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BROOKHAVEN HIGHLIGHTS

This report highlights the Laboratory's activities for fiscal year 1995, a period dating from October 1, 1994, through September 30, 1995. For more information about work described in this report or for more information about Brookhaven, contact the Public Affairs Office, Brookhaven National Laboratory, P.O Box 5000, Upton, New York 11973-5000, ph. (516) 344-2345.

On the Cover

The universities, industrial firms and other laboratories listed on the cover are just some of the many hundreds of Brookhaven's "users." These institutions, large and small, send their researchers year after year to do forefront science at the Laboratory's big machines — unique research facilities such as the Alternating Gradient Synchrotron, the High Flux Beam Reactor, the National Synchrotron Light Source and the Scanning Transmission Electron Microscope.

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LABORATORY PROFILE

As a research laboratory, Brookhaven is ever alert to new ideas and new ways to pursue them. Our forward-looking approach to forefront science is deeply rooted in an old BNL tradition: providing researchers who come to use the Laboratory's facilities with the very best tools for their work.

We call those researchers our "users," and the tools we provide them are our "user facilities." Since Brookhaven National Laboratory was founded in 1947, these facilities have been unique, innovative and, above all, of great use to the community of scientists from academia, industry and other laboratories who flock here year-round to take advantage of them.

The expertise that led to our facility with facilities began developing at BNL almost as soon as the Laboratory opened its doors and work began on the first two "big machines" — the Brookhaven Graphite Research Reactor (BGRR) and the Cosmotron.

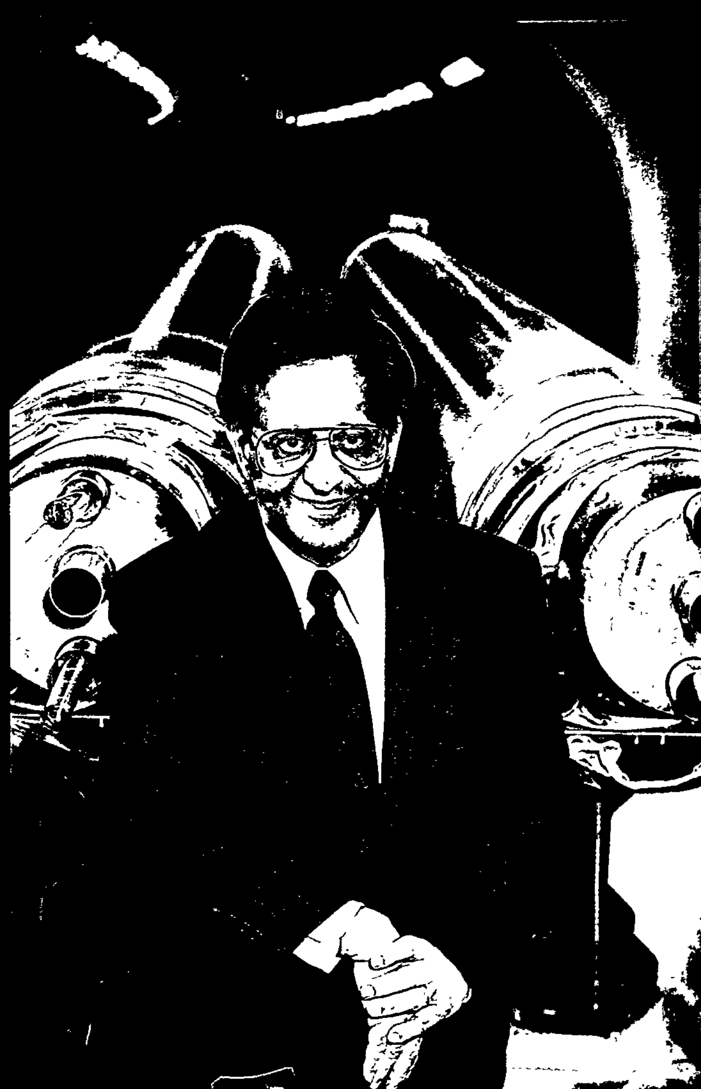
As advanced as those facilities were for their time, further pioneering designs by BNL teams led to their eventual obsolescence: With the discovery of strong focusing, the Cosmotron gave way to the 10 times-more-energetic Alternating Gradient Synchrotron (AGS). The BGRR was supplanted by the High Flux Beam Reactor (HFBR), which came on line 30 years ago with design innovations yielding more neutrons for researchers.

While our mix of facilities is constantly changing as new ones are built, older ones upgraded and others that have passed their prime decommissioned, we have concentrated on building machines that are organic in nature: fully capable of being improved in response to our staff's interaction with the user community.

A wonderful example of this is the AGS, where three experiments have captured Nobel Prizes in Physics for our users. I was an AGS user when it started accelerating protons in July 1960, and its design intensity was already impressive. We would have been amazed then to know that by April 1995, the AGS would again break its own world record for proton intensity, with 63.3 trillion protons per pulse — 6,300 times greater than its original design intensity!

Similar improvements mark the shorter history of our National Synchrotron Light Source (NSLS). Over the last 14 years, huge leaps have been made in its design parameters for flux, brightness, current and size of the electron beam. And the user community's approval is shown in its ever-increasing numbers — today, more than 2,200 researchers use the Light Source annually.

Now, our staff's ingenuity is critical to the Relativistic Heavy Ion Collider (RHIC), which will be Brookhaven's next major user



Inside the tunnel of the Relativistic Heavy Ion Collider, Laboratory Director Nicholas Samios stands in front of two of the superconducting magnets that are being assembled into the two rings in which heavy ions will speed in opposite directions and collide at six points, providing physicists with exciting new areas of research.

facility. By cleverly designing a tunnel to link the heavy ion-producing Tandem Van de Graaff with the AGS, our staff turned the two workhorse accelerators into an "injection system" for RHIC; the 1991 addition of the Booster to this accelerator chain enhanced the number of ion species that the AGS can deliver to RHIC.

Beyond RHIC, we are exploring several new facility options for the Laboratory. These include a possible pulsed-neutron source, a "next-generation" light source in which a free electron laser would produce deep ultraviolet light, and a muon collider, which would provide highly energetic particle reactions at a much lower cost and in a much smaller facility than any other existing or proposed accelerator.

The Brookhaven staff has always been able to come up with unique approaches to our facilities because they are more than designers — they are users too. In fact, as a result of peer-review competition, BNL researchers end up using these facilities about 20 percent of the time — a nice balance with the outside user community.

Keeping one's balance means keeping things in focus — but sometimes refocusing is in order. That's what Brookhaven is doing now in response to intensive reviews of the missions and efficiency of the national laboratories. So, while we believe our missions have always melded with the U.S. Department of Energy's core activities, we are also concentrating on enhancing our specific strengths even further. In addition to the "big machines" I've already discussed, these include:

- *Structural biology* — BNL can be a pillar of great strength in this field, with our renowned Protein Data Bank, which provides Internet users with a database of three-dimensional structures of biological macromolecules; our expertise in structural determination at the HFBR and NSLS; and our command of the increasingly important area of genome sequencing.

- *Brookhaven Center for Imaging and Neurosciences* — As the year ended, we were very close to dedicating a new, high-field magnetic resonance imaging (MRI) facility, which will be one of the center's three components, along with our existing facilities for positron emission tomography, or PET, and single photon emission computed tomography, known as SPECT.

- *Center for Radiation Chemistry Research* — Another new user facility about to be launched is the Pulse Radiolysis Facility (PRF), which radiation chemists will use as a high-tech stopwatch to examine the dynamics of chemical species that live only a few trillionths of a second. In this new center, the PRF will augment and be 1,000 times faster than our 45-year-old, two-million-electron-volt Van de Graaff accelerator.

- *Radiotherapy for cancer* — When clinical trials in boron neutron capture therapy (BNCT) got under way at the Brookhaven Medical Research Reactor in February, people desperately ill with the brain cancer glioblastoma multiforme were given a chance to help advance therapies for this invariably fatal illness and, perhaps, gain some relief of their own. BNCT adds another dimension to cancer therapy at Brookhaven, where the Radiation Therapy Facility run by the University Medical Center at Stony Brook offers outpatient treatment to cancer sufferers.

- *Applied areas* — Our researchers continue to look at better ways of remediating environmental problems, handling wastes and restoring the nation's infrastructure. This year, for example, some of our scientists demonstrated an encapsulation process for sealing radioactive, hazardous and mixed wastes in plastic for safe disposal, while others became part of a four-year pilot demonstration program aimed at cleaning up pollution in the New York-New Jersey Harbor.

As we refocus, we must also expand our focus to include not just the nation but the entire planet. It's a global society now, and, reflecting that, Brookhaven has forged research agreements with many other countries. Most recently, we signed a pact with the Japanese laboratory RIKEN, ensuring that, with their $20-million contribution, spin-physics research will be conducted at RHIC.

Another example of global cooperation is FACE — our free-air carbon-dioxide enrichment program for evaluating the effect of increased atmospheric carbon on plants' rate of photosynthesis. This critical environmental technology, first developed at BNL, is being used in locations ranging from Arizona to New Zealand.

And, of course, I'm looking forward to our working with the Large Hadron Collider now being built at CERN, which we consider our sister laboratory in Europe. BNL physicists are gearing up to make major contributions to both the detectors and the accelerator magnet program.

In addition to refocusing our scientific priorities, we have also been reviewing the way we do business: Due to tightening national budgets, we must become more efficient in our science and adopt best business practices in our operations.

Toward this end, we have had many introspective reviews of our operations — including our staff. While we have had to downsize over the past year, we have tried to do that as humanely as possible, mainly through voluntary layoffs. We also realize that our major resource — and the vitality of the Laboratory — is the quality of our people.

So, despite the funding restraints, it is our highest priority to maintain an environment conducive to making good people want to work here, and to continue to encourage creativity, innovation and ingenuity among our staff.

The stable environment necessary for these attributes to flourish was given a big boost this year when DOE awarded our Associated Universities, Inc. (AUI), management team another five-year contract.

AUI reflects our interaction with and commitment to academia and industry. With this relationship continuing, with our unique mix of facilities and other scientific endeavors, and with a strong core of talented people, I believe that we are well-positioned to meet the challenges that lie ahead.

N.P. Samios

NICHOLAS P. SAMIOS
DIRECTOR

A Center for Science with Science at the Center

Brookhaven's User Facilities

They come from across the country and from across the street. They come from large companies, small universities, national laboratories and institutions in between. They come to study molecules, muons, metals, microbes and magnetism.

They come to Brookhaven National Laboratory's user facilities.

For more than 4,400 scientists a year, including the Laboratory's own scientific staff, Brookhaven's research facilities offer access to state-of-the-art equipment that exists nowhere else.

These machines are true national resources, too large to be built or maintained by any single university or company and available to scientists whose research holds promise for truly new knowledge or applications.

Brookhaven's many "big machines" democratize science at the same time they centralize it. They provide equal research opportunity to corporate scientists and graduate students at a single facility built through federal investment. And once the machines have been built, it only takes a small investment each year to leverage their value further.

Brookhaven's assembly of all these great machines supports scientists doing cutting-edge research in physics, biology, medicine, environmental and energy sciences, chemistry, materials science and applied industrial areas. With so many user facilities on one site, scientists can even obtain complementary results on a sample using several different facilities.

From the intense x-ray and ultraviolet beams of the National Synchrotron Light Source to the neutrons of the High Flux Beam Reactor, and from the protons of the Alternating Gradient Synchrotron to the electrons of the Scanning Transmission Electron Microscope, these facilities provide the means for basic scientific discovery:

- National Synchrotron Light Source
- Alterinating Gradient Synchrotron
- Relativistic Heavy Ion Collider
- High Flux Beam Reactor
- Tandem Van de Graaff
- Brookhaven Medical Research Reactor
- Scanning Transmission Electron Microscopy Facility
- Accelerator Test Facility
- 60-inch & 41inch Cyclotrons

National Synchrotron Light Source

Each year, the National Synchrotron Light Source (NSLS) attracts more than 2,000 scientists from industry, universities and government laboratories, who perform both basic and applied research in biology, chemistry, geoscience, materials science, medicine and physics.

In 1995, the total was 2,206 from 357 institutions worldwide. Working side by side with these visiting researchers are Brookhaven's own scientific staff and hundreds of students. From AT&T Bell Labs and Argonne National Laboratory, to universities like Yale in Connecticut and Uppsala in Sweden, these scientific users travel from their home institutions to the NSLS, drawn by its beacon of synchrotron light.

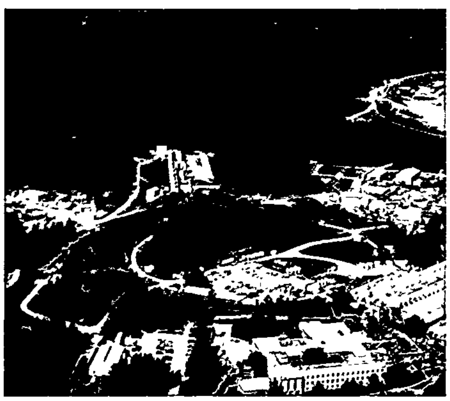
The NSLS produces high-energy photons in two electron storage rings — the vacuum ultraviolet (VUV) ring, which is optimized to produce light in the infrared, visible and ultraviolet ranges; and the x-ray ring, which produces very intense x-ray beams.

At the 74 experimental stations arrayed around the rings, research of all kinds proceeds year round, day and night. Much of it focuses on surfaces — scientists at the NSLS study catalysis, corrosion and conductivity in materials ranging from metals to high-temperature superconductors. The NSLS' light beams are also useful for examining biological molecules, crystals and other species. More information on structural biology at the Light Source can be found in that department's section later in this report.

Alternating Gradient Synchrotron

Over its 35-year history, the Alternating Gradient Synchrotron (AGS) has been home to experiments large and small, including three that led to Nobel Prizes in physics. Able to accelerate protons, polarized protons and heavy ions, the AGS this year again broke its own world record for proton intensity, generating pulses containing as many as 63.3 trillion of the subatomic particles each.

Also in 1995, approximately 850 scientists used the AGS, working at the large, collaborative experiments set up by teams of researchers. They came from 180 institutions, from as close as the State University of New York at Stony Brook and as far away as Brazil, China, Croatia, Germany, India, Ireland, Israel, Japan and Kazakhstan. And, of course, Brookhaven's own physicists use the AGS, too.

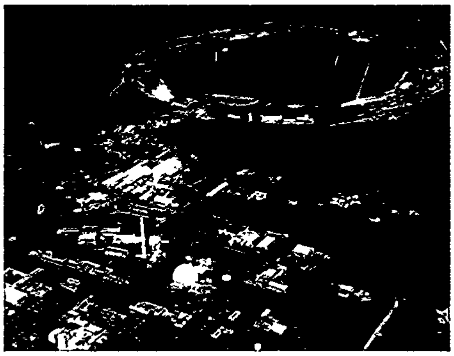


This year, 550 high-energy physicists used 13 different experiments to study matter at its most basic level, while 300 nuclear physicists collected data at the AGS from four large and six small heavy-ion experiments.

The AGS is also an important training ground for students, from undergraduates in summer internships to graduate students performing work for their doctorate degrees. This year, 180 students used the AGS — 105 in high energy physics and the balance in heavy-ion work.

Relativistic Heavy Ion Collider

How can a collider that is not even finished yet be considered a user facility? The answer is clear when you consider the vast number of scientists, engineers and others needed to plan, design and build the huge experiments for the Relativistic Heavy Ion Collider (RHIC).



In the photo above, you can see RHIC's 3.8-kilometer ring in the northern area of Brookhaven's site, where beams of speeding ions will collide and produce showers of particles for scientists to examine.

The four experiments already approved for RHIC are made possible only by the contributions of more than 840 users, including 725 scientists as well as engineers, technicians and students, spread over 22 states and 14 foreign countries.

In addition to 72 Brookhaven users, RHIC experimenters from diverse universities and several national laboratories help in the planning, design and construction of these massive experiments. The two largest, STAR and PHENIX, are already past the planning stage, with new components being built around the world. BRAHMS and PHOBOS, RHIC's two smaller experiments, are poised to begin construction in 1996.

The intense attention paid now to each experiment's myriad detectors and high-speed data collection systems will pay off in 1999, when RHIC comes on line. Then, speeding ions will collide and unleash showers of energetic particles, yielding data that are expected to provide us with a new understanding of the basic nature of matter.

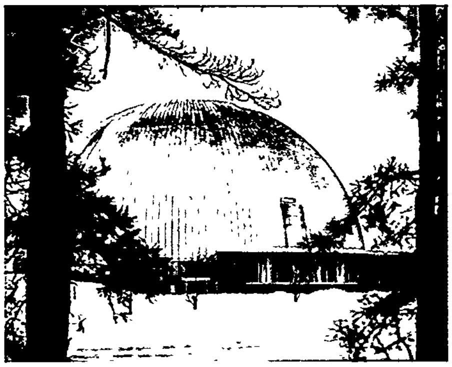
High Flux Beam Reactor

Celebrating its 30th anniversary in 1995, Brookhaven's HFBR, or High Flux Beam Reactor, is still one of the world's major centers for neutron-scattering studies in nuclear and condensed matter physics, chemistry and biology.

National Synchrotron Light Source Users, 1982-1995*

1982	90
1983	124
1984	210
1985	276
1986	507
1987	670
1988	828
1989	1215
1990	1550
1991	1725
1992	1897
1993	2193
1994	2228
1995	2206

***number of actual users at the NSLS during the year; does not include users with multi-year appointments who did not visit during the year.**



The HFBR's nine ports serve 15 experimental stations, most of them operated by the cooperating scientists in participating research teams from universities, national laboratories and industry. Users can also send in samples to be irradiated in the reactor's core.

In 1995, approximately 250 researchers from 73 different institutions and companies, including Brookhaven, used the HFBR. The reactor's staff performed 180 sample irradiations for other users.

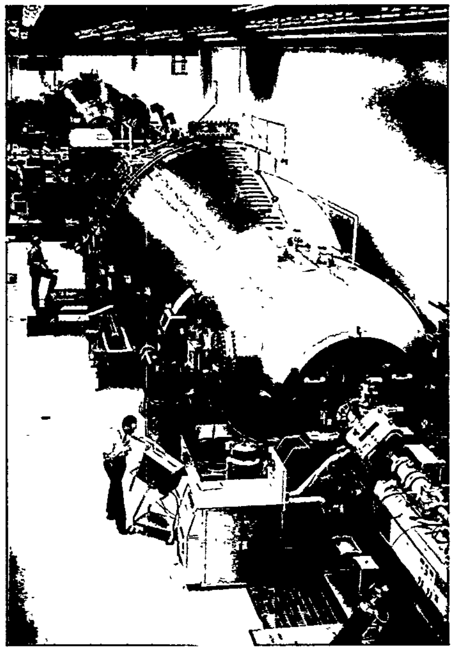
Prominent among the HFBR's research uses is structural biology, a field far removed from the original physics and chemistry mission for which the reactor was built. Magnetism, superconductivity and rare isotopes are still studied here. But the HFBR also serves well many scientists who study the puzzle of life — it is home to the nation's most active neutron-based structural-biology program.

Tandem Van de Graaff

Besides its duties as the starting point for heavy-ion beams for the AGS and, eventually, for RHIC, the Tandem Van de Graaff accelerator boasts applications of its own. During just nine months of the year, it attracts more than a hundred academic and industrial users — 119 in 1995 alone. A second tandem accelerator, much like the existing one, is being readied to make more beam time available to users.

These users came from 25 institutions this year, including 12 U.S. and three European companies, five American universities and five U.S. government research laboratories.

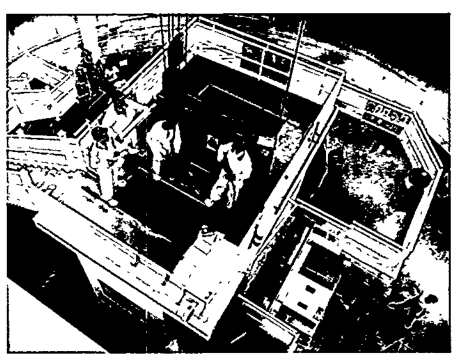
Many come to benefit from the Single Event Upset Test Facility, which uses accelerated heavy ions to simulate the cosmic rays of outer space. For satellite builders who need computer chips and other devices that are "hardened" to withstand the impact of such rays, the facility is quite valuable — both the U.S. and the European space agencies have called on the Tandem for such work.



A major industrial effort at the Tandem, by a U.S. company, uses the same speeding ions to trace microscopic tracks in plastic filter membranes.

Brookhaven Medical Research Reactor

The smaller cousin of the HFBR, the Brookhaven Medical Research Reactor (BMRR) is home to the Laboratory's clinical trials of boron neutron capture therapy (BNCT) for brain tumors. But its uses extend into other, basic medical and materials science projects.

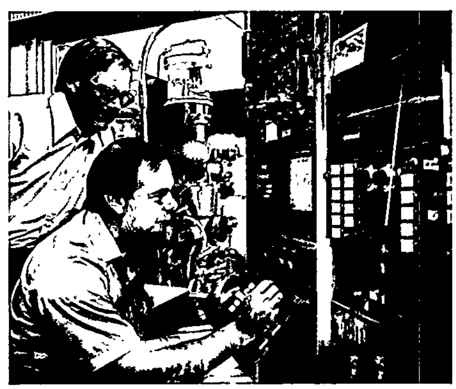


Brookhaven scientists make up the bulk of the BMRR's 75 users, including those who are working to improve BNCT, observe cells' reaction to radiation, and activate elements in limestone for radiological dating. But some 25 users from six outside institutions, including the State University of New York at Stony Brook, Washington State and Ohio State Universities and New York's Beth Israel Medical Center, also availed themselves of the BMRR in 1995.

Scanning Transmission Electron Microscopy

Brookhaven scientists and outside users come to the Scanning Transmission Electron Microscopy (STEM) Facility to see and "weigh" the smallest of the small — from single antibodies labeled with gold to the geometric capsule of a virus.

In addition to ongoing heavy use of the original microscope (STEM 1), which was commissioned in 1977, this year featured the completion of another STEM machine, known as STEM 3. Its purpose is to make



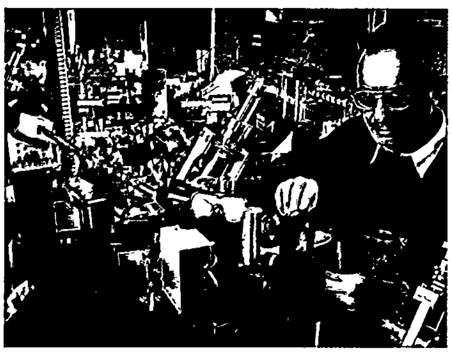
elemental maps of unstained biological specimens at a low dose of electrons. STEM 2, a microscope brought to the Laboratory in 1985, is no longer in operation, having been superseded by STEM 3.

About 50 users from nearly three dozen institutions put STEM 1 to use in 1995. The facility's staff examined samples that had been sent from Brookhaven's own labs, as well as from universities and government laboratories around the country.

Often, biological samples are too sensitive to radiation damage to be inspected under conventional electron microscopes without the addition of stains. But with STEM, unstained samples may be probed one point at a time with a low dose of electrons, which scatter and are recorded on sensitive detectors.

Accelerator Test Facility

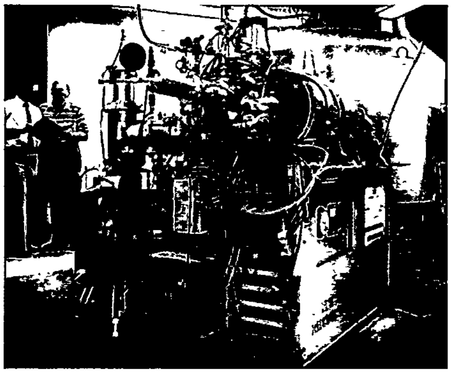
While many other Brookhaven user facilities start with a basic machine and receive new upgrades or experiments periodically, the Accelerator Test Facility is a never-ending series of experiments in accelerator physics — a work in progress. The "users" at the ATF are actually the designers of the next generation of accelerators and synchrotron radiation sources, testing their ideas and prototypes for new accelerator physics principles and devices.



In addition to users and contributors from diverse Brookhaven departments, over 30 scientists from private companies, universities and other national laboratories participated in 12 experiments on the ATF in 1995. Among the investigations is a prototype inverse free electron laser, which at the end of the year was on the verge of successfully accelerating electrons.

Cyclotrons

Brookhaven's two small cyclotrons — the 60-inch and the 48-inch — are most frequently associated with the positron emission tomography (PET) program, for



which they produce short-lived isotopes for medical imaging.

But in 1995, three other users from outside institutions called on the cyclotrons for help in their projects. The two machines, one of them more than 30 years old, helped produce isotopes for cancer studies and also aided in studies of radiation damage to electronic parts and activation of materials used in space-suit visors. ■

BNL's Users, 1995: Portrait of a Community

	Users	Institution (approx.)
NSLS	2,206	357
AGS	850	180
RHIC	840	81
HFBR	250	73
Tandem	119	25
BMRR	75	7
STEM	50	10
ATF	12	7
Cyclotrons	3	3
TOTAL	4,405	743*

*some overlap may occur

AUI: Turning Vision Into Reality

When a group of nine Northeastern universities came together in 1946 under the name Associated Universities, Inc. (AUI), their mission was clear: to establish a center for science that provided facilities far larger than those any one institution could build alone.

This center, they envisioned, would attract not only scientists from the founding institutions, but from all over the nation and around the world. It would be an unprecedented achievement — a home for large, state-of-the-art scientific machines and for the resident and visiting scientists who would use them to find the basic truths of nature.

Today, with thousands of users availing themselves of Brookhaven's resources each year, that vision has been fulfilled.

With AUI's guidance spanning nearly five decades, world-class user facilities have been built time and time again at Brookhaven. This success story began with the first nuclear reactor built for peacetime basic research, the Brookhaven Graphite Research Reactor, and continues to this day with the busiest scientific facility in the world, the National Synchrotron Light Source. The drive for user facilities of the future, most evident in the building of the Relativistic Heavy Ion Collider, is unceasing.

Over the years, AUI and Laboratory management have worked together to develop policies and create procedures for reviews and workshops. This work has both preserved and enhanced Brookhaven's reputation as a world-class institution. Impacting many areas of science, this alliance has been fostered by the dedicated service of hundreds of AUI trustees and visiting committee members.

This year, after extensive negotiations, AUI renewed its contract with the U.S. Department of Energy for the continued operation of the Laboratory through the end of the century. The contract marks a sharp deviation from previous contracts, which had been based on management and operating principles that had evolved over the last 50 years.

The new contract is "performance based," defining detailed performance criteria and calling for increased contractor accountability and risk sharing. It is expected to decrease micromanagement and result in improved performance and cost-effectiveness in all Laboratory operations.

Drawn from many institutions, AUI's 24 trustees help oversee Brookhaven's endeavors through numerous specialized committees. Attending a Board meeting at the Laboratory are trustees and officers: (back row, from left) Scott Lederman, AUI Treasurer; Morton Lippmann, New York University; Louis Girifalco, University of Pennsylvania; Thomas Davin Jr., AUI Vice President-Corporate Affairs and General Counsel; Ernest Henley, Chairman of AUI Board of Trustees, University of Washington; Robert Birgeneau, Massachusetts Institute of Technology (MIT); Robert Hughes, AUI President and trustee ex-officio; Marvin Kuschner, State University of New York at Stony Brook; Michael Fisher, University of Maryland; Martha Haynes, Cornell University; Andrew Sessler, Lawrence Berkeley National Laboratory; Aihud Pevsner, The Johns Hopkins University; Robert Adair, Yale University; Herman Feshbach, MIT; (middle row, from left) Jerome Hudis, AUI Vice President - Programmatic Affairs, Controller and Secretary; Paul Sigler, Yale University; John Armstrong, IBM Corporation; Donald Hess, University of Rochester; Leland Willis, AUI Vice President - Environment, Safety & Health; Robert Pound, Harvard University; (front row, from left) Paul Martin, Harvard University; Carol Whitley, AUI Assistant Secretary; William Sweet, Massachusetts General Hospital, AUI Honorary Trustee; Barbara Baird, Cornell University; and Val Fitch, Princeton University. Missing are: Barry S. Cooperman, University of Pennsylvania; Vera Rubin, Carnegie Institution of Washington; Malvin Ruderman, Columbia University; Joseph Taylor, Princeton University; and Richard Zdanis, Case Western Reserve University.

Using the Fiscal Division

These rows of figures add up to a majority of the Fiscal Division.

One Brookhaven service much used by users is the cashier's office. From behind the window grille, in addition to dealing with other Laboratory business such as travel expenses and petty cash reimbursement, the cashier receives housing bill payments from visiting scientists and cashes their personal checks. This function is part of Accounts Payable, which, together with General Accounting and Payroll, forms the Fiscal Division.

The Fiscal Division's main task is to ensure that the Laboratory's financial transactions are all in accordance with generally accepted accounting principles. The division oversees day-to-day accounting functions and assures cost-effective compliance with directives from the U.S. Department of Energy, including internal controls and financial reporting.

Other responsibilities are to supply research units with technical guidance in accounting and finance as required, to resolve complex fiscal-related problems and to carry out special projects assigned by the Director's Office.

The division keeps abreast with the latest technology for more effective, efficient procedures — this year, for example, a local area computer network to connect the division's offices was established.

Close working relationships are maintained between the division and the Laboratory's administrative offices, including those within the many scientific and support departments and divisions.

All in all, it is not just users — everybody uses Fiscal!

Team Spirit

As evidenced on these pages, Brookhaven has contributed many user facilities to the scientific community over the years. And all along, the Laboratory has opened those facilities to teams of scientists whose innovations have explored and enhanced each machine's possibilites: participating research teams (PRTs).

This "if you build it, they will come" principle of user-facility operation offers access to teams of researchers from any number of institutions. Brookhaven builds, maintains and upgrades the "big machine" itself, through U.S. Department of Energy funding. But one machine can support many beam lines and experiments — which is where the PRTs come in.

In a PRT, researchers from several universities, laboratories or companies, for example, may come together to fund and build a beam line at the National Synchrotron Light Source that they all can use. Each team's long-range research goals and detailed beam-line design must be approved by the Laboratory, and each must submit an annual progress report. Every three years, each PRT's tenure is reviewed through these reports.

If a PRT performs proprietary research that will not be published in the scientific literature, it must compensate Brookhaven for its use of the machine.

Users who have a less continuing need for research time at the NSLS or some other user facilities can participate in the general user program, which allocates up to a quarter of the beam time on PRT beam lines.

PRTs are the lifeblood of Brookhaven's user facilities, providing a constant flow of new faces, new ideas and new equipment through the Laboratory and reinforcing the concept of user facilities as centers for science.

RHIC Update

When Bro[illegible]vistic Heavy Ion Collider (RHIC), comes on line in 1999, a lifeblood of particles will course[illegible]-kilometer "arteries," or rings. These two concentric circles, made of 1,740 supercon[illegible]built by Laboratory-industry cooperation, will direct the beams of speeding ions and, as announced this year, polarized protons. But the collider will have "eyes," too — four huge experiments resulting from years of collaboration among more than 800 scientists and engineers. They will be able to "see" the showers of particles produced by collisions between the two beams, and perhaps even glimpse the first creation of a quark-gluon plasma since the Big Bang. Together with many other components that will make RHIC's lungs, brain and nerves, these vital systems made remarkable progress this year.

A Spin Around the RHIC Ring

A major addition to RHIC's physics program came in 1995 with the announcement that a collaboration with Japan's RIKEN Laboratory will outfit RHIC to collide beams of spin-polarized protons, as well as beams of heavy ions, at energies of 250 billion electron volts (GeV).

Through the new program of "spin physics," physicists hope to gain an understanding of the spin structure within nucleons, the particles that normally occur inside atomic nuclei.

Such investigations will complement the heavy-ion physics already planned for RHIC, which will collide ionized beams of gold or other elements in the search for quark-gluon plasma. This soup-like state of matter, in which quarks and gluons inside nucleons are loosed from their usual bonds, is thought to be similar to the state of the universe moments after the Big Bang.

The additional accelerator equipment and detectors required for a spin-physics program are being funded by a $20 million collaboration with RIKEN. Now, in addition to being the world's highest-energy collider of heavy ions, RHIC will surpass all other colliders for spin-polarized proton energies when it comes on line in 1999.

A Magnet a Day, and More on the Way

It will take 1,740 superconducting magnet components to make RHIC — 1,740 components that must be manufactured, assembled into completed magnets, installed in the RHIC tunnel and connected to one another in two parallel 3.8-kilometer colliding rings. Altogether, it is a $150 million endeavor.

Working with industry, RHIC's magnet designers, builders and installers are getting the job done. This year, industrial partner Northrop Grumman Corporation successfully delivered 235 dipole magnets under the second phase of its contract to build 371 of the assemblies. The company also continued to ship quadrupole magnet cold masses to the Laboratory from its plant in nearby Bethpage, completing 376 toward a goal of 432 by the end of the year.

Our other magnet partner, Everson Electric of Bethlehem, Pennsylvania, has completed its delivery of 300 sextupoles and 78 trim quadrupoles.

This year, the Laboratory's magnet-assemblers began bundling Northrop Grumman's quadrupoles and Everson's magnets into corrector-quadrupole-sextupole (CQS) assemblies, along with 432 corrector magnets made at Brookhaven. By the end of fiscal year 1995, our assembly line was producing completed CQS assemblies at a rate of nearly one each day, for a total of 105.

Once magnets are assembled, they board a truck for the short trip to the RHIC tunnel. The end of the year saw 189 dipoles and 66 CQSs already in the tunnel.

RHIC's rings of magnets feature alternating dipoles and CQS assemblies, the former to bend the ion beams and the latter to focus them. But first, the magnets must be strung together, through a complicated assembly of electrical wiring, welded pipes or bellows, superinsulation blankets, heat shields and outer vacuum shells. Twenty-six of these interconnects were in progress by year's end.

A train of room-temperature magnets leading into RHIC, the transfer line that originates at the Alternating Gradient Synchrotron (AGS), was ready for action by the end of the year. At that time, preparations were under way for a test beam of gold ions to be accelerated by the AGS and delivered to the transfer line in early fiscal year 1996.

Experiment Building Begins

While the parade of magnets continued to file into the RHIC tunnel, other scientists and engineers spent 1995 working on their part of the collider: the four experiments that will take position on the ring and keep watch over collisions.

Altogether, these experiments involve more than 800 collaborators, including physicists, engineers, technicians and students, from all over the world. Each experiment comprises a multitude of detectors and components, all of which have been designed for a specific physics purpose, and must be built, tested and installed into the finished whole.

The two massive RHIC experiments, STAR and PHENIX, are well into the construction phase, while the two smaller experiments, BRAHMS and PHOBOS, are ready to begin construction.

Among the year's accomplishments were: the fabrication of detector components at locations ranging from California and Pennsylvania to England, Russia and Japan; component testing at the Alternating Gradient Sychrotron; and, in March, the ground breaking for the STAR assembly hall.

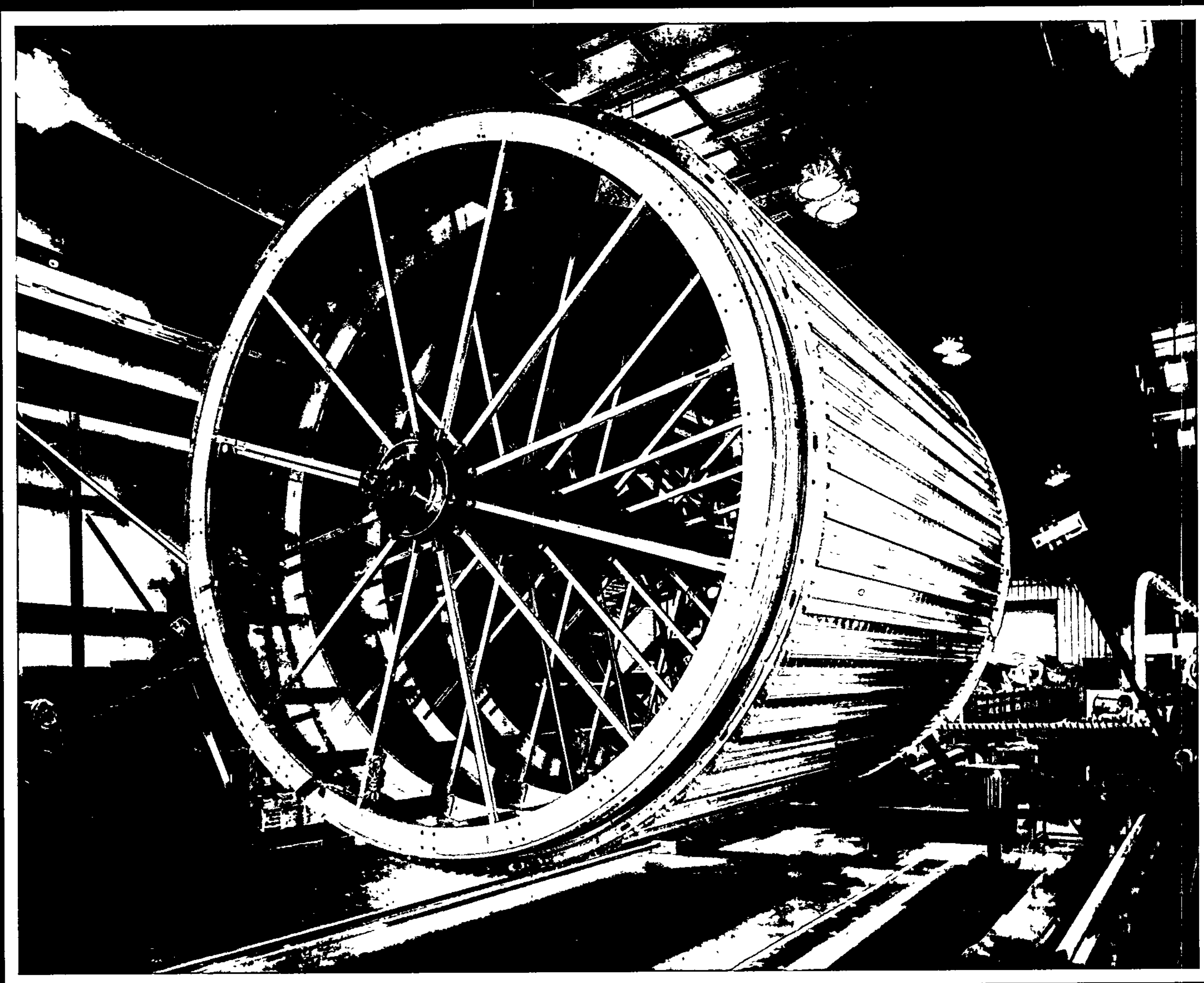
On a tour of the RHIC tunnel, Japanese spin-physics collaborators and Laboratory representatives pose near the collider's ever-growing string of superconducting magnets.

Looking ahead, the additional experimental equipment initiative accepted in March provides for new instrumentation in both STAR and PHENIX, to extend RHIC's physics capabilities. A new initiative is under way to provide the massive amounts of computing power required to analyze the data from RHIC's experiments. And, planning has begun to coordinate the collider's "end game" — the final stages of machine tuning and experiment installation that will take place before RHIC is commissioned.

Other 1995 Developments

While magnets and experiments make up much of what RHIC is all about, there are many other systems that need to be in place before the collider comes on line.

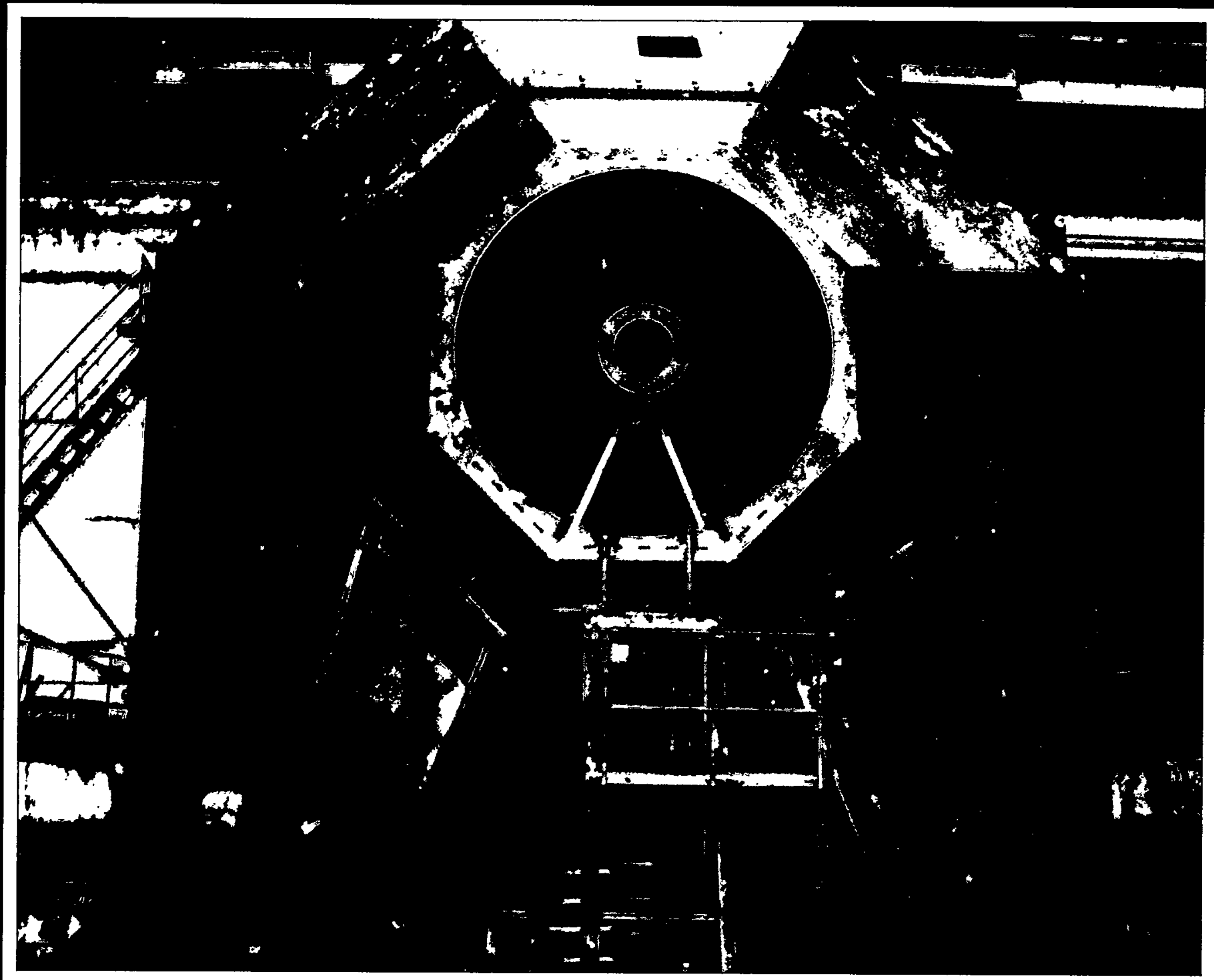
To keep the magnets cooled to superconducting temperatures — around 4.5



The outer skin of the time projection chamber, a 4.7-meter long component of RHIC's STAR experiment, under construction at Lawrence Berkeley National Laboratory.

kelvins, or -268.5° Celsius — a giant helium refrigeration system near the Collider Center is being readied. In June 1995, the compressor system for this 24 kilowatt refrigerator was tested successfully, with a test of the entire refrigerator expected for 1996.

Another aspect crucial to the operation of RHIC will be the shielding to enclose the radiation caused by the speeding ions as they race at relativistic speeds around the two rings. This year saw the beginning of a unique program to provide that shielding material for RHIC and save taxpayers $45 million — instead of disposing of the concrete-and-steel block shielding from the recently decommissioned Bevalac accelerator at Lawrence Berkeley National Laboratory, the U.S Department of Energy will ship 15,000 tons of the material to Brookhaven via rail. ■



The muon magnet for RHIC's PHENIX experiment, being assembled in St. Petersburg, Russia

Scientific Departments

Since its inception nearly 50 years ago, BNL has been a multidisciplinary laboratory. The Laboratory's eight departments reflect this diversity of research: Advanced Technology, Alternating Gradient Synchrotron, Applied Science, Biology, Chemistry, Medical, National Synchrotron Light Source and Physics. This breadth of expertise helps BNL's scientists and scientific visitors pursue their research at the leading edge of discovery — a place where the synergy of new ideas and unique machines combine to uncover the secrets of nature.

ALTERNATING GRADIENT SYNCHROTRON

The AGS D[redacted]tes the Alternating Gradient Synchrotron (AGS), the world's most intense high-energy sy[redacted]s to the Booster preaccelerator and other improvements highlighted in the first article of t[redacted]AGS can now deliver 6 x 10^{13} protons per pulse. Accelerating heavy ions since 1987, the AGS also pushes gold ions to a record 11.7 billion electron volts per nucleon, pointing to the future of nuclear physics at the Relativistic Heavy Ion Collider, now under construction at Brookhaven.

SETTING A WORLD RECORD FOR PROTON INTENSITY

After undergoing a major overhaul during the last decade, Brookhaven's Alternating Gradient Synchrotron (AGS) this year beat its own world record for proton intensity.

In March, it accelerated 60 trillion (6 x 10^{13}) protons with every pulse of its beam. This intensity is more than 60,000 times greater than the 1 x 10^{10} protons per pulse that was originally envisioned for the 35-year-old accelerator.

Today's powerful proton beam triples the number of kaon decay experiments that can be conducted simultaneously. Also, the AGS can now accommodate new high-precision experiments, such as one that aims to measure precisely the magnetic moment of the muon. This characterization of the particle's interaction with a magnetic field requires more intense beams than previously available.

Proton energy for AGS injection increased from 0.2 billion electron volts (GeV) to 1.5 GeV in 1991, with the completion of the Booster, which preaccelerates and injects protons into the AGS. In time, this increased energy enabled our researchers to increase the AGS proton intensity fourfold, to its current level. But first, many upgrades had to be made.

MAIN MAGNET POWER SUPPLY

The AGS's 0.8-kilometer circular tunnel contains 240 magnets, which guide and focus the particle beam. The major requirements of the magnetic field are that it be stable and reproducible, while also being flexible.

Every three seconds, 30 GeV of energy is imparted to the beam, while 50 megawatts of peak power in the accelerator's magnets keep the beam on track. The power flow has to be carefully shaped to meet the requirements of the various parts of each AGS cycle.

To control this large influx of energy, an array of computers and electronic feedback loops has been installed. Other computers have been added to diagnose problems with magnets and with the power-supply electronics. The upgraded controls system both programs and measures the voltage and current of the main magnet power supply and, hence, holds the magnetic field intensity at the required point of the cycle.

VACUUM SYSTEM

Begun in 1986, a major upgrade of the AGS vacuum system is now complete. The improved vacuum prevents protons from colliding with gas molecules as they travel at nearly the speed of light around the accelerator ring. Such collisions would cause beam loss, which limits the beam intensity and creates residual radioactivity in machine parts.

To counteract these potential problems, the AGS's operating pressure was lowered from 2-3 x 10^{-7} torr to 10^{-9} torr. New metal vacuum sealing technology was substituted for the older designs, and most of the elastomers and plastic components — which are prone to radiation damage — were replaced with metal seals and ceramic insulators. Also, the 240 dipole magnet chambers were refurbished, and as many new high-speed pumps were installed throughout the ring to maintain lower pressures.

TRANSVERSE DAMPER

As the AGS's beam intensity increases, the beam produces more electric current in the surrounding vacuum chamber, which makes the beam itself unstable. When the beam starts to "wiggle", it hits the chamber sides and is lost.

To prevent this problem, a new, more powerful transverse damper — a feedback system to stabilize the beam — has been installed. Electrodes inside the AGS vacuum chamber monitor the motion of the beam. When excessive motion is detected, high voltage is applied to metal plates in the transverse damper, known as the kicker, to generate an electric field in the vacuum chamber. The electric field then "kicks" the beam—putting it back on course.

Transition-Energy Jump System

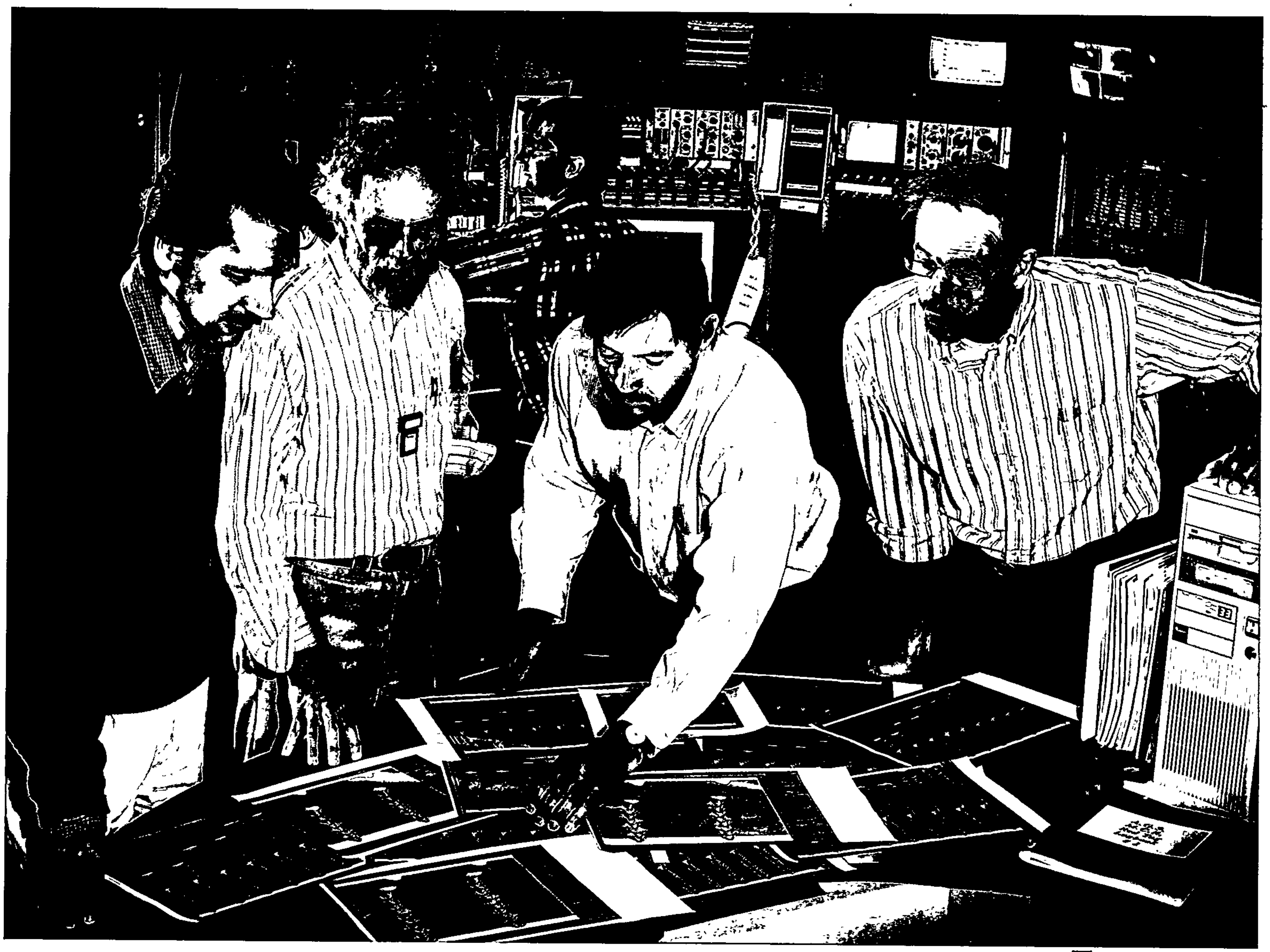
Protons travel together in bunches around the AGS ring, but protons on the outer perimeter of the bunches have a slightly longer distance to travel. This is not a handicap at lower energies, because these particles have a higher momentum and velocity, making them still faster than the other protons.

At higher energies, however, the difference in velocity becomes so small that they do take longer to travel around the ring. The beam energy at which this change occurs is called the transition energy. Associated with transition are beam losses, which tend to increase sharply with beam intensity.

To avoid these beam losses, AGS researchers developed a transition jump system. Using pulsed quadrupole magnets, this system minimizes the time that the beam spends close to the transition energy. A significant reduction of beam losses has been achieved with this system, which is indispensable for running the AGS at the present intensity levels.

High-Power RF System

The radio-frequency (rf) system in the AGS accelerates protons around the ring via electromagnetic waves operating in the frequency of radio transmission. The new proton intensity required a 400 percent increase in rf power — a feat successfully



Discussing transition energy data in the Alternating Gradient Synchrotron control room are (from left, foreground) Thomas Roser, Michael Brennan, Willem van Asselt and Leif Ahrens. David Gassner (background) is working at the control panel.

accomplished by AGS researchers who have been working on this project since 1991.

As part of this upgrade, the ten 20-year-old accelerating cavities were upgraded; ten new high-power amplifiers were installed, each capable of supplying 75 kilowatts of power to the beam; and a new rf beam-control system was built to provide new flexibility and to ensure smooth beam acceleration.

Radiation Safety

The task of increasing the AGS proton intensity includes safety committee reviews of shielding designs and beam design calculations for safe and efficient operation of the several accelerators involved. Also, measurements of the effectiveness of shielding are routinely done to assure the safety of workers near the beam enclosures.

Basic dose-reduction strategies were incorporated into designs of beam line components and radiation-resistant devices were installed. Our greatest dose reduction has come by way of accelerator improvement projects. These include improving the vacuum, beam injections and extraction devices, and acceleration and other beam control systems. Over the long term, such modifications reduce beam losses and personnel dose. ■

Searching for Rare Kaon Decays–And New Physics

Because it can produce the most intense proton beam in the world, the Alternating Gradient Synchrotron (AGS) is the world's premier source of an intense beam of kaons — subatomic particles formed when protons hit a target.

Joining a long line of physicists who have chosen the AGS as the vehicle for studying processes called rare-kaon decays is a team of researchers from the College of William and Mary; Richmond University; Stanford University; the University of California, Irvine; and the University of Texas at Austin.

More Kaons, Better Results

The researchers have begun taking data for Experiment 871 (E871), improving on E791 — their previous kaon decay experiment conducted from 1986 - 91 — by using a beam about 20 times more intense than before.

To accomplish their goal, the researchers have rebuilt the experiment's detector so that it is five times more efficient in collecting data. The detector must cope with the signals of the 100 million particles that pass through it every second, measuring their positions to a precision of 0.1 millimeters. The more intense beam and improved detector make the experiment 20 times more sensitive for finding rare kaon decays.

Kaons are naturally unstable particles, each made of a quark and antiquark. When they break down, or decay, they form two or more particles. Physicists believe kaons and other subatomic particles decay by a process in which the quarks in the particle first combine to form a heavy, intermediate particle. According to theory, this heavy particle can only exist for a very short time. Then, it decays into the final particles, which the experimenters can detect.

The way in which a kaon decays depends partly upon the masses of the intermediate, or virtual, particles created. In general, the heavier the virtual particle created, the rarer the decay mode. Some decay modes are common, while others are very rare, and some, according to physics theory, are only allowed if as-yet-unknown intermediate particles are made.

Alternative Routes

There are two ways to look for evidence of new physics — novel and unproven principles that would change the way physicists view all the matter in the universe. One way is to build increasingly energetic accelerators, like the Large Hadron Collider being built at the European accelerator laboratory, CERN. This would allow experiments at higher energies than now possible, where new phenomena may await discovery.

The other route is to look for very rare processes, which would also require new physics to occur. This approach relies on the fact that a process is considered rare when it occurs by producing a very massive intermediate particle that exists for only an extremely short period of time. This latter method of exploring matter is the forte of the AGS, since its intense beams can produce many kaons and, hence, detect very rare processes.

Building on the Past

Electrons, along with muons and tau leptons, are in the family of fundamental particles called leptons. Muons and tau leptons differ from electrons only in their masses.

In 1962, Brookhaven had a part in the history of understanding leptons when, working at the AGS, Leon Lederman, Melvin Schwartz and Jack Steinberger found that each lepton had a distinct neutral partner — a neutrino — and, thus, they discovered the muon-neutrino. In 1988, the discovery won them the Nobel Prize. The current collaboration hopes to gain from E871 some hint as to why there are three types of leptons.

In E871, the researchers are looking for the decay of a neutral kaon to an antimuon and an electron. This would be a very significant finding, since it contradicts current physics concepts. If an electron or muon is produced, the antiparticle for each must also be produced, according to conservation law.

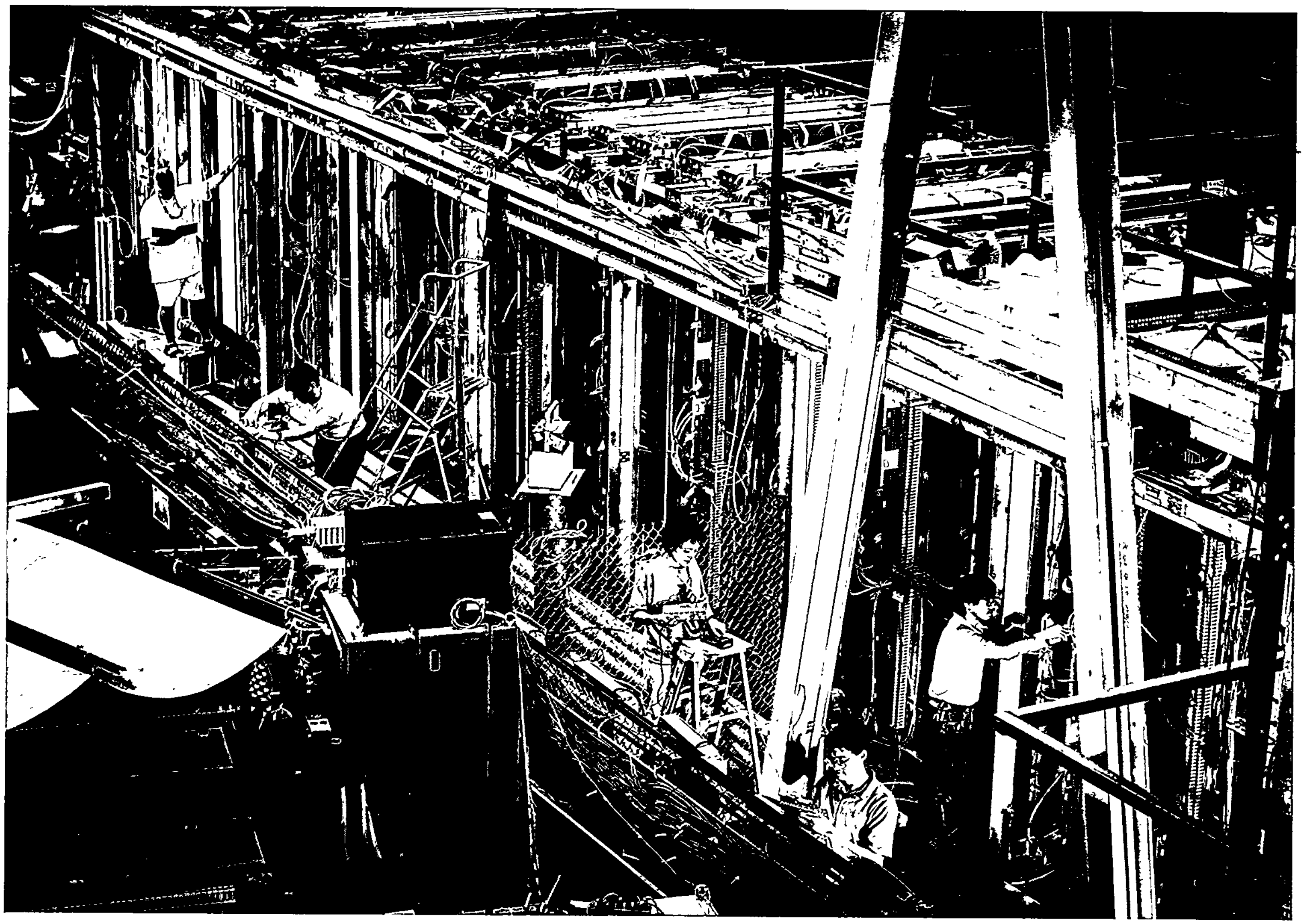
A well-known example of this law is conservation of electric charge. When a negative charge is produced, so is a positive charge, so the total charge remains unchanged.

Present physics understanding requires that, in addition to an electron, a positron or a positron neutrino be produced from the decay of a neutral kaon. Similarly, a muon would accompany the production of an antimuon or antimuon neutrino.

In its five-year run, E791 did not find any examples of a kaon decaying into an antimuon and an electron, but it showed that fewer than one in 3×10^{10} kaons could decay this way. This limit means that the mass of the intermediate particle produced during the decay — if it exists — is at least 100 trillion electron volts, or at least 100,000 times the mass of a proton. This is so massive that it could not be directly observed in any accelerator yet conceived. Nevertheless, its existence could be inferred by observing this decay mode of the kaon.

Looking Ahead

If this decay route is found, it would mean that another physical force exists — in addition to the four known forces of nature outlined in the standard model, the modern theory of physics. In effect, the standard model that now describes physics would have to be extended, and E871 would have discovered new physics. So, the scientists of E871 continue to monitor millions of proton-target collisions, looking for this phenomenon. ■



E871 collaboration members (from left) Dana Love, University of Richmond; Michael Hebert and Marize Pommot-Maia, both from Stanford University; and Mark Bachman and Nobu Kanematsu, both from the University of California, Irvine, are working beside the muon particle detection system at the Alternating Gradient Synchrotron.

PHYSICS

Research in the Physics Department focuses on the characteristics of matter. Particle physicists are interested in the building blocks of matter — quarks and leptons. Nuclear physicists study nuclear matter under extreme conditions, as well as the excitations and structure of atomic nuclei. And condensed-matter physicists examine properties of bulk matter and its surface, including such phenomena as high-temperature superconductivity. Also within the department, a facility to study the effects of simulated cosmic rays on materials is available to outside users.

SEEKING THE SUPER-CONDUCTING FACTOR

Scientists discovered the first high-temperature superconductor in 1986, in a Zurich laboratory. A compound of barium, lanthanum and copper-oxide, it was called Zurich-oxide.

From the moment it was announced, this exciting news meant that a wide range of applications for this new class of superconductors might be a reality in the future. For example, promising uses are thought to include components in electrical circuitry and defense technologies.

First discovered in 1911, superconductivity is the ability of a material to carry electrical current without losing energy. Materials do this once they are cooled below a "transition temperature," usually far below water's freezing point at 273 kelvins (0°C).

Until 1986, the highest achievable transition temperature for superconductors was 23 kelvins (–418°C). The new compounds, however, can become superconducting at 125 kelvins (–234°C) — a relatively high temperature. And they can be cooled using liquid nitrogen, a material that is much more economical than the liquid helium required to keep the others cold enough to superconduct.

STRUCTURE AND MAGNETISM

Researchers in Brookhaven's Physics Department are interested in understanding the mechanism of superconductivity and its connection with the basic structure and magnetic properties of these new superconducting materials.

So, in recent years, our physicists, together with collaborators from the Massachusetts Institute of Technology and Japan's Tohoku University, have investigated the magnetic order — the spatial arrangement of the magnetic atoms — of lanthanum copper oxide and similar compounds, using neutron probes at the Laboratory's High Flux Beam Reactor (HFBR).

Neutrons interact with a superconductor's atomic nuclei and magnetic dipoles, creating a diffraction pattern that enables scientists to investigate the atomic structure of these materials as well as gather data on their static and dynamic magnetism.

A SURPRISING CHANGE

Each copper-oxide superconductor has a layered structure, with planes of copper and oxygen atoms alternating with layers of differing compositions. Within the copper-oxide planes, the copper atoms are arranged in a simple square lattice, with an oxygen atom between each pair of copper atoms.

The density of electrons within these planes can be varied by modifying the chemical composition of the intervening layers. Surprisingly, the electrical conductivity of the entire compound can be varied over an enormous range, with only a small change in electron density. For example, the compound lanthanum copper oxide, an electrical insulator, can be changed to a superconductor by replacing a small amount of the lanthanum with the element strontium.

Without the strontium, the insulating copper-oxide compounds exhibit a special kind of magnetic order called antiferromagnetism, in which each copper atom acts like a tiny magnet, with the magnetic dipoles of neighboring magnetic atoms pointing in opposite directions.

As the electron density in lanthanum copper oxide is reduced by substituting strontium, however, the magnetic order is destroyed, and the compound becomes an electrical conductor. Neutron scattering experiments have shown that the loss of magnetic order occurs because the orientations of the magnetic dipoles of copper atoms fluctuate. Even while fluctuating, neighboring dipoles try to remain antiparallel, or opposed.

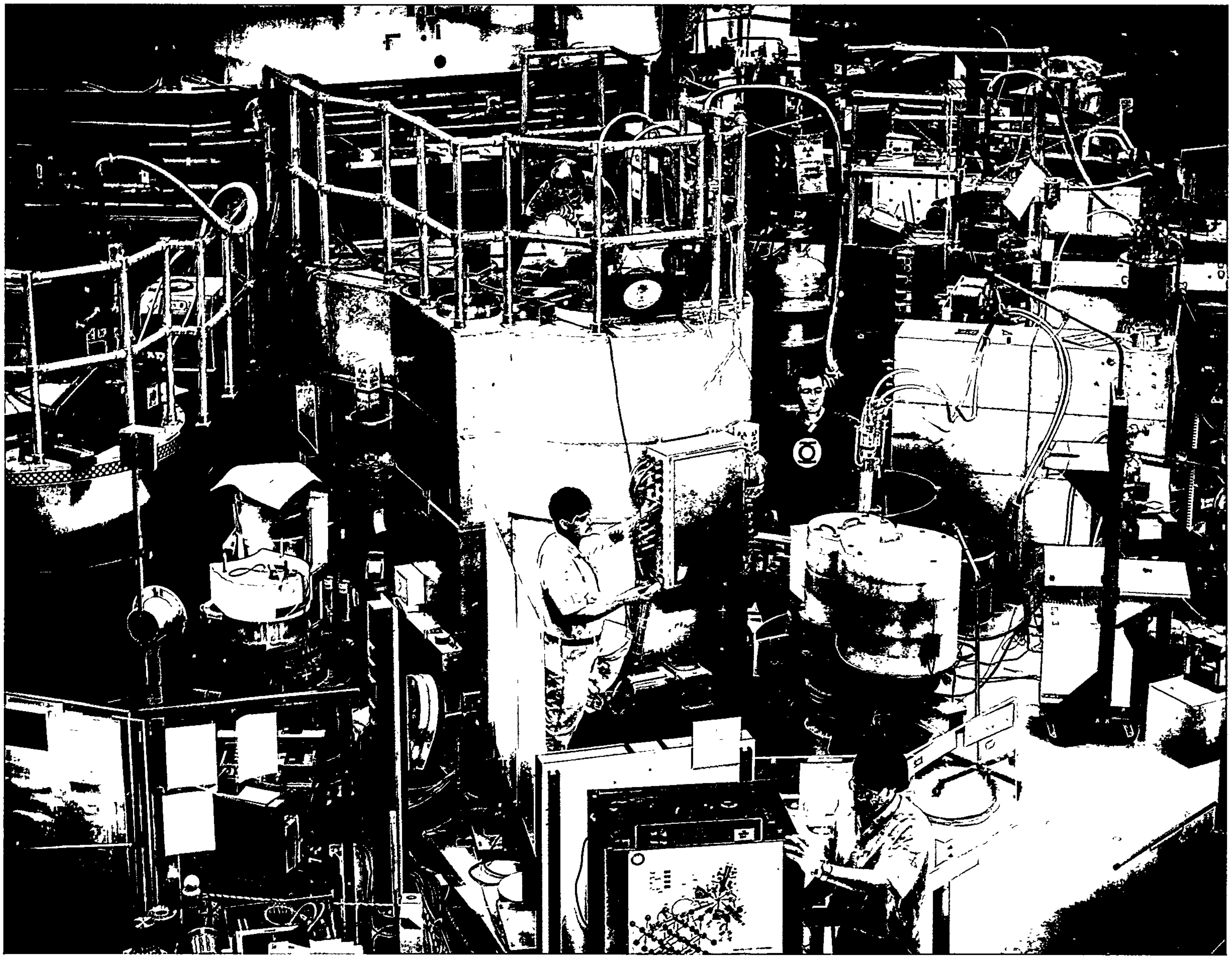
Until recently, scientists did not know if the changes in electron density and magnetism occurred uniformly within the copper-oxide planes or if distinct regions of electron deficiency and local antiferromagnetism coexisted. Recently, evidence of two distinct regions was obtained in experiments performed at the HFBR by collaborators from Brookhaven, Columbia University and the University of Tokyo.

A Theoretical Agreement

The researchers studied a special crystal of lanthanum neodymium strontium copper oxide. This substance has the correct electron density to be superconducting, but, surprisingly, is not. The researchers may have found the reason: They observed diffraction peaks indicating that regions of antiferromagnetic order occur in long stripes that alternate with electron-deficient stripes.

The static ordering of antiferromagnetic and electron-deficient stripes is coupled with an unusual distortion of the crystal structure; similar crystals without this distortion are superconducting. Now, scientists can explain previous neutron-scattering measurements of the superconducting crystals in terms of these newfound fluctuating stripe correlations of local antiferromagnetism and electron density.

The new experimental results are consistent with the theoretical work of collaborators from Brookhaven and the Uni-



At the High Flux Beam Reactor, (from foreground) John Tranquada, James Biancarosa, Benjamin Sternlieb and Richard Rothe Jr. prepare the H4M spectrometer for neutron diffraction measurements.

versity of California at Los Angeles. Such basic research has helped scientists to a better understanding of how superconductivity works and may bring industry closer to realizing its promising applications. ■

Solving the Mystery of Exotic Mesons

Short-lived elementary particles known as mesons were discovered in the early 1950s. Today, physicists are searching for exotic mesons — unusual combinations of quarks and gluons — and a large collaboration of physicists working at Brookhaven's Alternating Gradient Synchrotron (AGS) hopes to confirm their existence in the late 1990s.

Particle physicists have established two classes of elementary particles: baryons, which contain three quarks, and mesons, which are made of two quarks — a quark and an antiquark. Protons and neutrons are examples of baryons, while pions and kaons are in the meson class. The quarks that make up these particles are held together by gluons.

Two Kinds of Mesons

The laws of quantum chromodynamics predict that there is another kind of meson besides the ordinary two-quark particle — the exotic meson. This exotic meson would be made of either a quark, an antiquark and a gluon, or two quarks and two antiquarks. Confirming the existence of the exotic meson would take scientists one significant step further in validating the modern canon of particle physics known as the standard model.

The large collaboration at the AGS is an international team including physicists from Brookhaven, Indiana University, Northwestern University, Rensselaer Polytechnic Institute, the University of Massachusetts Dartmouth, the University of Notre Dame, IHEP Protvino in Russia, and Moscow State University.

Evidence of Exotic Mesons

Evidence of exotic particles was previously reported at the European accelerator laboratory, CERN; at the KEK facility in Japan; and at the Protvino accelerator in Russia.

But because the Brookhaven experiment, known as Experiment 852, is taking ten times more data than any of the others, researchers here are confident that their statistics will provide a definitive answer as to whether or not exotic mesons exist.

To search for exotic mesons, the researchers direct a negative pion beam, with an energy of 18 billion electron volts, at a liquid-hydrogen target located at the center of the AGS's multi-particle spectrometer. When the beam hits protons in the target, new particles are created.

If a pion and an eta particle are detected among these particles, then an exotic meson in a state of particular angular momentum could have been present, according to quantum chromodynamics. Specifically, the researchers would expect to look for signals of the exotic meson M(1405), named numerically for its mass and most likely to be found recoiling off a neutron or a proton.

Identifying the Exotic Meson

To identify an M(1405), the researchers examine three characteristics of the particle: charge, spin parity and charge conjugation. If the charge of a meson is found to be twice that of an electron, it is an exotic meson. Spin and parity describe how a particle behaves when its spatial coordinate system — its exact location in three-dimensional space — is rotated or inverted. An exotic meson would be expected to behave in certain characteristic ways that scientists could determine in experiments.

Charge conjugation is another mathematical operation that concerns exchanges of particles for antiparticles and vice versa, while leaving spatial coordinates the same. Every elementary particle has a counterpart called its antiparticle, which has the same mass, lifetime and spin, but the opposite charge. In this operation, the exotic meson can be distinguished by its charge conjugation quantum number.

This year, the collaboration has logged a very large amount of data — one billion significant pieces of information, called triggers. The more data the research team amasses, the closer they will be to finding exotic mesons. In a few years, the mystery of exotic mesons could be solved. ■

At the Alternating Gradient Synchrotron, (from left, front, counterclockwise) Dennis Weygand, Hans Willutzki, Suh-Urk Chung and Robert Hackenburg are working on Experiment 852 at the multi-particle spectrometer.

BIOLOGY

In the Bio[redacted], researchers aim to understand basic genetic and biochemical processes at the mole[redacted]ing how genetic information is organized and used, how DNA is damaged and repaired, [redacted]lar structures determine biological function. Human Genome Project work, including [redacted] of technology for large-scale DNA sequencing, is also a forte. Scientists and visiting users pursue their goals at facilities maintained at the National Synchrotron Light Source, High Flux Beam Reactor and Scanning Transmission Electron Microscope.

Fighting Disease on a Microscopic Level

• *A child in the U.S. comes down with a severe sore throat and fever, missing several days of school—a tiny virus known as adenovirus may be to blame. A different strain of the virus is the leading killer of children in the developing world.*

• *During an epidemic that claims hundreds of lives, a farmer in India succumbs to the ancient menace known as the plague, caused by the bacterium* Yersinia pestis.

• *After being bitten by a mosquito near an African swamp, a villager in Kenya develops the unbearable fevers of malaria as the parasite* Plasmodium falciparum *ravages her blood cells and liver.*

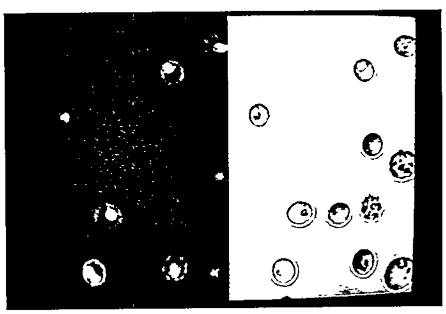
Around the world, millions of people suffer from infectious disease. And though these three cases seem quite different from one another, all of them have something in common: microscopic disease agents that are the subject of research in Brookhaven's Biology Department.

Drawing on the power of two of the Laboratory's user facilities, our scientists are contributing to the fundamental knowledge about each of these organisms.

The research centers around a class of enzyme known as proteases. These vital molecules act like molecular scissors, giving microbes the power to snip proteins into pieces and enable infection pathways or disable defense mechanisms.

All the studies are aided by a patented amino acid-rhodamine compound that becomes fluorescent when protease cuts it, providing a beacon of light for the scientists to follow.

By learning more about the structure and function of several proteases, each highly specific to their species, our work may give doctors the basis for dependable weapons against some of humanity's most dreaded diseases.



Human red blood cells, some of them infected with the organism that causes malaria, and all containing a substrate that fluoresces, or glows, when a certain malaria enzyme is present. With a light microscope (left), parasites are barely visible. But with a fluorescence microscope (right), a white glow on eight cells' surfaces tells the tale of malaria infection.

Adenovirus on an Atomic Level

The adenoviruses that cause respiratory disease and eye inflammation in humans and malignant tumors in animals are minuscule, only 70 nanometers, or millionths of a millimeter, in diameter. They are too small to contain everything they need to get into the host's body and reproduce — what they don't have, they borrow. But adenoviruses do have their own protease.

This enzyme is crucial to adenovirus' survival and is thought to play a part in giving a newly made virus the power to infect a cell.

This year, our scientists deciphered the protease's three-dimensional atomic structure and identified the location of all its 1,995 atoms, using the intense x-rays of Brookhaven's National Synchrotron Light Source (NSLS). The work was funded by the National Institutes of Health (NIH) as part of a nationwide effort to add to the arsenal of antiviral agents.

After painstaking work that culminated in the crystallization of the protease, a sample of it was placed in an NSLS beam line operated by the Biology Department. From the pattern of x-rays scattered by the sample, our scientists deduced its three-dimensional structure.

Now, the structure is already being used in a process known as rational drug design. In this approach, we are looking for specific sites on the protease that could become target points for antiviral compounds. We have begun searching computerized databases of drug structures, looking for any that might block the protease's active sites.

Another early possibility for antiviral action centers around a peptide, or short strand of amino acids, that normally links two branches of the protease's structure. Our researchers have designed and synthesized several different peptides that should bind to the protease but not link the two branches. Because these peptides may disable the protease, which needs to be active in order for the virus to reproduce, the NIH is testing these compounds to see if they could be used as antiviral agents.

A Plague on It

The NSLS provided the means for solving the adenovirus protease's structure. For work on the bacterium that causes plague, and the protease that is its disease-causing, or virulence, factor, we have turned to another of Brookhaven's user facilities.

Using the neutrons of the High Flux Beam Reactor (HFBR), we are trying to determine the structure of the protease in *Yersinia pestis*'s membrane, to find out how the bacterium uses this protein to become so virulent.

The technique used is called neutron diffraction. Brookhaven has developed special expertise in this, especially in the tricky area of preparing and examining membrane-bound biological samples.

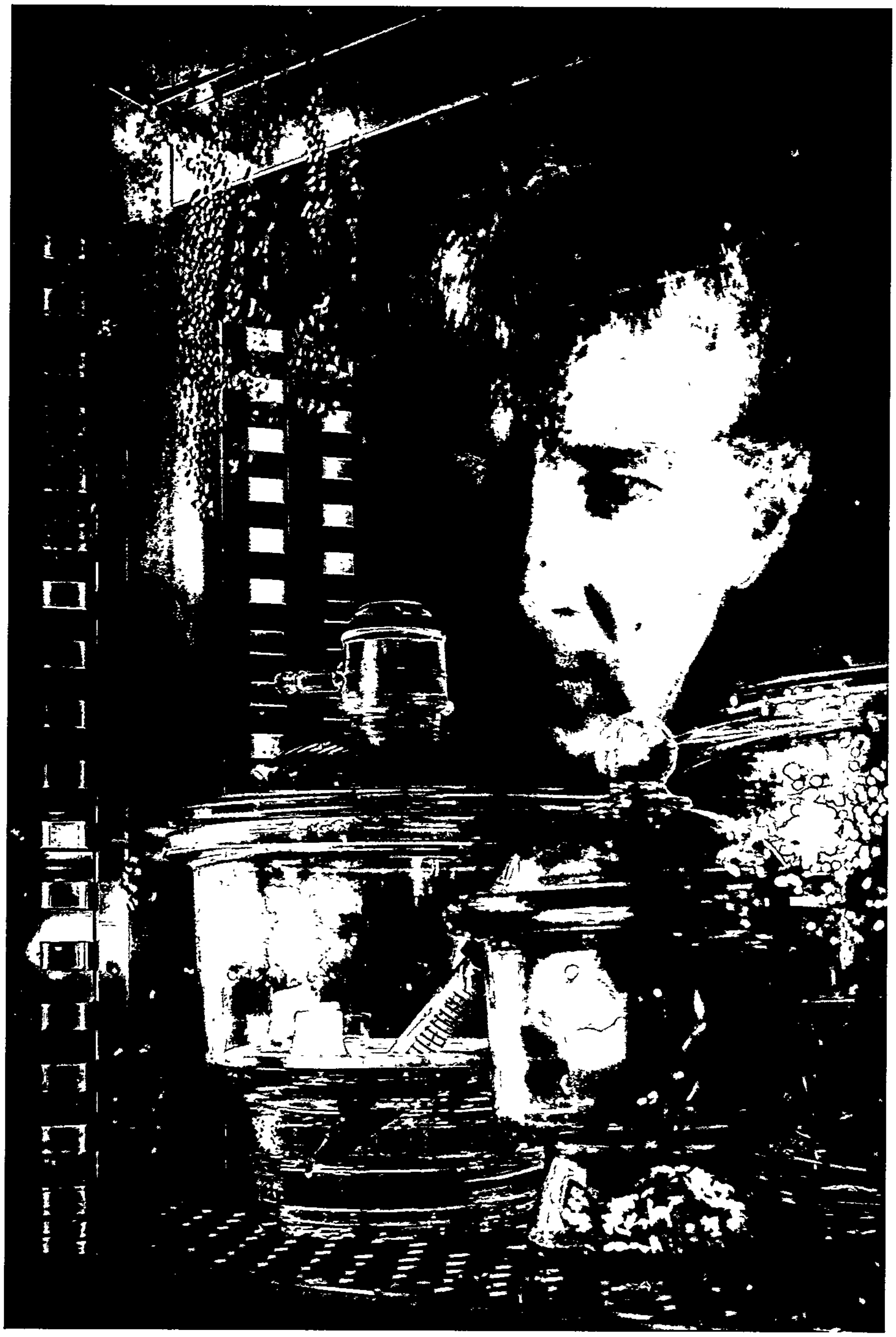
In addition to the protease's structure, the plague research encompasses the enzyme's production. Already, we have cloned and sequenced this dangerous organism's protease gene. Taken together, the results of our research on *Y. pestis* could give medicine the tools to fight one of humankind's most ancient and deadly scourges.

Investigating a Malaria Mystery

While the plague and adenovirus diseases are common, another disease caused by a microbe is pandemic: malaria.

The World Health Organization estimates that 300 to 500 million people contract malaria each year, more than 90 percent of them in Africa. About one percent of those infected, mostly children, die.

The parasite *Plasmodium falciparum*, which causes malaria by infecting blood cells, has developed resistance to many drugs. But basic research may lead the way to new ones: Our researchers have discovered that they can use the fluorescent rhodamine marker to locate *P. falciparum*'s protease, and therefore the parasite itself, inside cells.



To raise malaria-causing parasites, Wally Mangel uses candle jars like these. Inside human blood cells, malaria parasites whose protease has gone into action light up like fireflies.

While this work is still in early stages, *P.falciparum* has been shown to have an enzyme that could be purified, studied, sequenced and, eventually, blocked in an effective and specific anti-malaria tactic. And, the ability to use the rhodamine compound to see the parasites inside the blood cells they infect could provide the basis for an inexpensive diagnostic kit. ■

Weaving Genetics Into Cotton Production

For more than 30 centuries, the white fibers of the cotton plant have supplied the world with its most versatile fabrics. Plucked from their green bolls in fields from Mississippi to India, these thin strands of cellulose travel a journey of transformation into clothing, bedding and countless other items.

After years of careful breeding by agricultural scientists, today's cotton plants produce more and better cotton than ever before.

But now, the cotton industry is looking to Brookhaven's geneticists to reveal basic information about this important plant's genes, information that could further help increase cotton's performance and reduce its cost, and make the U.S. textile industry globally competitive.

This challenge is but the latest in our continuing series of research projects in plant genetics and builds on our existing expertise and equipment. Much of this work is basic research — by sequencing cotton's genes and solving the structure of important biological molecules, we help lay the foundation for untold future discoveries.

Focus on Fiber

Already, work has begun on learning more about the basic molecular and genetic processes of cotton fiber production in the plant.

Part of the industry's interest in cotton's genes stems from a need for further improvement of fiber strength, length and abundance to meet the demands of high-speed modern manufacturing equipment. Despite cotton's widespread use, many DNA-level questions must be answered before such improvements are possible — the kind of questions that our scientists are investigating.

For instance, how and when are fibers formed in the very first stages of boll growth? Which genes are switched on or off to keep each fiber growing or to tell the plant to stop adding to the strand? And, which enzymes guide cellulose formation?

Some of the first experiments begun under the Laboratory's cotton research this year were designed to answer these questions. Already, our scientists have pinpointed the exact moment at which a developing cell commits to becoming a fiber.

Their technique uses radiation to block cotton cells' ability to make DNA, but still allows the cells to differentiate into any of the many kinds of cells that make up the cotton plant. By irradiating cells at different stages of development and stopping their reproduction, our scientists have been able to observe the differentiation process and look for newly formed fiber cells.

This research should lead to information about which genes and enzymes are necessary for fiber production. Also planned is research into how cotton fibers elongate and how the short-fiber "fuzz" that coats cotton seeds is formed.

A Library Without Books

The researchers are also working toward building a library of genetic information on cotton, complete with a computerized system to record its holdings, and tags to mark important places in the plant's DNA.

Like any library, our cotton library will contain lots of letters, enough to fill many books. But in this genome library, they'll be the letters A,C,G and T, corresponding to the four bases that are the building blocks of DNA: Our researchers are set to begin a major gene-sequencing effort on cotton.

Instead of transcribing *all* of cotton's DNA, however, the team will only sequence the genes that the plant expresses, or uses to trigger the production of important molecules. They'll do this by capturing, cloning and sequencing the messenger RNA that carries the orders for gene expression from the cell's DNA.

Once a gene has been sequenced in this way, its function can be found by examining plants in which this gene has been "knocked out" by a mutation.

The library of information that will come from this research will be organized into a computer database specially designed at the U.S. Department of Energy's (DOE) Lawrence Berkeley National Laboratory. The library will be open to "patrons" too — it is designed to be compatible with an existing public database of previously decoded cotton genome information.

Magic Molecular Markers

While the pages and pages of genetic information will be useful enough, our scientists are preparing tags for the areas of cotton's chromosomes that control a plant's most important traits, from fiber quality to disease resistance.

The tags, called molecular markers, are snippets of DNA that are chosen because they contain repetitive, simple DNA sequences — GTGTGTGTGTGTGT, for example. These regions are especially attractive to researchers because they are most likely to differ from one plant to the next. So, variations in the number of repeats in these regions are a way to see differences between plants.

To see these variations, our scientists use a technique called polymerase chain reaction to make many copies of these repeats to "amplify" their presence, then measure the size of the repeats from each plant.

Molecular markers developed at Brookhaven could be used by those who breed new cotton strains. Today, this is done by inserting desirable new or altered genes into ordinary cotton plants, then crossing these plants with the "elite" varieties that produce commercial cotton and waiting for the progeny to grow.

With markers, breeders will not have to wait for experimental plants to grow to maturity in order to see if their breeding strategies worked. Instead, they will be able to perform a simple genetic test on a tiny plant to see if their desired gene has made it through the cross.

All of this work was funded through a $1.7 million, cooperative research and development agreement (CRADA) signed this year between Brookhaven and Cotton Incorporated, an industry association. The CRADA makes Brookhaven the headquarters laboratory for the cotton biotechnology project of the American Textiles (AMTEX) collaboration between the textile industry and the DOE national laboratories. ■

Surrounded by the cotton plants used in their research are Jack Van't Hof, John Sutherland, Susan Lamm, Denise Monteleone, Michael Blewitt, Eileen Matz, Katrina Reaves and Benjamin Burr.

National Synchrotron Light Source

The worl[redacted]ity for scientific research using x-rays and ultraviolet and infrared radiation is operated[redacted]ynchrotron Light Source Department. This year alone, a total of about 2,200 researche[redacted] 360 institutions performed experiments at the world's largest source of synchrot[redacted]researchers often work in collaboration with the Laboratory's staff scientists at the Lig[redacted]ucting a wide range of innovative experiments in physics, chemistry, biology, materials science and various technologies.

Creating a Map of Life

By defining the three-dimensional structures of biological macromolecules, scientists can create a map of life, a guide for exploring the biological and chemical interactions of the vast variety of molecules found in living organisms.

"Solving" the structure of a molecule — determining the exact location of each of its atoms — provides information on its function. Studies in structural biology may lead to new insights into how biological systems are formed and nourished, how they survive and grow, how they are damaged and die.

Exploring the Molecules of Life

At the National Synchrotron Light Source (NSLS), about 600 structural biologists from more than 100 institutions use an x-ray technique called protein crystallography at six dedicated beam lines to explore the molecules of life. They decipher the structures of proteins, complex combinations of amino acids that are an essential ingredient of every living cell.

Meanwhile, at numerous other beam lines, biologists use x-ray and ultraviolet light as probes to study proteins and other biological structures, such as DNA, virus particles and carbohydrates, for obtaining data that is not accessible via protein crystallography.

To accommodate this large number of users, a new $1.8 million structural biology wing was added to the NSLS during fiscal year 1995. The 6,300-square-foot addition contains eight new laboratories for preparation and storage of samples, important amenities for our many users.

A Growing Field

The first crystallographic structure of a protein — that of myoglobin, which supplies oxygen to muscles — was solved in 1958 with the use of conventional laboratory x-rays. Since then, the field of structural biology has grown tremendously — and today, it is estimated that more than 100 structures are solved each month by scientists throughout the world.

Within the last decade, the development of synchrotron light sources and powerful computers has made solving macromolecular structures easier and faster. Also, the rapid growth of genetic-engineering technology makes it possible for scientists to make large amounts of synthetic proteins for this research. Previously, researchers were limited to studying proteins in the minute quantities obtained from natural sources.

Synchrotron Light: Multiple Benefits

The NSLS provides x-rays that are 10,000 times more intense than those from a conventional x-ray source. This intensity results in higher resolution of data and images, which provides more detail, and allows scientists to study extremely small structures.

Another advantage of using a synchrotron source for this research is that the wavelength of the light can be fine-tuned to meet a scientist's needs. Thus, a three-dimensional structure can be determined from a single crystal, rather than from many crystals, which are hard to grow. Also, data collection at the NSLS is up to 50 times faster than it is using conventional light sources. With synchrotron x-rays, an entire series of data can be taken within a millisecond, while a protein crystal is in action, providing important information on its function.

Facets of Diffraction

Biological molecules are studied using three basic protein crystallography methods at the NSLS: multiple isomorphous replacement (MIR), multiple-wavelength anomalous diffraction (MAD) and Laue diffraction. All involve x-ray diffraction, in which x-rays hit a protein crystal and scatter off its atoms in a pattern recorded by detectors. The pattern relates to the placement of each atom in the molecule and can be deciphered by a computer.

While MIR involves using several crystals at a fixed wavelength, MAD requires only one crystal, which is exposed to many wavelengths of synchrotron light. Laue diffraction, which uses the full white synchrotron radiation spectrum, gives information on the dynamics of protein structure — how a crystal chemically changes over a short time-scale.

Designing Drugs and Enzymes

Many pharmaceutical companies do research at the NSLS to develop new drugs for treating numerous diseases, from the common cold to AIDS.

In this "structure-based" drug design, researchers use protein crystallography techniques to design inhibitors, molecules that attach to enzymes in disease-causing agents and block them. Knowing the precise structure of a molecule and its inhibitor can help researchers develop more effective drugs that also produce fewer unwanted side effects.

Other companies use the NSLS to engineer enzymes for industrial purposes. For example, some chemical companies are looking for an enzyme that would be suitable for making nylon by environmentally benign fermentation processes, rather than by using petroleum, which creates pollution.

A Unique Resource

New data on proteins and the other molecules of life discovered at the NSLS can be instantaneously shared with researchers, teachers and students who have access to the global Internet computer network.

Structural biologists working at the NSLS, along with researchers from all over the world, add to and obtain information from Brookhaven's Protein Data Bank (PDB), an archive for three-dimensional structures of proteins, nucleic acids and other biological macromolecules. The PDB

Malcolm Capel (left), BNL, and Xiaodong Cheng, Cold Spring Harbor Laboratory, prepare to mount a crystal for data collection at beam line X12B.

is a unique resource for the scientific community, as well as for others who wish to tap into its wealth of information.

Established in 1971, the PDB has grown considerably. Today, a user consults it almost every minute through the Internet, while others receive updated compact disks periodically. The number of structures stored has grown exponentially in recent years, with more than 100 now being added each month to the more than 4,000 already in the PDB. ■

Structural Biology at the NSLS — Progress and Promise

From the toxin that causes cholera to DNA's proteins, the numerous and varied structural biology experiments conducted at the National Synchrotron Light Source (NSLS) help scientists understand the biological principles that govern life's complexity.

The following are a few examples of the rich diversity of research at the NSLS beam lines dedicated solely to protein crystallography, a technique in which x-ray probes are used to study the structure of a protein in its crystalline form. Proteins, made of any of numerous combinations of amino acids, are components of all living cells. Knowing a protein's structure can elucidate its function.

Protein Crystallography: A Sampling

Beam Line X4A

Using a technique called multiwavelength anomalous diffraction (MAD), researchers from the Howard Hughes Medical Institute at Columbia University and Texas A&M University have determined the structure of the tyrosine kinase domain, or region, of the human insulin receptor.

A receptor is a site on a cell's surface that combines with a hormone like insulin, or another biological substance, to produce a change in cell function. Tyrosine kinase is just one of hundreds of enzymes that help govern hormones.

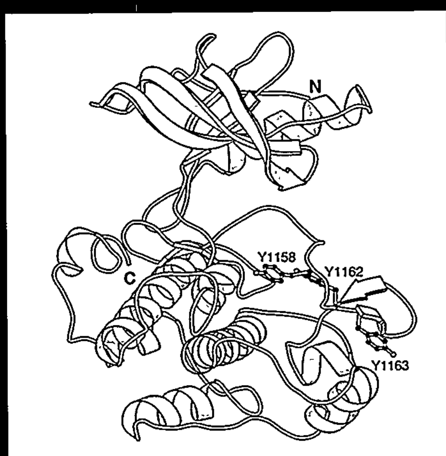
The tyrosine kinase of this study is related to type II diabetes, which does not respond to insulin. In nondiabetics, the body activates the insulin receptor when the blood's sugar level is high. The receptor binds to insulin, signaling the tyrosine kinase to go to work and set off a series of biochemical changes that cause blood glucose to be converted to glycogen, which holds energy in reserve. In type II diabetics, however, the insulin receptor molecule is defective in its ability to sense the presence of insulin, and the extra blood sugar cannot be converted.

Structural details about tyrosine kinase may provide important clues on how to prevent type II diabetes. Further, since it is the first tyrosine kinase for which the three-dimensional structure has been determined, it is a crucial first step in understanding cellular signals and metabolic functioning.

Beam Line X8C

Using the technique known as isomorphous heavy atom replacement, Argonne National Laboratory researchers have solved the structure of the toxin that causes cholera, an infectious gastrointestinal disease that began in Asia and has spread to South America and Mexico.

The soluble toxin that the Argonne team investigated is deposited in the intestinal



Tyrosine kinase unit from the human insulin receptor. The areas numbered Y1158, Y1162, and Y1163 represent the enzyme's activation sites.

Cholera toxin. The darker, bottom part and the long chain extending to the top part are the parts of the protein that bind to the lining of the intestine. The top section is the part that invades the interior of intestine cells and stimulates them to secrete water, bringing on cholera's symptoms.

tract of cholera disease victims by the bacterium *Vibrio cholerae.* The toxin stimulates cells to secrete water, causing profuse diarrhea, then dehydration and, finally, collapse.

Knowing the structure of the toxin, researchers can now probe the chemistry of the disease process in order to develop a more effective vaccine. The one available now does not produce complete immunity against cholera.

Beam Line X12B

Several years ago, researchers from Brookhaven and Cold Spring Harbor Laboratory, working at X12C, determined the structure of the bacteriophage T7's lysozyme. A bacteriophage is a virus that infects bacteria, and the T7 strain has been commonly used by Brookhaven biologists as a simple genetic model system, since it contains a single piece of DNA and only about 50 genes.

This year, because of the higher beam intensity and advanced instrumentation at X12B, a much higher-resolution structure for the lysozyme enzyme was achieved by Cold Spring Harbor scientists.

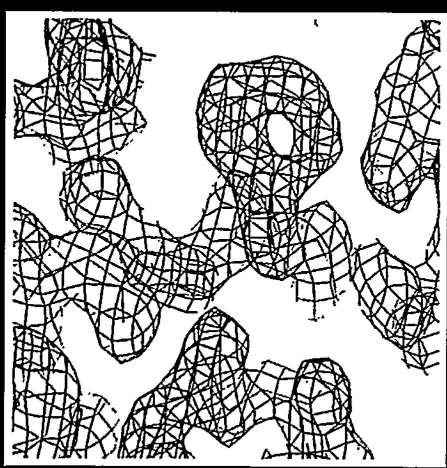
T7 lysozyme combines two functions in one small protein: It cuts open the bacterial cell wall, and it inhibits DNA transcription, or reading, by the T7 enzyme RNA polymerase. Transcription creates a messenger RNA molecule from a template DNA molecule, so that genetic information is transferred to messenger RNA and proteins can be made from those instructions.

Each lysozyme molecule appears to be able to perform only one of these functions at a time. Learning the structure of this protein may provide new basic insights into the processes of gene regulation and DNA replication.

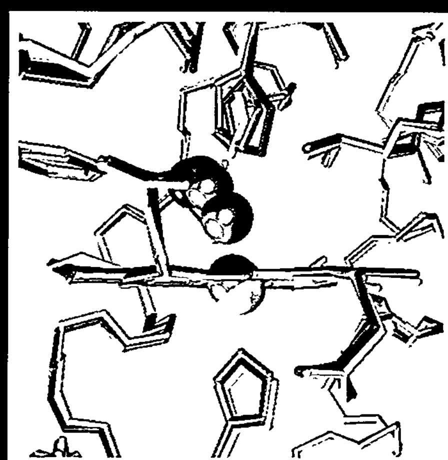
Beam Line X12C

Using x-ray diffraction techniques on this beam line, researchers from Brookhaven's Biology Department, Los Alamos National Laboratory, the Max Planck Institute for Medical Research and Rice University recently determined the structure of the oxygen-binding protein myoglobin in a transient state.

Myoglobin stores oxygen in the body's muscles and tissues. It is the first protein for which a crystal structure was determined, in 1958. Protein crystallographers have since studied this molecule extensively, compiling data on its structure, dynamics and function.



Phenyl ring (top center ring) of the amino acid phenylaline-91 of the T7 lysozyme protein.



Three states of carbon monoxide (CO) bound in myoglobin. The grey depicts the tight complex between the two, in which the dumbbell-shaped CO molecule is bound to an iron atom. White represents myoglobin with no CO bound to it, and black is the transient state, trapped at 20 kelvins, with the CO molecule released but lingering nearby.

To simulate the action of an oxygen molecule as it binds to myoglobin, the researchers substituted the poisonous gas carbon monoxide (CO). Although CO binds more strongly than oxygen, the myoglobin molecule will release CO when it is illuminated with visible light. To determine the structure of the myoglobin-gas complex, the scientists bound carbon monoxide to myoglobin molecules in a crystal, then froze the crystal to near absolute zero, and finally, released the CO with a bright light.

The structure they found revealed the carbon monoxide molecule resting near the iron atom to which it was bound. This finding now can be compared to myoglobin's structure when CO is absent or tightly bound. The researchers observed details of the subtle shape change that accompanies binding and release of gas molecules, and their results provide crucial data on the dynamics of how a simple protein works.

Beam Line X25

Researchers from Rockefeller University and the Howard Hughes Medical Institute have determined the structure of a protein known as the TATA-box binding protein, or TBP, using isomorphous crystallography.

TBP is the DNA-binding subunit of the RNA polymerase enzyme. It positions the polymerase on the DNA to initiate gene transcription (described in the section on X12B). When TBP attaches itself to a strand of DNA, the DNA bends into a V-shape, thus helping to position the enzyme.

This study helped researchers investigate how TBP recognizes various DNA sequences and directs transcription from them. Examining TBP's structure may help researchers understand how individual genes are turned on or off in a cell in order to make specific proteins. Using this information, they may learn how to design pharmaceuticals to block or stimulate the production of these proteins, thus curtailing genetic diseases.

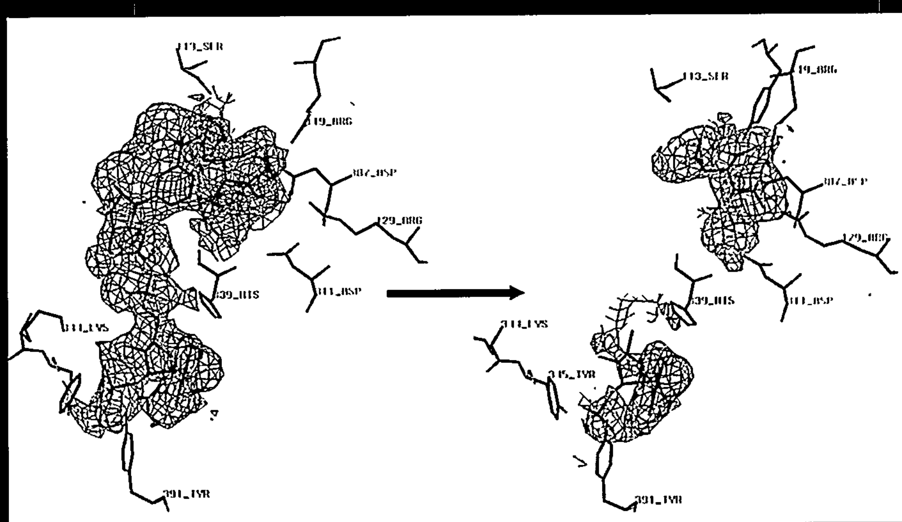
Beam Line X26C

Owned by the University of Chicago, X26C is the primary beam line for using the white-beam Laue method, in which numerous x-ray diffraction intensities can be measured from a single crystal. This method enables researchers to take "molecular movies" — images of proteins as they change their structures during a chemical reaction.

A collaboration from Brookhaven, the Fred Hutchinson Cancer Research Center in Washington State, the University of California, Berkeley, and the Molecular Research Council in England used the Laue technique to solve the structures of two intermediate chemicals formed during the catalytic actions of the enzyme isocitrate dehydrogenase (IDH). These intermediate chemicals are involved in a two-step process that is part of ordinary respiration: oxidation and expulsion of a carbon dioxide molecule.

In the two-step reaction studied, researchers observed the transformation of isocitrate, a direct product of sugar metabolism, to oxalosuccinate, an intermediate that had never before been observed. They also recorded the conversion of oxalosuccinate to α-ketoglutarate. Each of these enzyme intermediates is catalyzed, or chemically changed, by a different portion of IDH. These data provide insight into fundamental metabolic processes.

In an effort to obtain the best protein crystals for data collection, researchers at X26C use x-ray topography techniques to find defects in protein crystals — in much the way that physicians use x-rays to find broken bones. A collaboration from Brookhaven, the University of Alabama at Huntsville and the University of Manchester in England applied x-ray topography to



Two intermediate chemicals formed during the catalytic actions of the enzyme isocitrate dehydrogenase (IDH). The left figure depicts the oxidized form of the co-enzyme known as NADPH and isocitrate bound to IDH, and the right figure shows oxalosuccinate (top) and NADPH bound to IDH. The empty space in the middle of the right structure represents a loss of electron density in NADPH, probably caused by weak bonds in that part of the molecule.

protein crystallography for the first time to optimize crystal quality for experiments.

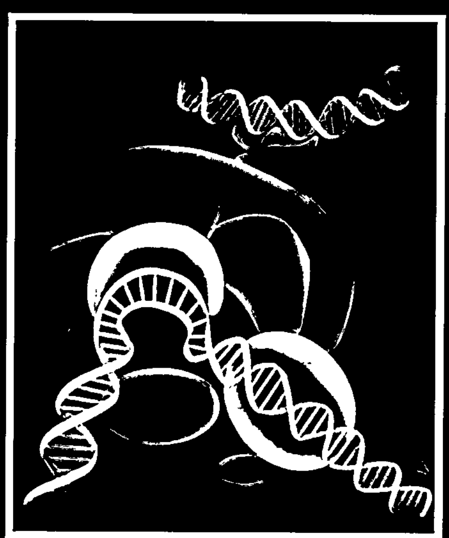
Crystals must be as perfect as possible in protein crystallography studies in order to give scientists the most precise structural data. Protein crystals were grown aboard a 1994 space shuttle mission and compared with those grown on earth. Using x-ray topography at X26C, the researchers found that protein crystals grown under constant temperature or in microgravity conditions found in space had fewer defects than those grown at slightly fluctuating temperatures or normal gravity conditions.

Diverse Biological Research

Complementing the protein crystallography research described above are various structural biology experiments performed on noncrystalline materials. Here is a small sampling of these experiments:

Beam Line X1

Using the leading scanning x-ray microscope in the world, a collaborative team from the State University of New York at Stony Brook and Lawrence Livermore National Laboratory has mapped the distribution of DNA and protein in the human sperm nucleus. They have found that certain sperm structures, such as the segment that makes the first contact with an egg during fertilization, are particularly rich in protein. The next stage of the project is aimed at understanding the structural basis of certain types of male infertility.



TATA-box binding protein bound with a 14 base-pair DNA sequence. The unusual saddle-shaped protein induces a conformational change in DNA.

Beam Line X9B

Researchers from the Albert Einstein College of Medicine and the University of Pennsylvania have used x-ray diffraction techniques on beam line X9B to analyze the structure of membrane proteins. The researchers have developed a novel method of attaching proteins to the surface of inorganic substrates in order to collect diffraction data. This creates a one-dimensional arrangement of the protein-membrane complexes, which is ideal for structural and functional studies.

Beam Line X11A

Researchers from North Carolina State University used the technique known as x-ray absorption spectroscopy to follow structural changes in ferritin, a protein that stores iron for use in hemoglobin and other iron-containing proteins. The technique allows researchers to look at how ferritin works in a solution that mimics the conditions in the human body, which is not possible using protein crystallography techniques. This basic research will help reveal how iron is used in the body and may be the pathway for designing better iron supplements.

Beam Lines U9 and U11

Structural biology experiments using ultraviolet light at these beam lines include two techniques: circular dichroism, which provides information on the structure of proteins, DNA, RNA and polysaccharides; and time-resolved fluorescence, which supplies data on molecular structure, photochemical reactions and interactions in nucleic acids and proteins.

For example, using time-resolved fluorescence, Brookhaven researchers are studying how the nucleic acid bases adenine and guanine respond to ultraviolet radiation. Such studies help us to understand the mechanisms by which the ultraviolet components of sunlight damage DNA and induce mutations and cancer. ■

Applied Science

Spanning** [redacted] **terests that includes energy science, the environment, health, technology and mathema** [redacted] **tment of Applied Science puts basic research to work solving problems innovative** [redacted] **cts include studying the chemistry of the earth's atmosphere, evaluating the efficiency** [redacted] **ducts, and finding new microbes that can digest harmful pollutants out of soil and waste** [redacted] **ugh cooperative efforts with industry, both the nation's economy and the frontiers of science are advanced.

Seeing the Forest and the Trees

The pine trees in a certain North Carolina forest have some new neighbors. But while the tall, straight trunks and proud branches of the newcomers stretch to the sky like any tree, they do not blend in with the forest.

That is because the 96 structures, made of bright aluminum instead of wood, are 20-meter towers built as part of a multimillion dollar experiment begun in 1995 by scientists from Brookhaven and the forest's owner, Duke University.

Its aims: to find out how the trees might cope with the carbon-dioxide-rich atmosphere of tomorrow, and how they may help reduce global change caused by increasing levels of atmospheric carbon dioxide (CO_2).

The forest in North Carolina is the latest in a series of experiments known as the free air carbon-dioxide enrichment (FACE) program. Both the program, and the technology and expertise used to build FACE facilities, originated and continue to be centered in BNL's Department of Applied Science.

The Future Is Now

The world's atmosphere naturally contains CO_2, but concentrations have risen dramatically in recent years. Environmental scientists predict that levels will continue to rise, if humankind doesn't slow the release of the gas from vehicles, industry and agriculture. Increasing amounts of CO_2 in the atmosphere could be a major driving force for global climate change due to an enhanced "greenhouse effect."

To plan for such a future atmosphere, scientists need to know now what effects the extra CO_2 might have on the plants that provide our food and shelter and turn CO_2 into breathable oxygen. The trees in the Duke forest, for example, are predominantly loblolly pines, a major source of timber in the South.

It is also important to learn how plants may be able to help remove CO_2 from the atmosphere and store it as carbon in the soil; this knowledge could indicate the ability of ecosystems to slow the rate at which atmospheric CO_2 is increasing.

FACE experiments allow scientists to study plants growing in their natural environments, climates and soil conditions, yielding a more accurate picture of plant reactions to increased CO_2.

As the first FACE facility to be built in a forest, the North Carolina experiment has been dubbed FACTS, for Forest-Atmosphere Carbon Transfer and Storage. The FACE concept has also been applied to cotton and wheat fields, as well as grazing meadows, and is being explored for several other important crop and natural ecosystems.

A New Kind of User Facility

Together, the forest and its six circular sets of aluminum towers form a new kind of scientific user facility, attracting dozens of scientists for large-scale cooperative experimentation not often found in the environmental sciences.

User facilities are common in physics —Brookhaven has its share. But instead of the new subatomic particles sought in physicists' accelerators, the forest "facility" will allow scientists to look for the biological symptoms of a changing environment, to open the "black box" of an intact forest ecosystem through an integrated program of basic research. Already, twenty-five researchers from eight institutions have signed on to pursue year-round studies at FACTS.

As with any user facility, the ability of many scientists to pursue research at the same time and place reduces costs and opens the door to deeper understanding and collaboration.

Enriching the Environment

At FACTS, air enriched with CO_2 recycled from fossil-fuel burning industries is pumped up through pipes suspended from the 16 aluminum towers in each ring, and then out through the forest.

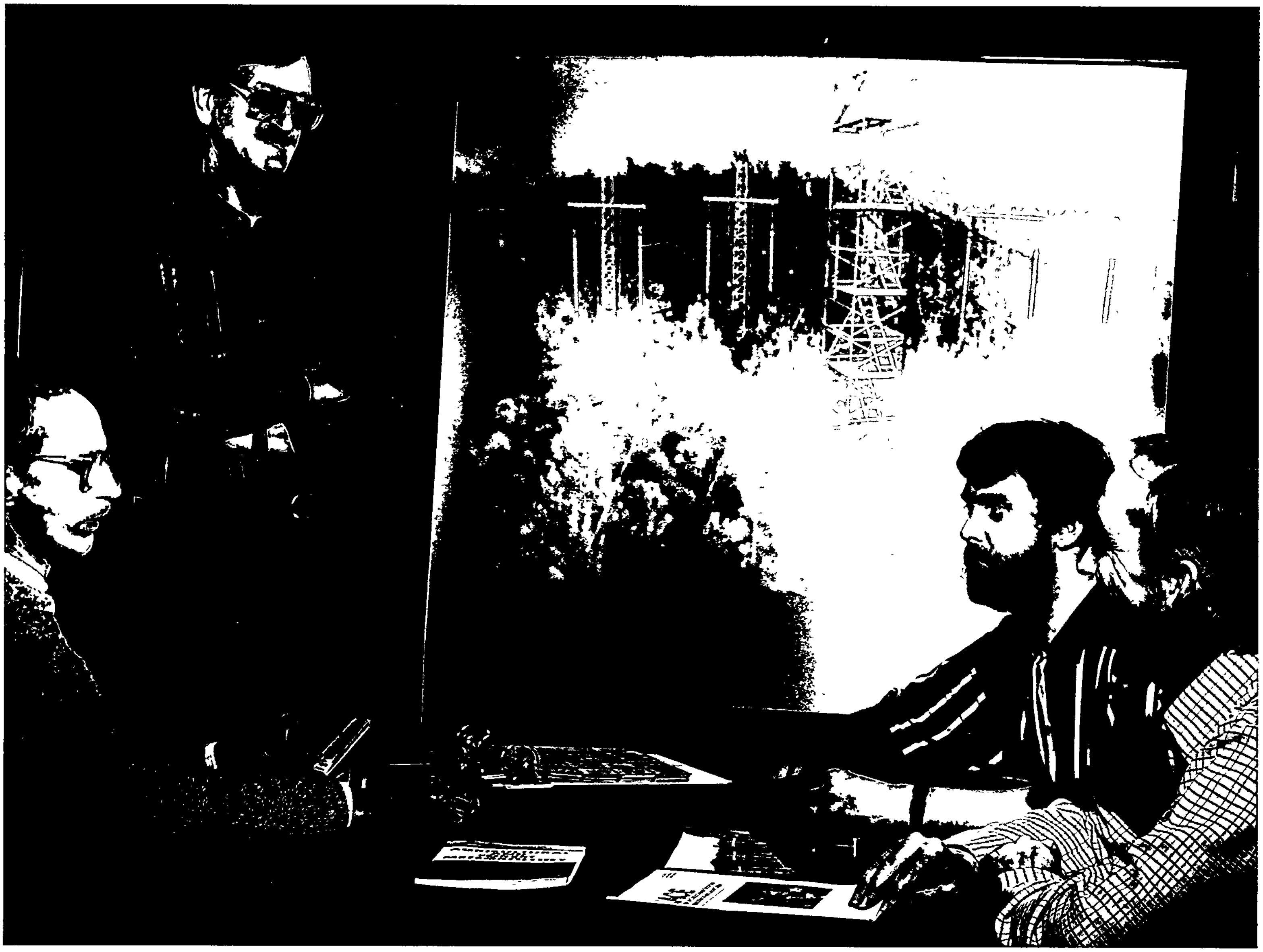
Simultaneously, dozens of ecologists, plant physiologists, geochemists and molecular biologists from institutions all over the country and abroad will be able to gather data about every aspect of the forest's trees, soil and microclimate.

They'll look on many levels, from the proteins controlled by the trees' DNA to the efficiency of water use by cells, and from the formation of leaves to the amount of extra CO_2 the trees take up. They'll also quantify the forest's ability to remove CO_2 from the atmosphere and sequester it in wood and soil carbon.

Each of these levels of organization may hold new clues as to how ecosystems deal with enhanced CO_2 levels. By combining information gleaned from numerous FACTS experiments, computer modelers will be able to get a more complete picture of the effects for the entire world.

The CO_2 itself will provide a "marker" for scientists to examine the trees' CO_2 uptake. Gas derived from fossil fuel combustion, such as that used in FACTS, has a ratio of the carbon isotopes ^{12}C and ^{13}C that is markedly different from that of atmospheric CO_2.

Furthermore, fossil CO_2 has no ^{14}C, a naturally occurring isotope of carbon that



John Nagy, George Hendrey, David Ellsworth and Keith Lewin discuss the FACTS carbon-dioxide-enrichment facility, pictured in the background.

First Findings from FACE Forest

Trees exposed to air containing "21st-century," elevated levels of carbon dioxide (CO_2) have a much higher rate of photosynthesis than normal. That was the first experimental finding, published this year, from the new FACE forest project co-sponsored by Brookhaven and North Carolina's Duke University.

Over the course of one season, a 65-percent increase was seen in the pace at which the forest's loblolly pines turned sunlight, water and CO_2 into food. But the rise was not accompanied by an increased demand for water, a phenomenon seen in past FACE experiments with other plant species.

The plant physiologists who carried out the study caution against viewing these first data as entirely good news. For instance, it is still not known if the increase in photosynthesis means the trees will grow faster and produce more wood in the CO_2-enhanced FACE atmosphere, or if they'll store the extra food in their roots. Future experiments will attempt to learn more about this response.

is always present in the atmosphere. After the trees assimilate the fossil CO_2, these isotopes will be easily detectable in their tissues — carbon fixed by photosynthesis can be traced through the forest ecosystem.

To provide the scientists with a record of FACTS CO_2 levels, infrared gas analyzers will keep track of gas concentrations in the air and send updates to the FACE controlling computer every second. In addition, dozens of air-sampling tubes placed throughout the plots will monitor the air, to record local CO_2 concentrations.

Taken as a whole, the FACTS user facility at the Duke forest will provide unique opportunities for basic research in plant and ecosystem physiology. In fact, its approach is the only way to obtain such information at the ecosystem level. ■

Fueling the Future: Natural Gas Vehicles

What will power American vehicles at the dawn of the next century?

With environmental regulations becoming ever more stringent, and the country's reliance on foreign oil growing more impractical, the answer to that question is shifting toward alternatives to today's gasoline and diesel fuels.

But which alternatives? In the near term, natural gas looks to be a most attractive choice, especially for personal cars, delivery vans, buses and taxis. It burns cleanly, is abundant in the U.S. and costs about the same as more widely used fuels.

For these reasons and more, experts estimate that five million natural-gas vehicles will be on the road by the year 2010. And scientists in our Department of Applied Science are working to help industry make these cars, light trucks and vans more appealing and economical.

Tanks: A Lot of Research

Our research concentrates on the tanks that will hold the vehicles' natural gas supply — both their structural design and the carbon-based adsorbent materials that are used inside them to trap gas molecules for better storage.

This year, several industrial partnerships emerged or continued in this quest for new fuel-tank options.

Under a $1 million, two-year contract with Thiokol Corporation, our researchers have begun to develop new tank designs that can safely hold pressurized gas. These tanks will improve on traditional space-wasting gas cylinders by conforming to vehicle storage areas and using up to 75 percent of the available room.

Also this year, our efforts in evaluating manufacturers' adsorbent materials continued. Millions of tiny pores in adsorbents' carbon skeletons trap gas molecules until they are needed, and our exploration of these microstructures could eventually make it possible to store 50 percent more gas than normal, and at a lower pressure.

This research will help maximize the amount of fuel that a natural gas vehicle can carry and the distance it can go without refueling. The lower compression pressures made possible by our pioneering work could give natural gas a 10-cents-per-gallon advantage over gasoline.

These advanced adsorbents got a real-life test run this summer, during a Georgia-based demonstration of natural gas-powered utility trucks that used fuel tanks filled with Brookhaven-tested adsorbents. The Atlanta Gas & Light Adsorbent Research Group was our partner in the project.

All of these projects are part of the U.S. Department of Energy's US CAR initiative to develop the next generation of vehicles, and are funded by DOE's transportation section.

High-Tech Help

To make it easier, safer and more efficient to store natural gas in the fuel tanks of future vehicles, industry is taking advantage of some of the Laboratory's high-tech tools.

Working at a beam line at Brookhaven's National Synchrotron Light Source (NSLS), our scientists examine the microscopic structure of adsorption materials sent here by their manufacturers for testing.

This work depends on the use of the NSLS' powerful beams of x-ray light as probes. Small-angle x-ray diffraction experiments have already revealed the layered, graphite-like structure of many samples.

Further x-ray diffraction using a benchtop laboratory instrument supplements the NSLS work, and our scientists have also developed an "adsorption reactor," which measures adsorbents' gas capacity in pressurized chambers.

Industry can then use this information to optimize future adsorbents, making their micropores as small as a nanometer in diameter and increasing the connective spaces between pores while keeping pore sizes consistent. Our research is also helping to expand basic knowledge about the microscopic structure of nanoporous materials in general.

Round Tank in a Square Hole

While adsorbents fill the inside of adsorbed natural gas tanks, the tanks themselves take up a lot of room in the vehicle. With traditional cylindrical natural gas tanks, similar to those used on propane barbecue grills, much of that space is wasted in a mostly square-shaped compartment.

The rounded shape is needed to keep the gas from bursting welded corner seams under high pressure. But our engineers are designing tanks that will conform better to a vehicle's chassis, saving space while still holding the gas safely and keeping costs and weights down.

In this project, sophisticated computer modeling called stress mapping makes it possible to test the strengths and show the weaknesses of new tank shapes before they are built. Designs are being produced for tanks to hold both adsorbed natural gas, held at 3,450 kilopascals (kPa, equivalent to 500 pounds per square inch, or psi), and compressed natural gas, pressurized to 24,840 kPa (3,600 psi). Once completed, the plans will be turned into reality by Thiokol and tested.

Driving for the Future

Even as tank designing and adsorbent testing research continue, our vision for the potential of natural gas vehicles grows.

The Atlanta demonstration on utility trucks is but the first step; adsorbed natural gas tanks could soon turn up in forklifts, golf carts and welding torches, as a way of demonstrating this promising approach on a wide scale.

And, if the technological developments of research at Brookhaven and elsewhere continue to improve the performance of natural gas, our environment and our economy may reap the benefits. ■

Jim Wegrzyn at the NSLS beam line where he tests carbon adsorption materials for natural gas vehicle fuel tanks.

MEDICAL

Brookhave[illegible]sical and chemical science resources and facilities are used by Medical Departme[illegible] develop new medical applications of nuclear technology and to understand effects o[illegible]agents on human health. Researchers improve radiotherapies and nuclear medicine procedures. They develop new radiopharmaceuticals and explore the mechanisms of disease, as well as uncover methods for noninvasive measurement of trace elements in humans.

Easing Bone-Cancer Pain Without Sedation

Every year, excruciating pain afflicts more than half of the 400,000 advanced stage cancer patients in the U.S. whose breast, prostate or lung cancers have metastasized, or spread, to the bone.

Narcotic drugs called opiates are prescribed to relieve this pain. But they have sedative side effects that diminish the quality of the remaining part of the patients' lives. Scientists in Brookhaven's Medical Department are therefore exploring the use of bone-seeking radioisotopes, which have no sedative effect, as pain relievers.

In preliminary studies, these efforts have been successful. Our researchers have isolated and developed a very promising radioisotope-labeled compound, tin-117m DPTA. This year saw the second phase of clinical therapy trials approved by the U.S. Food & Drug Administration (FDA) and done in collaboration with the University Medical Center at Stony Brook and the Tucson Veterans Medical Center, Arizona. And over 80 percent of 40 patients treated experienced substantial relief from their agony.

In fact, the first patient treated, who had been unable to get out of bed because of his pain, felt so good that he spent the next day outdoors. We evaluated the way the next 39 patients responded to tin-117m DPTA. Of the 80 percent who experienced relief, 60 percent had significantly less pain and were able to lead comparatively normal lives with the help of ordinary aspirin or with much reduced opiate consumption, and 20 percent became almost completely pain-free for followup periods lasting from 4 to 12 months.

How It Works

Tin-117m is produced at either Brookhaven's High Flux Beam Reactor or the High Flux Isotope Reactor at Oak Ridge National Laboratory, then attached to a pharmaceutical called diethylenetriaminepentaacetic acid (DTPA). When given to patients intravenously, tin-117m DTPA localizes preferentially in bone rather than in soft tissue or bone marrow. In addition, tin-117m emits electrons that have a very limited range in tissue, depositing most of their energy within 0.3 millimeters. The tumors on the bone receive 50 times more dose than reaches the radiation-sensitive bone marrow.

As a result, tin-117m does not suppress the bone marrow's production of white blood cells or platelets and, thus, preserves the body's ability to fight infection and the blood's ability to clot. This eliminates a major side effect of other radiopharmaceuticals also developed to deal with bone pain.

After about four years of laboratory development, the FDA approved the first phase of clinical therapy trials — a biodistribution study focusing on dosimetry and patient safety. After starting with 10 patients, this phase led to a 15-patient escalating-dose trial to determine the minimum dose needed for bone-pain relief and the maximum tolerated by the marrow. This test became part of Phase II, which, in addition to measuring dose escalation, concentrates on the compound's safety, efficacy and lack of toxicity.

No significant bone marrow toxicity was observed in doses up to twice the therapeutically effective level. We are planning studies using higher doses, since we need to know whether increasing doses would also increase the rate of patients' response to the treatment. Also, would the increased doses prolong their pain-free intervals?

Other Advantages

One of the advantages of tin-117m DTPA over other radiopharmaceuticals already approved or being developed is that patients can receive this medication as outpatients. Since patients will most likely receive only 10-15 millicuries of radioactivity, the FDA does not require them to be hospitalized, thus sparing them inconvenience and expense.

Also, in addition to giving off low-energy electrons that penetrate the bone metastases without damaging surrounding normal tissue, tin-117m DTPA emits gamma rays. These can be used with a gamma camera to make an image of the way the compound is distributed in the patient, which shows exactly where the tumor is and how far the disease may have spread.

Finally, tin-117m is not radioactive for long, having the short half-life of 13.6 days. Contact between the patient and other people therefore becomes less of a problem.

Based on these promising results alone, tin-117m DTPA may be the best agent yet for relieving bone pain. But we have discovered yet another potential advantage. The deliverable radiation dose to the tumor is three to ten times higher than that of other such products being developed for pain relief. Therefore, tin-117m DTPA may also prove useful for treating primary bone tumors, in addition to relieving the pain from metatastic bone involvement.

Further Developments

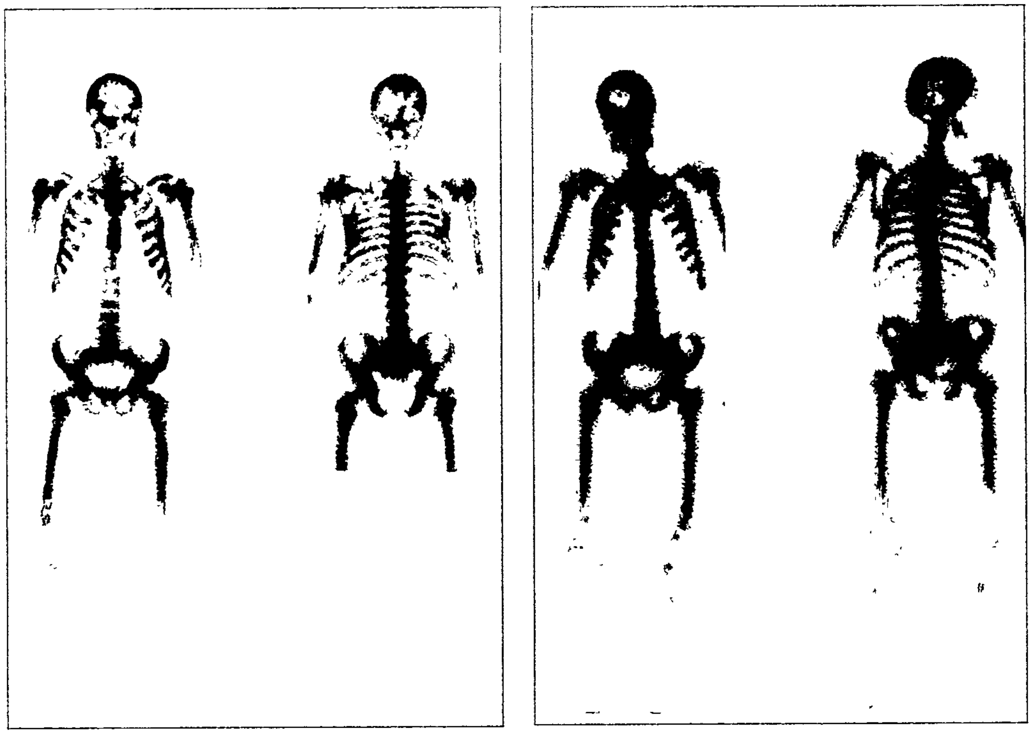
In May 1994, Diatech, Inc., a New Hampshire pharmaceutical company, licensed the technology in order to develop and market the patented tin-117m DTPA as a radiotherapeutic agent. And now that the encouraging Phase II clinical trials are almost complete, we are planning the next stage. Phase III trials are expected to begin

A major advantage of tin-117m DPTA is that it allows the spread of cancer to bone to be imaged using a gamma camera. Here, (from left) Harold Atkins, Leonard Mausner, George Meinken, Slawko Kurczak and Suresh Srivastava are ready to image a patient.

in late 1995 under an FDA-approved protocol.

In this next testing phase, patients will be given either tin-117m DTPA or one of the other products made to relieve bone cancer pain, such as the FDA-approved strontium-89 chloride, on the market as Metastron™. These will be random, double-blind trials, in which neither the patient nor the doctor will know which product is being administered. Patients, who will be treated in 10 to 15 centers located all over the world, will be observed to see whether they show an increased response rate to the tin or to the other product, and whether a similar comparison indicates less bone-marrow toxicity caused by the tin compound.

Other vital information to be determined in Phase III will be the time it takes for the onset of relief and how long the pain-free intervals last, in order to establish an optimum safe and effective dose of this promising new agent. ■



Typical images of a patient with advanced prostate cancer that has spread to the bone. The images on the left were made with Tc-99m MDP, routinely used to show the state of the bone metastases. The correlating images on the right were made eight days after the patient had 10.2 millicuries of tin-117m DPTA. The matching distribution of radioactivity shows the new agent's excellent bone-localizing properties.

Growing Old Gracefully

By the year 2000, some 31 million people in the United States will be over 65 years of age—and medical advances have ensured that many will celebrate their 80th or even 90th birthdays. But is living to a very old age always a pleasure?

"...Because people like me (I will be 80 in August) worry most about getting Alzheimer's disease, ... if your research could do anything to solve that most prevalent disability, we would all turn handsprings."

This exerpt from a letter received at Brookhaven's Medical Department gives an inside view of one major concern of old age. And Alzheimer's, which can also strike at younger ages, is only one of the conditions to fear. Even without Alzheimer's, the elderly can lose part of their mobility, memory or enthusiasm. Yet some "superpeople" in their 80s and 90s remain alert on all fronts. They walk, swim or play golf, do business on the stock market, start painting or join a choir.

To understand the process of growing old and how it can change some people's quality of life, doctors and scientists in Brookhaven's Medical and Chemistry Departments have started a pilot study at the Laboratory's PET facility. At this facility, which is part of the new Brookhaven Center for Imaging and Neurosciences, a technique called positron emission tomography, or PET, is used to image areas of the brain as it functions. Brookhaven's involvement with PET research was initiated in the early 1960s and has been used in studies on the effects of brain tumors, schizo-

Nora Volkow checks on a patient who is about to have a brain scan in the positron emission tomograph facility.

phrenia, Alzheimer's and Parkinson's diseases, and cocaine and alcohol abuse.

In the study on aging, no discovery of a "Fountain of Youth" is expected. But, once it is known how people's brains age, it may be possible to prevent or delay some of the effects by using appropriate treatment.

The current study is designed to obtain preliminary data from individuals ranging in age from 20 to over 80. Our PET researchers measure various aspects of brain chemistry function and cell loss. We take data to check whether cognitive and motor abilities correlate with the chemical changes seen in the brain, in order to establish a baseline of what to expect in aging brains.

Window Into the Brain

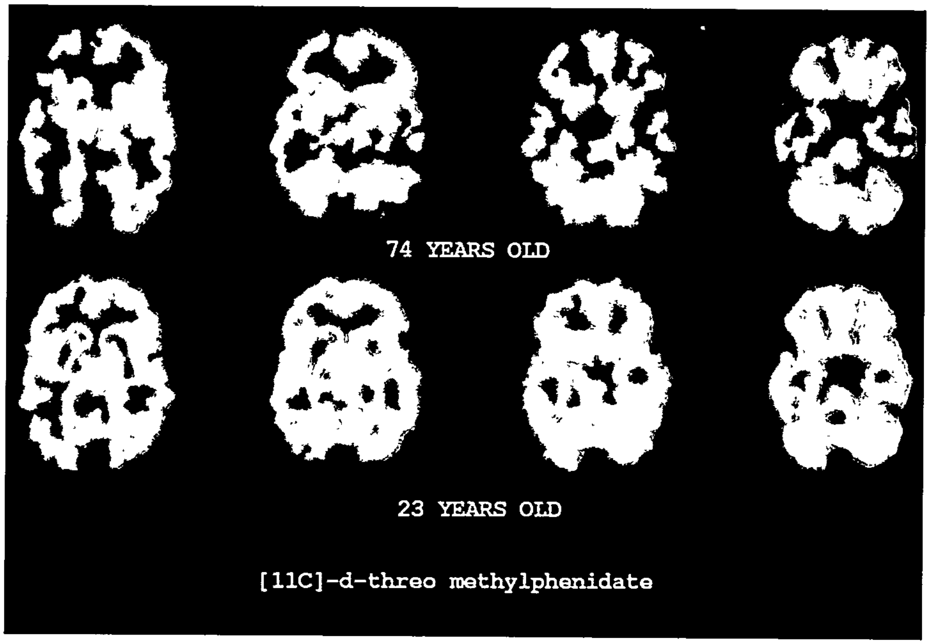
When PET is used, the patient is injected with a small amount of a short-lived radioactive tracer that is attached to one of a number of compounds that bind to specific brain sites. The tracer emits radiation, which is recorded by detectors that signal its location and concentration to a computer. The computer, in its turn, translates these data into a visible form, providing a "window" into the subject's brain as it functions.

In this way, we can measure the patient's brain metabolism; the concentration of receptors, which are molecules that receive messages into the brain; and the concentration of enzymes, which catalyze chemical changes — all in comparison with the patient's age. (See related story in Chemistry Department section.)

More Questions

While looking to see how the basic mechanism of aging is visible in the brain's chemistry, our scientists will also take data on aspects of the problem that may be of special significance. For example, what differences can be observed between the aging processes of men and women? Because women tend to live longer, it may be that estrogen plays a role in longevity. Specific hormonal treatments might therefore be a way to delay aging.

Special attention will be given to the brain cells containing dopamine. This chemical, which transmits messages between cells, is known to be important for motor function and motivation. An unusual decline in the number of dopamine cells may be matched by a decline in mobility, memory and mental liveliness in an aging person. If this or other such correlations are established, it may be possible to develop drugs that increase levels of dopamine or other chemicals in the brain and, thus, lessen the negative aspects of growing old. ■



In these two sets of PET brain images, four sequential planes of the brain are shown — the upper row being from a person of 74, the lower from a 23-year-old. The scan from the older brain shows much lower concentrations of dopamine transporter— important for motor function and motivation.

CHEMISTRY

The broa[redacted]earch in the Chemistry Department is directed toward a single goal: the fundamen[redacted]g of the properties of nuclei, atoms, molecules and living systems. Using the specialize[redacted]aratus and techniques available at Brookhaven, chemists discover detailed structura[redacted]opic information on solids, liquids and gases, the dynamics of physical and chemical change, and the mechanism of chemical transformation and drug action in the living human brain.

BEAMING AT CRYSTALS

Zeolites are a class of minerals, used by industry as catalysts and in detergents. So what could zeolites have in common with seashells and sea-creatures' skeletons? And why do they interest a group of scientists in Brookhaven's Chemistry Department?

To answer the first question, zeolites, seashells and skeletons are all crystalline. They each have features of particular interest, but to understand their structure and function thoroughly requires being able to detect incredibly minute changes — often in real time, as they take place. Until comparatively recently, the technology needed for such investigations did not exist.

In the 1980s, however, came beam line X7B. At Brookhaven's National Synchrotron Light Source, our chemists, in collaboration with scientists from the Swedish National Research Council, the University of Pittsburgh and other institutions, built this special research facility.

The new beam line depends on the Light Source's exceptionally intense x-ray beam, with its inherently high collimation — the term used to describe the way that the photons, units of light, all travel in one direction. With these unique advantages, as well as specially developed, state-of-the-art detection apparatus, researchers can now use the x-ray diffraction technique to make studies that previously were not possible.

THE X-RAY DIFFRACTION TECHNIQUE

In using x-ray diffraction to reveal crystalline structure, researchers project an extremely narrow, parallel beam of photons onto the crystal. As the light passes through the sample, its pathway is altered, or diffracted, by the atoms within. Instantaneously, the pattern of the diffracted light is recorded on the detectors waiting to receive it. By measuring the pattern and comparing it to previous results, then transforming these data into computer images, scientists can "see" the changing positions of the atoms in the crystal.

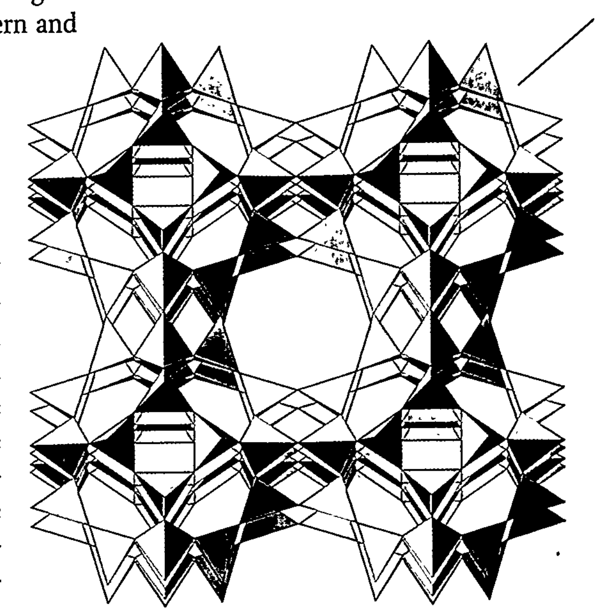
Because Brookhaven's synchrotron beam is so narrow and highly collimated, our researchers can resolve very complicated patterns in the data. Also, the data are recorded on image plates as the changes take place. Sophisticated computers are used to interpret the resulting images, and then scientists relate the changes to the physical characteristics of the material they are studying.

THE MOVING MINERALS

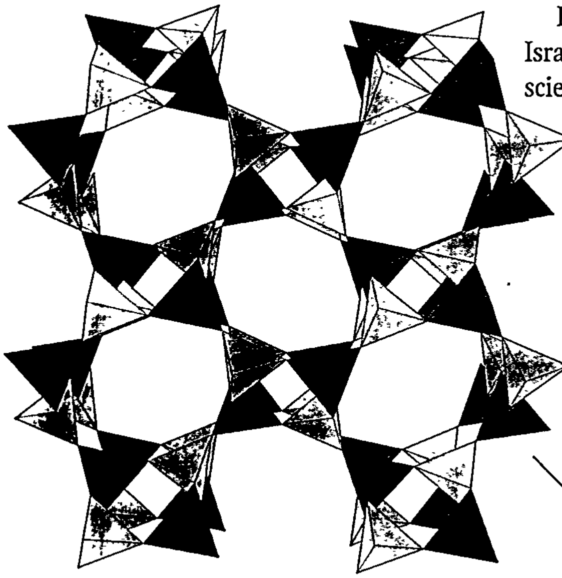
Zeolites are part of a large class of microporous crystals that contain channels and cavities within their crystal structures. These structures have been extensively documented by others, and it is known that parts of them are rigid, yet bend and flex during chemical action.

But, before the Brookhaven X7B investigations, nobody could observe the dymanics of the zeolite structure — how the movement of the framework affects the cavities under different conditions.

The new studies are so precise that our scientists have been able to obtain a series of images of the succeeding stages of crys-



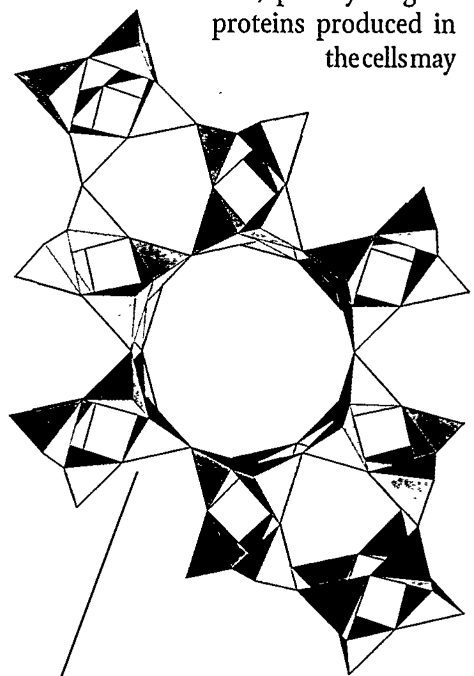
tal structures reacting to various conditions. Thus, for the first time, with researchers from Sweden's University of Lund, we are learning how the structures of zeolites change when we dehydrate them by heating. A second study, supported by the Danish Research Council, measures the kinetics of zeolite synthesis — the rate at which they form and crystallize — in real time.

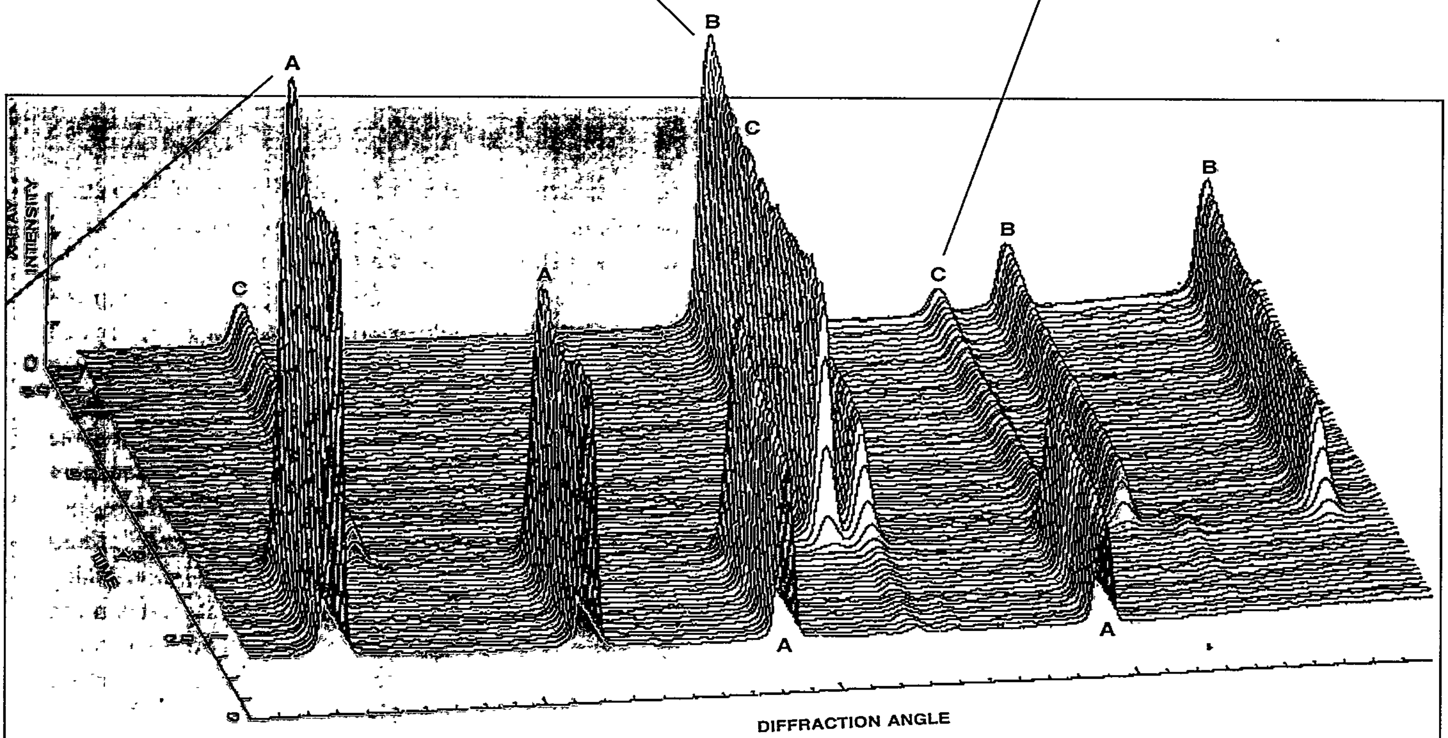


Beautiful Biominerals

In collaboration with scientists from Israel's Weizmann Institute of Science, our scientists also study shells and sea-skeletons. The simple, hexagonal structure of these "biomineral" materials resembles that of naturally occurring mineral calcite. Scientists have discovered, however, that the beautiful, single crystals found in the material of seashells or the skeletons of sea urchins and related mollusks have unusual shapes.

The X7B beam line researchers believe that, since these crystals grow in the living cells of sea creatures, specially designed proteins produced in the cells may





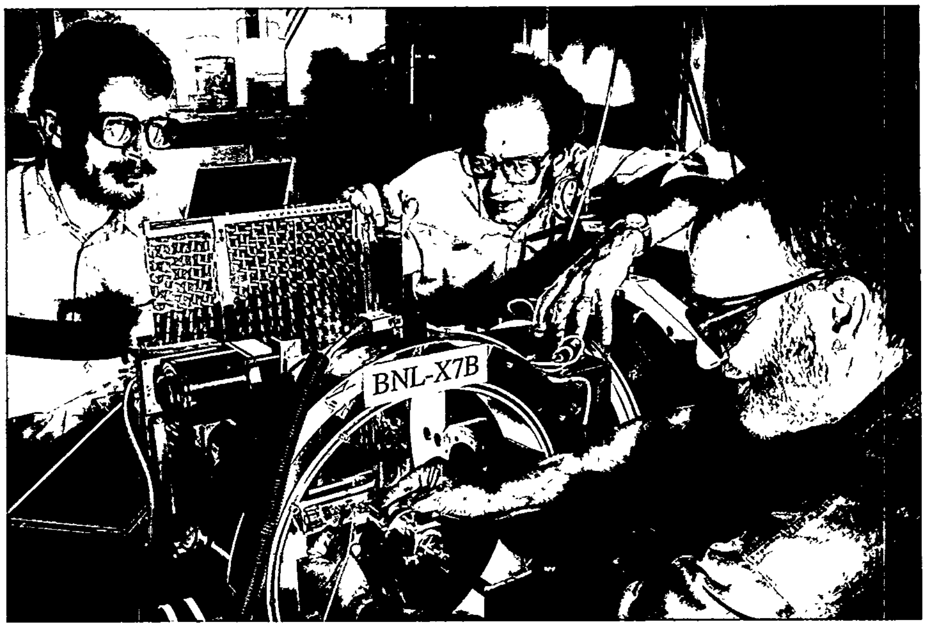
The lines in the central figure show the powder patterns resulting from a series of diffraction experiments, made over about 80 minutes (time elapsed is shown from foreground to background) and at different diffraction angles (increasing from left to right). First, zeolite LTA, labeled A in the foreground and seen in crystalline form in inset A, is heated quickly to 240° C. With time, other patterns form: zeolite Li-A(BW), labeled B, in crystalline form as inset B; and cancrinite, labeled C, inset C.

modify the way that the crystal grows, causing it to violate normal crystal symmetry. By examining the crystals from different creatures, we are obtaining new data that show the exquisite control that marine animals exercise on the crystallization process. This kind of information is essential for the fundamental understanding of how these materials are formed. It can eventually lead to significant applications in materials science and engineering fields.

Using the X7B Beam Line

Because it can meet many different specialized research requirements, the Chemistry Department's beam line X7B attracts numerous outside users, who are entitled to 25 percent of beam time, in accordance with Laboratory policy. Visiting scientists often work in close collaboration with Brookhaven staff scientists, all contributing ideas, time and intellectual stimulation for the benefit of basic research.

Users include scientists from the Georgia Institute of Technology, Northwestern University, the State University of New York at Stony Brook, the University of Chicago, the University of Houston and the University of Milan, in addition to groups from Denmark, Finland, Israel and Sweden. ■



Readying a sample for a diffraction experiment are (from left) Poul Norby, Thomas Koetzle and Jonathan Hanson.

PET "Fireflies" Trace Chemicals In the Brain

Late on summer evenings, out dart the fireflies — their tiny, luminous flashes signaling their position in the darkness.

A PET scan, which offers a "window" looking into a live body or brain, works in much the same way.

PET stands for positron emission tomography, a technique in which minute amounts of a compound labeled with a positron-emitting isotope are injected into the patient. The positrons are given off, generating two energetic, body-penetrating photons, or units of light. Like a firefly's glowing signal, the photons reveal the compound's position. By studying the distribution and concentration of the compound over time, researchers and physicians get information about what is happening in the body or brain.

In Brookhaven's Chemistry Department, the PET facility, with its roots in basic research in chemistry initiated in the 1950s, has gained world renown. Researchers from the Chemistry and Medical Departments have used PET to investigate schizophrenia, Alzheimer's and Parkinson's diseases, brain tumors, drug action and substance abuse.

In 1995, together with a new MRI, or magnetic resonance imaging facility, PET became part of a new Brookhaven Center for Imaging and Neuroscience, working to understand the relationship between mental and physical processes in the human brain.

Tying on Labels

Since knowing the compound's distribution is key, an essential part of PET research lies in labeling the compounds effectively. Fireflies have a natural advantage: Their luminescence comes from a substance produced in their lower abdomen. But for a PET compound to light up, chemists have to develop strategies such as nucleophilic or electrophilic substitution, in which they substitute a positron-emitting isotope for an atom of the compound being studied.

Specialized isotopes are made in the Brookhaven Chemistry Cyclotron, a small particle accelerator. One of these positron-emitting isotopes, fluorine-18, can be exchanged for the natural fluorine-19 in some compounds. Other organic compounds are labeled with carbon-11, which can replace carbon-12 in organic molecules. Carbon-11 has a half-life of only 20 minutes, taking only 20 minutes for half its radiation to decay. So, two or three studies can be made on one patient in one day, allowing test results to be more easily repeated.

By measuring the distribution and concentration of the labeled compounds as they are recorded by the PET detectors, scientists can map biochemical transformations. We also study the duration and action of drugs to determine how well patients respond to them, thus helping drug companies develop and refine treatments for various disorders.

Aging Effects

In one study, Brookhaven scientists are investigating the effects of normal aging on the dopamine system in the brains of men and women from 20 to 80 years old (see related story in the Medical Department section). Dopamine is a vital neurotransmitter, a chemical that carries signals between nerve cells, which are called neurons. Dopamine-producing neurons are known to be lost during normal aging, which may account for some of the changes in older people's motor and cognitive performance. Our researchers use PET with a multitracer approach to evaluate different aspects of the dopamine system.

For example, the metabolic activity of regions connected with the dopamine system can be evaluated using a glucose derivative labeled with fluorine-18, *2-deoxy*-2-[^{18}F]fluoro-D-glucose. Brain glucose metabolism reflects activity in the brain neurons. So, by measuring this metabolism in conjunction with specific aspects of the dopamine system, our researchers will be able to assess how significantly changes in the dopamine system affect motor and other functions.

In order to monitor the loss of dopamine neurons that might come with age, Brookhaven scientists have recently introduced the use of the compound called *d-threo*-[^{11}C]methylphenidate.

Methylphenidate, on the market as Ritalin, is a drug used to treat children with attention-deficit hyperactivity disorder. This drug is racemic, that is, made up of a mixture of two molecules, d-threo and l-threo, one a mirror image of the other. Only one of the two forms, d-threo, is active in the treatment. But the molecules are so difficult to separate that the drug is administered containing both.

For PET studies, our chemists prepared the active d-threo part of the racemic mixture, separating it from its l-threo partner, and succeeded in labeling it with carbon-11. Before this separation was possible, the d-threo and l-threo pair had to be labeled and used together, each emitting a tiny amount of radiation into the patient. With only the active, d-threo molecule in use, the radiation is halved. Also, because this remaining radiation is emitted only from active molecules, its position and concentration give a more exact measure of the dopamine neurons.

Therefore, in discovering the way to use just the active *d-threo*-[^{11}C]methylphenidate, Brookhaven chemists not only eliminated unnecessary background radiation, significantly improving the quality of the data obtained from the tests, but also, minimized the exposure of human subjects to radiation. In addition, this success in basic chemical research methodology will be useful to the pharmaceutical industry in designing the most effective drugs possible. ■

In developing new radiotracers for PET studies, Yu-Shin Ding was the first to label the d-threo compound with carbon-11.

Advanced Technology

Research [redacted]itiatives, waste and environment, safety and arms control — these are the Departm[redacted] Technology's principal fields of expertise. Reflecting a response to national needs, in[redacted]ar-energy work, many programs are expanding into areas of increasing technical diversity.

Explosive Research for Reactor Safety

Boom!

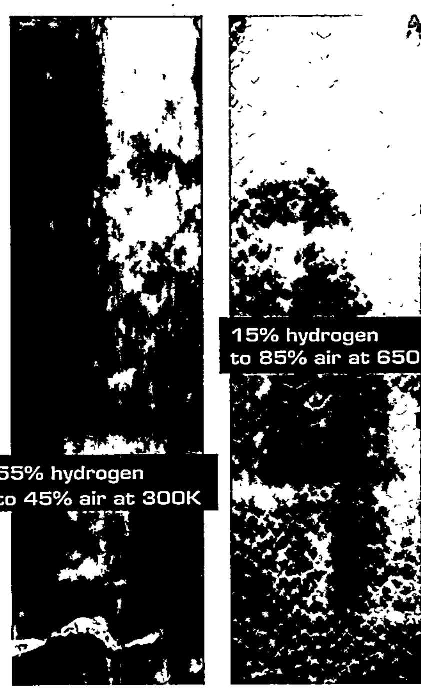
Within the stainless-steel pressure vessel, a small slug of oxyacetelene gas is detonated, starting a chemical reaction in the tube.

Instantly, intense energy is released, driving a shock into the mixture of hydrogen gas, steam and air already present. A detonation wave and the reaction zone that follows it zoom at roughly five times the speed of sound along the 21 meters of the tube, building up pressure of up to 30 times the initial gas pressure. The temperature rockets up to 3,000 kelvins (K), or 5,000° Farenheit (F). Colliding transverse waves travel along with the leading shock wave, and, where the transverse and forward-moving waves intersect, a fish-scale-like pattern is imprinted on the carbon-coated foil lining the tube.

The researchers performing this classic "smoked foil" experiment at Brookhaven's high-temperature combustion facility are Department of Advanced Technology scientists, investigating the phenomenon of detonation in hydrogen gas.

The dominant cell size of the fish-scale pattern (see photograph), which results from the coupled shock-induced chemical reactions, correlates with other dynamic detonation parameters, such as the energy needed to initiate detonation. So, results of this experiment give information on how a hydrogen, steam and air mixture reacts under conditions likely to produce explosions. For example, we find that the smaller the fish-scale pattern made by the mixture, the more likely it is to undergo a detonation.

This kind of information has been of vital concern for safety engineers at nuclear reactors, particularly since the 1979 accident at Three Mile Island. The partial core meltdown in reactor No. 2 produced hydrogen gas from the reaction of metal with water. Released into the containment building and mixed with air and steam, the hydrogen gas ignited and burned, increasing the pressure within the building, but not breaching it.



Smoked foil showing detonation fish-scale cell pattern.

Under certain other circumstances, however, the reactor's containment could have been breached, releasing radioactivity into the atmosphere. Concern over this possibility generated extensive research during the 1980s, and experiments done elsewhere show that some accident conditions could generate combustible gas mixtures at initial temperatures of up to 650 K (800° F). Classical detonation theory demonstrates that the higher the temperature, the easier it is for mixtures to detonate.

Brookhaven's Basic Research

To accommodate the new research needed to study these effects, Brookhaven built two combustion vessels: The small scale development apparatus, commissioned in 1992, and our high temperature combustion facility, dedicated two years later. In these facilities, our scientists are investigating the minimum hydrogen concentration necessary to initiate and sustain detonation at initial temperatures of up to 650 K. Our findings are then scaled and put into a database that can be used to estimate what could happen during a severe reactor accident.

At the smaller facility, our researchers found, for example, that the minimum hydrogen concentration necessary to detonate hydrogen-air mixtures at 300 K was 15 percent. But at 650 K, the minimum needed was only 9 percent. Also, the more steam in the mix, the less likely it was to explode — but, the higher the temperature, the less effective was the steam's damping effect.

These experiments served as a proving ground for designing the high temperature combustion facility. We successfully tried initiating experiments with gas — such as oxyacetelene—instead of the commonly used high-explosive charges that are hard to handle at high temperatures. This procedure is now a unique feature of the larger facility.

In the larger facility, we can test how readily mixtures containing lower concentrations of the gas under study detonate at initial temperatures of up to 650 K. For instance, the Brookhaven work was the first to find out the effects of temperature and pressure on mixtures as lean as 7.4 percent hydrogen.

We also investigate the effects of initial gas temperatures on what is called the deflagration-to-detonation transition. In a deflagration, a combustible gas mixture starts as a low-speed flame. The reaction propagates into the unreacted material at

At the high temperature combustion facility, (from right) John Boccio and Hisato Tagawa review data from an experiment; Charles Finfrock shows how gas samples are collected for analysis; Louis Gerlach, how vents are inspected on top of the tube; and Ted Ginsberg and Gaby Ciccarelli, how electric connections are checked in the heating system.

less than the speed of sound, sending pressure signals ahead, causing the flame to fold and thus accelerate. To make the transition from deflagration to detonation, the advancing flame must accelerate to supersonic speed.

To achieve this within the length of the combustion vessel, we insert arrays of special plates to enhance the turbulence ahead of a flame as it moves down the tube. Then, we measure flame velocity and vessel pressure to confirm whether transition has occurred. In other experiments, we are examining how a flame in a hydrogen mixture accelerates when openings have been inserted along the vessel to simulate pathways in a reactor's containment building.

Once these sets of experiments are completed in early 1996, both facilities will be made available to users from industry, academia and other laboratories, adding to the Laboratory's roster of user facilities as well as to the national effort to improve reactor safety. ■

Minimizing Radiation Dose to the Reasonable Max

It is noon on a typical business day at the ALARA Center in Brookhaven's Department of Advanced Technology — and already, ALARA's information service has been called on by many users from all over the world.

ALARA stands for As Low As Reasonably Achievable. The ALARA Center's name was chosen to highlight the aim of the project, which is to study ways of reducing the radiation doses received by workers in nuclear power plants. But the object is more than to reduce doses — it is to reduce them to a level that is as low as is reasonably achievable, bearing in mind the need to balance other social and economic necessities.

Brookhaven scientists set up the ALARA Center in 1983 at the request of the U.S. Nuclear Regulatory Commission (NRC), to comply with a directive from the U.S. Congress regarding oversight of radiation safety of workers at NRC-licensed facilities.

The concept of ALARA is basic to the whole philosophy and system of radiation protection. Although dose limits ensure that workers are as safe as in other "safe" industries, no industry has zero risk. But exposures and, therefore, risks, are kept as far below the safe limit, or as close to zero, as is reasonably achievable.

The center's main functions are to:

- Provide technical support to the NRC on policy, regulation, guidance and standards of dose minimization.
- Monitor efforts to reduce occupational exposure to radiation at nuclear facilities in the U.S. and abroad.
- Evaluate research on dose reduction and ALARA efforts.
- Inform the NRC of promising research and development related to ALARA.
- Focus the attention of industry and government contractors on ALARA practices and inform them of promising dose-reduction efforts.
- Act as a center where the nuclear industry can deposit, circulate and retrieve ALARA-related information.
- Examine areas where international collaboration may be valuable.

ALARA's Ace: ACEFAX

The ALARA Center maintains a number of databases containing information such as radiation-exposure data and bibliographies on ALARA-based radiation protection. The information collected at the center can be accessed by computer or by *ALARA Notes*, a newsletter with a regular worldwide distribution of over 2000. We also publish journal articles on subjects related to ALARA, such as robotics and how they can be used to promote the ALARA principle. But our communications trump card is the ALARA Center Exchange Interactive Fax Retrieval System, or ACEFAX.

Using ACEFAX is easy — all the receiver needs is a set of indices (provided by the ALARA Center) and a fax machine. Callers dial from all over the world and get recorded instructions to key in the index numbers of up to five documents, which are then automatically faxed back to the callers. Since ACEFAX started, the ALARA Center has seen a 200 to 300 percent rise in demand for such documentation.

Data Compiling

It is no accident that so much ALARA information is accessible. At the center, our staff have been collecting, summarizing, compiling and distributing these data for over a decade. To get the information we need, we visit power plants and investigate facilities, do in-depth surveys and research the literature. In addition, the ALARA Center hosts international workshops to make contacts and promote the exchange of information and ideas.

ALARA staff members also work on studies for the NRC. In one recent project, based on the facts we elicited from 25 U.S. nuclear plants, six contractors, and European, Asian and Canadian utilities, we identified groups of workers who receive elevated radiation doses and compared their number and the average dose they received to the total number and average dose of all radiation workers in a plant. We also identified the jobs that lead to high doses and described effective dose-reducing techniques. A subsequent article on doses to worker groups in the nuclear industry won the editors' award for excellence from the journal *Radiation Protection Management*, in 1995.

Have ALARA, Will Travel

Our staff provides not only information, but also expertise. The South Korean government recently voted to establish an ALARA center in Korea. Then, under the International Energy Agency's expert provision program, the Korean Institute of Nuclear Safety (KINS) requested that a Brookhaven specialist travel to Korea to help initiate the new center. In addition, the KINS president visited the U.S. ALARA Center at BNL, to sign a letter of intent between KINS and Brookhaven confirming their future collaboration and exchange of information.

Just as in the U.S., the new Korean center will fulfill its government's mandate to oversee the radiation safety of workers in nuclear facilities. Like the Brookhaven ALARA Center, it will provide the opportunity for improving the health and safety of radiation workers everywhere. ■

Displaying some of the available ALARA information are ALARA staff members (standing, from left) Tasneem Khan, Maria Beckman, James Xie, (seated) Bruce Dionne and Sandra Sullivan.

Research Divisions

Brookhaven's four research divisions offer critical support to the Laboratory's scientific programs. The Computing & Communications, Instrumentation, Reactor and Safety & Environmental Protection Divisions all collaborate with staff and visiting scientists to advance BNL's ongoing research. This work draws on the ingenuity of the divisions' many trained specialists, in the drive toward scientific frontiers.

REACTOR

The Reac[redacted]ates one of the world's leading research reactors, the High Flux Beam Reactor (HFBR), as[redacted]okhaven Medical Research Reactor. The HFBR's intense beams of neutrons support e[redacted]clear and solid state physics, metallurgy, nuclear and structural chemistry, and biology. Its[redacted]standing research includes topics such as the structure and behavior of metals, ceramics, and high-temperature superconducting materials.

ENGINEERING A BEAM

Nearly 100 mechanical, electrical, instrumentation and control drawings have been completed for the project. Calculations have been rigorously checked for safety and accuracy. The construction stage is almost at hand.

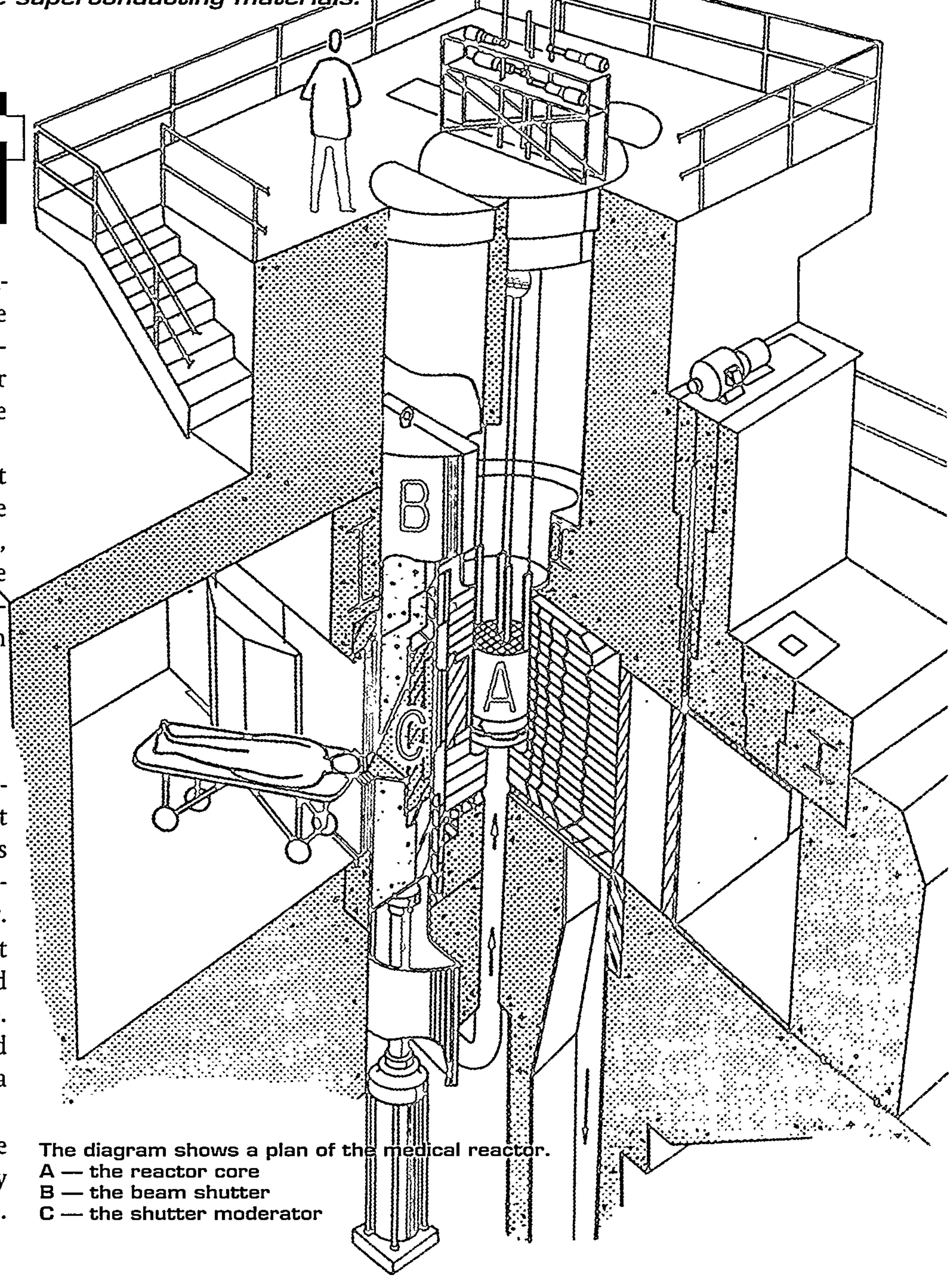
The project itself, upgrading a vital part of the neutron beam system in the Brookhaven Medical Research Reactor, calls on the considerable expertise of the Reactor Division staff. But the engineering challenge is easier to appreciate with some background information.

A MIGHTY LITTLE REACTOR

The medical reactor, run by the Reactor Division, is very small. At full power, it produces only three megawatts of heat, as compared to the 3,000-megawatt heat capability of a typical nuclear power reactor.

Yet our medical reactor has the best specialized beam of neutrons in the world for boron neutron capture therapy (BNCT). This promising therapy is being developed at Brookhaven to treat glioblastoma multiforme, a deadly brain tumor.

In BNCT, a compound containing the element boron accumulates preferentially in the patient's malignant tumor tissue.



The diagram shows a plan of the medical reactor.
A — the reactor core
B — the beam shutter
C — the shutter moderator

The tumor is then irradiated with neutrons produced by a nuclear reactor. Some of the boron atoms absorb neutrons and then split into two energetic particles that destroy tumor cells.

Commissioned in 1959, Brookhaven's medical reactor was the first to be specifically constructed for medical research, and it provided a low-energy, thermal neutron beam for clinical trials of BNCT in the early 1960s. But the neutrons did not penetrate deeply enough to destroy the tumor without harming surrounding healthy tissue.

Our scientists later found the answer: Intermediate-energy, epithermal neutrons, which can penetrate to deeper-seated tumors, are slowed down by body tissue. So, by the time epithermal neutrons reach the tumor, they are transformed into the slow, thermal neutrons that can interact with the boron in the cancer cells.

To get an epithermal beam, neutrons emerging from the reactor core at two million electron volts must be slowed down to a few thousand electron volts. This is done by filtering them through moderating materials that absorb some of their energy. In the late 1980s, BNL scientists and engineers, with researchers from Idaho National Engineering Laboratory, restructured the filtering system to produce the world's best epithermal beam for this therapy.

Frank Patti checks drawings for the Brookhaven Medical Research Reactor's new shutter designs.

Improving the Best

Then, in 1993, we rearranged the reactor fuel elements, increasing the neutron beam intensity by 40 percent. With more epithermal neutrons available, treatment time for patients in the 1994-95 first clinical trials was reduced to 40 minutes.

Even with the improved design, the neutron beam still had to pass through water surrounding the reactor core. The water both removes heat and slows fast neutrons down to the thermal energy that maintains the chain reaction in the core. Thus, the beam emerging from the reactor contains not only the desired epithermal neutrons, but is contaminated with some fast neutrons and many thermal neutrons also. The beam filter slows some of the fast neutrons to the epithermal range, and absorbs most of the thermal neutrons, but some remain to degrade the epithermal beam quality.

Our researchers looked for a way to convert the slow neutrons back into faster neutrons, in order to enhance, not degrade, the epithermal beam. The solution lay in a new shutter design.

New Shutter Design

The reactor shutter, which is hydraulically raised and lowered, contains a high-density concrete section that blocks the beam when the shutter is down. When it is up, the beam filters through a moderating section to the irradiation port, which is a window where the patient's head is positioned.

The key innovation in the new design is a set of uranium-containing plates, thin enough to need little cooling, which will be mounted on the back of the shutter. These converter plates will capture the unwanted thermal neutrons remaining in the beam from the reactor and use them to create a whole new set of fast neutrons. As these pass on though the moderating section, they will be slowed to epithermal energy, adding to the epithermal neutrons already in the beam and thus boosting the dose delivered to the patient's tumor.

Also, the new design improves the collimation of the beam, holding the neutrons in a straight, forward direction that enables them to penetrate deeper into the patient's brain.

With this new shutter in place, the epithermal neutron beam will be so intense and well collimated that a patient could be treated in as little as five minutes, if medically desirable. The extra efficiency will also result in lower fuel consumption in the core.

Remodeling the shutter is a complex engineering challenge. The first problem is space, because the shutter cavity size is fixed by the original reactor design, as well as by the need to place the patient as close to the reactor as possible to obtain the maximum neutron beam intensity. The uranium plates will generate about 80 kilowatts of heat, so a small cooling system is necessary. Also, the reactor operators must be able to replace or remove the plates, so space for remote handling equipment, radiation shielding and a transfer cask must be included.

These problems have been resolved, and the new shutter design is ready for final safety reviews. Within a year of receiving approval for construction, patients should be benefiting from the further improved beam. ■

SAFETY AND ENVIRONMENTAL PROTECTION

With the [redacted] technical support to Laboratory staff and visitors in areas of environment, safety and healt[redacted]d Environmental Protection (SEP) Division distributes its expertise around the Laborato[redacted]ordinated program of monitoring and assistance both on site and off, SEP staff help prot[redacted]nent and the health and safety of all who work at Brookhaven or live nearby. Division staff pride themselves on their level of support to the Laboratory's scientific facilities, both large and small, whether already existing or still under construction.

CUSTOMIZING SAFETY & HEALTH

When researchers arrive at Brookhaven to work in a lab or take data at one of our "big machines," they may need a while to learn about the unfamiliar scientific equipment or to find their way around the site.

But when visitors become part of the Brookhaven community, one thing is automatic: Their safety is our concern from the moment they arrive.

In fact, among the Safety & Environmental Protection (SEP) Division's staff is a group of 45 employees who work side-by-side with the Laboratory's employees and visitors at their workplaces to guard worker safety and health, and the environment, without interfering with research.

SEP's facilities support group applies its expertise in health physics, industrial health and industrial safety to custom-tailor a department's or division's safety program.

As the link between SEP and the rest of the Laboratory, the group gives organizations access to SEP's many safety-related services. Plus, it keeps an eye on regulatory matters and assists Laboratory organizations in complying with U.S. Department of Energy and other governmental requirements.

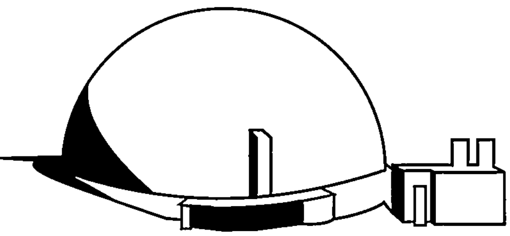
This year, the group developed a new decay and storage policy for slightly radioactive items, and revised two Laboratory standards to be more responsive to the research community. It also helped BNL's Office of Environmental Restoration develop a waste-minimization program that may save the Laboratory up to $100,000 a year.

While not physically present in every building on site, SEP's facility support staffers are available to every employee and visitor. Here are just a few examples of the many areas in which the group helps the Brookhaven employee and visitor community stay safe.

Health Physics — Many of the group's staff are not only generalists in the field of safety, but specialists in health physics — a vital trait on a campus of "big machines" and small laboratories that unleash the power of the atom for scientific discovery.

The accelerated particle beams and the nuclear research reactors for which Brookhaven is famous can produce radiation hazards, so BNL staff and visiting users alike are given training and dosimetry equipment. Facilities-support personnel monitor all work areas to ensure safety.

In addition, radiation and contamination areas are clearly marked, and all work in high-radiation areas is reviewed ahead of time to ensure the radiation dose is as low as possible. When needed, facilities-support group members issue protective clothing. The group also helps with the disposal of radiological waste.



This year, facilities support staff assisted in the health physics aspect of a new clinical trial of boron neutron capture therapy (BNCT) for brain tumors at the Brookhaven Medical Research Reactor: Their continuing assignment throughout the trial is to ensure the reactor's readiness and check patients for residual radiation after they have been treated.

Industrial Health — To protect worker health, facilities support personnel monitor several potentially hazardous factors in many workplaces.

This year, they conducted extensive noise surveys to determine which employees may need to wear ear-protecting equipment on the job. They sampled air in many of Brookhaven's older buildings for asbestos, and continued monitoring electromagnetic field radiation around the Laboratory's user facilities.

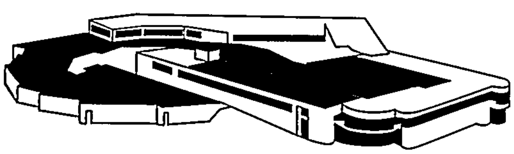
Replacing a waste line from a Laboratory facility that makes radioisotopes for medical uses is just one of many ways facilities-support staff help the Brookhaven community achieve their research goals safely and with minimal impact on the environment.

In many smaller labs, especially in the Biology and Medical Departments and the Departments of Advanced Technology and Applied Science, industrial health means careful management of chemicals. Facilities support employees ensure that documents detailing each chemical's vital information, called materials safety data sheets, or MSDSs, are up-to-date and available to all. They also provide personal protective equipment when it is needed.

Also this year, water samples were collected from many faucets and drinking fountains around the site, to ensure that the Laboratory's potable water supply met federal and state drinking water requirements.

Industrial Safety — Around the site, facilities support staff help protect employees and visitors and reduce industrial risks.

Among these are electrical hazards, found especially at the Alternating Gradient Synchrotron (AGS), the National Synchrotron Light Source, at both reactors, and in the site-wide work of the Plant Engineering Division. Accelerators and experiments demand huge amounts of power, so all who use, construct or repair these high-voltage systems are trained to handle them carefully. Workers also follow extensive "lock-out, tag-out" procedures, which double-check the shutdown of electrical systems before work begins.



The lasers in use at several locations around the Laboratory are another kind of special safety hazard; warning signs, training and protective goggles all help keep scientists safe when they use these important research tools.

The AGS and the Relativistic Heavy Ion Collider present yet another specialized safety concern: cryogenics. Detectors and magnet systems at both accelerators require high vacuums and super-cold conditions, so training and special personal protective equipment, such as face shields and gloves, are essential.

And finally, construction, whether of new facilities or upgraded experiments, is a constant at Brookhaven. Workers are trained and equipped to deal with both conventional and special construction hazards. ■

INSTRUMENTATION

In suppo[redacted]sts who use the Laboratory's many research facilities, the Instrumentation Division h[redacted]ation for inventing and developing sophisticated new methods and tools. In specialti[redacted]aser and optical metrology to the design and fabrication of intricate printed circuit bo[redacted]pacities as varied as vacuum deposition and electron microscopy, the Division serves its customers with utmost attention to precision and detail.

A Valuable Scientific and Technical Resource

From the Laboratory's "big machines" to its smallest experiments, precision instruments developed in the Instrumentation Division can be found all around the site, helping scientists gather data. They are often designed and built in collaboration with scientists from other departments, and with their ultimate users.

Monolithic circuits provide a good example. These complex, multi-layer circuits, made from silicon chips the size of a pin's head and packed with thousands of electronic components, are being developed in the division. They'll be used in everything from bread-box-sized experiments on user facility beam lines, to room-sized detectors at the Relativistic Heavy Ion Collider (RHIC).

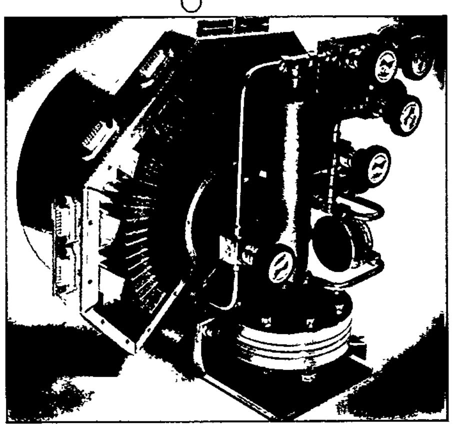
The following additional examples demonstrate how Instrumentation's ingenuity has provided unique solutions to specific problems faced by scientists working at Brookhaven and other research institutions:

National Synchrotron Light Source

On the equipment-filled experimental floor of the world's busiest scientific facility, the National Synchrotron Light Source (NSLS), Instrumentation's detectors and electronics help scientists measure the energy and intensity of ultraviolet (UV) light and x-rays.

Biologists, chemists and physicists, for example, use the division's position-sensitive x-ray detectors to determine the physical structure of samples, in a technique known as small-angle x-ray scattering. Instrumentation has begun working on even more versatile detectors for larger-angle x-ray scattering studies.

Scientists also use a technique called extended x-ray absorption fine structure to study biological and physical specimens. For this application, Instrumentation develops low-energy photon detectors suitable for experiments on both UV and x-ray beam lines.



With the highest resolution of any instruments in its class, this thermal neutron detector is used at the High Flux Beam Reactor.

Those who study the structure of thin films, or who use them in their work, make use of evaporated and sputtered coatings developed in Instrumentation. These mirror-like optical and electrical coatings, as thin as 30 angstroms, or 100-billionths of a millimeter, are made in specially designed vacuum chambers.

Finally, the division's optics and metrology group develops non-contact profilometers than can evaluate the shape and smoothness of flat and curved mirrors, used at the NSLS and other synchrotron sources to focus UV and x-ray beams. These are so accurate that they can scan the surface of a meter-long mirror to an accuracy of billionths of a meter.

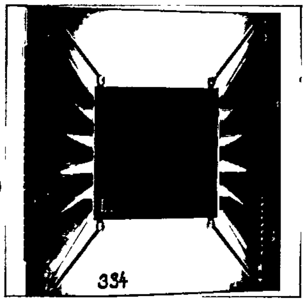
A new device under development, called an in-situ profilometer, will allow measurement of any mirror deformation under the heat stress of intense synchrotron radiation.

High Flux Beam Reactor

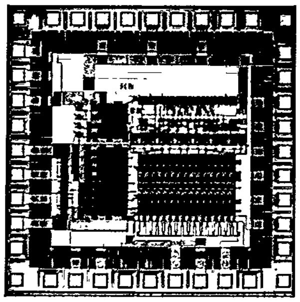
At the High Flux Beam Reactor (HFBR), experimenters study the structure of biological and physical samples using neutron-scattering techniques analogous to those used with x-rays at the NSLS. For example, a unique small-angle neutron scattering spectrometer gives biologists a view of molecules lodged in cell membranes. This is important in studying proteins on a virus's coat — and looking for places where specially designed pharmaceuticals could block their function.

The Instrumentation Division's position-sensitive neutron detectors make such experiments possible. One, which uses a rare isotope of helium, provides scientists with the highest resolution in the world for its type of detector for neutron diffraction studies.

Because access to the HFBR's beam lines is limited, these detectors are designed to operate without maintenance for long periods of time — one has lasted more than ten years without interruption.



A silicon pad detector, containing nearly 200 pads, each four millimeters square, that helps scientists at the NSLS determine fine structures with x-rays.



This monolithic circuit, designed for the PHENIX experiment at RHIC, measures only two millimeters square, yet carries 1,500 transistors.

Accelerator Test Facility

At the Accelerator Test Facility (ATF), where scientists and engineers constantly push the frontier of accelerator technology, Instrumentation's contributions are an important ingredient.

One ATF prototype accelerator, designed to cut drastically the distance over which electrons are accelerated, consists of a grating surface covered with etched pillars that are arrayed at specific intervals. Electrons from an electron gun near the grating pass parallel to the surface, in the furrow between rows of pillars, then are accelerated by a field produced by the impact of a pulsed laser field on the grating surface. To create the grating in silicon, Instrumentation uses a technique called reactive ion etching to make pillars one micron in diameter and ten microns high.

The division has also helped extensively in research aimed at finding the optimum metal coating for the electron gun's cathode. From this effort have come some of the highest current densities ever measured. Also, the division has adapted lasers that can emit bursts of intense light that last as little as a fraction of a picosecond, a unit equivalent to one trillionth of a second.

RHIC and AGS

Experiments at Brookhaven's large accelerators require silicon detectors that can determine the trajectories of the many charged particles produced by colliding beams. An innovative device called the silicon drift detector, originally developed by our scientists, yields the high-precision particle location of earlier detectors while possessing improved and more manageable electronics. Development continues on a drift detector capable of tracking a multitude of particles simultaneously — RHIC experiments will use hundreds of these.

Also destined for these detectors are monolithic circuit electronics, to transform analog signals from incoming particles into digital information that a computer can analyze. Such circuits are more compact, less expensive, more reliable and easier to make than conventional electronics.

For experiments at the Alternating Gradient Synchrotron, Instrumentation provides specialized semiconductor and gas-filled particle detectors. ■

Circuit Boards: On-Site Sophistication

With this computer-controlled drilling machine, circuit-board makers Pat Borello (left) and Ron Angona can drill holes for components more precisely and efficiently than ever before.

Specialized circuit boards are the place where thousands of electronic components interconnect in sophisticated circuits used throughout the Laboratory. These boards, not readily available commercially, are made right here at Brookhaven in the division's printed circuit board fabrication laboratory.

This year, the lab was upgraded to include all new, state-of-the-art equipment — making it an invaluable resource to the Laboratory community and American and international collaborators.

The lab can now prepare multi-layer fiberglass boards with drilled holes of unprecedented accuracy. With the new equipment, conducting circuit lines can be made much narrower, and spaced much more closely, than those on commercially mass-produced boards — as close as 0.025 millimeters.

COMPUTING AND COMMUNICATIONS

The Com[redacted]unications Division keeps Brookhaven on the cutting edge of scientific and administr[redacted] technology and communications capability. Its innovations extend into high-speed ne[redacted]t resources, data-processing facilities and tools, maintenance, programming and com[redacted]structure. While supporting the Laboratory's staff and visitors, the division's programmers and technology specialists also contribute their expertise to Brookhaven's scientific mission, including helping scientists at the National Synchrotron Light Source turn their data into even more useful three-dimensional digital images.

EXPLORING THE UNDERGROUND IN 3-D

Deep under the earth, in reservoir pools and saturated rock, the world's petroleum reserves lie silently, flowing slowly. Formed from the remains of plants and animals that lived millions of years ago, this rich liquid now feeds the churning engines of the world, which gobble it up at a furious pace.

To satisfy this insatiable appetite, the industry that siphons petroleum out of its subterranean domain is now looking in increasingly unlikely places for its supply.

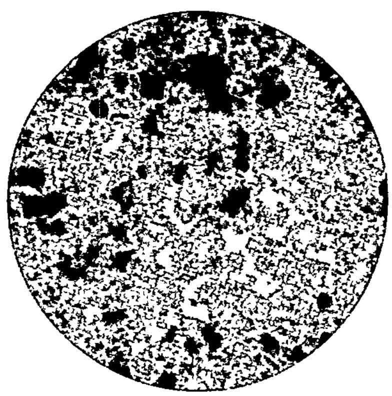
As an alternative to the dwindling number of petroleum lakes they used to tap, companies like Mobil Corporation are turning to areas they once would have overlooked, including small pools trapped in porous rock and sand.

Their quest for these reserves depends largely on research that examines the characteristics of this oil-laden earth — some of it done on Mobil's beam lines at Brookhaven's National Synchrotron Light Source (NSLS).

Now, a cooperative effort begun this year among researchers in our Computing and Communications Division (CCD), Department of Applied Science and at two major corporations is drawing upon Brookhaven's strengths to give the petroleum industry a powerful new tool for this kind of underground exploration.

FROM ONE TO THREE DIMENSIONS

Both the power of our user facilities and our expertise in high-power computing and data transmission play a large part in the project. By turning structural data collected at the NSLS into digital images and projecting it in three dimensions, the result will be a "virtual reality" view of real objects.



A single tomographic image, made at the NSLS, of a slice of oil-laden rock six millimeters in diameter taken from a drill core of sandstone rock being investigated for potential petroleum extraction. Oil is lightest gray, with rock in medium gray and water and air pockets in black.

Through this approach, petroleum engineers could one day explore the nooks and crannies of their potential oil fields in a room-sized theater, as if they were watching a 3-D movie. And with the help of high-speed networks and our expertise, they could do it from offices thousands of miles away.

Called synchrotron computed microtomography, the work is the subject of a cooperative research and development agreement (CRADA) among our researchers and scientists at Mobil and GTE Corporations.

The CRADA is funded in part by the U.S. Department of Energy's Advanced Computational Technology Initiative, which aims to help the oil and gas industry benefit from the vast computing resources of national laboratories such as Brookhaven.

FROM BEAM LINE TO COMPUTER

At two NSLS beam lines that they have used for nearly a decade, Mobil scientists use intense beams of x-ray light to reveal the microscopic structure of their samples in a technique called microtomography. The NSLS's capability for high-resolution imaging allows them to examine tiny core samples of rock and sand as small as six millimeters in diameter.

But useful as they are, the images that these NSLS users produce are limited to showing the structure of paper-thin slices of rock; scientists must infer the three-dimensional structure of the whole and look for interconnected pores, which are necessary for the oil to be easily extracted.

With the help of this new project, the guesswork will be vastly reduced, because Mobil's microtomographic data from many adjacent rock slices will be turned into a digitized computer image. In essence, it is like putting the sliced rock back together again — inside a computer. BNL computer scientists are developing the algorithms needed to do this.

From Computer to Screen

Once the recombined tomograph image has been made, it will be split into two parts, called stereo images, that can be aligned and polarized. Then, they will be projected onto a special three-meter-high screen that preserves the polarization of the light, giving the image a 3-D effect — the same principle as 3-D movies popular in the 1950s, but on a more sophisticated level.

Wearing special polarized glasses, petroleum engineers will have a clear view of how the rocks' pores interconnect, and how oil and water might flow through them. GTE Corporation has extensive expertise in this kind of visualization and will bring their experience to the collaboration.

The first viewing room will be built in CCD, half a block from the NSLS beam line where the data are collected. But through fiber-optic cables and asynchronous transfer mode (ATM) networking, this huge amount of digitized information could be transmitted anywhere almost instantly — for instance, to a screen in Mobil's headquarters in Dallas, Texas.

Through these high-speed networks, other companies could use the same method to visualize their petroleum core samples in 3-D. But petroleum engineering is just the beginning. Scientists and engineers in many other fields could embark on the same kind of cooperation that has sprung up between our NSLS users and computer scientists. ■

Ballard Andrews, CCD, and Betsy Dowd, NSLS, examine the tomography equipment used at the National Synchrotron Light Source to generate images of oil-laden rock.

LABORATORY PROFILE

The following pages summarize activities that have taken place at the Laboratory during fiscal year 1995. Included in this section is a description of numerous conferences, meetings, workshops and symposia held at BNL throughout the year, a listing of honors won by Brookhaven staff, and a year-end report on the Laboratory's budget. Also highlighted are programs that are under the administration of BNL support divisions and various offices.

MEETINGS

Just as broad as the range of disciplines represented at Brookhaven is the range of topics for meetings, conferences, workshops and symposia that are held here each year. Among 1995's gatherings were the following:

At a **Landfill Technology Workshop** held October 25 & 26, 1994, environmental remediation specialists from BNL and elsewhere discussed methods of characterizing the contents of "glassholes," small buried dumping areas.

The Laboratory's **Small and Small Disadvantaged Business Conference**, held on October 28, drew representatives of 135 firms to speak with Brookhaven procurement managers.

To honor Medical's Victor Bond in his 75th year, 130 radiation-effects researchers gathered on November 3 & 4 for a conference on **Physical Insult From and Biological Responses to Low-Level Ionizing Radiation.**

More than 20 of those who use the computer code MACCS in countries worldwide to calculate the probable consequences of nuclear accidents came together November 8-10 for the first meeting of the **International MACCS Users Group.**

Fifty representatives from area schools, hospitals and research institutions came to BNL on November 10 for a workshop on **Pollution Prevention Opportunities in a Laboratory Setting.**

In anticipation of upgrades and further research at the Brookhaven Linac Isotope Producer (BLIP), the facility's users gathered on November 15 & 16 for a **BLIP Users' Advisory Committee** meeting.

Representatives from the developing nations of Bulgaria, the Czech Republic, Ethiopia and Nigeria came to BNL for three weeks in January 1995 for a **Workshop on MARKAL-MACRO**, a computer model of nations' energy use and pollution.

One hundred and eighty American nuclear physicists gathered on January 27 & 28 at the home of their field's biggest focus, the Relativistic Heavy Ion Collider, for the **Nuclear Science Advisory Committee Town Meeting**, at which they discussed future directions in nuclear physics.

At an **Emergency Management Planning Group Seminar** on February 1, the Laboratory's security and emergency personnel welcomed their colleagues from local law enforcement agencies and the Federal Bureau of Investigation.

To learn about the Laboratory's emergency planning system, the **Suffolk County Local Emergency Planning Commission** held a meeting on site on February 14, with 40 attendees from institutions all over the county.

A **Plastics Recycling Workshop** held in the Department of Advanced Technology March 9 & 10 drew together 23 industry representatives and academic researchers to develop ideas for how to retrieve "hidden" plastics from durable goods for recycling.

Computer-based graphical user interfaces (GUIs) for structural biologists were the focus at a **Workshop on GUIs for Synchrotron Protein Crystallography** held March 19-21 for more than 60 scientists and computer specialists.

The ninth annual **Oil Heat Technology Transfer Conference and Workshop**, held March 22 & 23, brought together researchers and industry representatives to learn about new technologies in the field.

Forensic scientists from **Suffolk County's Crime Laboratory** explored potential cooperative efforts with Laboratory scientists and facilities in a March 30 visit.

In an April 24-28 gathering of 17 Russian and 16 American visitors for the first-ever **Laboratory-to-Laboratory Workshop on Materials Protection, Control and Accounting**, the emphasis was on safeguarding nuclear materials at Russian facilities.

Fifteen nuclear power plant regulators and administrators from Eastern Europe attended a training course on **U.S. Commercial Nuclear Power Fire Protection Practices** from May 8 through 25. An additional 15 came for another two-week session that began September 25.

Representatives of six local school districts gathered at the Office of Educational Programs on May 9 for the signing of documents related to the **School District Technical Assistance Initiative.**

More than 350 National Synchrotron Light Source (NSLS) users attended the 14th annual **NSLS Users Group Meeting**, held May 9 & 10 and featuring discussions of future budgets for NSLS operations and experiments, and examination of five areas of research.

Forty-six medical hypertension researchers gathered at Brookhaven on May 15 & 16 for an **International Symposium on Genetic and Salt Hypertension**, which recognized the Laboratory's contributions in developing strains of mice for such research.

Brookhaven teamed with the National Aeronautics and Space Administration to bring information on **Starting a Technology-Oriented Business** to interested entrepreneurs and patentees at a series of workshops on May 24 & 25.

Seventy New York school teachers and administrators teamed up for practical learning experiences at a **Conference on Math, Science and Technology Integration in New York State** held June 5 & 6.

Roughly 150 participants in the **AGS-RHIC Users Meeting** held June 15 & 16 for scientists at the Alternating Gradient Synchrotron (AGS) and Relativistic Heavy Ion Collider (RHIC) heard good news about the accelerators' performance, research and progress, tempered by uncertainty about future funding.

The U.S. Department of Energy's (DOE) fifth **Technology Transfer/Communications Conference** was hosted by Brookhaven from July 29 to 31, and 62 participants discussed the best ways to communicate the value of DOE-industry tech transfer partnerships to the public.

A hundred and thirty scientists working on the STAR experiment for RHIC gathered from August 7-12 for a **STAR Collaboration Meeting**, at which they discussed spin physics possibilities at RHIC and additional experimental equipment for STAR.

In a September 28-30 **Microbunches Workshop** that attracted nearly 100 accelerator physicists, the future accelerator-based production and use of electron bunches less than a millimeter in length were discussed.

Lectures

Aside from the usual packed calendar of scientific seminars and lectures in each of BNL's departments and divisions, several special lecture series and seminar programs aim to reach a broader audience.

• *AUI Distinguished Lectures*—In this series sponsored by Associated Universities, Inc. (AUI), these speakers addressed topics of general interest: Georges Charpak, 1992 Physics Nobelist and Joliot-Curie Professor at the Ecole Supérieure of Physics and Chemistry, Paris; Bruce Ames, director of the National Institute of Environmental Health Sciences at the University of California, Berkeley; and Russian theoretical physicist Lev Borisovich Okun, head of the Elementary Particle Theory Laboratory at Moscow's Institute of Theoretical and Experimental Physics.

• *Brookhaven Lectures* — The series' 35th year featured: Upendra Rohatgi, Advanced Technology, next-generation nuclear reactor safety; Robert Crease, Laboratory historian, BNL history in the Haworth years; Maurice Goldhaber, AUI Distinguished Scientist emeritus (300th BNL Lecture), universal properties of fundamental particles; Andrew Sandorfi, Physics, looking inside the proton with scattered laser light; William Marciano, Physics, high energy physics in the next millennium; John Sutherland, Biology, ultraviolet radiation damage to DNA; William Studier, Biology, DNA sequencing for the Human Genome Project; Thomas Roser, Alternating Gradient Synchrotron, spinning protons and Siberian snakes; Joel Sussman, Chemistry, crystal structure of acetylcholinesterase; and Charles Meinhold, Advanced Technology, historical and modern radiation protection.

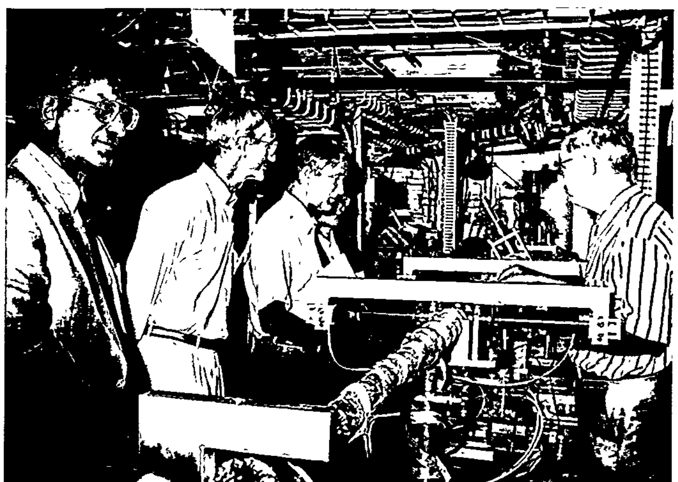
• *Pegram Lecture* — **D. Allan Bromley**, former science advisor to President George Bush and now Dean of Engineering at Yale University, discussed his experience in "Science and Technology: Advice and Policy," including his White House days and current insider's view of the science policy arena.

• *Brookhaven Women in Science Seminars* — Delivering this year's seminars were: astronomer Vera Rubin, Carnegie Institution of Washington; mathematics professor Dusa McDuff, State University of New York (SUNY) at Stony Brook; SUNY Stony Brook president Shirley Strum Kenney, jointly with the Women's Program Advisory Committee; Cornell University astronomy professor Martha Haynes; Ontario Cancer Institute senior scientist Cheryl Arrowsmith; Armstrong State College mathematics professor Anne Hudson, jointly with the Office of Educational Programs; and National Center for Toxicological Research research geneticist Suzanne Morris, jointly with the Medical Department.

• *Donald Van Slyke Lecture* — In this Medical Department lecture, Janet Rowley, professor of medicine at the University of Chicago's School of Medicine, discussed chromosome translocations.

• *Aditya Sambamurti Memorial Lecture* — The fourth year of this series featured Brian Winer, University of Rochester, speaking on his involvement in the discovery of the top quark at Fermi National Accelerator Laboratory.

• *Haworth Distinguished Lecture*—In the first year of his two-year appointment as a Leland Haworth Distinguished Scientist, Florida State University structural biologist Donald Caspar gave a Labwide lecture on virus-protein assembly and movement within crystals. Another Haworth scientist, Institute for Advanced Studies School of Natural Sciences professor Frank Wilczek, began his two-year tenure with a lecture on black holes and quantum mechanics. ■



At the Accelerator Test Facility (ATF), participants in the Second International Free Electron Laser (FEL) Users workshop, sponsored by Brookhaven May 21-25, examine the inverse FEL experiment installed on an ATF beam line. ATF head Ilan Ben-Zvi (left) also co-chaired a concurrent 17th International Free Electron Laser Conference, while Arie Van Steenbergen described the ATF's FEL experiment to the 267 participants.

Honors

This year, honors went to the following:

Walter Becker (Advanced Technology), **Peter Kroon** (Physics), **Joseph Levesque** (Safety & Environmental Protection), **Edward Murphy** (Plant Engineering), and **Alexander Pendzick** (Alternating Gradient Synchrotron) were all recipients of Brookhaven Awards in December for their key contributions in support areas and outstanding service to BNL through performance and achievements.

W. Robert Casey (Safety & Environmental Protection) won the American Board of Health Physics' William McAdams Outstanding Service Award in July, for advancing health physics certification and for leadership in the organization.

The late **Ralph Fairchild** (Medical) was honored posthumously by the Health Physics Society with a Distinguished Service Award in July.

Steven Kane (Safety & Environmental Protection) received the Edgar Monsanto Queeny Safety Professional of the Year Award from his peers in the American Society of Safety Engineers in June, for ensuring safe design and construction at RHIC.

Charles Meinhold (Advanced Technology) traveled to China in October 1994 to accept two honorary professorships for his contributions to radiological protection — one from the China Institute of Atomic Energy and the other from Suzhou Medical College.

Nicholas Samios (Director's Office), was presented with an honorary Doctor of Humane Letters from Hofstra University in December for contributions to science and technology, both as a physicist and as Laboratory Director.

Lewis Snead (Advanced Technology) was honored by the Nuclear Materials Committee with a Distinguished Service Award in February, for his contributions to materials science and service in science administration and as editor of the *Physical Review*.

Prantika Som (Medical) was the winner in the Science category of the Brookhaven Town Women's Recognition Awards in March 1995, for her work in diagnostic radiopharmaceuticals.

Dorry Tooker (Director's Office) was named the Representative of the Year by the Federal Laboratory Consortium for Technology Transfer in November 1994, for her enthusiastic approach to tech transfer. ■

Joanna Fowler, Chemistry (on facing page at left), and (above from left): Y.Y. Lee, Alternating Gradient Synchrotron, Samuel Krinsky, National Synchrotron Light Source, and Carl Dover, Physics, all captured the Laboratory's Distinguished Research & Development Award in December 1994, for their outstanding contributions to Brookhaven's scientific missions.

Administrative Actions

Robert Bari was appointed Chairman of the Department of Advanced Technology in June 1995.

Margaret Bogosian became Manager of the Office of Technology Transfer in June 1995.

Carol Creutz became the Laboratory's first female department chair in January 1995 when she became Chairwoman of the Chemistry Department.

Theodore Daniels was made Acting Head of the Computing & Communications Division in June 1995.

James Davenport became Chairman of the Department of Applied Science in October 1994.

Michael Hart joined the Laboratory as the Chairman of the National Synchrotron Light Source Department in September 1995.

Thomas Kirk came to Brookhaven as Associate Director for High Energy and Nuclear Physics in October 1994.

Denis McWhan was made Associate Director for Basic Energy Sciences in January 1995.

Richard Melucci began serving as the Laboratory's Budget Officer in September 1995.

Diane Mirvis became Head of the new Information Services Division in February 1995, when it was created to merge the functions of the Technical Information and Photography & Graphic Arts Divisions. Upon Mirvis' departure, **Mary White** become the division's Acting Head in July 1995.

ADMINISTRATION

Personnel Statistics

In 1995, employment at the Laboratory decreased slightly due to voluntary retirements, layoffs necessitated by tight budgets, and attrition.

Employment Statistics

	1995	1994	1993
Scientific Staff*	576	584	604
Scientific Professional Staff	650	619	639
Nonscientific Staff	1,992	2,064	2,106
Total	3,218	3,267	3,349

* Includes research associates.

Percent of Total Employees

	1995	1994	1993
Minorities	17.2	17.3	17.3
Women	23.1	23.4	24.3

Some 4,400 guest researchers, ranging from students to senior research appointments, took advantage of Brookhaven's world-class research facilities in 1995. These guest researchers came from 450 U.S. and 320 foreign institutions.

Fostering the Giving Spirit

Giving generously to others, a long-standing Brookhaven tradition, continued in 1995, with employees swimming their way to $6,759 worth of donations to the American Cancer Society in the fifth Swimarathon, donating 1,086 units of blood in two annual blood drives and an emergency drive, contributing $90,780 to community service organizations under the United Way umbrella, and bringing 23,080 pounds of food to collection points for the Food Drive.

Healthfest's Second Year

Whether they walked in the Fitness Walk, ran in the 5-kilometer Fitness Run, or attended a health and safety fair complete with 24 exhibitors, screenings and prizes, hundreds of employees enjoyed the Laboratory's second Healthfest, held from October 10 to 13. The festival of health, safety and fitness events again helped employees learn about ways to help keep themselves free from illness and injury at work and at home.

Visitors, Students Flock to Museum

An impressive number — 33,456 — of visitors took part in the Museum Programs Office's array of opportunities this year.

That total includes a record 24,328 schoolchildren, from kindergarten through high school, who took museum tours, learned about magnets and electricity during outreach programs in their schools or in the museum, or took part in the annual Science Fair or Model Bridge Contest.

Also visiting Brookhaven were 4,365 general visitors who came on Summer Sunday tours, and 1,857 college students and professionals who toured some of the Laboratory's world-class facilities.

Making a Connection with Local Students

Two programs began this year to bring Long Island youngsters in contact with Brookhaven professionals. To help at-risk local youth stay in school and act as role models, over 40 employees volunteered as mentors to elementary and middle school students in the Longwood School District as part of the New York State Mentoring Program.

Mentors meet with their students for an hour each week at their schools and develop a relationship that encourages the children to work harder at their studies and develop self-esteem. The mentees came to Brookhaven for a tour in August, to receive even more encouragement and career information.

Meanwhile, 30 local tenth-grade girls, chosen for their aptitude in science and math, came on site several times during the year to learn practical skills and career possibilities from Laboratory scientists and professionals. They were the first group to embark on three years of learning in the WISE, or Women in Science Excel, program administered by the State University of New York at Stony Brook.

O'Leary Visits, Tours Medical

Making her first visit to Brookhaven, U.S. Department of Energy Secretary Hazel O'Leary toured the Laboratory in December. Her itinerary featured a visit to the Medical Department facilities, where clinical trials are under way to test boron neutron capture therapy for brain tumors. O'Leary held a town meeting with employees to discuss the department's accomplishments in cost reduction and its goals for the national laboratory system.

Ride-Sharing Program Gets on the Road

To help prevent air pollution and lighten rush-hour traffic, and to comply with the federal Clean Air Act's requirements, the

Laboratory began an extensive ride-sharing program in 1995. A commuter assistance and information service was begun, and help and incentives were offered to encourage employees to commute together during peak periods. Employees got the latest ride-sharing news through a newsletter.

To help car and van pools get going, a computerized geo-coding system tapped a database of hundreds of registered employees living in the same area. Associated Universities, Inc., offered assistance in purchasing vehicles to groups interested in van pools and donated U.S. Savings Bonds as prizes for a lottery held for car and van pool participants.

New Division for Information Delivery

A new division, Information Services, was created in February from the merger of the Technical Information and Photography & Graphic Arts Divisions.

Combining many of the Laboratory's information creation, distribution and storage functions, the new organization's birth recognizes the overwhelming impact of technology on information services. The Information Services Division allows for more cost-effective and efficient production of reports, photographs, documents, Laboratory records, Internet resources and database systems to facilitate information access and retrieval.

During the year, Information Services debuted a new on-line Laboratory telephone directory, helped many departments and divisions generate and store their information products and create home pages on the Internet's World Wide Web.

Report Assesses Labs' Structure, Future

In a report commissioned by Energy Secretary Hazel O'Leary and compiled by a committee headed by Robert Galvin of Motorola Inc., Brookhaven and other national laboratories were praised for the quality and value of their science and technology.

In a "town meeting" on February 6 with Laboratory employees to discuss the report's finding, Director Nicholas Samios called Brookhaven "well positioned" in terms of commitment to basic research and building world-class facilities. He later testified before Congress regarding the report and the national laboratory system.

During a May visit that also included an address to users of the National Synchrotron Light Source, Galvin gave a Laboratory-wide talk that commended Brookhaven for its performance and for placing the emphasis on scientific user facilities.

BNL, Community Meet For Future Land-Use Plan

After a year-long future land-use planning process, better communication links were forged among Laboratory representatives, members of local civic groups and institutions, and officials from both county and state governments. The collaboration also helped the Laboratory prepare its Future Land Use Plan required by DOE to guide environmental restoration activities and help establish remediation standards.

The plan includes reviews of the Laboratory's land-use practices, present and future, and suggestions from stakeholders for possible future uses for the site. The process also prompted Suffolk County to compile a report that details the Laboratory's extensive positive impact on the Long Island economy.

Daughters Come to Work

Nearly 200 girls ages 9 to 15 participated in the Laboratory's first Take Our Daughters to Work Day, on April 27. First, the girls visited their parents or "host parents" in their workplaces, then heard about career options from Brookhaven women professionals.

The day concluded with a tour of many Laboratory facilities, including the RHIC tunnel, the firehouse, the Chemistry Department and the heavy machine shop of the Central Shops Division. Responses from the girls after the event were overwhelmingly positive.

New Waste-Handling Facility

Ground was broken in May for the Laboratory's new waste management facility, a $16-million state-of-the-art waste handling area that will permit a significant improvement in Brookhaven's ability to manage its wastes.

Located on an 18-acre site separate from and higher in elevation than the existing facility that it will replace, the new facility will be completed by September 1996. It will allow Safety & Environmental Protection Division staff to handle the Laboratory's waste more efficiently and with the utmost respect for the environment. Through minimization and reclamation practices, the Laboratory's waste output is expected to decrease in quantity and hazard.

More Rewards From Patent Licensing

A second round of royalties earned from licensing Brookhaven technologies was distributed to the Laboratory by AUI in June, with a total of $200,000 going to three departments — Medical, Biology and Applied Science — and to the Instrumentation Division.

AUI reinvests a share of its portion of licensing revenues in the Laboratory. Departments and divisions receive funding for research programs, seminars and other activities, to a large extent based on the royalties generated by technologies that were developed by their researchers.

Another Crop of Graduates

Twenty-one Brookhaven employees completed their master's degrees in mechanical engineering in 1995 after two-and-a-half years of evening classes held on site by Manhattan College. Their 33 credits were concentrated in the areas of nuclear power/facility restoration and waste management.

Thirty-three other employees received their degrees from 13 other institutions in 1995. All 54 graduates received assistance from the Human Resources Division's tuition refund program.

Recycling Cycles On

As the extensive recycling program coordinated by the Plant Engineering Division continued in 1995, Laboratory employees saved over 340 tons of white paper, mixed paper, bottles, cans, cardboard and tires from disposal in a landfill.

The division did some even more heavy-duty "recycling" of its own this year, converting two retired Laboratory fire trucks into general-use flatbed trucks that could be used for landscaping in summer and salt-spreading in winter. It also purchased an industrial screening machine that can separate trees, stumps and wood from soil at BNL's tree-composting area; this allowed the reclamation of nearly 5,320 cubic meters of top soil in this year alone.

Human Resources & Diversity

The Personnel Division received a new name and a new addition on July 1, when it became the Human Resources Division and welcomed the creation of the Diversity Office, which coordinates all the Laboratory's diversity, affirmative action and equal opportunity programs. The changes are intended to help Brookhaven celebrate its diversity and provide equal opportunity to all.

Reduction in Force, Cost-Cutting Efforts

Congressional budget action and DOE programmatic funding changes necessitated cost-cutting and reduction-in-force actions throughout the Laboratory toward the end of 1995. Approximately 90 employees left the Laboratory as a result, mostly through attrition and early retirement. Reviews of support divisions by the Cost Control Committee ensured that such programs were trimmed with minimal impact on Laboratory operations and scientific programs.

Energy Savings Continue to Climb

This was another year of projects designed to cut the Laboratory's energy demands, including: new insulation and siding on dormitories and wood-frame and concrete buildings; improvements at the steam plant; better temperature controls in several buildings; and modifications to air conditioning systems. Altogether, projects completed in 1995 will save Brookhaven $600,000 in energy bills each year, on top of the $1.2 million dollars already saved this year through demand-limiting efforts. ■

Dozens of Brookhaven employees, including BNL firefighters and those who volunteer for their local fire companies, helped in the massive fight against the wildfires that swept forested areas in Rocky Point and Westhampton in August.

SUPERFUND

As one of the more than 1,000 sites on the federal Superfund list for environmental cleanup, BNL continues to remediate contaminated areas of its site. This action is mandated by the federal Comprehensive Environmental Response, Compensation and Liability Act. At BNL, it is the responsibility of the Office of Environmental Restoration (OER).

Fiscal year 1995 saw a number of developments:

• The excavation of 21 cesspools and a septic tank, all unused for several years and located throughout the site. Soil from around each was removed and replaced with clean fill, and preparations were in place at the end of the year for all to be removed. The soil will be disposed of appropriately.

• The excavation and removal of six empty underground storage tanks that once contained hazardous and radioactive sludges from the Laboratory's reclamation facility and hazardous waste management facility. The tanks were packaged and shipped to Hanford, Washington, for disposal at a federally approved facility.

• The convening of a public meeting in November 1994 on Operable Unit (OU) V, the area around the Laboratory's sewage treatment plant.

• The release of a report detailing environmental contamination in OU IV in February.

• The remediation, five years ahead of schedule, of two Imhoff tanks. The tanks were used until 1967, first by the Army and then by BNL, to separate solids from liquids at the sewage treatment plant. Because the tanks had not been used for nearly 30 years, they were emptied as a precaution against potential leaks.

• The launching of a major groundwater study in August. The study will teach OER more about groundwater flow underneath the Laboratory site and beyond, and pave the way for better planning in BNL's remediation of contamination on its premises.

• The laying of a plastic-and-soil cap over an eight-acre landfill to prevent rainwater from carrying landfill contaminants to groundwater. This project was 80 percent done by September, with completion expected for November.

All remediation work is approved by New York State, the U.S. Environmental Protection Agency and the U.S. Department of Energy.

FINANCIAL REPORT

In fiscal year 1995 (FY95), Brookhaven's total budget was $415.6 million, a slight increase over FY94.

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 the research programs. In FY95, operating costs, which are the basis for statistical data listed below, were $296.7 million.
- Capital equipment funding, which amounted to $21.9 million in FY95, provides for major instrumentation, scientific apparatus, computers and office equipment.
- Construction funds are used for building projects. These monies decreased by 8.9 percent in FY95, to $97.0 million, largely due to an $8.0 million scheduled funding reduction from FY94 for the Relativistic Heavy Ion Collider, which is expected to be completed in 1999. Environmental restoration and waste management (non-defense) projects received $5.2 million for the waste minimization upgrade, and $100,000 for floor drain modifications. Infrastructure improvements included three new starts: applied science building phase I, funded for $600,000; sanitary system upgrade phase I, funded for $1 million; and loss prevention upgrade phase I, funded for $600,000.

Other ongoing facilities projects supported by the U.S. Department of Energy (DOE) were the potable water system upgrade ($1.9 million), roof replacement phase I ($100,000) and the fuel transfer facility ($2.5 million).

As in previous years, the principal source of BNL's funding was DOE, which accounted for about 78% of the operating budget and for all of the capital equipment and construction funds. ■

BNL Operating Costs (millions of dollars)	1995	1994	1993
High Energy/Nuclear Physics	85.1	79.8	84.8
Basic Energy Sciences	69.9	70.1	71.9
Biological & Environmental Research	27.3	26.4	26.3
Other DOE Programs	60.7	60.7	53.9
Other Programs	53.7	47.9	46.6
TOTAL	296.7	284.9	283.5

BNL Cost Elements

ORGANIZATION

Directorate

Nicholas P. Samios
Director
Martin Blume
Deputy Director
M. Sue Davis
Associate Director for Reactor, Safety & Security
Henry C. Grahn
Associate Director for Administration
Thomas Kirk
Associate Director for High Energy & Nuclear Physics
Denis B. McWhan
Associate Director for Basic Energy Sciences
Richard B. Setlow
Associate Director for Life Sciences
Michael J. Bebon
Assistant Director for Management & Physical Plant
Mark Sakitt
Assistant Director for Planning & Policy
Satoshi Ozaki
RHIC Project Head

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Advanced Technology
Peter D. Bond
Physics
Carol Creutz
Chemistry
James Davenport
Applied Science
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National Synchrotron Light Source
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Alternating Gradient Synchrotron
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Division Heads

W. Robert Casey
Safety & Environmental Protection
*Theodore Daniels
Computing & Communications
Lance L. Junker
Reactor
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Managers and Other Office Heads

John D. Axe
Center for Neutron Science
Anne S. Baittinger
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Technology Transfer
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Robert D'Angio
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Michael A. Guacci
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Mary-Faith Healey
Contracts & Procurement
Mark O. Israel
Fiscal
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Staff Services
Bernard J. McAlary
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Plant Engineering
Richard Melucci
Budget
Robert B. Palmer
Center for Accelerator Physics
Russel J. Reaver
Safeguards & Security
Marvin Shear
Quality Management
Richard J. Spellman
Central Shops
Karl J. Swyler
Educational Programs
*Mary White
Information Services

*** Acting**
Organization as of September 30, 1995.

Alternating Gradient Synchrotron

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Many of the staff of Brookhaven's Alternating Gradient Synchrotron (AGS) came out to commemorate their combined achievement on March 31, when this renowned scientific facility bettered its own world record for proton-beam intensity. Benefiting from the extra intensity were not only our researchers, but also about 850 scientists from the 150 outside institutions using the AGS for their experiments this year.

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