ANS NURETH-18

18th International Topical Meeting on Nuclear Reactor Thermal Hydraulics

August 18-23, 2019 | Portland, OR | Marriott Portland Downtown Waterfront

Hypothetical Accident Analyses on the Conceptual NIST Reactor with a Split Core Using RELAP5-3D

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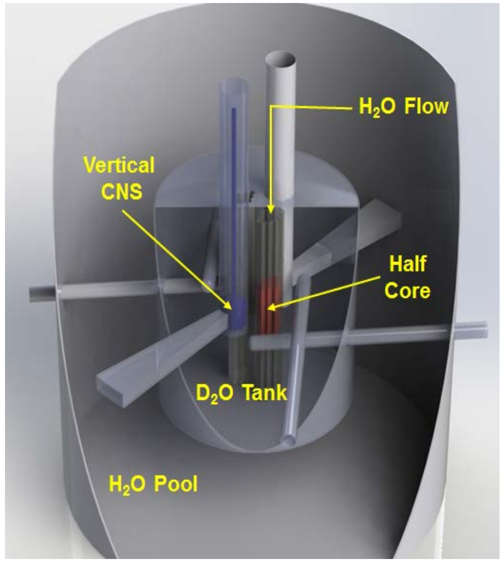
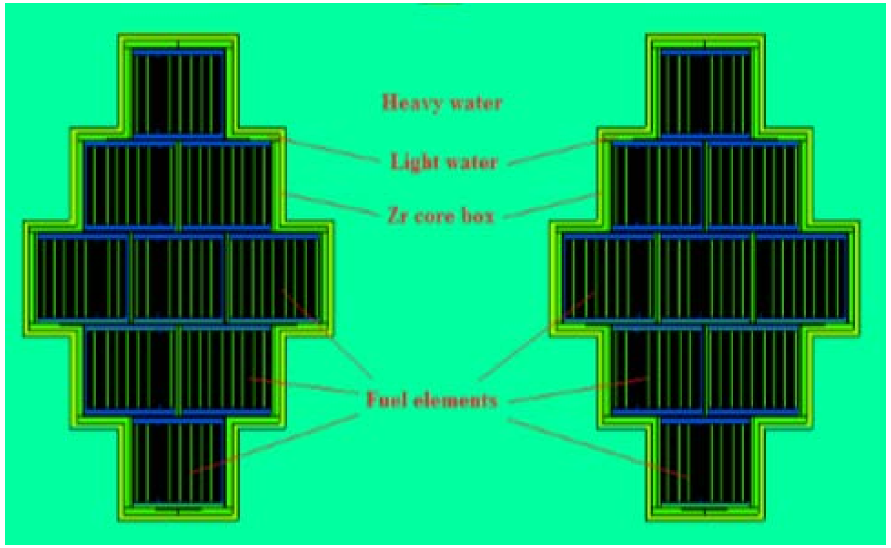
- Conceptual NIST Reactor
- Computational Models
- Results Comparison
- Conclusion and Future Work

Proposed NIST Reactor

- Tank in pool reactor

- 20MW thermal power and 30-day operating cycle





- Low enriched uranium (LEU) – U_3Si_2-Al

- Cooled by forced downward circulation

- Moderated by heavy water

Research background and Purpose

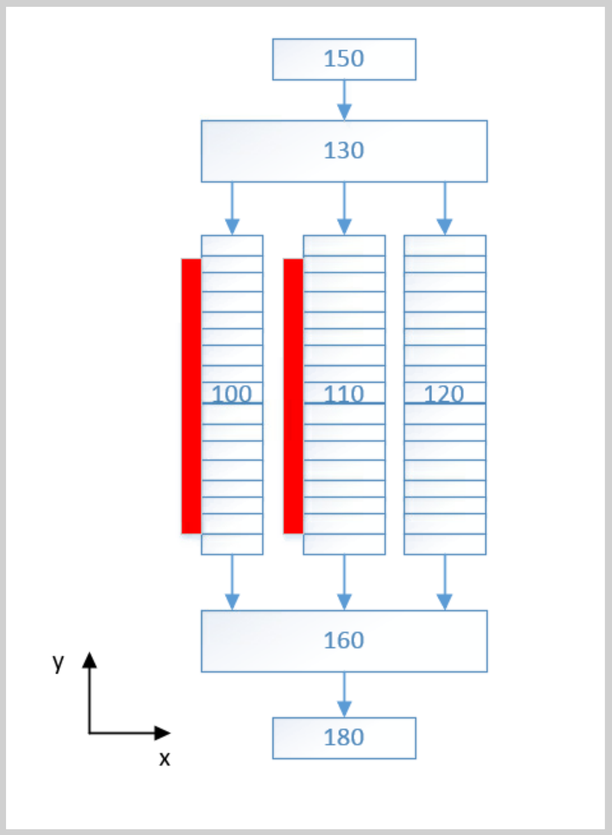
Preliminary neutronics and T/H safety analyses have been performed.

- Neutornics: Monte Carlo code MCNP.
- T/H Safety analyses: Modular channel code PARET.

To overcome computational modeling limits, RELAP5-3D will be used.

- Nodalization of the core and other important components of PCS.
- Comparison study of the system behavior predicted by both T/H codes.

Reactor Core Model in the Relap5-3D



Boundary Conditions

- Time-dependent control volumes and junctions

Upper and bottom plenum

- Branch

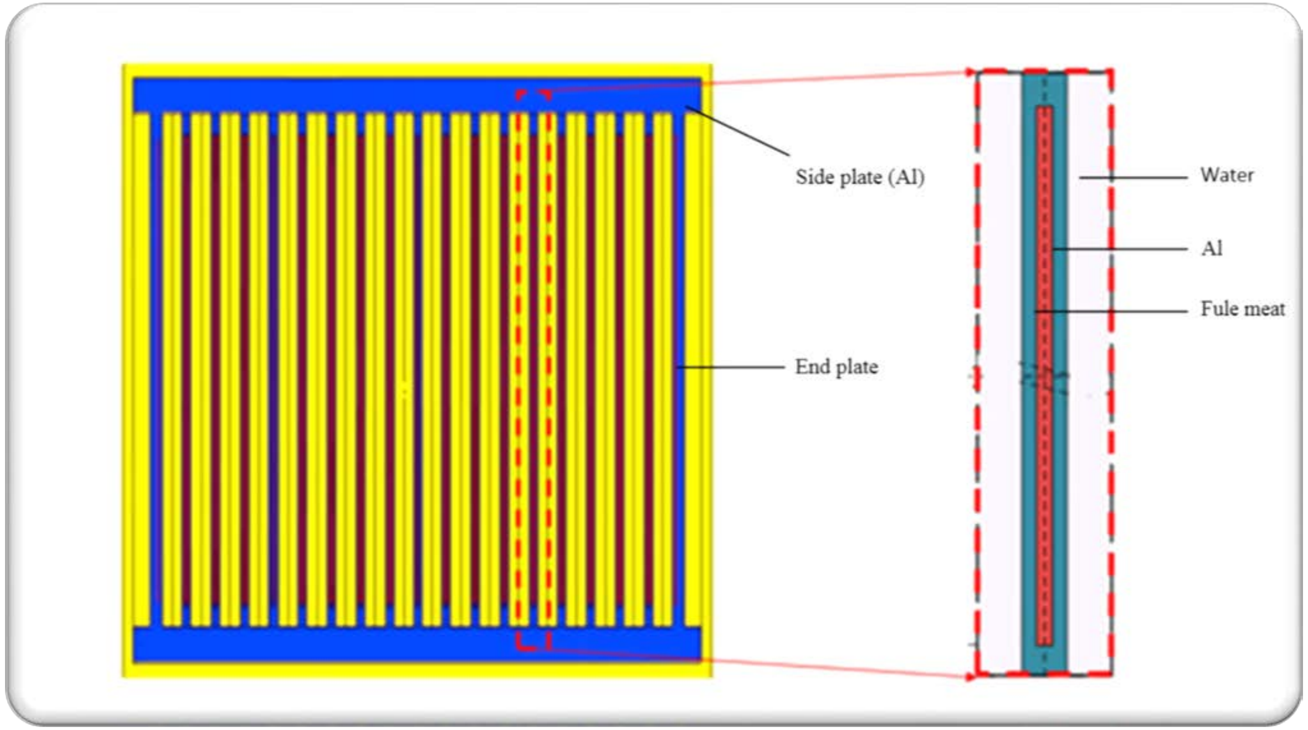
Hydrodynamic channels

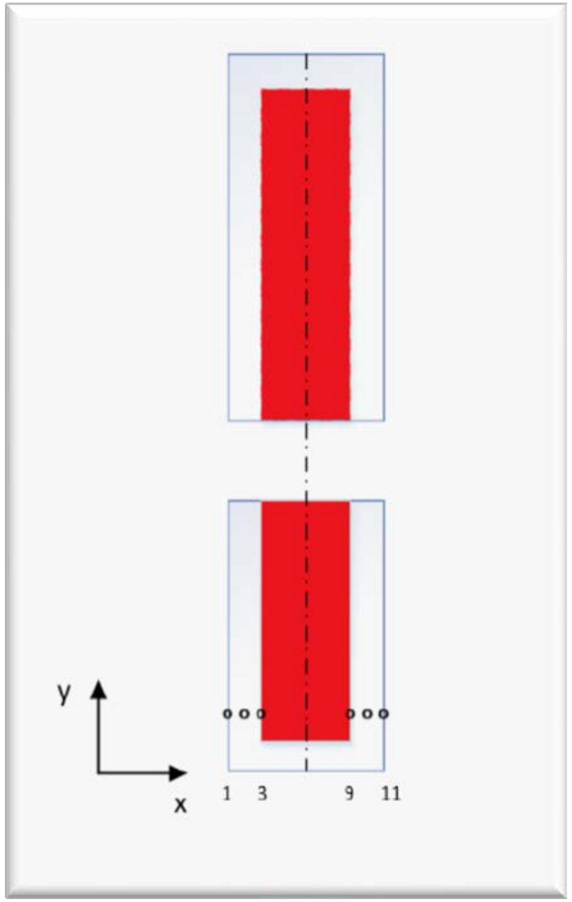
- Hot, average and bypass channel
- Divided into 17 control volumes

Fuel element

- Heat structures

MTR Fuel Element and Flow Channel Modeling



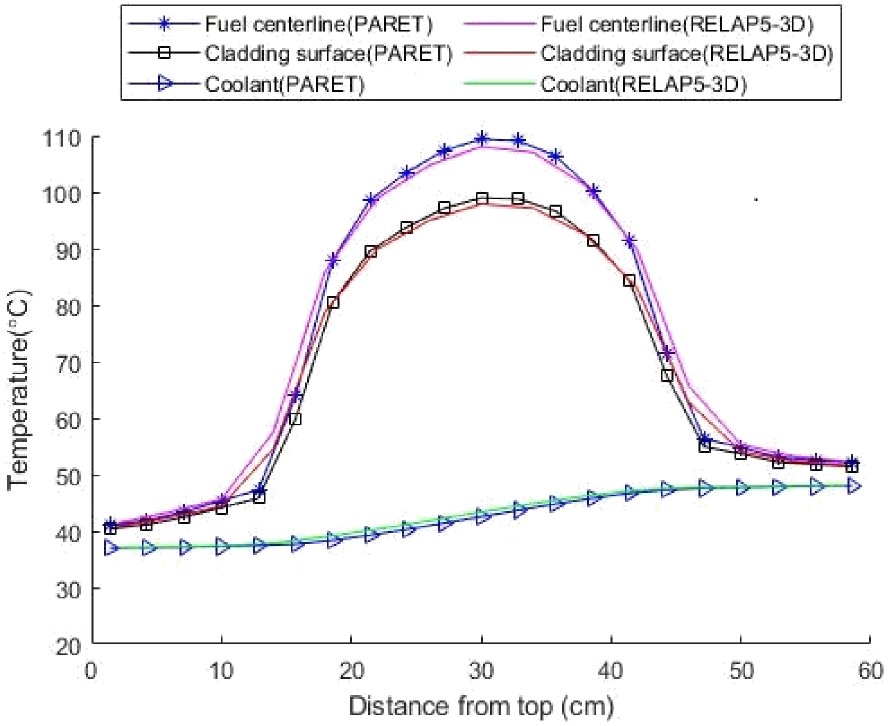


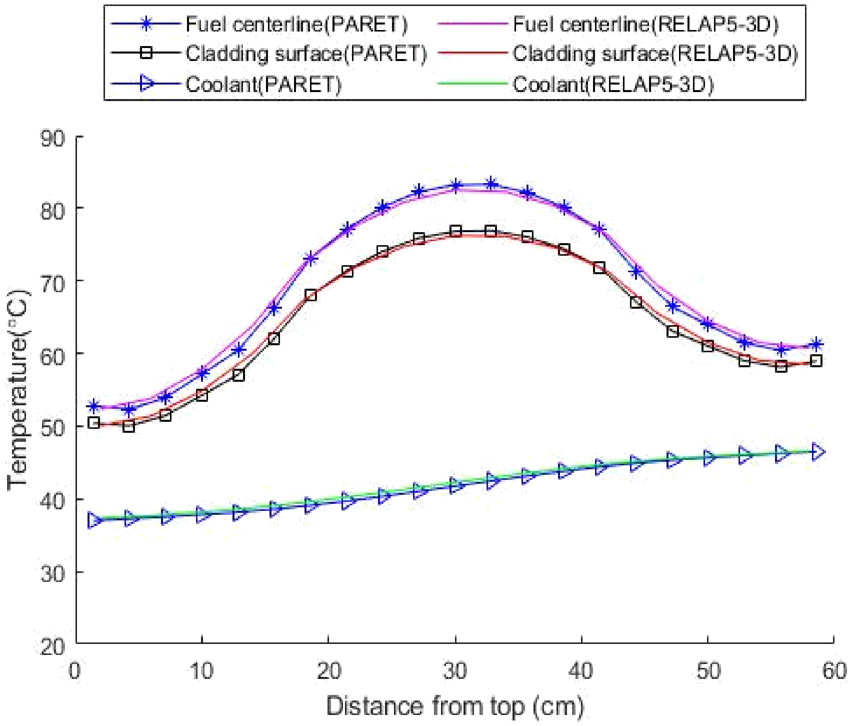
Key Parameters for RELAP5-3D Model

Materials	Values
Fuel meat material	U_3Si_2-Al
Fuel type	Plate type
Fuel density (g/cc)	6.53
Enrichment (wt%)	19.75
U-235 loading (g/plate)	391.47
Fuel assembly geometry	Values
Fuel assembly	18
Fuel plates per assembly	17
Aluminum plates	2
Fuel plate width (cm)	6.665
Fuel meat width (cm)	6.134
Fuel plate thickness (cm)	0.127
Fuel meat thickness (cm)	0.066
Cladding thickness (cm)	0.0305
Fuel plate length (cm)	60
Fuel meat length (cm)	67.28

Thermal-hydraulics	Values
Fuel thermal conductivity (W/m·K)	48
Cladding thermal conductivity (W/m·K)	180
Fuel volumetric heat capacity (J/m^3·K)	2.225E+6
Cladding volumetric heat capacity (J/m^3·K)	2.419E+6
Inlet coolant temperature (°C)	37
Core outlet pressure (kPa)	200
Total power (MW)	20
Inlet volumetric flow rate (gpm)	8000
Hydraulic diameter (cm)	0.56
Reactor kinetics	Values
Prompt neutron generation time (µs)	252.63
Effective delayed neutron fraction (β_{eff})	0.00718

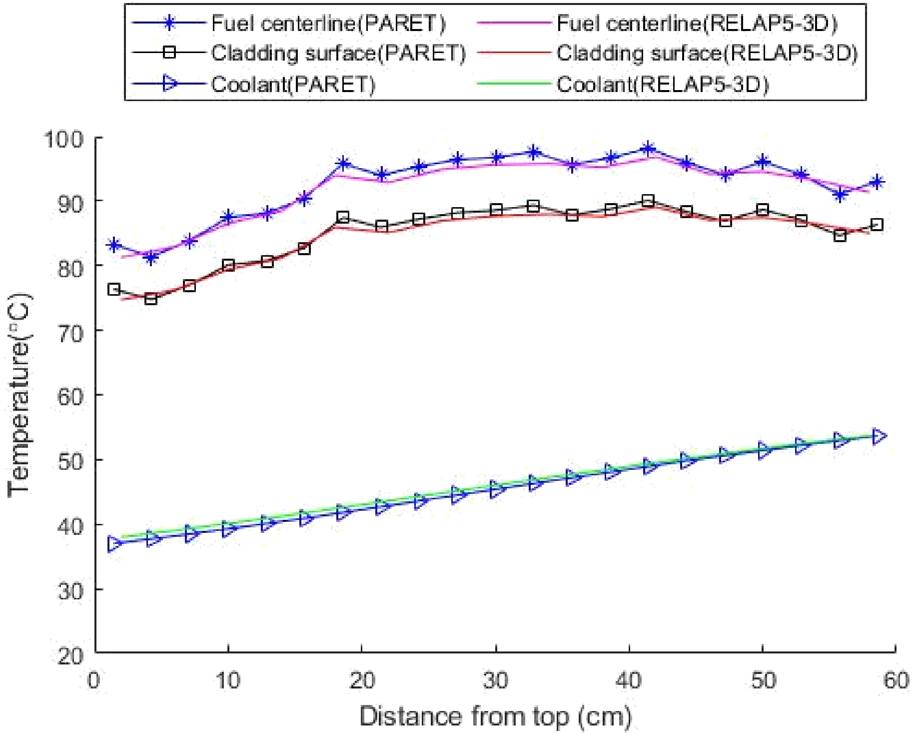
Temperature Comparison in Start-up (SU)

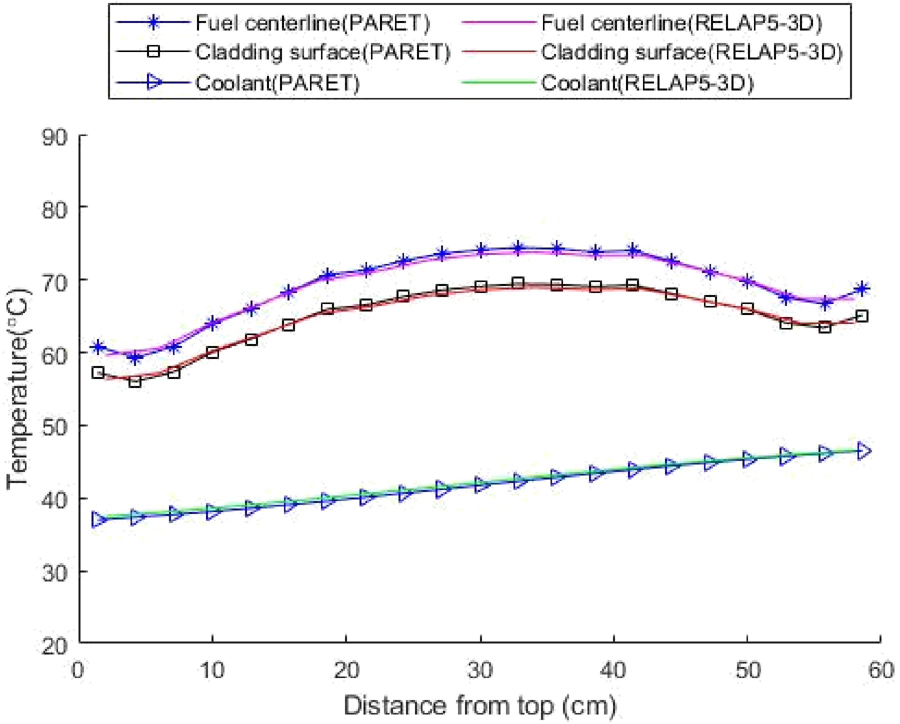




	Hot Channel			Average Channel		
	RELAP5	PARET	Deviation	RELAP5	PARET	Deviation
T (Fuel)	108.05	109.38	1.22%	82.52	83.27	0.90%
T(Cladding)	97.91	98.95	1.05%	76.25	76.90	0.85%
T(Outlet)	48.11	48.01	0.21%	46.56	46.49	0.15%
MCHFR	3.300	3.473	4.98%	5.379	5.654	4.86%

Temperature Comparison in End of Cycle (EOC)



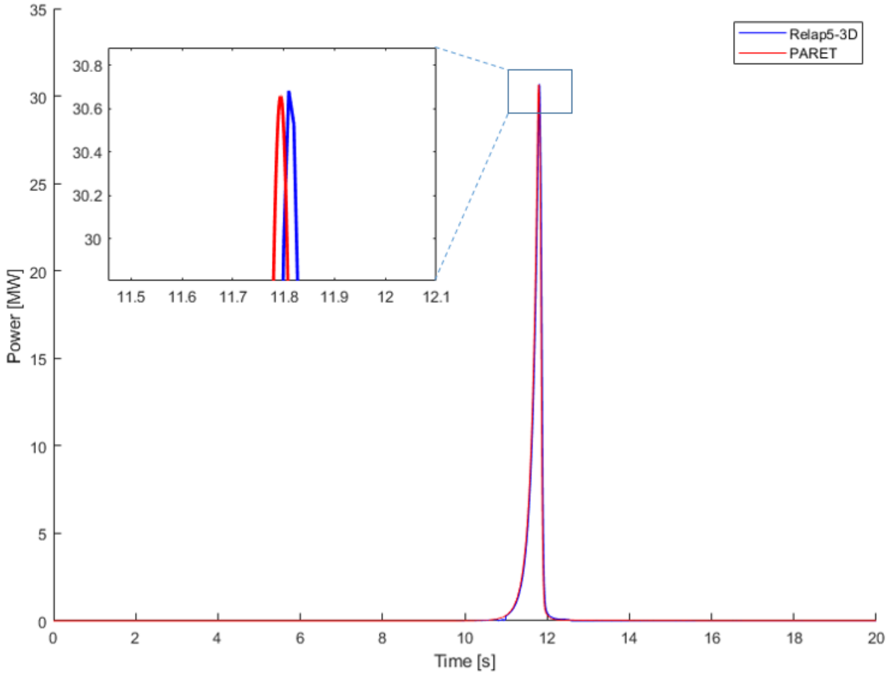


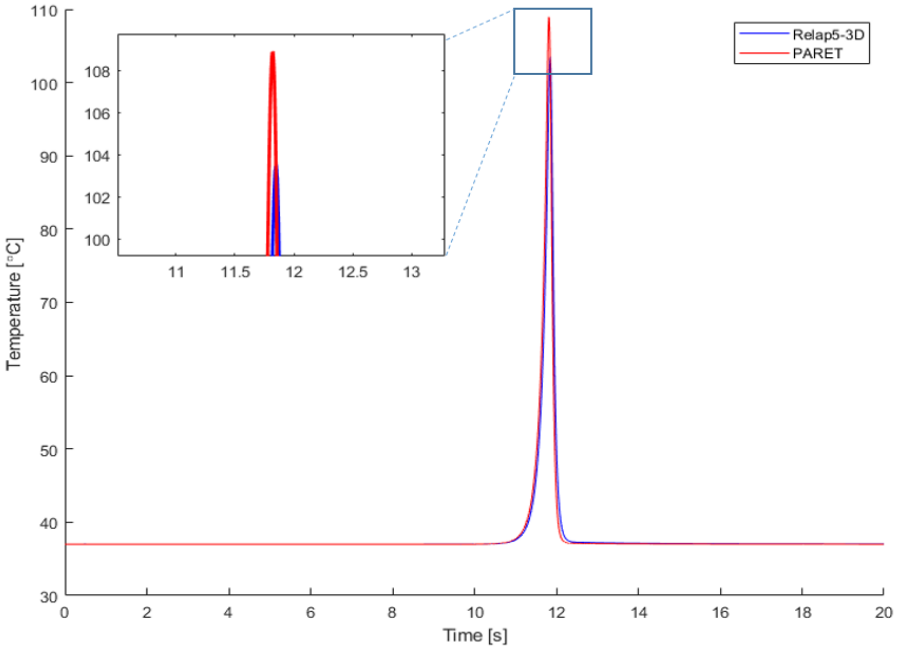
	Hot Channel			**Average Channel**		
	RELAP5	PARET	Deviation	RELAP5	PARET	Deviation
T (Fuel)	96.94	98.14	1.22%	73.80	74.44	0.86%
T(Cladding)	89.20	90.10	1.00%	68.96	69.43	0.68%
T(Outlet)	53.74	53.66	0.15%	46.54	46.50	0.09%
MCHFR	4.060	4.319	6.00%	6.894	7.245	4.84%

Slow Reactivity Insertion Accident (SRIA)

- A positive reactivity is gradually inserted into the initially critical reactor at the low power of 2 Watts (0.01% of full power).
- The reactivity insertion rate is assumed to be 0.1$/s to mimic a ramp reactivity insertion condition.
- The reactor scram occurs at the power of 24 MW (120% of full power) with a high reactor power trip signal.
- To take into the account of the operation time delay due to the mechanical and electronic circuit effects, a delay of 25 ms is imposed to the control rod reaction after the trip.
- All reactivity feedback effects and period trip are neglected in the analyses.

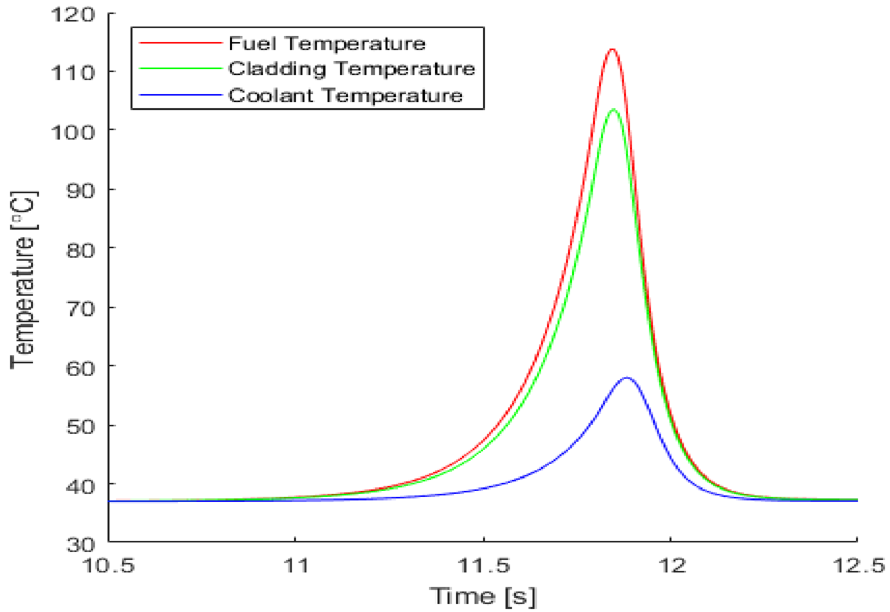
Power and peak cladding temperature changes in SRIA.

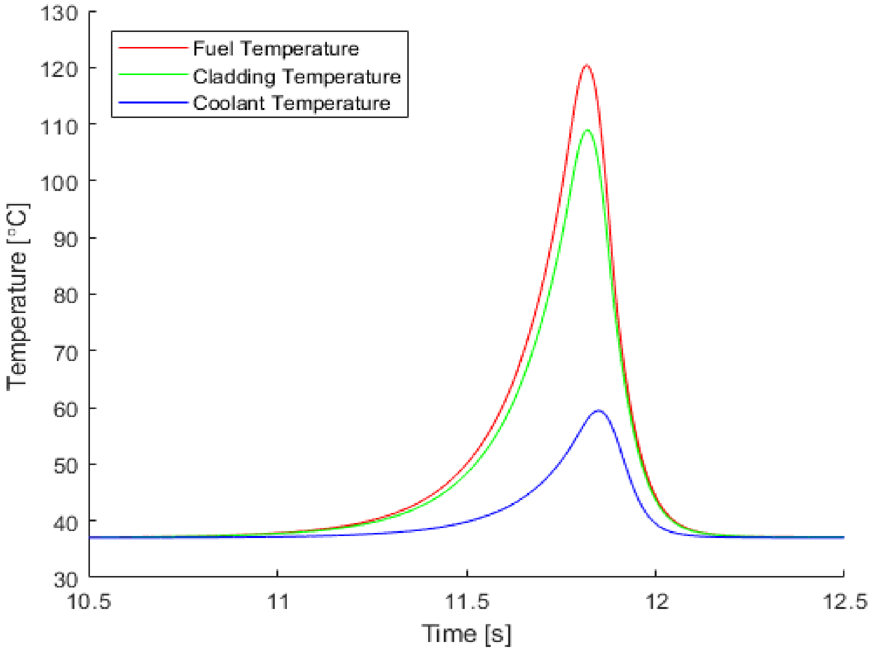




Core Status	RELAP5-3D	PARET	Deviation
Peak power [MW]	30.68	30.66	0.07%
Peak power time [s]	11.81	11.79	0.17%
Reactor trip time [s]	11.79	11.75	0.34%

Comparison of temperature changes in SRIA



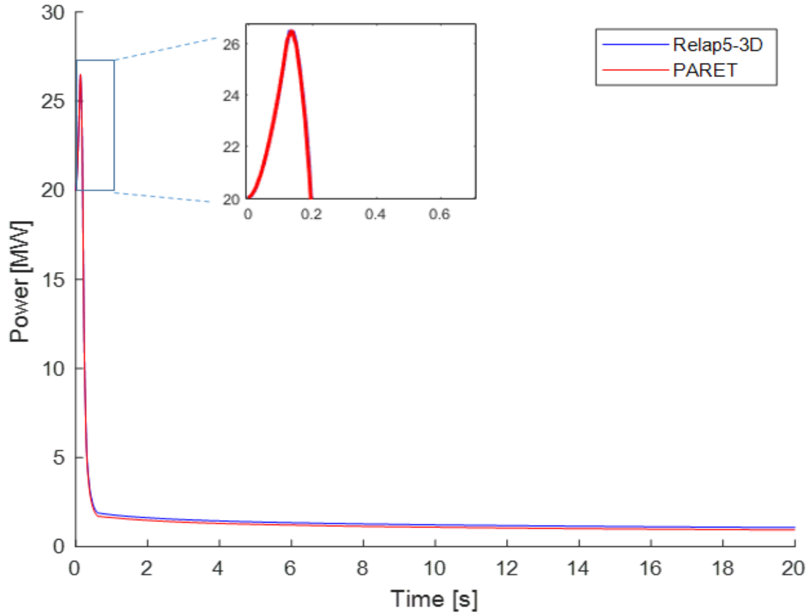


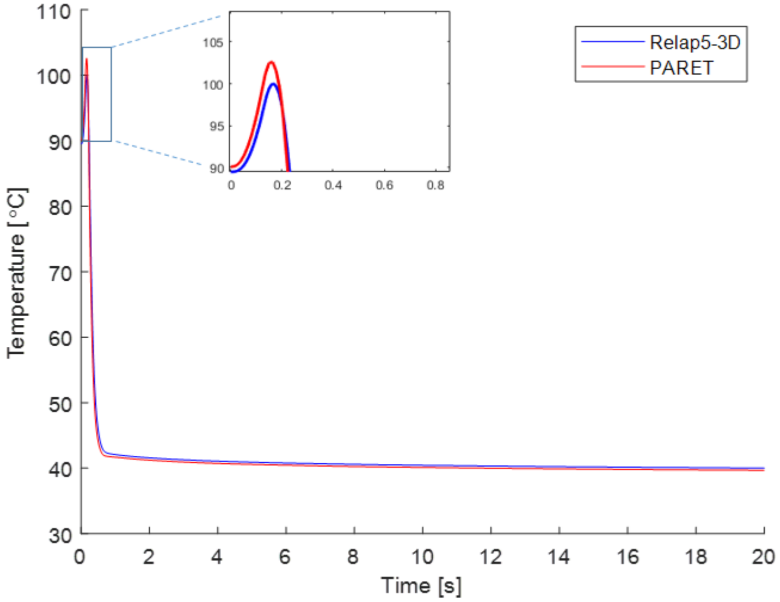
Core Status	RELAP5-3D	PARET	Deviation
Peak clad temperature [°C]	103.58	108.93	4.91%
PCT time [s]	11.85	11.82	0.25%
Peak fuel temperature [°C]	113.73	120.41	5.55%
PFT time [s]	11.85	11.82	0.25%

Large Reactivity Insertion Accident (LRIA)

- A step positive reactivity(1.5 $) is inserted into an initially critical core in 0.5s at full power to mimic the control rod abnormal accident during the reactor normal operation.
- The reactor scram occurs at the power of 24 MW (120% of full power) with the high reactor power trip signal.
- A time delay of 25 ms is considered and the control rods are assumed to be inserted with a speed of 1.2 m/s for reactor trip.
- All reactivity feedback effects and period trip are neglected in the analyses

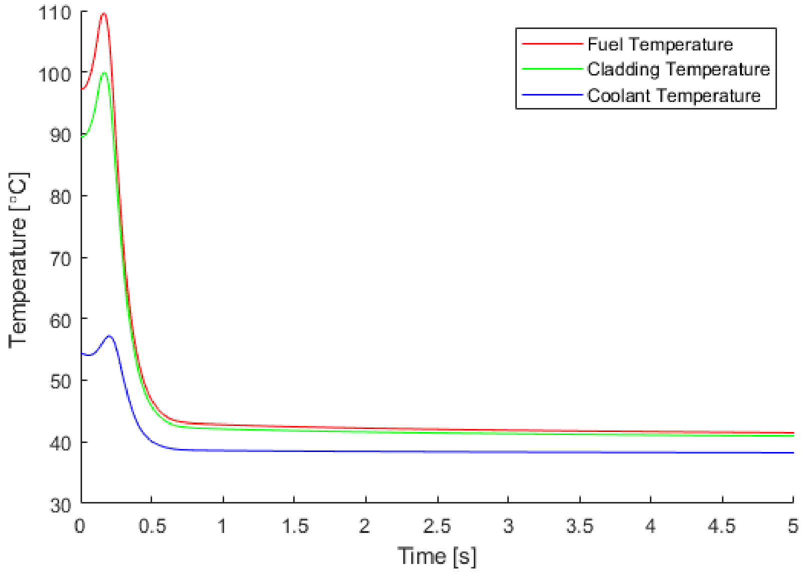
Power and peak cladding temperature changes in LRIA.

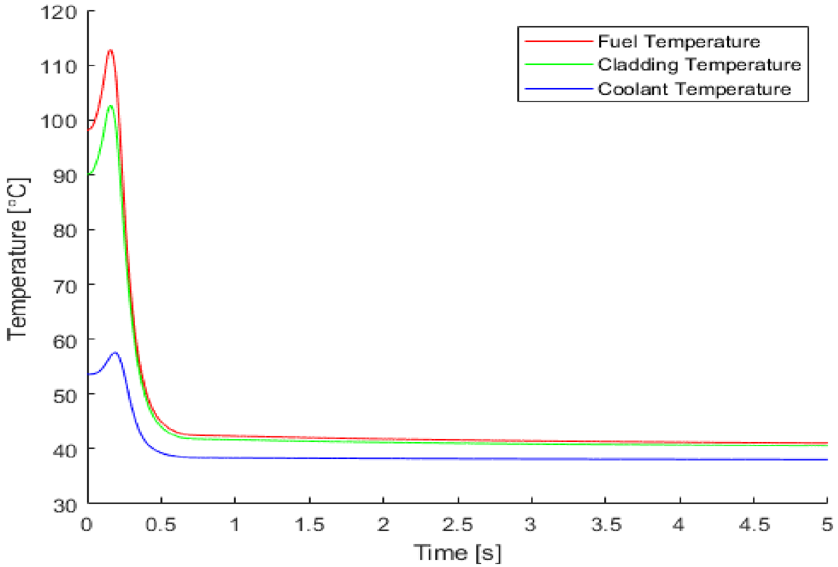




Core Status	RELAP5-3D	PARET	Deviation
Peak power [MW]	26.47	26.51	0.15%
Peak power time [s]	0.13	0.13	0.00%
Reactor trip time [s]	0.01	0.01	0.00%

Comparison of temperature changes in LRIA





Core Status	RELAP5-3D	PARET	Deviation
Peak clad temperature [°C]	99.96	102.58	2.55%
PCT time [s]	0.17	0.16	6.25%
Peak fuel temperature [°C]	109.57	112.68	2.76%
PFT time [s]	0.16	0.16	0.00%

Conclusions and Future Work

- The RELAP5-3D model to predict the thermal hydraulics properties of the conceptual NIST research reactor core was established.
- Both steady-state and reactivity insertion transient calculations were performed.
- Preliminary results produced by the RELAP5-3D have a good agreement with the ones from the PARET code, which verifies the correctness of the current model in a certain degree.
- In the next stage, some additional components in the primary cooling system of the reactor, such as heat exchanger and primary loop pump, will be developed in the RELAP5-3D model
- More design basis accident analyses such as the loss of flow accident (LOF) will be performed using the RELAP5-3D model.

Thank you!