Pacific Northwest
NATIONAL LABORATORY

DISCOVER

ADVANCED NONDESTRUCTIVE EXAMINATION RESEARCH

Leading the Way in Advanced Evaluation and Integrity Assurance of Materials

U.S. DEPARTMENT of ENERGY

PNNL NDE experts apply ultrasonic array testing methods to a wide range of components, enabling the analysis of dense materials manufactured through additive processes.

Photo by Andrea Starr | Pacific Northwest National Laboratory

NEXT-GENERATION NONDESTRUCTIVE EXAMINATION

At Pacific Northwest National Laboratory (PNNL), we specialize in nondestructive examination (NDE) research which is a critical tool used to evaluate the integrity of materials, structures, and components. NDE ensures that these assessments do not damage or compromise an object's ability to perform its designated function.

NDE research provides valuable insights into material systems throughout their lifecycle, including during manufacturing, post-fabrication, and in situ operation. NDEs conducted by PNNL offer a comprehensive understanding of material conditions and the degradation state of components. This information is crucial for extending the useful life of components and guiding mitigation, repair, or replacement decisions in the energy, infrastructure, and national security sectors.

Front cover. *Photo by Andrea Starr | Pacific Northwest National Laboratory*

PNNL utilizes electromagnetic acoustic transducers (EMAT) to evaluate defects and inconsistencies in metal tank components. This technology is instrumental in detecting, characterizing, and monitoring materials to aid in the management of aging reactors and nuclear waste tanks.

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MISSION APPLICATION AREAS

NUCLEAR ENERGY

PNNL has a longstanding history developing and evaluating both conventional and advanced NDE techniques for inspecting nuclear power plant components and cables in light water reactors and emerging advanced reactor systems. Our applications focus on detecting, characterizing, and monitoring components and materials to support the management of aging reactors. We develop advanced sensor systems capable of operating at high temperatures and in harsh radiation and corrosive environments, applying frontline modeling, simulation, and data analytics to enhance defect detection. Recently, PNNL has been active in advancing the next generation of NDE tools to qualify and monitor the integrity of materials and components fabricated using innovative manufacturing technologies for next-generation reactor systems. NDE is integral to PNNL's multidisciplinary program supporting the development and deployment of advanced materials and manufacturing processes in the nuclear industry.

ENVIRONMENTAL MANAGEMENT

PNNL is at the forefront of NDE efforts vital for the environmental management mission within the Department of Energy complex. As aging nuclear waste storage and processing infrastructure, such as tanks and pipelines, push beyond their originally designed lifespan, issues like corrosion and erosion threaten leak integrity. PNNL's Double-Shell Tank Volumetric Inspection Technology and Life Extension program addresses these challenges by developing and deploying advanced robotic NDE systems. These NDE technologies, paired with artificial intelligence (AI) and *in situ* repair solutions, are crucial to identifying and mitigating potential flaws, extending service life, and supporting the Hanford waste processing mission timeline. By ensuring the integrity of mission-critical infrastructure, PNNL helps maintain waste treatment schedules, manage mission costs, and minimize the risk of potential leaks.

TRANSPORTATION

NDE experts at PNNL conduct significant research on NDE technologies that can be applied to the rail, automotive, and aerospace transportation sectors. These areas focus on improving safety, reliability, and efficiency of transportation systems, extending the life of components and reducing maintenance costs. In rail transportation, we use ultrasonic, magnetic particle, and thermographic inspections to detect track defects, while acoustic emission testing and vibration analysis ensure rolling stock integrity. Techniques, such as computed tomography and digital image correlation, aid in material characterization of automotive transportation and Eddy Current testing and laser ultrasonics detect surface flaws.

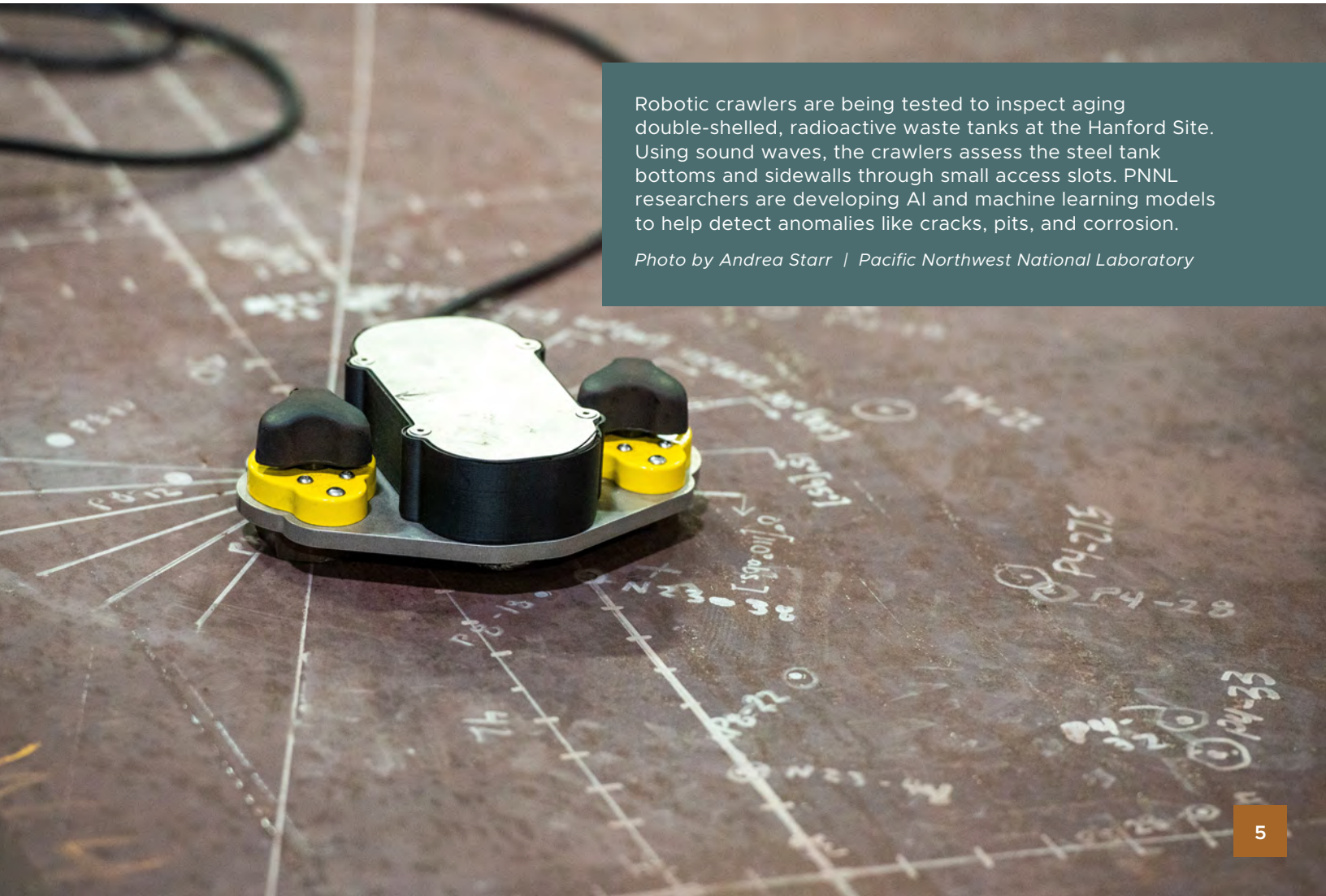
PNNL's development of advanced sensors and data analytics boosts NDE accuracy and features real-time monitoring systems and data fusion to conduct informed maintenance. Our work champions infrastructure integrity and safety to advance the future of the transportation industry.

NATIONAL SECURITY

PNNL supports national security missions in the areas of modern manufacturing, the qualification of strategic materials, and developing stand-off noninvasive methods to uniquely identify components for treaty verification. From 3-D imaging cracks within semiconductor materials made with advanced manufacturing technologies, to monitoring liquid levels in highly corrosive mixing cells and using ultrasound methods to verify unique identification signatures in secure components, PNNL has employed our experience with NDE methods to develop solutions to important national security challenges.

ADVANCED MANUFACTURING

Advanced materials systems and component structural designs challenge conventional NDE. Our researchers are locating new areas to understand and monitor components as they are fabricated using advanced manufacturing techniques. We are investigating the examinability of novel additive manufacturing materials for flaw and defect detection. In addition, we are creating robust sensing technology that can be attached to components and are capable of withstanding the extreme environments of a nuclear reactor to monitor material changes during longer periods of use without down time.



Robotic crawlers are being tested to inspect aging double-shelled, radioactive waste tanks at the Hanford Site. Using sound waves, the crawlers assess the steel tank bottoms and sidewalls through small access slots. PNNL researchers are developing AI and machine learning models to help detect anomalies like cracks, pits, and corrosion.

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CAPABILITIES

- Conventional and phased-array ultrasonics
- Advanced phased-array ultrasonics (full matrix capture, plane wave imaging, etc.)
- Linear and nonlinear ultrasonic techniques
- Laser ultrasonics
- Acoustic microscopy
- Electromagnetic methods (EMAT ultrasonics, eddy current, etc.)
- Time and frequency domain reflectometry
- Digital radiography and X-ray computed tomography with multiple X-ray sources (up to 450 kVp)
- Resonant ultrasound spectroscopy
- Infrared thermography
- Penetrant testing
- Computational modeling of physical processes on inspection signals
- Dielectric spectroscopy
- AI and automated data analysis
- Cable aging and integrity in the ARENA cable/motor test bed
- Radioactive materials inspection

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Photo by Andrea Starr | Pacific Northwest National Laboratory

In pursuit of innovative approaches to evaluate cable integrity, PNNL has developed a novel clam shell coupler device capable of identifying inconsistencies across different cable types.

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NDE EXPERTISE

PNNL's NDE experts are leaders in innovative research and development, bringing extensive experience across the nuclear, waste management, transportation, defense, and aerospace industries. Leveraging advanced examination facilities, leading-edge instruments, probes, sensors, and AI/machine learning models, the team is equipped to push the boundaries of nondestructive evaluation. Their work is further enriched by a collection of materials and components from vintage nuclear power plants, combined with advanced multiphysics-based modeling and simulation capabilities.

Comprising specialists from diverse PNNL mission areas, the NDE team takes a holistic approach to solving complex challenges. This multidisciplinary expertise drives the creation of novel, tailored solutions, ensuring PNNL remains at the forefront of the NDE field.

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NDE experts at PNNL utilize an advanced acoustic microscope to examine metal and other materials. Acoustic microscopy is a nondestructive technique that uses high-frequency sound waves to visualize the internal structure of materials at a microscopic level.

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