Transformational Challenge Reactor Demonstration Program

An accelerated, cost-effective approach to nuclear energy system development and deployment

Nuclear energy's approaching cliff

More than half of America's nuclear power plants could retire in the next 20 years, with all current nuclear reactor licenses expiring by 2055. Premature retirements could accelerate this trend, which would ultimately result in a loss of a fifth of the country's electricity supply and nearly 500,000 domestic jobs.[1,2] To replace the country's largest source of carbon-free energy, new reactors are needed; however, industry is constrained by the extreme costs of lengthy design and deployment timelines.

Using scientific innovation to advance nuclear energy

The overarching goal of the Oak Ridge National Laboratory's Transformational Challenge Reactor (TCR) Demonstration Program is to change the deployment costs of new nuclear power generation. To accomplish this, the TCR program will leverage advances in numerous scientific areas—materials, manufacturing, sensors and control systems, data analytics, and high-fidelity modeling and simulation—to accelerate design, manufacturing, qualification, and deployment of advanced nuclear energy systems. Through this innovative approach, the TCR program seeks to:

- integrate digital data for rapid nuclear innovation;
- accelerate the adoption of advances in manufacturing, materials, and computational sciences for nuclear applications; and
- dramatically reduce deployment costs and timelines for new nuclear technologies.

Delivering change through TCR

To achieve a paradigm shift in new nuclear costs, the TCR program will design, build, and operate a microreactor using a rapid advanced manufacturing approach. The program will accelerate innovation by:

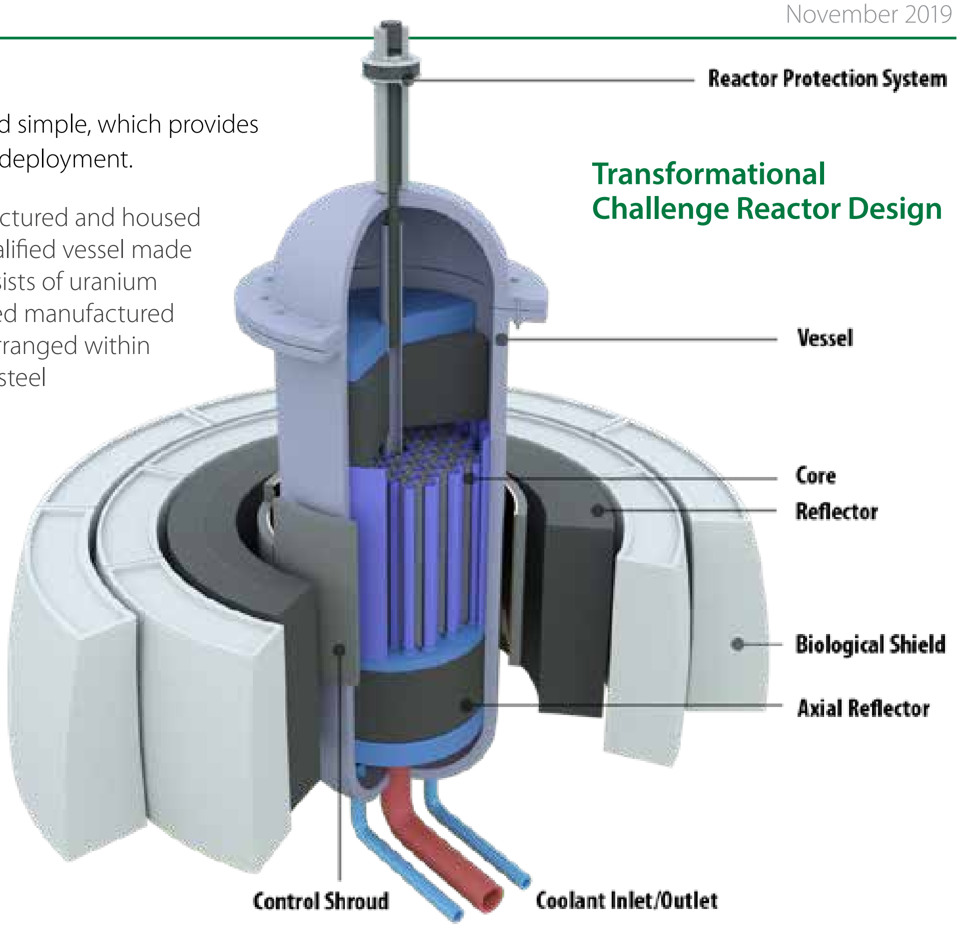
- establishing advanced nuclear energy system designs unconstrained by conventional manufacturing;
- developing processes for the advanced manufacturing of nuclear reactors;
- embedding sensors into key structures to obtain real-time information about their health for enhanced diagnostic and prognostic assessments;
- building a sound process for automated operating procedures to establish a pathway for autonomous operations;
- creating a digital platform by coupling data analytics with design and manufacturing information for rapid quality evaluation of manufactured products;
- demonstrating the value of integrating technology advances through operation of an additively manufactured microreactor; and
- engaging with industry, standards development organizations, and regulatory bodies to enable broad adoption of this new approach.

The demonstration delivers two distinct outcomes:

- a set of technological advancements at the ripe readiness level for adoption by industry.
- reestablishing the credibility of the national complex to undertake and deploy advanced nuclear energy systems at a low cost and reduced timeline.

Reduction in Cost, Schedule & Risk in Nuclear Energy

Design	Manufacturing	Regulatory	Operation
Design constraints relaxed. rapid innovation cycle possible with rapid demonstration.	Flexible, scalable solutions can be deployed because the machine can be rapidly adapted with assurance of consistent quality.	More efficient regulatory approaches because of depth of understanding gained while manufacturing and in use of embedded sensors.	Operational envelopes widened with insights into real-time and predictive performance. Autonomy is achievable.



The overall TCR system layout is innovative and simple, which provides low cost, reliability, safety and ability for rapid deployment.

Core. The TCR core will be advanced manufactured and housed inside a conventionally manufactured and qualified vessel made from grade 304H stainless steel. The core consists of uranium nitride coated fuel particles within an advanced manufactured silicon carbide structure. The fuel blocks are arranged within advanced manufactured grade 316L stainless steel structures and are interspersed with yttrium hydride moderator elements. The hydride moderator minimizes the amount of high-assay low-enriched uranium required to reach criticality.

Controls. The TCR reactor instrumentation and control (I&C) system consists of a reactor protection system interfacing with the central shutdown rod and a reactor control system driving the external control shrouds. Each system is independently capable of shutting down the reactor and keeping it subcritical under all conditions. The I&C architecture is designed with diversity and independence in mind. The control shrouds will move between the reactor vessel and an advanced-manufactured steel reflector. A concrete biological shield will enclose the vessel and reflector and will also be advanced manufactured.

Facility. The reactor system will be housed inside a vented confinement within an Oak Ridge National Laboratory building. Inside the confinement resides a single pressurized helium gas-cooled loop, including the circulator, vessel, and a heat exchanger moving the heat harvested from the core to the outside.

Safety. TCR is an inherently safe nuclear energy system based on proven, physics-based passive safety principles. An assessment of postulated and hypothetical accident scenarios will be performed to show that the system has safety margins that exceed requirements. To further enhance safety and limit the overall system footprint and environmental impact, TCR will operate at a thermal power of 3 megawatts. Safety assessments will be reviewed by the Department of Energy prior to granting authorization to conduct the operational demonstration.

Schedule. To maximize the transformative impact and kickstart a new nuclear era for the nation, adhering to an aggressive schedule of the TCR program is essential. Starting in 2019, the program targets designing, manufacturing, and operating a demonstration reactor by 2023. An agile approach to design, manufacturing, and testing is employed to meet this schedule and to deliver a new paradigm to designing and deploying nuclear systems.

[1] *https://www.nei.org/resources/statistics/us-nuclear-plant-license-information*
[2] *https://www.nei.org/advantages/jobs*

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