System Dynamics Analysis Tool for Reactor Systems with Solid and Liquid Fuels

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Objectives

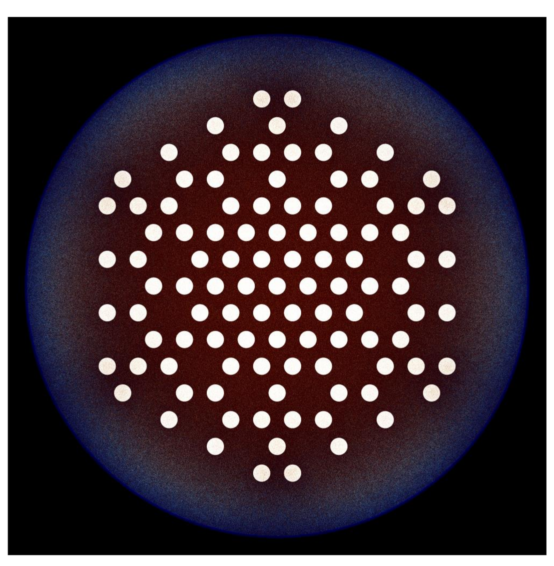
- Create a robust tool capable of accurately capturing the dynamic behavior of advanced nuclear reactors under various operating conditions.
- Use the tool to examine the unique dynamic behaviors of liquid-fuel reactors in contrast to solid-fuel reactors.

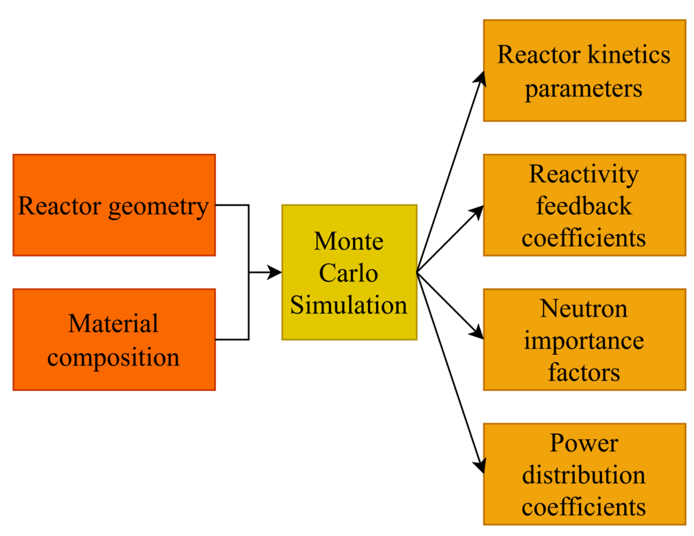
System Dynamics Analysis Tool

- The System Dynamics Analysis Tool (SDAT) consists of three models: Neutronics, thermal-hydraulics, and temperature reactivity feedback models.

Neutronics Model

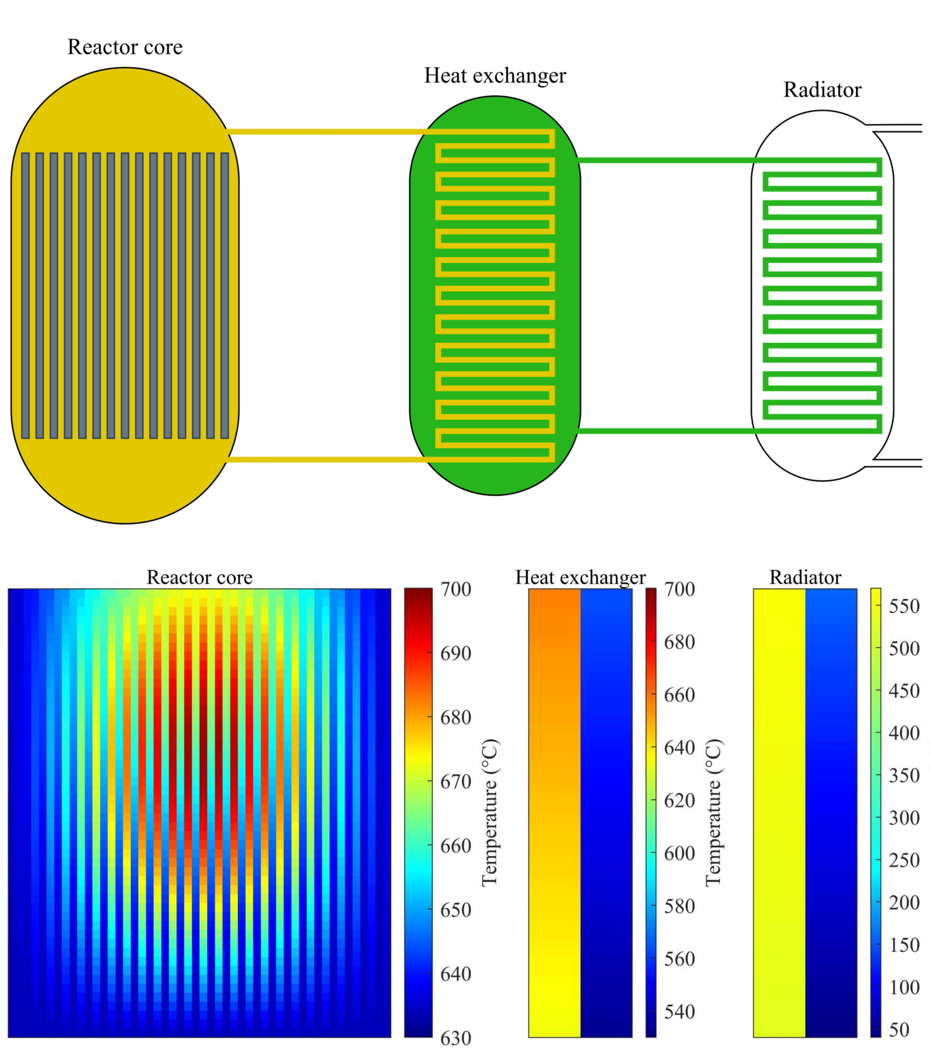
- The reactor kinetics model is used to describe the neutronic behavior in a reactor. Reactor kinetics parameters can be obtained from experiments or Monte Carlo simulation results.

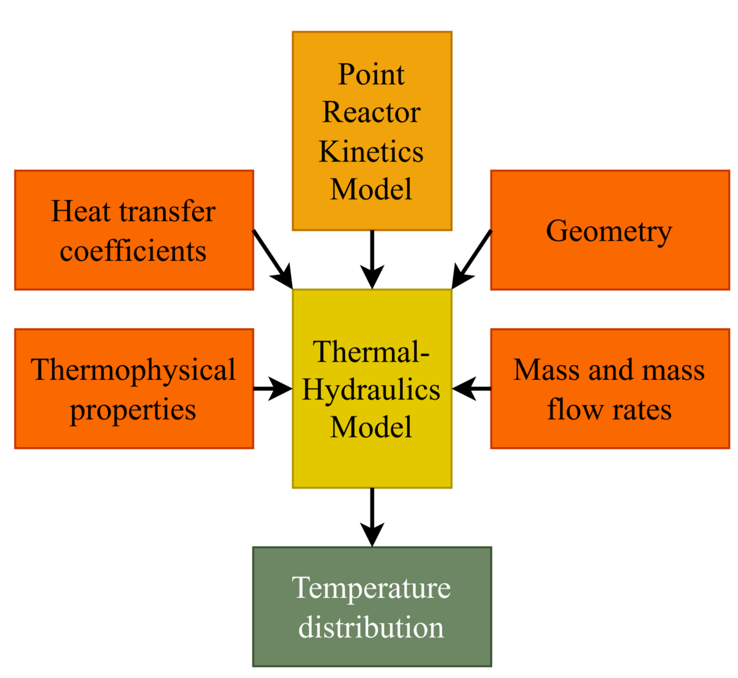




Thermal-Hydraulics Model

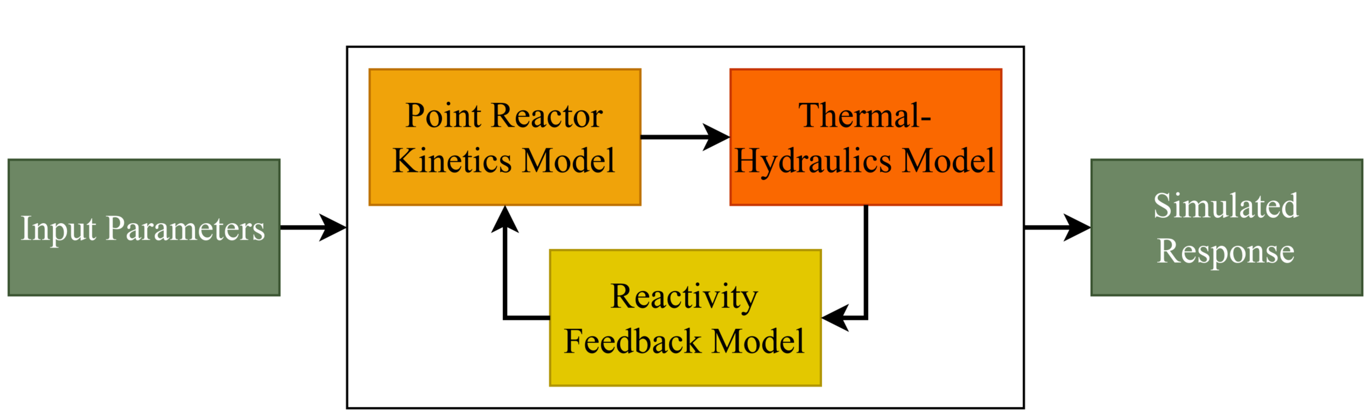
- The thermal-hydraulics model divides the reactor core into radial parallel channels with a uniform mass flow rate. With the symmetry in using power distribution coefficients, the core can be treated as a three-dimensional object where the heat transfer is ignored azimuthally. Heat and mass transfer equations will be written for all reactor components.





Reactivity Feedback Model

- The neutronics model feeds the reactor parameters in the thermal-hydraulics model. The thermal-hydraulics model will predict the temperature distribution in the reactor core. The temperature change in the reactor core will result in reactivity feedback that will be fed into the neutronics model.

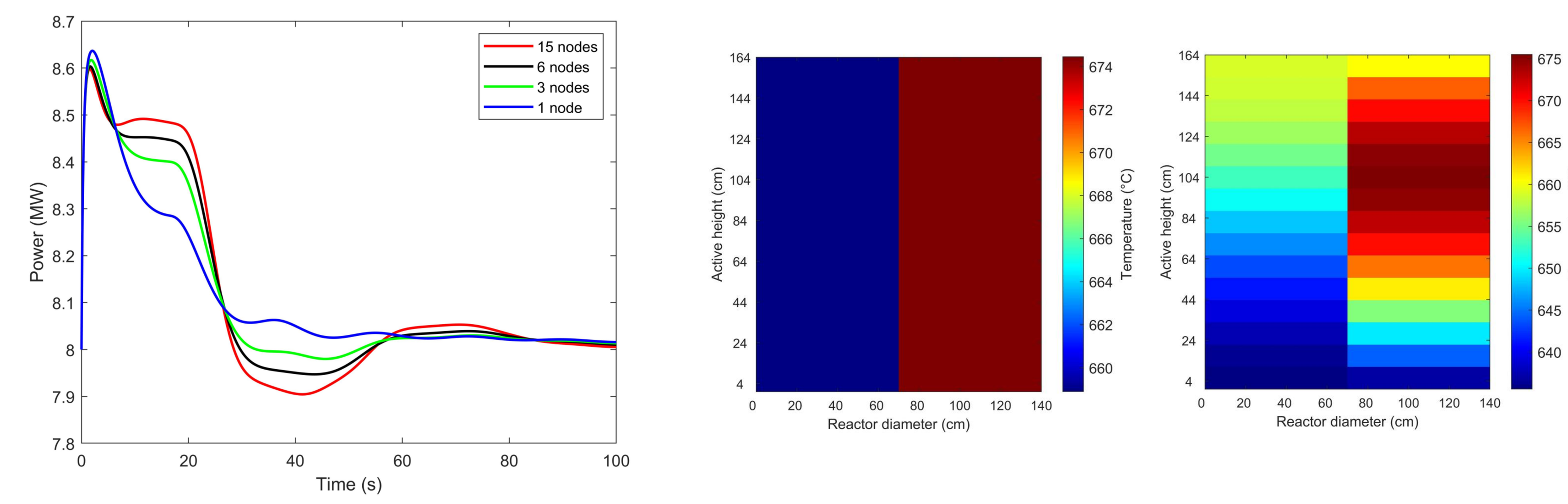


Tool Optimization

- In the optimization step, efforts will be directed toward optimizing SDAT models for a reactor to ensure a consistent simulation outcome. Any minor adjustments to the models' parameters will not induce fluctuations in the simulated results.

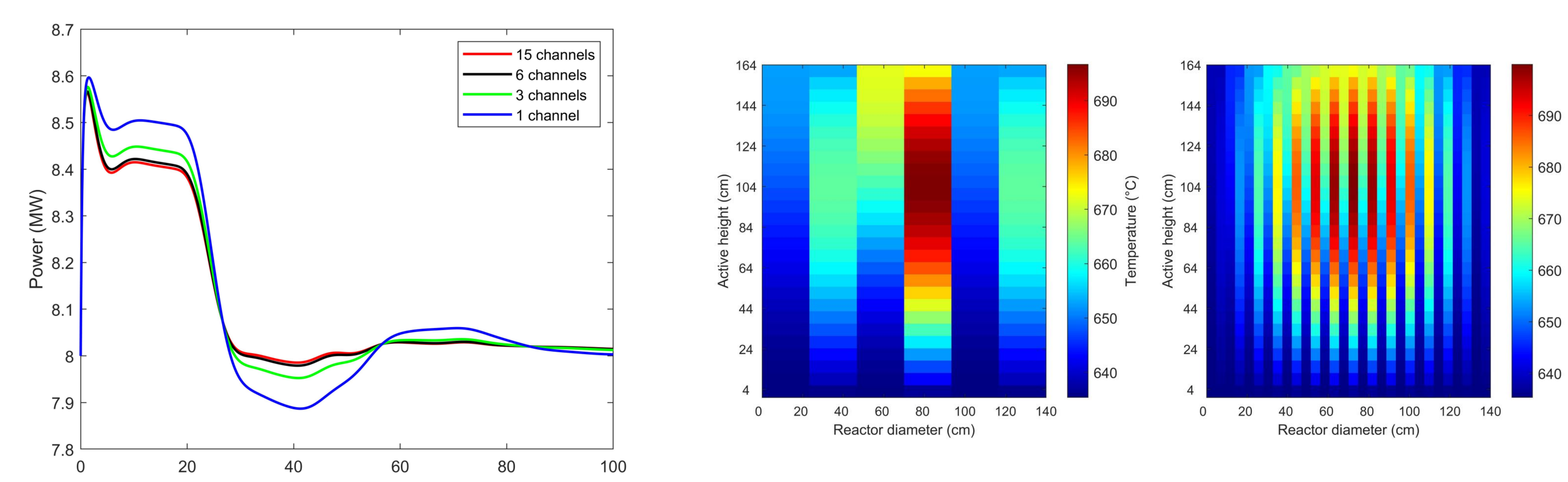
Axial Nodes

- The effect of using different numbers of axial nodes in a single channel was investigated.



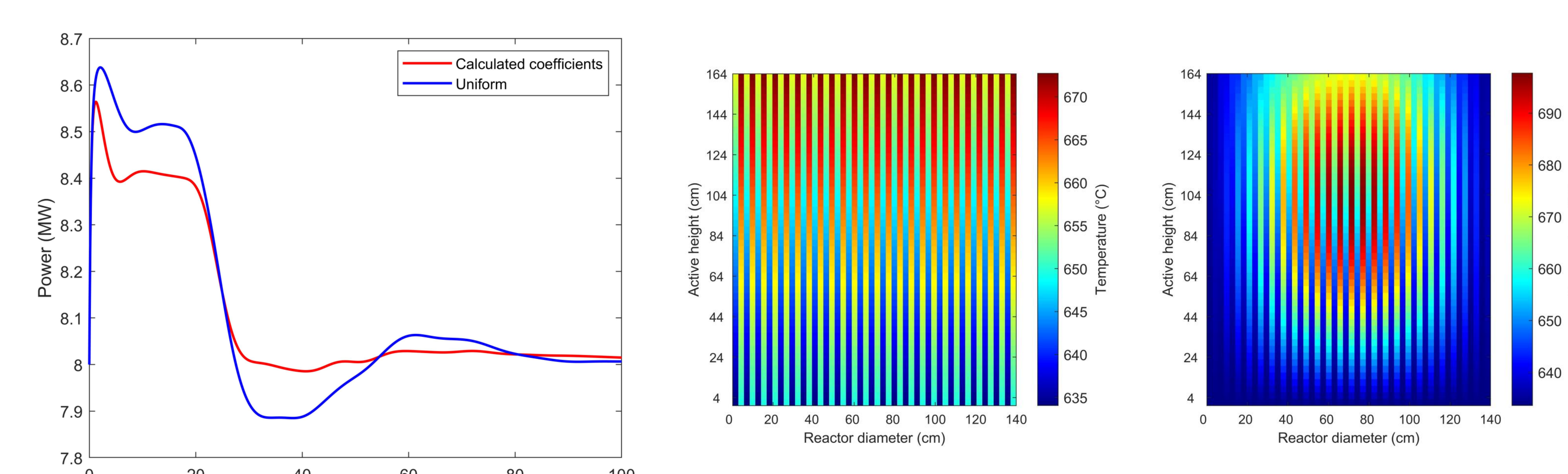
Radial Channels

- The effect of using different numbers of radial channels was investigated.



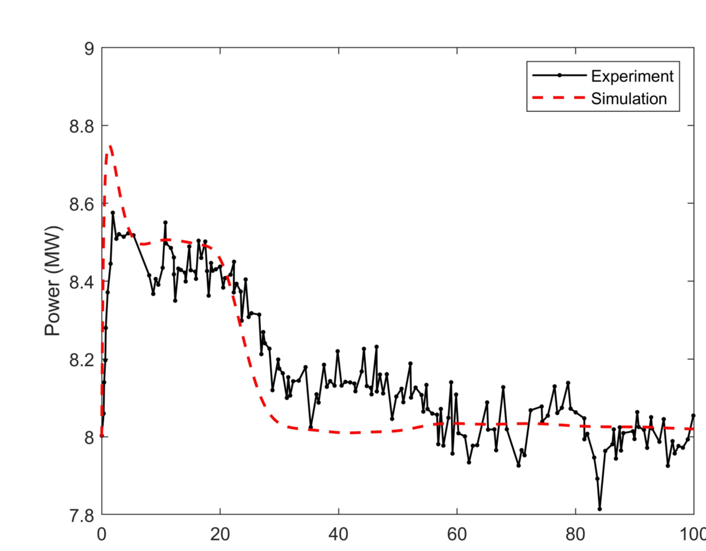
Power Distribution Coefficients

- Two models were compared to investigate the effect of the assumed power distribution coefficients and the neutron importance factors.

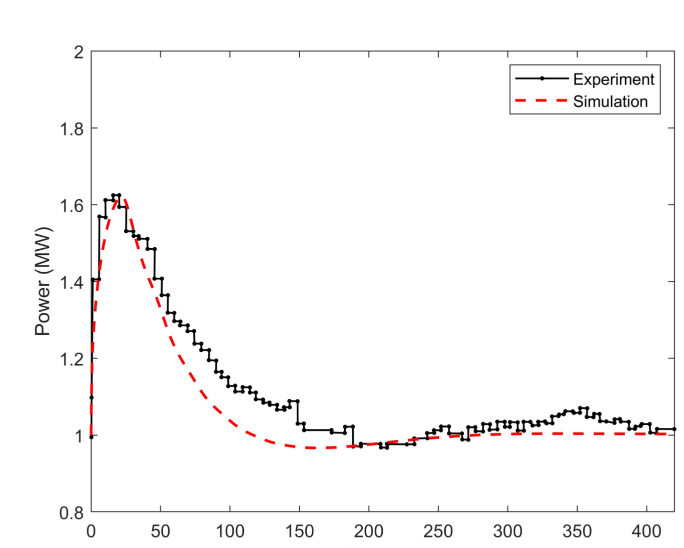


Validation

- The dynamic simulation tool simulated the Molten Salt Reactor Experiment (MSRE) following step reactivity insertions at different power levels. The simulation results were compared with those obtained from the experiment at Oak Ridge National Laboratory (ORNL).

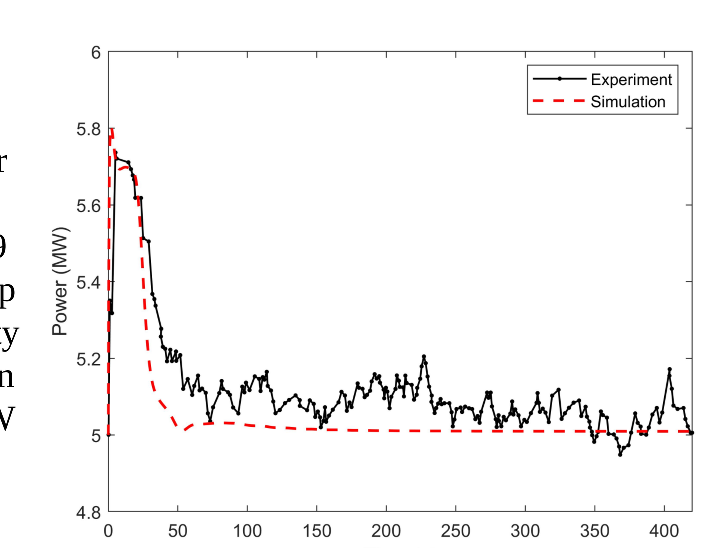


Reactor power after 13 pcm step reactivity insertion at 8 MW



Reactor power after 24.8 pcm step reactivity insertion at 1 MW

Reactor power after 19 pcm step reactivity insertion at 5 MW



Summary & Future Work

- The validation process verified the accuracy and reliability of the simulation tool, ensuring that it captures the main characteristics of the dynamic behavior of liquid fuel reactors.
- The next step is to use the tool for the simulation of a solid fuel reactor.

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