Microreactor Reference Plant Model

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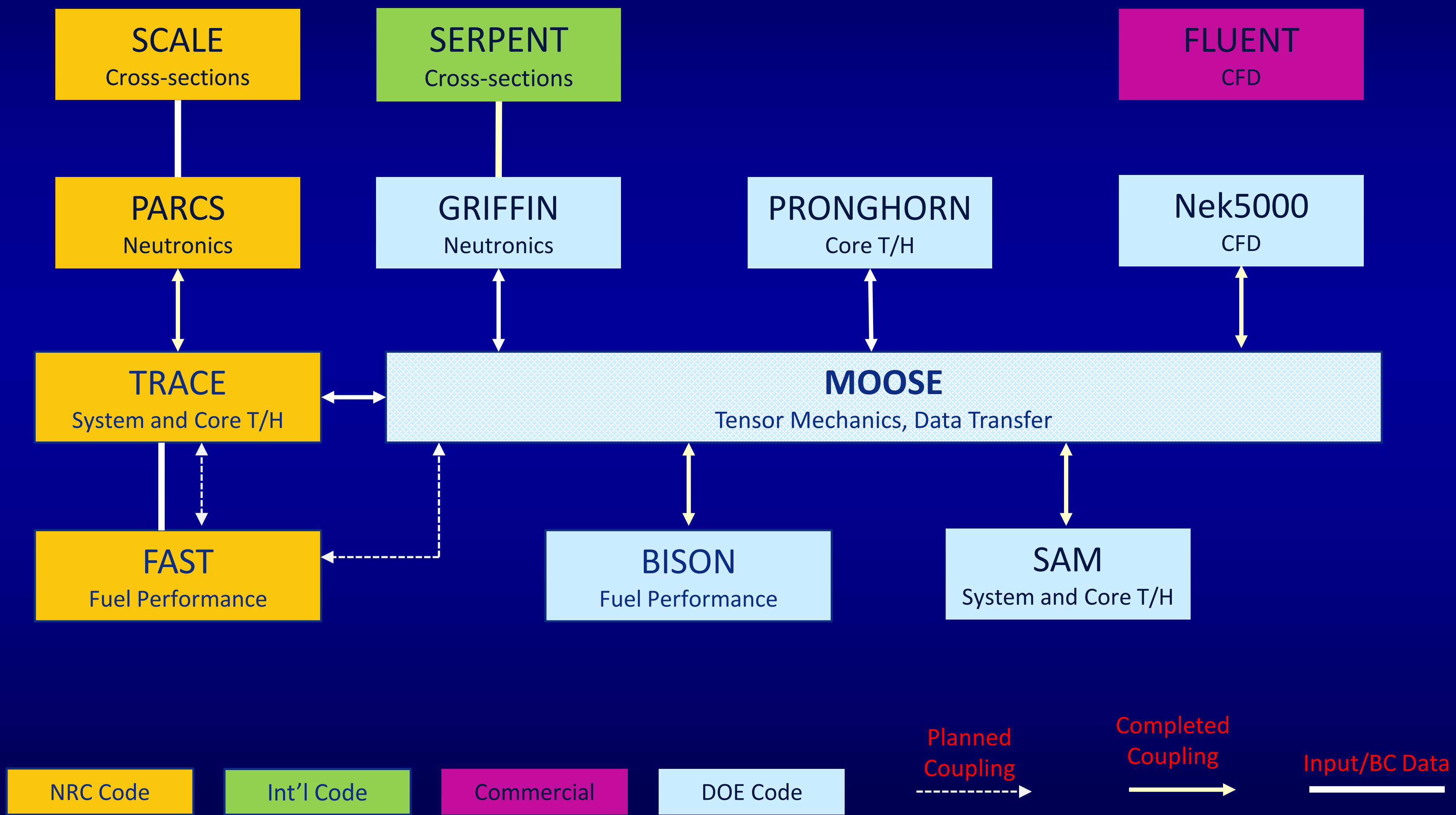
  - Rui Hu and Guojun Hu, Argonne National Laboratory
  - Javier Ortensi, Idaho National Laboratory

Introduction

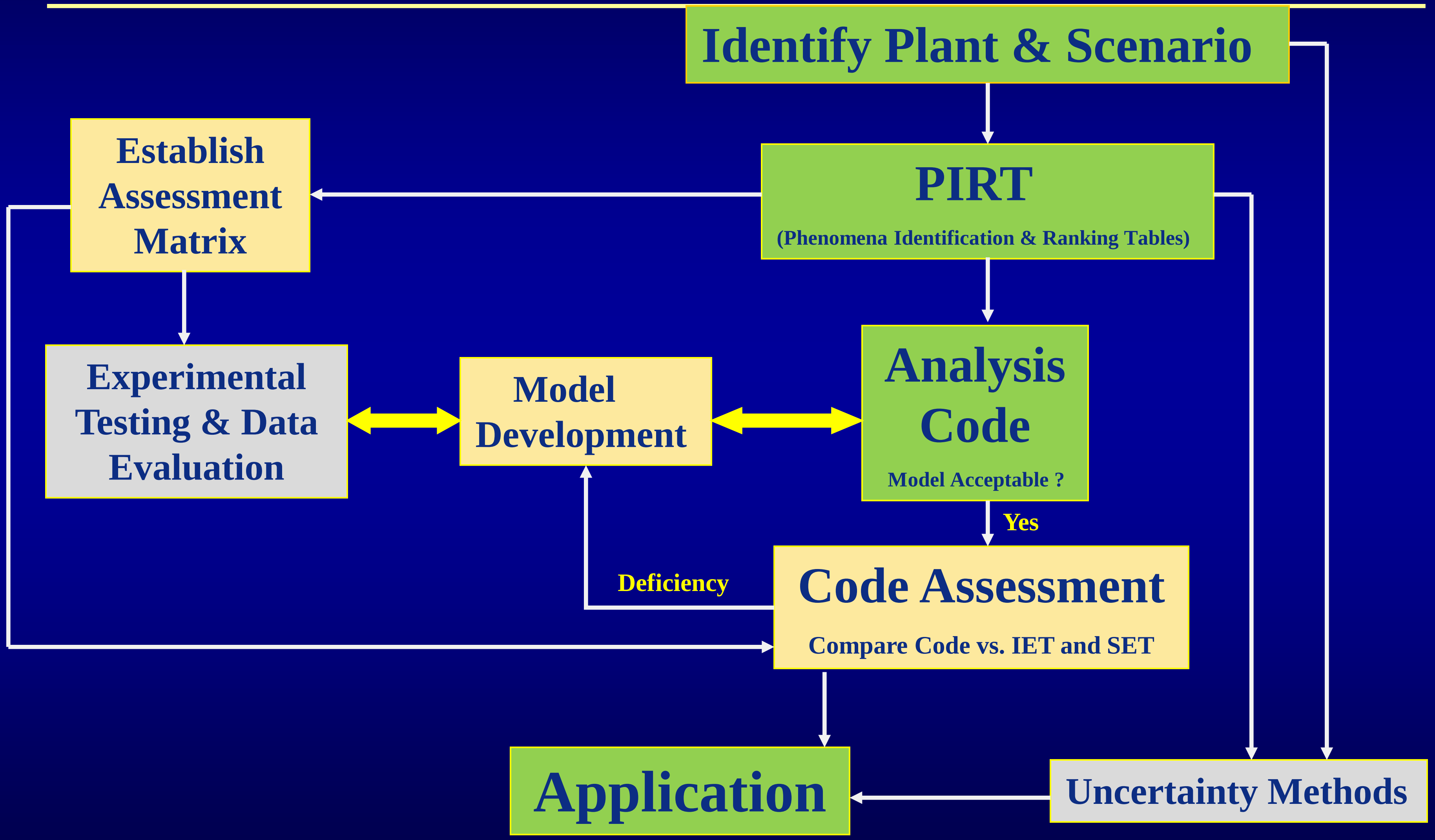
- "Strategy 2" of the Implementation Action Plan (IAP) is directed at identification & development of computer codes and tools to prepare the staff for evaluation of advanced non-LWRs.

- An important step in code readiness is development of a "reference plant" model which will:
  - *Contain many / most features expected in a design*
  - *Exercise code(s) to be used in analysis*
  - *Provide early identification of technical issues*

Comprehensive Reactor Analysis Bundle
"BlueCRAB"



Reg Guide 1.203 Code Development



PIRT and Scenarios: “Micro Reactors”

Scenarios

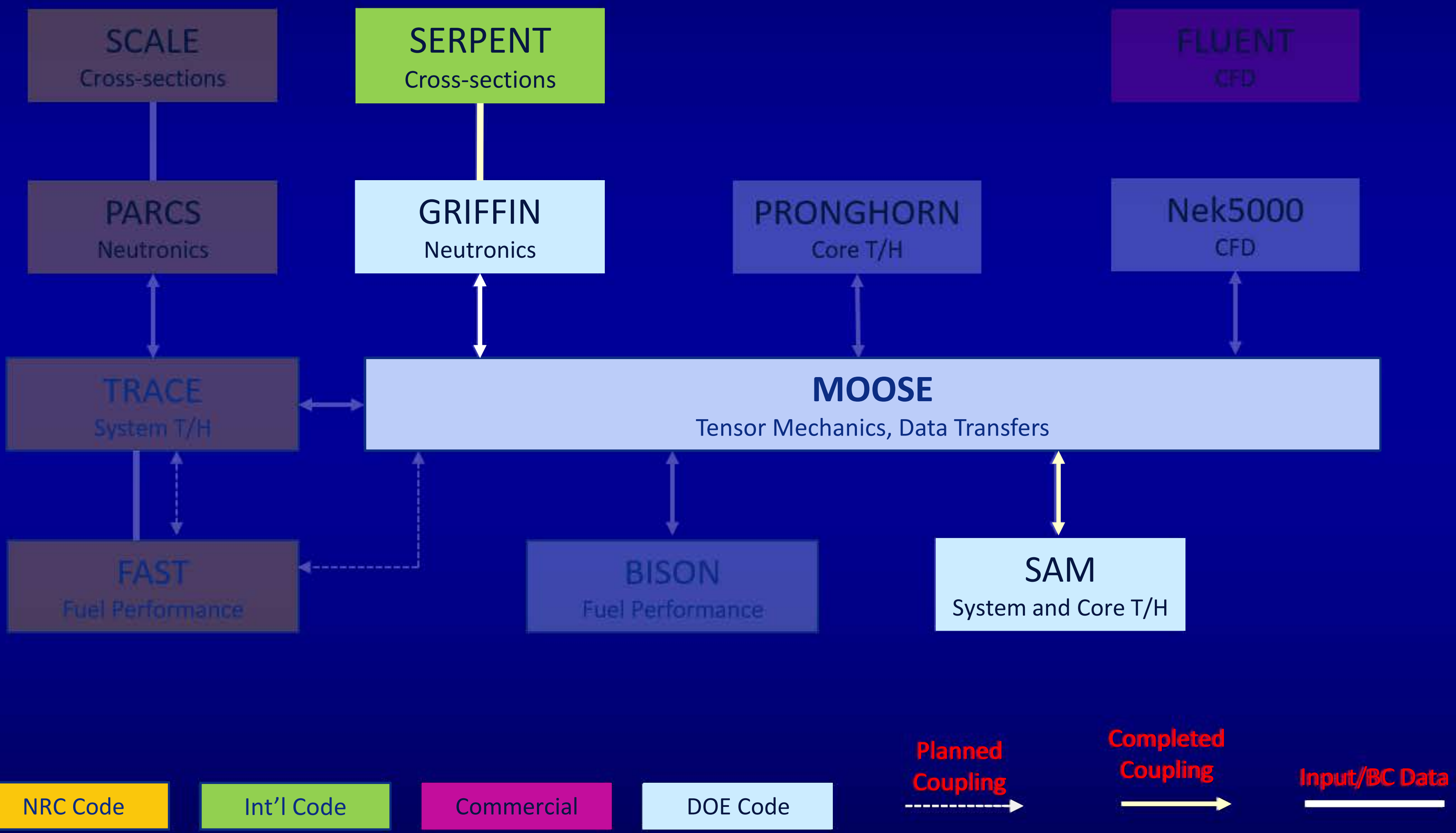
- loss of heat sink
- inadvertent reactivity insertion transients, including ATWS events
- localized heat pipe failure
- cascading loss of heat pipes
- seismic event (causing reactivity increase)
- events related to coupling the reactor to the power conversion unit
- monolith temperature and stress under normal operating conditions
- monolith temperature and stress under postulated accident conditions.

Phenomena

- monolith thermal stress (thermal expansion)
- single heat pipe failure (localized thermal conduction, gap conductance)
- machining and inspection of the monolith
- heat pipe performance (evaporator/condenser heat transfer, solidification)
- reactivity and core criticality (neutron leakage, reactivity feedback)

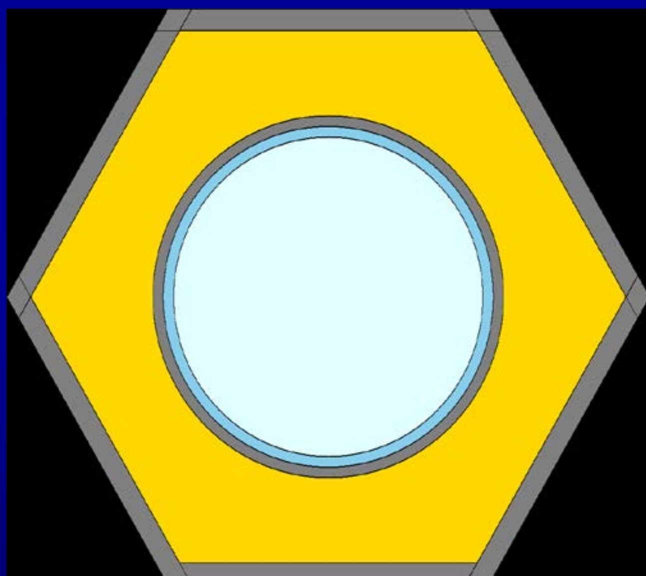
Comprehensive Reactor Analysis Bundle

BlueCRAB - MicroReactor

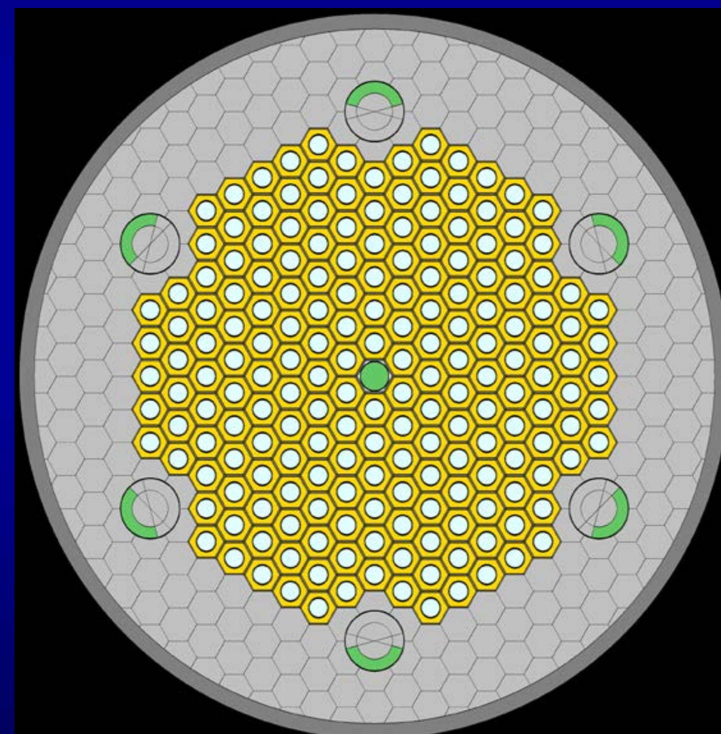


NRC's Microreactor "Reference Model"

- Based on the "Design A" microreactor described by Sterbentz et al [INL/EXT-17-43212, Rev. 1] , with several simplifications.

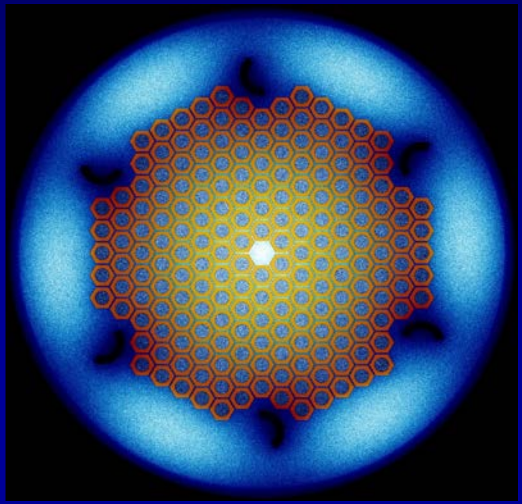


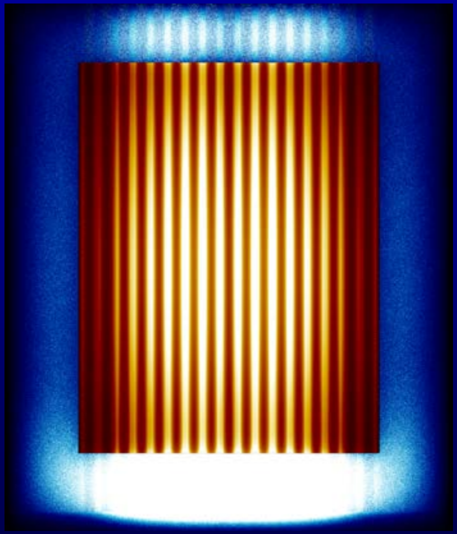
Fuel Element



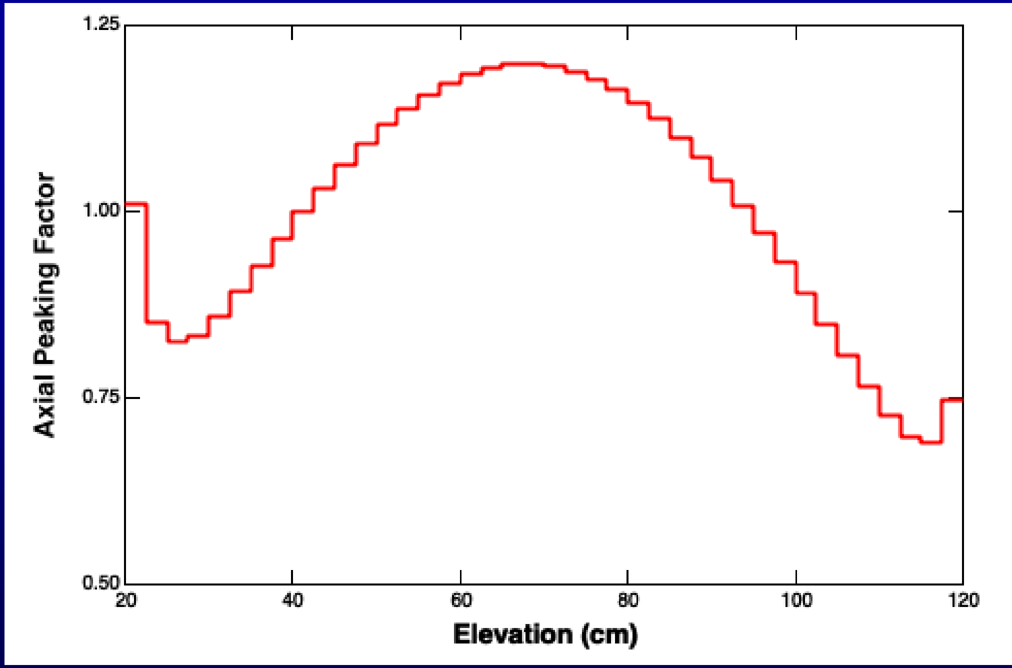
Reactor Core

SERPENT: Monte-Carlo Reference Solution

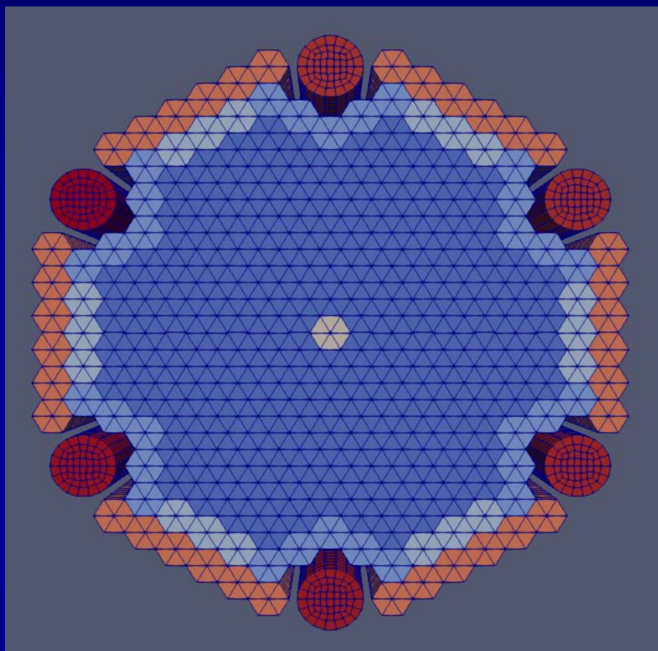


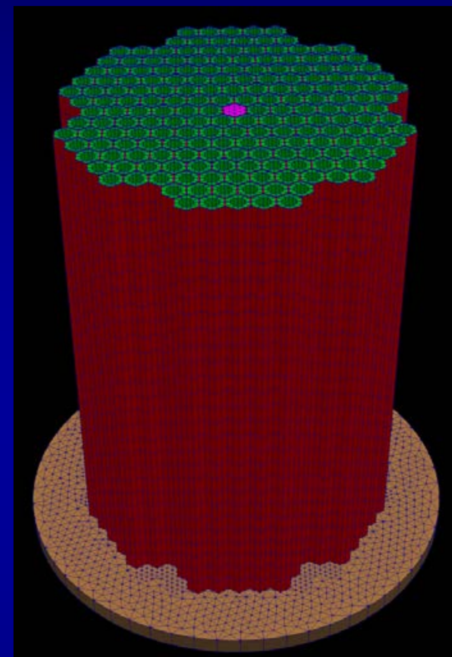


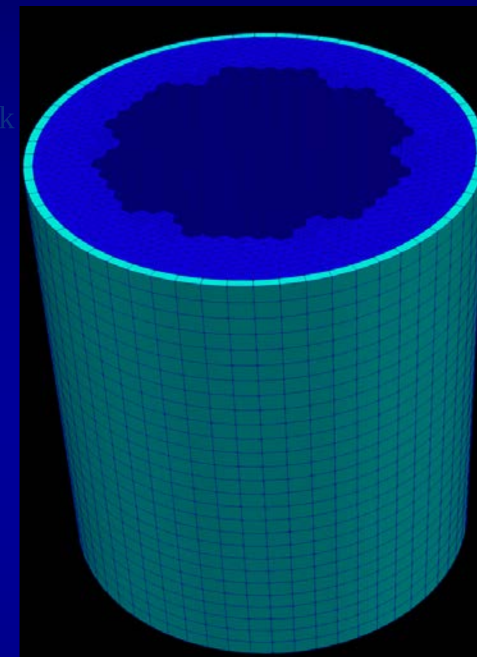
- SERPENT Calculations-
  - Cross-sections
  - Initial power distribution



Coupled Code Simulations



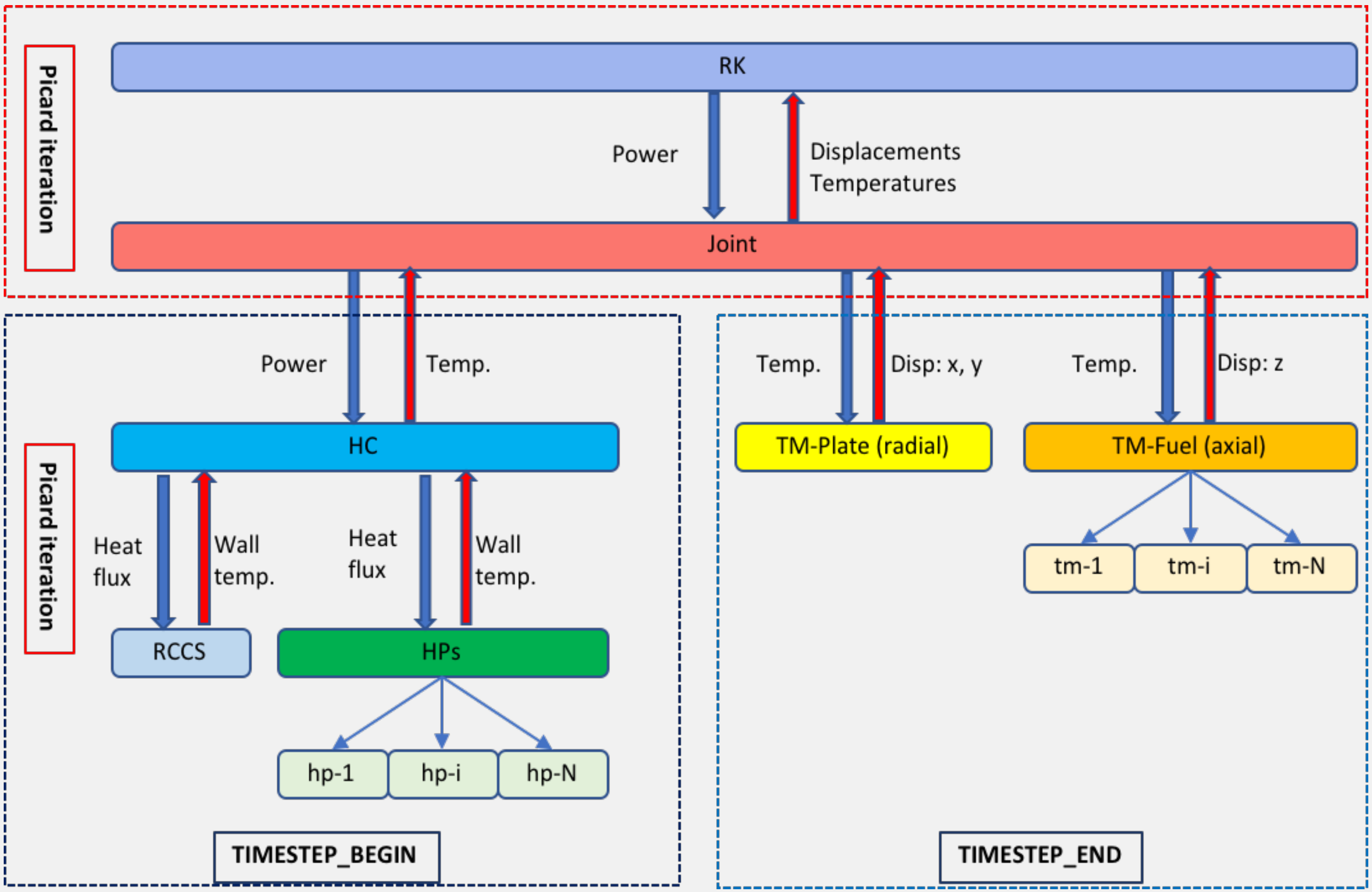




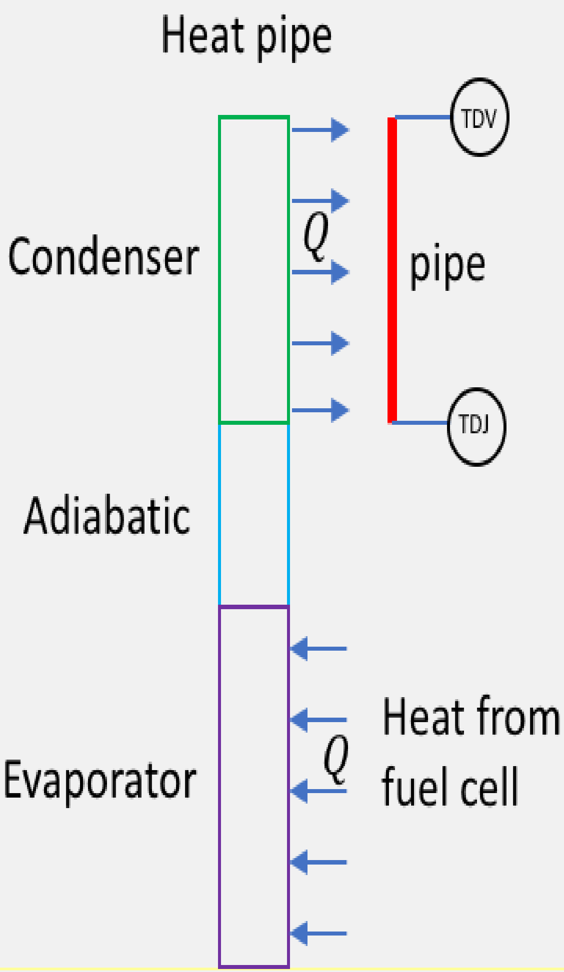
Reactivity Feedback Coefficients [pcm/K]	
Doppler Effect	-0.320
Axial Expansion	-0.905
Radial Expansion	-1.349
Combined Effect	-2.540

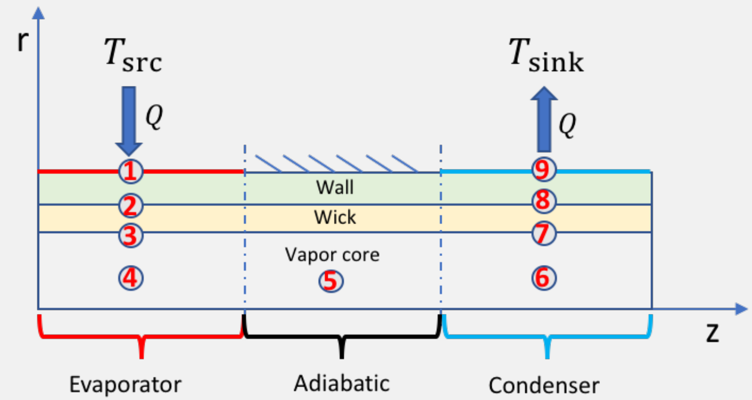
- MAMMOTH: Neutronics
- MOOSE: Tensor mechanics, conduction
- SAM: Heat pipes, secondary side HX

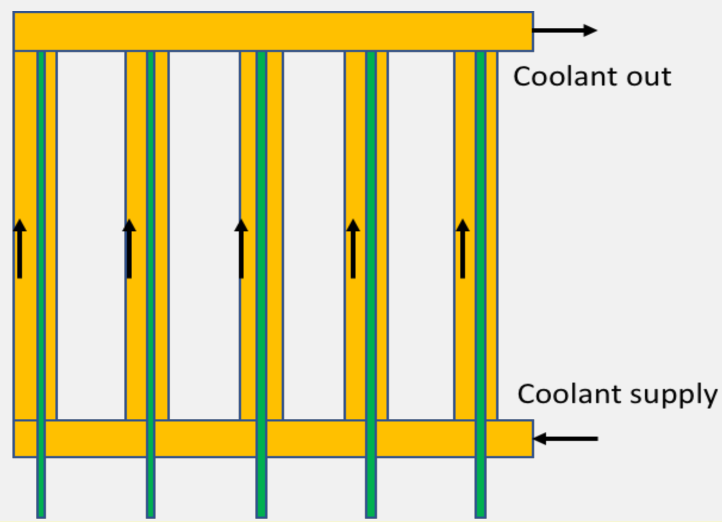
“MultiApp Code Coupling



SAM Heat Pipe Model

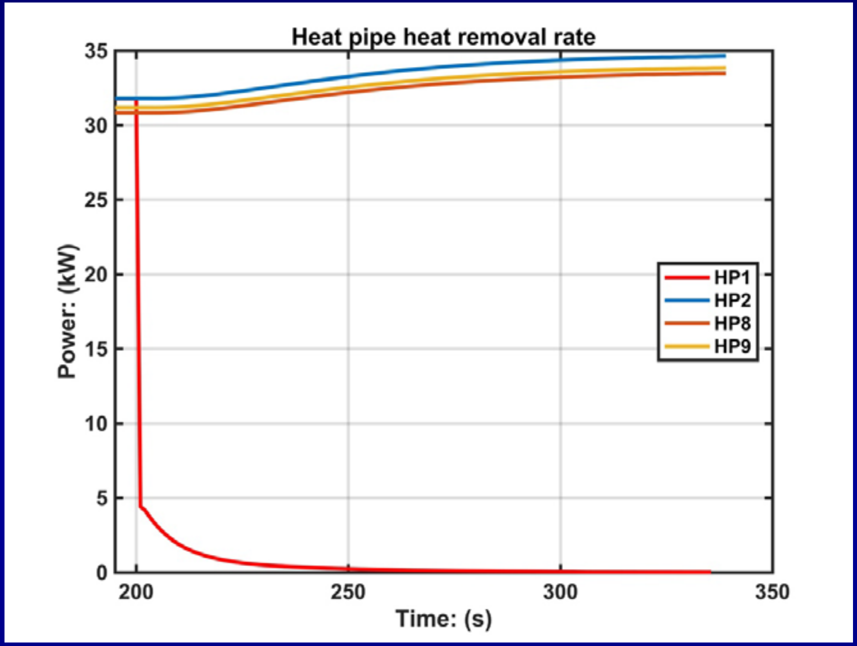






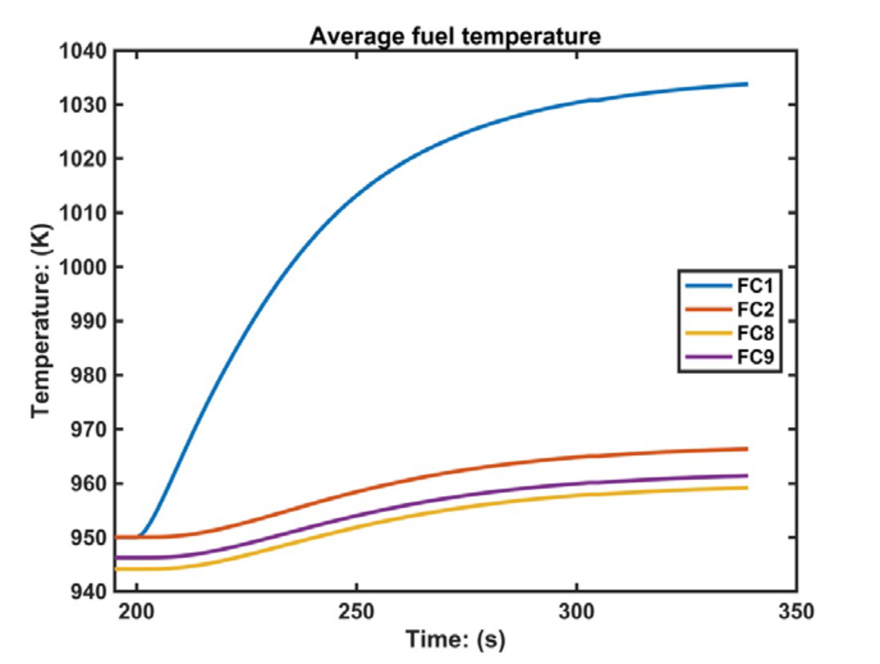
Heat pipes

Single Heat Pipe Failure

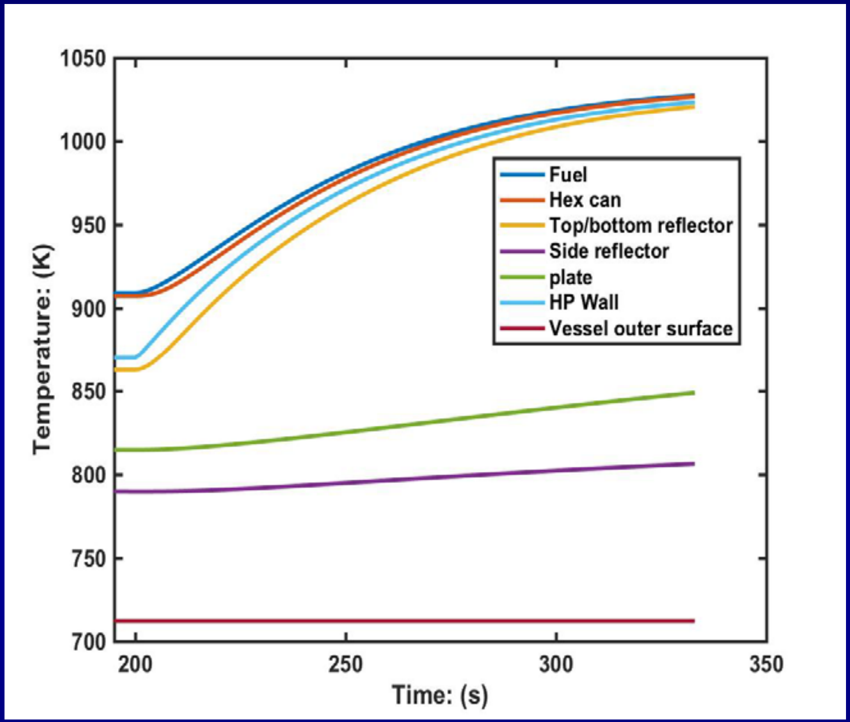


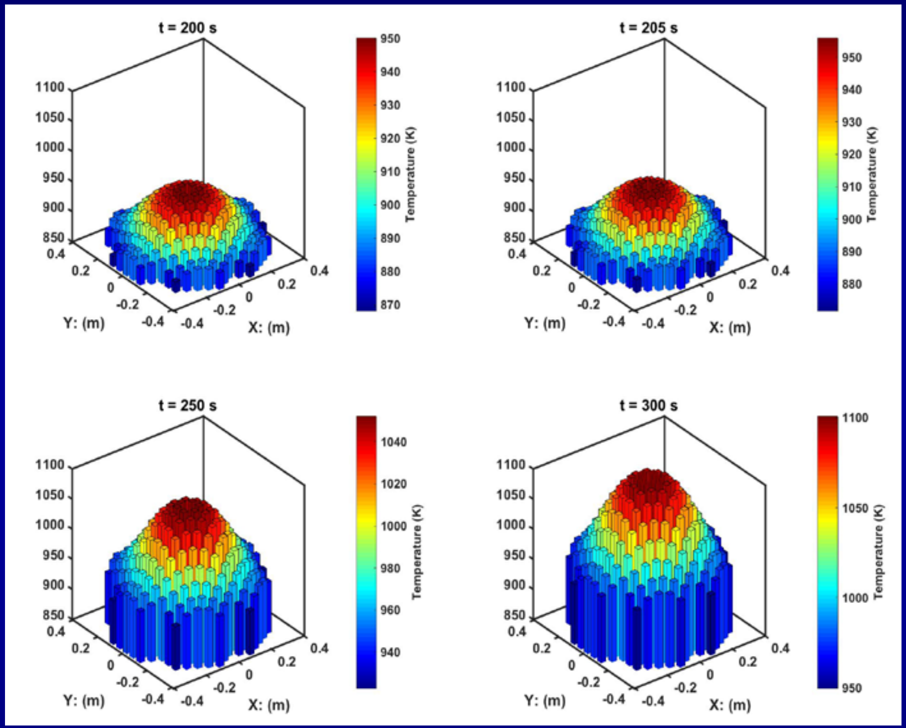
Fuel temperatures increase near failed HP and surrounding elements.

Heat removal by failed HP drops quickly, but increases in surrounding HPs.



Loss of Heat Sink





Heat removal by HPs stops and fuel temperatures increase. Strong negative reactivity due to core expansion results in decrease in core power.

Summary & Next Steps

- BlueCRAB system of codes has been demonstrated as capable of microreactor simulation.
- Verification & Validation remain important steps. Tests such as KRUSTY, MAGNET, MARVEL, Godiva can provide data for coupled code simulations.
- Improvement of heat pipe model, secondary side HX, "exterior" cooling models.
- Development of microreactor models to assist regulatory review and investigate safety margins.