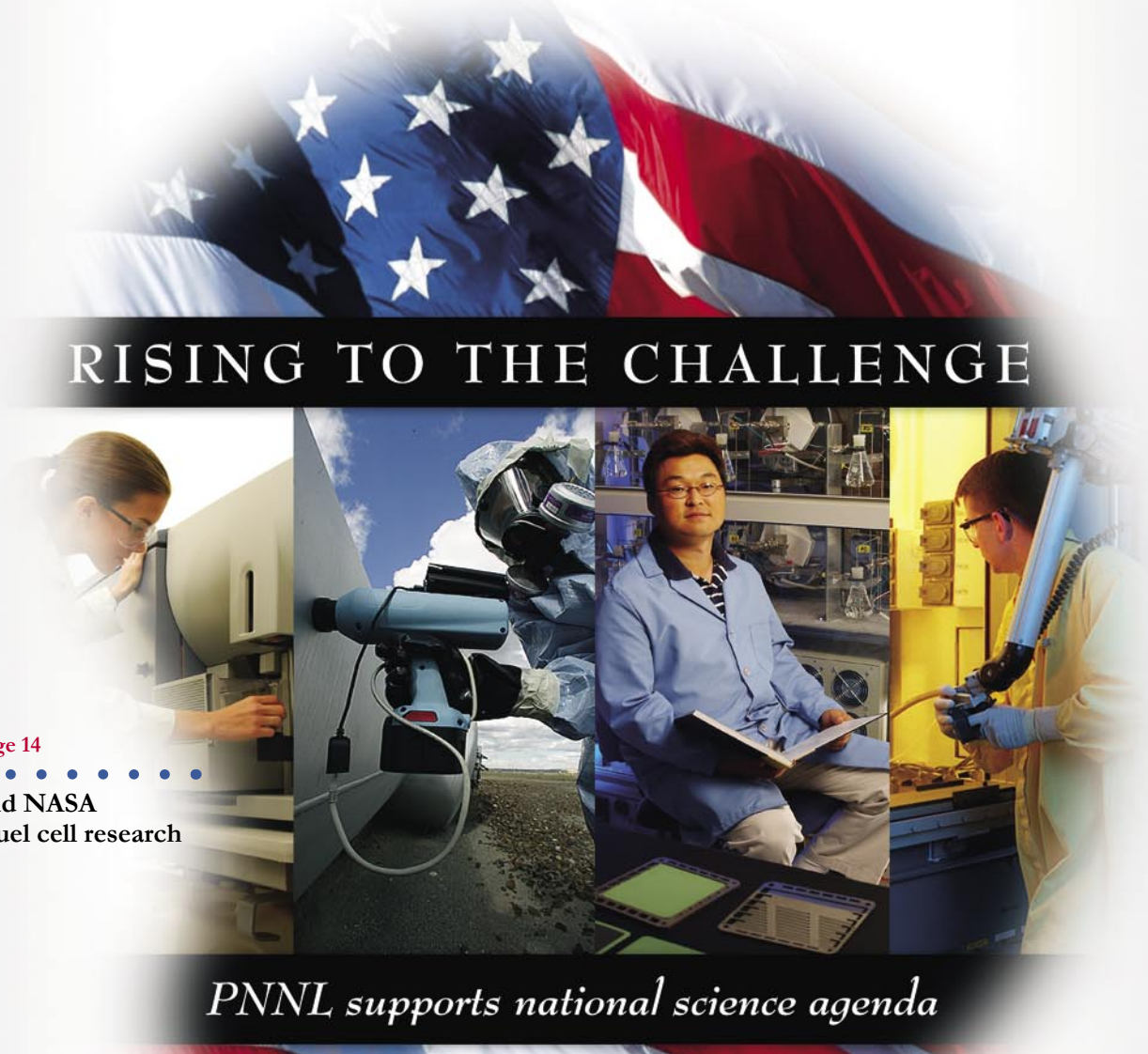
Breakthroughs

Science. Technology. Innovation.

WINTER 2004



RISING TO THE CHALLENGE

PNNL supports national science agenda

Inside | Page 14

PNNL and NASA team on fuel cell research

Inside | Page 15

Spectral library helps monitor chemicals

PACIFIC NORTHWEST NATIONAL LABORATORY

OPERATED BY BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

Breakthroughs

Published by: Pacific Northwest National Laboratory, a multiprogram research facility operated by Battelle for the U.S. Department of Energy's Office of Science.

Staff:
Editor: Ginny Sliman
Associate editor: Tim Ledbetter
Writers: Lisa Brown, Bill Cannon, Sue Chin, Judy Graybeal, Tim Ledbetter and Ginny Sliman
Graphic design: Chris DeGraaf

Frequency: Four times a year

Subscription price: Free
Current edition, archives and subscription information available at http://www.pnl.gov/breakthroughs

Direct general inquiries and distribution questions to:
Ginny Sliman
Phone: 509-375-4372
Fax: 509-375-6550
E-mail: virginia.sliman@pnl.gov

Direct business inquiries to:
Marketing Communications
Toll-free phone: 1-888-375-PNNL (7665)
E-mail: inquiry@pnl.gov
Web site: http://www.pnl.gov

Direct media inquiries to:
Media Relations
Phone: 509-375-3776
E-mail: greg.koller@pnl.gov

editor's screen

As our nation's leaders increasingly turn to science and technology for information to help them make important decisions—decisions that affect our health, economy and security—there is more focus on our national laboratories. Pacific Northwest National Laboratory is one of the U.S. Department of Energy's nine multiprogram national laboratories.

In this issue of *Breakthroughs*, leaders from each of PNNL's four divisions, energy, environmental technology, fundamental science and national security, discuss how each area of research at PNNL addresses President Bush's research and development agenda and their visions for beyond 2004. These "thought pieces" elaborate on research and technologies that will transform our country—from its energy systems to environmental issues and from improvements in human health to defense against terrorism.

This edition of *Breakthroughs* also takes a look at a new technology for helping disaster response teams communicate, a library that contains unique spectral signatures of hundreds of chemicals that can be used to detect toxic substances in the environment and a partnership between PNNL and NASA to advance fuel cell development.

Contents

AT A *glance*

PNNL wins record grant for proteomics center

Pacific Northwest National Laboratory has won a five-year, $10.2 million grant from the National Institutes of Health to support a center for basic research in proteomics. This is the largest NIH award in PNNL's 38-year history.

The grant designates PNNL as an NIH research resource center and will establish PNNL as a base for proteomics research worldwide. It will fund development of advanced instrumentation for studying the large and complex protein sets, which allow all living things to function. The ability to measure proteins, especially those present in trace amounts, and to observe changes in them is the key to understanding molecular-level cell function and disease progression, treatment and prevention.

The award will enable PNNL staff to collaborate on important biomedical projects with top NIH-supported researchers and expand their investigations into more complex mammalian systems relevant to human diseases. ●

DOE awards sixth "Outstanding" rating

The U.S. Department of Energy has awarded Battelle, operator of Pacific Northwest National Laboratory, an Outstanding rating for performance in fiscal year 2003. Outstanding is the highest designation bestowed by DOE. Battelle has achieved the rating annually at PNNL since 1998.

In a letter announcing the rating, DOE's Richland Operations Office Manager Keith Klein wrote, "...DOE continues to be very pleased with Battelle's overall performance. As in years past, the strong partnership between DOE and Battelle continues to move the Laboratory in an effective and efficient manner towards the future."

While some areas for improvement were identified, DOE noted the Laboratory excelled in all three categories reviewed—Scientific and Technological Excellence, Management and Operations Excellence and Leadership Excellence. ●

One person's garbage is another's power

The Marine Sciences Laboratory in Sequim, Wash., has turned to the garbage dump to power its operations. One hundred percent of MSL's electrical energy needs now are supplied by "green power" provided by methane gas from a sanitary waste landfill. Green power refers to environmentally preferred power, generated by resources regarded as having certain environmental benefits—such as wind, solar and geothermal.

Landfill gas-to-energy plants are recognized by the U.S. Environmental Protection Agency as the only renewable source of power that actually removes pollution from the air.

DOE has set a goal for each of its sites to purchase 3 percent green power by 2005 and 7.5 percent by 2010. PNNL's purchase of green power at MSL, coupled with its purchase of wind and small hydro-generated power for its operations in Richland, Wash., represents 15 percent of its total energy usage being generated by renewable sources. ●

Critical information for critical situations

Each year, tens of thousands of people around the world die in natural and human-caused disasters. In an emergency, the ability to obtain and track highly dynamic status information is crucial for control rooms, incident command centers (ICCs) and emergency operations centers (EOCs).

Researchers at Pacific Northwest National Laboratory have developed an innovative web-based operational status board (OSB) that allows the information regarding an emergency to be easily accessible to shelters, schools, hospitals and government offices. "In an emergency, getting the right information to the right people in time to make the right decisions can save lives and property," says Dave Millard, PNNL project manager.

OSB is a major component of EM*ADVANTAGE*©, a PNNL-developed emergency management system that supports all phases of emergency management and makes information available with constant, dynamic updates via desktop computer, the Internet and personal digital assistants.

Historically, emergency workers used a checklist drawn on a whiteboard as a status board within the EOC or ICC that was routinely updated. As information technology spread, status boards graduated to electronic Word documents, Excel spreadsheets and Web pages.

These techniques are adequate for sharing information within a single room. But disasters can potentially impact many different emergency response organizations and public facilities. "The timely sharing of information must be provided between EOCs, ICCs, mobile command centers, joint information centers and key public facilities as well as the general public," Millard says. "Operational status boards directly support the timely sharing of information between components of a site's extended emergency response program."

OSB has the ability to display and update dynamic information simultaneously at the diverse locations involved in emergency management. Using OSB, decision makers and emergency personnel can control the access and distribution of status information among multiple users, identify and view new information regardless of location, add or update pertinent information and share it in real time. Additionally OSB allows decision makers to update the structure and organization of an existing status board and create new status boards to respond to changing events and needs.

A key feature of OSB is the notification mechanism. As users access and view individual status boards, the notification system tracks their entry and automatically marks them as a subscriber. As a subscriber, each user will automatically receive notification of any new information relating to that specific status board.

OSB enables access to the information at an EOC from any personal computer with Internet access and a secure identification. •

special REPORT

Rising to the Challenge

PNNL supports national science agenda

In America today, our daily lives are colored by the uncertainties of war, energy shortages and a struggling economy. But confidence in science and technology to help solve these issues—and make even greater advances—remains high.

Science is fundamental to managing these daily challenges and emerging from them with a strong economy, a sustainable environment, healthy people and a peaceful world.

President Bush's research and development agenda reinforces the importance of science and technology in addressing some of the nation's most critical concerns.

The nation's research and development priorities include:

- **Understanding molecular-level life processes**
- **Ensuring a healthy environment**
- **Addressing technology barriers to a hydrogen-based economy**
- **Combating terrorism and securing the homeland.**

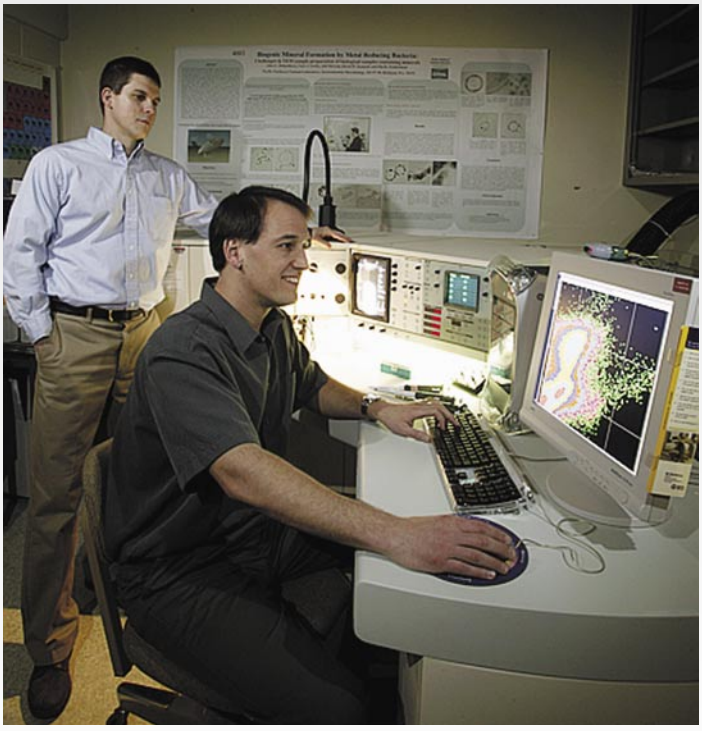
Fundamental and applied research at Pacific Northwest National Laboratory is addressing many of these R&D priorities through PNNL's work as a Department of Energy national laboratory. PNNL's four focus areas—national security, fundamental science, environment and energy—each produce breakthrough science and technology in support of our nation's needs.

Advances bring new zest to biological research

Harvey Bolton
Manager, Biological Sciences Division

The late U.S. President Herbert Hoover once remarked, "New discoveries in science...will continue to create a thousand new frontiers for those who would still adventure." Though we have witnessed significant advances in science and technology, there is much to discover. Each new understanding prompts new questions and challenges.

Such is the case with biology, the study of life. It is a fantastic time to be conducting biological science. The sequencing of the human genome—and the genomes of plants, animals and microorganisms—has provided the blueprint or "parts list" of life. Modern research capabilities, such as high-throughput mass spectroscopy, allow us to quantify all the proteins in cells. Microarray technologies can contain all the genes from an organism, permitting us to understand when these genes are expressed, and chemical analysis tools assist us in quantifying all the metabolites or small compounds resulting from the function of the cells. The information produced through these processes, when integrated in models, provides a system-level understanding of life.



Deciphering the mysteries of biological science will require outstanding research teams and state-of-the-art facilities and instrumentation. Researchers at PNNL are using high-speed flow cytometers to generate synthetic antibodies, an advance that is key to addressing a broad range of important biological problems.

At PNNL, our focus is on building a solid foundation for scientific inquiry, which includes assembling outstanding research teams. Our Biological Sciences Division, with approximately 170 staff members, is making great strides, from studying the structure and functions of single proteins on up to understanding the behavior of cells, organisms and systems. Such knowledge has multiple benefits. For example, it is key to a project we're working on for the Department of Homeland Security. This project focuses on developing antibodies that are very specific to the botulinum toxin, which could be used to harm people. Our work could lead to a method for detecting this toxin in the environment. We foresee breakthroughs in other areas, from clean energy development to carbon management, environmental cleanup and human health.

While great minds are integral to scientific inquiry, at PNNL we have done a good job of providing our great minds with unique capabilities for addressing state-of-science research questions. For example, our ultrahigh resolution mass spectrometers and separations systems provide for rapid characterization of all proteins in a cell, revealing information that allows us to study how an organism is influenced by the environment and how it interacts with other organisms. Step by step, we are building an understanding of the operation of entire biological systems.

Additionally, we are developing instruments to collect data, technologies to connect the instruments to computer networks and mathematical models that will use the data. We need to build the underlying information and computational structure that will collect all data, interpret it and help display it in ways researchers can readily understand and use.

To continue to make fundamental science discoveries for the benefit of mankind, we must continue investing. We must demonstrate the science that *could be and should be* accomplished with new tools and ideas. Along these lines, the DOE Genome Program is developing 21st century user facilities, including a whole proteome and metabalome facility, which will measure all of a cell's proteins and metabolites in a high-throughput mode.

We also need to support integration, both of scientific disciplines and capabilities, and continue collaboration with other national laboratories and internationally recognized research organizations. We value the opportunity to share our ideas and unique capabilities in integrated team science. It is one of the ways we can help answer the perplexing questions of life and successfully explore the thousands of new frontiers before us.

Systems biologists—modern-day Lewis and Clarks

Steven Wiley
Director, Biomolecular Systems Initiative

I compare PNNL's work with biological systems to the work of explorers—and settlers. We are like the explorers who set out to discover distant places, paving the way for the pioneers who settled them. In traditional biology, we have almost finished cataloging the different parts of living organisms and now we want to integrate what we know. We're ready to build the infrastructure we need to settle certain biological areas.

Systems biology is a program for understanding the network structure of cells—how cells take materials and data from their environment and process them to get energy and to get the information that allows them to survive.

All the problems we have in diseases, toxicity, dysfunctions of cells and health and illness are about a failure to communicate among cells or among organisms. We want to know how the machinery inside cells works so we can fix it if it goes wrong or modify it when we want to do other things.

The "settler" work at hand—synthesizing complex information and building a scientific infrastructure—is much more of an engineering task than a traditional biology task. The kind of expertise that biology needs to take the next big step in integrating information is in engineering and the physical and chemical sciences. We need to integrate these disciplines into biological research.

The goal of PNNL's Biomolecular Systems Initiative is to build a scientific infrastructure that allows researchers to take a systems approach to science. It's a very exciting time because, in a way, we are setting up a structure for the way science will be done 20 years from now. We're just at the beginning of this process of understanding life by understanding how cells work and understanding how to use cells to do all sorts of wonderful things.

In the Pacific Northwest, we envision a consortium of scientific and computer organizations that will turn the region into a powerhouse for personalized, predictive medicine. We're working with the Fred Hutchinson Cancer Research Center to identify biomarkers—proteins that we can find in samples of your blood to diagnose all sorts of diseases based on knowing what those protein patterns mean.

You can take a car and plug it into a computer and diagnose everything that's wrong. Why can't we take a serum sample from a person and analyze its composition in an hour, take that information, put it in a computer and say, "Oh, we know what's wrong with you."? To do that, we're going to need many new technologies.

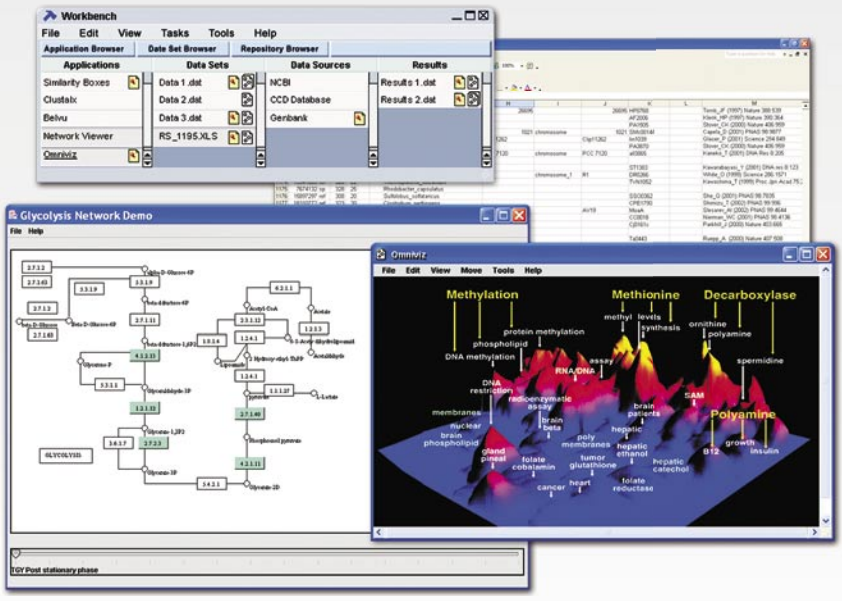
At PNNL, we have biologists, engineers, computer scientists and other scientists working on a variety of key projects.

We also are developing a systems infrastructure in three areas. First, we're investigating microbial communities. Microbes rarely work by themselves; they work as groups of organisms, so we have to figure out how microbes talk to each other as well as how they exchange information, carbon and energy.

PNNL's Jim Frederickson is leading our work with *Shewanella*, a bacteria that can turn water-soluble uranium into water-insoluble uranium and can live with or without the presence of oxygen. Understanding how *Shewanella* functions may lead to using it to help remediate contaminated waste sites. It also may help explain how early life on earth developed.

We're also examining how cells respond to oxidative stress, which happens when they are exposed to toxins or low doses of radiation. Finally, we are developing computer models of how human cells grow and divide. All of these areas will help us understand how human cells respond to environmental stress.

For more information about the Biomolecular Systems Initiative, see **http://www.sysbio.org**.

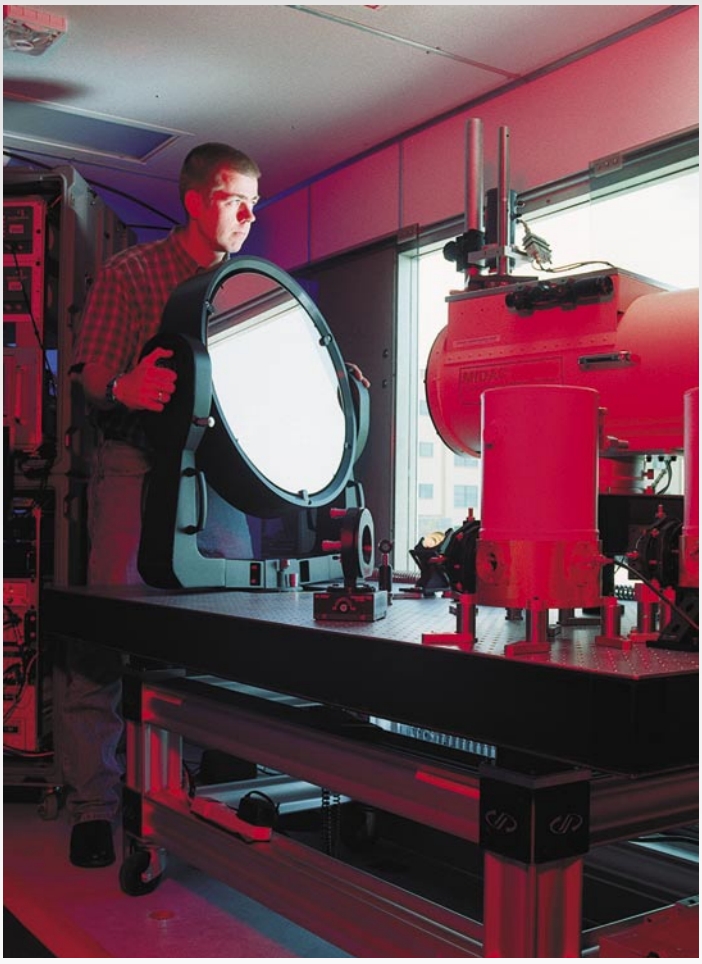


One of BSI's systems biology tools is Computational Cell Environment, a problem-solving environment that allows biologists to link, organize and provide access to scientific applications, data sets, data sources and experimental results using a logical and integrated approach.

Science and technology on the front line against terrorism

Mike Kluse
Associate Laboratory Director,
National Security Directorate

Winning the war on terrorism and securing the homeland will require innovative science and technology solutions. Pacific Northwest National Laboratory is in an excellent position to develop science and technology for strengthening America's ability to defend itself against terrorism.



This remote sensing system focuses on infrared detection of gases including chemical warfare agents and gases used for producing chemical and nuclear weapons of mass destruction. A laser beam is directed toward a building, vehicle or other object. Laser light scattered from the target is then collected with a receiver telescope, and imaged onto a detector. The resulting signal is processed to determine the chemical concentration in the atmosphere.

For years, our scientists and engineers have worked on identifying and understanding proliferation and terrorism signatures, systems to collect materials, sensors to quantify and characterize these materials and techniques that assist in analyzing possible terrorism events. The Laboratory has made significant contributions to counterterrorism and infrastructure protection. We have teamed with organizations to ensure our air and seaports are protected from terrorist attacks. Around the globe and at home, we've trained border enforcement officials—as well as U.S. Customs inspectors—to thwart the smuggling of chemical, biological or nuclear materials across borders.

Laying the groundwork for innovation

The terrorist attacks on the World Trade Center and the Pentagon in 2001 have elevated the need to develop and move technologies into use to combat terrorism and secure the homeland. As a leader in homeland security within the region and nationally, PNNL has established a Homeland Security Program Office to serve as a contact for our diverse homeland security-related research.

PNNL also is establishing the Northwest Center for Excellence for Homeland Security Science and Technology, which includes creating a national center for visual analytics in collaboration with the University of Washington, Washington State University and Oregon State University. In addition, the Laboratory is forming the Northwest Homeland Security Consortium with industry and government partners.

Finally, we're expanding capabilities at the Marine Sciences Laboratory in Sequim, Wash., to include a Coastal Security Institute. Through this institute, researchers will develop new technologies to meet national and international challenges associated with protecting marine and coastal environments.

Developing intelligence and counterintelligence tools

To anticipate the next generation of information visualization tools in today's information-rich environment, we need to integrate information from multiple sources, interpret the data and make decisions quickly. A key thrust at PNNL is Sensors and Information Analytics (SIA)—the processes for collecting, managing, synthesizing, analyzing and communicating raw data into knowledge, which enables discovery of the unexpected. Our aim with SIA is to develop

breakthrough analytic technologies to improve the probability of detecting and preventing strategic surprise.

We're also leveraging our reputation as world leaders in atmospheric monitoring and research to support the nation's counterterrorism efforts. PNNL, in conjunction with the federal government, is making a large investment in developing infrared sensors to detect and identify chemicals in the atmosphere and on surfaces, and to measure aerosols, particulates, winds, water vapor and temperatures in the atmosphere. Developing these sensors is key to detecting proliferation of nuclear, chemical or biological weapons.

Streamlining the military

PNNL is supporting the military as it moves from a Cold War environment with well-known adversaries to a warfare environment with many potential adversaries that are not well known, such as the many groups involved in the war in Iraq. We are helping the Army define its future support and logistics needs, both from an operations and technology standpoint.

In addition, we're helping the nation face the challenges associated with keeping weapons systems in inventory much longer than originally anticipated. By focusing on automated prognostics and diagnostics, we are inserting new technologies that allow weapons systems or subsystems to continuously monitor themselves and provide valuable information about their health and readiness. These technologies provide assurance that aging systems are in good working order or can alert people to potential problems so maintenance or repairs can be scheduled.

Taking a systems approach

The scientists and engineers behind our research are exceptional at accessing and integrating the broad technology base and capabilities that exist throughout PNNL. The power of this Laboratory is our ability to bring all of our capabilities together in multidisciplinary teams focused on our clients' needs.

Our ability to integrate across disciplines allows us to take a systems approach to solving problems. We can focus on one aspect of a problem or come up with a systems solution that addresses various aspects of the problem, ranging from early detection to decision-making and taking action.

Winning the war on terrorism and securing our homeland will take many years. To ensure that we grow our pool of scientists and engineers, who bring with them new ideas and new perspectives, we implemented a pilot program this year to train more people. The National Security Internship Program attracts and trains students in nuclear science, electrical engineering, computer science, physics and chemistry. Fostering young minds will ensure the security of this nation's future.

BRINGING DATA TO LIGHT

Being able to find the "needle" of information in a "haystack" of millions of words is a capability with many beneficial uses, particularly to secure the homeland. For more than three decades, scientists at Pacific Northwest National Laboratory have developed an array of information visualization tools to help find that crucial needle in the haystack.

Starlight, for example, effectively integrates structured, unstructured, spatial and multimedia data, offering comparisons of information at multiple levels of abstraction—simultaneously and in near real time. Starlight offers greatly enhanced information analysis and a gateway to new levels of understanding and decision-making.

The Innovation for Spatial Paradigm for Information Retrieval and Exploration (In-SPIRE) is a PNNL-developed information visualization technology that assigns a mathematical signature to text without requiring any knowledge or understanding of the content, and then automatically organizes the information and presents it graphically on a screen. Tools within the In-SPIRE suite enable analysts to explore relationships within the data that are expected, but almost always expose relationships that are unexpected and suggest further exploration.

Looking ahead, the Laboratory is leveraging its sizable information visualization investment for applications such as border security, detection of chemical and biological threats and counterterrorism. PNNL is focused on addressing capabilities needed to create a next-generation suite of predictive analysis and decision-support tools for early detection of terrorist action. This next-generation of information visualization technologies will provide a unique national resource for fighting the war on terrorism.

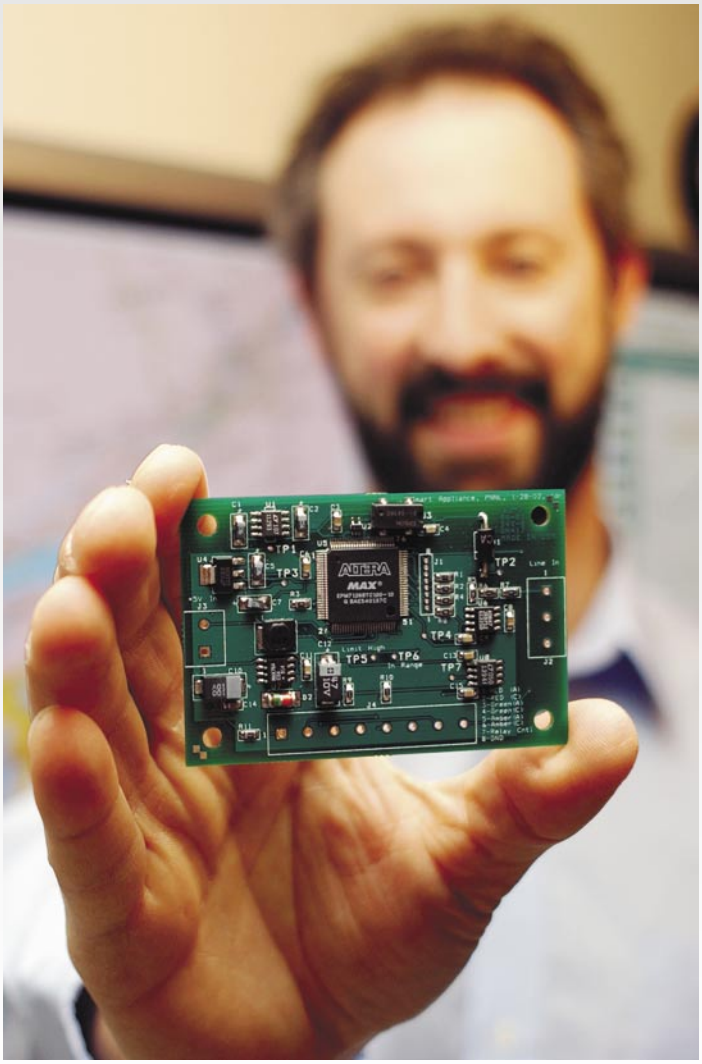
Starlight is a new information technology that expedites knowledge discovery and strategic decision-making.

Energy moves in new directions

Mike Lawrence
Associate Laboratory Director, Energy Science and Technology Directorate

Meeting our needs with cleaner, more efficient energy is absolutely critical to our quality of life. It helps provide for the continued prosperity of the United States as well as helping raise the standard of living in the rest of the world. Energy is important to global and national security and is at the core of DOE's mission.

As a nation, we're growing more conscious of the environmental consequences of energy use, particularly global warming, so we have to meet our need for increased energy in a way that protects the environment. Hydrogen is a potentially limitless energy source that doesn't emit greenhouse gases or carbon dioxide so it can play a major role in meeting our country's energy needs with further research and development. PNNL has a diverse portfolio of energy projects, including hydrogen, so we are well positioned to address many of the significant scientific challenges involved with transforming our current fossil fuel economy to a hydrogen-based economy.



A playing-card-sized integrated circuit developed by researchers at PNNL may help solve the nation's overworked electricity grid. Called a grid-friendly appliance controller, the circuit board would turn normal household appliances into ones that would better regulate energy usage and help prevent local and national blackouts.

Hydrogen economy supports grid modernization

In the transition to a hydrogen economy, current sources of electricity generation, such as coal, natural gas and oil, will be used to generate hydrogen. Fuel cells will use this hydrogen to produce electricity, particularly for transportation and for distributed generation.

Distributed generation is a concept that involves moving energy generation closer to the end user rather than transmitting it long distances. Fuel cells support distributed energy because they can be located at the point of use and energy production can be increased incrementally by adding more fuel cells as energy needs increase, reducing the need to build more power plants.

We're working on an exciting new way to modernize the energy grid and make distributed energy a reality. This concept, called GridWise™, allows a back-and-forth flow of information from generation to end use, where end users decide whether or not they want the electricity at a given price and the system is smart enough to operate automatically based on customer preferences.

The system's interactivity would monitor the grid in times of stress so that if there is a disruption and a plant goes down, interruptible appliances such as hot water heaters could immediately detect a problem and shut themselves down briefly, reducing the load and giving the system time to heal.

Fuel cells would be part of distributed generation in GridWise™ as would windmills, solar power panels and small hydro plants, in addition to large central station generation. All will be "plug and play" resources, but it will take an information-rich grid such as GridWise™ to make that happen.

It will take 20 to 50 years before we really see an impact from hydrogen on the market, but GridWise™ will start making an impact immediately because it will allow the

Scientists at PNNL are developing technologies to make current fossil fuel-powered energy systems—ranging from electric power plants to automobile engines—more efficient and cleaner.

electricity system to routinely operate at a higher capacity without the risk of overload. Taking steps toward energy efficiency is always the cheapest, simplest and best thing to do first.

Barriers to a hydrogen economy

Hydrogen storage is the single greatest challenge to making the hydrogen economy a reality. Although hydrogen has tremendous energy, it is dilute rather than dense, making it difficult to get large quantities into a small space, release it and have it continuously available. We are using our capabilities in the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) to look at various chemical storage mechanisms to ensure hydrogen can be reused and recharged safely in a practical time frame without pricing it out of the market. Our scientists are studying interfacial, small area chemistry to see how the hydrogen is bound up in molecules, how it is released and the catalysts that could be used to facilitate that release.

We also must ensure that the processes used to generate hydrogen are economical. We don't want to use more energy to produce hydrogen than hydrogen energy saves nor do we want to produce more greenhouse gases in the process. Examining entire systems rather than isolated points is key to ensuring hydrogen technology is economically viable and PNNL excels in this type of systematic approach.

PNNL researchers are conducting groundbreaking research to reduce atmospheric carbon dioxide emissions to levels that will prevent global warming. As part of this research, scientists are testing a unique method aimed at harvesting methane gas from frozen hydrates (right). The concept involves using CO_2 to "unfreeze" the methane hydrate to release methane gas. If successful, CO_2—a greenhouse gas—would remain deep underground as solid CO_2-hydrate while simultaneously producing methane gas for the natural gas market.

CLEANING UP ENERGY PRODUCTION

Scientists at Pacific Northwest National Laboratory are playing a lead role on a combined Department of Energy and industry effort to build a 275-megawatt coal-fired plant that will gasify coal to produce electricity and hydrogen. In that gasification process, carbon dioxide would be captured and sequestered.

The program, called FutureGen, aims to design and build energy plants that maximize the efficiency of fossil fuel energy generation while minimizing the environmental effects.

"Fossil fuels are too big a source of energy right now for us to get away from completely. But programs like FutureGen will help us deal with the environmental effects of fossil fuel energy generation properly," said Gary McVay, PNNL's director of fossil energy programs. "In our research, we're developing the fundamental underlying processes to make plants operate more efficiently and more environmentally friendly."

PNNL has partnered with the National Energy Technology Laboratory to develop technologies in support of the FutureGen vision. As part of the High Temperature Electrochemistry Center (HiTEC) team, PNNL researchers are applying their expertise in material science, solid state electrochemistry and surface chemistry to develop new materials and new ways to form and manufacture them to meet the cost and performance goals of the FutureGen plant.

In addition to making plants run more efficiently, PNNL researchers are working on methods to deal with greenhouse gases that may be released from coal-fired plants. "We're working on the mechanisms to capture the carbon dioxide that comes from the burning of fossil fuels and then sequester it deep underground, preventing it from contributing to global warming," McVay said.

In support of FutureGen, PNNL scientists are involved in the DOE's Midwest Regional Carbon Sequestration Partnership. The partnership, led by Battelle, which manages PNNL for DOE, will identify greenhouse gas sources in four Midwestern states and determine the technical feasibility and cost of capturing and sequestering emissions in deep geologic formations, agricultural lands, forests and degraded lands.

Linking environmental issues leads to expanded views

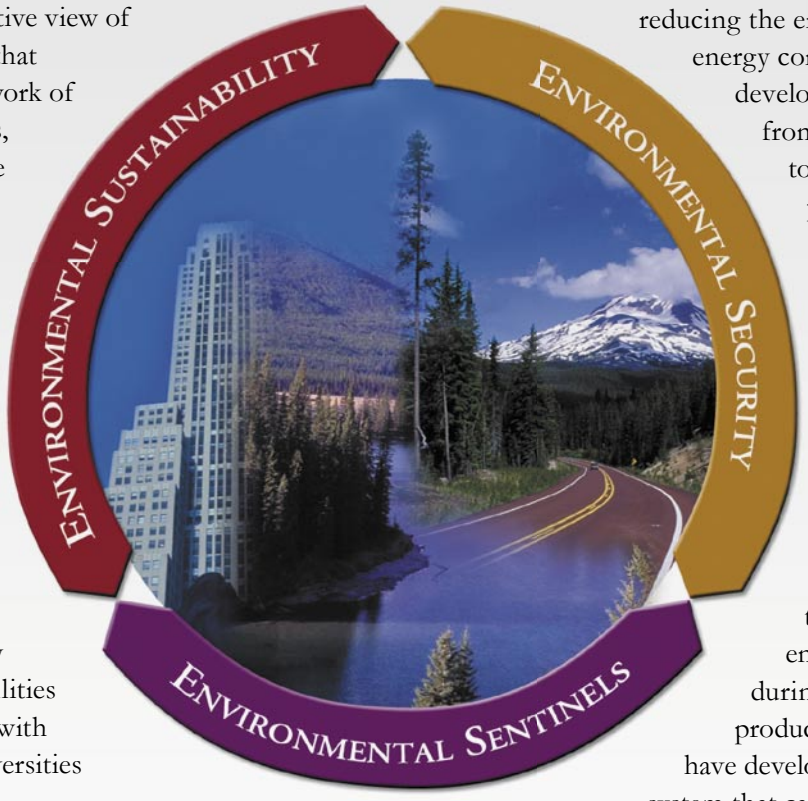
". . . environment and energy research initiatives are critical for achieving sustained economic growth while ensuring national energy security and a healthy environment."

John Marburger, Director—The President's Office of Science and Technology Policy

Rod Quinn
Associate Laboratory Director, Environmental Technology Directorate

Dr. Marburger sets out a formidable challenge—one that requires fundamental change in the purpose and scope of environmental science. Cleanup isn't enough; we must take a far more proactive view of environmental issues, one that considers the intricate network of ramifications that decisions, missions and activities have on each other and the environment.

At PNNL that means driving science to solve complex environmental issues for government and industry. We lead the environmental industry by focusing on prevention and prediction to help clients avoid problems before they occur. Our research capabilities and strategic partnerships with leading industries and universities make this possible.



We are moving forward in three areas: environmental security, environmental sustainability and environmental sentinels. Our research and technology in environmental security helps nations prevent or recover from attacks that affect the environment. For example, the Coastal Security Institute at the PNNL Marine Sciences Laboratory is developing a concept for sensor networks that will constantly monitor ocean conditions and exchange information on minute changes in the chemical, biological or radiological content of the water. These sensors will cover wider areas than current sensing methods and provide near real-time feedback.

Our research in environmental sustainability is creating the scientific underpinnings for reducing the environmental impacts of energy conversion and economic development. Activities range from legacy waste cleanup to developing catalytic processes for converting biomass to energy and value-added chemicals, and microchemical reaction technology for highly efficient energy conversion.

We are creating process technologies for capturing carbon dioxide and preventing this greenhouse gas from entering the environment during fossil-fuel energy production. Our researchers also have developed a water treatment system that can remove mercury from low-volume waste streams, and they are working on an engineered version for high-volume streams.

The third focus area, environmental sentinels, is the enabling science that will allow us to understand the impacts of human activity on complex environmental systems and to develop solutions to these impacts from

the cellular to ecosystem levels. We are developing and applying tools that provide information on the nature and distribution of pollutants and their effects on the health of organisms in those environments.

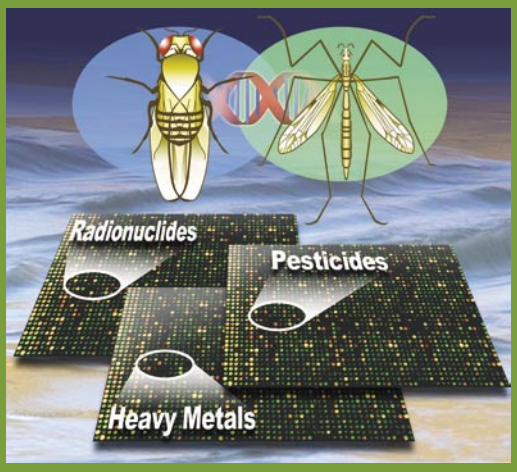
We also are helping the Environmental Protection Agency determine limits for the 80,000-plus endocrine-disrupting chemicals that enter the environment through human, agricultural or industrial use. In another project, researchers are exploring new ways to determine microenvironment health using DNA microarrays. (See *A Genetic Sleight-of-Wing*.)

We're excited about applying scientific advances from other research areas of PNNL, such as genetics and proteomics, to the development of science-based environmental solutions. Researchers already are investigating ways to use genetics, proteomics and other fundamental scientific research in microtechnology, biobased products and processing, advanced sensors, marine biotechnology and chemical toxicology.

Complex environmental issues often call for multi-partner collaborations. We are working with the world's foremost agricultural processors to develop high value chemicals from crop residues. Our collaborations with Washington State University on bioproducts and with Oregon State University on microtechnology are bringing education, research and industry partners together to solve fundamental issues in biobased product development and non-polluting energy.

Scientist Michael Blanton checks the proportions of chemical compounds in the seawater columns that supply water to fish tanks used in the endocrine-disruptor study.

A GENETIC SLEIGHT-OF-WING



Ecologists have come to rely on a tiny fly called the midge as an environmental sentinel—an entomological canary-in-a-coal-mine for rivers. They have learned that a variety of midge species thrive in healthy streams, whereas in polluted water, like that near a lead mine, midge species can dwindle to nothing. So by skimming the skins that pupating midges shed as they enter adulthood, ecologists can attain a cheap snapshot of a stream's living conditions.

Raw numbers, though, reveal nothing about changes in progress that portend environmental peril. What if stream life is on its way downhill, but the effects of a pollutant cannot yet be seen in the destruction of a species? What if you could trade that snapshot for a movie—catch stream degradation in the act and take corrective action before it is too late for the bio-indicator organism and other creatures living in the stream?

Charles Brandt, staff scientist and manager of Pacific Northwest National Laboratory's ecology group, wondered if he could produce this movie cheaply, with off-the-shelf technology. Knowing that cells under environmental stress will express proteins differently from healthy cells, Brandt supposed pollutants could be quickly identified by using the midge genome to scan for cell damage. One hitch: There is no midge genome map, and nobody was about to commission one.

Undaunted, Brandt cleverly substituted that of a distant relative: the thoroughly mapped fruit fly Drosophila. To test his idea, he assembled a team that included PNNL's Jack Small, Amoret Bunn and Matt Bleich as well as the Environmental Protection Agency's Ann Miracle, who exposed midges to various chemicals and extracted their RNA.

The researchers found that a chip containing the midge-cousin's genetic material will bind to protein-precursor RNA from ground-up midge larvae and yield a pattern specific to heavy metals, radionuclides, hormone analogues and pesticides to which the midges were exposed. "We also exposed midge larvae to strontium-90 so we could get RNA from a rad-exposed midge to test using the microarray," Brandt said.

At first, they needed 10 times the midge genetic material required to run the same test on a fruit fly. After tweaking the system, "we got the sensitivity to where we need only twice the amount," Brandt said. The researchers will continue refining the tests so that they can catalog the expression patterns that match all major classes of pollutants.

solutions UPDATE

PNNL and NASA team on fuel cell research

A PNNL researcher dispenses a sealant onto an individual fuel cell using a commercial robotic arm. The sealant is used to connect individual cells to one another to form stacks.

Pacific Northwest National Laboratory and the NASA Glenn Research Center will collaborate in solving one of the toughest technical challenges to the development of advanced solid oxide fuel cells (SOFC). The two research organizations have signed a Space Act Agreement to team on the development of sealing technologies for the stacks of SOFCs.

Solid oxide fuel cell stacks consist of a group of thin ceramic cells separated by gas seals between which electricity is generated through a combustion-less electrochemical process. The gas separation seals used between the individual cells prevent fuels and oxidants from intermixing. Robust seal materials and engineered architectures are essential to ensure the long-term stable operation of SOFCs.

"Our objective is to develop composite materials and designs that will improve the strength and fracture toughness of composite glass and glass-ceramic-based seals," said Ajay Misra, chief of NASA Glenn's Ceramics Branch. "The seals must stand up to the extremes of pressure, temperature and other environmental conditions that occur during extended operation."

"The arrangement complements PNNL's work in glass seals and NASA's expertise in glass and glass-ceramic composites," said Prabhakar Singh, who directs fuel cell development efforts at PNNL. "While each organization will continue to maintain its own research program, participants will jointly identify, prioritize, develop and test validate new fuel cell seal technologies." ●

Science of doing business

N⁴ links regional nanoscience and nanotechnology efforts

The Northwest Nanoscience and Nanotechnology Network—or N⁴—is magnifying communication about nano-related research in the Pacific Northwest region.

N⁴ was formed in the summer of 2003. "We wanted to link together the researchers, educators, organizations and industries that are leading a variety of activities in this emerging field of inquiry," said Pacific Northwest National Laboratory's Don Baer, who headed efforts to organize the group. "Many regional universities, laboratories and industries have leading positions in nanoscience and nanotechnology, or have identified important aspects of these fields that are especially relevant to the Northwest," he added.

The primary objectives of N⁴ are to foster communication among the region's participants in nanoscience and nanotechnology research; enhance the formation of research teams; and identify capabilities, skills and activities for collaboration with network partners. An additional aim is to create improved public awareness of successful nano-related research activities taking place in the Northwest.

The N⁴ concept is an outgrowth of the Joint Institute for Nanoscience and Nanotechnology, which was established by PNNL and the University of Washington in April 2001.

Interest in the network has been significant. By November 2003, six institutions and 25 individuals had joined, and the numbers continue to grow.

In the months ahead, steps will be taken to advance the network's effectiveness. For instance, PNNL will establish a secure Web site that will allow network members to privately interact and share their work. A Web site offering public information already is online, at **http://www.pnl.gov/NWnano/**. ●

science SPOTLIGHT

Spectral library sheds light on chemicals

A chemical's "John Hancock" can give it away. Just as a person's signature is unique and a sure way to weed out imposters and arrive at the truth, a chemical's spectral signature is a trustworthy form of identification. And such revealing information is becoming ever more vital in a world where detection of toxic substances could save lives and the environment.

At Pacific Northwest National Laboratory researchers have, for the past three years, been funded by the Department of Energy's Office of Nonproliferation to study the light that is absorbed or emitted by certain vapor phase chemicals—and to tie those characteristics to a unique spectral signature that can be read by both active and passive sensor devices. The result of the work is the DOE-PNNL Infrared Spectral Library, which contains signatures of more than 300 vapor phase chemicals and is growing by about 75 per year. Some of the chemicals are the "dual use" variety that have legitimate uses in industry but also could be used to make weapons.

"This collection of signatures is viewed as the definitive reference set by many of the users," said Steven Sharpe, one of the PNNL researchers involved in the effort. "When we started, it was widely thought that there was a need for remote sensing technologies that would measure chemicals, as well as a reference library of spectral signatures. We lobbied strongly that PNNL should be the laboratory developing the library, as this is in line with capabilities we have."

The research is conducted in the William R. Wiley Environmental Molecular Sciences Laboratory, a cutting-edge DOE research facility located at PNNL. Sharpe says most of the equipment employed for the spectral measurements is commercially available but has been modified for the purposes of this research.

The uses of the library's information are diverse and, considering some of the key issues facing the world, very timely. For instance, the library data, coupled with a sensing device, can determine if a smokestack is belching harmful emissions. Public safety is another potential application. A number of terrorist groups and countries have turned nerve and blister agents and other substances into weapons that could be unleashed on an unsuspecting public and cause great physical harm to individuals. In such cases, the availability of effective detection technologies would be extremely useful in identifying or responding to threats.

The contents of the spectral library are available to the general public. Currently there are nearly 100 subscribers—many of them companies that use the data as part of their environmental monitoring activities. Sharpe indicated that the project should wrap up within the next two years, and by then the database will contain about 500 signatures.

Sharpe noted that one of the requirements of the library is that the information must be produced in a fashion that is compatible with current or future instrumentation. That will help ensure that the data is relevant years into the future.

The DOE-PNNL Infrared Spectral Library Web site is located at **http://nwir.pnl.gov**.

NOTABLE Achievements

Staff members gain AAAS Fellow status

Tom Ackerman

Paul Ellis

Two researchers from Pacific Northwest National Laboratory have been named Fellows of the American Association for the Advancement of Science (AAAS).

Tom Ackerman, chief scientist for the U.S. Department of Energy's Atmospheric Radiation Measurement program, was recognized for pioneering studies of radiative properties of aerosols, for developing millimeter-wave radar for measuring cloud properties and for technical leadership of the nation's principal atmospheric radiation research program. Ackerman joined PNNL in 1999.

Paul Ellis was honored for his contributions to multinuclear magnetic resonance spectroscopy and its applications to bioinorganic chemistry, short-range structure and bonding and chemical catalysis. Following a 23-year career as a member of the chemistry faculty at the University of South Carolina, he joined PNNL in 1993 to lead the development and commissioning of the magnetic resonance instrumentation laboratories at the William R. Wiley Environmental Molecular Sciences Laboratory.

AAAS Fellows will be recognized in February at the AAAS National Meeting in Seattle. ●

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

P.O. Box 999, MSIN K1-39
Richland, Washington 99352

Address service requested

Printed on recycled paper. Printed in USA.
RL-P98-007 January 2004