OAK RIDGE National Laboratory

Additive Manufacturing–Enabled Agile Design: The Transformational Challenge Reactor

Benjamin R. Betzler, PhD
Senior R&D Staff and Group Leader
Research and Test Reactor Physics

Fifth Symposium on US-Japan Nuclear Energy Research Cooperation

23 November 2021

U.S. DEPARTMENT OF ENERGY

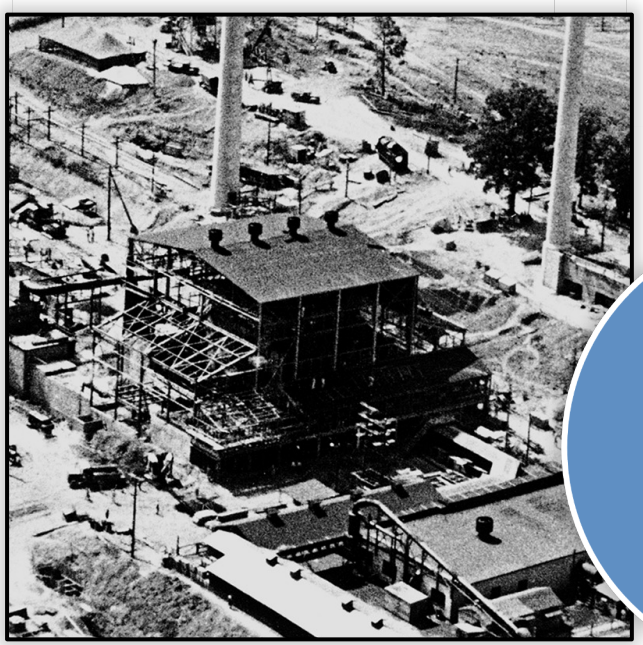
A transformational change in nuclear energy deployment is needed

Break the 40+ year hiatus in building a non-water advanced reactor in the United States

Leverage advances in **manufacturing** and **computational** sciences to deliver advanced nuclear technology at significantly reduced cost

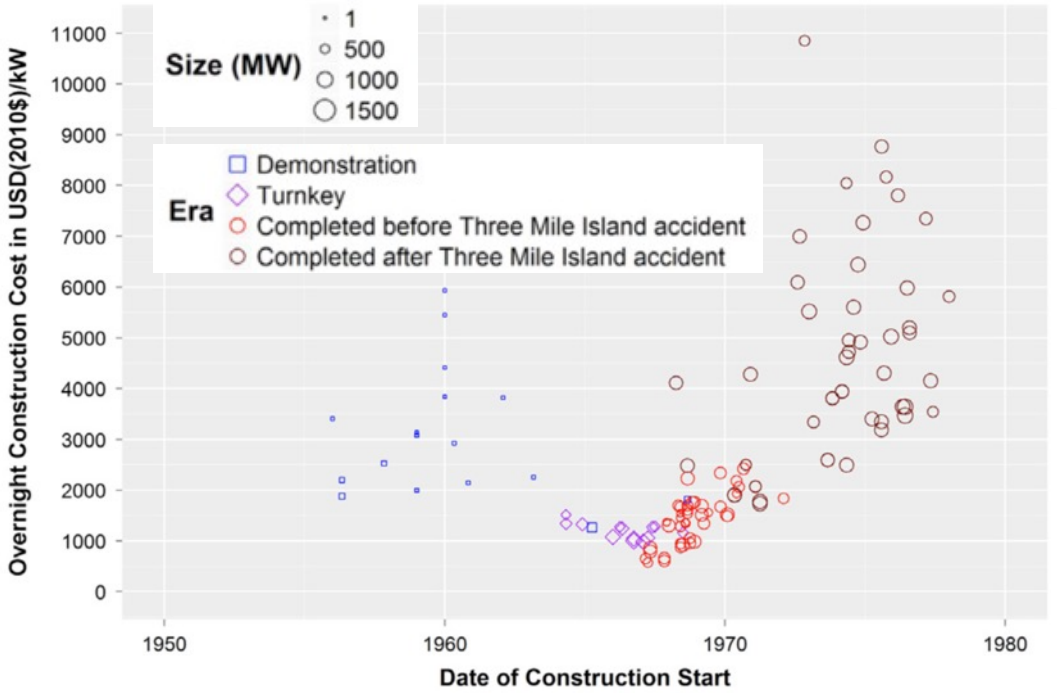
Inform the modern regulatory framework for licensing of advanced reactors

Transfer knowledge base at the right technology readiness level to industrial sector



First continuously operating reactor constructed in 9 months

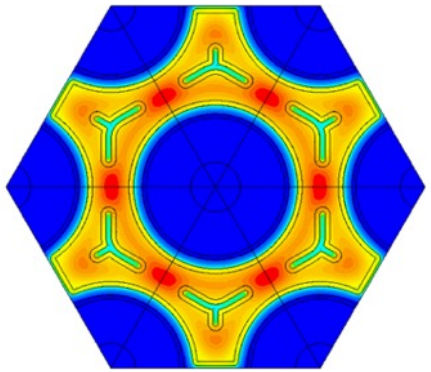
Source: US DOE



J. Lovering et al., *Energy Policy*, **91** (2016) 371.

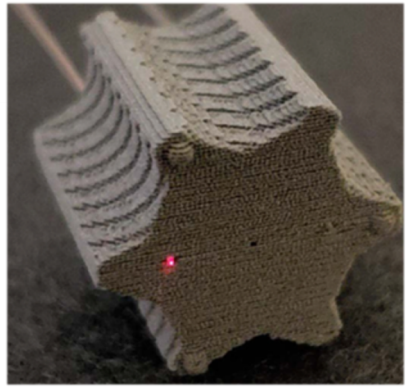
TCR is applying additive manufacturing (AM) and artificial intelligence (AI) to deliver a new approach for nuclear

Using AI to navigate an unconstrained design space and realize superior performance

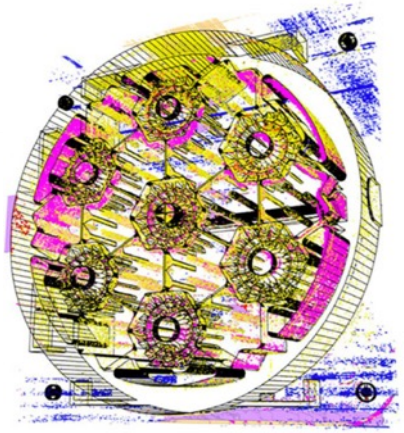


Leveraging AM to arrive at high-performance materials in complex geometries

Exploiting AM to incorporate integrated and distributed sensing in critical locations



Using AI to assess critical component quality through in situ manufacturing signatures

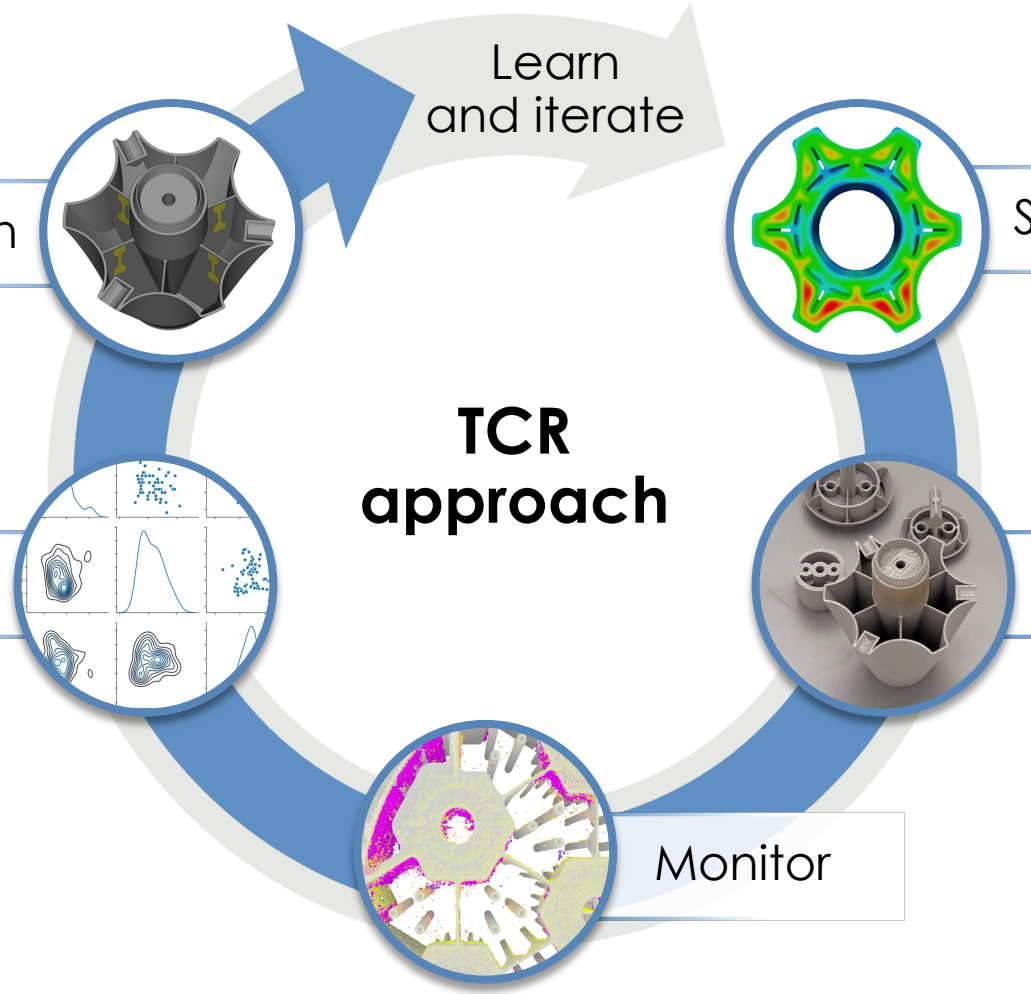


AI-informed design	Advanced materials	Integrated sensing and control	Digital platform

tcr.ornl.gov

The agile design and development approach employed by TCR is intended to accelerate deployment

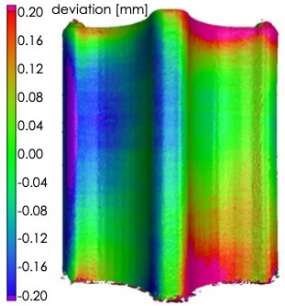
Agile approach breaks with traditional linear development models to exercise an iterative, dynamic development process

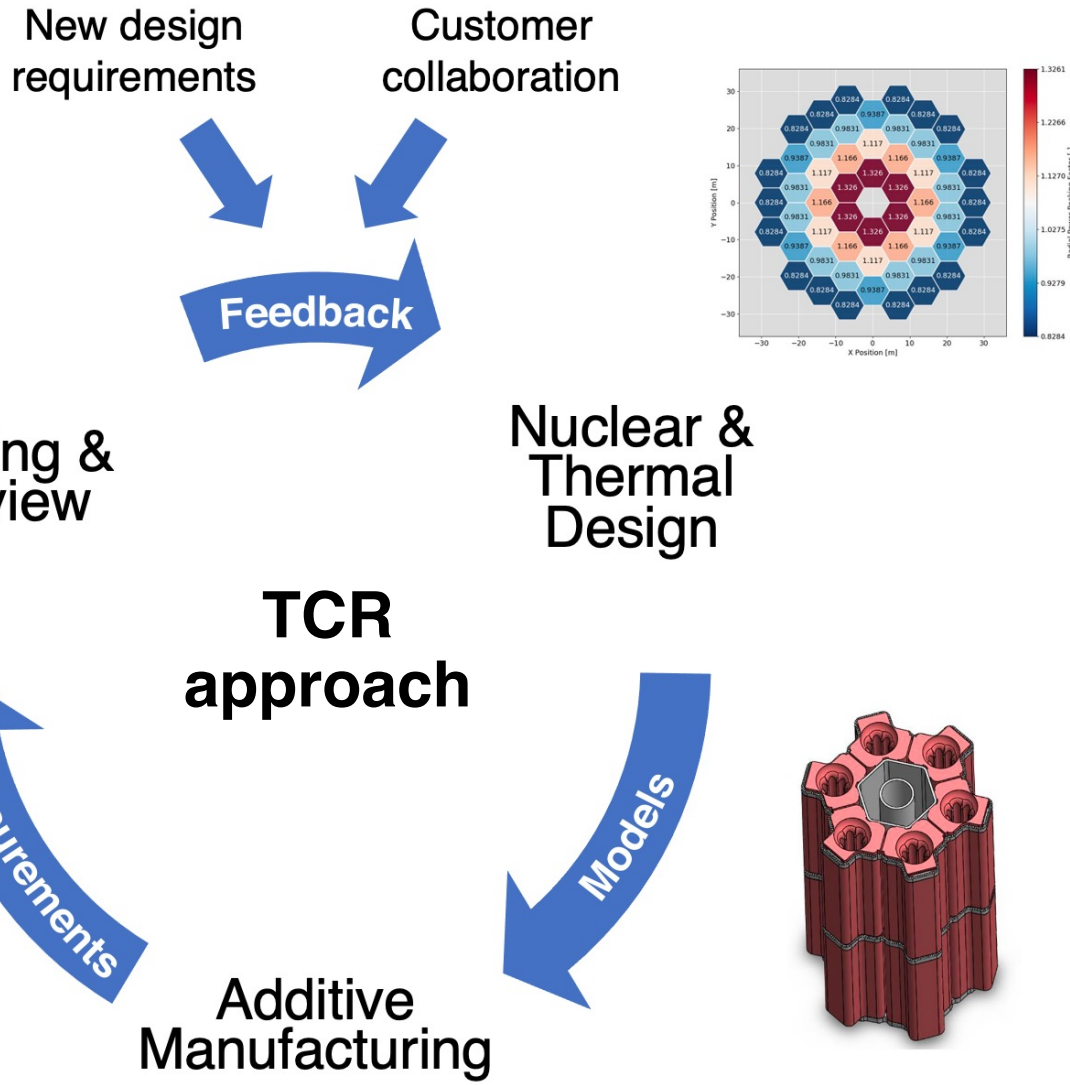


This approach lends itself to complex projects in which a large, multilaboratory, multidisciplinary team works closely to complete a product

The TCR program has applied these practices by starting from scratch and building toward reactor demonstration

- No preselected reactor technology
- Start with simple design requirements and rapidly assess feasibility of technologies to meet the demonstration
- Interdisciplinary design
- Printing prototypes
- Customer collaboration
- Welcoming changing design requirements

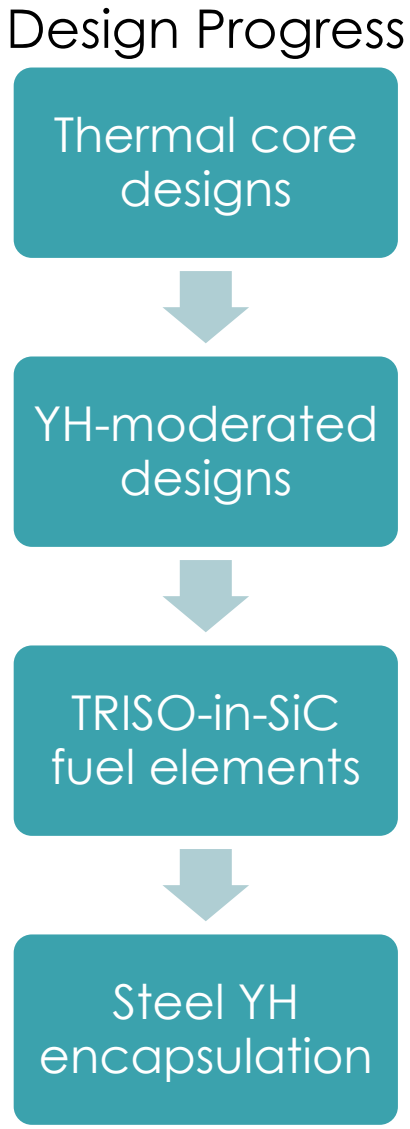




Iterative nuclear design process with AM

Core design down-selection process rapidly progressed

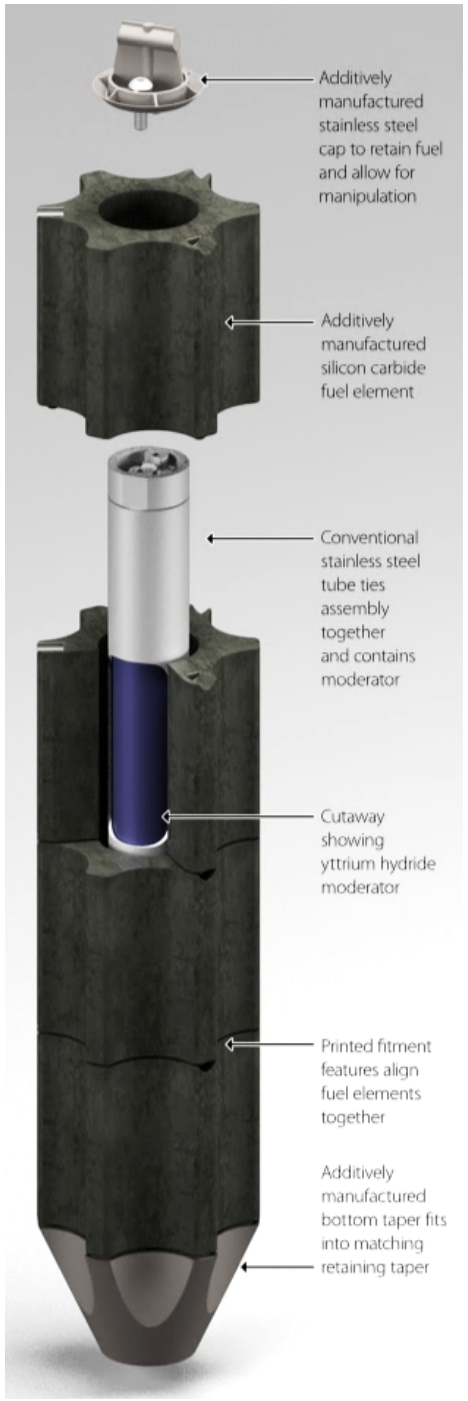
- Initial preconceptual core designs were fast reactors:
  High-assay low-enriched uranium availability limited fuel mass
- Incorporating moderators led to larger core sizes:
  Rapid advancement in YH manufacturing process enabled its selection as a moderator
- Scoping analyses examining maximum temperatures in postulated events favored tristructural isotropic (TRISO) fuel in SiC
  Rapid advancement in TRISO-in-SiC fuel element manufacturing process
- YH moderator must be encapsulated
  Steel encapsulation matured most rapidly



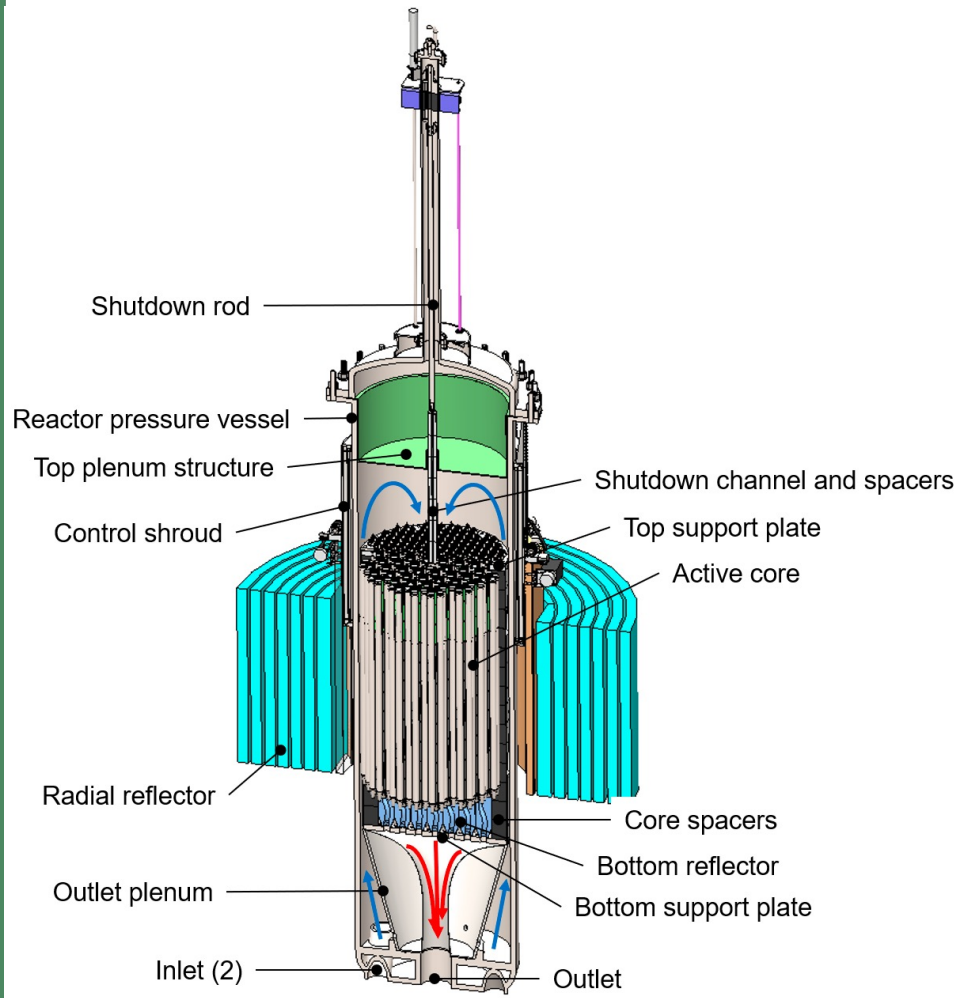
TCR core comprises highly advanced, safe, and robust constituents

- TCR fuel has multiple inherent barriers to radionuclide release and is encapsulated in refractory and oxidation-resistant SiC
- TCR uses the H-bearing moderator with highest known thermal stability
- Additively and conventionally manufactured Grade 316 stainless steel acts as the hydride sheath and provides assembly structure

Fully densified and assembled fuel assembly



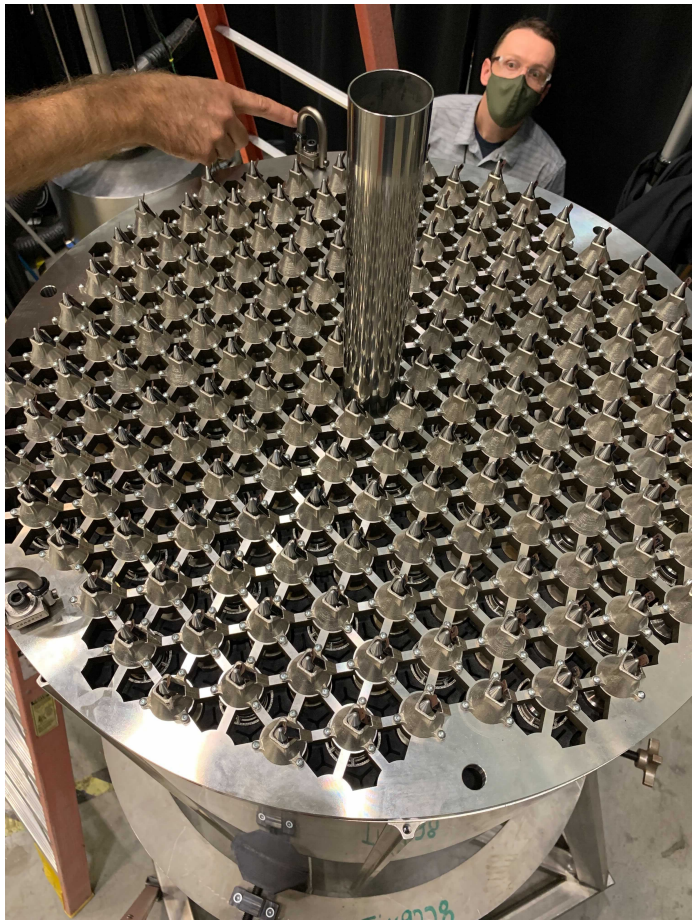
Demonstrated manufacturing, assembly, and handling processes with full-sized core mockup



TCR nuclear island

Full-sized fuel assemblies (surrogate)

Core barrel assembly



Installed top alignment plate

Legacy of the TCR lies in the application of advanced manufacturing technologies to advanced nuclear

- The TCR program is currently focused on transitioning these technology thrusts into the Advanced Materials and Manufacturing Technologies Program
- The TCR program will continue to demonstrate advanced certification approaches for economical applications of novel manufacturing technologies in the nuclear industry
- Continued development of advanced manufacturing technologies will only broaden their applicability in the nuclear reactor industry

Source: Tennessee Valley Authority and Framatome

Source: Kairos Power

tcr.ornl.gov/publications