INL's Dr. Isabella Van Rooyen holds the Additive Manufacturing as an Alternative Fabrication Technique (AMAFT) unit, developed to streamline the production of uranium silicide fuel pellets.

Advanced Materials and Manufacturing at INL

Nuclear reactors provide approximately 20% of U.S. electricity and more than half of the nation's low-carbon electricity. But growing demand for power, coupled with the economic challenges of maintaining aging nuclear plants has led to a push to develop a new generation of reactors. The new reactors being designed will be smaller, inherently safe and more cost-effective to operate.

Idaho National Laboratory (INL) is addressing the technical challenges of these advanced reactor technologies by creating a new generation of materials that can withstand extreme conditions while maintaining performance and safety. Accelerated nuclear materials discovery and qualification is one of the grand challenges of the Nuclear Science and Technology directorate at INL. These materials fall into three categories:

ACCIDENT-TOLERANT FUELS: The demands are high for the next generation of reactor fuels. They must meet performance needs while displaying exceptional accident tolerance. One potential fuel being evaluated by the industry is tri-structural isotropic particle fuel (TRISO), which encapsulates particles of uranium in materials that contain fission products and can maintain stability up to 1,800° C.

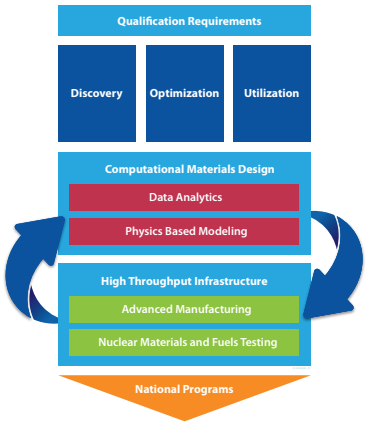
CLADDINGS: Many next-generation reactor designs use corrosive coolants such as sodium, calling for new cladding materials that remain stable in high temperatures under intense pressure. These include advanced alloys of materials such as ferritic steel.

REACTOR PRESSURE VESSELS: Just as important as the other reactor components is the reactor pressure vessel that houses the core. Decades of exposure to intense heat and radiation can lead to a variety of mechanical compromises. New steels are needed to provide the desired longevity to fully realize the potential of advanced reactors.

Historically, the qualification process for these materials has been a challenge, taking up to 30 years to establish long-term performance and safety. To address that challenge, the Department of Energy's Office of Nuclear Energy has established the Nuclear Materials Discovery and Qualification Initiative (NMDQi), with INL taking a leadership role. NMDQi is tackling the challenge with a streamlined approach that allows three key steps to be addressed in a serial fashion to reduce qualification time.

Idaho National Laboratory

NMDQi's approach to streamlining nuclear materials discovery and qualification.



1. **Modeling:** The Multiphysics Object-Oriented Simulation Environment (MOOSE) is a modeling framework developed by INL to predict the behavior of complex systems such as the inside of a reactor. Various MOOSE-based codes allow researchers to simulate the effects of high temperature, pressure and irradiation on fuel systems and other reactor materials.
2. **Fabrication:** Modeling is used to identify promising materials and designs, which can then be fabricated for testing. Recent advances in manufacturing technologies allow researchers to develop multiple promising candidates. Additive manufacturing techniques are then used to rapidly 3D print large numbers of materials samples, including fuel, to be tested simultaneously.
3. **Rapid Testing:** Even with the most advanced predictive modeling, real-world testing is still needed to verify material behavior. INL uses two test reactors to accomplish this critical step. The Advanced Test Reactor (ATR) provides high neutron flux that can simulate years of normal reactor operations in a matter of months. To establish safety in off-normal conditions such as sudden power increases, the Transient Reactor Test Facility (TREAT) delivers short bursts of intense neutron irradiation to determine safety margins.

NMDQi is partnering with the nuclear community throughout the country to address the technical and regulatory hurdles associated with developing and qualifying these new materials. With the tools and capabilities at INL's disposal, the ultimate goal is to shorten this process to approximately 10 years, reducing costs and bringing new technology to market more quickly to address the need for clean energy.

FOR MORE INFORMATION

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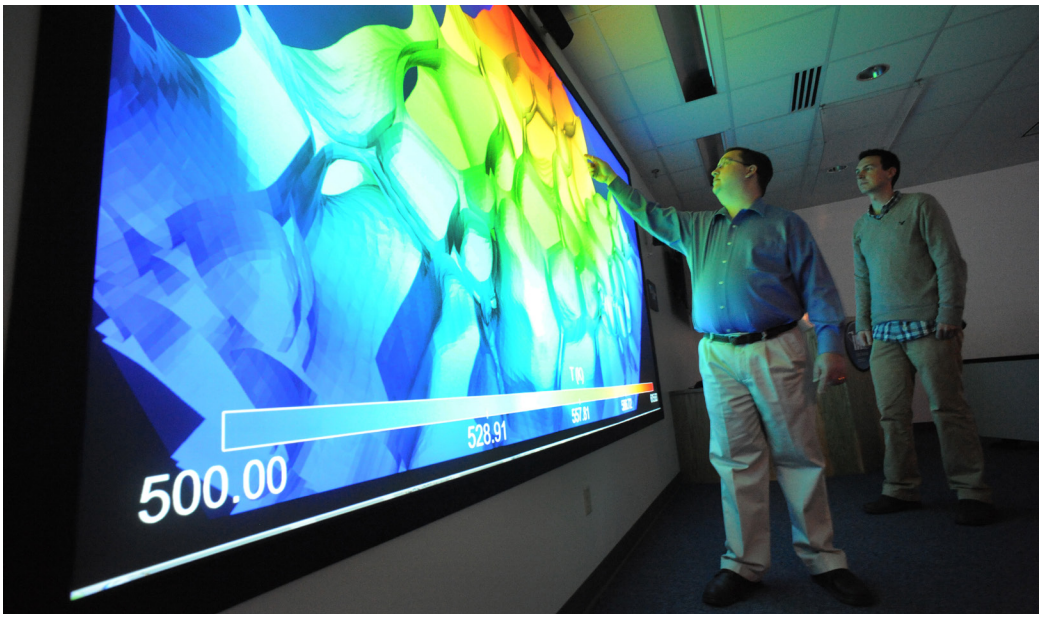

MOOSE-based codes run on INL supercomputers enable researchers to simulate the performance of new materials in nuclear reactors.

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