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Real Time Cyber-Physical Digital Twin Facility

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Purdue Consortium Supports Nuclear Infrastructure Revitalization, Workforce Development

By Paul Menser

A consortium funded through the U.S. Department of Energy's Nuclear Energy University Program (NEUP), DE-NE-0009525, has begun implementing a $6 million grant aimed at boosting advanced reactor R&D while building a workforce for the future.

Based at Purdue University's School of Nuclear Engineering, the consortium includes three universities, one community college network, three national laboratories and nine industry partners.

"This is a very important step [the] DOE-NEUP is taking," said Seungjin Kim, Purdue's Capt. James F. McCarthy, Jr. and Cheryl E. McCarthy Head and Professor of the School of Nuclear Engineering. "One thing other countries can't match is the United States' nuclear education and research infrastructure. I believe the U.S. is in the lead, but we need to do more to keep that lead."

Multi-faceted Approach

Kim first learned of the DOE funding opportunity in 2023. He said he felt a multi-faceted approach would be the best way to win the grant. For the educational component, he looked beyond advanced nuclear research to include training in skilled trades such as welding and pipefitting. This is why in addition to Purdue, MIT and North Carolina State University, the consortium also includes Ivy Tech

Community College, an Indiana-based network of community colleges with more than 40 locations.

> “Ivy Tech’s emphasis is workforce development in the skilled trades, which will be essential for the deployment of small modular reactors and advanced reactors,” he said.

The consortium includes researchers from three national laboratories: Idaho, Argonne and Brookhaven. Working in an advisory capacity, nine industrial partners signed on, including BWX Technologies, Constellation, Curtiss-Wright, Duke Energy, Framatome, GE-Hitachi, Sargent & Lundy, Westinghouse Electric Corp, and Oak Ridge Associated Universities, a nonprofit corporation that manages the Oak Ridge Institute for Science and Education.

Summer Camps

Leveraging the success of the already existing “Atoms at Work” summer camp for high school students led by the School of Nuclear Engineering, a three-day pilot workshop for high school teachers launched in summer 2025 at Purdue campus in West Lafayette, Ind. Through a series of lectures, hands-on lab activities, and facility tours, the teachers explored fundamental concepts of nuclear energy and identified practical ways to integrate them into their high school courses. This summer, the program will include participation from the DOE and industry partners to further emphasize nuclear education perspectives and career pathways in the nuclear field. Meanwhile, a summer workshop on advanced reactors, including small modular reactors (SMRs), is being planned at North Carolina State for university faculty and industry professionals. Another workshop in summer 2027 is planned for MIT, and the summer 2028 workshop is planned for Purdue.

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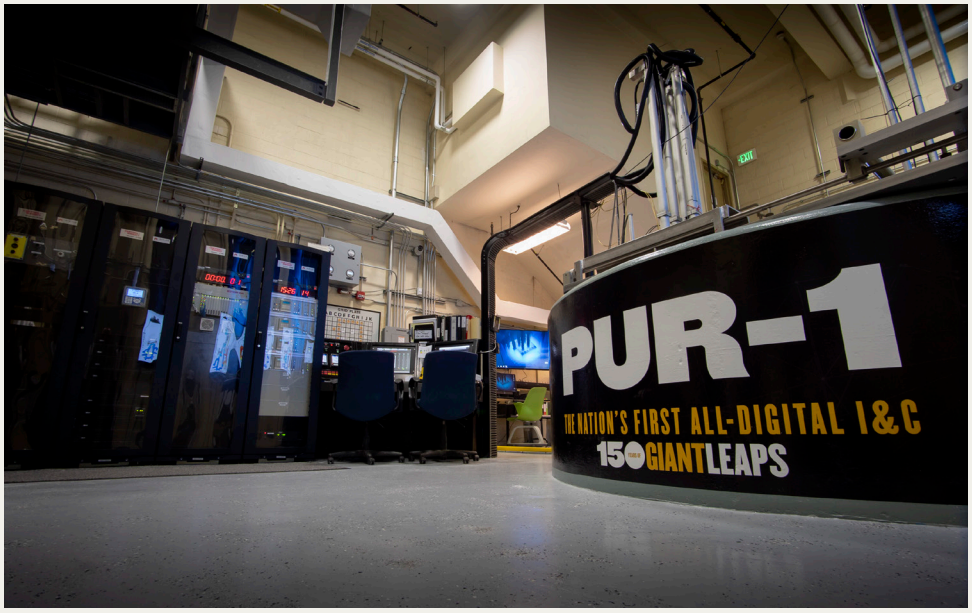
Purdue University Multi-dimensional integral Test Assembly (PUMA)

Upgrades to Key Learning Assets

By the end of this project in 2028, two of Purdue's unique assets, the Purdue University Reactor No. 1 (PUR-1) built in 1962, and Purdue University Multi-dimensional integral test Assembly (PUMA) built in 1996, will be upgraded. PUMA is the only existing scaled integral test facility for advanced light-water reactor designs. It is being refurbished with a full-scale reactor control room and balance-of-plant systems featuring digital twin capabilities that will enable predictive maintenance, optimized operations, and risk-free testing in a virtual environment.

PUR-1 is the first and only university reactor licensed by the U.S. Nuclear Regulatory Commission (NRC) for a fully digital instrumentation and control system. It is being enhanced with high-fidelity, two-way transmission control protocol/internet protocol (TCP/IP) communications. The digital replica of the physical reactor systems will facilitate simulations and analyses to further enhance research toward small modular and advanced reactor technologies.

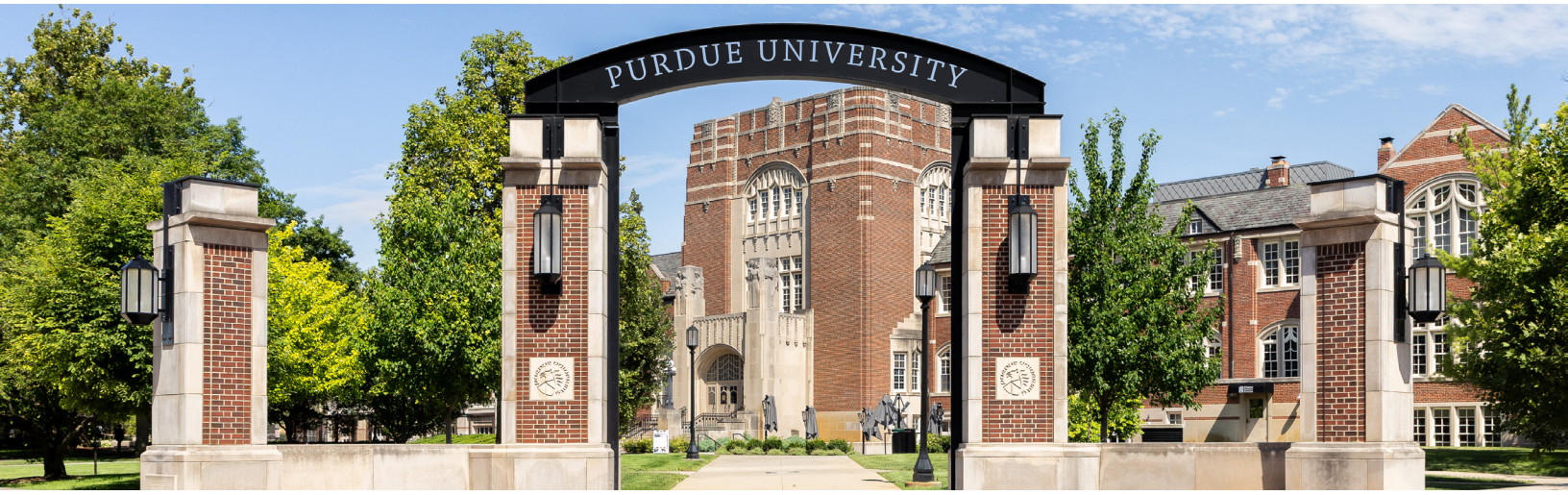


Purdue University Reactor No. 1

PUR-1 is the first and only university reactor licensed by the U.S. Nuclear Regulatory Commission (NRC) for a fully digital instrumentation and control system

These facilities will serve as valuable physical and cyber testbeds for research on Small Modular Reactors and Advanced Reactor technologies, including experimental simulation of a wide range of operational scenarios, remote monitoring, cyber security, human factors, as well as educational and training platforms for future nuclear energy workforce.

Complementary upgrades are planned at MIT and North Carolina State, enabling the sharing of unique equipment and instrumentation for studies of advanced nuclear technology concepts. When established, Kim said, the new and upgraded infrastructure will provide the broader nuclear engineering community with a test bed for cyber-physical research involving quantum-based cybersecurity, semiautonomous control, diagnostics, and sensor placement. The modernized facilities will have a long-term impact to the community, not only by enabling workforce development and enhancing student education and training, but also by supporting other university SMR programs, engaging researchers from national laboratories for research reactor developments, and motivating high school students through hands-on activities.



Infrastructure Revitalization

As the nation looks toward new SMRs and other advanced reactor designs, there is still a lot of underutilized nuclear infrastructure that can be modified or adapted for good use, Kim said. PUMA is one example. PUMA is a scaled intergral test facility, established with the funding provided by the U.S. NRC, to perform third-party confirmatory tests for the GE designed 600-megawatt Simplified Boiling Water Reactor. It has performed various tasks successfully, but has mostly remained inactive since that work was completed.

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"We recognize the importance of this facility," Kim said. "Very often, a facility might be idled after a project is finished. DOE recognized the missed opportunities." Under the NEUP grant, Purdue is adding a turbine and generator to simulate Balance of Plant, as well as an energy storage system to further enhance the facility's testing capabilities including the potential option of load-following for SMRs. With digital instrumentation and control systems, he expects to expand its capabilities to simulate any light water based SMRs.

Kim expects a ready supply of students eager to learn all aspects of the new technology. "Young people at the high school level are interested in learning more about nuclear energy and what it is capable of. They are also interested to learn about career opportunities in nuclear industry not only for nuclear engineers but for skilled trades," he said.

This consortium is building up the nuclear energy workforce, advancing research, and involving the community and next-generation. This effort is not only working toward the office of nuclear energy's mission, but advancing the nuclear energy future.

NEUP Nuclear Energy University Program

U.S. Department of Energy