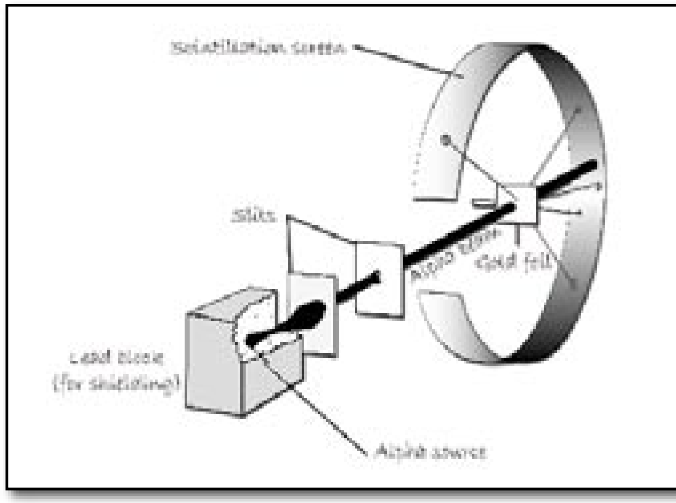
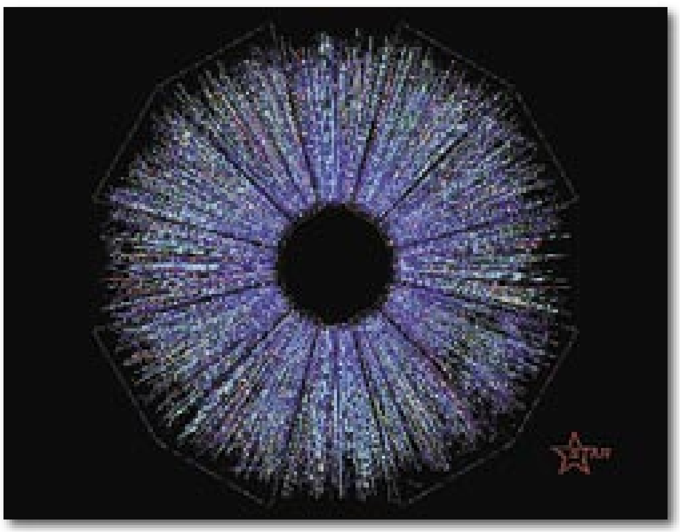
About the Cover

Understanding the Atom: Physics Past, Present, and Future

This year's cover for Volume 5 of the Journal of Undergraduate Research recognizes the "World Year of Physics" that celebrates the 100 years since Albert Einstein published three pivotal papers that have influenced the study and understanding of physics.

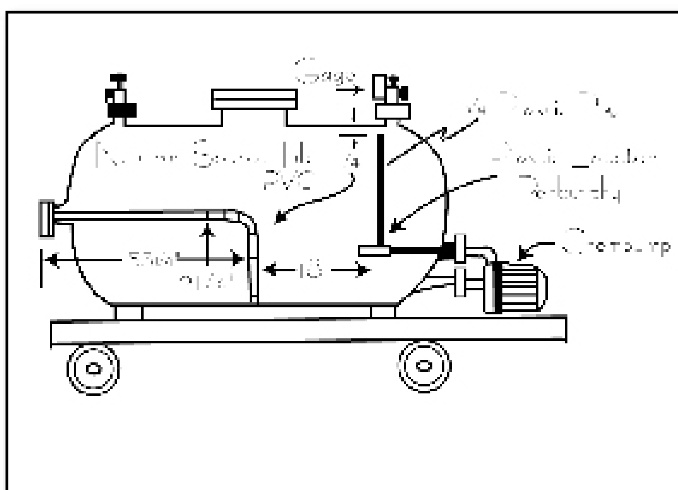
Rutherford's alpha beam experiment established the first model of the atom that distinguished between a dense, positively-charged "nucleus" and orbiting negatively-charged electrons. This schematic shows the layout of the experiment where alpha particles from a source inside a shielded lead block were directed in a beam towards a piece of gold foil. The surprising result was that some of the alpha particles deflected at large angles, almost coming directly back toward the source.





The Relativistic Heavy Ion Collider (RHIC) at the Department of Energy's Brookhaven National Laboratory (BNL) accelerates gold ions to speeds close to the speed of light and then allows them to collide. This image shows an end-view of a collision of two 30-billion electron-volt gold beams in the Solenoidal Tracker at the RHIC (STAR) detector. These experiments at BNL are searching for signatures of the form of matter that RHIC was designed to create – the quark-gluon plasma. Courtesy of Brookhaven National Laboratory-STAR Collaboration.

This image from the logbook of Dr. Ray Davis (2002 Nobel Laureate) depicts his sketch of a 500-gallon tank on a rail car with a solution of calcium nitrate in an experiment designed to detect solar neutrinos. The final experiment used a 100,000-gallon tank filled with perchloroethylene located deep beneath the earth in a former gold mine in Lead, South Dakota. This experiment led to the determination that neutrinos can change "flavors" as they travel from the sun to the earth. Courtesy of Brookhaven National Laboratory.



The equations in the background of the cover were derived by Niels Bohr in his paper titled, *On the Constitution of Atoms and Molecules*, published by Philosophical Magazine Series 6, Volume 26 in July 1913.

DISCLAIMER

A NOTE FROM THE EDITOR:
AUDE SAPERE...DARE TO THINK INDEPENDENTLY

The earliest scientists I know of were Babylonians (probably preceded by the Sumerians in the same Fertile Crescent) who about 3,600 years ago carefully observed and charted the rising of celestial bodies. They then used these "star charts" to predict when to plant and harvest crops. Such predictions helped them establish their agriculture and their civilization. Similar progress occurred in the Yellow River Valley in ancient China. In the millennia since, the human race has steadily progressed in its understanding of nature. Looking back, the challenges that faced people eking out livings in a harsh and often unpredictable world left great opportunities for early scientists. Science would slowly take hold as it progressed in its ability to provide a level of predictability and improve the human condition.

The Babylonian star charts are an example of how early science was based on careful and direct observation of natural phenomena. If the Sumerians and Babylonians did not go far beyond the direct observation of nature, such was not the case with the Greeks, who would attempt to look beyond the human percepts and into what was not obvious. A mechanistic view of the universe began to unfold most notably from the early atomists, Leucippus and Democritus and in some sense was brought to full light by Isaac Newton. Rapid growth in scientific knowledge would be seen in the era following Galileo, who is often cited as the first modern scientist. I suppose this is largely founded on his adherence to verifying theory with experimentation.

Modern scientific process is now fully entrenched in this experimental principle and largely operates under the premise that by studying components of nature in isolation it can keep the complexity of nature from overwhelming the human intellect. It then can attempt to understand the whole from its understanding of the individual components. This sort of fragmentation has led to the divisions of scientific study and the branching of science into disciplines such as physics, chemistry, biology and the further divisions of each of these into a dizzying array of sub-disciplines. There are signs of reunification in science and there are certain scientists who by their title reveal this trend…"biophysicists" for example.

> ***"The fragmentation of knowledge that until recently has been successful in explaining certain natural phenomena needs to change..."***

The science of a hundred years from now will likely look as different as today's science does from a hundred years past. It is difficult to comprehend how far we have progressed in such a short period of time. The 2005, World Year of Physics is a celebration of a time that saw the birth and maturation of the profound descriptions of the nature of the universe expressed by both Relativity and Quantum Mechanics. Quantum

Mechanics was the first modern scientific theory to challenge the deeply entrenched notion of the mechanistic nature of the universe. During this era, the progress in all the natural sciences has been more than most could have imagined. It has allowed the human species to explore the depths of our oceans, discover the limits of outer space, and to grow its population to over 6 billion.

"Humans now have such an impact on the surface geology of the earth, that they can be considered a major geological force."

Humans now have such an impact on the surface geology of the earth, that they can be considered a major geological force. At the same time, the ability of human intellect to explain its effect on the planet as a species is quite limited. The uncertain ramifications of global warming illustrate this limitation. Furthermore, sustaining human life at the levels of comfort that much of the western world has grown to enjoy and the remaining world desires will be increasingly difficult. Providing enough clean energy for a population that will likely reach 9 billion by the next century is an immense challenge without considering the numerous other daunting problems that could equally compromise the human condition.

The fragmentation of knowledge that until recently has been successful in explaining certain natural phenomena needs to change for us to fully overcome these challenges and will likely be a growing obstacle to our understanding of the complex nature of our world. It will take more than scientists working together. It will take them thinking differently in a less compartmentalized fashion.

Although physicists have realized the limitations of a mechanistic view of the universe, where even knowing what each of the variables in a system is doing does not allow one to fully predict the outcome, biologists still approach their science largely from a mechanistic point of view. We might find that the great advancement of biological sciences will be by taking example from the physicists and establishing some sort of theory that describes living systems in a non-mechanistic fashion. This is pure speculation, but the point is that great advancements will demand new thinking and for such it will need new and fresh thinkers.

Peter Faletra, Ph.D.

Editor-In-Chief

TABLE OF CONTENTS

Selected Student Papers Continued:

GROWING SCIENTISTS IN THE LAB

Science cannot be learned completely from books, a set of courses, or a full undergraduate curriculum. Science has to be performed to learn it. It is true that the formalism and the foundation of science must be learned from a curriculum by anyone aspiring to work in the field. But, the excitement and captivation of science are felt best in the research laboratory. Research is the key element of a graduate degree in science or engineering, but even at the undergraduate level I am convinced that research is crucial for understanding the direction of science and appreciating the intellectual challenge that it brings.

> ***"...the excitement and captivation of science are felt best in the research laboratory "***

We live in a society that depends on rapid development of new technological tools to fuel a large part of our economic expansion. Today's average automobile contains more computer control than the first manned module that landed on the moon in 1969. The materials available now for our computers, cars, appliances, fuel cells, and such have specialized tailored properties that were thought impossible a few decades ago. But, our world leadership in new technologies is threatened by the education of too few scientists and engineers in the U.S. For example, a few years ago the number of undergraduate physics degrees in our country had shrunk to a pre-Sputnik low. We have built and maintained our world dominance in technology development in part by bringing the best and the brightest from around the globe to our graduate schools and then to careers in our country. But, the post-9/11 restriction on visas is threatening to disrupt a sufficient flow of technical talent to our shores. The United States needs a rebirth of widespread student interest in fields of science and engineering. Yes, science can be a challenging course of study, but it is also a challenge to build a viable law practice or dig out of debt to establish a medical practice. I am convinced there is vast opportunity for trained scientists and engineers in our country, sometimes in fields that seem far from the classical ones. Undergraduate laboratory research can effectively help students appreciate more fully the beauty of science and capture their interest in building a career in science. That worked for me, as the chance to do research at my small college convinced me that this was the form of intellectual endeavor that would define my career. One of our top researchers at the Oak

> ***"...our world leadership in new technologies is threatened by the education of too few scientists and engineers in the U.S."***

Ridge National Laboratory came here as an undergraduate, became captivated by research, then received his doctorate from Yale, and returned here to lead our program in experimental nuclear astrophysics.

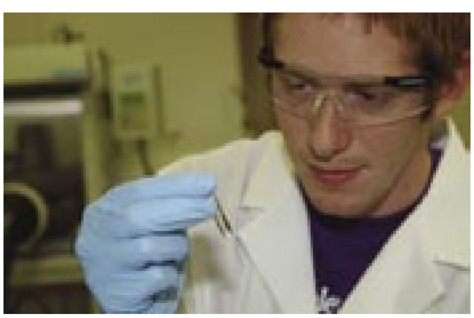
The undergraduate research internships supported by the Department of Energy Office of Science provide to students wonderful opportunities for a semester or a summer of research at a National Laboratory. Our National Labs are very special places that emphasize interdisciplinary research usually focused on the country's biggest technical challenges. We Americans have many questions about the future supply of energy, change of the global climate, realization of an economy based on nanotechnologies, application of genome science to the development of new drugs to cure disease on a large scale, and the next generation of clean, safe, and fuel-efficient autos. Undergraduates become involved in research programs in such areas at National Labs, and in so doing they catch the excitement of contributing to important areas of fundamental and applied science while also preparing themselves for careers. What an opportunity for the student and what a benefit for the country.

Lee L. Riedinger

Associate Laboratory Director for University Partnerships

Oak Ridge National Laboratory

AMES LABORATORY



Scientists at the Department of Energy Office of Science's Ames Laboratory seek solutions to energy-related problems through the exploration of chemical, engineering, materials and mathematical sciences, and physics.

Established in the 1940s with the successful development of the most efficient process to produce high-purity uranium metal for atomic energy, Ames Lab now pursues much broader priorities than the materials research that has given the Lab international credibility. Responding to issues of national concern, Lab scientists are actively involved in innovative research, science education programs, the development of applied technologies and the quick transfer of such technologies to industry. Uniquely integrated within a university environment, the Lab stimulates creative thought and encourages scientific discovery, providing solutions to complex problems and educating tomorrow's scientific talent.

Ames Laboratory is located in Ames, Iowa, on the campus of Iowa State University. Iowa State's 2,000-acre, park-like campus is home to approximately 25,000 students. Ames is approximately 30 minutes north of Des Moines, Iowa's capital city.

ARGONNE NATIONAL LABORATORY



Argonne National Laboratory descends from the University of Chicago's Metallurgical Laboratory, part of the World War Two Manhattan Project. The laboratory has about 2,900 employees, including about 1,000 scientists and engineers. Argonne occupies 1,500 wooded acres in DuPage County, Il about 25 miles southwest of Chicago's Loop. Argonne research falls into broad categories:

- Basic science seeks solutions to a wide variety of scientific challenges. This includes experimental and theoretical work in biology, chemistry, high energy and nuclear physics, materials science and mathematics and computer science.
- Scientific facilities help advance America's scientific leadership and prepare the nation for the future. These facilities are used by scientists thousands of scientists and students from the U.S. and abroad. The laboratory is also home to the Advanced Photon Source, the Center for Nanoscale Materials, the Intense Pulsed Neutron Source, and the Argonne Tandem Linear Accelerator System.
- Energy resources programs help insure a reliable supply of efficient and clean energy for the future. Argonne scientists and engineers are developing advanced batteries and fuel cells, as well as advanced electric power generation and storage systems.
- Environmental management includes work on managing and solving the nation's environmental problems and promoting environmental stewardship.
- National Security has increased in significance in recent years for the nation and for Argonne research. Argonne capabilities developed over the years for other purposes are helping counter the threats of terrorism.

Argonne's Division of Educational Programs provides workforce development for faculty and students from universities to regional K-12 schools.

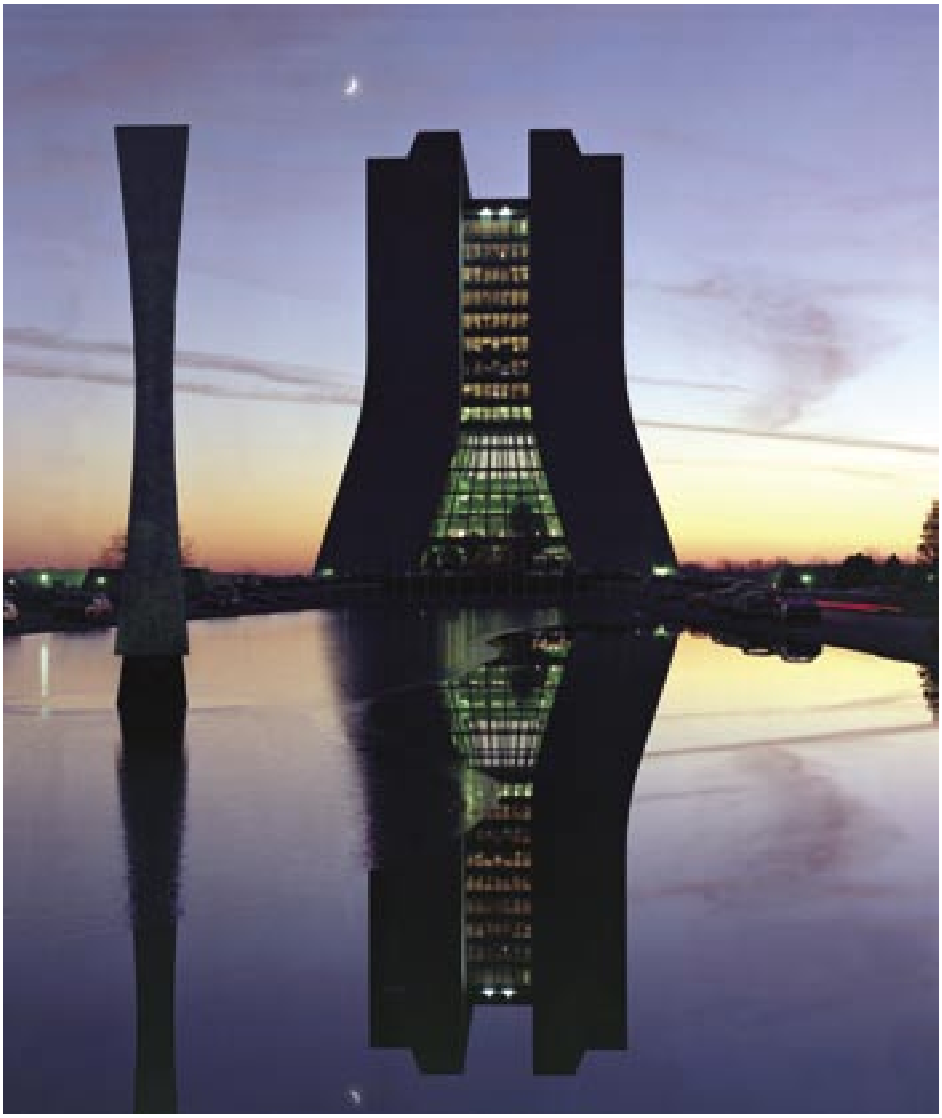
BROOKHAVEN NATIONAL LABORATORY

Established in 1947, Brookhaven National Laboratory is a Department of Energy, Office of Science multidisciplinary laboratory managed by Brookhaven Science Associates, a company founded by Battelle and Stony Brook University. Home to six Nobel Prizes, Brookhaven conducts research in the physical, biomedical, and environmental sciences, as well as in energy technologies and national security.

Located on a 5,300-acre site on eastern Long Island, Brookhaven builds and operates major scientific facilities available to university, industry and government researchers. Among those facilities are the world's newest accelerator for nuclear physics research, the Relativistic Heavy Ion Collider (RHIC), and the National Synchrotron Light Source (pictured here) where approximately 2,500 researchers use beams of light, from x-rays to ultraviolet and infrared, to study materials as diverse as computer chips and proteins. In the near future, the Center for Functional Nanomaterials will be built at Brookhaven, one of five proposed Department of Energy centers where researchers will study materials on the scale of a billionth of a meter, or only a few atoms.

A wide variety of both basic and applied research is conducted at Brookhaven. For instance, scientists are investigating the building blocks of matter using RHIC, the roots of drug addiction and brain metabolism using positron emission tomography, the effects of space radiation on astronauts using the newly built NASA Space Radiation Laboratory, and the effects of increased carbon dioxide in ecosystems. Brookhaven researchers also develop new technologies as varied as detectors for national security and oil burners with improved efficiency.

FERMI NATIONAL ACCELERATOR LABORATORY



Fermi National Accelerator Laboratory (Fermilab) is one of the world's foremost laboratories dedicated to high energy physics research. The laboratory is operated for the Department of Energy, Office of Science by a consortium of 90 leading research-oriented universities primarily in the United States, with members also in Canada, Italy and Japan.

Fermilab is located on a 6,800 acre site about 35 miles west of Chicago. Fermilab is home to the Tevatron, the world's highest energy particle accelerator. Around its four-mile circumference 1,000 superconducting magnets are cooled by liquid helium to -268ºC. Two major components of the Standard Model were discovered at Fermilab—the bottom quark and the top quark—and the first direct observation of the tau neutrino, the last fundamental particle to be observed, was at Fermilab.

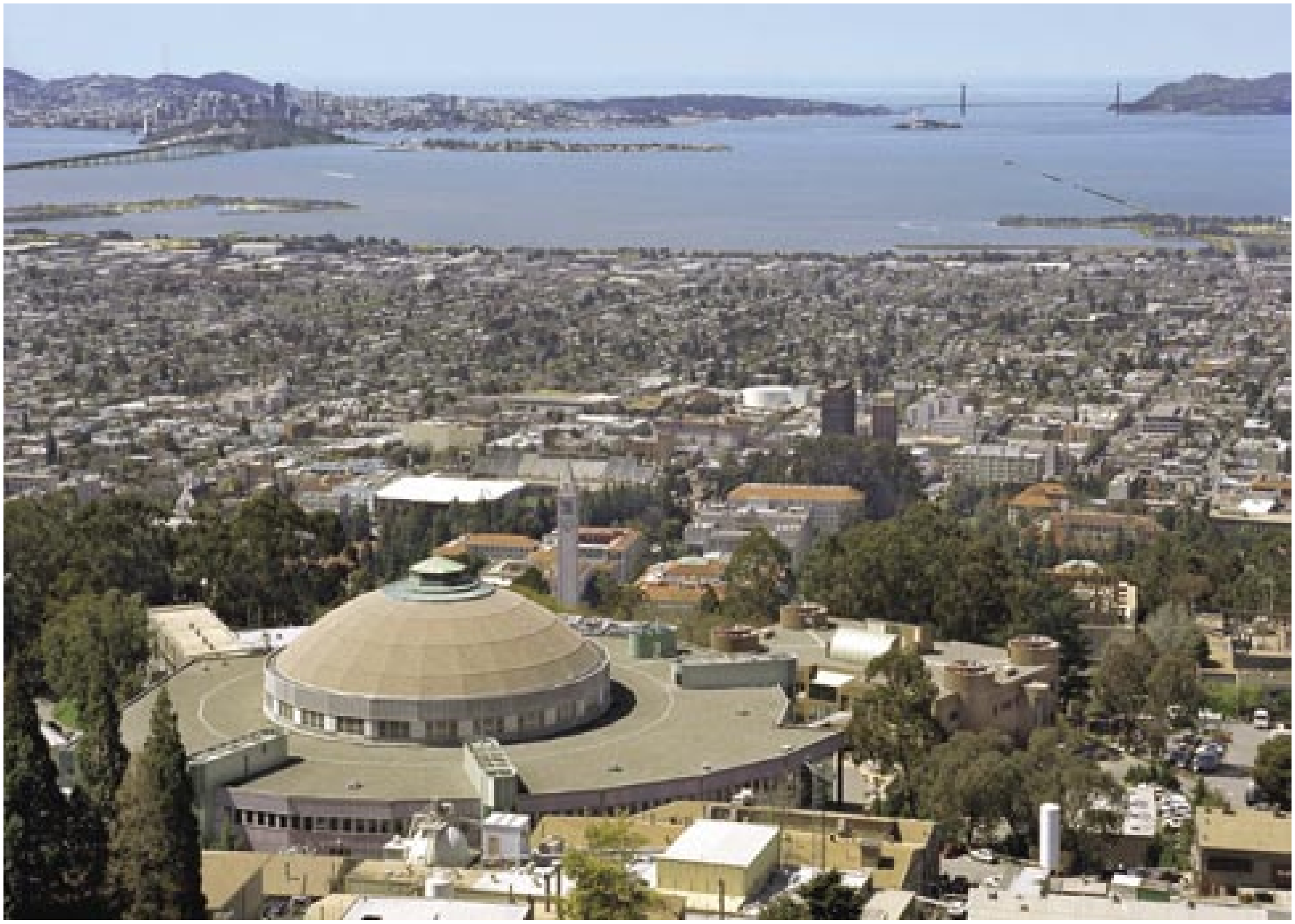
IDAHO NATIONAL LABORATORY

In operation since 1949, the Idaho National Laboratory (INL) is a science-based, applied engineering national laboratory dedicated to supporting the U.S. Department of Energy's (DOE) missions in nuclear and energy research, science, and national defense. The INL offers research opportunities in Generation IV Nuclear Systems, National Security, Advanced Computing and Collaboration, Subsurface Science, Biotechnology, and Engineering.

The laboratory is administered by DOE's Office of Nuclear Energy, Science and Technology. The INL is a major contributor to the international efforts to design Generation IV nuclear energy systems and advanced proliferation-resistant fuel cycle technology. It is home to one of the largest concentration of technical professionals in the northern Rocky Mountain region.

Located in southeast Idaho, the INL covers 890 miles of the Snake River Plain between Idaho Falls and Arco, Idaho. Offices and laboratories are also in the city of Idaho Falls (population 50,000), located about two hours from Grand Teton and Yellowstone national parks and other areas offering prime recreational opportunities.

LAWRENCE BERKELEY NATIONAL LABORATORY



Lawrence Berkeley National Laboratory's research and development includes new energy technologies and environmental solutions with a focus on energy efficiency, electric reliability, carbon management and global climate change, and fusion. Frontier research experiences exist in nanoscience, genomics and cancer research, advanced computing, and observing matter and energy at the most fundamental level in the universe.

Ernest Orlando Lawrence founded the Berkeley Lab in 1931. Lawrence is most commonly known for his invention of the cyclotron, which led to a Golden Age of particle physics—the foundation of modern nuclear science—and revolutionary discoveries about the nature of the universe. Berkeley Lab's Advanced Light Source is its premier national user facility centrally located on the lab site overlooking the San Francisco Bay.

LAWRENCE LIVERMORE NATIONAL LABORATORY


Lawrence Livermore National Laboratory (LLNL) is a premier applied science laboratory that is part of the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE). With more than 8,000 employees, LLNL is located on a one-square-mile site in Livermore, CA. A larger (10 square miles) remote explosives testing site (Site 300) is situated 18 miles to the east.

LLNL is managed by the University of California (UC) for the National Nuclear Security Administration (NNSA) within the Department of Energy (DOE). Being part of the University helps foster intellectual innovation and scientific excellence. This University connection allows LLNL to recruit and retain a diverse world-class workforce and partner with the UC's extensive research and academic community. These factors are essential to sustaining the laboratory's scientific and technical excellence.

Lawrence Livermore National Laboratory (LLNL) is a national security laboratory with responsibility for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. LLNL also applies its special expertise and multidisciplinary capabilities to prevent the spread and use of nuclear and other weapons of mass destruction and strengthen homeland security.

LLNL has pioneered the application of many technologies-from high-performance computers to advanced lasers-to meet national security needs. Today, the special capabilities developed for our stockpile stewardship and nonproliferation activities enable us to also meet enduring national needs in conventional defense, energy, environment, biosciences, and basic science. Research programs in these areas enhance the competencies needed for the laboratory's national security mission.

LOS ALAMOS NATIONAL LABORATORY

The Los Alamos National Laboratory (LANL), located in the Jemez Mountains of northern New Mexico, offers the opportunity for students to work at a multi-disciplinary, world-class research facility while enjoying a truly unique environment. Long known for its artistic community, northern New Mexico also offers a variety of exciting outdoor recreational opportunities, including rock climbing and hiking in the adjacent mountains and canyons, proximity to the Rocky Mountains, and exceptional skiing opportunities at many nearby locations.

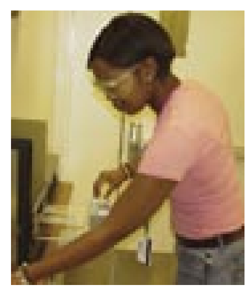
We offer a diverse research experience for undergraduate and graduate students as a means of assuring the continued vibrancy of the science, engineering, and technology at the laboratory. Serve your internship with us and you will have the opportunity to work in a team environment with some of the world's top scientists and engineers on critical issues involving our national security, environment, infrastructure, and security. We offer internship opportunities in areas that include: Biology, Chemistry, Computer Science, Physics, Mathematics, Materials Science, Environmental Science, and Engineering: Chemical, Civil, Computer, Electrical, Mechanical, Nuclear, Software.

If you are a problem solver and independent thinker, a team player, a good communicator, like a hands-on approach, and are self-motivated, we offer you the challenge of an internship at Los Alamos National Laboratory.

NATIONAL RENEWABLE ENERGY LABORATORY

The National Renewable Energy Laboratory (NREL) is the Department of Energy's primary national laboratory for renewable energy and energy efficiency research and development. From harvesting energy from the sun and wind, to advancing automotive systems, to developing biodegradable plastics form corn stalks, NREL develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals. NREL is home to three nationals centers of excellence: the National Center for Photovoltaics, the National Bioenergy Center and the National Wind Technology Center.

NREL has been awarded 37 R& D awards with two being awarded in 2004. NREL's research programs include basic energy research, photovoltaics, wind energy, building technologies, biomass power, biofuels, fuels utilization, solar industrial technologies, solar thermal electric, hydrogen, geothermal power, superconductivity, economic and policy analysis of renewable technologies, international development of renewable energy, and advanced vehicle technologies. *Research and Development*, *Discover*, *Scientific American* and *Popular Science* magazines have ranked many of NREL's research achievements among the nation's most significant technical innovations. NREL was recognized as one of the "Scientific American 50" for their contribution to science and technology.

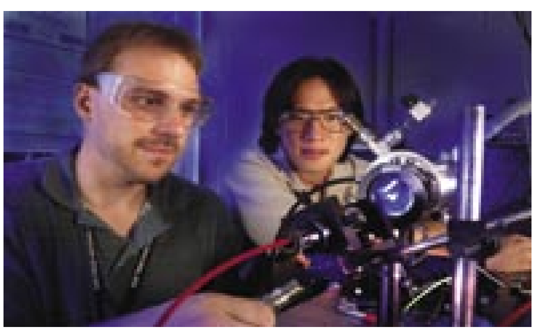


Innovative, challenging and dynamic—that's our culture. If you are interested in a research internship with an institution that believes creativity and individual uniqueness are at the core of our success, then explore your options at: www.nrel.gov. We value intern talent that adds to the rich pool of research findings produced by NREL each year. Intern accomplishments include:

- More than 11 students have been selected by the Office of Science to present major NREL research at the AAAS
- More than 50 past student interns have been hired on to join the NREL family
- Teacher researchers have produced over 50 renewable energy lessons for the classroom
- NREL's Office of Education partners with over 75 universities throughout the nation

NREL's main 327-acre site is in Golden, Colorado, just west of Denver. The Laboratory also operates the National Wind Technology Center on 307 acres about 20 miles north of Golden, adjacent to the Department of Energy's Rocky Flats Environmental Test Site. We are an equal opportunity employer committed to diversity.

OAK RIDGE NATIONAL LABORATORY



Oak Ridge National Laboratory is the Department of Energy's largest science and energy laboratory. Managed since April 2000 by a partnership of the University of Tennessee and Battelle, ORNL was established in 1943 as a part of the secret Manhattan Project to pioneer a method for producing and separating plutonium. More than 60 years later, ORNL's mission is to conduct basic and applied research that provides innovative solutions to complex problems.

ORNL, with funding that exceeds $1 billion, has a staff of more than 3,800 and approximately 3,000 guest researchers who spend two weeks or longer each year in Oak Ridge. The laboratory's six major scientific competencies, in support of DOE's Office of Science, include neutron science, energy, high performance computing, complex biological systems, advanced materials and national security.

ORNL is in the final stages of a $300 million project to provide a modern campus for the next generation of great science. A unique combination of federal, state and private funds is building 13 new facilities. Included in these new facilities will be the Functional Genomics Center, the Center for Nanophase Materials Science, the Advance Materials Laboratory, and the joint institutes for Computational Science, Biological Science and Neutron Science. ORNL has been selected as the site of the Office of Science's National Leadership Computing Facility for unclassified high-performance computing. On budget and on schedule for completion in 2006, the $1.4 billion Spallation Neutron Source will make Oak Ridge the world's foremost center for neutron science research.

UT-Battelle has provided more than $6 million in support of math and science education, economic development and other projects in the greater Oak Ridge region.

PACIFIC NORTHWEST NATIONAL LABORATORY

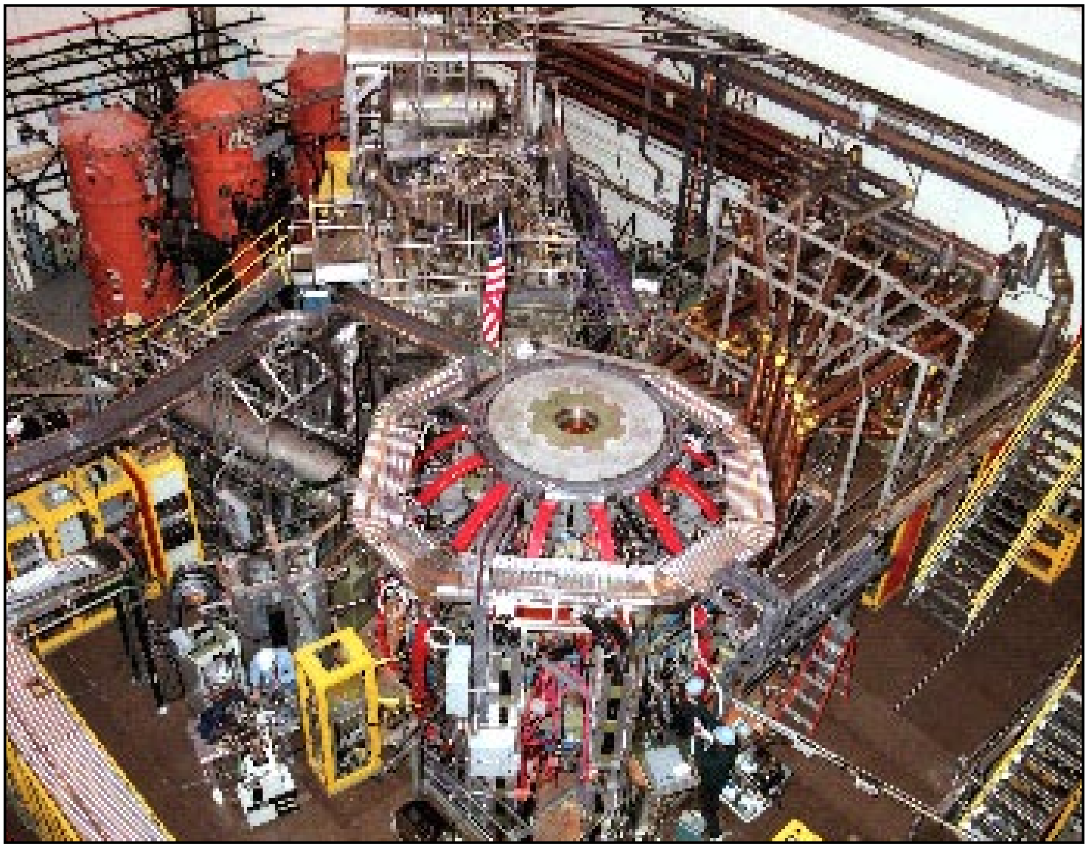
Pacific Northwest National Laboratory (PNNL) is a multi-purpose national laboratory dedicated to delivering innovative science-based solutions to some of the nation's most pressing problems. PNNL conducts fundamental and applied research to address important issues including securing our homeland, reducing our dependence on foreign oil, transforming the energy system, making information access easier, and protecting our natural resources.

PNNL's facilities form a world-class campus, including many laboratories recognized as best-in-class for many research areas. With an international reputation for studies in chemistry, biology, computer sciences, and a wide range of other fields, award-winning PNNL researchers rapidly translate theory into concrete solutions. Many of the laboratory's technologies have been developed into common consumer and industrial products including the compact disc (CD).

The Laboratory consistently attracts some of the world's leading scientific talents shaping the future of science through a variety of on-site educational programs. As mentors and research partners, the laboratory's staff trains young scientists and engineers to become tomorrow's inventors. Student research opportunities at PNNL include appointments in atmospheric science and global change, computational sciences, experimental chemistry, marine sciences, molecular biology, environmental studies, remediation, environmental microbiology, wildlife and fisheries biology, materials research, process science and engineering, economics and political science.

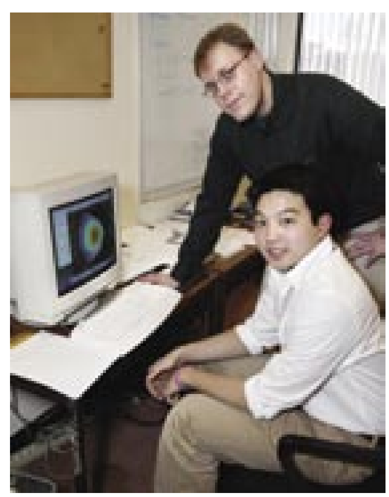
Located in southeastern Washington near the base of the Blue Mountains and the confluence of the Columbia, Snake and Yakima rivers, PNNL staff enjoy year around recreation, locally-produced fine wines, and the community's commitment to the arts.

PRINCETON PLASMA PHYSICS LABORATORY



The world's reliance on fossil fuels is imperiling our environment. Fusion, the energy source of the sun and the stars, offers an inexhaustible alternative. A fusion-powered electric generator would not produce hydrocarbon emissions, greenhouse gases, or long-lived radioactive waste; nor would it emit chemicals that cause acid rain. Consequently, the U.S. Department of Energy (USDOE) Office of Science has made the development of commercial fusion power one of its highest priorities.

USDOE's Princeton Plasma Physics Laboratory (PPPL) is one of the world's leading facilities for fusion R&D. Currently the laboratory operates the National Spherical Torus Experiment (pictured above) and is designing the National Compact Stellarator Experiment, both use magnetic fields to confine hot ionized gas (plasma) that serves as the fusion fuel. PPPL's theoretical physicists are developing computational physics models that can predict how various plasma configurations will perform, saving time and money.



PPPL experimental physicists collaborate with their colleagues worldwide in a free, mutually beneficial, exchange of information. Princeton researchers and engineers are using knowledge and skills gained in fusion research to solve other problems, including the development of plasma-based propulsion systems for space vehicles, studies of plasma phenomena that occur in the sun's corona and the earth's magnetosphere, and research on plasma sterilization of plastic food and beverage containers. PPPL is located about three miles from Princeton University's main campus in Princeton, NJ.

STANFORD LINEAR ACCELERATOR CENTER

The Stanford Linear Accelerator Center (SLAC) is one of the world's leading fundamental science research laboratories. SLAC designs, constructs and operates state-of-the-art particle accelerators and related experimental facilities used in physics studies probing the fundamental forces and structure of matter. The Stanford Synchrotron Radiation Laboratory (SSRL), a premier national user facility at SLAC, enables research requiring ultra high-intensity x-ray beams for molecular and atomic scale studies in physics, biology, chemistry, medicine, and environmental science. The Linac Coherent Light Source, a facility to provide even more intense x-ray capability is under development.

The BABAR experiment, an international collaboration investigating matter/anti-matter asymmetry, is the current focus of the high-energy physics program. In addition a vigorous R&D program is focused on development of the Next Linear Collider, as part of a world-wide effort for this future facility for high energy physics. The Kavli Institute for Particle Astrophyics and Cosmology, which began operation this year, is a joint SLAC/Stanford program with both experimental and theoretical activity at SLAC. SLAC is operated by Stanford University for the Department of Energy, Office of Science and is located at Stanford University, about 40 miles south of San Francisco, California.

THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

The Thomas Jefferson National Accelerator Facility (Jefferson Lab) is a U.S. Department of Energy, Office of Science national laboratory built for nuclear physics research located in Newport News, Virginia. As a user facility for university scientists worldwide, its primary mission is to conduct basic research that builds a comprehensive understanding of the atom's nucleus. With industry and university partners, it has a derivative mission as well: applied research for using Free-Electron Lasers based on technology the laboratory developed to conduct its physics experiments. As a center for both basic and applied research, Jefferson Lab also reaches out to help educate the next generation in science and technology.

Superconducting electron-accelerating technology makes the laboratory unique. Researchers use Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF)—the technology's first large-scale application anywhere—to conduct experiments. With high-energy electron beams from the accelerator, experimenters probe the subnuclear realm, revealing for the first time how quarks make up protons, neutrons, and the nucleus itself. Using this same superconducting electron-accelerating technology, Jefferson Lab and industry have constructed a laser of unprecedented power and versatility called a free electron laser. This laser offers unique capabilities for basic research and manufacturing processes.