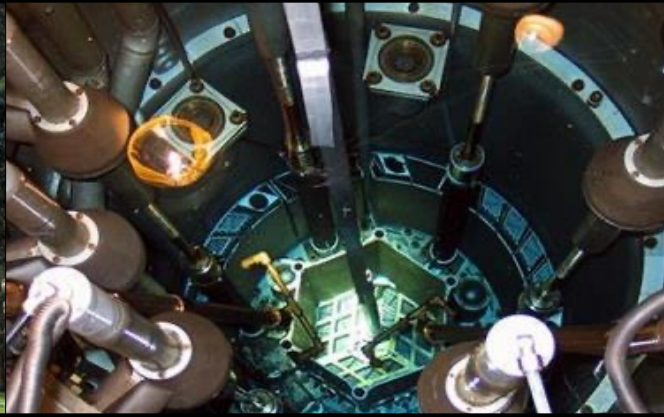


MIT Nuclear Reactor Laboratory

an MIT Interdepartmental Center



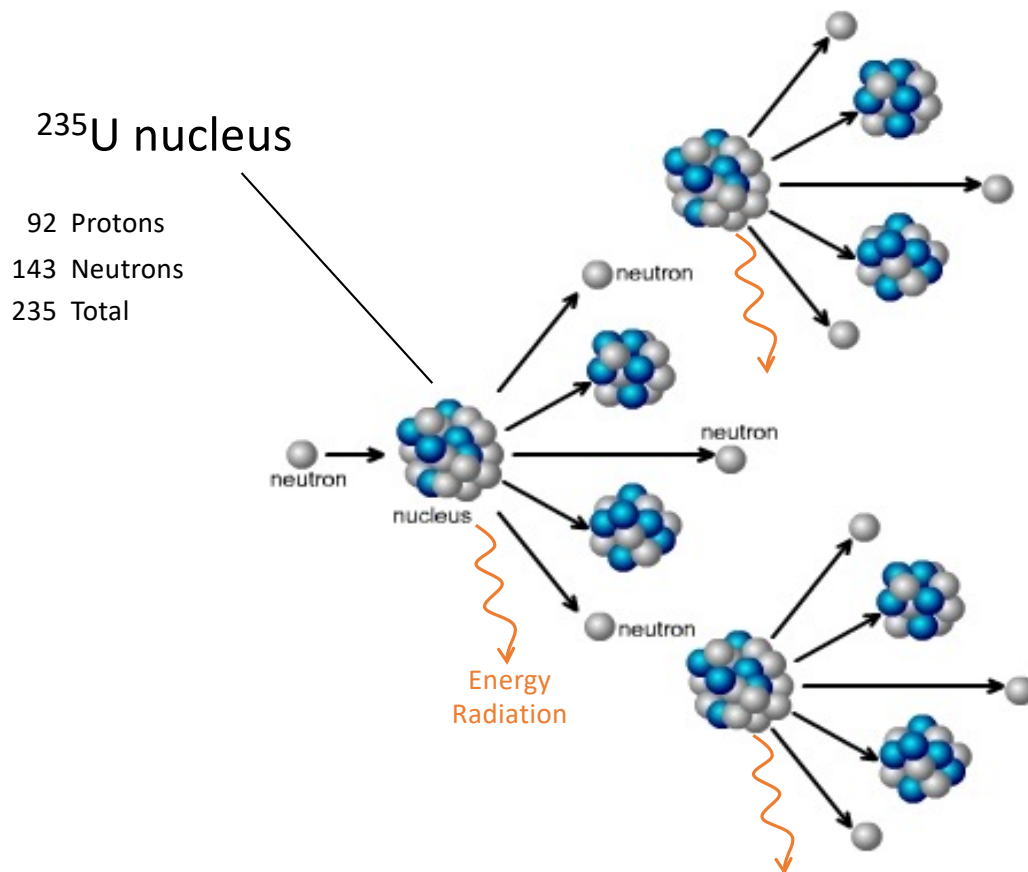
Digital Transformation for Education and Training

Lin-wen Hu, PhD
MIT Nuclear Reactor Laboratory

, Nuclear Outreach Program for High School Teachers, Purdue University, July 14-16, 2026

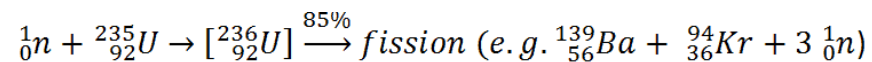


Nuclear Fission Reaction



- Common **fissile isotopes** for nuclear fuel are ^{235}U , ^{239}Pu (from ^{238}U), and ^{233}U (from ^{232}Th)
- Nuclear fission reaction does not require oxygen and does not produce CO_2 ,

Energy released per fission is 200 MeV, **10's of millions times more** than the energy released from burning an atom of fossil fuel!





Legacy of the First Nuclear Reactor CP-1

- The first nuclear reactor was erected in 1942 at the University of Chicago. A group of scientists achieved the first ***self-sustaining chain reaction***.

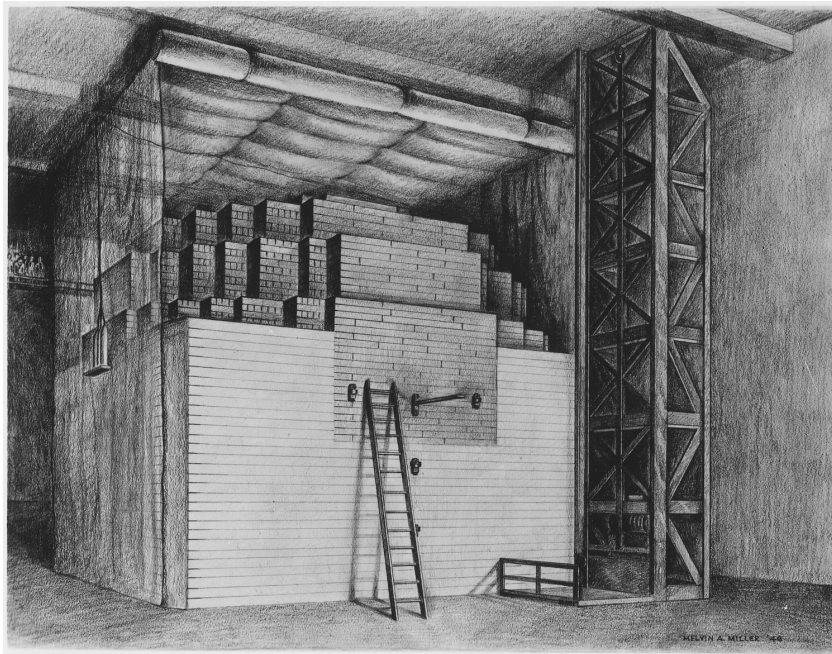
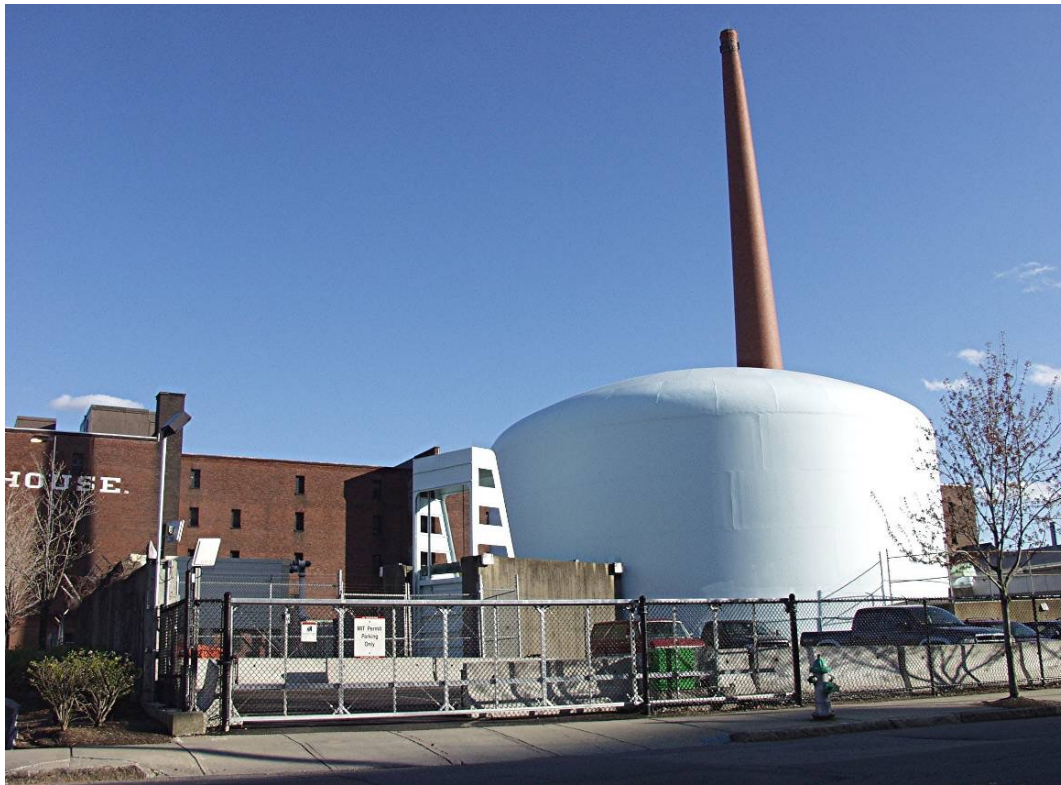


Image of Chicago Pile -1 (CP-1)



Inserting a Uranium fuel rod into the MIT Graphite Pile

The MIT Research Reactor



- Operated safely since 1958 as a ***university research reactor***.
- Licensed for 6 MW thermal power
- Operates 24/7
- Uses water as coolant
- Produces no greenhouse gases
- Produces no contamination
- Missions dedicated to education, research, materials testing and public outreach





MIT Reactor Core

- Water coolant temperature $< 55\text{ C}$.
- 27 positions with 24 fuel elements
- 6 control blades (boron), 1 regulating rod (cadmium)
- 3 dedicated in-core experimental positions



Nuclear Power Plants

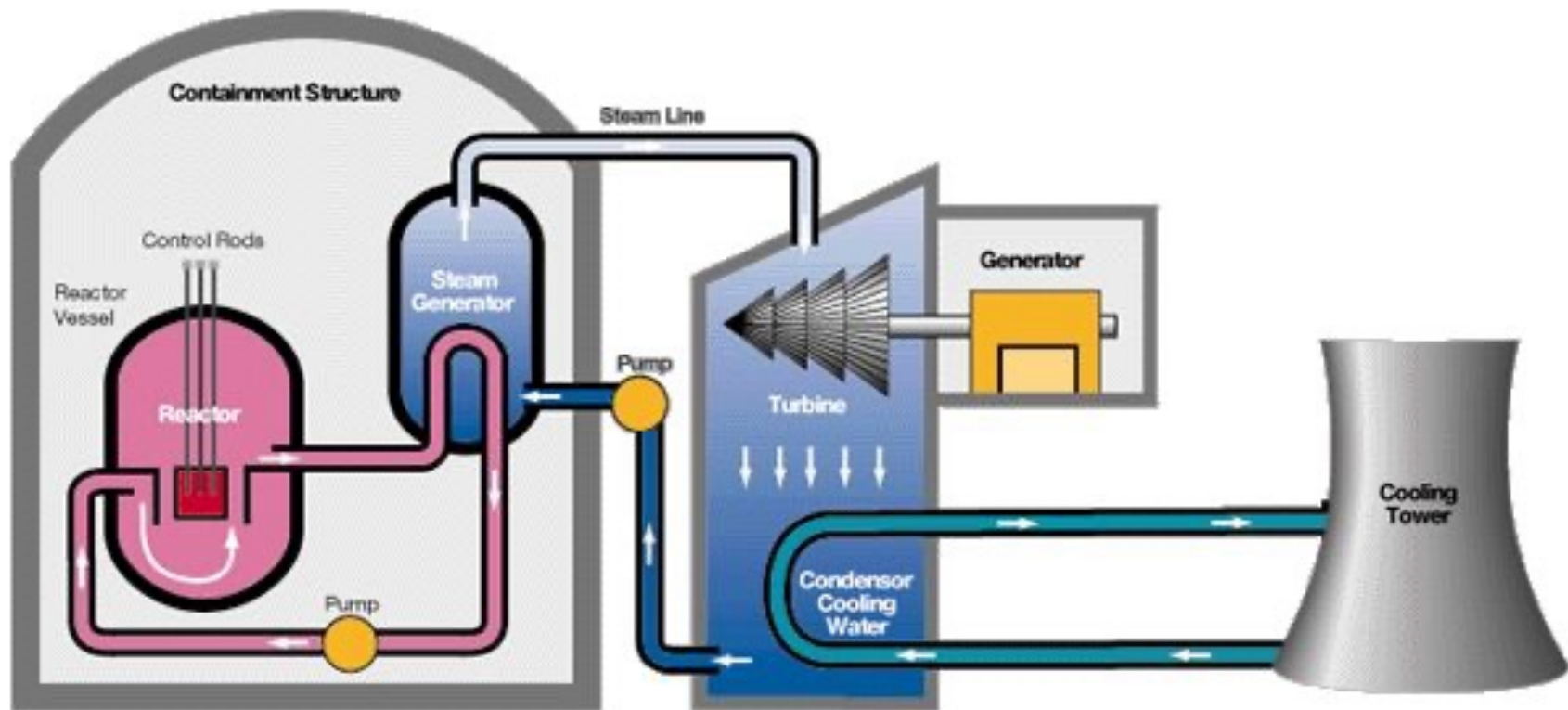
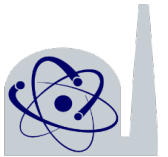


- Nuclear power plants have been a reliable electricity generation source since 1970's.
- In the U.S., Currently there are 94 operating nuclear power reactors. These produce roughly 20% of the national's electricity.
- Around the world, there are 440 nuclear power reactors supply about 10% of the world's electricity demand.



Diablo Canyon Nuclear Power Plant in California

Schematic Diagram of a PWR



Nuclear Reactor Control Rooms: Past v.s. Now

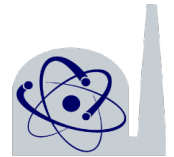


Analog Systems/Controls, Limited Data



Digital Systems/controls, Advanced simulation and modeling, Real-Time Visualization, Data Analytics

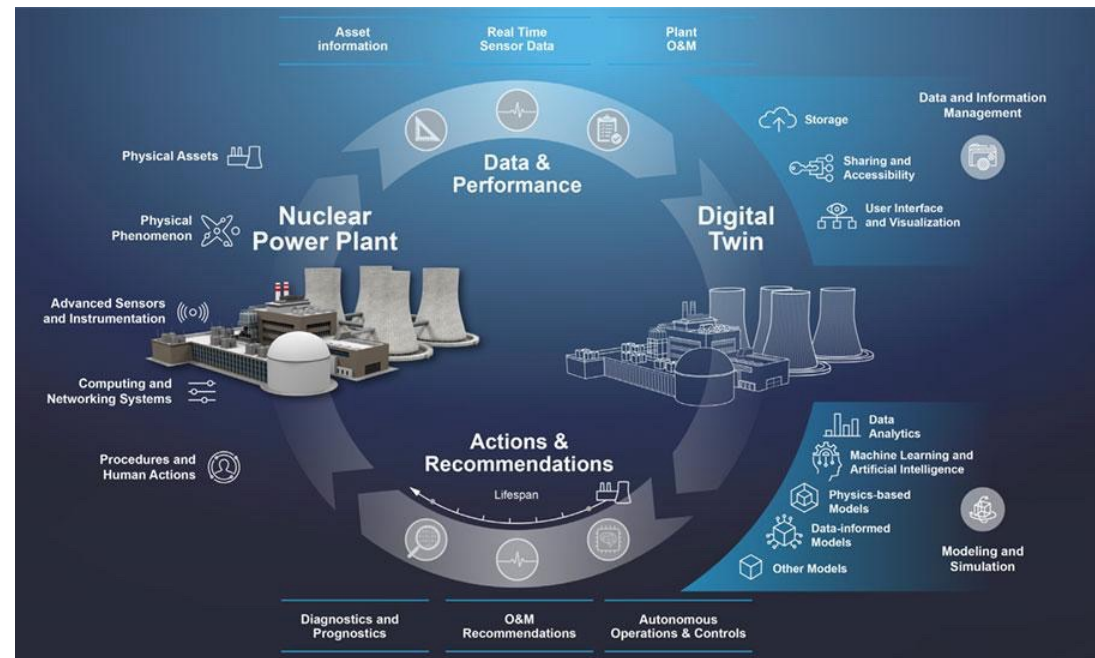
U.S. NRC's Research on Digital Twins



U.S. Nuclear Regulatory Commission (NRC) completed a future-focused research project to assess regulatory viability of nuclear DT. Recent reports focused on technical areas include:

- Advanced sensors, instrumentation and communication
- Nuclear safeguards and security
- DT and prognostic tools for condition monitoring

DTs will have significant impacts on advanced reactors and SMR reliability and safety.

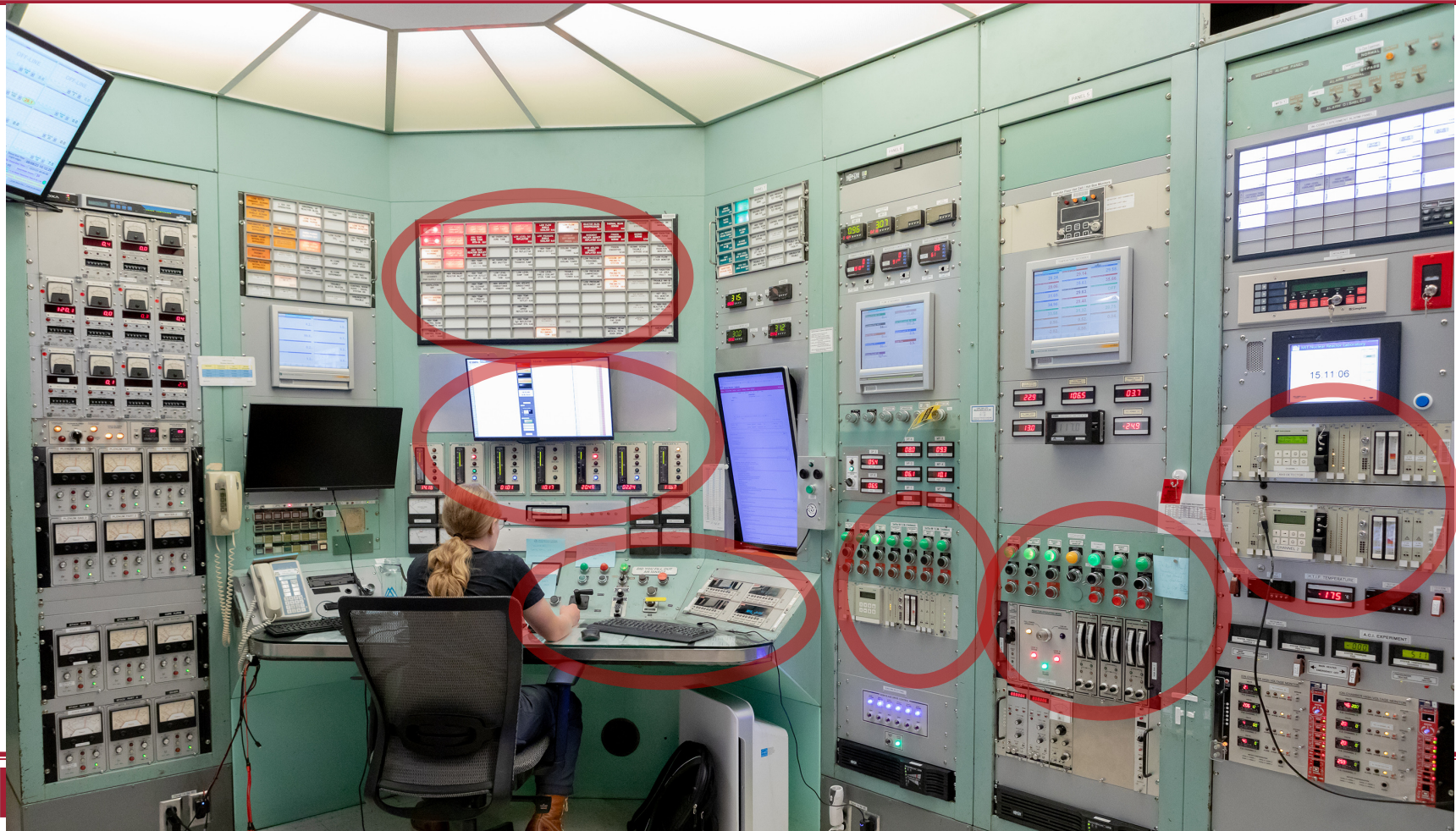
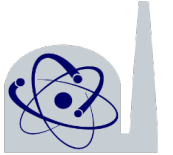


<https://www.nrc.gov/reactors/power/digital-twins#research>



Massachusetts Institute of Technology

MIT Reactor Control Room





Control Panel HMI Emulation

Several Human Machine Interfaces (HMI) are incorporated to emulate control panel, alarm panel, power history chart recorder, nuclear safety system, process system control, reactor protection system, and various instruments.



L. Hu, S. Hauptman, O. Ashy, S. Korolev, "Development of the MIT Research Reactor Simulator for Education, Training, and Research", *Transactions of the American Nuclear Society*, Vol. 124, June 2021.

Licensed Operator Training Experience



- Review of feedback mechanisms
- Interaction between core physics, thermal hydraulics, and reactor systems.
- Initial Conditions can be selected for various training scenarios.
- Demonstration of transient scenarios that cannot be practiced on physical reactor
- Demonstration of reactivity transients that are prevented by procedure control:
 - Cold slug accident by restarting a stopped secondary pump
 - Overcools primary, inserts positive reactivity, trips reactor off auto control
 - Xenon decay/burnout as reactivity insertion from precluded state
 - Startup procedure calls for “critical” at 50 kW on a +50sec period
 - Sitting with all absorbers full out leads to power increase, scram at 6.5 MW, shortest period 165 sec



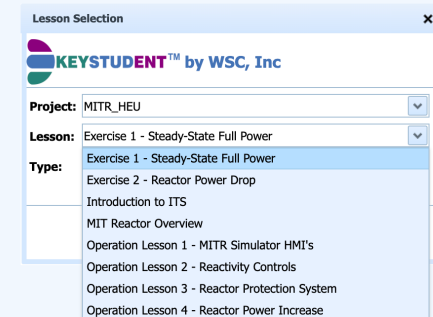
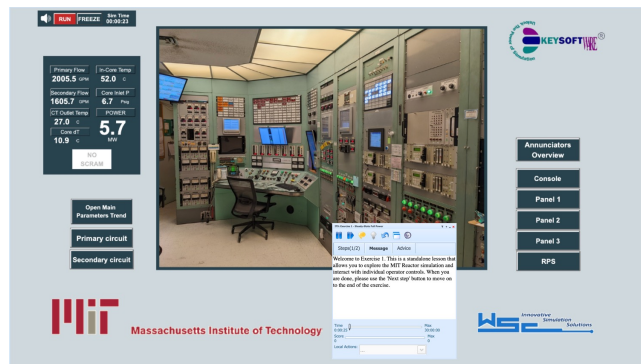
Annual Reactor Physics Requalification training, March 2023

S. Hauptman, L. Hu, “Application of MITR Simulator for licensed operator requalification and training” , TRTR/IGORR 2023



Education and Outreach Activities

- The MITR Simulator running on glasstop modules has been used for hands-on exercises for high-school student tours, MIT professional classes (reactor safety, reactor technology summer courses etc) and undergraduate nuclear engineering introductory course.
- Web-based MITR Simulator (WMS) was launched in September 2025, enabling MITR to provide additional method to access simulator for up to 30 external users. Incorporating WMS in community college curriculum is being evaluated for workforce development



Nuclear Reactor Design and Learning



Acknowledgements

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