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CONTENTS

A WORD ABOUT BNL
2

SCIENTIFIC DEPARTMENTS
14

RESEARCH DIVISIONS
68

LABORATORY PROFILE
78

A WORD ABOUT BNL

First-time visitors to Brookhaven National Laboratory notice the rolling lawns bordered by deep woods, the gentle sprawl of buildings and parking lots, and, certainly, the distinctive outlines of several of the large research facilities.

The site is large — 5,265 acres. And 3,300 employees interact with a nearly equal number of guest researchers and students who come to work at BNL during the course of a year, drawn by the Laboratory's unique facilities and expert staff.

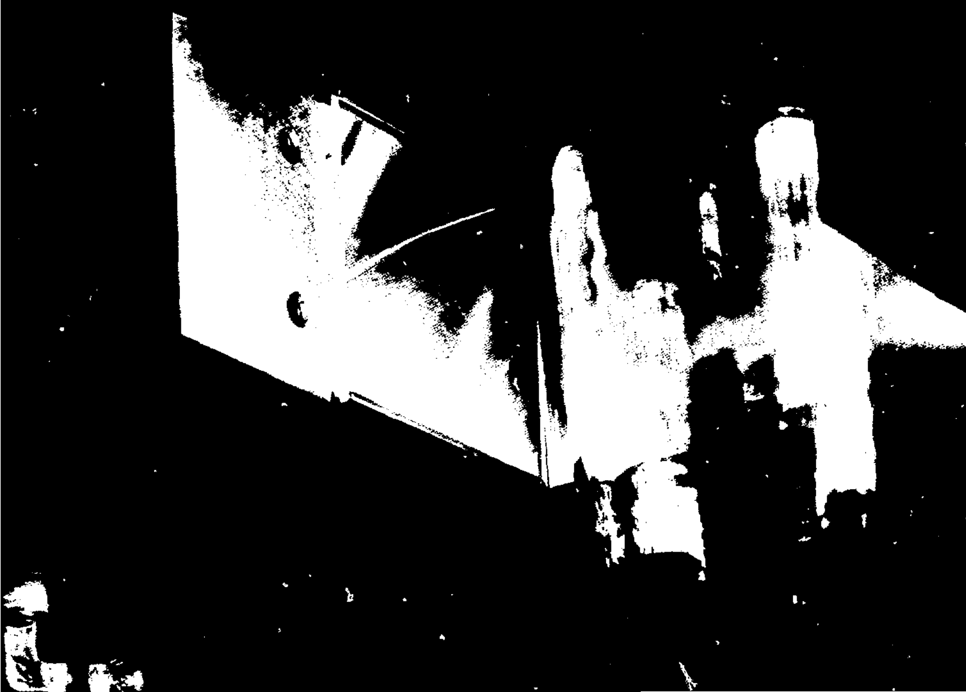
Established in 1947 on Long Island, New York, on the site of the U.S. Army's former Camp Upton, BNL is a multidisciplinary laboratory that carries out basic and applied research in the physical, biomedical and environmental sciences and in selected energy technologies. The Laboratory is managed by Associated Universities, Inc., under contract with the U.S. Department of Energy.

CONTENTS

BROOKHAVEN TODAY
4

WORLD-CLASS RESEARCH AND TOP SCIENTISTS CONVERGE AT BNL
6

BROOKHAVEN'S BIG MACHINES
12



". . . the high energy of the collisions of heavy ions in RHIC will produce conditions so extreme that we should be able to observe phenomena that have not occurred in the natural universe since the original Big Bang. This will be basic research at its very finest!"

Brookhaven Today

Since the Laboratory's doors opened in 1947, basic research has been our strength and the bedrock from which our programs have continually broadened and expanded.

This growth has been accompanied by an abiding commitment to top-quality research. No new area of study is ever adopted, no new facility is ever built without careful evaluation and complete confidence that the science is worth pursuing.

The most recent example of this approach is the Relativistic Heavy Ion Collider, or RHIC. For me, the highlight of fiscal year 1990 came when this exciting new accelerator was included for construction funding in the Presidential budget submitted to Congress in January. At the end of fiscal year 1990, the federal government's 1991 budget was not yet finalized, but I am certain that the RHIC project will be a line item in the final package.

Scientists expect that the high energy of the collisions of heavy ions in RHIC will produce conditions so extreme that we should be able to observe phenomena that have not occurred in the natural universe since the original Big Bang. This will be basic research at its very finest!

It gives me great satisfaction to reflect that when RHIC comes on line in 1997 as the world's newest accelerator, it will be receiving heavy ions through one of the world's oldest — our Alternating Gradient Synchrotron, the AGS.

The AGS turned 30 in 1990. But it has not just gotten older — it's gotten better, much better. It started as a proton accelerator, at age 24 it began accelerating polarized protons, and at 26, heavy ions. And all along, its intensity has steadily increased.

AGS intensity will increase even more next year, when the Booster comes on line. This small but mighty machine will preaccelerate particles before they enter the AGS, thus making it possible to accelerate ions up to gold in RHIC.

Another of our big machines — the National Synchrotron Light Source, or NSLS — enjoyed a fine year, attracting some 1,829 outside users to take advantage of one of the world's brightest sources of x-rays and ultraviolet light. With the commissioning of the new infrared beam line on the vacuum-ultraviolet ring, the NSLS also became the brightest broadband source of infrared radiation available today.

A BNL research team made use of that radiation in developing a novel instrument that opens up a new class of experiments with synchrotron radiation — a wavefront dividing infrared interferometer. It's installed at the infrared beam line and won an R&D 100 award this year — making this the fifth time that an NSLS device has won in that prestigious competition. Nice going!

Because Brookhaven is a multiprogram laboratory, we were able this year to initiate a comprehensive program on global change, combining our expertise in atmospheric science, oceanography, terrestrial ecology and applied mathematics. I'm pleased that we can contribute to this vital issue.

In another exciting project, our biologists are developing a method of determining the sequence of the nucleotide components of human DNA, the basic genetic material. This work is part of the new Human Genome Project, a program funded partially by the U.S. Department of Energy (DOE) to map the exact structure of DNA over a 15-year period. Our new method could be crucial to meeting that target within a reasonable budget. All in all, we have considerable expertise in this area, and I believe that Brookhaven would have many advantages as a regional center for genome studies.

Of course, throughout the year, there was much more forefront research, both basic and applied — more than can be mentioned here. And much of it involved not only Brookhaven staff but also users from universities, industry and other laboratories — some 3,335 strong — who came to work at our unique facilities or to collaborate with our scientists.

Interaction with industry has become ever more prevalent at Brookhaven, as we take a leadership role in helping our country improve its industrial competitiveness. We recognize that technology transfer is an increasingly important mission of the Laboratory, and I am pleased at the way we have pursued this in such areas as the BNL-based national effort to build a compact synchrotron that demonstrates the feasibility of x-ray lithography for the large-scale manufacture of computer chips.

All our research, of course, is being carried out with careful concern for the work's impact in three key areas: environment, safety and health, ES&H. I appreciate the input we received in these areas from the DOE Tiger Team that visited Brookhaven for a month last spring. The team came as part of a comprehensive program initiated by the Secretary of Energy to strengthen environmental protection and waste-management activities in DOE facilities nationwide. As I stated at the closeout meeting with the Tiger Team, "Scientific programs go hand-in-hand with safety and the environment. We need them both to excel."

Heightened awareness of ES&H issues is a relatively recent development, and today's standards are much more stringent than they were in the past. The effects of past practices are now showing up globally, nationally and locally.

For example, last November, Brookhaven was included on the Environmental Protection Agency's "Superfund" list because of the potential threat to the underlying sole-source aquifer from past disposal practices at the Laboratory.

As we work to correct our problems from the past, we also work to educate others about environmental issues. This year, BNL staff taught a 15-week course on environmental science to Long Island high school teachers. I expect that this will help pass on the new ES&H culture to our youth.

Of those youths, or out of the hundreds of young people who participate in our student programs each year, perhaps some will pursue science at Brookhaven in the years to come.

I have no doubt that the Brookhaven of tomorrow will have the same vibrancy and commitment to excellence as does the Brookhaven of today.

N.P. Samios

Nicholas P. Samios
Director

MOLTECH CORPORATION IS DEVELOPING NEW APPLICATIONS FOR ELECTRICALLY CONDUCTING POLYMERS THAT HAVE BEEN SYNTHESIZED AND CHARACTERIZED AT BNL, IN COLLABORATION WITH POLYTECHNIC UNIVERSITY. INVOLVED IN THIS EFFORT ARE (FROM LEFT) MOLTECH SCIENTISTS PAUL HALE AND LEONID BOGUSLAVSKY, BNL SCIENTIST AND MOLTECH PRESIDENT TERJE SKOTHEIM, AND YOSHI OKAMOTO OF POLYTECHNIC, WHO IS A CONSULTANT TO MOLTECH.

World-Class Research And Top Scientists Converge At BNL

Top scientists and world-class research facilities — that's what marks Brookhaven National Laboratory and that's what draws people from other institutions to BNL.

Brookhaven is a tremendous resource for our country. Through the years, BNL scientists have made noteworthy contributions in basic research in physics, chemistry, biology and medicine. And BNL's applied research has directly benefited humankind in such diverse areas as energy technology and medical diagnosis and treatment.

In addition, the Laboratory has a long tradition of designing, building and operating scientific facilities of immense complexity. These machines have given researchers the most sophisticated tools with which to probe the still uncharted regions of science.

It is the combination of resident expertise and one-of-a-kind facilities that makes BNL such a powerful magnet for outside researchers. In recent years, with the construction of the National Synchrotron Light Source (NSLS), the world's largest synchrotron radiation center, the number of guest researchers at BNL has risen dramatically.

Indeed, a remarkable statistic is worth noting: In fiscal year 1990, the grand total of guest researchers and student collaborators was about 3,335, nearly equal to the head count of 3,379 employees.

BNL guests and collaborators come from all over the United States and from practically every country in the world. They come from universities, private industry and other research laboratories. They sometimes stay for years at a time to pursue complex experiments. Or, as is the case with many students, they may stay only a semester, gaining valuable hands-on experience *doing* science.

COLLABORATIVE PROJECTS

For the most part, guests and collaborators work together with BNL staff, the partnership proving beneficial to all involved.

One such project involves BNL, Grumman Aerospace Corporation and General Dynamics, working in collaboration on the development of a compact synchrotron for x-ray lithography. This technique shows great promise as the successor to optical lithography, the current manufacturing technology that uses ultraviolet and visible light to make computer chips.

With optical lithography, the present manufacturing standard is 0.75 microns between circuit features and the limit is probably 0.3 microns (50 microns is about the width of a human hair). In contrast, because of the shorter wavelength of x-rays, x-ray lithography can easily produce chips with a 0.1-micron space between components and is projected to do perhaps ten times better than that.

The compact synchrotron project officially began in 1988 with a $32-million, five-year grant from the U.S. Department of Defense. That same year, IBM announced its success in making a 0.5-micron chip, at Brookhaven's NSLS.

If the U.S. can prove itself in the development of x-ray lithography, this will reverse the country's increasing dependence on foreign suppliers of supercomputer chips and increase its share in the world's semiconductor market.

Computer chips also relate to another collaborative project at BNL: Cosmic rays constantly bombard the earth. When a computer chip is hit by a cosmic ray, it can malfunction. This phenomenon, called single event upset, can also occur in space, in satellite computers. And whether in space or on land, the problem will get worse as circuit elements become smaller and more densely packed, as they will with x-ray lithography.

A testing facility was built at BNL in December 1987, for use by researchers interested in developing computer chips that are less sensitive to cosmic radiation. The facility uses heavy-ion particles to simulate the action of cosmic rays.

A coalition of government agencies built and operates the facility, and corporate customers have included General Electric, LSI Logic and McDonnell Douglas.

Yet another set of institutions is working with us in the field of photovoltaics, which are devices that make electricity from sunlight. BNL recently began a cooperative project with ASARCO Inc., Photon Energy Inc., Siemens Solar Inc. and the federal government's Solar Energy Research Institute, to evaluate the feasibility of recycling hazardous solid wastes produced by the photovoltaics industry.

The goal of the program is to develop environmental controls at reasonable cost. It will also help to ensure that further progress in this field will not be impeded by future environmental hazards.

This project is an outgrowth of our earlier work with the photovoltaics industry to identify and evaluate health and safety hazards. We also gave the industry guidance on ways of reducing risks in new manufacturing processes and materials used for photovoltaic systems.

TECHNOLOGY TRANSFER

With all the cooperative projects that involve other institutions and so many outside researchers using the Laboratory's facilities, much of what is developed at BNL is transferred to the private sector as a matter of course. But because of growing national concern that this

SHOJI NAGAMIYA, OF COLUMBIA UNIVERSITY, SPEAKS AT A WORKSHOP ON BNL'S RELATIVISTIC HEAVY ION COLLIDER (RHIC). WHEN COMPLETED IN 1997, RHIC WILL DRAW PHYSICISTS FROM ALL OVER THE WORLD WHO WILL USE THE COLLIDER TO RECREATE THE PRIMORDIAL SUBATOMIC PARTICLES THAT SCIENTISTS HAVE NEVER BEEN ABLE TO OBSERVE DIRECTLY.

BNL'S DOLLY JOHNSON (RIGHT) AND LONG ISLAND RESIDENT KAREN BLUMER, AN ECOLOGIST, CHECK THE WILD BLUE LUPINES PLANTED ON THE BNL SITE IN A PILOT PROJECT TO BOOST THE POPULATION OF THIS NATIVE LONG ISLAND PLANT. IN RECENT YEARS, THE LUPINE POPULATION HAS DWINDLED BECAUSE OF RESIDENTIAL AND COMMERCIAL DEVELOPMENT ON THE ISLAND.

country is losing its competitive edge in the international marketplace, there is increased scrutiny on technology transfer from federally funded research.

The U.S. government spends roughly $60 billion a year on research and development. Out of that, about $20 billion is spent at federal labs. Brookhaven is one of the nine multiprogram national laboratories funded by the U.S. Department of Energy (DOE).

Oriented towards the national goal of strengthening technology transfer, BNL has a formal program carried out by our Office of Technology Transfer.

A major activity of that office is patent licensing. When a researcher at the Laboratory invents a device or a process, the office first reviews the invention. If it has commercial application, then Associated Universities, Inc. (AUI), the corporation that manages the Laboratory under contract with DOE, has the option of patenting the invention. Once that is done, we actively seek companies that would be interested in licensing the invention for commercial use.

To date, AUI has licensed ten BNL inventions to private industry. For example, Mallinckrodt, Inc. holds an exclusive license to develop the technology of a red blood cell kit, which was originally developed at BNL and patented by AUI. The company awaits approval by the federal Food and Drug Administration before marketing the kit.

The kit attaches the radioactive isotope technetium-99m to red blood cells. The labeled blood cells are then used in diagnostic nuclear medicine procedures for imaging vital organs. At present, over two million such diagnostic studies are performed annually worldwide, so the easy-to-use kit will greatly improve health care.

The Electric Power Research Institute holds an exclusive license on BNL catalysts for methanol production. A clean and multipurpose chemical, methanol is a key ingredient in the synthesis of many products, such as formaldehyde and MTBE, a gasoline additive for increasing octane. Methanol is also a potential fuel because it burns cleanly.

The conventional method of making methanol is from a starter of synthesis gas, which is a basic mix of carbon monoxide and hydrogen. The process requires reacting synthesis gas with catalysts under conditions of high temperatures and pressures, and productivity is disappointingly low.

In contrast, the BNL-invented catalysts are extremely active and work efficiently at low temperature and low pressure. They can also react with syngas mixtures that contain considerable quantities of other gases, such as nitrogen and methane. The result is more economical production of methanol.

BASIC RESEARCH

BNL users — whether they work with our staff, use our facilities, or even consume products that were born of our research — are all beneficiaries of the Laboratory's root strength, our basic research programs.

While basic research seems esoteric to many people, in fact it is not always so far removed from real life. Consider, for example, theoretical physics, perhaps the epitome of basic research.

A recent project in this specialized field centers around a BNL-invented theory called self-organized criticality, which offers an explanation of how certain interactive systems work.

Already, this research has captured the attention of scientists and economists, as it has given insight into such unpredictable systems as earthquakes and the Dow-Jones average.

Interactive systems evolve naturally towards a condition called a critical state. In the critical state, a system appears to be stable, but in fact it is poised to evolve into another condition.

One way to visualize this is to imagine building a sandpile by adding grains one at a time, at random. As the pile gets steeper, small slides occur, then bigger ones. Eventually, the sandpile stabilizes in that the amount of sand added equals the amount falling off. At this point, the sandpile has reached a critical state. The result of adding just a little more sand is unpredictable, and avalanches of any size or duration can be triggered.

Researchers at IBM have built piles of sand, just as described, and their experiments have confirmed our theory of interactive systems.

We envision the application of this theoretical work into even broader areas — from the extinction of the dinosaurs, to the evolution of individual species, to the earth's climate.

IN THE SUMMER OF 1990, BNL HOSTED STUDENTS FROM ACROSS THE NATION AND FROM VARIOUS FOREIGN COUNTRIES, AS PART OF THE HIGH SCHOOL HONORS SCIENCE PROGRAM SPONSORED BY THE U.S. DEPARTMENT OF ENERGY. THE FOCAL POINT FOR THESE STUDENTS WAS THE NATIONAL SYNCHROTRON LIGHT SOURCE (BACKGROUND), A FACILITY THAT DRAWS RESEARCHERS FROM ALL OVER THE WORLD.

BNL'S BRENDA LASTER (RIGHT) USES SIGN LANGUAGE TO DISCUSS A SCIENTIFIC EXPERIMENT WITH EVA MARIE HOLLOWAY, A GRADUATE OF GALLAUDET UNIVERSITY, A SCHOOL FOR HEARING-IMPAIRED STUDENTS. HOLLOWAY WAS ONE OF THREE STUDENTS FROM GALLAUDET PARTICIPATING IN BNL'S 1990 SUMMER RESEARCH PROGRAM FOR COLLEGE STUDENTS.

In another scientific discipline, biology, BNL researchers have made fundamental contributions to the understanding of DNA, the material that makes up genes.

Recently, we have developed a new method of determining the sequence of the four basic components of DNA called nucleotides. The work is part of the new Human Genome Project, a 15-year national program funded by DOE and the National Institutes of Health to decipher the exact structure of DNA. As work progresses on the genome project, scientists will begin to unravel the mysteries of genetic diseases.

This is a monumental undertaking, considering the fact that the human genome contains three billion pairs of nucleotides. With current technology, it would be difficult for one person to sequence even 45,000 base pairs in one year.

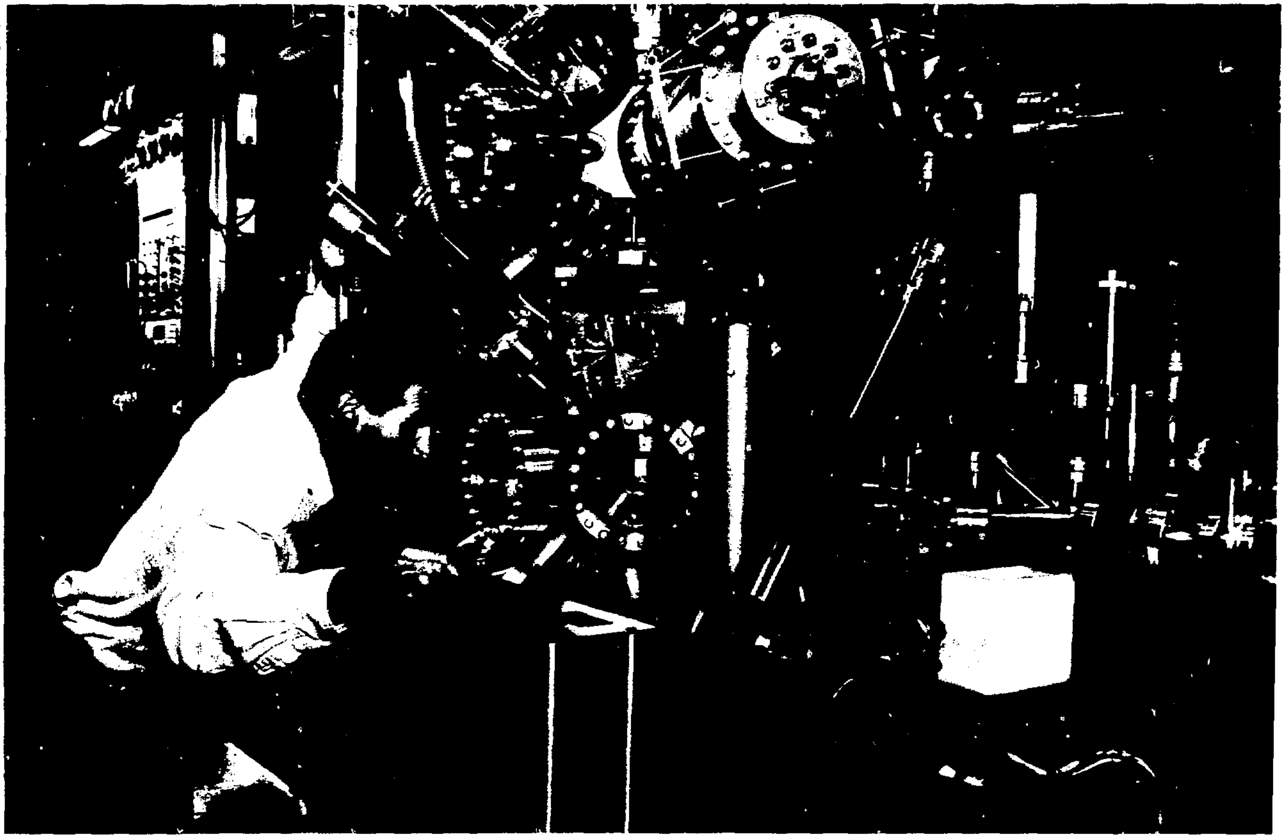
BNL's method uses statistical analysis and a new approach to existing molecular biology techniques to reduce dramatically both the time and expense of conventional sequencing methods. We will know over the next year of rigorous testing if the technique meets our expectations.

DISCOVERY

Science is a demanding enterprise — difficult, complicated and full of the unexpected. We at BNL are driven to pursue science because of an innate and compelling desire to understand ourselves and the world around us. We do it for the chance of discovery.

That's why underlying all programs at Brookhaven is a firm commitment to basic research. We believe that basic research lays the foundation from which all innovations follow — perhaps not today, but surely tomorrow. And tomorrow is where we set our sights.

AT THE NATIONAL SYNCHROTRON LIGHT SOURCE, PAUL CITRIN OF AT&T BELL LABORATORIES STUDIES HOW ATOMS BOND TO THE SURFACE LAYER OF A MATERIAL. THE NEW BEAM LINE CITRIN IS WORKING ON IS THE WORLD'S BEST FOR USING A TECHNIQUE CALLED SEXAFS, OR SURFACE EXTENDED X-RAY ABSORPTION FINE STRUCTURE, TO PROBE THE UNIQUE PROPERTIES OF SURFACES.



THE BOARD OF TRUSTEES OF ASSOCIATED UNIVERSITIES, INC. (AUI) MEETS QUARTERLY. GATHERED AT BNL IN JUNE 1990 WERE: (CLOCKWISE FROM LOWER LEFT) ROBERT V. POUND, HARVARD UNIVERSITY; BARRY S. COOPERMAN, UNIVERSITY OF PENNSYLVANIA; ROBERT E. HUGHES, AUI PRESIDENT; RALPH J. SCHWARZ, COLUMBIA UNIVERSITY; HUGH M. VAN HORN, UNIVERSITY OF ROCHESTER; JOHN R. WIESENFELD, CORNELL UNIVERSITY; PAUL C. MARTIN, HARVARD UNIVERSITY; DONALD K. HESS, UNIVERSITY OF ROCHESTER; JOHN A. ARMSTRONG, IBM CORPORATION; RICHARD A. ZDANIS, CASE WESTERN RESERVE UNIVERSITY; MARVIN KUSCHNER, STATE UNIVERSITY OF NEW YORK AT STONY BROOK; LOUIS A. GIRIFALCO, UNIVERSITY OF PENNSYLVANIA; WILLIAM H. SWEET, HONORARY TRUSTEE (HARVARD UNIVERSITY, RETIRED); VERNON W. HUGHES, YALE UNIVERSITY; VAL L. FITCH, PRINCETON UNIVERSITY; ROBERT K. ADAIR, YALE UNIVERSITY; AND AIHUD PEVSNER, THE JOHNS HOPKINS UNIVERSITY.

ASSOCIATED UNIVERSITIES, INC.

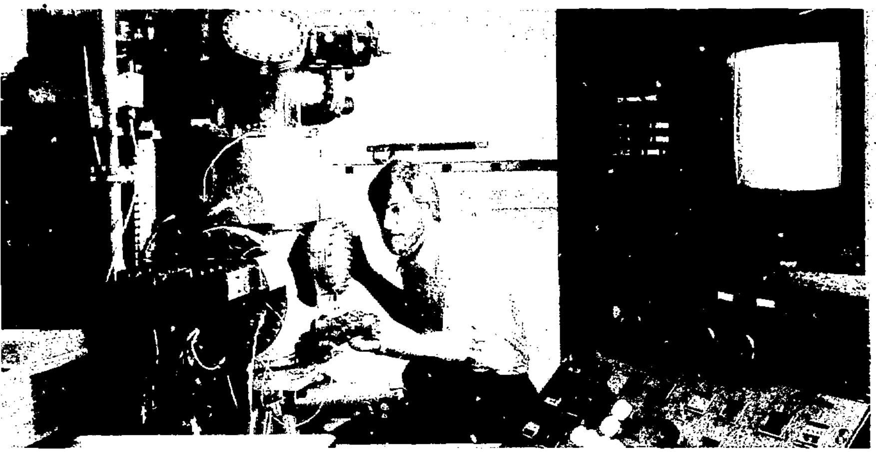
Associated Universities, Inc. (AUI) is the non-profit corporate entity responsible for the operation of Brookhaven National Laboratory, under contract with the U.S. Department of Energy.

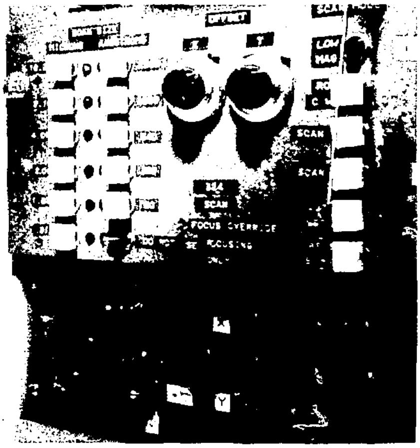
AUI was founded in 1946 in order to bring together the resources of academia and the federal government to carry out research endeavors not normally within the scope of a single university. The result was the establishment of BNL, a multidisciplinary institution that carries out advanced scientific research in many frontier areas of interest to universities, industry and government.

In 1956, AUI also established the National Radio Astronomy Observatory (NRAO), now headquartered in Charlottesville, Virginia. The observatory is funded by the National Science Foundation.

AUI is governed by a board of twenty-five trustees that are affiliated with universities and industry. Since AUI is an independent corporation and not a consortium, however, individual trustees do not represent their home institutions on the Board of Trustees.

The function of the trustees is to create and oversee the management structure of both BNL and NRAO, including appointment of each institution's director, and to ensure effective and successful accomplishment of the research programs. In recognition of its responsibilities, the board's membership reflects a broad balance of expertise in major areas of science, as well as extensive experience in senior administration. In addition, the trustees are served by seven Visiting Committees, which conduct independent, expert appraisals of the scientific programs at both institutions.





Brookhaven's Big Machines

Not only big in size, but also in influence, Brookhaven's four big machines form the heart of our research programs. These facilities affect the progress of science worldwide since their sophisticated capabilities are essential for experiments in a wide range of disciplines from biology and medicine to physics and materials science.

Each year, BNL's unique facilities — the Alternating Gradient Synchrotron, the High Flux Beam Reactor, the National Synchrotron Light Source and the Scanning Transmission Electron Microscope — attract approximately 2,800 researchers and students from universities, industries and other laboratories throughout the world. In performing hundreds of experiments annually with the aid of these big machines, researchers may choose to work independently or collaborate with BNL scientists.

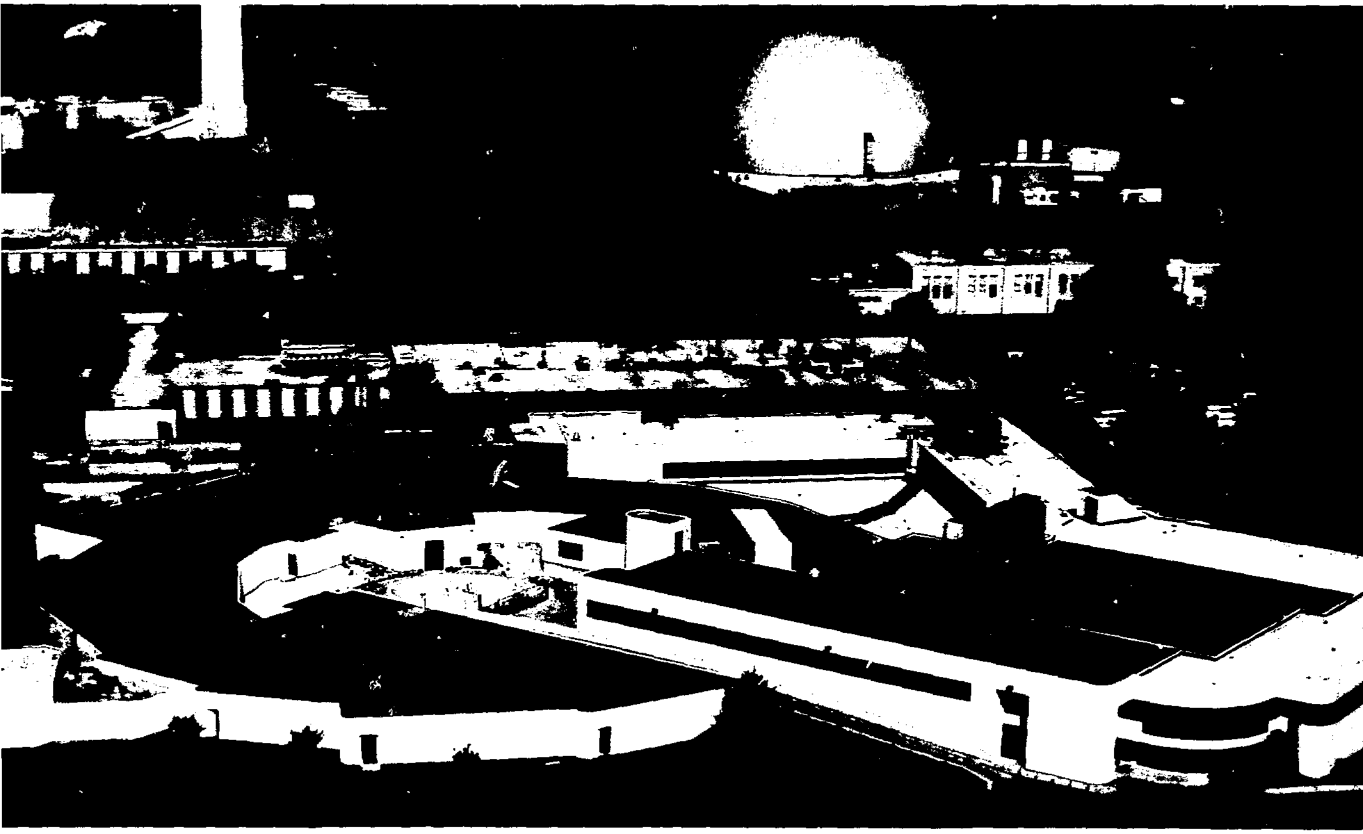
Brookhaven encourages collaborative efforts with industry, and industrial researchers who wish to use our facilities may contact the Laboratory's Office of Technology Transfer for assistance. By entering into a proprietary user's agreement with BNL, researchers may retain title to inventions or data generated during work at the Laboratory.

ALTERNATING GRADIENT SYNCHROTRON• Thirty years old in 1990, the Alternating Gradient Synchrotron (AGS) is still the world's most versatile accelerator. The AGS can accelerate protons to 33 billion electron volts (GeV), polarized protons to 22 GeV, and heavy ions up to 14.5 GeV/nucleon. It also provides the most intense beams of kaons in the world for rare kaon decay research. Both high energy and nuclear physicists from around the globe use the accelerator for their diverse experiments. In 1990, there were 640 researchers from 92 institutions performing experiments at the AGS.

HIGH FLUX BEAM REACTOR• Since it first began operating in 1965, the High Flux Beam Reactor (HFBR) has remained one of the world's most advanced research reactors. Each year, about 200 international researchers join BNL scientists in using the HFBR for neutron-based research in numerous fields, including biology, chemistry, physics and metallurgy. Since mid-1989, HFBR operations have been suspended for safety reviews, so that there is a large backlog of outside users with approved experiments waiting for its restart.

NATIONAL SYNCHROTRON LIGHT SOURCE• The world's largest synchrotron radiation center, the National Synchrotron Light Source (NSLS) is used for both basic and applied research in a wide variety of disciplines including physics, chemistry, biology, materials science and various technologies. The NSLS accelerates electrons in a curved path to produce a broad spectrum of radiation valuable for research, ranging from infrared to ultraviolet light and x-rays. Since it began operation in 1982, the NSLS has attracted researchers from academia, industry and other laboratories in ever-increasing numbers. In 1990 alone, 1,829 researchers from 292 institutions used the facility, about 50 percent more than the previous year.

SCANNING TRANSMISSION ELECTRON MICROSCOPE• One of three high-resolution microscopes in the world that can image single heavy atoms, Brookhaven's Scanning Transmission Electron Microscope (STEM) is used to view biological molecules without adding heavy metals to the sample for staining or shadowing. This microscope can magnify specimens up to ten million times and it provides a resolution of 2.5 angstroms. Fifty-six scientists from 37 outside institutions performed their experiments on STEM in 1990. BNL also operates a second STEM on site, donated by The Johns Hopkins University. It is used in pilot studies for obtaining chemical information by a technique known as electron-energy-loss-spectroscopy. •



NATIONAL SYNCHROTRON LIGHT SOURCE (FOREGROUND)
AND THE HIGH FLUX BEAM REACTOR (DOME IN BACKGROUND)

SCIENTIFIC DEPARTMENTS

Brookhaven has been a multidisciplinary laboratory from its inception. Indeed, the diversity of research that is carried out is reflected by the Laboratory's organization into nine different scientific departments.

To support BNL's multidisciplinary character even further, the Laboratory encourages research that crosses departmental lines.

It is BNL's breadth of expertise that helps keep us at the forefront of scientific discovery — a place where new ideas, new developments and new techniques flourish.

CONTENTS

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT
16

ACCELERATOR DEVELOPMENT DEPARTMENT
22

PHYSICS DEPARTMENT
28

DEPARTMENT OF NUCLEAR ENERGY
34

DEPARTMENT OF APPLIED SCIENCE
38

NATIONAL SYNCHROTRON LIGHT SOURCE DEPARTMENT
44

CHEMISTRY DEPARTMENT
50

MEDICAL DEPARTMENT
54

BIOLOGY DEPARTMENT
58

INTERDEPARTMENTAL RESEARCH
64

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT

The AGS Department operates the Alternating Gradient Synchrotron (AGS), the heart of Brookhaven's high energy and nuclear physics programs. In recent years, with the completion of a transfer line between the Tandem Van de Graaff and the AGS, heavy ions have joined protons and polarized protons as the particles drawing researchers from all over the world to carry out their experiments here. The latest AGS project to get under way is the construction of the Booster, which will extend both physics programs at the Laboratory.

THE AGS: THIRTY YEARS OLD — AND STILL GOING STRONG

Brookhaven's Alternating Gradient Synchrotron (AGS) celebrated its thirtieth birthday in 1990.

On July 29, 1960, the AGS became the world's most powerful accelerator when it first reached its design energy, hurtling protons through its half-mile-long tunnel at an energy of 30 billion electron volts (GeV).

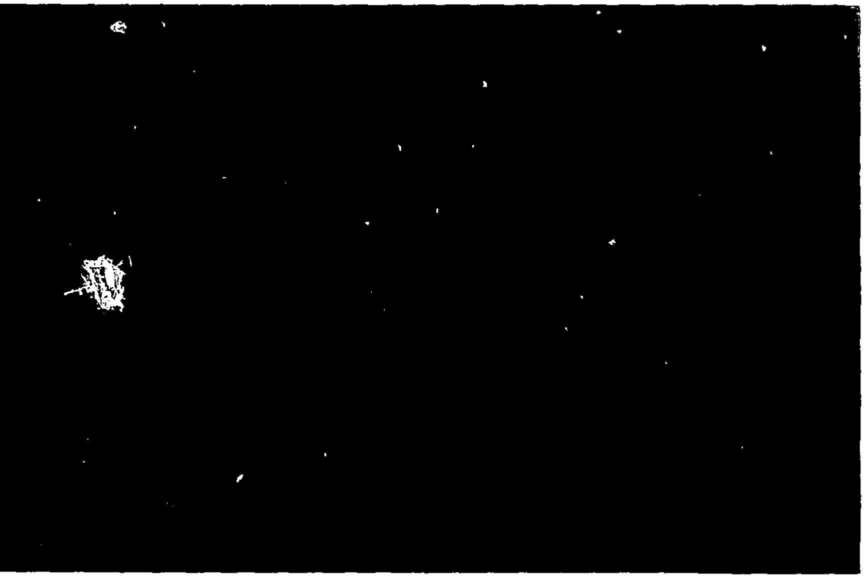
Today, though there are more powerful accelerators, none is more versatile than the AGS. It now accelerates many kinds of particles — protons, polarized protons and heavy ions — for frontier high energy and nuclear physics experiments. With the completion of the Booster, it is also slated to become the injector for BNL's Relativistic Heavy Ion Collider (RHIC).

The AGS has been continuously upgraded over the last three decades. A major upgrade was completed in 1986, when it was linked to the Tandem Van de Graaff accelerator, allowing researchers to begin heavy-ion experiments at the AGS. Over the years, the AGS's intensity has been increased two thousandfold, and it is now capable of accelerating protons at energies up to 33 GeV, polarized protons up to 24 GeV, and heavy ions up to 14.5 GeV per nucleon, for experiments at a total of 17 beam lines.

PIONEERING DESIGN

The AGS name was derived from alternating gradient focusing, a principle discovered at BNL in 1952 by Ernest Courant, M. Stanley Livingston and Hartland Snyder, and independently by Nicholas Christofilos in Greece. In this type of focusing, the field gradients of the accelerator's 240

ON JULY 29, 1960, RESEARCHERS WAIT IN THE MAIN CONTROL ROOM OF THE AGS FOR THE ACCELERATOR TO REACH ITS FULL DESIGN ENERGY OF 30 BILLION ELECTRON VOLTS. IT DID SO AT 4:13 P.M.



IN THE TUNNEL OF THE ALTERNATING GRADIENT SYNCHROTRON (AGS), HORST FOELSCHE CHECKS THE SEXTUPOLE CORRECTION COIL — THE AUXILIARY MAGNET THAT PROVIDES SMALL CORRECTIONS TO THE MAGNETIC FIELD THAT GUIDES THE BEAM AROUND THE AGS.

magnets are successively alternated inward and outward, permitting particles to be guided and focused at the same time.

Also called strong focusing, the principle was first used in the design of the 1.2 GeV Electron Synchrotron at Cornell University in 1953. Several years later, it served as the basis for the design of both the AGS and the Proton Synchrotron at CERN in Europe. Today, strong focusing is still the guiding principle for the design of most new accelerators, including the colossal Superconducting Super Collider now under development in Texas.

NOTABLE ACHIEVEMENTS

One of the most productive particle accelerators ever built, the AGS is well-known for the three Nobel Prizes won as a result of research performed there.

The Nobel Prize-winning discoveries are: The muon-neutrino, found in 1962 by a Columbia/BNL collaboration led by Leon Lederman, Melvin Schwartz and Jack Steinberger; CP violation, discovered in 1964 by James Cronin and Val Fitch, both then at Princeton University; and the J/psi particle, detected in 1974 by a BNL/Massachusetts Institute of Technology (MIT) collaboration headed by Samuel C.C. Ting of MIT.

Other notable achievements at the AGS include the discovery of the Omega-minus particle in 1964 and the charmed baryon in 1975, both by BNL Director Nicholas P. Samios, then head of the Physics Department's Omega Group.

At present, research at the AGS ranges from the search for a quark-gluon plasma in heavy-ion experiments run by nuclear physicists, to the quest for rare decay modes of particles known as kaons (K). For these rare K-decay experiments, which high energy physicists pursue to verifiy the standard model, the AGS is the premier accelerator today since it produces more kaons per hour than any other machine in the world.

THE BOOSTER AHEAD

Since 1986, the focus of the AGS Department has been on the Booster, a much smaller accelerator through which particles will be accelerated before entering the AGS, and which will further enhance the power and versatility of the AGS. When the Booster is commissioned in 1991, another new age in physics experimentation will dawn at the AGS.

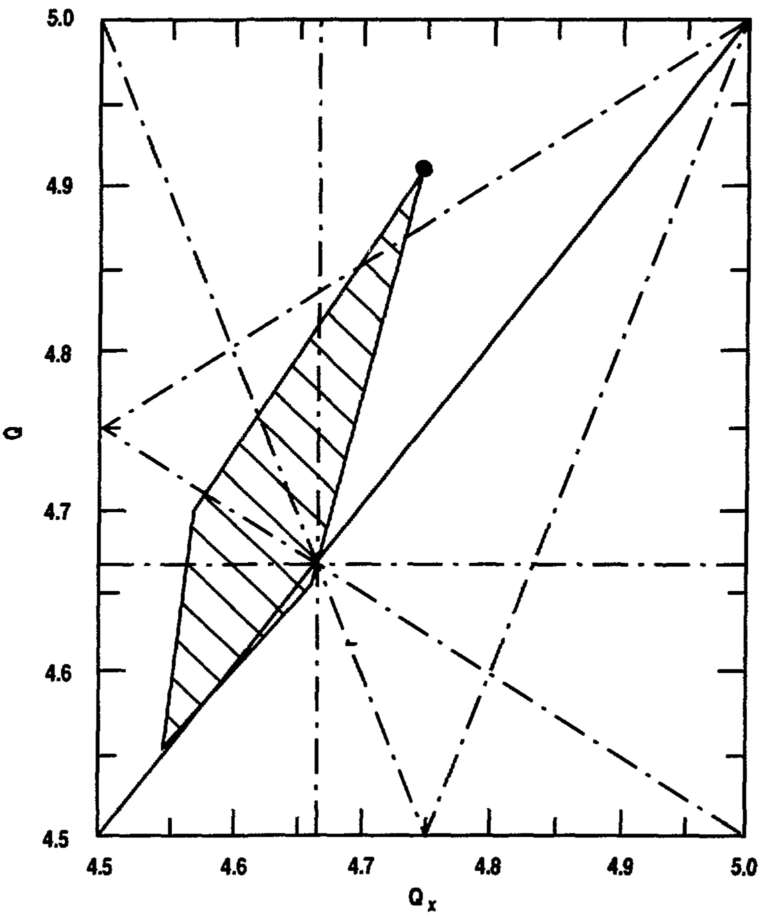
The Booster will improve the AGS in three ways: First, its proton intensity will increase fourfold to 5-6 x 10^{13} protons per pulse (p p) to satisfy the demand for beam time for rare K-decay and other experiments. Second, its polarized proton intensity will rise by a factor of 20, to 10^{12} p/p, for spin physics. And it will be able to accelerate all heavy-ion species for heavy-ion experiments and for future injection into RHIC.

In RHIC, heavy ions will collide at combined energies of 200 GeV per nucleon for gold and 250 GeV for protons, opening the door for a look at the conditions that existed in the universe just moments after the Big Bang.

MORE UPGRADING

To ready the AGS for the Booster and RHIC, an upgrading program has been in progress since 1984. Among the modifications under way are an improvement in the vacuum from 10^{-7} to 10^{-9} torr (see story p. 20). Also, a radio-frequency quadrupole preaccelerator, a fast beam chopper and a high-frequency dilution cavity have been installed, and a new, enlarged control room has been built. Among other improvements yet to be completed are major modifications to the radio frequency acceleration system and the main magnet power supply.

With the upcoming completion of the Booster and the start of RHIC construction, the AGS will enter its fourth decade as vigorously productive and as full of promise as it was in its first year — three decades ago.



A COORDINATE DIAGRAM IS USED TO DETERMINE THE SPACE-CHARGE EFFECT. THE SHADED REGION SHOWS THE ACTUAL FREQUENCY DISTRIBUTION OF THE BEAM DUE TO THAT EFFECT. THE RESONANCE LINES CROSSED BY THE SHADED REGION MUST BE CORRECTED FOR PROPER FUNCTIONING OF THE BOOSTER.

SMALL BOOSTER, BIG EFFECTS

Some 15 feet underground, northwest of BNL's Alternating Gradient Synchrotron (AGS), a 650-foot circular tunnel of corrugated steel pipe that is 11 feet in diameter has been under construction since 1988.

This tunnel is the site of the Laboratory's newest accelerator, the Booster. It is dwarfed by the AGS, which is four times larger. And when the Lab's next generation accelerator, the proposed two-and-a-half-mile-round Relativistic Heavy Ion Collider (RHIC) is built, the Booster will appear miniature by comparison.

But just as the best gifts often come in small packages, the accelerators that play key roles in the future of science are not always the largest.

That is the case with the Booster, for it will allow for the expansion of research in rare kaon (K) decay and neutrino experiments at the AGS as well as in polarized proton physics. In addition, it will provide the AGS with the ability to accelerate all heavy ions generated in the Tandem Van de Graaff accelerator, thus completing the injection chain for RHIC (see story p. 27).

THE BOOSTER TEAM

The promise of the Booster has become a timely reality, thanks to a team of about 100 scientists and engineers from the Alternating Gradient Synchrotron Department, working closely with the Accelerator Development and Physics Departments, and the Plant Engineering, Central Shops, Contracts and Procurement, and Safety and Environmental Protection (S&EP) Divisions. Since the $31.7-million project was approved by the U.S. Department of Energy in 1985, it has proceeded according to plan — meeting technical, schedule and cost requirements.

A WELCOME BOOST FOR SCIENCE

The Booster's name is based on its function. It boosts the energy and intensity of protons, polarized protons and heavy ions for the AGS.

The Booster will increase proton energy from 200 million electron volts to 1.5 billion electron volts for AGS injection. Currently, the average proton intensity in the AGS is 1.5 x 10^{13} protons per pulse (p/p). With the Booster, the proton intensity will increase fourfold to 5-6 x 10^{13} p/p to satisfy the demand for beam time for rare K decay and other experiments. Polarized proton intensity will increase by a factor of 20, to 10^{12} p p, for spin physics.

CHECKING THE INTERCONNECTION OF CORRECTOR MAGNETS IN THE BOOSTER TUNNEL ARE (FROM LEFT) ANDREW MCNERNEY, W.T. WENG AND Y.Y. LEE.

The AGS is currently equipped to accelerate heavy ions with a maximum atomic mass of 28, but the Booster, with a much better vacuum, will be able to accelerate heavier ions, up to gold (atomic mass 197). With gold ions coursing through it, the AGS will be ready to be the RHIC injector, and will also be capable of supporting its own fixed-target, heavy-ion research program.

STATE-OF-THE-ART DESIGN

The Booster has the most powerful radio-frequency (rf) systems for accelerating protons ever built at Brookhaven. Actually, four rf systems were designed by the AGS Department — two are required for accelerating protons, and all four are needed to accelerate heavy ions.

Crucial for guiding particles through the Booster are its 36 dipole and 48 quadrupole magnets. Also, specially configured quadrupole and sextupole magnets were designed by the Booster staff to correct the space-charge effect, a problem common to all low energy proton synchrotrons, in which particles stray from a stable orbit because of the electrical field effect from neighboring particles. Our pioneering research in this area has benefited other booster design projects in the U.S. and Canada.

Another important feature of the Booster is its ultrahigh vacuum system, which will operate at 3 x 10^{-11} torr. This will allow for the acceleration of partially stripped heavy-ion species as massive as gold to peak energy in the Booster. Subsequently, the electrons will be completely stripped from the ions and the ions will be injected into the AGS. At a current operating vacuum of 10^{-7} torr, the AGS vacuum system cannot accelerate ion species with masses heavier than sulfur. With the soon-to-be-completed vacuum upgrade in the AGS to 10^{-9} torr, partially stripped ions will be accelerated in the AGS.

To maintain this ultrahigh vacuum, all Booster components are fired in a special oven at 900°C for two hours. Also, all vacuum-system components undergo stringent cleaning and surface treatment.

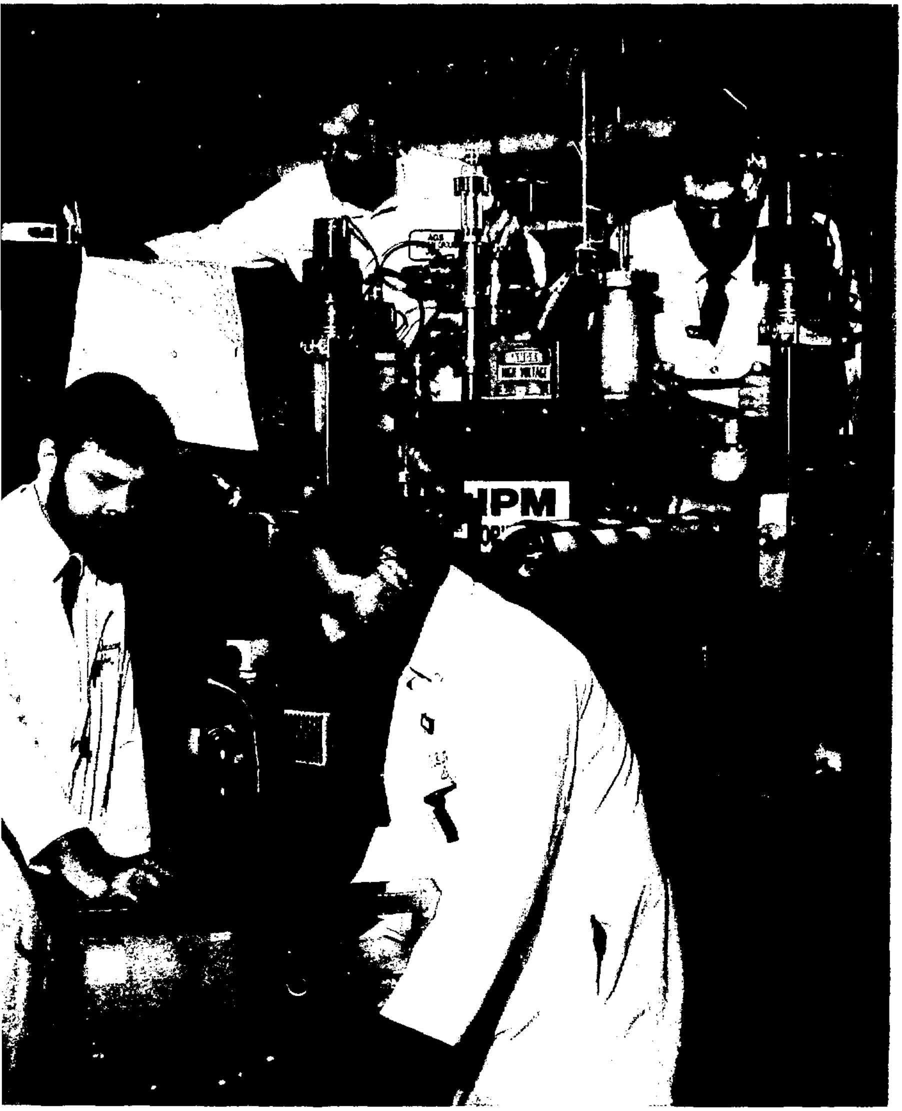
The vacuum system is made entirely of metal, so that it will not be susceptible to degradation from radiation. Its key components are 36 half-cell chambers, 12 quarter-cell chambers, pumps, gauges and the bakeout system.

Other challenges successfully met by the Booster team include compensating for the beam-loading effect, an electrical problem in which the beam-induced voltage distorts accelerating voltage. Also, the eddy current-induced dipole field distortion, due to a changing magnetic field, was successfully counteracted by the correction coil designed by the AGS scientists.

SAFETY FIRST

The Booster team worked closely with S&EP to design all safety features — from the sprinklers to the emergency exit interlock system. The AGS Experimental Areas Group designed, fabricated and installed 700 tons of concrete and ilmenite shielding between the AGS and the Booster. As a result, radiation levels in work areas of the Booster have been reduced to well below federal guidelines.

Everything is in place so that the Booster will be ready to do its job in 1991. And, when RHIC is built, it will be increasing its workload as time goes on, boosting science into new realms until well into the next century. •



AT THE ALTERNATING GRADIENT SYNCHROTRON, (FRONT, FROM LEFT) GARY MCINTYRE, STEPHEN GILL, (BACK, FROM LEFT) JOSEPH TUOZZOLO AND KIMO WELCH MAKE A FINAL APPRAISAL OF A NEWLY INSTALLED ION PROFILE MONITOR, A DEVICE USED TO DETERMINE THE PATTERN OF ACCELERATED PARTICLE BEAMS IN THE VACUUM SYSTEM.

Nothing Beats The New Vacuum

From automobiles to televisions, most machines need major repairs or replacement after a decade. That was the case with the vacuum system in Brookhaven's Alternating Gradient Synchrotron (AGS). After considerably more than a decade of service — 26 years to be exact — the vacuum system that played a key role in the AGS's illustrious history needed a complete overhaul.

A major upgrading program for the AGS vacuum system began five years ago and will be completed in 1991. The purpose of the long-term program is to improve the accelerator's reliability, increase ease of maintenance, and lower its operating pressure from 2-3 x 10^{-7} torr to 10^{-9} torr.

A perfect vacuum is the absence of all gas molecules. A pressure of 10^{-9} torr corresponds to 0.00000000013 percent of the density of gas molecules found in air at sea level.

When accelerated in the AGS, protons and heavy ions must travel a distance roughly equivalent to a round trip from the earth to the moon. A vacuum is needed in the AGS so that the particles do not collide with gas molecules along their extended journey. Such collisions would cause loss of the beam in the machine. Beam loss diminishes the intensity of the beam for use in experimental programs and creates problems of residual radioactivity in machine parts.

Completion of the Booster in 1991 (see previous story) will allow for the acceleration of intense beams of ionized gold, which will be injected into the AGS at 350 million electron volts per nucleon. Gold ions, with almost all their electrons removed when injected into the AGS, will be highly positively charged and, therefore, be attracted to negatively charged electrons. If a gold ion picks up electrons during acceleration, it will travel in a different orbit from the main gold beam and, thus, become lost.

The first phase of the vacuum improvement program involved the design, construction and installation of the instrumentation and control system. This system can monitor vacuum system pressures throughout the AGS at any moment, and it is able to retrieve historical data to reconstruct the system's status. It can also be used to quantify outgassing and gas leaks from the surrounding air into the AGS.

The quality of the vacuum in any system depends on balancing gas sources and gas sinks, that is, vacuum pumps. Therefore, improving the quality of a vacuum is a bookkeeping task. The new control system facilitates this bookkeeping. From computer workstations conveniently located about the AGS, scientists can monitor and control the status of any vacuum component.

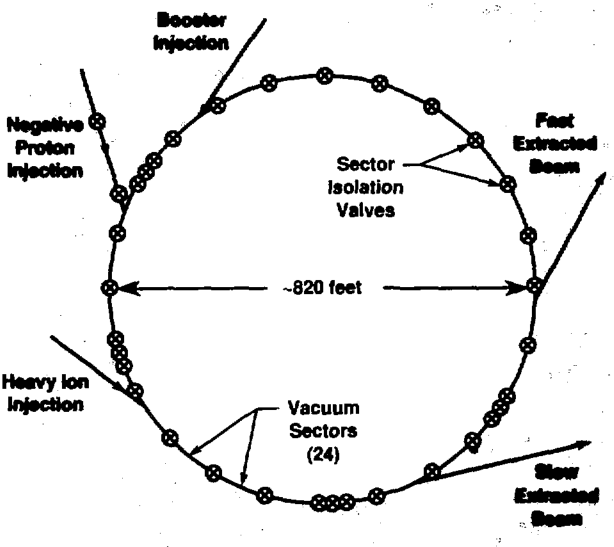


DIAGRAM OF THE AGS VACUUM SYSTEM.

Since the system was commissioned in 1988, the ledger of gas sources identified has included leaks from unreliable metal seals and fatigued components, and outgassing from plastic components and elastomer seals. New metal vacuum sealing technology was substituted for the older designs and most of the elastomers and plastic components were replaced with metal seals and ceramic insulators respectively.

Elastomer seals and plastic components are degraded by radiation exposure stemming from beam operation. Failure of these materials due to radiation damage results in vacuum leaks that cause machine downtime and exposure of maintenance personnel to radiation when doing repairs.

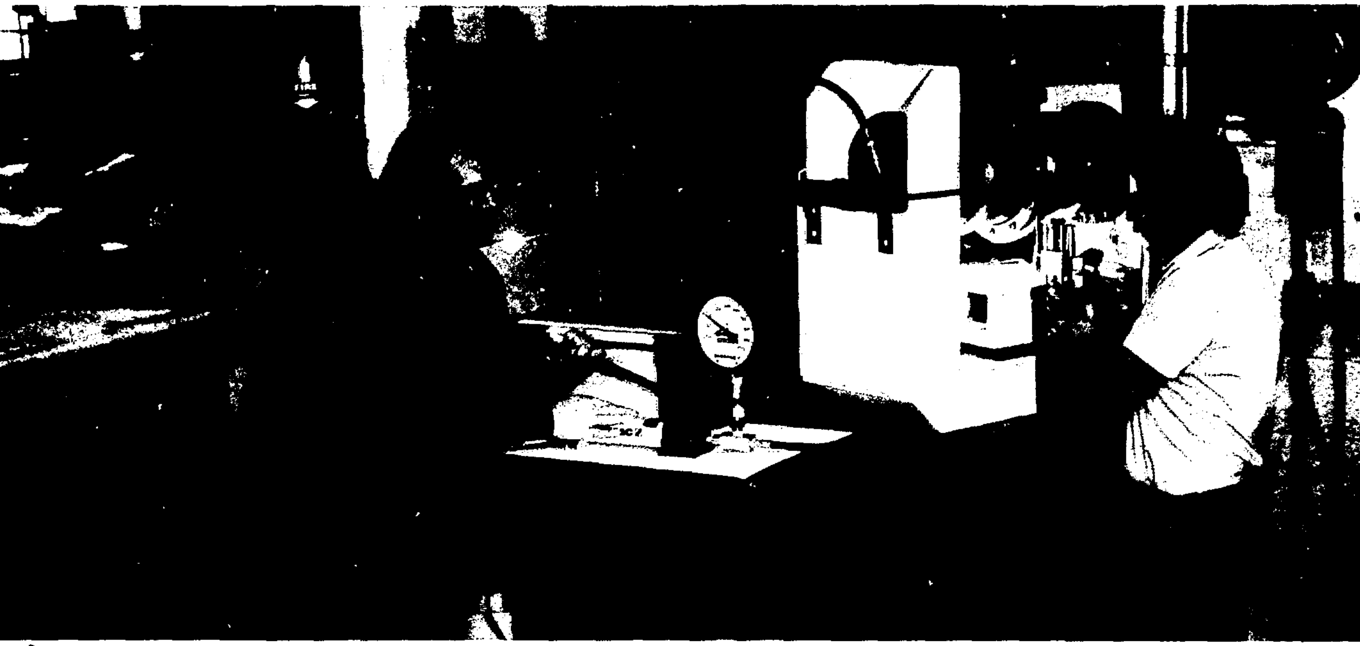
Therefore, elimination of elastomers and plastics, besides reducing sources of gas in the AGS, also greatly improves the reliability of the machine and minimizes exposure to radiation.

In 1991, the AGS team will complete the last phase of the vacuum overhaul. Included in the improvements will be the refurbishment of 240 dipole magnet chambers and the installation of a like number of new pumps throughout the ring. These pumps have greater speed, thus assuring achievement of lower pressures.

Dividends of the entire vacuum system overhaul are already being realized in AGS operating hours. The AGS downtime due to vacuum system failures in the last five years has gone from 188 hours in 1985 to 17.5 in 1990. When the job is complete, BNL scientists, as well as visiting researchers from throughout the world, will reap the benefits of more AGS experimental time for years to come. •

ACCELERATOR DEVELOPMENT DEPARTMENT

The Accelerator Development Department (ADD) plays a key role in designing and building the new generation of high energy and nuclear particle accelerators at the Laboratory. Thus, ADD consolidates Brookhaven's activities in the construction of the Booster for the Alternating Gradient Synchrotron and in the technical development of the Laboratory's Relativistic Heavy Ion Collider. Another mission of the department is to advance the technologies that are essential to particle accelerators through research and development in the areas of accelerator physics, cryogenic and vacuum technology, and the application of superconductivity. The department is also responsible for BNL's contribution to the national high energy accelerator initiative, the Superconducting Super Collider in Texas.



New Post Supports: Cost Cutters For RHIC

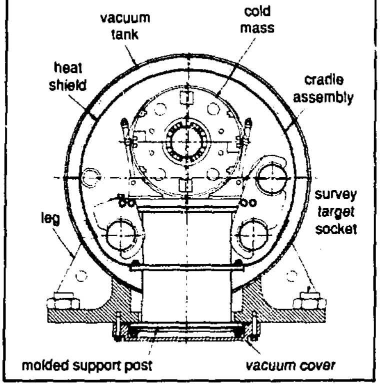
Shortly before the turn of the century, a new, unique accelerator — the Relativistic Heavy Ion Collider (RHIC) — will be built at BNL. Using this collider of the future, physicists will be able to explore the beginning of time and space.

By colliding heavy-ion particles at high energies in RHIC, scientists hope to detect the creation of a quark-gluon plasma — a dense form of matter that is believed to have existed just microseconds after the Big Bang.

Modern theory predicts the formation of a quark-gluon plasma. To recreate and test it, RHIC will be the premier tool. This world-class facility will provide researchers with the high-density, high-temperature conditions that are essential for this quest.

RHIC construction is expected to start in 1991, and many scientists and engineers in the Accelerator Development Department are now working together to design and test its myriad complex components. One crucial element in the design of RHIC is the magnet post supports.

Their job is structural — they will support and hold the accelerator's superconducting magnets, keeping them steady and permanently fixed in a position to guide heavy ions traveling at nearly the



CROSS-SECTION OF RHIC CRYOSTAT SHOWING MOLDED PLASTIC SUPPORT POST.

AT BROOKHAVEN'S MATERIALS TESTING LABORATORY, (FROM LEFT) CHRISTOPHER WHITE, MARK SARDZINSKI AND BOB DAGRADI SIMULATE RHIC OPERATING CONDITIONS TO TEST A PAIR OF CRYOSTAT POSTS.

speed of light around the two rings within the 2.5-mile RHIC tunnel. The post supports also will provide an excellent thermal insulation, making it possible for refrigeration to maintain the magnets at the ultracold temperature of about 4 kelvins.

Engineers in the Accelerator Development Department have completed a prototype for the 2,500 post supports that will be needed to hold RHIC's 1,600 superconducting magnets in place — and they have succeeded in making the design highly efficient. In fact, a total savings of about $6.3 million in RHIC construction costs will be realized by using our new, improved design.

RHIC's design calls for its magnets to be positioned on post supports inside an insulating vacuum vessel, called a cryostat.

Like a thermos bottle, the cryostat reduces thermal loss in order to keep the magnets' temperature at 4 kelvins, the temperature required for superconductivity. The cryostat's insulating vacuum and blankets of superinsulation shield the magnets from the heat of room temperature (about 300 kelvins) by reducing conductive heat paths and thermal radiation losses.

Using as their working model a basic design for post supports developed by Fermi National Accelerator Laboratory scientists, BNL engineers developed an injection-molded plastic post for RHIC magnets. The new RHIC post assembly is made of Ultem 2100 engineering thermoplastic, an inexpensive form of durable plastic manufactured by General Electric.

This new design simplifies fabrication of the supports, which in previous accelerators have been made of mechanical assemblies of fiberglass straps and tubes.

Post supports must have low heat conductivity because the top of the support is at the superconducting temperature of 4 kelvins, while the bottom of the support remains at room temperature. Since Ultem 2100 has about 20 percent of the thermal conduction of fiberglass, plastic supports can use thicker material for increased strength while slightly reducing refrigeration costs in running the superconducting magnets.

Increased strength is an important feature of the molded post design because the posts have to withstand the tremendous thrust forces that a magnet must tolerate during operation. The Ultem 2100 design can easily withstand the expected loads, whereas the previous design relied upon expensive fiberglass restraint straps to keep the magnet in position, an additional thermal load to the system. •

STEPHEN PLATE (FRONT LEFT) THOMAS DILGEN (BACK LEFT) AND EUGENE KELLY INSERT AN SSC MAGNET COLD MASS ON ITS SUPPORTS INTO A CRYOSTAT

Steady Progress on SSC Magnet Design

The finest race car with the highest performance on record would be a useless piece of machinery without a steering wheel. Similarly, the Superconducting Super Collider (SSC) could not operate without the superconducting magnets that will guide and focus protons along its 54-mile circular tunnel.

Since 1984, Brookhaven, Fermi National Accelerator Laboratory (Fermilab), Lawrence Berkeley Laboratory and the SSC Central Design Group have been collaborating on designing these SSC magnets.

Since then, approximately 140 scientists and support staff in BNL's Accelerator Development Department have built and tested 16 prototype 25,000-pound, 55-foot-long arc dipole magnets for the SSC. About 85,000 square feet of factory space in three BNL buildings is used to build the tooling for the magnets, produce the prototype magnets and test them.

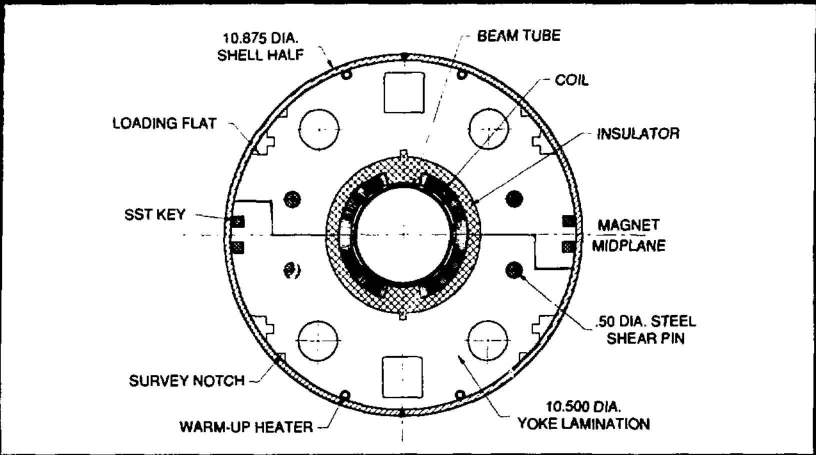
Approximately 8,000 curved dipole magnets will be needed to guide protons through the SSC tunnel, and another 2,000 navigating magnets will keep the protons focused on their narrow paths. To realize the desired proton collision energy of 40 trillion electron volts, the magnets must operate at a field strength of 6.6 teslas, or about 263,000 times the level of the earth's magnetic field.

The SSC prototype magnets use a niobium-titanium superconductor in a set of coils surrounded by a stainless steel collar and an iron yoke. The design adapts features from earlier superconducting magnet projects, such as the Tevatron at Fermilab and BNL's Colliding Beam Accelerator, which was cancelled in 1983.

The superconducting magnets will allow the SSC to operate on only a hundredth of the power needed for conventional magnets. A super-low temperature of −370°F is needed for superconductivity because that is the temperature necessary to eliminate electrical resistance in niobium-titanium coils. To maintain this temperature, cryogenic helium surrounds the coils and the iron yoke of the magnets.

All told, 8,000 SSC curved dipole magnets will require enough superconducting cable to wind around the earth's equator 25 times, and enough power and precision to steer a proton beam at its full energy in a path about one-millimeter wide for two days, traveling a distance equal to 180 round-trips from the earth to the sun.

The size of the beam tube of the magnets, called the aperture, is crucial for efficient operation. The original design of the magnets called for an aperture of four centimeters, hence BNL built the initial SSC magnets with an aperature of that size. Later, SSC scientists



CROSS SECTION OF A CURVED DIPOLE MAGNET FOR RHIC. At 9.7 METERS LONG, DIPOLES ARE THE LARGEST AND MOST IMPORTANT OF THE 1,600 SUPERCONDUCTING MAGNETS THAT WILL GUIDE HEAVY IONS AROUND THE COLLIDER'S 2.5-MILE-LONG TUNNEL.

RHIC MAGNETS

Construction of BNL's Relativistic Heavy Ion Collider (RHIC) will begin in 1991. Then, if the six-year building project stays on schedule, RHIC will begin operation in 1997, marking a new era in science.

In RHIC, two beams of heavy ions will whirl around a 2.5-mile-long tunnel in opposite directions. At six points around the accelerator, they will collide at an energy of 200 billion electron volts times the number of nucleons in each ion. From experiments to be performed at RHIC, scientists hope to discover a new form of matter thought to have been present just a moment after creation of the universe.

As in the Superconducting Super Collider (SSC), the magnets for RHIC are crucial for its functioning. Along with the SSC prototype magnets, scientists in Brookhaven's Accelerator Development Department have been designing and testing RHIC protoypes.

RHIC will require 1,600 superconducting magnets. About 1,400 of them will be built by industry, based on BNL's prototypes, and the balance will be built by BNL. All of the magnets will be tested at Brookhaven.

The RHIC magnets are simpler, smaller, and thus more economical than SSC magnets. They are 9.7 meters long, have no stainless steel collar and use only a single layer of superconducting coil. The yoke spacer in the RHIC magnets is phenolic, a thermosetting plastic, rather than the more expensive stainless steel used in the SSC magnets.

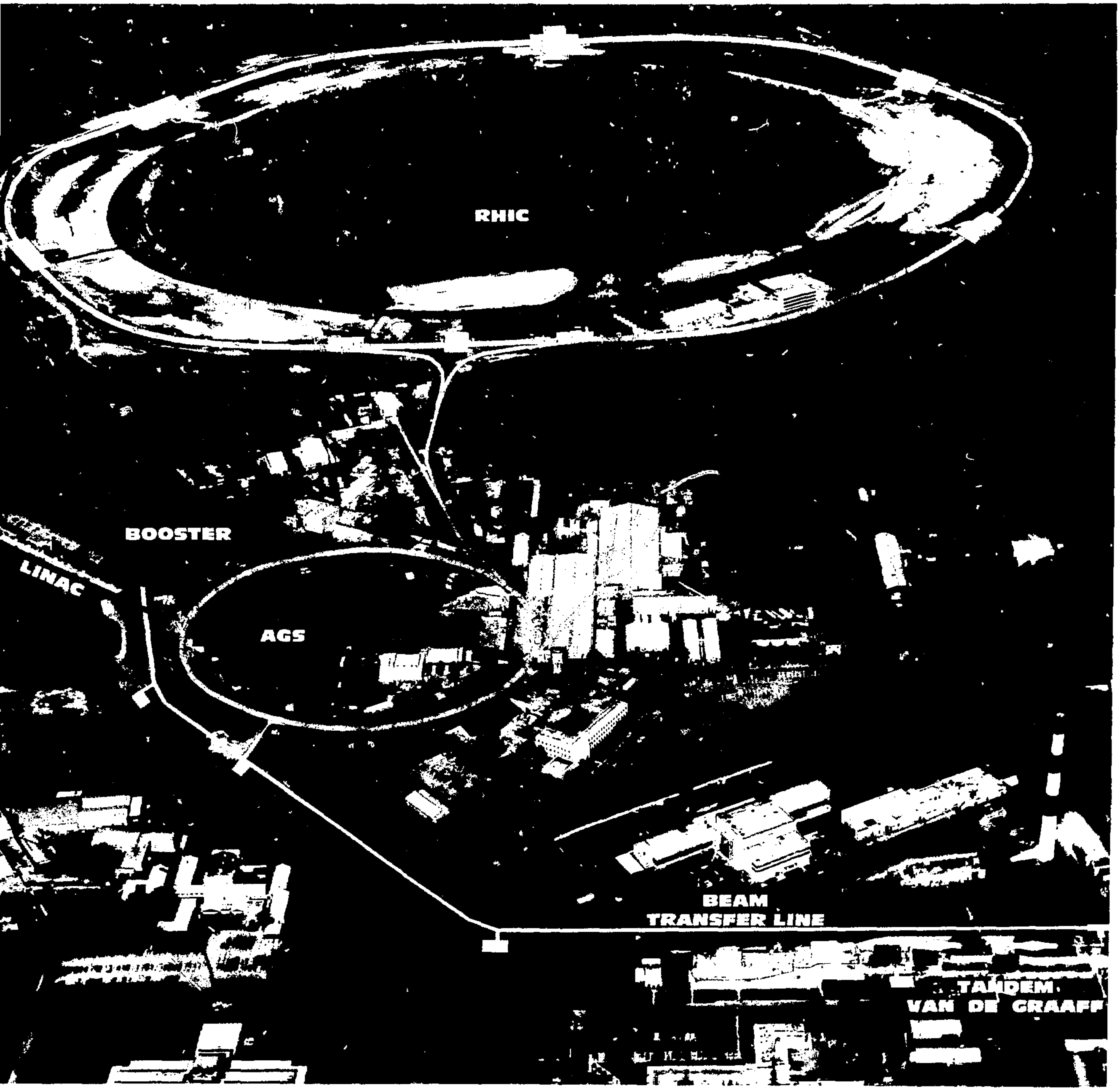
All RHIC prototype magnets tested in Brookhaven's MAG-COOL facility at their operating temperature of 4.3 kelvins have operated as planned — above the operating magnetic field of 3.45 teslas with a safety margin of approximately 25 percent.

Magnet production is expected to begin in 1992 and be completed by 1996. A year later, we expect that RHIC will be the world's premier tool for probing the new states of nuclear matter created by collisions of ultrahigh energy, heavy-ion beams.

decided that the collider required a magnet aperture that would provide an increased operating margin for beam stability.

At the request of the SSC administration, BNL researchers designed and produced new magnet prototypes with a five-centimeter aperture. These larger magnets will allow the SSC to operate at its maximum energy with less disturbance to the proton beams.

If the construction budget for the SSC is approved, and the building and testing of magnet prototypes proceeds on schedule, industrial production of the 8,000 magnets will begin in 1991. The SSC administrators will evaluate cost estimates from interested companies, and the selected contractor will use the prototype models developed by the collaboration to mass-produce superconducting magnets.



RHIC – The Final Link In The Chain

BNL physicists expect to start the new millennium poised to discover a new state of matter — ready, not only with the knowledge and creativity needed to accomplish this feat, but also, with the advanced machinery that makes such milestones possible.

This advanced machinery is actually a chain of four Brookhaven accelerators that starts with the Tandem Van de Graaff accelerator. The chain's last link — the Relativistic Heavy Ion Collider (RHIC) — is expected to be completed in 1997.

In RHIC, two colliding beams of heavy ions with atomic weights as heavy as gold (197) will collide at a combined energy of 200 billion electron volts per nucleon (GeV/n). This tremendous energy is expected to produce extremely dense matter at the high temperatures that are believed to have existed at only one other time — in the few microseconds after the birth of the universe. Both nuclear and high energy physicists are eager to explore this new form of matter when RHIC is commissioned.

While RHIC may still seem a long way off, we already have a head start on the project. At BNL, the 2.5 mile circular tunnel that will house RHIC's beam lines and experimental areas already exists, constructed for the Colliding Beam Accelerator, on which work ceased in 1983. And with the commissioning of the Booster in 1991, we will complete the chain of accelerators needed to inject ions as heavy as gold into RHIC.

FROM THE TANDEM TO RHIC

The first link in the accelerator chain was forged in 1986, when the Tandem Van de Graaff accelerator was joined with the AGS via a newly constructed 2,000-foot-long, 10-foot-diameter tunnel known as the Heavy Ion Transfer Line. In October of that year, the Tandem/AGS Heavy Ion Project was proven a success when oxygen ions, with an atomic weight of 16, were generated in the Tandem and sent via the new beam transfer line to the AGS, where they were accelerated to 14.5 GeV/n.

Then 26 years old, the AGS, a proton accelerator, had already been modified to accelerate heavy ions. Among the improvements installed to achieve this were a new injection system, an additional radio frequency cavity, and a new computerized control system that was connected to the transfer line through a BNL-developed cable system.

Several months later, in March of 1987, beams of silicon ions generated in the Tandem were also accelerated to the full design energy of 14.5 GeV/n in the AGS. Since silicon has an atomic weight of 28, compared to oxygen with an atomic weight of 16, more silicon nucleons were compressed into a single nuclear interaction, which provided scientists with a better chance to find the new high-density state of matter they wished to explore.

Currently, the AGS is able to accelerate ions with an atomic mass as heavy as 28, for use in experiments in which the beams collide against stationary targets of aluminum, carbon, copper, silver and gold. To accelerate all the ions the Tandem can generate, up to gold, one more accelerator is needed — the Booster.

The Booster, a rapid-cycling synchrotron in a 650-foot-long circular tunnel of corrugated steel pipe some 11 feet in diameter, has been under construction since 1988. This small accelerator will be able to accelerate ions as heavy as gold, and it will also provide the AGS with the capability to accept these ions when the older machine's vacuum system refurbishment is complete. Finally, the AGS will be able to accelerate these heavy ions for injection into RHIC.

Thus, heavy ions will be accelerated at increasingly greater energies as they travel at close to the speed of light from one accelerator to the next — from the Tandem to the Booster to the AGS to RHIC — leading scientists into new realms of matter and new discoveries at each link of the chain.

FOR EXPERIMENTS AT THE RELATIVISTIC HEAVY ION COLLIDER (RHIC), HEAVY IONS GENERATED IN THE TANDEM WILL BE SENT VIA THE TRANSFER LINE TO THE BOOSTER, AND CONTINUE TO THE ALTERNATING GRADIENT SYNCHROTRON FOR FINAL ACCELERATION BEFORE BEING INJECTED INTO RHIC.

PHYSICS DEPARTMENT

In the Physics Department, researchers study the fundamental constituents of matter, seeking to understand the forces through which these constitutents interact to form nucleons, nuclei, atoms and ordinary matter. Specialists in theoretical and experimental high energy physics, nuclear physics and solid state physics investigate a wide range of phenomena. These range from probing the most submicroscopic building blocks of matter, quarks and leptons; to elucidating the types of excitations and structure of atomic nuclei; to studying macroscopic effects in bulk matter, such as the new high-temperature superconductors.

Shedding Light On Heavy-Ion Physics

In three major experiments at the Alternating Gradient Synchrotron (AGS) — experiments 802, 810 and 814 — BNL physicists, as part of international research collaborations, are investigating extremely dense nuclear matter that is produced in high energy heavy-ion collisions.

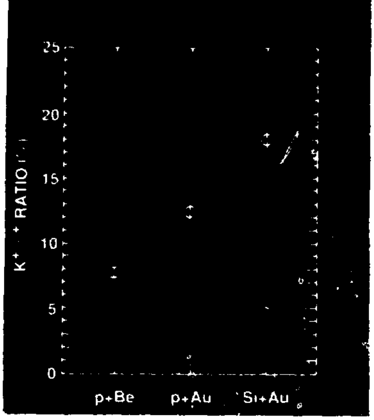
Heavy ions are charged atomic nuclei that are heavier than a helium nucleus (atomic weight 4). In 1986, heavy-ion experiments became possible at the AGS when that accelerator was linked by a beam transfer line to the Tandem Van de Graaff. The Tandem provides low energy beams of heavy ions of oxygen and silicon, which are then accelerated to high energy by the AGS.

In E802, which began in 1984 and concluded last year, scientists were specifically interested in the characteristics of protons, pions and kaons — particles that are emitted in collisions between target nuclei and the heavy ions accelerated by the AGS.

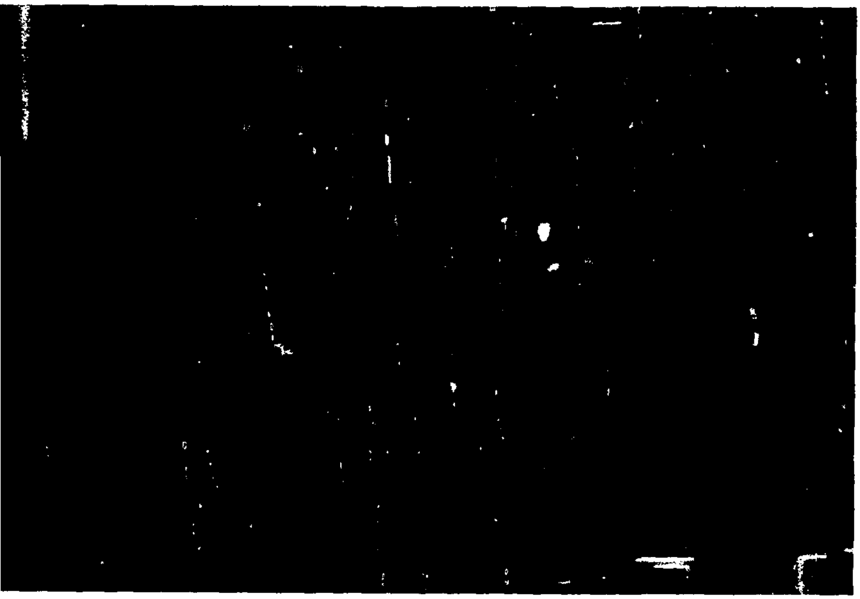
NEW FORM OF MATTER

In these experiments, researchers smash heavy-ion oxygen and silicon beams at an energy of 15 billion electron volts (GeV) per nucleon against targets of aluminum, carbon, copper, silver and gold, in an effort to understand heavy-ion reactions in this energy range. The goal is to find evidence of a quark-gluon plasma.

According to modern theory, a quark-gluon plasma is a form of matter believed to have been present at the birth of the universe. It is a state in which quarks, the fundamental constituents of all



THE GRAPH SHOWS THE RATIO OF POSITIVE KAONS TO POSITIVE PIONS PRODUCED WHEN PROTON AND SILICON PROJECTILES COLLIDED WITH BERYLLIUM AND GOLD TARGETS IN EXPERIMENT 802 AT THE ALTERNATING GRADIENT SYNCHROTRON.



CHELLIS CHASMAN INSPECTS ELECTRONIC CABLING ON THE SPECTROMETER NEAR THE TARGET OF EXPERIMENT 802 AT THE ALTERNATING GRADIENT SYNCHROTRON. THE GOAL OF E802 IS TO FIND EVIDENCE OF A QUARK-GLUON PLASMA.

baryons, including nuclear particles — protons and neutrons — are freed from their confinement in the individual nucleons and can move throughout a larger volume. When a heavy-ion projectile slams violently into a target nucleus, it is believed to create a high-temperature, high-density state that is favorable for the creation of a quark-gluon plasma.

With the aid of state-of-the-art computers, the E802 researchers systematically make many different measurements of particles that are born of these heavy-ion collisions at the AGS. The types and number of particles, their energy flow, their velocity, their angular and momentum distributions — all these characteristics are examined with the use of a magnetic spectrometer and other detectors in hopes of discovering evidence that might signify the formation of a quark-gluon plasma.

Even if discovery of a quark-gluon plasma proves to be elusive, these experiments are valuable. They provide measurements of the properties of nuclear matter under the conditions of extremely high baryon and energy density made in these collisions.

SURPRISING FINDINGS

The results of E802 are promising. One unusual finding — the type for which physicists were looking — was that the ratio of positive kaons (K) to positive pions (π) produced when silicon nuclei collide with gold is almost three times the ratio produced when protons collide at the same energy. These initial results were established firmly when the measurements were extended over larger angles and momentum ranges.

Subsequent measurements made with a proton beam imply a systematic increase in the K/π ratio with increasing target or projectile mass. Because there is a variety of theoretical interpretations of these results, additional investigation is needed to understand their significance.

Another surprising result was that the total transverse energy of the produced particles reaches the same maximum, whether the target is a gold nucleus or a copper nucleus (which is about half the size of gold). This indicates that the projectile oxygen nucleus in the beam was stopped in the target nuclei. It also confirms that high-density regions are formed in these collisions — a condition favorable for a quark-gluon plasma formation.

FURTHER MEASUREMENTS

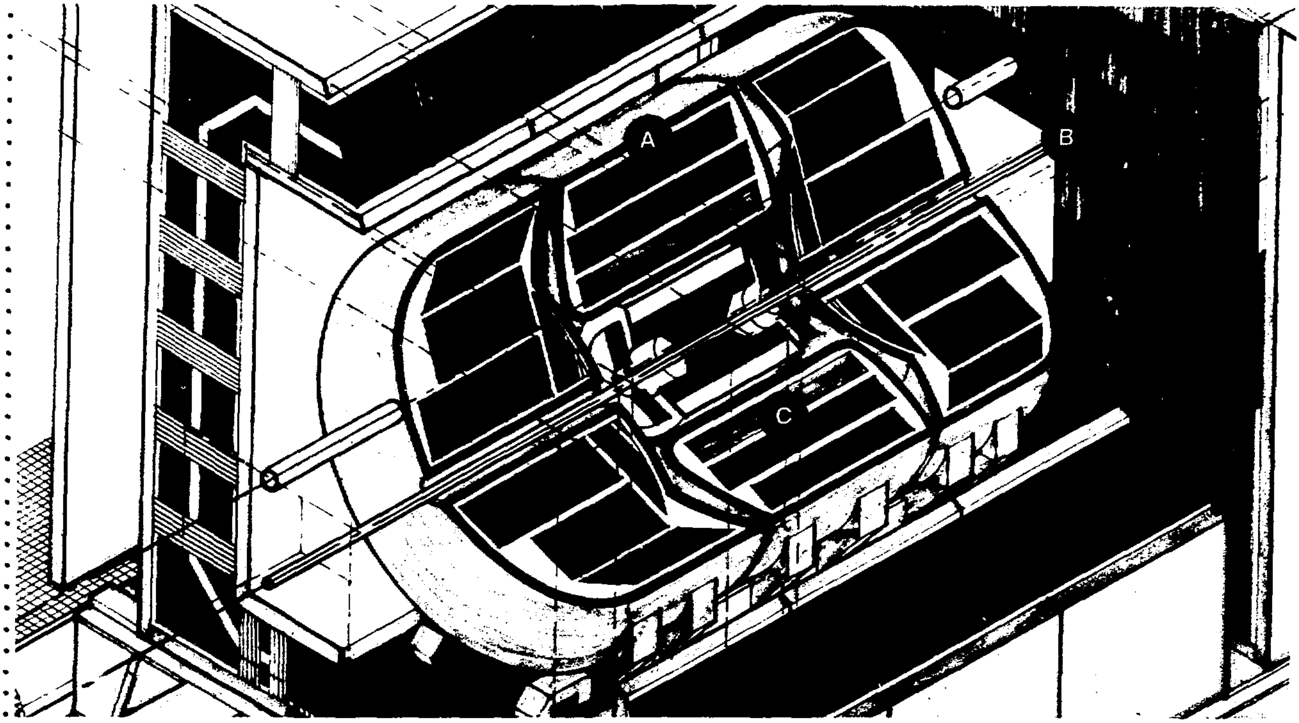
An extension of E802 is E859, which first started taking data in 1989. This second-generation experiment is expanding the range and scope of E802 by increasing the sensitivity of the spectrometer. The researchers' goal is to measure the size of the "hot spot," the boiling mass from which particles are emitted in these collisions. Also, they will study the spectra of the rarer particles, such as antiprotons and K^- particles.

In 1992, following completion of the Booster accelerator now under construction (see story p. 18), the AGS will be able to accelerate a gold beam. E866, a further extension of E802, is now conditionally approved to continue spectrometer measurements with the gold beam. These measurements are anticipated with great interest because the large size of the gold projectile is expected to enhance substantially all the effects of high baryon and energy density.

INTO THE FUTURE

The AGS heavy-ion experiments are limited in their search for a quark-gluon plasma by the beam energy. With construction of the Relativistic Heavy Ion Collider (RHIC), however, heavy-ion experimentation at Brookhaven will take a giant leap forward into exploring unknown forms of matter.

In RHIC, two colliding beams will produce energies of 200 GeV per nucleon. This will enable researchers to investigate the type of matter that existed in the universe just moments after the Big Bang. •



CROSS-SECTION OF DØ DETECTOR. A — CENTRAL CALORIMETER, B — TeV I BEAM LINE, C — CENTRAL DETECTOR.

From D-Zero To Top Quark

Its construction has taken eight years and approximately 160 physicists from 21 institutions, including seven physicists and about 20 technicians from BNL. It weighs 4,700 tons, but it has been designed to detect particles so small that millions of them grouped together would still be invisible to the naked eye.

This huge device is a high-energy physics detector, dubbed D-zero (DØ) after its location at the powerful Tevatron accelerator at Fermi National Accelerator Laboratory (Fermilab).

BEATING THE ODDS

Using the DØ detector, Brookhaven physicists, along with other physicists from all over the world,

(FROM LEFT) BROOKHAVEN PHYSICISTS HOWARD GORDON, SERBAN PROTOPOPESCU, BRUCE GIBBARD AND STEPHEN KAHN USE A VAX COMPUTER TO STUDY THE RESPONSE OF THE DØ DETECTOR TO HIGH ENERGY COLLISIONS.

hope to find the top quark. If this elusive subatomic particle is found, it would verify the standard model, the theory of matter as physicists know it today.

According to the standard model, all matter is composed of fundamental particles called quarks and leptons. The theory maintains that there are six quarks in three families — the up and down quarks, strange and charm quarks, and top and bottom quarks.

Five of these quarks have been discovered over the past three decades. Finding the sixth — the top quark — would be akin to getting the sixth and final number right in a lottery ticket — not just a matter of luck as in playing the lottery, but also a long shot. Brookhaven physicists hope that when DØ is completed in 1991, it will beat the odds.

MORE POWER, MORE PARTICLES

At the Tevatron, a beam of protons and a beam of antiprotons directed by powerful magnets are hurled repeatedly in opposite directions through a four-mile-long circular tunnel until they reach nearly the speed of light — and then they collide. The accelerator can produce about 50,000 of these collisions per second. Out of the billions of collisions that will take place daily in DØ, our physicists, with the aid of computer software that they designed specially for this purpose, will select for study only the collisions that produce top quarks.

Since top quarks are at least 80 times heavier than protons, a very high energy is needed to produce them. But Brookhaven scientists are hopeful that the Tevatron's maximum collision energy of two trillion electron volts will be enough to do the job. If not, then only two proposed colliders in the world would be powerful enough to enable physicists to find the top quark: the Large Hadron Collider, which is proposed to be built at CERN in Europe and would have eight times the collision energy of the Tevatron, or the Superconducting Super Collider, which is under development in Texas and will have a twentyfold increase in collision energy over Fermilab's accelerator.

CENTRAL CALORIMETER

In their team effort with many universities and other laboratories, Brookhaven physicists have designed a crucial piece of equipment in DØ — its central calorimeter.

After particles collide, their energies will be absorbed and measured by the calorimeter. Made of copper and uranium, the 600-ton calorimeter consists of 64 modules — 32 electromagnetic modules to detect the energy of photons and electrons, as well as 16 finely sectioned and 16 coarsely sectioned hadronic modules that will measure the energy of hadrons, particles made of quarks and gluons.

The central calorimeter complements two others at DØ, which will also measure energies from particles emitted at different angles. This combination of the three calorimeters is designed to catch most of the particles produced in the proton-antiproton collisions. The key elements in the calorimeters are uranium plates immersed in liquid argon, a combination that provides excellent energy resolution.

The particle collisions that will take place in DØ cannot be directly observed. Instead, the patterns they create will be recorded in a central computer and displayed on a video screen for scientists to interpret.

A VAX computer will filter collisions and record those pertinent to the task of finding the top quark. The unique software for the VAX and for the computers at satellite workstations involved with DØ has been created and tested by the Brookhaven group and other DØ collaborators.

COMPETITION AND CONFIRMATION

Another detector at Fermilab, known as the Colliding Detector (CDF), was completed in 1985. Each team of researchers at the Tevatron's respective detectors, CDF and DØ, is hoping to be the first to find the top quark. But the existence of two detectors is needed for confirmation as well as for competition, since each group will be expected to confirm the other's findings.

JIA WANG (LEFT) AND BENJAMIN OCKO PREPARE AN ELECTROCHEMICAL X-RAY DIFFRACTION CELL FOR STUDIES OF GOLD SURFACES AT BEAM LINE X22B AT THE NATIONAL SYNCHROTRON LIGHT SOURCE.

SURFACE STUDIES AT NEW DEPTHS

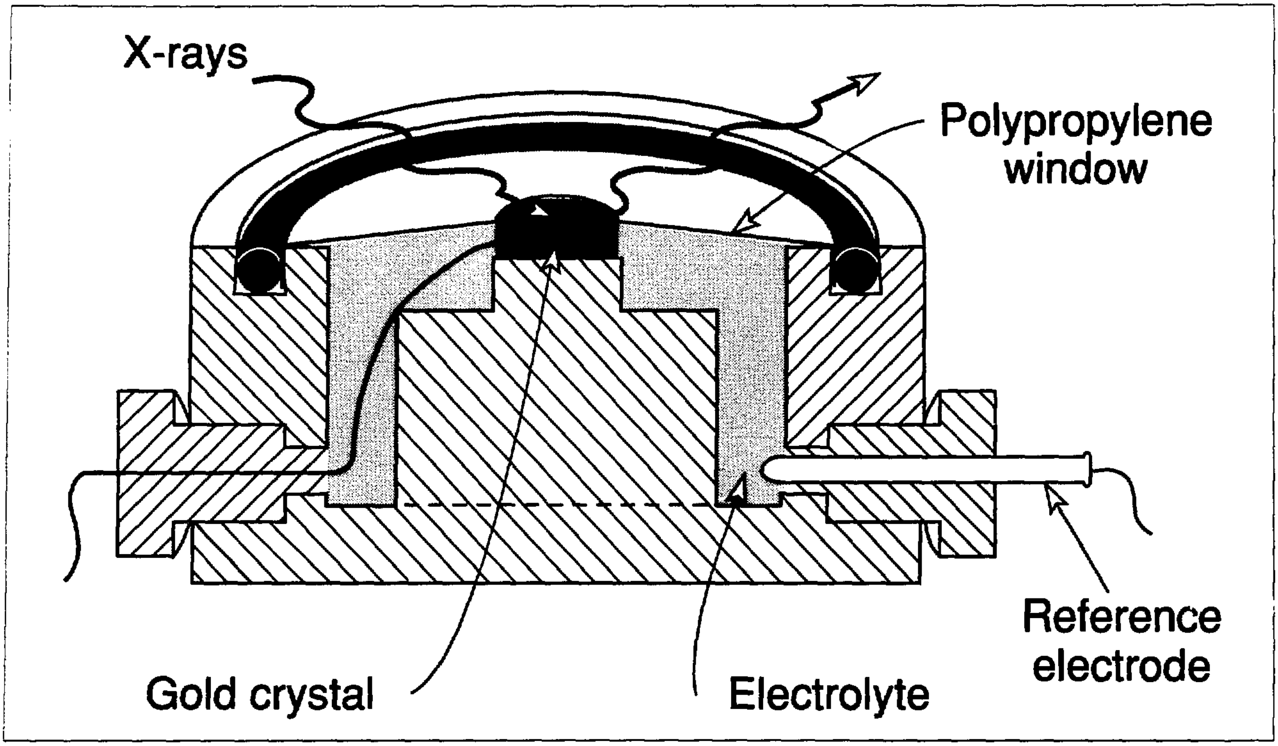
In recent decades, scientists have progressed rapidly in characterizing surface structures in a vacuum. These studies have revealed that the arrangement of the first layer of atoms on a metal surface may differ from the underlying atomic layers of the material — a phenomenon known as surface reconstruction.

But, until now, little was known about the characteristics of electrode surfaces in their natural electrochemical environment — in electrolytic solutions with an applied voltage. This year, thanks to innovative groundwork at BNL, Laboratory scientists are making strides in this area.

BNL physicists, collaborating with researchers in the Department of Applied Science, have developed a technique that makes these in situ electrochemical surface studies possible. A striking result of these studies on single crystal gold surfaces is that we now know that the surface gold atoms are very well-ordered in electrolytic solutions. Applying a sufficiently high negative voltage induces a surface reconstruction.

Understanding the atomic characteristics of surfaces is crucial to many industries, including the computer, polymer and coating industries. The investigation of electrochemical surfaces, in particular, is important for a fundamental understanding of batteries, metal plating, catalysis and semiconductor processing.

Our scientists use the intense x-rays generated at BNL's National Synchrotron Light Source to probe electrode structure in situ. At beam lines X22B and X22C at the Light Source, BNL researchers use x-ray diffraction to observe the surface structure of two crystal orientations of gold known as (001) and (111). This research is



A SINGLE GOLD CRYSTAL IS EXPOSED TO X-RAYS IN AN ELECTROCHEMICAL CELL TO STUDY THE CHANGES IN THE TOP SURFACE LAYER OF ATOMS A THIN LAYER OF ELECTROLYTE IS MAINTAINED ON THE SINGLE CRYSTAL SURFACE BY A THIN FILM OF POLYPROPYLENE

an important breakthrough because it provides researchers with the ability to investigate directly many factors that can affect the surface reconstruction.

In situ x-ray diffraction studies are carried out by mounting a small electrochemical cell, containing the gold sample, into a diffractometer, a device that allows the scattering angles of the sample to be precisely controlled by a computer. Photons from the x-ray beam at the Light Source hit the crystal's surface, scatter, and diffract. The intensity of the diffracted beam is measured by a detector, and the data are used to determine the arrangement of the surface atoms.

When a sufficiently high negative voltage is applied to the gold (111) surface, the reconstructed top layer forms a distorted hexagonal surface layer that contains more atoms than the underlying layers. This particular reconstruction is known as a striped phase, since the atoms are compressed in one direction so that the surface pattern is striped. At the most negative voltages, the stripes are separated by about 25 underlying atoms.

The striped phase appears to be a universal phenomenon for the gold (111) surface at sufficiently negative voltage, independent of the electrolyte species. The structure of the striped phase in electrolytic solutions is surprisingly similar to the structure in a vacuum at room temperature.

In addition, our researchers found that applying a positive voltage to the sample's surface causes a monolayer oxide film to form. Then, when a sufficiently negative voltage is applied, the surface oxide disappears and the surface reconstruction fully recovers.

This research shows that surface reconstruction is not limited to vacuum conditions. In situ measurements of metal surfaces under varying electrochemical conditions are now possible. Probing metal surfaces in these new ways may lead to greater depths of knowledge and advances in technology. •

DEPARTMENT OF NUCLEAR ENERGY

The tremendous power enclosed in the nucleus of an atom can be used safely — through a wide range of scientific work. In recent years, the safety of nuclear power reactors has become a highly emotional issue in this country. The Department of Nuclear Energy provides vital technical support to the Nuclear Regulatory Commission, which licenses and regulates power reactors. In performing its work, the department analyzes the safety of nuclear power and production reactors, investigates radiological hazards, studies advanced reactor systems, improves methods of safeguarding nuclear materials, and complies and evaluates data required by nuclear scientists all over the world.

How Risky Is Risk?

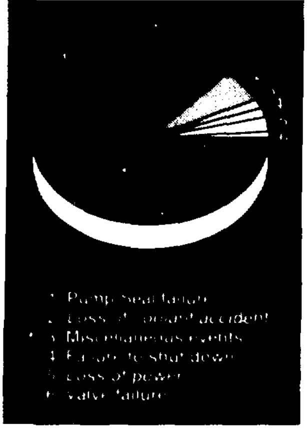
To run a nuclear power plant safely, how often should pumps and valves be checked? What happens if they fail? In the event of a severe accident, could radioactive material escape? How much? Might there be health effects on people living nearby? What actions can be taken to prevent or reduce these health effects?

Such questions are the vital concerns of all those who help in preventing nuclear accidents and their possible effects on the surrounding environment.

Because severe accidents at nuclear power plants are fortunately very rare, they cannot be used as a basis for making decisions about plant safety. Instead, the probability of a particular safety measure being needed for a plant is judged using an approach called "probabilistic risk assessment."

In Brookhaven's Department of Nuclear Energy, experienced scientists in a wide variety of disciplines have been gathered into a team to do probabilistic risk assessments. Their specialities include nuclear, electrical, chemical and mechanical engineering, physics, mathematics, computer science and meteorology. Together, they form a formidable asset in the field of nuclear power plant safety.

This Brookhaven resource is used extensively by the federal government's Nuclear Regulatory Commission (NRC). For example, in 1989, a controversy arose about emergency preparations for the Seabrook power plant in Massachussetts: How far around a plant



EXPECTED FREQUENCY OF POSSIBLE CAUSES OF CORE DAMAGE.

AT LEFT, RESEARCHERS (FROM LEFT) JI WU YANG, BOB FITZPATRICK, W. TREVOR PRATT, BOB YOUNGBLOOD, JOHN LEHNER AND DAVID DIAMOND ASSESS THE SAFETY OF REACTOR DESIGNS. AT RIGHT, BNL'S ROBERT BARI (LEFT) AND WALTER KATO (RIGHT) PRESENT (CENTER, FROM LEFT) W. TREVOR PRATT, ARTHUR TINGLE AND ERIK CAZZOLI WITH CERTIFICATES OF APPRECIATION FROM THE NUCLEAR REGULATORY COMMISSION, FOR THEIR WORK IN RISK ANALYSIS.

should its emergency planning zone extend?

The Brookhaven team was asked by the NRC to help evaluate the different plans. After in-depth research and data analysis, the team responded with a report on the implications of possible actions from a technical point of view. The findings made by our team were taken into account by the NRC in their evaluation of the proposed Seabrook plans.

An assessment of a plant first involves collecting facts. The BNL researchers inspect the power plant with regard to their own areas of expertise. They are supplied with data from plant records and they also use relevant data from other, similar plants.

Next, they analyze the information using methods that have been extensively tested to obtain the required level of accuracy. Finally, they may suggest areas of improvement. With these analyses and suggestions, the team assists the NRC in evaluating the safety of commercial nuclear power.

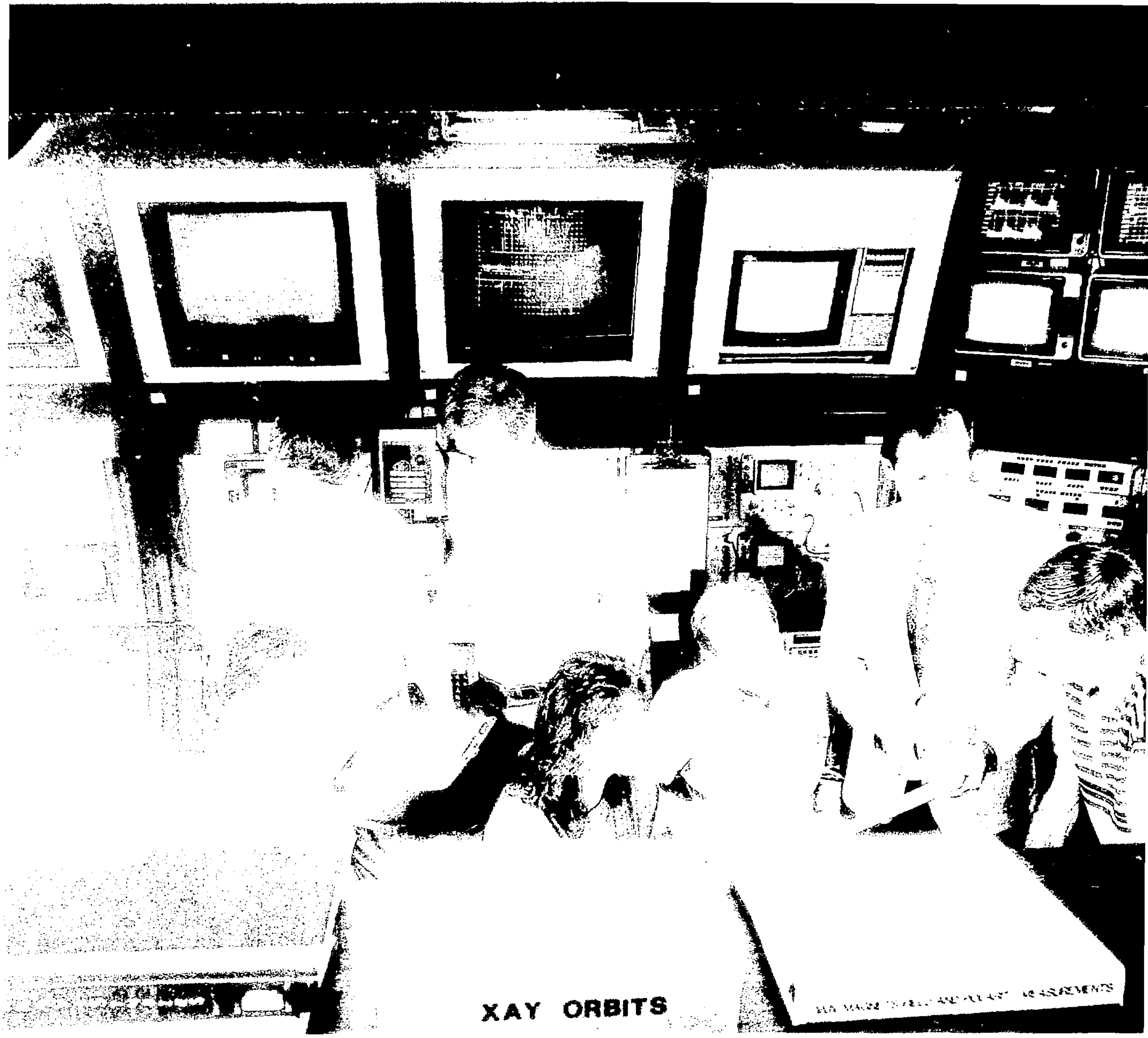
Previously, the NRC has asked Brookhaven scientists and engineers to write guidance documents to help the utilities perform probabilistic risk assessments of their plants and present their results suitably for a review.

In a new area of assessment, all U.S. utilities have been requested to perform an individual plant examination for each of their nuclear plants. Most of these plant examinations will take the form of a probabilistic risk assessment. Brookhaven staff have developed guidelines on how the utilities should organize the form and content of their submittals, how the submittals should be reviewed and how to store the vast amount of plant data that will be generated.

Another area in which the BNL team helps the NRC is in examining designs for new reactors. By comparing the design of the proposed plants with what is known about existing plants and by analyzing the plants using methods of risk assessment, the team can help increase the safety of the new designs.

In 1989, the high standards of risk analysis at Brookhaven resulted in members of the assessment team being honored with certificates from the NRC, recognizing Brookhaven's

"... outstanding contribution ... resulting in a significant advancement in the state of technology of probability risk analysis and a major contribution to the Nuclear Regulatory Commission's severe accident program." •


XAY ORBITS

BNL'S UNIQUE PROGRAM

One path taken by our researchers is in the field of probabilistic studies — analyzing risks associated with human reliability. By collecting data from actual events and relevant published research material, we amass information on the way people deal with machines. Then, by comparing the number of accidents caused by human error as opposed to hardware failure, our scientists can estimate the extent to which human action affects overall risk. At this point, we focus on identifying root causes and possible remedial actions.

In a second area, the Brookhaven researchers are studying advanced design concepts involving the way people react to machines. The aim is to upgrade present and future facilities, especially in display and control, so that human performance is improved.

For example, a present-day power plant operator usually sets control-room switches by hand. This could be done by computer while the operator supervises. The human element would thus be placed outside the work flow, a change that potentially could improve or degrade the final outcome.

Through experiment and analysis, our investigators explore the impacts that new technology would have on overall human performance.

The third way that we study human performance is new, developed by the Brookhaven team and duplicated nowhere else. Data show that identical plants run by different teams and management styles can have very different records of human performance and system problems. So, we look at the ways in which management and organization can affect human performance.

MANAGEMENT STUDIES

Our first step was to study published reports on the subject, mapping out known facts and those that were lacking. Working in cooperation with researchers from McGill and Purdue Universities and the University of California, Berkeley, we developed a computer model for nuclear power plant management and organization, and identified methods to collect field data to validate it.

Next, our researchers conducted four field studies, two in commercial power plants, and two in DOE facilities. For example, we examined different forms of communication and lines of authority. We also noted attitudes towards safety and individual risk, and how these enhance or detract from the general organization and from there, to safety.

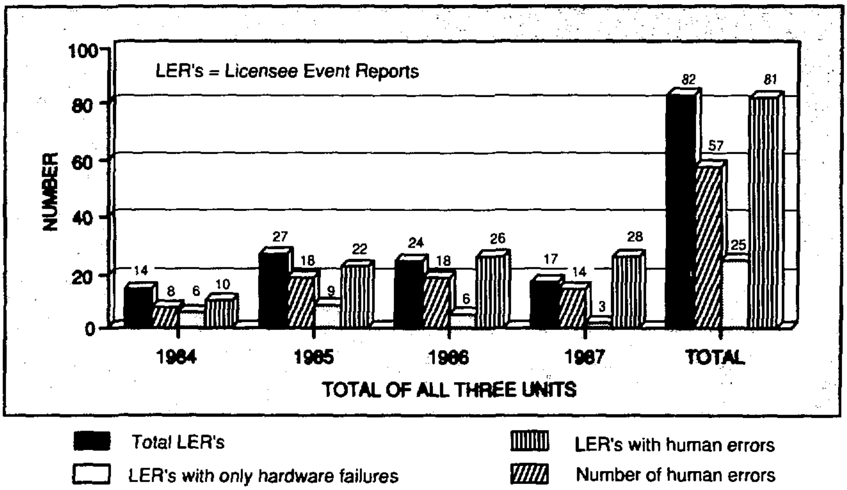
To carry out these field studies, we applied three techniques. The first uses task analysis — documenting which individuals are in critical positions in the organization and identifying their tasks and levels of responsibility.

Next, in the shadowing technique, trained Brookhaven staff observed various high-level managers during typical workdays.

The third technique involves the use of questionnaires to gain insights into employees' and managers' individual ideas about the way the organization is structured.

The first two techniques are based on interviews and observation and result in qualitative data. The questionnaires, which show the staff's attitudes and perceptions, give quantitative data. With approximately 2,000 completed questionnaires, Brookhaven now holds a growing data bank on safety culture.

The wealth of information gathered serves two purposes. First, it validates the original model made to assess the human element in power plant safety. In addition, it forms a valuable stock of referenced material on the intangible human attitudes on which this safety so largely depends. •



BAR GRAPH OF EVENTS REPORTED BY THE OCONEE POWER PLANT SITE. IN EVERY YEAR, EVENTS CAUSED BY HUMAN ERROR OUTNUMBER THOSE CAUSED BY HARDWARE FAILURE. THE LAST BAR FOR EACH YEAR SHOWS THAT A SINGLE EVENT MAY BE DUE TO MORE THAN ONE HUMAN ERROR.

DEPARTMENT OF APPLIED SCIENCE

Research activities in the Department of Applied Science encompass environmental, health and mathematical programs as well as programs in energy science and technology. Projects range from developing a coating system to reduce corrosion of steel surfaces, to measuring the rate of removal of atmospheric pollutants in convective rainstorms, to studying the kinetics of fossil fuel combustion. Highlighted this year are three stories: one on a new program concerned with global climate change, another regarding Brookhaven's initiatives in energy efficiency in the Northeast, and a third about our research on the microstructure of high-temperature superconductors. These programs all reflect the depth of fundamental research that underlies the breadth of vision required by applied science.

OF GLOBAL CONSEQUENCES

In 1990, the Department of Applied Science initiated a global change research program that takes advantage of the department's unique breadth of scientific disciplines. Under the umbrella of this new program, experts in atmospheric science, oceanography, terrestrial ecology and applied mathematics are working together to assess the effects of fossil fuel combustion on global climate.

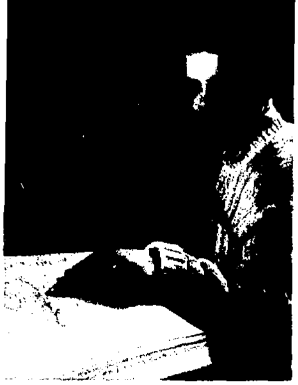
INCREASE IN CARBON DIOXIDE

The major by-product of the burning of fossil fuels is atmospheric carbon dioxide (CO_2). Since the beginning of the industrial revolution, about 100 years ago, CO_2 has increased in the atmosphere from 290 parts per million (ppm) to 350 ppm. Fifty years from now, the CO_2 level is expected to be double that amount.

CO_2 traps infrared radiation that would otherwise escape, thereby causing the earth to heat up. This phenomenon, known as the "greenhouse effect," may already have begun. Indeed, some data indicate that the average global temperature has increased by about 0.5°C in the last century.

Potential consequences include rising sea levels, changing precipitation patterns and shifting of agriculturally productive regions.

But *is* there a consistent warming trend? Or might the rise in temperature be due to natural variability?



MARTIN LEACH STUDIES THE ATMOSPHERE'S TEMPERATURE STRUCTURE, AS PART OF HIS WORK ON CLIMATE MODELS.

PAUL FALKOWSKI STANDS ON FIRE ISLAND, A 32-MILE LONG BARRIER BEACH THAT PROTECTS THE WATERS OF GREAT SOUTH BAY AND THE MAINLAND OF LONG ISLAND FROM THE POWERFUL SURGES OF THE ATLANTIC OCEAN. FIRE ISLAND IS EVER-CHANGING, SHAPED BY THE CONSTANT MOTION OF OCEAN WAVES REWORKING THE SHALLOW SEA BOTTOM.

FORECASTING

Despite the present high level of understanding of the earth's climate system, there are still many aspects of the global warming phenomenon for which understanding remains sketchy. The linkage between increases in CO_2 concentration and increases in temperature is nonlinear and poorly understood. In addition, global temperatures are affected by such variables as cloud reflectivity, the ocean's capacity to absorb heat, plant uptake of CO_2, and the production of aerosols.

Forecasts of global warming are based on computer models — programs containing mathematical equations that attempt to simulate the world's climate. Current computer models, however, have many approximations and assumptions that make their results questionable. For example, they fail to couple properly the change in the temperature of the atmosphere with the ocean's enormous capacity to absorb heat.

BNL EXPERTISE AND INSTRUMENTATION

Research under BNL's new program will contribute to a better understanding of global change and to improved computer models that describe the change. Some of the specific projects include:

- Using satellite imagery and computer modeling to test hypotheses related to the influence of emissions from energy activities on cloud-top reflectivity, as compared to natural influences.
- Investigating change in the biological uptake of carbon dioxide in the ocean since the beginning of the industrial revolution. This is to understand processes whereby CO_2 is removed from the atmosphere, as only about half of the CO_2 from fossil-fuel burning remains in the atmosphere.
- Examining new computing strategies in order to allow more complete climate models to be used.
- Developing a time-dependent climate model that couples the atmosphere and the ocean, for a better description of the influence of oceans in moderating the greenhouse effect.

Much of the work will be aided by unique tools developed at BNL. These include a plant exposure system that can study the effects of CO_2 enrichment on crops, spar buoys that can be moored at sea to collect environmental data, and sophisticated instrumentation to measure trace atmospheric constituents. In addition, BNL's 60-inch cyclotron can produce nitrogen-13 for studies of nitrogen cycles and, by inference, carbon cycles in the upper ocean and in marine sediments.

During this decade of the '90s, the federal government must develop a rational long-term energy policy for the 21st century. Such a policy must be based on the most objective scientific advice possible.

In order to plan wisely for the nation's future, it is necessary to understand the workings of the global environment and its response to perturbations. By pooling the Laboratory's special capabilities, personnel and facilities, BNL can make a major contribution to this national effort. •

CRUCIAL ENERGY ISSUES IN THE NORTHEAST

- **TRANSPORTATION**
  Potential for substituting alternative technologies and energy sources for petroleum derived fuels.
- **REGIONAL ELECTRICITY**
  Largely oil dependent and thus involves importing oil; also, imported hydropower is needed.
- **HOME SPACE HEATING**
  Regionally, 47% fueled by oil; nationally, 14% fueled by oil.
- **NATURAL GAS AVAILABILITY**
  Too distant from major producing areas of Texas and Louisiana for cheap, easy access.
- **AFFORDABLE ENERGY EFFICIENT HOUSING**
  Housing specifically designed for conditions in the Northeast.
- **COST OF ENERGY**
  Comparison of economic benefits and drawbacks of various energy sources.

TAKING ACTION ON ENERGY

The Northeastern states of the United States pay the highest energy prices in the nation. Heavily dependent on imported oil, this region is also increasingly dependent on imported electricity. As foreign energy prices rise, the home economy stands to deteriorate — and environmental problems such as acid rain still have to be resolved.

This bleak picture can be alleviated, however, by appropriate action — and action is already being taken.

In the fall of 1989, the Northeast Institute of Energy Efficiency (NIEE) was proposed. Headquartered at Brookhaven under the Department of Applied Science (DAS), the NIEE's mission would be to strengthen the energy economy of the Northeast by encouraging the use of renewable energy and energy-efficient technologies. As the Department of Energy's national laboratory in the Northeast, Brookhaven provides a natural focal point for such activities — and the NIEE could become a center of technical expertise for the region.

The Laboratory is a major resident source of information on energy efficiency in this area and able to access such information throughout the U.S. and the world.

In addition, DAS researchers have long experience in various forms of energy and energy-efficiency planning. Energy programs we have undertaken in the past have been helpful in very practical ways.

For example, the Brookhaven House was designed and built as an example of energy-efficient housing specifically tailored for the Northeast climate.

Also, Brookhaven's program to test devices designed to fit onto and improve existing oil heating systems led to the identification of a highly cost-effective and energy-saving retrofit method. This resulted in an explosion of sales of retrofit burners, with considerable heat savings for homeowners and energy savings for the region as a whole.

With this and other experience in energy-saving projects behind them, Brookhaven researchers are eager to respond to regional needs and set new energy-efficient ideas in motion. We have been interacting with outstanding people in the region's scientific and technological community, getting their ideas and opinions on the main energy problems of the Northeast and how to resolve them.

The range of policy and research initiatives already identified in this way include proposals to reduce air pollutants more cheaply, to promote mass transit, to extend oil-heat research to commercial buildings, and to develop affordable, energy-efficient manufactured housing for the Northeast climate and market.

By taking the lead in bringing such issues forward, the NIEE demonstrates its potential value, helping Northeasterners take control of their energy future. •

FOR THE PROPOSED NORTHEAST INSTITUTE OF ENERGY EFFICIENCY, RESEARCHERS BARBARA PIERCE AND JEROME LAMONTAGNE INVESTIGATE PROJECTS SUCH AS THE BROOKHAVEN HOUSE, SEEN IN THE BACKGROUND, WHICH WAS DESIGNED AND BUILT AT BROOKHAVEN NATIONAL LABORATORY AS AN EXAMPLE OF ENERGY-EFFICIENT HOUSING FOR THE NORTHEAST

USING A HIGH-RESOLUTION ELECTRON MICROSCOPE TO REVEAL THE MICROSCOPIC STRUCTURE OF HIGH-TEMPERATURE SUPERCONDUCTORS ARE (FROM LEFT) YIMEI ZHU, ROBERT SABATINI AND MASAKI SUENAGA.

SUPERCONDUCTOR DEFECTS

Tweed — warm, hard-wearing, fashionable — is made into clothes for so many occasions that there's no surprise when its traditional weave shows up almost anywhere.

Anywhere, that is, except in a state-of-the-art, high-resolution electron microscope. Yet this is where researchers in Brookhaven's Department of Applied Science (DAS) examine tweed patterns.

Of course, the "tweed" we are interested in has nothing to do with cloth. It's just a good description of one pattern we see when studying certain defects in the regular structure of high-temperature superconductors such as yttrium-barium-copper-oxide. By close investigation of the microstructure of this and other high-temperature superconductors, our scientists are discovering how structural defects occur, how they affect a superconductor's performance and how improvements might be made.

Superconductors are materials that allow electric current to flow through them with no resistance and, therefore, no dissipation. Until recently, known superconductors only worked if they were cooled by helium all the way down to about 4 kelvins (−450°F), which limited much of their practical use.

PROMISING DISCOVERY

In 1986, a new, "high-temperature" superconductor was discovered. This material became superconducting at a "high" temperature of above 77 kelvins, or −320°F. It could be cooled by liquid nitrogen, which is cheaper and easier to use than helium. The discovery promised greatly lowered costs in scientific and industrial applications such as electronics, magnets, power transmission and transportation.

Scientists everywhere probed the nature of the new material, which was a baked mixture of rare earth, alkaline metal, copper and oxygen. Variations on the original were produced — including lutetium-barium-copper-oxide, which was made by our DAS researchers and was the world's second compound to become superconducting at temperatures from 90 to 100 kelvins.

At Brookhaven, the Alternating Gradient Synchrotron, the High Flux Beam Reactor and the National Synchrotron Light Source ensured investigators a wide variety of techniques to use for different experiments. We became a unique center for scientific research in this field.

PROBLEM SOLVING

Many researchers were intrigued by the challenging problems that had to be solved before high-temperature superconductors could be fabricated into useful forms. For example, the brittle, granular nature of these ceramics made it impossible to coil them into wire shapes for making magnets used in particle accelerators.

Even more vital, however, was the need to improve the maximum amount of current that the new materials could carry: their critical current. Our researchers focused on examining the microstructure of the superconductors. While defects in conventional superconductors, such as a niobium-titanium alloy, actually enhance the amount of current they can carry, we found that in some high-temperature superconductors, the opposite is the case.

Our studies of yttrium-barium-copper-oxide showed that the most common defects are, first, the so-called "twin boundaries," where the edges of two grains of superconducting material meet in a special crystallographic orientation (Figure 1). Also, we found the tweed effect, which is caused by additional oxygen and other impurities widening the already distorted structural pattern at a twin boundary (Figure 2).

We were able to clarify the nature of these defects because of the extraordinary precision of the electron microscopy technique, coupled with a computer simulation technique that reproduces the image on a screen. Together, these techniques combine to give an image of such high resolution that each separate atom making up the superconducting samples can be seen — and their normal and defective patterns recognized.

We also developed a computer model of the way the atomic structure of a high-temperature superconductor is expected to look under different conditions. Because it is validated against images obtained by high-resolution electron microscopy, the model is helpful in clarifying data and pointing the way to new areas of investigation.

These studies, in conjunction with measurements of other properties of the samples, have helped to identify how some impurities lead to a lowering of the amount of current that can flow through the grains of the yttrium-barium-copper-oxide superconductor. This knowledge will help in the continuing search for new techniques to process the superconductors with fewer current-restricting defects. •

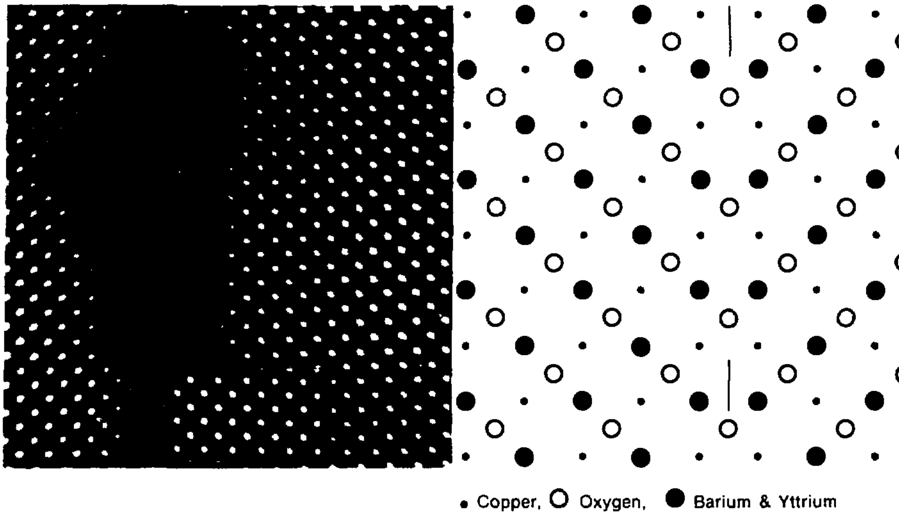


FIGURE 1. A HIGH-RESOLUTION IMAGE OF A TWIN-BOUNDARY DEFECT IN THE YTTRIUM-BARIUM-COPPER-OXIDE HIGH-TEMPERATURE SUPERCONDUCTOR IS SEEN ALONG WITH A SCHEMATIC WITH EXACT ATOMIC LOCATIONS. SUCH DEFECTS CAN BE HELPFUL IN IMPROVING THE SUPERCONDUCTOR'S PERFORMANCE.

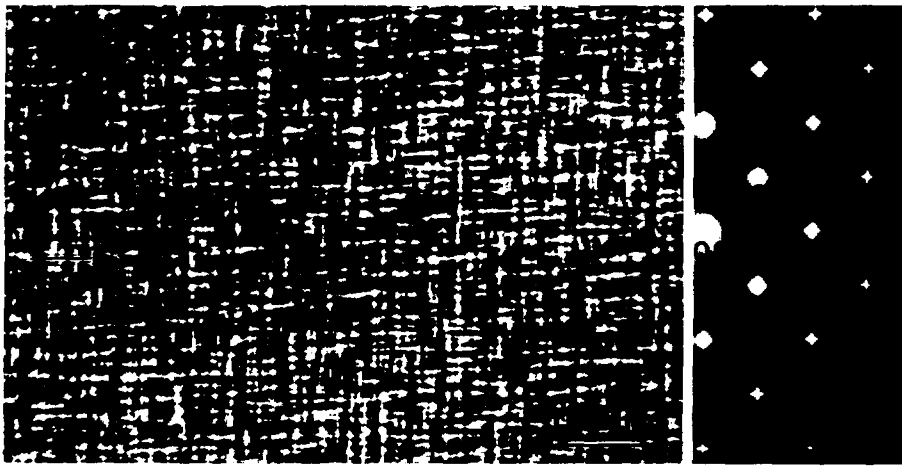


FIGURE 2. ELECTRON MICROGRAPH OF A TWEED PATTERN IN AN YTTRIUM-BARIUM-COPPER-OXIDE HIGH-TEMPERATURE SUPERCONDUCTOR WITH A CORRESPONDING ELECTRON DIFFRACTION PATTERN BESIDE IT THE STAR-LIKE STREAKS IN THE PATTERN INDICATE PERIODIC MODULATION IN THE ATOMIC ORDER RESULTING IN THE "TWEED" IN THE IMAGE.

NATIONAL SYNCHROTRON LIGHT SOURCE DEPARTMENT

The world's foremost facility for scientific research using x-rays, ultraviolet radiation and infrared radiation is operated by the National Synchrotron Light Source (NSLS) Department. In a single year, about 1,800 researchers from almost 300 institutions come to use this "best and brightest" source of synchrotron light.

Industry is well represented among the users, with 50 companies carrying out research at the NSLS. Guest researchers often work in collaboration with NSLS staff scientists, performing a wide range of innovative experiments in physics, chemistry, biology, materials science and various technologies.

New Visions With X-Ray Imaging

Just as artists look for the best light to create images, so do scientists. But while artists depend on visible light to record their unique perceptions of the world, scientists at the National Synchrotron Light Source (NSLS) use invisible x-rays to produce finely detailed images of specimens that are up to 50 times smaller than the width of a human hair.

Since the intensity of synchrotron-made x-rays is 10,000 times greater than conventional laboratory sources — and the brighter the light, the more detail that can be seen — scientists can make high-resolution images of extremely small or very dilute samples. Some imaging techniques also enable scientists to determine the concentration and often the chemical state of each element because the interaction of x-rays with matter is different for each element.

While visible light imaging with conventional microscopes has a 300-year history, it has only been within the last 20 years that lenses to focus x-rays have become available. Thus, the field of imaging using synchrotron light is new — yet its frontiers have been pushed forward dramatically in many fascinating directions, largely due to research at the NSLS.

Since 1982, BNL scientists have been joined at the NSLS by researchers from universities, other national laboratories and

AN EXTERIOR VIEW OF THE NATIONAL SYNCHROTRON LIGHT SOURCE HIGHLIGHTS ITS SLEEK DESIGN. CONTAINED WITHIN ARE TWO ELECTRON STORAGE RINGS — THE VACUUM ULTRAVIOLET RING (SEEN IN THE SMALL PHOTO ABOVE) WHERE RESEARCHERS WORK WITH INFRARED, ULTRAVIOLET AND SOFT X-RAY RADIATION, AND THE HIGHER-ENERGY X-RAY RING, WHICH PRODUCES HARD AND SOFT X-RAYS.

industry, who use synchrotron imaging for many different purposes. This work has yielded advances in such varied fields as biology and physics, chemistry and metallurgy, medicine and materials science.

One such example is x-ray microscopy, which has broadened the boundaries of the study of biological specimens. This imaging technique provides a much higher resolution than optical microscopes. Also, it compensates for some limitations of electron microscopy, such as limited penetrating power, limited contrast and radiation damage. Most crucial, it allows visualization of biological specimens in their natural state.

X-rays range from hard x-rays with a wavelength as small as 0.1 angstroms (Å) to soft x-rays with a maximum wavelength of 100 Å (5,000 Å equals the width of a human hair). At the NSLS, x-ray imaging is done at various beam lines at both the x-ray ring (hard and soft x-rays) and the vacuum ultraviolet ring (soft x-rays). By choosing a particular x-ray energy to match the task at hand, scientists can use various techniques to solve both basic research puzzles and technological problems.

Detailed images provide researchers with data on the structure of a wide variety of specimens, from chromosomes to semiconductor devices. Information on structure leads to greater understanding of how a specimen functions.

For example, the National Institute of Standards and Technology, in collaboration with industry, is examining natural and synthetic diamonds with diffraction imaging to determine how their grain and nitrogen content affect their function. Synthetic diamonds are used in high-precision cutting tools.

Synchrotron x-ray imaging is also advancing medical technology. For instance, researchers at Columbia University are studying bone-metal implant interfaces in artificial joints using computed microtomography. The data obtained are important in following the healing process and judging the chances of the bone's fracturing again.

In another medical application, patients with artherosclerotic heart disease can be evaluated with less risk of complication than in the past, through the use of a new technique known as transvenous angiography.

Because x-ray imaging techniques are just emerging, many of them are similar. As in any new technology, the most efficient techniques will prove long lasting, while others will fade with time. And most likely, still more will be invented, yielding new, unforeseen discoveries in this fast-growing field. •

BEAM LINE	TYPE OF IMAGING
X1	**SOFT X-RAY MICROSCOPY** — Uses soft x-rays from special magnetic device known as an undulator, which increases x-ray brightness a thousandfold and reduces image scanning time from almost an hour to a few minutes. A growing field, soft x-ray microscopy includes the following techniques. • **Scanning Transmission X-Ray Microscope** — Provides images of wet biological samples at resolution of 0.06 microns, using focused beam to scan and probe specimen. Current research includes studies of chromosome structure, secretion granules, cultured cells, and calcium deposits in cartilage. • **Photoemission Microscope** — Completed in 1990; used in ultrahigh vacuum for surface studies of nonbiological specimens such as alumina and other heterogeneous materials. Images at resolution of less than 0.5 microns. • **Gabor Holography** — Specimen and x-ray resist (type of detector) illuminated by plane waves created by undulator. Two-dimensional reconstruction at resolution of 0.06 microns. Possible use in imaging wet biological specimens in three dimensions. • **Fourier Transform Holography** — Spherical reference wave used to interfere with wave scattered from specimen, and interference pattern recorded on detector. Object numerically reconstructed.
X2	**COMPUTED MICROTOMOGRAPHY** — Similar to CAT scanning, but able to resolve features 1,000 times smaller. Used to observe inner structure of opaque, heterogeneous materials at micron levels. Parallel x-rays pass through sample on turntable yielding some 300 to 500 views as it rotates 180°. As x-rays hit phosphor crystal in detector, phosphor emits visible light, which is recorded. Computer then reconstructs three-dimensional image of sample. Used for measuring concentrations of various elements in unknown material. Chemicals absorb different wavelengths — the more concentrated a chemical is, the more strongly it absorbs a particular wavelength. Used to
X17B2	**TRANSVENOUS ANGIOGRAPHY** — Research program to look at progression of coronary artery disease. New transvenous technique uses very high intensity, high energy, monochromatic x-rays at NSLS Synchrotron Medical Research Facility. Safer for patients than traditional angiography. In conventional method, catheter inserted into patient's peripheral artery and threaded into selected coronary arteries to inject dye containing x-ray absorbing iodine. X-ray image shows site of blood-flow blockage
X19C	**TOPOGRAPHY** — Used to image defects in single crystals with 1 micron resolution. Analyze angles and intensities of scattered x-rays after reflected from specimen on to detector. From this data, image of specimen is generated. Planes of crystal have fixed spacing and orientation, and deviations in either one lead to differences in diffracted x-ray intensities. By examining differences between diffracted intensities from normal and distorted regions of crystal, defects can be analyzed and characterized. Investigations may lead to advances in understanding materials used in computer and communications industries, semiconductor and superconductor technologies.
X23A3	**DIFFRACTION IMAGING AND MICRORADIOGRAPHY** — Hard x-ray microscope provides real-time resolution of 0.5 microns, detects minuscule defects in wide variety of materials, including semiconductors and engineering materials, dental, medical and biotechnological materials. Data used to improve quality and increase yield for industrial applications. Diffraction imaging provides information on microstructure of crystals. Aggregates of atoms in crystalline substances imaged to detect deviations from perfect crystal lattice. Microradiography, a complementary technique, used to detect particular types of defects in crystalline and noncrystalline materials. One collaboration now studying underlying process of tooth decay in situ with aim of restoring natural tooth structures by chemical treatments.

First reconstructions at submicron resolution made in 1990. • **Diffraction From a Single Cell** — Under development. Objective would be to image noncrystalline specimens such as small biological cells, with resolution limited only by x-ray wavelength.

SCANNING TRANSMISSION X-RAY MICROGRAPH OF FIXED BUT WET UNSTAINED CELL FROM CHICK EMBRYO CULTURED ON SILICON NITRIDE MEMBRANE. THE LARGE NUCLEUS WITH TWO NUCLEOLI AND GRANULES ARE DOMINANT FEATURES. SPECIMEN AND IMAGE COURTESY OF CALIFORNIA INSTITUTE OF TECHNOLOGY.

BNL; California Institute of Technology; IBM; King's College, London; Lawrence Berkeley Laboratory; SUNY at Stony Brook; University of California, San Francisco

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examine fluid flow in porous rocks and other materials, observe distribution of metals in catalysts, study structure/function relationships in composite materials.

COMPUTED MICROTOMOGRAM OF INTERNAL WIRING OF CERAMIC PACKAGE USED TO MOUNT INTEGRATED CIRCUIT CHIPS IN MAINFRAME COMPUTER. IMAGE MADE IN COLLABORATIVE EFFORT BETWEEN IBM AND EXXON TO DETERMINE DEFECTS IN WIRING.

Exxon

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in coronary arteries. In new technique, first used at Stanford Synchrotron Radiation Laboratory, catheter inserted into peripheral vein reduces risk of medical complications. Dye circulated through arteries diluted by a factor of 30 before reaching heart; intense monochromatic x-rays compensate for dilution. Two simultaneous digital coronary artery images taken at x-ray energies above and below iodine dye absorption edge are subtracted logarithmically, leaving clear picture of coronary arteries.

BNL, LBL, North Shore U. Hospital, Palo Alto Veterans Adm. Hospital, Stanford Synchrotron Radiation Lab, Stanford U., U. of Tennessee

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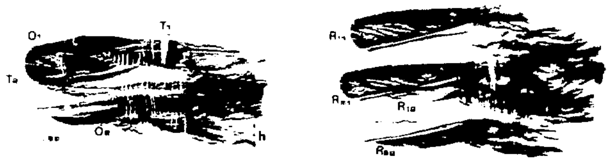

TWO TOPOGRAPHS OF LANTHANUM GALLATE ($LaGaO_3$) CRYSTAL SHOWING STRUCTURAL CHANGE THAT OCCURS IN ITS SINGLE CRYSTALS AS A FUNCTION OF TEMPERATURE. RESULTING SURFACE DISTORTION DIMINISHES APPLICABILITY OF THIS MATERIAL AS SUBSTRATE FOR SUPERCONDUCTING THIN FILMS USED IN MAGNETIC FIELD DETECTORS.

SUNY at Stony Brook, University of Illinois, University of Pennsylvania

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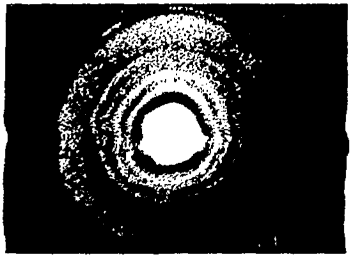

MICRORADIOGRAPH SHOWING SINGLE SILICON CARBIDE FIBER (WHITE RINGS) REINFORCED IN METAL MATRIX COMPOSITE (DARK AREAS). SILICON CARBIDE IS COATED BY VAPOR DEPOSITION AROUND GRAPHITE FIBER (LIGHT INNER CIRCLE). A TYPICAL MATERIAL STRENGTHENED FOR INDUSTRIAL PURPOSES.

National Institute of Standards and Technology

BEAM LINE	TYPE OF IMAGING
X26A	**COMPUTED MICROTOMOGRAPHY** — Used for imaging such diverse samples as insect bodies, catalysts, ceramics and nerve cells with resolutions down to 1 micron. Data collected by scanning a pinhole x-ray beam across sample during 180° rotation. Detector records both x-ray absorption and fluorescent x-ray emissions. Computer algorithm used to reconstruct distribution of x-ray attenuation coefficients or concentrations of elements in planes through sample. Three-dimensional images created by imaging consecutive planes. In 1990, BNL researchers visualized single nerve cell with 1 micron resolution — first time done using computed microtomography techniques. Elemental mapping in nerves may lead to better understanding of neurological disorders and related diseases. Other applications include studies of voids in ceramic materials, such as silicon nitride, and plasma coatings, used in jet engines.
X26C	**SYNCHROTRON RADIATION-INDUCED X-RAY EMISSION** — Uses x-ray microprobe to trace elements in the range of one part per million in such varied materials as ceramics and bone. X-rays used to ionize a sample's atoms, which then emit specific secondary x-rays. Since each element emits x-rays with characteristic energy, elements in sample can be identified and measured. Applications include noninvasive, in vivo study of lead in human body. Most lead settles in skeleton, so determining its concentration and location in bones is highly effective in measuring amount of lead exposure. Lead plays role in loss of intellectual capacity in children, and in such diseases as hypertension, kidney and heart disease.
U2, U6	**X-RAY LITHOGRAPHY** — Soft x-rays from the NSLS vacuum ultraviolet ring used to produce high-resolution computer chips. Chips made with x-rays can have greater density than those made with conventional optical methods. Such density promises vast increases in chip power and speed, since it takes less time for electrical signals to travel between closely packed components. Current technology can produce chips with about 10 million circuits. Future chips created with x-rays could contain over a billion circuits. Based on success at NSLS, IBM building x-ray lithography facility in East Fishkill, New York. IBM has transferred images as small as 0.1 microns on to typical
U8	**PHOTOELECTRON HOLOGRAPHY** — New technique used for imaging atomic structure of interfaces in single crystals with up to 0.1 Å resolution. Sample ejects photoelectrons at various angles that are recorded on detector. Through mathematical calculation known as Fourier transform, three-dimensional image of sample formed.
U13	**PROJECTION X-RAY LITHOGRAPHY** — A more recent technique in race to achieve smaller computer chips being developed by AT&T. Uses reduction imaging with mirrors, as opposed to IBM's contact printing on U2 and U6. AT&T has made images on chips with 0.05-micron spaces between features, but these not yet near production stage. (Conventional state-of-the-art chips imaged at 0.75 microns.)

COMPUTED MICROTOMOGRAM OF SECTION THROUGH SEVERAL- MILLIMETER-LONG, FREEZE-DRIED SCIATIC NERVE OF RAT, AT 1 MICRON RESOLUTION. WALLS OF INDIVIDUAL CELLS CAN BE SEEN AS WHITE CIRCLES AND CELL CENTERS AS BLACK. WHAT APPEAR AS PARALLEL LINES IN BOTTOM HALF OF TOMOGRAM ARE INDIVIDUAL NERVE CELLS LINED UP IN PLANE OF IMAGE.

Amoco, BNL, Catalytica Co., Columbia University, General Electric, Radiation Science, Inc., SUNY at Stony Brook, University of Linköping, University of Lund, University of Massachusetts-Amherst

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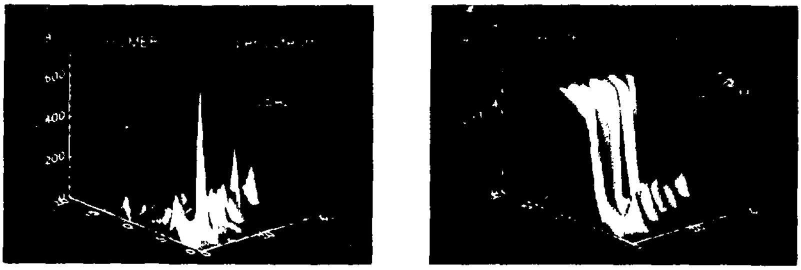

X-RAY MICROPROBE IMAGES SHOWING CONCENTRATIONS OF LEAD AND CALCIUM IN BONE OF 9-YEAR-OLD CHILD. LEAD IS CONCENTRATED OUTSIDE DENSE CALCIUM-RICH AREA OF BONE. THESE IMAGES HELP RESEARCHERS UNDERSTAND LEAD TOXICITY IN CHILDREN.

Abiomed, BNL, Harvard University, The Hospital for Special Surgery, Memorial Sloan-Kettering Cancer Center, University of Cincinnati, University of Minnesota

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silicon wafers used today. Researchers at U2 have made significant progress in understanding problems that must be overcome to mass-produce these advanced chips. In 1990, IBM fabricated functional one megabit, dynamic random-access memory chips. Subsequently, static random-access memory chips with geometries as small as 0.6 microns were fabricated as part of national x-ray lithography program contract sponsored by federal government. IBM continues work at NSLS using a new chip processing lab built there. Designed by IBM and built jointly with BNL's Plant Engineering Division.

IBM

Greater knowledge about structure of interfaces on atomic scale may lead to better understanding of solid-state interactions and production of more efficient integrated circuits.

IBM

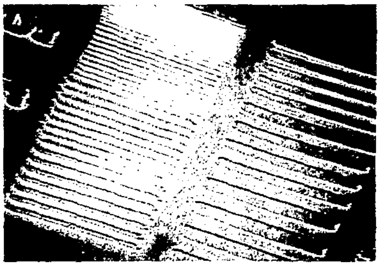
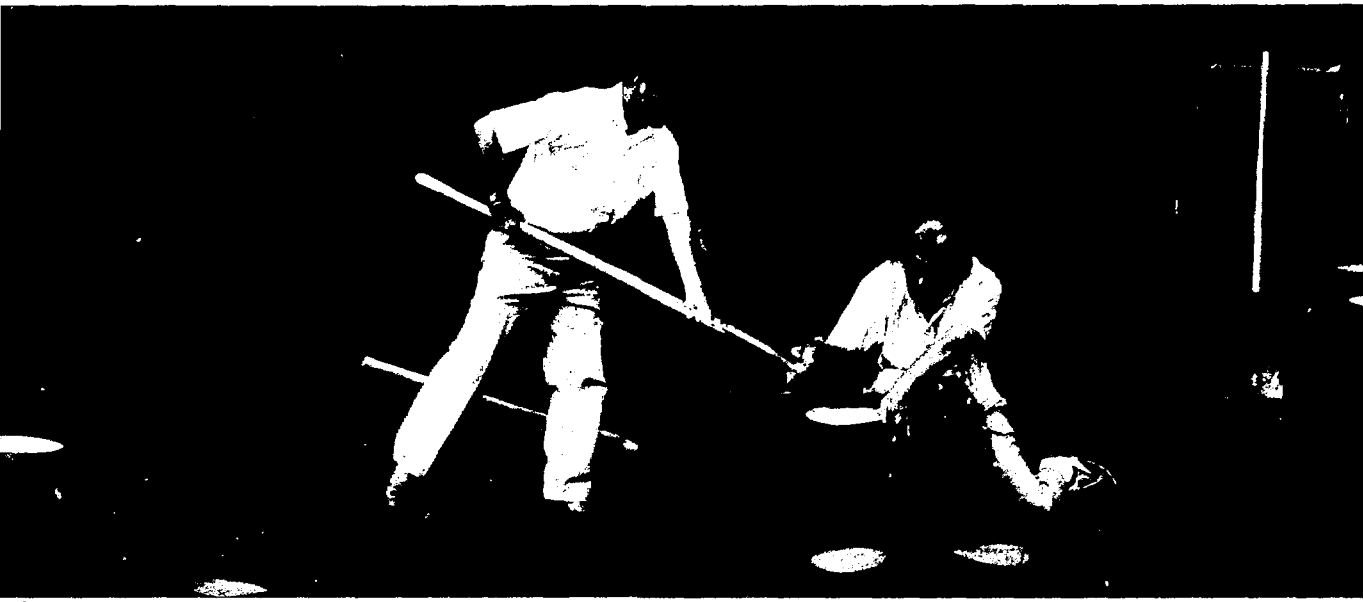


IMAGE OF MASK SHOWING FEATURES ON SILICON WAFER, RANGING IN SIZE FROM 0.05 MICRONS TO 1 MICRON. IMAGE OBTAINED USING PROJECTION X-RAY LITHOGRAPHY FOR MAKING SMALLER, MORE EFFICIENT COMPUTER CHIPS.

AT&T Bell Laboratories, BNL

CHEMISTRY DEPARTMENT

The Chemistry Department's many programs share a single goal: the fundamental understanding of the properties of nuclei, atoms and molecules. The broad range of research includes nuclear and radiation chemistry, radiopharmaceuticals, homogeneous and heterogeneous catalysis, state-to-state chemistry, and thermal and photo-induced charge-transfer processes. Detailed structural and spectroscopic information on solids, liquids and gases, and the dynamics of physical and chemical change are made possible by the special facilities, apparatus and techniques available at Brookhaven.



RADON: FROM SOIL TO LUNGS

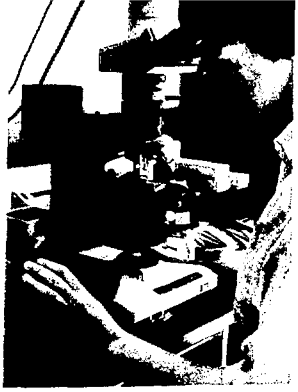
Radon, a colorless, odorless radioactive gas that is linked to lung cancer in humans, is found in soil in widely varying amounts all across the U.S. Since radon is one of the radioactive elements of uranium decay, uranium-rich soil contains a large amount of radon.

Thoron, also a radioactive gas, is derived from the decay process of thorium in soils. Thoron contributes an estimated 20 percent of the radioactivity that emanates from soil to air, while radon releases the balance. Radon's half-life is 3.8 days, and thoron's half-life is about 55 seconds.

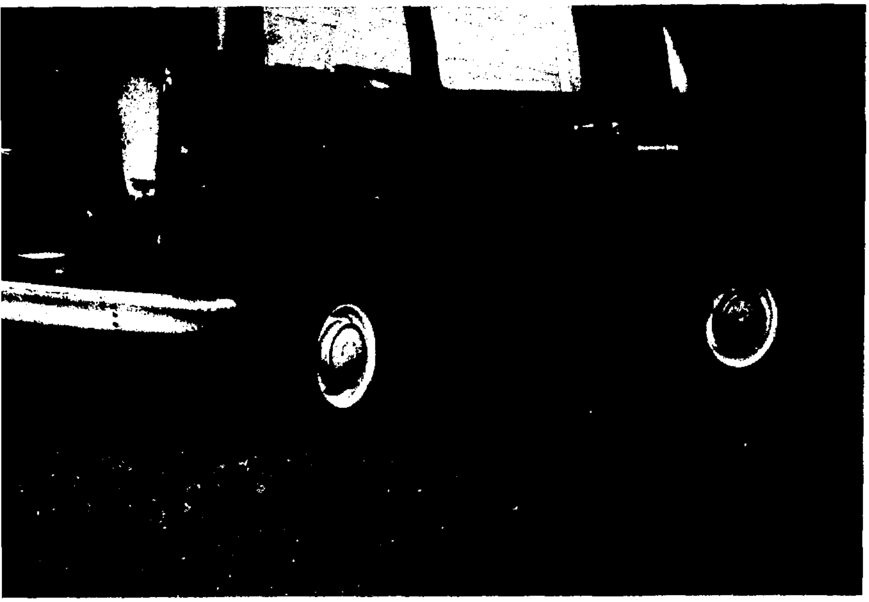
Trapped in soil, neither radon nor thoron is dangerous. But as much as 40 percent of these gases in soil can become airborne — and that is when they can become a health hazard. Some scientists estimate that as many as 20,000 lung cancer deaths annually may be caused by radon. Thoron is difficult to study because of its short life span, so little is known about the effects of exposure to thoron. There is growing evidence, however, that it, too, may contribute to lung cancer.

In Brookhaven's Chemistry Department, researchers are investigating how radon and thoron are released from soil into the air. Our chemists are formulating and testing a model for radon and thoron availability in soil to understand these gases' microscopic release processes.

Two types of soil were chosen to begin the project. First, samples were taken from Long Island's glacial moraine. (See side bar.) The Island's soil is usually sandy and contains relatively sparse amounts of radon and thoron, except in the



CHRISTINE EVANS, A GEOLOGIST FROM THE UNIVERSITY OF NEW HAMPSHIRE AND COLLABORATOR IN BNL'S RADON STUDIES, EXAMINES A PIECE OF CONWAY GRANITE. THE GRANITE BREAKS DOWN INTO SOIL THAT CONTAINS A HIGH LEVEL OF RADIOACTIVITY AND CAN LEAD TO RADON IN HOMES. (PHOTO COURTESY OF UNIVERSITY OF NEW HAMPSHIRE.)



WUU-JYH LIN (LEFT) AND GARMAN HARBOTTLE TAKE A SAMPLE OF EARTH FROM A LONG ISLAND MORAINE TO DETERMINE ITS RADIOACTIVITY LEVEL. WHILE SOME SOIL IN THE MORAINES WAS FOUND TO CONTAIN ABOUT THREE TIMES MORE THORIUM AND URANIUM THAN SURROUNDING SOIL, THE MAJORITY OF HOMES BUILT ON THE MORAINES WOULD NOT HAVE DANGEROUS RADON LEVELS.

moraine areas and in the black sands on beaches.

In collaboration with the University of New Hampshire, we are also studying Conway granite soils. These soils result from the weathering of granite.

The first stage in this process produces saprolite — rock that has started to disintegrate, making it easier for radon and thoron to escape. Compared to other soils in the U.S., Conway granite is known to have high concentrations of both uranium and thorium.

Conway granite is found in several New England states, and similar granite soils pose a large part of the radon risk on the eastern coast of the U.S., from Maine south through Georgia.

To measure the amounts of uranium and thorium in the soil samples, the Brookhaven chemists place their samples in a Marinelli cell, a container in which the soil surrounds a gamma ray counter. The radioactivity of uranium and thorium is then measured very accurately by gamma ray counts. Because each has a distinctive gamma ray spectrum, the researchers can determine the quantities of each in the soil.

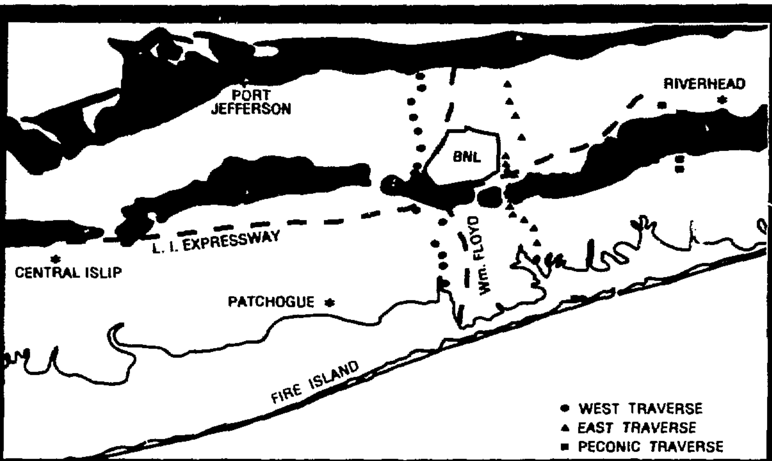
Then, to measure the amounts of radon and thoron gases that escape from the soil, a thin layer of soil is exposed to a flowing current of air to allow any of the radon and thoron that is able to escape to do so.

When this radon and thoron has escaped, our researchers rapidly place the soil sample into a tightly sealed counting cell, and a gamma ray measurement of radiation is taken.

Within the airtight container, thoron builds up in three days, while radon, because of its longer half-life, takes about one month to build up. Knowing the amount of radioactivity buildup from radon and thoron over a given time period, our researchers can perform a calculation to determine how much of each has escaped from the soil sample.

According to preliminary results, as much as 40 percent of radon and thoron in granite soils escapes to the air. Eventually, Brookhaven chemists will perform a comprehensive survey of radon and thoron availability in U.S. soils in cooperation with the National Soil Survey Laboratory in the U.S. Department of Agriculture.

The researchers will determine if there are any common characteristics in the more than 300 soils in the nation in terms of radon and thoron availability. From this information, they will be able to identify the areas of the U.S. where radon and thoron pose the greatest hazards.



THE MAP SHOWS THE AREA OF SUFFOLK COUNTY ON LONG ISLAND WHERE BNL RESEARCHERS TOOK SOIL SAMPLES TO DETERMINE THEIR URANIUM AND THORIUM CONTENT. THE SMALL GEOMETRIC SHAPES INDICATE EACH POINT AT WHICH A SAMPLE WAS TAKEN. THE HARBOR HILL MORAINE IS REPRESENTED BY THE TOP SHADED AREA, AND THE CENTRAL SHADED SECTION SHOWS THE RONKONKOMA MORAINE.

RADIOACTIVE GASES ON LONG ISLAND

Long Island's land surface was formed during the Ice Age, when glaciers drifting from the north dumped debris in what was then water, creating the Island's two terminal moraines — Ronkonkoma and Harbor Hill ridges. Radioactive gases emanate from the minerals transported by the glacier in these moraine soils.

To determine the extent of this radioactivity, Brookhaven chemists, in collaboration with the New York State Department of Health, analyzed approximately 50 samples of soil from both of Long Island's moraines (see map). They found that soil surrounding the moraines contained approximately 7 to 9 parts per million of thorium, but within the moraines the thorium level became much higher — up to 30 parts per million. A similar increase was found for uranium.

While the increase in radioactivity in the moraines is significant, it presents no cause for alarm. The majority of houses built on the moraines would have radon levels well below the action threshold of four picocuries per liter that the U.S. Environmental Protection Agency sets for radon.

Also, preliminary results of our research indicate that no thoron escapes to the air from Long Island soil, and only seven percent of radon becomes airborne. Our researchers surmise that because Long Island soil is relatively young, it has not weathered sufficiently to allow large amounts of radioactive gas to escape.

New Approaches To Biomass

What do sawdust, rye bread, blood cell surfaces and DNA have in common? They all contain carbohydrates, natural compounds that include sugars, starches and cellulose.

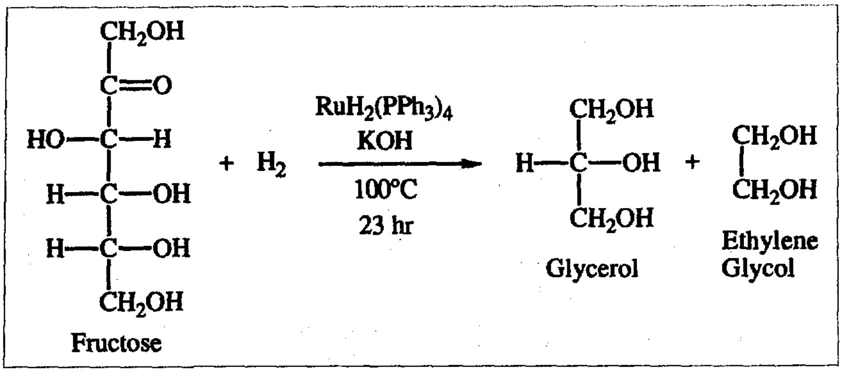
Composed of carbon, hydrogen and oxygen, carbohydrates are a more abundant raw material than oil or coal. Despite this prevalence, carbohydrates have not been widely used in industry.

At Brookhaven, chemists are exploring new ways to develop carbohydrates' hidden potential by designing new approaches to biomass conversion.

Traditionally, biomass conversion involves the fermentation of sugars with brewer's yeast to produce alcohol for varied uses, including fuel. The goal of our researchers' work is to replace nature's enzymes with a powerful new synthetic tool — homogeneous catalysts.

Chemists find carbohydrates difficult to work with because they are complicated molecules that undergo many reactions. Certain soluble metal compounds, known as homogeneous catalysts, can make selective chemical transformations easier. Our scientists have begun one of the first systematic studies of the application of these catalysts to carbohydrates.

One example of the catalysts being studied is $RuH_2(PPh_3)_4$, a complex containing two hydrogen and four phosphorus atoms bound to a central ruthenium metal atom.



THIS CHEMICAL EQUATION ILLUSTRATES THE MOLECULAR STRUCTURES AND OPTIMIZED REACTION CONDITIONS FOR THE BNL-DEVELOPED MODEL SYSTEM TO CONVERT BIOMASS TO USEFUL PRODUCTS.

In our research, this ruthenium catalyst was reacted with mannitol, a common sugar alcohol containing six carbon atoms. The intent of the experiment was to determine if hydrogen could be removed from just one of the three slightly different types of alcohol groups present in the mannitol.

While the initial goal was largely achieved, the experiment also yielded unexpected results. In the reaction mixture, we found trace amounts of two- and three-carbon sugar alcohols — ethylene glycol and glycerol. These products correspond to the *addition* of hydrogen to the mannitol, rather than its *removal*. The reaction was also surprising because it required the breaking of a normally unreactive carbon-carbon bond at room temperature. Related reactions had previously been observed using heterogeneous, or insoluble, catalysts, but only at temperatures of 200°C.

Since ethylene glycol and glycerol are valuable commercial compounds used in automotive antifreeze, polyester fabrics, paints and plastics, the results were exciting not only from the perspective of basic science, but also from a long-range practical point of view.

The next problem was to figure out how the ethylene glycol and glycerol were being formed. With that knowledge, it would be possible to alter the reaction conditions to increase the yield of these desirable products.

By a combination of reasoning and intuition, we modified the reaction to favor the addition of hydrogen, and changed the starting sugar from mannitol to the familiar sugar, fructose. Now the same ruthenium catalyst produced glycerol as a major product.

Subsequent study of the reaction permitted the system to be further optimized, making the reaction much faster and maximizing the yield of both ethylene glycol and glycerol.

In future experiments, different combinations of carbohydrates and catalysts will be explored with the goal of obtaining other important products, such as methanol. This will permit a more complete evaluation of the long-term potential of this new approach to biomass conversion.

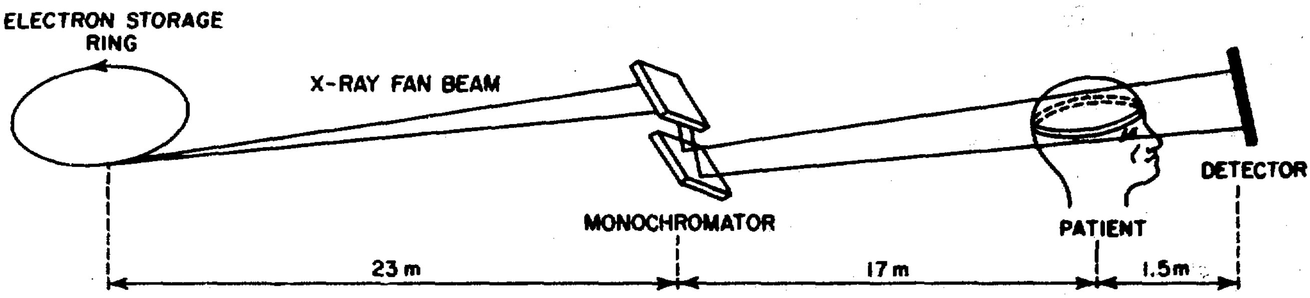
Eventually, the combination of carbohydrate chemistry and homogeneous catalysis might provide a way to use renewable carbohydrates as a substitute for fossil fuels. This substitution could help limit global warming, since green plants make carbohydrates by recycling carbon dioxide, a gas that is believed to be a major contributor to the greenhouse effect.

Already, some practical benefits have been achieved by BNL's innovative studies in carbohydrate chemistry. The need to analyze complex reaction mixtures led to improvements in techniques used to separate and identify sugars. Also, new synthetic reactions have been discovered that make it easier to change readily available carbohydrate molecules into those that are more difficult to obtain. Both of these results should prove useful to scientists in varied disciplines, including those trying to unravel the unique roles that carbohydrates play in biological systems. •

MARK ANDREWS (FRONT) AND GEORGE GOULD ANALYZE A REACTION IN WHICH SUGARS ARE CONVERTED INTO OTHER USEFUL CHEMICALS. A TINY AMOUNT OF THE REACTION MIXTURE IS INJECTED INTO THE GAS CHROMATOGRAPH (LOWER LEFT). SIGNALS FOR UNKNOWN REACTION COMPONENTS ARE DISPLAYED ON THE COMPUTER SCREEN AS SEPARATE PEAKS. THE TIME BETWEEN THE SAMPLE INJECTION AND A PEAK'S APPEARANCE IS COMPARED WITH KNOWN SAMPLES TO IDENTIFY THE UNKNOWN SAMPLE. THE SIZE OF THE PEAK INDICATES HOW MUCH OF THE MATERIAL IS PRESENT.

MEDICAL DEPARTMENT

The unique physical and chemical science resources and facilities at Brookhaven are used by Medical Department scientists to develop new approaches to medical applications of nuclear technology, as well as to understand human health effects of energy-related agents. Research includes improving radiotherapy and nuclear medicine procedures; developing new radiopharmaceuticals and methods for noninvasive measurement of human trace elements; and mechanisms of disease caused by energy-related agents.



MECT: A Better CAT

The Greek root for "slice" is "tomo" — and when doctors request computer-assisted tomography, known as CAT, they get a computer image of a cross-sectional "slice" of the patient's head or body.

Since its invention about 20 years ago, CAT scanning has been developed and used as an important radiological tool for diagnosing disease. But there is room for improvement. Some lesions are not detectable with present techniques.

Now, the U.S. Department of Energy has awarded scientists in Brookhaven's Medical Department a research grant to develop a refined CAT technique called MECT.

MECT — multiple energy computed tomography — will use monochromatic (single energy) x-rays from Brookhaven's National Synchrotron Light Source (NSLS) to produce "slices of life" that show more detail than ever before. Hence, the sensitivity and precision of MECT will be of great value in medical applications such as neuroradiology.

EXISTING CAT SCANNERS

During a CAT brain scan, an x-ray source sends a beam through the patient's head. As the x-rays travel from the source, their intensity is reduced, or attenuated, as they are absorbed or scattered by the skull and brain tissue. On the opposite side of the patient's head, an array of x-ray detectors measures the transmitted x-rays and provides a sort of x-ray "shadow" of the slice, called a projection.

The source and the detector array are rotated around the patient's head, giving a complete set of transmission projections. Using these data in a mathematical process called back projection, a

MECT MONOCHROMATOR.

AT LEFT IS A DIAGRAM OF A PATIENT HAVING A BRAIN SCAN BY MULTIPLE ENERGY COMPUTED TOMOGRAPHY. AT RIGHT, MEASURING AND DISCUSSING THE SILICON CRYSTAL ADJUSTMENTS IN THE NEW MONOCHROMATOR FOR THE MECT SYSTEM BEING DEVELOPED AT BROOKHAVEN ARE (CLOCKWISE, FROM LEFT) TOM OVERSLUIZEN, WILLIAM THOMLINSON, AVRAHAM DILMANIAN AND RICHARD GARRETT.

computer then integrates the information to reconstruct a picture representing actual slices of the brain.

MECT-EYE VIEW

Existing scanners use polychromatic x-rays, that is, x-rays with a wide range of energies. In body tissue, low-energy x-rays are stopped more easily than high-energy ones. Therefore, as the beam travels through the body, the energy spectrum changes and shifts towards higher energy. This effect, known as beam hardening, gives an image that appears fuzzy. The resulting "loss of contrast" may mean that an important lesion may be unidentifiable.

But Brookhaven's new MECT scanner will use monochromatic x-rays, with virtually no beam hardening. At the NSLS X17 beam line, a magnetic device called a superconducting wiggler enhances the beam intensity. MECT researchers are working there to develop an advanced monochromator that will enable them to tune to a narrow-energy beam of x-rays of any single value of energy ranging from 33 to 100 thousand electron volts (keV).

The monochromator will produce a fixed, fan beam about 20 centimeters wide and a few millimeters high. This beam will be projected onto the patient, who will be seated on a rotating chair, with a detector positioned behind his or her head.

MECT ADVANTAGES

One imaging method will be a technique called dual photon absorptiometry, currently being used to measure bone mineral density. In this technique, two CAT scans of the same slice are made at distinct energies, for example, at 40 and at 100 keV. The scan results are used to provide two CAT images.

One image shows the average concentration of body elements with low atomic numbers, that is, hydrogen, carbon, nitrogen, oxygen and sodium. The other shows the heavier body elements, such as phosphorus, chlorine, potassium and calcium.

Compared to the images given by existing CAT scanners, MECT images, thanks to their high contrast, will be about ten times more sensitive to changes in the concentrations of heavy elements.

This added sensitivity will be extremely valuable in improving early diagnosis and therapy of such conditions as stroke, in which the concentration of potassium and calcium is expected to change in the affected area.

In another special technique, called K-edge subtraction, the MECT scanner makes use of contrast agents — iodine or other heavy elements that enhance image contrast — to alert doctors to particularly small tumors or damaged blood vessels.

Probably the most important advantage of MECT will be the *quantitative* accuracy of its image contrast. On a scale ranging from black to white, the amount of gray in each point in a MECT image relates to the average concentration of body elements present. Doctors will be able to compare images from two patients with great reliability. In this way, neurological disorders that affect elemental concentrations of the whole brain will be more readily diagnosed.

AT WORK IN THE LABORATORY PURIFYING RADIOACTIVELY LABELED MONOCLONAL ANTIBODIES BY HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY ARE (CLOCKWISE, FROM LEFT) SURESH SRIVASTAVA, RONNIE MEASE, LEONARD MAUSNER AND MARK SWEET.

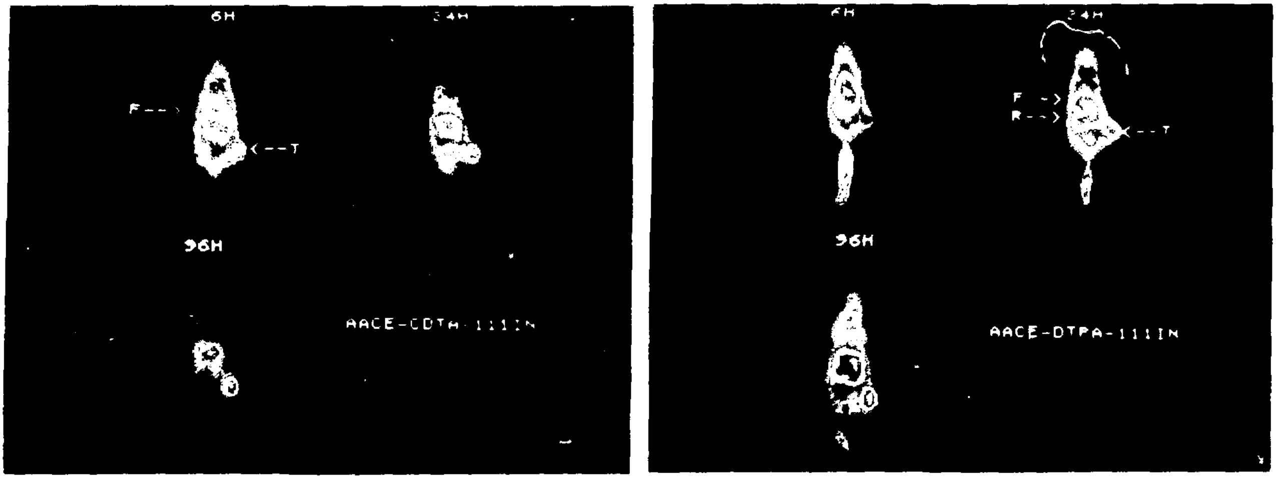
Meeting The Challenge

Scientists in Brookhaven's Medical Department are at the forefront of new research on radiolabeled monoclonal antibodies, the "magic bullets" that appear to be promising candidates for the diagnosis and treatment of many types of cancer.

These monoclonal antibodies, which are cloned to bind with tumor-associated antigens, track and attack tumor cells. When labeled with radionuclides and injected into the patient, the antibodies home in on their target, where the radionuclides, depending on their characteristics, either show the tumor's position for diagnostic imaging or deliver a lethal dose of radiation to the malignant cells.

Medical researchers at Brookhaven and all over the world began developing this promising technique in the early 1980s. By about 1985, laboratory tests of radiolabeled monoclonal antibodies were most encouraging — but setbacks arose when tests were made in vivo.

Once in the body, antibodies frequently became detached from their labels. This left the radionuclides free to accumulate in areas such as the liver and the bone marrow, giving unnecessary radiation doses to normal tissue.



THESE IMAGES SHOW HUMAN TUMORS GROWN IN MOUSE LIVERS BEING TREATED WITH TWO DIFFERENT CHELATING AGENTS EACH ATTACHED TO THE SAME ANTIBODY, WHICH SHOWS UP BRIGHTLY IN THE PICTURE. THE IMAGES WERE TAKEN AT 6, 24 AND 96 HOURS AFTER INJECTING THE ANTIBODY. AFTER 96 HOURS THE BROOKHAVEN-DEVELOPED CHELATING AGENT CDTA LEAVES THE RADIOACTIVE MATERIAL IN THE TUMOR WHILE LARGELY CLEARING NORMAL LIVER TISSUE. BY COMPARISON, THE OTHER AGENT, DTPA, DOES NOT CLEAR NORMAL TISSUE SO QUICKLY.

BACK TO BASICS

Brookhaven researchers decided to rethink the whole process. What was needed were better radiolabeling methods and linking techniques, as well as some way to control those radionuclides that might still separate in vivo from their antibodies.

Our scientists started by developing several "improved" radionuclides, with, for example, a property making them more likely both to concentrate in tumors and to remain there longer. At BLIP, the Brookhaven Linac Isotope Producer, radionuclides can be tailor-made by having high energy protons bombard stable elements to give the desired radionuclides. Among them, the radiometals copper-64, copper-67, cobalt-55 and lead-203 appeared the most promising.

In fact, copper-67 proved so successful that it is already being used in therapeutic trials in a program at the University of California Davis Medical Center in Sacramento.

To solve the potential problem of the radionuclides' nonselective buildup and general accumulation, our researchers worked on a method whereby detached radionuclides would promptly be excreted from the body.

They achieved this by incorporating the radionuclides into antibodies containing chelating agents such as cyclohexyl polyaminocarboxylates. These agents are bifunctional, one side binding to the radiometal and the other to the antibody, either with or without a linker molecule inserted in between. They are also hydrophilic (water soluble), and, thus, their primary route of excretion is in the urine. If they are firmly attached, the radionuclides go with them.

To be sure that the radionuclides would be firmly attached, our scientists developed additional general-purpose, rigid chelating agents with one section preorganized to receive and bind the radionuclide. In many cases, these chelating agents provide a cavity that holds the metallic radionuclides so well that they are very unlikely to break away.

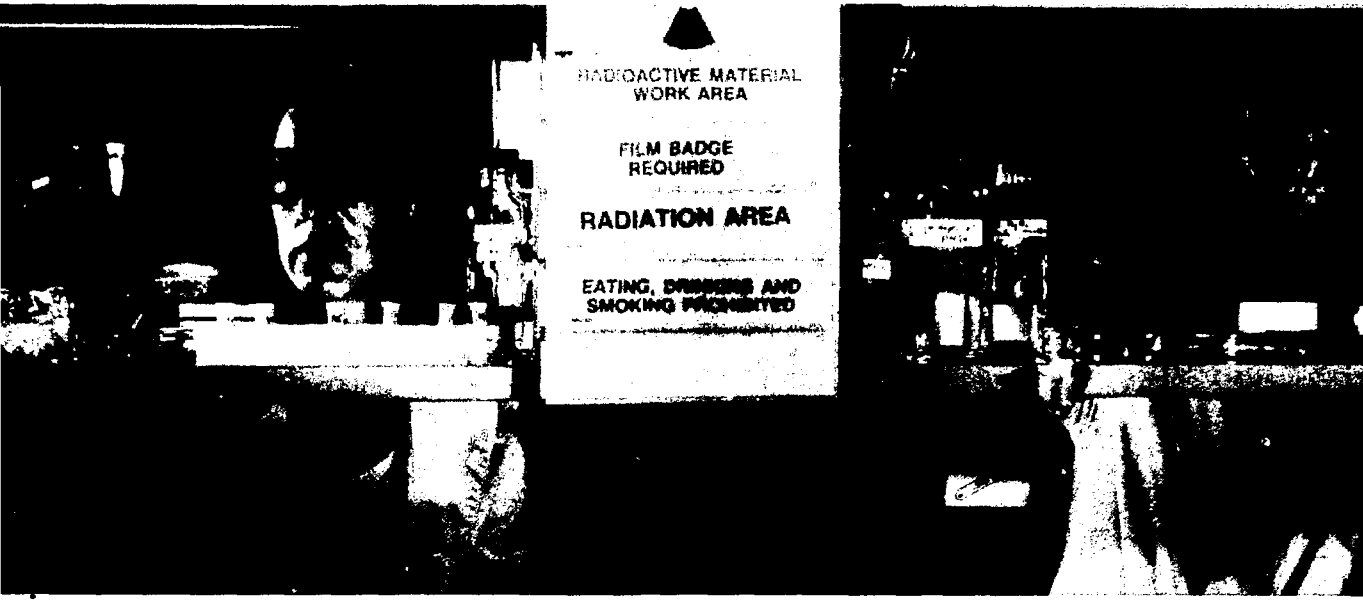
At the same time, the team was also working on new linkage techniques to be used in attaching the radiometal chelates to the monoclonal antibodies. They developed about six different kinds of metabolizable linkers to place between the antibody and the metal chelate. These linkers are expected to withstand the journey through the bloodstream to the tumor. But if, for example, the antibody should stray and be retained in the liver, the linkers will be destroyed by enzymes there.

The advantage of this approach is that the metal radionuclide will still be attached to the specially developed chelating agent. Therefore, it will be excreted — and no unwanted buildup of radioactivity will occur in the liver or other organs.

These new ideas being developed by Brookhaven's medical team are soon to be tested clinically, both in the United States and at the University of Nantes in France. If the tests are successful, we may overcome many of the present difficulties in using radiolabeled monoclonal antibodies for cancer diagnosis and treatment. •

BIOLOGY DEPARTMENT

Research in the Biology Department encompasses studies on molecular structure, molecular genetics, DNA damage and repair, and cell biology of plant and animal systems. The department contains the Scanning Transmission Electron Microscope facility and also operates experimental stations for molecular structural studies at the National Synchrotron Light Source and the High Flux Beam Reactor. The broad range of studies covered by our researchers is illustrated in the following stories, which describe a discovery of how cells can achieve transcription, the ability to change; fast new techniques in x-ray diffraction experiments; and how a cluster of 11 atoms of a gold isotope can be attached to a monoclonal antibody and used to destroy a cancer cell.



Nexus Controls Change

Whether you get lost in the desert for days without food, or merely stick to a really stringent weight-loss program, your body cells will respond to starvation — and change.

Less dramatically, as body cells mature, suffer disease and grow old, they make other, more ordinary changes every day.

One of the cell's principal means for producing change is known to biologists as transcription. The way in which transcription is controlled, however, has been less well-known, and researchers are still exploring this frontier of fundamental biology with intensive interest.

In 1990, scientists in Brookhaven's Biology Department, together with researchers from the University of California at Berkeley, San Diego and Los Angeles, discovered one of the ways in which this control is exercised.

Our scientists used Brookhaven's uniquely powerful Scanning Transmission Electron Microscope (STEM) to look at DNA (deoxyribonucleic acid, the carrier of genetic information in every cell). They found that two remote parts of a long, looping piece of DNA can come together. Each of the two parts is bound to a transcription-enhancing protein called Sp1. And when they combine, nexus, the name our researchers gave to this procedure of transcription control, occurs — and the cell is then able to change.

CONTROLLING NEXUS

To obtain these results, our biology team studied a piece of DNA, which has molecules made of a long, double-stranded chain of subunits. Each subunit contains, among other things, one of

WHEN THE REMOTE ENHANCER AND THE LOCAL PROMOTER ON A LOOPING STRAND OF DNA COME TOGETHER, NEXUS OCCURS.

IRIS MASTRANGELO AND PAUL HOUGH ARE PREPARING REACTIONS WITH DNA AND PROTEIN FOR THEIR WORK ON THE DISCOVERY OF NEXUS, A WAY IN WHICH ALL CELLS CONTROL TRANSCRIPTION, THEIR PRINCIPAL MEANS FOR PRODUCING CHANGE.

four bases: adenine (A), guanine (G), thymine (T), and cytosine (C). The bases bind in pairs of AT or TA, and GC or CG, and they form special, recognizable sequences, which perform different functions.

Our researchers chose a sample of DNA that contained the RNA start site. This is an original point in the base pairs where the DNA can start being copied into RNA. Short for ribonucleic acid, RNA acts as a DNA messenger, carrying instructions from the DNA into other parts of the cell, which then makes the required changes. The region of DNA upstream of the start site, from 0 to about 200 base pairs, is called the promoter, because it is here that protein factors promote transcription.

Only 25 base pairs up from the RNA start site is a TATA sequence. This region binds six or seven factors that keep cell activity just ticking over at a low, basal level. When the cell needs more RNA produced, it uses an activator — a protein that binds to a specific sequence upstream from the TATA, usually between 30 and 100 base pairs away.

One gene our scientists examined has a tk (short for thymidine kinase) promoter, which has an important activator sequence — GGGGCGGGGC — known as a GC box. The GC box binds a particular kind of protein called Sp1, the first activator protein to be discovered.

In some cells and for some genes, that is all that is needed. But most genes need an additional transcriptional modulator called an enhancer to start the RNA messenger service on its way.

The gene can find another GC box, able to bind Sp1, about 1,700 base pairs away. Functional tests in living cells show that this remote GC box enhances transcription strongly. But it has been difficult to discover how Sp1, bound over a few base pairs at such a distance, can stimulate transcription as if it were at the local promoter.

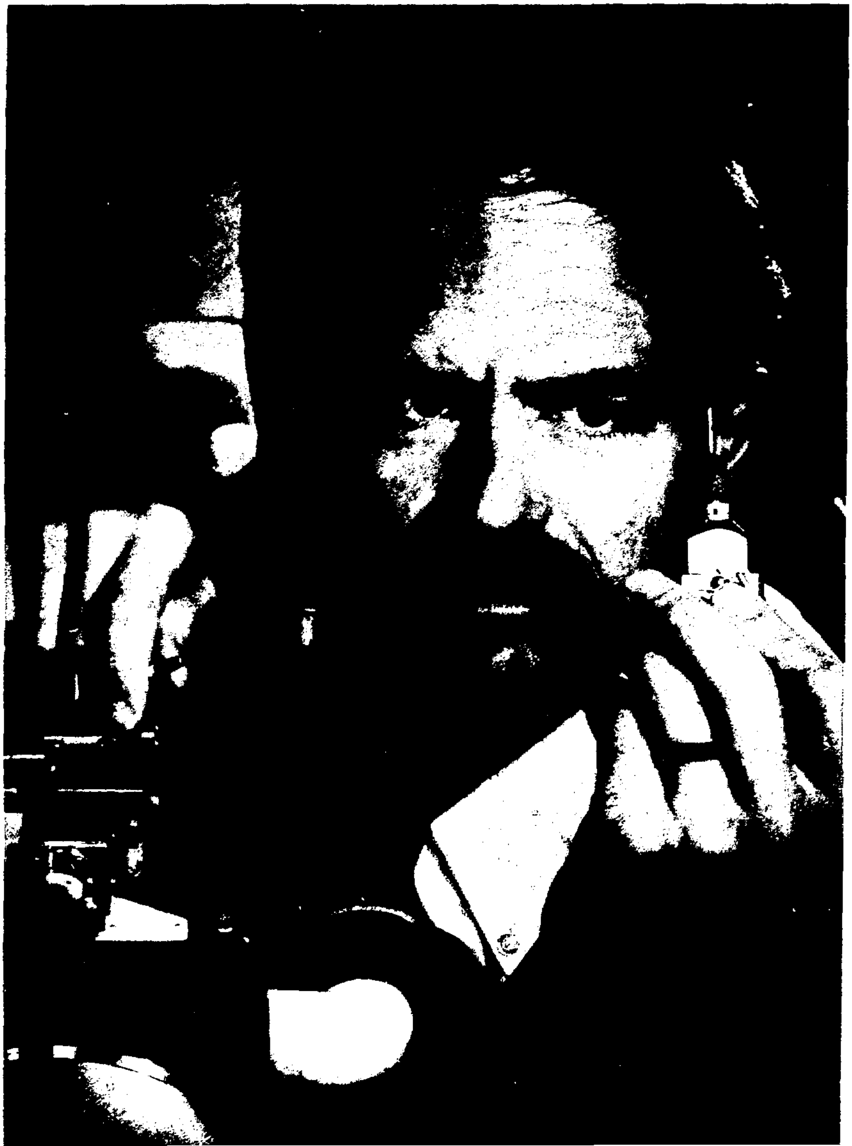
Already, however, our team had seen by conventional microscopy that two large masses of Sp1 could come together as the DNA strands flexed and looped. When they connected, the link was stabilized by the binding of remote and local Sp1.

Sp1, like many other proteins, tends to stick together and form multimers, or ordered groups of monomers, the term used to denote an individual protein. Because mass can be measured for each individual molecule by STEM, the researchers could determine that, at the GC boxes and within the nexus structures, Sp1 formed tetramers, or groups of four units. Nexus was seen in the form of single tetramers, but also in stacks of 2, 3 and greater numbers.

The tetramer as a nexus structure can account for an important feature of enhancers. The remote-control GC box was known to enhance transcription strongly, whether it was in the same orientation as the local box or an opposite orientation.

This is because each protein monomer unit binds the GC box through a formation resembling fingers. In the tetramer, two of the four monomers can bind GC boxes of one orientation, the other two of an opposite orientation. Thus, no matter which set of fingers binds the local GC box, a set is always available to grip the remote GC box in whatever direction it is oriented.

In the transcription process, everything's under control. •



ABOUT HALFWAY UP THE CAPILLARY TUBE HELD BY ROBERT SWEET IS THE CRYSTAL HE WILL MEASURE IN THE DIFFRACTOMETER BESIDE HIM.

FASTER DATA

With the arrival of two new techniques in x-ray diffraction, investigations into the structure of biomolecules are speeding ahead. The techniques dramatically reduce the time needed to take data. Structural biologists in Brookhaven's Biology Department and from other institutions use them in studies of crystals at BNL's National Synchrotron Light Source (NSLS).

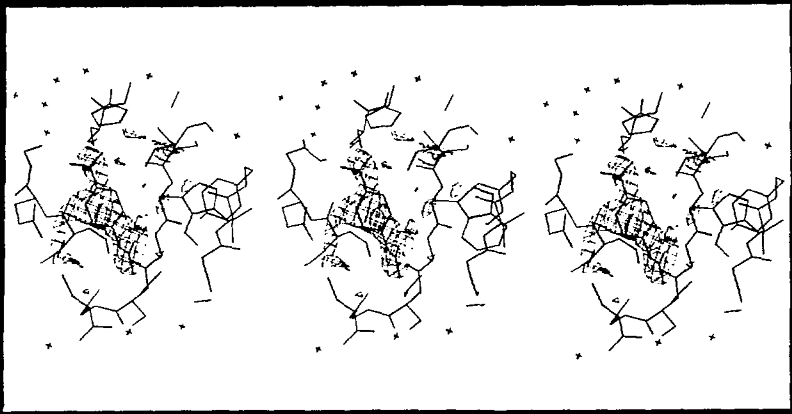
X-ray diffraction is a method of determining the detailed, three-dimensional atomic structure of molecules grown into crystals. X-rays that hit a crystal scatter and form a characteristic, and often symmetric, array of individual rays, known as a diffraction pattern. The pattern can be recorded on TV-based x-ray film for later analysis that will reveal the structure of the molecules in the crystal.

In September 1989, a highly advanced TV-based x-ray camera was installed at beam line X25. With an x-ray-sensitive surface of about 45 × 65 millimeters, the new camera gives a TV image that can be manipulated by computer, immediately showing the recorded data on a screen.

With their previous equipment, biologists might take from six to eight hours for a complete set of measurements. The new TV camera detector allows researchers to obtain all the measurements in just one or two hours.

A second "faster data" capability is also available. Usually, x-rays used on the specimen crystal are monochromatic — one single "color," or wavelength, which is indicated as tiny spots in an arrangement known as a diffraction pattern.

The new technique uses a "white" beam of x-rays, that is, all the colors at once. The resulting diffraction pattern shows up on an x-ray film as even more tiny spots in a more complicated arrangement. With this technique, a much greater number of diffraction points can be measured in a unit of time.



FOLLOW THAT HEN!

Hen tracks in chicken-wire cages — this is one way to describe one of the sources of information for biologists studying the structure of molecules. The biologists first grow crystals from the molecule, then perform an x-ray diffraction experiment. In this research technique, the x-rays hit the crystal specimen, then scatter in a pattern.

The structure first appears as "hen tracks in chicken wire" on a computerized screen. The "chicken wire" shows the places where the electrons, which are the part of the molecule that interacts with the x-rays, are most dense. Since electrons cluster round atoms, a line of "tracks" through the center of the chicken-wire pattern shows the location of the atoms in the molecule.

In the triptych above, which allows one to perceive the molecule in three dimensions, the first and third images are left-eye views and the middle one is for the right eye. To see a single image in 3-D, cover image 3 and relax the eyes to view image 1 with the left eye and image 2 with the right eye. If that doesn't work, cover image 1 and cross your eyes, viewing image 2 with the right eye and image 3 with the left.

PUTTING THE TECHNIQUES TO WORK

Interpreting the diffraction pattern, which gives the true structure of the crystalline specimen, is the most difficult part of using x-ray diffraction. One way that crystallographers solve this problem is by adding a small number of very heavy atoms of a different element to the specimen molecule. The disturbances that the atoms make in the diffraction pattern are used to decipher the results.

An additional advantage can be gained with the NSLS x-ray beam, in that experimenters can use any one of a wide range of x-ray wavelengths. If several atoms in the specimen absorb x-rays strongly at one particular wavelength, the diffraction pattern can again be rearranged by exposing the specimen to x-rays at several other wavelengths near that one.

In a set of experiments using the TV detector, Brookhaven biologists are exploiting these possibilities, growing protein crystals in which many natural sulfur atoms are replaced by the chemically similar element selenium. Nature helps: Synthetic amino acids containing sulfur can be made with their sulfur replaced by selenium — and then certain organisms will grow naturally on them. When these organisms mature, *all* their proteins will have selenium atoms.

Then these crystals are examined at several different wavelengths near the one at which selenium absorbs x-rays extra-strongly, and new information about their structure is obtained.

Once this process is fully developed, it could form the core of a nearly automatic method to determine structures of biological molecules.

In another set of experiments, using the "white" beam technique, Brookhaven biologists have started investigating the structure of the crystalline enzyme trypsin. They are looking at the way it changes as it acts as a catalyst in digesting proteins in the small intestine. As the trypsin's target, they use a small molecule that behaves very similarly to the natural protein. One difference is that they can control whether the molecule sticks to the enzyme or dissolves after being digested.

Using the very rapid data collection that is possible at the NSLS X25 beam line, the team will take several closely spaced diffraction photographs just at the moment they trigger the molecule's release from the enzyme in the crystal. From these photos, they hope to produce a three-dimensional "movie" showing four or five steps of the catalytic process.

AT WORK IN THE LABORATORY

(CLOCKWISE FROM TOP) LEONARD MAUSNER, ROBERT LEONE, I-NAN FENG, JAMES HAINFELD, KATHRYN KOLSKY AND GEORGE MEINKEN PURIFY THE MONOCLONAL ANTIBODIES THAT, WHEN LABELED WITH GOLD CLUSTERS, WILL BE USED TO FIGHT MALIGNANT TUMORS IN THE HUMAN BRAIN

GOLD RUSHES TO BEAT CANCER

A new kind of gold mine is being worked in Brookhaven's Biology Department. This gold is not destined for making jewelry or stabilizing money markets. Instead, it is being turned into a lethal weapon in the war against cancer.

The golden weapon will be used in radioimmunotherapy, a way to treat cancer using antibodies that can be produced against cancerous tumors.

Many of these antibodies can now be cloned in the laboratory and labeled with a radioactive element. Physicians then inject patients with these "magic bullets" — the nickname given to the labeled monoclonal antibodies that can bind to a malignant tumor and discharge a lethal dose of radioactivity to the cancerous cells. Because the effects of the radioisotopes that are used for the labels extend over a limited range, most of their radiation reaches the tumor cells, leaving almost all the nearby healthy cells unharmed.

One of the best isotopes for this work is gold-199, a radioisotope of gold that has an approximately 10-cell radius of killing power. Its lethal radiation decays within a few days, which allows a predetermined dose of radiation to be prescribed. In the past, however, this ideal element could not be used, because nobody knew how to attach it firmly to antibodies.

Suddenly, with a breakthrough discovery in 1987 by Brookhaven's biologists, the situation changed. Our researchers successfully synthesized a compound containing a cluster of eleven gold atoms and attached it to a human tumor antibody.

Although the clusters are too small to be seen by most microscopes, our scientists were able to do this work using STEM — the department's Scanning Transmission Electron Microscope, in which both antibodies and gold clusters are visible.

Our biologists then built a stock of antibodies labeled with gold-199, using monoclonal antibodies provided by collaborators at the Wistar Institute in Pennsylvania.

Next came the tests. Would the new anti-cancer ammunition readily recognize cultured human tumors and ignore other types of cells? Would this test be as successful in mice with implanted human tumors as it was in a test tube? Results of these studies, funded by a special research grant in nuclear medicine from the U.S. Department of Energy, have been encouraging.

Using a cluster compound brings a special advantage, for only one to three atoms of other radioisotopes can be attached to an antibody without destroying its activity. The gold cluster attaches 11 gold atoms per antibody, which still remains completely active in binding to tumors.

In addition, if all 11 atoms in the gold cluster are radioactive, a single antibody will deliver more of a punch to the tumor. For this reason, current work done in collaboration with researchers in the Medical Department is focused on producing gold-199 in which most of the atoms are radioactive. Once this has been achieved, a new series of tests will show whether the full dose of radioactivity will shrink tumors.

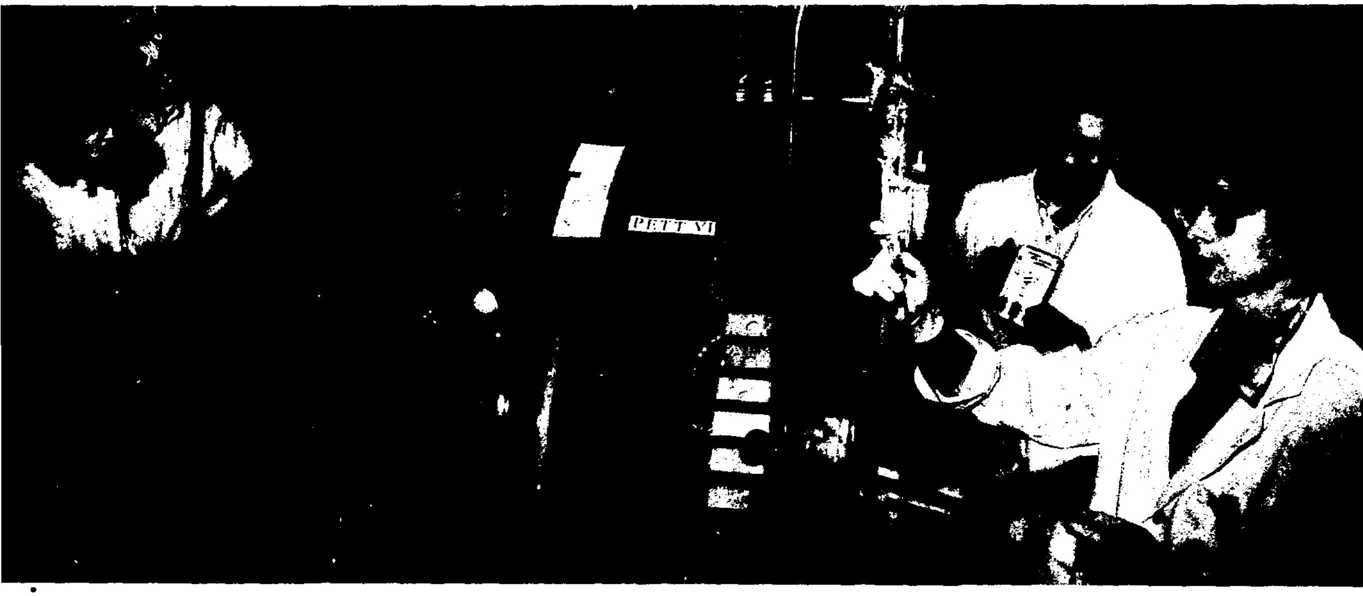
ON THE SCREEN, JAMES HAINFELD LOOKS AT THE GOLD-CLUSTER-LABELED, MONOCLONAL ANTITUMOR ANTIBODIES THAT ARE IN THE SCANNING TRANSMISSION ELECTRON MICROSCOPE IN THE BACKGROUND.

One difficulty with radioimmunotherapy thus far has been that some of the radioactivity has been reaching sensitive tissue, such as bone marrow, which means that the total dose reaching the tumor must be limited. Completely effective therapy can be achieved only if more specific antibodies can be produced.

With the "extra-strength" dose brought to the tumor by the antibodies labeled with gold-199 clusters, however, cancer may be treated more successfully by radioimmunotherapy. •

INTERDEPARTMENTAL RESEARCH

The lines between Brookhaven's nine scientific departments are frequently drawn more in gray than in black, as researchers from different scientific disciplines often join forces in tackling complex problems that are best solved with a multidisciplinary approach. The following stories — one that focuses on collaborative research between the Chemistry and Medical Departments and another that involves Applied Science, Chemistry and Physics — are but highlights of the interdepartmental research that goes on at the Laboratory. Through open lectures and seminars, science stories in the weekly employee newspaper, and other avenues of communication, research in all the scientific departments is shared with the entire Laboratory staff, thereby further encouraging collaborative work.



PET Studies: Fighting The Enemy Euphoria

Total exhilaration.

No talking, no thinking . . . blood rushing to the head . . . ears ringing.

Being powerful.

Being capable.

Being in control.

These are some of the feelings a cocaine addict gets with a fix. Whether smoked, snorted through the nose or injected, the euphoria that cocaine triggers in the pleasure centers of the brain is so intense that nothing else matters — not food, money, family or home. When the high is over, one obsession remains: getting another fix.

Locked into their dependency, cocaine addicts are unaware, or do not care, that the euphoria they crave masks other effects — the toxic damage wrought by cocaine on vital body organs.

At Brookhaven, researchers in the Chemistry and Medical Departments join forces in searching out the mechanisms by which cocaine damages the human body. They use the technique called positron emission tomography, or PET. The early development of this technique was pioneered in part by Brookhaven's Chemistry Department.

By measuring the concentration of a positron-emitting radionuclide in a specific area of the body, a PET scan allows researchers to "see" into a patient as if through a window.

For example, for a PET brain scan, a substance tagged with a short-lived radioactive tracer is

AT LEFT, JOANNA FOWLER AND ALFRED WOLF STUDY THE CHEMICAL EFFECTS OF COCAINE SHOWN BY POSITRON EMISSION TOMOGRAPHY (PET), WHILE BERNARD BENDRIEM FOCUSES THE PET CAMERA AND NORA VOLKOW ADJUSTS THE SALINE SOLUTION IN THE PATIENT. AT RIGHT, WOLF AND VOLKOW DISCUSS RESULTS OF A PET SCAN.

injected into the patient and taken up by the brain. Detectors record the amount of radiation emitted by the tracer. From this data, a computer reconstructs three-dimensional pictures of the brain as it functions, providing clues to disorders.

For the current cocaine studies, our research team labels cocaine with carbon-11, an isotope of carbon that can be used as a tracer. They inject a minute amount of the cocaine into the patient — a quantity so small that although it allows the characteristic action of cocaine to be traced, it has none of the usual effects of a fix. The researchers then follow and time the tracer's movement as it passes through the bloodstream to the brain.

These investigations have shown that the distribution of cocaine in the brain is very heterogeneous, some areas having a much higher uptake than others. The highest concentration is in the brain's basal ganglia. Our researchers have found that the kinetics of cocaine in the basal ganglia are similar to the time sequence of the euphoria experienced by users — the peak of euphoria comes at the moment of peak cocaine uptake in that area.

This indicates that the specific binding of cocaine into the basal ganglia is probably related to the intensity of euphoric feeling.

The timing of the euphoria after the cocaine has been injected shows no correspondence with other brain areas that bind cocaine.

Our researchers are also using the clear picture resulting from the carbon-11-labeled cocaine to study whether chronic use of the drug leads to changes in the quantity as well as the distribution of receptor sites. This may lead to information that could help explain cocaine addiction and tolerance.

In another series of tests, our investigators have measured and monitored the distribution of cocaine to the heart, lungs, liver and aorta of patients. Some damage can be traced to the direct interaction between cocaine and body cells.

The Brookhaven PET team has demonstrated that cocaine binds strongly to the human heart, as well as being taken up to a high degree into the aorta. They find that the organ with the highest concentration of cocaine, however, is the liver.

By applying their findings on the mechanisms of cocaine and its effects on the human body to the design of possible treatments, our researchers hope to help addicts overcome the enemy euphoria. •

MARSHALL NEWTON STUDIES A COMPUTER GRAPHICS REPRESENTATION OF AN INTERACTION BETWEEN TWO MOLECULES THAT ARE IN THE PROCESS OF EXCHANGING AN ELECTRON. THE DETAILS OF SUCH A PROCESS ARE DETERMINED BY QUANTUM THEORY CALCULATIONS.

QUANTUM QUERIES

How do electrons move from one site to another? How does the material through which they travel affect their speed and direction?

Answering these questions with calculations based on quantum mechanical theory can provide the key to understanding critical electron transport processes in chemistry, physics and biology.

Subatomic particles, such as electrons, do not follow Newton's laws of motion or the classical laws of electrodynamics. Instead, their movements must be explained by quantum mechanics.

In 1913, Danish physicist Niels Bohr suggested that the energy of the electron in the hydrogen atom is restricted to having only specific values. This became the basis for quantum theory as scientists practice it today.

Quantum theorists in BNL's Chemistry Department formulate quantitative predictions to determine how electrons move between different sites and what factors control the speed of this motion. As part of this work, they collaborate with the Laboratory's Department of Applied Science (DAS) to determine the speed at which electrons travel in photosynthesis. They also work with Physics Department researchers in applying quantum theory to gain a better understanding of superconducting materials.

Since electrons travel in dense, cloud-like formations, a single electron cannot be discerned. Therefore, quantum theorists predict where electrons are likely to be found by using calculated probability distributions obtained from so-called quantum wave functions.

SOLO ELECTRONS

Electron transport processes of interest to researchers typically occur in complex molecular systems that have large numbers of electrons. According to quantum theory, individual electrons cannot be distinguished in such systems. Nevertheless, most chemists think in terms of the movements of a single electron as it proceeds along a path connecting a donor and a receptor site.

Part of the subtlety of modern quantum chemical theory is that it provides a language that enables scientists to talk about a single electron as though, in fact, it could be distinguished, thus forming a bridge between basic theory and the intuitive point of view adopted by the practicing chemist.

ELECTRON TRANSPORT IN PHOTOSYNTHESIS

Together with scientists from DAS, the Chemistry Department's theorists are learning how electrons move in processes related to photosynthesis. One example of their research involves studying a dimer molecule consisting of two porphyrin molecules, pigmented compounds that form the active nucleus of photosynthetic systems.

Using lasers, Chemistry and DAS researchers had earlier discovered that the time it takes an electron, excited into movement by visible light, to move from one porphyrin to another may be as short as one picosecond, or one-trillionth of a second. BNL's quantum theorists have now helped to explain these findings by performing model calculations that have yielded results consistent with the picosecond time scale.

This research is helping our scientists to understand the transformation of solar energy into chemical energy, and it may eventually help in efforts to devise more efficient systems for the electron transfer process in photosynthesis.

INTERACTIONS IN SUPERCONDUCTORS

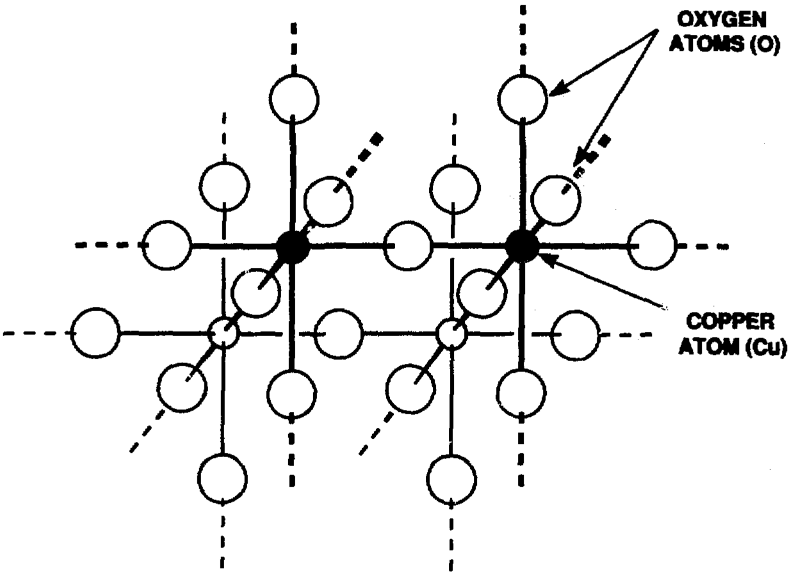
With BNL physicists, theorists from the Chemistry Department have also been studying the electronic properties of model materials used for high-temperature superconductors.

Becoming more prevalent in research and industry, superconductors, which conduct electricity with great efficiency, have been used for such applications as accelerator magnets, for magnetic imaging devices for medical diagnostics, and for high-speed magnetically levitated trains. An understanding of how superconducting materials work in terms of quantum theory is important for developing their maximum potential.

Our researchers are focusing on a phenomenon known as superexchange, which is characteristic of superconducting materials in which unpaired electrons on different positive metal ions are coupled indirectly by a mechanism involving intervening negative ions, such as oxides. These studies have been successful in quantitatively accounting for the strength of indirect coupling in superexchanges.

Understanding such interactions through quantum theory will give scientists greater knowledge of the crucial electronic properties of superconducting materials. •

Cu_4O_{20} SUBUNIT OF CRYSTALLINE La_2CuO_4



LANTHANUM COPPER OXIDE (La-CuO_4) IS A MODEL MATERIAL FOR SUPERCONDUCTING METAL OXIDES. QUANTUM CALCULATIONS WERE MADE FOR THE Cu_4O_{20} SUBUNIT OF THIS CRYSTALLINE SUBSTANCE (ILLUSTRATED HERE) TO UNDERSTAND ITS SUPEREXCHANGE INTERACTIONS.

RESEARCH DIVISIONS

Critical to the success of the Laboratory's scientific programs are activities in the four research divisions: Computing and Communications, Instrumentation, Reactor, and Safety and Environmental Protection.

These divisions collaborate with the scientific departments in support of ongoing research. The work requires innovative ideas, techniques and instrumentation, since science is by nature always reaching out to new frontiers.

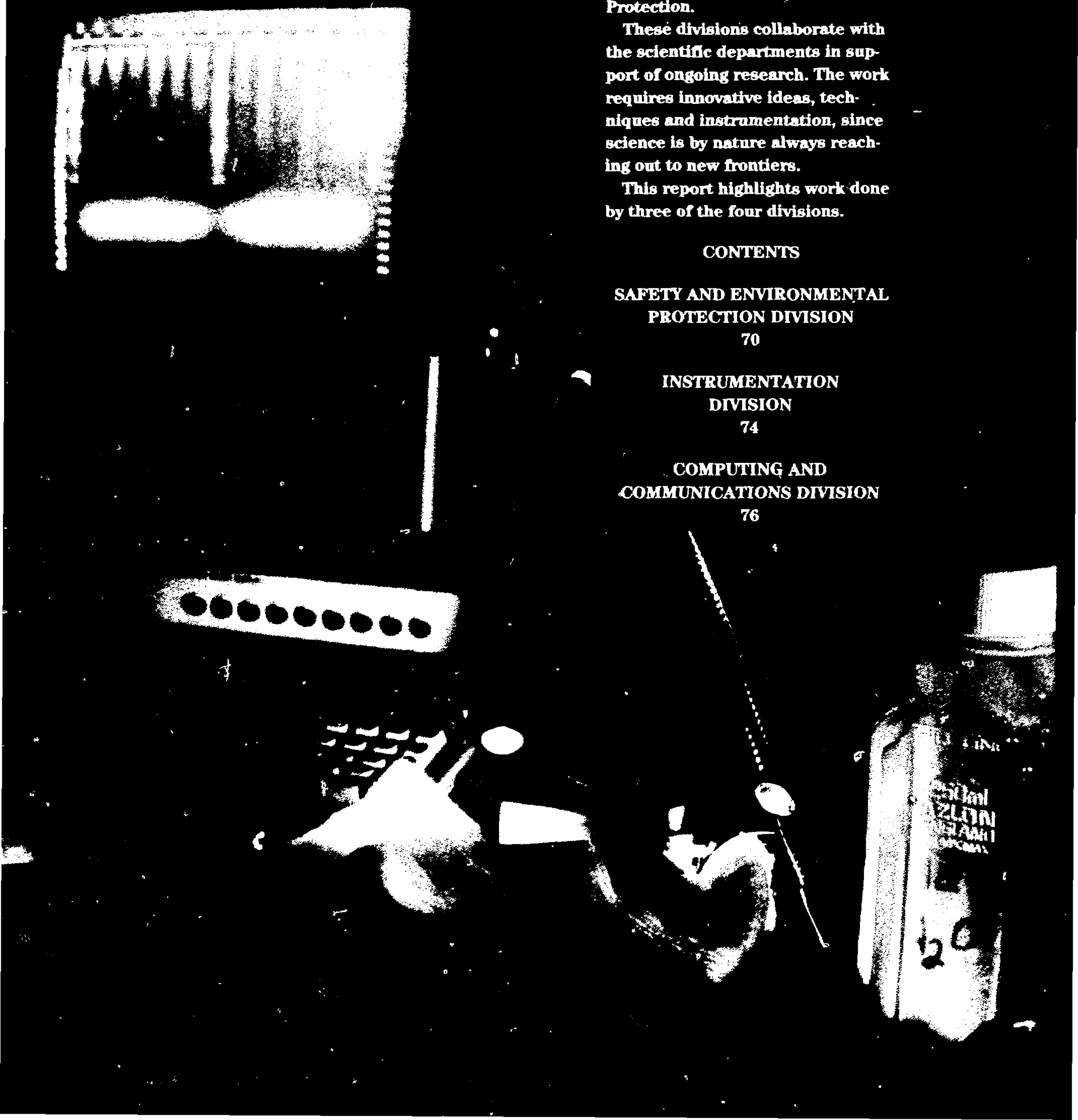
This report highlights work done by three of the four divisions.

CONTENTS

SAFETY AND ENVIRONMENTAL PROTECTION DIVISION
70

INSTRUMENTATION DIVISION
74

COMPUTING AND COMMUNICATIONS DIVISION
76



SAFETY AND ENVIRONMENTAL PROTECTION DIVISION

The Safety and Environmental Protection Division provides technical support and audit in the areas of health and safety. This includes monitoring the BNL workplace for possible chemical, physical and radiological hazards, as well as surveying the environment. The division manages the Radiological Assistance Program, which can respond to any type of radiation incident in the Northeast. It is also responsible for developing and maintaining instruments for radiation monitoring and industrial hygiene surveys. Further, the division oversees on-site construction safety and conducts safety reviews of new and modified facilities.

NEW SAFETY CULTURE AT BNL

In recent years, a new safety awareness has taken root at BNL, as well as at all U.S. Department of Energy (DOE) facilities nationwide. It reflects a heightened determination to address safety and environmental concerns effectively so that employees and the public are protected and research can continue without interruption.

Brookhaven has initiated several programs aimed at instituting this new safety culture. Taken together, they provide broad support for improving safety at the Laboratory.

TEAM SAFETY

In July of 1988, Brookhaven initiated a program called Team Safety. As its name suggests, the new program focuses on reducing time lost from work by providing our employees with incentives to work more carefully and by fostering team spirit for team safety.

Success to date has been dramatic. We have cut our lost-time injuries almost in half.

The program is coordinated by the Safety and Environmental Protection Division (S&EP). Participating teams come from the divisions of Central Shops, Plant Engineering, Safeguards and Security, and Supply and Materiel, as well as the Fire and Rescue Group within S&EP.

Each team works toward a goal of 12 consecutive weeks without lost-time injuries. When a team reaches its goal, it is honored at a luncheon and the team members are given vouchers that

SPEAKING AT A TEAM SAFETY LUNCHEON, JACK ELLERKAMP HOLDS A CHART THAT SHOWS THE DRAMATIC REDUCTION OF LOST-TIME INJURIES AT BNL SINCE THE LABORATORY'S TEAM SAFETY PROGRAM BEGAN IN 1988.

ATTENDING A TEAM SAFETY LUNCHEON ARE WINNING TEAMS FROM THE PLANT ENGINEERING DIVISION, WHICH ON THIS OCCASION INCLUDED ELECTRICIANS, REFRIGERATION AND AIR-CONDITIONING ENGINEERS, STEAMFITTERS AND STEAM PLANT OPERATORS.

can be traded in for various prizes.

Most of the teams have earned several luncheons, with Plant Engineering doing particularly well in the program.

REVIEW GROUP

Another initiative in the name of safety was the establishment of the Occupational Health Review Group. Composed of managers from S&EP and other Laboratory organizations, the group has been meeting with each department chairman and division head to review injury statistics and formulate goals and strategies for reducing all injuries, not only those that result in lost-work time.

A study of accident statistics can sometimes reveal recurring problems. For example, different injuries tend to occur when different types of work are done. If patterns can be found, then attention is focused on eliminating recurrence.

Departments and divisions have started submitting injury-prevention plans to the group, which will evaluate them. Eventually, the plans will be circulated so people can share ideas.

SAFETY BULLETIN

Also new on site is SuperSafe, a four-page bulletin that S&EP produces and sends periodically to supervisory staff, safety professionals and safety representatives in all buildings. Each bulletin contains a mix of information — ranging from a discussion of Laboratory policy on a particular safety issue, to a description of an S&EP program, to an article calling attention to a specific safety concern.

TIGERS VISIT BNL

Even as BNL was implementing these new safety measures, the Laboratory underwent a major assessment of its environment, safety and health (ES&H) programs by DOE, which is in the process of evaluating all its facilities. In the spring of 1990, a so-called Tiger Team from DOE visited the Laboratory to review

IN 1990, A LABORATORY TASK FORCE ON SAFETY AND ENVIRONMENTAL PROTECTION WAS FORMED TO STRENGTHEN THOSE PROGRAMS THROUGHOUT THE LABORATORY. AT THE CENTRAL STEAM FACILITY, TASK FORCE MEMBER GERALD KINNE (SECOND FROM LEFT), WHO IS ALSO BNL'S ASSOCIATE DIRECTOR FOR REACTOR, SAFETY AND SECURITY, CHECKS TO SEE THAT SAFETY REQUIREMENTS ARE BEING FULLY MET. WITH HIM ARE (FROM LEFT) MICHAEL BEBON, MANAGER OF THE PLANT ENGINEERING DIVISION (PE); PATRICIA WILLIAMS, SAFETY REPRESENTATIVE FROM THE SAFETY AND ENVIRONMENTAL PROTECTION DIVISION; AND LEWIS JACOBSON, SAFETY COORDINATOR FOR PE.

environmental compliance, health and safety procedures, and management practices.

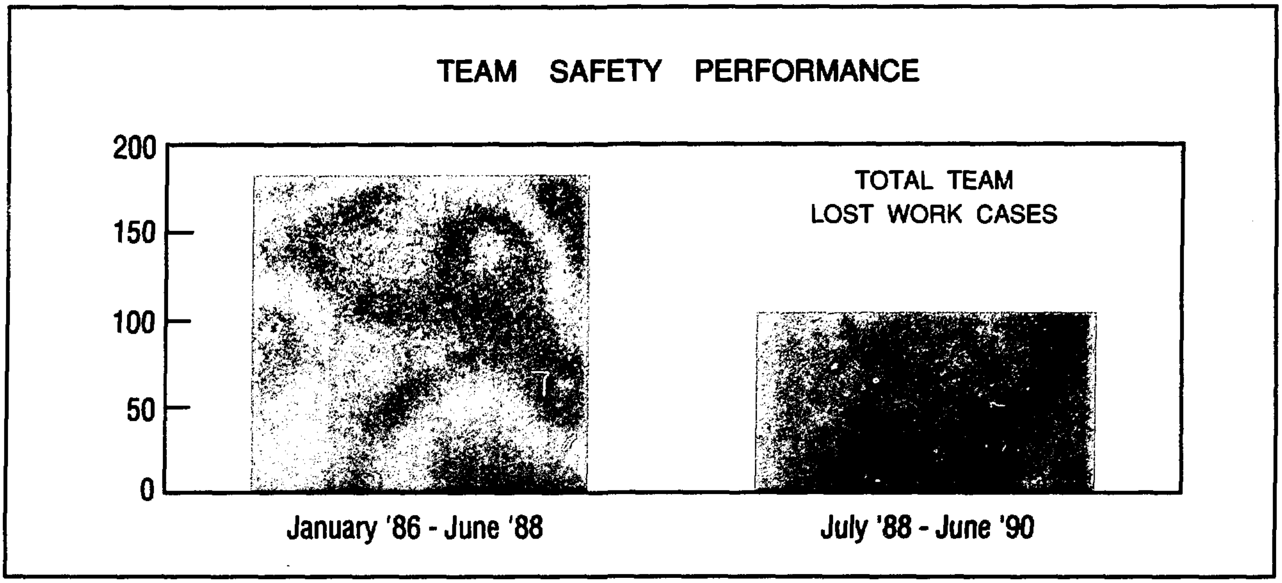
During the rigorous month-long review of our programs, the findings in the area of safety included 244 Occupational Safety & Health Administration (OSHA) violations. Of the OSHA violations — none of which were classified as "imminent danger" — 89 percent were corrected by the end of fiscal year 1990.

One recommendation made by the Tiger Team was that BNL establish more formal policies and procedures. In response, the Laboratory is developing a new Safety and Administrative Policy and Procedures Manual. The manual will establish minimum ES&H requirements for the operation of each department and division on site; establish line-management authority and responsibility for implementing and enforcing ES&H policy and procedures; and define the levels of ES&H training required. It will also be the standard against which a new committee of independent experts will audit BNL's ES&H compliance every three years.

As a further assurance that a new safety culture is established at BNL, the Laboratory is writing a five-year ES&H plan that will define long-term goals, identify deficiencies and outline corrective measures and upgrades.

Another issue raised by the Tiger Team was the need for additional training. A Laboratory task force for training-related issues was appointed to determine the appropriate requirements for ES&H training in the future. While BNL does train its employees in a range of areas, the training programs will be expanded, strengthened and formalized. In addition, education on OSHA standards will be incorporated into BNL's training programs.

THE TEAM SAFETY PROGRAM BEGAN IN JULY 1988. ALTOGETHER, PARTICIPATING TEAMS FROM CENTRAL SHOPS, PLANT ENGINEERING, SAFEGUARDS AND SECURITY, SAFETY AND ENVIRONMENTAL PROTECTION, AND SUPPLY AND MATERIEL SHOW A MARKED DECREASE IN LOST-TIME INJURIES FOR THE TWO YEARS FOLLOWING THE PROGRAM'S INITIATION, AS COMPARED TO THE PREVIOUS TWO-AND-A-HALF YEARS.



SUPERFUND

In November of 1989, BNL was named to the National Priorities List of the U.S. Environmental Protection Agency (EPA). This is a roster of hazardous waste sites that are considered high priority for cleanup under the federal Superfund Program.

BNL is located on Long Island, which draws its drinking water from a sole-source aquifer underlying all of the Island. The Laboratory's inclusion on the Superfund list is primarily due to past disposal practices, which complied with earlier standards, but resulted in groundwater contamination on the BNL site. This contamination is a potential threat to the Island's sole-source aquifer.

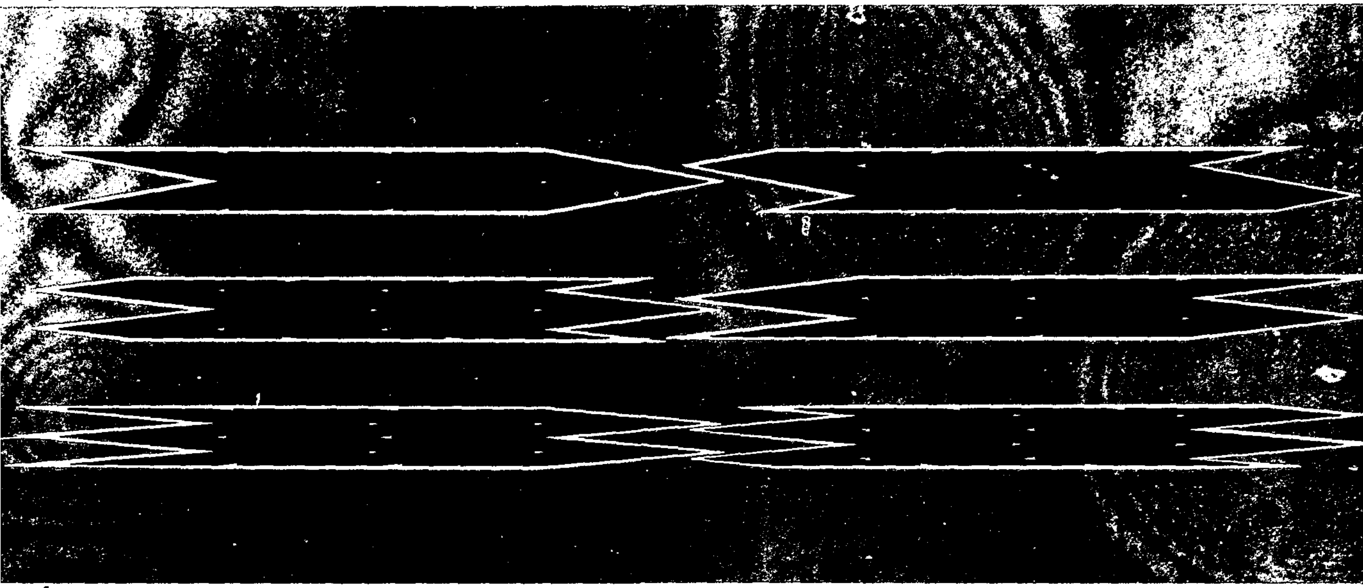
The principal areas of concern are the old landfill, the current landfill, a plume of chemical contamination in the groundwater, the hazardous waste management area, the sewage treatment plant and a 1977 oil spill.

An interagency agreement has been negotiated among the U.S. Department of Energy (DOE), EPA and the New York State Department of Environmental Conservation regarding the characterization and remediation of the contaminated areas. Accordingly, cleanup has already begun.

Throughout the process, the work will be reviewed by the same three agencies. As the federal agency that has jurisdiction over the BNL site, DOE is responsible for all cleanup costs.

INSTRUMENTATION DIVISION

Inventing and developing new tools and methods to make high-precision measurements in selected branches of scientific research is the primary activity of the Instrumentation Division. The staff develops new techniques in areas such as nuclear-particle detectors, low-noise hybrid and micro-electronic circuits, microstructures, and laser and optical metrology. The division specializes in providing unique solutions to specific problems in experiments at Brookhaven's major research facilities. The division's expertise also provides the Laboratory with special services in vacuum-deposition technology, electron microscopy and printed circuit board fabrication.



EXAMPLES OF CATHODE PAD PATTERNS USED IN THE ELECTRODE SHOWN IN THE PHOTO. ELECTRICAL SIGNALS FROM THE PADS ALLOW THE SIMULTANEOUS LOCATION OF MANY PARTICLES TO BE MADE WITH 100-MICRON ACCURACY.

DESIGNING DETECTORS

Before the end of the decade, physicists hope to use two giant, new tools — the Relativistic Heavy Ion Collider (RHIC) at BNL and the Superconducting Super Collider (SSC) in Texas — to delve still deeper into the mysteries of matter. Currently, BNL's Instrumentation Division is developing some of the detector techniques that will be a crucial part of large detectors at these next-generation accelerators.

Detectors are among the most important components of an accelerator experiment, since they register the hundreds of particles that result from some of the millions of collisions each second in today's accelerators. Detectors are designed to recognize the location, energy and nature of the particles that physicists are interested in exploring.

RHIC DETECTORS

RHIC will contain two beams of heavy ions traveling in opposite directions at nearly the speed of light around a 2.5-mile-long tunnel. Upon the beams' collision, states of matter such as those that existed at the birth of the universe will be created. These will be the particles that are detected.

EXAMINING INTEGRATED CIRCUITS ARE (FROM LEFT) SERGIO RESCIA, BNL, AND BO YU, UNIVERSITY OF PITTSBURGH. YU IS HOLDING A CATHODE PAD ELECTRODE THAT BNL SCIENTISTS ARE DEVELOPING FOR RHIC DETECTORS. GRAHAM SMITH, BNL, IS CALIBRATING ONE OF THESE PROTOTYPE DETECTORS CURRENTLY USED IN HEAVY-ION EXPERIMENTS AT BNL'S ALTERNATING GRADIENT SYNCHROTRON.

Scientists and engineers in the Instrumentation Division, in collaboration with BNL's Physics Department and a number of universities, are developing RHIC detectors, using as their starting point several detectors already built and operating in heavy-ion experiments at Brookhaven's Alternating Gradient Synchrotron (AGS). These RHIC detectors use an array of wires to produce a signal with an amplitude proportional to the energy lost by a charged particle.

RHIC detectors must be able to locate hundreds of particles simultaneously — many times the number of particles at the AGS — pinpointing their location to an accuracy of about 100 microns, about twice the diameter of a single human hair.

When a particle passes through a volume of inert argon or xenon gas in the detector, it ionizes, leaving a track of free electrons. These electrons are attracted to an array of high-voltage anode wires, and each electron causes an avalanche of more than 10,000 electrons along the wires, thus producing an electronically detectable signal, or charge. At the same time, an equal and opposite charge is induced on cathodes. From this information, the particle's position can be determined.

We are presently developing a new type of cathode that can detect many particles simultaneously. Each of these cathodes is composed of many small, specially shaped electrodes, or pads, connected to integrated circuits that convert the charge signal into a voltage signal. This is then sent to a computer, which calculates the center of gravity of the induced charge, showing where the particle traveled through the gas chamber. Since there are several thousand pads connected to the cathode in each chamber, several hundred particles can be detected at once.

RHIC detectors will need tens of thousands of preamplifiers to analyze the induced charge on each cathode pad and convert it to a voltage signal. Even though each of these preamplifiers is presently smaller than a postage stamp, using such a large number of them in each detector would be too cumbersome and expensive. Instead, our researchers are designing integrated circuits to do the same job more efficiently.

These integrated circuits, made of silicon, use electronic circuits known as pulse shapers to improve the signal-to-noise ratio. Memory elements store information on the energy deposited in the detector by the particles, and a digital converter transforms the stored charge into a number in the computer that provides researchers with information on the magnitude of the signal produced by the detector. A multiplexer reduces the number of signal cables in the detector, making it more economical as well as easier to use and maintain.

SSC DETECTORS

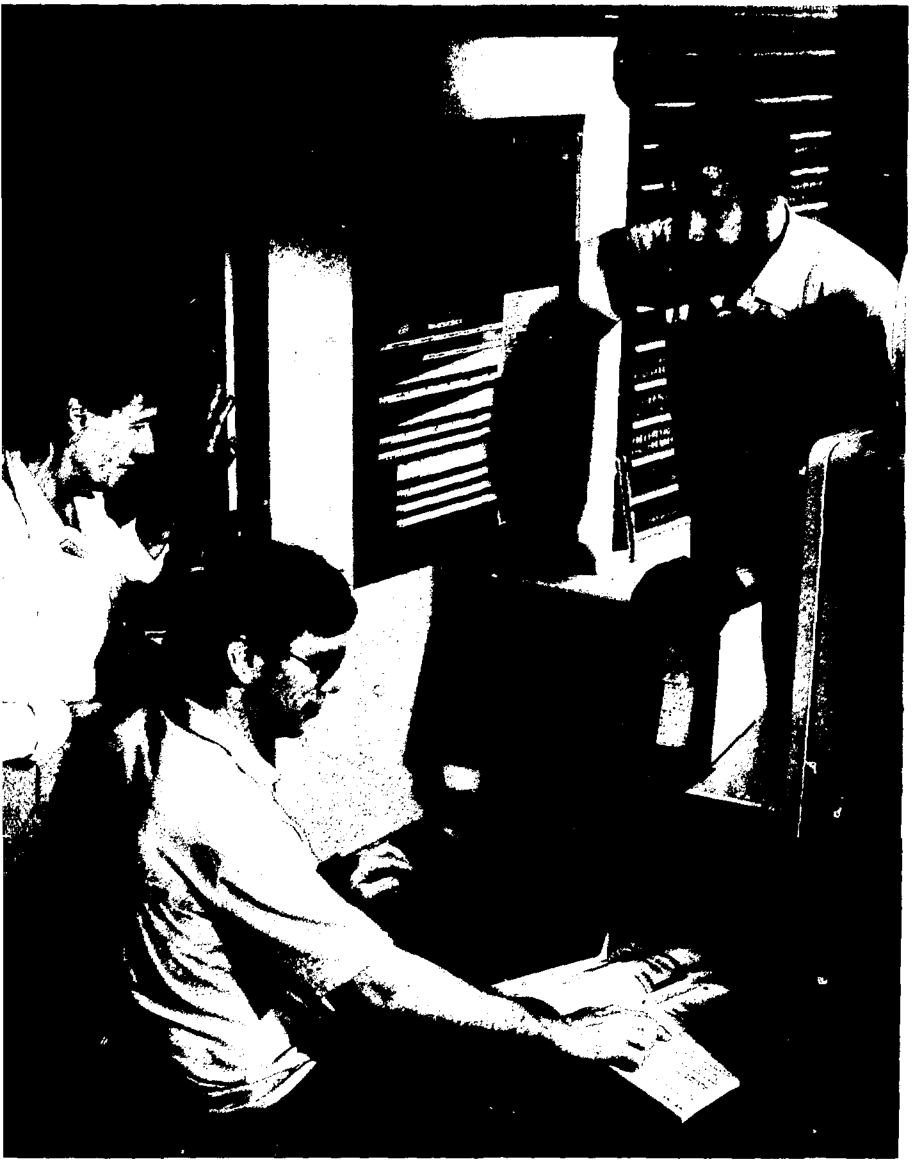
The SSC will be capable of producing at least 100 million collisions between protons every second, yielding hundreds of particles. Differentiating such immense numbers of particles with similar directions and energies is a tough challenge for detector designers, but the techniques we are developing provide a valuable base from which to build.

The SSC will need high-performance tracking detectors for each of the experiments planned. Some of the composite SSC detectors will weigh 40,000 tons and rise as high as a four-story building. BNL is one of numerous institutions that have started research on the design of these huge detectors.

The electronics for the SSC detectors will have to be designed to work at a faster pace than RHIC's detectors because the SSC beams will collide at rates 10 to 100 times faster. Also, radiation levels will be higher in the SSC, so that the detectors and electronics will have to be made of materials that can tolerate radiation.

COMPUTING AND COMMUNICATIONS DIVISION

The strong growth of computing and communications technologies vital to Brookhaven's scientific programs is the everyday business of the Computing and Communications Division. The division plans and develops future data processing facilities and tools; operates the major central computers and communications networks, including the telephone system; assists in all areas of programming; and provides computer systems maintenance services. Recently, much emphasis has shifted to the support of scientific and engineering computer workstations for different applications, such as CAD/CAM, a computer-aided design and manufacturing system.



WORKING ON A PROGRAM THAT WILL USE A NEW FACILITY FOR PARALLEL PROCESSING BEING DEVELOPED AT BROOKHAVEN ARE (FROM LEFT) ELIZABETH SYMONDS, DAVID STAMPF AND THEODORE DANIELS.

Many Computers Make Fast Work

As computer technology races ahead, calculations get faster and faster. But once they reach the speed of light, present techniques will not be able to rev them up further.

Yet a substantial increase in computer power will still be available — by using either parallel or vector processing.

In Brookhaven's Computing and Communications Division (CCD), computers are standing ready for use — the VAX 6450, a parallel processing machine; the ENCORE Multimax, a parallel computer; and the IBM 3090, which has both parallel and vector capabilities. Researchers able to take advantage of these CCD facilities will find their work completed well before it could be done using other methods.

To use either parallel or vector processing, the initial task is not treated as a single entity, but divided up, each part being solved separately and then combined at the end.

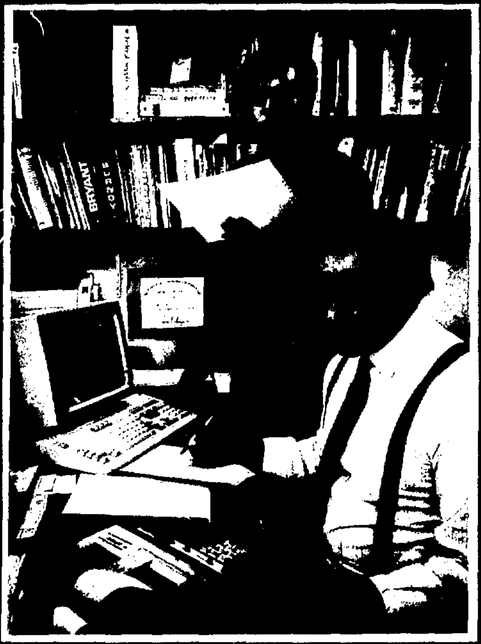
In parallel processing, several computers calculate in parallel, one on each part. An example of work that could benefit from this procedure might be climatology, in which subdivisions could include atmospherics and oceanographics.

Vector processing requires a single computer fitted with special hardware enabling it to handle at once a whole list of numbers, called a vector. This kind of process is extremely useful for calculations involving scientific notation.

All this number-crunching takes place at extremely high speed — even individual workstation computers are able to do tens of millions of operations each second. Because several computers, or several parts of one computer, are each calculating for a given time, the total computing time will be no less than the traditional, one-step-at-a-time method. But, because all the calculations are done simultaneously, the result is available sooner.

The compartmental approach of parallel and vector processing is well suited to handle the many facets of large-scale problems. But taking advantage of either method can be difficult for the uninitiated. CCD staff stand ready to help Brookhaven researchers make the best choice and write programs that are custom-made for their projects. As well as giving on-the-spot advice and assistance when required, CCD checks that any useful improvements on the market are made available on site.

Some of the researchers already using these new techniques at CCD are developing procedures for asynchronous parallel computing. In this method, the different parts of a repetitive calculation are not forced into a locked pattern. Some stages of the computation may use results of other stages that occur either earlier or later, adding a random aspect to the solution that in many cases produces better answers faster. This adventurous approach could revolutionize future computational capabilities.



DENNIS HALL AND BARBARA SIMPSON OF THE CONTRACTS AND PROCUREMENT DIVISION ARRANGE A PURCHASE FOR BNL.

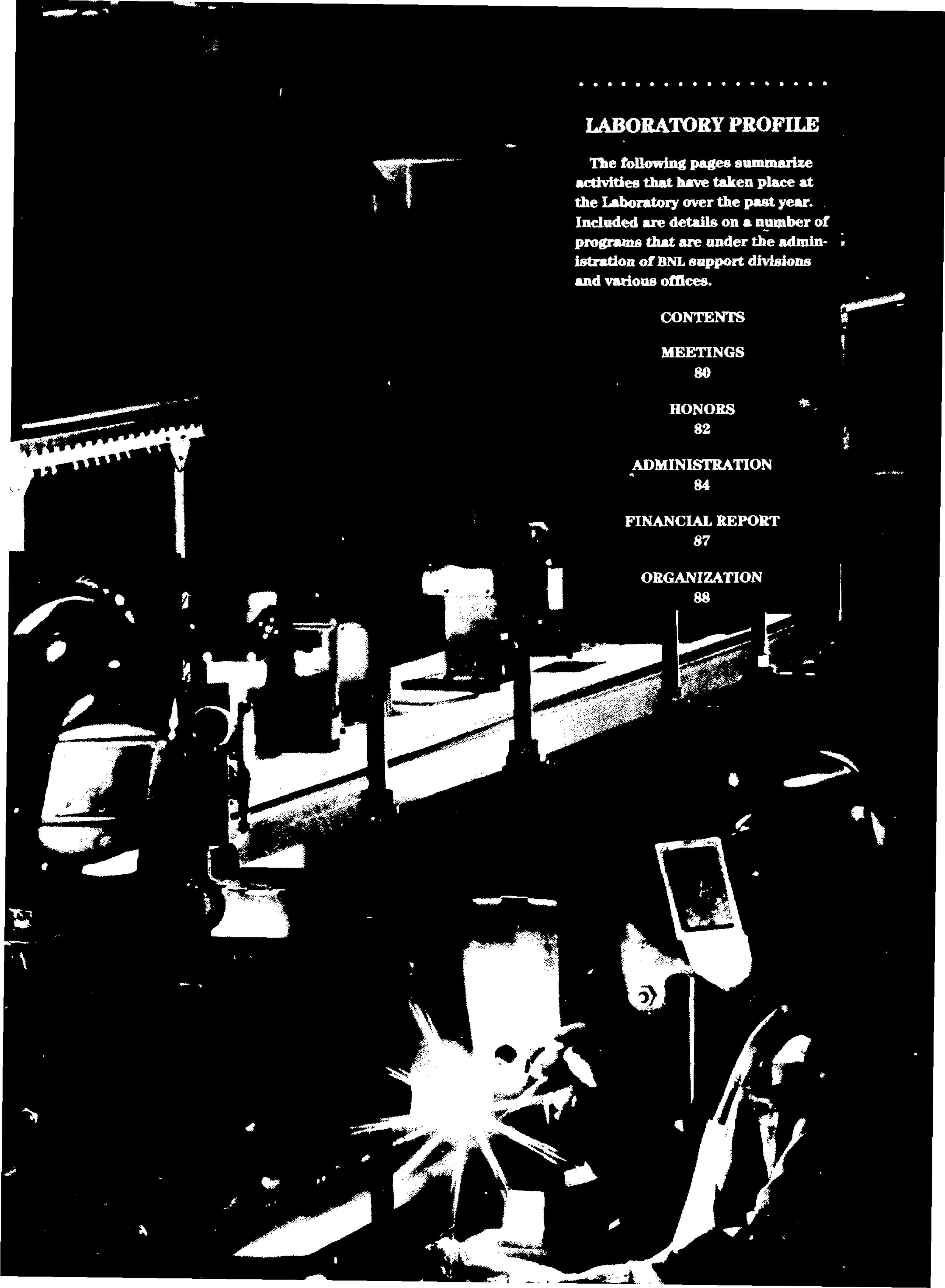
BUYING FOR BROOKHAVEN

To buy the latest mainframe computer and a service contract to keep it running smoothly, Brookhaven staff can call on the services of the Division of Contracts and Procurement (DCP), which manages all purchasing for the Laboratory. DCP handles anything from buying pencils to contracting for sophisticated research and development for a new project.

Once a need is identified, procurement is assigned to the appropriate buyer or contract specialist, who discusses the type of material or service needed, develops a source list and issues a solicitation for competitive quotes or proposals. Incoming quotes and proposals are evaluated and negotiated if necessary. Then an "award" is made — the official term for issuing a purchase order or contract.

In placing orders, buyers and contract staff consider quality, timely delivery, price — and, if possible, the opportunity to help small and small disadvantaged businesses. For their success in having such firms participate in the Laboratory's mission, DCP was itself awarded — winning the U.S. Department of Energy's Small Business Award two years in succession.

In 1990, Brookhaven purchased supplies and services worth approximately $84 million. The expertise of Contracts and Procurement staff ensures that each dollar is well spent.



LABORATORY PROFILE

The following pages summarize activities that have taken place at the Laboratory over the past year. Included are details on a number of programs that are under the administration of BNL support divisions and various offices.

CONTENTS

MEETINGS
80

HONORS
82

ADMINISTRATION
84

FINANCIAL REPORT
87

ORGANIZATION
88

SOME 160 PHYSICISTS FROM SEVERAL COUNTRIES MET AT BNL JULY 2-6 TO DISCUSS PLANS FOR SMASHING HEAVY-ION BEAMS TOGETHER AT THE LABORATORY'S FUTURE RELATIVISTIC HEAVY ION COLLIDER (RHIC). IN SESSIONS SUCH AS THIS ONE BEING ADDRESSED BY JOHN HARRIS, LAWRENCE BERKELEY LABORATORY, THOSE ATTENDING THE FOURTH WORKSHOP ON EXPERIMENTS AND DETECTORS FOR THE COLLIDER DISCUSSED THE KINDS OF EXPERIMENTS THAT WILL BE CONDUCTED AT RHIC AND WHAT KINDS OF DETECTORS SHOULD BE BUILT TO PERFORM THE MEASUREMENTS.

MEETINGS

Once again, in 1990, researchers flocked to Brookhaven to share their latest ideas and findings on a great variety of subjects at dozens of conferences, meetings, workshops and symposia, as in this representative sampling.

"DNA Damage and Repair in Human Tissues" was the subject of **Brookhaven Symposia in Biology No. 36**. Held October 1-4, the symposium drew about 100 scientists to BNL to share information about DNA lesion measurement in human tissue, the biochemistry and molecular biology of human skin, detection and analysis of human mutations, and DNA damage and repair in human skin, blood cells and internal organs.

The first **National Workshop on Accelerator Instrumentation** focused on how to monitor the critical characteristics of the beam within a particle accelerator. Held at BNL October 22-26 and sponsored by the U.S. Department of Energy (DOE), the workshop drew over 100 physicists and engineers from other national laboratories and industry.

The U.S. is taking a hard look at where it stands in the international race to manufacture high-density computer chips using x-ray lithography. Such was the thrust of the **Fifth BNL Workshop on Synchrotron X-Ray Lithography**, held November 16-17 and attended by 104 representatives of industry, government agencies and research laboratories.

A hands-on familiarity with some basic physics concepts was the lesson given to some 60 elementary school teachers on March 19, when they came to BNL to attend an **Elementary Science Teachers Workshop**, sponsored by the Long Island Physics Teachers Association and BNL as part of the nationwide "Operation Physics" program of the American Association of Physics Teachers.

The focus was on the future of high energy and heavy-ion physics at BNL at the **Annual Meeting of the AGS Users Group**, May 3-4. The meeting was highlighted by strong endorsements of the kaon-physics program at BNL's Alternating Gradient Synchrotron (AGS) and a call for letters of intent for first-round experiments at the Relativistic Heavy Ion Collider (RHIC), for which the AGS will be the injector.

The Brookhaven Linac Isotope Producer (BLIP) is a national resource for the production and distribution of medically useful isotopes. On May 14, the **BLIP Users' Committee** of BNL's Medical Department met at the Laboratory, as it does every two years in an advisory capacity, to assess the facility and the isotope distribution process.

An overview of the National Synchrotron Light Source (NSLS) and its present research, as well as a look to the future, were presented to over 400 attendees at the 1990 **NSLS Annual Users' Meeting**, held at BNL May 17-18.

Approximately 40 scientists from around the country met June 4-6 for BNL's **Global Climate Feedback Workshop**, as part of Brookhaven's global change research program. Participants discussed the complex feedback phenomena by which environmental elements such as ocean masses, land surfaces and water vapor interact to accelerate or reverse climatic changes and recommended research for resolving major areas of uncertainty in the field. •

ON THE LECTURE CIRCUIT

In addition to the hundreds of lectures and seminars that are sponsored by the various departments throughout the year, Brookhaven annually hosts a number of lecturers who speak at the Laboratory under the aegis of several special programs:

• AUI DISTINGUISHED LECTURES — There were four speakers in this series of lectures on topics of general interest: DNA fingerprinting expert Alec Jeffreys, Voyager mission project scientist Edward Stone, former U.S. Secretary of the Interior Stewart Udall, and Pulitzer Prize-winning science correspondent John Noble Wilford.

• BLACK HISTORY MONTH — This year's February speakers, sponsored by the Afro-American Culture Club, included best-selling author Mark Mathabane and New York State Supreme Court Justice Marquette Floyd.

• BROOKHAVEN LECTURE SERIES — Eight members of the BNL staff addressed their colleagues in this series designed to share details of developments in various fields of science with the rest of the Laboratory community, and to heighten awareness of the aims and potential of BNL.

The lectures were given by: Samuel Aronson, Physics Department, the fifth force; Paul Falkowski, Department of Applied Science (DAS), ocean photosynthesis and global climate; Jerome Hastings, National Synchrotron Light Source Department, x-ray scattering; Charles Hofmayer, Department of Nuclear Energy, seismic studies of reactor components; Keith Jones, DAS, elemental analysis using photon and ion beams; Trevor Sears, Chemistry Department, chemical dynamics using lasers; Richard Setlow, Director's Office, ozone depletion and melanoma; and John Warren, Instrumentation Division, micromechanics.

• BROOKHAVEN WOMEN IN SCIENCE SEMINARS — Speakers in this series included psychologist Beverly Birns, astronomer Bonnie Buratti, computer systems developer Louise Nielsen, educator Annette Saturnelli, sociologist Duffy Spencer and art historian Julie Wosk.

• HAWORTH LECTURES — The Haworth Distinguished Scientist appointments were established in memory of the Laboratory's second director Leland J. Haworth. Appointees spend time in residence at BNL, giving several lectures during those visits. This year's lecturers were science and technology analyst Harvey Brooks, chemist and Nobel laureate Yuan T. Lee, and bone marrow transplantation expert Dirk van Bekkum.

• PEGRAM LECTURE SERIES — In this series, named in honor of George B. Pegram, one of the founders of AUI, a speaker delivers a series of lectures on consecutive evenings. This year's speaker was chemist and Nobel laureate Roald Hoffmann.

• SECRETARIES' DAY SEMINAR — Cosponsored by the Personnel Division and the Upton Chapter of Professional Secretaries International (PSI) was a talk by PSI president-elect Cecilia Walker.

• VAN SLYKE LECTURES — Two lecturers spoke under this program, established in honor of the late BNL biological chemist Donald D. Van Slyke. They were Marian Koshland, professor of immunology, and hematologist Makio Ogawa.

Honors

John Axe (Director's Office) won the Annual Award for Sustained Outstanding Research in Solid State Physics in the 1989 Materials Science Research Competition sponsored by the U.S. Department of Energy (DOE). The research for which he won the award — "Neutron Scattering Studies of Structural Phase Transformations" — was done at BNL's High Flux Beam Reactor.

Per Bak (Physics) received the Samuel Friedman Foundation's 1990 Rescue Award in May for his "original contributions to the theories of surface phase transitions, quasi-crystals, and nonlinear dynamics."

Robert Bari (Nuclear Energy) was elected a fellow of the American Nuclear Society in June, for his outstanding contributions to nuclear reactor safety.

Victor Bond (Medical) was honored in May "for outstanding leadership and scientific vision in radiation biology and biophysics," with a Distinguished Associate Award from DOE.

Brookhaven earned a small business award from DOE in May, in recognition of the Laboratory's outstanding performance and support of the DOE small business program for fiscal year 1989.

For its leading role in advanced materials research, **Brookhaven** was honored in March by ASM International and the Institute of Metals, London. In 1989, BNL was the source of 31 technical papers in materials science.

The **Brookhaven Bulletin** won an Award of Excellence in the 1989 annual competition sponsored by the New York Chapter of the Society for Technical Communications in April.

Erik Cazzoli, William Pratt and **Arthur Tingle** (Nuclear Energy) received Certificates of Appreciation from the U.S. Nuclear Regulatory Commission (NRC) in March, in recognition of their outstanding contribution to NRC report number NUREG-1150. This work resulted in a significant advance in the state of technology of probability risk analysis and made a major contribution to NRC's severe accident program.

Ernest D. Courant (Accelerator Development) was guest of honor at colloquia held at Brookhaven in April, in recognition of his outstanding achievements in accelerator physics, including the discovery of strong focusing, during a career extending back over 42 years at BNL.

Eugene Cronkite (Medical) was presented with the 17th Robert de Villiers Award from the Leukemia Society of America in October. He received the society's highest and most prestigious award for his outstanding contributions to leukemia research.

Yreana-Renée Flack (Educational Programs) was honored with a proclamation designating June 16, 1990, as Yreana-Renée Flack Day in the Town of Brookhaven. She was recognized, in part, for her dedication and hard work in coordinating education programs both within and outside of the Laboratory.

Maurice Goldhaber and **Gertrude Scharff-Goldhaber** (Physics) were jointly recognized in January when Boston University established a prize in their honor, to be awarded to an outstanding graduate student in the entering class in physics each year, "to further the high ideals of excellence in both theory and experiment as exemplified by Gertrude and Maurice."

Leonard Hamilton and **Paul Moskowitz** (Applied Science) won a Federal Laboratory Consortium Award for Excellence in Technology Transfer in May, for identifying and evaluating health and safety hazards as well as risk management approaches for new manufacturing processes and materials used in photovoltaic energy systems.

Paul Kemp (Applied Science) earned an award for outstanding research from the U.S. Environmental Protection Agency through its annual Scientific and Technological Achievement Awards Program, as coauthor of a publication describing his research on a technique for assessing the effects of multiple contaminants on marine animal life.

Barbara Kponou (Instrumentation) was elected Outstanding Member of the Year for 1990 by the Twin Forks chapter of Professional Secretaries International.

Hong Ma (Physics) was among 20 of the nation's outstanding young scientists to be honored in April with the first annual Superconducting Super Collider (SSC) National Fellowships, to do SSC-related research at their home institutions during the next academic year.

Upendra Rohatgi and **Wolfgang Wulff** (Nuclear Energy) received Certificates of Appreciation from the NRC, "in recognition of valuable contributions made to the development and demonstration of the Code Scaling Applicability and Uncertainty Evaluation Methodology."

Gertrude Scharff-Goldhaber (Physics) was honored by the New York Academy of Sciences in March, in a special program to celebrate National Women's History Month. In June, she was one of four winners of the Outstanding Women Scientists Award, from the Metropolitan New York Chapter of the Association of Women in Science.

Meyer Steinberg (Applied Science) won a Federal Laboratory Consortium Award for Excellence in Technology Transfer in May, for "unstinting and continuing efforts in promoting the HYDROCARB process for producing clean carbon

AT THE INFRARED BEAM LINE AT BROOKHAVEN'S NATIONAL SYNCHROTRON LIGHT SOURCE. WHERE THEIR WAVEFRONT DIVIDING INFRARED INTERFEROMETER IS INSTALLED. ARE R&D 100 WINNERS (FROM LEFT) CAROL HIRSCHMUGL. PETER SIDDONS. K DIETER MOLLER AND GWYN WILLIAMS

fuels from coal up to the point of industrial acceptance and initial funding of a prototype system."

F. William Studier (Biology), a well-known expert in the sequencing of both viral and human DNA, was elected to membership in the American Academy of Arts and Sciences in May.

Betsy Sutherland (Biology) was recognized by the Town of Brookhaven in March, during National Women's History Month, for her scientific achievements, including studies of ultraviolet radiation, and damage and repair of human cells.

Norman Sutin (Chemistry), an internationally recognized authority on the kinetics and mechanisms of thermal and light-induced electron-transfer reactions of metal complexes and metalloproteins, was elected to the National Academy of Sciences in April and to the American Academy of Arts and Sciences in May.

Gwyn Williams and **Peter Siddons** (National Synchrotron Light Source), with BNL collaborators **Carol Hirschmugl** and **K. Dieter Möller**, won a 1990 R&D 100 award for their development of the wavefront dividing infrared interferometer, a novel instrument that opens up a new class of experiments with synchrotron radiation.

Alfred Wolf (Chemistry) was awarded an honorary doctorate from the University of Rome in November, for his pioneering contributions to the field of radiopharmaceuticals and the biomedical use of short-lived radioisotopes. •

ADMINISTRATION

PERSONNEL

In 1990, employment at the Laboratory remained generally steady (see chart).

Employment Statistics	**1988**	**1989**	**1990**
*Scientific Staff	645	619	619
Scientific Professional Staff	492	526	557
Nonscientific Staff	2135	2196	2203
*Total	3272	3341	3379
Percent of Total Employees			
Minorities	16.6	15.0	17.0
Women	23.1	23.3	23.8

*Includes research associates and visiting staff.

Some 3,335 outside users, ranging from students to scientists with research appointments, took advantage of Brookhaven's world-class research facilities in 1990. These guest researchers came from 377 U.S. and 212 foreign institutions.

EQUAL OPPORTUNITY

To reflect that the Laboratory's Affirmative Action Office has long been involved with many activities in addition to affirmative action, the office was renamed the Office of Equal Opportunity (OEO) in January. OEO's emphasis is on personnel placement and employee complaint coordination, but the office also has other duties, such as working with the Division of Contracts and Procurement to bring minority contractors to Brookhaven.

FOR SAFETY'S SAKE, NEW HARD HATS WERE ISSUED WITHIN THE PLANT ENGINEERING DIVISION (PE) IN SEPTEMBER — AND NOW THE OCCUPATION OF A HARD-HAT WEARER CAN BE IDENTIFIED BY THE COLOR OF THE WEARER'S PROTECTIVE HEADGEAR. THE HATS ALSO FEATURE SHOCK-REDUCING EIGHT-POINT SUSPENSION, A SNUG RATCHET FIT, THE PE LOGO ON EACH SIDE, AND A LABEL BEARING THE WEARER'S CRAFT ON THE FRONT. MODELING THE NEW PROTECTIVE HEADGEAR ARE: (TOP, FROM LEFT) THOMAS BOUCHER, JOHN MOLLICA, STEVE ECKHOFF, MICHAEL CURTIS, KEITH DETMAR, MARTIN KLEIN, (BOTTOM FROM LEFT) FRANK FERRARO, JOHN BIEMER, PATRICIA BENDER, JOSEPH MEAD, DAVID JOHNSTONE, JOSEPH LOPEZ, KENNETH CROWE AND FRANK TRAPANI.

EDUCATION CENTER

In May, BNL received approval from the U.S. Department of Energy (DOE) to build a new Science Education Center on site — a 4,700-square-foot facility to provide space for the staff and programs of the Laboratory's Office of Educational Programs (OEP).

ENERGY CONSERVATION AND SAVINGS

In March, the $15-million Central Chilled Water Facility officially began serving the site with chilled water for air conditioning, as well as compressed air for laboratory, instrument and service use. Completed in December by the Plant Engineering Division, the new facility produces 5,000 tons of chilled-water for cooling and 1,500 standard cubic feet per minute of compressed air. In addition to saving about 2,400 gallons per minute of well water, it will reduce the Laboratory's operating and energy costs.

These savings began after the facility's operation was demonstrated to the Long Island Lighting Company (LILCO), which then gave Brookhaven a rebate check for $400,000. In another LILCO program promoting energy conservation, the Laboratory earned an additional $239,491 rebate in September.

Since 1982, BNL has gotten most of its electric power from the Fitzpatrick Nuclear Power Plant, under a contract with the New York Power Authority (NYPA). In June, that contract was extended for five years, through June 30, 1995. Successive one-year terms may be added to the contract through June 30, 2000, with NYPA approval. This means that Brookhaven will continue to realize substantial savings on its electric bill. NYPA's 1990 rate was 4.9¢ per kilowatt hour (kWh), while LILCO billed BNL at an average rate of 9.1¢/kWh, bringing the average costs incurred for the Laboratory site to 5.67¢/kWh.

CAFETERIA MANAGEMENT

A five-year contract to manage the Laboratory's Cafeteria was awarded to Service America Corporation, effective October 1, 1989. Cafeteria management is overseen by the Staff Services Division.

SAFEGUARDS & SECURITY

The Safeguards & Security Division initiated three new programs this year that affected all employees:

- In October, a program was begun to replace all Laboratory identification cards. This was completed in December.
- To make the vehicle registration process easier and less costly, new vehicle stickers issued at the beginning of the calendar year were made valid for longer periods than in the past — most for up to three years.
- For safety's sake, the Police Group began issuing citations to drivers found speeding on site, under the speed control program that started on March 1.

WOMEN IN SCIENCE

Ten years of organization and accomplishment were celebrated by Brookhaven Women in Science with events throughout the week of October 30. In its first decade, the group was instrumental in helping to initiate such programs and projects as an on-site credit union, coordination of insurance benefits for married BNL couples, a parental leave policy, the proposal for a child-development center on site, and greater awareness of the Laboratory's sexual harassment policy.

AT THE RESEARCH LIBRARY

This year, the computer age came into its own at the Research Library operated by the Technical Information Division (TID). A series introducing the database research services offered by TID concluded in January. In April, new databases became available for individuals to peruse on their own — using a new CD-ROM drive installed in the library. And in June, TID introduced INFORM, an easy-to-use, menu-driven, computerized catalog of BNL's books and journals and BNL reports. INFORM can be accessed from any terminal connected via modem to Brookhaven's computer cluster, including two in the Research Library, making possible the retirement of the card catalog.

NEW BENEFIT OPTIONS

The Personnel Division announced two new benefit options this year.

Two types of flexible spending accounts — a Health Care Reimbursement Account and a Dependent Day Care Reimbursement Account — were offered to employees beginning in January. Participants deposit "before-tax dollars" in these accounts voluntarily through automatic salary reductions, then draw out money from the appropriate accounts to reimburse themselves for health care and/or dependent day care costs that they have incurred.

In March, BNL employees were presented with new investment choices when it was announced that retirement funds could now be allotted among 17 approved plans, rather than the previous three, including 12 new mutual funds.

CHANGE IN BANKS

After almost ten years on site, Barclays Bank closed its Upton branch at the end of March. In its place, the Teachers Federal Credit Union (TFCU) set up shop in the bank building on Technology Street. In moving to these larger quarters, TFCU substantially expanded their on-site services for employees.

MILITARY DUTY POLICY

In order to assist any Brookhaven employees placed on active duty in the armed forces during the Middle East crisis, in September the Laboratory announced several changes to its policy concerning military duty. Under these changes, reservists would: receive a three-month leave of absence, with the possibility of extensions should the need arise; continue to receive medical coverage for dependents; receive two weeks' leave with pay for the first two weeks of the call-up, to be reimbursed upon return to BNL; and receive pay for all accumulated vacation days.

NEW GAS TANKS

In accordance with Article 12 of the Suffolk County Sanitary Code, "Toxic and Hazardous Materials Storage and Handling Controls," the old gas tank at the BNL filling station was replaced in March by two 8,000-gallon tanks that meet all applicable federal, New York State and Suffolk County design standards and safety codes. The station is operated by an outside contractor, under the Staff Services Division.

GLANCE

A new form of communication started in Berkner Hall in April, when *GLANCE* began playing daily on a video kiosk near the Cafeteria.

Produced jointly by the Video Group of the Photography and Graphic Arts Division and by the Public Affairs Office, this videotaped program offers short segments on the people and work at Brookhaven, presented in a three- to five-minute, continuous format.

CELEBRATING EARTH AND SCIENCE

The global celebration of Earth Day on April 22 was immediately followed in the U.S. by the observance of National Science and Technology Week.

In recognition of these activities, the Tour Program in the Public Affairs Office planned three special events: a trip to Washington, D.C. with a Suffolk County teacher honoree to tell members of Congress about Brookhaven's Exhibit Center/Science Museum activities and other BNL outreach efforts; a DOE-sponsored poster contest for local elementary school children; and the grand opening of a new educational exhibit on magnetism, in the Science Museum.

RECYCLING PROGRAMS

To ensure that reusable materials are not thrown away, a pilot recycling program went into effect at the National Synchrotron Light Source in June. This program served as the model for the site-wide recycling program announced in September by the Plant Engineering Division. This program will begin next year with the collection of office papers and will gradually be expanded to include such materials as cardboard, glass, plastic, wood and metal.

LITTERBUGGY

Working in their spare time, employees in the Plant Engineering Division's Heavy Equipment Shop transformed two worn-out old golf carts into Brookhaven's newest on- and off-road vehicle for picking up roadside and lawn litter. Known as the Litterbuggy, the vehicle started its daily rounds on site in July.

OUTREACH WORKSHOPS

A series of lunchtime workshops on psychological issues and social problems that may affect employees' lives and work was initiated in September. Called Outreach, the program is organized by the Employee Assistance Program and offered free to all Brookhaven employees and their families. Throughout the coming year, the Outreach workshops will include such topics as anger, stress management, eating disorders, intimacy, and divorce and its aftereffects.

AUI SCHOLARSHIPS

In 1965, when Associated Universities, Inc. (AUI) announced the first winners of the new AUI Trustee Scholarships, ten children of BNL employees received awards of $900. In 1990, the 25th anniversary year of the AUI scholarship program, 14 sons and daughters of BNL employees were named winners, receiving $2,000 per year towards their college educations, for up to four years of study.

PATENTS AWARDED

During 1990, eighteen patents were awarded on inventions made by employees or former employees.

In March, the Patent Office and the Office of Research and Technology Applications — the two units that handled the various aspects of Brookhaven's interactions with industry — were reorganized and consolidated into the Office of Technology Transfer, in recognition of technology transfer as an increasingly important mission of the Laboratory.

ADMINISTRATIVE ACTIONS

John Axe was named Associate Director for Basic Energy Sciences, in March 1990.

Seymour Baron was reappointed Associate Director for Applied Programs for three years, beginning March 1990. As acting head of the Office of Technology Transfer, he appointed **Margaret Bogosian** as his deputy manager, in March 1990.

Virginia H. Brown was named Women's Program Coordinator, in October 1989.

Joseph Gisondo joined the Occupational Medicine Clinic to manage the Employee Assistance Program, in November 1989.

Gerald Kinne was promoted to Associate Director for Reactor, Safety and Security in March 1990, when that position replaced the former assistant directorship of the same function, as part of Brookhaven's response to the U.S. Department of Energy's (DOE) increased emphasis on safety and environmental protection at DOE facilities.

Derek Lowenstein was appointed to a second five-year term as Chairman of the Alternating Gradient Synchrotron Department in October 1989.

Denis McWhan became Chairman of the National Synchrotron Light Source Department in May 1990.

Satoshi Ozaki was named Head of the Relativistic Heavy Ion Collider Project, in October 1989. He continued in this position when he was also named Acting Chairman of the Accelerator Development Department, in June 1990.

Leon Petrakis assumed the chairmanship of the Department of Applied Science, in October 1989.

William J. Willis became Head of the Center for Accelerator Physics, in September 1990.

Financial Report

In fiscal year 1990 (FY90), Brookhaven's total budget of $302 million rose by 1.8 percent over FY89.

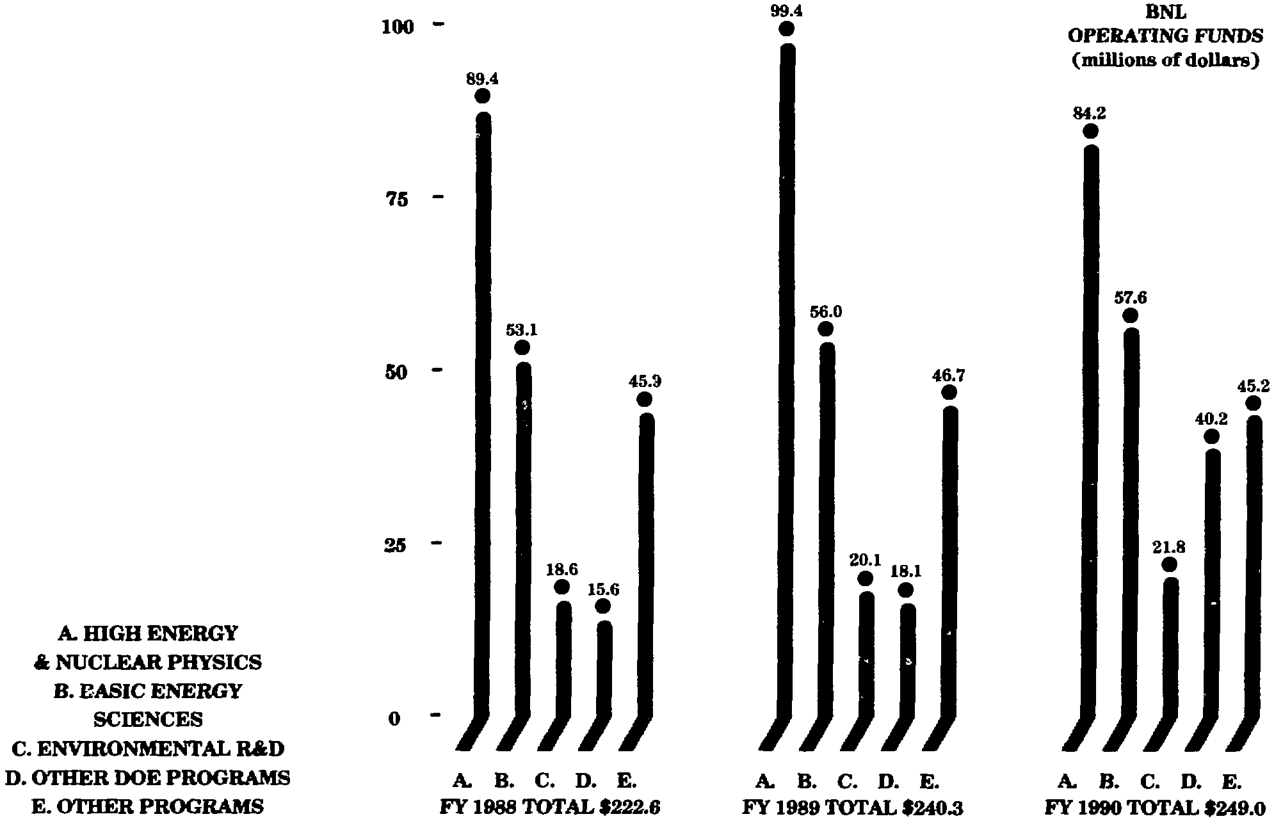
BNL's budget is divided into three areas:

- Operating funds support the Laboratory's various research programs. These funds pay the costs of salaries and wages, fringe benefits, materials and supplies, and energy associated with those research programs. In FY90, operating funds added up to $249 million. Funding of $18.8 million was received from the Superconducting Super Collider Laboratory for research and development work and is included in the Other DOE Programs category in the chart below.
- Capital equipment funding, which amounted to $22 million in FY90, provides for instrumentation, scientific apparatus, computers and office equipment.
- Construction funds are used for building projects. These monies decreased by about 11 percent in FY90, to $30.4 million, largely due to the completion of funding for the Booster project in FY89. The environmental improvements project received $1.5 million for asbestos and cesspool removal, while the environmental upgrades project received $2.8 million for underground tank removal and waste-site closure. The Laboratory also received $2.3 million for fire-safety improvements.

As in previous years, the principal source of BNL's funding was the U.S. Department of Energy (DOE), which accounted for about three-quarters of the operating budget and for all of the capital equipment and construction funds.

BNL COST ELEMENTS

Material & Supplies	20.0%
Electric Power	5.0%
Heating Fuel	1.0%
Fringe Benefits	16.5%
Salary & Wages	57.5%



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Seymour Baron
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*Acting

Organization effective as of September 30, 1990.

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