Breakthroughs

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SUMMER 2003

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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.

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Frequency: Three times a year

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

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editor's screen

More than half of the world's population lives near a coastline. We migrate toward the ocean to live and play and work. It provides natural beauty, food, livelihood, transportation and supports commerce. It takes a lot of abuse. And it offers a lot of possibilities.

In this issue of Breakthroughs, we look at how scientists at Pacific Northwest National Laboratory's Marine Sciences Laboratory in Sequim, Wash., have been working with the marine environment to solve diverse environmental problems and how their research is being expanded to include national security applications.

Experts in coastal assessment and restoration, these scientists have developed and implemented systems to maintain and restore coastal ecosystems. They are cultivating eelgrass for restoration as well as developing a technique for using eelgrass to remediate contaminated sediment in seawater and freshwater. As part of their national security work, scientists at the Marine Sciences Laboratory are exploring the use of bivalves as a tool to monitor the manufacture of chemical weapons.

The wet lab at PNNL's Marine Sciences Laboratory sits on Sequim Bay.

This issue also includes stories about PNNL's research to help make today's pervasive computing more natural, a regional program that promotes economic growth and a microtechnology that can be used as an alternative to conventional batteries. ●

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AT A *glance*

No more free ride for phytoplankton

They may not be terrorists, but they can be sneaky—phytoplankton. These single-celled algae can sneak into nonindigenous harbors and coastal waters via ships' ballast water. Toxins from the phytoplankton can be taken up by shellfish and become harmful to humans who consume the shellfish.

Researchers at Pacific Northwest National Laboratory are working to adapt the Laboratory's matrix-assisted laser desorption/ionization mass

spectrometry (MALDI-MS) technology to quickly and accurately identify the presence of toxic phytoplankton in ballast water and prevent its release into the wrong environment. The development of MALDI-MS for detecting and monitoring nonindigenous phytoplankton will address the U.S. Navy's need for a streamlined and cost-effective approach to assessing and managing microorganism transport in ballast water.

Future national security applications may include using MALDI to check cargo ship ballast water for phytoplankton and harmful bacteria. ●

New product offers alternative to toxic deicers

With the U.S. military using nearly 3 million gallons of toxic glycol-based deicer a year in addition to the nearly 30 million gallons of aircraft deicing fluid commercial airlines use, the U.S. Department of Defense looked to Battelle for a more environmentally friendly solution to deice aircraft. Working together, Battelle researchers at PNNL and Columbus, Ohio, developed a safe, biodegradable, nonglycol based product—Degradable by Design Deicer™ or D³.

D³ does not use environmentally harmful additives, reducing its toxicity levels far below other available deicing products. With D³, the biological oxygen demand is half that of standard propylene-glycol-based deicing fluids. The result is an effective deicer that minimizes environmental threats.

D³ has passed independent certification testing and was successfully demonstrated at the McKinley Climatic Chamber at Eglin Air Force Base in Florida, using commercial grade equipment under harsh snow and ice conditions. Battelle has filed for a patent for D³ technology and is pursuing partners to move this product into the marketplace. ●

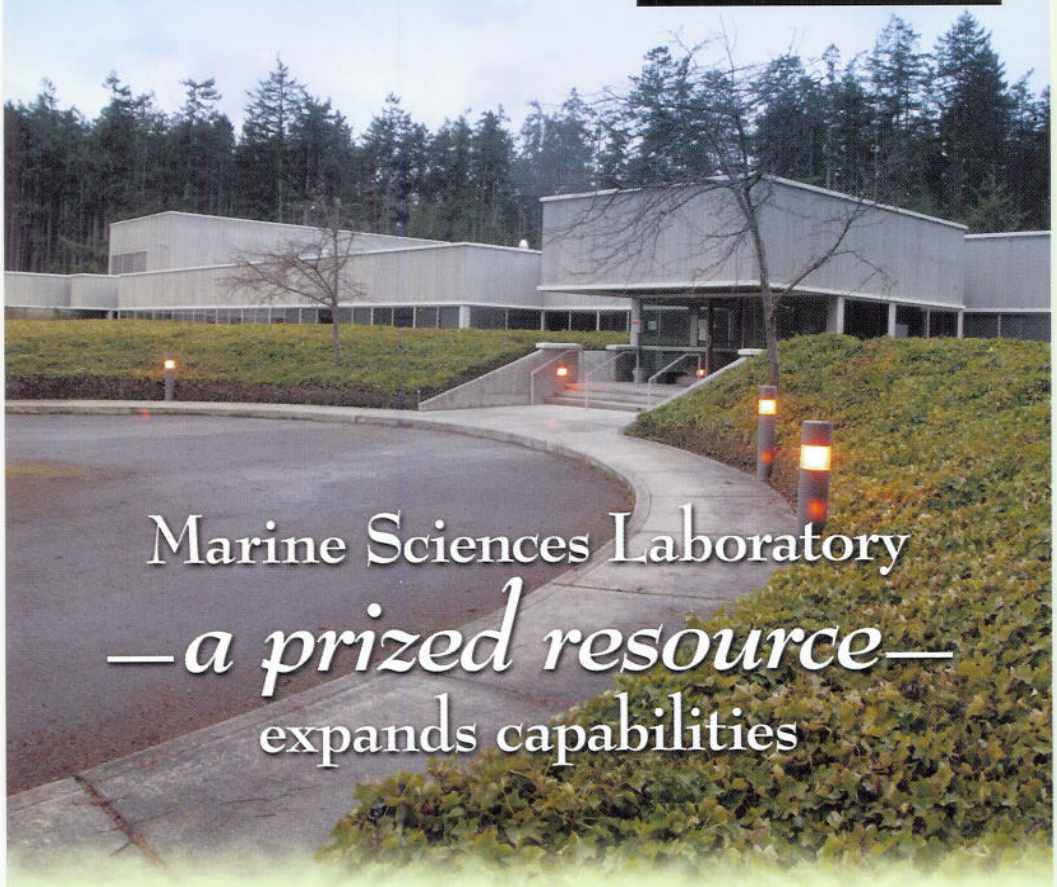
Proteomics research at home at PNNL

Proteomics, the study of proteins in living organisms, is one of the next major frontiers for the scientific community—and Pacific Northwest National Laboratory will play a significant role in unlocking the mysteries of proteins. Through its newly established Prototype Sample Processing and Proteomics Facility, PNNL will help pave the way to eliminating diseases such as muscular dystrophy and for creating targeted drugs.

Understanding proteins and how they work will greatly improve medicine, health care and environmental cleanup. While simple in concept, this research requires advanced technologies and tools. PNNL's new facility supports the U.S. Department of Energy's Genomes to Life research, combining the Laboratory's capabilities in computational chemistry, biomolecular science and advanced instrumentation to address this complex field of research.

Researchers are analyzing the proteome of several environmentally relevant micro-organisms, including radiation-resistant *Deincoccus radiodurans*, uranium-reducing *Shewanella oneidensis* and the photosynthetic *Rhodobacter sphaerodies*. Such analyses will help researchers identify the changes in protein expression

patterns related to environmental conditions so these microbes can be used for bioremediation, carbon sequestration and energy production. ●



Marine Sciences Laboratory —*a prized resource*— expands capabilities

Renewed interest in homeland security, continued need for environmental solutions and a growing market for industrial products have made Pacific Northwest National Laboratory's Marine Sciences Laboratory (MSL) in Sequim, Wash., a focal point for developing new capabilities. Nestled in the quiet harbor of Sequim Bay on the Olympic Peninsula, MSL was established in 1967 and features state-of-the-art facilities. Over the years, MSL staff have conducted advanced research aimed at preserving and protecting the coastal and marine environment.

For the past year, staff from PNNL's National Security and Environmental Technology research organizations have been working on a plan that will increase and diversify MSL capabilities. The plan's objectives are to identify, develop and implement a comprehensive strategy that sustains long-term growth and to increase business volume at MSL.

The plan will concentrate on three areas: enhancing coastal environmental research by finding innovative and cost-effective ways to assess, remediate and restore the coastal environment; developing a marine biotechnology market niche, including research and development in the areas of marine fermentation, marine biotoxin detection, biosensors and other innovative products; and building coastal security programs related to homeland and national security, coastal analysis and military operations.

Walter Pearson, associate director of the Marine Sciences Laboratory, and Paul Sliva, manager of strategic planning for PNNL's National Security Directorate in Richland, co-lead the plan to transform business at Sequim.

What is unique about MSL's capabilities?

Pearson: Our location, facilities and staff are our prized assets. MSL's location is close to ideal, with pristine water in Sequim Bay and a physical site on the water with room to grow. We are somewhat remote and have a reliable supply of excellent quality seawater, the perfect combination for environmental work.

MSL facilities include several unique features—in particular, the ability to conduct flow-through bioassays with sophisticated delivery of the pollutant. At most labs, when exposing aquatic organisms to pollutants, test water must be changed frequently to maintain chemical levels because pollutants often volatize into the air. At MSL, we can go beyond static renewal (of test water) to perform flow-through bioassays, and we have maintained such bioassay systems reliably for months.

Another unique feature is our ability to treat our effluent. When we conduct bioassays, the water goes through a purification system that removes the contaminants from the water. MSL is one of only two labs on the West Coast that has this capability.

MSL's wet lab is well-designed to accommodate diverse studies, from basic research on chemical sensory abilities of fish and crab to large-scale studies that examine the toxicity of dredged material.

We also have on-site analytical chemistry capabilities, which complement our bioassay programs. Through these capabilities, we are better able to provide comprehensive services to our clients and meet the quick turnaround requirements that are critical to our work.

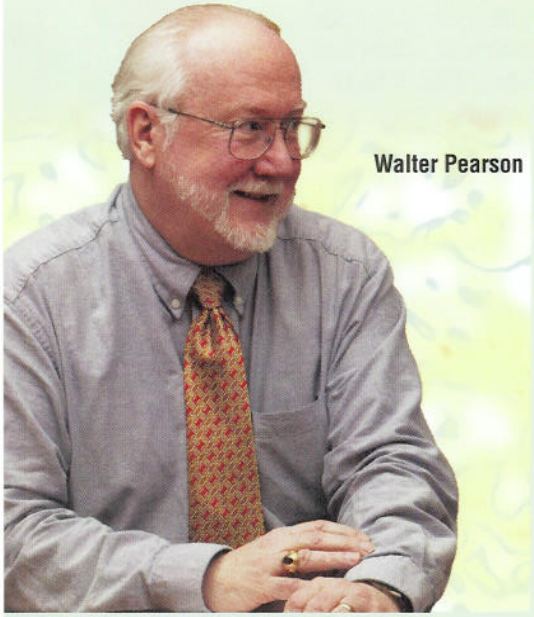
MSL has the ability to analyze ultra-low trace levels of mercury, arsenic and other metals, and to perform speciation techniques that

can determine what form the metal is taking in the environment. If these metals are bound or in a form that is not bioavailable, they might be less toxic to the environment. MSL's speciation capability allows us to provide information to our customers that will enable them to perform better risk assessments.

The staff are what make this place tick, however. They bring a diverse set of skills, and they work as a team. We have biologists and chemists talking about projects, designing them and executing them together. That's a capability that's often called for but not often achieved. I'm proud of our staff's ability to do that.

Finally, as part of PNNL and Battelle, we're able to call upon the capabilities and resources of the entire institute.

Sliva: From a national security standpoint, the Marine Sciences Laboratory is unique because of its location on the Pacific Northwest coast, which makes it ideal for anyone wanting to do national security research and development with a national laboratory. Our goal is to marry MSL's strong environmental assessment and restoration capabilities with PNNL's crosscutting science capabilities and apply them to solve national security challenges.



Walter Pearson

How has MSL's focus evolved over the past 36 years?

Pearson: Our ecotoxicology group conducted a lot of the pioneering research in oil spill fate and effect. Now the group is looking at other chemicals and biological organisms of environmental and national security concern and the bioavailability of metals. The ecotoxicology group also moved into dredged material evaluation in the 1980s and developed methods that are now standard in the field. The group recently transformed itself again and is developing a program to screen endocrine disruptors—chemicals in the environment that can disrupt hormonal systems in humans and wildlife, including fish, amphibians, mammals and birds.

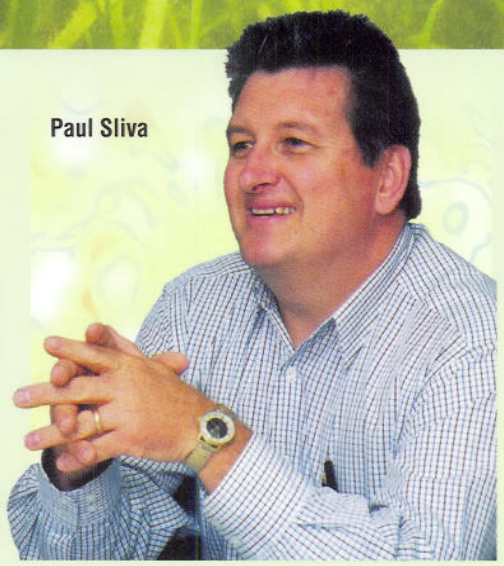
One of our other core groups—environmental chemistry—has maintained its expertise in metals and geochemistry. The group has developed many analytical techniques that have become standard practice in mercury and arsenic speciation detection.

We've also added a marine resources group that focuses on natural resource issues in the coastal zone. The group is looking at how to restore coastal habitat and the metrics necessary to determine whether a restoration is successful.

What issues and challenges does MSL currently face?

Pearson: The main challenge is renewing ourselves. Being at the cutting edge of new technology and applying those new technologies to the resolution of pressing environmental problems is what we do best. This requires major investments by Battelle, investments by the individual investigators in developing new science and technology and success in winning new projects.

Sliva: Another significant challenge is managing growth. There is a potential for tremendous growth if we are successful in expanding our national security programs along with the projected growth of current core business.



Paul Sliva

Having the infrastructure in place to accommodate that growth also is going to be a big challenge. If successful, we will eventually be asking ourselves when is the right time for new office and laboratory space.

Another challenge for MSL is balancing the project portfolio. We hope that we can use the national security work to diversify client sets, which will help us weather downturns in other business areas.

What is your vision for MSL?

Pearson: Our plan to transform MSL has three components: coastal assessment and restoration, the Coastal Security Institute and marine biotechnology.

Coastal assessment has been our core work, and we've been successful in it, but because we are at full capacity in our labs and offices, we need investment to keep MSL growing. The Coastal Security Institute builds on a lot of the skills and capabilities of our coastal assessment work. Coastal assessment helps us understand the environmental processes and environmental structure of the coastal system. This knowledge and experience can be applied to resolving coastal security issues.

Of the three components, marine biotechnology has the most long-term potential for transforming business

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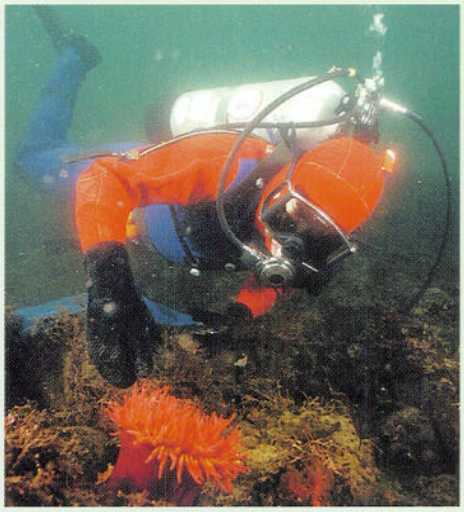
within the environmental arenas. Two aspects to marine biotechnology are of interest to us. One is the application of marine biotech to environmental issues—using the tools that are emerging from marine biotech, for example, to remediate contamination in marine environments.

We also are interested in research and development of industrial products. We hope to develop a niche that helps us move beyond bench-scale discovery to scale-up studies that prove one can produce a useful product from marine organisms in sufficient quantity to meet a demand in the marketplace and at a cost that will be economically viable.

Sliva: On the national security side, we envision building coastal security programs related to homeland and national security, coastal analysis and military operations. MSL will become a focal point and resource for R&D in a coastal environment for the Pacific Northwest.

We'd like to draw upon the core capabilities being done in coastal assessment, apply them to solve national security problems and reapply the new capability to address environmental challenges.

We see Sequim as a focus for developing various types of measurement and signature capabilities in a marine environment. Collecting this type of data in a marine environment



is quite challenging because the complexity of saltwater makes it difficult to analyze for targets of interest. But the coastal environment, including rivers and inland lake reservoirs, is an area we need to be concerned about.

We also envision Sequim as a potential resource to test new concepts and technologies for the U.S. Homeland Security Department. We're interested in netted sensors, for example, where a group of sensors talk to each other and to a central location. The suite of sensors could be chemical, radiological or biological. They may be floating on the surface, below the surface or below the surface and come up every now and then. The concept is open. For example, if something was moving through the water, like a chemical spill, different sensors would pick it up at different times. Because there's a time lag between each sensor picking up the movement, and each sensor "knows" its location, you get dynamic information. You can track the speed and the direction of the chemical spill. Netted sensors on the surface also could pick up something moving through the air.

How do MSL and PNNL's Richland campus work together?

Pearson: We have a well-developed connection with the Environmental Technology Directorate in Richland, our parent unit and one of PNNL's four research directorates. We have identified, proposed and won projects that use our combined capabilities. Very often that same client comes back to us later with a different project.

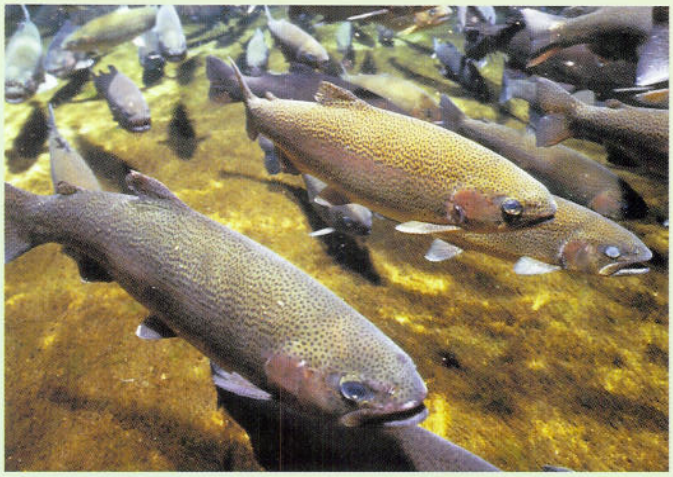
We now need to move from the project level to the institutional level. Our work with other directorates, such as our collaboration with the National Security Directorate, will accomplish this objective. Working together at the institutional level will transform MSL from being a shop that works on individual projects to an integrated laboratory that takes advantage of all its resources.

Sliva: We envision growing the business at MSL, but we also realize that we will team with staff in Richland to help complement Sequim's capabilities. Early on in the growth, there are going to be strengths in Richland unavailable in Sequim; for example, classified capability, which includes the ability to hold secure meetings. Our ability to work together as a national laboratory with a wide range of capabilities in science and engineering is what makes PNNL such a unique asset. ●

Short-term estrogen exposure cuts fish fertility

A new study by Pacific Northwest National Laboratory and the University of Idaho shows that exposure to estrogen affects adult fish as they swim through rivers, lakes and streams to spawn. The study suggests that when adult male fish are exposed to short-term and low concentrations of synthetic estrogen, their fertility can drop by as much as 50 percent.

Previous research reported that high concentrations of estrogen could change sex organs, causing juvenile male fish to develop female organs. Estrogen is an active ingredient in most oral contraceptives and often travels to surface waters through sewer systems. The PNNL study looked at the impact of a synthetic estrogen called ethynylestradiol, which is the chemical in oral contraceptives.



Irvin Schultz, the PNNL toxicologist who led the study, said the research reinforces that impacts aren't limited to juvenile fish.

"We can see that adult fish aren't immune to the effects of estrogen in waterways. Even short-term exposure to low levels of synthetic estrogen can impact fertility," Schultz said. He noted that results indicate fertility in a healthy male trout that has developed normally can be affected if that exposure takes place during a critical sexual maturation stage before spawning.

The experiment took place at PNNL's Marine Sciences Laboratory. Adult male rainbow trout were exposed for 62 days to three different concentrations of the chemical. The sperm of exposed fish were harvested, then used to fertilize eggs from a healthy female rainbow trout. A measurable decrease in fertilization was observed in the treated trout, compared with a control group. For more information see **http://www.pnl.gov/news/2003/03-20.htm**. ●

Biosentinels reveal what's in the water

We've depended on bivalves before. Their unique ability to preconcentrate toxins has made them useful sampling devices for contaminants such as metals, organic pollutants, radionuclides and bacteria that cause human disease.

In the era of chemical warfare, we may need these marine animals with two shells again.

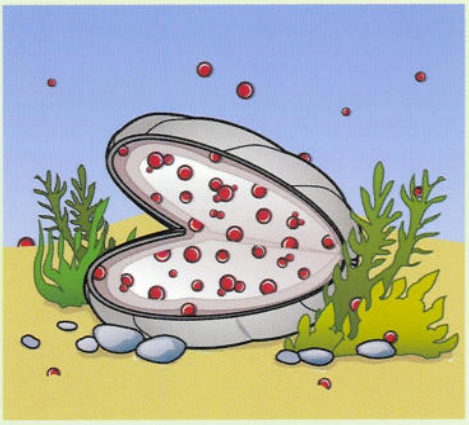
Researchers at PNNL's Marine Sciences Laboratory are studying the feasibility of using bivalves as a tool for monitoring the manufacture of chemical weapons.

While bivalves can regulate certain contaminants that are biochemically important to their survival, such as zinc and copper, their systems can't metabolize persistent organic chemicals, such as polychlorinated biphenyls (PCBs) or certain pesticides, so these contaminants stay in their systems for a long time.

"The advantage of using bivalves is they may have already preconcentrated chemicals 1,000 times more than what would be in a water sample," said Eric Crecelius, who manages the project for PNNL. "Bivalves also may retain contaminants for days to years longer than the water they live in."

The disadvantage of bivalves' ability to store contaminants is that researchers can't be sure how long the chemicals have been in the shellfish or if they came from a different source, such as fertilizer processing.

Researchers at MSL have designed a laboratory experiment to test bivalves' ability to accumulate chemical contamination in freshwater, marine water and estuary conditions. The experiment will test chemicals that may be used in chemical weapons processing or storage.



As part of the bivalve experiment, scientist Lyle Hibler is creating models to predict the movement of water in coastal environments. "If you understand the mixing going on in an estuary environment, you're more likely to collect samples in the right places," Hibler said. ●

Jaws IV: Algae takes on CO_2

Billions of tons of carbon dioxide from fossil-fuel-fired power plants are pumped into the air each day, contributing to global warming.

Scientists at PNNL's Marine Sciences Laboratory in Sequim, Wash., are looking at marine algae as a solution to global warming caused by carbon dioxide emissions from fossil-fuel-fired power plants.

Marine micro algae are bacteria that take up carbon dioxide during photosynthesis in a process called biofixation. During biofixation, micro algae transform fossil carbon dioxide into algae cell mass.

Scientists envision pumping carbon dioxide that would have gone through a smokestack into big outdoor ponds containing micro algae, converting the greenhouse gas into algae biomass. "One of the options for disposing of the algae is to produce renewable fuels that could be used in place of fossil fuels," said Michael Huesemann,

environmental research engineer at MSL. "This would create a closed carbon cycle where the carbon dioxide released from the combustion of algae-derived fuels would be fixed again by micro algae via photosynthesis, resulting in no net greenhouse gas emissions."

Huesemann and his colleagues are experimenting with algae species from as far away as Hawaii and Italy to find the algae with the highest growth rate and those that convert carbon dioxide into biomass most efficiently.

The scientists' goal is to develop a mathematical model to predict how algae will perform in outdoor ponds based on laboratory measurements of specific parameters, such as growth rate and photosynthetic yield. "It's much more efficient to plug specific parameters into a model and run it for different conditions like temperature and light intensity than to study 20 different species in outdoor ponds," Huesemann said. ●

Photosynthesis shines as remediation tool

Marine construction, wood treatment, agricultural chemical production, chlorine production—for decades we have been dumping waste into our harbors, many of which are now considered some of the most contaminated hazardous waste sites in the United States.

Battelle researchers at PNNL's Marine Sciences Laboratory have developed a promising technique for remediating contaminated sediments in seawater and freshwater ecosystems.

"The main limiting factor affecting the biodegradation of many organic contaminants is the availability of oxygen," said Michael Huesemann, who manages the project. "Oxygen is required for naturally occurring bacteria to oxidize, or biodegrade, organic contaminants."

Under normal conditions, very little oxygen gets into the sediment, diffusing only a few millimeters and allowing for the bioremediation of only a thin layer of sediment.

Huesemann believes he has found a solution with eelgrass and the simple process all plants use for nourishment—photosynthesis. "In eelgrass, we have a photosynthesis-driven oxygen pump that delivers oxygen into sediment for free, as long as there is sunlight," he said.

Although eelgrass roots grow only about six inches, they deliver oxygen much deeper into the sediment and therefore stimulate biodegradation in a much thicker layer than would occur by natural biodegradation where only the top few millimeters are bioremediated. "If you can remediate the top six inches of sediment with eelgrass, you have created a clean cap where animals can live," Huesemann said.

Tests at the Marine Sciences Laboratory showed that within five months about 60 percent of polycyclic aromatic hydrocarbons (PAHs) were removed in sediments planted with eelgrass, while during the same period only 24 percent of the PAHs were removed in unplanted sediments.

Readers interested in field testing this insitu sediment treatment technology should contact Huesemann at **michael.huesemann@pnl.gov.** ●

Culvert technology may help young salmon muscle their way upstream

Tens of thousands of culverts lie beneath roads in the Pacific Northwest, successfully moving water under the roadbed to preserve pavement and prevent flooding. At the same time, many are blocking juvenile salmon from migrating upstream to the habitat they need to survive and grow.

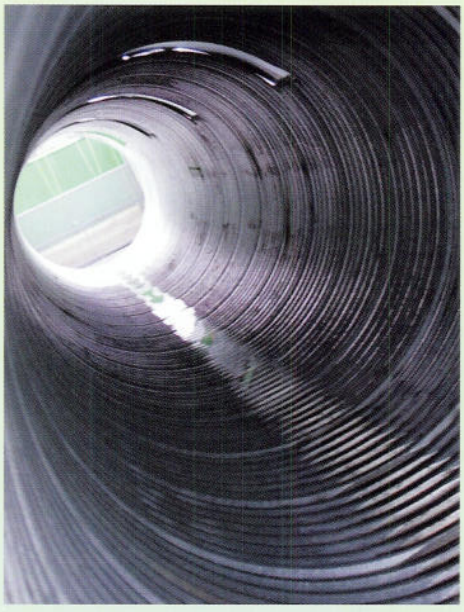
Pacific Northwest National Laboratory is participating in a consortium led by the Washington State Department of Transportation (WSDOT) that includes the transportation departments of other West Coast states and Alaska. The consortium funds a program to find viable retrofits for the thousands of culverts in the Pacific Northwest that may be preventing juvenile salmon from completing their life cycles.

The culvert test bed program promises not only to evaluate current and future retrofits, but to do so in a comprehensive way. "This project is a true interdisciplinary project because we're blending the expertise of hydraulics engineers, mechanical engineers, statisticians, fish biologists and fish behavior specialists to find a solution to a problem that faces the entire Northwest and has implications for culverts throughout the country," said Walter Pearson, who manages the project for PNNL. "We're doing this in a systematic, scientific way, using well-designed experiments in a well-engineered test bed."

Located at the Washington Department of Fish and Wildlife Skookumchuck Hatchery near Tenino, Wash., the test bed is a physical device, into which scientists can place a culvert. By changing the culvert's water flow and slope settings, scientists can measure hydraulic conditions, or how water flow interacts with the culvert system to influence water velocity or create turbulence.

Scientists are ready to begin trials with juvenile fish to determine how well fish pass through various retrofit designs. The test bed will enable scientists to set the hydraulics and observe fish behavior and then adjust the hydraulics and observe behavioral changes. "There are hundreds of possibilities for bed configurations. A particular design will stop passing fish at some flow or some slope and that's what we'll be looking for," Pearson said.

The culvert test bed allows researchers to evaluate current culverts and future retrofits.



Recent research has shown that upstream movement of juvenile salmon is important in their freshwater phase and preliminary tests of the PNNL system confirm this.

"Evidence of juvenile salmon moving upstream in our reference culvert was the last piece we needed to confirm the system will work," Pearson said. "We've proved the fish will move upstream in the culvert system. How many fish move upstream will determine the success of the various retrofit designs."

Attempting to retrofit culverts is not a new endeavor. Baffles, weirs, ladders and other physical structures have been added to culverts to enhance fish passage over the years, but little monitoring has been done to test the effectiveness of such additions.

Installation of the test bed is complete and researchers have tested the mechanics of the device. The science team has begun to test fish in the reference culvert system and will begin to test retrofit designs soon. WSDOT and its consortium funded PNNL through the U.S. Department of Energy to conduct the culvert test bed program for evaluating retrofit culverts. ●

MSL's approach to eelgrass is spreading

More than 60 percent of the world's population lives near the coast. In addition to the growing development and economic importance of coastal areas, there is a major push for maintaining and restoring coastal ecosystems.

Sustainable development, which once might have focused on maintaining an ecosystem, has blossomed into net ecosystem improvement, or restoring an ecosystem to "better" than its existing state.

This is the focus of the restoration team at PNNL's Marine Sciences Laboratory. "There are so many factors influencing plant restoration success that you can't control," said Ron Thom, who heads MSL's restoration work. "To deal with this uncertainty, we have to plan a net increase in ecosystem function on our projects."

To ensure the effectiveness of MSL's restoration work, Thom and his colleagues have developed a process for working with eelgrass—which is critical for providing shelter and food to young salmon and many other saltwater fish—that maximizes the probability of success. "Our whole program is set up in the adaptive management framework, that is, learn by doing and at the same time, acknowledge up front that there's uncertainty," Thom said.

Adaptive management is not a new concept, Thom said, but its application to habitat restoration is new. "MSL developed guidance on how to use adaptive management that is now being used nationally for restoration. It's not necessarily our specific methods, but adaptive management principles are now being applied to restoration programs in the Mississippi Delta and Florida Everglades."

Researchers harvest eelgrass that was cultivated at the Marine Sciences Laboratory and later replanted around the Clinton Ferry dock.

Thom and his team are pioneers in developing an understanding of growth requirements for eelgrass in the Northwest. They assess each potential site to see if it is suitable to grow the plant. If the probability of eelgrass success is high or moderate based on site assessment, researchers will plant.

The site is monitored with adaptive management principles in mind. "We're shooting for a certain goal but we may not make it because there are things we're uncertain about. So we set up alternatives up front and use monitoring to tell us which alternatives we'll need," Thom said.

Experimental alternatives are part of the adaptive management process. For example, the Washington State Department of Transportation recently called on experts from MSL and the University of Washington to minimize eelgrass destruction when it expanded the Clinton Ferry dock. Previous attempts to preserve existing eelgrass and replant beds destroyed by construction had often failed, but scientists' understanding of eelgrass plant needs led to a creative solution.

Scientists suggested dock designers put glass blocks in the dock's walkways. They also advised the underside of the dock be painted with a bright reflective coating. Both suggestions were designed to increase the amount of light the transplanted eelgrass plants receive.

Thom and his team salvaged eelgrass from the site before construction began and planted it in tanks at MSL, raising about 30,000 eelgrass starts. Later they replanted the dock area and a similar area for reference.

The ferry terminal project is a success. Scientists count 18,000 more eelgrass plants today than before dock expansion, a huge improvement. ●

It's not raining cats anymore

The mystery of why panthers were dropping dead from the trees in the Florida Everglades was solved fairly quickly. The mystery of how they were being poisoned with mercury took a little longer.

Scientists from PNNL's Marine Sciences Laboratory were part of a team of researchers involved with the initial assessment of mercury contamination in the Florida Everglades project between 1993 and 2000.

MSL, which has been a pioneer in mercury sampling and analysis techniques, specializes in finding extremely low levels of mercury in samples.

"It is so easy to contaminate a mercury sample. For many years, most of the data we saw was contaminated from poor sampling and analytical techniques. Now we're realizing just the degree of cleanliness required to do these analytical techniques," said Brenda Lasorsa, who managed the project for PNNL.

Because of PNNL's expertise in analyzing different chemical species of mercury, it acted as quality assurance lab for all the labs involved in the U.S. Environmental Protection Agency's assessment project. PNNL researchers analyzed a percentage of all samples done by other labs to verify accuracy, and they helped resolve data quality issues.

Just as they had suspected, researchers found industrial mercury from nearby urban areas being volatilized into the air, blown into the Everglades and rained out. While inorganic mercury is volatile, it is not easily absorbed by animals or human cells. But scientists found methyl mercury, a neurotoxin, in the dead panthers.

"We had thought the methyl mercury was occurring in the animals," said Lasorsa, "but we were surprised to find that sulfur-reducing bacteria in the sediment were responsible for producing it."

Scientists found that less oxygen in the Everglades water caused by drainage canals disrupting the natural through-flow of water, high sulfur-reducing bacteria production fed by fertilizer run-off from surrounding agricultural areas and mercury blown in from Florida's populated east coast, caused the Everglades to produce high levels of methyl mercury. "This situation is the worst possible scenario," Lasorsa said. "Inorganic mercury transformed to methyl mercury was going up the food chain from invertebrates in the water to the fish, the raccoons and, finally, the panthers."

"This started with the population boom in Florida in the 1920s and 30s, but it has only been in the last ten years that our detection limits for methyl mercury were good enough to see it was in the water," Lasorsa said. "Because of new clean techniques developed at MSL in the late 1980s and improved upon during the 1990s, we are now able to see inorganic and organic mercury at the sub part-per-trillion level. Detecting accurate low level concentrations helps us better understand how the mercury evolves and travels up the food chain."

PNNL scientist Brenda Lasorsa works in the clean room for ultra-low trace level mercury analysis.

The U.S. Army Corps of Engineers is studying the assessment data to devise a restoration plan for the Everglades. On contract with the South Florida Water Management District, PNNL's role might expand in the final project. In addition to quality monitoring, Lasorsa's team hopes to be involved in advising on how to mitigate the effects of the restoration, monitoring the wildlife and ecosystem and restoring natural vegetation. ●

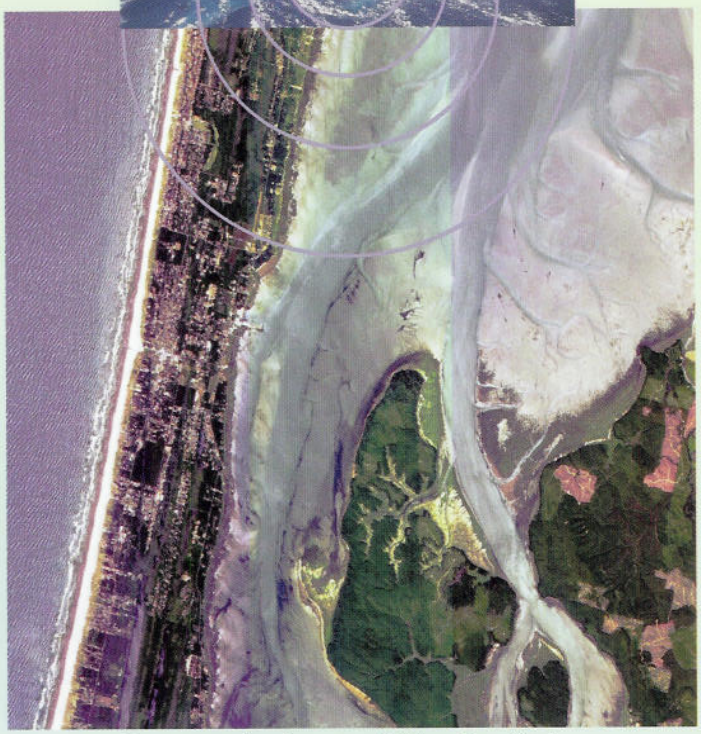
Measuring aquatic vegetation goes high-tech

Using people to manually characterize aquatic vegetation in the coastal environment may no longer be the best method of capturing features in a marine environment.

Scientists at PNNL's Marine Sciences Laboratory are combining satellite remote sensing technology and computer modeling to create better and faster analysis of vegetation coverage. "With one satellite image, you may be able to characterize an entire area by applying an algorithm to that image and converting it to a vegetation map," said Lyle Hibler, MSL computer modeling expert. "Two scenes, taken at different times, allow an analyst to observe changes over time, or trend analysis."

Characterizing submerged aquatic vegetation in the near shore environment is important for coastal resource managers who make decisions regarding ferry terminal dredging, water traffic and other issues. "Ferry terminal construction or maintenance can be detrimental to submerged vegetation, which is important habitat for fish and other marine life," Hibler said.

Although this combination of technologies has been used successfully to characterize floating vegetation offshore and to estimate the sea's surface temperature, using it to characterize vegetation in shallow water is a developing field. "We wanted to map submerged vegetation using the chlorophyll response signal. However, an abundance of free-floating material containing chlorophyll, such as dead plants and plankton, which are common in shallower water, can confound attempts to map the rooted vegetation," Hibler said.



Remote sensing imagery of Willapa Bay, Wash., from DOE's Multispectral Thermal Imager.

Near shore characterization also has several coastal security applications. The Marine Sciences Laboratory has worked on research and development projects supported by the National Imagery and Mapping Agency (NIMA), a national intelligence service, to better characterize the ever-changing features in the coastal zone.

Another coastal security application involves using remote sensing to detect algal bloom die-off, which could signal a toxic material in the water. A vegetation map also could help the military infer the water depth and vegetation characteristics of a coastal environment.

MSL researchers used satellite imagery from the U.S. Department of Energy's Multispectral Thermal Imager. MTI is a sensor with 15 spectral bands, ranging from visible to long-range infrared. It is used to derive a broad range of information on facilities, activities and characteristics, including surface temperature, materials, water quality and vegetation health. By covering several discrete wavelengths of light, MTI can provide a more continuous representation of the light spectrum compared to most other satellite sensors, and ultimately, finer image detail. The MTI project, sponsored by DOE's Office of Nonproliferation and Research Engineering, demonstrates advanced multispectral and thermal imaging, image processing and related technologies.

"Further studies will need to be conducted to integrate other sensors and observational data sets, in addition to the information from MTI, into full model applications," Hibler said. "A Willapa Bay, Wash., study has shown that additional coupling of remote sensing and computer modeling can provide a clearer understanding of some of the processes and water quality issues that affect marine habitat, such as light attenuation, impact of tides, salinity and turbidity." ●

MSL's fungal work leads to new research directions

Some people view fungi as mere mold—a nuisance. Many, however, see great potential in these unique organisms.

PNNL's Marine Sciences Laboratory in Sequim, Wash., possesses a rich history of fungi-related research and a collection of more than 200 strains of fungal species, some of which have been developed to perform environmental remediation and other tasks.

"We continue to explore the use of fungi for remediation, such as cleaning up contaminated sites, but we also are looking at more diverse research pathways," explained Senior Research Scientist Susan Thomas. "We have been moving toward the study of marine and aquatic fungi for applications related to marine sediment. We also are interested in learning how we might harvest natural products from marine fungi and how our work could apply to the detection of biological pathogens and other contaminants in marine systems with respect to environmental and coastal security issues."

Critical to new and existing areas of fungal research is MSL's extensive library of fungal species and scientists' experience with a variety of applications. Recently, for example, Thomas and colleague Meg Pinza, also a senior research scientist, completed a study on using fungi to degrade livestock manure and temper the waste-related odors commonly associated with dairy farms and feedlots. The work was prompted by colleagues at Battelle and PNNL who have been perfecting a Battelle-developed technology for cleaning manure treatment ponds.

Thomas and Pinza were tasked with finding a way to address the troublesome "cap" of manure, straw, sawdust and other materials that tends to form on treatment ponds and clog the cleaning technology. Researchers combined several fungal strains, which were applied via liquid mist to cap material obtained from a farm in northwestern Washington state. The treatment broke down the cap's components to reduce volume, remove excess nutrients such as nitrogen and phosphorus and at the same time destroy fecal coliform bacteria and reduce odors.

"This treatment process is natural, does not harm the environment and uses fungal strains that are native to the area, which is important. We would not introduce non-native fungi," Thomas emphasized.

"In addition to degrading the manure, we were asked if the fungi could produce a beneficial byproduct—mushrooms—that could be used as livestock feed. We selected a couple strains that yield clean, nutritious fruiting bodies and this is looking like a possibility," Thomas said.

Thomas and Pinza said farmers are looking to innovative technologies to solve emerging issues associated with animal waste and are very interested in the approach developed at MSL. "There are opportunities to use this technology in buffer zones near agricultural areas, around manure ponds and livestock enclosures," Pinza said.

In addition to waste treatment, the researchers believe significant opportunities exist for using fungi to clean up sediment along rivers and in upland areas. "A study we conducted involving remediation of highly contaminated sediment along the Willamette River near Portland was very successful," Pinza noted. ●

Scientist Susan Thomas (left) and colleagues at the Marine Sciences Laboratory are enthusiastic about fungi and its potential to supply innovative solutions to agriculture and many other fields.

Researchers help computing reach its full potential

It didn't take long for computers to turn typewriters, manual cash registers and similar devices into artifacts. Today, with everything from laptops to massive supercomputing capabilities, people have access to tools that perform complex tasks in a matter of seconds, saving vast amounts of time and money.

At Pacific Northwest National Laboratory, researchers are working to make computing devices even more responsive and productive for users.

PNNL's Rich Interaction Environments (RIE) research recognizes that computing is becoming more pervasive and that advanced computing tools and systems—such as automotive dashboard computers and smart appliances—can be made more natural, adaptable, socially adept and engaging.

"We want to be the producers of new, innovative software that will help pervasive computing technologies to succeed," explained David McGee, one of the pioneers in the RIE effort at PNNL.

PNNL began working in this futuristic discipline more than a decade ago. Most funding to support PNNL's work has come from the U.S. Department of Defense, and the need for homeland security-related applications is expected to continue to drive the development of pervasive computing technologies and software.

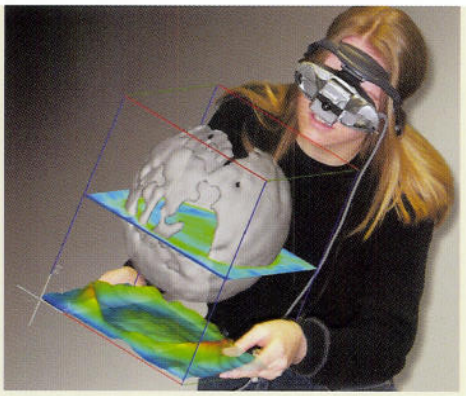
The Laboratory's RIE work is focused in four key areas that benefit both military and consumer applications. **Natural Interactions** enable people to use speaking, sketching, gesturing and touching to interact with computationally enriched objects that respond with useful information and data. **Adaptive Interfaces** understand people and situations. In a kitchen setting, for example, drawers with sharp knives lock when a child enters the kitchen. When a parent enters, restrictions are lifted and the stove displays recipes for the evening's dinner. **Socially Adept Systems** enrich rather than interfere with social situations. For instance, an employee enters the company's boardroom for a private meeting. The employee's phone is designed to sort incoming calls and determine whether they should be routed to voice mail or, based on their pertinence to the meeting, allowed to go through. **Multimedia Storytelling** offers systems that communicate information by engaging all of an individual's senses. Imagine a painting on the wall of a stockbroker's office that looks, sounds and smells like a river—and changes its characteristics to reflect changes in stock trading and price fluctuations.

Some of PNNL's achievements in RIE are featured below.

For more information about this research area, see **http://showcase.pnl.gov/show?it/rie-ba**. ●

Rasa offers military commanders the ability to integrate conventional command station tools, such as maps, pens and Post-it® notes, with digital information. This significantly reduces the amount of time required to comprehend battlefield situations and make appropriate decisions regarding placement of ground forces or other strategies. Commanders can write on an interactive map and speak instructions and directional coordinates, which are captured and reconciled by the interactive system. This tool could have many potential applications, particularly in activities involving maps.

The **Human Interface Workspace**, or "HI-Space" captures and tracks hand movements and the placement of physical objects above large tabletop displays. The system can produce real-time tracking of up to three pairs of hands simultaneously above the table in all three dimensions. Hand poses are recognized by HI-Space and can be used to interact with any computer program running at the table. This technological advance offers a new approach for presenting and analyzing information. It encourages group interactions using the same data within the same time and space, but also enables users at different locations to interact with each other using the same data set.



Augmented Reality and Multimodal Interaction allows a user to view virtual three-dimensional objects and information through a stereo head-mounted display, such that the objects appear to be integrated into their surroundings. The view of the objects changes in response to the user's head position, as if there were real objects in the room. Through hand gestures and voice commands, a 3-D pointer can be directed to move objects, rotate, zoom and slice through geometry using a cutting plane.

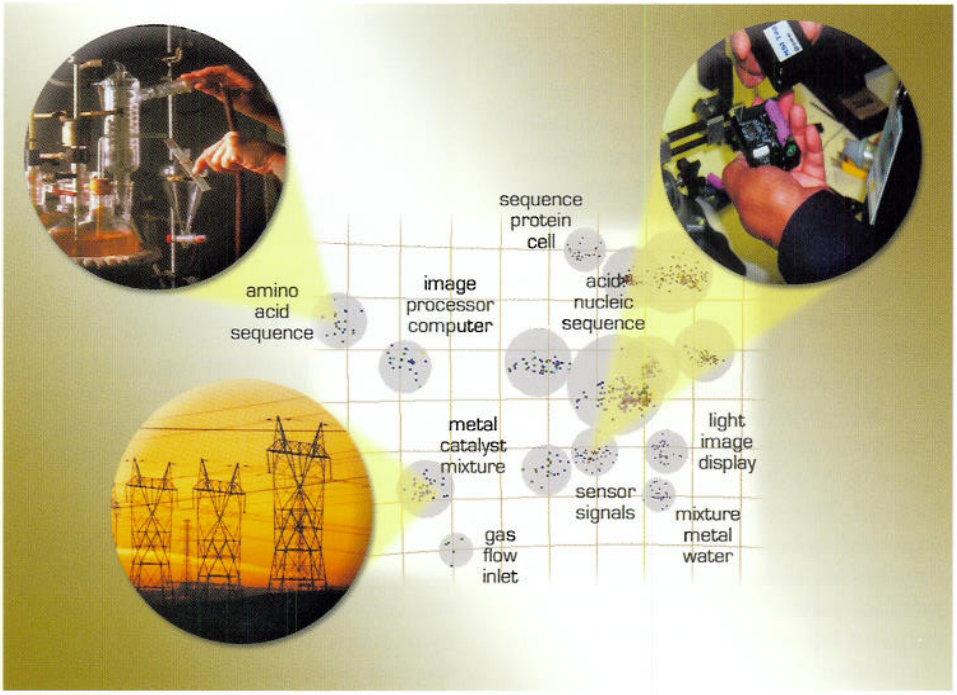
Regional program touts cooperation for economic growth

Pacific Northwest National Laboratory's Office of Northwest Regional Programs (ONRP) is emphasizing cooperation as a way to energize economic development efforts in Washington, Oregon and Idaho.

The office has brought together a network of research organizations into its Linking Regional Resources (LRR) program. Other members of that group include the Idaho National Engineering and Environmental Laboratory and many leading universities and research institutes in the Pacific Northwest.

"The LRR program reinforces the idea that there is strength in numbers. Working together, we can advance the economic agenda of the region," says Erik Stenehjem, director of ONRP. "In addition, this collaboration helps ensure that promising PNNL-developed discoveries have new opportunities for commercialization."

A key to the LRR concept is Starlight, an information analysis software developed at PNNL. Using this software tool, PNNL pools patent information gathered from LRR's participating institutes and universities. In addition to assembling a database of individual technologies, Starlight sorts through the patents and identifies common themes, "bundling" together those technologies that appear complementary and may possess collective value. "For instance, PNNL might have a sensor that, by itself, may not have a viable path to market. But when joined with a technology developed by another institute, the result may be a very valuable new capability," Stenehjem explained.



Resembling tiny stars spread out against the sky, the Starlight analysis tool's visual perspective shows how individual intellectual properties can be "bundled" into complementary, collective units. This approach provides a mechanism for identifying innovative new technologies that could lead to advances in scientific discovery, energy distribution, remote sensing and many other areas.

Taking single or bundled technologies to the next step—the marketplace—is not easy. "It is challenging to match technologies to the companies or individuals who can make commercialization happen," said Robin Conger, an ONRP project manager. "We believe the success of the LRR program will rely partly on our ability to build bridges to regional trade organizations representing the businesses, investors and entrepreneurs who know Northwest needs. These groups can help us facilitate technology transfer and commercialization," she added.

LRR organizers hope that successfully commercialized technologies not only will translate to new businesses and jobs in the Northwest, but also will produce goods and services, such as energy-efficient or environmentally friendly products that address a regional issue or enhance livability.

Although technology commercialization and economic development are primary aims of the LRR partnership, the program may produce other gainful outcomes. "Through LRR we can use the Starlight-generated data to develop a more comprehensive understanding of current research capabilities by state or by technology area. This will help prioritize future spending and investments as well as market our collective research capabilities," said Jill Farris, an ONRP project manager. ●

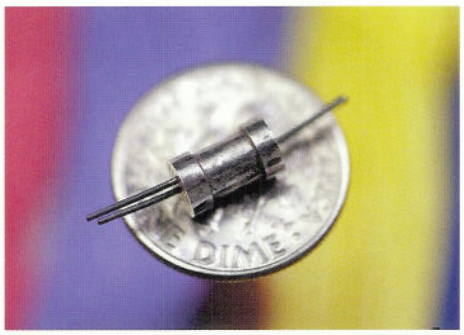
NOTABLE Achievements

Tiny technology offers potent solution for military, industry

It's petite yet powerful.

Researchers, with funding from the Defense Advanced Research Projects Agency, have developed a potentially high-energy microscale power system that can be used as an alternative to conventional batteries for microelectronic devices crucial to America's military troops. The heart of the system is a revolutionary fuel reformer—the world's smallest catalytic fuel processor—developed by Battelle researchers at Pacific Northwest National Laboratory. The tiny reactor, the size of a pencil eraser, is coupled with a microscale fuel cell. The complete package is expected to be about the same dimensions as a cigarette lighter, and produce power equivalent to small batteries but with one-third the weight.

Within the reformer, hydrogen is stripped from a hydrocarbon fuel, such as methanol, and the resulting hydrogen-rich gas is delivered to the fuel cell. The fuel cell then generates electricity by converting the hydrogen—and oxygen from the air—into electrical power and clean water.



The revolutionary milli-watt fuel processor system, which consolidates several chemical processes and operations into one package, is considered the smallest integrated catalytic fuel reformer in the world.

"Our miniaturized fuel processor incorporates several chemical processes and operations in one device," said Evan Jones, principal investigator of the fuel processing technology. This complete chemical processing plant holds two vaporizers, a heat exchanger, a catalytic combustor and a steam reformer, all scaled down from the conventional operations occupying several acres.

When ready for final deployment, the military envisions many useful applications for this emerging energy-generating technology. According to Terry Doherty, director of PNNL's U.S. Department of Defense programs, miniature sensors powered by the same technology could be scattered before advancing troops to monitor ground vibrations or detect dangerous toxic agents, relaying this information electronically to soldiers.

And because the hydrogen power source is produced only as needed, there is no need to store or carry a supply of the volatile gas, reducing risk and creating a lighter load for transportation.

Testing has revealed that performance from the reformer and fuel cell prototype is impressive. Researchers suggest that with additional system efficiencies and improvements, even greater performance may be achievable. Development now will focus on creating a deployable system suitable for military use or industrial applications. Potential industrial uses might include manufacturing and other production processes. For more information on catalysis and reaction engineering work, as well as microchemical and thermal systems, see **http://www.pnl.gov/cbpd/**. ●

Printed on recycled paper. Printed in USA
RL-P98-007 July 2003

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy
P.O. Box 999, MSIN KI-39
Richland, Washington 99352

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