Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

50 Years of Discovery in Action

U.S. DEPARTMENT OF
ENERGY

50 Years of Discovery in Action

In October 2014, the Department of Energy's Pacific Northwest National Laboratory kicked off a year of celebration to recognize 50 years of innovation. For five decades, we have been pushing the frontiers of science and technology in areas that inspire and enable the nation to live prosperously, safely and securely. And we've only just begun.

PNNL is one of ten national laboratories overseen by DOE's Office of Science and has been managed by Battelle since its inception in 1965. Through this enduring partnership—and by working closely with sponsors and collaborators—we have built upon our legacy to advance scientific understanding and develop solutions that are changing the world. We have a history of anticipating the nation's emerging needs and adapting to address them.

Our anniversary provided a rare opportunity to reflect on our rich past. The stories in this booklet first appeared in a 12-part *Tri-City Herald* series that featured some of the scientific challenges PNNL has tackled over the last 50 years and highlighted its vision for the future.

Tri-City Herald

Delta launches new era in Tri-City education

Woman fighting to get dog back from rescue agency

The first of these 50th Anniversary features provided background on PNNL's formation and work over the decades to address many of America's most pressing issues. Each month thereafter, the articles highlighted PNNL contributions in key areas including:

- Work to address environmental challenges and protect natural resources
- Research and development to increase energy efficiency and improve the reliability of the U.S. electrical grid
- The role Battelle and PNNL played in the region through support of civic and philanthropic organizations
- Health-related research, ranging from early work on understanding the effects of radiation to more recent efforts centered on detecting and treating cancer
- Biological and chemical sciences and engineering capabilities and how they are being applied to produce products and fuels from renewable biomass rather than petroleum
- Innovative solutions for cleaner, more efficient and sustainable transportation
- The use of supercomputers, computational science and mathematics to build new scientific understanding to address significant national challenges
- EMSL, or the Environmental Molecular Sciences Laboratory, a Department of Energy national user facility on PNNL's campus that makes scientific capabilities—people instruments and facilities—available to the global research community
- Capabilities and experience in nuclear science and nuclear safety and how they have been applied to national challenges over decades
- Technologies and tools to protect the nation from threats of weapons of mass destruction, terrorists and cyber-attacks
- Research that is helping build an understanding of underlying processes of atmospheric science and climate science and their potential impacts.

CONTENTS

Each of the stories featured in this document originally appeared in the pages of the *Tri-City Herald* newspaper as monthly full-page articles during the year-long celebration of PNNL's 50th anniversary.

The images here provide a snapshot of the entire series, as well as a quick reference to the page numbers for each story—should you want to jump to a specific article.

Full-scale versions of each article are also available on the PNNL News website: **www.pnnl.gov/news**

4 | October 2014

6 | November 2014

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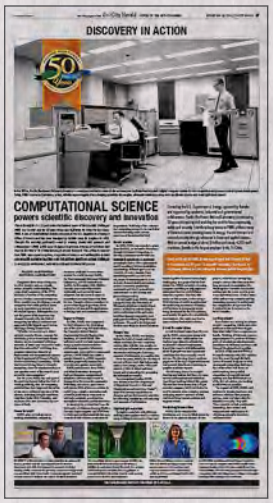

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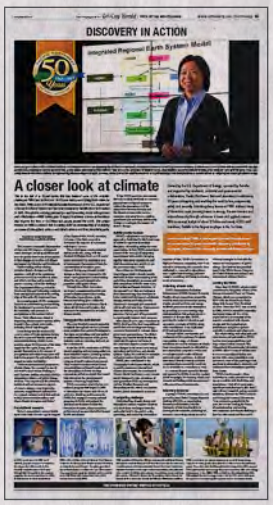

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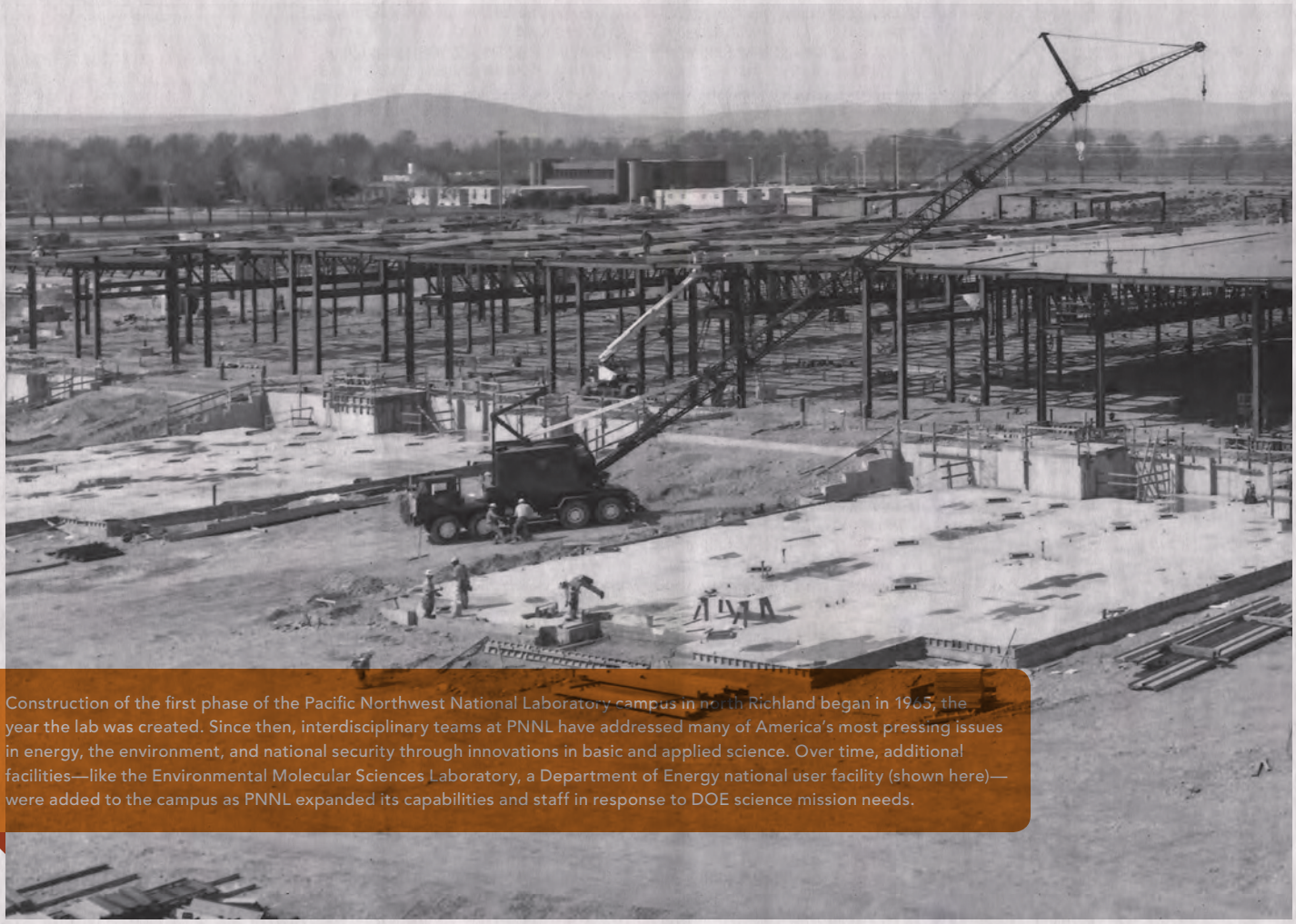
Celebrating a Golden Anniversary



Construction of the first phase of the Pacific Northwest National Laboratory campus in north Richland began in 1965, the year the lab was created. Since then, interdisciplinary teams at PNNL have addressed many of America's most pressing issues in energy, the environment, and national security through innovations in basic and applied science. Over time, additional facilities—like the Environmental Molecular Sciences Laboratory, a Department of Energy national user facility (shown here)—were added to the campus as PNNL expanded its capabilities and staff in response to DOE science mission needs.

This article first appeared in the October 27, 2014, issue of the *Tri-City Herald* and focuses on the historical significance and societal impact of the Pacific Northwest National Laboratory—to residents in Richland, Wash., citizens across the nation and the world, and to the advancement of science and technology.

Fifty years ago, one of the nation's leading research and development institutions began to take shape right here in the Tri-Cities. Pacific Northwest Laboratory was established by the Atomic Energy Commission and Battelle was chosen to operate it for the benefit of the nation and the world.

Today we're known as Pacific Northwest National Laboratory and are one of ten national laboratories overseen by the Department of Energy's Office of Science. And it's still operated by Battelle.

Through this enduring partnership—and by working closely with our sponsors and collaborators—we build upon our legacy of discovering science and solutions that improve the lives of Tri-Citians and people around the world.

As PNNL celebrates five decades of discovery, we invite the community in which we live and work to share in the pride of our accomplishments and our vision for the future. After all, most of our 4,300 employees call the Tri-Cities home—and as our neighbors, you've played a role in what has been achieved as well. And, for that we thank you.

With your support, we have and will continue to push the frontiers of science and technology in areas that inspire and enable the world to live prosperously, safely, and securely—as we address many of America's most pressing issues in energy, the environment, and national security.

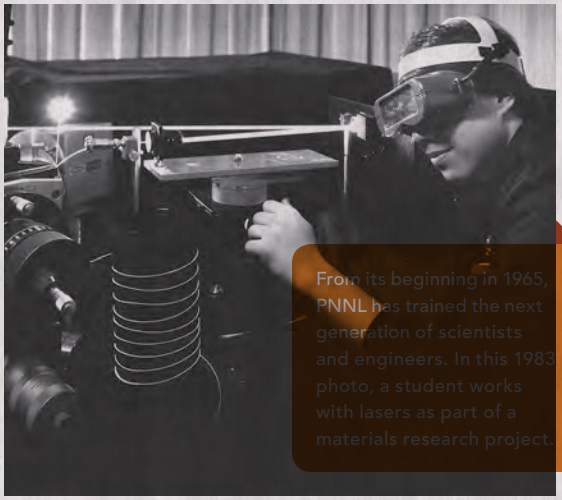
Throughout our anniversary year, we will be showcasing some of the scientific challenges we've tackled, what we've learned along the way, and what we believe is vital to discover next.

We'll share stories about how our scientists—your neighbors—invented the technology that led to development of compact discs, revolutionizing the way we play music and store data; of how your neighbors discovered the means of using acoustic holography to see inside the human body without needing to operate, and that using millimeter waves can detect weapons under terrorists' clothing before they board a plane—saving and extending lives; and how our research resulted in the means to track salmon so dams could be designed to be more fish-friendly, creating a sustainable balance between nature and hydropower.

Each month over the next year, we will share stories like these. We will highlight PNNL's research and development and how it provides fundamental understanding and new solutions that help:

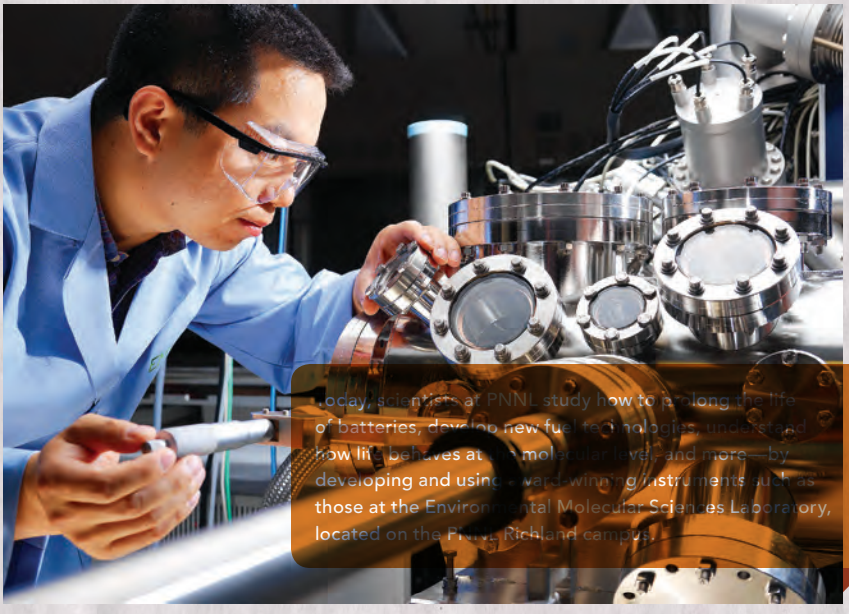
- Strengthen U.S. scientific foundations for innovation,
- Increase U.S. energy capacity and reduce dependence on imported oil,
- Prevent and counter terrorism and the proliferation of weapons of mass destruction,
- Reduce the environmental effects of human activities and create sustainable systems.

Some of the things we're able to do now seemed unimaginable to most of the world when PNNL opened its doors in 1965. But, that's what we do. Right now, with your support, we're imagining the next 50 years and beyond so when we get there, discovery will already be in action.



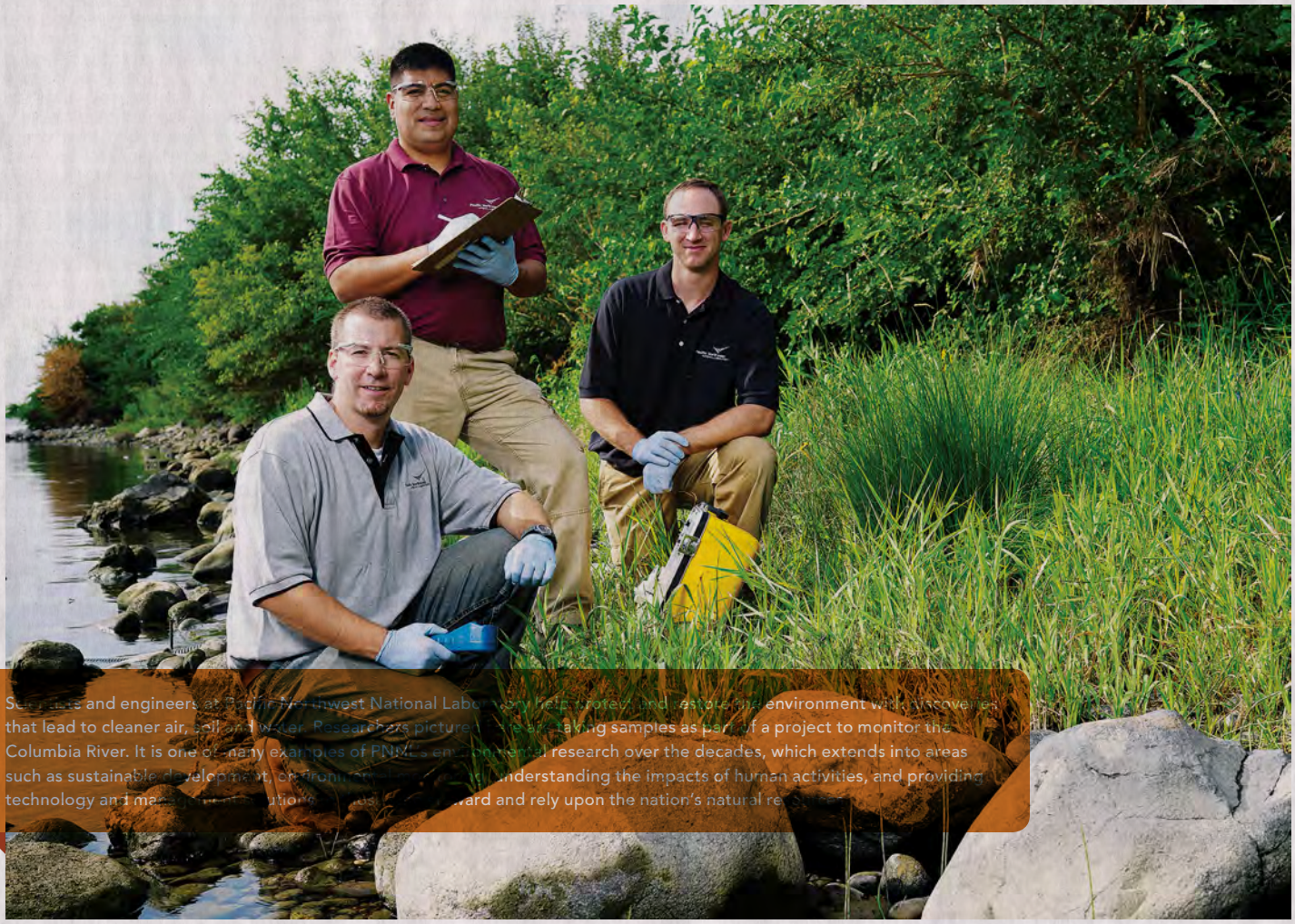
From its beginning in 1965, PNNL has trained the next generation of scientists and engineers. In this 1983 photo, a student works with lasers as part of a materials research project.

In 1965, engineers at PNNL developed Manny, the robot mannequin—that was humanlike in every detail—for the U.S. Army's best protective clothing for extreme use conditions.



Today, scientists at PNNL study how to prolong the life of batteries, develop new fuel technologies, understand how life behaves at the molecular level, and more—by developing and using award-winning instruments such as those at the Environmental Molecular Sciences Laboratory, located on the PNNL Richland campus.

Putting Science to Work



Scientists and engineers at Pacific Northwest National Laboratory help protect and restore the environment with discoveries that lead to cleaner air, soil and water. Researchers pictured here are taking samples as part of a project to monitor the Columbia River. It is one of many examples of PNNL's environmental research over the decades, which extends into areas such as sustainable development, confronting climate change, understanding the impacts of human activities, and providing technology and management solutions to move forward and rely upon the nation's natural resources.

This article first appeared in the November 24, 2014, issue of the *Tri-City Herald* and focuses on PNNL's work to address environmental challenges and protect natural resources.

When a 65-foot crack was discovered in the Wanapum Dam in February, Grant County Public Utility District called in Pacific Northwest National Laboratory's aquatic research experts to determine whether lowering the water for the repair would increase the risk to endangered salmon.

PNNL researchers evaluated adult salmon passage through the quickly modified fish ladder along the Columbia River, and the results provided the assurance needed to allow it to continue operating through the salmon migration season and dam repair process.

"This is just one example of how we draw upon our scientific heritage to address a broad range of 21st Century environmental and ecological challenges," said Jud Virden, associate laboratory director for PNNL's Energy and Environment Directorate. "We have nearly 1,000 professionals committed to research for a healthier planet, including wildlife and habitat restoration, sustainable development, land and water resource management, and balancing the operational requirements of industry with environmental stewardship."

PNNL may be better known locally for supporting DOE by developing ways to treat complex environmental contamination, especially at the Hanford Site. Its researchers have spent decades understanding how contaminants move and developing ways to stop their movement, thereby protecting human health and the environment from exposure.

"With our expertise in waste forms, waste processing and subsurface geochemistry, PNNL is committed to delivering scientifically defensible solutions to help reduce the cost and risk of Hanford cleanup," Virden said.

In the 1970s, PNNL researchers were pioneering work in vitrification—a process for turning mixed waste into a stable glass waste form suitable for disposal. The innovations provided the foundation for technology applied today at DOE's Savannah River Site, and eventually at Hanford, to deal with millions of gallons of tank wastes from the Cold War weapons programs.

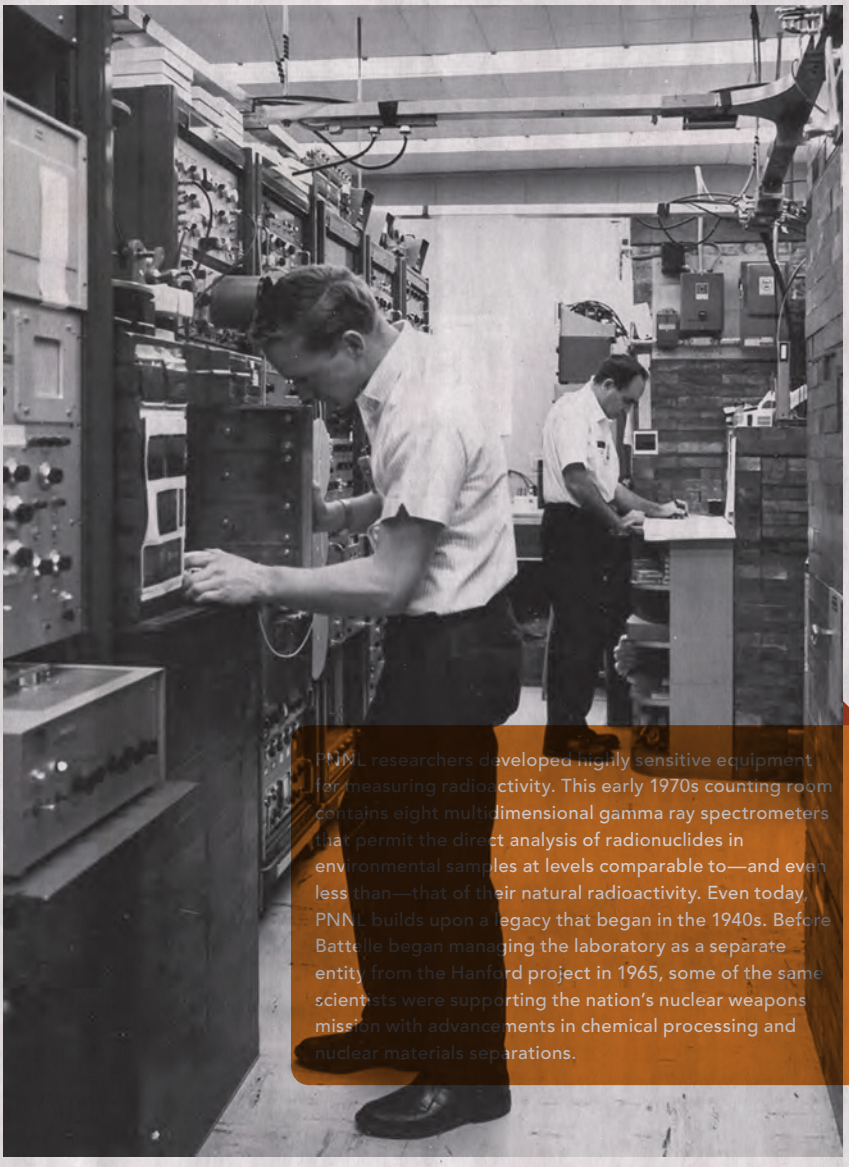
More recently at Hanford, PNNL researchers developed a novel high-performance computing code that provides workers with an unencumbered view of the subsurface. This makes it easier to detect leaks in underground waste storage tanks, potentially saving DOE a projected $5 billion over the life of the tank waste project.

BEYOND HANFORD

As early as 1979, PNNL researchers were sampling and analyzing pollutants from industrial centers—such as carbon gases from coal-fueled plants—and studying the concentration and transformation of pollutants in the atmosphere. The data is used to develop regional air pollution models to better determine and resolve the environmental impacts of fossil fuels.

On the international front, PNNL led efforts to collect and maintain information on the 1986 Chernobyl Nuclear Power Plant accident in Ukraine. Scientists analyzed the levels of radiation after the plume arrived in the United States and used research aircraft to collect air samples of the fallout.

At the Marine Sciences Laboratory in Sequim, Wash., PNNL scientists have spent more than 45 years conducting research related to marine and coastal resources, environmental chemistry, water resources modeling, ecotoxicology and biotechnology. This facility, located on the Strait of Juan de Fuca, remains DOE's only



PNNL researchers developed highly sensitive equipment for measuring radioactivity. This early 1970s counting room contains eight multidimensional gamma ray spectrometers that permit the direct analysis of radionuclides in environmental samples at levels comparable to—and even less than—that of their natural radioactivity. Even today, PNNL builds upon a legacy that began in the 1940s. Before Battelle began managing the laboratory as a separate entity from the Hanford project in 1965, some of the same scientists were supporting the nation's nuclear weapons mission with advancements in chemical processing and nuclear materials separations.

Late PNNL researcher Richard Fitzner studied factors that enhanced or reduced survival of broods of Great Basin Canada geese, which included using radio transmitters to follow their movement on the 120-square-mile Arid Land Ecology Reserve. The area was renamed the Fitzner/Eberhardt Arid Lands Ecology Reserve to commemorate Fitzner and fellow researcher Les Eberhardt after they died in a 1992 plane crash while studying the area. PNNL's work at ALE began in the 1960s and has encompassed plant and animal ecology, geology, surface and groundwater hydrology, climate, soils and soil/water interactions, and contaminant transport.

marine research laboratory.

In response to the 1989 Exxon Valdez oil spill in Alaska, the PNNL team in Sequim conducted ecological assessments and other studies. Then PNNL followed up later to gauge the success of cleanup activities.

Long before this year's quick fix at Wanapum Dam, PNNL had a proven track record of providing science and technology to improve fish passage and survival along the Columbia River Basin's system of hydroelectric dams. Performing research since the early 1990s for DOE, the U.S. Army Corps of Engineers, Bonneville Power Administration, and public and private utilities, PNNL's research assists in the development and operation of environmentally sustainable hydropower—keeping the lights on across the Pacific Northwest.

"At PNNL, we have a unique ability to rally interdisciplinary teams, collaborate with public and private partners, and leverage funding with the shared vision of providing new knowledge, viable answers and a meaningful understanding of today's environmental challenges," Virden said.

PNNL's environmentally focused research and development takes a broad look at interrelated factors—such as biology, hydrology, chemistry, engineering and economics—to gain a clear view of environmental impacts from population growth, resource exploitation and other complex issues. With this knowledge, researchers can also propose solutions.

"In support of DOE, we help inform decision makers and provide the basis for driving innovation that leads to a cleaner future, a restored environment and a stronger economy," Virden said. "Looking forward, I am proud that PNNL will continue to put science to work on environmental challenges—from cleaning up Hanford to protecting the planet."

PNNL researchers are studying the hazards migrating fish face as they travel to and from the ocean. The data collected by PNNL's Sensor Fish can help boost fish survival rates. This photo from 2000 shows the initial Sensor Fish design, which has since been updated to be smaller and more rugged, and to provide more detailed information. Data collected from the device is helping make conventional hydropower and newer, small hydro facilities more fish friendly. This research helped redesign conventional dams to increase power generation while also reducing the impacts to fish and habitat and improving water quality.

At the U.S. Department of Energy's Environmental Molecular Sciences Laboratory, located on PNNL's Richland campus, researchers integrate theory, experiment and numerical simulation to understand the movement of contaminants in the subsurface. Researchers around the world have access to this national user facility's more than 100 experimental instruments, from microscopes to spectrometers to a supercomputer. Scientists use the nuclear magnetic resonance spectrometer shown here to investigate radiologically active samples, leading to an enhanced understanding of radionuclide behavior in the environment.

Keeping the Lights On

More than 30 years ago, Pacific Northwest National Laboratory worked with the Bonneville Power Administration to design and implement the largest effort to gather real energy-use data up to that time. These foundational data enabled the U.S. Department of Energy to begin setting design standards, including the Super Good Cents homes of the Northwest, which debuted in 1984. The data also provided the [illegible] energy efficiency measures [illegible] included in building energy codes and led to the first efforts to set minimum efficiency [illegible] for appliances. Improving [illegible] efficiency in buildings and appliances significantly reduces the impacts [illegible] energy use by decreasing total energy [illegible] consumption, peak energy demand and the nation's carbon footprint.

This article first appeared in the December 29, 2014, issue of the *Tri-City Herald* and focuses on PNNL's work to increase energy efficiency and improve the reliability of the U.S. electrical grid.

Imagine a volunteer force of clothes dryers and water heaters, marching in to save the region from a widespread power outage. While it might sound like science fiction, the DOE's Pacific Northwest National Laboratory developed a technology in the late 1990s that brings this concept to life.

The Grid Friendly™ Appliance Controller responds to distress signals on the grid and can instantly, inconspicuously and temporarily turn off certain functions of household appliances to relieve stress on the system. With even a few minutes' reprieve, grid operators could restore the balance between supply and demand—and prevent a problem from cascading out of control. A network of hundreds or thousands of appliances responding together could provide a fast, inexpensive safety net for the grid. This technology has been licensed to a company interested in developing it for commercial use.

"Our nation's energy needs have changed dramatically. Nobody was charging smart phones, running supercomputers or plugging in cars when the first power lines were strung," said Carl Imhoff, who leads PNNL's electricity infrastructure research. "Today, PNNL is looking at how to meet a growing demand with reliable, secure and affordable electricity, while integrating renewable resources—like wind and solar—to bring the entire system into the information age."

NEED FOR EFFICIENCY

Each year, the nation spends $300 billion and contributes 70 percent of its total electricity consumption to meet the energy demands of residential and commercial buildings. For more than two decades, PNNL researchers have supported DOE's Building Energy Codes and Appliance Standards programs by finding ways to decrease consumption, lower consumer energy bills and reduce the greenhouse gases emitted by electricity generation.

In the 1980s, PNNL worked with the Bonneville Power Administration on a multi-year program to gather real-time and comprehensive energy consumption data. The data collected informed early efficiency measures in the Northwest, becoming the foundation for DOE's building codes and appliance standards efforts, which are saving homeowners millions of dollars in annual energy costs.

Engineers and energy economists at PNNL draw upon applied building science, whole-building energy simulation and analysis to write and develop easy-to-implement, enhanced building energy efficiency codes, which can be adopted and enforced by state and local governments to make new buildings more comfortable and affordable.

Similarly, appliances are more efficient and affordable because of energy efficiency standards set by DOE. These standards are supported by technical and economic analyses performed by PNNL experts in Richland, Wash. and Portland, Ore.

LIGHTING THE FUTURE

When highly efficient, sub-compact fluorescent lights were introduced in the 1970s, the bulbs didn't fit in existing fixtures and were significantly more expensive than conventional incandescent bulbs. PNNL helped manufacturers reduce the size, improve the performance and lower the cost of CFLs. Today, researchers support industry in delivering a new generation of even more efficient lights that use light emitting diodes, or LEDs.

In 2007, Seattle City Light worked with PNNL to explore using LED streetlights to reduce its carbon footprint, save money and improve customer service. The

Concepts like this Grid Friendly™ Appliance Controller were tested in real homes by people who volunteered to participate in the 2006 Olympic Peninsula Smart Grid Demonstration project that pioneered key smart grid concepts for DOE.

Researchers support a DOE program to evaluate commercially available light emitting diode products. PNNL also runs a facility that integrates robotics, sensors and software to test new lighting products before they go to market.

PNNL developed a Smart Charger Controller that tells the battery in a plug-in hybrid vehicle when to start and stop recharging based upon existing stress on the electric grid. A previous PNNL study showed that an intelligent existing power grid could meet the needs of about 70 percent of all U.S. light-duty vehicles if battery charging was managed to avoid new peaks in electricity demand. The controller automatically recharges electric vehicles during times of least cost to the consumer and lower demand for power.

resulting $16.7 million invested by Seattle City Light to convert 41,000 residential street lights to LED fixtures between 2010 and 2014 is saving the city $2.5 million annually.

MIXING IN RENEWABLES

Managing the energy system and ensuring reliability has become increasingly challenging as more electricity is produced by wind or solar energy instead of by more predictable, large-scale power production plants. Working with industry, researchers built a tool that accurately predicts whether an intermittent renewable resource will be available to meet demand and the impact of detected shortages.

Wind power efforts date back to 1980, when researchers wrote a national wind energy atlas used by industry, utilities and government agencies to assess the economic feasibility of installing turbines.

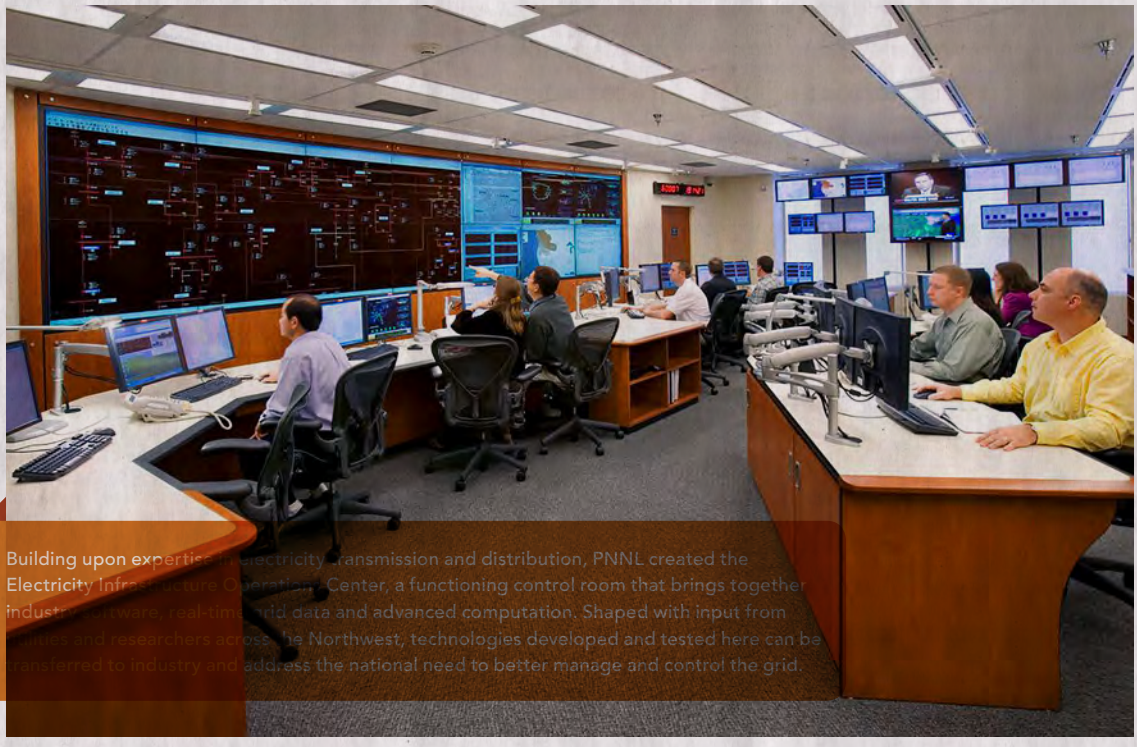
Today, PNNL scientists are developing energy storage technologies to help make renewable energy available when and where it's needed. Researchers also are determining the performance and cost requirements to make these technologies commercially viable.

USHERING IN THE MODERN GRID

The power grid is a complex and interconnected network. It's possible for a minor disturbance to quickly escalate, like the major East Coast blackout in 2003. PNNL has developed a detection and visualization tool that allows grid operators to "see" growing problems. By combining real-time data with new analytic methods, these tools give operators the information they need to quickly take steps to prevent blackouts.

PNNL also developed VOLTTRON™, a software platform where appliances and devices such as lighting and electric vehicles are represented by "agents" that can communicate to more efficiently manage, prioritize and balance energy use. The source code for VOLTTRON™ is publicly available so researchers and others can use it to develop applications.

"It's easy to take our electricity system for granted," said Imhoff, who also chairs DOE's Grid Modernization Laboratory Consortium. "The lights come on when we flip the switch. Our bills are among the lowest in the nation. But quietly, behind the scenes, PNNL is helping to keep the lights on and providing a more efficient and resilient energy infrastructure."



Building upon expertise in electricity transmission and distribution, PNNL created the Electricity Infrastructure Operations Center, a functioning control room that brings together industry software, real-time grid data and advanced computation. Shaped with input from utilities and researchers across the Northwest, technologies developed and tested here can be transferred to industry and address the national need to better manage and control the grid.

A Community Partner for 50 Years

IT'S BATTELLE!

- To Operate Laboratories At Hanford

Offer Described As Outstanding; Objectives Met

Battelle Memorial Institute of Columbus, Ohio, will be the new contractor for Hanford laboratories.

Senators Henry M. Jackson and Warren G. Magnuson, both D-Wash., announced today, the Battelle proposal was selected by the Atomic Energy Commission as a "basis for negotiations" which will begin immediately.

The actual transfer is expected to take several months and to be completed by January.

One other proposal was submitted, Jackson said. It came from the Illinois Research Institute.

The AEC said both proposals were outstanding, but it was felt that Battelle could meet the "over-all objectives" better.

NEW BUSINESS

The AEC said an important factor would be the ability of the new operator to generate new business in the Tri-City area.

Jackson said Battelle will make a "sizable capital investment" at Hanford, expected to be about $5 million during the 5-year contract, and for above that over a longer time.

Battelle officials have expressed interest in building outside the Hanford plant and contacted city officials about the old Camp Hanford area.

The city now is attempting to buy 393 acres of land through General Services Administration.

Jackson said also that Battelle has plans to develop "a close and effective relationship between the laboratories and universities of the area, including graduate and post-doctorate programs."

1,800 WORKERS

General Electric Co. has operated the laboratories since 1946. Employment now is about 1,800 people—or about 22 per cent of the Hanford payroll.

The GE laboratory has an annual operating budget of about [illegible]

In January, the AEC and GE announced that work at Hanford would be transferred to other contractors.

Battelle Memorial Institute is the first replacement contractor.

In addition to the Columbus laboratories, with more than 2,200 employes, Battelle has [illegible]

Dr. B. D. Thomas, director of Battelle Memorial Institute (right), discusses [illegible] with Senators Warren G. Magnuson (center) and Henry M. Jackson, both D-Wash. The Senators today announced that Battelle [illegible] Hanford laboratories.

Chance Seen As Challenge

Battelle Memorial Institute is "enthusiastic" about its selection, [illegible] physics and metallurgy department, who has been in Richland

HOME OWNED HOME OPERATED INDEPENDENT

Tri-City Herald

Reactions

Tri-City Growth Seen

Selection of Battelle Memorial Institute to operate Hanford Laboratories was described today as a decision which will have long-range benefits for the Tri-Cities and the state.

Sen. Henry M. Jackson, D-Wash., in Spokane today for a series of meetings, said "the selection of Battelle gives industry in the Pacific Northwest a facility they have never had before.

"It will bring into being over the long term new industrial products and new industries," he added.

"We are now armed with the tool that will give birth to these new industries that will mean more jobs and stability for [illegible]

"We have never had a laboratory that was [illegible] backing up all of the industry [illegible] that has made so much to the growth of such highly technical and scientific communities as the San Francisco Bay area and Boston," Jackson asserted.

Research Holds Key

Sen. Warren G. Magnuson in-

When Battelle assumed management of what is now Pacific Northwest National Laboratory in January 1965, it also began its role to support art and education in the community, as well as local civic and health and human services organizations. Battelle's contributions to these causes, along with investments in land, facilities and equipment, add up to $103 million.

The following article first appeared in the January 26, 2015, issue of the *Tri-City Herald* and focuses on the role Battelle and PNNL play in the community—through their support of a variety of civic and philanthropic organizations that include arts, education, health and human services, and civic and economic development.

On May 28, 1964, Tri-City Herald readers saw the big, red headline, "IT'S BATTELLE!"—announcing that the Atomic Energy Commission had selected Battelle to operate the Hanford Laboratories in Richland. Battelle assumed management in January 1965, and 50 years later, Battelle still manages and operates the lab, which is now under the auspices of the U.S. Department of Energy and known as Pacific Northwest National Laboratory.

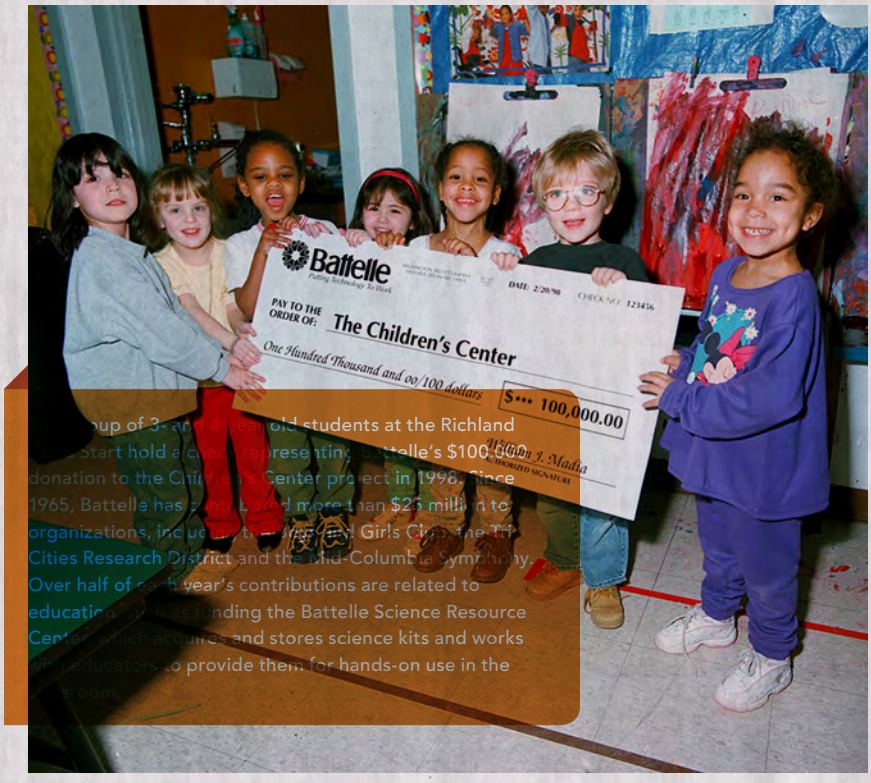
"For 50 years, Battelle and PNNL have played a meaningful part in enriching the Tri-Cities community that most of the 4,300 Battelle employees at PNNL call home," said Mike Kluse, laboratory director. "Since 1965, Battelle has invested more than $25 million to improve science, education and the quality of life in the Tri-Cities." Along with DOE's majority investments, Battelle has contributed another $138 million in land, facilities and equipment.

Battelle was founded as a research organization and charitable trust, as described in the will of Gordon Battelle, a wealthy industrialist who was intrigued by the idea of linking research, science and industry to solve problems. When Battelle died in 1923, he left more than $1.5 million to create what is now the world's largest nonprofit research and development organization, with more than 22,000 employees at 60 locations around the world.

Battelle's will specifically defined how earnings would be distributed to "such charitable institutions, needy enterprises, or persons..." as the Battelle's Board of Trustees deemed would do the "greatest good for humanity."

Similarly, DOE's mission also includes technology transfer and economic development. Certain aspects of supporting education and the community are required in Battelle's contract with DOE to manage PNNL.

"We embrace the fact that being part of this community is both our mission and our legacy," Kluse said.



A group of 3- and 4-year-old students at the Richland Head Start hold a check representing Battelle's $100,000 donation to the Children's Center project in 1998. Since 1965, Battelle has supported more than $25 million to organizations, including the Boys and Girls Clubs, the Tri-Cities Research District and the Mid-Columbia Symphony. Over half of each year's contributions are related to education, such as funding the Battelle Science Resource Center, which acquires and stores science kits and works with educators to provide them for hands-on use in the classroom.

A HISTORY OF GIVING

In fiscal year 2014, Battelle invested about $527,000 in Tri-City area philanthropic and civic organizations. Its largest capital donation in the community—more than $2.3 million between 2003 and 2012—went toward the new Hanford Reach Interpretive Center, which opened in July. A few other notable examples among Battelle's many contributions include:

- Supporting operations and start-up costs for Delta High School, a science, technology, engineering and mathematics—or STEM—high school in the Tri-Cities (more than $1.2 million).
- Earning a spot among top corporate givers to the United Way of Benton and Franklin Counties (about $2.3 million since 1982).
- Contributing to the 2003-2008 capital campaign to build the Academy of Children's Theatre's new building in Richland ($285,000).
- Providing disaster relief donations to the American Red Cross in 2005-2006 in response to the 2004 tsunami and Hurricane Katrina ($40,000).
- Funding a shredder truck in 2003-2005 for Columbia Industries that provides employment for disabled people ($75,000).

A SPIRIT OF VOLUNTEERISM

The workers at PNNL are involved in many causes near and dear to them throughout the community. Through a volunteer program called "Team Battelle," staff members can propose projects and recruit fellow employees, their families and retirees to volunteer their time and talent to help those projects succeed. In fiscal year 2014, Team Battelle volunteers gave over 43,000 volunteer hours to projects representing 56 local organizations related to arts and culture, civic and community services, education, and health and human services.

Current Team Battelle projects range from support for Junior Achievement to the Leukemia and Lymphoma Society's Team in Training, the Friends of Badger Mountain, the Tri-Cities Food Bank, and the Three Rivers Folklife Society's Tumbleweed Music Festival.

In honor of PNNL's 50th Anniversary, Battelle made

PNNL welcomes interns, offering learning experiences and opportunities for collaboration in many fields. For example, PNNL is a host site for a DOE Office of Fossil Energy program that focuses on graduate and undergraduate minority students from historically black colleges, tribal colleges and universities, and Hispanic-serving institutions. Here, Courtney Henry, a North Carolina A&T undergraduate student, works with PNNL's Novella Bridges to help develop a therapeutic radiation delivery system for the treatment of solid tumors in breast cancer.

Battelle's volunteer organization, Team Battelle, supports hundreds of organizations across the community. In addition to helping many projects, like the Tri-Cities Food Bank (shown here), Team Battelle also supports many seasonal activities such as the Habitat for Humanity's "Evening with the Angels" holiday project and "For the Love of Giving" and the Camp Patriot Fun Run.

an $80,000 contribution to Habitat for Humanity to construct a home in Kennewick. Team Battelle volunteers will work on the home from start to finish. Coincidently, Team Battelle's initial "pilot" project in 1998 also supported Habitat for Humanity. Volunteers built and auctioned a playhouse and donated the proceeds to the organization.

ECONOMIC IMPACT

A study to analyze the economic impact of PNNL on Washington's economy revealed that PNNL directly and indirectly supported more than $1.3 billion and 6,800 jobs in the state during fiscal year 2013, as well as another $1.2 billion dollars and more than 6,400 jobs through closely related economic activities.

The study quantifies economic impacts such as PNNL's funding and total spending, jobs, wages, purchased goods and services, healthcare, visitor spending, spinoff companies, education support, and corporate charitable contributions.

There are 76 companies in Washington with foundational technology or expertise from PNNL. In 2013, these companies earned about $570 million in revenue and employed 2,219 people.

INVESTING IN THE FUTURE

Battelle and PNNL are committed to inspiring and preparing the next generation of scientists, engineers and innovators. Since 1982, employees involved in wide-ranging STEM education programs have engaged with 325,000 students, teachers, professors, educators and community members—and more than 4,300 people from these groups in fiscal year 2014 alone.

PNNL and Battelle are founding collaborators of Delta High School, a public STEM school that opened in 2009. PNNL initiates and facilitates collaborations between PNNL scientists and engineers and Delta staff and students.

PNNL collaborates with Washington State Leadership and Assistance for Science Education Reform, or LASER, which is involved in efforts to implement new science standards for kindergarten through twelfth grade.

PNNL also helped found a program called Mathematics, Engineering and Science Achievement, or MESA, that was designed to increase the number of underrepresented minorities with post-secondary STEM degrees and careers.

A LASTING LEGACY

"It's humbling to think of how Battelle's consistent presence has shaped the community where I live and some of my children and grandchildren have made their homes," Kluse said. "I am proud to know that Battelle and PNNL are part of the underlying support helping our community thrive."

From Dosage to Diagnosis

Pacific Northwest National Laboratory's health research has its earliest roots in developing the standards and devices for setting and measuring radiation doses received by nuclear workers. Today, PNNL's science and technology focus is on analyzing biological systems to better understand and predict how those systems respond to environmental exposures, disease and treatment.

This article first appeared in the February 23, 2015, issue of the *Tri-City Herald* and focuses on PNNL's health-related research—from its earliest days building an understanding of the effects of radiation, to more recent work centered on detecting and treating cancer and more.

Imagine a world where the word cancer isn't a dreaded diagnosis, but a disease that is easily detected and treated. Researchers at the Department of Energy's Pacific Northwest National Laboratory may help make that future a reality. They are leveraging capabilities in analytical chemistry and proteomics—or the study of proteins, their structures and functions—in a search for cancer biomarkers that may reveal cancer at its earliest stages.

"PNNL researchers conduct studies and experiments to understand biological systems to advance DOE's energy and environment missions," said Doug Ray, associate laboratory director for PNNL's Fundamental & Computational Sciences Directorate. "Our research contributes to bioenergy and bioremediation, as well as enabling the early detection of disease and improving therapies."

By drawing upon the unique instrumentation and expertise at PNNL and at DOE's Environmental Molecular Sciences Laboratory—a national user facility on PNNL's campus—researchers are exploring the fundamental differences between cancer cells and their normal counterparts, which can lead to earlier detection of disease. They are searching for biomarkers that could indicate prostate, breast and ovarian cancers.

In the 1990s, researchers at PNNL developed and commercially licensed a patented process to make ultrapure yttrium-90, an important radioisotope for cancer therapy. An automated Y-90 generator that milks Y-90 from its strontium source, purifies it and strips it into a usable form—ready to attach to a cancer therapy drug—has since been patented and is available for commercial licensing.

PNNL's work in human health has roots that date back to 1943—nearly 20 years before the Hanford Laboratories were separated from the Hanford Site, and Battelle began managing what is now PNNL. In those early years, researchers were investigating the health effects of radiation.

In the 1960s, PNNL developed the standards and devices for setting and measuring radiation doses received by nuclear workers. Tens of thousands of people, including children, have been measured by whole-body counters since then to relate the amount of radioactive materials in their bodies to sources such as food and water.

In 1992, a PNNL-developed technology that measures exposure to radiation was named one of the year's top 100 innovations by R&D Magazine. The technology led to a new generation of devices called dosimeters, which measure the radiation dose received by radiation workers. It was a significant improvement over conventional dosimetry technologies because it was more sensitive, lasted longer and cost less. The benefits appealed to Landauer, a Chicago-based company that collaborated with PNNL and licensed the proprietary technology for use in its commercially available dosimeters.

PNNL supports a DOE research program dedicated to low-dose radiation exposure, which could affect pilots and other frequent fliers, health care workers, nuclear workers, or victims of terrorism events such as dirty bombs. In one project, researchers are using a three-dimensional skin model to examine the effects of low-dose radiation on humans.

Over the years, PNNL's fundamental biological research has included a wide variety of health studies, primarily sponsored by the National Institutes of Health, that include improving the materials for bone implants, understanding the effects of electromagnetic fields and radon, and cancer detection and treatment.

One cancer treatment is based on researchers' improvements in the chemistry for producing an ultra-pure medical isotope called yttrium-90 from nuclear waste. With these advancements, researchers helped create a targeted cancer treatment for brain, neck and kidney tumors, as well as pancreatic and prostate cancer, that is now used in cancer drug products worldwide.

In addition to a legacy of health research, PNNL is also tackling health challenges found in today's headlines. Last month, PNNL published a study about exposure to BPA, or bisphenol A, which is used to make some plastics and to seal canned foods. The study revealed that coating the mouth with

This palm-sized detector is used by medical radiology technicians, cancer treatment specialists and others to measure the radiation they receive at the workplace. The technology was developed at PNNL and commercialized by Battelle and Landauer, the world leader in providing

food containing BPA, like soup, does not lead to higher than expected levels of BPA in blood. Researchers concluded that oral exposure does not create a risk for high exposures, consistent with the U.S. Food and Drug Administration decisions that BPA is safe for use in food packaging.

PNNL researchers are collaborating with the University of Wisconsin-Madison on a project designed to provide a detailed molecular understanding of how humans respond to viral pathogens like Ebola, West Nile virus and influenza. PNNL's role includes acquiring molecular data and creating computer models. Models that predict how bodies behave when infected by the viruses can help researchers find new approaches to prevent or fight infection.

As part of the LungMAP consortium, a team of PNNL investigators and collaborators are mapping the molecular components of normal lung development. This "molecular atlas" will help expand the understanding of lung development in children during the critical period between about four months before birth until about two years old. The results could help reduce the high mortality rate in premature babies.

A fairly new area of research for PNNL is taking a closer look at the microbiome, or the community of all microorganisms that typically inhabits a particular environment, such as a body site or ecosystem. PNNL's Microbiomes in Transition program is taking a multidisciplinary approach to develop multi-scale models that will improve the understanding of how microbiomes function. Studies range from examining the impact of climate change on microbial communities in certain ecosystems to determining the long-term impacts of antibiotics on the gut microbiome in humans.

Ray described PNNL's health research as two sides of the same coin. "We have spent decades working to understand how human health, the environment and the climate are affected by legacy nuclear production and conventional energy systems," he said. "At the same time, we leverage those research efforts to also broadly improve human health."

Researchers at PNNL can apply their capabilities and leverage investments in equipment and instruments to conduct research for DOE, as well as other sponsors. Health-related research at PNNL is funded primarily by the National Institutes of Health, in addition to the Department of Defense, the Environmental Protection Agency, Centers for Disease Control and others. PNNL received about $25 million from NIH in 2015 for health research in areas including cancer, infectious disease, diabetes and heart, respiratory and digestive health.

Scientists at PNNL use state-of-the-art nuclear magnetic resonance capabilities at the Environmental Molecular Sciences Laboratory to conduct proteomic research such as identifying breast cancer suppressor proteins. Researchers from around the world can access this and other resources available at the DOE national user facility to conduct research related to health, energy and the environment.

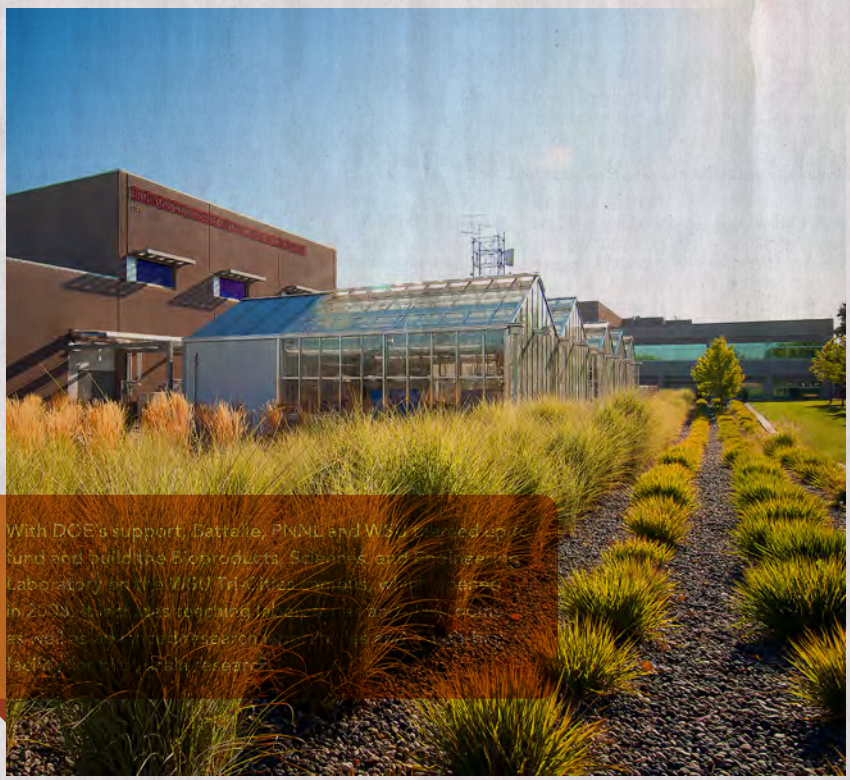
Better Bio-based Products and Fuels

In the 1990s, PNNL researchers used this equipment to explore and advance the use of hydrothermal processing to convert wet biomass streams into fuel gas. Today, this equipment is at the site of a Florida-based industrial partner that will use it to convert algae to biocrude oil. PNNL researchers will help with the startup of the equipment in support of the effort.

The following article first appeared in the March 30, 2015, issue of the *Tri-City Herald* and focuses on PNNL's biological and chemical sciences engineering capabilities, and how they are being applied to produce products and fuels from renewable biomass rather than petroleum.

Finding cleaner energy sources and reducing our nation's dependence on imported oil are among the national priorities on the Department of Energy's Pacific Northwest National Laboratory's to-do list.

Researchers at PNNL are addressing those challenges by applying their broad capabilities in biology, chemistry and engineering to help deliver the environmental and economic benefits of using renewable resources to produce high-value industrial and consumer products.



With DOE's support, Battelle, PNNL and Wa[illegible] fund and building Bioproducts, Sciences and [illegible] Laboratory on [illegible] in 2008. [illegible] research [illegible]

"PNNL has been developing and applying novel thermal, chemical and biological processes to convert biomass to industrial and consumer products, fuels, and energy for four decades," said Jud Virden, associate laboratory director for PNNL's Energy and Environment Directorate. One of PNNL's first biomass projects involved a pilot plant in Albany, Ore., that tested a process called liquefaction to convert wood into biocrude oil.

FROM TRASH TO TREASURE

In the 1990s, PNNL researchers were working on methods for turning agriculture commodities, byproducts and wastes into higher-value products. Many of these efforts focus on agricultural residues such as wheat straw and corn stover left behind after harvest, forest residues, and byproducts from food processing. For example, researchers have explored the potential of using hulls, peelings and pulp—often discarded by food processing plants as waste—as valuable bio-based feedstocks.

In collaboration with other national labs, PNNL developed a process that converts sugars from corn processing into a cost-effective, environmentally friendly source of chemicals used to make a number of products, including textiles, paints and inks, food additives, and automobile parts. In this process, the sugars are fermented to produce succinic acid. With the help of catalysts, the succinic acid is then converted into the chemicals used to make an assortment of industrial and consumer products.

Considering another agricultural waste as a potential feedstock, PNNL and Washington State University began a two-year project in 2001 to develop technology that would generate higher-value products from dairy manure solids. The team used the chemical building blocks from the waste to produce a range of products, including chemicals commonly used to manufacture antifreeze and certain plastics.

STARTING WITH THE BASICS

Much of PNNL's bioproducts and bioenergy research centers on the fundamental understanding of the underlying chemistry and biology at play during biomass conversion. This research is enabled by advances in computation and unique surface science tools at the Environmental Molecular Sciences Laboratory, the DOE national user facility at PNNL.

For example, researchers are looking at how to make the catalysts that drive important reactions more durable because they often can't survive the hot water generated during conversion processes. In one project, PNNL researchers studied the catalysts used in a process called steam reforming, which turns methane from biomass into a mixture that can be further converted into transportation fuels. Through experimental and theoretical approaches, they were able to better understand the performance of the catalysts and can potentially develop longer-lasting catalysts.

In another project, scientists studied the behavior of specific atoms during the process of converting a bio-based feedstock into biofuel. While the reaction where oxygen atoms are removed has to be quick and efficient, it is a complex reaction with a lot of intermediate steps. Researchers discovered that the starting size of the molecule affects how and when the oxygen atoms are split from the hydrocarbon chain, an important step in the speed of the reaction.

"This highlights the hallmark of PNNL's research in this area," said Doug Ray, associate laboratory director for PNNL's Fundamental & Computational Sciences Directorate. "It's just one example of years of research focused on the underlying chemistry of catalysts and development of novel catalytic processes that convert sugars and organic acids to higher

PNNL scientists and engineers created a continuous process to produce biocrude oil from green algae. The biocrude can be then be used in conventional refinery processes to produce aviation fuel, gasoline or diesel fuel. Genifuel Corp. licensed the technology and built a pilot-scale production plant in Colorado to further test and advance the process.

value products and chemicals."

In another project, scientists from PNNL and WSU investigated the possibility of using bacteria rather than oil as a source of isoprene—a chemical compound that is used for aviation fuel and to produce synthetic rubber. With the help of computer modeling, researchers predicted how environmental changes ultimately affected the volume of isoprene produced by the bacteria and can determine how to optimize production.

ADVANCING SOLUTIONS

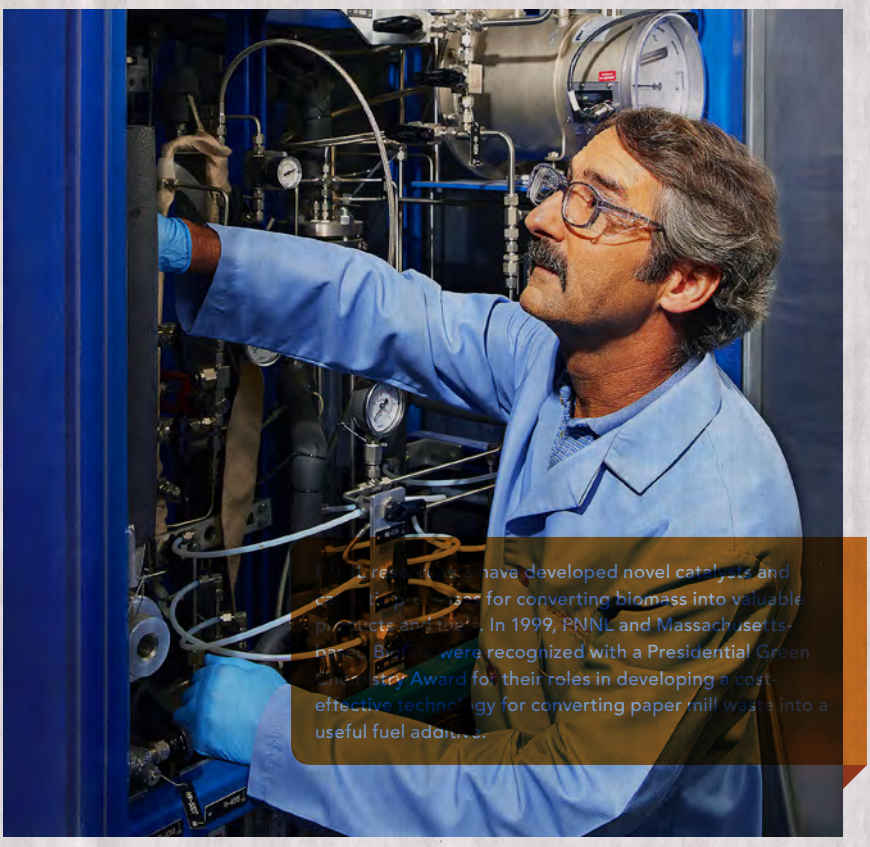
In addition to basic science, PNNL leverages its scientific capabilities to conduct applied research and develop products that address industry needs.

In 2004, PNNL researchers who contributed to the development of the Degradable by Design Deicer™ were recognized in a national award from R&D Magazine that highlights the year's top 100 innovations. The award acknowledged the family of biodegradable fluids used to remove and prevent the formation of ice on aircraft, runways, roadways and pavement. In addition to the reduced environmental impact, these bio-based materials are less corrosive and less toxic than conventional deicers.

In another technology transfer success story, PNNL partnered with Archer Daniels Midland Company (ADM) to quickly move a bio-based product breakthrough from development to full-scale deployment. PNNL developed a catalytic process to convert glycerol, which is a low-cost byproduct of biodiesel manufacturing, into propylene glycol, a chemical that is typically made from petroleum and found in common household products. ADM licensed the process and built a production facility in 2011 that produces 100 million metric tons of propylene glycol a year.

On the fuel side, PNNL developed a continuous process to produce biocrude oil from algae that has been licensed to Genifuel. Unlike traditional extraction methods that require drying the algae and separating out the energy-rich oils, this process converts whole, wet algae into biocrude oil. This development's roots can be traced back to the 1975 wood liquefaction project. Today, researchers are extending this process to convert other wet, carbon-rich and low-cost byproduct streams, like food processing waste and waste water sludge, into biocrude oil.

"Along with DOE as our primary sponsor, we work with private industry, academia and government to advance scientific discoveries and develop technologies for clean, cost-effective alternatives to conventional products and processes that rely on imported oil," Virden said. "These efforts address national and global energy independence and help grow and diversify the state and local economy."



PNNL researchers have developed novel catalysts and catalytic processes for converting biomass into valuable products and fuels. In 1999, PNNL and Massachusetts-based Biopulping were recognized with a Presidential Green Chemistry Award for their roles in developing a cost-effective technology for converting paper mill waste into a useful fuel additive.

Keeping America on the Move

ers at Pacific Northwest National Laboratory are advancing tech ologies t
widespre in hybrid vehicles, including develop nent of th d
Charge atiomatic y recharges electric ve les wh n t e is
city on t lectric grid and when it would cost co sumers the

This article first appeared in the April 27, 2015, issue of the *Tri-City Herald* and focuses on some of PNNL's scientific and technological contributions for cleaner, more efficient and sustainable transportation solutions.

The transportation sector consumes more than 70 percent of all the petroleum used in the United States and accounts for about 28 percent of the total energy we use, according to the National Academies.

At the Department of Energy's Pacific Northwest National Laboratory, researchers apply their scientific and engineering capabilities to reduce the impact of transportation on the environment, increase fuel efficiency and decrease the nation's dependence on imported oil.

"We've been working with auto-makers, engine manufacturers, and truck original equipment manufacturers for more than 20 years to develop new energy delivery systems, as well as technologies to make vehicles lighter and reduce emissions," said Jud Virden, associate laboratory director for PNNL's Energy and Environment Directorate. "We have a long history of using our chemistry and materials science capabilities to solve transportation problems with technologies that ultimately get deployed in the market."

LIGHTEN UP

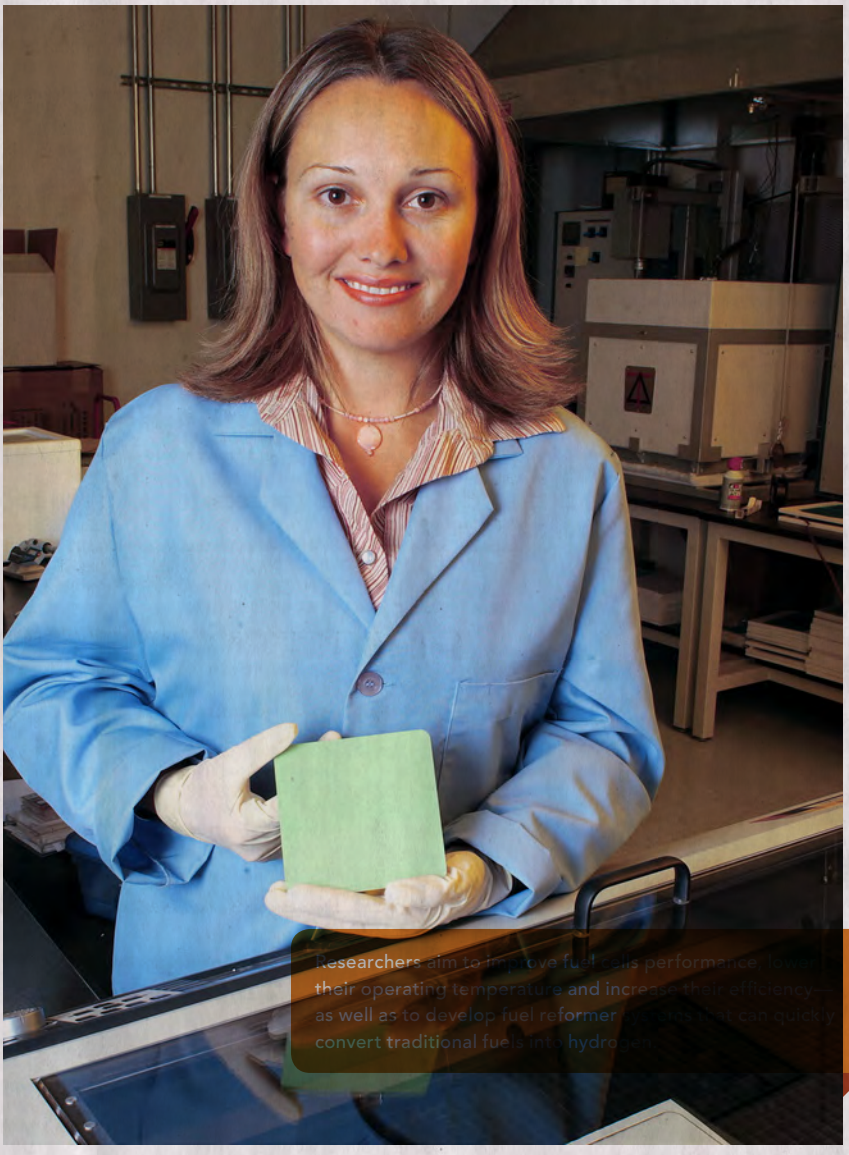
PNNL has spent decades developing lightweight, durable materials that reduce a vehicle's overall weight and increase fuel efficiency. With the help of its computer modeling capabilities, PNNL researchers can simulate how materials will behave during manufacturing and in their actual use before the first prototype is ever built.

More than 20 years ago, PNNL began advancing a technology called superplastic forming that allows automobile parts to be formed from aluminum sheet materials instead of heavier materials, while maintaining their strength. The process involves identifying the right materials and heating them to the right temperatures, so that metal alloys can be shaped and manipulated using processes typically used on plastics. It allows more complicated shapes to be manufactured in less time and with fewer parts.

In 2000, PNNL was recognized with a Federal Laboratory Consortium (FLC) Award for its efforts to commercialize a cost-effective superplastic forming process for aluminum alloys. PNNL developed computer models that reduce the time needed to form complex parts, making it more practical to use this process in high-volume manufacturing. This technology was transferred to General Motors, MARC Analysis and Kaiser Aluminum and has been used in the Cadillac STS and Chevy Malibu Maxx.

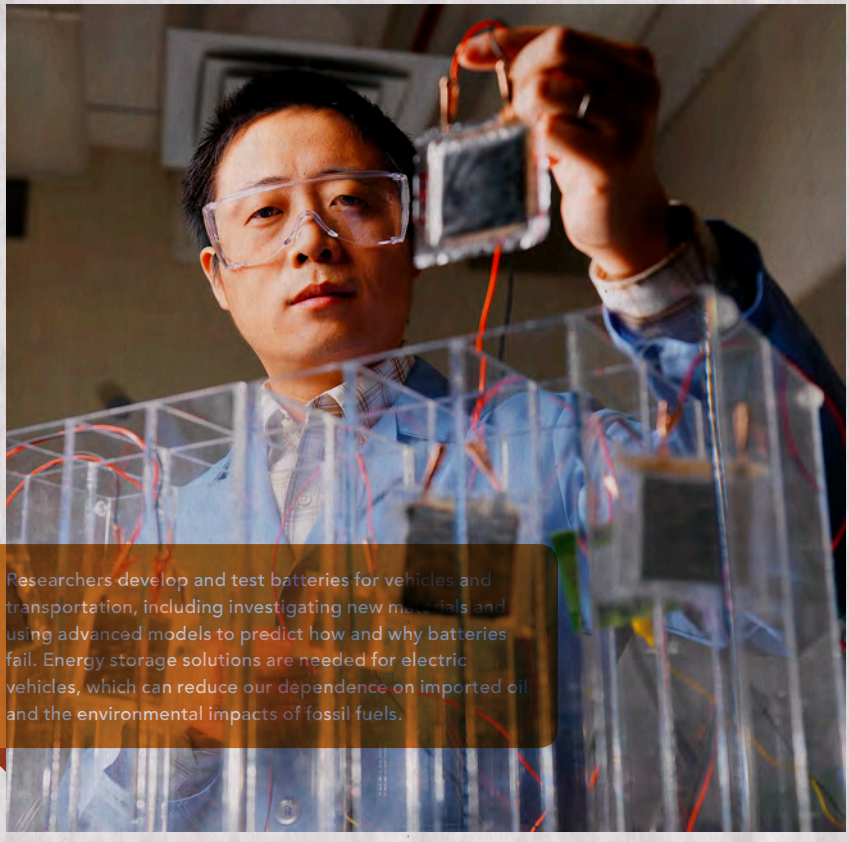
Today, PNNL is working on a project to construct special lightweight fuel tanks for vehicles fueled by natural gas. Because natural gas exists as a vapor and contains less energy per volume than gasoline, it has to be compressed into pressurized fuel tanks to increase its energy density. Using superplastic forming, tanks made of aluminum can be made to fit a vehicle's limited space better than a standard cylindrical tank.

Another approach to trim the weight from vehicles is a joining process called friction-stir welding, which allows two metals to be joined without melting them. While PNNL didn't invent this technique, researchers did develop the tooling and parameters for this process that enable high-volume production of aluminum tailor-welded blanks by a commercial partner. The TWB Company is ready to supply these "blanks," or semi-finished parts, to automobile manufacturers. Ford, Honda, GM and others are evaluating the technology for their use.



Researchers aim to improve fuel cells performance, lower their operating temperature and increase their efficiency as well as to develop fuel reformer devices that can quickly convert traditional fuels into hydrogen.

At PNNL's exhaust emissions laboratory, researchers can use a suite of instruments to develop and evaluate vehicle exhaust after-treatment systems. As seen here, a diesel car can be on a chassis dynamometer—a treadmill for vehicles that provides realistic road operating conditions for testing new technologies.



Researchers develop and test batteries for vehicles and transportation, including investigating new materials and using advanced models to predict how and why batteries fail. Energy storage solutions are needed for electric vehicles, which can reduce our dependence on imported oil and the environmental impacts of fossil fuels.

FURTHERING FUEL CELLS

PNNL is known for advancing fuel cells and related fuel processing systems. Instead of burning gasoline—like a conventional engine—fuel cells use a chemical conversion to produce electricity from hydrogen cleanly, efficiently and quietly.

In 1999, PNNL joined the Solid State Energy Conversion Alliance, or SECA. This collaboration among the federal government, private industry, academic institutions and national labs focuses on developing low-cost, modular solid oxide fuel cell technology that could use various fuels for a variety of applications including stationary power and transportation. PNNL coordinates SECA's Core Technology program, which addresses technical challenges identified by industry teams.

Fuel cells can provide the auxiliary power that would allow long-haul truck drivers and recreational vehicle enthusiasts to use the heat, air conditioning and electronic devices while stopped, without idling the engine or draining the battery.

Researchers at PNNL were recognized when Battelle and Delphi received a 2009 FLC Award for Excellence in Technology Transfer for their efforts to develop and deploy an auxiliary power unit for transportation.

Currently, PNNL is overseeing a demonstration project that involves using fuel cells to power refrigeration units in delivery trucks for frozen and refrigerated goods. These units are typically powered by a small diesel engine.

CHARGE IT UP

According to a 2007 PNNL study, if all the nation's light duty vehicles were powered by electricity instead of petroleum, the capacity in our existing power system that sits idle at certain times of the day could fuel 70 percent of them.

Researchers have developed a smart charging system that allows plug-in hybrid vehicles to receive signals from the electricity grid so they can be charged when this idle generation and transmission capacity is available, which could help lower consumers' electric bills and increase grid stability. AeroVironment, Inc. has licensed the PNNL-developed technology with plans to incorporate it into a prototype charging system.

Researchers are also looking to improve the batteries for electric vehicles, with a focus on improving performance and lowering costs. For example, lithium-sulfur batteries could allow cars to travel farther than the lithium-ion batteries used today; however, their overall lifespan is shorter. PNNL researchers are looking at how to increase the number of times lithium-sulfur batteries can be recharged so they last longer.

CLEANER DIESELS

Diesel engines may be more fuel efficient than their gasoline engine counterparts, but they also produce more harmful emissions.

PNNL partnered with engine manufacturer Cummins Inc. and Johnson Matthey, a supplier of catalysts, to improve lean-burn diesel catalytic converters for powerful vehicles. As a result of their efforts, the catalytic converter first used in the 2007 Dodge Ram—and later in other fuel-efficient diesel vehicles like the Volkswagen Jetta TDI—was able to meet 2010 emission standards, while improving fuel efficiency by 25 percent over conventional engines.

"This is a perfect example of how a fundamental understanding of the problem helped pave the way to a solution," Virden said. "Together with DOE and industry, PNNL is keeping America on the move, while addressing national and global challenges like climate change, pollution and energy independence."

Researchers developing advanced materials, including lightweight materials for vehicles, use processes such as friction stir welding that offer benefits over conventional manufacturing processes. For example, friction stir welding allows metals to be joined without melting them like welded joints.

Computational Science Powers Discovery and Innovation

In the 1970s, Pacific Northwest National Laboratory's researchers worked in state-of-the-art computer facilities that included a digital computer system for data acquisition and process control system development. Today, PNNL is home to Constance, a fast, reliable supercomputer that is helping scientists do complex, advanced research in areas such as climate science and smart grid development.

This article first appeared in the May 25, 2015, issue of the *Tri-City Herald* and focuses on how PNNL uses supercomputers, computational science and mathematics to build new scientific understanding that could help address significant national challenges in energy, the environment, national security and fundamental science.

Computers have come a long way in a few decades and, as a result, so has scientific understanding. The room-sized computers of the 1970s had only a fraction of the computing power of today's personal computers. Now, scientists are developing exascale computers that could perform about as many operations per second as 50 million laptops. Although the size and the power of the hardware has changed dramatically, the field of computing has always informed our approach to the biggest, most vexing challenges facing humankind.

"Whether we are trying to detect national security threats, manage the electricity grid or understand climate change, we are inundated with huge amounts of data—and we need to make that data actionable," said Doug Ray, associate laboratory director of fundamental and computational sciences at the Department of Energy's Pacific Northwest National Laboratory. "DOE has been a driving force in scientific computing since the Manhattan Project and operates some of the world's most powerful supercomputers."

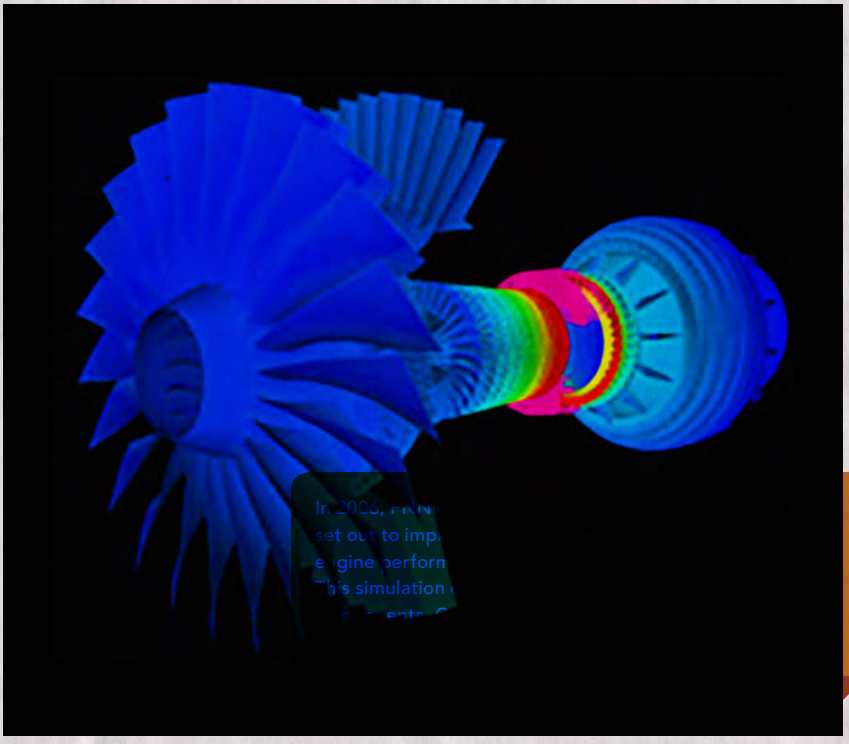
For 50 years, PNNL has anticipated the need and helped define the field of working with big data. Its computing contributions have improved the safety of our skies; informed our view of the climate, including drought conditions right here in the Mid-Columbia; and made possible new chemistry for new types of fuels.

POWERFUL STUFF

PNNL plays a leading role in making outstanding computing resources available to researchers around the world through EMSL, the Environmental Molecular Sciences Laboratory, a DOE national user facility. In November 2014, EMSL's Cascade was ranked the world's eighteenth most powerful supercomputer, but the vistas it opens to researchers are more important than its size. Cascade allows researchers to answer their biggest questions about molecular science and its applications to biology and environmental science.

SUPER SOFTWARE

In 1986, PNNL was recognized by R&D Magazine for developing one of the year's top 100 innovations, the Computer Aided Genetic Engineering/Genetic Engineering Machine, or CAGE/GEM. This software toolkit can help researchers design genetic structures before performing expensive laboratory experiments. Licensed to a commercial partner, CAGE/GEM can isolate a genetic element in a DNA sequence and then graphically manipulate it to create new genetic constructs.



EMSL collaborators from PNNL and other institutions developed high-performance computational chemistry software that is used by thousands in the research community. NWChem, released as open-source software in 2010, allows researchers to tackle large, complex molecular-scale scientific problems in areas such as catalysis, materials, geochemistry, atmospheric chemistry and biochemistry.

In one project, a researcher from the University of Alabama is using EMSL's Cascade supercomputer and NWChem to study new catalyst materials for more controlled and efficient production of bioproducts. With help of the software and computing resources, he can better understand and predict certain reactions at the molecular level.

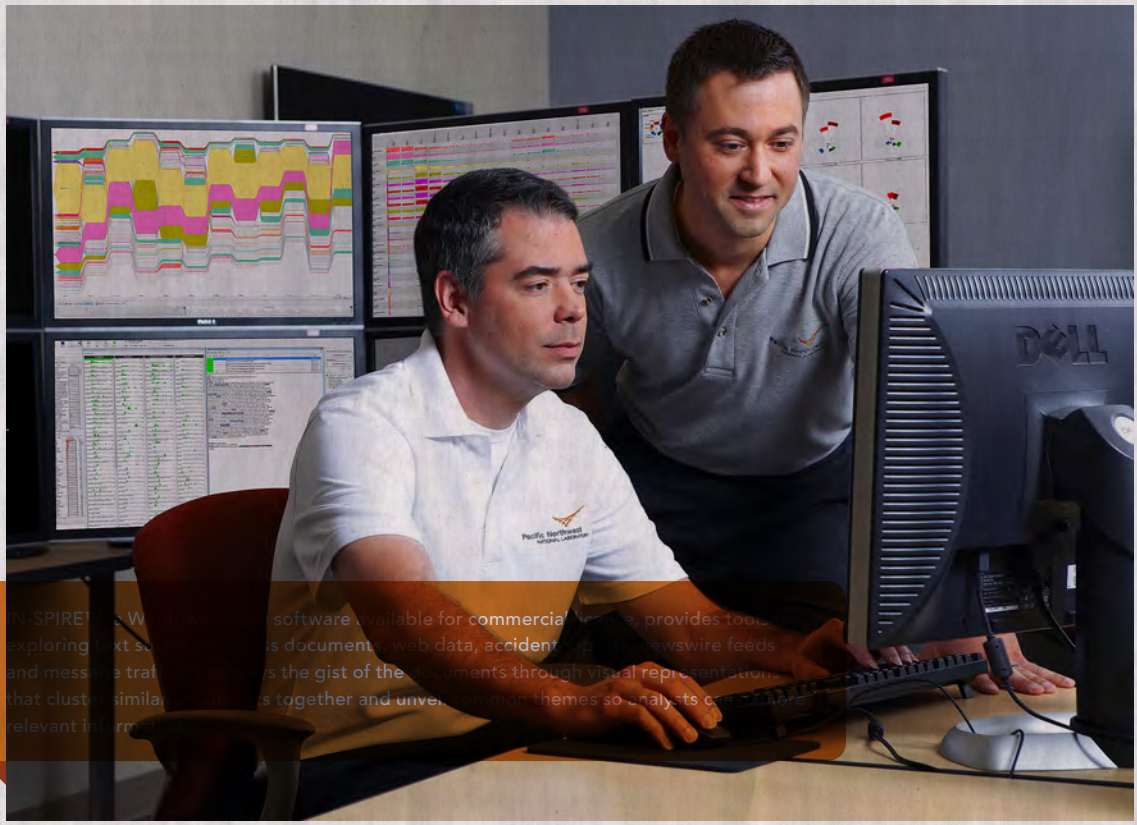
MODEL MODELS

In 2006, PNNL was awarded a grant from SciDAC, or Scientific Discovery through Advanced Computing, to develop a computer model that can simulate biogeochemical processes on multiple scales. The sophisticated model combines various simulations representing different processes on a variety of scales ranging from microbial growth in pores to the migration of contaminants to rivers or wells. It could enable researchers to more accurately predict the movement and fate of groundwater contaminants to aid cleanup and protect human safety.

On the health front, PNNL supports a project led by the University of Wisconsin-Madison to build virtual models of the liver and the lung to better understand at the molecular level how humans respond to viral pathogens like Ebola, West Nile and influenza. The goal is to design and develop new drugs to thwart infection.

PICTURE THIS

In the 1990s, PNNL was helping define the



IN-SPIRE™, a software available for commercial license, provides tools for exploring text such as news documents, web data, accident reports, newswire feeds and message traffic. It analyzes the gist of the documents through visual representations that cluster similar documents together and uncover common themes so analysts can share relevant information.

PNNL's Katrina Waters conducts research that uses data from integrated gene and protein expression to reconstruct cell response networks. Her research may enable predictive and toxicity pathways.

field of visual analytics, which combines the way computers analyze data with the way people see and analyze information to enable new discoveries and insights from large amounts of information or complex data.

Over the years, PNNL has developed several software tools that help people analyze text, image, audio, video and numerical data to detect patterns, trends and relationships by presenting the information visually.

As a recognized leader, PNNL was chosen to lead the Department of Homeland Security's National Visualization and Analytics Center™, created to increase capabilities to discover and predict terrorist activities by collecting, combining and analyzing vast amounts of information.

LIGHTWEIGHT MATERIALS

As lighter materials with different melting points replace steel in vehicles, using welding to join parts of cars and trucks together becomes increasingly challenging. In a project led by Ford Motor Co., PNNL scientists are using computer modeling to help engineers understand how to weld different materials together. Xin Sun, who works on this project, is also using a DOE-developed model to understand the underlying mechanics of damage and fractures in transparent armor being developed for the U.S. military, used mainly for protective windshields and windows. Her work may lead to more resilient battlefield vehicles.

A TOOL FOR SAFER SKIES

A tool developed more than 10 years ago by PNNL researchers along with NASA and other collaborators can analyze large datasets collected by an aircraft's onboard instruments. It provides experts with information about flight patterns and operational conditions that they normally would not see. The Morning Report

analyzes gigabytes of the day's flight information and presents data the next morning in graphic or tabular reports.

The Morning Report is a simple desktop application, but there are some serious mathematical and statistical algorithms working behind the scenes. The tool has been licensed to a flight recorder company, but it could also be used to monitor other complex systems, analyzing massive amounts of data and identifying typical patterns and atypical events.

PREDICTING FUTURE SKIES

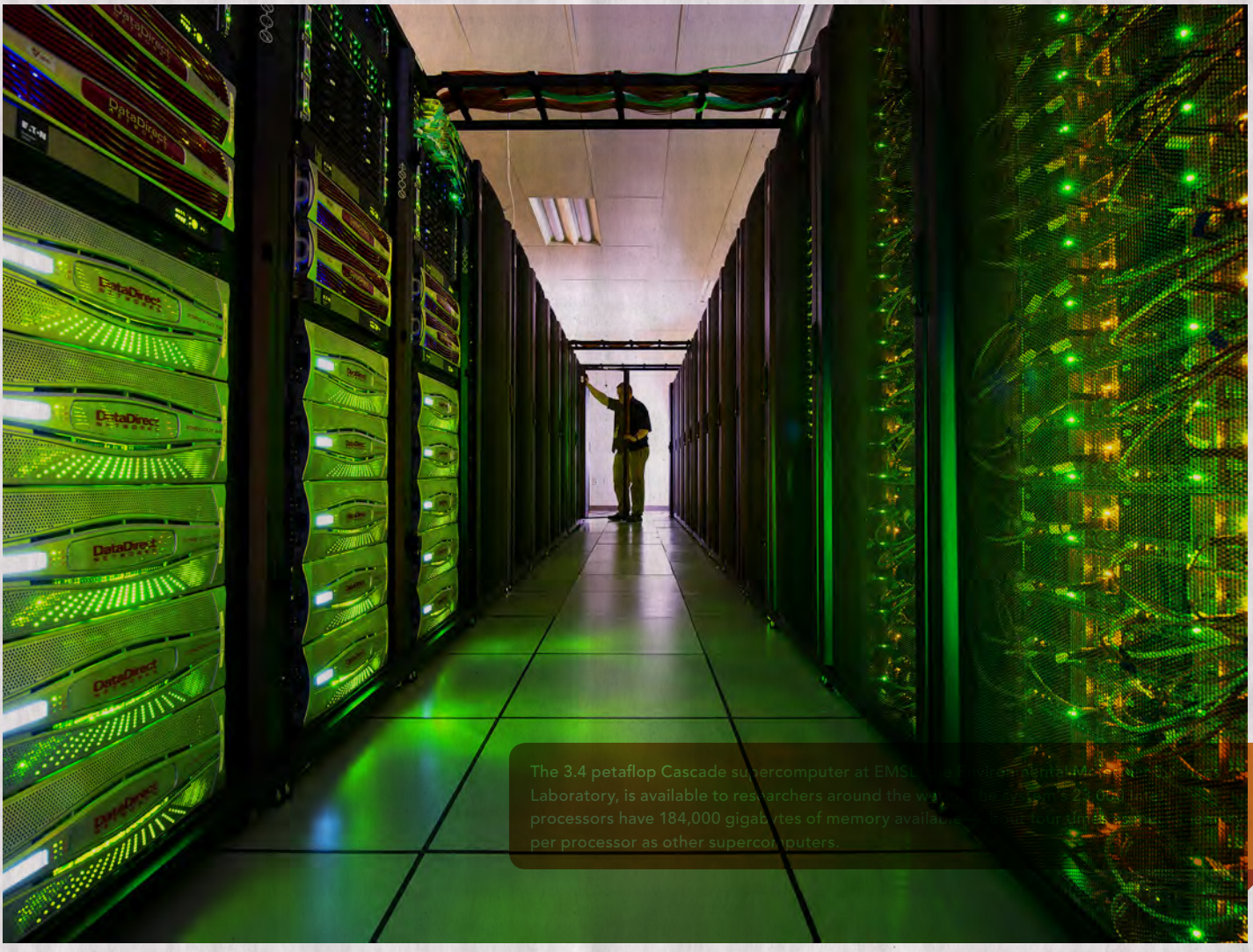
PNNL set the standard for developing new ways to think about the future of our planet's climate. In one project, scientists are untangling complex factors that determine how long snowpack in mountains like Washington's Cascades lasts before melting into the water used to grow crops and water lawns. It takes some of the nation's top scientists and top computing resources to understand the complexities of a process that is central to our lives here in the Mid-Columbia.

LOOKING AHEAD

Researchers are striving to advance exascale computing, which may solve problems a thousand times bigger than what today's best computers can handle. Working at that scale requires supercomputers to perform different parts of calculations simultaneously, sometimes on different hardware, and then put the pieces back together.

In 2013, DOE awarded PNNL's Sriram Krishnamoorthy $2.5 million over five years through its Early Career Research Program to work on exascale computing challenges. Part of his effort will focus on understanding how parallel computing solves problems and making sure that different pieces of the full calculation are working as efficiently as possible.

"In support of DOE, PNNL will continue to develop hardware and software solutions that generate, analyze, store and share data for scientific research," Ray said. "Our expertise in high-performance computing, data science and computational mathematics is advancing scientific discovery and innovation."



The 3.4 petaflop Cascade supercomputer at EMSL [illegible] Laboratory, is available to researchers around the w[illegible] processors have 184,000 gigabytes of memory availa[illegible] per processor as other supercomputers.

Opening Doors to Collaboration

The Environmental Molecular Sciences Laboratory was dedicated in 1996 and opened its doors to the global research community in 1997. Since then, EMSL has welcomed more than 12,000 researchers to build cross-disciplinary teams to tackle some of the most challenging scientific issues facing the nation.

This article first appeared in the June 29, 2015, issue of the *Tri-City Herald* and focuses on EMSL, or the Environmental Molecular Sciences Laboratory, a DOE national user facility on PNNL's campus that makes scientific capabilities—people, instruments and facilities—available to the global research community.

Solving scientific challenges often takes time, teams, tools and tenacity. Understanding the chemical nature of manmade soot particles, how they form and how they contribute to climate change is certainly no different.

A study by collaborators from several research institutions working together and using the unique tools of EMSL—a Department of Energy national user facility also known as the Environmental Molecular Sciences Laboratory—suggests that fundamental models of soot formation are not completely accurate.

Researchers from EMSL, the University of Dayton Research Institute, the University of Toronto and Stanford University examined the chemical composition of young soot particles in diffusion flames of a jet fuel surrogate blend. In diffusion flames, combustion takes place at the flame surface only and the interior of the flame contains unburnt fuel like that of a candle. The scientists relied upon EMSL's specialized instruments, including high-resolution spectrometers and a technique called nanospray desorption electrospray ionization, to conduct their study.

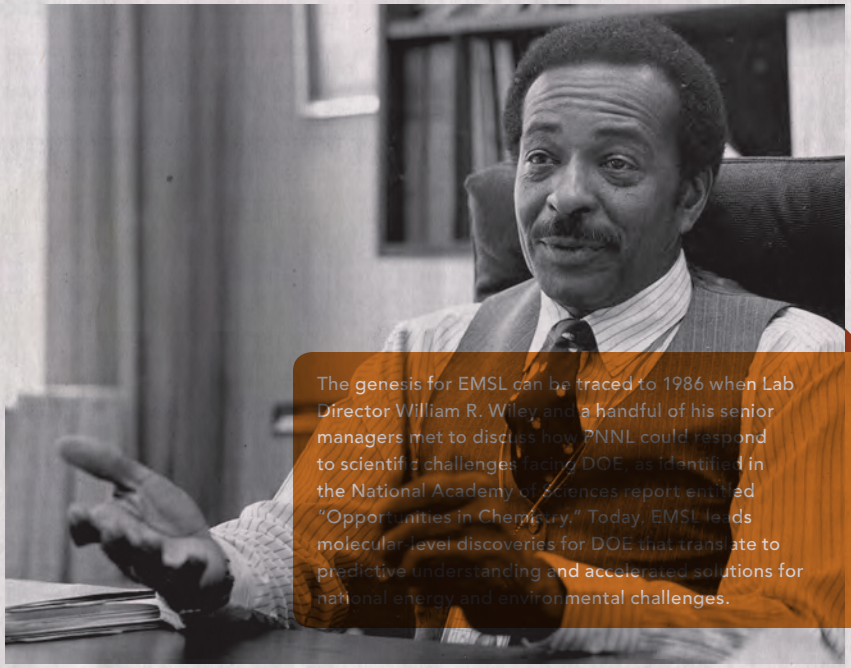
Their research could ultimately lead to improved climate-model representations of the chemical and physical properties of anthropogenic soot, greater insight into the role of soot in cloud formation and cleaner aviation engines through more accurate soot models.

Projects like this illustrate the collaborative research made possible by EMSL, which is located on Pacific Northwest National Laboratory's campus and funded and sponsored by the DOE's Office of Biological and Environmental Research.

"At the end of the day, our mission is scientific impact—to advance our understanding of the science of complex adaptive systems, whether biological, climate, soil or energy materials," said Allison Campbell, EMSL director. "We accomplish great impact by drawing together members of the scientific community and assembling the people, resources and facilities to solve problems. And we've proven it works."

FROM THE BEGINNING

EMSL's vision is to pioneer discoveries and effectively mobilize the scientific community to provide the molecular science foundations for DOE's research priorities and our nation's critical biological, environmental and energy challenges. It enables groundbreaking research by connecting the scientific user community to extensive scientific expertise and capabilities, as well as providing an operational environment that supports problem solving beyond what is possible in a typical university, industrial, or even single national laboratory setting.



The genesis for EMSL can be traced to 1986 when Lab Director William R. Wiley and a handful of his senior managers met to discuss how PNNL could respond to scientific challenges facing DOE, as identified in the National Academy of Sciences report entitled "Opportunities in Chemistry." Today, EMSL leads molecular-level discoveries for DOE that translate to predictive understanding and accelerated solutions for national energy and environmental challenges.

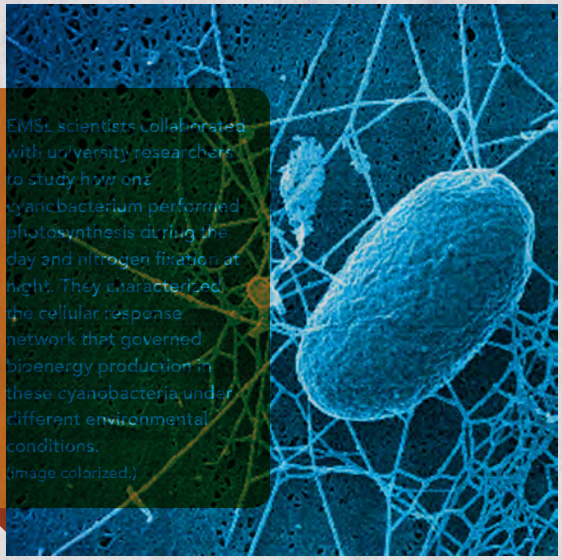
In the 1980s, William Wiley began articulating the need to create a user facility that would "facilitate integration between the physical, mathematical and life sciences." Wiley, who was PNNL director from 1984 to 1994, and his team proposed a center for molecular science that would bring together theoreticians with experience in computing modeling of molecular processes and experimentalists from the physical and life scientists.

The team recognized that the ability to characterize, manipulate and create molecules would enable scientific advancements. They helped pioneer the establishment of a user facility that would provide researchers across the nation with advanced instrumentation for molecular-level chemistry with a focus on developing the science and technology necessary to clean up environmental problems at government sites such as Hanford.

EMSL was dedicated in Wiley's honor in October 1996, a few months after he unexpectedly passed away. His wife, Gus, cut the ribbon at the ceremony. The facility began operation about a year later. Since then, scientists from all 50 states and more than 35 countries have used EMSL to support their scientific efforts.

COME COLLABORATE

EMSL makes its nearly 200 staff members, 150 experimental instruments and a high-performance supercomputer available to the international research community, typically at no cost, through a variety of proposal opportunities. Some of these cutting-edge instruments are truly one-of-a-kind; others are only available at a few research institutions around the world. They include mass spectrometers, microscopes, nuclear magnetic resonance spectrometers, surface characterization tools and more.



EMSL scientists collaborated with university researchers to study how one cyanobacterium performed photosynthesis during the day and nitrogen fixation at night. They characterized the cellular response network that governed bioenergy production in these cyanobacteria under different environmental conditions. (Image colorized.)

PNNL and EMSL staff members work with nearly 700 scientists a year to advance their research in support of DOE's mission to provide innovative solutions to the nation's environmental and energy challenges. Collaborators come from academia, other national laboratories and industry.

EMSL EXAMPLES

As a user facility, EMSL provides the scientific expertise and instruments to give researchers a deeper understanding of molecular-level processes. This knowledge helps predict how aerosols and terrestrial systems affect climate; makes possible new clean, affordable and abundant energy; and supports legacy waste cleanup—among other things.

In the renewable energy arena, a project that included scientists from EMSL, PNNL and Washington University in St. Louis, Mo. is focused on the role of chemical reactions involving reduction and oxidization in blue-green algae called cyanobacteria, which could be used in producing chemicals and biofuels. With the help of EMSL's research capabilities, the team is learning about what causes these bacteria to start and stop photosynthesis and other important energy production functions so they can better use it to make renewable energy.

Recently, EMSL researchers have changed the scientific community's understanding of the behaviors of electrodes in rechargeable batteries, which can help address the need for efficient and reliable energy storage technologies. This advancement stemmed from multiple research efforts by EMSL's Chongmin Wang. In related efforts, scientists from Stanford University, Massachusetts Institute of Technology and Lawrence Berkeley National Laboratory along with EMSL observed the molecular and physical changes that occur during the batteries' actual charge-discharge cycle. Their results will help design new materials for high-capacity, low-cost, long-lasting and environmentally friendly batteries.

Other efforts are focused on understanding climate change, such as research that discovered tiny organic particles in the atmosphere that have been linked to air quality and climate change evaporate hundreds of times slower than was previously assumed. New information like this is helping scientists improve air quality and climate models.

EMSL scientists are helping uncover the processes of hydrology, biology and chemistry occurring in the soil at a molecular level. They have identified thousands of molecules from organic matter that are present in as little as 100 milligrams, or one-fiftieth of a teaspoon, of soil. And they are developing an understanding of the chemical processes involved in the carbon that is underground and how its lifecycle can impact the atmosphere and, as a result, provide data for climate models in accurately predicting climate change.

NEW ADDITIONS

In 2009, DOE announced a $60 million investment in new capabilities for EMSL from the American Recovery and Reinvestment Act. These funds were used to upgrade existing capabilities as well as develop and deploy totally new systems and capabilities, including a Quiet Wing and a radiochemistry facility called RadEMSL.

The Quiet Wing is among the most advanced quiet laboratories in the world for high-resolution imaging capabilities and houses a suite of ultrasensitive microscopy and scanning instruments. RadEMSL opened in 2010 to accelerate scientific discovery and deepen the understanding of the chemical fate and transport of radionuclides in ecosystems at and below the surface.

THE FUTURE OF SCIENCE

Collaboration is the future of scientific understanding and innovation. "Team is in our DNA," Campbell said. "PNNL brings together the expertise, instruments, tools, computers and people at EMSL to make collaborations—and discoveries—possible."

Scientists from around the world can advance their understanding of carbon cycling, microbial biology and climate change using a new 21 Tesla Fourier Transform Ion Cyclotron Resonance mass spectrometer, one of many specialized research instruments available to the research community at EMSL.

Nuclear Knowledge for the Nation

Pacific Northwest National Laboratory builds upon its rich history and heritage to focus its nuclear science and technology capabilities on current challenges such as cleaning up contaminated sites, safe and secure storage of spent nuclear fuel, next-generation nuclear energy and preventing the trafficking of illicit nuclear materials. In 1967, researchers were continuing the fundamental scientific and technical work that provided the basis for the design, fabrication and reprocessing of weapons grade nuclear fuels (left). Also in the mid-1960s, researchers devised a computer code, called COBRA for Coolant Boiling in Rod Arrays, which allowed for three-dimensional, multiphase hydrothermal modeling of reactor and other complex systems (right).

The following article first appeared in the July 27, 2015, issue of the *Tri-City Herald* and focuses on PNNL's capabilities and experience in nuclear science and nuclear safety—and how they have been applied to energy, national security and environmental challenges over the decades.

The diverse research portfolio of the U.S. Department of Energy's Pacific Northwest National Laboratory builds upon PNNL's history and heritage in nuclear science and nuclear safety.

For example, PNNL invented a technology to turn radioactive waste into glass for safe long-term storage. Its researchers came up with a computing code that allows a clear view of subsurface contaminants at Hanford's radioactive waste storage tanks despite metal objects that interfere with conventional imaging methods. They are helping determine whether existing nuclear plants can continue operating safely. And they develop technologies to prevent nuclear materials from being smuggled across international borders.

"The world-class nuclear expertise that we have developed while supporting DOE's nuclear mission over 50 years has positioned PNNL to address today's nuclear challenges in advanced reactor design and waste processing, plus nuclear materials and process science," said Jud Virden, associate laboratory director for energy and environment.

In 1965, Battelle was awarded the contract to manage what was then the Hanford Labs. Today, the multi-program national lab is no longer part of Hanford, but continues to draw upon its long-standing capabilities in actinide chemistry, radionuclide detection and nuclear safety.

"Our scientists and engineers deliver scientifically defensible solutions—saving taxpayers millions of dollars—for cleaning up contaminated sites, producing safe and efficient nuclear energy, and detecting and deterring the transport of nuclear materials," Virden said.

HELPING HANFORD

Nearly 30 years after plutonium production ended at Hanford, cleaning up the radioactive and chemically hazardous waste generated by those processes remains one of the nation's largest environmental challenges.

Various forms of waste, which have changed over time, are stored in facilities well beyond their planned lifetimes. PNNL applies its specialized expertise to support cleanup of Hanford's tank farms and deployment of the waste treatment plant under construction today.

In the 1970s, even before the cleanup mission, PNNL researchers developed

In the late 1990s, PNNL develo[illegible] Automa[illegible]d Radioxenon Sampler Analyzer [illegible] which [illegible]alyzes air samples for radioactive xenon, or radioxenon, that seeps from underground nuclear explosions and could be used to detect nuclear testing. PNNL nuclear radiation detection technologies such as this were able to detect the radioactive isotope xenon-133 entering the continental United States on March 16, 2011, following the release from the Fukushima nuclear reactors in Japan a few days earlier.

a technology for incorporating high-level radioactive waste in a stable glass form suitable for permanent geologic disposal. The technology was deployed at Hanford, the West Valley nuclear site in New York and the Savannah River Site in South Carolina.

By expanding the understanding of the fundamental processes controlling environmental contamination and waste behavior, researchers are building a foundation to reduce the cost and risk of legacy waste cleanup at contaminated sites. They are developing a predictive understanding of system performance involving tank waste processing, immobilization and disposal; environmental remediation; and site closure. Their leadership in subsurface science is helping protect the soil and groundwater along the Columbia River. But PNNL's nuclear science and technology reaches far beyond Hanford.

CONTAINING CHERNOBYL

After the Chernobyl Nuclear Power Plant accident in Ukraine in 1986, PNNL researchers were assigned to lead the collection and maintenance of information on the accident, including analyzing radiation levels after the plume arrived in the United States and collecting air samples using research aircraft.

PNNL also helped develop the 1997 Shelter Implementation Plan, outlining how to solve the technical problems left by the reactor core meltdown. While the damaged reactor core was quickly protected to reduce immediate risks, PNNL staff members—including several who relocated to Ukraine—supported the planning, design and construction of a complex, long-term confinement structure. The gigantic arch structure is being constructed 650 yards away and then rolled into place over the reactor. It will keep radioactive material from escaping and allow the old reactor to be dismantled safely.

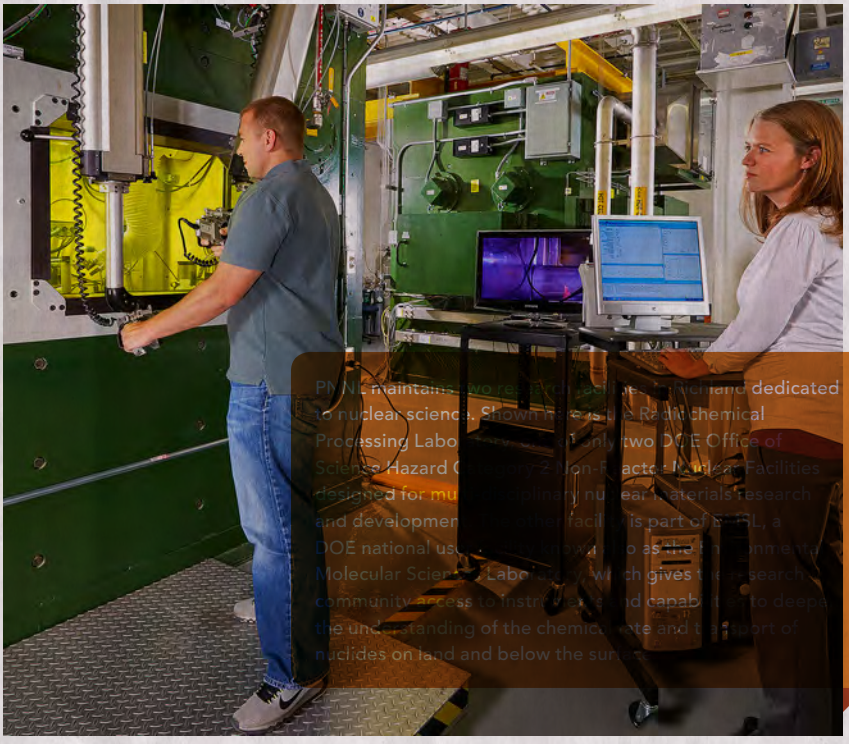
IMPROVING INTERNATIONAL SAFETY

In the 1990s, PNNL provided technical leadership to an international effort to reduce risks at Soviet-designed nuclear reactors. Led by DOE and working cooperatively with nine host nations, other national labs and U.S. businesses, PNNL helped correct major safety deficiencies and establish self-sustaining nuclear safety infrastructures, mostly in the former Soviet Union. For about 10 years, the International Nuclear Safety Program focused on 21 nuclear plants with 65 operating reactors.

FOLLOWING FUKUSHIMA

After the 2011 earthquake and resulting tsunami led to a nuclear power accident in Fukushima, Japan, PNNL-developed technology for ultra-trace detection was immediately put to work to provide technical readings for Japanese leaders managing the crisis. The same equipment detected the first signals of nuclear fallout when it made its way to the atmosphere over the United States and helped determine the nature and magnitude of the release.

PNNL still supports response and recovery efforts at Fukushima, drawing upon Hanford cleanup experience to address Japan's most pressing challenges in reactor recovery and environmental remediation. PNNL also is helping the U.S. Nuclear Regulatory Commission (NRC) assess the implications of the Fukushima accident for U.S. nuclear power plants.



PNNL maintains two research facilities in Richland dedicated to nuclear science. Shown here is the Radiochemical Processing Laboratory, one of only two DOE Office of Science Hazard Category 2 Non-Reactor Nuclear Facilities designed for multidisciplinary nuclear materials research and development. This facility is part of PNNL, a DOE national user facility known as the Environmental Molecular Sciences Laboratory, which gives the research community access to instruments and capabilities to deepen the understanding of the chemical, physical and transport of nuclides on land and below the surface.

POWERING THE FUTURE

The 99 nuclear power plant reactors in the United States—many built more than 35 years ago—produce nearly 20 percent of the nation's electricity. For three decades, PNNL has provided technical support to the NRC in its mission to ensure these plants can continue to operate safely and reliably, including the license renewal process. Already, 74 plants have received 20-year license extensions, 10 have applications pending and more are expected.

PNNL experts also supported the NRC in the environmental and safety reviews that cleared the path for the first construction of new power plants in the U.S. in more than 30 years.

PNNL conducts fundamental research and development across the full nuclear fuel cycle. This includes materials science that supports the safe operation of reactors and storage and transportation of spent

PNNL has developed and deployed vitrification technologies to encapsulate nuclear waste in glass for safe and long-term disposal. Here, researchers are analyzing the performance of glass used in waste treatment. PNNL is testing, evaluating and providing engineering support and regulatory guidance to aid the development of a Bulk Vitrification for converting tank low-activity tank waste into a stable waste form suitable for disposal.

fuel. Researchers also explore and assess new processes for recycling spent fuel, the safety performance of spent fuel repository concepts, and technologies for the next generation of safer, more economical reactors.

SUPPORTING GLOBAL AND NATIONAL SECURITY

Building on its nuclear expertise, PNNL has a strong history and extensive experience in proliferation prevention. In the 1990s, PNNL was advising the Russian government on security improvements in weapons production facilities as part of DOE's Materials, Protection, Control and Accountability Program.

PNNL also develops technologies to detect trace levels of radioactivity that could be evidence of nuclear explosions around the world.

In support of the National Nuclear Security Administration's global nuclear security goals, PNNL researchers develop, integrate and test radiation methods and technologies for identifying weapons of mass destruction and terrorist activities and for supporting international treaties and agreements.

PNNL supports the Department of Homeland Security and U.S. Customs and Border Protection in protecting the U.S. borders by preventing terrorist weapons, including weapons of mass destruction, from entering our country. Working closely with these sponsors, PNNL played a key role in installing and deploying radiation portal monitors that can detect radiation emanating from nuclear devices, dirty bombs, special nuclear materials, natural sources and isotopes commonly used in medicine and industry.

ADDRESSING SCIENTIFIC CHALLENGES

PNNL is advancing nuclear science for a stronger nation. Recent efforts focus on understanding, harnessing and exploiting the chemistry that controls interfacial processes in radioactive material and radiation environments.

"These efforts build upon our 50-year history," said Tony Peurrung, associate laboratory director for national security. "And through them we are paving the way for solutions in environmental cleanup, safe and secure storage of spent nuclear fuel, the next-generation of energy production, and preventing the trafficking of illicit nuclear materials."

Innovations Protecting the Nation

Scientists at PNNL's Shallow Underground Laboratory utilize an electroforming process to produce high purity copper used in ultra-low background detector research and development for environmental, national security and fundamental physics applications. This research supports activities including international treaty verification to prevent and counter acts of terrorism.

The following article first appeared in the August 31, 2015, issue of the *Tri-City Herald* and focuses on how PNNL draws upon its broad scientific capabilities to develop technologies and tools to protect the nation from treats of weapons of mass destruction, terrorists and cyber-attacks.

The tragic events of Sept. 11, 2001 made clear the critical need to develop and deploy new and different ways to protect the nation. And the Department of Energy's Pacific Northwest National Laboratory draws upon its nuclear heritage, broad scientific capabilities and national security expertise to do just that.

"In October 2002—13 months after Sept. 11—we powered on the first radiation detector designed to detect potential threats by scanning international cargo for radiation sources at U.S. borders," said Tony Peurrung, associate laboratory director for national security. "Before 9/11, there wasn't a single radiation portal monitor (RPM) deployed at our country's borders. Today, U.S. Customs and Border Protection uses the nearly 1,400 RPMs installed in the last 10 years to scan 100 percent of privately owned vehicles and cargo at U.S. land border crossings and 99 percent of all cargo arriving in the U.S. by sea," he said.

PNNL supports the Department of Homeland Security's effort to deploy these systems, which are capable of detecting radiation emanating from nuclear devices, dirty bombs, special nuclear materials, natural sources, and isotopes commonly used in medicine and industry.

"This is an example of how we embrace our mission to lessen the threat of weapons of mass destruction or mass effect—which include terrorism or cyber-attacks that could severely impact the health and welfare of our society and the economy," Peurrung said.

While PNNL's national security work intensified in response to 9/11, it started five decades ago with strong roots in radiological and nuclear work and has grown in breadth and impact ever since.

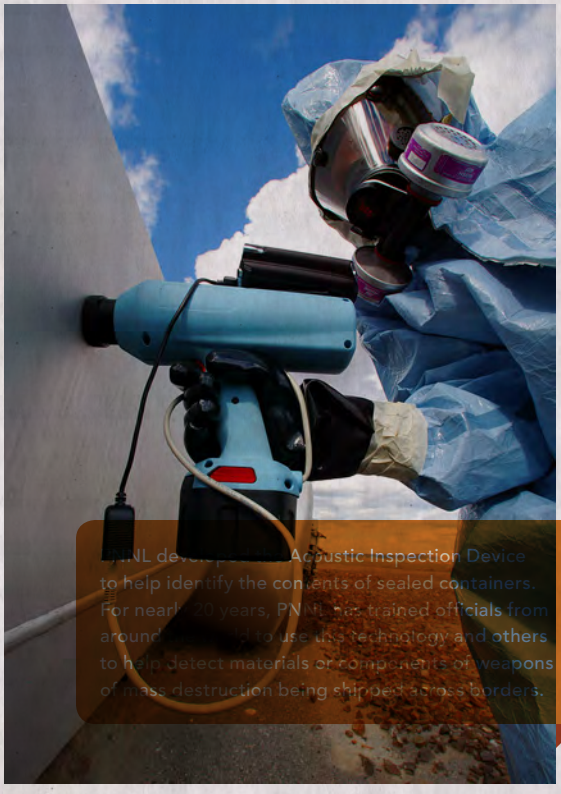
DETECTION AND PROTECTION

PNNL builds upon its radiological detection expertise to support detection of trace amounts of radioactivity that could be evidence of nuclear explosions around the world, including underground tests of nuclear weapons.

For example, one technology developed in the late 1990s analyzes air samples for radioactive xenon. Another detects fission products in the form of particulate debris from atmospheric nuclear explosions. Both technologies were transferred to a commercial partner that manufactures safety and diagnostic equipment and were recognized with a Federal Laboratory Consortium award for technology transfer in 2000.

One novel approach to detecting conventional explosives "sniffs" the air similar to the way bomb-sniffing dogs can detect trace amounts of explosives. This direct, real-time vapor detection technology samples the air and converts the small number of explosives molecules to ions that can then be detected and identified almost instantaneously. While this technology is only in the prototype stage, it has the potential to revolutionize security operations including airport screening, port security and military applications.

On the chemical and biological weapons front, PNNL scientists solve research and development challenges related to chemical and biological detection and forensics. Their work focuses on identifying appropriate "signatures" for these agents, collecting and preparing samples, and developing detection and analysis technologies.



PNNL developed the Acoustic Inspection Device to help identify the contents of sealed containers. For nearly 20 years, PNNL has trained officials from around the world to use this technology and others to help detect materials or components of weapons of mass destruction being shipped across borders.

In 1998, Vice-president Al Gore learned about PNNL's Scene Pro technology—an interactive system that could enable law enforcement personnel to quickly capture, s[illegible] and relay vast amounts of information at crime scenes and other field scenarios.

AIDING FIRST RESPONDERS

Being the first to respond to major events—whether natural or manmade—comes with its own challenges. Over the years, PNNL has helped develop tools for first responders that lighten their load as well as provide tools to help them understand and address the situation more quickly.

PNNL researchers devised a small, inexpensive microscopic lens that can be printed with a 3-D printer and attached to a smart phone camera to produce up to 1000x magnification, which makes it possible to see tiny anthrax spores and plague cells.

Back in 1996, a PNNL-developed, three-dimensional ultrasound medical imaging device for Army MASH units was tested by the Army in Bosnia. The system allowed medics in the field to share images electronically with other doctors and specialists who could then help with diagnoses and treatment.

ON A GLOBAL SCALE

As early as 1997, PNNL was helping equip and train the law enforcement officials whose job is to thwart the trafficking of chemical, biological or nuclear materials across international borders. PNNL staff members have assisted officials from more than 60 countries in the interdiction of weapons of mass destruction through training at the Volpentest Hazardous Materials Management and Emergency Response Federal Training Center, or HAMMER, which is located on the Hanford Site.

PNNL global security experts also engage with foreign nationals from as many as 100 countries a year to enhance global security through a variety of means including technology assessments, energy security, and remote monitoring and response.

Just last December, PNNL staff members participated in an integrated field exercise in Jordan to simulate an on-site inspection. Those participating in the fictional exercise, which was organized by the Preparatory Commission for the Comprehensive Nuclear Test Ban Treaty Organization, had to determine whether a nuclear explosion had been conducted.

AIRPORT SECURITY

It's hard to travel through a major U.S. airport without walking through a scanner developed by PNNL and licensed for commercial use. Unlike metal detectors, the millimeter-wave holographic scanning technology can detect nonmetallic weapons or explosives, even if they are concealed under clothing. This technology's roots date back to the 1970s when PNNL was a pioneer in developing 3-D holograph imagery for nondestructive evaluation of nuclear reactors. The whole-body scanner was first patented in 1995 and licensed in 2003 for security applications. Just five years later, the first scanner was deployed at the Los Angeles International Airport. Today, there are more than 1,300 systems in 250 airports across the country and around the world.

Expanding on this approach, PNNL is developing a technology that could bring an end to having to remove your shoes as part of airport security measures.

The Biodetection Enabling Analyte Delivery System, or BEADS, developed by PNNL could be used to detect protein signatures including E. coli, salmonella, ricin and other toxins or biological weapons with high specificity and high sensitivity in dirty environments.

Researchers are exploring the use of low-profile millimeter-wave arrays that could be integrated into the floor of the body scanners to also scan the soles of passengers' shoes as they pass through.

SAFETY ON THE CYBER FRONT

Cybersecurity is a hot topic these days. PNNL is developing tools and approaches, some made possible by recent advances in science, to discover and analyze evolving threats so that quick action can be taken both to stop the attack and determine its source.

One such tool is called MLSTONES, which stands for Machine Learning String Tools for Operational and Network Security. It allows analysts to share signatures of threats with others, without sharing sensitive data. By leveraging technologies and methods from biology and DNA research, PNNL researchers have translated biology and bioinformatics concepts onto cyber defense data. For example, one process creates cyber "proteins." Analysts can learn the function of a cyber protein by its relationship to those that are similar—much like the process biologists use to discover similar proteins. Analysts can look for the defining characteristics of a "family of behaviors" that could be used to identify and attribute new threats based on similarities to events they have seen before.

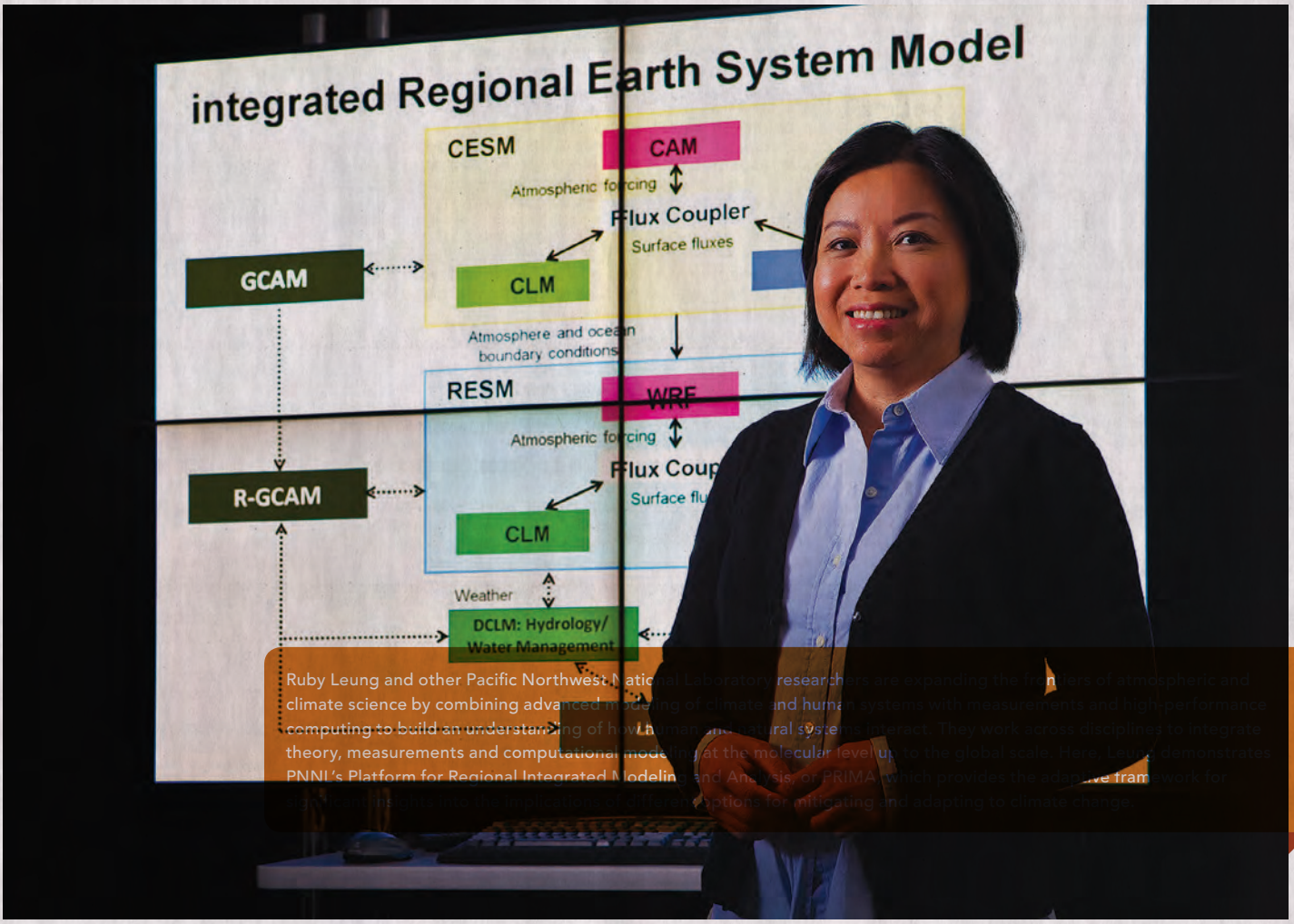
LOOKING AHEAD

PNNL will continue advancing national security solutions, whether that means coming up with entirely new tools or improving existing technologies with new capabilities, in support of DOE's National Nuclear Security Administration, the Department of Homeland Security and other sponsors. These methods and solutions have to evolve just as the threats evolve, especially in areas such as chemical and biological warfare and cybersecurity.

"Our national security work is thriving because we have a whole national laboratory behind us," Peurrung said. "We leverage the breadth and depth of PNNL's science and technology to deliver innovations to protect the nation."

[illegible] at PNNL's Radiochemical Processing [illegible] advance radiological material processes and [illegible] environmental, nuclear [illegible] national security [illegible] specialized capabilities, along with the ability to [illegible] are highly active and dispersible materials, [illegible] not available elsewhere.

A Closer Look at Climate



Ruby Leung and other Pacific Northwest National Laboratory researchers are expanding the frontiers of atmospheric and climate science by combining advanced modeling of climate and human systems with measurements and high-performance computing to build an understanding of how human and natural systems interact. They work across disciplines to integrate theory, measurements and computational modeling at the molecular level up to the global scale. Here, Leung demonstrates PNNL's Platform for Regional Integrated Modeling and Analysis, or PRIMA, which provides the adaptive framework for algorithm insights into the implications of different options for mitigating and adapting to climate change.

The following article first appeared in the September 28, 2015, issue of the *Tri-City Herald* and focuses on PNNL's research that is helping build an understanding of underlying processes of atmospheric science and climate science, as well as their potential impacts.

This summer's unusually high number of days over 100 degrees, widespread water shortages, ravaging wildfires and poor air quality have been an eye-opener to how changes in weather and climate can impact our lifestyles and livelihoods.

Understanding and predicting potential climate changes and their impacts—with all of the underlying processes as well as variables in cause and effect over time and around the planet—is a huge scientific challenge. The Department of Energy's Pacific Northwest National Laboratory conducts basic and applied research at the cutting edge of this critically important issue.

In a recent project, PNNL researchers focused on understanding and modeling the fundamental processes that govern the variability and extremes in precipitation in the western United States. Their efforts were aimed at improving climate models and the ability to predict the regional water cycle, including floods and droughts.

Considering that the western U.S. receives most of its precipitation during the cold season and that the snowpack accumulated during winter storms provides about 70-90 percent of the water supply for the region, being able to predict fluctuations in the amount of precipitation and when it may come will help better prepare for and mitigate their impact on water availability.

"From an environmental perspective, climate change has emerged as one of our world's most serious challenges," said Charlette Geffen, who leads PNNL's atmospheric science and global change division. "Our expertise in the scientific, technical and socioeconomic aspects of climate change research provides accurate, comprehensive information for regional, national and global analysis to help inform decision makers and shape climate strategies worldwide."

In 1980, researchers at PNNL led a national program designed to determine the causes and effects of acid rain. The DOE study was part of a 10-year National Acid Precipitation Assessment program, the most comprehensive effort at that time on the acid rain problem.

FOUNDATIONAL RESEARCH

Today's atmospheric science builds upon work done decades ago in support of the Hanford Site. PNNL scientists led some of the first research to determine the impacts of a potential radiological release.

They relied upon a meteorological station at the site, along with the Hanford Diffusion Grid—a 120-meter tower surrounded by concentric arcs of instruments that measured how the concentration of harmless gases released during experiments would change as they were dispersed by the wind—and gained new understanding about the fate and transport of a potential radiological release.

Through this effort, researchers developed computational models and gained a fundamental understanding of boundary layer physics, or the interactions taking place within the blanket of atmosphere closest to Earth where all life lives and breathes, that also has to be accounted for in today's climate models.

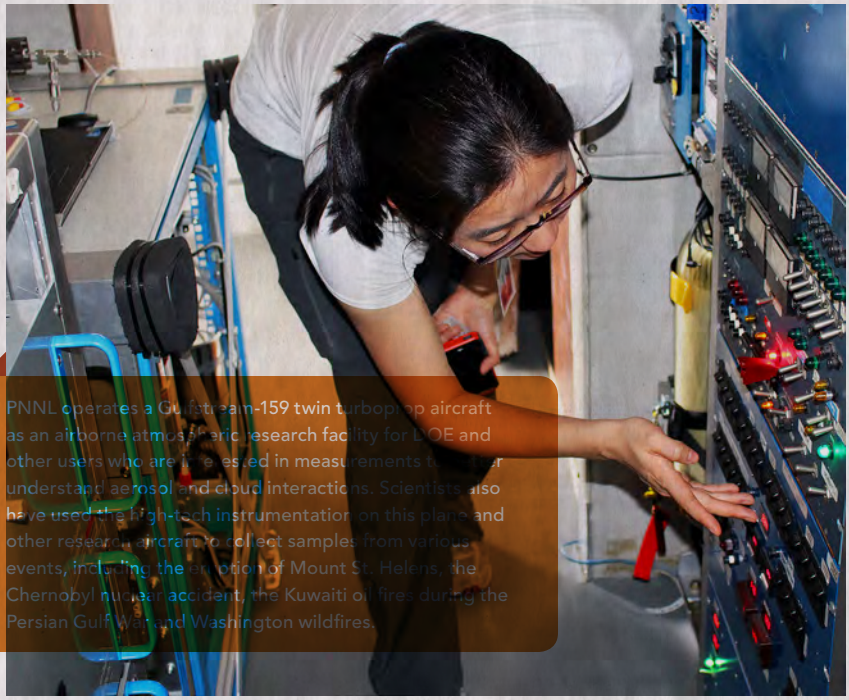
ENERGY AND THE ENVIRONMENT

The early Hanford research expanded to include atmospheric studies in terrain more complex than eastern Washington's flat, open surroundings and was applied to understand the impacts of the power industry, such as extracting shale oil, on the environment.

In the late 1970s, researchers at PNNL started sampling and analyzing pollutants from industrial centers, including carbon gases from coal-fueled power plants, using an aircraft's onboard equipment. They wanted to understand pollutant concentrations and transformations in the atmosphere to better develop regional air pollution models that would help determine the environmental impacts of burning fossil fuels.

PNNL researchers also led a ten-year national program that began in 1980 to determine the causes and effects of acid rain. Building on this research, PNNL has engaged in many national programs to better understand the chemical mechanisms behind the formation of ozone, other secondary pollutants and aerosols that affect human health and climate.

Today, PNNL provides assessments that take an integrated look at economic, physical and ecological systems to explore the consequences of the interactions between humans and the climate system under various scenarios, exploring how to stabilize greenhouse



PNNL operates a Gulfstream-159 twin turboprop aircraft as an airborne atmospheric research facility for DOE and other users who are interested in measurements to better understand aerosol and cloud interactions. Scientists also have used the high-tech instrumentation on this plane and other research aircraft to collect samples from various events, including the eruption of Mount St. Helens, the Chernobyl nuclear accident, the Kuwaiti oil fires during the Persian Gulf War and Washington wildfires.

gas emissions and develop strategies to mitigate the impacts of climate change.

BUILDING BETTER MODELS

PNNL's collaborative and integrated approach is facilitated by the broad range of scientific expertise in multiple disciplines all residing within the same organization. In fact, PNNL researchers pioneered the concept of integrating measurement with models, bringing together laboratory experiments and field observations into models to get the maximum value of both.

Researchers are developing and improving predictive climate models that build on their understanding of the underlying atmospheric processes and their interactions with the water cycle, land surface and human decisions. At the regional level, they are looking at short-term and long-term timelines to better understand the impacts of climate change, such as predicting how the Northwest's snowpack and watersheds will be affected over time. Some projects focus on defining very detailed processes that are part of larger models to significantly improve their accuracy.

More than 20 years ago, researchers at PNNL developed the first computational model that used an integrated energy-economic framework to estimate future greenhouse gas emissions. The Global Change Assessment Model divides the world into 32 regions and looks at five-year time steps to examine long-term changes in the interrelated energy, agriculture and land use, and climate systems. Today, it is available to scientists and policy makers around the world.

PNNL also contributed to the Community Earth System Model, which is used by numerous international climate assessments; the Accelerated Climate Model for Energy, a new climate model designed to take advantage of next-generation DOE supercomputers; and the Weather Research and Forecasting model, which can simulate local to global atmospheric processes.

A COMPUTING CHALLENGE

Understanding climate change and atmospheric science requires scientists to look at these challenges from the molecular level to the global scale, generating and analyzing tremendous amounts of data. DOE's investments in high-performance computing have been critical to advancing this research. New mathematics, innovative algorithms, more sophisticated testing and more complex modeling will bring increasing levels of accuracy.

COLLECTING CLIMATE DATA

DOE's Atmospheric Radiation Measurement (ARM) Climate Research Facility allows researchers around the world to study the interactions among clouds, aerosol particles and energy feedback processes in the atmosphere by providing access to cutting-edge instrumentation that gathers massive amounts of climate data. PNNL provides the technical direction and operations oversight of ARM, along with contributions from eight other DOE national laboratories.

Through ARM, instruments and

PNNL researchers are conducting tests on research buoys being deployed to better predict the potential of offshore wind for producing power. These and other fundamental studies being led by PNNL support DOE's goal to make wind energy fully cost-competitive with other energy technologies. In the 1980s, PNNL created the first national wind atlas that mapped the wind energy resource for the U.S., which built upon its expertise in conducting atmospheric studies in complex terrain.

equipment at three primary locations representing a range of climate conditions are used by scientists to obtain long-term measurements to characterize how atmospheric properties evolve and to evaluate models under different meteorological conditions. Archived data from a fourth location and field campaigns from around the world are freely available to researchers as well.

A research aircraft owned by Battelle and operated by PNNL is used to conduct ARM campaigns for studying clouds and aerosols and linking aerial measurements with ground-based instruments.

INFORMING DECISIONS

A group of PNNL researchers also are part of the Joint Global Change Research Institute (JGCRI), an organization formed in collaboration with the University of Maryland in 2001 to investigate the scientific, technological, economic research questions raised by different strategies to deal with the causes and consequences of global change. The institute has provided input to the White House, Congress, the United Nations and national and international advisory bodies.

LEADING THE FUTURE

More than 20 PNNL scientists have contributed to the global efforts of the Intergovernmental Panel on Climate Change, which was recognized in 2007 with the Nobel Peace Prize along with former Vice President Al Gore. Since the IPCC was created in 1988, PNNL's scientific leadership has helped shape all five of the organization's assessments of the impacts associated with climate change and the technological, institutional and policy options available to mitigate and adapt to it.

By collaborating with other national laboratories and universities, PNNL tackles even larger problems and helps others in their research. The Atmospheric Measurements Laboratory at PNNL allows teams of collaborators to access a specialized facility and partner with senior scientists to seek answers to some of the most important questions in atmospheric chemistry and understand how atmospheric particles form clouds.

"PNNL has the people—from leadership in senior scientists to early career scientists with fresh ideas and innovations—that allow us to make significant contributions in this field," said Allison Campbell, acting associate laboratory director for PNNL's Earth and Biological Systems Directorate. "Our science is grounded in the past, but we are leading the future of understanding and solving environmental and climate challenges that face this nation and the world."

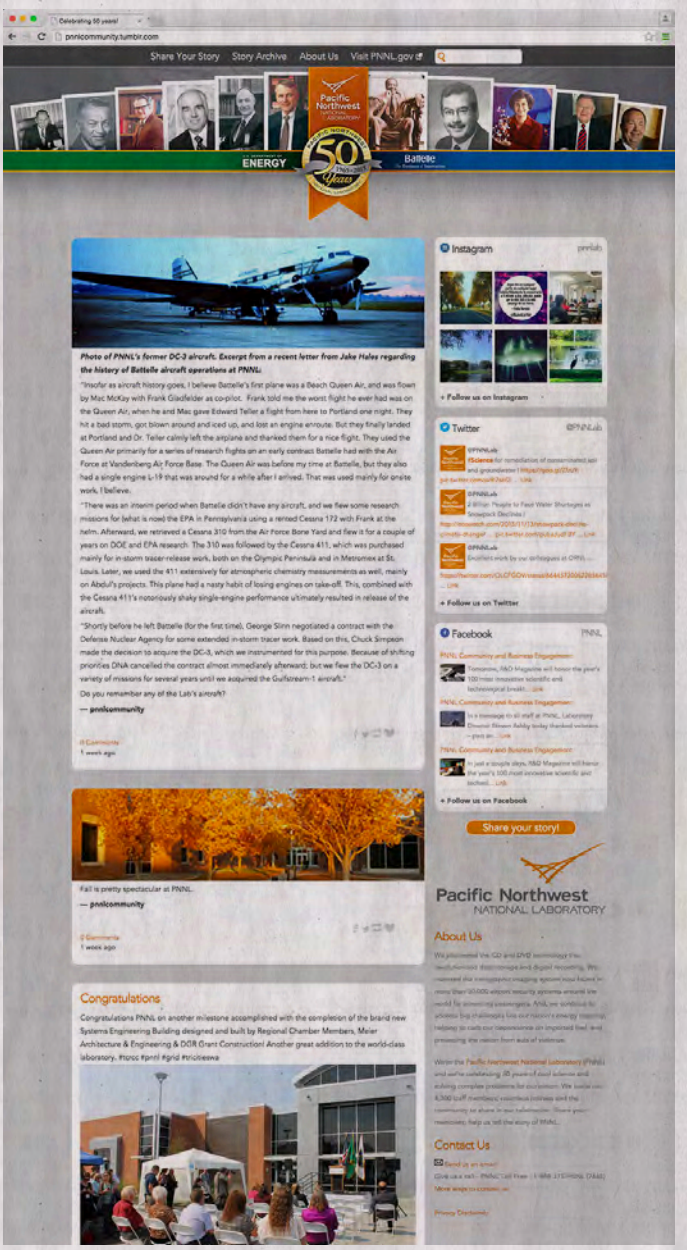
PNNL offers a state-of-the-art Aerosol Test Chamber located in the Atmospheric Measurements Laboratory to study the aerosol lifecycle. The glow, generated by ultraviolet lights, simulates the sun. Data derived from experiments using the chamber will be used for model validation and incorporated into climate models developed by PNNL.

LEARN MORE

about PNNL's continued legacy of scientific discovery

Additional stories, remembrances, anecdotes, celebrations, and photographs—all contributed by current and past employees, retirees, and the local community—are featured on our commemorative PNNL 50th Anniversary website:

http://celebrate.pnnl.gov



Video interviews from some of PNNL's top science and technology experts are featured in a new online, interactive brochure highlighting the impactful work that makes us DOE's premier chemistry, environmental sciences and data analytics laboratory:

http://www.pnnl.gov/discoveryinaction

TIMELINE

A chronological snapshot of PNNL milestones and research highlights from the past 50 years.

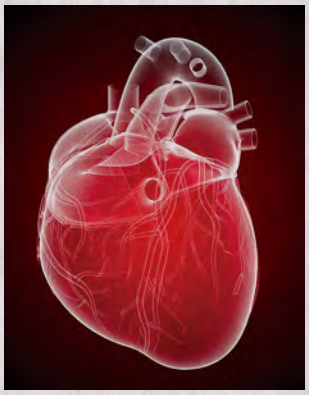
1960s

Foundation for the Future

1965
Battelle begins operation of Pacific Northwest Laboratory

1967
Researchers invent basic technologies that form the foundation of holography

1969



▲ Scientists investigate the requirements for successful artificial heart implantations

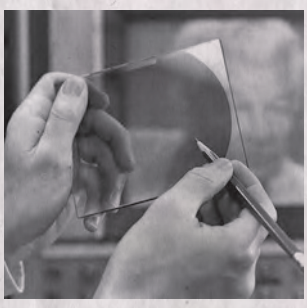
1969
PNL earns first IR 100 Award (now R&D 100 Award) for the Acoustic Emission tester

1970s

Building on Success

1970
PNL acoustic holography technique provides live images from inside the human body

1974



▲ Optical digital recording discovery supplies critical design element for compact discs and players

1974
PNL's Marine Research Laboratory (now Marine Sciences Laboratory) opens in Sequim, Wash.

1977
New PNL technology incorporates radioactive waste in glass for permanent disposal

1978
Researchers develop materials that thwart roots and vegetation from invading septic tanks, roadways and other infrastructure

1980s

Innovations for the Nation

1980

▲ Researchers collect and analyze Mount St. Helens ash to determine potential environmental and health hazards

1980
PNL innovation turns sewage sludge into synthetic asphalt

1983

▲ Portable Blood Irradiator invention shows promise in suppressing early rejection of organ and tissue transplants

1987
Researchers design processes to convert agricultural wastes into a cattle feed supplement, and food processing wastes into methane fuel

1989
Engineers develop holographic imaging system that rapidly identifies hidden weapons, explosives and other contraband ▼

1990s

Expanding Horizons, Exciting Solutions

1990
Radiochemists discover process for extracting highly pure yttrium-90 from nuclear waste for cancer treatment

1991

▲ PNL designs early-stage portable acoustic inspection devices to identify security threats

1995
PNL officially becomes Pacific Northwest National Laboratory

1997

▲ William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) at PNNL opens

1997
Researchers develop visualization software products that extract useful information from massive amounts of data

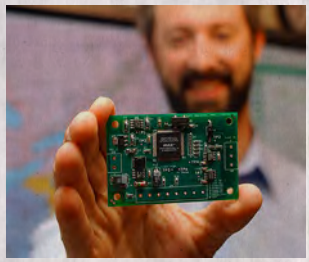
1999
Novel PNNL climate model analyzes global warming's potential regional impacts

2000s

21st Century Discovery

2000
PNNL leads core technology component of the Solid State Energy Conversion Alliance's low-cost solid oxide fuel cell development

2000



▲ Prototype Grid-Friendly™ Appliance Controller chip enables home appliances to communicate with the power grid and adjust their electricity use

2004
The Department of Homeland Security selects PNNL to lead the National Visual Analytics Center™

2007

▲ Technology combines an electrically charged gas with a specialized catalyst to reduce diesel emissions; used in Dodge Ram and VW Jetta TDI

2007

▲ Work begins on pilot-scale pretreatment processes, which support the Hanford Waste Treatment and Immobilization Plant

2008
PNNL's largest construction project commences, resulting in new research facilities for biological and computational sciences and nuclear research.

2010s

The Quest Continues

2011

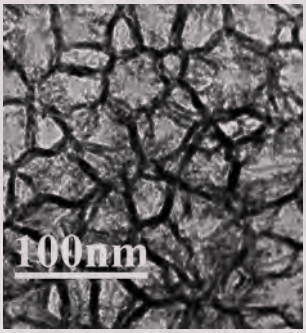
▲ Archer Daniels Midland Company operates new processing facility that uses a PNNL innovation to convert plant-derived materials to a commodity chemical

2011
PNNL detection technology provides technical readings to Japan decision-makers after Fukushima nuclear accident, and detects the first signs of nuclear fallout in U.S. atmosphere

2012

▲ PNNL creates Advanced Carbon Dioxide Removal Unit to capture CO_2 inside submarines, creating a healthier environment for crews

2014



▲ A silicon nanomaterial innovation enhances energy storage and could lead to better batteries with longer life

2015
Major DOE five-year regional grid demonstration project successfully concludes; Battelle-led effort tested PNNL's transactive control concept

50 Years of Discovery in Action

Become a member of our growing virtual community—find us online at **www.pnnl.gov** or through any of the following social media services:

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

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Owned by the U.S. Department of Energy; operated by Battelle; and supported by academic, industrial and governmental collaborators, Pacific Northwest National Laboratory inspires and enables the world to live prosperously, safely and securely. Interdisciplinary teams at PNNL address many of America's most pressing issues in energy, the environment and national security through advances in basic and applied science. With an annual budget of about $1 billion and nearly 4,300 staff members, Battelle is the largest employer in the Tri-Cities region of Washington state.