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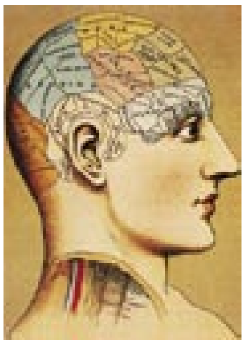
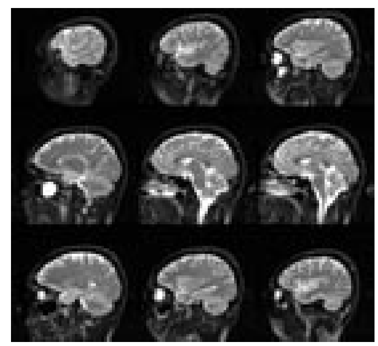
ABOUT THE COVER

MEDICAL IMAGING: PAST, PRESENT AND FUTURE

This radiograph is one of the first ‘x-ray’ images ever taken. Wilhelm Conrad Roentgen (1845-1923) took this image of the hand of his co-worker, Albert von Kolliker. It was shown for the first time at the conclusion of a lecture and demonstration at the Wurzburg Physical-Medical Society on 23 January 1896. In 1901 Roentgen was awarded the first ever Nobel Prize in physics for his discovery.
http://www.xray.hmc.psu.edu/rci/ss1/ss1_2.html



Before modern cognitive science and neurology was phrenology. This was the “science” of character divination, faculty psychology, theory of the brain, and what the 19th-century phrenologists called “the only true science of mind.” Phrenology came from the theories of the idiosyncratic Viennese physician Franz Joseph Gall (1758-1828). This diagram shows where phrenologists believed functions of the brain were located.



This magnetic resonance image (MRI) is the brain of one of the summer 2004 Science Undergraduate Laboratory Internship (SULI) students at the Stanford Linear Accelerator Center (SLAC). MRI’s use a very powerful magnet to re-align the magnetic moments of atoms in the patient. Different tisses will return to their relaxed state in different amounts of time. This allows the machine to identify the tissue as it scans the entire subject. The image shown required three minutes to scan. Current research is focused on functional MRI, which can measure changes in the brain based on activities.

This is a photograph from the Positron Emission Tomography (PET) facility at Brookhaven National Laboratory. The PET facility at BNL is a world leader in brain research, including how drugs, mental illness, nicotine, alcohol and even normal aging affect the brain. This device uses gamma ray detectors to measure decays from radioisotopes that are injected into the patient. Different radioisotopes can be used to ‘tag’ different molecules and observe biological processes in the body.
http://www.bnl.gov/pet

This photograph shows a mockup of a portable Positron Emission Tomography (PET) scanner that will be used to image the brain of an awake rat. Presently, animals used in developing drugs for humans must be anesthetized in order to obtain PET images. However, the anesthesia often interferes with the brain functions being studied. This device will allow images to be obtained without the use of anesthesia and will also allow the study of behavior during the PET scan. The work is being carried out at Brookhaven National Laboratory in collaboration with Stony Brook University, and is supported by the Department of Energy¹s Office of Biological and Environmental Research. First tests of the actual device are expected by the end of 2004.
http://www.chemistry.bnl.gov/ratcap/

A NOTE FROM THE EDITOR:

WHERE WILL YOUR EDUCATION AND IMAGINATION TAKE YOU?

There are a host of reasons why any one of us chooses to go to college. One of the primary considerations is to choose the educational institution that can provide the major field of study we want to pursue. The importance placed on choosing a major field of study becomes most acute for those who see it as the gateway to entering their desired profession. One thing seems evident…the main objective of attending college is to get an education, and the immediate object of an education is to learn. We learn generally two things in our education…information and what we can do with that information. Most people would agree that what we do with information is what makes the information valuable, and what each of us does, to some degree, is what makes each of us valuable. I suppose that is why so many people place so much personal worth on what they do.

In our modern society, one of the "rights of passage" to independence is graduation from college and taking the first steps in a "career". In some respects, the word career is an overstatement in that it suggests a definite path through a professional life. The only certainty here is that the path through any career is uncertain. For the sake of clarity, we might choose to make a distinction between a career and a profession. A career might be defined as "the general course or progression of one's working life or one's professional achievements," while a profession could be defined as "an occupation, such as law, medicine, or engineering, that requires considerable training and specialized study." Framed in these terms, we might choose a profession for our lives but the careers we follow will be far more uncertain. I know professionals who, as they move through their careers, still define themselves by the professions for which they received their most intensive training. For example, I am a biologist and my career might take me in many directions, but I will always be first and foremost a biologist. I will always look at the world with the eyes of a biologist and take interest when I listen to engineers or physicists speaking on the same issues I am speaking, but through the eyes of their respective "professions".

After the years we spend in school and in training, we will eventually enter the workforce in a "chosen" profession. The object here is to be the one who is doing the choosing. The economic and employment landscape that faces us when we graduate might be quite different than when we entered college. Engineers, for example, have often seen quite dramatic oscillations in employment. This can leave an individual with few choices, particularly if their education did not build in the breadth and agility they need to be able to adapt to changes in their profession. For those who have worked hard in college, choices in employment are generally limited more by imagination than education.

My experience has been that the students who have acquired a good set of technical skills (e.g., instrumentation and advanced scientific techniques) in combination with solid proof of writing and verbal skills, have found the easiest route to rewarding jobs in and out of their professions. This is one of the strongest reasons why we created our journal and encourage poster presentations of research. They are opportunities for our students to show how they applied their technical skills in an advanced research setting and then clearly communicate their research to the scientific community.

The extent of our education is a particularly interesting element of our careers. Certain professions will completely lock out people without advanced degrees – medical doctors and lawyers, for example. But there is often a tendency to dwell on the Ph.D. degreed professionals. It is instructive to remember that for every Ph.D. in most scientific fields there are more than a dozen masters and bachelor degreed people working. Although some people still think of a scientist as only those with a Ph.D., this is an outdated notion. There are many people with bachelors and/or masters degrees who find themselves working side by side with “terminally” degreed people. These people have positions that are just as rewarding, both monetarily and intellectually. A strong argument can be made for anyone to think carefully before deciding to pursue a Ph.D. This is not to discourage anyone in this regard, but to free you from the notion that you can be a scientist only if you have a Ph.D. degree.

Peter Faletra, Ph.D.

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STUDENTS AS SCIENTISTS: THE BENEFITS OF MENTORED RESEARCH EXPERIENCES AT DOE NATIONAL LABS

A recent study found that 38% of Ph.D. scientists and engineers working in the U.S. were born outside the country. The three-year study was conducted by the National Science Foundation's National Science Board taskforce on U.S. workforce trends in science and engineering. The taskforce also found that the U.S. is losing its ability to import foreign scholars, due to increasing foreign competition for science and engineering professionals and increased difficulty for foreigners to obtain appropriate visas. To meet future economic and national security needs, the National Science Board recommended the U.S. develop programs to "increase the numbers of U.S. citizens pursuing science and engineering studies and careers".[1]

One way we, as educators, can address these issues is to increase students' interest in science and engineering careers. That means more than motivating students to learn science, it means giving them opportunities to conduct hands-on science research. The Science Undergraduate Laboratory Internship (SULI) program, an undergraduate research program administered by the U.S. Department of Energy's Office of Science, does just that. The SULI program is a paid internship that places students at DOE National Labs for a period of 10 or 16 weeks. Students are assigned a research project and placed under the guidance of a mentor. The goal of the program is to expose undergraduates to real research conditions at world-class research facilities.

"...a program like this allows students who are not fully engaged by classroom learning to succeed in the more interactive environment of the research arena"

What exactly does a research internship like this add to the undergraduate experience? Research experiences are an effective way to learn. Involving undergraduate students in research allows students to experience scientific research firsthand and see how the scientific community really works. What's more, a program like this allows students who are not fully engaged by classroom learning to succeed in the more interactive environment of the research arena. A 2003 study of retention in graduate programs conducted by the Educational Testing Service found that undergraduate students who conducted research received more prestigious fellowships and were more likely to complete a doctoral degree.[2] Thus, participating in a research internship better prepares students to make important decisions about their educational future. At the Department of Energy's Thomas Jefferson National Accelerator Facility, students in the SULI program: (1) learn about the research process and gain valuable hands-on research experience by working on unsolved, open-ended research problems; (2) learn to think analytically and logically as they put ideas together; (3) increase their disciplinary knowledge and their understanding of how that knowledge is applied; (4) learn about the world of graduate school life; and (5) are provided with opportunities to interact with working scientists. According to Sarah Phillips, Jefferson Lab SULI student, 1998

– 1999, “My experience in the undergraduate research program at Jefferson Lab was a crucial part of my decision to become a particle physicist. Before that summer, I was unsure of what a physicist really did, since my only experience was with classes. In working with Dr. Allison Lung on the G0 experiment, I found a mentor who demonstrated what a career in physics truly entailed. She also guided me to other opportunities to further my education. At JLab, I had the thrill of applying my skills and working with people from all over the world toward a common goal: learning more about the physics of the nucleus. I wanted to continue in this goal, and so I went to the College of William and Mary as a graduate student, received my Master’s degree, and am presently pursuing my Ph.D.”

Research internships can greatly enrich the undergraduate education experience by providing students with opportunities to discover new knowledge alongside working scientists – their mentors. In simple terms, a mentor is a teacher who guides and motivates by example, who encourages students’ making of creative mistakes, and who challenges students to arrive at solutions for avoiding similar mistakes in the future. Dr. Douglas Higinbotham, a Jefferson Lab scientist and SULI mentor since 2002, says, “I want SULI students to leave the program knowing what graduate research and life is going to be like; and if they come out of the program with the information they need to figure out if they want to pursue graduate research, we have succeeded. For the ones that decide that basic research is not what they want to do, I feel that they will at least carry an appreciation of basic science with them for the rest of their lives.” Research often requires skills that differ from those required to successfully complete traditional coursework.[3]

“My experience in the undergraduate research program at Jefferson Lab was a crucial part of my decision to become a particle physicist.”

Mentors, like Dr. Higinbotham, often observe the disconnect that students feel between their classroom experience and the realities of doing research. In the classroom, experiments are designed to work; but in a research experience, students often work on experiments that have never been done before. These experiments may not go as planned or may yield unexpected results. Undergraduate students who serve on a research team experience the rewards, challenges and frustrations of original research, and they develop critical thinking skills as they analyze unexpected results and conclusions. SULI students at Jefferson Lab not only collect and analyze data, but they also present it in both written and oral forms. They are taught that presenting experimental results is a very important part of the scientific process, and they’re encouraged to take advantage of every opportunity to do so. As future scientists, students must learn to present ideas and results to their colleagues, as well as to the general public and specialists in other fields. Scientists need to ensure that the public is aware of and understands what research is and why it is important. SULI students learn to explain their work in ways that the public can understand, making the students better advocates for science. Students who complete a research internship at a DOE National Lab develop effective research skills, improve their critical thinking abilities, and enhance their communication skills. Most importantly, exposing undergraduates to research increases their interest in science and engineering careers. Allowing undergraduates to experience life as a research scientist firsthand encourages students to go back to the classroom, complete their graduate education and enter the workforce as Ph.D. scientists in the field of their choice.

Jan Tyler

Thomas Jefferson National Accelerator Facility

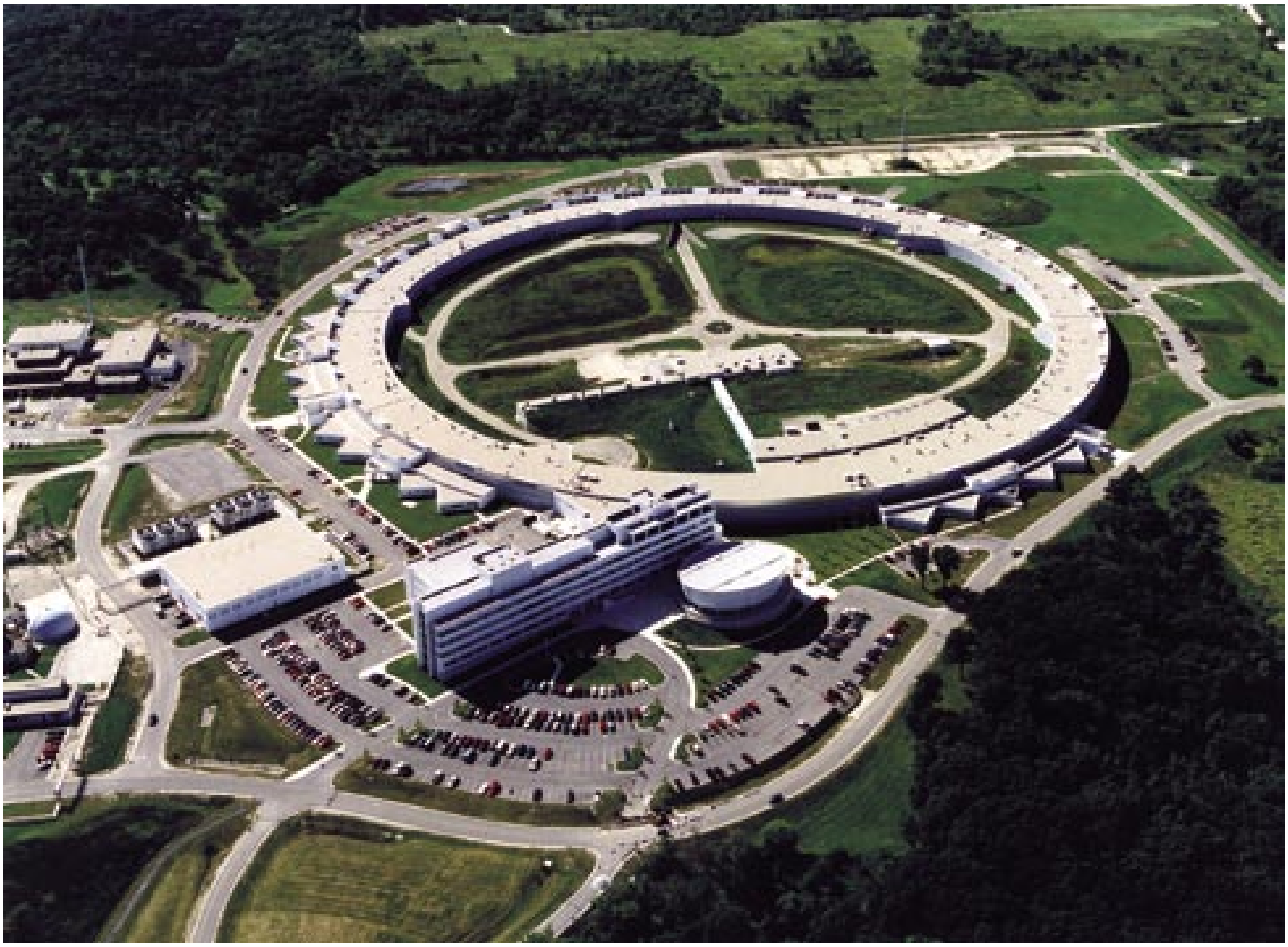
National Academy of Sciences (1997). Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering. National Academy Press

1 "National Science Board, Citing Census Stats on Foreign-Born Scientists and Engineers, Releases Workforce Report with New Sense of Urgency" National Science Foundation Press Release November 2003

2 Bishop, Patricia (2004) "Undergraduate Research Programs and Their Benefit to Graduate Education" Graduate News, January 2004

3 Ishiyama, John (2002) "Participation in Undergraduate Research" College Student Journal, September 2002

ARGONNE NATIONAL LABORATORY



Argonne National Laboratory (ANL) is a Department of Energy, Office of Science facility. Argonne occupies two sites. The Illinois site is surrounded by a forest preserve about 25 miles southwest of Chicago's Loop. About 3,200 of Argonne's 4,000 employees work at the Illinois site. Argonne-West occupies about 900 acres about 50 miles west of Idaho Falls in the Snake River Valley. It is the home of most of Argonne's major nuclear reactor research facilities. About 800 of Argonne's employees work there.

ANL was once again recognized for its outstanding science this year. The 2003 Nobel Prize in physics was shared with Alexi Abrikosov, of the Argonne National Laboratory's Materials Science Division. Research at ANL includes basic experimental and theoretical work in materials science, physics, chemistry, biology, high-energy physics, mathematics and computer science. Biomedical research includes pioneering work in cancer diagnosis and therapy. ANL scientists and engineers are developing advanced batteries and fuel cells, as well as advanced electric power generation and storage systems. ANL has developed many of the technologies for nuclear power reactors in operation today, and is developing systems for the future. In addition the lab is working on many environmental concerns including spent nuclear fuel disposal, and new technologies for decontaminating and decommissioning aging nuclear reactors. ANL is home to the Advanced Photon Source, a 1,104 meter circumference synchrotron radiation light source producing high-brilliance x-ray beams used to carry out basic and applied research in the fields of biology, physics, chemistry, environmental, geophysical, and planetary sciences along with innovative x-ray instrumentation. The facility is used by scientists at Argonne and other National Laboratories as well as universities, private companies and scientists from other nations.

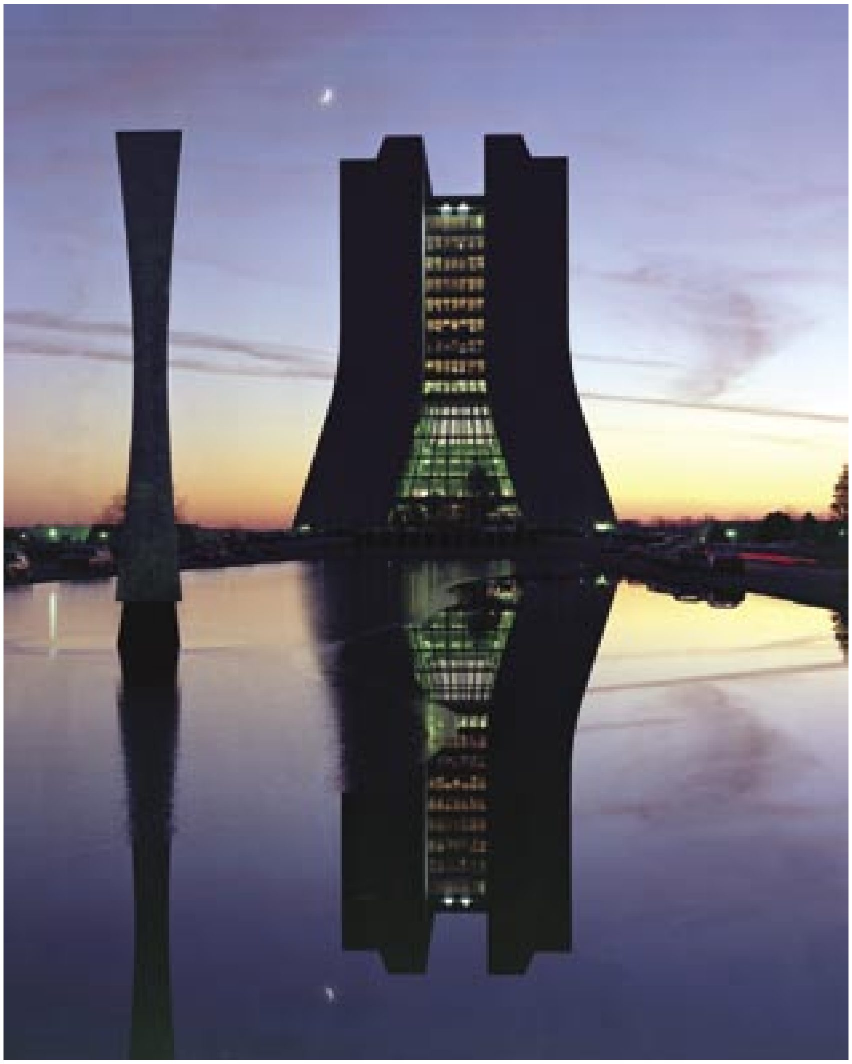
BROOKHAVEN NATIONAL LABORATORY

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 89 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 45 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 ENGINEERING AND ENVIRONMENTAL LABORATORY

The Idaho National Engineering and Environmental Laboratory (INEEL) is a multi-purpose National Laboratory delivering specialized science and engineering solutions for the Department of Energy (DOE). The INEEL offers research opportunities in Generation IV Nuclear Energy Systems, National Security, Advanced Computing and Collaboration, Subsurface Science, Environmental Stewardship, Advanced Waste Management Solutions, Biotechnology, and Engineering.

The laboratory is administered by DOE's Office of Nuclear Energy, Science and Technology. The INEEL, in partnership with Argonne National Laboratory-West, will become a major contributor to Generation IV nuclear energy systems and advanced proliferation-resistant fuel cycle technology. It is home to one of the largest concentrations of technical professionals in the northern Rocky Mountain region.

Located in southeastern Idaho, the INEEL covers 890 square miles of the Snake River Plain between Idaho Falls and Arco, Idaho. Offices and laboratories also are 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.

NATIONAL RENEWABLE ENERGY LABORATORY

The National Renewable Energy Laboratory (NREL) is the nation's leading National Laboratory for research and development in renewable energy and energy efficiency technologies. NREL's mission is to develop renewable energy and energy efficiency technologies and practices, advance related science and engineering, and transfer knowledge and innovations to address the nation's energy and environmental goals.

NREL's research programs include basic energy research, photovoltaics, wind energy, building technologies, biomass power, biofuel, 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. NREL was selected for their work in increasing the efficiency of photovoltaic solar cells. NREL's research into multi-junction solar cells has led the way to more efficient cells, offering the potential of cheaper electricity from the sun. Multi-junction solar cells use multiple layers of semiconductor material to absorb light and convert it into electricity more efficiently than single-junction cells. The cost of electricity from photovoltaic panels that convert sunlight directly into power has dropped from several dollars per kilowatt-hour, to 20-25 cents a kilowatt-hour today. NREL's 300-acre campus is nestled at the foot of South Table Mountain in Golden, Colorado.

OAK RIDGE NATIONAL LABORATORY

Originally known as Clinton Laboratories, Oak Ridge National Laboratory (ORNL) was established in 1943 to carry out a single, well-defined mission: the pilot-scale production and separation of plutonium for the World War II Manhattan Project. From this foundation, the laboratory has evolved into a unique resource for addressing important national and global energy and environmental issues. Today, ORNL pioneers the development of new energy sources, technologies, and materials and the advancement of knowledge in the biological, chemical, computational, engineering, environmental, physical, and social sciences.

In addition, ORNL is responsible for the civil construction, project management, design integration, and ultimately the operation of the Spallation Neutron Source (SNS). Designed and constructed by a partnership of six Department of Energy National Laboratories (Argonne, Berkeley, Brookhaven, Jefferson, Los Alamos, and Oak Ridge), the SNS is a new, accelerator-based science facility that will provide neutron beams greater than ten times more intense than any other such source in the world. SNS will provide the opportunity for up to 2,000 researchers each year from universities, National Labs, and industry for basic and applied research and technology development in the fields of materials science, magnetic materials, polymers and complex fluids, chemistry, and biology.

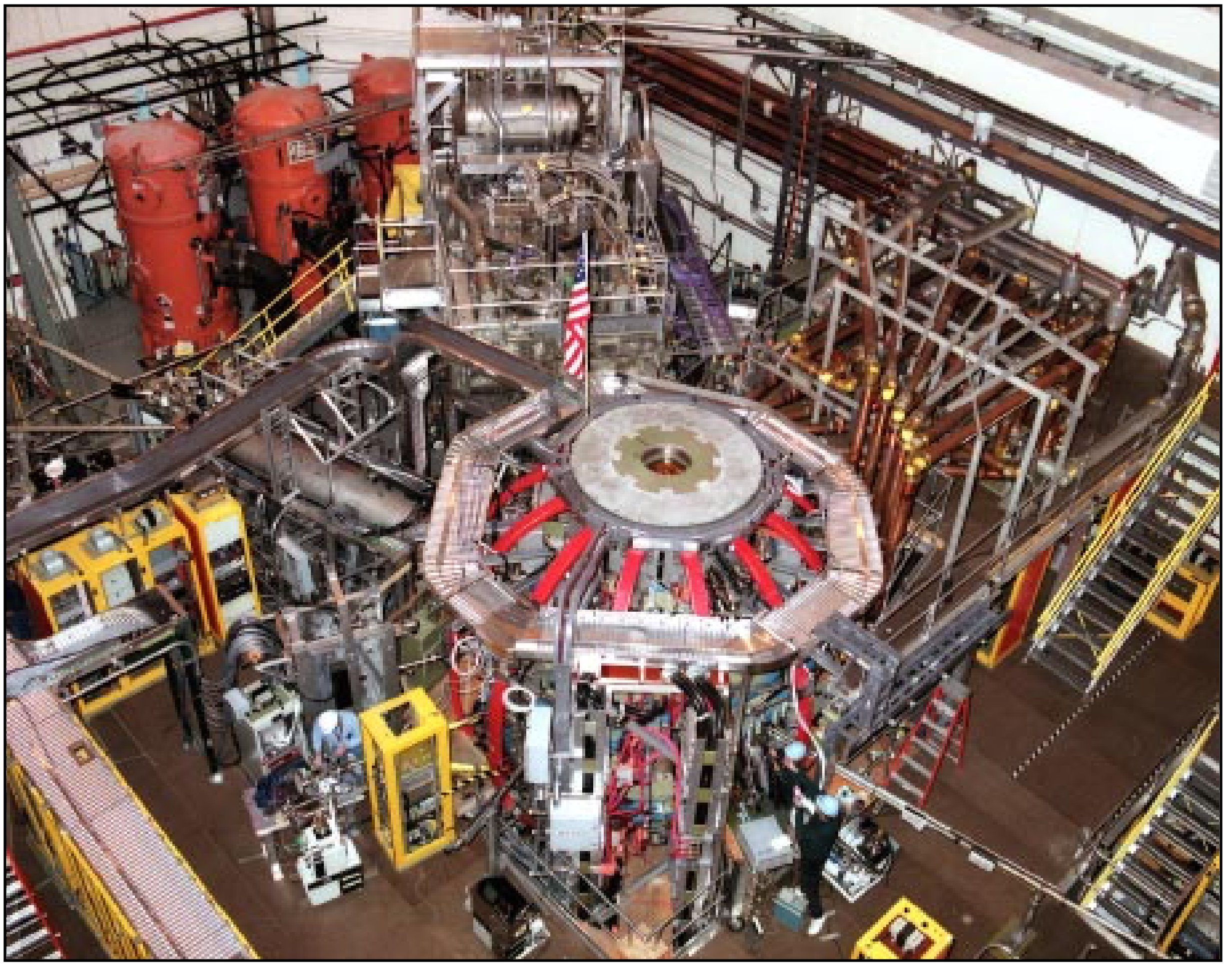
PACIFIC NORTHWEST NATIONAL LABORATORY

Pacific Northwest National Laboratory (PNNL) delivers breakthrough science and technology to meet key national needs. Pacific Northwest applies its capabilities to meet selected environmental, energy, health and national security objectives, strengthens the economy, and supports the education of future scientists and engineers.

Pacific Northwest performs basic and applied research to deliver energy, environmental, and national security for our nation. The Laboratory is recognized worldwide and valued regionally for its leadership in integrating chemical, physical, and biological sciences to rapidly translate discoveries into solutions to challenges in energy, national security, and the environment. The laboratory has built an international reputation through fundamental studies in chemistry, biology, computer sciences, and a wide range of other fields. This expertise has been developed through an emphasis on understanding complex systems, from molecular to global scales. Research opportunities at the laboratory for students 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.

PNNL is located at the confluence of the Columbia, Snake and Yakima rivers in southeastern Washington, the communities of Richland, Kennewick and Pasco.

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.