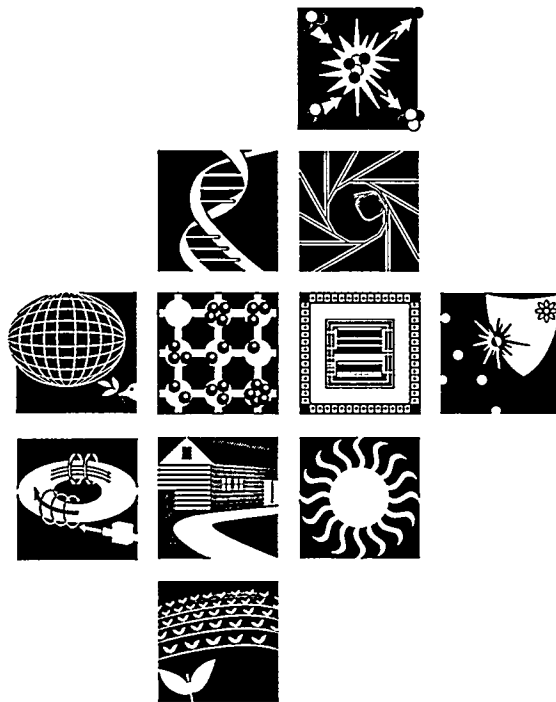


RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES
VOLUME TWO: LABORATORY MATRIX



DECEMBER 1994

PREPARED BY THE MULTIPROGRAM
NATIONAL LABORATORIES

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Preface

For nearly fifty years, the U.S. national laboratories, under the direction of the Department of Energy, have maintained a tradition of outstanding scientific research and innovative technological development. With the end of the Cold War, their roles have undergone profound changes. Although many of their original priorities remain—stewardship of the nation's nuclear stockpile, for example—pressing budget constraints and new federal mandates have altered their focus. Promotion of energy efficiency, environmental restoration, human health, and technology partnerships with the goal of enhancing U.S. economic and technological competitiveness are key new priorities.

The multiprogram national laboratories offer unparalleled expertise in meeting the challenge of changing priorities. This volume aims to demonstrate each laboratory's uniqueness in applying this expertise. It describes the laboratories' activities in eleven broad areas of research that most or all share in common.

Each section of this volume is devoted to a single laboratory. Those included are:

- Argonne National Laboratory
- Brookhaven National Laboratory
- Idaho National Engineering Laboratory
- Lawrence Berkeley Laboratory
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Renewable Energy Laboratory
- Oak Ridge National Laboratory
- Pacific Northwest Laboratory
- Sandia National Laboratories

The information in this volume was provided by the multiprogram national laboratories and compiled at Lawrence Berkeley Laboratory.

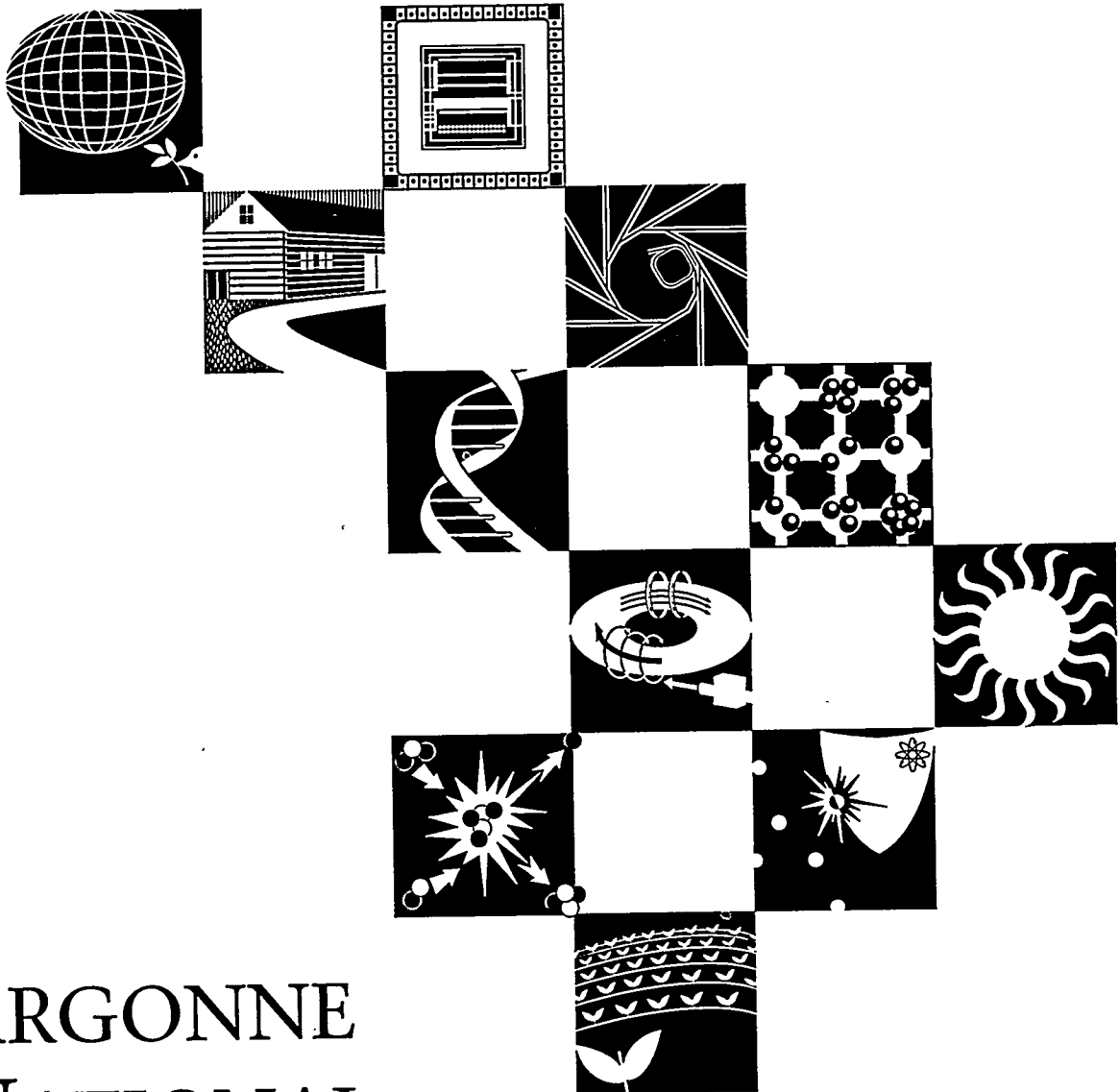
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RESEARCH PROGRAMS
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NATIONAL LABORATORIES



ARGONNE
NATIONAL
LABORATORY



Argonne National Laboratory

Argonne National Laboratory is operated by the University of Chicago for the U.S. Department of Energy (DOE). It was America's first national laboratory, and today its annual operating budget of approximately \$450 million supports more than 200 research projects. Of Argonne's 4,900 employees, more than 1,700 are scientists and engineers, of whom approximately 850 hold doctoral degrees. Argonne research falls into four broad categories—engineering research, physical research, energy and environmental science and technology, and the Advanced Photon Source. We are especially active in areas related to U.S. economic competitiveness, collaborating with industry and universities in state-of-the-art R&D to help sustain and enhance a technologically advanced U.S. economy capable of creating high-wage jobs for American workers. Since 1984, Argonne has been the source of more than 30 spin-off companies and today works actively with industry to grant exclusive licenses to Argonne inventions with commercial potential. Argonne is the only multi-program national laboratory in the Midwest, located on 1,700 acres 25 miles southwest of Chicago. A satellite 800-acre facility, Argonne-West, is near Idaho Falls, Idaho.

Energy Efficiency

Much of Argonne's aggressive industrial-technology efforts center on heightened energy efficiency as a path to increased competitiveness, job creation, and enhanced profitability for U.S. industry. Prominent are Argonne's collaborative efforts with the AMTEX Partnership, linking more than 40 textile companies with DOE national laboratories; Argonne's work with the U.S. Council for Automotive Research (USCAR) and its Partnership for a New Generation of Vehicles; and Argonne's major role in USCAR's Advanced Battery Consortium. Argonne also focuses on the metal, electric utility, pulp and paper, petroleum, and chemical industries.

In the drive to develop batteries for electric vehicles, Argonne researchers developed the first rechargeable bipolar lithium metal sulfide battery. It has the potential to run a car about 250 miles before recharging and last for 100,000 miles, with the power to accelerate from 0 to 60 mph in 8 seconds. When fully developed, Argonne's battery could provide up to five times as much energy per pound as current battery technology and last 10 times longer. Argonne also is teaming with 3M Corp. and Hydro-Quebec to develop lithium-polymer batteries for electric vehicles. Lithium-polymer batteries combine durability and low weight in a small volume.

Capitalizing on its central location in the Midwest, Argonne established an especially vigorous outreach program with the broad goal of bringing energy-efficiency and other productivity benefits to manufacturers and other private and public organizations in the region. One innovative manifestation of that program is our work with local community groups to rehabilitate inner-city buildings to make them more energy-efficient, and generally to exploit ANL technologies to promote local industrial development. To make our energy-efficiency expertise more accessible, Argonne is developing a user-friendly database describing capabilities of interest to industry.

We also are working with DOE and the Departments of Commerce and Transportation on major initiatives involving partnerships with U.S. transportation industries: fuel-efficient and environmentally benign automobiles, intelligent vehicle highway systems, and advanced freight railroad technology. Argonne is a regional manufacturing technology provider as part of the new Chicago Manufacturing Technology Center.

Superconductivity offers significant energy-efficiency potential, and Argonne operates the largest federally funded program in superconductivity research. Coils of superconducting wire have applications which include efficient motors and generators, energy-storage devices, and improved magnetic imaging systems for medical diagnosis. We have created several technologies from these new ceramic-like materials, and in 1994 developed innovations like the longest high-temperature superconducting wire and the strongest magnetic field.

Energy Supply and Renewables

Energy—from existing and from new sources—today is a primary global concern. The United Nations expects the world's population will double and energy demand quadruple over the next 50 years. Argonne's energy R&D efforts span a broad range of current and potential sources, focusing on ways to produce, store, and use energy effectively in a world where industrial growth and environmental quality are goals of equal import to energy availability.

As an internationally recognized nuclear engineering R&D site, Argonne offers government and industry unique test facilities and expertise in all nuclear energy technology disciplines. Among ANL facilities available are those for fuels and materials irradiation testing, fuel and test-article manufacturing, safety testing, reactor physics testing, fuel cycling (including waste treatment), and destructive and nondestructive examination of fuels and safety systems.

Argonne's current nuclear-energy research objectives include creation of centers for nonproliferation technology, spent nuclear fuel characterization and mixed-waste treatment, reactor and fuel-cycle safety in the U.S. and abroad, and decontamination and decommissioning technology.

In fusion energy research, Argonne's central goal is developing vanadium-based alloys and a reliable, high-performance, low-activation "first wall and blanket" system. Another Argonne fusion-related objective is contribution to the design and international development of a high-energy (14-MeV) accelerator-based neutron source for testing candidate materials for fusion power systems.

In non-nuclear energy R&D, Argonne is pursuing solid oxide and molten carbonate fuel-cell technology; supporting research for coal liquefaction technology; probing fundamental combustion processes; studying the structure and behavior of coal, petroleum, and other fossil energy sources; and working to extend the potential of photovoltaics through a deeper understanding of radiation and photochemistry.

Climate Change

Among Argonne's significant core capabilities are:

- Field, laboratory, and modeling investigations of atmospheric transport, transformation, and deposition of pollutants associated with energy production and use.
- Quantifying emissions, particularly greenhouse gases, associated with energy production and use, and other human activities worldwide.
- Modeling and assessing the direct and indirect effects of potential global climate change, including possible mitigation steps.

Argonne scientists manage the initial Cloud and Radiation Testbed (CART) site of the multi-laboratory Atmospheric Radiation Measurement (ARM) program. They also have a principal role in establishing the site and developing and operating the instrumentation installed there. ARM is designed to improve knowledge of the interaction of clouds with solar and terrestrial radiation, recognized as the largest uncertainty in models of global climate change.

Because cloud and radiation profiles through a great depth of the atmosphere are being investigated, innovative methods of remotely probing the atmosphere are necessary. Laboratory scientists are developing, improving, and applying the capabilities of acoustic, microwave, and light systems to monitor continuously the detailed structure of wind, temperature, and moisture throughout the lower atmosphere. Continuous data from the instruments, at previously unattainable temporal and spatial density, are supplied to scientists worldwide.

The first CART site includes 40 instrumented locations spread across 54,000 square miles of Oklahoma and Kansas. Additional CART sites will be established in the tropical western Pacific and on the North Slope of Alaska; short, field campaigns will be carried out over other locations of great interest, such as the Gulf Stream.

Environmental Technology

Internationally recognized, multi-disciplinary environmental programs at Argonne link ANL with industry, government agencies, and academic partners. These teams' continuing goal is innovative solutions for environmental challenges of regional, national and global significance. Notable environmental opportunities for Argonne, its teams, and its program lie in the areas of environmental management and waste restoration, natural resources, energy systems analysis, environmental assessment, and information systems.

Argonne serves as a one-stop implementation center for applied R&D, featuring expedited site characterization, development and application of decision tools for site management, and development of innovative remediation technologies and processes. We also develop supporting programs in decision analysis, cost engineering, technology implementation, risk assessment and management, and information systems. In addition, Argonne serves as the lead laboratory in nuclear reactor deactivation, decontamination, and decommissioning.

To further national stewardship and management of natural resources, Argonne is building capability in increasingly prominent R&D areas such as ecological risk, geographic information and development systems, and ecology-related disciplines—the latter's particular objective is support for the National Biological Survey of the U.S. Department of the Interior, a program to describe and evaluate long-term trends.

In energy systems analysis, Argonne works closely with the DOE Office of Energy Efficiency and Renewable Energy in areas of energy efficiency, demand side management, integrated source planning, and global change. Global change is an especially pressing international issue, with Argonne's systems expertise particularly relevant in evaluating technological and process approaches to moderating growth of greenhouse-gas emissions forecast to occur largely in Asia.

Achieving the nation's broad environmental goals requires making cost-effective analyses and decisions more rapidly, particularly in areas where environmental considerations must be balanced with national objectives for industrial competitiveness, energy costs, and national security. Argonne's demonstrated and growing skill in information systems can help improve decision speed and quality, especially in functions such as information retrieval, integration of large-scale databases, and the use of advanced visualization and simulation technologies as analytical tools.

Health and Biotechnology

Argonne's health and biochemistry research is a mechanistic, synergistic program focused on increasing our ability to understand the fundamental mechanisms of life and to implement valuable applications in injury and illness prevention, and disease therapy. It teams biological disciplines—cellular, molecular, structural, and computational—in a coordinated thrust to reveal fundamental molecular mechanisms governing phenomena such as cell replication, differentiation, mutagenesis, and carcinogenesis.

Argonne's Structural Biology Center (SBC), a major national user facility for macromolecular crystallography, holds especially significant potential for contributions to the nation's health. Fitted with x-ray optics, advanced electronic detectors, and sophisticated hardware, its two beamlines at Argonne's Advanced Photon Source will substantially exceed the performance of any existing facility. Each year, hundreds of users from throughout the U.S. will obtain high-quality data on the structure of large biological molecules such as proteins, DNA and RNA, and biologically important complexes.

The SBC is but one part of Argonne's mechanistic biology vision and initiative. In another component, Argonne biologists are engaged in a major program of DNA sequencing as part of the DOE Human Genome Project. ANL's approach, sequencing by hybridization, promises to increase genome-sequencing efficiency by orders of magnitude. Argonne proved this research concept by employing it to accurately analyze three DNA segments of unknown sequence. Further planned technological developments include computer simulations, and algorithm and software development.

Another element in Argonne's mechanistic-biology initiative, Computational Biology, will investigate relationships between structure and function in biologic macromolecules. This activity is central to our ability to predict biological structure, and thus function, from genetic sequence. It builds upon our recognized capabilities in computational chemistry, high-performance computation, and graphic representation.

In concert, Argonne's mechanistic-biology elements establish a basis for progress in areas including:

- Protein folding and design.
- Molecular recognition and pharmaceutical design.
- Enzyme catalysis and design.

Materials and Chemistry

Materials and chemical sciences have long been core Argonne capabilities. Argonne establishes and maintains unique chemical and materials research facilities for users nationwide, and regularly designs and develops more capable instruments for those facilities. Among those facilities are the Advanced Photon Source (APS), the Intense Pulsed Neutron Source, and the High-Voltage Electron Microscope/Tandem Accelerator.

A hallmark of Argonne materials-research projects is the integrated application of multiple scientific disciplines and specialized facilities.

Significant programs probe:

- Fundamental physics of high-temperature superconductors, including development of new applications.
- New magnetic materials suitable for permanent magnets.
- Improved interface and surface properties of materials, particularly to benefit materials processing, catalytic action, and environmental effects.
- New techniques for electron beam microcharacterization that provide improved analytical methods at greater spatial resolution.
- An integrated understanding of materials damage resulting from electrons, ions, and neutrons.

At the APS, Argonne's materials-science research will center on the Basic Energy Sciences Synchrotron Radiation Facility and will coordinate basic and applied work in engineered materials and related fields into integrated thrusts involving industrial partnerships.

Chemical science centers on advancing basic knowledge in six fields:

- Heavy-element separation sciences, with special relevance for the management of the nation's radioactive wastes.
- Natural and artificial photosynthesis for the effective use of solar energy.
- Fundamental combustion processes to elucidate key chemical reactions that dictate fuel efficiency.
- Radiation and photochemistry, with special attention to chemistry in extreme environments such as nuclear waste tanks.
- Structure and behavior of coal, petroleum, and other fossil-energy sources.
- Metallic clusters and other novel catalysts for greener chemical processes and the effective conversion of fossil materials.

Chemical research at the APS will use synchrotron radiation to study the time-dependent position of nuclei during processes such as natural and artificial photosynthesis. Other chemical-research programs focus on the separation of hazardous, nonradioactive metal ions to help prevent industrial pollution, and basic research to underpin the development of future refineries.

Computing and Information Infrastructure

Argonne emphasizes collaborative R&D partnerships with industry, universities, and other national laboratories as it strives to develop the parallel algorithms, software tools, and visualization technologies needed to realize fully the scientific potential of massively parallel computers. Among industrial partners are General Motors, Allied Signal, and various pharmaceutical and petrochemical companies. Reflecting the real-world composition of their R&D teams, scientists in Argonne's High-Performance Computing Research Facility emphasize design prototyping and testing in real applications that stress system capacities.

With resources including its massively parallel, state-of-the-art IBM SP1 computer system, Argonne expects to make seminal contributions to the next generation of DOE scientific computing, as well as to National Information Infrastructure programs in areas including high-end telecommuting, Internet technology, and multimedia. To achieve that objective, Argonne researchers are:

- Working on scalable input-output environments for teraflops machines.
- Playing a lead role in developing a message-passing interface.
- Planning novel approaches to large-scale data storage and access.
- Developing other new tools such as FORTRAN M.

Argonne intends to pioneer the use of advanced networking technology that can later serve as a model for general use. An important step is Argonne's initiative to establish a Computing and Communications Infrastructure Futures Laboratory (CCIFL) featuring a virtual-reality environment, a multimedia laboratory, and an advanced communications technology laboratory. The CCIFL project involves joint work with vendors, as well as partnerships with users in industry and at Argonne's R&D programs and facilities.

In decision systems and improved information management systems, Argonne's extensive development program emphasizes the application of emerging technologies—such as artificial intelligence, heuristic systems, and object-oriented databases—to management challenges facing the federal government and American industry. Among programs being designed is an initiative to integrate multispectral-imagery processing technologies into a distributed user network for decision support and planning.

High-Energy and Nuclear Physics

Argonne was born of pioneering research in nuclear physics, the precursor of present-day high-energy and nuclear research. Today ANL continues to perform cutting-edge research on the physics of elementary particles and is one of the major national centers for research in nuclear physics.

Argonne's current high-energy physics program includes five large-scale experiments at stages ranging from conceptual design to active data taking and physics analysis. In addition, there is an energetic theory program, with both fundamental and phenomenological investigations, and R&D on advanced methods of particle acceleration that may lead to future research facilities.

Current active experiments include the Collider Detector Facility at Fermilab, ZEUS at the German Electron Synchrotron, Soudan 2 in an underground laboratory in Minnesota, the Toroidal Apparatus at CERN's Large Hadron Collider, and the STAR detector at Brookhaven National Laboratory.

Argonne has pioneered the development of particle acceleration using wakefields created by intense beams of lower energy particles. A first-phase demonstration accelerator is now beginning a program of experiments. Later stages will attempt to meet a standing accelerator physics challenge of acceleration by 1 GeV in 10 meters.

The recent national peer review of all DOE-funded nuclear physics programs ranked Argonne's experimental research programs at the top. The ANL program has three major components. The largest is in heavy-ion research, which is centered on the Argonne Tandem Linear Accelerator System (ATLAS), operated as a major national user facility. This research into the structure and low-energy dynamics of atomic nuclei has led to the discovery of new phenomena and new symmetries. Building on the unique superconducting technology of ATLAS, a proposal is being developed for a new Exotic Beam Facility, foreseen as the probable next major national facility in nuclear physics.

In medium-energy physics, Argonne researchers focus on lepton scattering and are leaders in the development of polarized targets. Their work helps to characterize the properties of nuclei on the subnucleonic level and to understand the role of quarks and gluons in shaping the character of nuclear forces. The research is carried on at CEBAF, Fermilab, and at other facilities around the world.

The nuclear theory program addresses many-body problems and the dynamics of quarks and gluons in nuclei and neutron stars. Using the IBM SP1 at Argonne, the group has recently set world standards in nuclear many-body calculations.

Nuclear Nonproliferation

Nuclear nonproliferation is the new, primary national-security challenge in the post-Cold War world. Four factors position Argonne as a logical, major contributor to addressing that challenge:

- A long-standing, broad expertise in nuclear reactor science, engineering, and research and development.
- Unique nuclear-related facilities.
- Close ties with the U.S. and world nuclear power industry and with the international reactor community.
- Its status as a nonweapons laboratory with major experience in nuclear technology.

Argonne's national-security programs increasingly emphasize arms control verification policy and technology, low-enrichment fuel, export control, and international safeguards including development of new information and methods to better detect and evaluate the clandestine use of nuclear-energy facilities to produce fissile material for weapons. Specifically, Argonne's nonproliferation-related efforts today are concentrated in the areas of:

- Reduced enrichment for research and test reactors.
- Development of safeguards instrumentation and procedures.
- Training of fuel-cycle facility inspectors.
- Assessment of foreign nuclear reactors and fuel-cycle facilities.
- Analysis of foreign civilian reprocessing programs.
- Evaluation of designs of extended burn-up reactors.
- Evaluation of management of spent fuel from foreign research reactors.
- Denaturing of weapons-grade plutonium with spent fuel.
- Assessment of options for disposition of Russian weapons plutonium.

National Research Facilities

Argonne serves its scientific and technological colleagues and customers in industry, government, and academe through major, world-class research facilities. These sophisticated tools draw leading scientists and engineers from varied disciplines, and many team with Argonne's staff for joint research.

Advanced Photon Source (APS). A national user facility, the APS will offer x-ray researchers super-intense x-ray beams, the brightest ever produced, for many areas of basic science, industrial technology, and biological and medical research. Prestigious national committees judged this x-ray source the highest priority among facilities for materials-science research. The APS is to start experiments in 1995, within budget and ahead of schedule. Its capabilities for research in energy, communications, and health are enabling new partnerships among DOE, industrial, and academic researchers—partnerships promising to enhance U.S. competitiveness in critical technological areas.

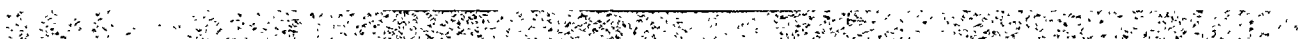
Intense Pulsed Neutron Source (IPNS). A productive, cost-effective facility with 13 neutron-scattering instruments, IPNS operates the largest user program among DOE neutron sources. Its value to national users was reflected in a recent recommendation by a Basic Energy Sciences Advisory Committee panel that IPNS operations be doubled.

Argonne Tandem Linear Accelerator System (ATLAS). A leading national user facility in nuclear structure physics, ATLAS is a superconducting heavy-ion accelerator for all ions up through uranium. ATLAS employs a unique superconducting radio-frequency technology developed at Argonne and now being copied around the world. The facility is heavily used by university groups and serves some 250 scientists.

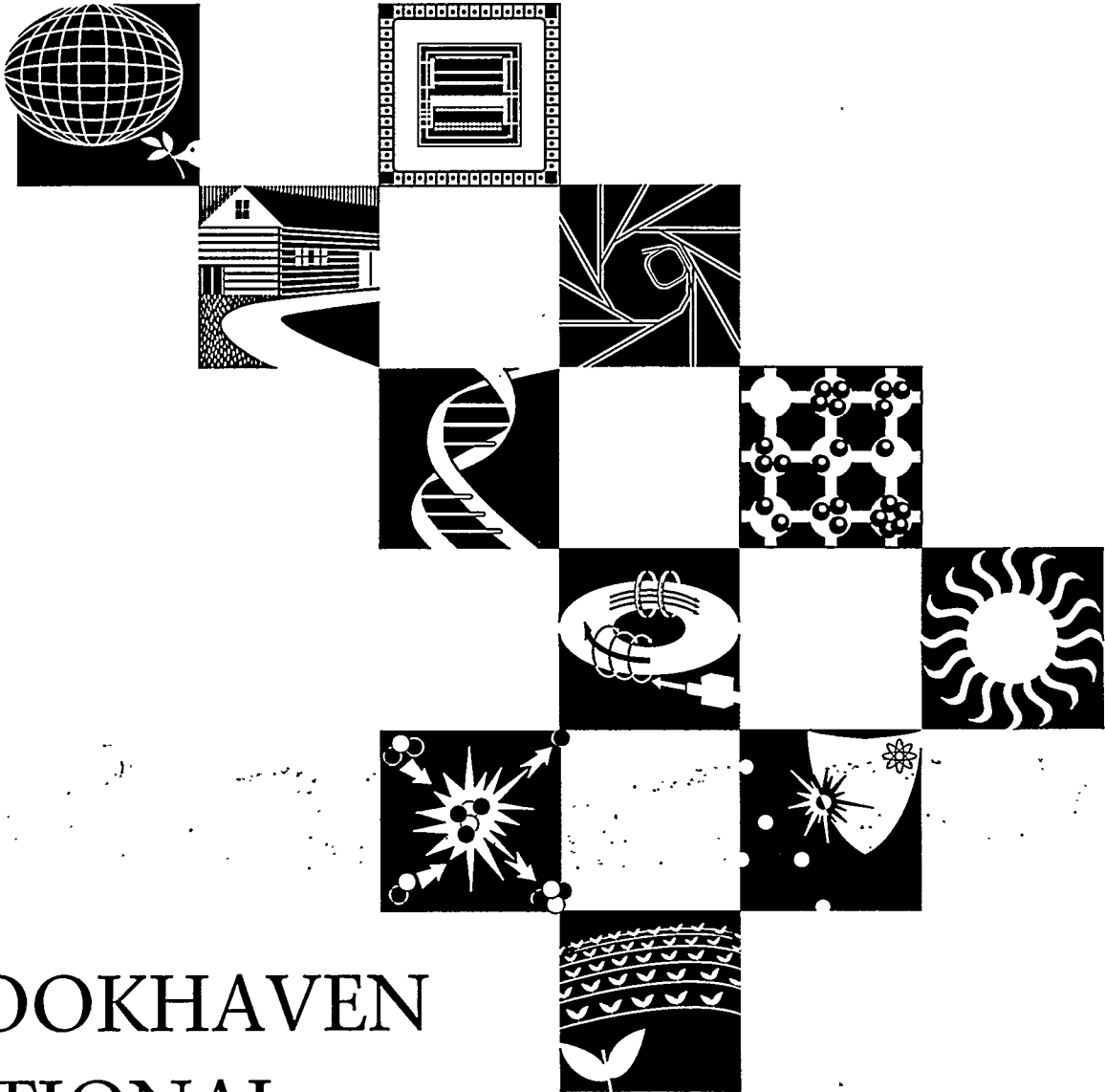
Structural Biology Center (SBC). Based on capabilities of Argonne's Advanced Photon Source, the SBC grew from a call by a National Science Foundation panel for a new research resource in macromolecular crystallography. The center will feature state-of-the-art x-ray optics and electronic detectors, serving hundreds of biologists and crystallographers each year. Its planning and operation are directed by a users group of 11 distinguished scientists.

High-Performance Computing Research Facility. Currently featuring a state-of-the-art massively parallel IBM SP1 system, this facility emphasizes R&D partnerships with industry, other national labs, and universities for solving Grand Challenge problems in such areas as computational chemistry and computational biophysics. Its mission is development, design prototyping, and testing of next-generation software, systems, and algorithms for DOE scientific computing and National Information Infrastructure programs.

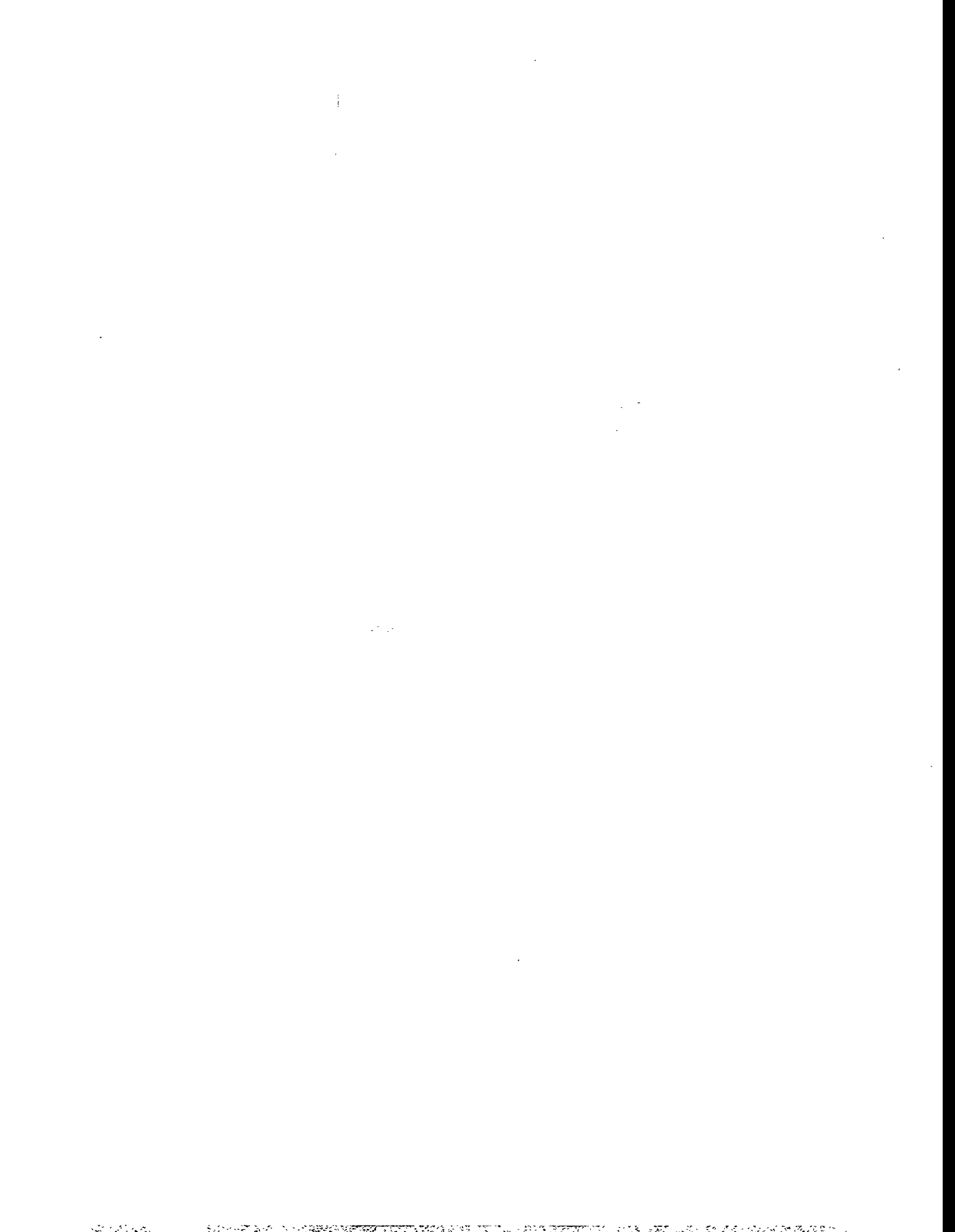
High-Voltage Electron Microscope/Tandem Accelerator Facility. This facility combines capabilities for advanced high-voltage microscopy, ion implantation, ion bombardment, and ion beam analysis.



RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



BROOKHAVEN
NATIONAL
LABORATORY



Brookhaven National Laboratory

Brookhaven National Laboratory (BNL) is operated by Associated Universities Incorporated for the U.S. Department of Energy (DOE). Established in 1947 at Camp Upton, the Laboratory has turned this former army camp into what is now an internationally renowned scientific research institution. At BNL, we probe basic questions about the nature of our universe and the laws under which it operates. At the same time, our science and technology programs play a major role in determining how well this country responds to changing needs in energy, national security, environmental quality, education, and health. The Laboratory sits on a wooded 5,265-acre site on Long Island, approximately 70 miles from New York City, employs about 3,300 people, and has an annual budget of approximately \$400 million dollars.

Energy Efficiency

Brookhaven contributes significantly to the national goal of enhanced energy efficiency. We have developed, for example, a prototype software simulation package that can be used by local governments to manage motor vehicle congestion on the nation's highways. We are partnering with the private sector to develop improved roadside traffic sensors that can supply the information necessary to avert or minimize high congestion periods. We have a Cooperative Research and Development Agreement (CRADA) with the American Textile Industry to review and develop new, energy-efficient processes and components used in the manufacture of fiber, cloth, and clothing in the U.S.

Brookhaven is the national research center for the study of energy-efficient oil-heat systems. Fifteen years ago we began a program of laboratory and field testing (followed by consumer education) that resulted in the near-100% acceptance of the flame retention head burner by the oil-heat industry and consumers; cumulative energy savings through 1994 are 0.75×10^{15} BTU. More recently, we have developed a monitoring system called the Flame Quality Indicator.

Over the past decade BNL has led the DOE effort to improve the efficiency of ductwork and other thermal distribution systems in residential and small commercial buildings. Working with LBL in a model of inter-laboratory cooperation, we have established the energy savings potential for improvements in this area.

On the BNL site are two important examples of energy-efficient houses: the award-winning Brookhaven House and a factory-built Danish house that the American housing industry could "reverse engineer" to obtain the ideal approach to heating and cooling in northern and southern U.S. climates.

BNL researchers also have expertise in coal-burning and diesel-engine technologies: we are beginning a CRADA with Consolidated Edison on condensing economizers for coal-fired power plants and we are about to begin development of an advanced diesel-engine cogeneration system. With its strong program in energy systems modeling, BNL is providing technical support to the DOE Policy Office in the development of the Least Cost Energy Strategy required by the Energy Policy Act of 1992.

Energy Supply and Renewables

The aim of Brookhaven's electrical-power program is to provide safe and secure energy supplies for the future. We assist the Nuclear Regulatory Commission (NRC) with its independent evaluation and review of six advanced reactor designs being aggressively pursued by U.S. industry. Common to all these advanced designs is a reliance on passive systems and inherently safe processes such as natural circulation and gravity feed.

Accelerators provide another potential method for the large-scale production of electrical energy. Compared to fission reactors, accelerator-driven power sources have attractive safety characteristics—such as subcritical operation—and require only small inventories of plutonium and fission products.

BNL is a regional leader in the development and application of new infrastructure technologies for energy production in the 21st century. The U.S. energy production infrastructure has not taken advantage of the many advances in materials, instrumentation, robotics, manufacturing, and information management that have taken place in the last few decades. We at BNL are part of a New York regional academic and industrial consortium organized to meet the challenge of modernizing the energy infrastructure.

BNL has played a major role in the development of materials for geothermal energy production. We have created advanced high-temperature, CO₂-resistant, lightweight well-cementing materials, high-temperature chemical systems for lost-circulation control, and corrosion-resistant coating and bonding systems.

Energy-systems modeling is a strength at BNL. Our models integrate the entire energy system—including supply and end-use sectors—and investigate the implications of changes in the energy system on the national economy and on environmental emissions. We provide technical support to the DOE Policy Office in the development of the Least Cost Energy Strategy required by the Energy Policy Act of 1992.

Climate Change

BNL is making unique contributions to our understanding of the influence of anthropogenic atmospheric aerosols on climate. Work at Brookhaven highlighted the role of sulfate aerosols, derived largely from energy production, as climate-forcing agents and the possibilities of interhemispheric comparisons of temperature anomaly trend and cloud albedo in quantifying this role.

Research supported by the Atmospheric Chemistry Program focuses on understanding the chemical processes that govern the transformation, transport, and deposition of atmospheric trace species—both manmade and natural—and determining the spatial and temporal distribution of these species in the atmosphere.

BNL scientists study the transport, transformation, and ultimate fate of air pollutants emitted by energy-related activities. Constituents of interest include nitrogen, reduced carbon compounds, sulfur, and atmospheric oxidants such as ozone and organic peroxides.

There is only limited understanding of the exchange of anthropogenic carbon dioxide between the ocean and the atmosphere. We participate in the Ocean Margins Program, which is quantifying the processes that affect the cycling, flux, and storage of carbon and other biogenic elements on ocean margins. We also participate in the DOE Ocean Research Program, which is conducting a global survey of the CO₂ stored and transported by the oceans.

The Free-Air CO₂ Enrichment (FACE) Program addresses an important component in the process of quantifying global change: the role of terrestrial plants. BNL leads an international team of scientist who are constructing and testing a new FACE facility at the Swiss Federal Institute of Technology, Zurich and collaborating with the New Zealand Ministry of Agriculture and Fisheries to set up a BNL FACE experiment in that country's grasslands.

With its strong program in energy systems modeling, BNL explores and analyzes strategies for reducing greenhouse gas emissions. Our program provides technical support to the DOE Policy Office in the development of the Least Cost Energy Strategy required by the Energy Policy Act of 1992.

The Tracer Technology Center at BNL has developed a unique, ultrasensitive (sub 10⁻¹⁵) Perfluorocarbon Tracer (PFT) technology for a range of applications. These include atmospheric pollution transport (multiple PFTs tracking air pollution into the Grand Canyon for the Environmental Protection Agency); environmental leak detection (locating dielectric oil leaks from electric cables for recovery and tracing secondary recovery fluids in petroleum reservoirs at the Naval Petroleum Reserve and for private oil companies); and energy efficiency.

Environmental Technology

BNL, with the sponsorship of DOE's Office of Technology Development, has developed an economical, robust treatment for radioactive, hazardous, and mixed wastes. This treatment, the polyethylene encapsulation process, has successfully progressed from proof-of-principle through bench-scale process development to full-scale technology demonstration.

BNL is developing subsurface barrier materials to minimize the migration of buried wastes at DOE sites. In this program, we have investigated the durability and performance of potential barrier materials under typical waste site conditions. Testing indicates that we have achieved these high performance and durability characteristics. BNL is also involved in a range of DOE and EPA programs to experimentally characterize soils and sediments from contaminated sites in the U.S. and abroad.

BNL is the principal NRC contractor for evaluating the low-level waste source term (rate of release from the disposal facility). A series of computer models is being developed to predict the source term in the aqueous and vapor phases.

A recent initiative at BNL is the Northeast Waste Management Enterprise (NEWME), a collaborative effort of Brookhaven, industry, and academia. NEWME's objective is to develop new and innovative technologies that subsequently can be transferred to industry for demonstration and implementation.

Brookhaven is increasing its already substantial role in developing precompetitive programs in environmental science and technology. In order to maximize the value of these programs to DOE and the U.S. commercial sector, we are seeking to establish partnerships with the private sector to guarantee that the products of our R&D can be rapidly commercialized.

Based on the application of patented biochemical processes elaborated by selected microorganisms, a number of technologies are in development that can be applied to remediation of environmental problems associated with fossil-fuel and nonfossil-fuel energy production.

The BNL Tracer Technology Center has tested and demonstrated sensitive, nonpolluting perfluorocarbon tracers for applications in both outdoor and indoor environments.

BNL is also developing advanced grouting materials for the *in situ* stabilization of contaminated soils and for the installation of impermeable, long-lived caps and subsurface barriers around waste sites.

Health and Biotechnology

We are addressing radiotracer development from a range of perspectives: from methods for the economical production of radionuclides (especially the short-lived medical isotopes such as ^{18}F , ^{123}I , and ^{124}I) and the design and synthesis of radiotracers with specificity for particular molecular targets to the study of normal human physiology and the changes occurring in neurological and psychiatric disorders and cancer.

The Imaging Center at Brookhaven is dedicated to basic and clinical research and to the integration of Positron Emission Tomography, Magnetic Resonance Imaging, and Single Photon Emission Computed Tomography to investigate synergistic uses of multiple imaging studies of the brain and other organs.

Brookhaven develops and maintains a bioassay program for field campaigns in the Marshall Islands.

BNL's As Low As Reasonably Achievable Center assists DOE's Office of Environment, Safety, and Health to implement its recommendations to the Secretary of Energy by evaluating the impact of pending reductions in occupational dose limits and by evaluating a proposed reduction in the radiological design criteria for external sources of radiation in noncontinuously occupied controlled areas.

With over 20 years of experience in health and environmental risk analysis, BNL has contributed significantly to the DOE waste management program. We have developed methods and provided realistic estimates of health risks at DOE facilities as a guide to prioritizing clean-up activities.

We are systematically studying biochemical processes elaborated by thermophilic and other organisms capable of living under extreme environmental conditions. Extremophiles use biochemical pathways at temperatures and pressures not tolerated by mesophilic organisms.

Our interacting programs of basic research in molecular genetics, biochemistry, and structural biology support the goals and missions of DOE. These programs create a vital and stimulating environment in which complex facilities for structural biology and genome sequencing can be developed, maintained, and made accessible to the wider research community. Research programs currently focus on the replication, damage, and repair of DNA; mutagenesis, oncogenesis, and the effects of sunlight; gene function and control of gene expression; structures and functions of proteins, ribosomes, chromatin, and membrane complexes; viral structure and viral entry into cells; proteases in blood clotting, viruses, and malaria; energy conversion in photosynthesis; molecular genetics of vegetable oils; and genome mapping and sequencing.

Materials and Chemistry

BNL scientists and engineers are studying the efficient capture, conversion, and storage of solar energy. Through experimental and theoretical studies, we are researching the factors that control excited-state lifetimes and ground- and excited-state electron-transfer rates of transition-metal complexes and other donor/acceptor systems. BNL researchers are investigating the roles of molecular structure, chemical modification, and the surrounding media in natural photosynthetic systems. We are conducting chemical and mechanistic studies of transition-metal centers in high and low oxidation states.

The energetics and dynamics of molecular collision phenomena and the microscopic factors affecting the structure and dynamics of short-lived intermediates in gas-phase chemical reactions are being explored. We are investigating the spectra of small free radicals, the dynamics of photodissociation, and the estate-to-state dynamics of gas-phase reactions and energy transfer processes using experimental and theoretical methods.

We address chemical catalysis from a multifaceted perspective. Studies of the reactivity of transition-metal hydride complexes elucidate the factors that determine the rates and mechanisms for cleavage of metal-hydrogen bonds and their reaction with unsaturated organic substrates in homogeneous media. We are also examining the role of metal-hydride electrodes in the electrochemical storage of hydrogen. The structure of adsorbates on metal surfaces are being determined by a variety of methods, including studies at BNL's National Synchrotron Light Source (NSLS).

Advances in characterizing irradiation properties of materials for spallation-target applications and life-extension issues have demonstrated "suitability for service" of several key materials. University and industry collaborations on thermal-spray applications have resulted in innovative restoration and encapsulation solutions for hazardous and nuclear waste.

Several BNL programs focus on chemical and physical processes relevant to energy conversion, production, utilization, and storage. They span a range of experimental, structural, and theoretical investigations and take advantage of unique BNL facilities such as the NSLS and the High Flux Beam Reactor. This approach has fostered interdisciplinary and collaborative efforts with academia, other national laboratories, other research institutions, and industry.

We investigate properties of superconducting oxides with high critical temperatures; methods of superconductor fabrication including thin films, new materials, and composite conductors; synthesis and characterization of electroresponsive molecular and polymeric systems; mechanisms of corrosion; structure-sensitive properties of advanced permanent magnet materials; and the structure and properties of surface-modified materials and interfaces.

Computing and Information Infrastructure

Brookhaven has invested significant effort in the development of new parallel software tools to assist in applying massively parallel and distributed computing technology to a range of scientific applications. Much of this work was carried out as BNL's contribution to the Partnership in Computational Science consortium under the auspices of DOE's High Performance Computing and Communication Initiative. We have targeted two application areas: contaminant transport in ground water and first principles computation of materials properties.

As part of the Atmospheric Radiation Measurement in support of global climate change research, BNL's Scientific Information Systems group has been heavily involved in the development and implementation of the network-based data collection and management system.

High-Energy and Nuclear Physics

Research in high-energy physics is performed at the Alternating Gradient Synchrotron (AGS), where diverse activities such as searches for and studies of rare decay modes of kaons, searches for exotic particles, precise measurements of the magnetic moment of the muon, and studies of neutrino mass are in progress or under development. Our primary objective is to test aspects of the so-called standard model of high-energy physics. We have been major participants in the D0 collider experiment at Fermilab—where the current focus is the search for the top quark— from its inception. We also had a major role in the GEM experiment at the Superconducting Super Collider and are now involved in the ATLAS experiment at the Large Hadron Collider. Our theory program is world class and includes high-performance computing.

In nuclear physics, Brookhaven is now the focus for the U.S. relativistic heavy-ion program. This field is an exploratory one which has the potential to study nuclear matter under conditions of extremely high density and temperature and perhaps to explore conditions that existed in the earliest days of the universe. Researchers at BNL currently are working on a number of experiments at the AGS and are preparing for experiments at the Relativistic Heavy-Ion Collider (RHIC)—which is the highest priority new project in the national nuclear physics program. Other activities in nuclear physics, although smaller, also focus on forefront activities. The Tandem van de Graaff facility, which serves as the injector for heavy ions for the AGS and RHIC, also serves several industrial and other users for commercial applications.

The observation of solar neutrinos was pioneered by BNL scientists using ^{37}Cl as a radiochemical neutrino-detector. This experiment resulted in the well-known "solar neutrino problem": the detected neutrino flux is only about one-fourth of the prediction of the so-called Standard Solar Model. To pursue the discrepancy between theory and experiment (which could have far-reaching implications), Brookhaven scientists several years ago developed a new kind of radiochemical detector. The detector is based on the capture of a neutrino by ^{71}Ga to produce radioactive ^{71}Ge , which is detected. Many of the radiochemical procedures and the equipment needed for the extraction, purification, and counting of ^{71}Ge were developed at Brookhaven.

Nuclear Nonproliferation

BNL programs and staff in the arms control, nonproliferation, and international safeguards areas make unique and significant contributions in support of several U.S. government agencies, including DOE, DoD, DOS, and the Arms Control and Disarmament Agency.

BNL also carries out a number of studies, research and development programs, and hardware development projects that further the aims of U.S. nonproliferation policy. Among these are innovative verification systems such as portable photoacoustic spectroscopy for field measurement of inspection samples, Special Nuclear Materials source simulators that can test safeguards detection equipment, nuclear materials accountability computer-based interactive training, and neutron time-of-flight systems for treaty-limited-item verification.

BNL staff represent a unique, independent, and objective pool of recognized expertise, demonstrated capability, and institutional memory in the nonproliferation and safeguards area.

National Research Facilities

Alternating Gradient Synchrotron (AGS). The AGS is an international user facility at the leading edge of both the "high-intensity frontier" and the emerging field of relativistic heavy-ion physics. The world's most copious source of protons, antiprotons, pions, kaons, and neutrinos for high-energy physics research, the AGS is the world's only source for high-energy heavy ions (gold) and high-energy polarized protons. Each year the facility supports more than 800 experimentalists from over 100 institutions.

Relativistic Heavy-Ion Collider (RHIC). Currently under construction, the RHIC project is scheduled for completion in 1999. The AGS complex will be the injector, providing a broad spectrum of heavy ions (up to gold) and high-energy polarized protons. This unique facility will enable research in heretofore unexplored regions. Interest in the facility is such that over 600 users are participating in first-round experiments.

High Flux Beam Reactor (HFBR). HFBR provides medical isotopes and very intense neutrons to beamlines that support research in nuclear and solid-state physics, metallurgy, nuclear and structural chemistry, and biology.

National Synchrotron Light Source (NSLS). NSLS is the premiere facility providing x-ray, vacuum ultraviolet, and infrared radiation for research programs in physics, biology, chemistry, geology, medicine, metallurgy, and materials science. In 1993, over 2600 researchers from 450 institutions, including over 70 commercial firms, used the NSLS.

Scanning, Transmission Electron Microscope (STEM). STEM enables researchers to topographically map uncertain, heavy-atom-cluster labeled specimens at a resolution of 20 Å. These studies focus on understanding DNA-binding proteins, viruses, and multi-enzyme complexes.

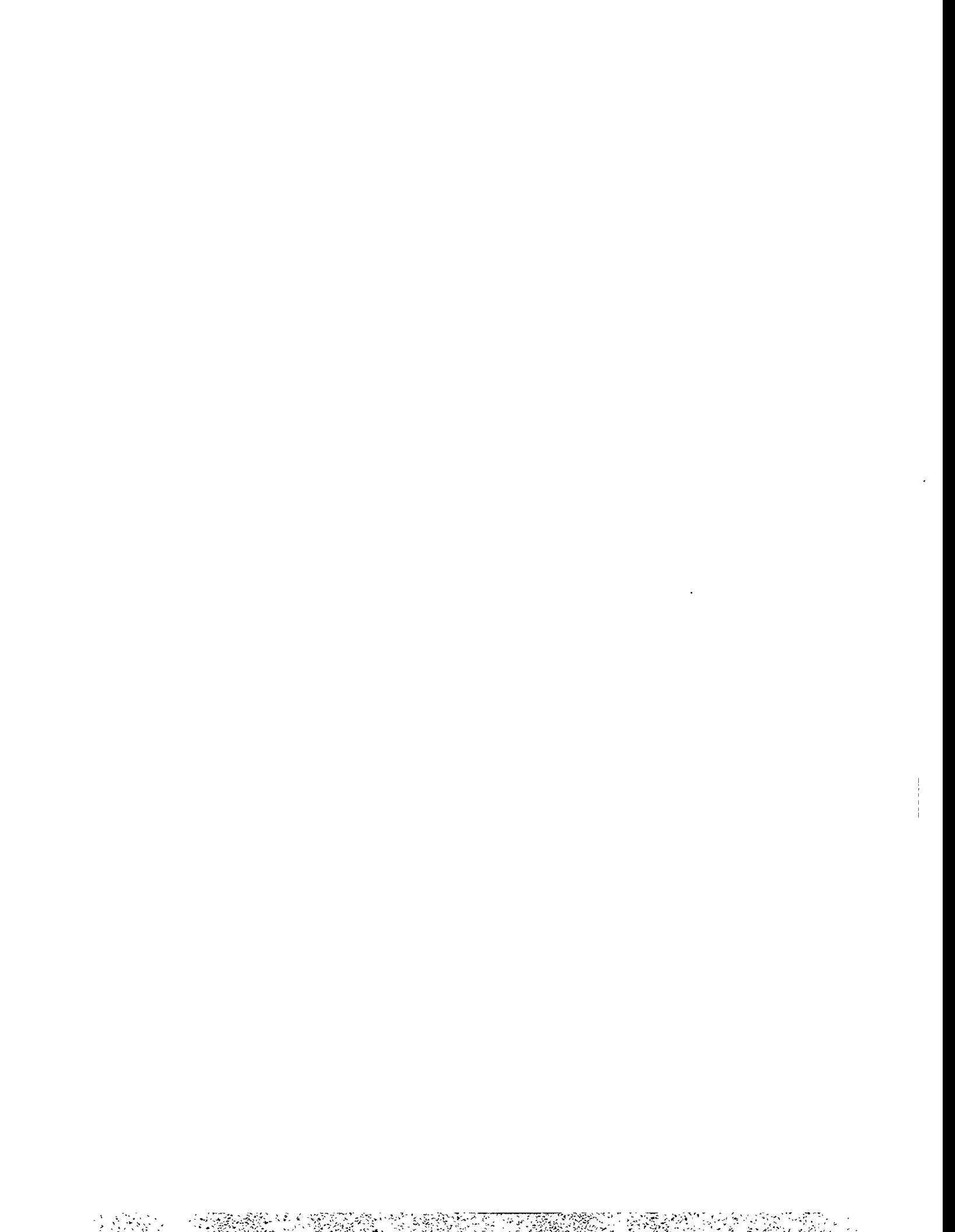
Positron Emission Tomography (PET)-Cyclotron. Designed to investigate the basic processes underlying disease and to evaluate possible clinical applications, PET is growing rapidly.

Radiation Treatment Facility (RTF). Responding to the needs of cancer patients and medical researchers, RTF's 25-MeV beam treats both superficial and deep tumors.

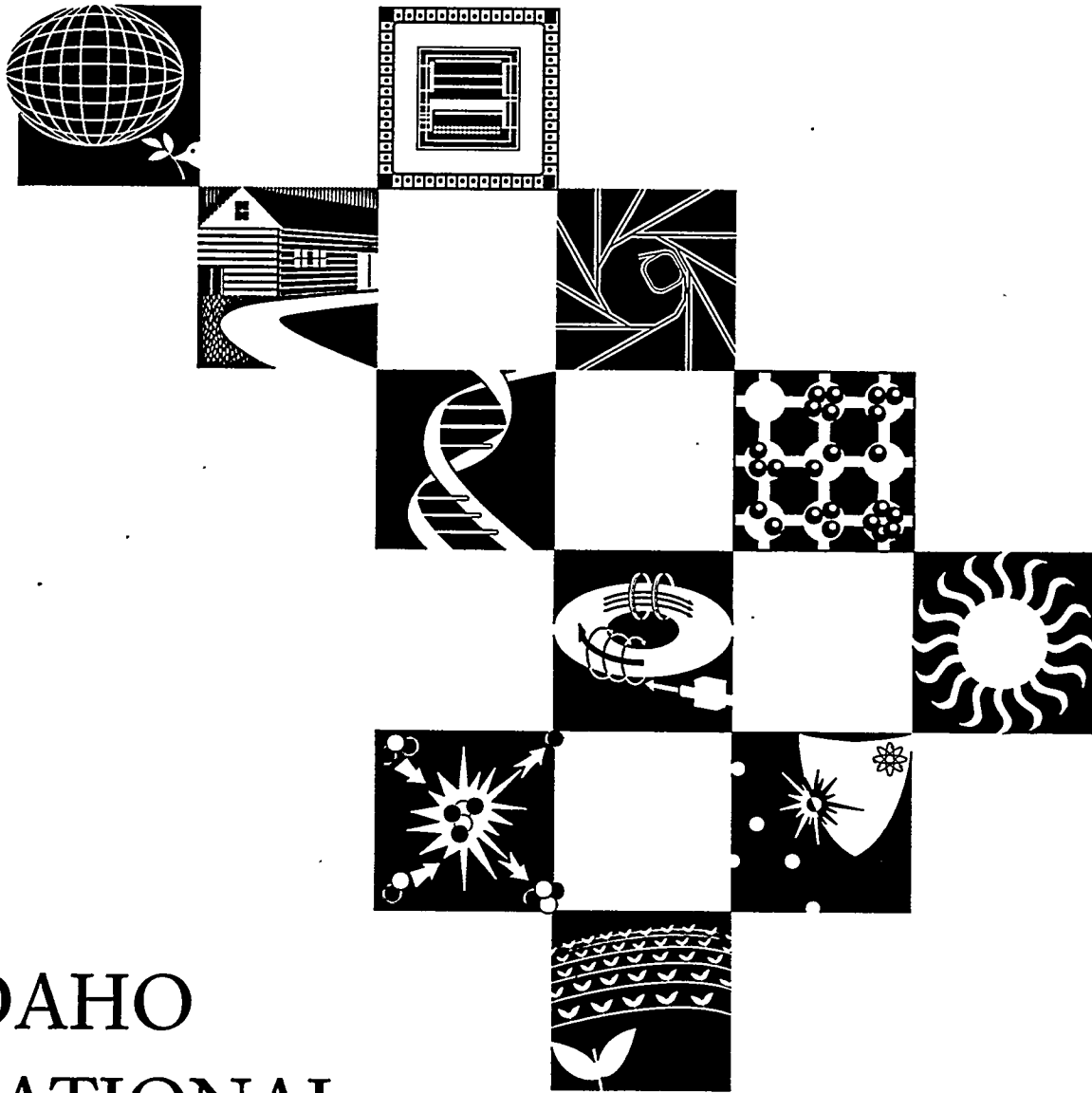
Brookhaven Linac Isotope Producer (BLIP). BLIP creates difficult-to-produce radionuclides for the nuclear medicine community and for industry.

Protein Data Bank (PDB). A world-wide repository for 3-D structural information for proteins, PDB will soon include biological macromolecules.

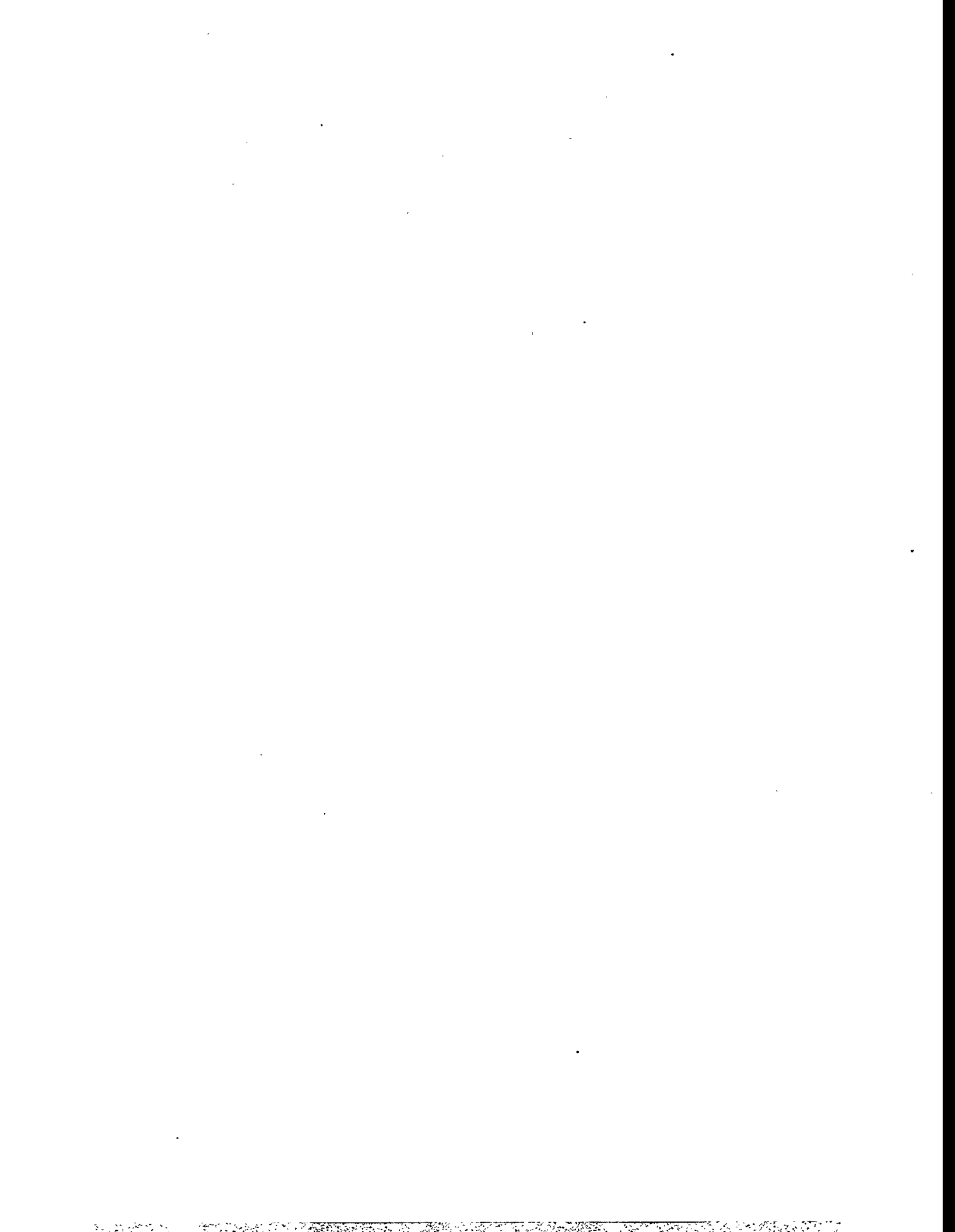
Brookhaven Medical Research Reactor. In this facility, researchers study neutron capture therapy. They have successfully treated brain tumors in rats and have initiated similar treatment in humans.



RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



IDAHO
NATIONAL
ENGINEERING
LABORATORY



Idaho National Engineering Laboratory

The Idaho National Engineering Laboratory (INEL) is situated on 890 square miles of the Snake River Plain in southeastern Idaho. INEL solves critical problems on energy production and use, the environment, U.S. economic competitiveness, and national security. Over the years, INEL has constructed 52 reactors, most of them first-of-a-kind facilities, and operated them in a safe and environmentally responsible manner. Some of INEL's key capabilities are in processing technology, advanced manufacturing, remote handling automation, radioactive and hazardous waste management, materials irradiation and isotope production, earth and environmental sciences, instrumentation and sensors, safety and risk assessment, and human/system integration. Home to the largest concentration of technical professionals in the northern Rocky Mountain region, the INEL site is a designated National Environmental Research Park where scientists from the U.S. Department of Energy (DOE), other federal and state agencies, universities, and private research foundations conduct ecological studies.

Energy Efficiency

The INEL provides DOE and private industry with technical and programmatic support in energy conservation and advanced material processing. These activities include technology and process research; engineering; and technical management of research and development projects contracted with industry, universities, and laboratories nationwide. The major objective is to improve the efficiency and productivity of U.S. industry. Some specific targets for improvement are materials processing practices and technologies in metals and minerals industries, with current emphasis on steel, aluminum, metal casting, foundries, and glass. Pulp and paper industry processes, advanced separations, and industrial process control technologies are also of interest. The more general subject of global energy sustainability, including conservation and resource optimization, is emerging as a new area of concentration. In all activities related to energy efficiency and industrial productivity, we are applying emerging systems-based resource management tools, which have been developed or are being developed directly in response to issues of global sustainability and industrial ecology.

Energy Supply and Renewables

In addition to delivering reliable technology for commercial nuclear reactors, we have been heavily involved in hydropower- and geothermal-generated electricity as sources of renewable energy. These INEL programs are internationally recognized. In the hydropower programs, INEL and industry are pursuing advanced turbine designs. We also maintain a leadership role in developing concepts to restore the salmon runs to the Columbia and Snake Rivers. In the geothermal program, INEL continues to be recognized as a leader in geothermal reservoir modeling. We are also pursuing such initiatives as recycling paper as a fuel source for steam and power generation, alternate fuel vehicles, and new types of fuel cells.

In 1994, INEL provided private industry, the DOE Assistant Secretary for Energy Efficiency, and the state of California with testing and evaluation of batteries, electric and hybrid vehicles, and associated vehicle subsystems in support of the DOE program to commercialize zero- or low-emission vehicles. Further, the INEL electric vehicle program continued developing advanced drivelines, energy storage technologies (including ultracapacitors), and the infrastructure for electric vehicle commercialization.

Climate Change

One important engineering response to global climate change is efficient conversion and use of energy. To meet the energy demands of an increasingly industrialized and rapidly growing global population in an environmentally sustainable manner, it is necessary to develop an energy infrastructure that both optimizes resources and technology and also satisfies customer requirements. In response to this challenge, we are applying systems dynamics to the study of energy infrastructure alternatives that could lead to sustainable supplies of global energy. An important part of the INEL activity is identifying opportunities for conservation and appropriate energy-efficient technologies that would minimize global climate changes. To develop a comprehensive and effective response to issues of global climate change, we are collaborating with private industry and leaders in the emerging disciplines of global sustainability and industrial ecology.

Environmental Technology

The INEL applies environmental technology to remediating, managing, and preventing environmental problems both in the national and international communities. Our programs include developing new and enhanced technologies to remediate buried and stored transuranic-contaminated mixed wastes within the DOE Complex; other Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) wastes in and outside the DOE; and wastes from mining, timber activities, and agriculture. We have the advanced capabilities and technical expertise to support programs for developing, implementing, and commercializing environmental technologies in the following areas: industrial biotechnology and process engineering; systems development and integration, including advanced control theory; hardware and software engineering, simulation, and modeling; materials design, application, and testing; remote handling, automation, and robotics; hazardous, radioactive, and mixed waste treatment technology development, testing, and demonstration; advanced sensor development and experimental applications through rapid prototyping; advanced *in situ* geophysical measurements and related interpretation methodologies; and advanced nondestructive evaluation systems.

Health and Biotechnology

Health-related programs at INEL include computational analysis of ultrasound transducers for medical imaging, buried-waste health-risk assessment, boron neutron capture therapy, and a variety of activities to support information infrastructure needs for the health care industry.

We develop and transfer to industry bioprocessing and environmental processing systems for natural resources and remediation applications. Bioprocessing of minerals focuses on recovery of metals from low-grade ore, bioleaching of phosphate ore, and *in situ* mining. Fossil fuels biological processing technology development centers on coal desulfurization and solubilization, microbially enhanced oil recovery, and natural gas conversion to added-value products. Examples of environmental engineering processing technology development are denitrification of mixed wastes, soil and gravel washing for hydrocarbon/solvent removal, and life-cycle assessment. Current industrial applications development areas are biofiltration of volatile organic compounds from wood-drying operations, biological reduction of SO_x and NO_x from combustion gases, recovery of textile dyes from waste streams, and production of organic chemicals from renewable resources. Our research in applied microbiology, molecular genetics, and biochemical engineering supports development of novel bioreactors, biomaterials, and processing systems for enhanced U.S. industrial competitiveness.

Materials and Chemistry

Chemical and materials activities at INEL focus on synthesis, processing, sensor, and characterization technologies. We identify critical processing variables and their control points, devise robust sensors to measure these variables under manufacturing conditions, and develop control systems based on process knowledge to produce chemical and material products that meet customer performance criteria for an integrated system. Some of our applications are in high-level radioactive waste processing, new materials and processes for synthesizing chemicals, supercritical processes for textile industry wastes, and inorganic polymers for membrane separations in harsh environments.

Computing and Information Infrastructure

The INEL computing and information program employs a distributed computing infrastructure that encompasses mainframe, minicomputer, and PC technology; skilled information, software, communications, and hardware engineers for systems integration and development; and a base of computing resources (software, system designs, simulation tools, etc.) that is nationally

Nuclear Nonproliferation

INEL supports the arms control, intelligence, and law enforcement communities with advanced development, fabrication, and training. The emphasis is on detecting materials associated with nuclear, chemical, and biological weapons. We develop prototype communications and command and control systems. We store and handle highly enriched reactor fuel. We are making our uranium handling expertise available. We irradiate materials and produce isotopes for various national security applications. We perform research and advanced development for nuclear and solar power subsystems for space applications as prime power and propulsion.

High-Energy and Nuclear Physics

Nuclear physics activities at the INEL range from basic research (providing the nuclear community with data) to advanced nuclear instrument and technique development for nondestructive analysis and process control applications. An on-line mass separator with a ^{252}Cf source is used to study nuclear decay parameters of selected isotopes of importance to fission and fusion energy programs and other areas in basic and applied sciences. Evaluations of nuclear data are performed for the Evaluated Nuclear Structure Data File and for publication of Nuclear Data Sheets. This activity represents our participation in the International Nuclear Structure and Decay Data Evaluation Network to provide mass-chain evaluations. In addition, we participate in collaborative nuclear physics efforts with other national laboratories in heavy-ion nuclear physics experiments, relativistic heavy-ion physics experiments, and in double beta decay experiments.

Advanced nuclear instruments, techniques, radiation detector systems, and data acquisition methods are developed for nondestructive analysis, process control, waste management, materials science, arms control and nonproliferation, and industrial applications. One example of this type of technology development: prompt gamma-neutron activation analysis techniques for the nondestructive assay of chemicals, industrial materials, and hazardous materials, including chemical munitions.

Nuclear Nonproliferation

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Nuclear Weapons Research and Development

INEL produces tritium by irradiating Savannah River Site (SRS) targets in the Advanced Test Reactor (ATR). This program is designed to validate the predicted production rates using SRS-type targets in the ATR and assess the feasibility of producing tritium in the ATR for extraction at SRS. The program makes forecasts of optimum production, compares actual and predicted production rates, provides cost estimates for production mode operation, and assesses environmental shipping requirements for future production.

National Research Facilities

Major INEL national research facilities and their primary areas of research include:

Idaho Chemical Processing Plant. Spent nuclear fuel and calcine waste.

Advanced Test Reactor. Reactor fuels, materials irradiation, radioisotopes, and activation analysis for trace components.

Radioactive Waste Management Complex. Transuranic waste, mixed waste, remediation, and disposal of low-level waste.

INEL Research Center. Materials, biological, and chemical processing; advanced manufacturing; earth and environmental sciences; instrumentation and sensors; and electric and hybrid vehicle testing and battery testing.

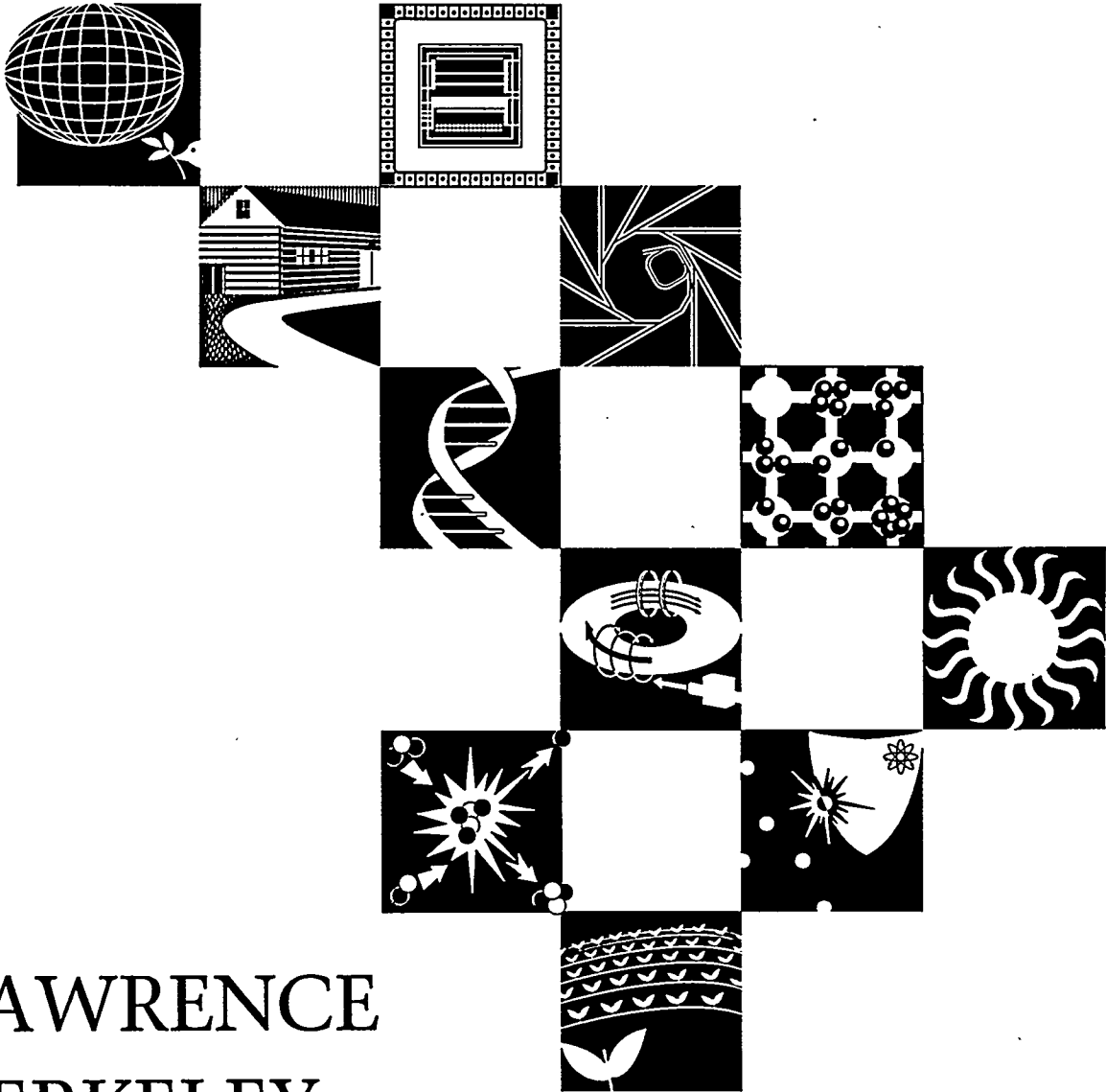
Specific Manufacturing Capability. Advanced manufacturing

Radiological and Environmental Sciences Lab. Radiological and environmental sciences.

Test Area North Hot Shop/Cells. Examination, handling, analysis, or disassembly of highly radioactive or contaminated assemblies.

Computer Simulation Laboratory. Complex systems analysis.

RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



LAWRENCE
BERKELEY
LABORATORY

Lawrence Berkeley Laboratory

Lawrence Berkeley Laboratory (LBL) is a national laboratory operated by the University of California for the U.S. Department of Energy (DOE). Founded in 1931 by Professor Ernest O. Lawrence, LBL supports a wide range of unclassified research activities in the physical, biological, and environmental sciences and in engineering and mathematics. Its dedication to scientific excellence has garnered a host of awards—including nine Nobel prizes. Furthermore, LBL research has spawned entirely new industries such as nuclear medicine and medical imaging. And its pioneering research in energy conservation has saved the nation billions of dollars. In today's competitive marketplace, LBL serves the national interest by establishing partnerships with U.S. industry. These productive collaborations are leading to new and viable technologies that contribute to the U.S. economy.

Energy Efficiency

Energy efficiency programs at LBL have contributed to significant reductions in energy use on both a national and worldwide level. These programs have created technologies, processes, and analytical methods in the areas of building technology, transportation, utilities, industry, and policy development.

LBL has made noteworthy contributions to energy efficiency in buildings. Our advanced glazing materials and window systems are in wide commercial use. These include low-emissivity, or "low-E," windows, now found in 30% of all U.S. homes. Also available to the public are our solid-state ballasts for fluorescent lighting systems. Other consumer products now under development include high-efficiency, radio-frequency-powered electrodeless lamps, and energy-efficient fixtures. In the area of software, we have created DOE-2, the world's preeminent computerized tool for building-energy analysis, as well as next-generation interactive design tools based on DOE-2. Under development are technologies expected to have a dramatic impact on building equipment and appliance energy standards. These advances are expected to appreciably lower energy consumption in the U.S.

We are working on a number of programs with widespread practical application in transportation, including advanced battery and fuel cell systems and the thermal management of vehicle interiors. Our fundamental studies on combustion and emissions and our energy and emissions impact analyses will serve as the basis for regional, national, and global transportation policy planning.

Another LBL focus is the development of methodologies for integrated resource planning and demand-side management programs to be used by electric and gas utilities. Such programs aim at improving the economical delivery of services to customers. Other programs focus on the industrial sector, including the development of energy-efficient chemical separations and advanced catalysts for more efficient industrial processes.

We have conducted a broad range of national and global studies that either provide the technical and economic basis for policy development or analyze existing and proposed policies. These include national energy-consumption forecasting, international comparisons of energy use, and recommendations for energy technologies to developing countries. A current program is "Cool Communities," which identifies technologies that can reduce urban heat islands.

Energy Supply and Renewables

LBL has several programs that make near-term and long-term contributions toward an abundant, secure energy supply for the U.S.

As a natural extension of our historic core competency in accelerators, we are deeply involved in the development of inertial-confinement fusion energy, with the long-range goal of developing heavy-ion accelerators for fusion-energy production. Heavy-ion fusion uses intense beams to implode and ignite, or "drive," small targets containing thermonuclear fuel. Our program investigates the generation of high-power, high-brightness beams of heavy ions (which offer key advantages over photons and lighter ions); understanding of the scaling laws that apply in this hitherto little-explored physics regime; and validation of new, potentially more economical accelerator strategies. We are now designing ILSE—the Induction Linac Systems Experiments—which will, over several years, address most of the remaining beam-control and beam-manipulation issues at partial driver scale.

Research on energy resource development includes gas and oil recovery efficiency and geothermal resources. For example, we initiated the California Oil and Gas Alliance to help solve unique problems faced by producers in the state. One set of projects addresses production improvement in the diatomite rocks under Kern County, which have trapped some 10 billion barrels of oil that is very difficult to extract with current technology. Our geothermal program is aimed at extending the useful energy-producing life of reservoirs through reinjection of water and through better understanding of the properties and mechanisms controlling reservoir behavior. It has made great contributions to understanding and optimizing production at The Geysers, which is the world's largest operating geothermal reservoir.

We also conduct fundamental research on combustion processes in fossil fuels, including fluid mechanics, underlying chemical reaction processes, and computer simulation, with the goal of increased efficiency and decreased environmental impacts from fossil fuel use. Researchers at the Advanced Light Source, a national research facility established at LBL, are making discoveries that will lead to accurate, reliable models for predicting combustion properties. Such models will improve the design of engines, burners, and other combustion devices.

Climate Change

LBL is making unique contributions to research on climate change, both nationally and globally. This research covers three broad areas: reducing carbon dioxide emissions, increasing the number of CO₂ sinks, and understanding how energy-producing activities that generate atmospheric aerosols can cause global climate change.

We have made great advances in understanding the source of carbon dioxide emissions and developing measures to mitigate them. Our efforts in this area include a U.S. and global study characterizing how energy is used in buildings; a U.S. study on various approaches to reducing energy growth, with an emphasis on buildings; and analyses of measures that can be used in developing countries to reduce the growth of energy demand.

Enhancing CO₂ sinks is essential for mitigating carbon dioxide emissions. To that end, we have established a global forestry network, involving leading researchers in countries with major forests. This network focuses on improving data available on the extent and rate of deforestation in key countries, as well as exploring options to reduce deforestation and increase reforestation.

Our research on global climate change concentrates on selected atmospheric climate-change mechanisms including basic research on sulfate and organic atmospheric aerosols. We do not know at this time whether these types of aerosols, produced by human activity, mask other global warming mechanisms. This is a fundamental unanswered question in the area of climate modeling.

Environmental Technology

Technologies for improving the environment—regionally and globally—rank high on LBL's agenda. We are conducting a broad-based program of research aimed at understanding the formation, transport, transformation, mitigation, and ecological effects of pollutants on the environment. Our sophisticated, innovative technologies are helping to solve environmental problems around the world.

We have developed computer codes to predict the migration of contaminants in soil and rock and the effectiveness of remediation strategies. Many of these codes are now used in the private sector. We have also developed a database that makes available to the toxicology research community worldwide the results of 4000 experiments with 1400 chemicals, enabling researchers to assess carcinogenic risk.

We are creating and testing innovative methods for site-characterization and remediation. Field testing is under way on advanced methods for characterizing contaminant plumes and geologic structures. We are also helping to solve agricultural pollution problems in one of the world's most productive agricultural regions—the Central Valley of California.

We are collaborating with industry and municipal water districts to develop new methods for removing and recovering toxic metals from aqueous waste streams. Also under development are methods for removing pollutants from flue-gas streams and converting them to commercial feedstocks. Research at LBL's Advanced Light Source is increasing the understanding of combustion processes—work that will lead to improvements in the design of engines and burners, and ultimately to reduced consumption of fossil fuels. Our genetic ecotoxicological studies are shedding light on the effects of pollutants and increased UV exposure from ozone depletion.

In addition to pollutants outdoors, we are studying hazards of the indoor environment, including radon and tobacco smoke. Developing systematic methods to characterize sick and healthy buildings is a goal of this program.

LBL's environmental technologies are being applied at many sites. Of particular interest is our collaboration with Russia to develop a remediation strategy for the contaminant plume at Chelyabinsk—the world's most radioactively contaminated site. Conducted under the Russia-U.S. Binational Agreement, this work is a good example of the vitality and worth of LBL's environmental technologies.

Health and Biotechnology

LBL's health and biotechnology capabilities include such diverse activities as the rational design of pharmaceuticals, the search for the mechanisms of aging, and bioremediation strategies for waste cleanup. Particularly noteworthy is our research on coronary artery disease, disorders of red blood cell formation, metabolic aspects of neurological diseases, and the biology of breast cancer. This diversity springs from our wide array of facilities and programs.

Several major facilities serve as centers for intellectual and technical exchange. The Advanced Light Source is ushering in a new generation of structural biology studies through opportunities in x-ray microscopy, electron crystallography (pioneered at LBL), and x-ray absorption spectroscopy. The Center for Functional Imaging (CFI) links advanced imaging techniques and radiopharmaceutical chemistry with cell and molecular biology, data analysis, and mathematical modeling. LBL's transgenic mouse facility serves as a valuable resource for testing atherosclerosis treatments and for on-going clinical heredity studies. We are expanding this facility to accommodate the needs of our partners in the biotechnology industry as well as other studies at LBL.

The Resource for Molecular Cytogenetics, a collaborative effort between LBL, U.C. San Francisco, and industry, serves the biomedical community with three core projects: comparative genomic hybridization, computer-assisted microscopy, and probe development. These have uses in screening for prenatal and neonatal genetic abnormalities, cancer gene localization, and diagnosing solid tumors.

LBL's Human Genome Center excels in the direct method for highly efficient genomic DNA sequencing. A key component in its success is LBL's leadership position in the development of automated instrumentation for genome analysis. Integrated with our transgenic mouse facility and the Resource for Molecular Cytogenetics, the Center offers the biotechnology industry and the medical community ready access to sequence information.

Our work in biomolecular design merges biochemistry and computational biology to analyze and manipulate chemical structures. Catalytic antibodies with novel specificities and reactivities are being tailored for bioremediation applications or for the destruction of cancer cells, viruses, or even atherosclerotic plaques.

The Lipoprotein and Atherosclerosis Program has established an unprecedented link between a major community-based cardiology diagnosis and treatment facility and a major cholesterol research program. The Hematopoiesis Program, which focuses on characterizing the body's long-term ability to produce blood cell precursors, and our emerging program on aging fill a void in the national laboratory system.

Materials and Chemistry

Many of the high-technology products on which society depends are based on advanced high-performance materials. The materials and chemical sciences programs at LBL focus on three goals: performing forefront research, applying that research to commercial needs, and training the field's next generation of leaders.

Fundamental research in physics has led, in collaboration with a small start-up company, to the development of detectors based on high-temperature superconducting materials. They can be used to diagnose medical abnormalities or in the search for oil in remote locations. Fundamental research in chemistry has led to advances in nuclear magnetic resonance that are already the basis for commercial instruments used routinely in the oil and gas industry. And studies based on the structure and function of the membranes that surround living cells have led to the development of simple sensors that quickly turn color in the presence of agents such as the influenza virus and botulism and cholera toxins.

LBL has led the organization of the DOE program in nanoscale materials for energy applications. Our investigators have, for example, demonstrated the synthesis of light-emitting semiconductor crystals containing as few as 50 atoms. (Nanoscale investigations are enhanced by two user facilities—the Advanced Light Source and the National Center for Electron Microscopy—described in the “National Research Facilities” section of this booklet.) Another active program explores the possibilities for discovering new materials through the parallel synthesis of hundreds of thousands of variants of a basic structure on a single thumbnail-size chip, followed by rapid screening of this “library” for the desired novel property.

The combustion dynamics program (also supported by the Advanced Light Source) advances basic knowledge of chemical reactions in combustion and advanced energy production technologies. Surface-science programs examine important optical and electronic properties of advanced materials, basic mechanisms for catalysis of hydrocarbon fuels, and combustion emissions. The battery program studies reactions between metallic lithium and organic electrolytes to improve the energy density of lithium, with the goal of consumer-safe rechargeable lithium batteries. And fundamental actinide chemistry and processes that impact environmental remediation and restoration are being studied in such areas as nuclear waste disposal, geological repository, nonproliferation, nuclear safeguards, and decorporation of actinides in humans.

Of late, there has been an increased emphasis on focusing our research in areas of materials science that underlay problems faced by U.S. industry. But this focus is not new to LBL's Center for Advanced Materials (CAM). Since its inception in 1985, CAM has worked in partnership with industry in areas vital to U.S. economic strength.

Computing and Information Infrastructure

LBL has long been active in revealing and realizing the potential of the Internet for the scientific community. To contribute to the growing information infrastructure, we have programs in three of the national gigabit network testbeds, giving us a unique perspective on advanced network technology.

We are building new on-line systems and using them in unique ways, such as in analyzing digital video to provide a source of information for scientific analysis and as a means of remote instrument control. We are also using these systems for research on scalable, economical approaches to high-volume, high-speed data storage. Our work on regional health care information systems and energy demand management systems is contributing to the development of the National Information Infrastructure. This research is also laying the foundation for national "collaboratories" that will let scientists use national research facilities from any location.

Our network research has already led to several innovations, including new methods of congestion control for global-scale networks and high-speed data-transport techniques that are now used in almost every commercial implementation of the Internet protocol suite (TCP/IP). We have also provided the technology for the first large-scale use of Internet-based multimedia applications, creating a system for worldwide network-independent teleconferencing.

The Petabyte Access and Storage Solutions (PASS) Project is a special application of LBL's experience with scientific data. The project is addressing the data access and management problems of the next generation of large-scale scientific experiments. Distributed, object-oriented database techniques developed from this work are now being used or evaluated for use in experiments at high-energy physics laboratories around the world.

Research in our Data Management Program is also making unique contributions to the scientific paradigm. As a result of this program, we have developed innovative approaches to scientific data management and tools that are used by universities, private industry, and various DOE projects, such as the Human Genome Project. These tools, which include object models, efficient structures for handling very large data sets, and techniques for structuring complex scientific data, provide scientists with uniform access to data and free them from having to worry about unnecessary details.

High-Energy and Nuclear Physics

LBL was founded as a high-energy and nuclear physics laboratory and continues to provide leadership in both fields. This research is supported and complemented by premier programs in designing and building particle detectors and in many areas of accelerator physics and technology, including design and analysis, superconducting materials and magnets, and beam electrodynamics.

The 88-Inch Cyclotron supports a broad, diverse nuclear physics research program. In nuclear structure, the Gammasphere facility supports a world-class program focused on the structure of nuclei at high angular momentum. We have developed laser techniques for trapping radioactive atoms to make fundamental measurements in nuclear physics. Another 88-Inch Cyclotron program, unique in the U.S., examines the nuclear and chemical properties of the heaviest elements.

Continuing our pioneering work in relativistic heavy-ion physics, we are among the leaders in the STAR experiment that will begin taking data at Brookhaven's Relativistic Heavy Ion Collider (RHIC) in 1999. We initiated the use of large time projection chambers (an LBL invention) to support RHIC's primary goal of producing a quark-gluon plasma to simulate conditions in the early universe.

Our Tevatron participation at Fermilab includes two detector collaborations: CDF, which recently announced evidence for the top quark, and D0. One major contribution to D0 was the development of the silicon vertex detector to precisely measure particle tracks. Building upon this expertise, we have a major role in the ATLAS detector at CERN's Large Hadron Collider. On another frontier is PEP-II, a B-meson "factory" being built at the Stanford Linear Accelerator Center to study CP violation and thus explain the predominance of matter over antimatter. We originated its technical basis and are now partners in its construction.

A related instrumentation effort derives from our leadership position in the design and fabrication of detectors for high-energy physics and nuclear science applications. These devices are at the forefront of modern technology involving state-of-the-art custom integrated circuits coupled to advanced semiconductor detector designs.

Astrophysics programs include a search for distant supernovae (six discovered thus far) to determine the mass density of the universe and thus its ultimate fate; direct detection of the yet-undiscovered dark matter thought to account for most of the mass in the universe; investigations of the cosmic microwave background and thus the origin of the universe; and Sudbury Neutrino Observatory studies of the sun and supernovae.

Nuclear and particle theory and the evaluation and dissemination of nuclear and particle-physics data are also strengths of our program.

Nuclear Nonproliferation

Besides contributing to the strategic benefits of a secure, abundant energy supply and a superior overall technology base, Lawrence Berkeley Laboratory does considerable R&D work that is directly or closely applicable to national security. Some of this work (notably ion-source R&D for the Strategic Defense Initiative neutral-beams program) has been carried forward in its practical development under the sponsorship of DoD, directly and through defense contractors. However, the ideas and technologies almost invariably originated in the pursuit of pure knowledge—an unpredictable but abundant source of practical spin-offs.

Facilities and scientific developments funded by the DOE Office of Energy Research in materials science, particle detectors, x-ray and particle beam generation, and optics have found important national security applications. These uses include the production of very-large-scale integration (VLSI) electronics via advanced lithographic techniques, design and fabrication of electromechanical micromachines, and large flat-panel displays. Our capabilities in materials sciences are rapidly making possible the design of new compounds and “designer” materials with properties specific to user needs. Through the Cooperative Research and Development Agreement (CRADA) process, many of these technologies are rapidly being transferred to the industrial sector.

In addition to these transferable and developable technologies, LBL operates several national user facilities at the forefront of research in fundamental sciences. These facilities and the accompanying reservoir of talent have great potential relevance to DOE and DoD activities in treaty verification, arms control and disarmament, and nonproliferation. The newest of these facilities is the Advanced Light Source, the world's brightest source of UV light and soft x-rays. With this tool we can now perform rapid precision spectroscopy on subpicogram quantities of contaminant materials, even when the materials are buried slightly below the surface of a sample. Our National Center for Electron Microscopy provides a second means to characterize trace materials with sizes of 10 Å or less. For the detection of extremely minute quantities of radioisotopes, LBL operates a very low background counting facility. Together these facilities represent an unparalleled capability for verification studies.

National Research Facilities

LBL has designed, built, and now operates five national research facilities offering users advantages that are unmatched elsewhere in the world. Well known nationally and internationally, these facilities attract academic, government, and industrial scientists from nations around the globe.

Advanced Light Source. This third-generation synchrotron-radiation facility produces America's brightest beams of ultraviolet and soft x-ray light. Its light is used to conduct research and development in virtually all scientific disciplines. Currently, 92 scientists are active users at this facility, and their number increases monthly as new experiment stations come on-line.

88-Inch Cyclotron. In operation since 1962, this facility is a versatile, reliable accelerator of ion beams as light as hydrogen and as heavy as uranium. Although its primary mission is to support research in nuclear physics and nuclear chemistry, its beams are also used by the U.S. aerospace industry for testing semiconductors under the conditions of outer space. In operation seven days a week, the facility serves over 200 researchers per year.

Gammasphere. When completed in late 1995, this large gamma detector array, located at the 88-Inch Cyclotron, will be the premier national facility for research on nuclear structure. The Gammasphere is now operating in an early-implementation phase, with 36 of the planned total of 110 high-resolution detectors in place.

National Center for Electron Microscopy. This facility contributes substantially to research in materials science, biology, and geology. The heart of the Center consists of two microscopes—the High-Voltage Electron Microscope, the most powerful of its kind in the U.S.; and the Atomic Resolution Microscope, which has a resolution of 1.6 Å, enabling the visualization of the atoms in a substance. Over 100 scientists currently use the facility.

National Tritium Labeling Facility. This facility offers specialty equipment and professional assistance to biomedical researchers in producing tritiated compounds to be used as tracers in chemical and biomedical research. The facility is unique in its ability to produce biological compounds with very high specific activity and radiochemical purity. Nineteen scientists, about half of whom are from industry, currently use the facility.

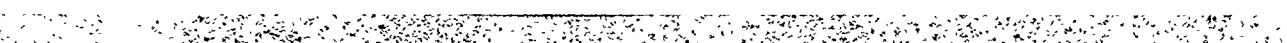
In addition to these national facilities, other research facilities available at LBL include the Center for Computational Seismology, the Sky Simulator, the Mobile Window Thermal Test Facility, the Low-Background Counting Facility, the Biomedical Isotope Facility, and the LBL-U.C. Berkeley High-Speed Imaging Test Bed. Specific information on their capabilities and access to them is available upon request.

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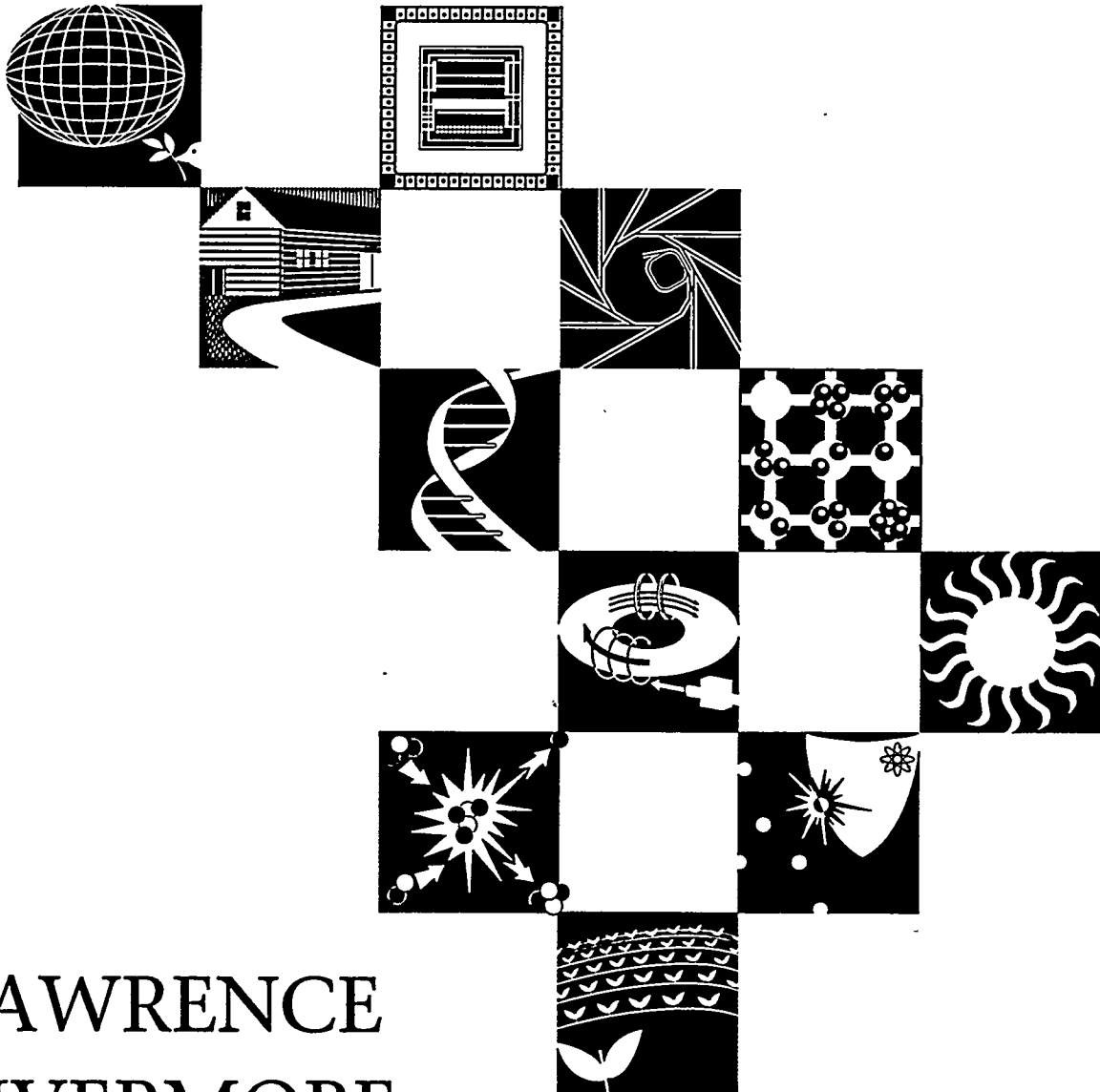
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RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Lawrence Livermore National Laboratory

The Lawrence Livermore National Laboratory (LLNL) is one of three laboratories operated by the University of California for the U.S. Department of Energy (DOE). Founded in 1952 to provide thermonuclear research, LLNL is today a multiprogram national security laboratory. Its major focus areas are (1) global security and reducing the nuclear danger, (2) global ecology and harmonizing the economy with the environment, and (3) bioscience and revolutionizing the understanding of human health. LLNL programs in stockpile stewardship, nonproliferation, environmental science, energy, inertial confinement and magnetic fusion, bioscience and biotechnology, physics, chemistry and materials science, engineering, and computations support these three areas. Many LLNL-developed technologies have been transferred to U.S. industry, establishing new industries and revitalizing existing ones. LLNL is also working directly with industry to develop new technologies and processes and make scientific and technological breakthroughs that benefit all parties. LLNL continues its 40-year tradition of serving the national interest through the application of innovative, ground-breaking science and technology.

Energy Efficiency

Various LLNL advances are finding application in products or processes to increase energy efficiency, particularly in industry and transportation. For example, we are working with Caterpillar Inc. and North Star Steel to develop the superplastic properties of ultrahigh-carbon steels. The superplasticity of these highly wear-resistant steels will permit fabrication of near-net-shape components, thus reducing the energy used in manufacturing.

We are developing a high-specific-power aerocapacitor and a nanostructure multilayer capacitor for electric vehicles. We are developing thermoelectric materials using multilayer quantum-well films that will allow the engine's exhaust heat to be converted to electricity for cooling or heating hybrid-electric vehicles.

In other projects, we are working to lower the operating temperature and increase the efficiency of solid-oxide fuel cells. Using LLNL-developed thin-film multilayer technology, we are fabricating cells that improve the conductive properties of solid-oxide interfaces and lower their operating temperatures from 1100 to 700°C, allowing automotive uses. Our electromechanical battery is based on the flywheel concept of energy storage and uses a unique arrangement of permanent magnets. Our new zinc/air battery uses small particles of zinc combined with oxygen from the air to produce electricity at a chemical conversion efficiency of more than 97%.

We have assisted the California Department of Transportation in defining a communications standard for automatic vehicle identification for electronic toll collection. We have also developed an imaging technique of electrical impedance tomography that can "see" the infiltration of water into pavement. As a member of CALSTART, we are modeling advanced aluminum-spaceframe vehicle structures and evaluating novel schemes for improved safety in small electric or hybrid vehicles.

We are working with Boeing Commercial Airplane Group and Vought Aircraft Co. to evaluate various high-temperature polymer composites for use on the high-speed civil transport—the world's first economically viable, supersonic passenger plane. In partnership with Cummins Engine Co. and Sandia California, we are developing technologies to reduce nitrogen oxide emissions from diesel engines. And we recently licensed a new low-cost radar technology to a Southern California manufacturer. This technology could be used in a collision-avoidance system for automobiles or to create intelligent-vehicle highway systems.

Energy Supply and Renewables

LLNL is investigating many approaches to ensuring a safe, secure, abundant, and affordable supply of energy for the U.S. We are engaged in industry partnerships to find, produce, and refine domestic petroleum using LLNL-developed technologies. We have developed the hot-recycled-solids retorting process for producing oil from oil shale economically and reliably. And we are investigating methods for catalyzing the conversion of methane to transportable liquid fuels.

LLNL has more than 50 programs related to fission energy and a broad range of nuclear-system-design and safety-analysis projects. LLNL has devoted nearly 20 years to developing the atomic vapor laser isotope separation (U-AVLIS) process for low-cost enrichment of uranium for commercial reactor fuel. This effort has culminated in the U.S. Enrichment Corporation's recent decision to begin implementing AVLIS technology. Completion of this task will be a demonstration of LLNL's ability to develop and transfer economical industrial processes for very competitive markets.

Hydrogen offers promise as an alternative fuel. It can be produced from numerous domestic sources, is nonpolluting, and can be used as a power source for electric vehicles and power plants. We are working with U.S. industry and other research institutions to develop technologies for hydrogen production, storage, and use in hybrid-electric vehicles.

LLNL is exploring both the inertial confinement (laser) and magnetic confinement approaches to fusion energy. The goal of our inertial fusion work is to produce thermonuclear fusion in the laboratory with significant energy yields for both defense and civilian applications. We recently upgraded the experimental capabilities of the Nova facility, the world's most powerful laser facility.

The National Ignition Facility (NIF) is being designed as a 1- to 2-MJ glass laser, powerful enough to demonstrate thermonuclear ignition and fusion burn and to produce net energy gain. Achievement of ignition and burn will enable us to establish the requirements for the driver, fusion capsule, and reactor technologies for generating electricity. NIF will open up new research areas (e.g., x-ray lasers, x-ray holography) and new technologies (e.g., ultrafast, ultrahigh-peak-power lasers). On October 21, 1994, Secretary of Energy Hazel O'Leary announced DOE's intention to proceed with the engineering and design of the NIF and noted that LLNL was the Department's preferred project site.

In magnetic fusion, we are participating in the research, development, and engineering design of the International Thermonuclear Experimental Reactor (ITER). We are also heavily involved in the Tokamak Physics Experiment, to be built at the Princeton Plasma Physics Laboratory, and with General Atomics Inc. and their DIII-D tokamak. We are also developing computational tools for modeling tokamaks in a large-scale, integrated manner.

Climate Change

LLNL expertise in atmospheric science is being applied to the study of global climate and climate change. Through our Program for Climate Model Diagnosis and Intercomparison, we are attempting to learn why current global atmospheric and climate models show important disagreements. As part of this effort, and in cooperation with the United Nations, we are leading the Atmospheric Model Intercomparison Project. The goal of this international project is to compare general circulation models using a standardized numerical experiment to explain the differences in their results and to suggest improvements.

Our project on chemical and ecological relations in the earth system is developing a comprehensive and flexible framework for modeling Earth systems to understand how biogeochemical processes affect global climate. So far, we have constructed a framework that includes models of the physics and chemistry of the atmosphere, oceans, and land surfaces. We are starting a series of experiments to elucidate the role of these processes in shaping global climate conditions.

Using our two-dimensional, global-chemistry model, we are examining the effects of global warming and are establishing an index relative to carbon dioxide for methane, nitrogen oxides, and chlorofluorocarbons. We are also developing a new three-dimensional, atmospheric-chemistry model for studying how trace gases (such as nitrogen oxides from fossil-fuel emissions) affect ozone. And we are using our global climate models to assess how local and global changes in climate affect vegetation and the carbon dioxide balance.

We are conducting a field experiment of the effect of increased carbon dioxide on fir trees. Trees, and in particular fir trees, are responsible for 80% of the conversion of carbon dioxide to oxygen. With carbon dioxide concentrations increasing worldwide, we need to know whether this increase will affect these trees adversely or beneficially. We have collected about 6000 seedlings of two species of conifer, *Taxus brevifolia* and *Pinus ponderosa*, consisting of 80 clone families, from diverse regions of California. We have begun a three-year exposure to elevated carbon dioxide concentrations.

Working with Sandia and Los Alamos, we are developing techniques to measure conditions in the lower atmosphere (20-km altitude). In particular, we are designing and constructing a fully eye-safe cloud-detection lidar (laser radar) for use in high-flying unmanned aerospace vehicles. This small (20-kg) lidar system can detect backscatter from clouds, profile thin cirrus clouds, and measure cloud top heights. It will be flown on the high-altitude Perseus vehicle in the spring of 1995.

Environmental Technology

LLNL is developing technologies to correct the environmental damage of past activities, devising new and modified processes to prevent further damage, and studying the interrelated forces that affect the global environment to accurately predict the effects of human activities. Many of our environmental technologies are widely applicable, and we work with the private sector to adapt them to specific needs.

We have developed a number of innovative and cost effective approaches for environmental cleanup and waste treatment. For example, dynamic underground stripping (developed by LLNL and U.C. Berkeley researchers) uses injected steam and electricity to heat the soil, releasing contaminants so they can be extracted, treated, and disposed of. Crucial to this technique's success is electrical resistance tomography, an imaging method that makes it possible to "see" what is occurring underground and thereby monitor and control the process. The effectiveness of this technique was demonstrated this past year on an underground gasoline spill at the LLNL site; dynamic underground stripping accomplished in weeks what would have taken years using conventional pump-and-treat methods.

LLNL is modifying its hot-recycled-solids retorting technology, developed initially for oil shale retorting, to destroy mixed waste in liquid form. Recent studies at our modified on-site pilot plant demonstrated the feasibility of using retorting to remove organic compounds and decompose sodium nitrate, both of which are constituents of the mixed waste stored in underground tanks at the Hanford, Washington, facility. We are exploring other waste-treatment applications of this retorting process, including the destruction of high explosives and the decomposition of other toxic chemicals.

Bioremediation involves the use of naturally occurring micro-organisms to decompose underground contaminants. Several species of contaminant-destroying bacteria have been identified and grown in the laboratory. A field test of the microbial filter concept was conducted this year at the Kennedy Space Center. Quantities of a strain of bacteria capable of decomposing trichloroethylene (TCE) were injected in wells around the spill. As TCE encountered the microbial filter, it was metabolized and broken down into harmless byproducts. Downstream sampling confirmed that the bacteria did halt the spread of the contaminant.

LLNL's environmental technologies are used locally, nationally, and worldwide. For example, we are assisting Russian scientists to assess the extent of radioactive and chemical contamination in the Southern Urals, where extensive mining, metallurgy, and nuclear materials production have contaminated soil and water over thousands of square miles.

Health and Biotechnology

LLNL's programs in biology, biotechnology, and health care are developing technological solutions for problems associated with human health assessment and fundamental biology.

LLNL's Human Genome Center is a key participant in the international Human Genome Project. Our contributions include a physical map of human chromosome 19, which consists of recombinant DNA clones that span the chromosome. These clones will provide the basis for gene discovery and linkage to disease. We have found the genetic defect for myotonic dystrophy, the most common form of adult muscular dystrophy. We have developed optical imaging methods for measuring DNA strand length, new imaging techniques such as fluorescence *in situ* hybridization, whole chromosome paints, and atomic-force and scanning tunneling microscopy. Other new technologies include gene-mapping software, DNA-sequencing instrumentation, robotics and flow systems, and chromosome-specific recombinant DNA libraries.

LLNL has isolated, cloned, and mapped human genes involved in the repair of DNA damage due to ultraviolet light or chemical mutagens. We are studying the link between defective repair proteins and several human DNA repair disorders that predispose to cancer. One of the genes we discovered is responsible for the disease xeroderma pigmentosum. Unraveling the nature of DNA repair will influence the way certain genetic disorders are treated.

Evaluation of human health risk requires techniques for assessing exposure to toxic agents. LLNL has developed bioassay methods that identify persistent chromosome changes, making it possible to estimate the effect of very low doses of potentially harmful agents. Our chromosome painting techniques, which use fluorescent dyes attached to DNA, can identify chromosomal translocations long after radiation exposure. We are using these and other methods to quantify chemical and radiation exposure in a variety of exposed populations.

We are also investigating the effects of mutagens formed during the cooking of food. Using LLNL's accelerator mass spectrometer (AMS), we can measure extremely low levels of carbon-14-labeled adducts (simple molecules chemically linked to DNA; thought to be a precursor to genetic damage and cancer) in mice that have eaten food mutagens. The ultrasensitivity of the AMS may allow us to monitor low-level exposures (one part per billion) in environmental samples and humans.

We recently transferred the information and materials necessary for the commercialization of our new high-speed flow cytometer/cell sorter to the private sector. We are developing an industrial instrument for high-speed, high-throughput electrophoresis that should increase tenfold the rate of the separations required in DNA sequencing. In 1994, we formed the Center for Healthcare Technologies to consolidate LLNL efforts in biotechnology and facilitate their transfer to industry.

Materials and Chemistry

Chemistry and materials science affect almost every aspect of our lives, from the production of cleaner, cheaper energy to national defense and U.S. economic competitiveness. LLNL's chemistry and materials science, physics, and engineering intertwine in the development and application of advanced materials.

We have developed advanced materials (and the processes for fabricating them) that can withstand extremes of temperature or long-term exposure to ionizing radiation, that are strong yet lightweight, that are nonreactive in corrosive environments, that are superconducting or electrically insulating, and so on. These materials can be found in nuclear weapons, magnetic fusion machines, lasers, military vehicles, satellites, and space probes. The development of these materials has often led to new manufacturing capabilities and new industries.

Fundamental research in physics, combined with advanced computing, has led to the design of novel materials high-temperature superconductors and microelectronics. Research into the atomic level behavior of surfaces and interfaces has led to exciting industry partnerships, among others, to improve computer disk drives and storage devices.

We make multilayer materials of elements from all parts of the periodic table using atom-by-atom synthesis techniques. By combining a fundamental physics understanding of these materials with new processes for depositing thin or thick materials (0.5 to 500 μm thick, up to 50,000 individual layers), LLNL has moved multilayers into the world of bulk structures such as high-performance capacitors and thermoelectrics.

LLNL is the world-leader in the development of aerogels—porous materials with an ultrafine cell and pore size, high surface area, and a solid matrix of interconnected colloidal-like particles with characteristic dimensions of 10 nm. This nanostructure is responsible for the aerogel's unique optical, thermal, acoustic, mechanical, and electrical properties. LLNL has developed several types of aerogels as well as ways to tailor their structure and properties. Aerogels are finding increasing use as superinsulators, coatings for ultrasonic transducers, supercapacitors, thin-film dielectrics, gas adsorbents, catalysts, and filters. LLNL is working with the Lawrence Berkeley Laboratory and Aerojet Corporation to develop cost-effective manufacturing of aerogels.

Cermets are another material pioneered at LLNL. These ceramic-metal composites are both strong and lightweight. They are well suited for use as vehicle parts, space components, in heavy industrial equipment, and as law-enforcement shields and military armor. We are working with industry to transfer the technology for fabricating these materials and to tailor their properties for specific applications.

Computing and Information Infrastructure

Scientific computing has become essential to scientific research. LLNL supports two supercomputing centers, the Livermore Computer Center and the National Energy Research Supercomputer Center (NERSC), both of which are moving from conventional supercomputers to a massively parallel processing environment.

NERSC serves the computing needs of more than 150 energy-research sites throughout the U.S. NERSC also supports the Energy Sciences network (ESnet), which provides reliable, state-of-the-art networking services to DOE and major energy-research facilities worldwide. NERSC staff operate the computing center and ESnet 24 hours a day, 7 days a week.

As part of the U.S. government's High Performance Computing and Communication program, LLNL is applying its computing resources to Grand Challenge problems (e.g., climate modeling, fusion energy) and industrial problems of national importance (e.g., combustion dynamics, structural engineering). The magnitude and complexity of these problems demands increases in computing speed and performance that can only be met with massively parallel processing. LLNL's new Meiko CS-2 massively parallel machine is providing invaluable experience in how best to exploit this new computing architecture.

Also required are thousand-fold increases in network capacity and data storage volume. LLNL is joined with 20 private companies and 6 national laboratories in the National Storage Laboratory (NSL), which is located at LLNL. The NSL is a collaborative research project to investigate, demonstrate, and commercialize the required hardware and software technologies. A prototype storage system that can accommodate diverse data types, very large data sets, and very high rates of data transfer is up and running at NERSC.

LLNL is also making important contributions to the information superhighway, the National Information Infrastructure, including projects to design, develop, and test components for routing light pulses onto optical fibers, x-ray lithography for high-density integrated circuits, the development of inexpensive high-resolution flat-panel displays, large-scale optical switches for connecting fiber optics, systems for high-speed, high-capacity distributed storage, and software for easily navigating the information highway.

Our SISAL language project is an ongoing effort to develop high-performance, functional-language programming systems for parallel computers. LLNL is working with a major U.S. computer vendor to develop a mixed SISAL-FORTRAN programming environment for a commercial multiprocessor system. We are also working with BioNumerik, a small pharmaceutical company, to develop SISAL computer codes for designing anticancer drugs.

High-Energy and Nuclear Physics

Through research in high-energy and nuclear physics, LLNL is investigating the fundamental nature of matter. Because many of the research facilities required for this work are specialized and costly, LLNL collaborates widely with other universities and laboratories.

To learn why matter gained predominance over anti-matter at the time of the Big Bang, LLNL is collaborating with Lawrence Berkeley Laboratory and the Stanford Linear Accelerator Center (SLAC) to build the B Factory at SLAC. This facility will accelerate electrons and positrons around two storage rings and then crash them together, creating b-quarks. LLNL has major responsibilities for the design and construction of several accelerator components. LLNL is also contributing to the design of a new detector that will detect the decay products of the B-meson that contains the b-quark and its antiparticle.

We are participating in experiments at Brookhaven National Laboratory to study nuclear matter in extreme collisions, looking at the particles produced by these reactions and searching for strange matter (i.e., matter containing strange quarks). Also with Brookhaven, we are collaborating on the design and construction of PHENIX, one of two large detectors for the Relativistic Heavy Ion Collider. PHENIX will measure photons, electrons, and muons and will be used to search for a new form of matter, the quark-gluon plasma.

We have applied the latest theoretical models to LLNL's databases of cross sections and angular distributions for neutrons and protons incident on various nuclei from 20 to 250 MeV. We can now calculate proton-emission spectral at all angles for 60-MeV neutrons incident on carbon—calculations that are essential for nuclear design and radiation oncology.

Using LLNL's databases of high-quality atomic and nuclear data, we have developed computer codes to model the dose distributions in the human body caused by beams of neutrons or protons. These sophisticated techniques solve problems of radiation transport and particle reactions using Monte Carlo methods and maps of the body from CAT scans. These codes will be extremely valuable in the treatment of cancer.

We are investigating the properties of condensed matter, including measurements on the electrical conductivity of ultradense hydrogen at densities approaching its metallization density, at which it is predicted to be a high-temperature superconductor. LLNL has also developed the electron beam ion trap (EBIT), a unique experimental device for producing and trapping ions in extremely high charge states that allows us to test theories of relativity and quantum electrodynamics.

Nuclear Nonproliferation

LLNL and the other national security laboratories are uniquely able to determine if another country is developing nuclear, chemical, or biological weapons. At LLNL, we also have special capabilities and methods to render nuclear devices safe, such as the Nuclear Emergency Search Team, the Forensic Science Center, and the Conflict Simulation Laboratory to help counter the proliferation of weapons of mass destruction and deal with the threat of nuclear weapons in the hands of terrorists or others hostile to the U.S.

One of our major contributions to stemming nuclear proliferation is the development of remote sensors and analysis techniques to detect signs of existing or emerging capabilities to produce nuclear, chemical, or biological weapons. Among the systems we have developed are remote optical measuring systems, which can identify and monitor airborne chemicals, and temperature measuring systems, which can provide airborne or space-based assessments of the functions of suspect facilities (e.g., from the temperature signatures of smoke stacks or cooling ponds).

Our arms-control activities continue to make important contributions to national and global security. We provide technical support in developing U.S. policy for arms control and treaty verification. For example, we provided key International Atomic Energy Agency team members who searched and assessed Iraqi activities for nuclear facilities after the Persian Gulf War. In a major new thrust, we have assembled an LLNL-wide network of expertise to support the government in its interactions with weapon scientists and institutions in the states of the former Soviet Union (FSU). The goal is to speed weapon dismantlement and defense conversion in the FSU and to build confidence between the U.S. and the new republics.

Recently negotiated arms-limitation treaties present special verification challenges. Permitted weapons or weapon components must be identified with tamper-proof, counterfeit-proof electronic tags or seals. We have developed candidate seals for tracking and accounting for containers of weapons-grade fissile materials (from dismantled nuclear weapons). We have also developed communication devices that can remotely query tagged containers.

Our counterproliferation efforts include analyzing signatures of possible clandestine proliferation activities and processing the information to discover concealed purposes; we then consider potential responses to proliferants and assess the economic, political, and environmental consequences of each one. We are also developing technical capabilities to find and neutralize battlefield and terrorist nuclear threats. We have designed and deployed the only device capable of disabling some terrorist weapons. In our Conflict Simulation Laboratory, we can simulate (both interactively and in real time) and assess the effectiveness of counterproliferation and interdiction responses.

Nuclear Weapons Research and Development

The focus of LLNL's work in defense and nuclear technology is to reduce the global nuclear danger while maintaining a strong U.S. defense.

Stockpile stewardship—that is, ensuring the safety and reliability of the U.S. nuclear stockpile—in the absence of underground nuclear testing requires an enhanced, science-based understanding of nuclear weapons. This understanding also supports our activities in nonproliferation, treaty verification, and other areas where knowledge of nuclear weapons is required. To enhance our predictive capabilities to assess nuclear weapon safety and performance, we must increase the complexity, completeness, and accuracy of our numerical simulations. To this end, we are moving to massively parallel processing—acquiring new machines, adapting existing codes, and developing new software to realize the advantages of this new computing environment. We are also enhancing our non-nuclear experimental capabilities and designing the National Ignition Facility.

In the area of dismantlement, we are developing safe and environmentally responsible methods for reusing or disposing of high explosives as well as technologies and procedures for verifying the dismantlement of nuclear weapons, processing the materials for disposition, and placing nuclear materials under international safeguards. LLNL is the lead laboratory for defining DOE's downsizing roles in plutonium and uranium fabrication and high explosives.

Technologies developed for the nuclear weapons program are also being applied to civilian science and technology and DoD missions, including highly intelligent weapons, high-performance explosives, and high-technology countermeasures.

Inertial confinement fusion (ICF) provides a research base for the development of fusion energy, with potential for producing pure thermonuclear burn. LLNL's dual-use ICF program also supports stockpile stewardship by allowing study of the physics of material processes at extremely high-energy-density. We are applying ICF technology to the basic sciences and to state-of-the-art solid-state lasers. The near-term objective of our ICF program is to produce the science and technology base required for a multilaboratory National Ignition Facility that will achieve fusion ignition and moderate energy gain.

A number of LLNL's laser and optics technology activities address such issues as light pulse generation, multipass amplifier development, fast light pulse switching, frequency converter design optimization, laser diagnostic development, and laser alignment and wavefront control. Target physics issues include large instability growth implosions, laser-plasma interaction instabilities, techniques for measuring time-resolved symmetry, interface motion, and capsule shock timing and symmetry. We also develop state-of-the-art computational models of the complex interdependence of atomic and plasma physics, radiation transport, and electron conduction.

National Research Facilities

LLNL operates two national user facilities, the Center for Accelerator Mass Spectrometry and the National Energy Research Supercomputer Center, as well as a host of other unique research facilities. Many of these facilities are available for use by outside scientists, providing experimental capabilities beyond the scope of most universities and private research laboratories.

Center for Accelerator Mass Spectrometry. CAMS is the world's most versatile and productive accelerator mass spectrometry facility, providing some 12,000 measurements of isotopic ratios in the past year. CAMS serves LLNL programs in bioscience, climate change, radiation dosimetry, and nonproliferation. External users and collaborators, numbering some 400 in the past year alone, include investigators from universities, other government agencies, and private companies. They come from the U.S., Canada, Mexico, Australia, Sweden, Denmark, Italy, and the United Kingdom. CAMS serves external programs in archaeology, art history, clinical and nutritional medicine, and geoscience.

National Energy Research Supercomputer Center. NERSC serves more than 5000 users at 150 research sites in DOE national laboratories, universities, and industry and some 50 international sites. NERSC maintains the Energy Sciences network (ESnet), a nationwide computer-data communications network that supports multiple-program open research. NERSC is also heavily involved in the National Storage Laboratory collaboration and the National Education Supercomputer Program.

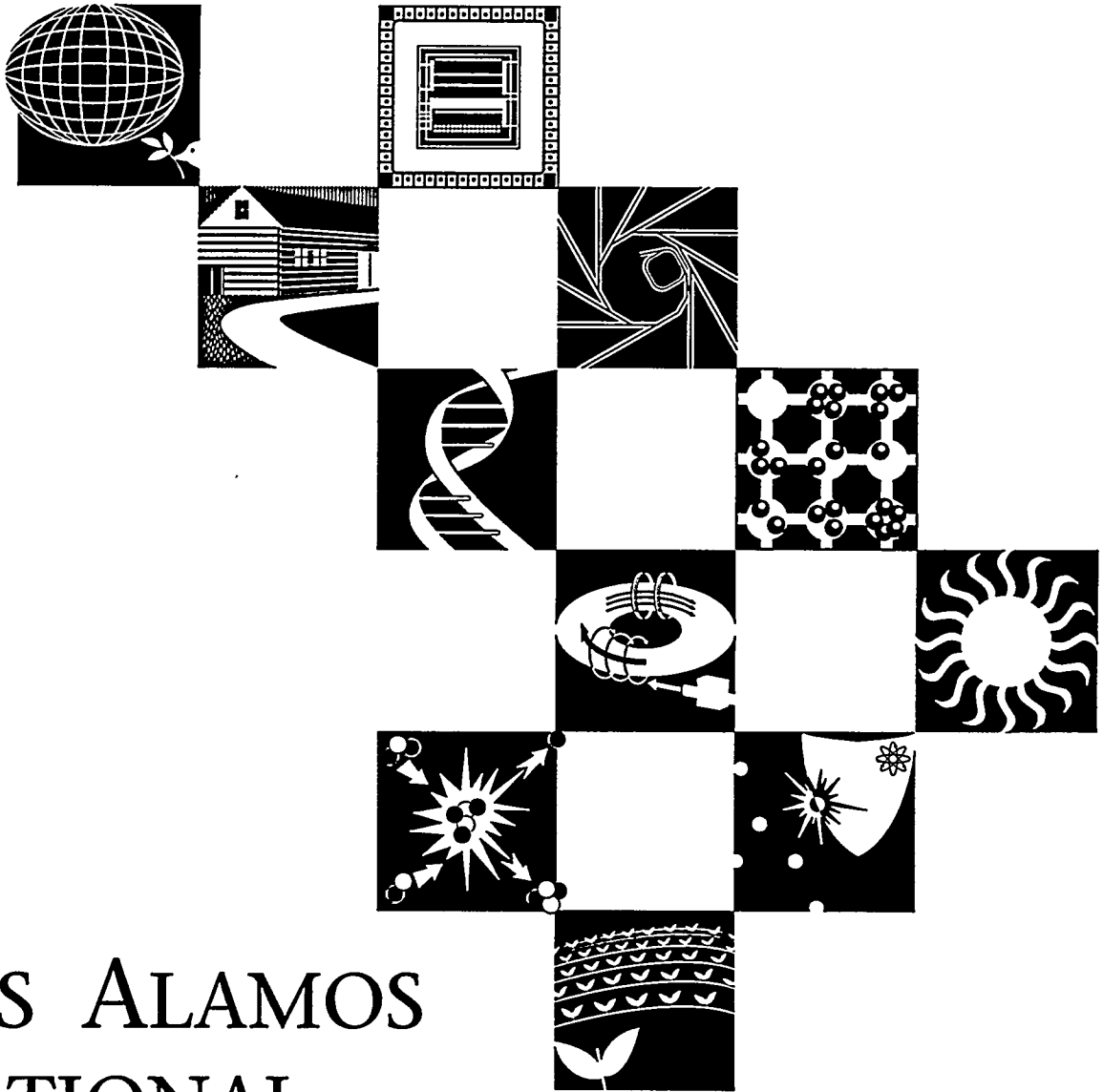
Nova Laser. LLNL's Nova laser is currently the world's most powerful glass laser. It is capable of producing up to 125 kJ of 1.05- μm laser light in a 3-ns burst from its ten laser beams. This facility is used for fundamental plasma physics research, weapon physics and weapon effects studies, and fusion energy research.

Atmospheric Release Advisory Capability. ARAC provides real-time emergency predictions of the atmospheric transport and deposition of radioactive, chemical, and particulate materials. ARAC is operated by LLNL for the DOE and DoD; expansion to a national capability has been proposed.

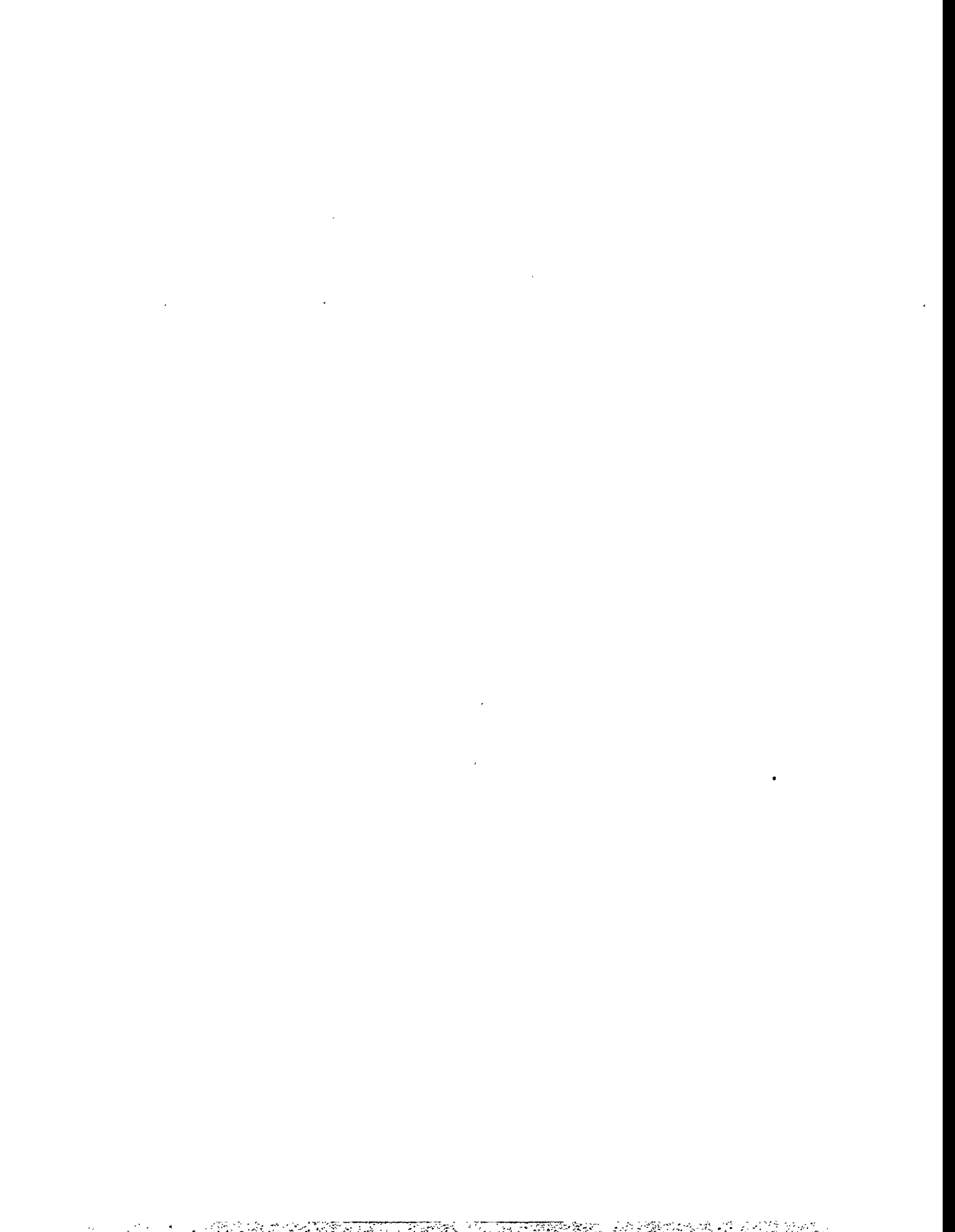
Forensic Science Center. This center houses state-of-the-art analytical tools, from gas chromatograph/mass spectrometers to ultratrace DNA detection techniques, for analyzing chemicals in minute samples of water, air, soil, and vegetation of importance in nonproliferation, treaty verification, and law enforcement activities.

Site 300 Contained Firing Facility. The flash x-radiography machine, with high-speed optical cameras, pin-dome technology, and multibeam velocimetry, is the most versatile and complete explosives test facility in the world. The cumulative investment in this facility is \$85 million.

RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



LOS ALAMOS
NATIONAL
LABORATORY



Los Alamos National Laboratory

Los Alamos National Laboratory (LANL), one of the three original national laboratories, was established in 1943 and is operated by the University of California for the U.S. Department of Energy (DOE). Its central mission is to reduce the global nuclear threat through science-based stockpile stewardship and support, nuclear materials management, assistance in nonproliferation and counterproliferation, and environmental restoration to reverse the legacy of 50 years of production. We are achieving this mission by integrating knowledge in diverse areas of science and technology with specialized facilities in eight broad areas of core competence. These are (1) theory, modeling, and high-performance computing; (2) complex experimentation and measurement; (3) nuclear and advanced materials; (4) nuclear weapons science and technology; (5) analysis and assessment; (6) earth and environmental systems; (7) bioscience and biotechnology; and (8) nuclear science, plasmas, and beams. Los Alamos also forms strategic partnerships with government, academia, and industry in programs designed to enhance national economic competitiveness.

Energy Efficiency

Los Alamos has been involved in energy efficiency programs related to transportation, industry, and utilities for more than 15 years. We have consistently made significant contributions to national and worldwide energy savings and waste minimization.

In the transportation arena, Los Alamos has been an international leader in Proton Exchange Membrane (PEM) fuel cell research. This work has resulted in a 100% reduction in required amounts of noble metal catalyst with a 15% increase in fuel cell performance. Our fuel processor, or reformer, technology has been adopted by General Motors, and twelve General Motors employees have joined us in Los Alamos. We recently signed a Cooperative Research and Development Agreement (CRADA) with Dow Chemical to further develop the conducting polymer used in PEM fuel cells. We believe that this fuel cell can triple the fuel efficiency of current automobiles.

The KIVA computer code for modeling hydrodynamic and thermochemical processes in combustion is used by virtually every automobile manufacturer in the world. Two years ago, we licensed KIVA II to CRAY, and last January, we signed a multilaboratory high-performance computing CRADA with the U.S. Council for Automotive Research (USCAR) to beta-test the most recent version of the code. KIVA is being used to develop spark ignition engines that meet lean-burn, low-emission requirements. It has also helped to improve efficiency in other combustion processes, such as in coal-fired power plants.

Los Alamos pioneered the Materials by Design program, in which computer simulations of quantum chemistry were used to explain the unique properties of certain intermetallics that can be used in high-temperature, highly efficient energy conversion. This program's success led to a Catalysis by Design program aimed at improving the efficiency of petroleum refining. The ultimate goal is to reduce NO_x emissions in automobile engines. This latter program has also resulted in a multilaboratory CRADA with USCAR.

In 1990, Los Alamos and Sandia National Laboratories jointly initiated the Industrial Waste Reduction Program, which works with industry to achieve energy efficiency through waste minimization. We struck formal agreements with Motorola, Hughes, Boeing, Du Pont, and the Chemical Manufacturer's Association. Our efforts have succeeded in replacing solvents with supercritical carbon dioxide (SCCO) while improving energy efficiency. Los Alamos has the largest SCCO training facility in the world and is working with a variety of industrial partners to place this technology in manufacturing processes.

Through the Superconductivity Technology Center, Los Alamos is partnering with industry to develop high-temperature superconducting materials that can be used in engineering applications.

Energy Supply and Renewables

Los Alamos has had more than twenty years' experience in programs addressing energy supplies and renewable energy. Many of these programs had their genesis as a consequence of our core competencies in the nuclear weapons program. For example, we have been involved in site characterization at the Yucca Mountain civilian radioactive waste repository. This work is directly related to our geophysical and geochemical characterizations at the Nevada Test Site. Los Alamos has made definitive contributions in dating the volcanism that characterizes the geologic formation and hydrology at Yucca Mountain.

Similarly, our experience in geology, drilling, and seismology gained through nuclear weapons testing led to the hot dry rock (HDR) geothermal energy program. The feasibility of HDR was established at Fenton Hill, NM, in 1979. A still hotter engineering system was tested for more than a year in the early 1990s. Advances in drilling technology, seismic monitoring, and high-temperature logging tools have not only helped the geothermal industry but are now being transferred to the oil and gas industry as well.

In 1989, Los Alamos and Sandia National Laboratories established the Oil Recovery Technology Partnership (now the Oil and Gas Technology Partnership), whose purpose was to transfer advanced technologies from the two laboratories to the petroleum industry. As a result, the laboratories have assisted industry in identifying additional oil reserves that otherwise would not have been available for recovery. Recently, Los Alamos led the development of a partnership with the petroleum industry called the Advanced Computational Technology Initiative. This initiative, to be funded at \$40 million in FY 1995, will apply the vast computational capabilities of the DOE national laboratories to uncover new petroleum resources.

In 1988, Los Alamos proposed the formation of the Superconductivity Pilot Centers as a revolutionary way for the DOE national laboratories and industry to partner. Three centers were established at Los Alamos, Oak Ridge, and Argonne National Laboratories. They were so successful that legislation was introduced to institutionalize the new ways of working with industry. This led to the 1989 National Competitiveness Technology Transfer Act, which gives the laboratories added flexibility in working with industry. Two key results of the legislation were the abilities of the laboratories to sign CRADAs and to protect industry's information from the Freedom of Information Act. In addition, the advances in high-temperature superconducting materials at Los Alamos are allowing us to begin developing engineering systems that will use these materials.

Climate Change

Los Alamos performs research concerning climate change on a broad front that encompasses basic theory, modeling and computer simulation, observations, and assessment. In all of these areas, we commonly form collaborations with the best university and agency experts.

In the theoretical sphere, significant work is being done on nonlinear aspects of climate dynamics. The question of whether climate change is predictable has been singled out by the JASONs as the most important issue in the DOE's Global Change Program. Researchers at Los Alamos are combining their unique capabilities in nonlinear dynamics and in computational fluid dynamics to assess the limits of the climate system's predictability.

In computer modeling, Los Alamos is deeply involved in many phases of regional and global climate dynamics. This work involves atmospheric chemistry, the hydrological cycle, advection of smoke such as that from the Kuwaiti oil fires, and ocean dynamics. Much of it is conducted through an institutional collaborative research program with LLNL and four campuses of the University of California. At Los Alamos, the DOE-funded Computer Hardware, Advanced Mathematics, and Modeling Program has produced the fastest running, most detailed and highly resolved global ocean model yet created.

Observations at Los Alamos have extended to field research on marine stratus clouds, which form a highly sensitive system. For the Atmospheric Radiation Measurements/Unmanned Aerospace Vehicles (ARM/UAV) program, we are developing the novel Hemispheric Optimized Net Radiometer, which will measure radiative fluxes in the atmosphere with unprecedented accuracy. Our optical and infrared calibrations laboratories are helping to ensure that all of the payload instruments are appropriately characterized for these critical measurements. The Multispectral Thermal Imaging program is directed at nonproliferation measurements, but it also demonstrates technologies that apply to remote sensing for climate research. Our lidar efforts also provide measurements relevant to climate research, as in the Central Equatorial Pacific Experiment. As part of the DOE's ARM program, LANL is responsible for the design and implementation of the site in the tropical western Pacific as well as for the formulation of operations for all sites. Finally, we are proposing a collaborative Arctic Rim Initiative with countries of the former Soviet Union to study climate and environmental change.

Through the years, Los Alamos has developed expertise in assessment to evaluate the complex interactions of climate change and to study the economic impacts of strategies to reduce the magnitude of the changes. Examples include assessing pollution over Mexico City and giving advice on the impacts of expected climate changes in Central America.

Environmental Technology

Building upon a fifty-year history of excellence in multidisciplinary problem-solving, Los Alamos is helping to solve user-defined environmental problems in a timely, cost-effective manner. In response to an earlier national need, for which the LANL was established, we contributed to the development of nuclear weapons. In the same spirit, we are answering the current mandate to address the technologically complex environmental issues within Los Alamos and throughout the world.

We seek to commercialize our environmental technologies to aid U.S. industry's competitiveness and create jobs. Our environmental sites and facilities are being used as testbeds for relevant new approaches. Of some 60 technical approaches, three have been commercialized, eleven are ready for commercialization, and eight have other arrangements with industry.

Plume Remediation and Containment. We are using four specific instrumental methods to assess the chemical form of uranium at the Fernald site to aid successful soil washing. We have developed complexing agents that solubilize specific contaminants and are demonstrating new permeable, reactive barriers that allow water flow but remove pollutants.

Underground Storage Tanks. An LANL-developed hydrothermal processing pilot plant effectively removes organics and nitrates from tank waste. We have also improved models for historical tank layering and for the determination of nominal waste compositions.

Waste Treatment. Testing has extended to packed-bed, silent-discharge-plasma, and electron-beam oxidation methods for destroying organics. We are also using supercritical carbon dioxide to clean circuit boards and water-soluble chelators to minimize waste in the electroplating industry.

Decontamination and Decommissioning. SensorCoat, a strippable polymer that simultaneously indicates by a color change where uranium exists and complexes the uranium into the polymer, is being perfected.

Landfill Stabilization. Proven, certified landfill cover methods minimize the intrusion of water into landfills.

Pollution Prevention. Waste generators are demonstrating segregation of noncontaminated, low-density solid waste from low-level plutonium waste.

Sensors, Instrumentation, and Simulations. A new detector, available from Eberline Instruments, detects alpha radiation in wastes and soils by detecting the alpha particle ionization rather than the particle itself.

Robotics and Automation. Automation of the analytical chemistry laboratory is being accomplished by a Los Alamos-lead consortium of national laboratories and industry.

Analytical Methods. We are adapting the standard EPA SW-846 procedures to meet the needs of transuranic waste analysis.

Health and Biotechnology

Our bioscience efforts were begun to assess the health effects of nuclear weapons. Research on the cellular and molecular effects of radiation and toxic waste provided critical knowledge for the safe conduct of the defense program and for the cleanup of environmental remediation sites. Today, the integration of our bioscience capabilities with our defense technologies, in partnership with the U.S. medical and biotechnology industries, is providing solutions to important national problems—health care, the environment, and economic competitiveness. An early example of the integration of bioscience with our defense technology was the development of flow cytometry. This technique harnessed unique computing capabilities and instrumentation and led to significant advances in cellular and molecular biology, oncology, epidemiology, genetics, and radiobiology.

The integration of Los Alamos capabilities in genomics, computational and theoretical biology, physics, and chemistry with its unique user facilities provides special opportunities for the study of biomolecular structure and dynamics. Advances in our understanding of biomolecular structure and function, combined with genetic engineering, are creating a revolution in health care with the development of molecular medicine. Los Alamos is poised to play an increasingly important role in this arena. Knowledge of biomolecular structure and function also leads to biotechnology applications in energy, environmental remediation, and waste treatment. We are currently developing biomolecular materials for energy storage or transport and biological agents for environmental remediation, enhanced oil recovery, and mixed waste treatment.

Today we are expanding our health care capabilities by drawing more broadly from our defense technology base to provide technologies to the medical community and its associated industries. Examples of Los Alamos contributions include simulation models for minimally invasive diagnostics and therapies, computer analyses of occupant safety in automobiles, pressure sensors for detection of abnormalities in the human body and feedback during laser therapies, optical biopsy systems, robotic systems for automated clone gridding, computer analyses of magnetic fields in the brain, bioreactors for monitoring glucose levels, laser therapy for removing blood clots in arteries and vein grafts, advanced prosthetics, and advanced surgical technologies. Many clinical procedures are empirically based and are seriously lacking in outcomes research. The unique, broad disciplinary expertise and systems approach at Los Alamos can effectively advance these procedures.

Materials and Chemistry

Materials. Materials science has been a key player in essentially all the major programs at the defense laboratories, especially at Los Alamos. Since the war years, the focus has changed from building prototypes with minimal amounts of nuclear and advanced materials to finding new alloys and forms of materials that ensure greater long-term stability and manufacturability. For example, Pu-Ga alloys allow stabilization of the delta phase, which makes them metallurgically superior to the room temperature form of pure plutonium. Current concerns with nuclear materials have led to novel programs, such as the Lab-to-Lab Stabilization Partnership Program—a set of collaborations between the DOE laboratories, U.S. industry, and scientific defense institutions in the former Soviet Union.

Our expertise in nuclear materials has had indirect benefits elsewhere. The investigation of the electronic structure of the actinides led to the study of compounds with comparable f-electron behavior. Many such compounds with U, Pu, Np, Ce, and Yb were found to have "heavy-fermion" characteristics, or very high effective electron masses. This understanding, in turn, laid the foundation for interpreting high-temperature superconductivity and other correlated-electron phenomena. Recent developments in the processing of wires containing high-temperature superconductors have demonstrated the feasibility of their use in commercial applications, such as in motors, fault current limiters, and transmission lines.

The underlying theme of materials work at the defense laboratories has been the development of materials for the central mission, followed by expansion into other arenas. Extensive research on uranium and uranium alloys, for example, led to the use of a corrosion-resistant U-6Nb alloy in weapons. The development of high-strength U-Ti alloys helped demonstrate the superior performance of U-3/4%Ti as a kinetic energy penetrator material. The original application (in the early 1970s) was in the GAU-8 cannon round. The effectiveness of current rounds based on U-3/4%Ti was demonstrated by the performance of the A10 aircraft and M1 tanks in the Gulf War.

The development of novel, advanced materials has been a recurring accomplishment at Los Alamos. A 1990 R&D 100 award recognized the contribution of composites based on molybdenum disilicide to the science of high-temperature structural materials. This class of high-temperature, oxidation-resistant materials is being studied for use in jet engines, burner nozzles, and other high-temperature applications. Development of improved conducting polymers has brought the performance of electrochemical capacitors into the range where they may be useful as storage devices for electrical energy. Recent advancements in fuel cell membrane materials have significantly lowered the amounts of precious metals required in the cells, thereby improving their prospects for commercial development.

Chemistry. Chemistry activities support LANL's and DOE's missions in national defense as well as in civilian and industrial needs. In national defense, instrument development for nuclear and non-nuclear signatures is our forte. Examples are our ability to characterize nuclear proliferation activities by measuring the isotopic abundance of actinides in the environment and our use of airborne lidar for chemical and biological weapons detection. We have a number of other projects in low-observable (stealth) technology, theater missile defense, nonlethal defense and offense, advanced munitions, battlefield simulations, virtual prototyping of laser weapons, optical countermeasures, and combat friend or foe identification.

To meet civilian needs, our chemistry expertise supports the plans to store wastes at Yucca Mountain and at the Waste Isolation Pilot Plant (WIPP). We also support the characterization and remediation of environmental restoration sites around the world, particularly those containing radioactive and mixed wastes. Los Alamos chemistry efforts are helping the Environmental Protection Agency improve data quality and helping DOE-Albuquerque develop a mixed-waste plan. We develop portable units for treating plating wastes, reactive wastes, uranium chips, lead, mercury, compressed gases, and low-level mixed waste. We are developing catalysts for pollution prevention and a multicomponent tracer technology for reservoir characterization. Hundreds of students enhance their education in chemistry at Los Alamos through graduate research assistantship and postdoctoral programs and other opportunities. Our staff receives numerous awards, produces publications, and serves on prestigious technical advisory boards.

We address the needs of commercial industry in many ways. Chemical research has yielded 17 CRADAs, 9 licenses, and 85 proprietary information agreements. From 1990 to 1994, LANL chemistry won 13 R&D 100 awards. We successfully pursue connections through industrial sector associations. Examples of technology transfer include advanced manufacturing techniques, revolutionary DNA sequencing and sizing techniques, advanced medical diagnostics with isotopes, novel biomedical optical imaging methods, development of waste management technologies, new assay techniques that help examine cell growth, advanced laser-based detection and monitoring methods, chemical synthesis techniques, efficient energy use, advanced materials, and a unique electronic materials etching process.

Computing and Information Infrastructure

Los Alamos has developed extensive expertise in high-performance computing and communications. This capability, developed initially to support the nation's nuclear weapons program, includes housing one of the world's most powerful high-performance computing centers. Our production computing center includes classified and unclassified facilities consisting of five Cray Research, Inc. YMP supercomputers and two Thinking Machines Corporation CM200s, as well as extensive data storage and output services. These supercomputer resources are available to about 8000 scientists and engineers from Los Alamos and across the country.

In 1989, Los Alamos established the Advanced Computing Laboratory as the focal point for research, development, and deployment of an advanced computing environment. Addressing Grand Challenge problems such as global climate, material properties and processing, flow in porous media, nuclear weapons safety, and fusion energy required a new generation of technology—the Los Alamos Grand Challenge Computational Environment (GRACCE). This environment was designed around the massively parallel computer and built upon a gigabit-per-second local area network. It sports a new High-Performance Data System that enables high-fidelity simulations to be stored and visualized at high data rates. As we near the end of FY 1994, the GRACCE technologies are in full swing. These have provided the tools to simulate Grand Challenges at an unprecedented level of fidelity.

Los Alamos is also a member of the CASA gigabit testbed network, whose focus is to investigate the use of distributed supercomputing over wide-area high-speed networks. Los Alamos made the key contribution of a HIPPI/SONET gateway, a device that connects local HIPPI-based networks to standard SONET wide-area networks.

Los Alamos is developing technologies for a National Information Infrastructure. The Sunrise project was initiated in FY 1994 to develop common information-enabling tools for advanced scientific research and for application of that research to industry. It will enhance the capabilities of important LANL research programs and define a new style of collaboration between computer science and scientific research. In one major application area, telemedicine, Los Alamos is collaborating with the National Jewish Center to capture patient drug records and link them with scanned images.

Finally, we have formed the Computational Testbed Initiative (CTI) to make the computational expertise and capabilities of Los Alamos accessible to industry and small business. Today there are more than 20 major long-term industrial partners at the CTI. The Industrial Computing Initiative, funded by DOE, has placed a Cray Research T3D massively parallel computer system at Los Alamos. Eight industrial partners are working with Los Alamos scientists to develop applications for the T3D.

High-Energy and Nuclear Physics

Fundamental high-energy and nuclear physics research at Los Alamos has led to a rich interplay with the rest of LANL, encouraging advances in theory, accelerator physics and technology, and diverse applications of neutron scattering (e.g., weapons physics, materials science, and structural biology).

The 800-MeV, high-intensity Clinton P. Anderson Meson Physics Facility (LAMPF) has featured research in nuclear structure, nuclear reactions, neutrino physics, and fundamental electroweak physics for more than 20 years. The research is conducted by scientists from U.S. and foreign universities and laboratories. Here, scientists engaged in the LSND experiment search for neutrino oscillations. The MEGA project is seeking forbidden decay modes of the muon. Studies of pion single-charge exchange are being conducted with the Neutral Meson Spectrometer. LAMPF also feeds the WNR and LANSCE neutron facilities, where researchers pursue the answers to a broad range of questions. Topics include parity violation and time-reversal invariance in the scattering of epithermal neutrons from compound nuclei. Plans are being laid for a high-intensity pulsed source of ultra-cold neutrons.

Los Alamos has a long and distinguished tradition in theoretical high-energy and nuclear physics. Physicists here can take advantage of the superb computing facilities.

Los Alamos physicists also conduct a wide variety of experiments at major accelerator facilities around the world. LANL physicists have pioneered use of the Drell-Yan process to probe the quark and gluon structure of the nucleon at Fermilab. Activity in the field of relativistic heavy ions includes major roles in the NA-44 experiment at CERN and at the PHENIX detector at the Relativistic Heavy Ion Collider.

Los Alamos programs in nuclear and particle astrophysics include the SAGE experiment, which utilizes gallium to detect low-energy neutrinos from the sun; the Sudbury Neutrino Observatory detector, which will detect solar neutrinos with a heavy-water detector; the CYGNUS high-energy cosmic gamma-ray detector; and Milagro, which will be the world's first large-aperture high-duty-factor telescope for cosmic gamma rays below 1 TeV.

Nuclear Nonproliferation

With the expertise and knowledge from its nuclear weapons program, Los Alamos has had more than 30 years of significant contributions to the nation's arms control, verification, and nonproliferation needs. Recent global developments have increased the scope and intensity of this effort.

Nuclear Explosion Detection. Los Alamos and Sandia have joint responsibility for space-based technologies to detect nuclear tests in the atmosphere or in space. Our expertise in the phenomenology of nuclear explosions is also being applied to detection of underground tests through seismic, acoustic, and ionospheric monitoring.

Proliferation Detection. Los Alamos has worked for several years on a Proliferation Detection Technology initiative. This is a complex of programs using satellite, airborne, and surface carriers to spot programs for weapons of mass destruction. Techniques include multispectral thermal imaging, very-low-light observations, laser systems to detect and identify atmospheric effluents, and systems to collect and identify very low concentrations of chemicals. LANL's ability to respond rapidly to military needs was demonstrated in the Gulf War when a laser system for detecting atmospheric clouds of biological agents was readied for deployment in a matter of weeks.

Safeguards. Since 1967, Los Alamos has developed safeguards to monitor nuclear materials and prevent their diversion from commercial to military use. This has included developing most of the International Atomic Energy Agency's nondestructive inspection equipment and training all the agency's inspectors. Newly established programs involve work with scientists in former Soviet republics to ensure materials control and accountability.

Export Control and Capability Assessment. Los Alamos work with the intelligence community is defining likely proliferant pathways and providing high-quality information about their existence. LANL scientists support government agencies in controlling exports and otherwise working to restrict the flow of information, technology, and equipment to proliferant countries.

Nuclear Threat Response. The Nuclear Emergency Search Team, with participants from Los Alamos and elsewhere, is equipped and trained to evaluate nuclear terrorist threats and to take disablement action if needed.

Negotiations Support. The national security laboratories provide personnel and expertise to support U.S. arms control negotiators. At the 1986-90 Nuclear Testing Talks, more than 20 LANL scientists provided varying levels of support; similar support is available for future negotiations.

Chemical and Biological Weapons. Though traditionally applied to problems in nuclear nonproliferation, many of the technologies described above are applicable to chemical and biological nonproliferation as well and are made available to government agencies as appropriate.

Nuclear Weapons Research and Development

The nuclear weapons mission has provided the foundation for much of the scientific expertise and unique capability at Los Alamos. The future goals of nuclear weapons R&D activities are directed toward responsible stewardship and management of the nation's nuclear weapons capability.

Our foremost challenge in the post-cold-war environment is to assure continuing confidence in the safety, reliability, and robustness of the nuclear stockpile without nuclear testing. To achieve this goal, we are pursuing parallel but synergistic objectives. We are increasing our emphasis on basic understanding and experimental measurement of the key physical and chemical processes connected with nuclear weapons aging, reliability, and safety. These are supported by our strong capabilities and facilities for materials science (nuclear and non-nuclear), high explosives, and atomic phenomena. We are developing a new generation of synergistic and interactive computational models and simulation capabilities. Concurrent development of better above-ground experimental tools will significantly increase our ability to gain information that could previously be obtained only through nuclear tests.

In basic physics, we are enhancing our existing experimental and diagnostic capabilities in pulsed x-ray radiography with the dual-axis radiographic hydrotest facility to better understand implosion hydrodynamic and boost physics. Secondary physics parameters are being investigated through experiments with existing pulsed power machines (e.g., Pegasus and Procyon) and laser facilities (Trident) and with the development of a new pulsed power facility (Atlas) for producing high-temperature, high-density plasmas. Basic materials properties and aging effects will be achieved at an advanced neutron scattering facility (LANSCE) that builds upon the existing 800-MeV proton accelerator (LAMPF). These new experimental capabilities are designed to give Los Alamos the integrated theoretical, experimental, and computational capability to mitigate the loss of nuclear testing and to attract competent weapons scientists and engineers. We are also contributing our expertise in nuclear weapons science and technology to the world-wide control of weapons of mass destruction.

Los Alamos is providing significant expertise and unique facilities to assist DOE in the safe dismantlement of retired nuclear weapons in the U.S. and in the former Soviet Union. Also, we are actively contributing to technical solutions for the storage and management of excess nuclear materials. Looking to the future, Los Alamos is taking a leading role in fundamental studies and experiments on accelerator-based concepts for the burnup of fissile materials and the transmutation of nuclear waste.

National Research Facilities

Los Alamos operates five national research facilities:

The Clinton P. Anderson Meson Physics Facility (LAMPF). This international user facility can simultaneously accelerate and deliver variable-energy, high-intensity proton beams, negative hydrogen-ion beams, and polarized negative hydrogen-ion beams to experimental areas. Research focuses on frontier studies related to the fundamental properties of matter, condensed matter physics, radioisotope production, and neutron scattering.

The Manuel Lujan Jr. Neutron Scattering Center (LANSCE). LANSCE is a pulsed spallation neutron source equipped with time-of-flight spectrometers for condensed-matter research. It yields a higher neutron beam flux than any other spallation source. Research programs include solid-state physics, chemistry, metallurgy, crystallography, biophysics, materials science, and nuclear physics.

The National High Magnetic Field Laboratory. LANL operates facilities at Florida State University, the University of Florida, and Los Alamos. Resources include resistive and hybrid magnets with high fields, a large NMR facility, and a pulsed field facility that houses the world's largest quasi-continuous magnet. Current research topics include condensed matter physics and high-temperature superconductivity, materials, chemistry, structural biology, medical diagnostics, and engineering.

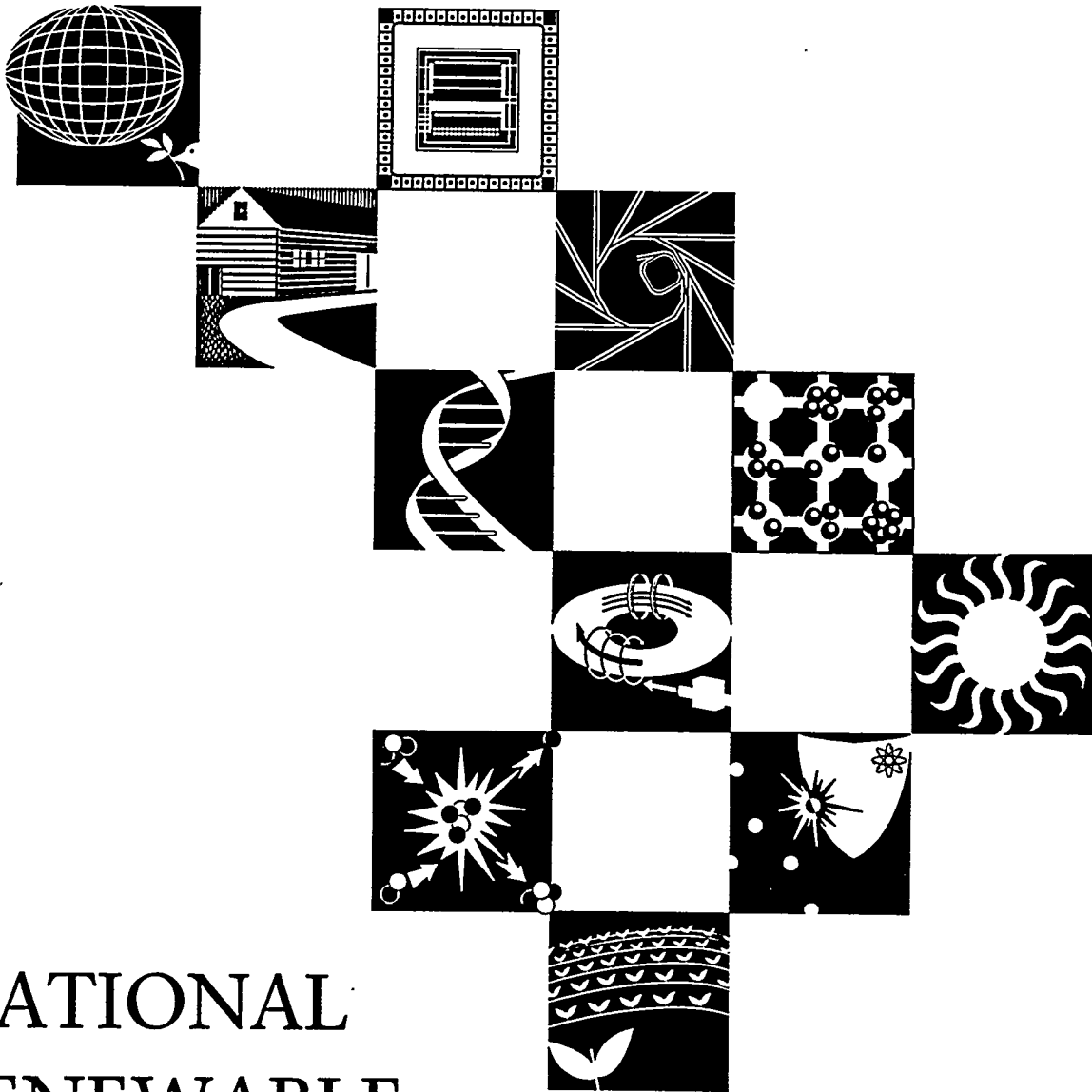
The National Flow Cytometry Sorting and Research Resource (NFCR). Thanks to a competitive grant from the National Institutes of Health, NFCR was established in 1982. Among applications of this technology are detection of rare cancer cells, monitoring rejection of transplanted organs, and elucidating cellular characteristics of the AIDS virus.

The Advanced Computing Laboratory (ACL). The ACL was founded in 1988 to pursue high-performance computational science with parallel processing computers. In December 1991, it became one of two High-Performance Computing Research Centers in the country. The ACL promotes technology transfer to industry, academia, and other national laboratories.

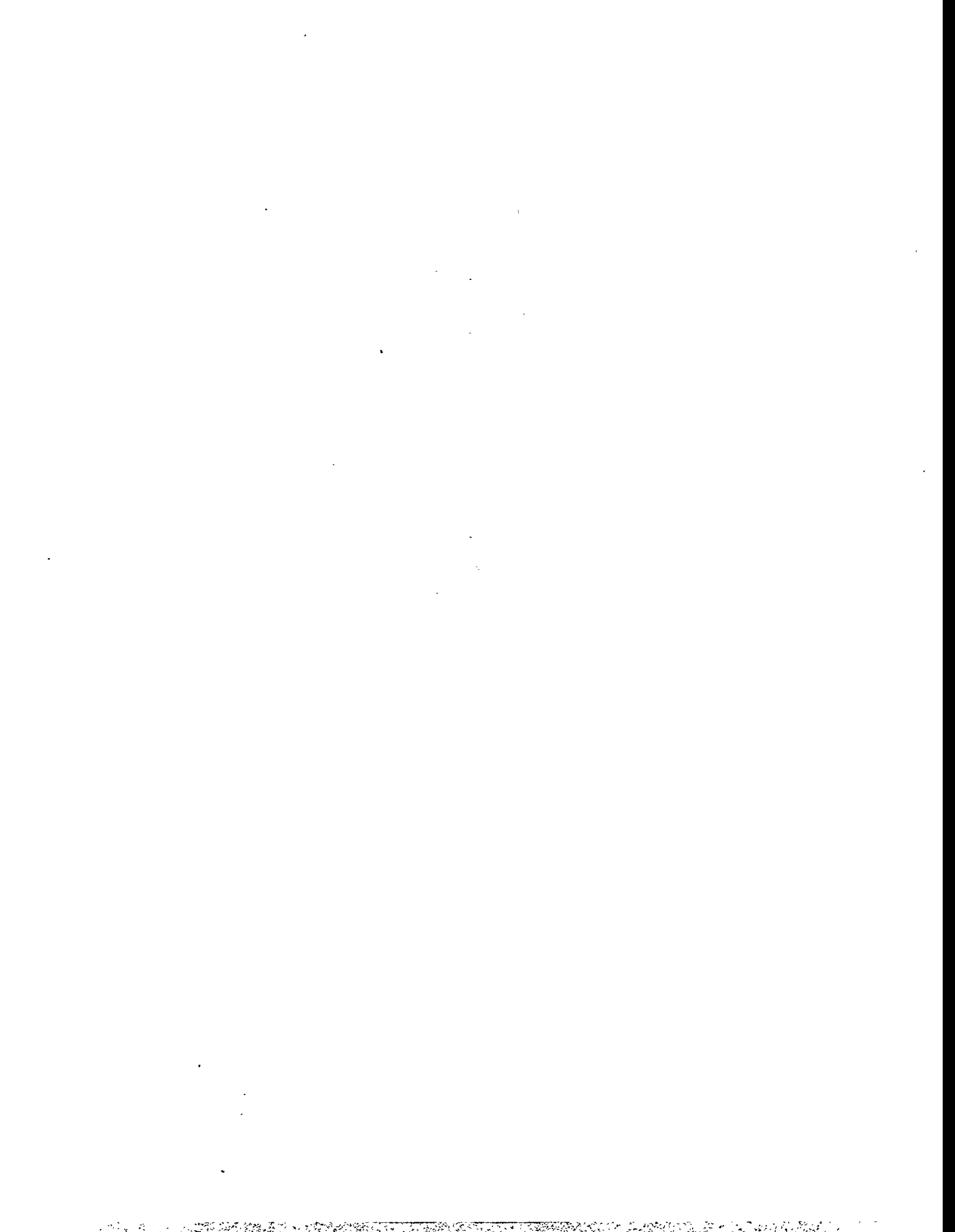
The National Stable Isotope Resource (NSIR). The NSIR advances biomedical applications of compounds labeled with the stable isotopes ^{13}C , ^{15}N , ^{17}O , ^{18}O , ^{33}S , ^{34}S , and ^{77}Se . Current NSIR core research is directed toward developing efficient synthetic routes for labeled amino acids and nucleotides.

Other significant facilities available at Los Alamos include the Ion Beam Materials Laboratory, Scanning Tunneling and Atomic Force Microscopes, the Bright Source Laser, the Los Alamos Critical Experiments Facility, the Trident Nd:YAG laser, the Tritium Systems Test Assembly, the Pulsed High-Energy Radiographic Machine Emitting X-rays, and the Plutonium Facility.

RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



NATIONAL
RENEWABLE
ENERGY
LABORATORY



National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) has a compelling mission: "[to lead] the nation toward a sustainable energy future by developing renewable energy technologies, improving energy efficiency, advancing related science and engineering, and facilitating commercialization." Moreover, NREL is the only U.S. Department of Energy (DOE) laboratory solely dedicated to developing renewable energy technologies and related energy efficiency technologies. Its duties include helping to build a viable renewable energy industry. To help meet its challenging mission, NREL has developed, has nurtured, and continually utilizes four core competencies: development of advanced materials and prototype components; development and characterization of renewable energy, energy efficiency, and waste conversion processes; systems and process engineering and integration for renewable energy and energy efficiency technologies; and partnerships for market and technology development. Our current technical staff of more than 500 represents the largest concentration of expertise focused on renewable energy technologies in the world. This highly trained staff is further augmented by unique experimental and user facilities.

Energy Efficiency

NREL is a national leader in developing efficient ways with energy. Much of our energy efficiency work is tied to buildings programs, industrial processes, and waste utilization and conversion. In numerous areas, our energy efficiency work complements our renewables programs.

Our buildings work is a good example of this. Through the Building America program, we are working closely with partners such as Ryland, General Electric, and Honeywell to simultaneously develop energy-efficient, low-cost housing. NREL is one of the lead laboratories for DOE's Federal Energy Management Program, which is aimed at reducing energy use in federal buildings by 30%. We're assisting federal agencies in fostering public-private partnerships to help implement renewable energy and energy-saving technologies. We're also developing a novel methodology, known as Short-Term Energy Monitoring, to help building owners such as federal agencies evaluate whole-building performance.

In collaboration with industry, NREL is developing more energy-efficient processes and methods for reducing material waste. We are also collaborating to find novel ways to reuse and recycle materials and components from consumer goods such as carpet wastes and wood products. Our waste utilization work focuses on recovering energy from waste materials that are destined for landfills. It has resulted in a novel consortium involving five industry partners and a number of Cooperative Research and Development Agreements (CRADAs) that are based on NREL technology.

For example, we've developed a selective pyrolysis process that recovers caprolactum from waste nylon-6 carpet at a cost projected to be less than half the current selling price of petroleum-derived caprolactum. Allied Signal, Inc. is funding more than half of a \$6.3 million CRADA to demonstrate and commercialize this process. We're also developing technologies to convert municipal solid waste streams to usable energy sources such as methane and heat. These efforts can help improve environmental quality while reducing the burden on overflowing landfills.

Energy Supply and Renewables

To foster the development of renewable technologies and a corresponding industry, NREL carries out its activities through a process called vertically integrated research and development and through productive alliances with industry, universities, national laboratories, and other stakeholders. These key groups are involved in all stages of technology evolution and development—from basic research through applied research to engineering, product development, and manufacturing. We apply our vertically integrated process, along with cutting-edge research and engineering, to our more than 20 programs in renewables and closely related technologies. These programs include photovoltaics, wind energy, solar thermal electricity, biofuels, industrial processes, solar thermal industries, buildings, biomass power, fuels utilization, and geothermal energy.

Our unique approach has led to many NREL technical innovations and to CRADAs with industry partners. Such agreements now total more than \$68 million, with industry providing 74% of the total funding. Currently we also have collaborative, contractual relationships with more than 300 industry and small business partners and 75 universities. In addition, NREL has generated more than 25 spin-off companies.

Our innovations have produced 16 R&D 100 awards (including 8 in photovoltaic materials research), more than 120 patents, and 5 Federal Laboratory Consortium awards for excellence in technology transfer. Our technical contributions have also helped lower costs and dramatically improve the performance of numerous renewable energy technologies. For example, we've developed a novel wind turbine blade that improves energy capture by 30% on an annual basis but costs the same amount as a conventional blade. We've also developed a process to convert common, inexpensive cellulosic biomass to ethanol. Our approach increases ethanol yields from corn by up to 13% and decreases production costs by a corresponding amount. Our renewables work has also spawned numerous photovoltaic cell designs and corresponding manufacturing recipes that have set world records for efficiency.

Climate Change

Concern about the use of fossil fuels and the resulting climate change has been rising in recent years. NREL is helping to address this issue in a number of ways. In addition to developing numerous renewable alternatives that can replace or reduce the use of fossil fuels, we are supporting DOE and the nation in addressing climate change directly.

NREL continues to play a key role in providing development support to DOE for implementation of the Climate Change Action Plan (CCAP). The plan seeks to reduce U.S. greenhouse gas emissions to their 1990 levels by the year 2000 and relies on voluntary industry participation. Key NREL staff assisted in the stakeholder involvement and communications elements of CCAP. NREL's Wind Program will develop, issue, and execute a Request for Proposal to support the wind component of the Renewable Energy Market Mobilization Collaboration, a CCAP action item.

We are currently carrying out atmospheric radiation measurements in support of climate change model development. These measurements take advantage of NREL's state-of-the-art metrology and instrumentation capabilities, developed to provide assessment information for renewable resources such as solar, wind, and biomass.

Carbon dioxide remediation through our microalgae research represents about 20% of the entire U.S. effort for CO₂ remediation. We are examining the highly promising potential of microalgal culture to recapture carbon dioxide in the flue gas exhaust from fossil fuel power plants. Microalgae grow and recapture the gas up to five times faster per unit area than do terrestrial plants. Power plants, which contribute more than one-third of all U.S. CO₂ emissions, may be faced with tougher emissions requirements in the future. Besides helping utilities meet these mandates, the microalgae, which can be converted into biofuel or oil, can serve as a clean-burning fuel source. NREL is currently collaborating with the Public Service Company of New Mexico to assess the potential for microalgae production at the San Juan Power Plant in Waterflow, New Mexico.

Environmental Technology

NREL is researching the use of solar energy to destroy hazardous wastes in air, water, and soil. Known as solar detoxification, or "solar detox," the approach comprises two different technologies. The first uses a solar-activated catalyst to destroy toxic organic pollutants; the second uses concentrated sunlight to directly (photolytically) break the bonds holding the contaminants together. Solar detox, which does not require fossil fuels as an energy source, mineralizes the organic contaminants into CO₂ and easily handled dilute acids, whereas most technologies transfer them to other media or release them into the atmosphere.

We are recognized as the focal point of this research nationwide. We work with industry and academia to help bring this technology to the environmental remediation and waste management marketplace. Our research and development activities extend to heterogeneous and homogeneous catalysts and a broad range of related chemical systems and components. This collaborative work has helped lower costs and improve the performance of solar detox systems. During the past several years, these improvements have been most dramatic in the gas-phase processes, making them competitive with conventional technologies.

Under separate CRADAs, NREL has teamed with United Technologies Research Center and IT Corp. to further develop and demonstrate NREL's photocatalytic reactor. This device uses ultraviolet light and special catalysts to destroy volatile organic compounds in indoor air. We're also collaborating with IT Corp. and SEMATECH on a CRADA to destroy volatile organics emitted by semiconductor manufacturing processes with the NREL-developed reactor.

We are also looking into other uses of ultraviolet light to destroy contaminants. Three federal agencies—the Department of Energy, the Department of Defense, and the Environmental Protection Agency—have joined together to study the use of highly concentrated ultraviolet light from NREL's High-Flux Solar Furnace to destroy organic environmental contaminants in soil.

Materials and Chemistry

NREL's materials and chemistry research focuses on gaining in-depth understanding of complex material and chemical phenomena. Our work is also aimed at ultimately translating these findings into practical solutions that support the development of renewable energy and energy-efficient technologies. In addition, we carry out atomistic modeling of semiconductors and fundamental investigations of photochemical, photoelectrochemical, and photobiological processes. The goal is to identify and synthesize novel materials and systems for future applications.

Much of our materials work focuses on synthesizing and characterizing photovoltaic and other optically or electrooptically active materials, such as those used in reflectors, optically activated catalysts, absorbers, and coatings. As a result, NREL has developed numerous new photovoltaic materials. Our work has produced patents; eight R&D 100 awards for the development of advanced diagnostics, measurement systems, and novel materials; and numerous CRADAs. Our basic materials research has even contributed significantly to the startup of Golden Photon, a new industry member.

Recently, our researchers set a world record of 16.4% efficiency with an innovative solar cell made of copper indium gallium diselenide. NREL developed the cell with a new fabrication approach that reduces manufacturing costs and increases conversion efficiency. This research earned a *Popular Science* magazine "Best of What's New" award for being among the top 100 products and achievements of 1993. Results from a CRADA with Martin Marietta Technologies, Inc. should lead to scale-up and commercialization of this technology.

Like our materials research, our chemistry work has been the basis for technical breakthroughs that advance processes, systems, and products. NREL has developed and used chemometric approaches with fast spectroscopic techniques to study complex organic systems and to control related processing applications. These activities have spawned important developments, like our selective pyrolysis processes that recover energy and chemical building blocks from waste materials.

National Research Facilities

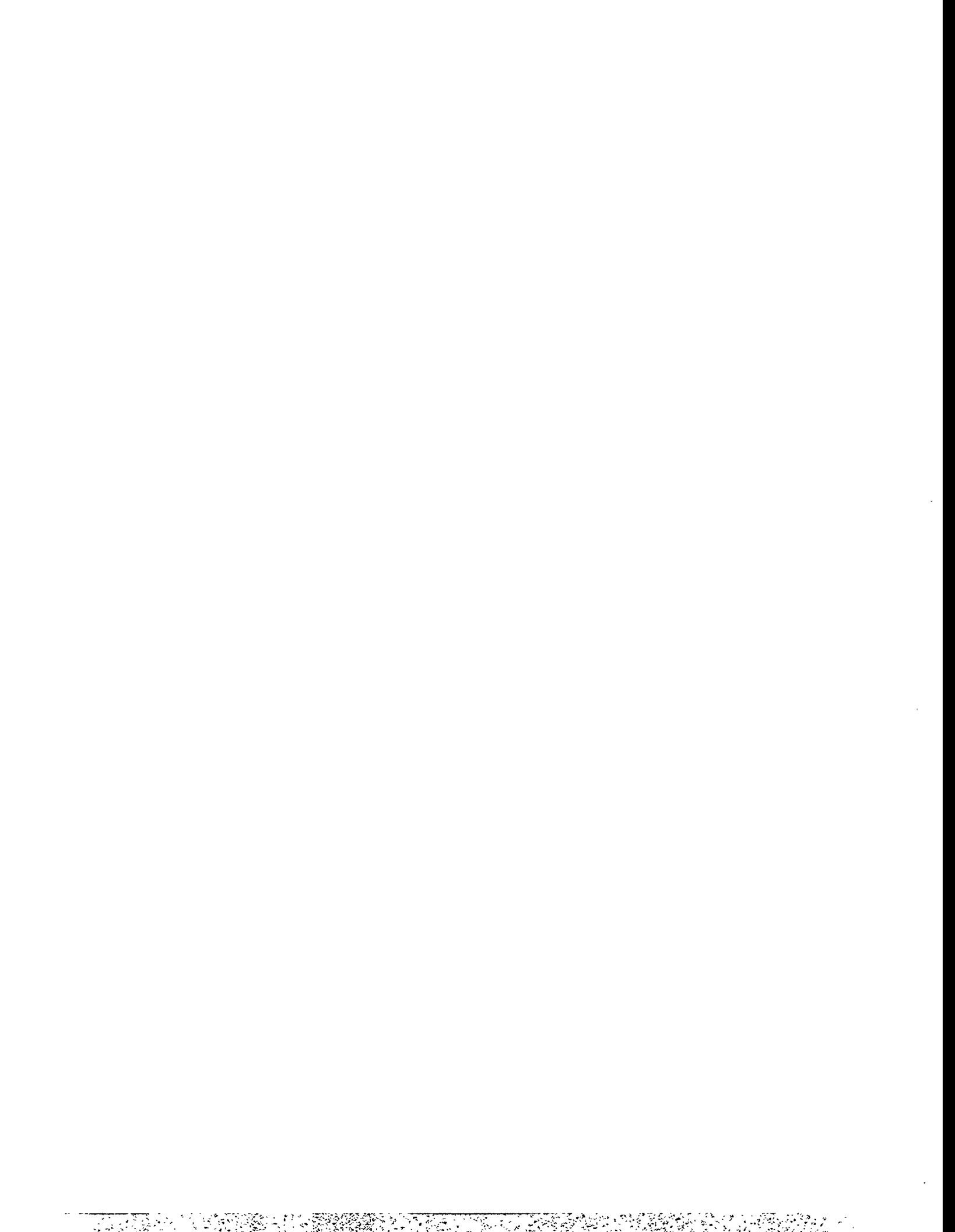
NREL operates numerous laboratory, test, and office facilities occupying nearly 600 acres in Golden, Colorado. We take pride in being easily and openly accessible to a broad range of industry, university, and laboratory partners. Several facilities are key to these collaborations.

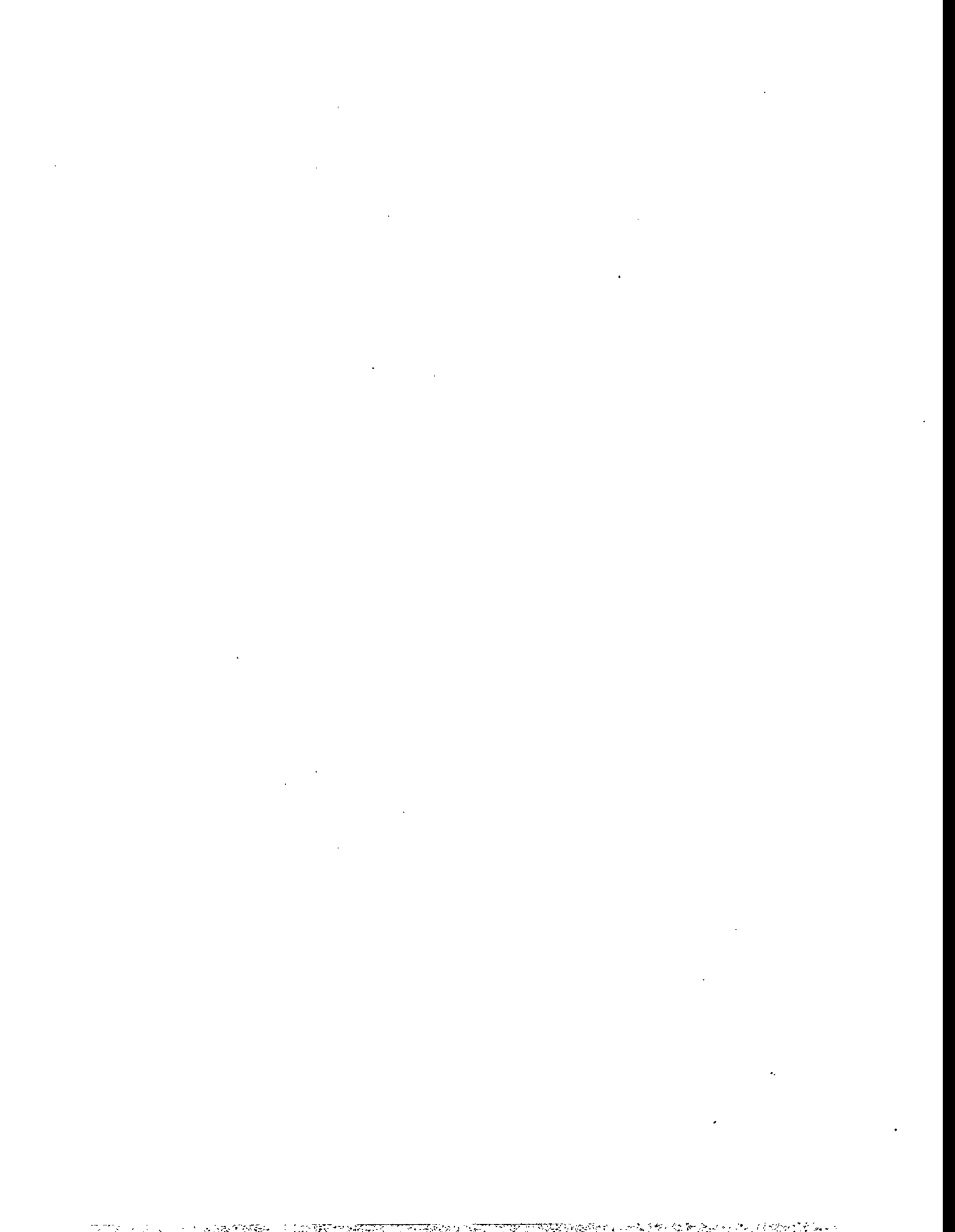
Solar Energy Research Facility. This research and development facility is vital to the support of the industry-focused photovoltaics program. The facility contains three contiguous modules and 42 individual laboratories arranged in a floor plan designed for smooth work flow. New materials are formulated and developed, then fabricated into devices, as they progress through this facility. In the final stage, the performance of the materials and devices is characterized and studied through a wide range of sophisticated diagnostic processes and tools.

Alternative Fuels User Facility. This facility is a designated national user facility with offices and laboratories designed to accommodate visiting industry members and NREL staff. Research here is focused on the commercialization of bioprocessing technologies. The Process Development Unit, also part of this facility, is a pilot bioprocessing plant used to generate design data for the commercialization of fuel bioprocessing.

Solar Industrial Mesa Top Area (SIMTA). This facility contains the High-Flux Solar Furnace, a designated national user facility capable of concentrating sunlight to 50,000 times its normal intensity. The SIMTA supports collaborative and independent industry, academic, and laboratory evaluations directed at the use of high-flux solar radiation. This research is applied to materials synthesis and processing, waste destruction, and solar component testing. The SIMTA is also a low-flux receiver/reactor facility used to support industry in testing and evaluating solar detoxification system components, catalysts, and materials.

National Wind Technology Center. This 280-acre facility houses numerous laboratories and test sites to support industry users in evaluating their components (e.g., assessing blade fatigue and resonance characteristics) and whole turbine systems in a well-characterized wind environment.





Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is a Department of Energy (DOE) multiprogram laboratory. It is managed for the DOE by Martin Marietta Energy Systems, Inc. Its mission is to conduct basic and applied research and development (R&D) to advance the nation's energy security, environmental quality, scientific knowledge, educational foundations, and technological competitiveness. ORNL works in collaboration with other DOE laboratories, other federal agencies, industry, and universities. ORNL's mission comprises activities in the following areas, which are representative of its core competencies: (1) energy production and end-use technologies, (2) environmental sciences and technologies, (3) engineering and manufacturing sciences and technologies, (4) physical, chemical, and materials sciences, (5) computational sciences, (6) biological and life sciences, (7) scientific and technological user facilities, (8) science and technology transfer, and (9) education. ORNL is committed to excellence in all of its activities.

Energy Efficiency

The Energy Efficiency and Renewable Energy Program is the largest energy R&D program at ORNL. Its goal is to assist government and industry in the analysis, development, and deployment of advanced, cost-effective technologies and programs to improve energy efficiency. ORNL has led or provided critical analysis for many energy policy studies, ranging from the NSF/RANN program in 1970 to the recent National Energy Strategy, the Energy Policy Act, and U.S./European total fuel cycle analysis studies. ORNL has developed cost-effective energy auditing procedures that are becoming widely used. All of our programs involve strong collaboration with industry and the public sector through user agreements, Cooperative Research and Development Agreements (CRADAs), cost-shared subcontracts, and other technology transfer mechanisms.

Buildings. The Buildings Technology Center is a unique facility for joint laboratory/industry/university development and evaluation of advanced insulating materials, thermal envelope systems, HVAC building equipment, and appliances. Important developments resulting from these collaborations include advanced absorption heat pumps, non-CFC foam insulations, more energy efficient roofing systems, and improved insulation systems and standards.

Transportation. The Advanced Propulsion Technology Center at ORNL supports a unique multicylinder engine test facility for studying the internal combustion engine and the control of emissions. Work in this area includes evaluation of alternate fuels, experimental catalysts, and unconventional approaches to improving combustion characteristics. ORNL leads the Lightweight Materials and Ceramic Technology Program for the Partnership for a New Generation of Vehicles.

Industry. ORNL has lead responsibility for the Advanced Industrial Materials Program and the Continuous Fiber Ceramic Composites Program, both of which develop improved materials and processes to enable higher energy efficiency in industry. Applications include metals processing, pulp and paper, petrochemicals, and advanced turbine systems for cogeneration. Other major ORNL industrial programs include Electric Motor Systems, Chemical Heat Pumps, Bioprocessing of Alternative Feedstocks, and Cellulosic Waste Minimization and Bioconversion. The High Temperature Materials Laboratory, a popular, industry-driven user facility, bridges the gap between fundamental research and practical applications.

Utilities. ORNL leads the DOE's efforts on electric and magnetic field effects; electrical transmission and distribution, including development of real-time system control; and integrated resource planning.

Energy Supply and Renewables

ORNL has a long and noteworthy history of R&D on most of the major energy supply technologies, including biomass, fission, fusion, and fossil technologies. Our overall goal is to develop energy technologies that are safe, environmentally friendly, conserving of resources, and economically attractive. An important characteristic of all ORNL's energy R&D programs is a close working relationship with industry, aimed at bringing advanced technologies to both domestic and world markets.

In the area of biomass energy, ORNL has the national lead responsibility for developing advanced technologies and techniques for producing and harvesting energy crops. This program—known as the Biofuels Feedstock Development Program and undertaken for DOE—is directed toward lowering costs, reducing environmental impacts, and extending the resource base for biomass energy crops in various parts of the country. To promote technology dissemination, the program involves participation by universities, the pulp and paper industry, and the National Renewable Energy Laboratory.

Fossil energy R&D at ORNL is strongly oriented toward materials. In fact, ORNL leads the DOE's efforts on advanced materials for fossil energy systems—including materials for hot gas cleanup, high-temperature turbines, and heat exchangers. Our Fossil Energy Materials Program includes participants from other national laboratories, universities, and industry. Much of the industrial participation is through CRADAs.

Our magnetic fusion work supports the national fusion program by providing advanced technologies for fueling, management of plasma impurities, radio-frequency heating and current drive, materials, and remote maintenance. ORNL heads the U.S. effort to develop an accelerator-based 14-MeV neutron source for materials testing. ORNL developed, built, and operated the world's largest stellerator, and we lead the development of the spherical tokamak, a concept that could provide the basis for a large neutron source for engineering-scale tests of reactor components and systems. Much of ORNL's fusion work involves collaborations and partnerships with research laboratories around the world.

Nuclear fission power is traditionally an area of technical strength at ORNL. The DOE and the Nuclear Regulatory Commission are major sponsors of the work. ORNL provides leadership in several nuclear fission areas: heavy section structural components (e.g., pressure vessels) testing, analysis, and evaluation; digital sensors and controls; and gas-cooled reactor fuel development and testing. ORNL pioneered the development of research reactors used around the world. We currently lead the development of the Advanced Neutron Source, which will be the world's most powerful research reactor.

Climate Change

Many of the decisions that will determine our direction in the next millennium hinge on issues that are complex, interwoven, and global in scale. Examples are greenhouse gases, climate change, ozone depletion, deforestation and desertification, resource depletion, sustainable development, and the spread of pollution. ORNL, via its Center for Global Environment Studies, provides an interdisciplinary base from which we can explore these vital issues.

ORNL's effort has three main goals: improving the understanding of the global-scale workings of environments in air, on land, and in water; developing the capabilities to anticipate the long-term, large-scale effects that human actions have on the biosphere; and identifying appropriate options for technological and societal responses that provide for a sustainable future. The central and unifying framework for our work is global systems analysis: developing increasingly sophisticated models that reflect the dynamic interactions of numerous subsystems. These include global vegetation; human cultures and behaviors; Earth systems such as atmospheric chemistry, ocean composition and circulation; and the links between air, land, and sea. Our long-term goal is to develop models that reflect the complex interplay of demographics, land-use patterns, economics, ecological relationships, and other factors that influence the Earth's environment.

We are emphasizing three areas:

Data Systems. Through our experience with the Carbon Dioxide Information Analysis Center, the Atmospheric Radiation Measurement Archive, the World Data Center for Trace Gas Dynamics, and the Distributive Active Archive Center for Biogeochemical Dynamics, we have developed expertise in the documentation, quality assurance, and analysis of large global databases.

Global Models. ORNL has worked with global carbon cycle models since the mid-1970s and is recognized for its expertise in terrestrial carbon dynamics and the development of integrated carbon cycle models.

Integrated Assessments. As policy questions come to the forefront of global change issues, ORNL brings its extensive experience in environmental assessments to these complex global environmental issues.

Environmental Technology

The environmental technology program at ORNL embraces interdisciplinary R&D topics. These are designed to help us understand and solve major environmental problems related to environmental quality, energy resources, science and technology, and industrial competitiveness. The program is anchored in a strong, fundamental research effort that extends to various applied programs. The environmental issues addressed include global climate change, nuclear and hazardous waste management, and environmental restoration of contaminated sites. Various disciplines are represented: biology, chemistry, engineering, physics, ecology, ecosystem sciences, geology, toxicology, computational sciences, and the social sciences.

Our environmental technology program has produced many advances in environmental science and technology. Examples include experimental approaches to quantifying environmental effects at scales ranging from local to regional, landscape, and global; new methods to assess and mitigate environmental risks; databases for toxic substances, environmental remediation, and global climate change; technologies to prevent, minimize, separate, treat, immobilize, package, and dispose of radioactive, hazardous, and mixed wastes; environmental transport models to allow predictions about the fate of contaminants in environmental media; and novel detection systems for monitoring contaminant migration.

The Oak Ridge Reservation provides a unique opportunity for field-scale investigations of contaminant migration and behavior and for demonstration of remediation technologies. The history of waste disposal operations at Oak Ridge is such that virtually every type of contaminant (e.g., radionuclides, organics, metals, and nitrates) has been introduced into the ground by a variety of different techniques (e.g., seepage pits, trenches, and injection wells). The hydrogeological complexity of the setting (a valley and ridge sedimentary system), coupled with the high rainfall, makes the Reservation the most technically challenging remediation environment in the DOE system.

The ORNL program is distinguished by its contributions to ecological theory, global element cycle modeling, risk assessment, environmental data systems, integrated assessment, and *in situ* remediation technology.

Health and Biotechnology

Research in biotechnology and health is a major area of emphasis at ORNL. Staff from fifteen divisions work in biomedical, bioprocessing, and environmental studies.

Biomedical Research. This research focuses on improving our understanding of the human genome and on better instrumentation for biomedical applications. Mouse genome studies provide models for understanding the human genome in terms of genome structure-function relationships and models for understanding the basis for hereditary human diseases. A strong structural biology program focuses on genome analysis by x-ray and neutron diffraction, three types of mass spectrometry, several forms of scanning probe microscopy, and electron microscopy with holographic analysis. Our protein engineering program seeks to understand how changes in the structural features of large molecules affect their biological activity. We are designing and synthesizing radiopharmaceuticals to deliver radioactive isotopes to a targeted disease site in the human body to make tumor diagnosis and inactivation as specific as possible. And we have developed an endoscope that uses laser light to identify cancerous regions of the human esophagus with nearly 100% reliability.

Bioprocessing Research. This research uses living organisms or their viable fractions to produce new products, thus providing the critical link between fundamental science and innovative industrial application. Industrial applications of bioprocessing have affected the areas of fossil energy, chemical processing, fermentation, environmental control technology, agriculture, and biomedical advances. The Bioprocessing Research and Development Center (BRDC) emphasizes bioprocessing systems that can economically produce fuels and chemicals from renewable feedstock, less energy-intensive bioprocessing of coal and petroleum, and the use of solar-energy-driven bioprocesses. BRDC's work is concentrated in three areas: applied biosciences research (biophotochemistry, enzymology, and microbiology), bioengineering R&D (advanced bioreactors, biocatalysis, and bioseparations), and bioprocess engineering (bench- and pilot-scale operations, off-site demonstrations, and technology transfer).

Environmental Research. In this work, we focus on applying molecular biology to solve environmental problems. We have developed biological markers that enable evaluation of environmental health through a series of molecular measurements that enable population-level predictions. These tools have been used, for example, to help the Canadian government evaluate the cause of the demise of the Beluga whale population in the St. Lawrence Seaway. Bioremediation research is concentrating on *in situ* cleanup of organics. Studies have been conducted at both the Savannah River and Hanford sites, and plans are currently being formulated to work with General Motors and Ford on remediation applications.

Materials And Chemistry

ORNL maintains an extremely broad R&D program in the materials and chemical sciences. It has a budget of nearly \$200 million and is staffed by approximately 600 scientists and engineers. The ORNL materials and chemistry R&D program produces more than 1000 technical publications annually, including 500 refereed journal articles.

The advanced materials program encompasses research related to ceramics and composites, metals and intermetallic alloys, surfaces and thin films, optical materials, semiconductors, superconductors, and materials processing and characterization. Distinguishing capabilities exist in high-temperature ceramics and composites, intermetallic alloy development, surface science and technology, materials, microanalysis, ion implantation, welding and joining, radiation effects, synthesis, polymers, composite materials, and computational science. The chemistry research program encompasses chemical energy, analysis, separations, and heavy element chemistry. Distinguishing capabilities exist in high-temperature aqueous chemistry, mass spectrometry, photosynthesis, catalysis, electromagnetic separation and solvent extraction, and advanced instrumentation for environmental and biomedical applications.

The integration and balance of these R&D activities, ranging from basic research through applied development to industrial collaboration, are program strengths. Over the past eight years, this research has resulted in the issuance of more than 110 patents, resulting in 35 licenses with industry. The royalty value is more than \$1.5 million. The estimated impact of ORNL's materials and chemical sciences research on the private sector is more than \$300 million per year. Products include high-performance ceramics and alloys, ion-implanted prostheses, mass spectrometers, chemical process instrumentation, and transmutation-doped silicon. In addition, more than 75 industrial CRADAs, with a lifetime value of over \$95 million, have been executed. We also have 31 Superconductivity Technology (Pilot Center) Agreements.

Collaboration with other institutions is an integral part of the ORNL materials and chemistry research program. Each year we host more than 700 guest scientists and 2000 visitors—25% or more of whom come from industry. Four major materials-related user facilities are an important part of our external interactions: the High Temperature Materials Laboratory, the Shared Research Equipment Program, the Surface Modification and Characterization Facility, and the Neutron Scattering Facility. These facilities annually serve approximately 300 users—20% of whom are industrial researchers.

Computing and Information Infrastructure

The ORNL Computing and Information Infrastructure Program encompasses several major research and development areas: software tools, gigabit networking, terabyte to petabyte storage technology, visualization, evaluation of developing systems, informatics, and software and algorithm development for massively parallel systems. Prime examples of this focus are a parallel version of CYNA-3d, a major engineering and design materials processing code, and scaLAPACK, a package of scalable high-performance algorithms for matrix computations.

ORNL's DOE High Performance Computing Research Center, one of only two so designated, will soon have more computing power than any other U.S. scientific center. This computing power enables ORNL to be a leading participant in Grand Challenge studies in materials, groundwater transport, and climate modeling.

Our software tools research has led to widely used software packages such as PVM (Parallel Virtual Machine, for parallel computing across networks), an IR 100 winner for 1994; XNETLIB (an X-Windows-based software and information exchange tool); ParaGraph (a commercialized parallel algorithm performance evaluation tool); and the DNA sequencing code GRAIL (which supports the Human Genome Project), an IR 100 winner for 1992.

ORNL has been a leader in the evaluation of computer systems, emphasizing parallel architectures since the acquisition of the first commercial 64-processor parallel computer in 1986. We subsequently have acquired several different parallel computers with "Serial #1" tags. Benchmark data, such as those obtained with numerical packages like LINPACK, are available electronically from ORNL for essentially all parallel computers.

Outreach to industry and education is an integral part of the Laboratory's computing mission. The Computational Center for Industrial Innovations, a DOE National User Facility, was established in 1994 to expedite industrial use of high-performance computers. In addition, ORNL manages such educational support programs as Adventures in Supercomputing, which targets disadvantaged high school students, and the Saturday Academy for Computing and Mathematics for high school seniors.

High-Energy and Nuclear Physics

The Holifield Heavy Ion Research Facility (HHIRF), operated at ORNL since 1984, is being converted for use with radioactive ion beams. When this conversion is completed in late 1995, the Holifield Radioactive Ion Beam Facility (HRIBF) will be the only facility in North America dedicated to the acceleration of radioactive ion beams. With a replacement value in excess of \$90 million, this facility will provide unique opportunities for research in nuclear physics and nuclear astrophysics. It will serve a national and international community of users.

The ORNL nuclear physics program centers on research to be conducted at HRIBF. The majority of our efforts in experimental nuclear physics, therefore, will be devoted to physics with radioactive ion beams. Accordingly, we are developing powerful new detector systems for such work, including a facility dedicated to astrophysics studies. This facility will be based on the Daresbury recoil separator, which is being shipped from the U.K. to ORNL. The availability of radioactive beams opens the possibility of studying a wide variety of nuclear structures and techniques, including extension of spectroscopy of self-conjugate and mirror nuclei, exotic nuclear shapes, new regions of deformation, proton-neutron interaction, spectroscopy near the proton drip line, and proton radioactivity. The nuclear astrophysics program will use the new beams to advance our understanding of novae, supernovae, x-ray bursts, and other explosive nucleosynthesis systems.

In addition to the research program exploiting the HRIBF, two major programs involve experiments primarily performed at other sites:

Relativistic Heavy Ion Program. This program is participating in the search to determine the properties and formation conditions for the quark-gluon plasma (the primordial form of matter hypothesized to have been created by the "big bang"). Collisions between heavy nuclei at ultrarelativistic energies offer the only likely method of achieving the necessary conditions in the laboratory. Initial work by the ORNL group centered on use of the CERN SPS accelerator within the framework of the WA80/93/98 collaborations. More recently, the group has taken a lead role in designing and building the PHENIX detector for the Relativistic Heavy Ion Collider being constructed at Brookhaven National Laboratory.

Giant Resonance Program. This program focuses on the identification and systematic characterization of collective modes in the nuclear continuum and on their interaction with and damping into the underlying spectrum of more complex nuclear states. This field was pioneered at the ORNL Physics Division more than 20 years ago, and ORNL remains a world leader. This group has assembled a large array of BaF₂ detectors and ancillary equipment, optimized for detecting high-energy photons. This portable array has been used in an extensive physics program at six major nuclear physics facilities in the U.S. and Europe.

Nuclear Nonproliferation

ORNL provides expertise and technology in support of the U.S. nonproliferation goals in the areas of intelligence, safeguards, and counterproliferation. Three key technical areas form the cornerstone of the ORNL program: advanced chemical analysis and processing, electronics and signal processing, and materials. Much of the focus of our program is on developing smaller instruments, designed to be field portable and rugged, for use by inspection teams as well as for covert applications. In addition, ORNL experts in nuclear fuel cycle and chemical processing are often called on to lend assistance to technical assessments and inspection teams.

ORNL is a world leader in the development of ion trap mass spectrometry (ITMS). We have developed methodologies for examining vapor and liquid effluents from nuclear weapons facilities and from chemical weapons storage facilities as well as protocols for analyzing minute traces of high explosives. We have developed a powerful new technique for analyzing solid microparticles with ITMS. In addition, we have successfully downsized the conventional laboratory ITMS, turning it into a rugged field-portable instrument with enhanced capabilities at 20% of the usual size, and we will be downsizing the instrument even further. Many other of our developmental projects relate to chemical instrumentation.

Work in the area of electronics and signal processing also focuses on making smaller, faster devices for field use. ORNL is a world leader in applying geophysical diffraction tomography to imaging below the earth's surface. We have developed algorithms to use virtually any interrogation technique for real-time imaging in the field and have applied them in the U.S. and overseas. Prototype systems have been developed for analyzing the fissile material content of declared and suspected nuclear weapons. We have also developed several microelectronic devices that may be useful in covert monitoring scenarios, including miniature infrared and radio frequency beacons and one of the world's smallest high-resolution cameras.

ORNL has played a major technical support role in assessing the proliferant status of compliant and noncompliant nations through its expertise in uranium enrichment, fuel cycle, and other chemical and nuclear processing technologies. For example, our facilities include the only operational electromagnetic isotope separation (EMIS) system in the U.S. Experts at ORNL assisted in quickly identifying the EMIS components found in Iraq, components that formed a key element of that country's suspected nuclear weapons development program, as well as the EMIS components for the Iraqi centrifuge program. Several ORNL staff members are on loan to the National Security Program Office, providing support to ongoing nonproliferation intelligence analyses. These activities provide the technical basis for key policy decisions on nonproliferation.

Nuclear Weapons Research and Development

The ORNL nuclear weapons R&D program has made significant contributions in support of manufacturing the mechanical and structural components of nuclear weapons, in the preparation and distribution of special isotopes used in testing nuclear devices, and in the collection and dissemination of information on radiological effects. Historically, 25 to 30% of the Defense Program funding provided to the Y-12 manufacturing plant is spent at ORNL. The ORNL contribution to manufacturing includes automation, safety analysis, criticality alarm systems, and nuclear component packaging.

Typical of the contributions to manufacturing was the automation of the enriched uranium processing operations at the Y-12 plant, which led to significant cost reductions and productivity improvements. This would not have been possible without the close working relationship between ORNL and the production plant. This automation support included the design, fabrication, installation, and maintenance of automatic systems for chemical unit operations, furnace operations, and precision machining operations. Criticality alarm systems were developed and installed in the production facility by ORNL staff.

ORNL has two unique isotope facilities, the Radiation Shielding Information Center (RSIC) and the Radiochemical Engineering Development Center (REDC), that support the defense community and other customers. The RSIC is a technical institute serving DOE radiation research and development programs by collecting and disseminating information related to nuclear weapons and other radiation. The scope of the effort includes the physics of the interaction of radiation with matter, radiation production and transport, radiation detectors and measurements, engineering design, shielding, and computing codes for shielding. This center contributes to solving problems related to weapons, weapons effects, nuclear propulsion, inertial and magnetic fusion, and fission reactors. It is a National Resource Center for all forms of radiation and the only center of its type in the DOE.

The REDC is the sole U.S. supplier of ^{252}Cf for industrial, medical, and research use. It is an extension of the Transuranium Element Processing Program and part of the National Transplutonium Element Program. The REDC provides irradiated target assemblies and post radiation chemical processing to recover isotopes for weapons diagnostics used by the DOE weapons laboratories. The REDC is the only DOE facility capable of ^{233}U storage and distribution.

National Research Facilities

ORNL is the home of 13 unique and sophisticated experimental science facilities. Available to researchers throughout the nation and the world, these facilities serve about 800 users each year, two-thirds of whom are scientists and engineers from universities, industry, and other government laboratories. A strong educational benefit is provided through the many graduate students who perform their thesis research at ORNL's user facilities

ORNL's user facilities include:

The Buildings Technology Center. This center, which includes the Large Scale Climate Simulator, provides the U.S. building industry with easy access to the nation's most versatile facility for testing and analyzing building envelope and equipment systems.

The High-Temperature Materials Laboratory (HTML). The HTML comprises user centers for materials analysis, high-temperature x-ray diffraction, physical properties, mechanical properties, ceramic specimen preparation, and residual stress mapping. Successful integration of basic and applied research with technology deployment is a hallmark of the HTML.

The Holifield Radioactive Ion Beam Facility. This facility will be able to provide, in addition to beams of stable isotopes, radioactive ion beams with energies and species unobtainable elsewhere in the world, permitting the study of reactions important to the understanding of stellar evolution.

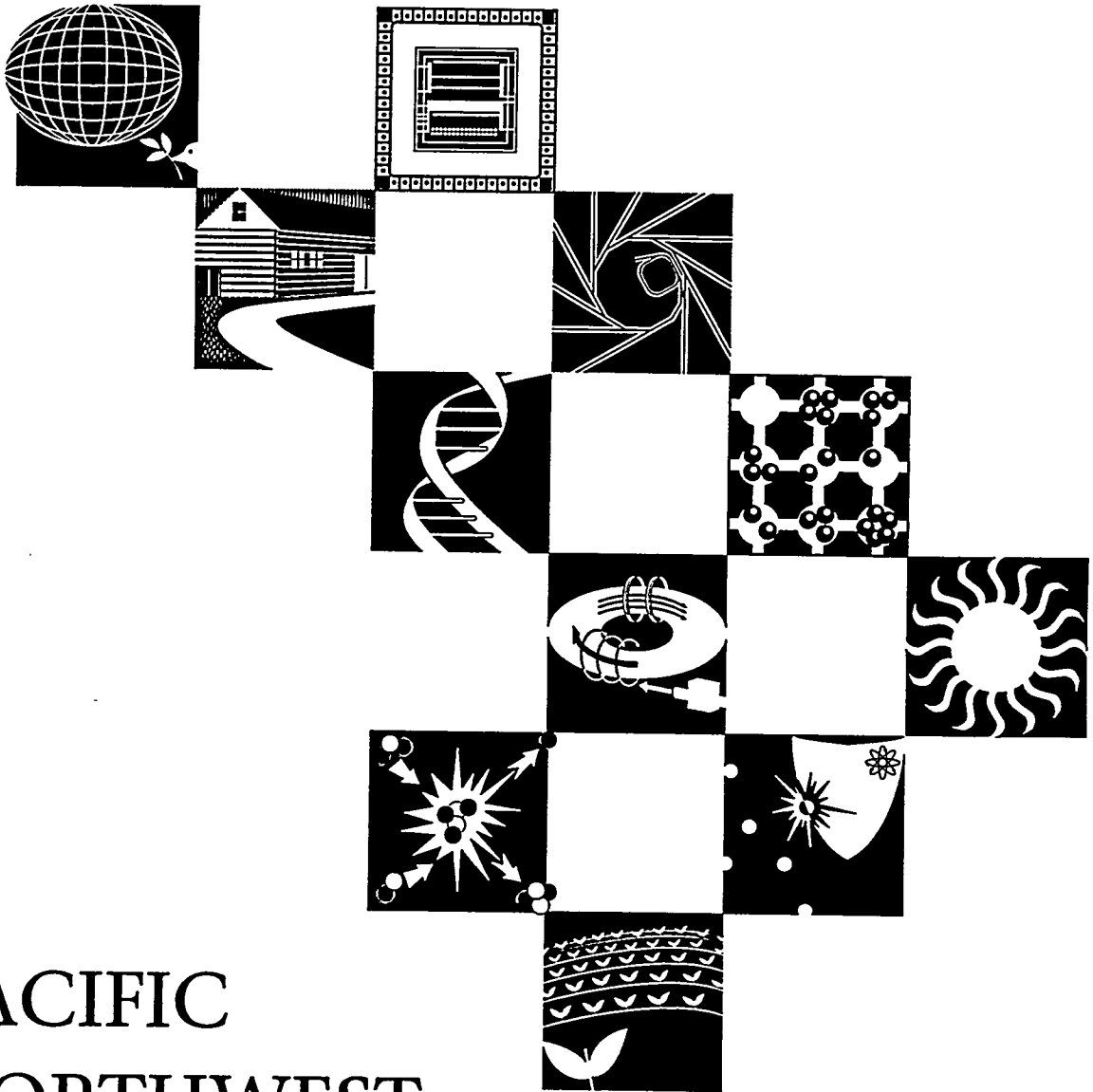
The High Flux Isotope Reactor (HFIR). The HFIR is an 85-MW Be-reflected light water reactor with the highest thermal neutron flux in the world. It is used for the production of isotopes for medical, industrial, and research applications as well as for materials irradiations, neutron activation analyses, and neutron scattering studies.

The High Performance Computing Center. One of two DOE high-performance computing centers, this facility has one of the world's most powerful massively parallel processing supercomputers. A prime goal is to expand its use by others, particularly by U.S. industry. The center is responsible for three Grand Challenge problems: groundwater transport and remediation, materials simulation, and global change.

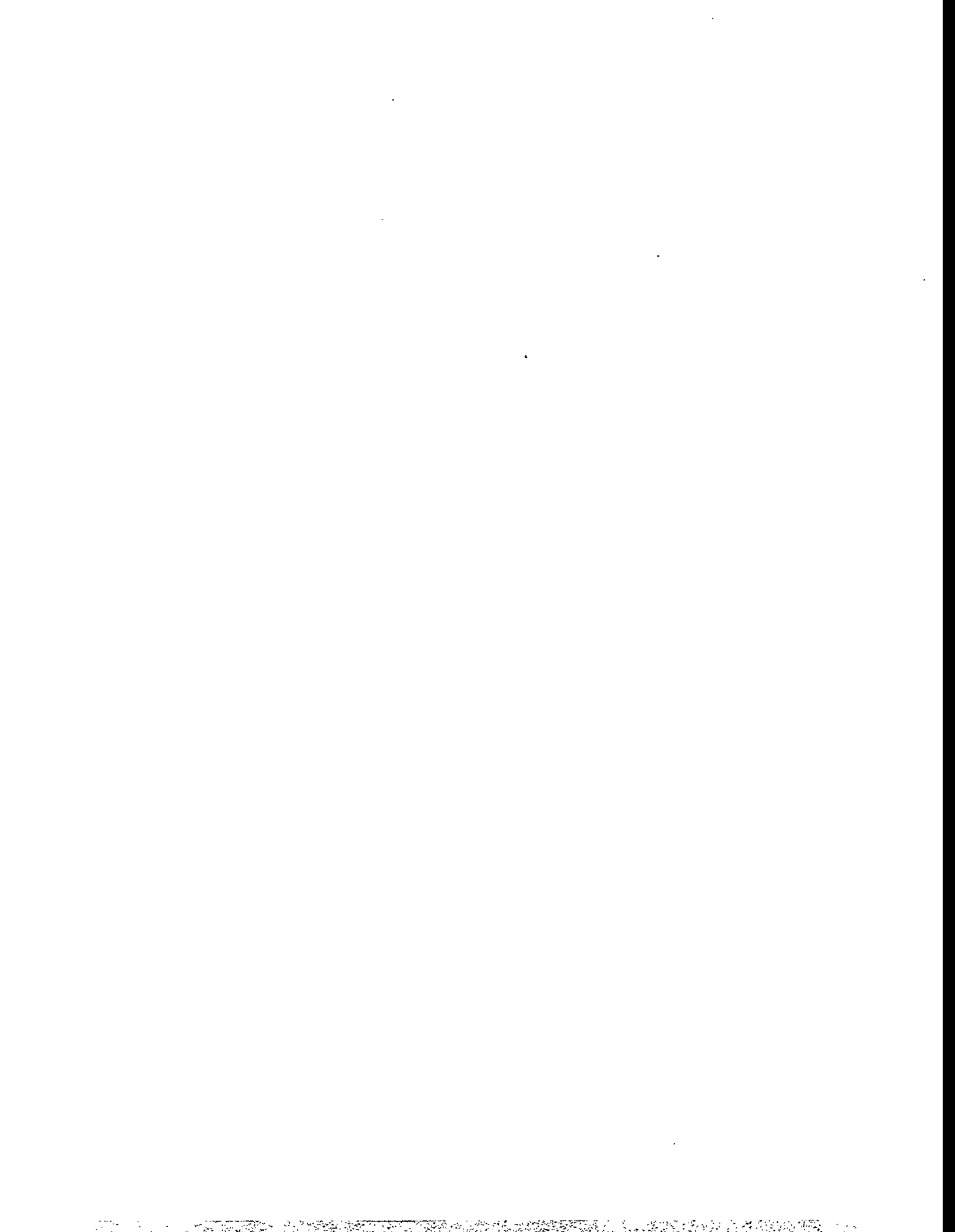
The Mammalian Genetics Facility. This facility has the largest collection of mouse mutants in the world—over 250,000 mice and 800 mutant strains—thus providing a unique national resource for genetics research.

Other user facilities at ORNL include the Atomic Physics EN Tandem Accelerator, the Bioprocessing Research Center, the National Environmental Research Park, the Neutron Scattering Research Facility, the Oak Ridge Electron Linear Accelerator, the Shared Research Equipment Program, and the Surface Modification and Characterization Research Center.

RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



PACIFIC
NORTHWEST
LABORATORY



Pacific Northwest Laboratory

The Pacific Northwest Laboratory (PNL), operated by the Battelle Memorial Institute, is a multiprogram national laboratory located at the Hanford site in southeast Washington. The primary missions of PNL are the advancement of science and the rapid development and deployment of technology, with a specific focus on environmental and energy issues. PNL's core competencies are integrated environmental research, process science and engineering, and energy systems development. Our environmental research portfolio includes work in global environmental change, chemical physics, marine sciences, geosciences, hydrology, and biosciences. Work in process science and engineering encompasses a broad range of environmental remediation research and development, development of new chemical separations methods, and U.S. Department of Energy (DOE) waste treatment and safety programs. PNL's energy systems development expertise is in economics and policy analysis relative to energy production and environmental issues, and in energy transmission and distribution systems and technology.

Energy Efficiency

PNL is a long-time participant in the search for more efficient ways to use the nation's energy resources. Focusing on individual sectors (buildings, utilities, transportation, and industry) and on cross-sector planning and analysis, PNL's energy efficiency research has two goals: (1) finding ways to more fully utilize the existing energy infrastructure and (2) developing a new generation of distributed energy systems.

PNL is working with the building industry to develop national energy standards for commercial and residential buildings. PNL is also working with state governments, adapting the national standards to the needs of each state and developing approaches for enhanced compliance. We are collaborating with Federal installations to design and negotiate large utility-funded, energy-efficiency projects and with developing and redeveloping nations (including states of the former Soviet Union) to set up Energy Efficiency Centers that will help transfer and deploy U.S. energy technology. PNL is also developing environmentally benign microtechnology devices—microtechnology heat pumps and heat engines are the current focus of this research—with plans to soon include chemical process technologies.

Another PNL objective is to increase the reliability and capacity of the nation's electrical delivery systems. Working closely with utilities and government agencies, we develop real-time power system monitoring and control systems, investigate the potential for superconducting magnetic energy storage for utility load management and system control, and analyze options for distributed utilities. A leader in studies of electromagnetic field (EMF) hazards, PNL pioneers exposure mitigation strategies through our unique shielding materials and EMF characterization facilities. We are working with utilities to develop advanced thermal energy storage systems. In one promising approach, molten salts are used to store energy to meet intermediate peak loads.

In work funded by internal investments, partnerships with private companies, and participation in the U.S. Consortium for Automotive Research, PNL is developing lightweight materials and corrosion-resistant coatings and pioneering methods to minimize emissions.

In collaboration with industrial partners, PNL is targeting basic industrial processes such as chemical conversion, separations, and synthesis for energy efficiency improvements. In a partnership established by PNL with the American Textiles Collaboration, for example, researchers are examining membrane concepts for recovering textile dyes now classed as wastes. Other technology development efforts include a life-cycle assessment modeling system, low-temperature plasma conversion technology, inorganic ion-exchange synthesis processes, supercritical fluids cleaning technology, and catalyst recovery and cleaning processes.

Energy Supply and Renewables

PNL is developing advanced materials and material-processing techniques to support the commercial development of advanced fossil-energy technologies such as fuel cells, advanced oil refining technology, and coal liquefaction. PNL also provides environmental support related to measuring, analyzing, and mitigating the environmental problems of the fossil-energy industry.

PNL programs include the Advanced Materials and Electrochemical Processes program, which emphasizes broad, clean, and efficient use of coal and other fossil fuels, and the Advanced Materials for Solid Oxide Fuel Cells program, which emphasizes major generic issues of solid-oxide fuel cell performance and manufacturing.

A three-year Cooperative Research and Development Agreement (CRADA) has been established between PNL and the Phillips Petroleum Company to develop a novel process for treating spent catalysts from petroleum refining processes. Developed at PNL, this process uses electrochemistry to remove accumulated contaminants that reduce process efficiency. The technology is more environmentally friendly than conventional spent catalyst treatment processes and provides opportunities to improve the efficiency of processes for converting crude oil to transportation fuels.

PNL contributes to the U.S. nuclear energy industry, primarily in support of the Nuclear Regulatory Commission (NRC). We assist in upgrading NRC regulations; identifying, evaluating, and mitigating safety problems related to nuclear power plant aging; assessing codes and standards for advanced reactor concepts; decommissioning reactors; training and testing plant operators; and evaluating operator requalification programs. Our work for DOE's Office of Nuclear Energy involves technical support for uranium enrichment programs; facility, operations, safety, and maintenance procedure development; and technology development for radioisotope research.

Climate Change

Global climate change research is a central feature in PNL's integrated environmental research portfolio. PNL's work in this area includes basic process research in the physical, environmental, and social sciences and in policy research. We provide program management support to DOE, and we conduct peer-reviewed research programs.

PNL leads the two largest DOE projects in the national global change research program—the Atmospheric Radiation Measurement (ARM) program and the Computer Hardware, Advanced Mathematics, and Modeling Program. For the ARM program, we are developing field sites to study atmospheric radiation and the impact of clouds on the earth's radiation budget. The first of these sites supports research in climate processes and is increasingly important in validating and calibrating satellite data. PNL staff helps plan future DOE research in oceanic, economic, and environmental effects, and PNL scientists fill staff and consulting positions for subcommittees in the newly formed Committee on Environment and Natural Resources. Several PNL scientists are key participants in the 1995 Intergovernmental Panel on Climate Change (IPCC) assessment report.

PNL scientists are significant contributors to process research in global environmental change. We have used our electro-optic capability to develop radiometers, but we emphasize modeling. PNL has a credible capability in GCM modeling, and we are leaders in the development of regional-scale climate and climate-effects models. We have contributed significantly to new process parameterization schemes for clouds, land-surface processes, oceanic penetrative convection, and air/sea gas transfer. We develop economic models that predict future emissions of greenhouse gases. We led the MINK study, which examined how climate data can be used to assess the economic impact of climate change.

PNL staff contribute economic analyses in support of DOE reports to Congress. PNL has provided these analyses of other countries—analyses that have led us to identify cost-effective ways to increase energy efficiency and to reduce carbon dioxide emissions in centrally planned economies. As a result, Energy Efficiency Centers have been established in Poland, the Czech Republic, Russia, Bulgaria, China, and the Ukraine. The centers assist these countries by improving the efficiency of their energy systems, reducing their environmental impact, and dealing with problems of environmentally sustainable development.

PNL is developing an international assessment of the ability of the social sciences to address the social and economic impacts of global climate change. Designed to fill the same role for the social sciences that the IPCC assessments fill for the physical and biological sciences, this work will be completed in 1995.

Environmental Technology

PNL's environmental technology programs focus on the cleanup of contamination at DOE sites. PNL is adjacent to the Hanford site, an ideal location for leading technology development in support of DOE's environmental mission. Following 50 years of plutonium production, the Hanford site contains structures, soils, and groundwater contaminated with hazardous chemicals and radioactive substances. The hazards of retrieving this waste material and the restrictions on transporting it dictate that much technology development be done on site.

PNL seeks the best available solutions to the environmental problems that confront DOE. To this end, 47 of our technology development efforts have industrial partners, 30 have university partners, and 20 include other national laboratories.

Public distrust and opposition are major barriers to the use of new technologies at DOE facilities. PNL's public involvement program encourages the early involvement of stakeholders in the decision-making process. Stakeholders thus gain an understanding of the problems, risks, costs, and benefits of proposed solutions. This inclusive process leads to public acceptance, which translates into political support for cleanup technologies.

PNL is committed to environmental technology: 50% of our budget, 50% of our discretionary resources, 50% of our spin-off companies, and 33% of our R&D 100 Award technologies support environmental technology.

A multiprogram national laboratory, PNL provides strong leadership in several environmental technology areas. For example, PNL manages the Volatile Organic Compounds in Arid Soils Integrated Demonstration, which applies technology to the cleanup of a 5- by 7-mile carbon tetrachloride plume near Hanford. PNL also pools resources with industrial consortia to solve common environmental problems. Based on successful relationships with the textile and automotive industries, we are establishing collaborative relationships with the chemical manufacturing, mining, and petroleum industries to solve environmental problems faced by these industries. PNL was recently selected to lead DOE's effort to remediate underground high-level-waste storage tanks at all DOE sites. PNL's new Environmental Molecular Science Laboratory will be a national user facility for the study of environmental interactions at the molecular level and the development of the scientific understanding necessary to support environmental cleanup.

PNL is a valuable national resource for environmental technology development and deployment. We focus on providing the best available solutions and on ensuring their acceptance by the public. We bring together our resources and those of the nation's best industries, universities, and national laboratories to solve the environmental problems facing DOE and the nation.

Health and Biotechnology

PNL's multidisciplinary research program assesses health risks associated with energy and defense technologies and their byproducts. PNL's research ranges from laboratory studies on fundamental molecular, cellular, and tissue interactions of chemicals and radiation to the analysis of human health risks from these agents and the development of protective guidelines. Advanced techniques are used in molecular and structural biology studies, toxicological measurements and modeling, human exposure assessments, and health risk analyses. Our results will enable cost-effective goals for waste management and environmental restoration at DOE, DoD, and industrial waste sites.

In PNL's Environmental Molecular Science Laboratory, we are developing advanced spectrometers and high-performance computers that are unparalleled worldwide. For example, we are studying macromolecular structure with the world's first commercial 750-MHz NMR spectrometer, and we are developing the world's first 1000-MHz NMR system. Our unique spectroscopic and computing capabilities allow us to analyze DNA and DNA-protein interactions in normal and perturbed cells. The resulting information helps us understand molecular-level changes in genetic materials caused by exposure to chemicals and radiation. Coupling structural and molecular biology with computer modeling provides new insights into the activity of genetically engineered enzymes and other protein products.

PNL has developed a single-cell microbeam irradiator that can deliver a single proton or alpha particle to the nucleus of a cell, which enables testing of the biological response to precisely controlled doses of densely ionizing radiation. We can thus determine the extent of chromosome and DNA damage resulting from environmentally relevant doses of alpha particles with an energy similar to radon emissions.

Our inhalation exposure facilities can characterize the toxicity of inhaled gases and airborne particulates administered by nose or whole-body exposure. These facilities are complemented by modern analytical chemistry and aerosol physics capabilities and the expertise of our staff.

PNL's techniques for quantifying exposure to neutrons, charged particles, photon radiation, and mixed radiation fields are widely recognized. A PNL dosimetry technique, the recent recipient of an R&D 100 award, can be used in personnel dosimetry and in the on-line digital recording of doses received in medical irradiation procedures. Dosimeters developed at PNL have been deployed in space missions, at DOE sites as field monitors, at accelerator facilities, and in medical dosimetry.

Our integrated program of health risk assessment couples radiation dosimetry, physiologically based pharmacokinetic modeling, mechanistic modeling of the processes that cause disease, and biostatistical modeling of health risks resulting from exposure to low levels of chemicals and radiation.

Materials and Chemistry

PNL's research in materials science and chemistry emphasizes understanding the fundamental chemical and physical phenomena associated with the nation's environmental issues, connecting scientific understanding to practical applications, and facilitating the commercialization of PNL's technical discoveries. These directions form the technical basis for the Environmental Molecular Science Laboratory, PNL's new collaborative research facility, currently under construction, which will enhance our already strong capabilities in materials science and chemistry.

PNL's chemistry, chemical physics, and bioscience research programs focus on a molecular-level understanding of the effects of contaminants introduced to the environment and on the waste management and remediation issues of DOE's defense waste problems. Specific program elements emphasize understanding contaminant flow in soils and groundwater, the chemical fate of contaminants in the environment, fundamental contaminant chemistry and chemical physics associated with minerals and mineral interfaces, the consequences of exposure to chemicals and radiation, and issues relating to the analysis of waste and potential remediation technologies.

Materials science is often the basis for developing the new technologies needed to advance engineering and scientific endeavors. Modern materials science depends heavily on traditional "wet" chemistry, particularly for synthesis and processing. At PNL, materials, chemistry, and chemical physics programs are shared by several research centers to ensure that fundamental science is integrated into applied programs. We are distinguished by our focus on synthesis, processing, and materials-environmental interactions.

New synthesis methods developed under DOE-supported fundamental science programs have produced diverse industrial applications. These include new ceramic processing technologies that have led to commercializable improvements in solid-oxide fuel cells and low-cost aluminum alloys (which superplastically deform at high rates) that have enabled aluminum to be used in lightweight components for automobiles. (PNL's new alloy is commercially produced by Kaiser Aluminum.)

Biomimetic Ceramic Synthesis, a process that mimics biological hard tissue formation, was developed at PNL. In this process, ceramic layers can be deposited on nearly any complex-shaped substrate. Because the ceramic can be deposited at low temperature (<140°C), plastics can be easily coated and no toxic waste is created. Most ceramic materials can be deposited, allowing such varied applications as coated bone implants to reduce rejection, abrasion-resistant coatings on plastics, and inexpensive corrosion-resistant coatings on complex metal and plastic components for automotive fuel delivery systems.

Computing and Information Infrastructure

PNL's capabilities in computing and information infrastructure provide the decisive means to further scientific research and develop advanced technology solutions. At PNL, information visualization and distributed information systems are two advanced technologies that combine with other capabilities to build first-of-a-kind systems engineering solutions and unique high-performance scientific environments.

Information visualization broadens scientific visualization to include masses of text, forms, and documents; business, manufacturing, and scientific databases; video, audio, and imagery; and the interactions of these media to further the processes of discovery and situation assessment. Our information visualization staff has deep technological understanding and broad interdisciplinary capabilities. They serve as science advisors on Federal research agency committees and task forces and are involved in national graphics forums. A particular focus is human/computer interaction.

The availability of desktop computers and workstations, coupled with the wide deployment of high-bandwidth data networks, has resulted in decentralized data management, an increase in data sources, and a growing demand for access to this heterogeneous, distributed data. The PNL Tank Waste Information Network System links high-level, radioactive tank waste data in distributed heterogeneous databases across the DOE complex—enabling users to retrieve tank-related data from any participating site. As a part of the Environmental Molecular Science Laboratory project, PNL uses advanced data models to address the challenge of managing and accessing large volumes of scientific data. We also operate the ARM data processing center, which stores scientific atmospheric data.

Integrated computer environments are an emerging catalyst for scientific discovery and information exchange. An example is PNL's Extensible Computational Chemistry Environment, which will provide integrated tools to theoretical and experimental chemists for molecular research. PNL is a leader in the implementation of such distributed computing environments and supports many computing architectures and platforms.

PNL provides solutions to complex information management and computation problems. Our information system developers can develop systems that require diverse domain expertise and technical capabilities. PNL's Systems Engineering Process provides a disciplined approach to first-of-a-kind systems and practical guidance to software project teams. Our high-performance computing effort combines computer science, numerical analysis, and scientific domain expertise to develop optimal computational applications over a range of parallel computational hardware.

Nuclear Nonproliferation

PNL is a major contributor to the nation's nuclear intelligence, arms control, and nonproliferation activities. Some of the nation's most qualified technical experts in the areas of production reactor design and operation, plutonium processing chemistry, and transuranic high-level waste management are at PNL. These experts both contribute to and lead technical efforts focused on limiting the spread of nuclear weapons.

PNL has major technical capabilities in particle and effluent analyses. We work to improve these capabilities and other proliferation detection capabilities under the sponsorship of DOE and other government agencies. Similarly, the nation's leading plutonium production intelligence capability is at PNL. PNL staff are assigned to the United Nations Special Commission, the International Atomic Energy Agency (IAEA), and the U.S. Nonproliferation Center. They routinely act as technical consultants and representatives to a wide range of formal government-to-government initiatives related to nuclear weapons treaties, plutonium production cutoff, and weapons material control, protection, and disposition. Inspectors and inspection technology from PNL support U.S. and U.N. missions to Iraq and the former Soviet Union. PNL staff are playing a pivotal role in coordinating DOE support for the new DoD initiative in counterproliferation, which is leading to wider involvement by the national laboratories in chemical, biological, and missile systems nonproliferation.

The Hanford site is proving to be an important asset in furthering U.S. nonproliferation objectives. PNL facilitated the first-ever IAEA and Russian inspections of the weapons plutonium storage facilities at Hanford. Many other Hanford site activities and facilities are being opened for inspection and consultation on improving Russian material control and accountability and on nuclear reactor safety.

National Research Facilities

PNL's major user facilities and collaborative research programs support DOE-funded research that seeks solutions to complex environmental problems. They support research that ranges from fundamental environmental research to field studies in the air, soil, and water.

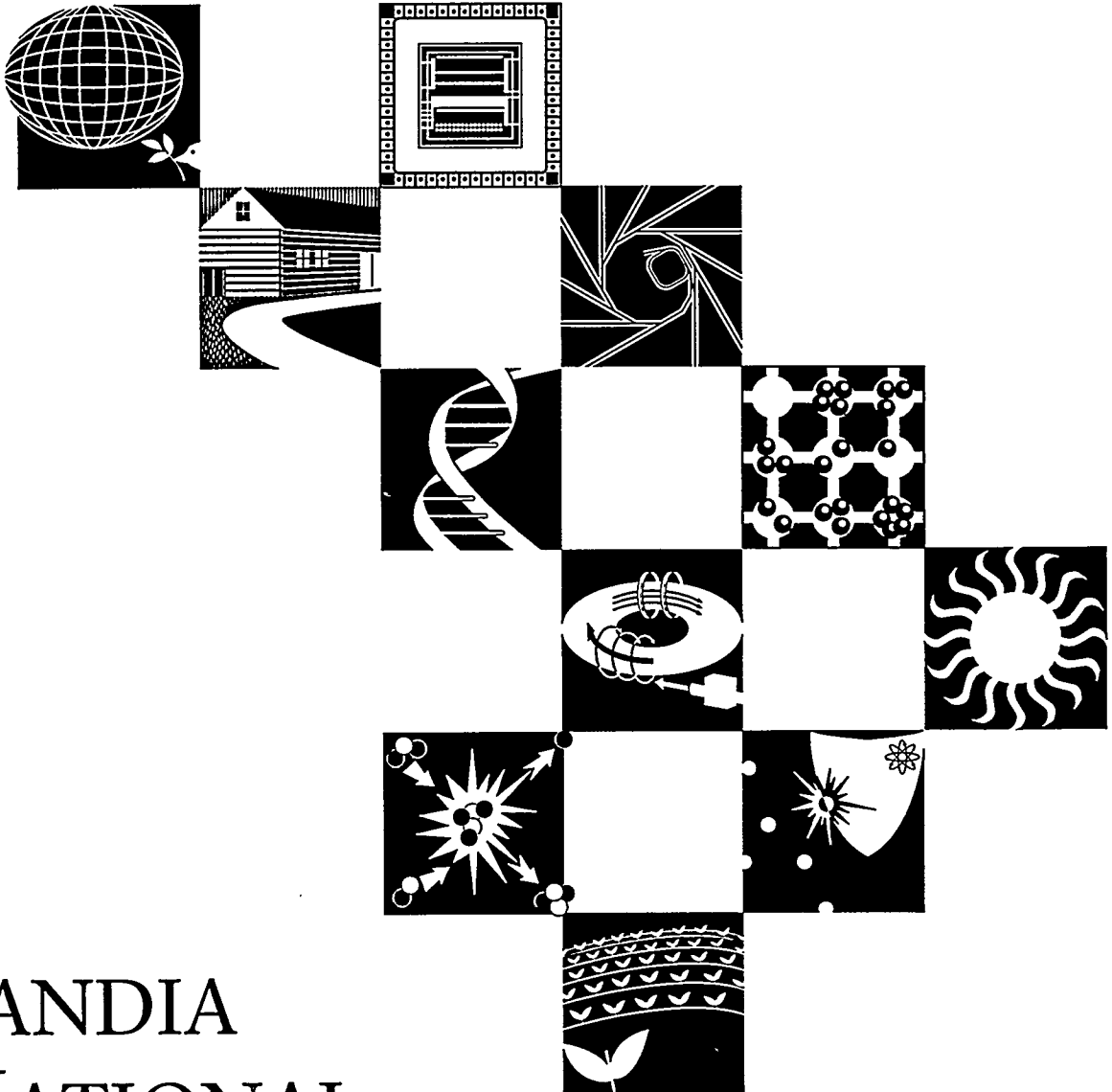
National Environmental Research Park and Arid Lands Ecology Reserve. The National Environmental Research Park at Hanford encompasses four land-use areas: an industrial zone, the Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve, the Department of Interior's Saddle Mountain Wildlife Refuge, and a Washington State wildlife management area. The ALE Reserve is dedicated to long-term, integrated studies of the relationships between air, water, and land in the shrub-steppe ecosystems of the western United States. Resources available to collaborating scientists include plant-gas exchange chambers, greenhouses, site information from the Geographical Information System, large weighing lysimeters, and remotely sensed imagery. Field station facilities also provide office and laboratory support.

Atmospheric Radiation Measurement (ARM) Program. PNL manages DOE's national ARM Program, which was created to address uncertainties in models of the global climate system and, ultimately, to improve our ability to predict climate change and the impact of energy use on the earth's environment. Major components of the program are its primary field measurement sites and its data system. The ARM field measurement sites are unique in the range of instrumentation installed to study atmospheric solar and infrared radiation propagation and the impact of clouds on the earth's radiation budget. The data system uses the Internet as its operational backbone, thus giving ARM researchers access to a variety of computational resources. The first ARM field site is operational in Oklahoma, and more than 70 teams (about 300 researchers) from universities and other national laboratories use data from the site. The United Nations' World Climate Research Program uses the Oklahoma site for its regional water budget measurements.

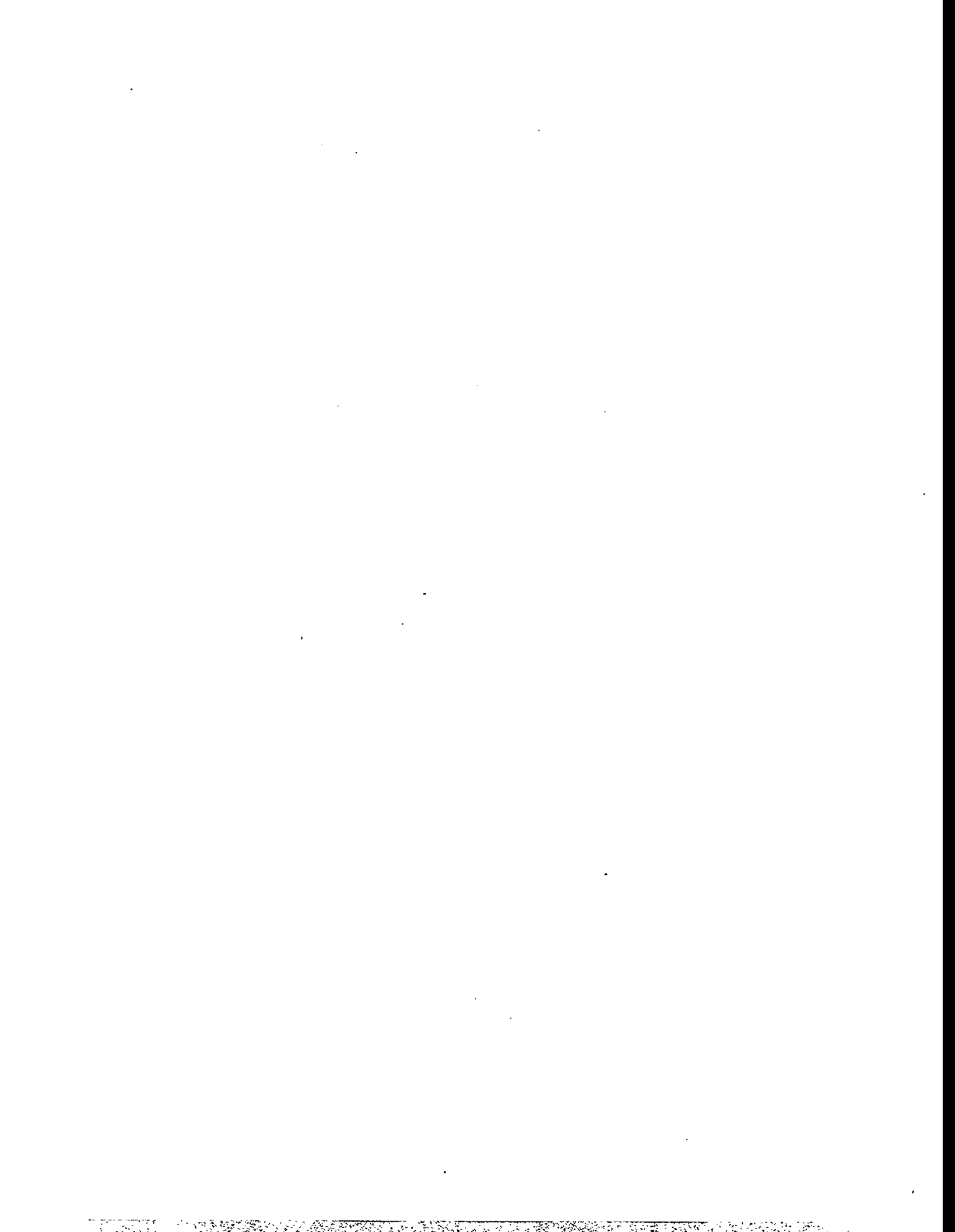
Environmental Molecular Science Laboratory (EMSL). Now under construction at PNL, EMSL will develop new technologies for DOE missions (energy, environment, and economic competitiveness) and national needs. Development of advanced equipment for the new facility is ongoing in interim facilities at PNL. Examples of the advanced equipment developed thus far include a 750-MHz nuclear magnetic resonance spectrometer and a KSR2 parallel computer. EMSL is expected to be operational in FY 1998.

PNL operates other collaborative research facilities, including a fluid dynamics laboratory, which supports basic research and application-specific studies (for example, the study of radioactive samples), and a subsurface environmental research facility for studying the transport and transformation of pollutants in soils.

RESEARCH PROGRAMS
AT THE DEPARTMENT OF ENERGY
NATIONAL LABORATORIES



SANDIA
NATIONAL
LABORATORIES



Sandia National Laboratories

Sandia National Laboratories, operated for the U.S. Department of Energy (DOE) by Martin Marietta Corporation, is one of the nation's largest and most diverse science and technology laboratories. Sandia was founded in 1949 at the request of President Harry S Truman. The Laboratories' 5,300 technical personnel are drawn from all disciplines of engineering and the physical sciences. Executive management offices and the larger laboratory complex are located in Albuquerque, New Mexico. This site comprises five technical areas and extensive field testing facilities. Another laboratory complex in Livermore, California, benefits from proximity to world-class research universities and the intense high-technology environment of the San Francisco Bay area. Sandia has major responsibilities in nuclear weapons, nonproliferation and arms control, energy, the environment, and economic competitiveness. Noted for its science-based approach to engineering, Sandia focuses on four integrated capabilities: advanced manufacturing, electronics, information, and pulsed power technologies. Sandia's mission is to provide comprehensive, timely, and cost-effective solutions to our nation's challenges in defense, energy security, environmental integrity, and industrial technology.

Energy Efficiency

Sandia's Energy and Environment business sector, working in partnership with industry, is making significant contributions to the ability of U.S. companies to develop products and processes that offer enhanced energy efficiency and reduced environmental impact.

At our California site, we operate the Combustion Research Facility (CRF). This is a major user facility where advanced diagnostic and computational techniques are used to improve the efficiency and reduce the emissions of a variety of combustion devices. The CRF's programs have featured long, productive partnerships with the automobile and truck engine industries. Here, the focus has been on in-cylinder processes in engines with reduced emissions and increased fuel efficiencies. Other programs concentrate on strategies for efficient use of coal in electrical power stations, where various coals must now be blended to meet sulfur emission requirements and retain efficiency. We are also working with the petroleum industry to reduce emissions from refinery operations while maintaining their high energy efficiency. Moreover, CRF technical capabilities are now being applied in other areas, including steelmaking, semiconductor processing, environmental monitoring, and analytical instrumentation.

Sandia plays a major role in partnering with the U.S. Council for Automotive Research to develop a new generation of vehicles. Specifically, Sandia is contributing in the areas of manufacturing, advanced materials, combustion and emissions catalysts, design and simulation tools, and advanced power sources. These power sources include batteries, fuel cells, and supercapacitors.

Another focus for Sandia's energy programs involves working with electric utilities and battery system suppliers to develop and utilize advanced storage battery technologies for load-peaking applications. Energy storage technologies are becoming key elements in system efficiency as utilities move to distributed, smaller-scale, generating systems.

Through partnership with industry, Sandia is developing new materials, catalysts, membranes, sensors, and separation processes and improved materials processing techniques. All of these contribute to improved process efficiency and pollution prevention. Sandia expertise in sensors is being applied to industrial process control. Our high-performance computing capabilities, computer-aided materials design (CAMD), and computer simulation capabilities are helping to revolutionize industrial materials and catalyst development. Specific examples include the use of CAMD to design catalysts that convert natural gas and carbon dioxide into useful chemical feedstocks and liquid fuels and the development of a new process to produce metal-ceramic composites at net shape, eliminating waste from machining.

Energy Supply and Renewables

In fossil energy, Sandia partners with industry to improve the efficiency of natural gas and oil exploration. Moreover, we apply geomechanics and geophysical instrumentation capabilities to improve characterization of reservoirs and manage production. The Natural Gas and Oil Technology Partnership, a new paradigm for cooperative, industry-driven technology transfer, is the result of our collaboration with Los Alamos National Laboratory. In fossil-fuel processing, our effort is focused on developing catalysts for conversion of coal and natural gas to liquid transportation fuels.

At our Combustion Research Facility in California, we have an industry-driven research program on combustion of pulverized coals. Results impact the design and operation of advanced high-efficiency coal combustors and prediction of the rates and character of ash deposits in present power boilers. We support the U.S. Strategic Petroleum Reserve Program with geotechnology expertise, resulting in operational practices and planning that have achieved more than 15 years of safe storage. We also develop cavern testing techniques. Currently, a broad range of geophysics, drilling, and instrumentation capabilities is focused on diagnosing and minimizing the effects of salt-creep-induced water leakage into one facility holding 73 million barrels of stored oil.

We support DOE programs in renewable energy by developing photovoltaic, solar thermal, geothermal, wind, and biomass power technologies. Federal development of these technologies is being conducted as a series of partnerships involving all levels of government, commercial suppliers and developers, end users, and facilitating organizations. These partnerships address relevant issues and bring expertise to development projects. Market pull drives the development, rather than technology push. In biomass power, biomass-derived alternative fuels are being characterized at our combustion facility, and the cost-effectiveness of using waste biomass fuels is being improved.

We participate in the development of two major types of modular solar thermal electric systems: power towers and parabolic dish and engine systems. Presently, five major 50/50 cost-shared cooperative activities, with a total value over \$100 million, are under way within the program, and more are being initiated. Our photovoltaic program has activities in all aspects of the technology, emphasizing manufacturing and deployment.

Our technologists work with leaders in the wind energy field to develop component manufacturing processes, product inspection capabilities, and system operation procedures that are significantly lowering the costs of wind energy. Indispensable assistance to the geothermal energy industry is given by reducing drilling costs and expanding the resource base. This development of drilling technology represents another partnership with industry.

Climate Change

Over the past several years, global climate change has come to the forefront of the world's and the nation's science and policy agendas. Though most scientists agree that energy-related emissions will cause a man-made greenhouse warming, there is significant uncertainty about the magnitude and timing of this effect and its regional distribution. To better understand these issues, our country has embarked on a U.S. Global Change Research Program, the Department of Energy being a major participant. Sandia expertise has been tapped for support in remote sensing, field testing, systems engineering, and massively parallel processing in two ways.

Atmospheric Radiation Measurement. We provide remote sensing and field operations expertise for the DOE's Atmospheric Radiation Measurement (ARM) program. ARM is a multilaboratory program to improve the understanding of radiation-cloud interactions by studying these processes at a series of Cloud and Radiation Test (CART) sites. Sandia roles include the management of one of the CART sites (the North Slope of Alaska site) and development of techniques to measure water vapor and cloud distributions—two of the key uncertainties in current climate models. Working with NASA, we developed and are currently applying a new laser remote sensing technique, Raman lidar, to provide water vapor profiles with high vertical resolution. We developed algorithms for extracting geometric information about cloud fields from whole-sky imaging cameras. Now, we are applying the power of massively parallel computing to fuse these data with satellite and radar data to produce three-dimensional maps. The CART site is scheduled to begin operation in FY 1997.

Development of Unmanned Aerospace Vehicles. Sandia serves as Technical Director of DOE's multilaboratory program to use unmanned aerospace vehicles (UAVs) for climate measurements. While the initial phases of ARM have emphasized ground-based measurements, airborne measurements are also needed to provide information about radiative fluxes, water vapor profiles, and cloud-top properties in the atmosphere. UAVs have the greatest potential for providing the required high-altitude, long-endurance measurements. Therefore, with funding from the Strategic Environmental Research and Development Program, DOE has initiated a multilaboratory ARM-UAV program. This program is developing the instrumentation and measurement techniques needed to capitalize on the small UAVs now under development by industry. Successful demonstration of these technologies will also open new markets in environmental and scientific sensing to this emerging sector of the aerospace industry. FY1993–1994 saw major progress toward these goals. In less than six months, we developed and integrated a baseline radiometric payload for a UAV. On its maiden engineering test flight, this payload worked flawlessly, yielding publishable scientific data—the first-ever climate-relevant measurements from a UAV.

Environmental Technology

Sandia's national security mission has led to the establishment of a strong research and development technology base. Our environmental technology program draws upon this technology base and applies much of it to solving the diverse environmental problems facing DOE and the nation. For more than 45 years, Sandia has been DOE's lead laboratory for designing, prototyping, testing, and evaluating the advanced electronics and mechanical systems needed for safe and reliable weapons. This systems approach to problem solving has helped us address all aspects of environmental issues. Also, our knowledge and experience in weapons systems electronics, information systems, and materials technologies have been applied to solve a variety of environmental problems.

We now lead many of DOE's programs addressing waste treatment, site cleanup, environmentally conscious manufacturing, and hazardous material transportation. These efforts include the Waste Isolation Pilot Plant, the Yucca Mountain High Level Waste Repository Project, and the DOE Mixed Low Level Waste National Strategic Planning Program. We have also developed robotics control software systems that are being transferred to industry and universities, and we have developed viable alternatives to the use of chlorofluorocarbons in electronics production. The demonstration and commercialization of these environmentally sensitive software and fabrication techniques have evolved through cooperation with numerous U.S. companies, including Deneb Robotics, Allied Signal, and Motorola.

Our environmental technology program also gains from the research and development efforts of our energy programs—efforts involving 300 engineers and scientists at a level of more than \$130 million per year. For example, our technologies for geothermal drilling, coal liquefaction, and solar energy can also be of service as advanced drilling techniques for environmental restoration, ion-exchange resins for radioactive waste treatment, and solar detoxification for water purification. These and other dual-use technologies have resulted in significant industry partnerships and national recognition through R&D 100 Awards and commercialization agreements.

An added capability of Sandia's environmental program comes from the combined efforts of our New Mexico and California sites. Because California often leads the nation with progressive environmental regulations, our California site has forged several alliances with California regulators to demonstrate new environmental technologies for site cleanup and waste treatment. Sandia's 40,000-square-foot Combustion Research Facility, originally established to improve the efficiency of gasoline engines, has evolved to address a wide range of environmental topics. The insights provided by our California site and our significant technology base have allowed Sandia's environmental program to develop and commercialize technologies that are both technically sound and socially responsible.

Health and Biotechnology

Sandia has designed its health care program to address two major national needs. The first is to reduce health care costs while maintaining or increasing the quality of health care delivery. Health care costs now consume 14% of the Gross Domestic Product (GDP) and are growing faster than the GDP. These costs reduce the international competitiveness of our industries and limit our ability to invest in the nation's infrastructure. Another major national need resides in the defense programs of the DOE. The DOE has stewardship of the nation's nuclear weapons and depends heavily on Sandia to meet this responsibility. Sandia also must maintain preparedness to meet future defense needs. We have planned our health care program to synergistically develop solutions for both national needs.

The history of Sandia's staff is one of outstanding service in the nation's interest, particularly in defense. Staff members are also keenly interested in working on other national needs, such as the development of technologies for reducing health care costs. They have successfully demonstrated the usefulness of their defense technologies skills in developing new or improved medical technologies that may reduce health care costs. There is a basic similarity between technologies of defense and those of health care. Thus, while developing health care technologies, the Sandia staff is concomitantly honing those skills that will be needed to meet the future defense requirements of the nation. Below are a few examples.

The noninvasive glucose monitor is based on an infrared absorption technique combined with chemometrics that allows rapid, painless measurement of blood glucose in diabetics. Recent clinical trials performed elsewhere indicate that the more often blood glucose is monitored and insulin administered, the fewer medical problems diabetics have.

Computer vision analysis of stellate lesions in mammograms is based on pattern recognition. A preliminary clinical trial demonstrated improved radiologist accuracy in detecting stellate lesions in mammograms. The earlier detection of breast cancer leads to earlier and less costly treatment.

Laser burn debridement uses an intelligent control system for the detection and laser vaporization of eschar, or burned skin. This system will assist surgeons in treating burn victims by allowing accurate detection and precise removal of the eschar to aid successful grafting. When completed, the system should improve recovery functionality and reduce recovery time.

Tele-robotic microsurgery uses a robotic system for surgical procedures on eyes. These procedures require very precise movements of the cutting tools to minimize collateral damage, work that is difficult for human hands. The tremors or oscillating motions of humans are always present and increase with age. This robotic system will allow for filtration of the oscillatory motion to improve surgical procedures and extend surgeons' operating lives.

Materials and Chemistry

High-performance, high-reliability materials and processes have been a hallmark of Sandia's involvement in the design and development of nuclear weapons. Decades of research have led to the development of outstanding capabilities in the joining, synthesis, design, and characterization of metals, ceramics and glasses, electronic materials, and polymers. Sophisticated models have been developed to solve problems in materials processing, manufacturing, performance, and reliability. Applications include catalysts for energy conversion, advanced processes for "green" manufacturing, and fabrication of tailored materials.

The Liquid Metal Processing Laboratory is a unique production-scale facility for research in melting, casting, and process control. Sandia conducts process research and produces prototype hardware for internal programs and industrial consortia. Better understanding of process-material interactions and advanced process controls is improving specialty metals. Basic research into transfer mechanisms, solidification, and arc physics has led to a number of patented technologies that are currently in use in industry. Recent studies (with General Motors) have identified characteristic signals and developed closed-loop control technology for induction hardening.

The Sol-Gel Program is directed at understanding sol-gel processing of thin-film and monolithic materials. Research is ongoing in precursor synthesis for sol-gel fabrication and in the manufacture of thin films in multicomponent materials systems. Researchers at Sandia are modeling the dynamics of thin-film deposition. They are also investigating control of thin-film structural evolution and ceramic microstructure. Thin ceramic films have been synthesized at Sandia for applications ranging from decoupling capacitors to anti-reflection coatings for glass solar tubes and mirrors.

A Sandia project has recently revealed the fundamental chemistry of fullerenes through a combination of experiment and theory. This research has unveiled the underlying patterns of single and multiple addition to the fullerenes. An article documenting this work in *Science* was the fifth most highly cited chemistry paper in 1993. Through a Cooperative Research and Development Agreement (CRADA) with a small business, Sandia researchers are directing their efforts toward the preparation of high-surface-area materials. Related research is also being conducted on carbon nanotubes.

Other synthesis studies include developing model electro-rheological fluids that are stable, noncorrosive, and fast acting. A novel inverse micellar approach was developed for the synthesis of size-selected metal, semiconductor, and oxide nanoclusters that exhibit unusual and adaptable properties. We have also discovered a new class of shock-initiated energetic materials, which we call Ballotechnics, that have unique potential applications in defense technologies.

Computing and Information Infrastructure

Sandia computing has focused on applications and environments for very-high-performance massively parallel (MP) supercomputers. During the 1980s, Sandia's collaboration with nCUBE demonstrated the practicality of MP supercomputing, helping generate the broad interest that it now enjoys. A new partnership with Intel is assuring continued U.S. leadership in this field: a team from Sandia and Intel retook the world record for computational speed from Japan in May 1994.

Sandia has developed more than two dozen applications for MP supercomputers. Our shock physics code is the DoD code of choice for armor, and it was recently applied to comet impacts. Materials science codes are enabling the design of materials with application-specific properties. Efficient light-emitting diode (LED) materials identified computationally are being grown by Hewlett-Packard for use in lasers and displays. A partnership with BIOSYM focuses on the design of catalysts for energy production and pollution minimization. An MP chemically reacting flow model is allowing the first three-dimensional simulations of semiconductor manufacturing processes.

Software environments are being developed to solve large problems and to assure software interoperability. The Sandia-University of New Mexico Operating System (SUNMOS) has doubled the memory and throughput available on Intel Paragons worldwide, and it forms the basis of a CRADA with Oracle and nCUBE. SUNMOS is being commercialized by Intel. Our mesh-generation software is used extensively at Ford and Goodyear. Sandia software that partitions problems for solution on parallel computers has been licensed to 60 sites.

Sandia's need to conduct large-scale simulations over long distances (from New Mexico to California) has driven work in high-speed wide area networks and in high-speed encryption and decryption. Sandia is a member of several gigabit testbeds (AT&T's experimental university network and the Bay Area Gigabit Testbed) and has partnered with communications companies to help form the National Information Infrastructure Testbed (NIIT). Sandia's work in synchronizing high-speed encryption devices over long distances has won national awards.

Sandia has unique expertise in information surety because of its historical nuclear weapons responsibilities. This expertise is being used with industrial partners to protect financial transactions and medical records. Patented algorithms for calculating digital signatures have been implemented by the National Institute of Standards and Technology.

The Technology Information Environment for Industry (TIE-IN) is opening a new mechanism for technology transfer: remote electronic access to national laboratory technology through smart front-ends.

High-Energy and Nuclear Physics

Sandia's programs in high-energy and nuclear physics are complementary to those at other DOE laboratories. We emphasize new accelerator technologies that can produce extreme instantaneous power levels (>50 TW) and currents (>10 MA) at modest voltages (tens of MV). Pulsed power accelerators were originally developed to simulate the output of nuclear weapon explosions on electronics, but they have been broadly applied to inertial confinement fusion, beam-matter interaction, and generation of large x-ray yields. The three most powerful accelerators in existence are applied to defense programs at Sandia. The Saturn accelerator produces 20 TW of 1-MeV x rays, Hermes III produces 15 TW of 20-MeV x rays for radiation-effects science and simulation, and PBFA II produces 10 TW of 9-MeV lithium ion beams for ion-driven fusion target experiments. With its total yield of more than 600,000 joules, Saturn is the most energetic source available in a short pulse (20 ns).

With the cessation of underground testing, these accelerators provide critical validation of radiation effects in electronics. As we continue the development of the x-ray physics capability on Saturn and PBFA II, these accelerators will provide excellent platforms for studying material opacities and equations of state in radiation-dominated systems. They will allow measurements to be made without the complications of very large space and time gradients. These systems are also becoming rich sources for information about high-energy-density physics, astrophysics, plasma physics, and hydrodynamics in addition to elucidating electromagnetic power flow and the effects of extreme magnetic fields (>1 MG) and electric fields (>1000 MV/m) on matter. They are the sources of the most intense beams of ions, electrons, x rays, and microwaves available anywhere. One goal of our x-ray physics programs is to extend the yield of Saturn to 2 million joules in PBFA II and to 15 million joules in the Jupiter accelerator.

Sandia is the DOE center for pulsed-power research. The capabilities described above have been made possible by the rapid invention and development of new pulsed power accelerator technologies in the last ten years. These have included laser-triggered switching for precise multimodule synchronization (1 ns), inductive voltage addition to 20 MV, and vacuum magnetic insulation of enormous currents (10 MA).

Commercially valuable applications of pulsed-power accelerators are now becoming possible with the recent development of high-average-power accelerators (100 kW in RHEPP-I and 350 kW in RHEPP-II, both at Sandia). Applications include hardening of materials, deep welding (several inches), destruction of toxic chemical wastes, and sterilization of medical instruments and wastes. In each of these areas, Sandia is working jointly with universities, other DOE laboratories, and industry.

Nuclear Nonproliferation

Sandia supports DOE in intelligence, proliferation detection, arms control, verification technology, and policy development. We have one of the oldest and largest such programs in support of U.S. national security policy. Sandia aids DOE in four nonproliferation areas:

Verification and Control Technology. Sandia has developed instrumentation to verify compliance with a wide variety of international treaties. Our current activities include efforts to improve satellite sensors that can detect and locate nuclear bursts in the atmosphere and to assist LANL in improving detection of detonations in space. Sandia acts as the system integrator for all of DOE's space-based systems. In addition, our seismic detection and data processing systems can monitor proliferation-related underground and underwater nuclear testing. We have established capabilities in adversarial analysis, vulnerability analysis, and analysis of foreign systems and capabilities.

Export Control, Nonproliferation, and International. We assess foreign weapons development capabilities and develop guidance for export control. Sandia has originated several containment, surveillance, material control, and accountancy systems now used by the International Atomic Energy Agency.

In support of the U.S. Comprehensive Threat Reduction Program, we assist DOE in demonstrating advanced physical protection technologies to states of the former Soviet Union. In addition, Sandia is focusing resources to discourage nations from acquiring weapons of mass destruction (WMD). We have initiated a program of Cooperative Regional Security, which is designed to encourage cooperative monitoring in critical regions such as the Middle East, thereby reducing the incentives to acquire WMD.

Nuclear Safeguards and Security. We develop technologies and systems for protecting nuclear materials and DOE facilities. Some of these technologies are directed at detecting and delaying outside adversaries, and some prevent insider attempts at sabotage, theft, or diversion of material or information. They include a broad spectrum of sensor technologies, image processing of sensor output, information surety technology for access control, and access delay technology that is being extended to provide nonlethal weapons for the use of other federal agencies.

Intelligence. Sandia provides tools and analysis techniques for the intelligence community. For example, we provide tools for assimilating and evaluating the wide range of information that is now available, especially information that relates to proliferation of WMD and their delivery systems. We also evaluate information surety, a special expertise required by the nuclear weapons program. In addition, we are developing new sensor systems and evaluating foreign technologies for a variety of customers.

Nuclear Weapons Research and Development

Sandia's Nuclear Weapons program provides the science and technology infrastructure needed to support multiple defense programs. It emphasizes technology that helps us maintain and improve our understanding of nuclear weapons systems and enables their design, engineering, production, certification, and eventual dismantlement.

Conceptual Design and Assessment. This program consists of groundbreaking projects where new weapon components are developed through proof-of-concept demonstrations. Recent Sandia accomplishments in this area include the conceptual design of a Stealthy Standoff Glide Bomb and the design definition for a global verification and location system. The system allows treaty verification, real-time inventory, strike assessment, and remote enabling of weapons.

Physics. Pulsed power systems are the heart of Sandia's physics program. These systems are used for verifying component and weapon subsystem reliability and as prototype systems for inertial confinement fusion.

Tritium. This program is centered on the design of tritium reservoirs and their associated gas-transfer systems. We are presently working on a new system with Los Alamos.

Explosives. Sandia weaponizes concepts developed jointly with Los Alamos and Lawrence Livermore Laboratories.

Systems Engineering Science and Technology. We are developing a direct optical initiation firing set, a standardized neutron generator with a greatly expanded lifetime, an imaging radar for a precision guidance system, automatic planning and programming of intelligent machines for 21st century weapons production, and virtual reality concepts to facilitate the safe dismantlement of weapons.

Electronics, Photonics, and Mechanical Components. This program is primarily a Sandia responsibility. We have extensive facilities for prototyping these components, including facilities for microelectronics fabrication, semiconductor research, and printed wiring board fabrication. In addition, we are the site for the three-laboratory (LANL, LLNL, and SNL) flat panel display project.

Computation and Modeling. We are engaged in extensive development of massively parallel computing, for which Sandia holds the world record for performance (143 Gflops). Networking research is supported by Sandia's coordination of NIFT activity.

Chemistry and Materials. Sandia is recognized for its Liquid Metals Processing Laboratory, its Thermal Spray Research Laboratory, its sol-gel processing and welding research, and materials activities related to electronics fabrication.

National Research Facilities

Sandia's research facilities serve primarily to satisfy DOE programmatic needs while offering access to outside users. They are available to U.S. industry, universities, academia, other laboratories, state and local governments, and the general scientific community.

Combustion Research Facility. Each year, several hundred visiting scientists use this facility to improve their understanding and control of combustion processes. Projects include studies of combustion-generated pollutants and applied studies of processes in internal combustion engines.

National Solar Thermal Test Facility and Design Assistance Center. This facility is used for tests requiring intense heat and for collecting light with large-scale optics. Specific high-thermal-flux applications include investigating the thermophysical properties of materials and testing various solar applications.

Electronics Quality/Reliability Center. This facility is a world leader in electronics reliability and failure analysis. It deals with all electronic components, from cables and connectors to high-speed integrated circuits.

Laser Applications (LAZAP). LAZAP consists of a large Cassegrain beam director and telescope and several high-power lasers. It also includes control, tracking, and safety equipment. The telescope can track satellites from low-earth to geosynchronous orbits as well as perform fixed pointing and sidereal rate tracking.

Nuclear Facilities Resource Center (NUFAC). The Hot Cell Facility provides a means of handling and examining radioactive materials, usually following exposure in one of the reactors. NUFAC also includes the Gamma Irradiation Facility and the Radiation Metrology Laboratory.

Intelligent Systems and Robotics Center. This research and development facility applies intelligent systems and robotics technologies to areas such as manufacturing, environmental cleanup, weapons production and dismantlement, and biomedicine.

Explosives Components Facility (ECF). The ECF has the full range of capabilities necessary to support research in energetic materials and components.

TIE-IN Scientific and Engineering Applications. Using TIE-IN, industry partners obtain technical solutions via direct access to Sandia's computers, software, databases, rapid prototyping equipment, and testing and diagnostic equipment.

Materials and Process Diagnostics Facility. The facility offers expertise in microscopy, metallography, microprobes, plasma sprays, liquid metals, and joining. Process sensors, polymer degradation, and sol-gel processing are also strong capabilities.