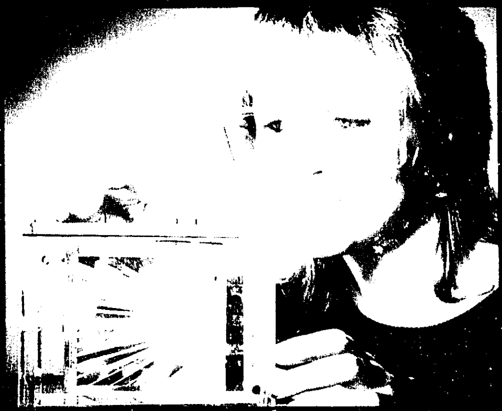
BROOKHAVEN

REPORT ON RESEARCH

1993



BROOKHAVEN

NATIONAL LABORATORY

HIGHLIGHTS

ON THE COVER: BNL scientist Geraldine Lamble collaborates with Michael Kelley of Du Pont on environmental remediation studies at the Laboratory's National Synchrotron Light Source. Using this detector and a technique called x-ray absorption fine structure, which can be done at the Light Source because it delivers highly intense and tunable x-rays, the researchers are investigating the behavior and treatment of metal contaminants in soils.

This report highlights the Laboratory's activities for fiscal year [illegible] 30, 1993. For more information about work described in this report [illegible] Affairs Office, Brookhaven National Laboratory, P.O. Box [illegible], Upton, Long [illegible] New York [illegible].

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ABOUT BROOKHAVEN

Employees number around [illegible], and about 4,000 guest scientists and students come each year to use the Laboratory's facilities and work with our staff. The Laboratory encourages technology transfer in a variety of ways, and BNL's world-renowned facilities are especially attractive to industrial companies.

Manfred Grindel (left), of Continental Optical Corporation, and BNL's Peter Takacs are partners in a Cooperative Research and Development Agreement to optimize the Long Trace Profiler for commercial applications. The instrument can detect flaws in mirrors used in synchrotron light sources, as well as in space telescopes, such as the Hubble.

Almost 50 years ago, Brookhaven was created in a partnership between the federal government and academia, to probe the most basic questions about the nature of the universe.

Those were much simpler times. Funds were more abundant and the underlying motive behind government's support of basic and applied research was clear-cut: Do it and do it first and do it best.

Today, thankfully, the last World War is fifty years behind us, the Cold War is over, and our former enemies are our present allies and colleagues. But we still compete. And this aura of friendly but fierce competition is driven largely by economics.

This is a great opportunity for Brookhaven and also a great opportunity for the U.S. to take advantage of the wealth of basic research that scientists have undertaken at the Laboratory — research that forms the nucleus of scientific knowledge that we are applying to solve some of the most difficult problems of our times.

Consider the Brookhaven scientists whose basic research into the nature of radioisotopes yielded the discovery and development of the radioactive tracer technetium-99m, which is used today in 85 percent of all diagnostic procedures in nuclear medicine worldwide.

Or consider the BNL physicists whose interest in the basic nature of superconductivity led them to patent a unique application for this phenomenon: magnetically levitated (maglev) trains. Soon, maglev could be providing high-speed rail links around the country.

And consider the Brookhaven biologists whose basic studies of the structure of DNA led this year to the announcement of a new method that promises not only to cut down on the time involved in DNA sequencing, but also to slash the costs involved — good news for the national Human Genome Project's goal of deciphering the three billion base pairs in the human genome.

Meeting national challenges is natural for a strong, sustained basic research program. And to do this, I am sure, no one has resources quite like Brookhaven's: Nowhere else can one find the unique combination of "big machines" and special laboratories that make it possible to look at scientific questions from all angles.

The National Synchrotron Light Source (NSLS) is the most used facility at BNL — and, in fact, the most used scientific facility in the world. Industrial scientists made up nearly 15 percent of some 2,600 researchers who flocked to the NSLS this year to study the material, chemical, biological and medical sciences.

To pursue questions in these fields from a complementary angle, users come to the High Flux Beam Reactor, Brookhaven's forefront nuclear-scattering facility.

In terms of longevity, our most-used "big machine" is the Alternating Gradient Synchrotron (AGS). Since it began operating in 1960, its proton intensity has increased more than a thousandfold, and heavy ions and polarized protons have been added to its particle repertoire. The leaders of three AGS experiments have won Nobel Prizes for their research here.

Perhaps similar accolades await users now gearing up to explore new worlds — oddly enough by examining the very oldest moments of the universe — when our Relativistic Heavy Ion Collider begins its reign as one of the forefront accelerators of the world, by the end of this decade.

Supporting these major facilities are many others, each smaller but with its own unique attribute.

In using Brookhaven's facilities, large and small, I believe we must strike a balance between basic and applied research. This view is shared by the Committee on Science, Engineering and Public Policy of the National Academy of Sciences, National Academy of Engineering and Institute of Medicine. In its 1993 report, *Science, Technology, and the Federal Government — National Goals for a New Era*, the committee noted:

> . . . it has proved impossible to predict reliably which areas of science will ultimately contribute to important new technologies. History is rich in examples of scientific research that have led to practical applications in areas far removed from the original work. . . .
>
> For investigators who do such fundamental research . . . the original motivation is seldom to develop new applications; rather, it is the desire to discover and to understand natural processes. . . .
>
> Modern research has done more than change the material circumstances of our lives. It has changed our ideas about ourselves and our place in the universe, about human history and human future.
>
> . . . leadership in science has become one of the defining characteristics of great nations. The United States has risen to a position of global prominence in part through its strengths in science and technology.

While we reaffirm our commitment to basic research, we must also reaffirm our mission to respond quickly to national needs. We did this in the 1970s, when the national energy cri-

sis demanded quick, innovative solutions. We did it again in the 1980s, when the Strategic Defense Initiative required a site for radiation-damage studies.

Today, a great national need is to enhance our economic competitiveness. Being economically competitive still means doing it first and best, but within tighter budgets. This has prompted us to form new partnerships with industry.

For example, the medical industry is looking our way. As the concept of a national health plan crystallizes, it has become crystal clear that medical-imaging techniques will improve medical care for all — while keeping costs down. Representative of these techniques are two Brookhaven approaches that are continually opening new windows into the brain — positron emission tomography, or PET, and single photon emission computed tomography, known as SPECT.

Another likely area for industrial participation, of course, is Brookhaven's research in biotechnology and structural biology. Led by the breakthrough in DNA sequencing, these lines of work should be rich in practical application.

What makes it possible for Brookhaven to segue so smoothly between basic research and applied technology is our highly motivated, innovative technical staff.

We have remained scientifically competitive over the years thanks in large part to the pool of talented people available to us on Long Island. In turn, to help our community remain competitive, we are an active partner in the Long Island Research Institute — a nonprofit corporation for promoting technology transfer.

Another reason for Brookhaven's success has been its commitment to the principles of Total Quality Management (TQM). The modes of operation that we have continually used in our scientific program meet all the standards of that management system. Recognizing that TQM is a great concept when properly applied and molded to each individual institution, we are also applying its principles to nonscientific areas.

We are also looking to the future of science — at BNL and elsewhere. For example, the mandate of our Center for Accelerator Physics is to study unique approaches to particle acceleration that can meet the biggest challenges in physics, both creatively and cost effectively. As a result, we're investigating next-generation light sources, neutron sources and particle accelerators.

As a multiprogram laboratory, Brookhaven has a rich history of basic research evolving into practical application, of successfully integrating basic and applied research to meet the requirements of both academia and industry. As we look to a strong future, building on this productive past, we would be wise to reflect on the foresight of Vannevar Bush, who directed the federal Office of Scientific Research and Development during World War II and had this to say about postwar scientific research:

> Since health, well-being, and security are proper concerns of Government, scientific progress is, and must be, of vital interest to Government. Without scientific progress the national health would deteriorate; without scientific progress we could not hope for improvement in our standard of living or for an increased number of jobs for our citizens; and without scientific progress we could not have maintained our liberties against tyranny.

This still holds as we prepare to enter the 21st century.

N.P. Samios

Nicholas P. Samios
Director

BNL's Office of Technology Transfer includes (clockwise from center) Margaret Bogosian, Vale Myles, Maria Yanez, Michael Furey, Arlene Wolochuk, Alison Schwarz, David Languilli and David Pascarella. Dorry Tooker is missing from the photo.

With 3,300 employees working together on first-class science research and with world-famous facilities valued at replacement cost in excess of $2.8 billion, Brookhaven National Laboratory is a tremendous resource.

For whom?

For scientists and students.

For government agencies and for universities.

For corporate giants and entrepreneurs.

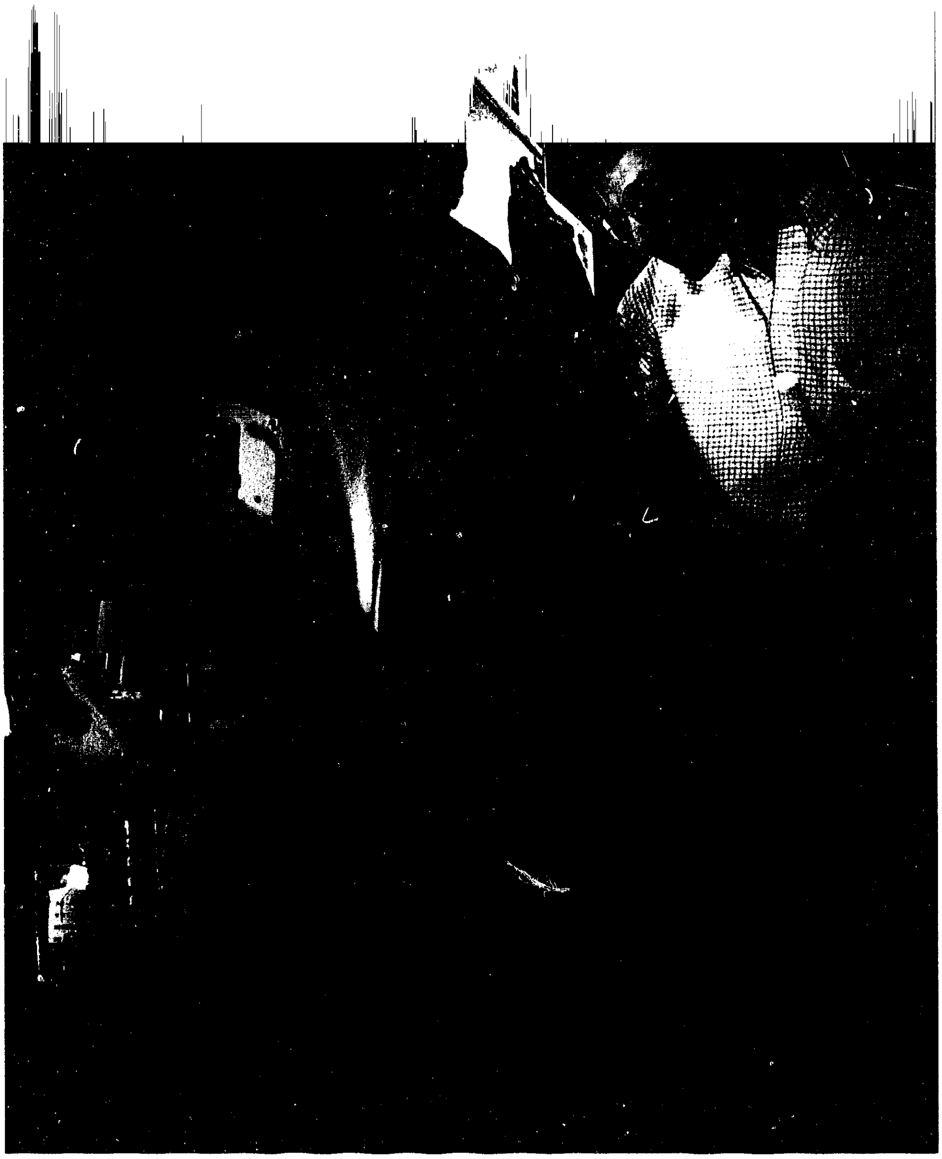
For all these and more, BNL offers unparalleled opportunities for scientific exploration.

It is the mission of the Laboratory's Office of Technology Transfer to match the new knowledge, processes and products that emerge from BNL research with organizations in the U.S.

that can use them: American industry, nonprofit research groups, and state and local governments. And, through technology transfer, *all* of America ultimately benefits from the investment this country has made in BNL since our establishment in 1947.

The economic reality of today makes this effort particularly important, as the U.S. strives to increase its competitiveness in the global marketplace.

BNL's Office of Technology Transfer oversees seven main technology transfer mechanisms: personnel exchanges with other institutions; access by visiting scientists to the Laboratory's user facilities; sponsored research funded by industry, universities, nonprofit research organizations, and state and local government; patenting and licensing; technology maturation projects; an outreach effort to acquaint industry with BNL; and cooperative research and development agreements known as CRADAs.



The CRADA between BNL and Boron Biologicals, Inc., is expected to produce cheaper boron compounds for boron neutron capture therapy, an experimental cancer treatment. Michael Makar (left) and Jeffrey Coderre prepare a cell culture to evaluate the effectiveness of a boron compound.

EMPHASIS ON CRADAS

CRADAs have become a major focus of our tech transfer effort, due to the fact that the federal government has recently enhanced its support of CRADA activity.

CRADAs are aimed at U.S. industry by joining federally developed technology or technical capabilities with the manufacturing and marketing know-how of industry. Thus, CRADAs can help boost U.S. economic competitiveness.

Costs for doing research and development under a CRADA agreement are shared between BNL and the industrial partner, with both contributing people, facilities, instruments and/or materials. The industrial partner may also contribute funds. Research results are exchanged, but patent and data rights are negotiated.

At present, BNL has 17 active CRADAs, and we anticipate that at least 15 new CRADAs will be put in place in fiscal year 1994 (FY94). A look at the dollars committed from the U.S. Department of Energy (DOE) shows the increase in CRADA activity at BNL. In FY92, $1.1 million was committed for CRADAs. For FY93, nearly $2.2 million was committed. For FY94, BNL's CRADA funding from DOE is expected to be several million dollars, with at least that amount in matching contributions from industrial partners.

In March, DOE asked the national laboratories to submit proposals for 1994 CRADAs. BNL's Office of Technology Transfer responded with 74 proposals, which covered a range of fields from materials science to biotechnology to environmental cleanup.

Each proposal met the specific DOE parameters for the 1994 CRADA request: that each CRADA have a term of one to three years; require from $100,000 to $500,000 in DOE funding each year; have matching funds from the industrial participant; use BNL's capabilities to meet industrial needs; and have promise of commercial impact, such as new products, more jobs or increased competitiveness.

In a CRADA, both the Laboratory and the industrial partner benefit from the inevitable cross-fertilization. A less formal opportunity for collaboration can occur through personnel exchanges, which in turn often lead to CRADAs.

PERSONNEL EXCHANGE

A personnel exchange gets the parties acquainted, whether it involves a BNL scientist working in industry or vice versa. For small companies, in particular, it is a low-risk way to evaluate any new venture.

Personnel exchanges also lead to a cultural exchange between BNL and industry. Through them, our researchers gain an in-depth understanding of the commitment that American companies make to research and the caliber of that research, while industrial scientists get a hands-on introduction to the Laboratory's technical capabilities.

In 1992, for example, BNL's Physics Department began a personnel exchange program with the Pennsylvania-based company II/VI, Inc., which was interested in our expertise on materials characterization applied to detectors. A year later, a CRADA was signed to develop room-temperature, solid-state gamma- and x-ray detectors. The interaction has led to the development of new methods to characterize the company's crystalline materials grown for these detectors.

The detectors are intended for industrial and medical applications, including monitoring air or liquid effluents from power plants, medical imaging and space research. It is a new area for the company, which primarily builds laser windows and optical materials for commercial and defense programs.

USER FRIENDLY

BNL's interaction with industry is enhanced in another way — through our user facilities. Available to outside researchers, these facilities are:

- National Synchrotron Light Source
- High Flux Beam Reactor
- Alternating Gradient Synchrotron
- Scanning Transmission Electron Microscopy Facility
- Double MP-Type Tandem Accelerator Facility
- Positron Emission Tomography Facility
- 60-Inch Cyclotron
- JSW 168 Small Cyclotron

Our tech transfer office puts in place the contractual agreements for use of each of these facilities. Two options are available for outside users.

Nonproprietary, usually basic, research may be performed at any of the designated user facilities, subject to scientific merit of the proposed research and availability of the facility.

Similarly, proprietary research may also be performed, but with the user paying BNL's full-cost rate for use of the machine.

For example, the Laboratory has an established eight-hour shift rate for use of a beam line at the National

Visitors to Brookhaven often remark that the Laboratory has the ambience of a university campus. Certainly contributing to that feeling is the 5,300-acre site, with large stands of woods and generous expanses of lawn. But there is a deeper reason for Brookhaven's campus-like atmosphere.

Throughout its history, BNL has been nurtured, guided and shaped by Associated Universities, Inc. (AUI), the nonprofit corporation that operates Brookhaven for the U.S. Department of Energy. As its name suggests, AUI was founded by nine northeastern universities, in 1946. It was formed as an independent corporation solely for the purpose of establishing a government research laboratory in the Northeast.

BNL was established in 1947, bringing together the resources of academia and government to build "big machines" and carry out research that would be beyond the means of a single university. The primary purpose then, as it is now, was to advance science in all frontier areas of interest to universities, industry and government. As BNL flourished, AUI turned to another area of science where the need for large centralized facilities had become of pressing importance — astronomy. In 1956, AUI established the National Radio Astronomy Observatory (NRAO), which the corporation operates for the National Science Foundation.

AUI's role in technology transfer is vital. Because AUI can retain title to inventions made at either BNL or NRAO, both laboratories see a more rapid and smooth transfer of their most promising inventions to the commercial sector. That occurs for several reasons: Industry negotiates directly with AUI, rather than the federal government. BNL and NRAO have greater freedom in making important licensing decisions. Closer interaction between the inventor and the interested commercial party is possible. Then, if additional developmental work is required, it can be started early in the process. In the end, the inventor gets personal satisfaction from seeing his or her invention enter the marketplace and also shares in the royalties if financial gains are made.

AUI is governed by a board of trustees, who are drawn from the original sponsoring institutions as well as from other universities, research labs and industrial organizations across the country. Board-appointed visiting committees provide the board with independent, expert appraisals of BNL's scientific programs. The board also elects corporate officers to carry out the day-to-day business of the corporation.

Synchrotron Light Source (NSLS). In return, the proprietary user has the option to take title to any inventions resulting from work at the facility and to treat as proprietary all data generated there.

An especially bright beacon for industry, the NSLS is used by more than 70 for-profit corporations, and 28 of these companies are doing proprietary work. With 2,600 users annually, the NSLS holds the world record as the research facility used by more scientists — from industry, universities and laboratories combined — than any other facility worldwide.

Understandably, research at the NSLS is wide-ranging: Du Pont is studying lead contamination in soils. The University of Kentucky has identified all the major molecular forms of sulfur in coal, in research aimed at determining which coal desulfurization methods are most effective. AT&T Bell Laboratories is working to improve fiber-optics communications. Exxon is probing platinum surfaces in order to design better industrial catalysts.

HELPING OTHERS

BNL's user facilities, of course, are also used by our resident staff. We can also arrange to do research for private industry, utilities, nonprofit organizations, universities, and state and local governments.

One such project is proprietary work for Hoffmann-La Roche Inc., one of the world's leading pharmaceutical companies. Our researchers are examining a new drug developed by Roche for Parkinson's disease, using BNL's Positron Emission Tomography Facility to determine what dose to give patients. Based on our results, the company has already begun clinical trials of the drug.

Doing research for outside parties is a major tech transfer tool because it makes BNL's unique facilities and capabilities available to others.

THE BASICS — PATENTS AND LICENSES

Special expertise at BNL leads naturally to patentable inventions. Associated Universities, Inc. (AUI), as contractor-operator of BNL, has the right to take title to patents that cover technologies invented at the Laboratory with federal funding (see sidebar on AUI).

To date, AUI has taken title to more than 60 inventions. They can be grouped into such areas as genetic engineering, biochemical processes, environmental remediation, radiopharmaceuticals, materials and instrumentation.

A guiding principle followed by AUI in its licensing program is to make the technologies in its licensing portfolio available to industry under reasonable license terms, thereby expediting the development and widespread use of industrial applications for the inventions.

For example, in 1986, AUI issued the first license on a patented gene-expression system that was developed in our Biology Department. To date, we have issued 142 licenses for this system based on T7 RNA polymerase in the bacterium *E. coli*. The numerous companies involved are using the method to make enzymes,

Gathered at BNL for a meeting are trustees and officers: (bottom row, from left) Carol Whitley, AUI Assistant Secretary; Michael Fisher, University of Maryland; Robert Hughes, AUI President; Val Fitch, Princeton University; Ernest Henley, University of Washington; Aihud Pevsner, The Johns Hopkins University; (second row) Jerome Hudis, AUI Vice President — Programmatic Affairs, Controller and Secretary; Vera Rubin, Carnegie Institute; John Armstrong, IBM Corporation; Marvin Kuschner, SUNY at Stony Brook; Robert Pound, Harvard University; (third row) Leland Willis, AUI Vice President — Environment, Safety & Health; Marvin Ruderman, Columbia University; Andrew Sessler, Lawrence Berkeley Laboratory; Vernon Hughes, Yale University, honorary trustee; Robert Birgeneau, Massachusetts Institute of Technology; (fourth row); Thomas Davin, AUI Vice President — Corporate Affairs; Donald Hess, University of Rochester; Barry Cooperman, University of Pennsylvania; Herman Feshbach, MIT; and Barbara Baird, Cornell University.

proteins and other genetically engineered products.

The Laboratory expects to see similar widespread use of a patented corrosion-resistive coating system, developed in BNL's Department of Applied Science. At present, the coating system has been licensed by two firms, Novamax and TRW, and numerous other companies have expressed interest in it. It's not surprising — the environmentally safe coating system, using organic polymers and zinc phosphate, protects steel surfaces against corrosion, and enhances adherence of paints and plastics to steels.

The patent licensing program fosters the commercial development of technologies developed at BNL and provides the Laboratory with a source of research funding through royalty revenue. In FY93, gross royalty revenue totaled $678,000, with approximately $147,000 of this income being available to support research at BNL.

NURTURING THE PROMISING

Promising research at BNL can now be supported by new DOE money earmarked for what are called technology-maturation projects. The money is specifically intended for internal use, to nurture a technology that has promise for commercial applications, but needs further development before industry would be interested in commercialization.

In FY93, DOE funded the Laboratory's first such project — an instrument that is being developed in our Chemistry Department, to support the field of positron emission tomography. Researchers there have developed methods for separating different radioisotopes that are used to diagnose various brain disorders. The instrument will take the radioisotopes in their raw form and process and extract them into usable forms.

REACHING OUT

Technology transfer is mandated by Congress, with the first piece of legislation dating back to 1980 (see sidebar on legislation). So, over a decade ago, the Laboratory first established a formal office to carry out technology transfer.

The initial thrust in those early years was to put together databases so that industry could find out who was doing what.

Now, BNL reaches out to industry in a variety of ways that together constitute a deliberate marketing effort to acquaint industry with the Laboratory's technology base.

We participate in exhibitions and technology conferences throughout the country. For example, we were involved in the National Technology Initiative in FY92, which was carried out through periodic exhibitions jointly sponsored by DOE, NASA, the Department of Commerce and the Department of Transportation. This initiative was a major promotional effort to acquaint U.S. industry with the technical capabilities of the federal laboratories.

We promote the publication of articles in trade journals and other media outlets.

We are members of the Federal Laboratory Consortium, which maintains an extensive database to advise U.S. companies as to where they can locate particular technical expertise in the federal laboratory system.

We do direct mailing of literature to targeted industries describing specific technologies that are ready for commercialization.

We operate the Utility R&D Center, which conducts seminars several times each year for technical representatives from utilities in the Northeast.

In 1992, to aid in making further connections with industry, the Laboratory and AUI joined with Cold Spring Harbor Laboratory and the State University of New York at Stony Brook to found the Long Island Research Institute (LIRI), an independent, nonprofit corporation for promoting technology transfer. North Shore University Hospital-Cornell University Medical College joined LIRI later.

Working with experts from the scientific and business communities, the institute's staff identifies promising technologies, evaluates their market

At the NASA 2001 Conference, held in California in 1991, Dorry Tooker (right), of the Office of Technology Transfer, spoke to conference attendees about tech transfer opportunities for industry at BNL. With her was John Dunn, who presented his research on Lyme disease.

potential and devises strategies to effect commercialization.

LIRI has targeted for initial review the fields of biology and biotechnology, medical sciences and technology, environmental and energy technologies, materials science and technology, and information technology and software.

Thanks to LIRI's making the initial contacts and bringing the parties together, BNL recently entered into a CRADA with a small Long Island company, Perfect Sense, Inc., to evaluate the applicability of a tracer technology to monitor hospital isolation wards. Developed in our Department of Applied Science, the technology uses perfluorocarbon compounds, or PFTs, which are inert and easily detected. The CRADA also involves University Hospital at Stony Brook.

THE FOUNDATION OF BASIC RESEARCH

BNL's multipronged approach to technology transfer is a mirror of the Laboratory's multidisciplinary nature. BNL carries out research in the physical, biomedical and environmental sciences and in selected energy technologies. And, while we boast about the breadth of our research, we are also proud of the depth of our work, for the Laboratory's emphasis has always been on basic research.

Basic research provides a rich brew from which any number of inventions can arise. Both the T7 RNA polymerase gene-expression system and the zinc-phosphate coating system described earlier, for example, grew out of basic research programs.

We know at BNL that the voyage from laboratory to marketplace is long and often slowed by detours. But BNL remains deeply committed to the process. In basic research, we see the foundation for goods and services of the future. And, we see the importance of technology transfer in strenthening U.S. economic competitiveness.

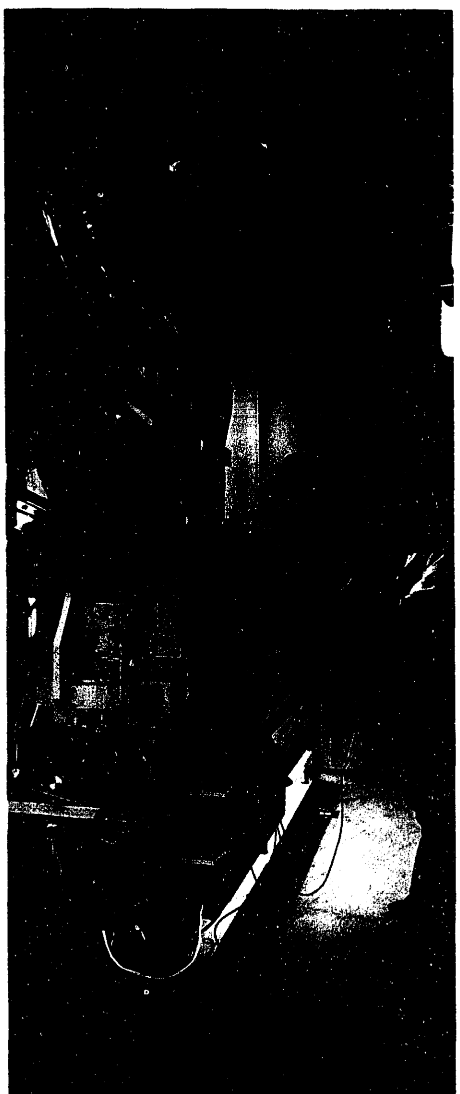
Using an electrochemical analyzer, (from left) Lawrence Kukacka, Toshifumi Sugama and Neal Carciello test steel samples treated with their patented zinc-phosphate coating system, which has been licensed by Novamax and TRW.

ACTIVE PROPRIETARY RESEARCH AGREEMENTS

Under a proprietary research agreement, a company or institution pays BNL to conduct research on its behalf. Because the company pays for all BNL and U.S. Department of Energy costs, it is entitled to any resulting intellectual property. In some cases, BNL researchers are applying BNL-developed technologies to satisfy specific industry requirements. In other cases, the Laboratory's unique equipment and capabilities are used to test a company-developed product, in an effort to speed commercialization of that product. Proprietary research agreements match BNL's unique research capabilities with technical needs identified by industry.

COMPANY	BNL DEPARTMENT	RESEARCH
Boron Biologicals, Inc.	Medical	Biological testing of new boron-containing oligonucleotides.
Costar Corp.	Physics	Preliminary design study and cost estimate for a foil irradiation facility at the Tandem.
Electric Power Research Institute	Applied Science	Perfluorocarbon tracers to locate leaks in high-pressure, fluid-filled electrical cables.
Electric Power Research Institute	Applied Science	Development of homogeneous catalysts for preparation of synthesis gas.
Electric Power Research Institute	Advanced Technology	Temperature limits determination for dry storage of spent nuclear fuel.
ESEERCO	Applied Science	MARKAL model to evaluate carbon dioxide emission control measure in New York State.
ESEERCO	Advanced Technology	The extended storage of ion exchange resins in polyethylene high-integrity containers.
ESEERCO	Advanced Technology	High-speed interactive computer simulations for PWR power plants.
Gas Research Institute	Applied Science	Material studies for preventing corrosion in condensing environments.
Hoffmann-LaRoche, Inc.	Chemistry	PET studies of the drugs L-deprenyl and Ro 19 6327, for Parkinson's disease.
LILCO	Applied Science	Corrosion protective coatings for electric generation applications.
UAW-Ford NJCHS	Advanced Technology	UAW-Ford/BNL IPAG information system demonstration project.

Brookhaven's "big machines" are a boon to scientists searching for answers to complex questions in such diverse fields as biology, chemistry, physics and materials science. The forefront facilities that form the core of the Laboratory's research programs — the National Synchrotron Light Source, the Alternating Gradient Synchrotron, the High Flux Beam Reactor and the Scanning Transmission Electron Microscope — attract over 3,500 scientists from around the world each year to perform basic and applied research at Brookhaven. Industry, universities and other laboratories use the sophisticated machines for a wide variety of specialized experiments. Brookhaven encourages collaborations with industry, and our Office of Technology Transfer assists industrial researchers who wish to use the big machines. Researchers may retain title to inventions and data generated during their work at the Laboratory by entering into a proprietary user's agreement with BNL.



National Synchrotron Light Source

NATIONAL SYNCHROTRON LIGHT SOURCE

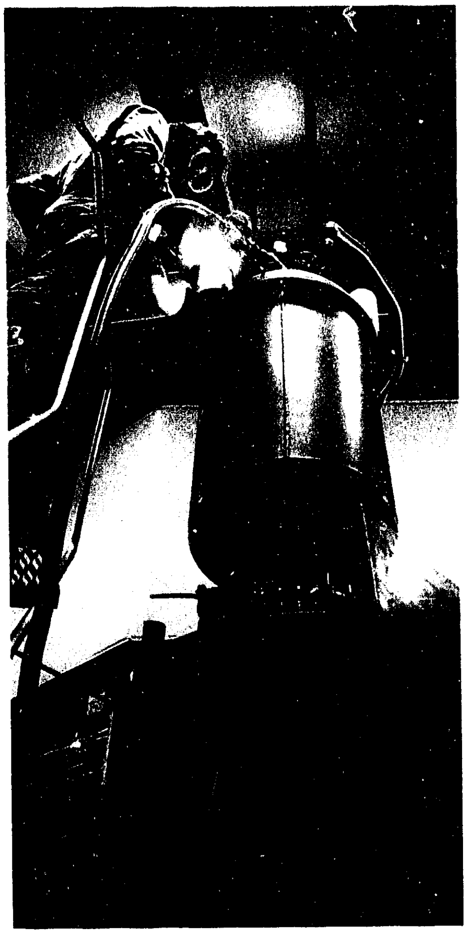
At Brookhaven's National Synchrotron Light Source — the world's largest synchrotron radiation facility — researchers use x-rays, ultraviolet light and infrared radiation to probe the atomic and electronic structure of materials.

This research has yielded advances in numerous fields, including biology and physics, chemistry and geophysics, medicine and materials science. Approximately 2,600 researchers from industry, universities and laboratories performed experiments at the NSLS during fiscal year 1993.

ALTERNATING GRADIENT SYNCHROTRON

The site of three discoveries in physics that led to Nobel Prizes, the 33-year-old Alternating Gradient Synchrotron (AGS) is still at the forefront of scientific investigation.

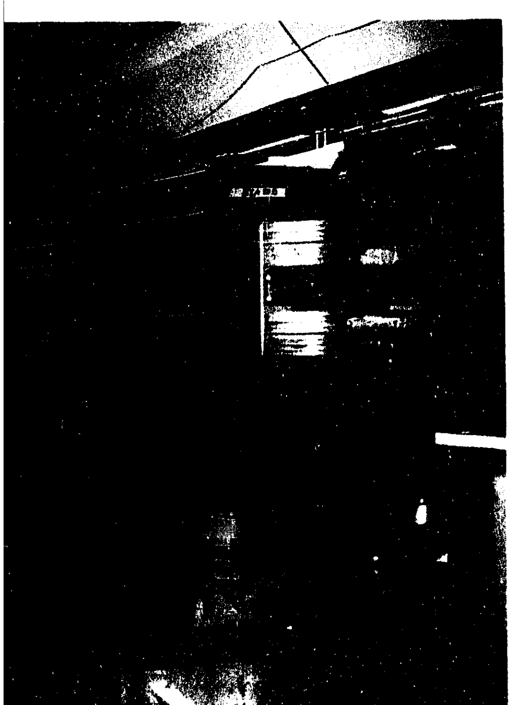
The world's most versatile accelerator, the AGS can accelerate protons to 33 billion electron volts (GeV), polarized protons to 22 GeV, and heavy ions up to 14.5 GeV/nucleon. It also produces the most intense kaon



High Flux
Beam Reactor

beams in the world, making the facility a mecca for researchers interested in performing rare kaon decay experiments. This year, about 800 high energy and nuclear physicists from 113 institutions studied the structure of matter at the AGS.

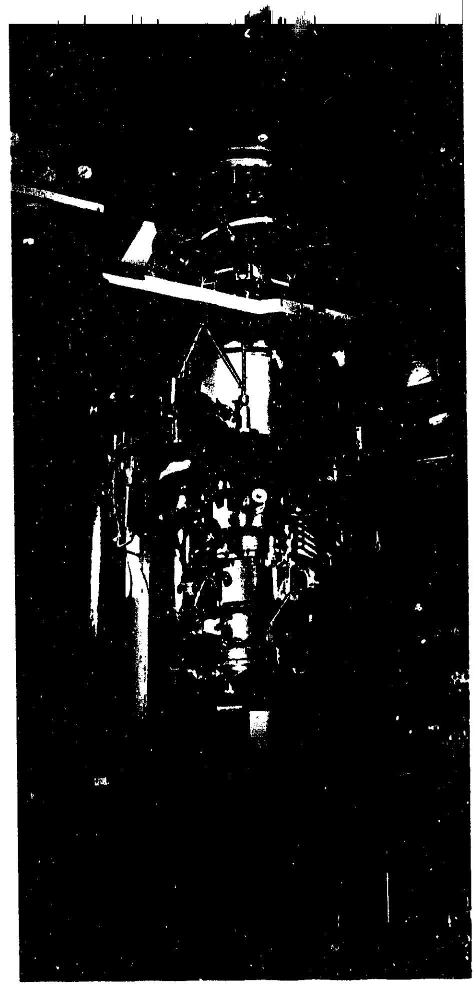
Alternating Gradient
Synchrotron



HIGH FLUX BEAM REACTOR

Since it began operating in 1965, the High Flux Beam Reactor (HFBR) has remained one of the world's premier research reactors. A worldwide community of scientists uses intense beams of neutrons produced by the reactor to conduct experiments in nuclear and solid state physics, materials science, biology and chemistry.

The HFBR operated on a reduced schedule due to safety upgrades during 1993, but still hosted about 175 scientists from industry, universities and other laboratories. During the downtime, the facility was further enhanced with the commissioning of a state-of-the-art high-resolution neutron powder diffractometer, which is used to determine the atomic structure of polycrystalline materials.



Scanning Transmission
Electron Microscope

SCANNING TRANSMISSION ELECTRON MICROSCOPE

One of three microscopes in the world that can image single heavy atoms, the Scanning Transmission Electron Microscope (STEM) is used by scientists from around the world to view biological specimens without adding heavy metals to the sample for staining or shadowing. STEM also allows researchers to determine the masses of proteins and DNA.

With a resolution of 2.5 angstroms (2.5 ten-billionths of a meter), the microscope can magnify samples up to ten million times. About 60 researchers from 35 institutions used STEM last year.

A second STEM at Brookhaven, donated by The Johns Hopkins University, is used in pilot studies for gaining chemical data using a technique known as electron-energy-loss-spectroscopy.

Two superconducting sextupole RHIC magnets arrived at BNL in August 1993, from Everson Electric Company in Pennsylvania. Inspecting one of the Everson magnets are (from left) Roy Lebel, Melvin Lindner, Jay Redding and Erich Willen.

Technology transfer was a prominent activity this year in the construction of the Relativistic Heavy Ion Collider (RHIC).

Back in June of 1992, BNL signed a $42.7 million contract with Grumman Corporation's Electronics Systems Division. Under this largest single procurement contract for RHIC, Grumman will build 373 superconducting dipole magnets.

The dipoles, along with an assortment of other magnets, will help guide subatomic particles called heavy ions as they circulate in opposite directions around two intersecting rings built in a tunnel 3.8 kilometers (2.4 miles) in circumference. Traveling at nearly the speed of light, the beams will collide head-on, creating the hot, dense plasma of quarks and gluons believed to have existed in the early universe immediately after the Big Bang.

TECH TRANSFER ON MAGNETS

Starting in September 1992, Grumman personnel came on site to work side-by-side with BNL staff in building two dipole magnets. By the time the magnets were completed, in June 1993, the Grumman people had learned the intricacies of building a RHIC dipole and in the process had come up with suggestions that would improve mass production of the magnets at Grumman.

Grumman's production facility is located in Bethpage, on Long Island. It will contain 13 major workstations, with at least one large piece of equipment at each workstation. The pre-

Fiscal year 1993 (FY93) marked the third year of construction of the Relativistic Heavy Ion Collider (RHIC), which will be the world's foremost facility for nuclear physics research. In January, the Accelerator Development Department was dissolved and its functions incorporated into the RHIC Project. RHIC's original construction schedule called for completion in 1997, with roughly $500 million in construction, research and development, and start-up funds from the U.S. Department of Energy. Because of a budget shortfall this year and greater reductions anticipated for FY94 and FY95, the schedule will be affected and the total project cost will escalate. The RHIC Project is staffed by about 320 people, including scientists, engineers, designers, technicians and various support personnel. In spite of the budget restrictions, the staff is working vigorously toward completing the project by the end of the decade.

liminary and final design reviews of Grumman's tooling were completed during the year, and BNL also started the formal review of the procedures that Grumman will use to build the magnets.

Grumman also began purchasing and installing tooling and equipment in the production area. As a cost-saving measure, the company will be using BNL's own cable insulating line, in which superconducting cable, supplied by Oxford Superconducting Technology in New Jersey, will be wrapped with kapton insulation. Delivered to Grumman in late summer, the equipment was installed and running before year's end.

Grumman has also begun receiving beam tubes, which will hold the circulating heavy ions at ultrahigh vacuum during RHIC operation. These were purchased by BNL in Germany, from Mannesmann, and checked at BNL for leaks in the vacuum before being sent on to Bethpage.

In December 1992, Grumman won a second contract, this one to build 432 RHIC quadrupole magnets, at a cost of $6 million. Thanks to another money-saving idea, BNL will be sending Grumman a machine to wind coils for the quadrupoles.

Then in August 1993, Everson Electric Company of Pennsylvania sent to BNL the first two of 300 superconducting sextupole magnets for RHIC. They hold the distinction of being the first superconducting magnets produced by U.S. industry for use in an accelerator. Everson is also building 78 special trim quadrupoles for the collider.

IN-HOUSE MAGNETS

While Grumman and Everson were busy with their magnets, the RHIC staff was also working this year on special magnets that are being built in-house.

RHIC will need 432 eight-centimeter and 78 thirteen-centimeter corrector magnets, as well as 78 thirteen-centimeter quadrupole magnets. The corrector magnets will fine-tune the steering and focusing of the beam, and the special quadrupoles will focus the beam to a tiny spot at each collision point. A production line is now operating, and four corrector and four quadropole magnets were completed before the end of the fiscal year.

ATTENDING TO THE ACCELERATOR

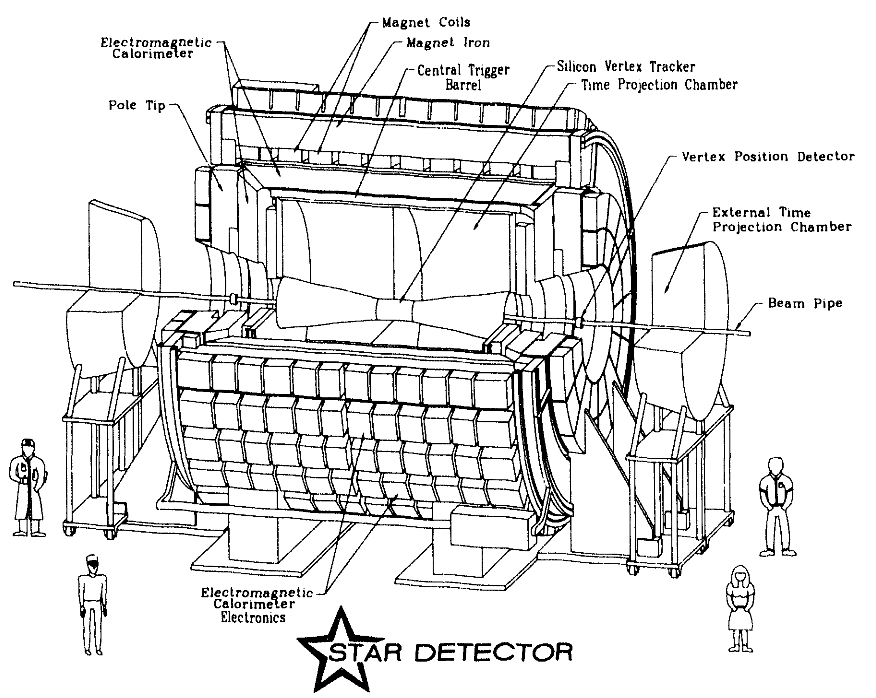
FY93 saw substantial work in the RHIC tunnel, to prepare the accelerator infrastructure for the magnets that will come in FY94.

Installation of magnet stands and cable trays was begun in the 5 and 7 o'clock sections around the circular tunnel. The cable trays will carry power for the accelerator, as well as signal cables that convey information about the beam, vacuum and cryogenics.

Civil construction, being done through the Laboratory's Plant Engineering Division (see sidebar), got under way in several locations.

The 10 and 12 o'clock areas are being built, as well as the service buildings to house utilities at the six intersection points around the ring.

Access tunnels at 8 and 12 o'clock were begun. Along with the experi-



mental hall at 4 o'clock, these access areas will be used to move magnets into the tunnel.

DETECTORS

Just as much progress was made during the year on the collider proper, the pace was quickened in the area of RHIC physics. Even though the machine has years to go before completion, the nuclear physics community who will use RHIC is working intently to complete the detectors for the first RHIC experiments.

Efforts are mainly focused on two large detectors, each a major construction project in its own right, with approximately $35 million alloted to each from the RHIC Project. These detectors will be the general-purpose workhorses of the research program.

The STAR detector is being built by a collaboration of about 160 scientists from about 20 institutions, mostly in the U.S., with a sprinkling from Europe.

The STAR collaboration received initial construction funding of $7 million, in January 1993, after the detector's conceptual design report passed a thorough, six-month review by BNL's High Energy/Nuclear Physics Program Advisory Committee and the baseline cost schedule was approved by the RHIC Project, with the concurrence of the Department of Energy.

The detector is based on a solenoid magnet and a time-projection chamber for tracking and identifying particles called hadrons. Lawrence Berkeley Laboratory will build the time projection chamber. The magnet is BNL's responsibility. Made of 1,800 metric tons of steel, with an aluminum coil, the magnet will be six meters in diameter and six meters long.

The second large detector, PHENIX, is being planned by a truly international collaboration, with over 300 researchers from about 40 institutions around the world.

The PHENIX collaboration submitted a conceptual design report in January 1993, which was subsequently reviewed and approved. Details of cost

In constructing the Relativistic Heavy Ion Collider (RHIC), the RHIC Project relies heavily on the services of the Plant Engineering Division.

It's no wonder, considering the division's charge: to meet BNL's needs for engineering, design, construction, operation, maintenance and repair of the Laboratory grounds, physical plant and associated equipment.

Close to 400 people work in the division, mostly in the trades. Specific to RHIC, the division's tasks are twofold: to refurbish the existing tunnel and to coordinate and oversee the civil construction required to complete the project.

In civil construction during FY93, the division concentrated its efforts as follows:

With the help of Ammann and Whitney, an architectural/engineering firm, and Sea Crest Construction, the division began the work of enclosing the experimental areas at the 10 and 12 o'clock regions, as well as adding access tunnels at either side of 8 and 12 o'clock. These tunnels, along with existing access at 4 o'clock, will be used to move magnets into the tunnel.

Construction work at 12 o'clock also includes preparation for a future RHIC detector. During this first phase, a 4-foot concrete base slab and headwalls were constructed. Shielding will be placed on the base slab during machine operation.

Another construction company, Carter-Melence, began working on the foundations and base slabs for the 2, 4, 6 and 8 o'clock service buildings.

During the year, Plant Engineering architects and engineers also began conceptual planning and detail design to modify the experimental halls that will someday house the large RHIC detectors — STAR in 6 o'clock and PHENIX in 8 o'clock.

The division maintains rigorous safety standards in all its work, which is also subject to independent safety checks by the Safety and Environmental Protection Division as well as the RHIC Project.

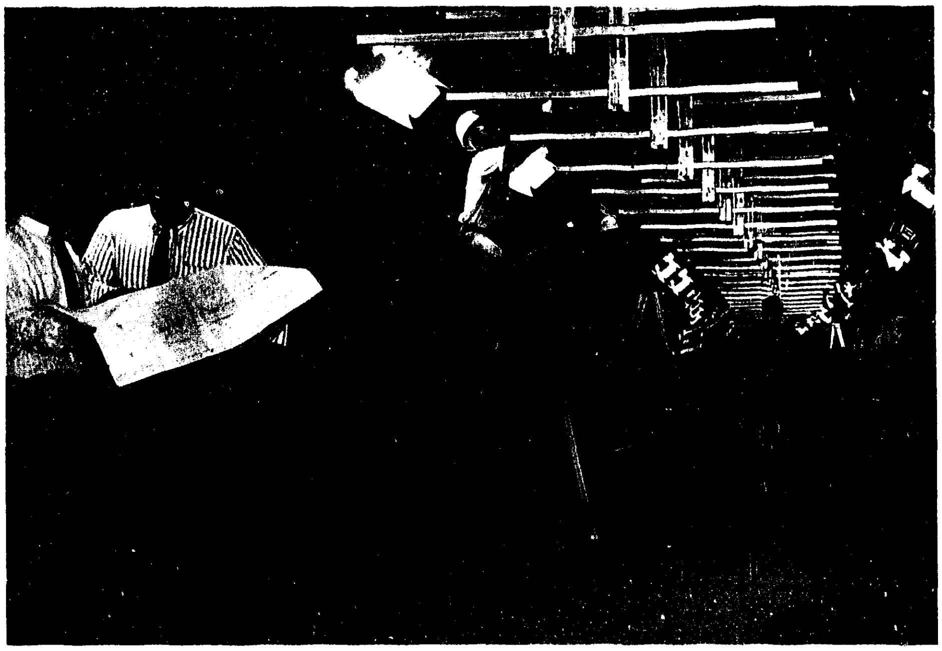
As the photo shows, civil construction is well under way at the 8 o'clock location on the RHIC ring. Plant Engineering staffers (clockwise, from bottom right) Michael Schaeffer, George Capetan, Joe Giuffre and Tom Nehring help coordinate the work.

are still to be worked out, but construction will likely begin in FY94.

Aside from the money to come from the RHIC Project, PHENIX will have the equivalent of $7-8 million contributed by the Japanese, in the form of components for the detector. The Russians will collaborate with the PHENIX team in building most of the steel structure for the magnet and also in providing another detector component.

Lawrence Livermore National Laboratory will do the engineering design for the PHENIX magnet, as well as carry out more general tasks, such as structural analysis, procurement details and quality assurance. Management of the whole experiment lies in BNL hands.

PHENIX is technically very complex because it will have many different types of detector systems, each with its own technology. Integration will be vital, and, through the next fiscal year, that issue must be thoroughly reviewed and then resolved.

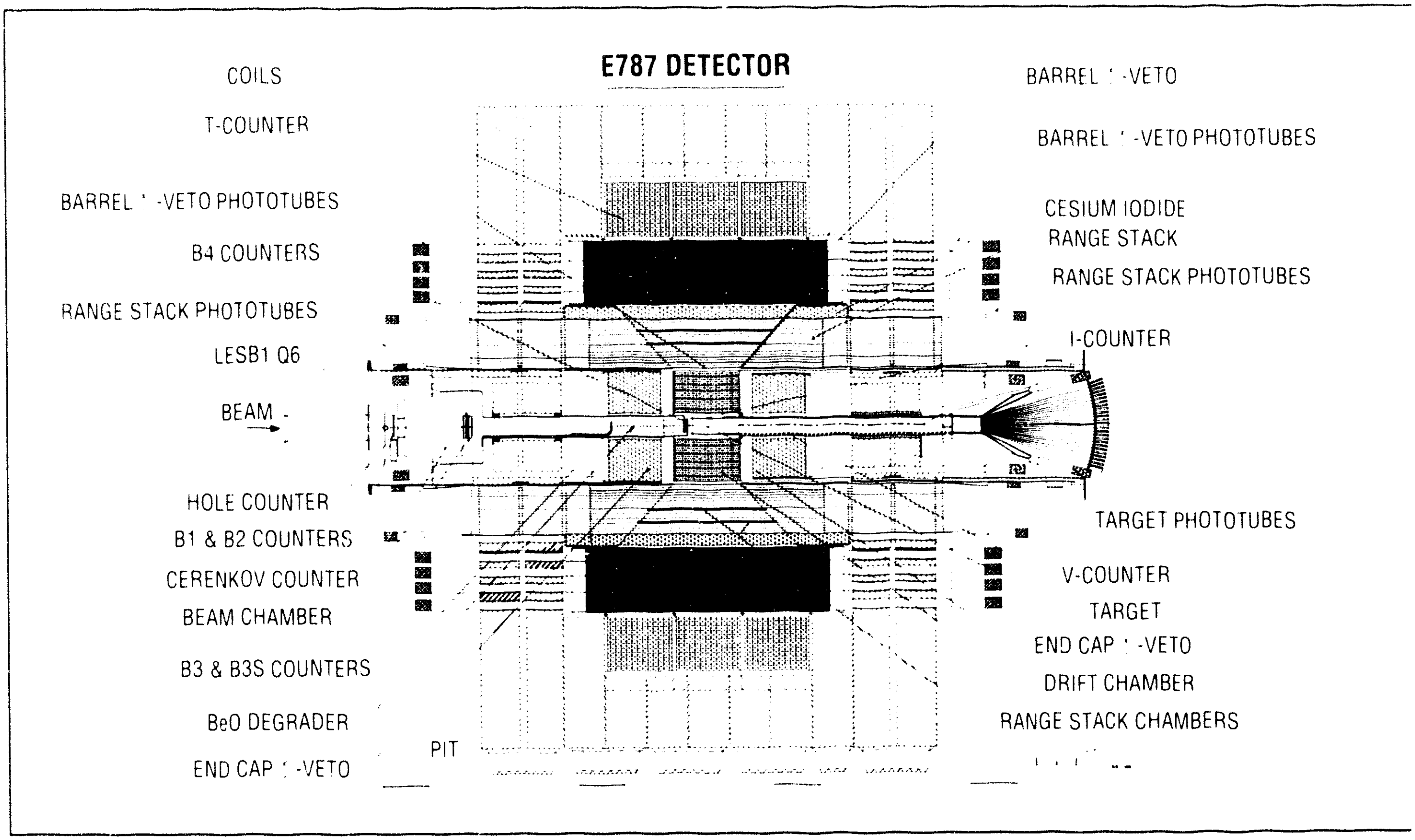


Inside the RHIC tunnel, (from left) P.K. Feng and Bob Lambiase review engineering drawings while electricians from Gordon L. Seaman, Inc., install electrical cable trays. Working for the Long Island electrical contractor are (from left) Neville Hughes, Bob Hall, Gene Everett, Jim Oliveri, (back) Rich Pitka and Brian Garcia. The bolts protruding from the tunnel floor will soon hold stands for RHIC magnets.

Satoshi Ozaki (center), head of the RHIC Project, chats with Isaac Huang (left), University of California, Davis, and Takumi Muto, Kyoto University, Japan, during the week-long RHIC School '93. Held in August, the workshop on physics and detector techniques for RHIC was attended by about 65 physicists from around the world.

SCIENTIFIC DEPARTMENTS

At Brookhaven's PET facility for medical imaging, Stephen Dewey (foreground) studies how the brain responds to common prescription drugs used to treat schizophrenia, in an effort to learn more about the biochemical mechanisms that cause certain side effects. Working with him are Don Warner and Naomi Pappas.



Schematic of the second-generation detector for Experiment 787 at Brookhaven's Alternating Gradient Synchrotron accelerator.

Winning Kaon Data

"If we win, we win, but if we lose, then we still win."

That is the motto of Experiment 787 (E787) at the Alternating Gradient Synchrotron (AGS), a collaboration involving Brookhaven, Princeton University and the Canadian laboratory TRIUMF, now joined by the Japanese laboratory KEK and the Institute of Nuclear Studies of the University of Tokyo. Like two other experiments currently at the AGS, E787 is looking for what are known in physics as rare kaon decays.

Kaons are subatomic particles made up of a pair of even smaller, elementary particles called quarks, specifically one quark and one antiquark. Because kaons are inherently unstable, they spontaneously break down, or decay, into two or more particles — and, in the process, temporarily transform into other intermediate particles that emit still more particles.

Kaons do not decay in only one way. Moreover, the frequency of any decay mode depends upon, among other things, the masses of the intermediate particles invoked along the way. Some routes are common, while others are strictly forbidden according to physics theory. Certain decay pathways, however, while not taken too frequently, do sometimes occur. Hence, when a kaon decays along a rare or forbidden route, it is called a rare kaon decay.

The AGS Department operates the Alternating Gradient Synchrotron (AGS), one of the world's most intense high-energy proton synchrotrons. Commissioned in 1960 to accelerate 1×10^{10} protons per pulse, the AGS is now more than 2,000 times more intense — accelerating 2.47×10^{13} protons per pulse, thanks to the Booster preaccelerator and other improvements. This enables particle physics experiments at the AGS to take the high-intensity route toward new physics. Accelerating heavy ions since 1987, the AGS now pushes gold ions to 11.7 billion electron volts per nucleon — a record established last year that started a new era of heavy-ion physics at the AGS and points to the future of nuclear physics at the Relativistic Heavy Ion Collider, now under construction at Brookhaven.

Since 1988, E787 has been searching for one such suppressed but theoretically allowed decay that has never been detected experimentally: a positively charged kaon decaying into a positively charged pion, a neutrino and an antineutrino. The interest in this decay centers on the fact that, when the antiquark within the kaon decomposes, infrequently it is momentarily transformed into an antitop quark — the antiparticle of the top quark, the predicted-but-so-far-undiscovered sixth quark.

If E787 spots this decay and it occurs significantly more often than theory calls for, then E787 will have discovered new physics — the "win, win" scenario.

If, however, E787 is the first to sight this decay and its measured frequency matches what has been predicted, then the experiment will have made an important confirmation of the modern physics theory of elementary particles known as the standard model. In that case, the experiment can also obtain a limit on the mass of the top quark and the coupling of the top quark to normal matter. This would be the "lose, win" scenario.

NEW UPPER LIMIT

The standard model predicts that the probability of a positively charged kaon decaying into a positively charged pion, a neutrino and an antineutrino is two out of ten billion total kaon decays. While E787 has yet to detect this specific decay, the experiment's collaborators have announced a new upper limit of 5.2×10^{-9} the frequency of this rare kaon decay, based on this year's analysis of 1989 data. Ongoing analysis of data through 1991 is expected to yield a new upper limit with three times the sensitivity.

To improve on this limit — if not to see the suppressed rare kaon decay and, perhaps, virtually spot a top quark — two things are needed: a more intense kaon beam and an upgraded, second-generation detector to perform more precise measurements.

So, to take advantage of the additional beam intensity provided by the recently completed AGS Booster and a new secondary beam known as LESB3, E787 neared the completion of detector upgrade this fiscal year. With most of its new systems completed, the second-generation detector will be ready to take data at the start of the AGS run in March 1994.

DETECT ONLY A PION

Detecting a positive pion, only a positive pion and nothing else has been the goal of both the first and second generations of the E787 experiment. Though a neutrino and antineutrino are also produced by this decay, they interact too weakly to be detected. Since a kaon often decays into a charged pion plus a neutral pion and since a neutral pion immediately decays into two photons, the experiment must be able to detect the two photons as well — to rule out their presence when claiming to sec only a positive pion.

Unlike other rare kaon decay detectors at the AGS in which the kaons decay in flight, the E787 detector stops its kaons in a scintillating fiber target before they decay. Already installed as part of the upgrade is a second-generation scintillating fiber target. It is five times brighter than its predecessor and has less than half of the non-scintillating material in which unseen background noise might hide.

The particles resulting from the kaon decays then travel through what is called a drift chamber, which measures momentum. To determine the trajectories of charged particles, the time that it takes the electrons that these particles knock off gas molecules to reach the known locations of the

Checking the connections of the range stack of Experiment 787 are: (top) Steven Kettell, (bottom, from left) Laurence Littenberg, Steven Adler, (center, from left) Kelvin Li and I-Hung Chiang.

wires within the chamber is measured.

A huge solenoid magnet surrounds the entire detector. It bends charged particles traversing the chamber in characteristic fashion, depending upon their charge and momentum. The upgraded drift chamber has five times less mass, which results in twice the momentum-resolving power of the first-generation chamber.

Around the drift chamber is an array of scintillation counters. To measure energy and range, these devices count the flashes of light produced in a fluorescent material by the ionizing radiation associated with the particles passing through. In correlating these two measurements with the momentum measured in the drift chamber, the particles can be identified. For the second-generation detector, more scintillation light is collected, and the counter array has finer resolution.

NEW TECHNOLOGY

Surrounding the counter array and forming end caps near the drift chamber are detectors that are sensitive to photon interactions. These are used to eliminate from the experiment's consideration any of the more frequent kaon decays that produce photon interactions.

The first version of the E787 detector used a sandwich of lead and plastic scintillator; the updated detector uses cesium iodide crystals. A new technology, these crystals permit better resolution of electromagnetic particles. To allow more complete vetoing of background processes that produce photons, a supplementary veto array will surround the entire range stack.

Finally, in the first-generation detector, proportional chambers embedded in the range stack improved the range measurement. In the updated version, however these have been replaced with what are called straw-tube chambers, which have five times less non-interacting mass.

Since a large window still exists between the predictions of the standard model and the new upper limit that was established this year by E787, next year, the upgraded experiment should either encounter new physics or provide confirmation of the standard model.

RECTIFYING POWER SURGES

If the lights in your house dim every time your refrigerator kicks on, then you can understand what would happen in the labs and offices around Brookhaven every couple of seconds when the Alternating Gradient Synchrotron (AGS) draws a pulse of power — if it weren't for the motor-generator and a set of controlled rectifiers.

By storing energy in its huge rotating flywheel, the motor-generator enables the AGS to cycle at a peak

Two rows of the original "excitron" rectifiers, as pictured in 1970.

power of 60 megawatts (MW) per pulse, while drawing continuous power of only 8 MW from the electric grid with only a 5 percent swing in demand. If the AGS were hooked directly to the alternating-current power line without the motor-generator acting as a buffer, drawing 60 MW per pulse would cause la ,ge voltage dips both at the Laboratory and for the electric utility's other customers.

For comparison, the average house draws a peak power of 10 kilowatts — or 6,000 times less than the peak demand of the AGS and 800 times less than it draws continuously from the electric grid.

The controlled rectifiers turn the continuous, alternating current from the generator into shaped pulses of direct current needed by the AGS magnets to produce the desired properties of the accelerator's particle beam. The rectifiers are located between the motor-generator and the AGS magnets that bend and focus particles circulating around the accelerator.

The rectifiers also return to the motor-generator most of the energy that is stored in the magnetic field of the magnets. This energy is released when the magnet cycle is turned off and is turned into mechanical energy, which increases the flywheel's rotational speed.

Though the AGS dates from 1960 and continues to be the accelerator providing the world's most intense proton beam, the 96 controlled rectifiers used until this year relied upon technology from the 1920s. While very futuristic looking, the original but-now-obsolete water- cooled, mercury-cathode rectifiers were first purchased for less than $10,000 each. Over time, however, they became irreplaceable and cost $40,000 each to repair.

THE NEXT 30 YEARS

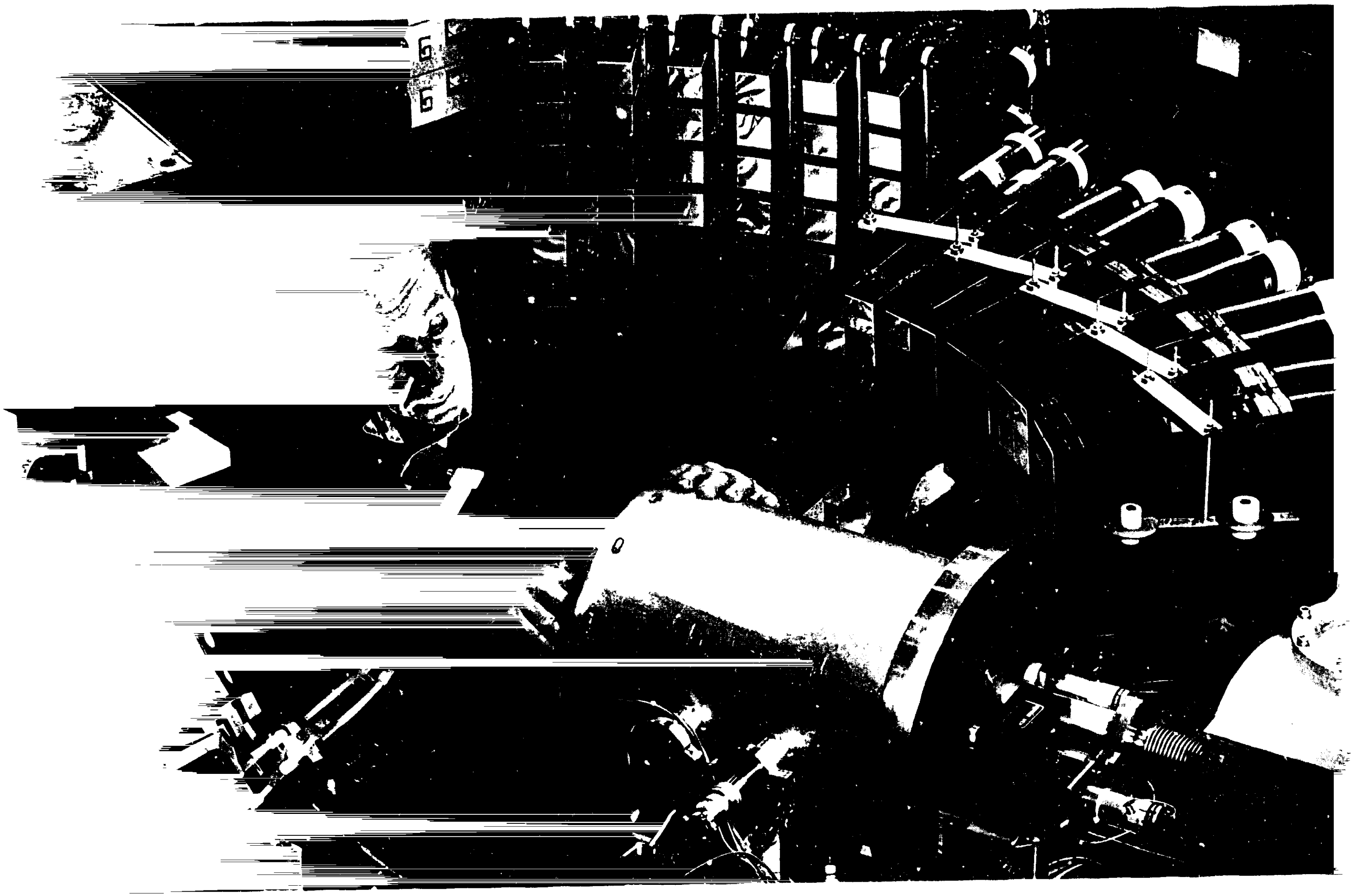
So, to help ensure the reliability of the AGS's power supply for at least the next 30 years, the 96 original rectifiers have been replaced with more modern silicon-controlled rectifiers. Following five years of design, procurement, installation and commissioning, the eight new rectifier modules first proved that they could control pulsed power to the magnets during a proton-beam run over the summer of 1993 and a heavy-ion beam run that fall.

The room that once contained eight wall-to-wall rows of 12 original rectifiers now has eight ordinary looking cabinets full of solid-state rectifier equipment, leaving half the floor space available for computer control equipment, consoles and a laboratory.

Not only has this upgrade increased the energy efficiency of the rectifier system, but it has also increased the flexibility of the accelerator's pulsed-cycle operation, since the rectifiers are now controlled by computers instead of by manually operated switches.

As a result, the AGS's magnets can be operated in any pulsed cycle desired — thus ensuring that the AGS will continue as an accelerator for high energy and nuclear physics in its own right and, in a few years, begin serving as an injector for BNL's Relativistic Heavy Ion Collider.

Replacing the original 96 "excitron" rectifiers with eight new silicon-controlled rectifiers (right, in cabinets) made space for a control room (left). Seen in the control room are: (foreground) Jon Sandberg, (left) Richard Cassella and Brian Culwick. To the right are Anastasios Saoukas (back) and Viorel Badea. Missing from the photo are Joseph Geller, Ioannis Marneris and Neils Schumberg.



Surrounded by what are called phoswich detectors, Chellis Chasman examines the cannister holding the target for Experiment 866 at the Alternating Gradient Synchrotron.

THE GLITTER OF GOLD ON GOLD

For nuclear physicists investigating extremely dense nuclear matter produced in high-energy collisions of an accelerator beam with a fixed target, nothing glitters more than gold on gold — that is, beams of gold ions and targets made of gold.

Gold is one of the 92 naturally occurring atomic elements. Strip some electrons off any atom and it becomes an ion. Heavy ions are charged nuclei of atoms that weigh more than the two lightest elements, hydrogen, atomic weight of 1, and helium, atomic weight of 4.

Since April 1992, nuclear physicists at Brookhaven have been using beams of gold ions accelerated to world-record energy within the Laboratory's Alternating Gradient Synchrotron (AGS). The purpose has been to explore dense states of nuclear

In the Physics Department, researchers study the characteristics, behavior and internal structure of matter. Experimentalists and theorists in condensed-matter physics, nuclear physics and particle physics investigate matter from the macroscopic to the submicroscopic level. Particle physicists are interested in the submicroscopic building blocks of matter, quarks and leptons. Meanwhile, 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 radiation on microchips is available to outside users.

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matter, with the ultimate goal of finding evidence for what is called the quark-gluon plasma.

An AGS collaboration that is now doing experiment number 866 (E866) has been searching since 1986 for this phenomenon. The E866 collaboration involves researchers from 11 institutions, including nuclear physicists from Brookhaven's Physics Department. Preliminary data from E866's gold-on-gold experiments were analyzed this year and have revealed more evidence for the existence of high-density nuclear matter.

In specific combinations of three, quarks make up the nucleons called protons and neutrons, which, in varying numbers, are the constituents of every atomic nucleus. Because of the nature of the force holding quarks together, quarks are confined within nucleons, and, thus, cannot be found free individually. As their name implies, gluons are the particles that bind quarks together.

Theory, however, indicates that there may be another kind of matter, in which quarks combine in larger numbers than found within protons and neutrons of ordinary nuclei. Freed from the confines of the individual nucleons, quarks would then circulate within a volume extended beyond the size of a nucleon to roughly the size of a nucleus, thus forming the quark-gluon plasma.

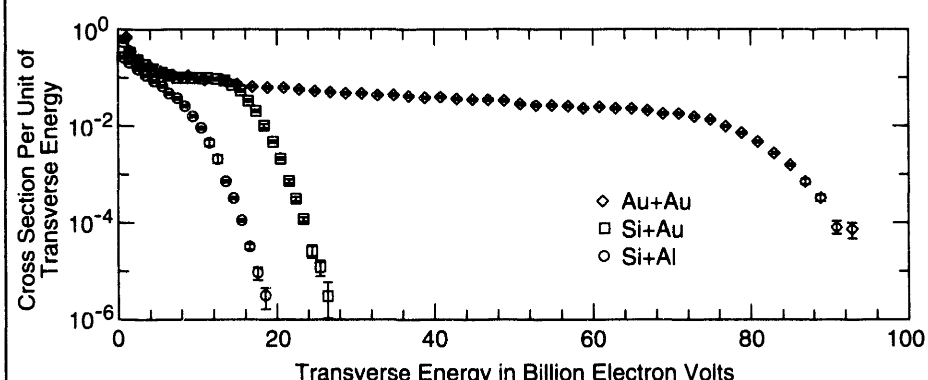
Researchers believe that quark deconfinement occurs during what is called a phase change, which is made possible by the addition of energy.

Common phase changes include the transition that occurs when heat energy is absorbed by ice to make water, and, similarly, the transition that water makes to become water vapor. Putting even more energy into the system causes water vapor to dissociate into its constituent hydrogen and oxygen atoms — a state that can be called a plasma. Similarly, nucleons within the nucleus are thought to be able to dissociate into a quark-gluon plasma under extreme conditions of energy density, pressure and temperature.

At Brookhaven, two methods are being pursued to produce conditions that are extreme enough for the formation of a quark-gluon plasma. The first, used by E866 at the AGS, involves bombarding a gold target with high-energy gold ions. These collisions produce proton and neutron densities that are about 10 times normal matter — a condition that may result in quark-gluon plasma.

The second method — and the one more favored for quark-gluon plasma production — is to collide even higher energy gold ions, as is planned at BNL's Relativistic Heavy Ion Collider (RHIC). Within RHIC, the energy will be so high that the colliding nuclei are expected to pass through one another, leaving a quark-gluon plasma with enormous energy density at very high temperature behind them. It is believed that this state will be very similar to the energetic conditions that occurred shortly after the Big Bang, the birth of the universe.

In search of evidence of a quark-gluon plasma, earlier experiments involving the E866 collaboration at the AGS used ions lighter than gold. E802, the first-generation experi-



Graph of one of the first results from E866, a measurement of the energy, transverse to the beam direction, of particles produced in gold-on-gold (Au + Au) collisions. Transverse energy, the amount of energy redirected from the initial beam direction, is a measure of the severity of the collision between the projectile and the target: the more produced transverse energy, the more severe the collision. The horizontal scale represents transverse energy; the vertical scale shows the cross section per unit of transverse energy emitted in produced particles and is proportional to the probability that an event with a given transverse energy will occur in a collision. The graph compares results from gold on gold to data obtained by earlier experiments involving silicon on gold (Si + Au) and silicon on aluminum (Si + Al). Although the total energy of the gold beam (2.3 trillion electron volts) is larger than that of the silicon beam (0.4 trillion electron volts), the transverse energy released in the gold-on-gold collision is significantly larger than was expected. From this, it is inferred that matter involved in this brief collision must be very dense.

ment, employed oxygen and silicon beams, and targets of aluminum, copper and gold to survey the broad characteristics of the reaction. The second-generation experiment, E859, continued using silicon beams, but to examine rarer events and to characterize the size of the reaction volume. E859 was made possible by the commissioning of the AGS Booster with heavy ions, in March 1992.

The heavier the ion making up the beam, the larger the volume of the mass involved in the collison of the beam with its target — and the greater the chance that the quark-gluon plasma will be formed. So, now, using the heaviest beam of ions available at the AGS — gold — and targets made of gold, E866 this year began its search with the best beam available.

Like its predecessors, E866 is interested in the general character of the collisions of ion beams and target atoms. Specifically, all three experiments have studied both head-on and near-miss collisions.

Head-on collisions are called central collisions, while near misses are called peripheral collisions. The more central the collision, the more particles that are produced. These produced particles are inventoried as to species and energy, to provide information about the type of collision and, as a result, conditions within the collision region that produced them.

It is still not known how energetic a collision would have to be to form a quark-gluon plasma. Having explored the high-nuclear-density avenue for making a quark-gluon plasma at the AGS, members of the E866 collaboration are now planning to take the high-temperature, low-nuclear-density route to when RHIC is completed in the near future.

MASTERING ALUMINUM'S MELTING POINT

Think of aluminum, and what pops into mind is the pop-top can. But think again — because pure aluminum lacks the strength and other favorable properties necessary for it to be made into beverage cans.

When, however, this lightweight silvery and soft metal is alloyed with other elements such as magnesium, silicon, copper, zinc or manganese, its increased strength and useful production properties allow it to be worked into the likes of soda cans, house siding, engine blocks, aircraft skins, cooking foil and tennis rackets.

In this way, aluminum is not unlike most metals, as most in commercial use are alloys, not pure metals.

Because of its many desirable chemical, metallurgical and physical properties, aluminum has become the most widely used nonferrous metal.

As a result, aluminum is being used as the first test case by researchers in Brookhaven's Physics Department. These condensed-matter theorists are attempting to develop a way of calculating the properties of metals and their alloys — such as the melting point, crystal structure and heat of formation — based on physics theory alone.

PHASE TRANSITIONS

In their study of substances in solid, liquid and dense gaseous states, condensed-matter physicists have much interest in the critical behavior of matter as it undergoes phase transitions. Phase transitions include not only the changes materials undergo between solid, liquid and gaseous states, but also the changes associated with certain materials as they become, say, ferromagnetic or superconducting.

With aluminum as the first metal under consideration, the first phase transition under calculation is the melting point, the temperature at which a solid changes to a liquid.

Though this phase transition is common, theorists have only recently obtained the computational power necessary to study it in any detail. So, to date, not much theoretical research has been done on melting.

The melting point is also the temperature at which the solid and liquid phases of a substance — such as ice and water — can coexist in equilibrium because the energies of both phases are the same. Using what is called the embedded-atom method and molecular-dynamics simulations, our researchers have been able to calculate the energies of both the liquid and solid phases of aluminum at their equilibrium point and, hence, the melting temperature at which this equilibrium takes place.

CLOSER APPROXIMATIONS

From experimental measurements, aluminum is known to make this phase transition at 934 kelvins (K). So far, our theorists have calculated this transition within 130 K or within 14 percent.

In attempting to refine this calculation by using more accurate theories, our researchers have centered their work this year on the distribution of electronic charge in a random array of 108 aluminum atoms.

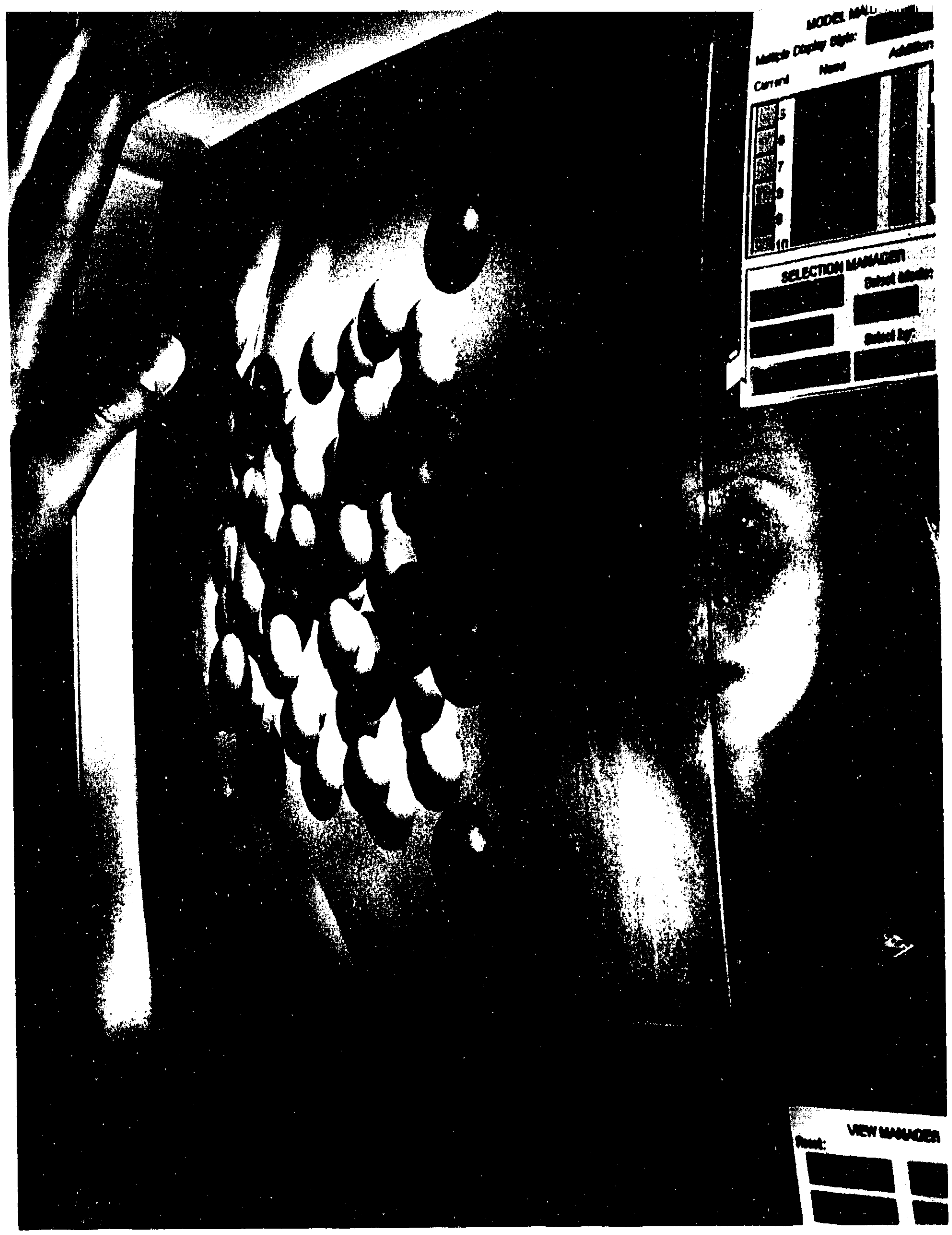
By using the computer to simulate the molecular dynamics of atoms as they melt, the phase transition could be seen in 10,000 time steps. This time study revealed that, at melting, the atoms leave their positions in the solid crystal to roam freely through the sample.

Once refined with improved algorithms and more powerful computers (see story "Supercomputer Research Parallels Grand Challenge Efforts," Interdepartmental Research, page 56), even closer approximations of aluminum's melting temperature are expected. When the right answer has been calculated for both the metal and its alloys, this method can then be used to predict the melting points of aluminum alloys that have yet to be made.

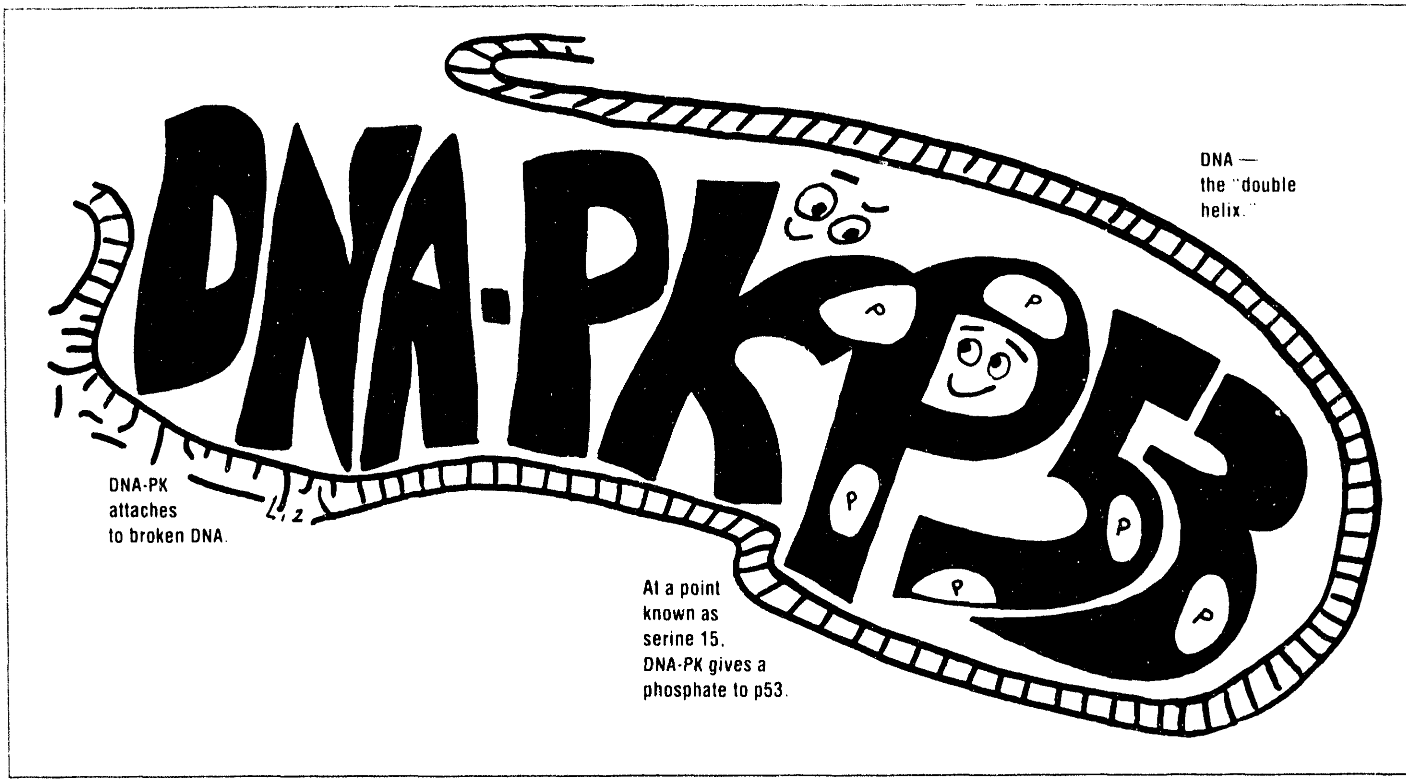
While condensed-matter physicists have an intrinsic interest in the behavior of matter undergoing phase transitions such as what takes place at the melting temperature, their basic science can be applied to determine which new alloys have the highest melting points and, therefore, the most usefulness when employed in the likes of engine blocks.

After mastering melting points, Brookhaven scientists will extend this calculation so that other physical characteristics of aluminum, other metals and their alloys can be calculated.

When this is done, the method will be useful for predicting which of those not-yet-in-existence alloys will be most stable, easiest to work with, least expensive and most environmentally sound to make into, say, pop-top beverage cans — before any money has to be invested in making and testing them.



Francine Evans, a collaborator from the State University of New York at Stony Brook, is reflected on a computer screen displaying the crystal structure of an aluminum-magnesium alloy. Within BNL's Physics Department, research on aluminum and its alloys is led by James Davenport, with Nithayanathan Chetty, Jishan Mei, Shobhana Narasimhan, Michael Weinert and others.



INTRODUCING DNA-PK — NEW INSIGHT INTO CANCER

It's 10 p.m. Do you know where your children are?

This familiar question from the start of Channel 5's late evening news reminds parents of their duty as guardians of their children.

Biologists are finding that a similar guardianship may be given to living cells by protein kinases — one of the many types of enzymes in the cell. Like parents, certain protein kinases monitor the cell's environment, including the state of DNA in the cell, checking to see if the DNA should be duplicated or if the cell should divide, and sending messages to different cellular machinery if there is trouble.

A recent estimate suggests that two to three percent of all human genes may be for protein kinases. There could be more than a thousand different kinases, each with its own function. One — the DNA-activated protein kinase, or DNA-PK for short — was discovered by a researcher from Brookhaven's Biology Department, where it is now being studied in depth.

Our researchers have found that DNA-PK is unique among the 100 or so known protein kinases in that it is activated by DNA, the material in chromosomes that carries genetic information. While many enzymes use DNA as a substrate to work on or as a template for copying the information stored in chromosomes, DNA-PK is different — it uses DNA as a signal for action. Our biologists believe that, when DNA is damaged or when several enzymes want to use the same DNA segment at once, DNA-PK may provide cells with a way to adjust the activities of enzymes or other proteins that interact with the DNA.

Protein kinases work by adding a phosphate group to proteins, which changes the protein's structure slightly and can change its biochemical activity. To learn more about how DNA-PK works, we are looking at the

Research in the Biology Department encompasses studies on molecular structure and genetics, DNA damage and repair, and cell biology of plant and animal systems. The department maintains the Scanning Transmission Electron Microscope facility and also operates experimental stations for molecular structural studies at the National Synchrotron Light Source and at the High Flux Beam Reactor. Research interests range from fast new techniques in x-ray diffraction experiments to skin cancer studies and DNA sequencing.

sites where phosphate groups are attached to proteins.

DNA-PK has been found to add phosphates to several of the DNA-binding proteins in the cell's nucleus. One of the most exciting recent Brookhaven findings is that DNA-PK can add phosphates to a protein called p53, which regulates cell growth. This discovery is extremely interesting because cells from almost all human cancers contain mutant p53 genes.

All cells contain two copies of the p53 gene, which manufactures p53 protein. If both genes are healthy, the p53 proteins they make help suppress tumor formation and growth. They act by binding to DNA and preventing a cell from making certain proteins that are required for cell growth. Hence p53 is called a tumor-suppressor.

If, however, one or both p53 genes become mutated so that the cell can no longer make good p53 protein, then cells can grow when they should not. Thus, mutation of p53 can be an important step to cancer.

Because p53 contains several sites at which phosphates can be added, it is likely that protein kinases are involved in controlling the way p53 functions. We started looking to see if phosphate could be added at any of these sites by DNA-PK.

Before a protein can be phosphorylated, a kinase must recognize its target protein substrate by certain features. One of these is a particular sequence of amino acids, the blocks from which proteins are made. By isolating and identifying small fragments of the p53 protein that contain phosphate groups, our researchers, working together with colleagues at other institutes, have been able to identify most of the sites where phosphate can be added to the p53 protein.

While Hong Zhang (back) selects phage-containing fragments of the DNA-PK gene, Carl Anderson (right), who discovered DNA-PK, Margery Connelly (front) and John Sipley examine a new peptide substrate for it.

Our biologists identified two sites where phosphate can be added specifically by DNA-PK — the amino-acid serine at positions 15 and 37 of the p53 protein. These serines are in a segment of the p53 amino-acid sequence that interacts with the genes' information-copying machinery that enables proteins to be made.

Even more interestingly, they found that, when mutant p53s from tumor cells do not work with the gene expression machinery, they are improperly phosphorylated at one of the DNA-PK sites. Research is now focused on finding out whether this is a cause or an effect, and whether phosphate at these sites alters the way the p53 protein interacts with the gene expression machinery.

A significant technical difficulty in studying DNA-PK has been the lack of a simple, specific assay for the enzyme — that is, an experimental procedure to find out if the enzyme is present, and, if so, in what quantity. Using the information learned from their studies on p53, our biologists developed a simple, rapid assay for DNA-PK and are now working on another assay to find out precisely when DNA-PK becomes active in living cells. This information would be invaluable in understanding how DNA-PK functions.

We are also working to isolate the gene for DNA-PK, which will help determine if, like the p53 gene, it is mutated in certain human diseases.

Knowing how cells monitor their DNA and how cell growth is controlled is critical for understanding causes of cancer and many other human diseases — and for developing better treatments. Exploring DNA-PK's function, its connection with DNA damage and cell growth control, and new genes for DNA-controlled enzymes promises to extend present knowledge significantly in these areas.

MUTANT SITES REVEALED IN KEY PROTEIN

From time immemorial, when living cells have needed to make protein, a fundamental component of the cell — the ribosome — rolls up its sleeves and gets to work.

So, since protein is essential to life, ribosomes are very ancient. In fact, they are so old that the ribosomes of bacteria and humans, for example, have diverged considerably over the course of evolution.

This divergence explains how many antibiotics work. They act on bacterial ribosomes, preventing the spread of disease, yet without affecting the ribosomes in the human cells nearby.

A problem has arisen, however — certain bacteria have become resistant to an antibiotic.

Researchers in Brookhaven's Biology Department, along with colleagues from Duke University Medical Center, are the first to have determined the structure of one key ribosomal part — the protein S5. Strangely enough, ribosomes not only make protein, they also contain 50 protein molecules as well as three ribonucleic acid (RNA) molecules. All these are combined to form the two subunits that make up the ribosome.

S5 is located on the smaller subunit, and this research has provided the first high-resolution information about this subunit. The information revealed will be essential to an eventual understanding of the complicated method whereby ribosomes translate the genetic code into protein.

To determine the structure of S5, the biologists used x-rays from Brookhaven's National Synchrotron Light Source. There, we have produced an x-ray beam line specifically for studying the structure of large biological molecules. We have also developed special instrumentation that allows the x-ray wavelength to be tuned accurately, an important feature for the success of this work.

RIBOSOMES AND ANTIBIOTICS

An effective antibiotic is thought to bind to a specific part of a bacterial ribosome's RNA and distort it, preventing the distorted ribosome from working normally — thus, killing the bacteria. Human cells are not harmed because of the significant differences between the shapes of bacterial and human ribosomes.

But bacterial ribosomes can become resistant to an antibiotic. For example, streptomycin, once widely used to treat tuberculosis, is virtually useless today because most TB bacteria have become resistant to it.

This situation is the result of mutations. In the bacteria's ribosomal protein, mutations arise that can compensate for the antibiotic's distortion of the ribosome. Therefore, the ribosome can still function, even with an antibiotic present.

In protein S5, for example, mutations occur that make the ribosome resistant to spectinomycin, an antibiotic used to fight gonorrheal infections. Other mutations in S5 change the way that it responds to streptomycin.

MUTANT SITES LOCATED

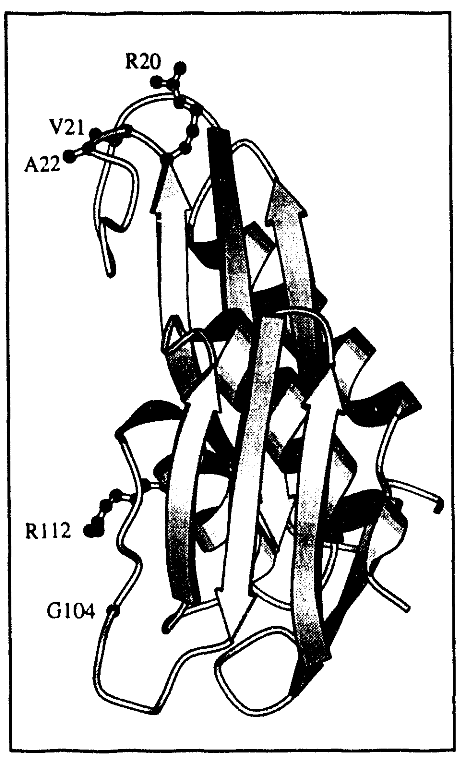
The researchers at Brookhaven were the first to locate the sites of such mutations in a three-dimensional study. As a result, it will be possible for investigators to start analyzing how the mutations have their effect.

Ribosomes are interesting in another way — as the center of a paradox in which something that is itself made up of proteins is used to make proteins. Early in the evolution of life, ribosomes were probably made up of RNA alone. Scientists hope to find out how ribosomal proteins evolved and became part of the protein-making machinery.

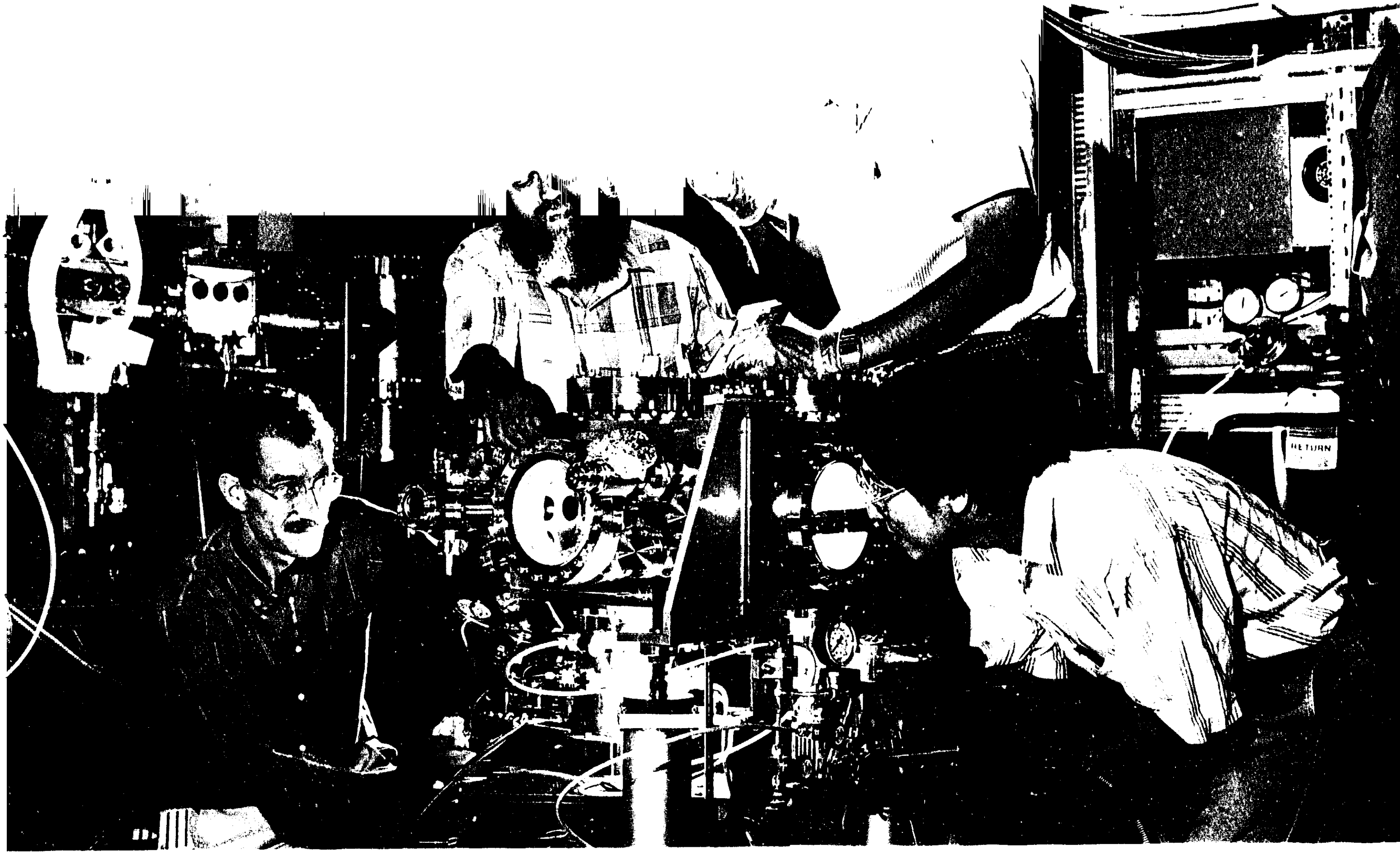
Also, ribosomes are an ideal model in which to study how proteins and RNA recognize each other. This interaction is important in many processes, such as the life cycle of RNA viruses — for example, the AIDS virus.

At Brookhaven, work will continue uncovering the structure of other ribosomal proteins and also understanding how these proteins bind to RNA.

Venki Ramakrishnan, Sue Ellen Gerchman (left) and Helen Kycia look at a computer-generated picture of the ribosomal protein S5, obtained from x-ray diffraction data. S5 was originally crystallized in 1983 by Stephen White, of Duke University, who now collaborates on this research with the Biology Department team.



Structure of the S5 molecule, shown as a "ribbon diagram" that follows the protein chain. The marked sites, when they mutate, change the ribosome's response to antibiotics.



At beam line X13 at Brookhaven's National Synchrotron Light Source, (from left) Jerome Hastings, Peter Siddons, Erik Johnson and Chi-Chang Kao align the high-vacuum reflectivity apparatus.

NSLS ATTRACTS MAGNETISM STUDIES

Although magnetism was discovered more than 2,600 years ago, scientists have only begun to understand the phenomenon during the last 70 years. And, it is just within the last decade that synchrotron radiation has been used as a probe to explore magnetic materials on the atomic scale.

Today, research in magnetic materials is crucial for developing state-of-the-art magnetic recording devices for the $40 billion recording industry. Magnetic thin films, just a few atomic

The world's foremost facility for scientific research using x-rays, ultraviolet and infrared radiation is operated by the National Synchrotron Light Source Department. In a single year, a total of about 2,600 researchers from almost 450 institutions perform experiments at the world's largest source of synchrotron light. Guest researchers often work in collaboration with staff scientists at the Light Source, conducting a wide range of innovative experiments in physics, chemistry, biology, materials science and various technologies.

layers thick, are needed in both the storage media and the recording heads of all popular recording devices, including tape recorders and computers. They are also a crucial component in specialized recorders for collecting data in research, industrial and military applications, and they are used in devices for transmitting data from satellites and spacecraft.

Since the 1980s, several new techniques for probing magnetism have been developed at Brookhaven's National Synchrotron Light Source (NSLS). These innovative methods allow researchers to study the phenomenon in more detail and with better accuracy and precision than ever before. So far, researchers from approximately 25 institutions — from BNL and IBM to the University of Munich in Germany — have performed studies on numerous magnetic materials at the NSLS.

X-RAYS: POWERFUL MAGNETIC PROBES

Traditionally, neutron probes have been used to gain information on the atomic structure and interactions in magnetic materials. In the 1970s, researchers from AT&T Bell Laboratories were the first to theorize that magnetic structure also could be investigated using x-rays.

Few experiments were performed at that time because x-ray sources were not powerful enough to be used routinely as atomic-scale probes. But, in the 1980s, with the commissioning of such high-brightness synchrotron sources as the NSLS, researchers began to use x-rays to gain new data on magnetic materials.

On an atomic scale, a material's magnetism is attributed to the orbital motions and spins of electrons in its atoms. This is true of any magnetic material, including about one-fifth of the elements in the periodic table that are naturally magnetic, and the thousands of magnetic alloys and compounds.

The nucleus of an atom is surrounded by electrons that both spin, or rotate, on their own axis, and travel in an orbit around the nucleus, much as the earth spins on its axis and travels in an orbit around the sun. A material's magnetic moment is the sum total of all its electrons' orbital motions and spins.

Certain properties of magnetic materials that are important to their functioning can best be investigated with x-rays. In addition, extremely small samples can be studied using x-rays, while studies that use neutrons as probes, such as those conducted at Brookhaven's High Flux Beam Reactor, require relatively large samples.

Other advantages of using x-rays to probe magnetic materials are that they provide high resolution and are therefore sensitive to even slight structural distortions. Further, the x-ray beam polarization and energy can be chosen to meet the requirements of a specific experiment.

Polarization involves the alignment of x-ray beam components, which can form a linearly or circularly polarized beam. In general, when x-rays are directed onto a sample, the beam is scattered. By measuring the intensity and polarization of the scattered x-rays, researchers can learn about the spin and orbital contributions to a sample's magnetic moment.

The ability to perform these measurements will be significantly enhanced when BNL and Argonne National Laboratory complete their design and construction of a polarized wiggler at NSLS beam line X13. Scheduled for completion in 1994, this combined permanent magnet/electromagnetic device will provide circularly polarized x-rays, which are particularly sensitive to the spin of electrons in magnetic materials.

In 1987, Brookhaven, AT&T Bell Laboratories and Cornell University researchers discovered another phenomenon that expanded the usefulness of x-rays for probing magnetic materials. While tuning a polarized beam to different energies in an x-ray scattering experiment, they noticed that there was a dramatic increase in the scattering signal when the incident x-ray energy was tuned to the absorption edges of the sample — the energies at which the absorption of x-rays markedly changes. Consequently, the magnetic properties of materials such as thin films, or those with small magnetic moments, can be probed at synchrotron sources.

VARIED TECHNIQUES, DIFFERENT DATA

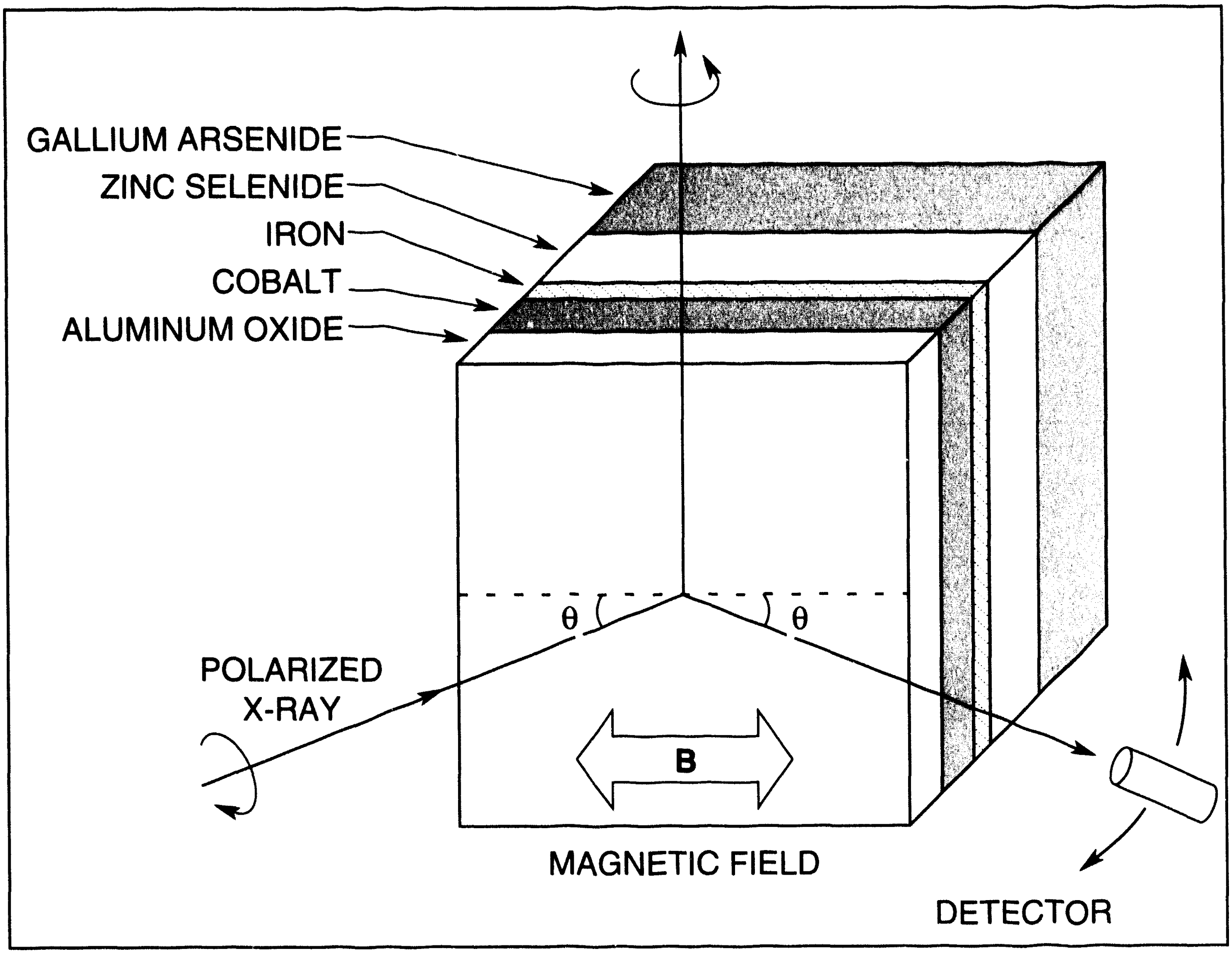
At the NSLS, materials as diverse as the rare-earth metal holmium and multilayers of iron-chromium-iron are studied using seven different techniques (see chart). To investigate fully various structural and electronic properties of magnetic materials, often three or four techniques might be used on a single sample.

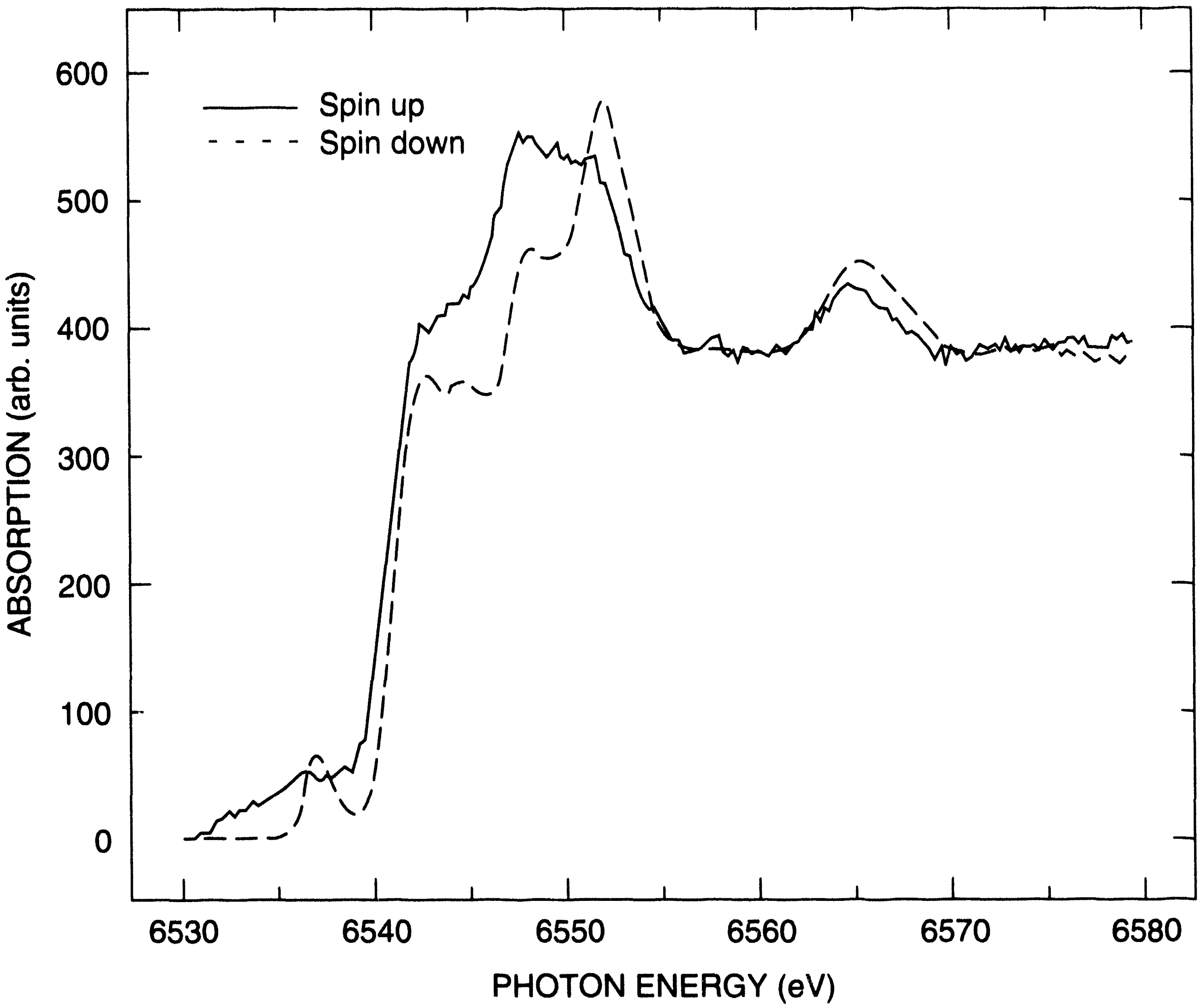
Scattering and magnetic reflectivity are x-ray techniques that reveal magnetic structure — the orientation of the magnetic moments of the atoms in a material. In ferromagnetic materials, the magnetic moments spontaneously organize in a parallel direction, while in antiferromagnetic materials, magnetic moments are aligned antiparallel to each other. This structural information is important for determining possible applications.

Each magnetic material has its own critical temperature below which the magnetic moments are ordered, either ferro- or antiferromagnetically. Scattering is also the best x-ray technique for studying the details of this ordering as the temperature is varied near the critical temperature.

Except for nuclear resonance scattering, a technique that includes the excitation of nuclei, the remaining techniques — spin polarized photoemission, magnetic circular dichroism, the Faraday effect, and spin-resolved x-ray absorption fine structure — are all forms of x-ray spectroscopies, which involve the excitation of electrons. Depending on the magnetic properties of the sample, this excitation is manifested as x-ray absorption or emission of radiant energy. These techniques give insight

In magnetic reflectivity, also known as soft x-ray magneto-optical Kerr effect, x-rays hit the multilayer sample and are reflected onto the detector, which measures the reflected intensity of light as a function of photon energy, polarization, incident angle and direction of the magnetic field. Element-specific magnetic moments and their distribution can be determined using this technique.





Spin-resolved x-ray absorption fine-structure measurements show the difference in photon absorption between spin-up and spin-down states in manganese fluoride. This technique allows researchers to determine the distribution of magnetic states in a material.

into the spin dependence of the energy spectrum of magnetic materials.

X-ray spectroscopies enable researchers to look in detail at the separate contributions made by the electron orbit and electron spin to a material's magnetic moment — data that are important for understanding how a magnetic material functions. These techniques are complementary to structural determinations, since they allow scientists to delve into the underlying reasons why magnetic structures evolve in particular ways.

Over the last decade, the NSLS has been a focal point for developing pioneering techniques to probe magnetic materials. Most likely, new techniques will emerge that provide more insight into magnetism — the industrially valuable but not-completely-understood phenomenon discovered over two-and-a-half millennia ago.

SPIN POLARIZED PHOTOEMISSION — Probes thin films of magnetic materials, just a few atoms thick, and multilayers, which are thin films sandwiched together. An intense flux of photons excites electrons in the sample, and they come out spinning, either up or down. When the electrons hit a gold atom target, the direction of their spin can be determined to reveal information about the magnetic properties of the sample.

U5

MAGNETIC CIRCULAR DICHROISM (MCD) — Used to determine, with element and site specificities, the electron orbital and spin contribution to the magnetic moment of transition metals and rare earths. MCD is the difference in the absorption of light by magnetic systems using circularly polarized light in which an electric field rotates in either a left or right direction. The absorption of soft x-rays depends on the polarization of light and the relative direction of the sample's magnetic moment.

U4B

FARADAY EFFECT — Describes the rotation of the plane of polarization of an x-ray beam as it passes through a magnetic sample. Measures essentially the same quantities as MCD (see above), but this technique does not need circularly polarized x-rays, and, without requiring correction factors, is capable of providing absolute measurements. The technique is limited to measurements in the 6 to 12 kilo-electron-volt range, but this covers most magnetic elements of interest.

X12A, X27A

MAGNETIC REFLECTIVITY — Similar to MCD (see above); measures the magnetic moment of solids, alloys, thin films or multilayers. It also measures the distribution of magnetic moments in the sample. Photons hit the sample and are reflected onto a detector, which measures the reflected intensity of light as the photons' energy and angle are changed. The reflected intensity allows researchers to determine the orientation and distribution of the sample's magnetic moments.

U4B, U13UA, U15

SPIN RESOLVED X-RAY ABSORPTION FINE STRUCTURE — Measures energy of unoccupied electronic orbits of a magnetic material. When photons hit the sample, electrons are knocked out of occupied orbits into unoccupied ones. By looking at different x-ray emission energies, researchers can separate spin-up and spin-down electronic states. Magnetic materials show energy differences between these states.

X25

SCATTERING AND RESONANT SCATTERING — Used to determine magnetic structure of surfaces, multilayers and bulk solids. X-rays hit the sample, scatter, and an analysis of the intensity of scattered x-rays gives the positions of magnetic moments in the material. When the x-ray energy is tuned near the excitation energy — the energy at which electrons move from one orbit to another — the magnetic scattering signal becomes much larger. This effect is called resonant scattering.

X14, X16, X20, X22, X23, X25

NUCLEAR RESONANT SCATTERING (MÖSSBAUER EFFECT) — Measures the splitting of nuclear transitions, or changes in the energy states of a nucleus, in certain isotopes. Through the size of this splitting, the strength of the magnetic field at the nucleus of the isotope — for example, iron-57 — is measured. Earlier Mössbauer experiments traditionally used radioactive sources. The recent use of synchrotron radiation has many advantages: Samples in confined environments, such as high-pressure cells, can be used; field directions as well as magnitudes can be determined.

X12, X14, X25, X27

A large collaboration is studying the surface magnetism of thin films, such as cobalt-copper-cobalt multilayers. These films may be used in magnetic memory technologies, including cassette tapes, compact discs and computer storage discs.

Argonne National Laboratory; AT&T Bell Laboratories; BNL; IBM; National Institute of Standards and Technology (NIST); SUNY Stony Brook; U. of Texas

The technique is used to probe the magnetic structure of a wide variety of systems, including surfaces, thin films, alloys, ferrites and proteins. For example, AT&T Bell Laboratories researchers found that a film less than one-atom thick of chromium and iron is magnetic and its magnetic moment is antiparallel with that of iron.

AT&T Bell Laboratories; BNL; U.S. Naval Research Laboratory (NRL)

BNL and Ames Laboratory researchers measured the Faraday effect of holmium in a holmium-iron compound in order to understand the nature of the electronic transitions responsible for magnetism to occur in it.

Ames Laboratory; Argonne National Laboratory; BNL; U. of Manchester, England

BNL, together with AT&T and the Naval Research Laboratory, is studying various cobalt thin-film multilayers to understand the alignment of the magnetic moments and their relative orientation within the various layers of the sample. These multilayers are potential candidates for future recording heads in computers.

AT&T Bell Laboratories; BNL; European Synchrotron Radiation Facility (ESRF), France; NRL

BNL researchers used a manganese fluoride sample to develop this technique. At room temperature, they made spin-resolved measurements of the material. As shown in the figure on page 37, there is a clear difference between the states with spin-up and spin-down.

BNL; University of Helsinki, Finland

Many groups have studied the evolution of magnetic order as the ordering temperature is varied. Above the ordering temperature (T_C), critical fluctuations are observed. Below T_C, the rate at which the average magnetic moment increases with decreasing temperature gives insight into the ordering process.

AT&T Bell Laboratories; BNL; European Institute of Transuranium Elements, Germany; ESRF; IBM; Massachusetts Institute of Technology; McMaster U., Canada; NRL; NIST; Oak Ridge National Laboratory; Rice U.; Risø National Laboratory, Denmark; U. of Keele, England

BNL, Cornell University and SUNY Stony Brook researchers found changes in the magnetic field of iron as its temperature changed. As the temperature increased, the intensity of the detector's signal oscillated, and the oscillations became slower as the field became weaker.

BNL; Cornell U.; SUNY Stony Brook; U. of Hamburg, Germany; U. of Munich, Germany

Developing a MARKAL model for China are (from left) BNL's Samuel Morris and John Lee (seated), Shoufeng Zhao from the China Institute of Nuclear Industry Economics, Beijing, and Xiaolin Xi from Lawrence Berkeley Laboratory.

MARKAL — READY TO GO!

When planners and policymakers have to decide on the best way to get energy for a particular purpose, they face an almost endless array of questions:

- Would coal cost less than hydroelectric power?
- Will oil reserves last until 2025? Or longer?
- What about the environmental effects of a new gas plant?

These are tough questions, with complicated answers. Plus, if it takes too long to get those answers, then they become out-of-date and possibly irrelevant.

From our Department of Applied Science, however, comes MARKAL to

Research activities in the Department of Applied Science encompass programs in health and mathematics as well as energy science, technology and the environment. Projects range from developing a coating system to reduce corrosion of steel surfaces, to measuring the rate of removal of atmospheric pollutants in convective rainstorms, to investigating phase relationships in various high-temperature superconductor systems — all demonstrating the depth of basic research that underlies the broad vision required by applied science.

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the rescue. A powerful, flexible computer model of boundless energy, MARKAL is a practical tool built to help utilities, industries or governments analyze complex energy questions in a reasonable time.

And now, thanks to recent innovative work by Brookhaven researchers, this "Superman" power is contained in a user-friendly, "Clark Kent" package. MARKAL's complex technology, which once ran only on a giant, main frame computer, has been made accessible on personal computers — compact and ready to go.

Short for MARKet ALlocation, MARKAL is a computer model that represents the vast network of an energy system. It was designed at Brookhaven in the 1970s at the request of the International Energy Agency, for use in a program to analyze energy systems composed of many different technologies.

In the early days of the model, additions and corrections were tested and used almost instantly in a cooperative venture of more than 15 countries ranging from Japan to Sweden to the United Kingdom. Since then, it has remained in continuous, worldwide use.

As a result, MARKAL is dependable and flexible enough to analyze national, state, provincial or local energy systems. It also presents results consistently so that comparisons are easier to make.

To construct an energy system that satisfies specified energy services, the model selects from its database the least costly technologies and resources that will meet required environmental and resource constraints. It demonstrates the most efficient use of existing facilities and plans ahead for new investments.

The user must load the appropriate facts in the database — and interpret the implications of the technically feasible paths identified by MARKAL.

In a recent example of what MARKAL can do, our researchers studied the best way of cleaning coal to reduce carbon-dioxide emissions. We evaluated several different methods of reaching the reduction target, including, for example, switching from coal to gas or to renewable energy sources such as solar power.

In one procedure, carbon dioxide is "scrubbed" from the gases being emitted from the power plant chimneys. MARKAL showed that, from present data, using already existing carbon-dioxide scrubbers would cost less than some of the more expensive renewable fuels. This kind of information is very useful to utility planners.

Brookhaven scientists are now working with the U.S. Department of Energy to use MARKAL as the basis of a congressionally mandated, least-cost energy strategy.

MARKAL has yet other advantages. In collaboration with experts at Stanford University and Chalmers University in Sweden, MARKAL was coupled with a powerful economic computer model to form a new model called MARKAL-MACRO. This allows analyses to be made with economic issues factored in: For example, the development of a technology can be followed during specific economic-growth conditions. This dual program estimates costs and evaluates technologies in order to reduce environmental risks, such as air pollution and global climate change.

MARKAL-MACRO is written in GAMS, a widely-used computer language that runs on software found at many universities. This will open up the availability of MARKAL even further.

Thus, as decision makers are finding more and more complicated problems to resolve, MARKAL is racing ahead to help find the logical solutions.

METAL HYDRIDES: BUILDING BETTER BATTERIES

Laptop computers are a boon to business. But these sleek, portable machines are only as dependable as their batteries, and their malfunction is a user's nightmare. Irreplaceable information might be lost, and, for computer mavens, writing with old-fashioned pen and paper is tedious and slow.

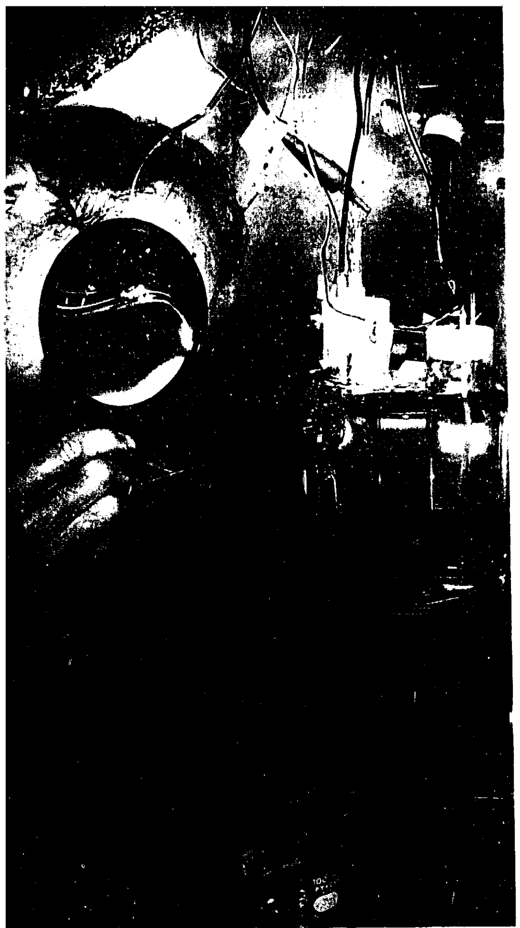
Recently, rechargeable metal hydride-nickel batteries have been replacing nickel-cadmium batteries in some of the most sophisticated laptop computers. These new batteries have several advantages over conventional ones: They are relatively nontoxic, store more energy per unit of weight, and have a longer life cycle.

Metal hydrides are made when hydrogen is absorbed by a metal or metal alloy (see sidebar). The metal hydride alloys used in laptop-computer batteries consist of as many as eight metals. Various combinations of metals improve the storage capacity and extend the life cycle of the electrode in the battery — but why this is so is not completely understood.

Basic research performed by our Department of Applied Science (DAS) researchers on the electrochemical properties of rechargeable metal hydride alloys may yield data that will help industry make better batteries.

For their experiments, DAS researchers have constructed an electrochemical cell that uses a wire electrode made of palladium nickel (PdNi) — an alloy that is too expensive to be

In their laboratory, (from left) James Reilly, Stephen Feldberg and John Johnson discuss results of the discharge of a palladium-nickel-hydride electrode.



James Reilly examines the bubble formation on a palladium-nickel-hydride electrode.

What will be the fuel of choice in the next century?

With a finite supply of fossil fuels, and a dearth of other options, the world's energy problem will not be easily solved.

One plausible solution is the use of hydrogen as fuel. The most abundant element in the universe, hydrogen has the highest energy-density per unit of weight of any chemical fuel. In addition, it is essentially pollution-free, since its combustion product is water. Further, hydrogen can serve in varied energy converters, from batteries and fuel cells to internal-combustion engines.

A major obstacle to using hydrogen for fuel is storing it safely and compactly. In the mid-1960s, however, Brookhaven researchers thought of a promising concept to solve the problem. They were the first to suggest and demonstrate the use of metal hydrides for hydrogen storage.

Most metal hydrides are formed by the contact of a metal with hydrogen gas above a critical pressure. When the pressure is lowered below the critical value, the metal hydride decomposes and hydrogen is released. This cycle can be repeated many times.

The BNL researchers found early on that the most practical storage compound was an iron and titanium alloy combined with hydrogen to form iron titanium hydride. It was successfully demonstrated on an engineering scale in a project conducted by BNL and a New Jersey-based utility, Public Service Electric and Gas, by storing excess power generated by nuclear plants during off-peak periods.

Several automotive companies, including Daimler-Benz and Mazda, have also applied the storage technology developed at Brookhaven to show the feasibility of hydrogen-fueled cars. These pollution-free vehicles may solve transportation problems as traditional energy supplies dwindle.

used as a battery electrode, but ideal for fundamental studies because of its physical and chemical stability.

This electrochemical cell has a conventional design. One compartment contains the working PdNi electrode and a hydrogen reference electrode, which measures voltage. The other contains a platinum counter electrode. The cell electrolyte is aqueous potassium hydroxide.

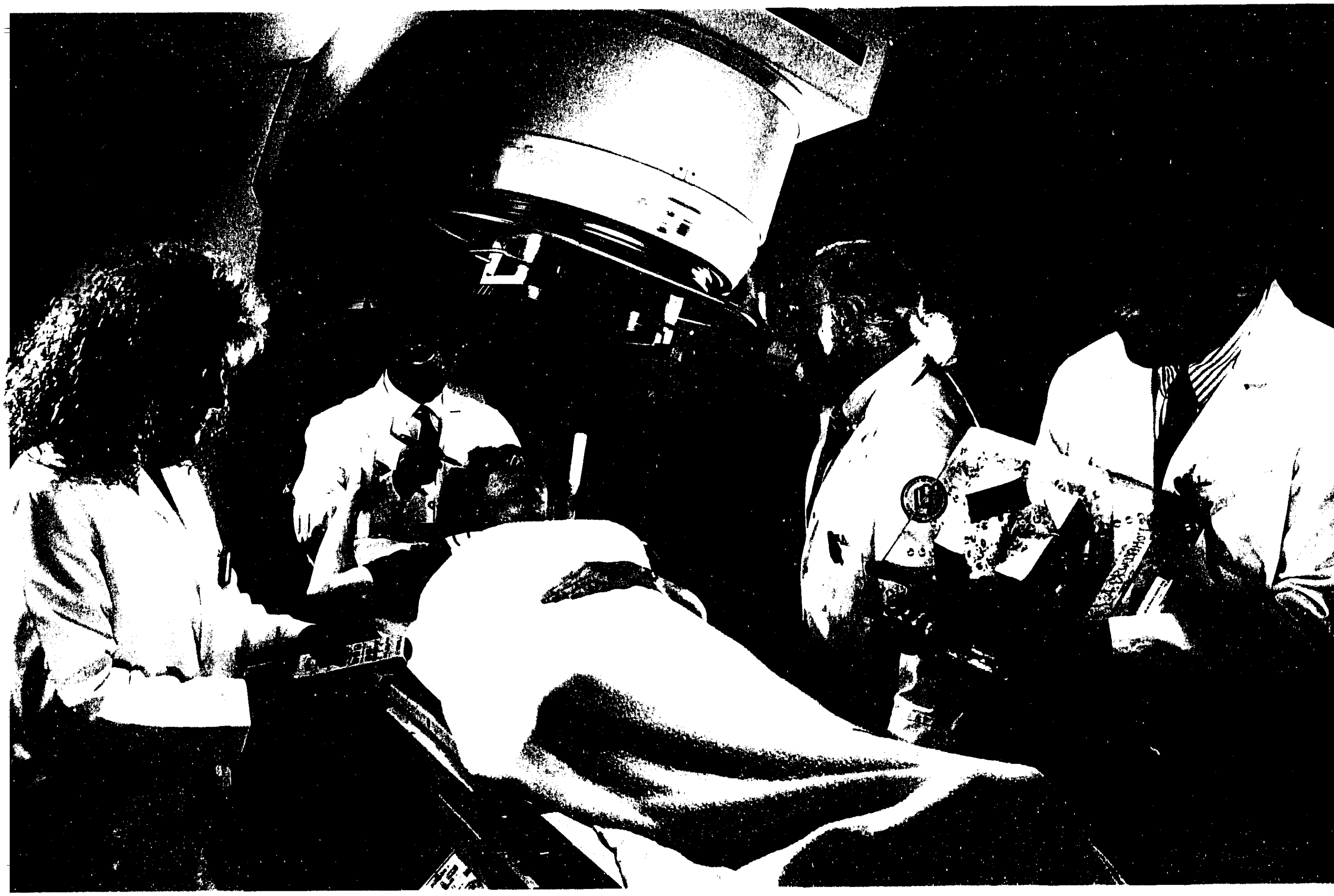
The electrochemical reactions of interest are observed when the PdNi electrode is charged with hydrogen in a process similar to the way in which a battery is charged. Electrons are added to the electrode from an external power source, which causes water in the electrolyte to decompose, forming hydrogen and oxygen. The hydrogen then reacts with the PdNi alloy to form palladium nickel hydride.

During discharge, the process is reversed — electrons are withdrawn from the electrode through an external circuit, and the hydride decomposes, releasing hydrogen, which reacts with the hydroxide ion in the electrolyte to form water.

When the surface of the PdNi electrode is activated with a catalyst — for example, a small amount of Pd — it can be charged and discharged quickly and easily. When high positive voltages are applied to the hydride electrode, its decomposition rate increases. But, at a certain point, increasing voltage does not increase the decomposition rate because the reaction is limited by processes taking place in the bulk electrode.

A rate-limiting process is the slowest step in a sequence of reactions. In this case, the rate-limiting process appears to change at different stages of the reaction. Initially, it may be the growth of the metal phase as the hydride decomposes; later, it may be diffusion of hydrogen through the metal phase to the surface of the electrode.

Further experiments are under way to identify the actual rate-limiting processes and to gain basic information about the solid state and electrochemical processes that occur in charging and discharging a metal hydride electrode. These investigations are important to the design and development of better batteries.



A cancer patient at the Radiation Therapy Facility is set up for treatment by: (from left) Helen Iorio, Yat Hong Lau, Lucian Wielopolski, and Raymond Beers, all with the University Hospital at Stony Brook.

HIGH-TECH CANCER THERAPY WITH OLD-FASHIONED CONCERN

In addition to surgery and chemotherapy, radiation treatment is a major weapon found within a physician's arsenal in the battle against cancer.

Radiotherapy consists of exposing cancerous tumors to radiation — beams of electrons from accelerators, or beams of photons from accelerators or cobalt sources. While electrons are used for more superficial cancers, photons are used to treat deeper tumors. Once absorbed by the tumor, the energy from these forms of ionizing radiation causes biochemical reactions within the cancer cell that can cause the demise of the tumor.

Until two years ago, eastern Long Island cancer patients who needed radiotherapy involving electron or photon accelerator beams had to seek

Brookhaven's unique physical and chemical science resources and facilities are used by Medical Department scientists to develop new medical applications of nuclear technology. Research goals include: development of novel radionuclides and radiopharmaceuticals for the diagnosis and treatment of cancer; application of nuclear medicine procedures in basic neuroscience and for the diagnosis and treatment of disease; development of new and improved radiotherapies; non-invasive measurement of the elemental composition of the human body by neutron-activation methods; and elucidation of the cytogenetic and biomolecular changes associated with leukemogenesis.

treatment at University Hospital at Stony Brook (UHSB). Also until two years ago, researchers and their collaborators in Brookhaven's Medical Department did not have a dedicated accelerator to use in their development of the cancer treatments of tomorrow.

So, when the Radiation Therapy Facility (RTF) opened in a pavilion of Brookhaven's Medical Research Center in September 1991, it answered both the needs of local cancer patients and Brookhaven's medical researchers. And, in complementing the RTF's high-tech approach to cancer treatment, its staff also provides a dose of old-fashioned care and compassion, as many of the RTF's 420 patients to date have attested.

SATELLITE HOSPITAL

A satellite of UHSB's Department of Radiation Oncology, the RTF is the second cancer-radiation center to be established within a U.S. national laboratory. Moreover, the Philips SL-25 medical linear accelerator used to deliver the radiation at the RTF is not only one of the most advanced in the world, but it is also the only one in Suffolk County.

As a result, all cancers that are treated with radiation therapy can now be treated on Long Island — at Brookhaven's RTF. The maximum photon energy of 25 million electron volts allows the treatment of the deepest tumors. Meanwhile, the range of nine electron energies allows the most accurate treatment of superficial tumors, thus causing less injury to healthy tissue behind the cancer.

Also as a result of the RTF, two research projects initiated by BNL-UHSB collaborations have gotten under way: one involving RTF brain-tumor patients, and another with lung-cancer and breast-cancer patients. More research involving RTF patients and/or the facility's linear accelerator is in the planning or development stages.

ROUTINE OPERATIONS

During its first two years of operation, the RTF has been used to treat 420 cancer patients, and some 10,764 patient visits have been logged. The largest group of patients — 35 percent — has been treated for prostate cancer.

By averaging 25 patient visits a day, the RTF has been used 25 percent more than was projected. This average has been made possible by the fact that the linear accelerator has been reliable an average of 99.7 percent over the past two years — thus exceeding the manufacturer's expectations of 97 percent reliability.

Reliability has allowed clinical operations to become routine, thus permitting the pursuit of research this year.

The first study under way involves eight patients with brain cancer. Using Brookhaven's Positron Emission Tomography, or PET, facility, the function of the patients' brain tissue is being evaluated and correlated with the magnetic resonance imaging performed to observe the effects of the radiation during brain-tumor treatment. Preliminary studies have shown significant increase in brain function after radiation treatment, which is associated with a decrease in brain-tumor activity.

The second study is an extension of the Medical Department's longstanding research into nuclear medicine techniques to measure lung function. With four people with lung cancer and four people with breast cancer in this study, collaborators are looking at the patients' ability to clear particles of the inhaled radiotracer technetium-99m DTPA from their lungs. The purpose of the study is to develop a method of early detection of radiation pneumonitis, the inflammation of the lung that is often caused by radiation treatment.

To ensure that the RTF's linear accelerator continues to be at the forefront of radiation treatment and research, several upgrades are planned. One will increase the machine's dose rate, so as to allow total skin electron therapy, which is necessary, for example, to treat patients with skin lymphoma. The other upgrade is the installation of a beam collimator with independently moving jaws, so that the area to be exposed to radiation does not have to be restricted to a rectangular shape.

PATIENTS PLEASED

Not only are Long Island's cancer patients being treated at a state-of-the-art facility, but they also are being treated as special individuals in a warm, caring environment.

While most radiation-oncology centers are located in the windowless basement of large hospitals within concrete cities, the RTF is located on Brookhaven's park-like grounds, in the sprawling Medical Research Center, with its generous views of lawns, trees and grazing deer.

More important than the setting are the people who provide the cancer care. As former patients and their families have expressed in thank-you notes:

"Money can't buy the TLC, the compassion, the concern and the interest shown by the entire staff."

"Having come from [a New York City hospital] to Brookhaven was like going from darkness to light: the smiles, the friendliness, the warmth — that was one of the best medicines."

"My [spouse] and I were both very depressed when we found out that [my spouse] needed radiation treatment — but all of you gave us a lift."

"While it wasn't the best of circumstances under which to meet new people, I feel fortunate to have met all of you."

"My heartfelt thanks to all of you wonderful people for turning a dreaded experience into something close to enjoyable!"

EASING THE PAIN OF METASTATIC CANCER

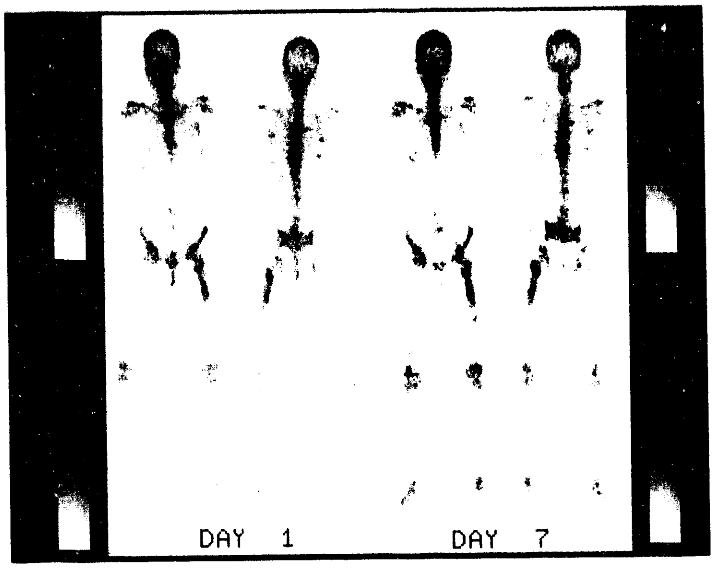
For most people, the possibility of developing cancer is a frightening thought. But, for those who already have the disease and whose cancers have spread to the bone, metastatic cancer is an excruciatingly painful reality.

Some 60 to 80 percent of patients with breast or prostate cancer and approximately 50 percent of those with lung cancer will develop bone metastases. And patients with one of these three types of cancers make up about 80 percent of the 400,000 U.S. patients with bone metastases. Of these, about half experience severe and chronic pain.

Narcotic drugs have traditionally been used to relieve this pain. But, while patients receiving narcotics may be pain-free, they are often too sedated to appreciate life. So, there has been renewed interest in the development and approved use of non-narcotic pharmaceuticals labeled with radioactive isotopes that localize in the bone and reduce the bone pain caused by metastatic cancer.

One radioisotope that has been used for decades to relieve this pain is phosphorus-32. It has, however, an unfortunate side effect—phosphorus-32 also doses the bone marrow with so much radiation that it depresses the

Preparing tin-117m DTPA for patient therapy trials now under way at Brookhaven are: (from left) George Meinken, Leonard Mausner, Johannes Klopper and Suresh Srivastava.



(Left) Anterior and posterior whole-body images taken one and seven days after the administration of tin-117m DTPA to a patient with breast cancer that has spread to the bone.

(Right) Pelvic and chest regions of the same patient imaged before the tin-117m DTPA study using the common bone-scanning agent, technetium-99m MDP.

bone marrow's ability to fight opportunistic infections and interferes with blood clotting. Three other such agents have similar drawbacks.

So, the aim in developing new radiopharmaceuticals for this purpose has been to find agents that concen trate in bone with tumor involvement, but have minimal impact on bone marrow.

NEW, PATENTED AGENT

One such new radiopharmaceutical has been developed in Brookhaven's Medical Department. This patented agent may not only be superior in relieving bone pain, but, compared to other such agents, it may also deliver significantly more dose to the bone tumor than to the marrow.

This agent centers on a form of tin called tin-117m. It is an ideal therapeutic agent for several reasons. First, it has a short half-life of 13.6 days, which means it is not radioactive for long. Second, it gives off low-energy electrons, which do not penetrate far beyond where the agent is deposited in the body. Third, because the agent also emits gamma rays, its localization within the body can be studied with a gamma camera.

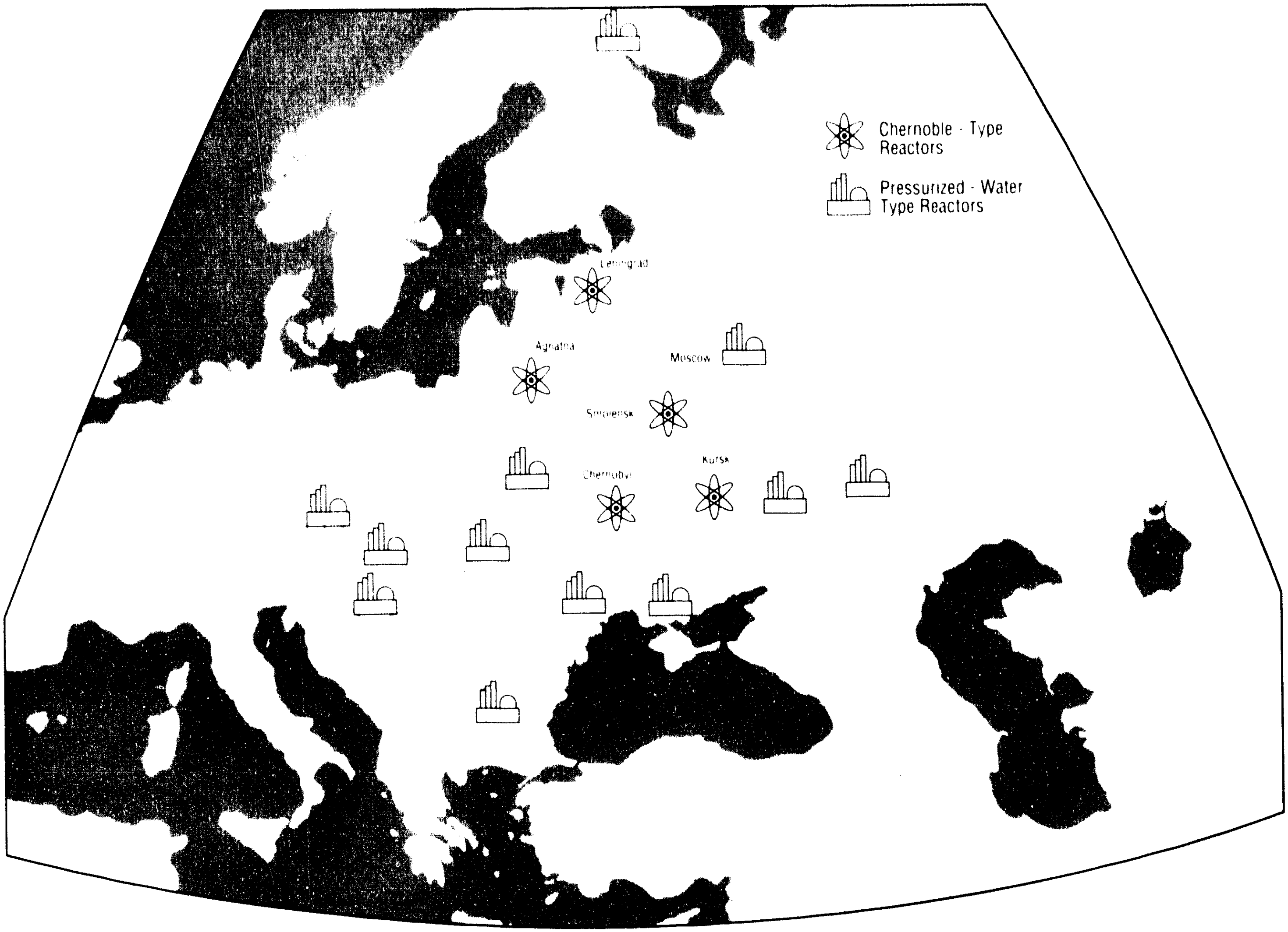
Not commercially available, tin-117m is produced at the Laboratory's High Flux Beam Reactor and then attached to a pharmaceutical called diethylenetriaminepentaacetic acid (DTPA). Infused intravenously, tin-117m DTPA localizes preferentially in bone rather than in soft tissue or bone marrow. As a result, the bone tumor receives 50 times more dose than the bone marrow.

These statistics were obtained by measuring the distribution of tin-117m DTPA at specific intervals after administration, using SPECT, or single photon-emission computerized tomography. While the data were originally developed using animal models, they were subsequently confirmed by a biodistribution and imaging study of ten patients with breast or prostate cancer that had metastasized to the bone.

Because tin-117m DTPA localizes preferentially in bone, with almost five times more going to the tumor than to normal bone, larger therapeutic doses of tin-117m DTPA may be used for pain therapy before encountering bone-marrow toxicity. As a result, Brookhaven scientists and their collaborators think that it may even be possible to use a dose of tin-117m DTPA high enough to destroy the metastatic bone tumor.

With approval from the Food and Drug Administration (FDA), the first phase of clinical trials with tin-117m DTPA were begun in fall 1992, in collaboration with the State University of New York at Stony Brook. Expected to be completed in about a year, this phase will determine if tin-117m DTPA is effective in killing the pain, and, if so, at what range of doses.

If it is effective, after further clinical trials, the Laboratory will license the technology to pharmaceutical companies. To date, several inquiries have been received about transferring this technology to private industry and, in the process, expanding the availability of a better quality of life for terminal metastatic cancer patients.



INTERNATIONAL SAFETY PROGRAM PROMISES JOBS FOR U.S. INDUSTRY

No more Chernobyls!

That was the cry worldwide in 1986, after the Soviet Union's Chernobyl-4 reactor exploded and released radioactive material into the environment. Thirty-one workers died, 200 people at the site were hospitalized due to excessive radiation exposure, and, even now, long-term health and environmental damage are still of concern.

The Soviet Union has now dissolved, but Russia still operates eleven Chernobyl-type reactors. Another four are in use in Lithuania and Ukraine. Though these graphite-moderated, boiling water reactors have been upgraded, their design is seriously flawed. In addition, over 42 Soviet-designed, pressurized-water reactors are operating in Russia, Ukraine, The principal directions of the Department of Advanced Technology are in three areas: technology initiatives, waste and environment, and safeguards, safety and arms control. Previously known as the Department of Nuclear Energy, the department's name change reflects a response to programmatic trends and national needs, and, while nuclear energy work remains firmly based, many programs are expanding into areas of increasing technological diversity.

Hungary, Bulgaria, the Czech Republic and Slovakia, with 16 others under construction.

To help prevent another Chernobyl, these reactors must be properly maintained and their safety upgraded — a formidable task given the absence of effective nuclear regulatory authorities and funding resulting from the Soviet Union's fall. Therefore, the U.S. has joined with Britain, Canada, France, Germany, Japan and Italy in instituting a new program to assist Russians and Eastern Europeans in establishing a nuclear-safety culture similar to that developed over the years in the West.

BROOKHAVEN AS MANAGER

Managing this $100-million program is the International Nuclear Safety Project Office (INSPO) in Brookhaven's Department of Advanced Technology.

Brookhaven was selected by the U. S. Department of Energy, with the concurrence of the U.S. Agency for International Development and the U.S. Department of State. Based on our long experience in providing technical project management of international safeguards programs for the U.S. government, the decision was also a result of our internationally recognized, in-depth knowledge of the safety of Soviet-designed reactors and U.S. safety practices. Brookhaven's scientists therefore provide technical insight on key safety issues, as well as interface with the experts in the host country.

BOAs DECONSTRICT INDUSTRY

Under this program, many U.S. industrial firms will be helping Russian and European authorities ensure the safety of their nuclear plants.

By a series of contracts known as BOAs — short for Basic Ordering Agreements — our program will be able to call on any member of a group of precontracted companies, each of which is expert in a particular technology. These companies will have been selected from among the firms that answer a public announcement made by INSPO.

For safety issues that have been identified, a solution would be discussed and decided jointly by experts from INSPO and the country in question. At this point, INSPO could immediately call on the appropriate BOA firm to tackle the job and, in addition, train local personnel in the new approach and procedures.

Of the program's funds, about 90 percent is expected to be placed by INSPO with these subcontracted companies. Thus, some $90 million will be available to U.S. firms of the required caliber. Russian firms will also provide technical assistance.

THREEFOLD THRUST

INSPO sees the thrust of the new safety project as threefold.

First, our staff will help to establish training centers in Russia and Ukraine, working closely with nuclear power plant owners and operators to develop safe operating and maintenance procedures.

Second, INSPO will propose short-term risk-reduction measures, such as better electrical backup systems and better ways to fight fires, until the Chernobyl-like, graphite-moderated plants and older pressurized-water-reactor plants can be suitably modified or replaced.

Third, we will help improve the newer pressurized-water reactors so that they meet Western safety standards. In addition, our staff will provide training for the plant operators, and suggest measures to improve plant reliability and capacity.

The outcome of this unique, historic program will depend, in great part, on the quality of Brookhaven's management support and technical expertise. Our past experience in this field, which includes expert input in the analysis of U.S. reactor safety and the Chernobyl disaster, will be of great value in the course of this project.

Ann Reisman, Jack Mulligan and (back) William Horak prepare for a project meeting.

FINGERPRINTING CHEMICALS FROM AFAR

Identifying chemicals in the laboratory presents few problems to modern scientists. But how about chemicals outside?

In Brookhaven's Department of Advanced Technology, our researchers are developing a method of detecting and identifying chemical effluents from far away. To do this, we combine a known phenomenon — Raman scattering — with the latest laser, detector and computer technology.

This remote sensor technique has broad applications that range from detecting the presence of chemical weapons or illegal narcotics to verifying environmental cleanup.

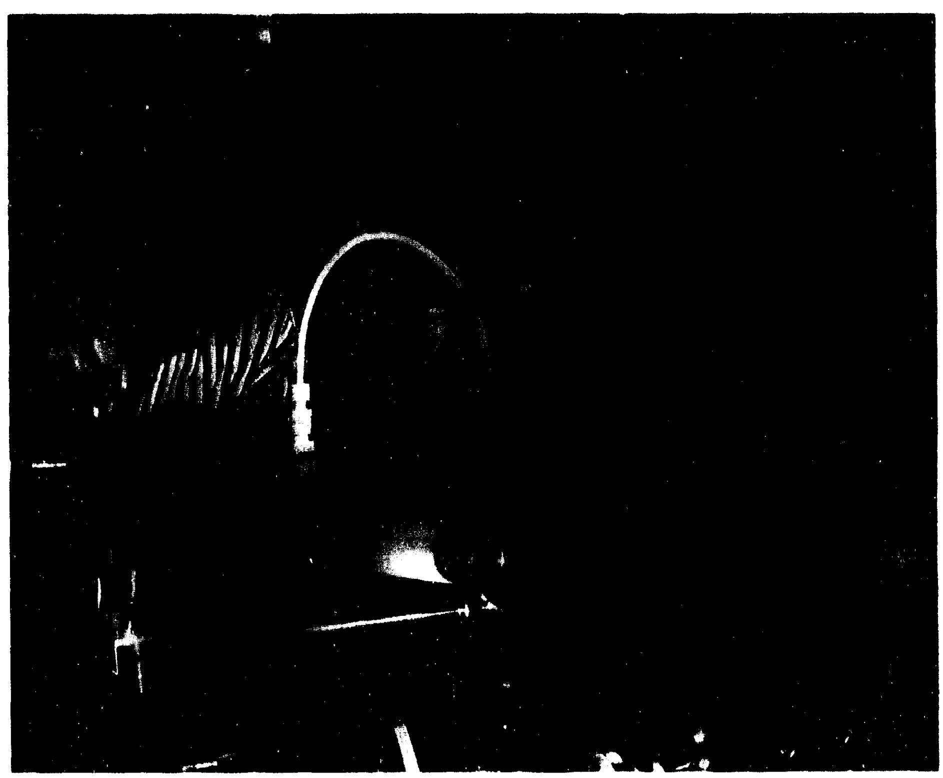
THE RAMAN EFFECT

When a molecule is irradiated with light, it can scatter some of that light inelastically, that is, with the incoming and outgoing light having a different wavelength. In Raman scattering, the wavelength of the scattered light is shifted by amounts related to the vibrational structure of the molecule.

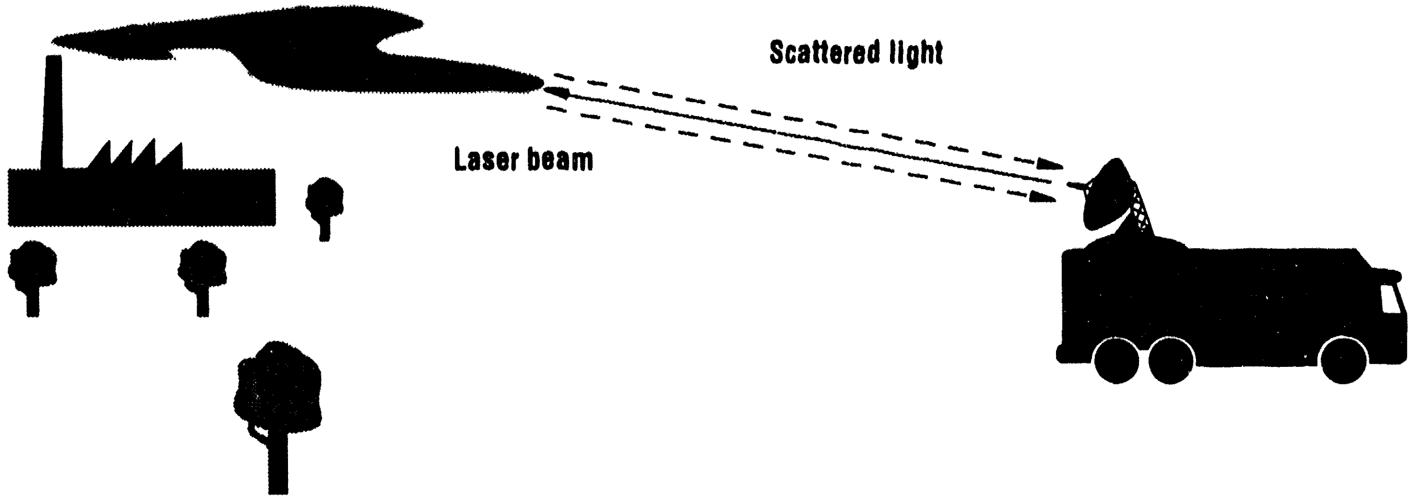
Because each type of chemical has its own vibrational structure, the pattern made by the intensities of the scattered light is unique to that type of chemical. Therefore, when the outgoing light is caught in a spectrometer, the pattern it forms — the Raman spectrum — gives a unique "fingerprint," characterizing that molecule. From these data, the chemical can be identified and measured.

Usually, the intensity of the Raman scattered light is too low to be sensed at more than a few tens of meters away.

It is possible, however, to increase the intensity of Raman scattering signals — and that is the basis of this Brookhaven project.



In their specially designed laser laboratory, (from left) Arthur Sedlacek, David Harder and Cheng-Lin Chen prepare to find the spectral fingerprints of a chemical sample using resonance-enhanced Raman spectroscopy.



In detecting and identifying chemicals by remote Raman scattering, laser light (solid arrow) is directed from a mobile lab toward the area being investigated. The light hits molecules and is scattered. Part of the scattered light (dashed arrows) is analyzed by a spectrometer in the mobile lab. The resulting spectral patterns provide the unique "fingerprints" of chemicals present in that area.

USING RESONANCE RAMAN

Incoming light that irradiates a molecule can cause one of the molecule's electrons to jump to a higher energy state. This is called an electronic transition, which for many chemicals falls among the visible and ultraviolet wavelengths. When the energy of incoming light matches the energy of an electronic transition, the intensity of the Raman scattering can be enhanced up to a million times, and is called resonance Raman.

It was suggested at Brookhaven that resonance Raman should be used to detect chemical agents. We then proposed a program of research and development to explore the best way to achieve this. The U.S. Department of Energy's Office of Arms Control recognized the technique's potential value for arms control and initiated a program.

Our scientists first developed a special laser laboratory, then started experiments to measure the resonance Raman scattering for the chemicals of interest. When this work is complete, investigators will be able to identify chemicals by matching an unknown fingerprint to a library of resonance Raman spectra, using pattern recognition software in a laptop computer.

ADVANCED TECHNOLOGY

The success of this technique has depended not only on intensifying the scattering signals, but also, on advanced technology. The Brookhaven team uses state-of-the-art spectrometers and computers, which make the signals easier to record and analyze. Other key ingredients have been more efficient detectors and more varied and powerful lasers.

Current lasers have many advantages for Raman spectroscopy. For example, they are now tunable and much smaller. Also, because they can operate at ultraviolet wavelengths below 300 nanometers (nm), they can be used in daylight.

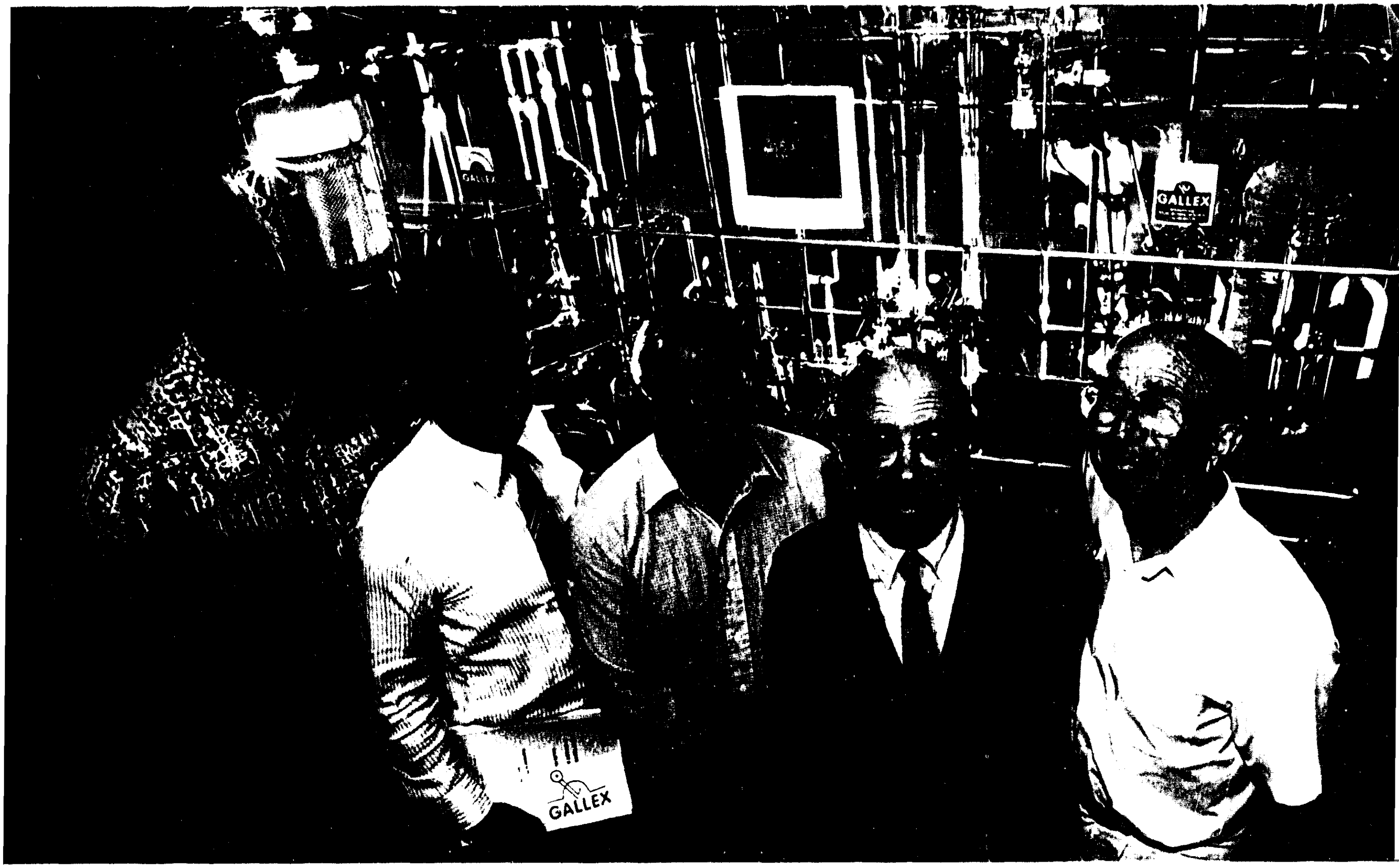
Daylight use works because the ozone layer in the earth's upper atmosphere blocks all the sun's light at wavelengths below 300 nm. So, scattered laser light below this level can be detected with no interference from the sun. And, although atmospheric absorption due to surface-level ozone, oxygen and nitrogen limits the use of wavelengths below about 250 nm, there remains a spectral "window" ranging from about 300 nm to approximately 250 nm.

When the molecular resonances fall within that window — the case of most of the chemicals of interest — excellent results can be expected.

FUTURE PLANS

Once the basic research is complete, our scientists will concentrate on practical considerations — selecting the best lasers, computers and software for field portability. Equipment will have to be rugged, self-operational for fairly long periods, and fit on a small truck or airborne platform — a mobile detective lab.

Such a mobile lab could be used to check for chemicals that indicate the production of chemical weapons, as well as chemicals of interest for pollution control and environmental monitoring.



In their laboratory are the Brookhaven scientists in the GALLEX collaboration (from left) Keith Rowley, Richard Hahn, Frank Hartmann, Joseph Weneser and Raymond Stoenner

SOLVING THE SOLAR NEUTRINO PUZZLE

The sun — a dense, gaseous globe of radiant heat — has a core temperature of 15 million kelvins. This radiation is so intense that it warms and lights the earth from a distance of approximately 150 million kilometers.

Brookhaven researchers are studying the 4.5-billion-year-old star by investigating neutrinos — uncharged, elementary particles that are created when nuclear fusion produces the sun's energy by converting hydrogen to helium. Because they react so weakly with other particles, neutrinos can only be observed indirectly, in specially designed experiments using extremely sensitive detectors.

SEARCHING FOR NEUTRINOS

In the 1970s and early '80s, chemists from Brookhaven, along with researchers from the Max Planck Institute for Nuclear Physics in Heidelberg, Germany, designed an experiment to find data that may be helpful in answering two basic questions: How does the sun make its energy? What are the properties of neutrinos?

The broad range of research in the Chemistry Department includes programs in nuclear and radiation chemistry, radiopharmaceuticals, homogeneous and heterogeneous catalysis, state-to-state chemistry, and thermal and photo-induced charge-transfer processes. All share a single goal: the fundamental understanding of the properties of nuclei, atoms and molecules. In this work, the special facilities, apparatus and techniques available at Brookhaven enable chemists to discover detailed structural and spectroscopic information on solids, liquids and gases, and the dynamics of physical and chemical change.

These plans reached fruition in GALLEX, which stands for gallium experiment. Along with BNL scientists, researchers from nine other institutions in Germany, Italy, France and Israel form the GALLEX collaboration.

At the Gran Sasso Underground Physics Laboratory, shielded from cosmic-ray interference deep in a tunnel under Italy's Apennine Mountains, GALLEX researchers have placed a tank containing 30 metric tons of gallium in the form of an aqueous solution of gallium chloride and hydrochloric acid. When a neutrino enters the tank, the isotope gallium-71 is transformed to radioactive germanium-71, which has a half-life of 11 days.

Every three weeks, a few atoms of neutrino-produced germanium-71 are removed from the tank, purified and placed in a one-milliliter-volume counter that measures radioactive decay. The measurements reveal the number of reactions caused by neutrinos. Counting neutrinos with this technique has been ongoing since 1991 and will continue at least until 1996.

FOUR EXPERIMENTS, FEW NEUTRINOS

In 1992, the GALLEX collaborators found approximately two-thirds the number of neutrinos predicted by theory. Their newer results, reported in 1993, supported earlier findings.

Three other major experiments designed to study neutrinos have also found fewer neutrinos than predicted by the theory that explains energy production in the sun.

In 1967, BNL researchers had set up a pioneering solar neutrino experiment in a deep gold mine in South Dakota. The active ingredient in this solar neutrino trap was chlorine, since neutrinos can change the isotope chlorine-37 into argon-37, an isotope that can be detected by its radioactive decay.

In this experiment, only about one-fourth of the expected number of argon-37 atoms, and, therefore, of neutrinos, were counted. Thus, scientists concluded that either the solar model — the theory of how the sun produces energy — or their ideas about neutrinos had to be modified.

Another experiment, called SAGE, set up in Russia by Russian and American scientists, also uses gallium to capture neutrinos. In 1990, SAGE scientists announced that they had found essentially no evidence of neutrinos, but they reported in mid-1992 that their later experiments observed neutrinos at roughly the same level as GALLEX.

Finally, a Japanese experiment uses a different technique: scattering of neutrinos from electrons contained in a huge volume of water. In 1990, these scientists reported finding about half the predicted number of neutrinos.

A NEW VIEW OF NEUTRINOS

Of the four neutrino experiments, only GALLEX and SAGE — the ones that use gallium — are sensitive to low-energy neutrinos, which are the major product of the sun's nuclear fusion. The other two experiments can detect only the higher-energy neutrinos from the sun.

Because the results of all four experiments cannot be explained by the solar model, many scientists conclude that the answer to the solar neutrino puzzle can be found in the realm of new physics. That is, the neutrino must have properties that previously were not considered.

The preferred explanation is that the neutrino, previously believed to have a zero mass, actually has a miniscule mass. If this is so, results from the four experiments imply a neutrino mass of only a few thousandths of an electron volt. For comparison, an electron has a mass of about 500,000 electron volts, so that it would be about 100 million times heavier than a neutrino.

AN ARTIFICIAL SUN

To test GALLEX's accuracy, the collaboration is planning to replace the sun in the experiment with an artificial neutrino source.

Scientists will create a highly radioactive source of the isotope chromium-51, which will produce neutrinos at a rate six times higher than that of the sun. Because this radioactive chromium has a half-life of one month, it will be made in the Siloé reactor, in Grenoble, France, and shipped immediately to the experimental site in Italy.

With a known source, the scientists will be able to measure exactly how many neutrinos are emitted. They can then determine if their results for neutrino-produced germanium-71 are accurate. This comprehensive test of GALLEX is expected to begin in 1994.

COMBUSTION IN ACTION: CHOREOGRAPHED COLLISIONS

Lighting a flame may seem to be a simple, instantaneous act, but it is actually a complex process that requires hundreds of chemical reactions. One goal of researchers in Brookhaven's Chemistry Department is to identify and understand the individual reactions that contribute to combustion.

Chemists approach complex systems like combustion by isolating simple, individual reactions for detailed study. A computer model of combustion is then built, using the many simple reactions as building blocks. The computer models can guide combustion engineers in their search for maximum fuel efficiency and minimum pollution.

In their study of combustion chemistry, BNL researchers have focused on one crucial reaction: the collision of hydrogen atoms (H) with molecular oxygen (O_2) to form a hydroxyl radicals (OH) and oxygen atoms (O). This step contributes to the explosive chain reaction that dominates the ignition stage of combustion.

COLLIDE AND SEEK

In their experiment, Brookhaven chemists shine pulses of ultraviolet laser light into a low-pressure mixture of hydrogen bromide (HBr) and O_2 gases. The energy of the laser light excites the HBr and splits it into H and Br atoms. The energetic H atoms react with the first O_2 molecule they encounter, producing OH and O.

The outcome of the reaction is measured with a second laser, tuned to specific ultraviolet wavelengths to excite the OH. The excited OH radicals emit fluorescent light, which is measured with a sensitive light detector.

By controlling the time between the first laser pulse that creates the H atoms and the second laser pulse that detects the OH radicals, our scientists are sure that they are observing the results of single reactive collisions. Inside the cylinder of an engine or in the flame of a furnace, the reaction would occur too fast to be measured, even with nanosecond lasers. But, because the experimental gas mixture is 15,000 times lower in pressure than a normal atmosphere, molecular collisions are slowed down, allowing reactions to be observed — one collision at a time.

Oh, Oh, OH!

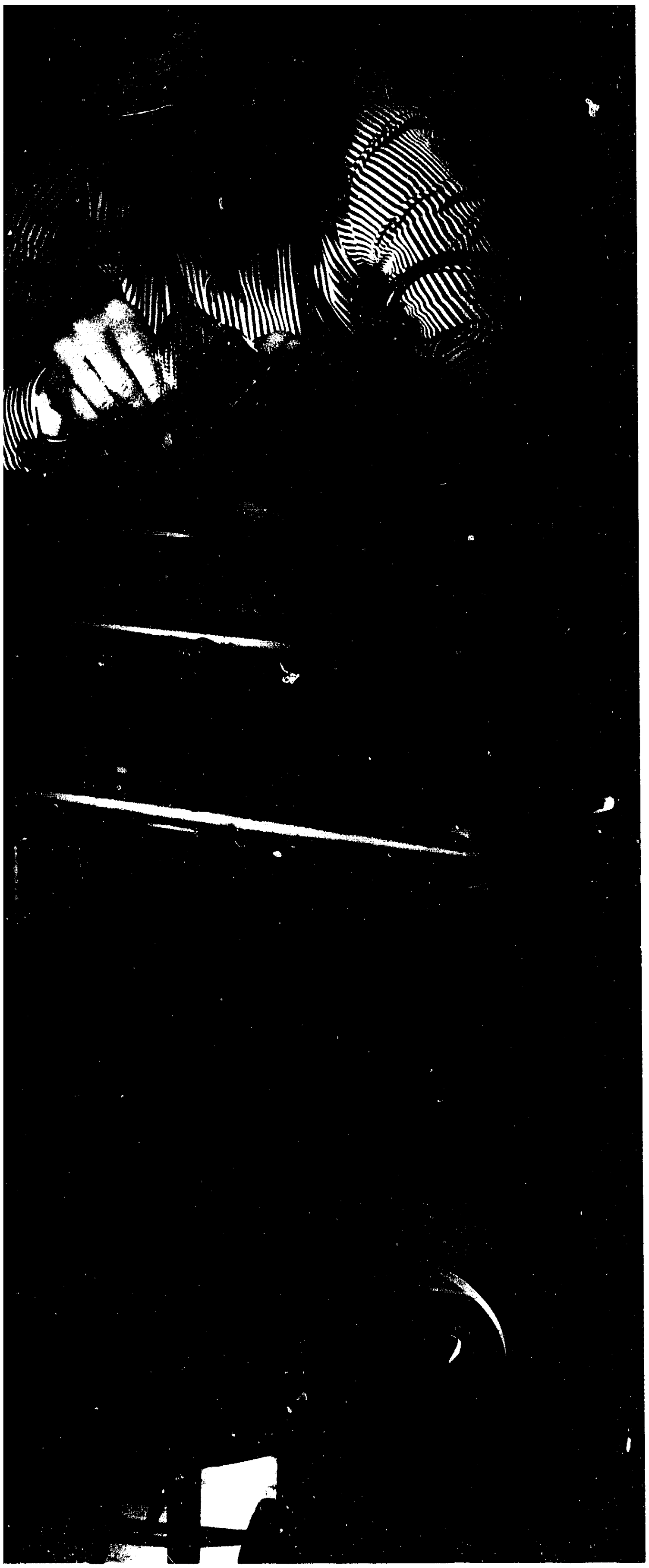
The original and most challenging part of the experiment is to reconstruct the choreography of the atoms and molecules as they change partners during the reaction For example, in one type of reaction, H may stick to O_2 and all three atoms may rotate before breaking apart into O and OH.

Alternatively, H may speed past O_2, snatching up one O atom, leaving the other behind.

To distinguish between these and other possible mechanisms for the reaction, Brookhaven chemists measure the speed and direction of the OH. They base their measurements on the Doppler effect, the same phenomenon that changes the perceived pitch of a train whistle as it rushes past an observer. Similarly, the hydroxyl radicals moving either toward or away from the OH detection laser absorb light at slightly different wavelengths.

With precise laser experiments, the speed and direction of OH can be determined from the Doppler measurements. The researchers can then calculate the angles between the incoming H atom and the outgoing OH radical, confirming previously untested predictions of the OH angular distribution in the reaction of $H + O_2 \rightarrow OH + O$.

Brookhaven's measurements have successfully demonstrated this new technique for studying reactions and added a new level of detail to our understanding of combustion.



Gregory Hall connects signal cables to a light detector in his laser-initiated combustion experiment.

Discussing the results of a parallel computer simulation of an aluminum-magnesium alloy are: (standing, from left) Nithayanathan Chetty, Physics Department; Robert Marr, Department of Applied Science (DAS); Michael Weinert, Physics; (seated, from left) Francine Evans, State University of New York at Stony Brook; James Davenport, Physics; and Ronald Peierls, DAS.

SUPERCOMPUTER RESEARCH PARALLELS GRAND CHALLENGE EFFORTS

Hook up several light fixtures in series and electric current will only be able to flow through the elements in this circuit sequentially. In other words, all the lights have to be on at the same time.

But, if the lights are connected in a parallel circuit, then either the fixtures can all be on or each fixture can draw current independently, depending on the need for light.

The flexibility of parallel circuits has been extended from electrical circuits to the arrangement of chips within computers: While serial computers are wired so as to solve steps of

The lines between Brookhaven's scientific departments and research divisions are more frequently drawn in gray than in black, as researchers from different scientific disciplines often join forces to tackle complex problems that are best solved using a multidisciplinary approach. The following story discusses research involving Brookhaven's Department of Applied Science and Physics Department, as well as their collaborators from other institutions.

a problem sequentially, parallel computers are set up to solve problems using separate circuits working simultaneously on different aspects of the same problem.

Today, this bright idea has been extended, until there are now massively parallel computers — supercomputers having 1,000 or more processors working in parallel. It is as if more than 1,000 computer workstations were all hooked together to work independently toward a collective solution. And massive computations with minimum communication between the 1,000-plus processors are the specialty of massively parallel machines.

So, to put this unprecedented computational power to creative use, Brookhaven's computer scientists in the Department of Applied Science have teamed with departmental colleagues and other collaborators, and with researchers in our Physics Department to work on two challenges of national significance.

GRAND CHALLENGES

In performing this work, we join scientists across the nation who have been asked to use massively parallel computers to tackle various "grand challenges" — fundamental problems in science or engineering that could have significant economic, political or scientific impact. To carry out the computations involved in these challenges, however, researchers are restructuring their problems to take advantage of all the massively parallel computer's processors.

Our work on the advanced software technology and improved algorithms necessary to undertake these challenges on a massively parallel computer is being funded through a federal program on high-performance computing and communications. This is an interagency effort to make the next generation of computers available sooner for industrial design, manufacturing, scientific research, and communications and information management.

Our first challenge is to understand how pollutants move in groundwater. This is a massive computational problem because it involves solving equations describing fluid flow in porous materials, while allowing for complicated boundary shapes, motion in three dimensions and multiple chemical reactions within a plume of moving pollutants.

In collaboration with computational science groups at six other institutions, Brookhaven researchers have been developing new numerical approaches, which will not only be effective in solving such large problems, but also can be structured to take advantage of the new massively parallel computers.

The second challenge is to model the nature of metals and their mixtures, such as aluminum and its alloys (see story "Mastering Aluminum's Melting Point," Physics Department, page 28), with the hope that this information will aid in the development of new materials for use in advanced technology.

By using a massively parallel supercomputer on this project, our scientists have increased the number of aluminum atoms that can be modeled from 10 to over 1,000. This has resulted in greater accuracy in theoretical calculations of aluminum's physical properties, such as its melting point.

COMPUTATIONAL SCIENCE PARTNERSHIP

In undertaking our two challenges, we are part of a research consortium called PICS, short for Partnership in Computational Science, which involves two other national labs and seven universities.

Our grand-challenge research is performed using a massively parallel supercomputer called the Intel Paragon XP/S, which is located at Oak Ridge National Laboratory in Tennessee, and accessed via computer network. In developing the codes for this massively parallel supercomputer to run, we are testing them on a smaller version of this machine, which is located at the State University of New York at Stony Brook.

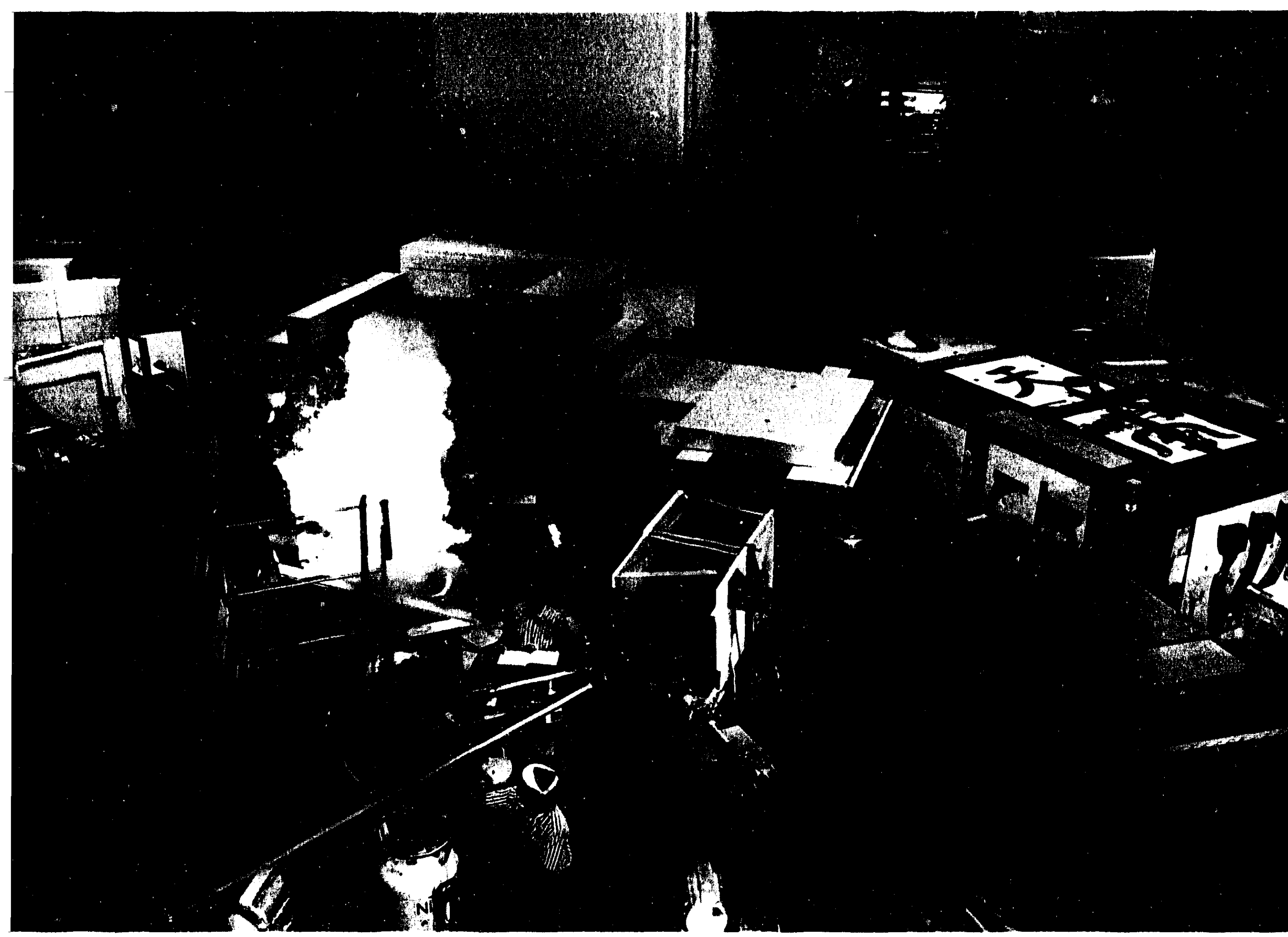
With ultimately more than 2,000 processors, this computer is able to perform more than 150 billion floating-point calculations per second. This means that 150 billion numbers can be added, subtracted, multiplied or divided in one second, resulting in unprecedented computational power.

As questions are posed correctly to the computer and the right answers lead to further questions, our computer scientists and their collaborators will not only succeed in taking on the challenge of a new machine, but also help solve several national problems.

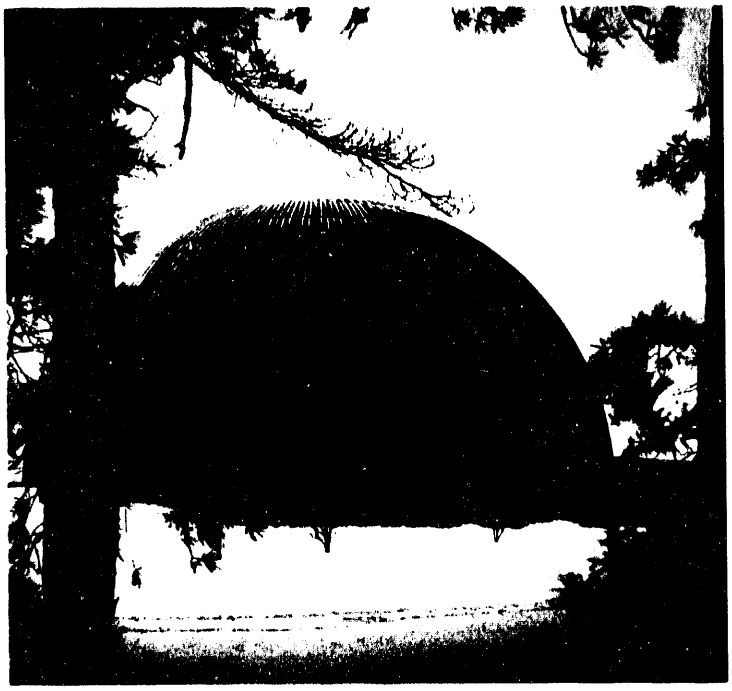
RESEARCH DIVISIONS

BNL's long-standing basic research on the bacterial virus T7 has lead to a Cooperative Research and Development Agreement with Novagen, Inc., to make protein display vectors — powerful research tools for probing interactions of biological molecules. These vectors may also have important medical applications, such as the design of new drugs and medical tests. Working in a biology lab are (from left) Alan Rosenberg, Kathleen Griffin, Jutta Paparelli and Bill Studier.

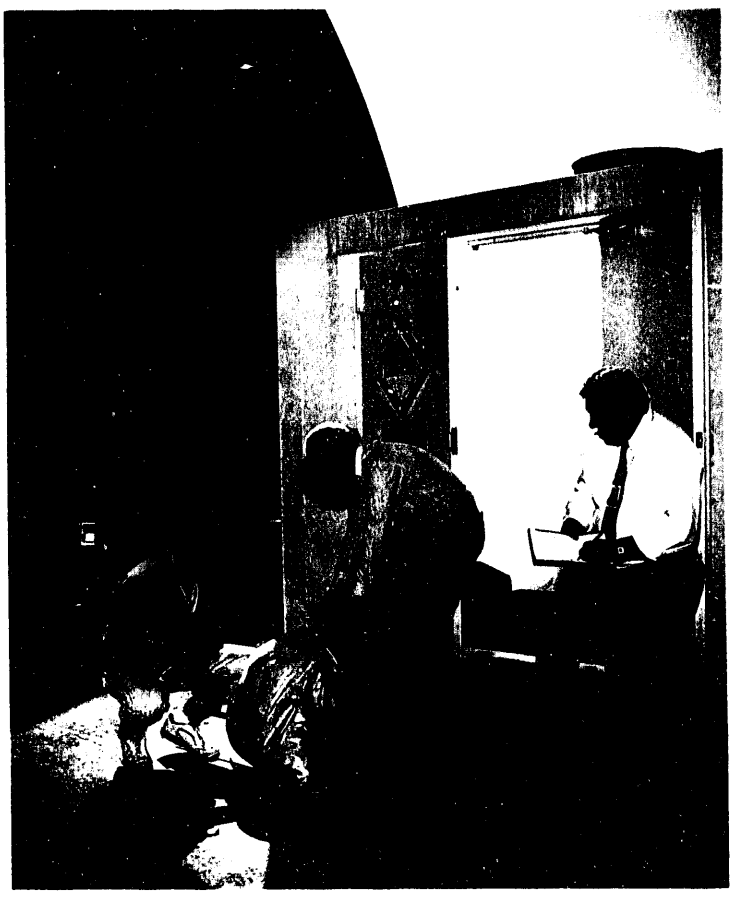
The Reactor Division operates one of the world's leading research reactors, the High Flux Beam Reactor (HFBR), as well as the Brookhaven Medical Research Reactor. The HFBR's intense beams of neutrons support experiments in nuclear and solid state physics, metallurgy, nuclear and structural chemistry, and biology. Its tradition of outstanding research includes award-winning investigations into such topics as the structure and behavior of metals and ceramics, and high-temperature superconductor materials.



The HFBR exists so that experiments can be performed. On the experimental floor at any one time, up to 15 experiments may explore different aspects of matter using the nine beams of neutrons that emerge from the reactor in a spoke-like pattern. At left, where the TRISTAN experiment focuses on nuclear structure research on unstable nuclei, Dean McDonald and Ronald Gill fill the dewar of a superconducting magnet with liquid nitrogen while Rick Casten supervises. The beam shielding painted to look like international children's blocks (right) supports another experiment. For good results, researchers depend heavily on the high-quality performance standards of the technical and managerial staff of the reactor.

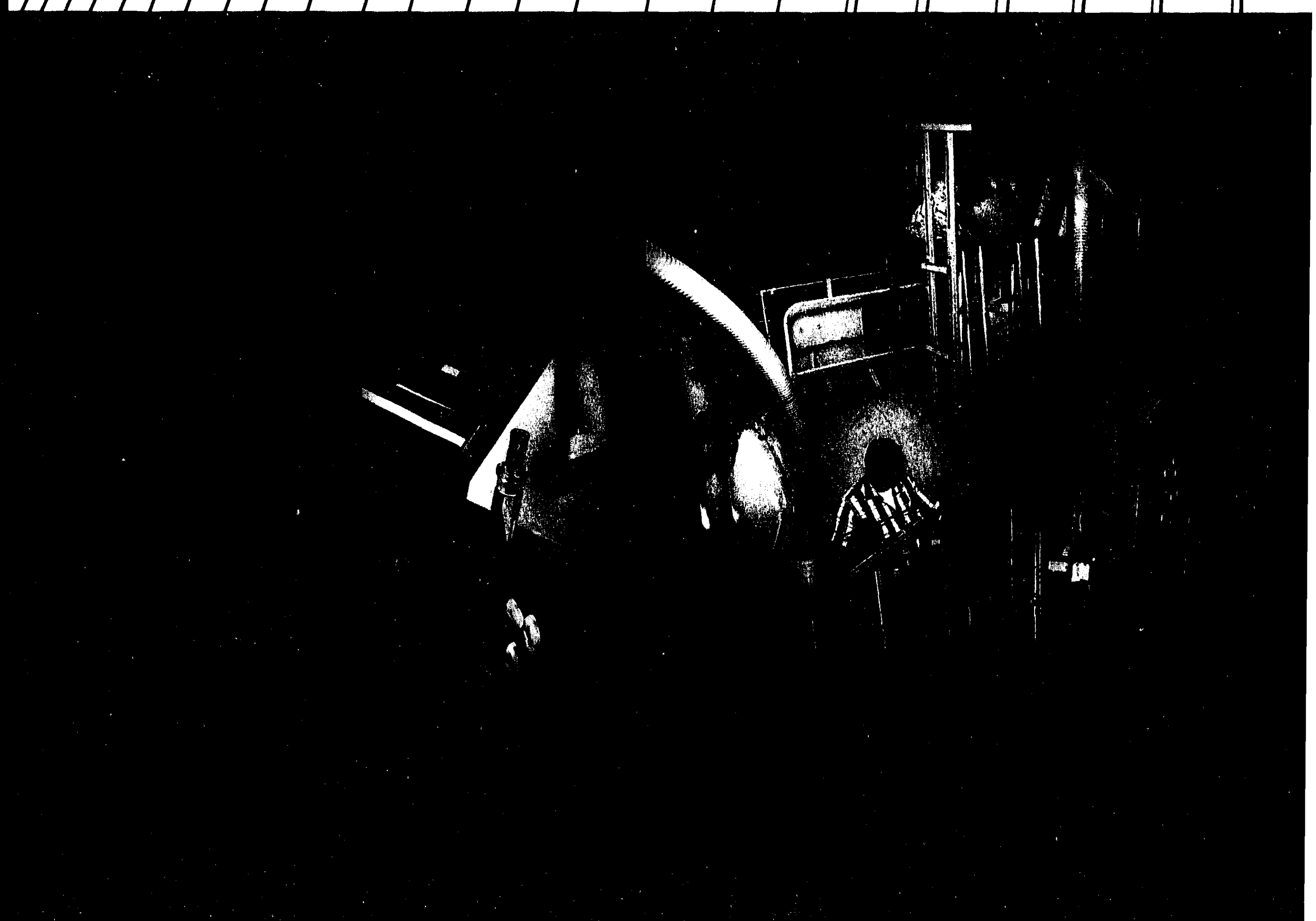


High Flux Beam Reactor



Nick Houvener (right) provides safety oversight while radioactive waste handling procedures are carried out by Nate Foster (left) and Joel Scott. This independent assessment typifies the vigilance that ensures safe reactor operations.

Samples of different materials are irradiated in the HFBR for materials testing, neutron activation analysis, or producing medical isotopes. Discharging a sample from an irradiation thimble at the reactor top are Andrew Levine and Joel Errante.



Steven Coleman is at his station in the HFBR control room, where two operators and two supervisors are on duty around the clock to provide for the safe and efficient operation of the reactor.

The Safety and Environmental Protection Division (SEP) provides technical support to the Laboratory staff in environmental, safety and health issues. This includes monitoring the BNL workplace, as well as surveying the environment. The division manages the Radiological Assistance Program, which can respond to any radiation incidents in the Northeast. Further, the division coordinates design reviews, construction-site inspections and operational readiness reviews the start-up of new or modified facilities. SEP also provides periodic assessment of the Laboratory's other environmental, safety and health programs.

Radiation Protection — Current Trends

In Brookhaven's radiation protection program, which is the responsibility of the Safety and Environmental Protection Division, two apparently opposing trends actually complement each other. One trend can be characterized as "less," and the other, as "more."

The trend toward "less" applies to the radiation dose received by workers in a year.

As new materials and designs improve machinery components, shielding and facilities, the radiation dose per worker has substantially decreased. For instance, the total collective dose for all Brookhaven workers in 1977 was 700 person rems, a measure of radiation. Fifteen years later, in 1992, the collective dose was 42 person rems (see graph).

At the same time, the trend toward "more" applies to the amount of protection our workers receive. Added protection results from our commitment to finding the best work and maintenance procedures, and putting them into practice. Protection is also increased as new materials and technology reduce exposure.

One example of increased protection from improved technology is found in film badges, or dosimeters.

Workers wear these badges to measure their total exposure to radiation. Every month, the badges are changed and the returned badges evaluated. Until the mid-1980s, film badges were processed at Brookhaven. Then, in 1985, we determined that an outside vendor could provide this service more cost-effectively.

Now, as a result of changing requirements from the U.S. Department of Energy (DOE), the division is building a facility to process the badges on site. Being able to "do it ourselves" will allow the division to report on dosimetry results more quickly, as well as provide more flexible reports for the varying needs of the departments and divisions. The new dosimetry system will incorporate both thermal luminescent dosimeters, or TLDs, and solid-state detectors instead of film to monitor beta, gamma, x-ray and neutron radiation in the laboratory.

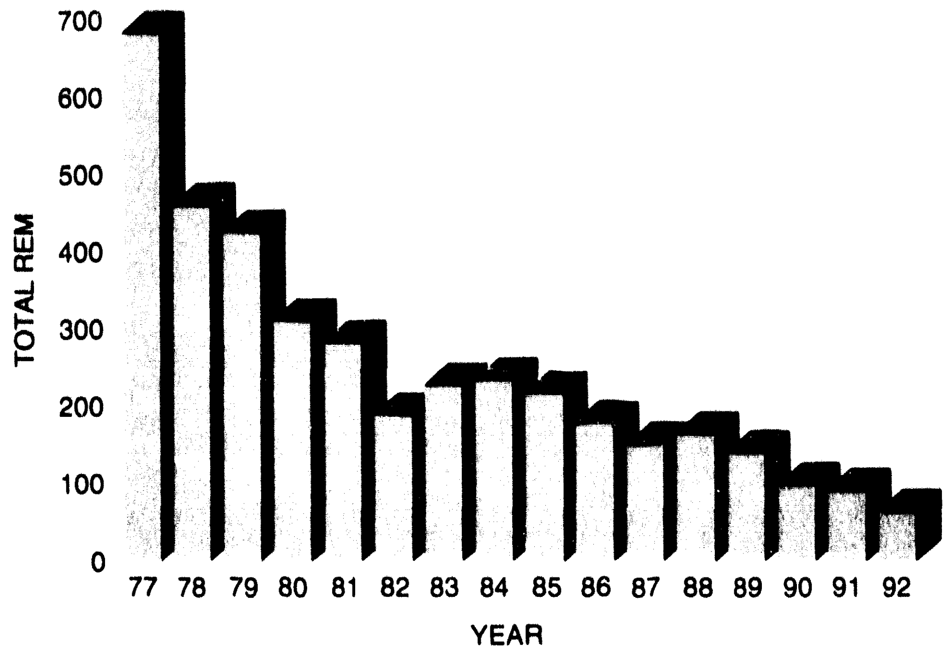
Dosimeters measure the external dose of radiation from external sources. Another way in which Brookhaven workers are monitored is by being checked in a whole-body counter, a device that directly and noninvasively measures exact amounts of the radioactive elements within the human body.

This procedure is only needed to monitor a few groups of our workers. Most employees experience no occasion when they could inhale or be injected with radioactive materials.

But, the facility stands ready for use by occasional groups doing work where such a risk may occur.

The facility can also be used to evaluate exposures from work in non-BNL locations. Just after the Chernobyl-4 reactor explosion in 1987, for example, some 55 travelers returning from what was then the Soviet Union needed an accurate check on the radioactivity they had absorbed from the accident. They were measured in Brookhaven's whole body counter.

In these ways, among others, the division constantly verifies the effectiveness of the DOE's safety regulations are fulfilled and that all possible improvements — less exposure, more protection — are put into practice.



Total collective radiation dose for BNL workers was reduced from 700 to 42 person rems between 1977 and 1992.

While Joyce Robinson takes the role of a patient, Bruce Murray demonstrates a whole body gamma scan using the whole body counter, which measures exact amounts of radioactive elements in the human body.

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

MONOLITHIC CIRCUITS: SMALLER, SMARTER CHIPS

Webster's defines a monolith as "a single large block or piece of stone." In stark contrast, monolithic integrated circuits are chips made of a single slice of silicon as small as a grain of sand.

These miniature chips will be used in the detectors of two world-class accelerators under construction in fiscal year 1993 — the Relativistic Heavy Ion Collider (RHIC) at Brookhaven, which has a 3.8-kilometer circular tunnel, and the colossal Superconducting Super Collider (SSC) in Texas, which is about 100 kilometers in circumference.

Paradoxically, the smaller the chips in their detectors, the better these huge machines will function.

These new chips, custom-designed by researchers in BNL's Instrumentation Division, will lead to greater economy in building and operating detectors, as well as better accuracy and precision in the physics experiments conducted at RHIC and the SSC.

The detectors in these accelerators produce small bursts of electrical charges as subatomic particles pass through them. These signals must be amplified and converted to a form that can be recognized by computers before they can be used to obtain data on the millions of particles that will emanate each second from these new colliders.

To do this job, a channel, or electronic path made up of hundreds of transistors, is needed. Using a new process to make miniature chips, designers can place up to 16 channels on a single silicon chip.

CUSTOM-MADE CHIPS

Our scientists design monolithic circuits using sophisticated computers. They also model the miniature circuitry based on specifications for electronics prepared in collaboration with scientists from Brookhaven's Physics Department and the SSC Laboratory, as well as other researchers who are designing detectors for these two accelerators.

When the model chip design is complete, it is sent to a semiconductor company to be fabricated by a process called photolithography.

In this technique, a slice of silicon is coated with light-sensitive film, and selected areas are inscribed microphotographically to produce the specific patterns of the chip. With photolithography, a transistor can be made as small as a few microns — less than one-tenth the thickness of a human hair. To make the miniature chips, Brookhaven has worked with companies in California's Silicon Valley, Florida's Space Coast, Korea, Russia and Taiwan.

The Instrumentation researchers will test some of the model chips this year on small gas-and-liquid detectors, which are similar to the detectors for RHIC and the SSC. Eventually, we hope also to use monolithic circuits to enhance the performance of x-ray detectors at Brookhaven's National Synchrotron Light Source.

MILLIONS OF CHANNELS

Since subatomic particle collisions cannot be observed directly, the computerized information from these events in one segment of a detector is recorded in a channel. Physicists link the detector segments together to determine the path of a particle. In the SSC, for example, millions of segments are required to record particle tracks.

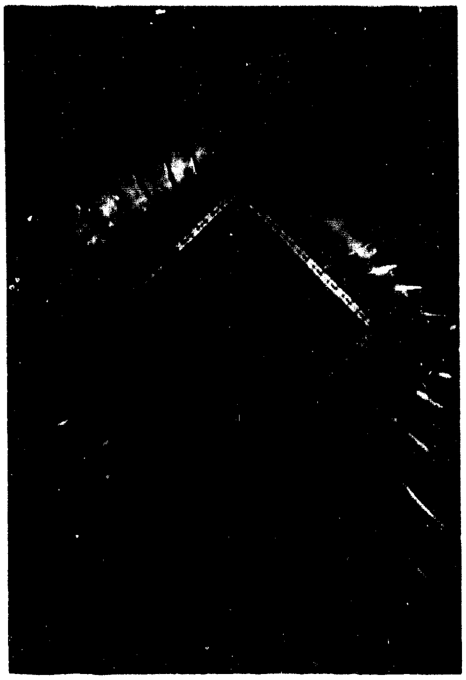
Even though 16 channels are packed into a single chip, it will be small enough to be placed inside a detector without crowding other parts of the apparatus. Scientific data will be improved by using these chips because, in contrast to larger circuits, they do not impede a particle's path through a detector.

Since each monolithic circuit may contain enough digital "intelligence" to perform its own calibration and data processing, costs are reduced by eliminating extra cabling and circuitry. When these components are integrated together on a single silicon chip, its speed of operation can be increased significantly, and, in some cases, the power requirements can be reduced.

Next year, Brookhaven researchers plan to include six functions into one eight-channel chip. Few attempts have been made to pack so many sophisticated functions onto a single silicon chip.

Dramatic progress in monolithic integrated-circuit technology means that the number of transistors that can be placed on a single chip of silicon doubles every three to four years. By riding this technology wave, Instrumentation researchers expect to be able to offer more complex and powerful electronic systems custom-tailored to the needs of scientists for many years to come.

Photomicrograph by William Marin Jr. showing an 8-channel preamplifier designed in BNL's Instrumentation Division.



Paul O'Connor tests a prototype monolithic circuit for use with gas detectors.

The Computing and Communications Division supplies vital support to Brookhaven's scientific programs by capitalizing on the latest high-speed networking technologies; planning and developing future data-processing facilities and tools; operating major central computers and communications networks, including the telephone system; providing computer-systems maintenance services; and assisting in all areas of programming. The division also supports scientific and engineering workstations for applications such as computer-aided design and manufacturing systems.

RIDING THE INFORMATION SUPERHIGHWAY

Soon, a researcher at BNL and a radiologist at University Hospital at Stony Brook will be able to examine a medical image at the moment it is produced at BNL — both at their separate locations.

Thanks to a technological revolution that combines and enhances the capabilities of the telephone, television and computer, medical images will be transmitted instantaneously back and forth between Brookhaven and Stony Brook with extremely high resolution, permitting accurate interpretation and diagnosis.

To make this technological feat possible, BNL's Computing and Communications Division is overseeing the Laboratory's collaboration with the State University of New York (SUNY) at Stony Brook, Cablevision and Grumman Data Systems to establish a high-speed communications network between Brookhaven and SUNY Stony Brook. Cold Spring Harbor Laboratory and numerous local hospitals may be future partners in this project, which will eventually link Long Island to an international high-speed communications network known as the information superhighway.

SUPERFAST MEGA-DATA

A high-speed switching technology called asynchronous transfer mode (ATM) will be set in place to bring BNL on-line with the information highway. ATM allows packets of video, voice or text data to be mixed together and sent via fiber-optic cable through special-purpose computers known as switches. At the final destination, the information is reassembled so that it can be understood.

Initially, ATM will be able to send information across the BNL-SUNY Stony Brook network at a speed of 155 million bits per second. Eventually, this will increase to 2.2 billion bits, or gigabits. That's roughly equivalent to 16,000 typed pages in the blink of an eye.

Cablevision, a large cable TV company, began wiring Long Island with fiber-optic cable in 1989. This cable, which transmits information by pulses of light, will be used by the BNL-SUNY Stony Brook collaboration as part of the ATM technology.

Additionally, Grumman Data Systems, which has expertise in network imaging and computer-based patient records in regional health-care centers, will aid in medical image handling and transfer via ATM.

TECHNO-SCIENCE

Eventually, ATM may be employed at Brookhaven for desktop video conferences, in which users can both see and hear — via video and telephone — the people with whom they are interacting at a distance. In addition, this cutting-edge technology will permit users to tune in to a lecture on their computer screens from anywhere ATM technology is in place.

The BNL-SUNY Stony Brook link to the ATM system will also enable researchers to set up and monitor experiments from remote locations throughout the network.

This would be particularly helpful at the Laboratory's major user facilities, such as the National Synchrotron Light Source, where approximately 2,500 researchers from all over the world perform experiments each year. Hooked up to the ATM network, these researchers would be able to control experiments and obtain data without traveling to the experimental site.

Another use of the ATM system would be visualization — creating dynamic computer graphics — and sending the images as they are formed to and from the Intel Paragon supercomputer located at SUNY Stony Brook. For example, orbiting satellite images of weather patterns could be sent to Stony Brook's supercomputer as they are being created at Brookhaven. These could be calibrated and sent back to Brookhaven so that researchers at both institutions could view them simultaneously.

George Rabinowitz (left) and Mark Oros install asynchronous transfer mode high-speed switching technology to bring BNL on line with the information superhighway.

When Brookhaven's Relativistic Heavy Ion Collider (RHIC) begins operations at the end of the decade, the accelerator's giant detectors will spill out data at the rate of 300 megabits per second — more than an encyclopedia of information each second.

To access and analyze these data, Brookhaven's Computing and Communications Division, in collaboration with the RHIC Project, will be installing an asynchronous transfer mode (ATM) network that will connect computers at RHIC researchers' workstations in the accelerator's experimental halls to a central processing and storage computer for RHIC data.

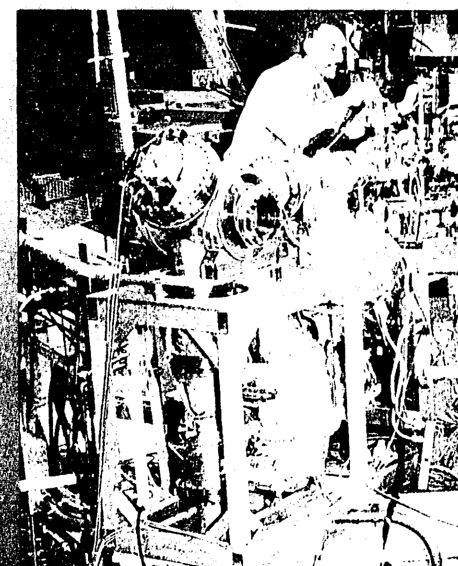
Further, installation of ATM switches will allow units of computer information to be sent through fiber-optic cable to BNL researchers hooked up to the system in their offices and laboratories. This technology will enable on-site researchers to review and analyze their data without actually being at the RHIC experimental halls.

Using a program called GEANT, developed at CERN, the European physics laboratory, and widely used in the physics community, the RHIC researchers will have an analysis tool of unprecedented power. It will enable experimenters to simulate events of interest in future experiments and view representations of these events in complex detector geometries. The availability of high-speed ATM networks will make it possible for researchers to modify the parameters of the images displayed on their own workstations.

To install the new ATM network at BNL, our Internet system will be upgraded a hundredfold, from a speed of 1.54 megabits to 155 megabits per second.

The local ATM network is expected to be in place by 1994, so that RHIC designers will be able to work with a variety of sophisticated visualization tools.

LABORATORY PROFILE



Gwyn Williams stands at the infrared beam line at the National Synchrotron Light Source, where he collaborates with Exxon, AT&T Bell Laboratories and Grumman, in addition to a number of universities and laboratories. This infrared beam line, the only one in the U.S., is attached to the ultraviolet ring of the Light Source, which is the best infrared source in the country.

Participants in September's Radiological Assistance Program seminar gather by a helicopter specially equipped with an aerial radiation monitoring system.

At our multiprogram laboratory, researchers study and discuss a broad range of subjects. Throughout 1993, many of these topics took center stage at conferences, meetings, workshops and symposia held at Brookhaven, such as those sampled here:

As the home of the Relativistic Heavy Ion Collider, BNL was chosen as the location for the 108th meeting of the New York State Section of the American Physical Society, a symposium on **"New Physics With Heavy Ions,"** October 16-17

The **Workshop on Stability of Particle Motion in Storage Rings** was attended by about 90 physicists from around the world and ran October 19-24.

About 100 scientists from 14 countries attended the week-long **Sixth International Symposium on the Production and Neutralization of Negative Ions and Beams,** November 9-13, at which physicists from many diverse fields reviewed progress in the development of negative-ion sources and in the understanding of fundamental processes of these sources and the production of neutral beams.

BNL hosted a two-day workshop March 8-9, to begin organizing a northeastern consortium to aid the U.S. Department of Energy (DOE) in **environmental restoration and waste management** at its facilities nationwide.

To explore the ground between particle and nuclear physics that would be covered by the proton and hadron beams at existing accelerators, Brookhaven, Fermi National Accelerator Laboratory, Indiana University, Los Alamos National Laboratory and TRIUMF sponsored a second workshop on **Future Directions in Particle and Nuclear Physics at Multi-GeV Hadron Beam Facilities,** attended by some 225 participants, March 4-6.

About 180 fuel-oil marketers, equipment manufacturers and researchers learned about recent oil-heating technology advances and participated in discussions on advanced oil-heating systems, at the **Oil Heat Technology Conference and Workshop,** on March 25-26.

A unique collaboration involving the American textile industry, DOE and its laboratories, AMTEX is part of a new DOE effort to use the capabilities resident at the DOE labs to solve U.S. industry's technical problems and improve its competitiveness in a global market. On May 25-26, BNL hosted a meeting of the **AMTEX Operating Committee.**

Approximately 400 of the National Synchrotron Light Source's 2,600-plus users attended the **1993 Annual NSLS Users' Meeting,** May 19-23, which pointed out how, as the nation changes its priorities from national defense to international competitiveness, the NSLS remains a national resource both for basic science and applied research with commercial applications.

The challenge of carrying out planned physics programs with increasingly restricted funding was the underlying theme of much of the **Alternating Gradient Synchrotron and Relativistic Heavy Ion Collider (RHIC) Users Annual Meeting,** June 3-4.

Now in its construction phase, the STAR detector will be one of the largest experiments at RHIC, and members of the **STAR Collaboration** met July 12-16, to discuss the detector's progress and plan for the future.

A conference on **The Impact of Microdosimetry on the Radiation Sciences** was held in the Medical Department on August 9.

RHIC School '93, a workshop on physics and detector techniques related to research at RHIC, attracted some 65 participants, August 23-27.

Vsystem is a computer software package used to build and customize facility control systems, and 35 participants attended the **First Workshop on Applications of Vsystem Software and Users' Meeting,** held September 8-10.

Representatives of 11 northeastern states attended the **Radiological Assistance Program (RAP) Seminar,** held on September 15-16 and sponsored by DOE to give an overview of DOE's radiological resources, including the RAP teams that provide assistance to state and local agencies in the event of a radiological emergency.

About 120 researchers from 16 countries came September 19-22 for the **Fifth International Workshop on Targetry and Target Chemistry,** a forum for discussing problems associated with accelerator-produced radionuclides, especially those used in the imaging technique known as PET, for Positron Emission Tomography.

A conference on **Recycling Technologies and Market Opportunities,** held on September 20, was attended by about 75 people.

Approximately 150 accelerator, particle, nuclear and condensed-matter physicists joined others from BNL, universities and other national and international laboratories for a look at the future of accelerator technology, at the **Symposium on Frontier Applications of Accelerators,** on September 28.

LECTURES

On any given day at Brookhaven, there are likely to be several speakers addressing the Laboratory's researchers in lectures or seminars sponsored by our departments and divisions. Beyond that, several speakers reached BNL's lecterns under the aegis of special programs.

• ***AUI Distinguished Lectures*** — Addressing topics of general interest were Dixy Lee Ray, zoologist, environmental activist and former governor of Washington State; and Arno Penzias, Nobel laureate and President of Research at AT&T Bell Laboratories.

• ***Brookhaven Lectures*** — In this series' 33rd year, the speakers were: Per Bak, Physics, self-organized criticality; Stephen Dewey, Chemistry, using PET to investigate the brain; Howard Gordon, Physics, D-Zero experiment; Leonard Hamilton, Applied Science, realistic risk assessment; Garman Harbottle, Chemistry, neutron activation in archaeology; Samuel Krinsky, National Synchrotron Light Source (NSLS), a brighter NSLS; Robert Palmer, Center for Accelerator Physics, mysteries of superconducting magnets; James Powell, Advanced Technology, the particle-bed reactor; Gregory Van Tuyle, Advanced Technology, making tritium using accelerators.

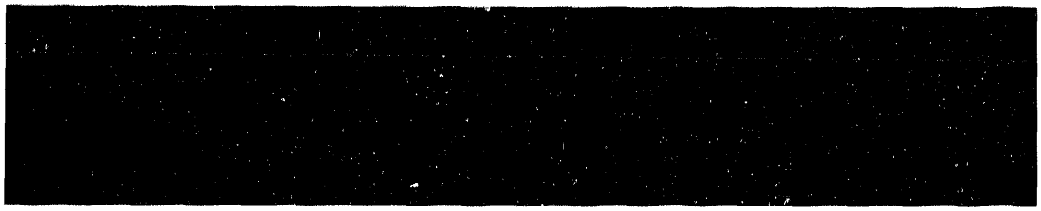
• ***Haworth Lectures*** — In residence at BNL under this appointment was theoretical physicist Andrew Sessler.

• ***Pegram Lecture*** — Nobel laureate James D. Watson, Director of Cold Spring Harbor Laboratory and codiscoverer of the molecular structure of DNA, was the 22nd Pegram Lecturer, going "Beyond the Double Helix" in a two-part lecture series.

• ***Office of Educational Programs Seminars*** — The laboratory role in science education was addressed by Ruth Ann Verrell, U.S. Department of Energy.

• ***Brookhaven Women in Science Seminars*** — In this series, lecturers were: Jean Thomas, professor of macromolecular biochemistry; biochemist Maryka Bhattacharyya; and chemistry professor Cynthia Friend.

• ***Aditya Sambamurti Memorial Lecture*** — In this series' second year, the speaker was Jack Ritchie, assistant professor of physics, University of Texas at Austin, and co-spokesman for E871 at BNL's Alternating Gradient Synchrotron.



At the Laboratory, the following were honored this year:

BNL's Travel Office (Staff Services) received the 1992 SABRE Star Award in July 1993, for its expertise in using the SABRE computer-reservation system to conduct official BNL business travel with American Airlines.

The **Brookhaven Bulletin** won an Award of Achievement in the Technical Publications Competition of the New York Chapter of the Society for Technical Communications, in April 1992.

Throughout the year, **75 Brookhaven employees** were named recipients of the Laboratory's Spotlight Awards for extending short-term extraordinary effort in response to department or division needs.

Per Bak (Physics) received BNL's Distinguished Research & Development Award, in December 1992, for his pioneering work on the phenomenon of self-organized criticality.

Walter Bay and **Paul Coleman** (Plant Engineering) were honored with a U.S. Department of Energy (DOE) In-House Energy Management Award in October 1992, for their leadership in improving the Laboratory's energy efficiency.

John Blewett (retired) won the American Physical Society's 1993 Robert R. Wilson Prize in May 1993, for his contributions, beginning in the 1930s, to accelerator physics and technology, including the experimental verification and first indirect observation of synchrotron radiation, the first application of the alternating gradient focusing concept to linear accelerators, and many developments in the design and construction of accelerators and storage rings.

Martin Blume (Director's Office) was elected to the American Academy of Arts and Sciences in May 1993.

Roseann Callister, Betty Organek and **Fred Rodriquez** (Contracts & Procurement) were recognized as outstanding buyers within their division, in October 1992.

Kenneth Davis (Plant Engineering), **William Foyt** (National Synchrotron Light Source), **Lance Junker** (Reactor), **Robert Miltenberger** (Safety and Environmental Protection) and **Anastasios Soukas** (Alternating Gradient Synchrotron) were winners of the Laboratory's Brookhaven Award, given in December 1992 for their key contributions to support areas and their performance and achievements that represent outstanding service to BNL.

M. Sue Davis (Director's Office) was honored for her scientific accomplishments and contributions to Brookhaven Town, in March 1993, at the town's annual Women's Recognition Night, part of its observance of Women's History Month.

Stephen Dewey (Chemistry) won a $70,000 Established Investigator Award from the National Alliance for Research on Schizophrenia and Depression, to study how the brain responds to certain therapeutic drugs used in the treatment of schizophrenia, effective May 1993.

Val Fitch and **Vera Rubin** (Associated Universities) each received the prestigious National Medal of Science from President Clinton at a White House ceremony in September 1993.

Yreana-Renée Flack (Educational Programs) was presented with an Excellence in Education Award by the Long Island Black Educators Association in March 1993, for designing and implementing the Environmental Education Outreach Program.

Robert Hall (Advanced Technology) won a 1992 Federal Laboratory Consortium Award of Merit for outstanding work in technology transfer, particularly for his creativity in developing key points of contact in multiple utility companies.

Walter Kato (Advanced Technology) was awarded a medal — the Kun-Santou Zuiho-sho, or the Order of the Sacred Treasure, Gold Rays with Neck Ribbon — from the Japanese government in March 1993, for his contributions to nuclear safety and nuclear engineering education in Japan.

Tasneem Khan and **John Baum** (Advanced Technology) coauthored the paper "Doses to Worker Groups in the Nuclear Industry," which won the Editors' Award as best paper of the year in the journal *Radiation Protection Management*, in the November/December 1992 issue.

Maya Paczuski (Physics) was one of 12 postdoctoral researchers in the U.S. to be awarded the first Distinguished Postdoctoral Research Program appointments by DOE, receiving a year's stipend of $52,800 and a travel allowance to pursue her theoretical study of the critical properties and surface-ordering effects in the metallic element holmium, beginning in January 1993.

Robert Palmer (Center for Accelerator Physics), **Nicholas Samios** (Director's Office) and **Ralph Shutt** (RHIC Project) shared the 1993 W.K.H. Panofsky Prize of the American Physical Society in April 1993, for their 1964 discovery of the omega-minus particle, which validated the quark model of elementary particles.

Krsto Prelec (Alternating Gradient Synchrotron) was a recipient of the Laboratory's Distinguished Research & Development Award, in December 1992, for his contributions to research and development of ion sources and to accelerator physics.

Albert G. Prodell (RHIC Project) was honored by the Shoreham-Wading River School District when one of the district's school buildings reopened in September 1993 as the Albert G. Prodell Middle School, acknowledging his almost three decades of service on school boards.

E. Parke Rohrer (Director's Office) was named one of DOE's first three recipients of the Secretary's new Outstanding Contractor Program Manager Award in January 1993, for his considerable contributions to the development of magnets for the Superconducting Super Collider.

Nicholas Samios (Director's Office) was the recipient of the Long Island Distinguished Leadership Award for May 1993, presented by *Long Island Business News*.

Richard Setlow (Director's Office) received an honorary Doctor of Medicine from the University of Essen, Germany, in September 1993, in recognition of his achievements in the elucidation of the molecular mechanisms of the repair of DNA damage, and its implications for understanding the origin and therapy of malignant diseases.

Sharon Smith (Applied Science) was awarded an honorary Doctor of Science degree at Long Island University's Southampton Campus commencement ceremonies in May 1993, for being a "scientific explorer extraordinaire" in her oceanographic research.

Prantika Som (Medical) was honored by Japan's Tohoku Medical Society in February 1993, with a plaque and a citation commemorating her contributions to the society through her work, which focuses on cardiovascular nuclear medicine.

Masaki Suenaga (Applied Science) was a recipient of the Laboratory's Distinguished Research & Development Award, in December 1992, for his materials science research and engineering of superconducting materials.

Peter Takacs (Instrumentation) was a recipient of the Laboratory's Distinguished Research & Development Award, in December 1992, for his significant contributions to the metrology of mirror surfaces. In spring 1993, Takacs shared a Circle of Excellence Award from the trade magazine *Photonic Spectra* for developing the Long Trace Profiler (LTP) for detecting nanometer-sized defects on high-tech mirrors. Then, in September 1993, BNL and Continental Optical Corporation of Hauppauge were joint winners of a 1993 R&D 100 Award for the LTP II.

Joseph Wall (Biology) was a recipient of the Laboratory's Distinguished Research & Development Award, in December 1992, for international leadership in developing the scanning transmission electron microscope (STEM) as a powerful probe for structural biology, and establishing and maintaining the highly productive STEM user facility at BNL.

Allen Weiss (Advanced Technology) earned a Certificate of Appreciation from the U.S. Nuclear Regulatory Commission (NRC) in October 1992, for his seven years of coordinating the NRC's annual Water Reactor Safety Information Meeting, where some 500 nuclear scientists from all over the world report on the past year's research on reactor safety.

William Willis (Director's Office) was elected to the American Academy of Arts and Sciences in May 1993.

Winners of the Brookhaven Award were: (from left, standing) Lance Junker, Robert Miltenberger, William Foyt, (seated) Anastasios Soukas and Kenneth Davis. Each honoree received $2,000 and an engraved memento.

EQUAL OPPORTUNITY

In November, over 300 students and 30 counselors participated in a Career Awareness Event at the Laboratory. Organized by the Office of Equal Opportunity, the event was intended to encourage young people to pursue careers in scientific and technical fields. This activity included an official welcome, a tour of the Science Museum, a career seminar, panel discussion on college options, lunch with employees and talks with BNL staff about matching education with career goals. The participants came from 17 different school districts, and 77 percent were minority students.

PERSONNEL STATISTICS

In 1993, employment at the Laboratory remained generally steady (see chart below), although tight budgets required some reductions in staff, most of which were voluntary.

Employment Statistics

	1993	1992	1991
Scientific Staff*	604	598	588
Scientific Professional Staff	639	622	568
Nonscientific Staff	2,106	2,144	2,204
Total	3,349	3,364	3,360

Percent of Total Employees

Minorities	17.3	17.0	17.9
Women	24.3	22.7	24.5

*Includes research associates and visiting staff.

Some 4,290 guest researchers, ranging from students to scientists with research appointments, took advantage of Brookhaven's world-class research facilities in 1993. These guest researchers came from 479 U.S. and 326 foreign institutions.

MOVING TO METRIC

To comply with an Executive Order requiring each federal agency to use the metric system of measurement in federal government procurements, grants and other business-related activities, to the extent economically feasible, Brookhaven joined with the other national laboratories on October 10, 1992 — the tenth day of the tenth month — to announce plans and actions that will ensure the U.S. Department of Energy's (DOE) compliance with the order.

BNL's implementation is described in our Metric Transition Plan, which spreads tasks related to "metrication" throughout the Laboratory. The BNL Training Office, for example, is responsible for coordinating education and training in metrication. The Plant Engineering Division handles conventional construction; the Central Shops Division, mechanical fabrication; the Supply and Materiel Division, central stores. The BNL Quality Assurance Office coordinates the changing of specifications and standards, while the Division of Contracts and Procurement gives special attention to the effects of conversion on small and disadvantaged businesses.

DEFENSIVE DRIVING

In April, the Safety and Environmental Protection Division and the Occupational Medicine Clinic announced that a Defensive Driving Course would be offered on site. The response was so strong that the course has been offered at the Laboratory almost continually since then. By the end of the year, almost 600 employees and their family members had completed 21 six-hour courses, becoming eligible for a 10 percent discount on insurance premiums for three years — and becoming safer, more defensive drivers.

EVACUATION EXERCISE

Every two years, DOE asks that Brookhaven demonstrate that the site can be evacuated quickly in the event of an emergency. Thus, an evacuation exercise was held on December 3. Although employees were alerted that the exercise was forthcoming and reminded about proper evacuation procedures, they were not advised of the date. When the site sirens signaled the start of exercise, the Laboratory community responded quickly and calmly, ensuring a successful evacuation.

LITERACY VOLUNTEERS

Literacy Volunteers of America (LVA) is an organization that provides free, individual, private and confidential tutoring to people who wish to learn to read or become better readers. To bring these benefits of LVA to Brookhaven employees, visitors, guests and spouses, BNL became involved in LVA training workshops in November. When the year ended, 17 BNLers had completed the basic reading training program to become tutors, tutor instructors and skill testers. Currently, 15 people within our community are being tutored by BNLers.

PURCHASING POWER

BNL purchased about $34 million in supplies and services from Long Island businesses in fiscal year 1993. These local purchases account for about one-third of all goods and services purchased by the Laboratory this year.

One of Brookhaven's major Long Island contracts was awarded in December, when BNL's Division of Contracts and Procurement handled a $6-million agreement for Grumman Corporation to produce 432 superconducting quadrupole magnets for BNL's Relativistic Heavy Ion Collider (RHIC), Grumman's second contract for RHIC magnet work.

Of Brookhaven's total purchases of over $124 million this year, over 56 percent were made with small and disadvantaged companies.

PROGRESS ASSESSMENT

Near the end of January, a 16-member Progress Assessment Team from DOE came to Brookhaven to assess the Laboratory's progress toward establishing and maintaining good environmental, safety and health programs and practices. The team came as a follow-up to the DOE Tiger Team's visit of 1990.

During its two weeks on site, the Progress Assessment Team reviewed such areas as the corrective action program, the self-assessment program, directives and conduct of operations, environment, fire protection, industrial hygiene, occupational safety and health, oversight and organization, and planning and training at the Laboratory and at the DOE Brookhaven Area Office.

The final report of the team's visit, which was issued in July, stated: "The Progress Assessment Team has found much progress at BNL since the 1990 Tiger Team review. . . . There has been significant progress in the area of worker safety. . . . There is a growing awareness of ES&H [environment, safety and health] in the workplace . . . that making such progress . . . involves the commitment of many employees from the Laboratory Director on through all organizations."

RUMOR HOTLINE

To provide another way for employees to get quick, factual answers to their questions about the Laboratory, the Public Affairs Office initiated the Rumor Hotline, in February. By dialing Ext. ASK1 (2751), employees are assured that their questions will be treated seriously and in complete confidentiality. The hotline complements Tune In!, the office's long-established letters-to-the-editor program.

ON-SITE CONTRACTORS

As of March, employees didn't have to travel far to book their personal travel to faraway places. That's when a branch of Omega World Travel opened in Berkner Hall to help members of the BNL community make their personal travel arrangements. One of the largest woman-owned, full-service travel agencies in the U.S., Omega has had a contract with Brookhaven's Travel Office in the Staff Services Division to arrange the Laboratory's official trips, since 1987.

Management of the on-site Gulf service station changed hands in July, when the contract was awarded to Upton Industries.

RESOLVING ES&H CONCERNS

A new avenue for resolving concerns about environment, safety and health at the Laboratory opened in March when the employee relations counselor in the Personnel Division was formally designated to handle such complaints from BNL employees, contract workers and guests who are not satisfied with the response from management. In overseeing an investigation of the situation and its correction, the counselor makes every effort to handle the matter confidentially.

NEW VEHICLES

Several new vehicles began operating on site this year. As the year began, 20 mini trucks joined the Laboratory's on-site motor fleet. With three-cylinder engines that run on unleaded gas and get 45 miles per gallon, the Mitsubishi trucks have a top speed of about 25 miles per hour.

In February, a 150-ton lattice-boom crane was delivered to the Plant Engineering (PE) Division, to provide the lifting power to move accelerator and experimental equipment at the Alternating Gradient Synchrotron and at RHIC. And PE's spanking white, 36-yard, 10-wheel refuse truck began making its rounds in March, replacing two 16-yard trucks used on site for 25 years.

Also in service since March is BNL's newest fire truck, manufactured by E-One. Members of the Fire/Rescue Group in the Safety and Environmental Protection Division were commended for developing the specifications for the 16-ton pumper with its customized cab compartments. Because of its innovative design, the manufacturer now calls that version the BNL model and features it in its sales literature.

GRAPHIC ARTS

Around Brookhaven, WordPerfect has become the favored word-processing program for preparing most docu-

ADMINISTRATIVE ACTIONS

W. Robert Casey was reappointed Head of the Safety and Environmental Protection Division, in January 1993.

M. Sue Davis was appointed Associate Director for Reactor, Safety and Security, in December 1992.

Victoria L. McLane accepted a one-year appointment as BNL's Women's Program Coordinator, beginning in May 1993.

Russel J. Reaver was named Manager of the Safeguards and Security Division, in January 1993.

Norman Sutin began a second term as Chairman of the Chemistry Department, in December 1992.

Karl J. Swyler began serving as Acting Manager of the Office of Educational Programs, in May 1993.

Mark S. Wiesenberg joined the Laboratory as Head of the Computing and Communications Division, in October 1992.

Leland F. Willis assumed the newly created position of Vice President for Environment, Safety & Health of Associated Universities, Inc., in January 1993.

ments. Recognizing this, in April, the Technical Publishing Center of the Photography and Graphic Arts Division began offering to prepare, edit and print WordPerfect documents from IBM low- or high-density disks, from handwritten documents or from DOS files. Macintosh software programs were also made available for text input and editing.

Also in April, a new Komori Sprint 26 offset press was delivered to the division. Safer and faster than its 22-year-old predecessor, the new press employs the latest in photo-offset technology, such as automated settings and water-based chemicals.

CHILD DEVELOPMENT CENTER

To brighten the Easter holiday for the area's elderly in April, the youngsters attending BNL's Child Development Center (CDC) entered into a partnership with the on-site Brookhaven Nutrition Center, which, sponsored by the American Red Cross, prepares almost 700 hot meals daily for delivery to the homebound and to senior citizens' centers throughout the area.

First, CDC children ages 3 to 5 colored 100 each of eggs, place mats and baskets. Then, the nutrition center's staff incorporated these items into pre-Easter food trays, to the delight of hundreds of recipients. Now that this connection has been made, the CDC and the Nutrition Center plan to continue it on other holidays.

In May, the CDC's kindergartners learned firsthand about police work at the Laboratory. One day, they toured BNL Police Headquarters, where they learned about fingerprinting and watched a police training film; the next day, officers returned the visit, stopping by the kindergarten in a patrol car.

TEAM SAFETY

A review of BNL's almost five-year-old safety-incentive program known as Team Safety brought some rule changes and improvements in rewards to workers enrolled in the program, in May. Team sizes were adjusted to eliminate an advantage for smaller teams, and, while each team is still challenged to remain accident-free for three months at a time, the new rules encourage individual workers to continue accident-free for as long as possible and reward them for each year they are not hurt on the job.

SALARY FREEZE

In May, President Bill Clinton and Secretary of Energy Hazel O'Leary announced that DOE would freeze the salaries of the employees of its management and operating contractors for fiscal year 1994, including those of BNLers.

BERA NEWS

A new Bridge Club was the 49th organization to join the roster of clubs and activities recognized by the Brookhaven Employees Recreation Association (BERA). Formalized in June, the new club is using some old equipment formerly owned by the Laboratory's original Bridge Club, which was formed along with BERA in 1948 but had not been active in over a decade.

SMOKING BAN

As of June 14, smoking was prohibited in all Laboratory vehicles and buildings, with the exception of residential units and the smoking section of the Brookhaven Center Club. Recognizing that this change would be difficult for some employees, the Occupational Medicine Clinic helped those wishing assistance in kicking

Kindergartners at BNL's Child Development Center egg-statically display their creations, which were delivered to the area's elderly at Eastertime with food trays prepared by the on-site Brookhaven Nutrition Center, sponsored by the American Red Cross.

the smoking habit with a free smoking-cessation program.

CHANGE OF ADDRESS

The Laboratory's official address changed in July with the addition of a Labwide post office box — P.O. Box 5000. The change was required to take advantage of the increased efficiency in the processing and delivery of mail offered by the U.S. Postal Service's computerized mail-processing machines.

RADCON TRAINING

Laboratory staff who work with radiation are required to demonstrate that they are qualified in the radiation protection elements that are identified in DOE's Radiological Control, or RADCON, Manual.

To help employees fulfill these requirements, the Safety and Environmental Protection (SEP) Division initiated a new series of RADCON training courses in the fall of 1993. And, as an alternative to formal classroom training for individuals who have had prior radiological training, earned qualifications at another facility or completed formal education in health physics or radiological controls, SEP also began offering challenge exams for each course.

UNION CONTRACT

With the contract between BNL and Local 2230 of the International Brotherhood of Electrical Workers (IBEW) due to expire on July 31, both parties agreed to extend the contract for two months while negotiations continued. At the end of September, a new agreement was reached, extending IBEW's contract with the Laboratory for the full year ending July 31, 1994, with all of the conditions of the existing contract remaining fully in force.

IBEW represents about 550 bargaining unit employees in six BNL divisions: Central Shops, Photography and Graphic Arts, Plant Engineering, Safety and Environmental Protection (fire fighters), Staff Services, and Supply and Materiel.

MUSEUM PROGRAMS

In 1993, a record 26,553 people participated in the many programs handled by the Public Affairs Office's Museum Programs. Among those participants were more than 5,800 people who joined a summer Sunday tour to learn about BNL research at the Laboratory's museum; close to 300 teens who tested their engineering and design skills at the annual model bridge contest held on site; over 4,100 fifth graders who took a break from their usual classroom routines for a hands-on magnetism lesson that's brought to the schools; and nearly 700 college students who enjoyed tours of the Laboratory specially geared to their academic interests.

Brookhaven's museum, previously known as the Exhibit Center, was given a new name in September: The BNL Science Museum was renamed to reflect the fact that it presents information not only on BNL research, but also on general science.

WOMEN'S PROGRAMS

In July, 21 BNL women were among more than 5,000 participants at the 25th National Training Program sponsored by the organization Federally Employed Women and held in Las Vegas. Brookhaven participants in this training and networking opportunity for women were drawn from eight departments and divisions.

SUPERFUND

The Office of Environmental Restoration (OER) is in charge of remediating areas of known contamination, as well as identifying and cleaning up other areas of potential problems. To date, OER has identified 27 areas of concern that need to be investigated further. These areas are grouped into seven operable units, two of which are highlighted in this report.

Operable Unit I, located in the southeast section of the Laboratory property, consists primarily of two inactive landfills, the waste-management facility and an area of groundwater contamination, which had been initially remediated by a spray aeration technique. During the year, the work plan and the sampling and analysis plans for Operable Unit I were completed and approved.

Operable Unit IV consists of the Laboratory's steam plant and a 1977 fuel-oil spill at that location. For this unit, extensive sampling and analysis have been completed, in order to identify the extent of contamination, the ways people may be exposed and the risks to people and the environment. Cleanup actions are now being determined.

OER has had a community relations coordinator on staff for a full year now. As a result, BNL has established regular contact with 14 civic groups and two umbrella organizations that also represent many others.

The community relations program is a major line of communication with the surrounding communities, enabling BNL to educate and inform the public about ongoing or planned environmental remediation on site, as well as give the public an opportunity to voice concerns and get answers to any questions. Site tours are also available, and civic groups can arrange to have OER staff address specific topics at their meetings.

All remediation work must be approved by New York State, the Environmental Protection Agency and the Department of Energy (DOE). As the federal agency that has jurisdiction over the BNL site, DOE is responsible for cleanup costs.

In fiscal year 1993 (FY93), Brookhaven's total budget was $400.4 million, an increase of 4.1 percent over FY92.

BNL's budget is divided into three areas:

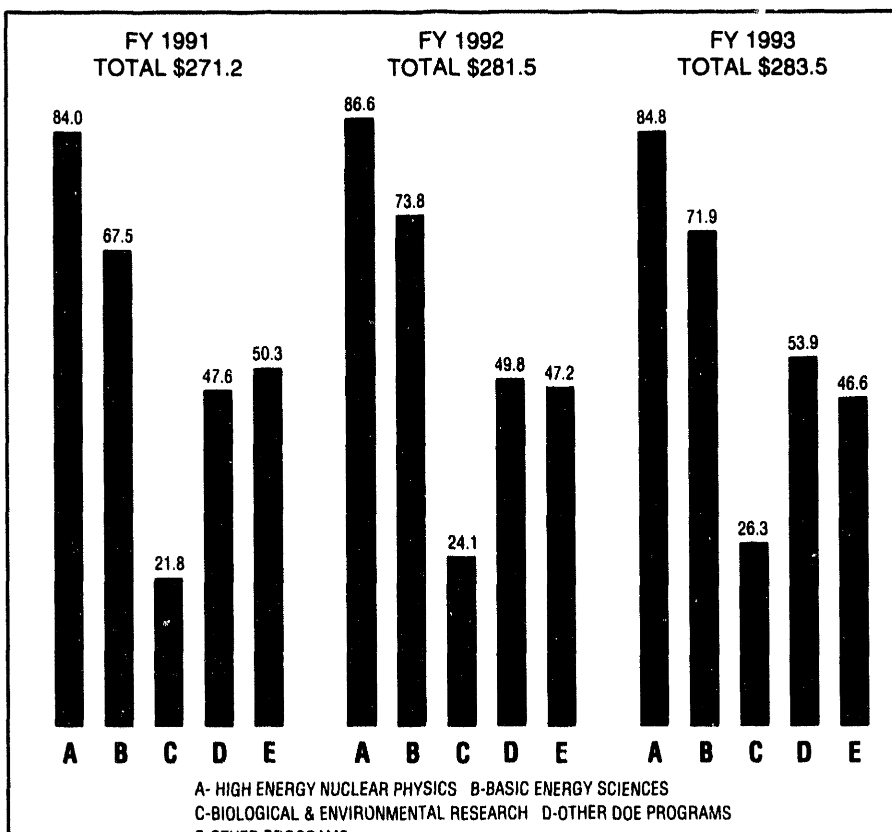
• Operating funds support the Laboratory's various research programs. These funds pay the costs of salaries and wages, fringe benefits, materials and supplies, and energy associated with the research programs. In FY93, operating funds added up to $283.5 million. Included in those operating funds was $5.7 million received from the Superconducting Super Collider Laboratory for research and development work, which is included in the "Other DOE Programs" category in the chart below.

• Capital equipment funding, which amounted to $19.9 million in FY93, provides for major instrumentation, scientific apparatus, computers and office equipment.

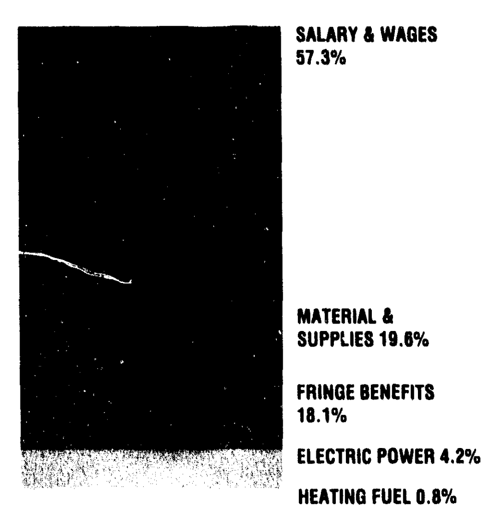
• Construction funds are used for building projects. These monies increased by about 33 percent in FY93, to $97 million, largely due to funding of $70 million for the Relativistic Heavy Ion Collider project. Environmental restoration and waste management (nondefense) projects received $1.7 million for hazardous waste management, waste-site closure and waste minimization. The Laboratory also received $1.8 million for the structural biology addition at the National Synchrotron Light Source, $1.5 million for the potable water system upgrade, and $2.8 million for the sanitary system upgrade phase I.

As in previous years, the principal source of BNL's funding was the U.S. Department of Energy (DOE), which accounted for about 84 percent of the operating budget and for all of the capital equipment and construction funds.

BNL OPERATING FUNDS (millions of dollars)



BNL COST ELEMENTS



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Organization as of September 30, 1993.

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