Breakthroughs

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Protecting freedom

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Breakthroughs

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editor's screen

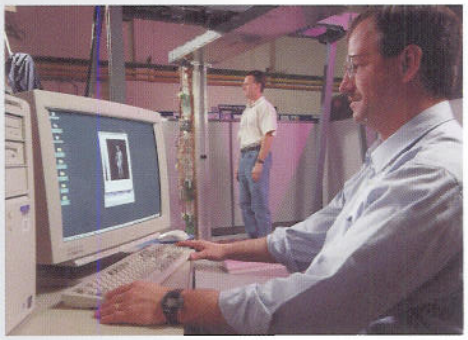
Science for safety and security

The haunting images and somber voices we saw and heard in the hours and days that followed the Sept. 11 terrorist attack on New York and Washington, D.C., will remain with us for the rest of our lives. As the tragic events of that day unfolded, many people in America began questioning the safety and security of our nation for the first time.

While the terrorist attacks heightened society's focus on research and development activities in support of national security and counterterrorism, Pacific Northwest National Laboratory has been working in this area for decades. Many of the Laboratory's scientists and engineers have devoted their lives to conducting research and developing technologies that help keep America—and the world—safe.

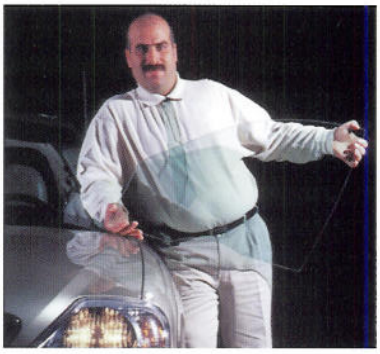
In this issue of *Breakthroughs*, we highlight the Laboratory's ongoing work in important areas such as the early identification of chemical and biological weapons and airport security. While we have room for only a few examples, Pacific Northwest National Laboratory is contributing to a spectrum of activities that protect the very safety and security so many of us have taken for granted until recently.

Contents



AT A *glance*

Weight loss program for glass



Today's average car sports about 150 pounds of glass, so it's clear why the automotive industry has set a goal to cut this weight by one-third, despite the challenge of preserving safety and performance features. Less weight means improved gas efficiency and lower emissions.

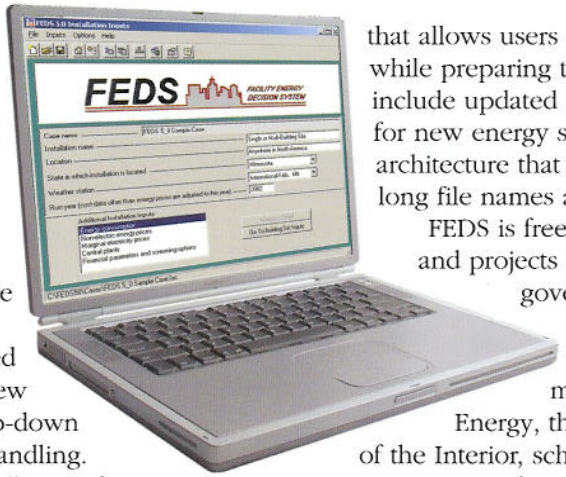
With a dedicated suite of models and experimental tools, Pacific Northwest National Laboratory and its automotive and glass manufacturing partners have developed a prototype windshield that is 30 percent lighter and retains key optical, thermal and safety properties. Related efforts at the Laboratory have focused on testing the strength of various lightweight glass designs, high-speed impact windshield testing and understanding how temperature, humidity and flaws impact glass strength. ●

Dreams come true for proteomics research

When researchers at Pacific Northwest National Laboratory talk about their DREAMS, they're talking about a new method for analyzing proteins. This method can obtain nearly twice the information about proteins in a single experiment than its conventional counterparts. DREAMS—short for Dynamic Range Enhancement Applied to Mass Spectrometry—is a powerful new mass spectrometry technique that analyzes a greater number of proteins and increases speed and accuracy of analysis. It also provides a more thorough understanding of an organism.

Pacific Northwest scientists designed DREAMS to automatically remove proteins that exist in large numbers from those that appear in fewer numbers. By isolating the low-level proteins often missed using other methods, DREAMS can help unlock clues to important cellular processes such as disease development. ●

More user friendly FEDS 5.0 out soon



Identifying cost-effective energy-saving systems and retrofits for buildings is now even easier. Created by Pacific Northwest National Laboratory researchers, FEDS (Facility Energy Decision System) allows users to assess possible energy-efficiency improvements in multiple buildings and at multiple sites as well as compare cost-effective energy-savings potential.

The latest FEDS upgrade, scheduled for release in spring 2002, has an all-new Windows-style user interface with drop-down menus, more icons and standard file handling.

To make FEDS 5.0 more user friendly, Pacific Northwest researchers have added a new help routine that allows users electronic access to help instructions while preparing their input. Other improvements include updated performance and price information for new energy systems and retrofits, and 32-bit architecture that allows other improvements like long file names and faster run times.

FEDS is free for federally funded projects and projects funded and performed by state government agencies. More than 1,200 copies of the software have been distributed to branches of the military, the U.S. Department of Energy, the U.S. Postal Service, the Department of the Interior, schools and other agencies. ●

For more information about FEDS see **www.pnl.gov/FEDS.**

special REPORT

A partner in peace

Building better weapons, stronger defense programs and superior military power might be the first things to come to mind when one hears the words "national security." At Pacific Northwest National Laboratory, however, many researchers are working on programs aimed at keeping people safe and the world at peace. We asked Mike Kluse, Associate Laboratory Director for Pacific Northwest's National Security Directorate, about the Laboratory's role as a partner in peace and what has changed since the tragic events of Sept. 11.

You describe Pacific Northwest National Laboratory as a partner in peace. Can you explain what you mean?

I think that the Laboratory can play this role in two broad areas. The broadest is what we're doing to support global security. Global security is not just countering terrorism, but also preventing the proliferation of weapons of mass destruction—both the know-how and the materials. Global security also involves addressing problems or situations that can lead to conflict, such as environmental issues and energy supply. We play a leadership role in those aspects of global security as well as by helping halt the spread of weapons of mass destruction.

The second area—asset protection and infrastructure protection—is more focused. There is a strong emphasis on technologies for protecting critical infrastructure elements of the United States including our energy systems, communications systems and computer security. We are helping understand the vulnerabilities of these systems and determining what techniques and technologies could be applied to mitigate them.

What has changed since Sept. 11?

There is certainly a whole new sense of urgency in the country relative to increasing the capability to detect potential terrorist activities, coming up with more fool-proof mechanisms to understand how terrorists carry out their missions and addressing how one might counter these from a technological and operational standpoint. I think this Lab has a lot to offer. We're not just starting to focus on these concerns, we've been doing this for years. We 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 events.

Even before Sept. 11, we have been making significant contributions to countering terrorism and infrastructure protection. We have been addressing concerns over cyber security—attacks on government networks or exploiting government networks. We have been working on detecting smuggling or potential smuggling of nuclear, chemical or biological materials that could find their way into weapons of mass destruction.

We have been developing technologies and helping train international border guards on how to detect smuggling activities for years. Now, we're starting to conduct this training domestically because we realize U.S. forces need the same training.

What are the upcoming areas of focus?

Right now, tools to rapidly detect chemical and biological weapons are not widely deployed. We're working to improve the nation's ability to rapidly and accurately detect biological agents in the environment. We can no longer wait for people to lose their lives to realize there is a problem. Building and deploying systems for early detection and warning is definitely an area of focus. Then, we have to look at how to protect against these threats or counter them.

We're also trying 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 in a timely manner. This Laboratory has been working on information visualization tools and data mining tools for the past 20 years and these tools really play into today's national security environment. Now we need to look at multimedia inputs and more automated integration

of visualization tools and a variety of sensors to capture information on a near real-time basis. We will be tailoring these tools to meet the specific timely requirements of a range of users—including battle commanders, pilots, security officers and intelligence analysts.

While much of our work is focused on keeping the peace, we also support the military as it makes its transformation from a Cold War environment to what is called an asymmetric warfare environment. For example, we're helping the Army define the support and logistics it will need in the future, both from an operations and technology standpoint.

We also are 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 can insert new technologies that allow 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.

Can you tell me a little more about what the Laboratory is doing internationally?

We're working with Russia and the states of the former Soviet Union to protect and safeguard the nuclear material and know-how that is left over from the Cold War era. Similarly, we're looking at ways to employ the scientists and engineers from the former Soviet Union who were integral to their weapons program. By finding peaceful applications for their expertise, there is less of a chance that they will migrate to other countries, potentially taking nuclear weapons materials, technology or knowledge with them.

I also would highlight the direct impact of the International Nuclear Safety Program. We've been involved in providing in-place safety upgrades to a number of Soviet-designed nuclear reactors to prevent accidents like the one that occurred at Chornobyl. Enhancing the safety of Soviet-designed reactors is critical to energy security,

both in the United States and worldwide. Another major accident would have significant implications on the entire nuclear industry, including in this country where there is a renewed interest in nuclear energy as a source of power given recent domestic shortages.

This Laboratory has been known as an environmental technology laboratory. How does national security research and development fit in?

It's not that big of a stretch. We're drawing on the same fundamental science, the same technology and the same knowledge that were developed here to understand the impact of plutonium production on the environment during the height of the original Hanford mission. For example, this Laboratory is a leader in atmospheric sampling. We're turning around those same capabilities and using them to detect nuclear testing or to monitor for compliance with international treaties. It would be virtually impossible to perform a test of a nuclear device or nuclear weapon—above or underground—that the technologies developed at this Laboratory could not detect.

What is unique about Pacific Northwest's contributions in national security?

I think our scientists and engineers are exceptionally good at accessing and integrating the broad technology base and capabilities that exist throughout the Lab—whether in national security, environmental technology, energy or fundamental sciences. The power of this Laboratory is our ability to bring all of our capabilities together in multidisciplinary teams focused upon the needs of the client.

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 the various aspects of the problem ranging from early detection to decision-making and taking action.

I'll give you an example of how it works for biological defense. To be able to protect against a biological threat, one needs to understand the fundamental biology associated with the threat to understand how it interacts with the body. With that knowledge, you could begin to develop a vaccine or drug to counter the effects. You also would have to understand fate and transport to understand how the biological agent moves and changes from the time it is released to the time it enters the human body. If you back up even further, you would need to know how a biological agent could be turned into a weapon and how it would be operationally deployed. You've got to have people who understand military operations and how weapons are built as well as biologists and atmospheric scientists. It takes a lot of expertise to systematically solve a problem like defending against biological or chemical weapons—and we have it all under one roof.

What are your lasting impressions about the Laboratory's national security work?

I have been at this Laboratory for four years and from the day I walked in, I've been impressed by the commitment of the people to solving critical national security problems.

From improvements at Soviet-designed nuclear reactors in Ukraine to protecting and controlling nuclear materials, finding peaceful applications for the expertise of weapons scientists in the former Soviet Union and developing technologies for treaty verification, I've seen first-hand how this Lab is making a difference. ●

Spectrometers...

spec•tros•co•py (spĕc-trŏs´ kə-pē) n. The science that deals with ... spectrum analysis.

spec•trum (spĕk´ trəm) n. An array of entities...ordered in accord with the magnitude of a common physical property.

There are many varieties of spectra, the most familiar is the spectrum of light, as produced by a rainbow. Spectrometers are the tools used to measure spectra to provide important insights into the properties of matter.

Pacific Northwest National Laboratory is using four kinds of spectroscopies to develop sensors that can be used to detect weapons of mass destruction: mass spectroscopy, Raman spectroscopy, neutron spectroscopy and optical spectroscopy. In mass spectrometry, the ordered array of entities is the masses or molecular weights of proteins. Molecular weights are important in identifying the protein. In optical spectrometry, which includes the ultraviolet and infrared part of the spectrum, absorption or emission of light provides information about the structure of chemical species or composition of a mixture of chemicals. In Raman spectrometry, a subset of optical spectroscopy, the change in the light's wavelength caused by its interaction with matter provides detailed information about the molecular structure of that matter that cannot be obtained from emission or absorption. In neutron spectrometry, the kinetic energy distribution of neutrons provides important information about their source or interaction history.

...versatile tools for weapons detection

Building a file on potential pathogens

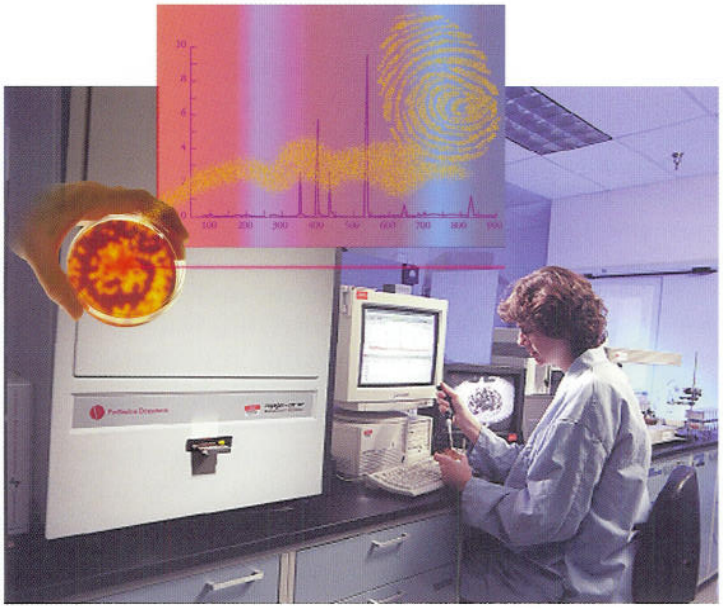
Forget fingerprinting bioterrorists. Fingerprint their weapons.

Researchers at Pacific Northwest National Laboratory are using mass spectrometry to build an automated library of information that can be used as a rapid means of identifying and analyzing bacteria, a potential weapon of mass destruction.

MALDI-MS, Matrix-Assisted Laser Desorption/Ionization Mass Spectrometry, identifies bacteria by measuring the mass of a cross section of their cellular proteins. Using a series of multiple laser shots, MALDI-MS simultaneously volatizes, separates and detects the proteins in a matter of microseconds.

MALDI-MS relies on special statistical algorithms developed at the Laboratory to recognize the unique features of bacteria. The statistics-based software constructs and compares MALDI fingerprints automatically, in addition to providing a confidence level. "The automated process prevents bias in interpreting the MALDI spectra," said Karen Wahl, senior research scientist on the project. "So a non-technician may operate the device and get the same results as an expert."

Pacific Northwest scientists are working with DARPA to develop a field portable MALDI-MS system that would be less expensive than lab-based models.

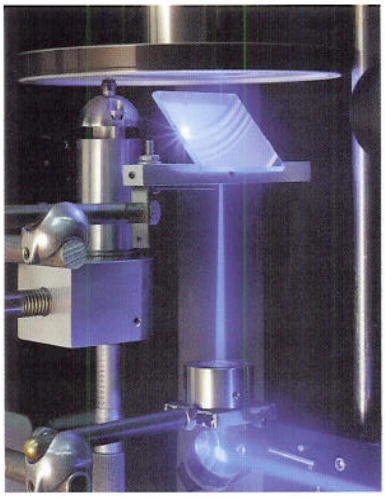


Fingerprinting chemicals

While MALDI-MS fingerprints bacteria, Raman spectrometry fingerprints chemicals. When configured a particular way, a Raman spectrometer can detect dangerous chemicals in translucent containers, including glass as dark as a beer bottle and plastic as opaque as a bleach bottle.

Pacific Northwest scientists are proving that Raman spectrometers work for materials found in the real world, whether they be in dark containers or on the ground, as well as developing a library of chemical fingerprints to match with Raman spectra.

In field tests, the spectrometer correctly identified both liquid and solid samples in a variety of containers and solid samples in the environment



with close to 100 percent accuracy. Because the database includes spectra from many of the most hazardous chemicals, lack of a spectral match eliminates many dangerous chemicals from suspicion. "In many cases, knowing what a compound isn't may be more important than making a reasonably correct identification," said Bob Wright, a senior scientist involved with the spectrometer.

Laboratory scientists are currently developing improved algorithms to help identify chemicals in mixtures. "You're more likely to find chemicals mixed with other things in the real world," Wright said. "Users might need to identify chemicals that are mixed with a carrier material or even disguised with other materials."

Detecting neutrons helps identify plutonium

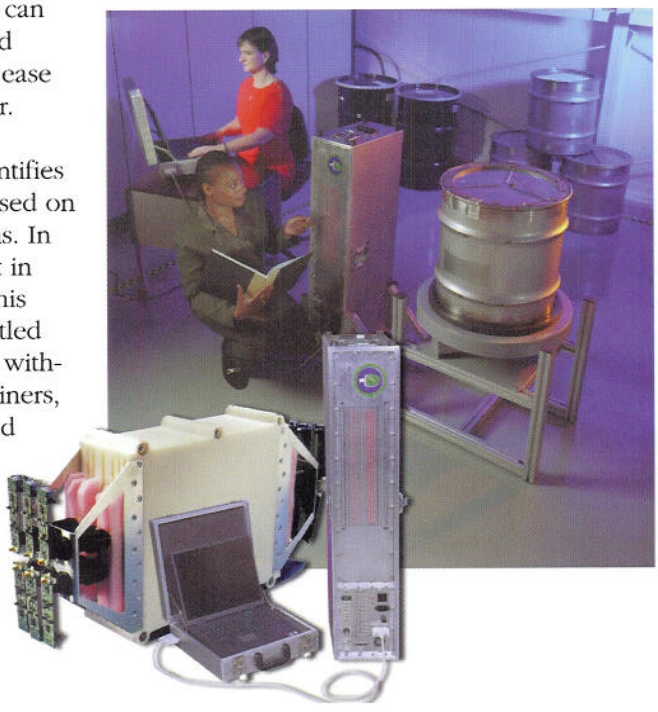
Fast, portable and accurate, the neutron spectrometer can detect plutonium in sealed containers with the same ease it detects fat in hamburger.

Pacific Northwest's neutron spectrometer identifies radioactive substances based on the energy of the neutrons. In line with growing interest in global nonproliferation, this device may allow dismantled weapons to be inspected without opening sealed containers, thus preventing the spread of sensitive information.

The neutron spectrometer uses the Laboratory's patented glass fiber technology to create a sensor that detects both neutrons and gamma rays. "This sensor is unique because it is the only inspection tool based primarily on neutron measurement that is portable and fast," said Mary Bliss, chief scientist for the project.

The detector consists of six layers of glass fibers sandwiched between sheets of plastic. Fast moving neutrons pass through the plastic, which slows them down and allows them to interact with the Laboratory's scintillating optical fibers to produce light. This light travels to the end of the fiber, where photomultiplier tubes convert it to an electrical signal. The layer where the neutrons are detected provides information about the neutrons' energy, which is analyzed to identify their source. "With this kind of information, we can identify radioactive material or the 'flavor' of weapon that emitted the neutron in five minutes or less," Bliss said.

Experts prefer using neutron detection over gamma ray detection to confirm plutonium, an important ingredient in nuclear weapons, because neutron detection provides more detailed information about the plutonium, and its accuracy is less affected by surrounding materials. This device also is one of the few solid-state detectors in a world of pressurized gas detectors. "Solid-state detectors are more rugged and transportable for field operations than their counterparts. High-efficiency gas tubes contain too much pressure to be flown on commercial airliners," Bliss said.



Beyond detecting weapons, the neutron spectrometer also could be used commercially to measure fat in hamburger and determine the steam or water content in pipes. The spectrometer has a patent pending and Bliss expects the device to be commercialized sometime in 2003 for use by arms control experts.

Using the infrared spectrum to detect chemicals

Scientists in Pacific Northwest's remote sensing and electro-optics group are developing sensors that use infrared light to find chemical traces of explosives, weapons, narcotics and other contraband associated with terrorist activities.

The way a chemical of interest radiates or absorbs infrared light as a function of the light's wavelength (color), is called the infrared spectrum. The chemical's infrared spectrum forms a unique optical "fingerprint" that can be used to identify contraband, illicit production processes, or warn occupants of public buildings or military units of chemical attack with high reliability. Researchers are particularly interested in mid-wavelength infrared (MWIR) light because optical fingerprints are more likely to be unique in that region of the spectrum.

Pacific Northwest and Bell Laboratories also are jointly developing a new type of MWIR laser, called a "quantum cascade laser." DARPA is funding this project because the laser is essential to the practicality of the new sensing techniques and has other military applications.

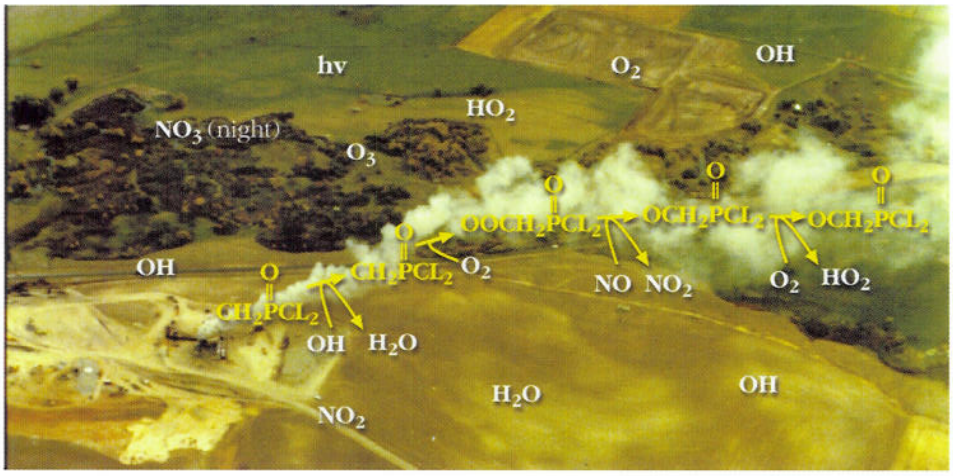
In related work, Pacific Northwest scientists are measuring the spectra of about 550 vapor-phase chemicals in collaboration with the researchers developing the sensors. These measurements are needed because the infrared spectra of most chemicals have never been measured with the resolution or accuracy needed to identify chemicals with high confidence. ●

Chemicals sign in

What happens to chemical vapors that are released to the air? Fate and transport analysis, a holistic way of looking at chemicals in the environment, involves a modeling system that shows how a chemical changes in the presence of other chemicals and how a chemical moves through the air, water and soil.

"In the same way forensic chemistry and fingerprints are used in the courtroom to link crime evidence to the circumstances of who, what, why and how, scientists are using fate and transport analysis to investigate chemical residuals or 'signatures,'" said Kathy Probasco, a senior research scientist at Pacific Northwest National Laboratory involved in fate and transport studies. "Environmental signatures tell which chemical is present and provide clues about the source." Fate and transport analysis is currently used to analyze pesticide and herbicide residues, industrial process vapors and vehicle exhaust emissions.

To improve analyses, Pacific Northwest scientists are developing a chemical kinetics chamber that tracks various chemical reactions in a controlled environment and provides information on the chemical signatures present. The chamber can react chemicals with light, moisture, dust, soil, vegetation or other chemicals. "We are performing cutting-edge research to understand gas-phase kinetics and how chemicals change in specific environments. This research will ultimately lead to new sensor technology," said David Maughan, who developed the chamber.



Today, Probasco's work on fate and transport analysis is applied to national security efforts. "If you're building a sensor to detect a chemical in the environment, you need to know what's going to happen with the chemical," Probasco said. "How that chemical will change depends on the climate, soils and vegetation, and distance from the sensor. A chemical released in a wet climate may have a very different signature than the same chemical released in a dry climate."

By combining fragments of information from diverse sources in the process of data fusion, fate and transport analysis offers researchers a big picture view of chemicals in the environment. This understanding can help researchers develop more accurate and effective sensors and hazard assessment technologies. ●

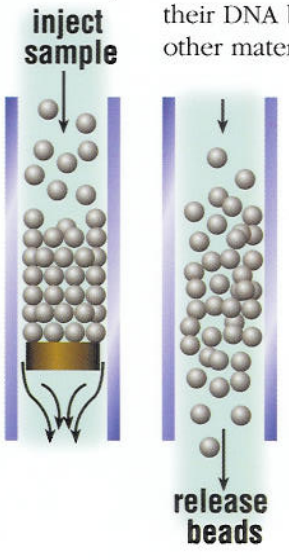
Biothreat detection takes concentration

Detecting potential biological threats is part of the Department of Energy's plan for homeland defense, and a new automated device developed by Pacific Northwest National Laboratory provides a key piece in biothreat detection technology.

BEADS, short for Biodetection Enabling Analyte Delivery System, purifies and concentrates environmental samples containing potential biothreats. BEADS can be used as the front end for sensitive detectors because it captures contaminants of interest from dirty environmental samples. "BEADS isolates what's important in the sample," said Cindy Bruckner-Lea, a scientist involved in the project. "Some compounds like humic acids in soil can interfere with detection, but washing away interfering compounds in the sample makes for better detection."

In addition to purifying and concentrating samples, BEADS has its own detector and can link to other detectors. Currently, BEADS is linked to detectors at other national laboratories as part of a DOE plan to use it on biodetection units for homeland defense applications.

Here's how it works. Liquid samples flow over a packed bed of beads, literally tiny glass, polymer or magnetic spheres. Solid samples, such as soil, are liquefied and then pass over the beads. Bacteria, spores, viruses or their DNA bind onto the beads, while the other material is washed away. When enough contaminants are collected, they are extracted from the beads and analyzed, or analyzed in place.



Because BEADS is automated, it can be used in situations that may be dangerous to people, such as monitoring water sources like rivers or reservoirs during military operations. It also may be installed in ships, spacecraft or submarines to make sure limited water supplies are not contaminated. ●

Information analysis—by Starlight

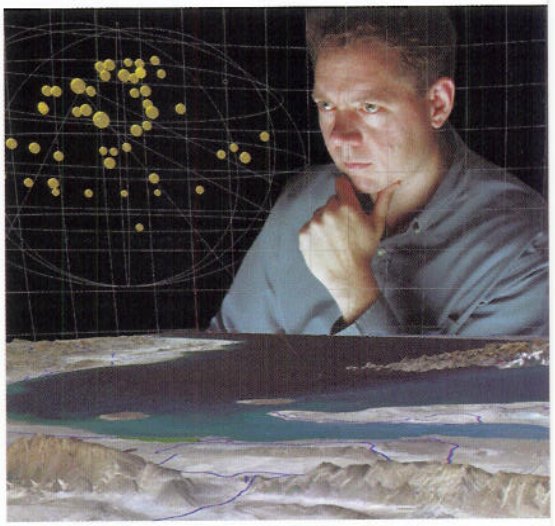
Much like individual stars coalesce to form constellations, information visualization software developed at Pacific Northwest National Laboratory helps decision-makers see the importance of individual pieces of data by showing how they relate to one another.

The Laboratory's Starlight software—originally developed for the intelligence community—allows users to analyze data files with up to 100,000 records quickly and easily. Starlight uses shapes to represent pieces of information such as documents or news-wire reports. When relationships exist within the information, the shapes cluster together on the system's three-dimensional display.

"The idea is that you're 'looking' at the information," said John Pinto, project manager. "You can recognize subtle relationships more easily by looking at visual metaphors than at tables of data."

As an example, Pinto described how Starlight might be used to look for correlations in a database containing records about chemical spills. An analyst could begin by grouping records according to the cause of the spill to reveal general trends. Sorting the data a second time, she could apply different colors based on related details such as the company responsible, age of equipment or geographic location. Maps and photographs could be integrated into the display, making it even easier to recognize connections among multiple variables.

The Laboratory began developing Starlight about five years ago, with funding from the Land Information Warfare Agency, a part of the Army Intelligence and Security Command. Starlight integrates visual representations of reports, radio transcripts, radar signals, maps and other information.



The Laboratory is pursuing other commercial applications for Starlight, which could include law enforcement, patent analysis and medical and legal research. ●

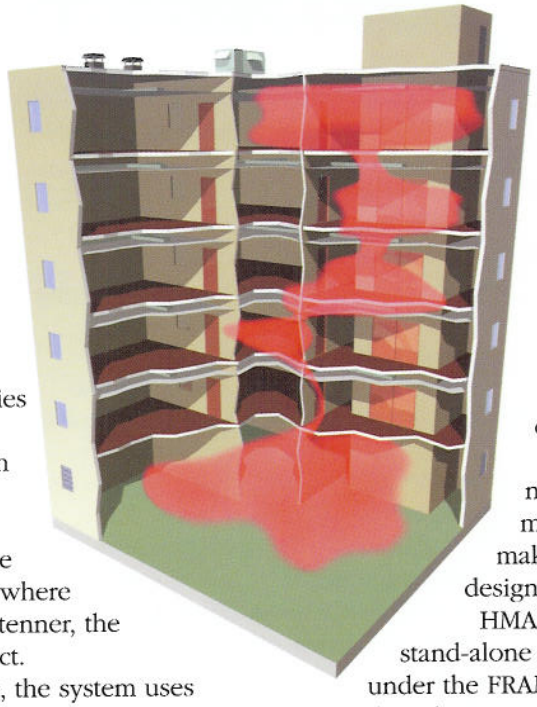
For more, see **http://www.pnl.gov/nsd/commercial/**

Assessing every breath you take

What are your chances if a terrorist dumps a big batch of chlorine bleach into the ventilation system of the government building where you work?

Researchers at Pacific Northwest National Laboratory have developed a sophisticated modeling system that assesses health and safety impacts of contaminated indoor air.

Health Modeling and Assessment System (HMAS) uses several different software programs and analytic capabilities to predict what will happen and how people will be affected in a building with contaminated airflow.



The system involves several steps. First it runs a vulnerability analysis on the building. "We create scenarios based on where the facility is open to attack," said Bob Stenner, the Laboratory scientist who heads the project.

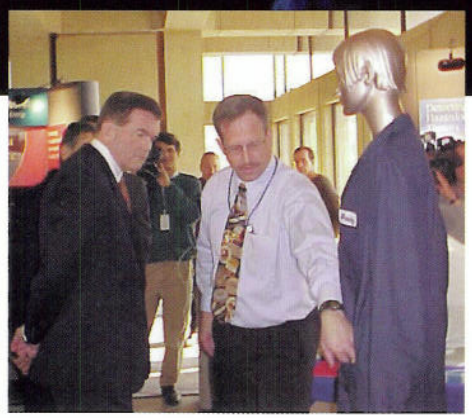
Based on an analysis of the building, the system uses models to estimate contaminant dispersion for various attack scenarios and determines how long different chemicals will persist. The human element is next. How long will people stay in the building, how long will they be in rooms with specific concentrations and what effect will it have on human lives? "If you get this kind of dose, you'll get these kinds of symptoms, and this is what you could do in terms of emergency health care," Stenner said.

Users then consider exposure management or "how can we do it differently?" Flipping off the HVAC to restrict contaminants to a smaller area, evacuating people to a different floor and even determining safe areas within the building are all possible safeguards against this type of attack.

Finally, the system provides necessary information for building managers considering remodels to make buildings less vulnerable, or even designing new buildings.

HMAS is an integration of several stand-alone models and databases operating under the FRAMES architecture. Pacific Northwest developed Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES) so users can integrate one stand-alone program with another program or set of programs and link them to disparate databases simply and easily. ●

Airport security scanner for safer skies



In the futuristic action film *Total Recall,* the character played by Arnold Schwarznegger tries to sneak hidden weapons past a security checkpoint only to find that the high-tech detector quickly spots the hardware concealed under his clothing. The movie takes place in 2084, but at Pacific Northwest National Laboratory, researchers already have spent more than 12 years developing a Personal Security Scanner that allows security guards to "see" concealed weapons, including plastic explosives and other nonmetallic threats.

Looking much like a conventional metal detector, the Personal Security Scanner projects ultrahigh frequency, low-powered radio waves onto the front and back of the person being screened. These harmless waves—known as millimeter or centimeter waves because they have wavelengths of about one centimeter—penetrate clothing and bounce off the person and the items he or she may be carrying.

An array sensor captures the reflected waves and sends the information to a high-speed image-processing computer. The computer produces a high-resolution, three-dimensional image from the signals.

Pacific Northwest's expertise in three-dimensional holograph imagery is based on a program established at the Laboratory in the 1970s to develop nondestructive evaluation technologies for nuclear reactors.

As these capabilities are applied in new ways, some new challenges have arisen. "The images show human features, so we are developing processing techniques that we call privacy algorithms," said Doug McMakin, an engineer who helped develop the technology. "We're working toward converting the images into gender-neutral, wire-frame images or silhouettes," he said.

Eventually the system may be fully automated so that it would detect and identify a concealed object and then alert security guards to the threat. At this point, however, the human brain is still needed to interpret the image. "We're exploring different methods to help operators accurately identify risks, and to do so in a way that also addresses privacy concerns," McMakin said.

Over the last few years, McMakin and his colleagues also have focused on reducing the time it takes for the system to scan a person and process the data to avoid bottlenecks at security checkpoints. In recent years they have cut the time down to less than 10 seconds per person.

Federal agencies have funded this research and development since 1985 and in 1989 the Federal Aviation Administration became interested in the technology's potential for screening airline passengers. The Personal Security Scanner could possibly be used at points of entry for mass transit systems; government buildings such as courtrooms, embassies and prisons; and crowded public places such as sports arenas and concert halls. It was originally developed to identify dangerous objects that people might bring into a facility, but it also could protect against theft by identifying concealed items that people might try to sneak out of a museum or nuclear facility.

With continuing changes in security laws and regulations driven by the terrorist attacks on Sept. 11, Pacific Northwest is actively negotiating with several parties to commercialize this technology. Commercialization and licensing efforts may result in the establishment of a locally based product engineering operation using third-party manufacturing to enlarge the FAA's supply chain for security products. ●

Border training helps reduce dangerous smuggling

Stopping the traffic of components, materials and commodities used to make weapons of mass destruction could reduce the number of weapons produced.

That's the intent of a joint program between the U.S. Customs Service and Pacific Northwest National Laboratory that provides classroom and hands-on training to foreign border guards, customs patrol and frontier police. The classes teach attendees how to spot red flags that should trigger a search, as well as how to use specialized technology to detect and identify items used to make nuclear, chemical or biological weapons of mass destruction.

The program is supported by U.S. Customs, State Department, Department of Defense, Department of Energy and other government agencies. It has provided training to personnel from countries in Central and Eastern Europe and the former Soviet Union since 1997.

Students spend half their time in the classroom learning to detect, identify, interdict and investigate the illicit movement of items that may be used for weapons of mass destruction. "Our students work with materials and commodities that may be used to make weapons of mass destruction, and they work with weapon components and missile delivery systems," said William Cliff, program supervisor.

Topics include biological weapons like anthrax and how it spreads and chemical precursors for manufacturing weapons such as mustard agent. Students learn to recognize the signature of various radioactive isotopes, including special nuclear materials like weapons grade plutonium and uranium, industrial and medical isotopes.

Field exercises, held at the DOE's Hazardous Materials Management and Emergency Response (HAMMER) training center, help students sharpen their intuition about smugglers and hone identification and response skills. Students are confronted with situations similar to those they may encounter on the job in their home countries.

Two technologies used in the field exercises, the Ultrasonic Pulse Echo and the Materials Identification System (MIS), were developed at the Laboratory. The ultrasound device, a hand-held gun that transmits ultrasonic pulses and detects return echoes, can determine the contents of a sealed container and is sensitive enough to distinguish between diet and regular Coca-Cola. The device helps users find objects or compartments in liquid-filled containers and solid materials, including shipping drums and metal ingots.

MIS allows inspectors to touch a piece of metal with a probe and compare it with a database of known materials. MIS can identify material that may be used for nuclear weapons applications so border guards can prevent the shipment from reaching its destination. Both MIS and the ultrasound system excel at picking out commingled items, a common smuggling approach.

In part, the border training program protects U.S. interests by reducing the risk a foreign country could accumulate sufficient components to construct weapons that might eventually reach the United States. "Every country that has built some kind of nuclear device, including the U.S. in World War II, got some materials from outside," Cliff said. "That's why the transportation corridor is so important."

As a result of the Sept. 11 incidents, Cliff said he expects border enforcement training at HAMMER to double. ●

Sophisticated imagery analysis paints clearer pictures

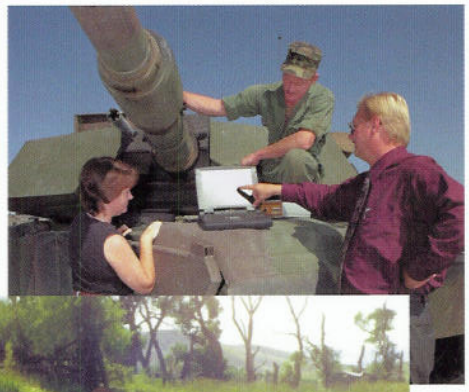
Pacific Northwest National Laboratory launched its Imaging Science and Technology Initiative (ISAT) in 2001 to cover a broad range of potential applications, including counterterrorism.

The initiative's ultimate goal is to assist experts in numerous fields who rely on imagery make more timely and beneficial decisions. These fields include national security, biological sciences, natural resources and energy. In national security, for example, remote sensing satellite imagery could be used to monitor treaties or to identify terrorist training camps or other threatening activities. Closer to home, personnel scanning at airports involves some type of imaging, such as an x-ray or millimeter wave system that detects not only metal, but also plastic and ceramic weapons.

Pacific Northwest scientists are developing a flexible, easy-to-use suite of image analysis tools based on new mathematical methods and advanced imagery visualization technologies. These tools will enhance image analysis and understanding, whether the images are from space satellites or laboratory microscopes. ●

Modernizing the military

New technologies are playing an increasingly significant role in nearly every aspect of society, and the military is no exception. From software to identification systems, diagnostics to emergency management, Pacific Northwest National Laboratory has developed technologies that could support the military as it moves into the 21st century.



Dog tags go digital

Researchers at Pacific Northwest have developed a "digital dog tag" based on the Laboratory's radio frequency technology that could quickly provide critical information to those who are responsible for assessing injuries, administering treatment and transporting wounded military personnel in the field.

The Tactical Medical Coordination System, or TacMedCS, consists of two components—the tag and the reader. The tag is a silicon chip and antenna encapsulated in rubber that would store an electronic record of a person's medical history, condition and treatment. The second component includes a device that beams radio frequency waves to "read" and update information stored on the tags. It also contains a global positioning system to track a patient's location, a wireless modem and a computer.

After developing a proof-of-concept system and conducting initial field testing in collaboration with the Naval Aerospace Medical Research Laboratory, researchers now face the challenge of making the reader portion of the system smaller and lighter so it could easily be carried by Navy corpsman providing medical treatment.

Are the tanks ready?

The Laboratory's prototype system to diagnose and predict failures in the turbine engines of the Army's M1 Abrams main battle tank helped pique the Army's interest in prognostic technology. REDI-PRO, or Real time Engine Diagnostics-Prognostics, was designed to continuously monitor data from sensors on the Abrams' engine and uses artificial neural networks, rule-based algorithms and predictive trending to recognize normal and degraded operating conditions. The same approach to prognostics is applicable in other military vehicles.

Decision details on the desktop

The Laboratory's EMAdvantage is a suite of information system tools created to prepare for emergencies at chemical weapons storage depots. The Federal Emergency Management Information System (FEMIS) gives the Utah Comprehensive Emergency Management Center the capability to quickly and easily communicate key information between the Deseret Chemical Depot, Tooele County and the Utah State Comprehensive Emergency Management Agency.

Originally developed for the Army, FEMIS served as the basis for hazard emergency management software that is being customized and enhanced for various applications. A version of EMAdvantage installed at the Minatitlan Refinery in Mexico was customized to address situations specific to the oil industry and translated into Spanish. Earth Alert—another extended version—can speed the process of declaring national disasters by allowing users to collect and communicate damage assessment data directly from the field using wireless handheld devices. EMAdvantage is available to government and commercial users.

Sending in the GOAT

Engineers at Pacific Northwest have developed the concept for a battery-powered robot that might one day take the place of soldiers doing reconnaissance surveillance in the field. Under a $500,000 contract from DARPA, Laboratory engineers and two development partners created the conceptual design for the Goes Over All Terrain Robotic Vehicle.

Known as GOAT, the machine would maneuver at speeds of up to 15 miles per hour and would be equipped with global positioning equipment, sensors and cameras. Independent wheels, arms that could move individually and remote radio frequency controls would allow GOAT to traverse difficult terrain and cross water.

Based on GOAT's scalable design, the team is designing and fabricating a smaller version targeted for use in urban areas and inside buildings where it could be deployed in terrorist and hostage situations. The modular design also allows GOAT to be quickly adapted with different wheels and tires for use in caves and other hazardous exploratory work. ●

See **www.pnl.gov/news/back/army.htm**. An animation of GOAT appears at **www.pnl.gov/breakthroughs/media/win-spr02/goat.avi** or **www.pnl.gov/breakthroughs/media/win-spr02/goat.mov**.

Biological

science takes on a new dimension

"We've been learning more and more about less and less," said H. Steven Wiley, a senior chief scientist at Pacific Northwest National Laboratory who leads the Biomolecular Systems Initiative. While Wiley meant to be humorous, he was summing up the challenge facing today's life scientists and the reason systems biology is the wave of the future.

When scientists are investigating complex systems, they usually start at a high level and break things down into smaller pieces as they discover more specific details. Researchers then begin specializing in trying to understand how individual parts of the system might work.

Pacific Northwest's Biomolecular Systems Initiative takes a systems approach to biology to build solutions to critical environmental and health problems. Defining how to bring together diverse types of information is at the heart of the initiative.

"Biology is very complex. It is governed by physical and chemical processes as well as higher level processes. To fully understand living systems, people need to think about how to take knowledge from different fields of science and find a way to integrate it."

"Unlike physics and chemistry, which are guided by well-established rules and laws, the life sciences have been predominantly descriptive. We are only now entering a phase where the underlying principles can be understood," Wiley said.

The Laboratory's initiative integrates data in ways that allow scientists to begin understanding how higher level systems work. Laboratory researchers are building mathematical models to simulate living systems. Scientists compare data collected in experiments with their models and use high-powered computers to explore both their results and the simulations. They test and revise the models as they learn. "Eventually, the result will be a mathematic model that accurately represents what is happening in the subsystems of a cell," Wiley said.

One application for the new models would be drug design. Researchers can learn why a drug degrades in the body and how the drug travels through cellular pathways. With that knowledge, they can find ways to change the drug to make it last longer. "We're learning more about the relationship between the small parts and the entire system," Wiley said.

Pacific Northwest is involved in all aspects of systems biology, pursuing computational science, research instrumentation, experimental studies and mathematical modeling.

"The future of life sciences and the benefits it will bring will be enormous. It will completely revolutionize science and technology," Wiley said.

The U.S. Department of Energy supports systems biology research because it can lead to solutions to problems in energy, health, national security and the environment including carbon sequestration, bioremediation and global warming.

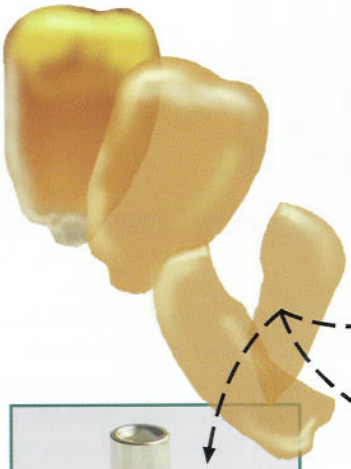
"It's amazing to think that we can have the knowledge of how living things work captured in a network of computers and be able to tap into thousands of parts of a cell at laboratories around the world, Wiley said. "I think we'll be there within 50 years." ●

For more see **www.biomolecular.org**.

Science of doing business

Opening new markets for agricultural byproducts

Consider corn hulls—an inexpensive, plentiful, bovine banquet.



Each year the U.S. corn milling industry generates almost 14 billion pounds of fiber as hulls are removed so that the starch, protein and vegetable oil within the corn kernels can be processed. Cattle feed is the primary use for this fiber byproduct and is typically the lowest value product of corn milling.

But new processes developed through a Cooperative Research and Development Agreement between Pacific Northwest National Laboratory, the National Corn Growers Association and food processor Archer Daniels Midland (ADM) are expected to change all that.

Researchers at Pacific Northwest and ADM have developed processes that will reclaim greater value from this resource by separating the corn fiber into its basic components—lipids, carbohydrates, proteins. These products will then be used to produce fuel ethanol and the building blocks for industrial chemicals, as well as higher value food, feed and consumer products. "We're taking something that had very low market value and opening up lucrative new markets for it, while also creating new supplies for existing, higher-margin markets," said Todd Werpy, program manager for Pacific Northwest's Environmental Technology Directorate.

Working together, the research teams have developed a financially attractive process that enables optimal extraction of specialty lipids and significant amounts of sugars. "In essence, we've developed an economically attractive disassembly process to get out what we knew was in the fiber, but couldn't be recovered cost-effectively in the past," Werpy said.

By separating the lipids from the fiber that comes off the kernel, trace amounts of sterols can be extracted using the new process. Although small in volume, the sterols have high-value applications as food supplements and in many consumer products, including cosmetics, shampoo and other personal care products. While the market for sterols is not a new one, there has been limited supply and this process will help keep pace with consumer demand.

The carbohydrate portion of the hull—what was previously sold only as cattle feed—yields various sugars, most of which can be chemically converted to propylene glycol and ethylene glycol, compounds used in industrial and consumer products, including plastics, polyesters and antifreeze. These chemicals create substantial value and have significant global markets. The remaining sugar will be used to make fuel ethanol, a high-value product that reduces U.S. oil import requirements by almost 2 billion gallons every year.

"We believe this process can be financially successful on a commercial scale," Werpy said, speaking for the ADM, Corn Growers and Pacific Northwest team. Benefits include opening new markets for grain processors, making corn a more profitable crop for farmers and reducing U.S. needs for petroleum, since this new supply of ethanol will replace petroleum-derived fuels and chemicals.

Researchers also envision comparable uses for low-value byproduct streams produced by other segments of agribusiness, such as wheat and rice milling, oil seed crushing and dairy processing.

The Laboratory, ADM and National Corn Growers will define an optimal, integrated process in 2002. Depending on the results of this work and availability of funds, the team hopes to test the complete process at pilot scale during the following two years, with full-scale commercial implementation anticipated soon after. ●

NOTABLE Achievements

DOE rates Laboratory operation 'Outstanding'

For the fourth consecutive year, the U.S. Department of Energy's Richland Operations Office awarded Battelle the highest rating possible for its operation of the Pacific Northwest National Laboratory.

"The high quality of scientific and technological work performed at PNNL is gaining more national and international recognition," said Paul Kruger, DOE's Richland Operations Office Associate Manager for Science and Technology.

DOE evaluates Battelle's performance on several "critical outcomes" that were developed jointly by DOE and the Laboratory. DOE determined that the overall performance in each of these areas was outstanding for the 2001 fiscal year.

Science and Technology

The Laboratory has demonstrated continued success in its Biomolecular Systems, Computational Sciences and Nanoscience and Nanotechnology initiatives. Battelle continues to create and maintain strategic partnerships that strengthen the Laboratory's scientific capabilities.

Operations

According to DOE, Battelle has operated the Laboratory facilities in a way that supports and integrates its science and technology mission and the protection of workers, the public and the environment.

Leadership and Management

Regional partnerships, including academic and industry relationships, enable the Laboratory to become recognized as an asset to the surrounding community, region and nation. The Laboratory helped create eight companies in southeastern Washington in 2001 and continues to support the community's economic development activities.

During a visit to the Laboratory in late 2001, DOE Secretary Spencer Abraham also announced his intention to extend Battelle's contract to manage and operate the Laboratory for an additional five years. The current contract expires in 2002. ●

$8.4 million in research grants awarded

The U.S. Department of Energy has awarded Pacific Northwest National Laboratory $8.4 million to fund research projects aimed at solving some of the nation's most complex environmental cleanup challenges. The awards are part of DOE's Environmental Management Science Program (EMSP) and are highly competitive among national labs and universities.

Pacific Northwest's $8.4 million in grants accounted for 21 percent of the total $39.6 million DOE awarded to institutions across the country. Most of the Laboratory's award, $7.3 million, was targeted at high-level radioactive waste research. "The Lab is traditionally very strong in this area and we've made commitments to remain that way," said Roy Gephart, program manager at the William R. Wiley Environmental Molecular Sciences Laboratory. Pacific Northwest received 26 percent of DOE's total EMSP grants in high-level waste.

The remaining $1.1 million in awards was for research in facility decontamination and decommissioning. The Laboratory's awards in this area focus on the use of natural products to stabilize and remediate contaminated systems with secondary waste streams that are smaller and less hazardous.

Congress established the EMSP awards in 1996 to encourage new knowledge leading to less costly, more innovative and safer waste cleanup technologies. Gephart emphasized that the Laboratory is helping establish the science base for more efficient and effective cleanup. "That's what EMSP is all about. If we solve the underlying scientific issues, technologists can exploit these innovations at Hanford and other DOE sites." ●

For a list of projects, go to **www.pnl.gov/breakthroughs/media/win-spr02/emspaward.pdf**.

Giving an EDGE to sustainable design

Pollution prevention and energy efficiency are not only good for the environment, they are good for the bottom line.

Researchers at Pacific Northwest National Laboratory have developed tools for sustainable design, a term that describes a systematic approach to ensuring that facilities, products and processes are addressing the "triple bottom line"—the environment, economics and social equity.

The Environmental Design Guide for Engineers, or EDGE, is a software tool that provides information about more than 250 opportunities to incorporate sustainable design into projects, including measures that help reduce life-cycle costs while increasing energy efficiency and material efficiencies. Users can browse the opportunities in search of ideas appropriate for their facility. They also could use EDGE as a mechanism to document opportunities already included in the design, those being reviewed for consideration and those that don't apply.

"Facilities, products and processes should not be isolated from the

environmental economic and social systems surrounding them," said Kim Fowler, who helped develop the tool. "Sustainable design involves balancing the needs of humans with costs and the environment to ensure that new designs are considering the triple bottom line."

EDGE allows users to evaluate sustainable design opportunities based on how difficult it would be to implement the recommended actions and the potential avoided costs.

For architects, engineers and sustainable design experts, EDGE can be used to generate ideas or as part of a design assessment. It also can document design decisions for a certification process, such as the U.S. Green Building Council's Leadership in Energy and Environmental Design, a rating system that evaluates a building's environmental performance.

"EDGE offers concepts that, when implemented, will reduce the environmental impact and avoid costs throughout the life of a facility—from design, construction, operations and decommissioning," Fowler said.

Pacific Northwest offers sustainable design strategies that integrate physical science, engineering and social science. In addition to EDGE, the Laboratory has developed tools and conducted assessments as part of its work for the U.S. Department of Energy's Sustainable By Design project. Since 1993, this effort has allowed DOE to avoid approximately $24 million in construction and operating costs.

The EDGE software is available to DOE and its contractors at no cost. ●

For more, see **www.pnl.gov/doesustainabledesign/tools/edge.htm**.

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