 million in economic output and 5,190 FTE jobs on Long Island; and

  - $704 million and 5,400 jobs throughout New York State.

- By FY 2014, Brookhaven National Laboratory expects its employment to grow to 3,350 – an increase of nearly 16 percent.

- Between FY 2010 and FY 2014, Brookhaven Lab plans to invest $1.047 billion in construction of new and renovation of existing facilities. During the same period, the Lab will also

1 Throughout this report, "Long Island" refers to Nassau and Suffolk Counties in New York State

Brookhaven's Center for Functional Nanomaterials

spend $1.113 billion on purchases of goods and services.

- Taking into account the projected increases in spending on payroll, purchasing and construction – and assuming current levels of visitor spending – it is estimated that between 2010 and 2014, Brookhaven Lab will, on an average annual basis, generate approximately:
  - $849 million in economic output and 6,531 FTE jobs on Long Island; and
  - $947 million in economic output and 7,092 FTE jobs throughout New York State, including Long Island.

Research at Brookhaven National Laboratory

- The foundation on which Brookhaven Lab's role as a leading center of scientific research is built (and what distinguishes it from most university and corporate research centers) is its strength in designing, developing, building, and operating major research facilities such as the National Synchrotron Light Source (NSLS), the Relativistic Heavy Ion Collider (RHIC) and the Center for Functional Nanomaterials (CFN) – and in part on its expertise in using these world-class facilities to address complex scientific challenges.
- The work done at Brookhaven Lab spans a wide range of basic and applied research in fundamental physics, basic energy sciences and energy technology, the life sciences, nanoscience and nanotechnology, environmental sciences and national security.
- Brookhaven Lab's strength in these and related areas is reflected in the fact that twelve scientists in the last half-century have been awarded seven Nobel Prizes based on research conducted at the Laboratory.
- Research currently or recently conducted at Brookhaven Lab – by its own scientists and by researchers who come to Brookhaven from around the world to use its facilities – illustrates both the breadth of the Lab's scientific enterprise and its potential benefits. Some examples include:
  - Research that uses RHIC to recreate conditions thought to have existed a microsecond following the Big Bang at the beginning of the universe, helping physicists better understand both the evolution of the universe and the nature of matter;
  - Development of superconducting materials that can conduct electricity much more efficiently than conventional copper cables;
  - Research that will enhance the productivity and efficiency of plants that could be a source of biofuels in the future;
  - Development of a new type of accelerator-driven thorium-based nuclear reactor that would be cleaner, safer, and more secure than uranium-based reactors;

- Research using biological imaging technology, some of which was developed at Brookhaven Lab, to study the mechanisms of drug addiction, obesity, and other diseases, potentially leading to new and more effective treatments;

- Development of new types of radiation detectors that will be more efficient and easier to deploy at ports, airports, and other locations that might be vulnerable to radiological attack; and

- Development of new techniques for extracting mercury from contaminated soil.

- More than 3,000 university, corporate, and government researchers – including nearly 700 from universities, companies, and public agencies in New York State – used NSLS, RHIC, CFN and other facilities at Brookhaven National Laboratory in fiscal year 2009 to conduct their own research. Stony Brook University is the single largest source of outside researchers using Brookhaven Lab facilities – accounting for about eight percent of all outside users in fiscal year 2009 and 37 percent of all New York State-based users.

- Although Brookhaven Lab is a national laboratory, its reach is global. For example:

  - About 100 institutional partners from 50 countries collaborate on various research programs using RHIC.

  - Since 1997, Brookhaven Lab has partnered with RIKEN, one of Japan's leading scientific institutions, through the RIKEN-BNL Research Center, which is located on the Laboratory campus.

  - The Laboratory also engages in collaborative research with major international companies such as Bayer and Toyota. Researchers from non-U.S. institutions and companies account for about one-sixth of all external users of the Lab's research facilities.

From Discovery to Deployment

- Brookhaven National Laboratory combines impressive strengths in basic science with the ability to translate its intellectual capital into solutions to some of the nation's most pressing problems. The Laboratory works to move new knowledge from discovery to deployment in several ways.

- Brookhaven Lab licenses its technologies to companies that invest in further development and then bring them to the marketplace. Between FY 2004 and FY 2009, the Lab entered into 92 new agreements for further development and commercial use of technologies born at Brookhaven Lab. During the same period, the Laboratory generated more than $42 million in royalties from companies to which it had licensed its technologies in the past.

- The Laboratory puts its intellectual capital to work by collaborating with companies on applied research and development projects. The Lab's partners on such projects include

"Brookhaven National Laboratory combines impressive strengths in basic science with the ability to translate its intellectual capital into solutions to some of the nation's most pressing problems."

major corporations such as General Motors, Johnson & Johnson, and United Technologies. But they also include small to mid-sized New York State companies engaged in developing a wide range of new technologies. These companies include:

- Advanced Energy Systems, located in Medford;
- Clear Vascular, located in New York City; and
- SuperPower, Inc., located in Schenectady.

- Brookhaven Lab is also working with public agencies and industry partners in a variety of collaborative efforts aimed at addressing major national needs – and at the same time strengthening New York State's economy. Examples include:
  - The Laboratory's participation in the State's Smart Grid Consortium and the Battery and Energy Storage Technology Consortium.
  - Brookhaven's partnership with Stony Brook University in its Advanced Energy Center (AEC), a research facility created to develop alternative energy sources and protect natural resources by taking advantage of cutting-edge technologies.
  - The Lab's collaboration with BP Solar and the Long Island Power Authority in the development of New York State's largest solar electric power plant – a 37-megawatt power plant, to be constructed on the Brookhaven Lab campus and scheduled for completion in 2011.

Strengthening Science Education

Improving education at all levels in science, mathematics, engineering and technology has been cited in several national reports as being critical to America's future prosperity. In addition to its role as a major research center, Brookhaven National Laboratory supports its scientific mission by helping to prepare the next generation of scientists and engineers. The Lab offers informal educational programs and research experiences for elementary school students through post-doctoral fellows, as well as professional development programs for teachers. In FY 2009, more than 34,000 elementary, middle, and high school students, about 250 undergraduate and graduate students, and more than 2,000 teachers participated in educational programs at Brookhaven Lab.

Participants in the Open Space Stewardship Program

- Brookhaven Lab's Open Space Stewardship Program is working with 35 local school districts to integrate exploration of the outdoor environment into their science curriculum. About 2,500 students participated in the program in FY 2009.

- Each year, about 100 high school students participate in summer research workshops and internships at the Laboratory.

- Brookhaven Lab provides professional development programs for teachers, and research internships for more than 250 undergraduate and graduate students each year – either through their work with scientific staff who are conducting research at the Lab or through special programs for college and university students, such as the Lab's annual summer courses on nuclear non-proliferation and nuclear chemistry.

- The Faculty and Student Teams program gives faculty and undergraduate students from colleges and universities an opportunity to develop their skills and knowledge while using Brookhaven's research facilities for the summer. This program specifically targets institutions with students underrepresented in science, engineering, math and technology. In 2009, 25 of these teams conducted research at Brookhaven.

Brookhaven National Laboratory and the Future of New York State's Economy

Brookhaven National Laboratory's impact on New York State's (and Long Island's) economy is likely to be even greater during the next five to 10 years. This is so for several reasons:

- During the next five years, Brookhaven Lab expects to invest more than $1 billion in construction of new research facilities and in upgrading existing buildings and infrastructure. This will create new business and employment opportunities in Long Island's construction industry.

  Even more important, it will greatly enhance Brookhaven Lab's research capabilities. NSLS-II, now under construction on the Laboratory campus, will provide capabilities for the study of materials and physical processes at a level of detail and precision that will be available nowhere else in the world. NSLS-II will make it possible for Brookhaven Lab, its partners, and external users to attract new funding in the life sciences, nanotechnology, energy and many other areas.

- Expansion and improvement of Brookhaven Lab facilities will result in more jobs; the Lab expects employment to increase by 16 percent by 2014.

- Brookhaven Lab has made a strong commitment to increasing its capacity to move from discovery to deployment – through creation of a new directorate for Global and Regional Solutions, and through new initiatives such as the Technology Maturation Program, which provides funds to help researchers bridge the gap between initial development of new technologies and their ability to attract private investment.

- Addressing major challenges such as finding new sources of renewable energy or more effective treatments for crippling diseases increasingly requires collaboration across sectors, across institutions, and across disciplines. With a growing network of New York State collaborators – at universities, in state government, and in industry – Brookhaven Lab is well-positioned to take advantage of this trend.

Introduction

Brookhaven Lab researchers are developing new solid-state storage materials for energy applications.

This report highlights several aspects of Brookhaven National Laboratory's impact on the economy of New York State and that of Long Island.

Part One of the report provides a brief overview of Brookhaven Lab, its facilities and operations.

Part Two analyzes the impact of the Lab's spending on payroll, purchasing and construction on Long Island's and New York State's total economy.

Part Three discusses the wide range of research conducted at Brookhaven Lab.

Part Four presents the multiple ways in which the Lab works to bring the new knowledge it develops from discovery to deployment.

Part Five describes the Lab's involvement in efforts to improve science education in elementary, middle and high schools, as well as programs for undergraduate and graduate students.

Finally, Part Six discusses several reasons why Brookhaven Lab's impact on the economy of Long Island and New York State is likely to be even greater during the next five to 10 years than it is today.

Acknowledgments

This report would not have been possible without the help and cooperation of many at Brookhaven National Laboratory. Appleseed would especially like to thank Samuel Aronson, Marge Lynch, Kathleen Geiger and Jeanne Petschauer.

We would also like to thank those who provided data for our analysis and met with us to discuss the Laboratory's contributions to Long Island and New York State, including: Lanny Bates, Mike Bebon, Jim Davenport, Steve Dierker, Mike Furey, Paul Geiger, Doon Gibbs, Bob Gordon, Fritz Henn, Mike Holland, Chi-Chang Kao, Pat Looney, Michael Marx, Emilio Mendez, Jim Misewich, Erik Pearson, Nick Samios, Gerry Stokes, Ron Townsend, Steve Vigdor, Ken White, and Creighton Wirick.

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Part One: Brookhaven National Laboratory - An Overview

Brookhaven National Laboratory – located in the Town of Brookhaven on Long Island, New York – is one of seventeen U.S. Department of Energy national laboratories, and one of ten owned by the DOE Office of Science. Four of these labs (as shown in Figure 1) are single-purpose research facilities; and six – including Brookhaven Lab – are "multi-program" labs, conducting basic and applied research across a broad range of sciences. Brookhaven Lab is the only multi-program DOE lab located in the Northeast.

Brookhaven National Laboratory was established in 1947 by a consortium of nine major research universities, working in collaboration with the U.S. Atomic Energy Commission (AEC). Camp Upton, a former Army base located in Suffolk County, Long Island, was chosen as the site for the Lab. In its early years, much of the research conducted at the Laboratory supported the AEC's mission of developing and promoting peaceful uses for atomic energy. Since then, Brookhaven Lab's role has evolved, and now encompasses a wider range of scientific and technological challenges.

Today, Brookhaven National Laboratory is managed by Brookhaven Science Associates – a limited-liability company founded by the Research Foundation of the State University of New York on behalf of Stony Brook University, the largest academic user of Laboratory facilities, and Battelle Memorial Institute, a nonprofit, applied science and technology organization – under contract with the Department of Energy's Office of Science. Six of the universities that were among the Lab's founders – Columbia, Cornell, Harvard, MIT, Princeton and Yale – still play a role in guiding its work through their membership on the board of Brookhaven Science Associates.

Brookhaven National Laboratory as an Enterprise

Brookhaven National Laboratory is a major enterprise with:

- An operating budget of more than $500 million
- Nearly 2,900 employees; and
- 4.0 million square feet of space in 334 buildings located on about 5,300 acres

In many respects, the lab complex resembles a small city, with its own police and fire departments, its own infrastructure, and on-site housing which can accommodate more than 400 visiting researchers.

Research Facilities and Education

The work done at Brookhaven National Laboratory includes research in nuclear and particle physics aimed at answering some of the most basic questions in science, as well as research that more directly addresses national needs in areas such as alternative energy technologies, climate change, health care and national security.

Figure 1: Map of U.S. Department of Energy Office of Science National Laboratories

"The foundation for Brookhaven Lab's work is its strength in designing, developing, building and operating large, complex research facilities"

The foundation for Brookhaven Lab's work in all of these areas is its strength in designing, developing, building and operating large, complex research facilities, such as:

- The **National Synchrotron Light Source (NSLS)**, which began operating in 1982, is one of the world's most powerful tools for observing the structure and behavior of matter at the atomic level;

- The **Relativistic Heavy Ion Collider (RHIC)**, commissioned in 2000, is one of the world's most powerful particle accelerators; it is used by physicists to explore fundamental questions about the nature of matter and the origins of the universe; and

- The **Center for Functional Nanomaterials (CFN)**, opened in 2008, is one of five research centers created by the Department of Energy to explore a variety of problems and opportunities in energy science and technology at the nanoscale.

These and other facilities are used by Brookhaven Lab's own scientists, and by even larger numbers of university, industry, and government researchers. In fiscal year 2009, more than 3,000 visiting scientists and other researchers used the Lab's facilities for work in areas as diverse as nuclear physics, new energy technologies, climate change, nanotechnology, medical imaging and material sciences.

Recent work at Brookhaven National Laboratory has dealt with topics as diverse as:

- Studies in quantum chromodynamics – the theory that describes interactions among the smallest component particles of the nucleus of an atom.

- Research on superconducting materials that could lead to major im-

Brookhaven's Relativistic Heavy Ion Collider

Artist's rendering of Brookhaven's National Synchrotron Light Source II

provements in the efficiency and reliability of electric power transmission systems.

- Development of new catalytic materials that could greatly improve the efficiency of fuel cells.
- Brain-imaging studies that have led to a better understanding of drug addiction, which may lead to effective new treatments.
- Working with NASA to study the possible effects on humans of exposure to radiation in space.
- Development of a new method for removing mercury from contaminated soil and industrial waste.
- Development of new technologies for detecting radiological threats – such as "dirty bombs" – in urban areas.

To ensure that it can offer the most cutting-edge tools for scientific research to facility users from across the country and around the world, Brookhaven Lab continually invests in both upgrading its existing facilities and developing new ones. For example, a next-generation synchrotron – **NSLS-II** – is now under construction at the Laboratory. When it is completed in 2014, NSLS-II will be the highest-performance synchrotron light source in the world – and will provide capabilities for both basic and applied research that will be available nowhere else.

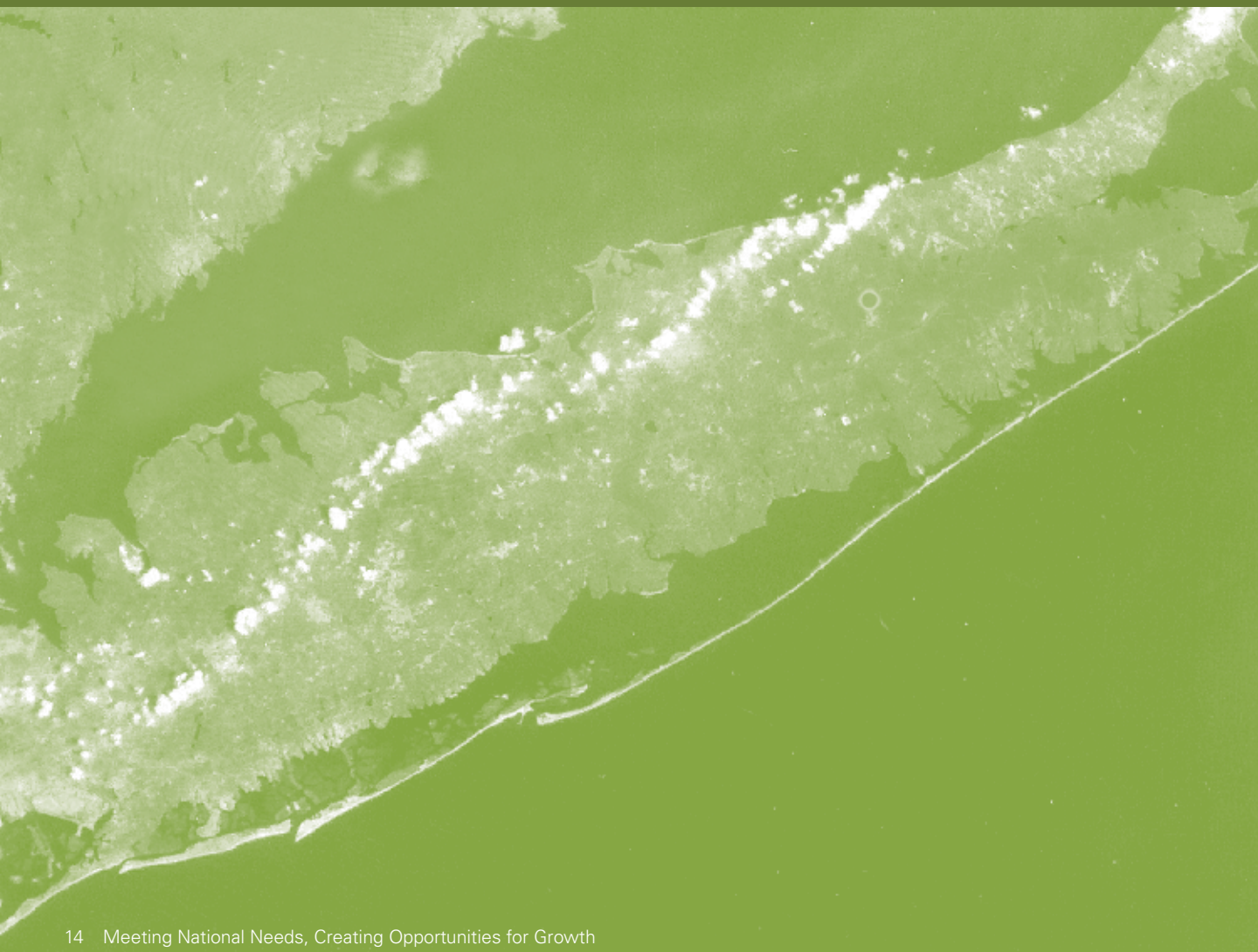
In addition to its role as a major research center, Brookhaven Lab supports its scientific mission by helping to prepare the next generation of scientists and engineers. The Lab offers informal educational programs and research experiences for students ranging from elementary school students through post-doctoral fellows, as well as professional development programs for teachers. In fiscal year 2009, more than 34,000 elementary, middle and high school students, about 250 undergraduate and graduate students, and more than 2,000 teachers participated in educational programs at the Lab.

A Source of Growth for New York State's Future

During the next five to ten years, New York State's success in charting a path toward renewed economic growth will depend in part on the state's continued leadership in scientific discovery, its capacity for technological innovation, and its agility in turning new knowledge and new technologies into new products, businesses and jobs. As both a growing science-based enterprise and a source of scientific discovery and technological innovation, Brookhaven National Laboratory will continue to be a uniquely valuable asset – for Long Island, New York State, the nation and the world.

Part Two: Brookhaven National Laboratory as an Enterprise

Brookhaven National Laboratory is a significant – and growing – contributor to both the Long Island and New York State economy, bringing hundreds of millions of dollars into the state each year from federal and other sources, most of which is spent within the state. During fiscal year 2009, the Laboratory employed nearly 2,900 people, spent more than $212 million on purchases of goods and services (other than construction) and invested $74.7 million on construction and major maintenance projects. The Lab also brought in thousands of outside researchers and other visitors who stayed in local hotels, shopped in local stores and ate in the area's restaurants.



This part of the report highlights Brookhaven National Laboratory's role as a major Long Island enterprise.

Revenues and Expenses

As shown in Figure 2, Brookhaven National Laboratory spent a total of generated $573.4 million in fiscal year 2009. About 59 percent (nearly $340 million) of the Laboratory's spending in FY 2009 went toward personnel costs, including salaries, wages and benefits; 22 percent on payments to contractors and subcontractors; and 19 percent on supplies, services and utilities.

Almost all of Brookhaven Lab's funding came from federal sources, including $498.0 million (about 86 percent) from the Department of Energy, $14.4 million (about 3 percent) from other Department of Energy national laboratories, $9.0 million from the Nuclear Regulatory Commission and $29.9 million from other federal agencies. Reimbursement for services provided to other organizations totaled $21.7 million (about 4 percent).

Brookhaven National Laboratory as an Employer

As of the end of fiscal year 2009, Brookhaven National Laboratory employed 2,893 people – about 94 percent of them in full-time positions. Between fiscal year 2006 and 2009, employment at the Laboratory grew by 12 percent – a gain of more than 300 jobs. During the same period, payroll employment in New York State fell by 0.7 percent – and on Long Island, by 1.8 percent.[2] Brookhaven Lab's full-time and part-time employment between 2006 and 2009 is shown in Figure 3.

During fiscal year 2009, Brookhaven National Laboratory paid its full- and part-time employees nearly $250 million – 96 percent of which was paid to full-

2 New York State Department of Labor, Current Employment Survey

Figure 2: Revenues and expenses, fiscal year 2009

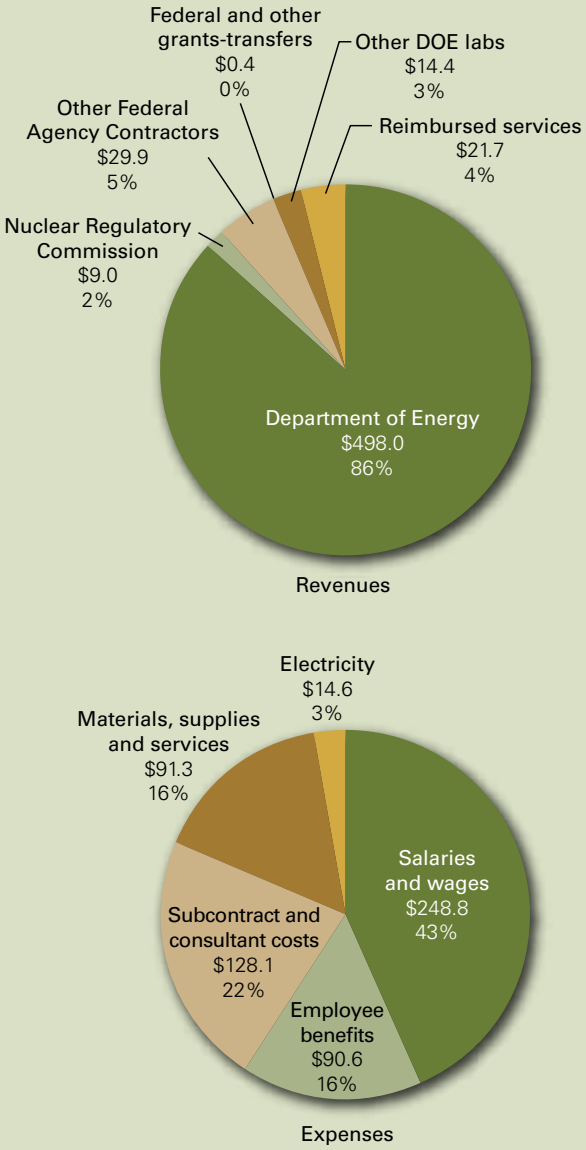


Figure 3: Brookhaven National Laboratory employment, 2006 -2009

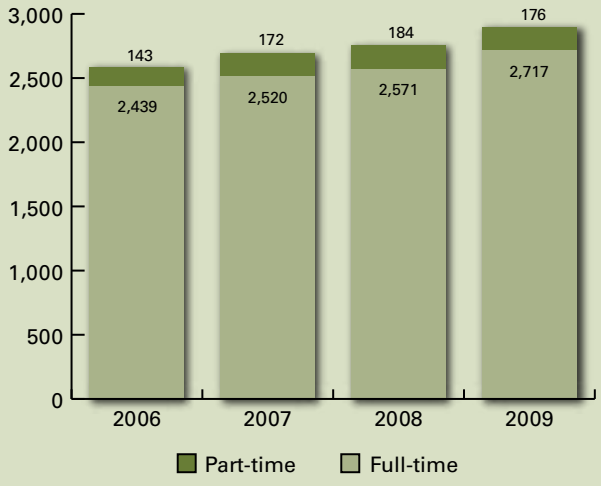


Table 1: Average earnings of full-time, full-year employees by occupational category, fiscal year 2009

Occupational category	Average earnings
Management	$ 159,998
Scientific	112,481
Engineer/scientific associate	99,559
Information technology	91,312
Administrative	63,904
Technical	81,115
Bargaining unit	72,960
All others	67,038
Average	$ 91,904

time employees. Virtually all Laboratory employees – more than 98 percent – live in Nassau or Suffolk County.

Quality of Employment at Brookhaven National Laboratory

Brookhaven National Laboratory is a high-quality employer, as reflected by the wages and salaries paid to its employees and the benefits it provides. In fiscal year 2009, the earnings of all full-time, full-year Brookhaven Lab employees averaged more than $91,900. Table 1 shows the average earnings of full-time, full-year Laboratory employees (excluding benefits) by occupational category. To put these numbers in context, the average annual wage-and-salary earnings of all employees of private businesses in New York State in 2008 were $60,282; and the average earnings for all employees of private businesses on Long Island were $50,211.

In addition to providing competitive wages and salaries, Brookhaven Laboratory provides a comprehensive set of employee benefits that include:

- Medical and dental insurance
- A Child Development Center for children (age six weeks to five years) of employees, guests or contractors of Brookhaven Lab
- Fitness facilities, including a swimming pool, weight room and gym
- Educational benefits, including training programs, English as a second language courses, and tuition reimbursement for part- and full-time employees.

Brookhaven National Laboratory supports the continuing education of its staff through training programs held on-site and off-site, and through tuition reimbursement with local colleges and universities.

- In fiscal year 2009, 312 employees participated in the Brookhaven Lab's tuition reimbursement program, for a cost to the Lab of about $515,600.

- About 973 employees attended on-site training programs led by outside firms, but sponsored by the Lab in fiscal year 2009.

- Another 2,800 people participated in on-site training programs in courses primarily taught by employees.

In addition to these programs, some Brookhaven Lab departments sponsored special off-site technical training for their staff in areas that include software and hardware training, plant engineering, and security.

Purchasing and Construction

In fiscal year 2009, Brookhaven Lab spent $212 million on purchases of goods and services (other than construction). As shown in Figure 4, purchases from New York State companies totaled $75.2 million – 36 percent of all Laboratory spending on supplies and services. Businesses based on Long Island accounted for about 83 percent of all in-state purchasing.

As Table 2 shows, purchases of goods and services from Long Island vendors included spending on electronics, consultants, service contracts, architecture and engineering services and equipment.

As Table 3 shows, leading categories of goods and services purchased from vendors elsewhere in New York State included job shoppers (short-term technical workers), electronics, software, and architecture and engineering services.

Brookhaven National Laboratory purchases of goods and services directly support jobs in these and other New York State industries. Appleseed estimates that the $75 million the Laboratory spent on in-state purchases of goods and services in fiscal year 2009 directly generated 295 full-time-equivalent jobs in New York State, including 255 FTE jobs with Long Island vendors.

As shown in Figure 5, Brookhaven Lab spent $74.7 million in fiscal year 2009 on construction and renovation of Lab fa-

Figure 4: Brookhaven National Laboratory purchasing by location of vendor, FY 2009 ($000s)

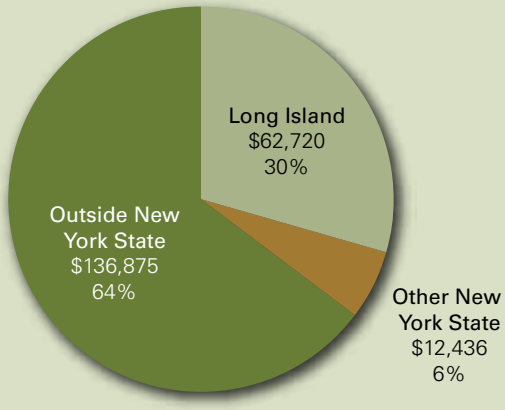


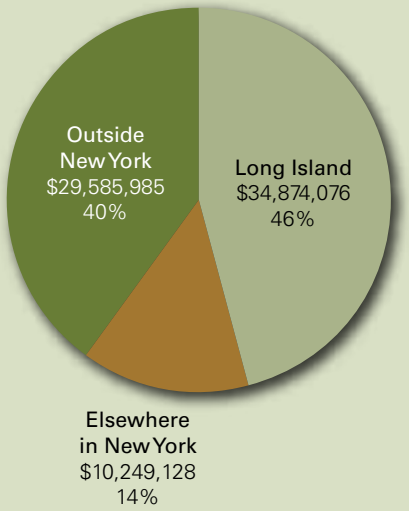
Table 2: Top 10 categories of goods and services purchased from Long Island vendors

Category	Long Island
Electrical & Electronics	$ 5,407,349
Management Consultants	3,196,033
Service Contracts	2,954,610
Architect-Engineering Services	2,089,348
Apparel/Safety/Misc Equipment	1,696,965
Research & Development	1,047,420
Automotive Supplies/Vehicles	1,022,700
Vacuum Equipment	989,886
Repairs	569,194
Environmental Engineering	510,653

Table 3: Top 10 categories of goods and services purchased from New York State vendors outside Long Island

Category	Other New York State
Job Shoppers (mechanical engineering)	$ 3,784,596
Electrical & Electronics	2,211,543
Lab Supplies	1,365,937
Software Maintenance and Support	1,118,755
Architect-Engineering Services	825,100
Service Contracts	728,829
Software	282,655
Apparel/Safety/Misc Equipment	254,361
Plumbing Supplies	252,256
eProcurement	224,433

Figure 5: Spending on construction, by location of contractor, fiscal year 2009



cilities, of which $45.1 million was paid to New York State-based contractors.

Appleseed estimates that in FY 2009 Brookhaven National Laboratory's spending on construction directly supported 314 FTE jobs with New York State contractors in construction and related industries, including 238 FTE jobs with Long Island contractors.

Brookhaven Lab has long sought to increase the participation of minority- and women-owned businesses in its procurement program. The Laboratory estimates that in FY 2009 more than $39 million was spent on purchases from minority- and women-owned businesses – about 13.6 percent of the Lab's total spending on goods and services and construction.

Indirect and Induced Impact of FY 2009 Spending

Brookhaven National Laboratory's impact on the local and state economy goes beyond the direct impact of its spending on payroll, purchasing and construction; it also includes "indirect and induced" or "multiplier" effects. Companies on Long Island and elsewhere in New York State, from which the Laboratory buys goods and services, use some of the money they earn from the Lab to buy goods and services from other local businesses; and those businesses in turn buy some of what they need from still other companies within New York State. Similarly, the Lab's employees spend part of their take-home pay locally – for housing, utilities, food, child care, entertainment and other routine household needs.

The indirect and induced effects of Brookhaven Lab's direct spending on payroll, purchasing and construction in fiscal year 2009 totaled nearly $290 million in economic output on Long Island, and approximately 1,660 FTE jobs. Similarly, the Lab's spending indirectly generated $324 million in economic output and 1,822 FTE jobs throughout New York State (including Long Island).

Thus, the direct, indirect and induced

Table 4: Economic impact of Brookhaven National Laboratory as an enterprise on Long Island and New York State, fiscal year 2009

	Direct Laboratory Spending		Indirect and induced impact of spending by vendors, contractors and employees		Total impact
	Payroll	Purchasing/ construction	Payroll	Purchasing/ construction	
Long Island	$ 250 million 2,893 jobs	$ 97.6 million 542 FTE	$ 215.4 million 1,185 FTE	$ 74.0 million 472 FTE	$ 637.5 million 5,092 FTE
All of New York State	$ 250 million 2,893 jobs	$ 120.3 million 671 FTE	$ 227.6 million 1,239 FTE	$ 96.3 million 583 FTE	$ 694.5 million 5,386 FTE

effects of Brookhaven Lab's spending on payroll, purchasing and construction – and the spending by Laboratory employees and in-state suppliers that Lab spending made possible – generated about 5,092 full-time-equivalent jobs throughout Long Island in FY 2009, and $638 million in economic output.

Statewide, the direct, indirect and induced effects of Brookhaven Lab's spending on payroll, purchasing and construction generated about 5,386 full-time-equivalent jobs throughout New York State in FY 2009, and $695 million in economic output.

The economic impact of Brookhaven National Laboratory's spending in FY 2009 is summarized in Table 4.

Brookhaven National Laboratory's Impact on State and Local Tax Revenues

While Brookhaven National Laboratory is a U.S. Department of Energy institution – and therefore not subject to state and local taxes – the Laboratory did nonetheless contribute to the state and local governments through income tax withholdings, unemployment insurance and payments in lieu of taxes.

As Table 5 shows, Brookhaven Lab withheld $12.9 million for New York state income taxes, and $84,158 for New York City income taxes in FY 2009. The Lab also paid $517,117 in unemployment insurance in FY 2009. In addition to taxes paid directly by the Lab, the Department of Energy paid $1,076,944 in payments in lieu of taxes to the Town of Brookhaven on behalf of the Laboratory.

The Impact of Off-site Spending by Users and Other Visitors to Brookhaven National Laboratory

Brookhaven Lab welcomes visitors to its campus for a variety of reasons each year. Visitors include:

- Users of Lab facilities, such as the National Synchrotron Light Source, Center for Functional Nanomaterials and Relativistic Heavy Ion Collider;
- Attendees of conferences, seminars and other scientific events;

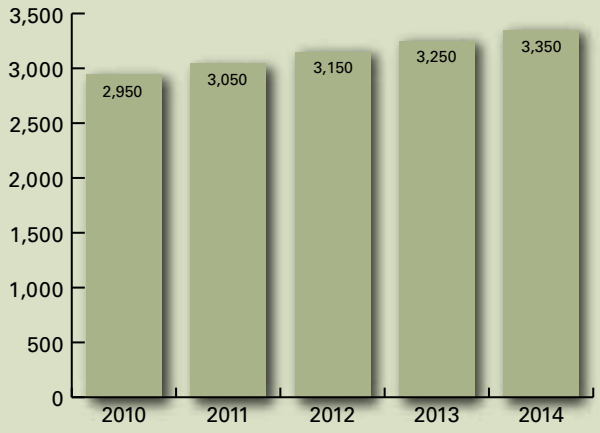
Table 5: Payments of state and local taxes, fiscal year 2009

Tax	Amount
New York State income taxes	$ 12,888,218
New York City income taxes	84,158
State unemployment insurance taxes	517,117
Payments in lieu of taxes	1,076,944
Total	**$ 14,578,219**

Table 6: Net new off-site spending by Brookhaven National Laboratory visitors in fiscal year 2009

Spending	Visitors from outside Long Island	Visitors from outside New York State
Lodging	$ 2,577,664	$ 2,064,551
Food	655,329	519,483
Transportation	1,655,568	1,312,377
Entertainment	896,766	710,871
Total	**$ 5,785,327**	**$ 4,607,281**

Figure 6: Projected Brookhaven National Laboratory headcount, fiscal years 2010-2014



- Contractors who are working for the Laboratory; and
- Other members of the public for special events and tours.

Based on data provided by Brookhaven Lab, Appleseed estimates that the Lab drew about 22,500 local visitors (that is, visitors who live on Long Island) for events such as the Lab's five "Summer Sundays," concerts, athletic, cultural and other events. In addition to these local visitors, about 2,500 visitors came to the Laboratory from elsewhere in New York State, and another 5,000 visitors came from outside New York State. These visitors primarily included the Laboratory's on-site guest researchers and users of the Lab's facilities, outside contractors and vendors, and attendees of seminars and conferences.

In analyzing the economic impact of visitor spending on Long Island, Appleseed excluded visitors who reside on Long Island; and in analyzing the economic impact of visitor spending on New York State, Appleseed excluded visitors who reside in New York State. Appleseed also took into account the fact that Brookhaven Lab provided more than 62,000 "room-nights" of housing to guests – primarily facility users and guest researchers – and that visitors purchased some of their food and beverages on-site.

As shown in Table 6, Appleseed estimates that visitors who reside outside Long Island added about $5.8 million to the Long Island economy in fiscal year 2009 through spending on hotels, food, transportation and entertainment. Appleseed further estimates that visitors who reside outside New York State contributed about $4.6 million to the New York State economy through local off-site spending.

Using the IMPLAN model, Appleseed estimates that this spending directly translated into 73 FTE jobs on Long Island and 57 FTE jobs in New York State. When the multiplier effect is calculated, this spending generates 24 additional FTE jobs and $3.67 million in output on Long Island; and 20 additional FTE jobs and $4.63 million in output in New York State.

Table 7: Economic impact of Brookhaven National Laboratory as an enterprise on Long Island and New York State, fiscal year 2009

	Long Island		New York State	
	Output ($000s)	Jobs (FTEs)	Output ($000s)	Jobs (FTEs)
BNL Payroll				
Direct	$ 250,392	2,893	$ 250,392	2,893
Indirect/Induced	215,448	1,185	227,591	1,239
Subtotal	$ 465,840	4,078	$ 477,983	4,132
BNL Purchasing				
Direct	$ 62,763	255	$ 75,156	294
Indirect/Induced	48,788	297	60,707	347
Subtotal	$ 111,551	552	$ 135,863	641
BNL Construction				
Direct	$ 34,874	238	$ 45,123	314
Indirect/Induced	25,229	175	35,567	236
Subtotal	$ 60,103	413	$ 80,690	550
BNL Visitor Spending				
Direct	$ 5,785	73	$ 4,607	57
Indirect/Induced	3,670	24	4,630	20
Subtotal	$ 9,455	97	$ 9,237	77
Grand Total	**$ 646,949**	**5,140**	**$ 703,773**	**5,400**

Adding It All Up: Brookhaven National Laboratory's Fiscal Year 2009 Impact

When the number of Brookhaven National Laboratory employees is combined with the number of jobs supported by the Laboratory's spending on supplies, services, and construction, and the number of jobs generated by the spending of employees and visitors, Appleseed estimates that in fiscal year 2009, the Lab directly and indirectly accounted for approximately $647 million in economic output and 5,140 FTE jobs on Long Island, and $704 million in economic output and 5,400 FTE jobs in New York State. Table 7 summarizes the Lab's overall economic impact on Long Island and in New York State.

Projecting Brookhaven National Laboratory's Future Impact: FY 2010-2014

The impact of Brookhaven National Laboratory as a major regional enterprise could be even greater during the next several years than in FY 2009. Brookhaven Lab officials have projected Lab employment, and spending on payroll, purchasing and construction for fiscal years 2010 through 2014. In this part of the report, we assess the economic impact of the Lab during that period.

Projected Employment and Payroll, FY 2010-14

As shown in Figure 6, Brookhaven National Laboratory projects that full- and part-time employment at the Lab will rise to 3,350 by 2014 – a 16 percent increase over its total employment in 2009.

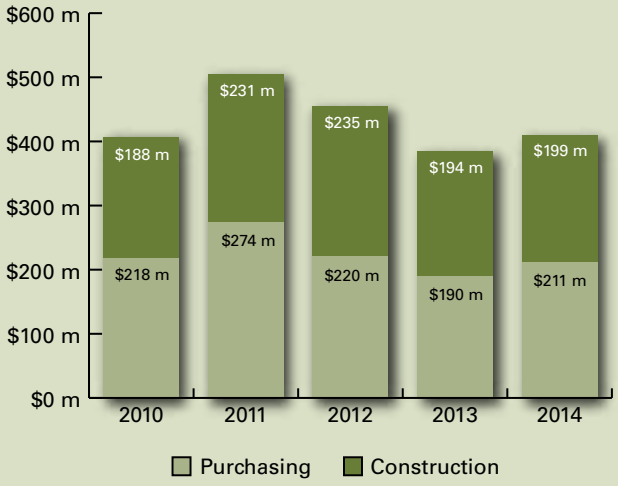
As shown in Figure 7, the Laboratory expects to increase its payroll to $306 million by 2014 – a 22 percent increase over its 2009 payroll.

Projected Purchasing and Construction Spending, FY 2010-14

As Figure 8 shows, from FY 2010 to FY 2014 Brookhaven National Laboratory expects to spend between $190 million and $274 mil-

Figure 7: Projected Brookhaven National Laboratory payroll, fiscal years 2010-2014 ($ millions)

Figure 8: Projected spending on goods and services and construction, FY2010-2014 ($ millions)



lion per year on purchases of goods and services. The Laboratory also expects to spend between $188 million and $235 million per year on construction and major maintenance. (For both purchasing and construction, year-to-year variations in part reflect costs related to building and equipping major facilities such as NSLS-II.) Over this five-year period, spending on goods, services and construction would thus total $2.16 billion – an average of about $432 million per year.

Major projects at Brookhaven Lab during this period will include completion of NSLS-II, construction of which began in 2009, as well as other projects planned to begin in the next several years. Several of these projects are listed below in Table 8. They include:

- The 80,000 square-foot Interdisciplinary Science Building, which will house energy-related researchers and their laboratories.
- A dedicated Cyclotron Isotope Research Center (CIRC) that can produce radioactive isotopes for biomedical research and therapy.

Projected Direct and Indirect Impact of Brookhaven National Laboratory Spending, FY 2010-14

If we assume that the same proportion of Brookhaven Lab employees will live on Long Island and elsewhere in New York State as in fiscal year 2009 – and that the Lab's future spending on goods, services and construction will be geographically and categorically consistent with the Lab's spending in fiscal year 2009 – we can estimate the direct, indirect and induced impact of the Lab's spending through fiscal year 2014.

In Table 9, we show the average annual impact of the Laboratory's spending over five years:

- On Long Island, we project that Brookhaven Lab's spending on payroll, purchasing, construction and visi-

Table 8: Planned major construction projects, to begin in the next several years

Year to start	Project	Total project cost
2009	Interdisciplinary Science Building	$ 66,300,000
2010	Accelerator Physics Upgrade to LHC ($2-3 million spent on Long Island)	14,000,000
2011	Renovate Science Labs	50,000,000
2012	Large Hadron Collider ($15-20 million spent on Long Island)	78,200,000
2013	Cyclotron Isotope Research Center (CIRC)	42,800,000

Table 9: Average annual economic impact of Brookhaven National Laboratory during the next five years, FY2010-2014

	Long Island		New York State	
	Output ($millions)	Jobs (FTEs)	Output ($millions)	Jobs (FTEs)
BNL Payroll				
Direct	$ 297.8	3,150	$ 297.8	3,150
Indirect/Induced	256.3	1,410	270.7	1,474
Subtotal	$ 554.1	4,560	$ 568.6	4,624
BNL Purchasing				
Direct	$ 65.9	268	$ 79.0	309
Indirect/Induced	51.2	312	63.8	365
Subtotal	$ 117.1	580	$ 142.7	673
BNL Construction				
Direct	$ 97.7	804	$ 126.5	1,057
Indirect/Induced	70.7	491	99.7	661
Subtotal	$ 168.5	1,295	$ 226.2	1,718
BNL Visitor Spending				
Direct	$ 5.8	73	$ 4.6	57
Indirect/Induced	3.7	24	4.6	20
Subtotal	$ 9.5	97	$ 9.2	77
Direct	$ 467.3	4,295	$ 507.9	4,573
Indirect/Induced	$ 381.9	2,236	$ 438.8	2,520
Grand Total	$ 849.1	6,531	$ 946.7	7,092

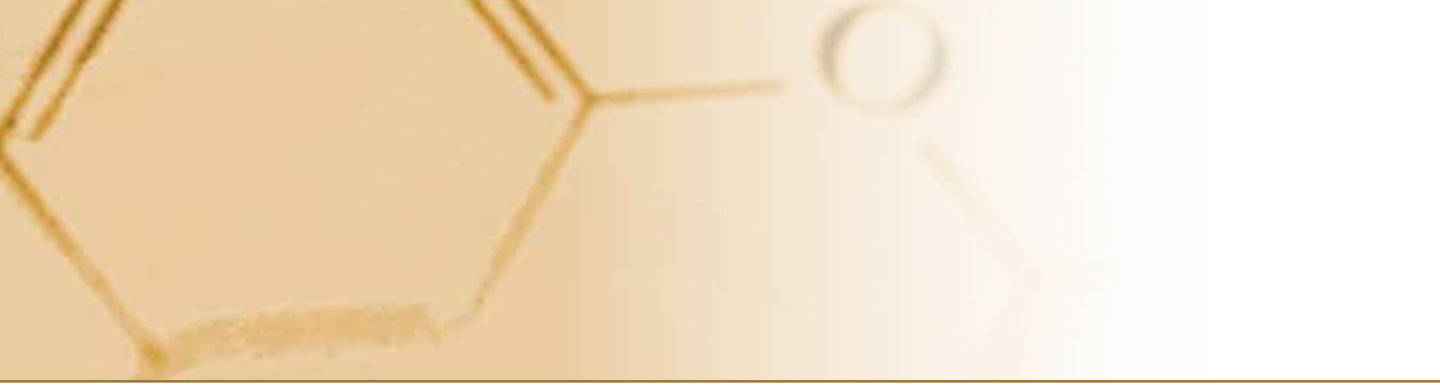
tor spending of $467 million per year would directly support 4,295 jobs (including 3,150 jobs at the Lab). This spending would generate another $382 million in economic output and 2,236 jobs on Long Island through the multiplier effect, for an average total of approximately $849 million in output and 6,531 FTE jobs each year.

- Throughout New York State, we project that Brookhaven Lab's spending on payroll, purchasing, construction and visitor spending of $508 million per year would directly support 4,573 jobs (including 3,150 jobs at Brookhaven Lab). The spending would generate another $439 million in economic output and 2,520 jobs in New York State through the multiplier effect, for an average of approximately $947 million in output and 7,092 FTE jobs each year.

Part Three: Research at Brookhaven National Laboratory: Meeting the Nation's Needs, Creating Opportunities for Growth

Advancing the frontiers of scientific and technological research, and using the new knowledge it develops to help find solutions to some of the nation's most pressing problems, is at the heart of Brookhaven Lab's mission. The research conducted at the Lab can be characterized from several perspectives.

Over the past 30 years, Positron Emission Tomography (PET) research at Brookhaven has focused on the integration of basic research in radiotracer chemistry with the tools of neuroscience to develop new scientific tools for applications in human health.



Expertise in Designing, Constructing and Using Large, Complex Facilities

Brookhaven Lab's strength in scientific research is built on certain core assets and capabilities, including:

- Complex, highly sophisticated research facilities, such as the National Synchrotron Light Source (NSLS) and its successor, NSLS-II, the Relativistic Heavy Ion Collider (RHIC), and the Center for Functional Nanomaterials (CFN) – as well as the expertise needed to conceive, design, develop, build such facilities, and to help researchers use them to address a wide range of scientific questions.

- A concentration of both facilities and expertise in high-powered scientific computing, including the New York Center for Computational Sciences (described below). These resources are vitally important in an era when the ability to develop and manipulate very large data sets is essential to progress in many fields of science.

- Expertise in the development and use of imaging technologies – technologies that are used in fields as diverse as research on cancer and autism, and studies of complex materials.

Taken together, Brookhaven Lab's facilities and expertise represent a concentration of resources that few other research centers in the U.S. can match.

Multiple Fields of Science

Brookhaven National Laboratory's research enterprise encompasses several major fields of scientific inquiry, including:

- Nuclear and particle physics
- Energy science and technology
- Life sciences
- Environmental sciences
- Material sciences and catalysis
- National security.

Brookhaven Lab's strength in these areas provides a basis for addressing a wide range of challenges, both scientific and technological.

In-house Research for DOE – and Research By and For Others

Research at Brookhaven National Laboratory can also be characterized by who is doing it, and for whom. As noted in Part One, the Laboratory's facilities – particularly NSLS, RHIC and the Center for Functional Nanomaterials – are used by a wide range of university, corporate and government researchers. Each year, more than 3,000 researchers come to Brookhaven Lab from institutions, companies and agencies in New York State, throughout the U.S. and from around the world – both to use the Lab's facilities, and to tap the expertise of its scientists and engineers. Supporting the work of this diverse user community is a central element of the Lab's mission.

At the same time, a substantial part of the research done at Brookhaven Lab is conducted by the Laboratory's own scientists and engineers – numbering more than 1,000 – in pursuit of goals set by the Department of Energy's Office of Science. Brookhaven Lab scientists also do "work for others," a broad category that includes research sponsored and funded by other federal agencies such as the National Institutes of Health, state government agencies and corporate partners.

Computing Power for Today's (and Tomorrow's) Research

From studying the role of genes in cancer to the development of a more efficient electric power grid to modeling the impact of climate change, today's research challenges increasingly require the application of massive amounts of computing power – and just as important, expertise in developing the complex analytic tools needed to extract new knowledge from massive volumes of data. These requirements led in 2007 to establishment of the New York Center for Computational Science. The Center, which is located on the Brookhaven Lab campus, is a partnership between the Laboratory and Stony Brook University. Its hardware includes two IBM supercomputers, Blue Gene/L and Blue Gene/P, with a total capacity of 128 teraflops. Acquisition of the two machines, which are owned by the University, was financed through a grant from New York State, while USDOE funds paid for the facility renovations and infrastructure improvements needed to support the Center.

The Center's resources are now being used by scientists at Brookhaven Lab, Stony Brook, and other New York institutions and companies to support a broad range of research. Its work is emblematic of the continued expansion of the Lab's already-extensive collaboration with Stony Brook – and (as discussed below in Part Four) a growing partnership with New York State.

Basic and Applied Research – From Discovery to Deployment

The work done at Brookhaven National Laboratory ranges from basic scientific discovery on questions as fundamental as the nature of matter and the origins of the universe, to the application of new knowledge to practical problems such as the design of more efficient fuel cells or more effective treatments for drug addiction.

The dichotomy between basic science and applied research should not be overstated, however; they are instead points on a continuum that ranges "from discovery to deployment." Much of the work that is done at the Laboratory falls into a broad category that has elsewhere been called *use-inspired basic research*,[3] research that uses the tools and methods of basic science to find answers to certain fundamental questions – not simply out of scientific curiosity, but because answering those questions is central to the search for solutions to critical real-world problems.

Moreover, the process of moving from basic science to practical application is often not a straight-line progression. In the course of developing even the most promising new technologies, applied researchers may run into roadblocks that can only be overcome – or gotten around – by going back to basic science. There are thus major advantages to having basic and applied research done in tandem – and Brookhaven Lab provides a venue for doing precisely that.

Both in the Department of Energy and elsewhere in the federal government, research priorities are increasingly being defined by the need to respond more effectively to major challenges facing the U.S. – such as energy security, climate change, and the need to find new sources of economic growth. Effective integration of basic and applied

3 Donald Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Brookings Institution, 1997), p. 73.

science is an essential ingredient in successful problem-oriented research.

Research at Brookhaven National Laboratory – A Sampler

A comprehensive description of the research conducted at Brookhaven Lab is beyond the scope of this report. Instead we offer here several examples of work recently completed or under way at the Laboratory – including research conducted by Lab scientists, by external users, and through collaboration between the Lab and external users. Together, these examples convey a sense of the scope, scale and diversity of Brookhaven Lab's research enterprise – and its promise for the future.

Quarks, Gluons and the Nature of Matter

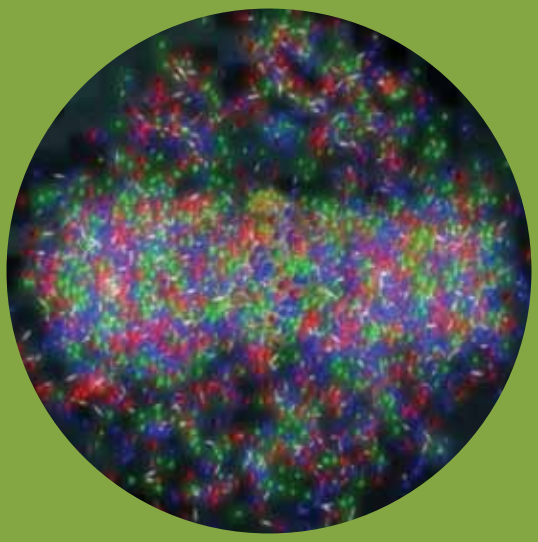
Nuclear physicists at Brookhaven National Laboratory have for several years been studying quarks and gluons – the particles of which protons and neutrons are made, and the most basic components of matter. Using the Laboratory's Relativistic Heavy Ion Collider (RHIC) to recreate the conditions thought to have existed in the instant immediately following the Big Bang, international collaborations of nuclear physicists, including Brookhaven Lab physicists, have discovered that the "quark-gluon plasma" from which protons and neutrons emerged appears to have been a "perfect" liquid rather than a gas, as had been predicted. Through further experiments, these scientists are now working toward a better understanding of this quark-gluon soup and its transition to the matter we know today – and thus a better understanding of the nature of matter itself.

Conducting Electricity More Efficiently

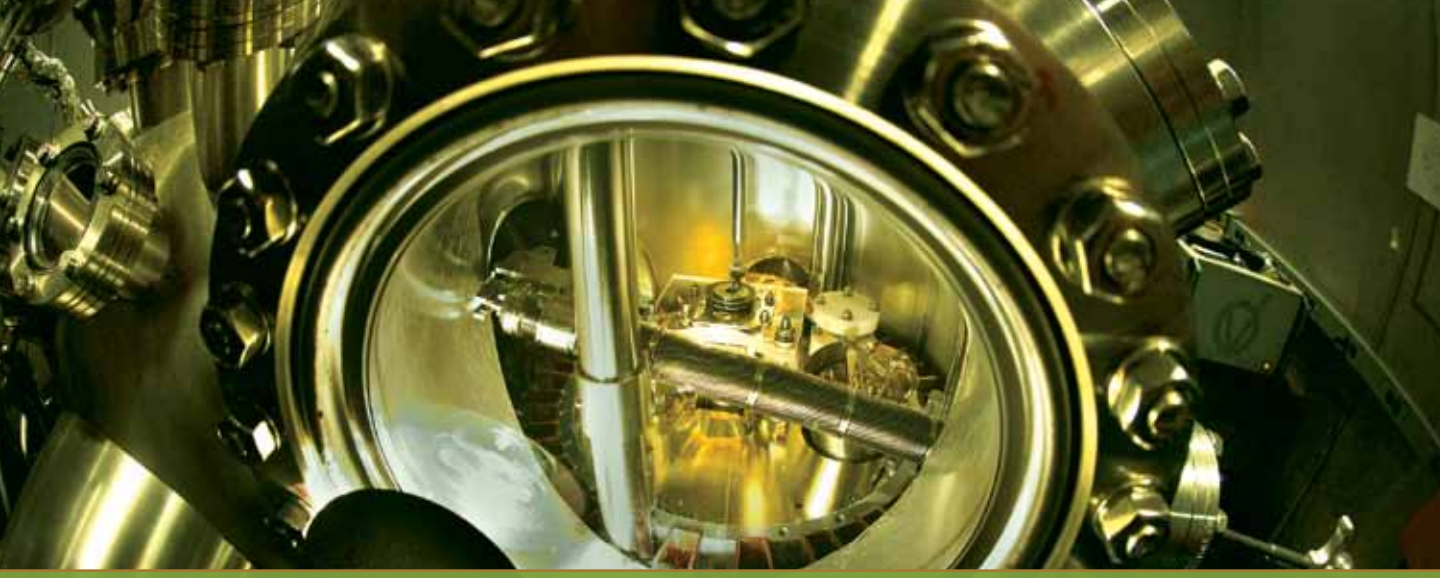
The materials normally used to conduct electricity (such as ordinary copper wires) generate resistance to electrical current, turning electrical energy into wasted heat. The longer the distance over which electricity is transmitted, the more energy is typically lost to resistance. Scientists have long known, however, that at very low temperatures – close to "absolute zero," or -273 degrees Celsius – certain metals become superconductive; that is, they conduct electricity with virtually zero resistance. While intriguing, the need to maintain extremely low temperatures makes these materials impractical to use in every-day, large-scale energy transmission.

For the past twenty years, scientists at Brookhaven National Laboratory have been studying a new class of complex materials that become superconductive at much higher temperatures. These "high-temperature superconductors" hold great promise for improving the efficiency with which electric power is transmitted. By developing a deeper understanding of how these materials are structured and what governs the transition to superconductivity, Laboratory researchers hope to be able to design new types of wire and cable that will be consistently and economically superconductive at normal temperatures. A Long Island Power Authority (LIPA) transmission system commissioned in 2008 uses first-generation high temperature superconductor (HTS) wire technology studied at Brookhaven Lab. The system – three individual HTS power cable phases running in parallel – is capable of carrying 574 megawatts of power in a right-of-way only four feet wide.

In April 2009, Brookhaven Lab won a five-year grant under the federal government's Energy Frontier Research Center program. The grant, which will provide $2 to $5 million per year for the next five years, will allow Brookhaven Lab – in collaboration with Argonne National Laboratory and the University of Illinois – to expand its research on high-temperature superconductivity.



RHIC's "perfect" liquid measures 4 trillion degrees. That's 250,000 times hotter than the center of the sun — hot enough for protons and neutrons to melt to form a quark-gluon plasma.



"...the Laboratory's nanostructured catalysts highlight its ability to use the tools of both basic science and applied research to help develop cleaner forms of energy."

Making Cheaper Solar Cells From Polymers

The high cost of photovoltaic cells made from crystalline silicon is a primary reason why solar power is usually more expensive than electricity generated from conventional sources. If solar cells could be made from less costly materials, solar power would be more competitive. Researchers at the Center for Functional Nanomaterials are now working to develop lighter-weight, flexible solar panels made from conducting polymers.

This work exemplifies how Brookhaven Lab's unusual mix of facilities helps its scientists combine use-inspired basic research with more applied research. Using NSLS, the Lab's scientists are seeking to understand more clearly how these materials are structured at the nanoscale, and how they function at that level to turn light into electricity. They can then use the sophisticated tools available at CFN to structure the polymer cells in ways that make the photovoltaic process work more efficiently. When operational, NSLS-II will greatly advance the Laboratory's ability to characterize nano-structured materials made at the CFN.

Creating More Efficient Catalysts

Brookhaven National Laboratory researchers are also working on developing new electrocatalysts – the materials that are used in fuel cells to convert hydrogen into electricity. The most efficient catalyst currently available is platinum – but it is relatively expensive. Scientists at the Laboratory have developed a technique for creating a layer of platinum that is just a single atom thick; it works as effectively as conventional platinum catalysts, but uses only one-tenth as much of the precious metal and is more stable. The Lab is now working with several companies to test the use of this material in fuel cells and to scale up the process for manufacturability.

Other approaches to using nanostructured materials to develop catalysts for a variety of energy applications are also being explored. A particularly promising approach combines copper, gold or other metal nanoparticles with nanostructured oxide supports to improve catalysts that are used to purify hydrogen for industrial uses — for example, in fuel cells. Like its work on organic photovoltaics, the Laboratory's nanostructured catalysts highlight its ability to use the tools of both basic science and applied research to help develop cleaner forms of energy.

Building Better Biofuels

A major national priority in energy research is the development of cellulosic ethanol – ethanol produced from a variety of plants that (unlike corn or sugar cane) are not also used for food, and that can also be grown on land not suitable for food production. Scientists at Brookhaven

Lab have been exploring ways to enhance the productivity and efficiency of plants that could in the future be a source of cellulosic ethanol. They have, for example, identified certain natural microbes that, when added to the soil, accelerate the growth and increase the mass of poplar trees – a species that can thrive in climates and on lands where food crops cannot.

Brookhaven Lab scientists are also exploring how the mix of lignin and cellulose in the cell walls of plants is determined. By increasing the proportion of cellulose, they hope to be able to increase the volume of ethanol that can be derived from any given volume of plant material.

A New Type of Nuclear Power

Physicists at Brookhaven National Laboratory are studying the feasibility of developing a new type of nuclear power plant that would be fueled with thorium, rather than uranium. In this new model, a nuclear chain reaction would be initiated by using a rapid-cycling accelerator to irradiate the fuel.

An accelerator-driven, thorium-based reactor would offer several advantages. The chain reaction could be stopped simply by turning off the accelerator – almost literally by throwing a switch – and it would produce less nuclear waste than uranium-based reactors. Moreover, thorium is by itself much less hazardous than uranium or plutonium – and without a particle accelerator, cannot be used as nuclear fuel. This new type of reactor, if proven feasible, could thus greatly reduce the environmental, safety and security concerns associated with increased use of nuclear power.

Exploring the Neural Pathways That Lead to Addiction and Obesity

In the 1970's, scientists at Brookhaven National Laboratory pioneered the use of positron emission tomography (PET scanning) to study brain functions; and today they continue to use this technology to explore a wide range of health issues. In 2008, for example, a team of Brookhaven Lab researchers found that pathologically obese subjects exhibit a pattern of reduced levels of dopamine receptors in the brain – a pattern closely resembling that found in drug addicts. Because dopamine plays a critical role in governing motivation and reward functions in the brain, this finding suggests that just as addicts use drugs to compensate for reduced dopamine sensitivity, obese people overeat to achieve the same effect. This discovery could in the future lead to the development of new ways to treat obesity.

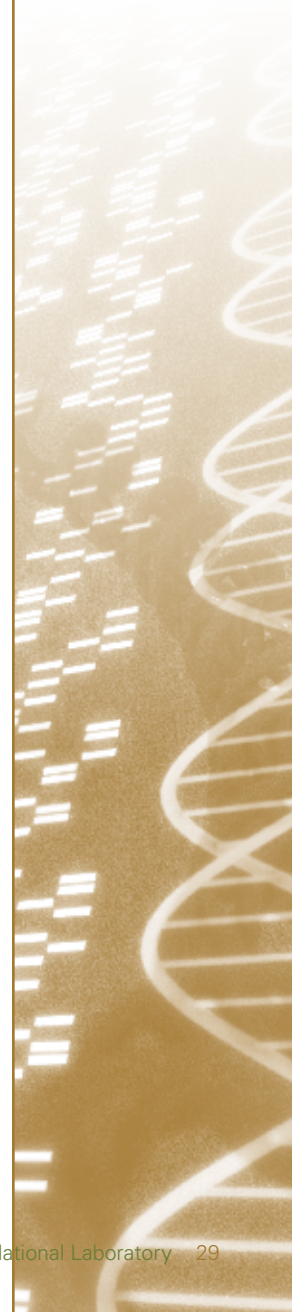
Understanding the Effects of Space Radiation on Human DNA

Researchers at Brookhaven National Laboratory's NASA Space Radiation Lab, as well as users of this facility, are exploring why the heavy ion radiation to which humans are exposed in space causes more damage to DNA than other types of radiation (such as gamma rays and x-rays) that are more common on Earth – and why it is more difficult for DNA that has been damaged by such radiation to repair itself. Their work could lead to a better understanding of how space travelers could more effectively be protected against space radiation – and also a better understanding of how to deal with the effects of radiation on Earth.

Completed in 2003, NASA's $34 million Space Radiation Lab is located at Brookhaven Lab because the Lab has the only facilities in the U.S. capable of generating heavy ion beams at the high energy levels required for space radiation studies.

Building a DNA Assembly Line for Nanomaterials

The ability to produce precisely-structured combinations of



nanoparticles, consistently and in large volumes, will be critical for many applications of nanotechnology. Researchers at the Center for Functional Nanomaterials have developed a method for using strands of DNA to connect nanoparticles in very specific patterns. The technique could enable the Laboratory's scientists and engineers to create an "assembly line" for high-volume production of very high-precision nanostructures – including structures that consist of just a few particles.

Designing Better Radiation Detectors

Researchers at Brookhaven National Laboratory are developing a new type of radiation detector that uses cadmium zinc telluride (CZT) crystals, rather than germanium. Existing germanium-based models are large, bulky and have complex cryogenic cooling requirements. CZT-based detectors could be smaller, faster and easier to deploy in the field. They could thus be of great value in detecting radiological threats – such as attempts to smuggle nuclear material into the country – and in responding quickly to radiological incidents, whether accidental or deliberate.

This work draws on the Laboratory's strengths in a number of areas – materials science, crystal fabrication and the design of specialized instrumentation for the new detectors.

Removing Mercury from Contaminated Soil

Researchers at Brookhaven Lab have developed a new method for removing mercury from contaminated soil and from various types of industrial waste. Rods containing a special sulfur-based reagent are inserted into the soil or waste material. Over a period of several months, mercury is attracted to and then binds with the reagent, forming mercury sulfide – a stable, insoluble compound that is trapped within the rods. The rods can then be removed, and safely transported to a hazardous waste disposal facility. Because it eliminates the need to excavate and remove the soil for treatment off-site, the new process could reduce both the cost of remediation and the environmental risks inherent in disturbing and transporting the mercury-laden soil. In 2009, the Laboratory was granted a patent on this "*in situ* mercury stabilization" process.

An Asset for New York State Researchers

As noted above, Brookhaven Lab facilities (including NSLS, RHIC, CFN, and the New York Blue Supercomputer) are used by thousands of university, government and corporate researchers – from New York State, from elsewhere in the U.S. and from around the world. From Buffalo to Brooklyn, research conducted by external users of Laboratory facilities contributes to the

Collaborating with Stony Brook on Energy Research

One of the results of Brookhaven National Laboratory's extensive collaboration with Stony Brook University has been to strengthen the capabilities of both institutions in the area of energy research and development. One notable manifestation of this partnership is Stony Brook's Advanced Energy Center (AEC). Established in 2006, AEC seeks "to integrate fundamental science, nanotechnology and engineering to design the next generation of advanced energy systems." Bringing together and supporting the work of scientists and engineers at both institutions, the Center is focused on the development of new alternative fuels, improving the performance of conventional fuels, "smart grid" research and other energy-related topics. The New York State Energy Research and Development Authority and the New York Power Authority are also partners in the Center, as are a number of major New York State companies. The Center is scheduled to move into a new building on the Stony Brook campus in the fall of 2010.

vitality of New York State's economy in several ways.

- Access to Brookhaven Lab facilities enhances the ability of scientists at New York's research universities and other institutions to secure funding from federal agencies and other outside sources.

- The opportunity to conduct research at Brookhaven Lab can greatly enhance the education of graduate and undergraduate students at New York institutions.

- Use of the Lab's facilities can help New York State companies with a wide range of applied research needs.

In fiscal year 2009, a total of 3,069 researchers from other institutions, agencies and companies used Brookhaven Lab's facilities for some part of their work – of whom 683 (about 22 percent) were affiliated with New York State institutions, agencies and companies. These researchers ranged from senior faculty and research scientists at some of New York State's leading universities and corporate research centers to post-docs and graduate students; and they range from some who spend most of their time on the Brookhaven Lab campus, to others who work at the Lab one or two days a week, to some who may visit the campus only a few times each year.

NSLS accounts for the greatest number of the Laboratory's external users; of the 683 external users affiliated with New York State institutions or companies in fiscal year 2009, about 75 percent were NSLS users.

Table 10: Major New York users of Brookhaven National Laboratory's facilities

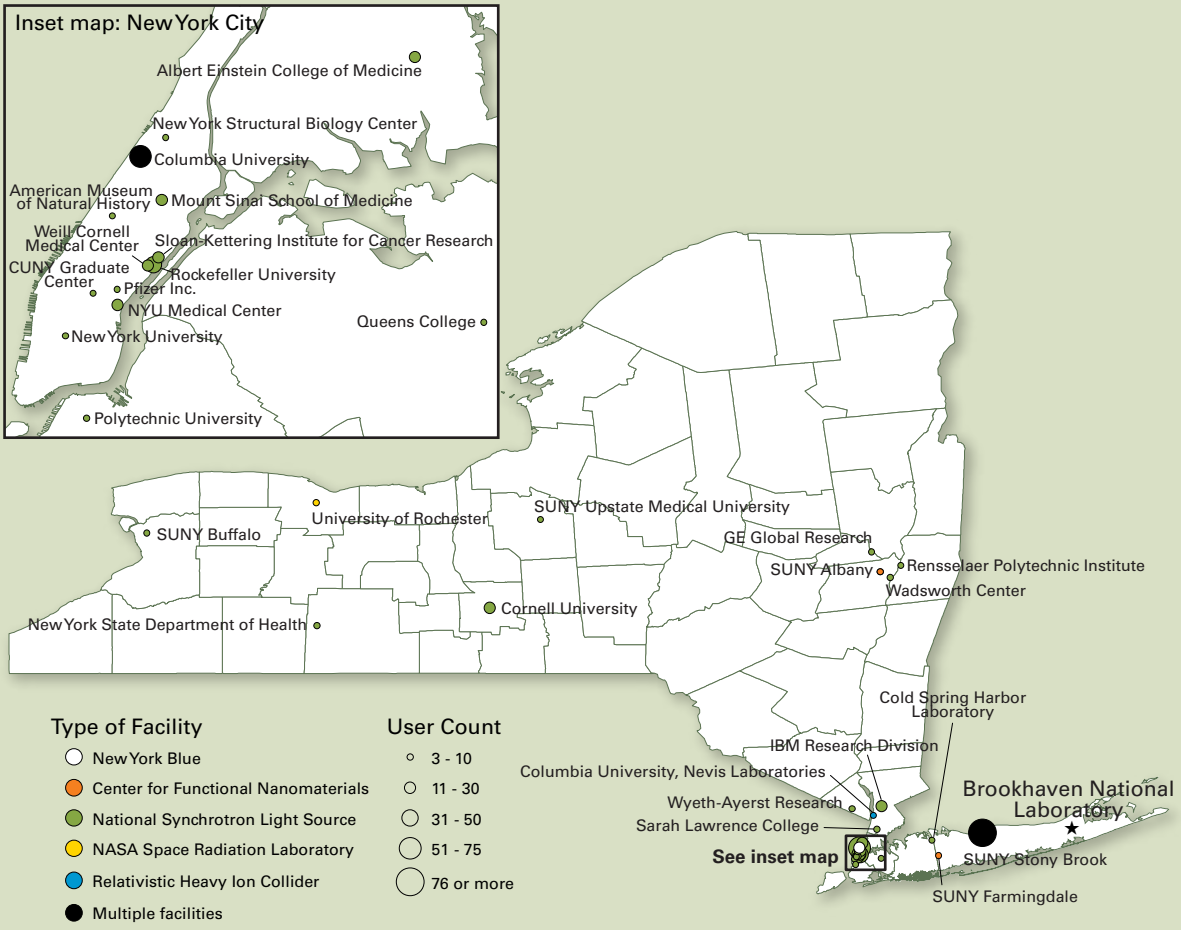
Institution	Number of users
SUNY @ Stony Brook	256
Columbia University	120
Cornell University	39
New York University	38
Rockefeller University	35
Albert Einstein College of Medicine	19
Mount Sinai Medical Center	16
Sloan-Kettering Institute for Cancer Research	16
IBM Research Division	13
SUNY Upstate Medical University	10

Among New York State's universities and other research centers, Stony Brook University accounts for by far the largest number of users – 256, or about 37 percent of all New York State-based users of Brookhaven Lab's facilities. Other New York State institutions that are among the leading users of Laboratory facilities include Columbia University (with 120 users), Cornell University (39), New York University (38), and Rockefeller University (35).

Table 10 lists the New York State institutions with the largest numbers of users of Brookhaven Lab facilities. Figure 9 provides another perspective, showing the location of the 28 New York State institutions and companies with at least 3 users of Brookhaven facilities in fiscal year 2009.

In order to get a better understanding of how New York State researchers use Brookhaven Lab's facilities, the significance of those facilities in their work and its impact on New York State's economy, Appleseed surveyed New York State-based users of major Laboratory facilities. The survey form was prepared by Appleseed, and distributed by the Lab to all New York

Figure 9: Map of New York State universities, government agencies and companies with at least 3 users, 2009



State-based external users of its facilities in October 2009. In total 26 responses were received from external users of Brookhaven National Laboratory.

- Users of the National Synchrotron Light Source (NSLS) were the most responsive, with 20 returned surveys, including 13 from university or government users and 7 from industry users.

- Five responses were from users of the Center for Functional Nanomaterials (CFN), including four university or government users and one industry user.

- One university user of the Relativistic Heavy Ion Collider (RHIC) responded to the survey.

This represents an approximate response rate of 4 percent of all New York State-based external users – although a substantially higher percentage of all principal investigators among these users. To obtain a more in-depth understanding of the role of Brookhaven National Laboratory facilities in their research, follow-up telephone interviews were conducted with several university and industry respondents.

Because of the limited number of responses to the survey, we have not sought to quantify the overall impact of research conducted by external users on New York's economy – for example, by estimating the total dollar value of externally sponsored research that is to some extent dependent on access to Brookhaven Lab facilities. Nevertheless, responses to the survey provide some insight into the value of these facilities to external users. The following are some highlights.

- Among users based at New York State universities and other research institutions, external funding for projects that involved the use of Brookhaven Lab facilities ranged from $46,000 to $980,000 with a median value of $400,000. One researcher from a leading New York State medical school stated that over a period of several years, his group had won approximately $10 million in NIH funding for projects that involved the use of NSLS.

- The number of people employed on these projects – including faculty members, post-docs, technicians, administrative staff and graduate students – ranged from 1 to 18, with a median value of 9.

- Two-thirds of all respondents from universities and other research institutions said that they or other members of their research groups had published articles in scientific journals based on their work at NSLS or RHIC.

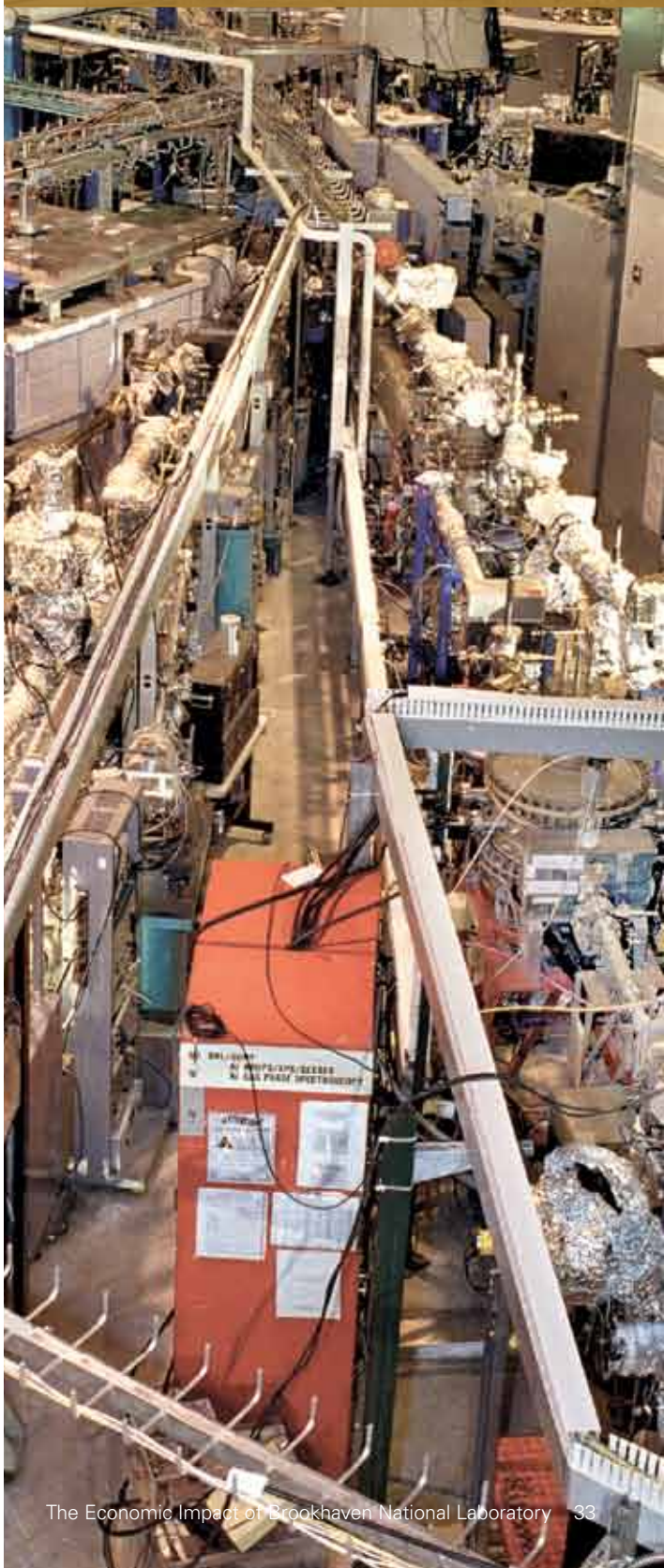
- About half of all university respondents said that graduate students working in their labs had completed PhD's based on work done at Brookhaven Lab.

- More than half of all respondents based at universities or other research institutions said that their work at the Lab had helped them secure additional research funding.

Comments from users highlight the value that New York State researchers place on their use of Brookhaven Lab's facilities.

> *The NSLS has been critical to me for establishing my research program.*
>
> *There is no other place in the world at the moment where [my research] could have been done.*
>
> *Without NSLS…our project would have been cancelled.*

"From Buffalo to Brooklyn, research conducted by external users of Laboratory facilities contributes to the vitality of New York State's economy…"



NSLS experimental floor

Access to NSLS is the most essential resource at our disposal. Not having access to NSLS would dramatically affect our research capacity.

Some researchers noted that without easy access to Brookhaven Lab facilities, their work would have progressed much more slowly.

NSLS is essential for our work…Our physical proximity to [it] has greatly accelerated our progress.

My group's progress would have been much slower…had it not been for the frequent access to NSLS facilities.

It is very important to have the synchrotron facility nearby so that we do not need to fly and carry samples… to other facilities in other states.

Several university researchers affirmed the value of Brookhaven Lab facilities in the development of young scientists and the creation of opportunities for future researchers:

For me, it's impossible to give my grad students and post docs the training they need without the proximity to NSLS.

Many undergraduate students in the university have had first- hand experience with experimental research because of our involvement and activities in RHIC science.

Several New York State companies are also regular users of the Laboratory's facilities. The leader of a research group at one of the state's leading technology companies notes that:

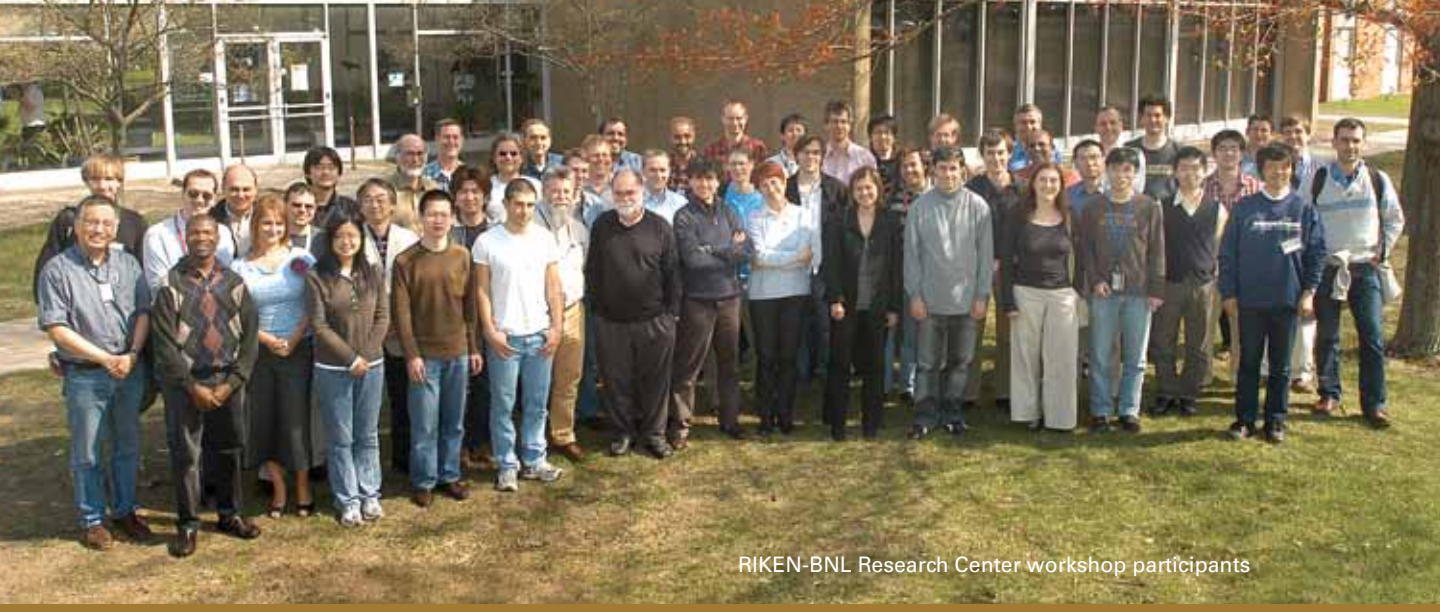
The access to large quantities of beam time [at NSLS] has provided my company with a unique and valuable tool for quickly assessing and developing new materials for microelectronics applications.

Another corporate researcher notes that:

The NSLS has given us unmatched capability to examine cells of our sodium battery technology in-situ during cycling. Although it has not yet led to quantifiable improvements of the technology, it has given us a much deeper understanding of what is happening inside the cell. Without this knowledge we would be blind. We have been able to measure reaction rates, measure temperature, voltage and current effects on phase distribution, and study degradation mechanisms.

While research can often be valuable in itself, its economic impact ultimately depends on how effective research institutions, governments, established companies and entrepreneurs are in putting it to use. The next part of the report considers Brookhaven National Laboratory's role in this process.

NSLS attracts users from around the world



RIKEN-BNL Research Center workshop participants

A National Lab with Global Reach

Brookhaven National Laboratory is a national laboratory – but it is in many respects a global research institution. The international dimension of Brookhaven Lab's research is evident on several levels.

Brookhaven Lab has long worked in partnership with some of the world's leading scientific institutions. The **STAR Collaboration**, for example, uses the Lab's STAR Detector – a massive, 1,200-ton piece of scientific equipment – to track the results of the ion collisions generated by RHIC, and analyzes the meaning of the data produced by the detector. As of 2009, the STAR collaboration involved more than 600 scientists at 55 universities and research institutes in 12 countries.

In 1997, the Laboratory entered into a long-term partnership with one of Japan's leading scientific research agencies – Rikagaku Kenkyusho (or RIKEN), the Institute for Physical and Chemical Research. Today the **RIKEN-BNL Research Center**, located on the Brookhaven Lab campus, is a focal point for scientific collaboration between the two countries. RIKEN invested $20 million in the initial development of the Center, and provides several million dollars each year in operating support. Each year, RIKEN sends some of Japan's most talented young scientists to Brookhaven Lab – to work with their American colleagues, to use the Lab's world-class facilities, and to learn about the advances in science and technology taking place at the Lab.

Brookhaven National Laboratory has been a partner in the development of the **Large Hadron Collider** (LHC), located near Geneva, Switzerland – which is the world's most powerful collider. Brookhaven Lab scientists and engineers designed and built several key components of the LHC; and the Lab provides some of the massive computing power needed to support the LHC's work.

Brookhaven Lab is also the lead U.S. participant in the **ATLAS Project**. One of the largest international scientific projects ever undertaken, ATLAS is using the Large Hadron Collider to explore several basic problems in physics. A total of 164 government labs, universities, corporations and other organizations –including 43 in the U.S. – are participating in the project.

Researchers at Brookhaven Lab also work with major multinational corporations on specific projects. Companies with which the Lab has collaborated during the past year include **Bayer Bioscience**, **Toyota**, and the **China Nuclear Design Company**.

In addition to working collaboratively with major institutional and corporate partners, Brookhaven Lab attracts hundreds of visiting scientists from around the world each year who come to the Lab to use facilities such as RHIC and NSLS. During fiscal year 2009, 494 researchers from outside the U.S. used these facilities. The leading countries of origin for non-U.S. users of Brookhaven Lab facilities included Japan (93 users), Canada (80), the U.K. (49), France (42), Germany (38), and China (38).

Part Four: From Discovery to Deployment

Brookhaven National Laboratory, as noted in Part Three, combines impressive strengths in basic science with the ability to translate its intellectual capital into solutions to some of the nation's most pressing problems.

A new Long Island Power Authority transmission system uses the first generation of a high-temperature superconductor wire technology first studied at Brookhaven Lab.

This part of our report discusses the multiple ways in which the Laboratory takes new knowledge from discovery to deployment. They include:

- Licensing technologies originated at Brookhaven Lab to companies that develop practical applications of these technologies, and bringing them to the market place;
- Collaboration with companies on applied research and development projects; and
- Working with public agencies, non-profit organizations and industry partners in collaborative efforts to address major national needs – and at the same time strengthen New York State's economy.

Patenting and Licensing Brookhaven National Laboratory Technology

One of the ways in which Brookhaven Lab translates the results of its research into new products is by obtaining patents on new technologies originated at the Lab, and then licensing these technologies to companies that develop them for commercial use. Between 2004 and 2009, as shown in Table 11, Brookhaven Lab:

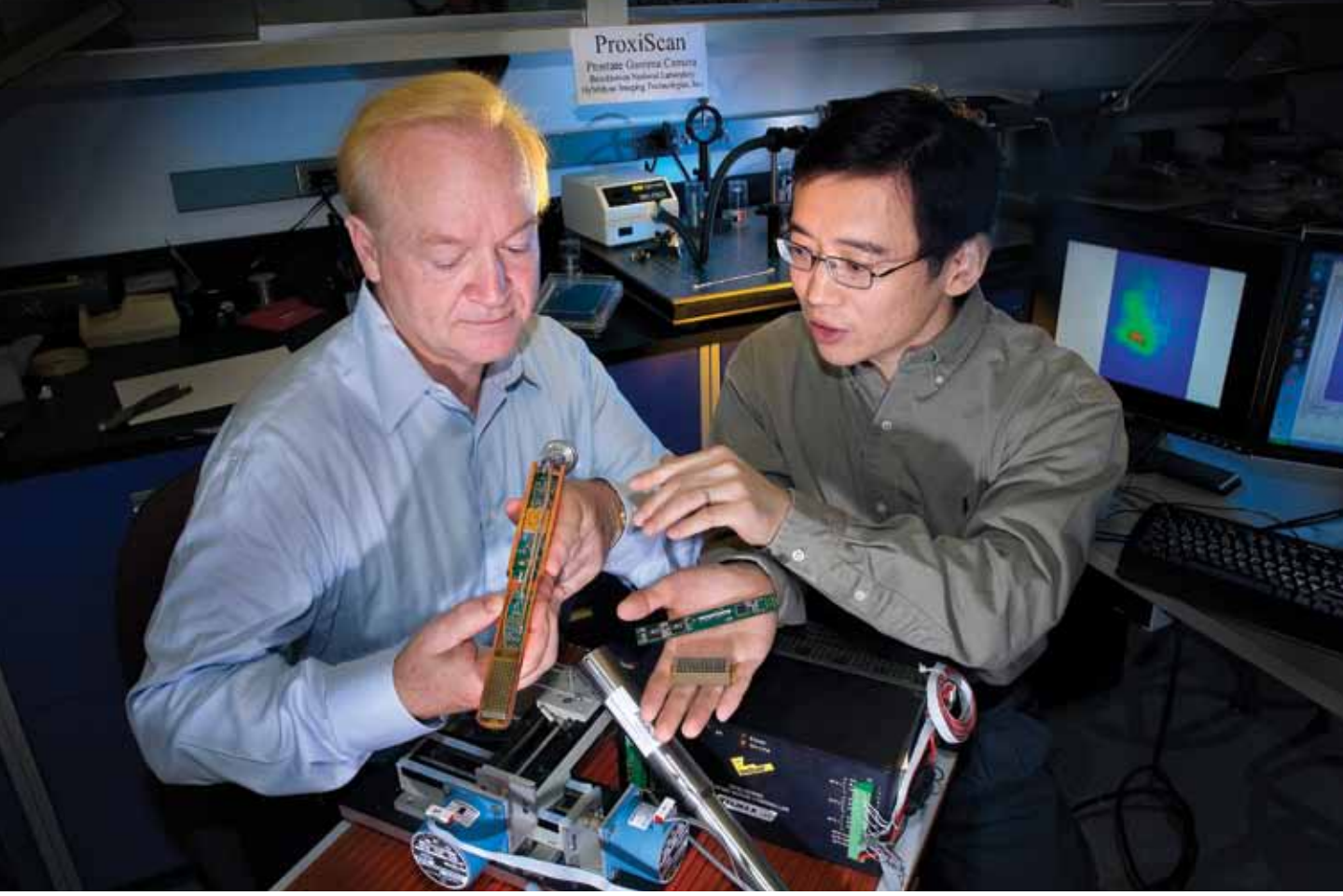
- Filed 143 new patent applications;
- Was awarded 76 new patents;
- Executed 92 new licenses and option agreements for commercial use of technologies patented by Brookhaven Lab; and
- Generated $42 million in gross licensing revenue.

Patenting and licensing promising new technologies can be an effective way to ensure that these technologies attract private investment and are put to use – providing not only a potential source of economic growth but in many cases significant benefits to society as well.

- **Catalyst Pharmaceutical Partners** of Coral Gables, Florida, has licensed nine patents from Brookhaven Lab for use of vigabatrin – based on the Lab's pioneering research on addiction – to treat a variety of addictive behaviors. Believing the medication can show promise in treating addiction, the National Institute on Drug Abuse recently announced that it will fund Phase II (b) clinical trials. Even modest success in reducing drug use among cocaine and meth addicts could yield enormous economic benefits, through reduced health care costs, lower crime rates and increased productivity.
- Using a gamma imaging technology licensed from Brookhaven Lab, **Hybridyne Technologies** of Toronto has developed a compact, high-resolution camera system called ProxiScan that can provide earlier detection and more precise, more localized imaging of cancerous tissue in the prostate gland. Development of the gamma camera was cited by *R&D magazine* in 2009 as one of the year's 100 best

Table 11: Technology transfer activity, fiscal year 2004 through 2009

	2004	2005	2006	2007	2008	2009
Gross licensing income ($000s)	$ 3,377	$ 5,325	$ 6,121	$ 7,909	$ 9,463	$ 10,007
Invention disclosures	27	34	21	28	33	33
New patent applications filed	17	24	8	25	33	36
Patents issued	13	15	16	14	8	10
Commercial licenses / options executed	15	17	16	20	17	7
Research licenses / options executed	39	39	40	41	49	35



Brookhaven National Laboratory and Hybridyne Imaging Technologies, Inc., received an R&D 100 Award for the invention of ProxiScan™, a device that can detect prostate cancer in detail at an early stage.

technological innovations. In March 2010, the camera was cleared by the Food & Drug Administration for sale in the U.S.

In other areas, Brookhaven Lab is seeking to license recently-patented technologies for commercial use. For example, the Lab is looking to partner with industry for further development of a new "**medical synchrotron**" for cancer treatment, patented by Brookhaven Lab in 2008. The new device would be able to target tumors more precisely than the proton-therapy systems currently in use, with less damage to healthy tissue. It would also be more compact and easier to operate and maintain than today's massive proton-therapy installations – and is expected to cost less as well.

Breakthrough technologies such as this often create opportunities beyond the development, design and manufacture of the machines themselves. In this case, for example, new software will have to be developed to run the machine. And when the technology is ready to be introduced into clinical settings, hospitals and cancer centers will be investing in the development and staffing of new treatment facilities.

Cooperative Research and Development

In some cases, Brookhaven National Laboratory scientists and engineers work collaboratively with corporate researchers to explore questions or solve problems that are of interest to both parties. In fiscal year 2009, Laboratory scientists and engineers worked on 43 "cost-shared research projects" – most of them involving cooperative work with private companies, as well as several with university or other non-profit institutional partners. Brookhaven Lab's partners on these projects include major global corporations such as Bayer Bioscience, Dow, General Motors, Johnson & Johnson, Toyota and United Technologies. But they also include a number of smaller and mid-sized companies – including several based in New York State.

- **Brookhaven Technology Group**, based in Brookhaven and founded by a former Laboratory scientist, is working with the Lab's Instrumentation Division on the development of a small-scale tandem accelerator for use in medical applications. The company has been working with the Instrumentation Division

on various practical applications of accelerator technology since 1999.

- **Clear Vascular**, based in New York City, has been working with Brookhaven Lab scientists since 2003 on the development of vascular stents coated with tin-117, a radioactive material. The goal is to create a stent that could also provide highly localized radiological treatment for vascular problems, without the need for a separate radiological procedure.

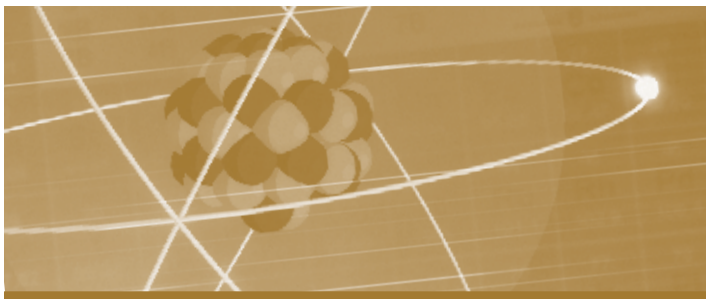
- As part of Brookhaven Lab's work on nuclear non-proliferation, **Ion Focus Technology** of Miller Place, New York, has since 2003 been working with scientists at the Laboratory and in the former Soviet Union on the development of a compact, portable deuterium-tritium neutron generator. This machine could be used to treat cancer patients in remote areas that lack easy access to established cancer treatment centers. The project is being funded under a U.S. initiative that seeks to engage nuclear scientists in the former Soviet Union in commercial R&D projects involving nuclear technology.

- In 2008, the **Long Island Power Authority** started transmitting electricity through a 138-kilovolt transmission line made with superconducting wire – the world's first commercial use of a superconducting transmission line. The new cables used on this line can carry 150 times the power that can be transmitted through conventional copper cables of the same size. The new LIPA cables were developed by **American Superconductor, Inc.**, a long-time Brookhaven Lab collaborator based in Devens, Massachusetts, based in part on research conducted at the Lab.

  Since 2007, Brookhaven Lab scientists have also been working with American Superconductor on the development of second-generation (or 2G) superconducting wire, made with yttrium barium copper oxide (YBCO), which will be even more efficient than the 1G wire used in LIPA's transmission line. LIPA is already planning to install cables made with the new material.

- In 2009, Brookhaven Lab also entered into an agreement with **SuperPower, Inc.**, a Philips NV subsidiary based in Schenectady, New York, for studies of specialized materials used in the manufacture of high-temperature superconducting wire.

Brookhaven National Laboratory also does contract research for a variety of industry, university and government partners. During fiscal year 2009, Laboratory scientists and engineers worked on 38 of these "work for others" projects. As with cost-shared research, the Lab's partners on these projects include several New York State companies and institutions.



Producing Isotopes for Cancer Treatment

While the licensing of technologies first developed at Brookhaven National Laboratory provides opportunities for private companies to invest in these technologies and bring them to market, in one case the Laboratory is itself directly involved in the production of a critically important medical resource.

Brookhaven Lab has one of only two facilities in the U.S. for production of medical isotopes, which are essential to the practice of nuclear medicine. (The other is at the Department of Energy's Los Alamos National Laboratory.) Using facilities linked with RHIC, Brookhaven Lab technicians produce isotopes for companies and institutions throughout the U.S. that use them in treating a wide variety of cancers.

Production of medical isotopes at Brookhaven Lab is financed through a combination of Lab internal funds and payments from the companies and institutions that buy them. Brookhaven Lab's current facility employs eight people. There is potential for growth of this business at Brookhaven Lab because of increasing demand.

- In a project funded by the New York State Energy Research and Development Authority, Brookhaven Lab has since 2008 been collaborating with the **Fulton Companies** of Pulaski, New York, on the development of boilers that can burn both conventional diesel oil and a variety of biofuels.

- Brookhaven Lab is working as a subcontractor to the New York City-based **Society for Energy and Environmental Research** on a Department of Energy-funded project involving the development of fuels for both transportation and stationary use derived from solid waste materials (such as grease and sludge).

In addition to these formal "cost-shared research" and "work for others" projects, the Laboratory is collaborating with New York State firms in a number of other areas.

- Scientists at Brookhaven Lab have worked closely with **Advanced Energy Systems** (AES) of Medford, New York, on the design and manufacture of superconducting radio-frequency cavities – key components used in particle accelerators, both at the Laboratory and elsewhere. In addition to being the company's leading customer, the Lab is also, in effect, a partner; Brookhaven Science Associates has invested $2 million in equipment that AES uses to manufacture these advanced components. AES also uses testing facilities at Brookhaven Lab. In 2009, the company employed 25 people in Medford, and was planning additional hiring in 2010.

- Researchers at Brookhaven Lab are collaborating with **Scientific Innovations, Inc.** of East Hampton, New York, and AES on the development of new systems for detecting explosives using gamma resonance technology (GRT). With greater power to "look" inside trucks, railroad cars, shipping containers and baggage, the new technology could provide greater reliability than existing systems in detecting and identifying explosive materials. GRT-based detector systems would also be more compact and more mobile than existing systems.

- Even as NSLS-II is being built, a new generation of instruments is being developed to help researchers take full advantage of its

Developing New York's Solar Power Infrastructure

Increasing the deployment of solar technology is important not only for reducing America's dependence on imported oil and reducing greenhouse gas emissions – but also for learning more about how to solve the practical challenges confronting the solar energy industry. In 2009, Governor David Paterson announced an agreement under which BP Solar will develop a 37-megawatt solar power plant on a 200-acre site on the campus of Brookhaven National Laboratory.

Construction of the new plant is scheduled to begin in the fall of 2010, and will be completed in May 2011. The project is backed by a 20-year contract with the Long island Power Authority, under which LIPA will purchase the electricity produced by the plant; and by additional funding from the New York State Energy Research and Development Authority. The plant will be the largest solar installation to date in New York State; and will put LIPA among the leading utilities nationwide in the deployment of solar technology.

As part of the project, a new photovoltaic research center will be developed on the Laboratory campus. The new center will focus on testing different materials for use in solar cells, wiring, storage devices and other components, with the goal of improving the efficiency and economic viability of solar power. This research will also focus on developing smaller solar facilities on the Laboratory campus, to help meet the Laboratory's own energy needs.

capabilities. Among them is a new type of "x-ray photoelectron spectroscopy" (or XPS) microscope which is being developed by a team led by Brookhaven National Laboratory. When combined with NSLS-II, the new XPS microscope will provide a 1,000-fold higher resolution than existing microscopes. Making this new technology work requires a highly-specialized type of mirror that makes it possible to focus x-ray beams with an extraordinary degree of precision. After finding that no U.S. companies make the type of mirror required, Brookhaven Lab team members contacted **Optimax Systems, Inc.**, a manufacturer of high-precision optics based in Ontario, New York (near Rochester). Working with the Brookhaven team members, Optimax was able to develop a mirror that met the team's requirements – and that could provide the company with a new niche product that could be sold not just to Brookhaven Lab but also to other synchrotron research centers around the world.

Supporting Major New York State Initiatives

In addition to its work with individual companies, Brookhaven National Laboratory is a participant in two major State initiatives aimed at securing New York State's place in the development of new energy technologies, and businesses and jobs based on these technologies.

- **The New York Smart Grid Consortium**, founded in 2008 and formally incorporated as a non-profit organization in 2009, is an alliance of public agencies, universities, major utilities and other companies. The Consortium's purpose is to improve the efficiency and reliability of the state's electric power systems, more effectively integrate renewable sources of energy into that system, improve service to customers, and strengthen New York State's economy by accelerating and coordinating the development and deployment of smart grid technology throughout the state.

Brookhaven Lab has been an active participant in the consortium since its formation. The Lab's work on the development of superconducting materials and their use in transmission of electric power is particularly relevant to the consortium's goal of enhancing the efficiency and reliability of the grid; and its high-performance computing capabilities can be a particularly valuable resource for the complex network modeling exercises required for the ongoing development of a smart grid.

Brookhaven National Laboratory and New York State: An Expanding Partnership

Brookhaven National Laboratory's partnership with New York State runs both ways. The human and intellectual capital that the Laboratory provides in areas such as battery technology and smart grid development is matched by the State's investment both in the Lab's facilities and in specific areas of research. In recent years the State has invested in the development of the New York Center for Computational Sciences (described in Part Three); and the New York State Energy Research and Development Authority has been a major sponsor of "work for others" research at Brookhaven Lab.

Among the State's most valuable contributions to the Lab's success has been its commitment to providing low-cost electric power from the New York Power Authority. The State's commitment of 15 megawatts of NYPA hydropower per year for 15 years will be particularly essential for meeting the massive power requirements of NSLS-II – and was a critical factor in securing the Department of Energy's commitment to fund the development of the new light source.

A New Focus on Technology Deployment and Regional Development

In 2009, Brookhaven National Laboratory created a new position, Associate Laboratory Director for Global and Regional Solutions. The new directorate brings together Brookhaven Lab's departments of Energy Sciences and Technology and Nonproliferation and National Security, as well as the Lab's Office of Technology Commercialization and Partnerships. Goals for the new directorate include:

- Strengthening Brookhaven Lab's capabilities in applied science and engineering;
- Improving the Lab's performance in technology deployment; and
- Increasing the Lab's regional economic impact – for example, by increasing the number of new business ventures on Long Island and elsewhere in New York State that are engaged in the commercialization of technologies first developed at Brookhaven Lab.

Achieving these goals involves not only a strengthening of Brookhaven Lab's internal capabilities, but also strengthening its relationships with partner institutions and agencies – such as the College of Engineering and Applied Sciences at Stony Brook, and the New York State Energy Research and Development Authority – whose strengths complement the Lab's.

- In 2009, Governor Paterson announced the creation of the **New York Battery and Energy Storage Consortium** (NY-BEST), a coalition of public agencies, universities and companies whose goal is "to position New York as the leader in energy storage technology research, development and manufacturing." Advancements in battery and other energy storage technologies are essential for increasing the efficiency and lowering the cost of electric and plug-in hybrid vehicles, and for improving the performance of solar, wind and other alternative generating systems. Brookhaven Lab is working closely with other members of the consortium. Researchers at GE, for example, are using NSLS to develop a better understanding of the inner workings of sodium batteries – which will be used as an alternative power source for trucks and other heavy-duty vehicles, and which GE will manufacture in Schenectady.
- Brookhaven and Stony Brook University (SBU) are partners in the **Advanced Energy Center** (AEC), a research facility created to develop alternative energy sources and protect natural resources by taking advantage of cutting-edge technologies. The Center, being built at SBU and supported by $35 million in New York State funding, will be the largest facility of its kind on Long Island, and the centerpiece of a partnership among several academic institutions, research institutions, energy providers and corporations. AEC's mission is to develop innovative energy research, education and technology deployment with a focus on efficiency, conservation, renewable energy and nanotechnology applications for new and novel sources of energy. More than 80 projects are already in development in such areas as renewable energy sources, fuels and conservation. AEC's goals include reducing dependence on foreign oil imports, ensuring that the country is able to meet the increas-

ing demand for energy in an environmentally sound manner, and developing a focus on renewable energy and nanotechnology applications for novel sources of energy.

- In 2009, Governor Paterson designated Stony Brook University to lead the **New York Energy Policy Institute**, a new consortium of New York State institutions whose mission will be to coordinate the work of the state's many centers of energy-related research, to connect policy-makers to that research, and serve as a source of information and guidance in the making of State policy on energy issues. Stony Brook is partnering with Rensselaer Polytechnic Institute and Syracuse University on this initiative, with several other colleges and universities – and, as it does in many areas of energy research, with Brookhaven National Laboratory as well. The Laboratory's role in providing both intellectual and human capital to the work of the institute is highlighted by the fact that Gerald Stokes, Associate Lab Director for the Lab's new Directorate on Global and Regional Solutions (described above) will simultaneously serve as President of the Energy Policy Institute.

Strengthening Technology Deployment and Business Development at Brookhaven National Laboratory

From formal licensing of its intellectual property, to R&D partnerships with New York State companies, to participation in state economic development initiatives, Brookhaven National Laboratory is working to ensure that the new knowledge developed at the Lab translates over time into economic growth on Long Island and elsewhere in New York State – and into innovations that also benefit society at large. Nevertheless, the potential impact (both economic and societal) of research now being conducted at Brookhaven Lab is probably significantly greater than its actual impact to date.

In order to close this gap between potential and actual impact, the Laboratory has recently taken several steps to strengthen its capacity to move from discovery to deployment. In 2008, the Lab created a new **Technology Maturation Program**, which uses royalty income from previously-licensed Brookhaven Lab technologies to support work aimed at preparing newer technologies for commercialization. In 2009, the Lab's Office of Technology Commercialization and Partnerships awarded a total of $360,000 to five projects.

In 2009, for example, the Technology Maturation Program awarded funding to a team of scientists from Brookhaven Lab and Stony Brook University, led by David Schyler of the Lab's Medical Department, to continue the development of a new, non-invasive technology for detecting the growth or spread of tumors in cancer patients. This new technology uses a ring of miniature PET scanners that can be worn around the patient's wrist to measure the rate at which a tumor is consuming energy – an indicator of whether (and at what rate) it is growing.

Brookhaven National Laboratory is also collaborating with the Small Business Development Center at Stony Brook to provide assistance to Laboratory employees who are interested in exploring the creation of technology-based businesses. Since 2008, an experienced SBDC consultant has worked part-time at the Lab, helping Lab scientists and engineers understand the requirements for a successful technology-based venture, and providing connections to investors and other resources.

Close up of the PET part of the simultaneous PET/MRI breast imaging system, showing the individual detector units. This device was developed at Brookhaven Lab in a collaboration of the Medical Department, Physics Department, Instrumentation Division, and Stony Brook University.

Part Five: Educational and Community Programs at Brookhaven National Laboratory

Since the 1990's, several reports have highlighted the importance of education in science, technology, engineering and mathematics for the nation's future prosperity. In 2007, a report prepared for the National Academy of Sciences stated that:

> *An educated, innovative, motivated workforce – human capital – is the most precious resource of any country…Yet there is widespread concern about our K-12 science and mathematics education system, the foundation of that human capital in today's global economy.*[4]

The report noted that "Students in the U.S. are not keeping up with their counterparts in other countries…" In a 2003 study of fifteen-year-olds in 49 developed countries, the Organisation for Economic Cooperation and Development found that those in the U.S. ranked 19th in science literacy and 24th in math.

Brookhaven National Laboratory has long been an active participant in efforts to strengthen science and technology education – especially on Long Island. Through its Office of Educational Programs, the Laboratory develops and offers programs for students and teachers, and connects them with the Lab's varied resources. Programs range from hands-on science activities for elementary school students, to summer research workshops and internships, to professional development for teachers and university faculty.

In 2009, Brookhaven Lab educational programming served 34,781 K-12 students and 2,033 teachers from New York State. An additional 66 New York State undergraduate students participated in research internships, along with 160 others from across the country. These programs were supported by 377 researchers and staff members, who volunteer their time in addition to their work at the Lab.

Programs for K-12 Students

Brookhaven Lab's Office of Educational Programs offers a diverse set of age-specific educational opportunities for area elementary, middle, and high school students. Several examples are provided below:

- Since 1985, the **Science Learning Center** has offered a variety of interactive exhibits, hands-on labs, and educational programming for elementary, middle and high school students. More than twenty "discovery activities" at the Center are available throughout the year to students in grades 1 through 8, at no charge. Activities for younger students include Mini-Magnets, in which students learn about magnetism; and Spectroscopy, where students learn how scientists use light waves to identify elements.

The Science Learning Center also offers opportunities for middle and high school student groups through its Exploration Laboratory Program. Workshops are offered in biology, physics, astronomy, chemistry, integrated science, and engineering.

In 2009, programs at the Science Learning Center served 29,588 K-12 and 1,491 teachers, along with parents and other chaperones who accompanied them to Brookhaven Lab.

- In 2006, Brookhaven Lab launched the **Open Space Stewardship Program**, as a means of promoting exploration of the external environment as part of the K-12 science curriculum. Now in its fourth year, the program has expanded to thirty-five districts on Long Island. In 2009, 2,500 students, more than 100 teachers, and 12 Lab staffers were involved in this program. Many of the students and teachers made presentations and displayed their work at an annual celebration held at Brookhaven Lab.

- More than 100 local schools participate in the **Elementary School Science Fair** at the Laboratory, which includes the grade level winners from individual science fairs at Suffolk County Schools. Each year, nearly 470 projects, representing the work of more than 500 local students, are entered into the elementary school science fair. About 60 Brookhaven Lab volunteers, augmented by local teachers, assist with the event.

- The annual DOE **Regional Middle School Science Bowl** at Brookhaven Lab includes a model hydrogen fuel cell car competition and a math and science academic competition, and is part of the DOE's National Middle School Science Bowl. Brookhaven also runs the annual DOE High School Regional Science Bowl Competition. About 300 area students, 50 teachers, and 100 Brookhaven volunteers participate in the DOE Regional Science Bowls each year. The winning team for each of these competitions participates in the DOE National Science Bowl competitions.

4 National Academy of Science, *Rising Above the Gathering Storm* (2007) p. 31.

Collaborations with New York State Institutions

Brookhaven National Laboratory engages in a number of long-term collaborations with higher education institutions in order to increase access to math and science careers and improve education in New York State.

The New York State-funded **Science and Technology Entry Program** and **Collegiate Science and Technology Entry Program** have for several years encouraged New York State colleges and universities to partner with the Laboratory for several years. Through these programs, middle and high school students have experienced hands-on science activities and college students have had ten-week research internships. Programs were originally initiated with Hofstra University and now include Stony Brook University, Suffolk County Community College, City University of New York Schools and other New York institutions.

Brookhaven Lab currently works with Stony Brook University to increase minority participation in the sciences. Examples include several National Science Foundation-funded partnerships, such as the **Louis Stokes Alliance for Minority Participation** and **Geoprep: Building a Geoscience Pathway for High Needs Long Island High Schools**, which was recently awarded $1.9 million in NSF funding.

Brookhaven Lab also collaborates with Queensborough Community College in a $1.6 million, NSF-funded bridge program, aimed at encouraging students to stay in the sciences and transfer to four year institutions. Brookhaven Lab provides support through student internships, faculty research collaborations, and access to research equipment access.

The **Dowling College Center for Minority Teacher Development and Training** targets minority undergraduate and high school students pursuing careers in teaching. Over the last five years these students have worked with Brookhaven Lab's Science Learning Center staff to deepen their knowledge of science and to develop inquiry-based science teaching skills

In 2009, Brookhaven announced a new agreement with **Syracuse University** that will give Syracuse faculty and students access to the Lab's research facilities. The agreement will give both undergraduates and graduate students access to facilities not available at the University (or elsewhere in Central New York State) and will allow them to pursue research and teaching in nanotechnology, the life sciences, energy technology and other fields.

- About 100 students participate in Brookhaven National Laboratory's **High School Research Program** and other summer workshops each year. The six-week research program pairs high school students with Laboratory scientists, giving them an opportunity for direct involvement in significant research. Students also have the opportunity to continue their work during the school year. In February 2009, four Brookhaven Lab high school summer interns were recognized in the Intel Talent Search Competition as a result of their work in the Research Program.

- Brookhaven Lab provides additional opportunities to ninth-grade minority high school students through the **Minority High School Apprentice Program**, a program aimed at better preparing under-represented populations for careers in math and science. In 2009, 15 students participated.

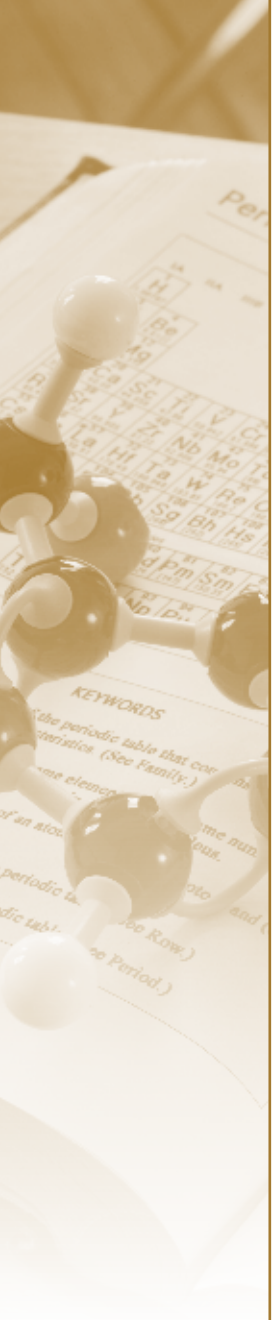
As noted above, more than 34,000 students in grades K through 12 participate directly in the Laboratory's educational programs; but there are also thousands of others who benefit indirectly from these programs. They include, for example, students whose teachers participate in the Lab's professional development programs (described below); and the many thousands of Suffolk County students who participate in the Science Fair competition at the elementary school level, even though they are not selected to represent their schools in the final round at Brookhaven Lab.

Programs for Undergraduate Students

Brookhaven National Laboratory offers a variety of opportunities for undergraduate students to experience world-class research. In 2009, 226 students participated in these programs.

In 2009, 181 undergraduate students participated in the Department of

"About 300 area students, 50 teachers, and 100 Brookhaven volunteers participate in the DOE Regional Science Bowls each year."



Energy-funded research internship program at Brookhaven. For example:

- Brookhaven Lab is a participant in the national **Science Undergraduate Laboratory Internship (SULI)** program, in which undergraduates are given the opportunity to engage in research with a Lab staff member and have the chance to present their work at the end of the experience. In 2009, 76 students participated in this program.

- The **Community College Institute** operates at national laboratories across the country and provides research and training opportunities for community college students for ten weeks each summer. In 2009, 15 students participated in this program, supervised by 13 Brookhaven Lab researchers.

- In the **Faculty and Student Teams** program, faculty and undergraduate students from colleges and universities are given the opportunity to develop their skills and knowledge through access to Brookhaven Lab facilities for the summer. This program specifically targets institutions with students underrepresented in science, engineering, math and technology. In 2009, 25 of these teams conducted research at Brookhaven Lab.

- The **Nuclear Chemistry Summer School** provides 12 undergraduate students six weeks of intensive training in areas not typically available at universities. These students gain an introduction to the diverse opportunities this field presents in areas such as energy and nuclear medicine.

From 2006 through 2008, 311 undergraduate students from 49 New York State colleges and universities worked as interns at Brookhaven National Laboratory. Together, New York State students accounted for 63 percent of all undergraduates who held internships at the Lab during those years.

Brookhaven National Lab also provides a variety of other opportunities for undergraduate students.

- Brookhaven Lab's **Winter Mini-Semester** offers coursework to 20 New York State college students and 25 students from outside New York State each year.

- In 2009, the **Brookhaven Science Associates Scholarship Program** awarded scholarships totaling $165,000 to 29 students attending New York State colleges or universities.

Programs for Graduate Students

As noted in Part Three, NSLS, RHIC and other Brookhaven Lab facilities are a valuable resource for the training of hundreds of graduate students each year, through their work with faculty members who use these facilities in their research. However, the Lab also offers several other programs for graduate students.

- The **Homeland Security Scholars and Fellows** program provides opportunities for graduate students to work on a number of projects at Brookhaven Lab that are supported by the Department of Homeland Security.

- The Laboratory offers a summer course on **Nuclear Non-Proliferation and Safeguards**; in 2009, 4 undergraduates and 20 graduates participated in this course.

- In the **Graduate Research Internship Program**, both Masters and PhD students are given the opportunity to do research with a Brookhaven Lab researcher on a mutually agreed upon project in the life or physical sciences, computer science, engineering, and mathematics.

Tours and educational programs at Brookhaven Lab get kids excited about science.

Brookhaven National Laboratory as a Community Resource

One of the keys to attracting and retaining high-skilled workers is the availability of varied cultural, intellectual and entertainment activities. Each year, the Laboratory is host to a variety of events that are available both to Lab employees and their families, and to the broader community.

- The Lab's annual summer series of open houses, **Summer Sundays**, is one of the Laboratory's largest community outreach programs. In 2009, over five consecutive, free Sunday events in July and August, the Lab welcomed some 6,000 visitors. Each week, a different "big machine" for science was opened to the public; informative talks detailing the Lab's cutting-edge research were presented; hands-on science activities were offered; and an exciting new science show complementing the type of research performed at the featured facility was performed.

- In addition to Summer Sundays, the Laboratory hosted 140 tours for 2,155 visitors in 2009. Also in 2009, 32 Lab employees presented 54 talks to 5,244 people at libraries, schools, Rotary Clubs and civic association meetings within the Long Island-New York City metropolitan area.

- Brookhaven Lab also stages a number of musical performances each year that are open to the community. The Brookhaven Employee Recreation Association's Music Club — with sponsorship from Brookhaven Science Associates — hosted 12 concerts in 2009, including jazz, rock and classical performances, each open to the public. Brookhaven Lab's free Lunchtime Recitals, sponsored by Brookhaven Science Associates, are offered about five times per year and draw visitors from inside and outside the Lab.

- Each year since 1996, Brookhaven National Laboratory has co-sponsored and hosted the Pine Barrens Research Forum, an annual forum for presentation and discussion of research on Suffolk County's Central Pine Barrens forest. This forum attracts prominent scientists, educators and agency representatives.

Brookhaven National Laboratory also contributes to local communities in the region by providing training and support to first responders. For example, the annual Wild Fire Academy provides training over a ten-day period to between 400 and 500 firefighters and emergency responders – from New York and from across the nation.

Part Six: Brookhaven National Laboratory and the Future of New York State's Economy

As this report has shown, Brookhaven National Laboratory is a significant contributor to the economy of New York State – and in particular, to the Long Island economy – both as a major enterprise in its own right and through its role in the discovery, development and deployment of new knowledge. During the next five to ten years, the Laboratory's impact on New York State's economy is likely to be even greater than it is today.

Major Investments in New Facilities

Between fiscal year 2010 and fiscal year 2014, Brookhaven Lab expects to spend more than $1 billion on construction of new facilities and on upgrading its existing facilities and infrastructure. As noted in Part Two, this investment is expected to support an average of 670 FTE jobs with Long Island contractors in construction and related industries through 2014.

More important in the long run, however, will be the expansion of the Lab's research capabilities that this investment represents. When it is completed, NSLS-II will (as noted previously) be the world's most powerful light source. It will provide both Brookhaven Lab scientists and external users with the capability to conduct research in the life sciences, nanoscience and technology, and energy science and technology that will be available nowhere else in the world.

Other investments will also enhance the Laboratory's capabilities. The new Interdisciplinary Science Building will provide an environment that will be much more conducive to collaboration among Lab researchers in addressing the complex challenges of energy science and technology. Even smaller-scale projects, such as modernization of existing lab buildings, will enhance Brookhaven Lab's ability to attract the most talented researchers.

Beyond 2014, other major initiatives now being considered – such as construction of a new, next-generation version of RHIC, called e-RHIC – could follow the same pattern: a major investment in a large, complex facility, followed by increases in research activity at the Lab.

Growth in Employment – and in External Users

As noted in Part Two, new investments in Brookhaven National Laboratory's facilities will be accompanied by an increase in employment and payroll at the Laboratory – including both scientists and engineers and the administrative, technical and support staff needed to sustain their work. By 2014, the Lab is expected to employ approximately 3,350 people.

Longer-term, the continued investment in new facilities and continued growth of Brookhaven Lab's research enterprise could lead to increased employment. Brookhaven Lab's internal estimates suggest that employment at the Laboratory could increase by as much as 25 percent between 2009 and 2019 – an increase of more than 700 jobs.

Brookhaven National Laboratory's investments in major new facilities will also support the continued growth of the Laboratory's external user community. The number of external light source users is expected to grow from about 2,100 in 2009 to 3,500 after NSLS-II becomes operational in 2015. Growth of the external user community will lead not only to additional local spending by visitors – it will also raise Long Island's visibility as a major center for cutting-edge science.

"Between fiscal year 2010 and fiscal year 2014, Brookhaven Lab expects to spend more than $1 billion on construction of new facilities and on upgrading its existing facilities and infrastructure."

Greater Emphasis on Moving from Discovery to Deployment

Brookhaven National Laboratory has long been known for the strength of its basic science. But for many years Brookhaven Lab lagged behind other national laboratories in the area of applied research, and in the further development and deployment of new technologies based on research conducted at the Lab.

Even as it reinforces its leadership in basic discovery science, Brookhaven Lab has in recent years begun to focus more attention on applied research, on the commercialization of new technologies, and on using the Lab's intellectual capital to promote economic development. And as the examples cited in Part Four demonstrate, this work has already begun to show some promising results.

Nevertheless, Brookhaven Lab's efforts in this area are still at an early stage. During the next five to ten years, the payoff from the Lab's increased emphasis on moving from discovery to deployment – as measured in the development of new products, new and expanded businesses, and new jobs – is likely to increase significantly.

Opportunities for Collaboration

Science – and in particular, the use of science to address some of the nation's most pressing health, economic, energy, environmental and national security problems – is increasingly a collaborative enterprise. Today Brookhaven National Laboratory is deeply involved in collaborative efforts across all of these areas. Examples cited previously include the Laboratory's participation in New York State's "smart grid" and battery technology consortia, and its collaboration with BP Solar and LIPA in the development of a 37-megawatt solar power plant – the largest in New York State – on the Brookhaven Lab campus.

Building on the foundation that is already in place, Brookhaven Lab is ac-

Brookhaven accelerator physicist with a siberian snake magnet from the Relativistic Heavy Ion Collider.

tively seeking to expand its collaboration with academic, government and industry partners in New York State. Foremost among these partners is Stony Brook University. As noted previously, Stony Brook is a partner with Battelle Memorial Institute in Brookhaven Science Associates, the entity that manages Brookhaven National Laboratory under a contract from the U.S. Department of Energy. Beyond this formal role, the University has a long history of collaboration with Brookhaven Lab in multiple areas of research – several of which have been described in this report.

Other joint initiatives could further contribute to both scientific progress and economic growth. For example, Brookhaven Lab and Stony Brook University have already established a Joint Photon Sciences Institute, which will be devoted to taking advantage of NSLS-II's unique capabilities to spur new advances in materials, life sciences and energy. Building on one of Brookhaven Lab's core strengths, the Laboratory and the University are also exploring the creation of a joint center on bio-imaging.

Perhaps the most important new initiative in this area is the proposed creation of a formal Research Alliance involving Brookhaven National Laboratory, Cold Spring Harbor Laboratory – one of the world's leading research centers in molecular biology and genetics – and Stony Brook. Closer collaboration among these three institutions could provide capabilities "greater than the sum of the parts" in a number of important areas, such as:

- Studies of, and development of new treatments for, cancer, obesity, drug addiction, autism and other diseases;
- Developing new biofuels that do not compete with food crops, and improving their performance; and
- Exploring how climate change might affect plant life in the Northeast, and how agriculture and other industries will need to adapt.

Through collaboration with these and other partners, Brookhaven National Laboratory will be well-positioned to address more effectively some of the nation's leading challenges – and at the same time to help grow the Long Island economy, and the economy of New York State.

"During the next five to ten years, the Laboratory's impact on New York State's economy is likely to be even greater than it is today."

Artist's rendering of Brookhaven's Interdisciplinary Science Building

Appendix A: IMPLAN Methodology

In assessing the economic impact of Brookhaven National Laboratory's spending in Long Island and elsewhere in New York State, Appleseed used information provided by Brookhaven Lab on employment, and on its spending on payroll, purchasing and construction. We used the IMPLAN modeling system to estimate the multiplier effect based on the payroll and purchasing data. This system is used widely in analyses of this type. It is tailored to reflect the economic structure of each county in the U.S., and is updated annually based on industry and household spending data gathered by the U.S. Bureau of Economic Analysis and the U.S. Bureau of Labor Statistics.

Using IMPLAN, we estimated the number of full-time-equivalent jobs with local companies that Brookhaven Lab supports through its purchases of goods (such as electricity and equipment) and services (such as security and external engineering services) and its construction projects. Along with its own direct employment and payroll, this spending represents the Lab's direct impact. We also used IMPLAN to calculate the indirect and induced or "multiplier" effects of the Lab's spending on payroll, purchasing and construction. Indirect effects represent the impact of money spent by the Lab's suppliers and contractors on purchases of goods and services from other local companies. Induced effects represent the impact of household spending by Brookhaven Lab's employees who live in Long Island and elsewhere in the state, and by employees of its Long Island- and other New York-based suppliers and contractors.

The same types of calculations were repeated to estimate the impact of spending by visitors to Brookhaven National Laboratory.

This report was prepared by Appleseed, a New York City-based economic development consulting firm that works with government, corporations, and nonprofit institutions to promote economic growth and opportunity.

80 Broad Street
13th Floor
New York, NY 10004

www.appleseedinc.com

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