OAK RIDGE National Laboratory

Multiphysics Simulations of Molten Salt Reactors

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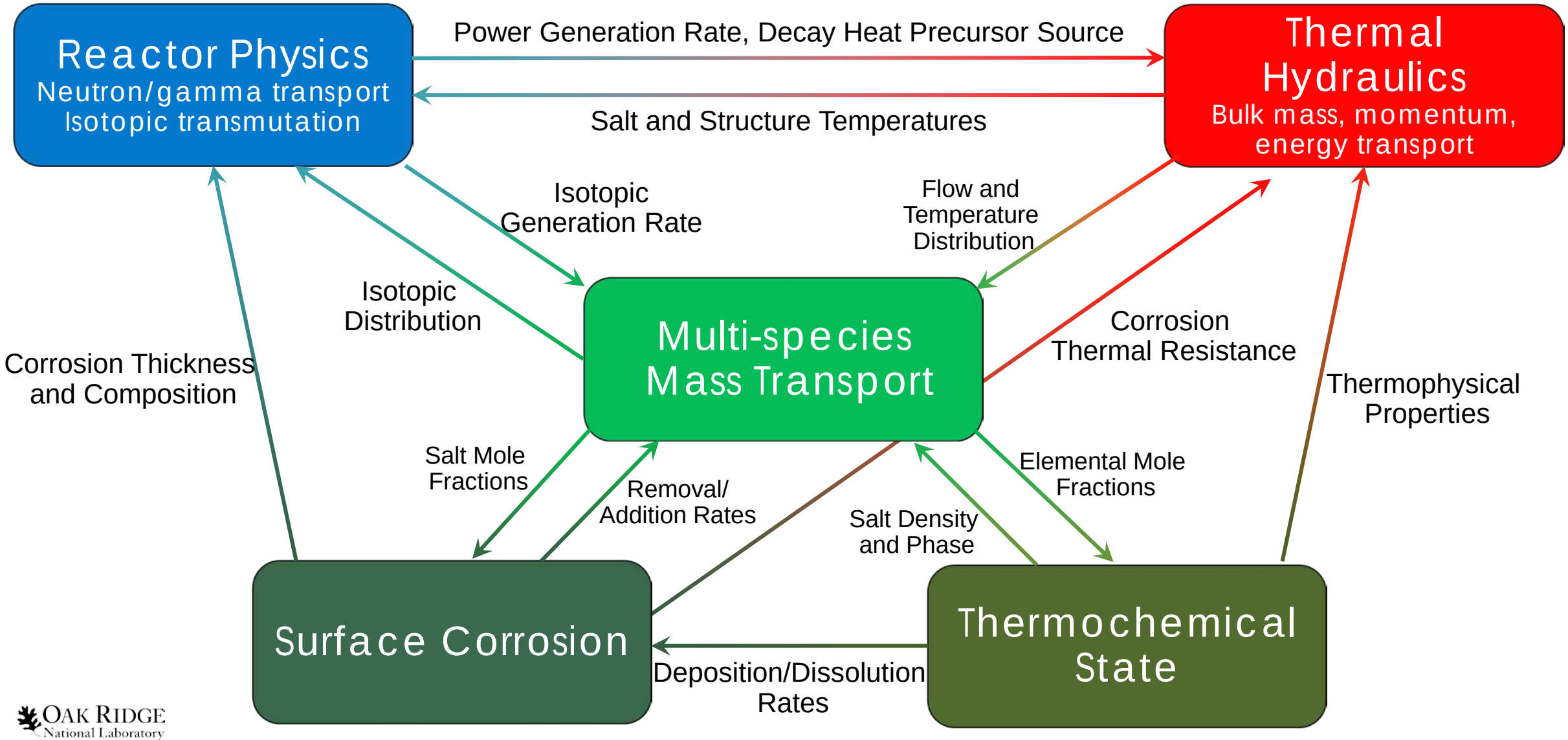
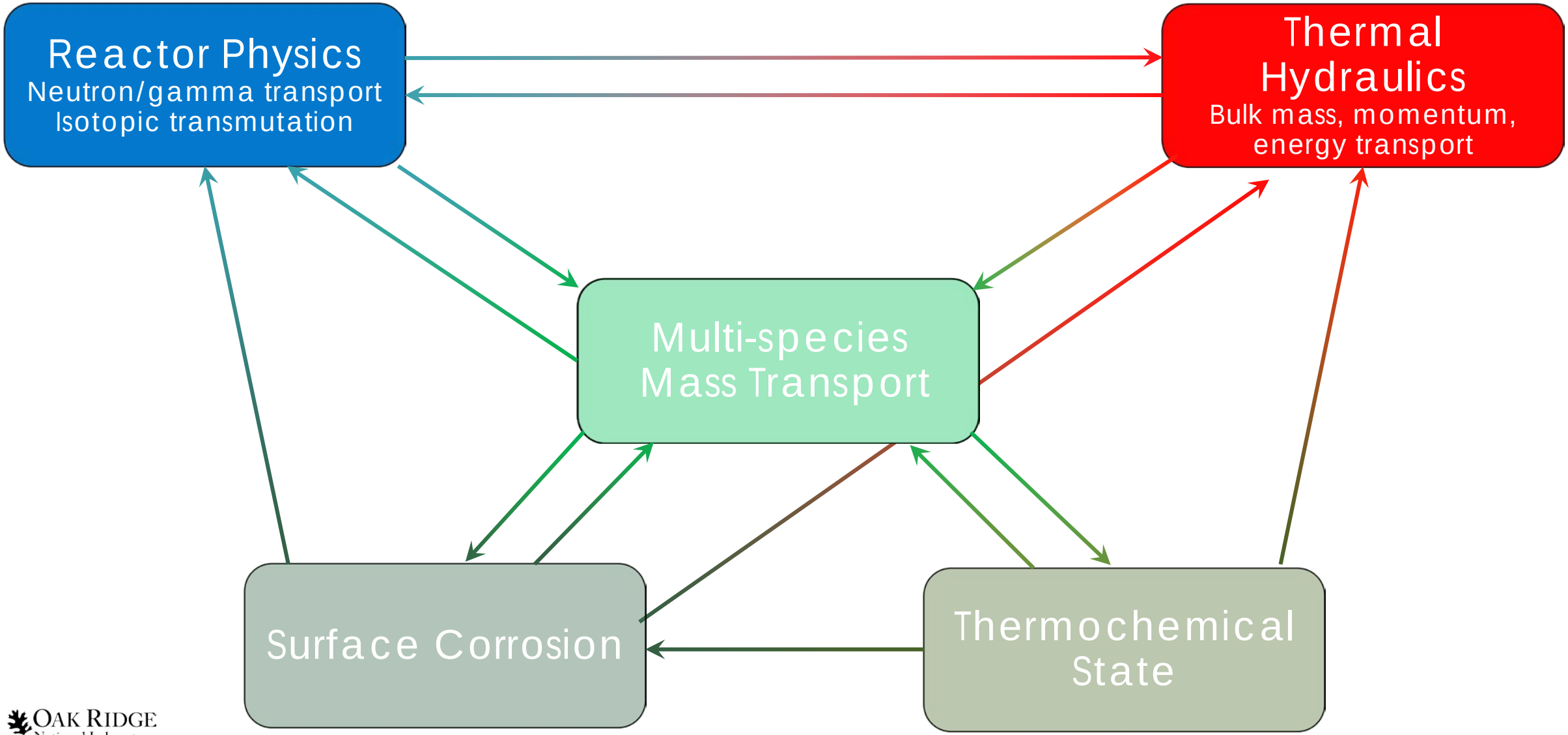
U.S. DEPARTMENT OF ENERGY

Multiphysics simulations are required for MSRs

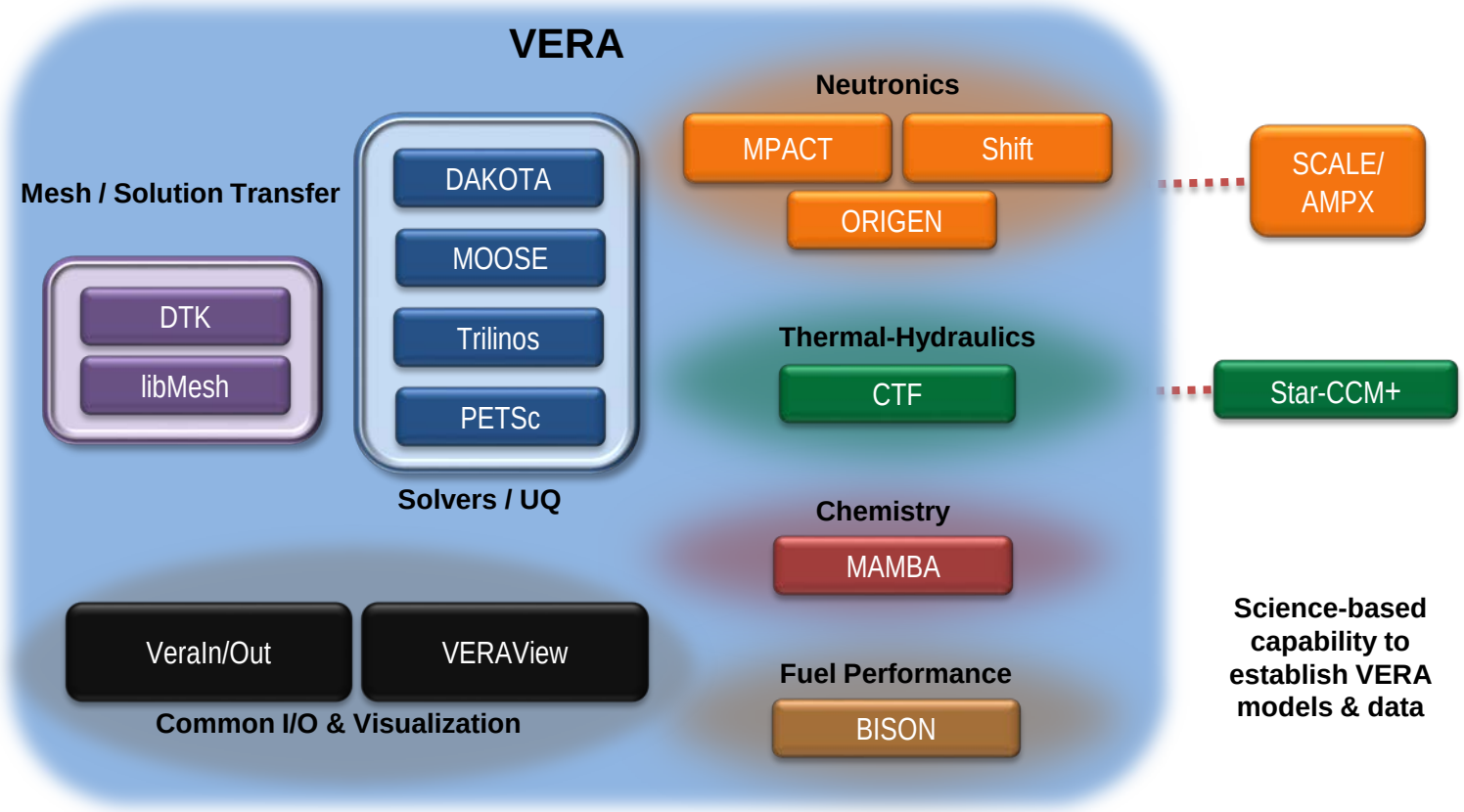


Existing Reactor Physics and Thermal Hydraulics



Adapting CASL tools for MSR analysis

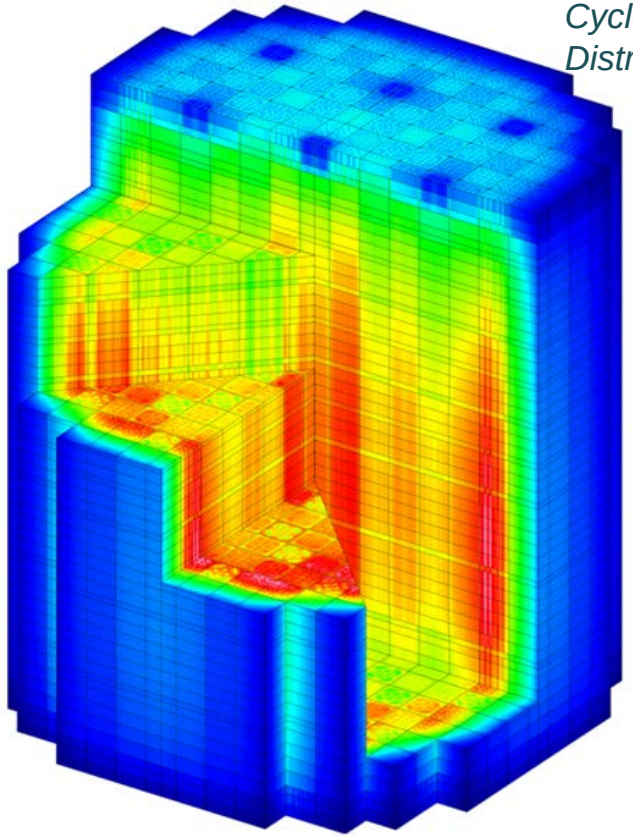
- In FY17, ORNL funded an LDRD to adapt tools developed for the CASL program to model molten salt reactors



VERA Core Simulator Methods

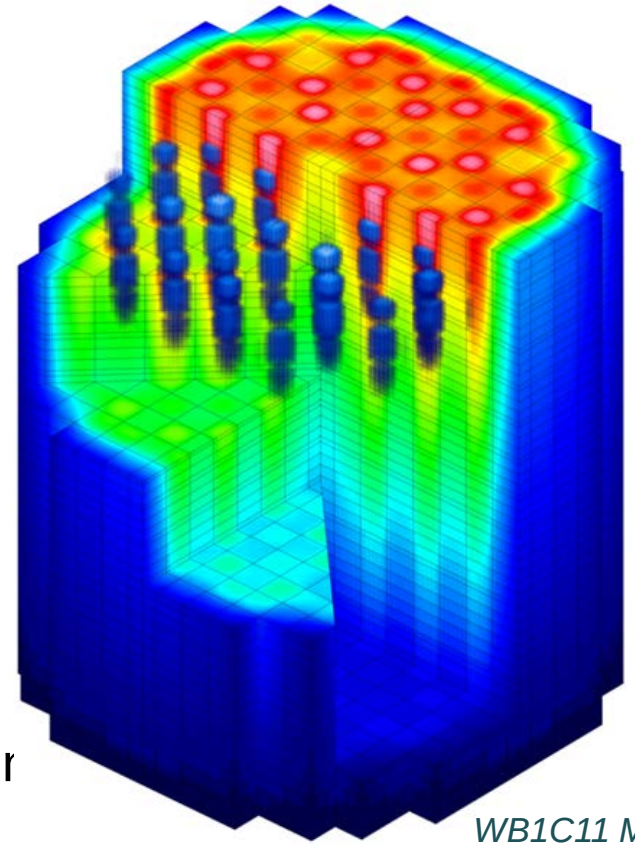
Virtual Environment for Reactor Applications

WB1C11 Beginning-of-Cycle Pin Power Distribution

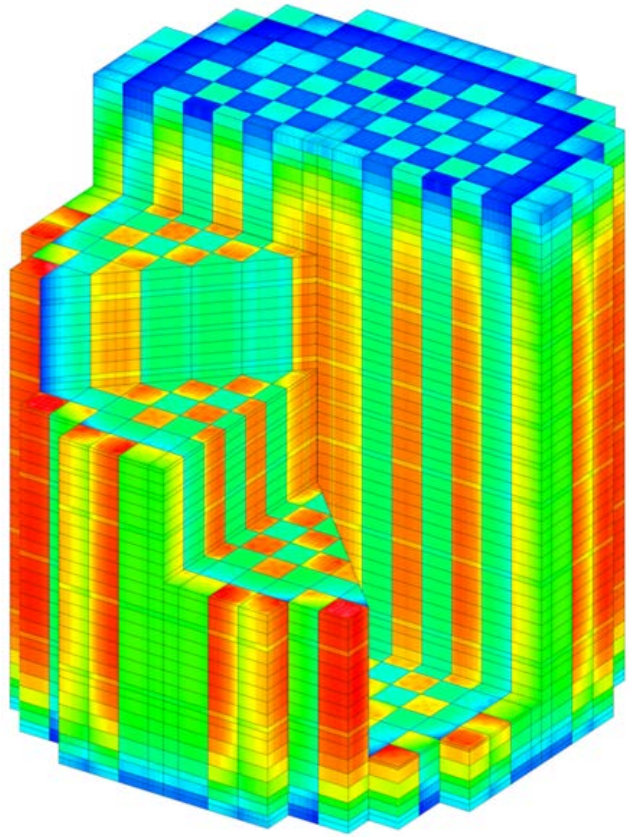


CTF

Subchannel thermal-hydraulics with transient two-fluid, three-field (i.e., liquid film, liquid drops, and vapor) solutions in 14,000 coolant channels with crossflow



WB1C11 End-of-Cycle Pin Exposure Distribution



MPACT

Advanced pin-resolved 3-D whole-core neutron transport in 51 energy groups and >5M unique cross sectior regions

ORIGEN

Isotopic depletion and decay in >2M regions tracking 263 isotopes

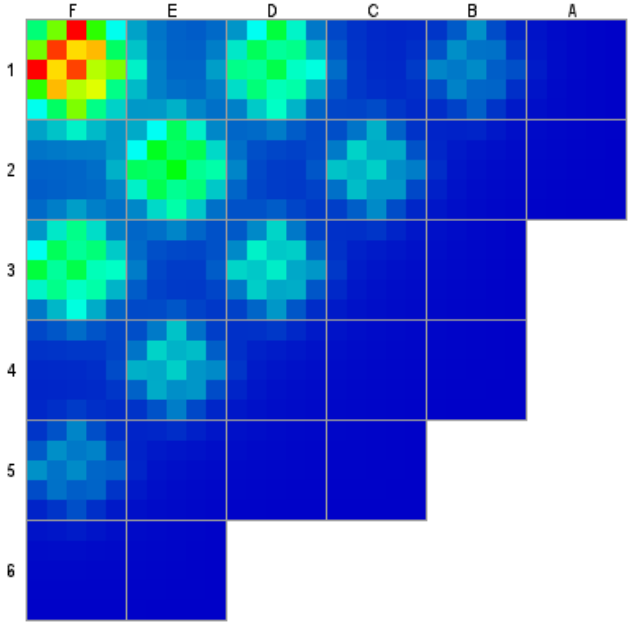
WB1C11 Middle-of-Cycle Coolant Density Distribution

Demonstration of coupled calulation

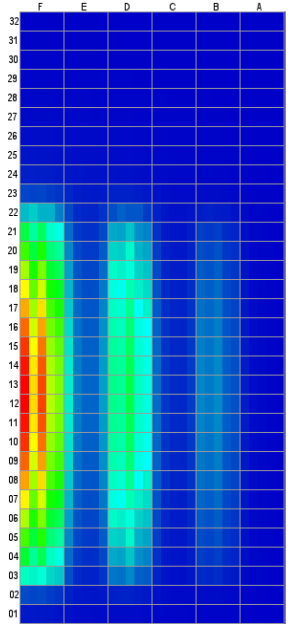
Critical configuration

First moderator bank inserted to 66%

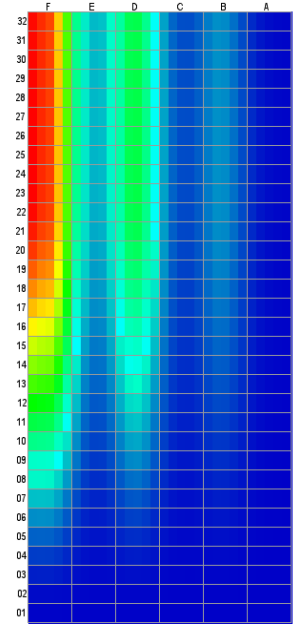
Radial Power Distribution

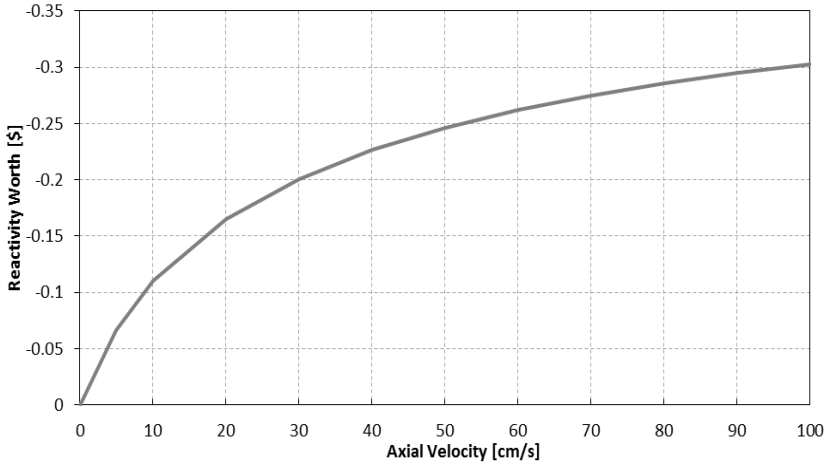


Axial Power Distribution



Axial Temp Distribution

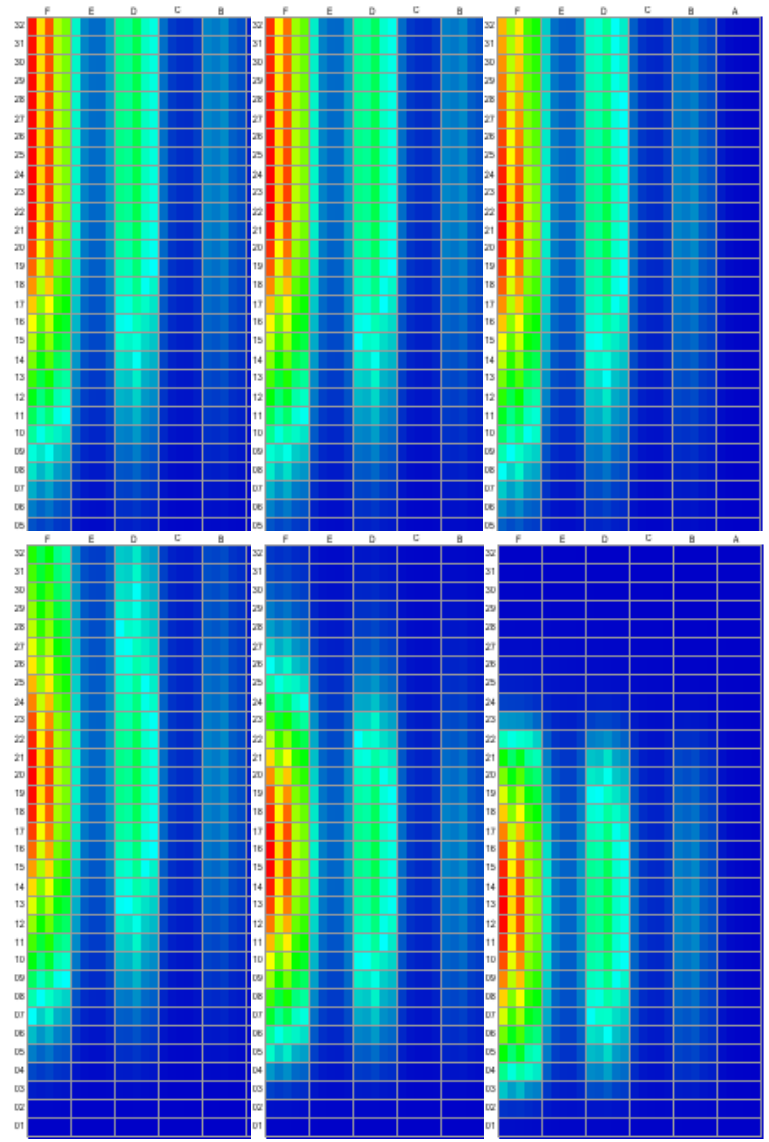




Group 1
T=55.45 s

Group 2
T=21.80 s

Group 3
T=6.36 s



Group 4
T=2.19 s

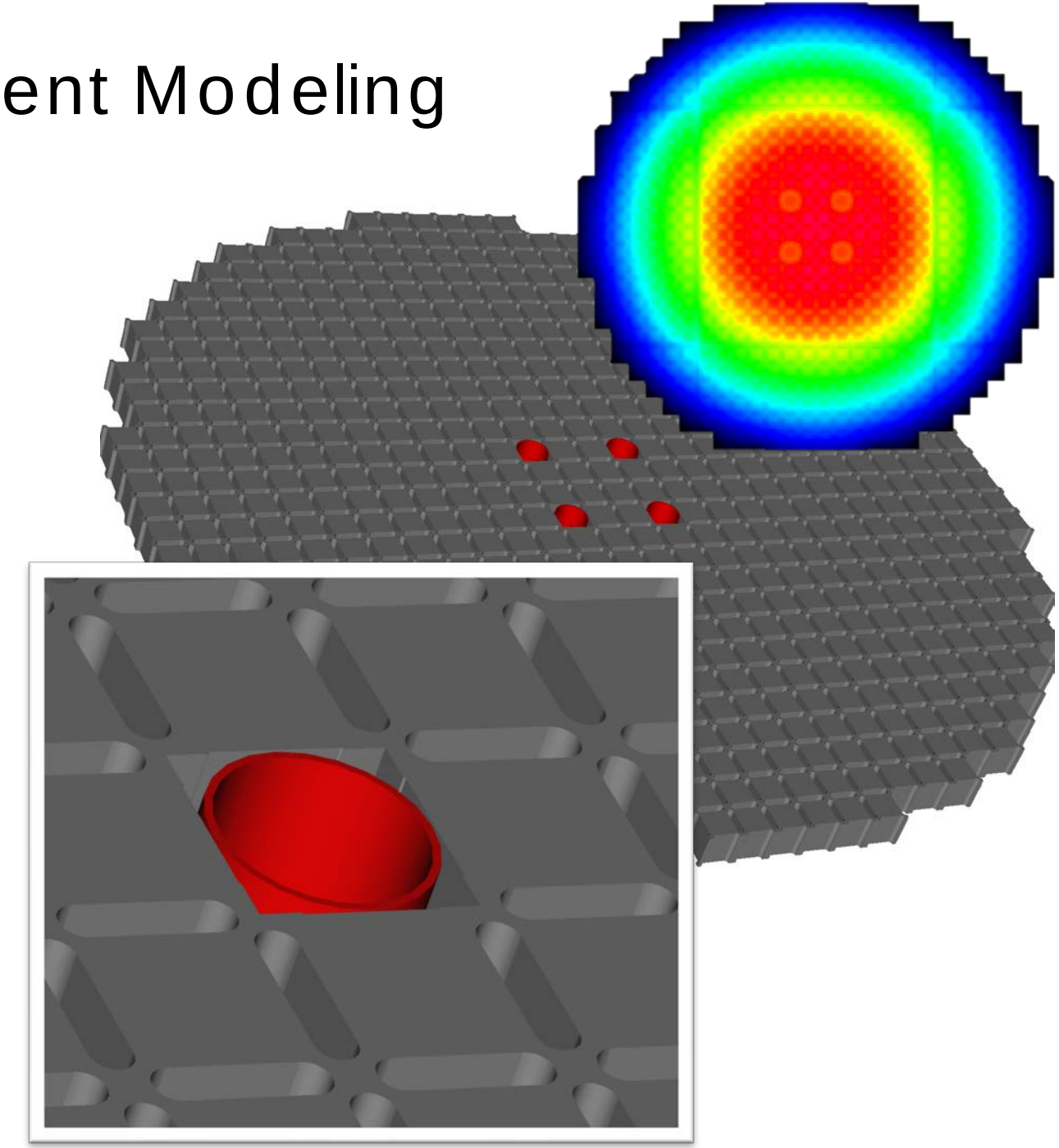
Group 5
T=0.51 s

Group 6
T=0.08 s

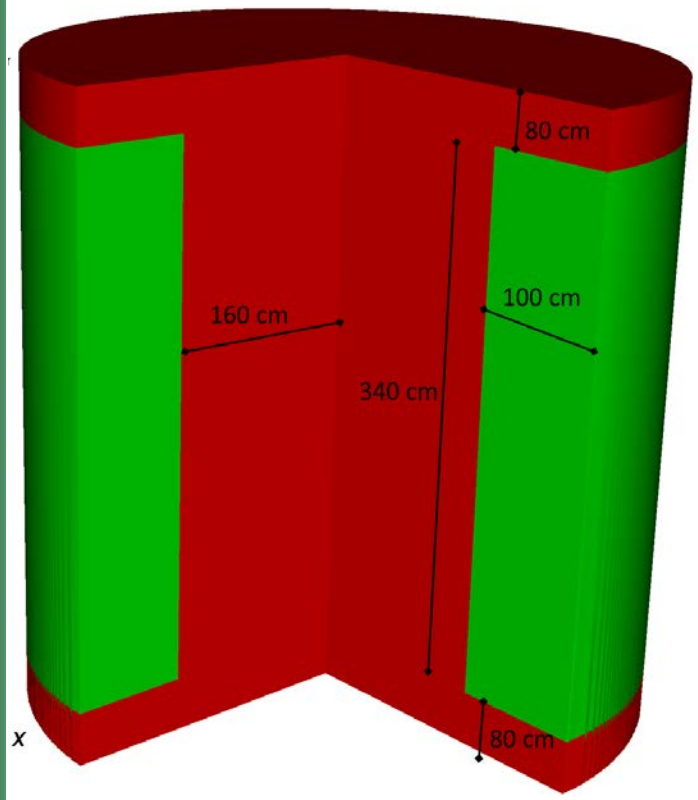
Delayed Neutron Precursor Concentrations

Molten Salt Reactor Experiment Modeling

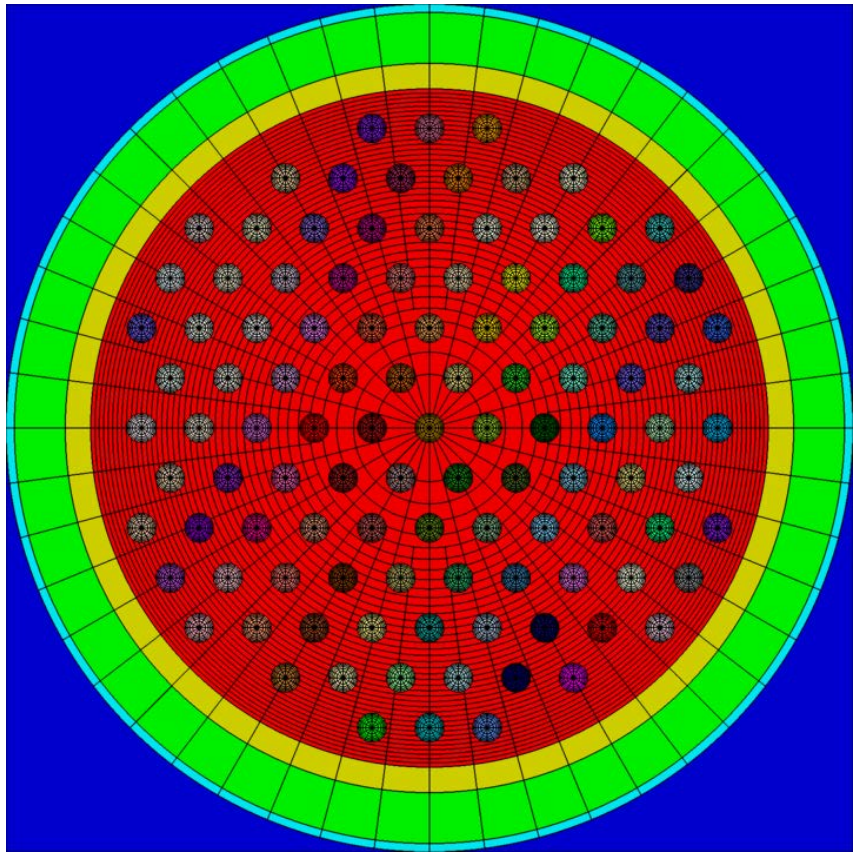
- Extending geometry capability to support wide range of advanced reactors
- Setting up models based on first critical with U-235
- Gathering data on additional critical configurations and transient tests



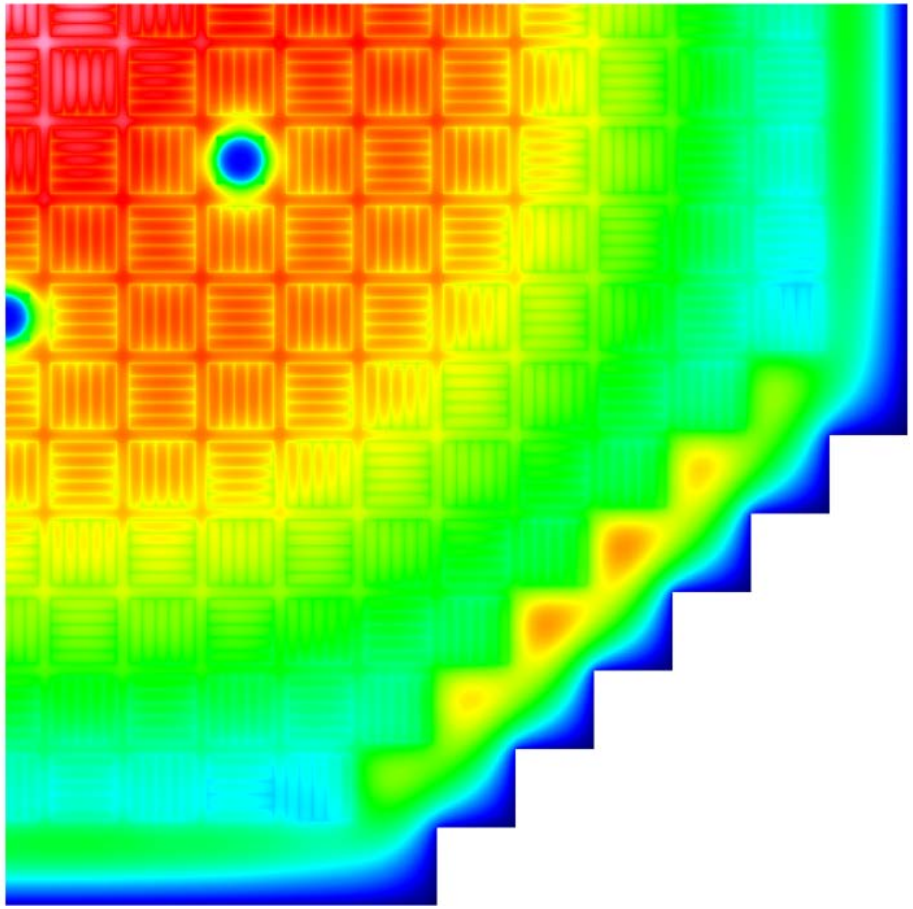
Extending geometry to support more reactors



Molten Chloride Reactor



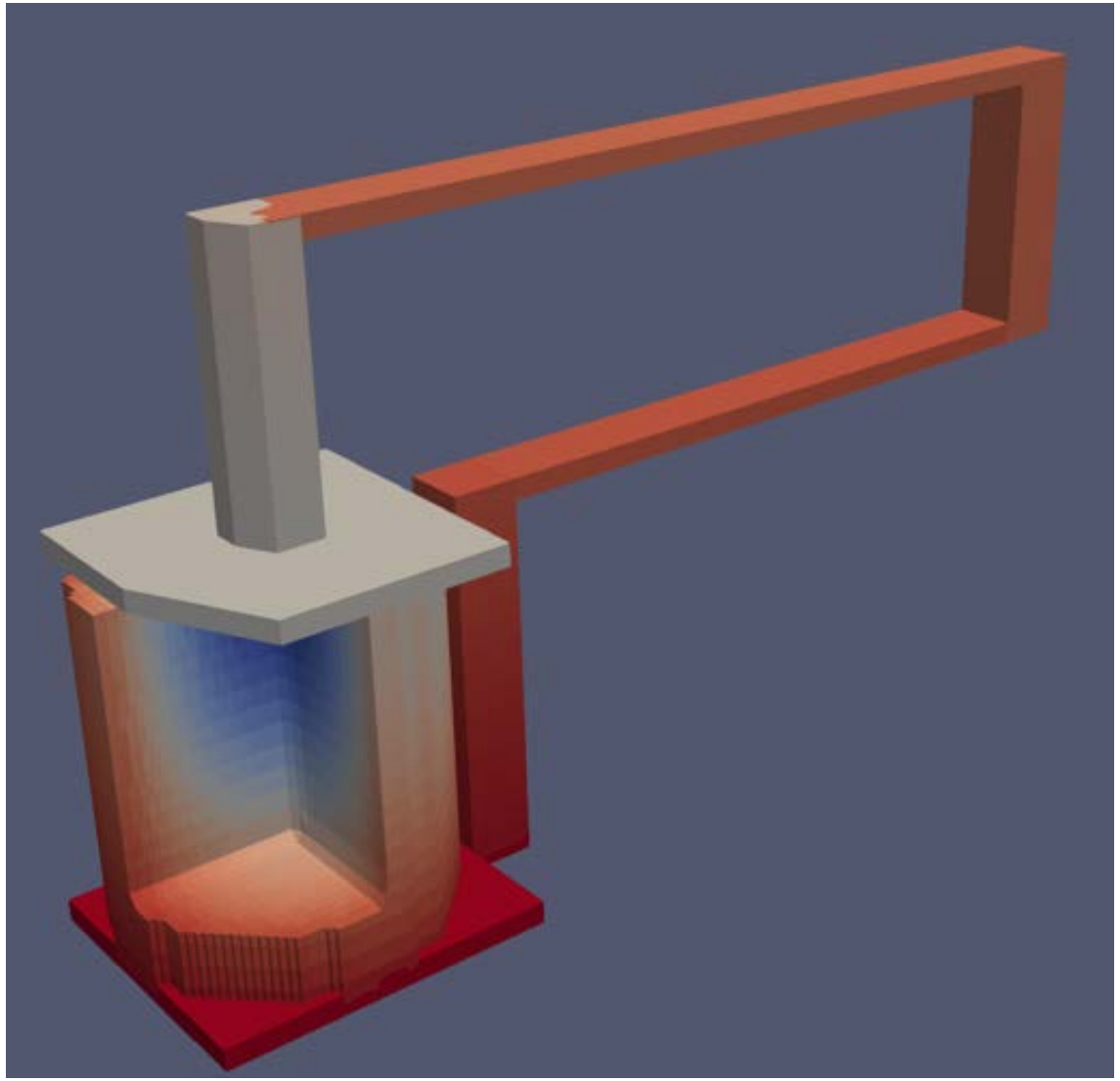
Hexagonal Pitch Graphite Moderated



Molten Salt Demonstration Reactor

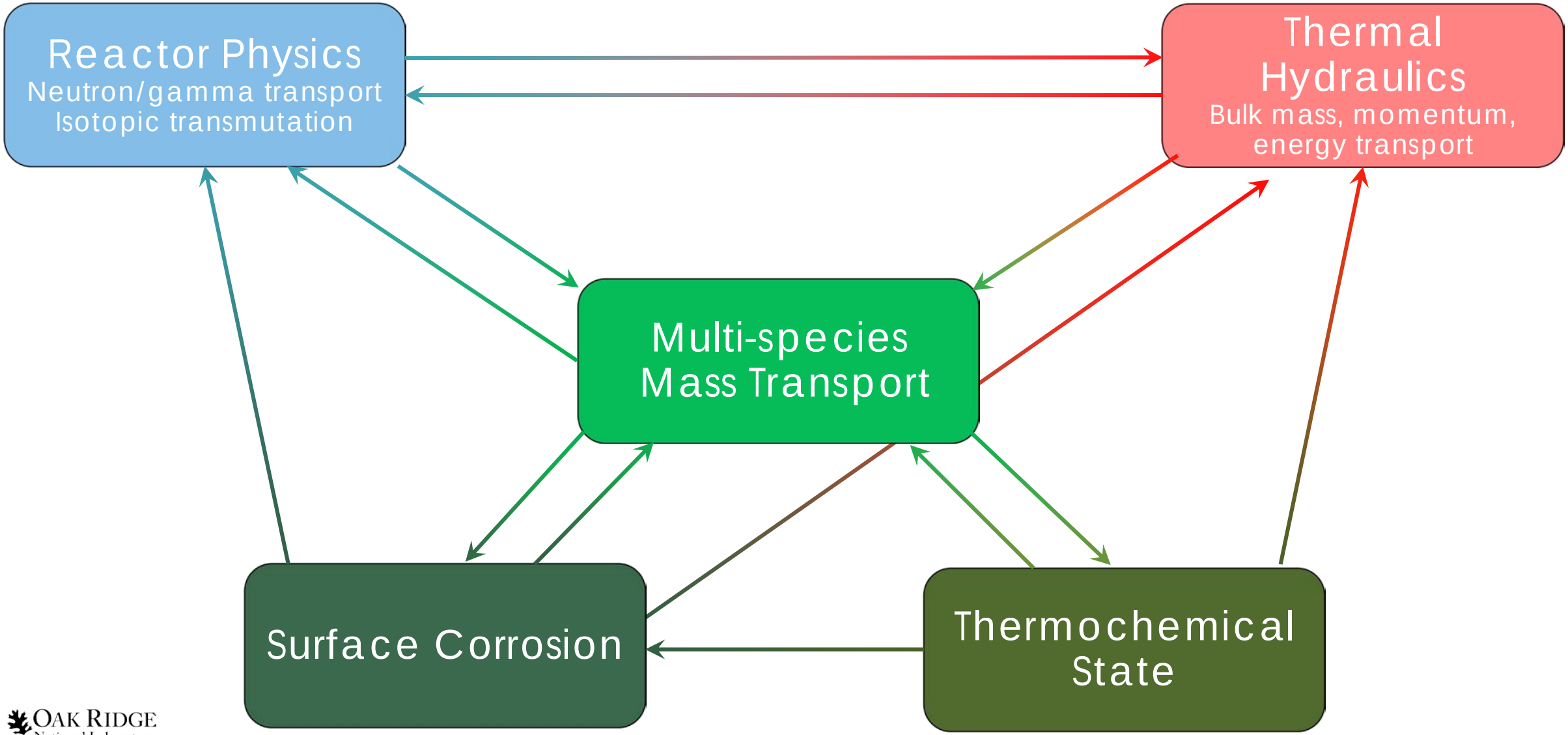
Extensions to CTF

- Extensions to add salt properties
- Addition of system components for testing
- General species transport module
- Interface with mass transport
  - Chemical reactions
  - Nuclear production/decay
  - Corrosion/deposition models



Density in Primary Loop MSRE Model

Build in unique capability related to MSRs



Two-phase boundary condition

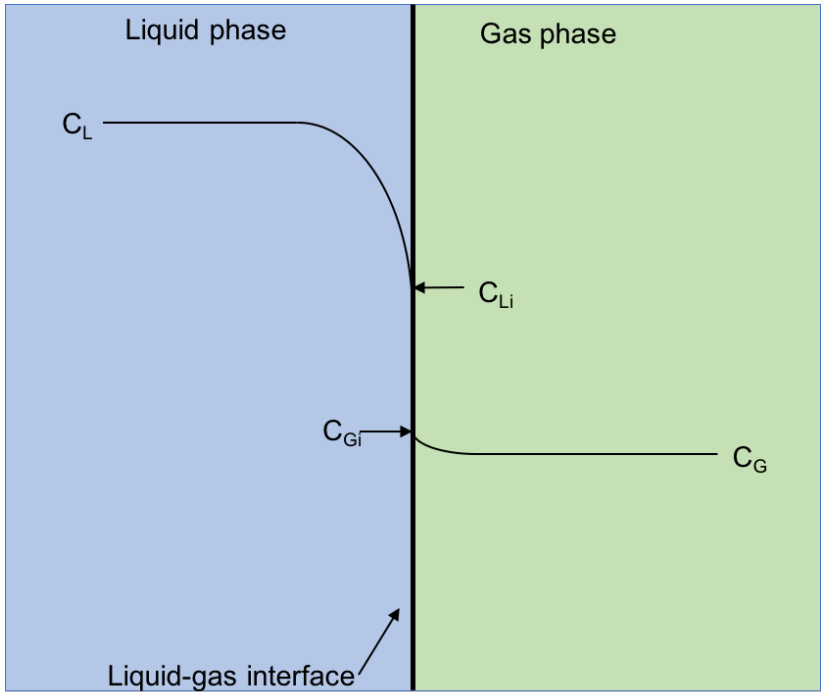
- Convection boundary condition

$$-D_j \left.\frac{dN_j}{dx}\right|_B = k_{cj}(N_{j(interface)} - N_{j\,bulk})$$

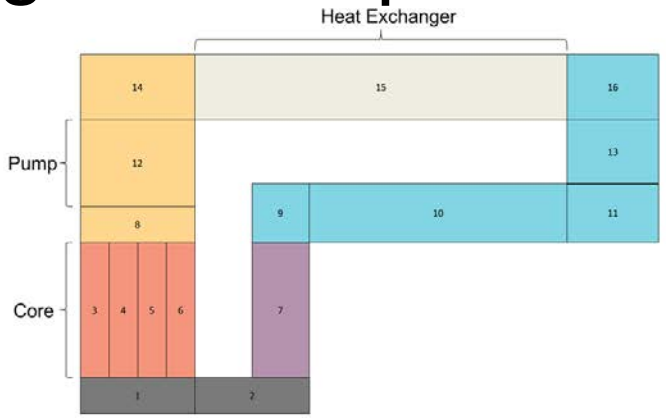
- Liquid gas interface

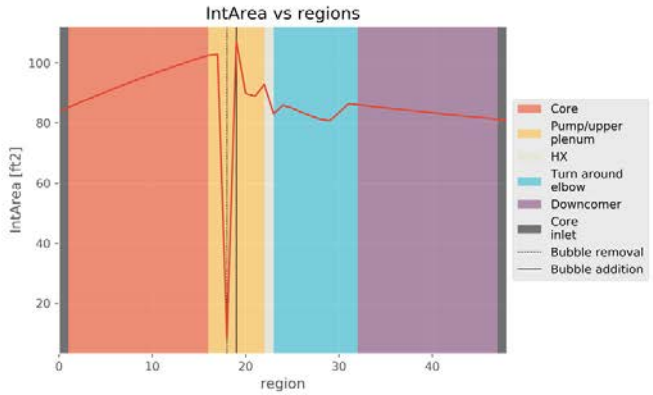
$$N_{Li} = KN_{Gi}$$

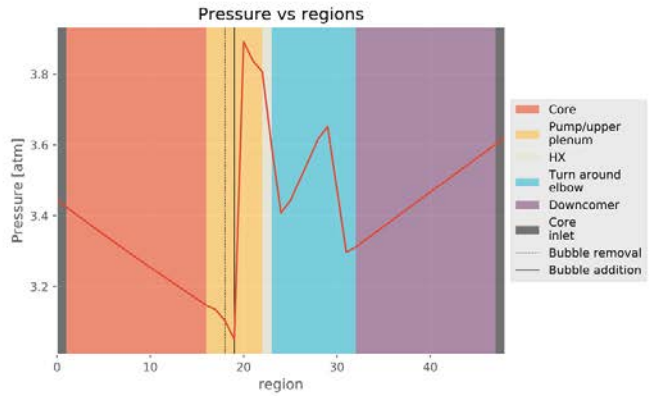
- K is a proportionality constant which can be estimated using Henry's Law
- $N^{Interface} = HRTN^{bubble}$

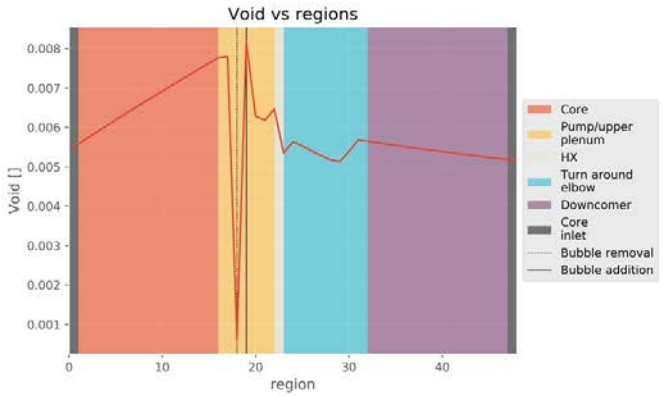


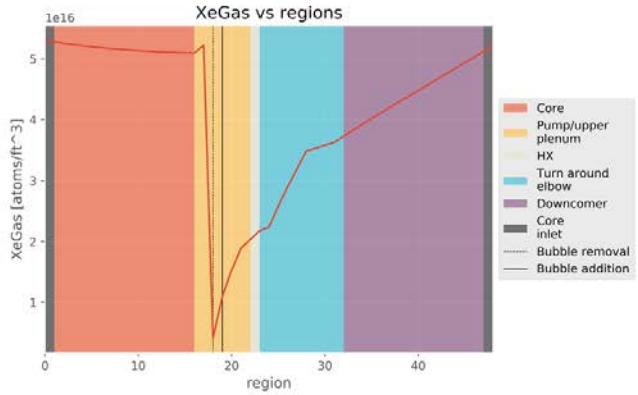
Initial results gas Transport

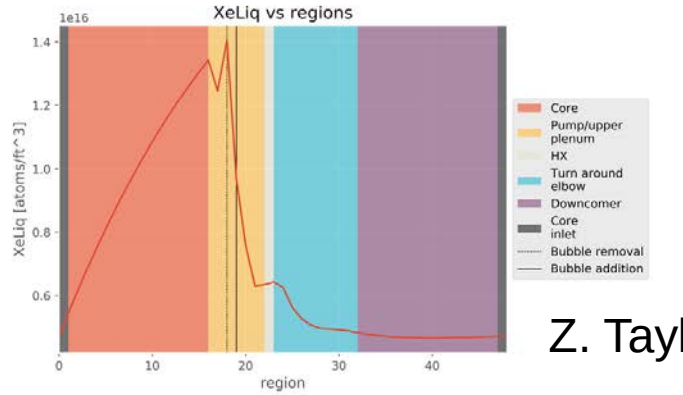






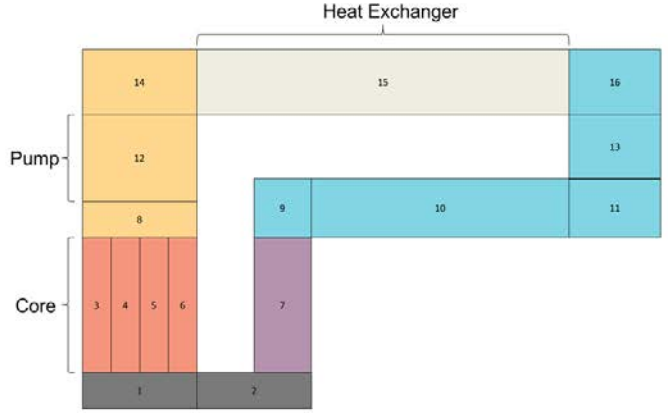


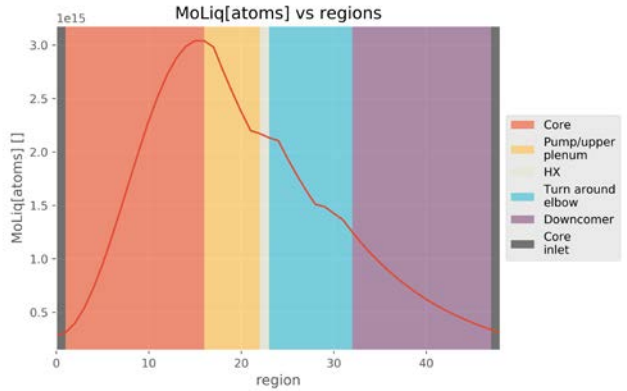


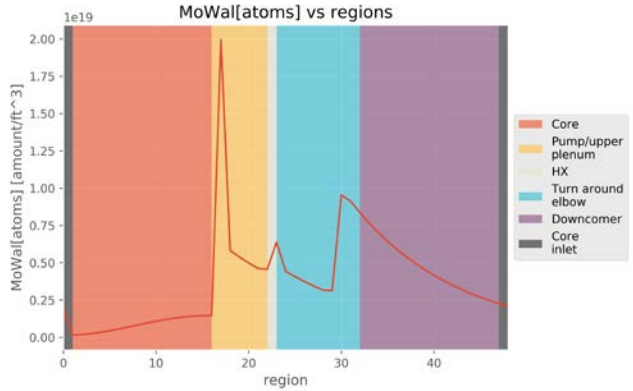


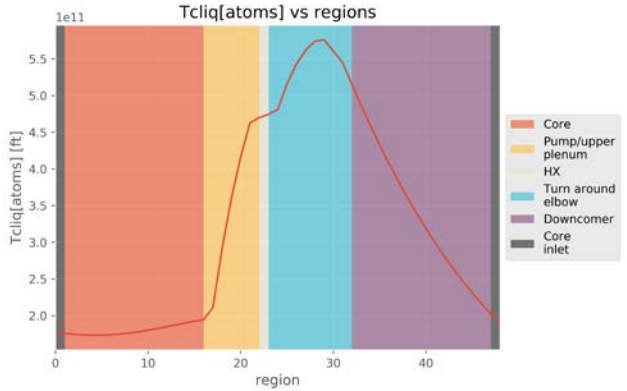
Z. Taylor UTK

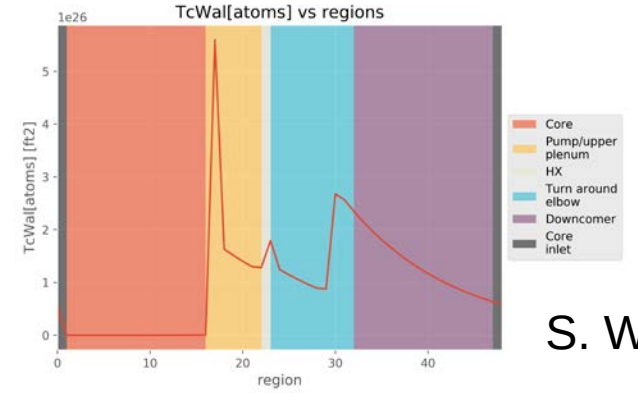
Initial Results noble metal transport











S. Walker RPI

Mass Transport with Nuclear Decay

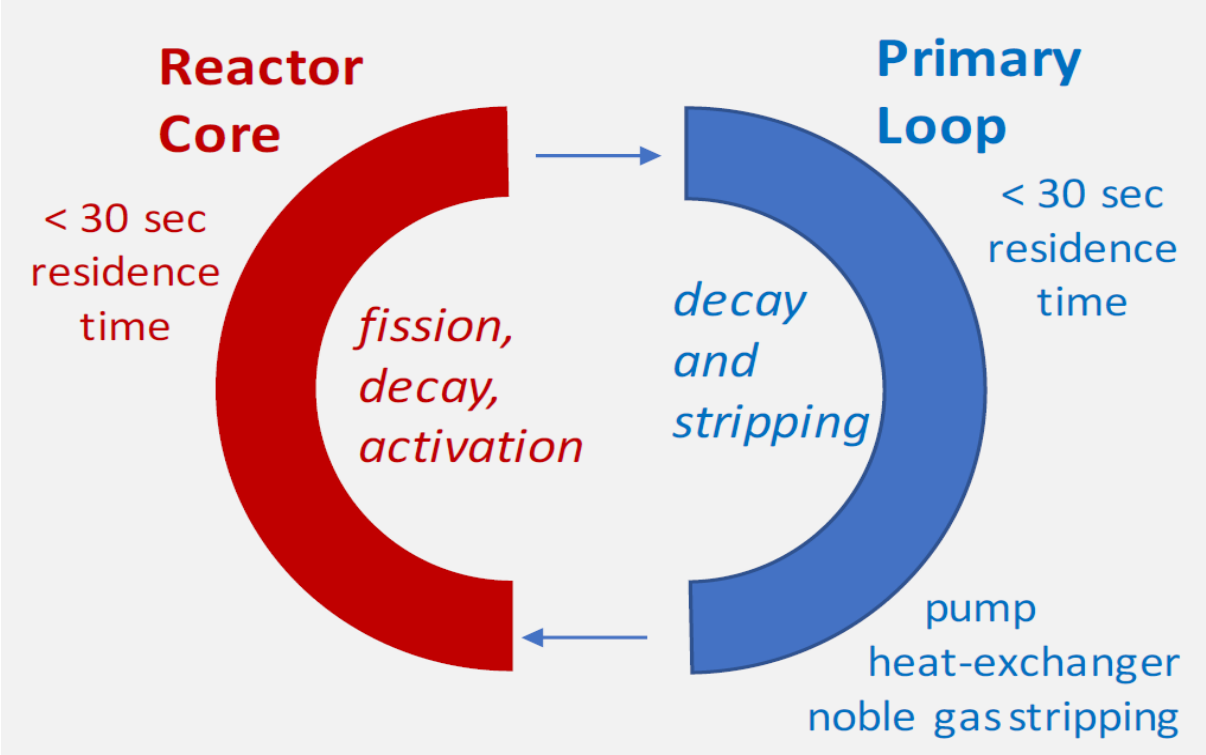
$^{137}I \rightarrow ^{137}Xe \rightarrow ^{137}Cs$

25 sec. 4 min.

$^{99}Zr \rightarrow ^{99}Nb \rightarrow ^{99}Mo \rightarrow ^{99}Tc$

2.1 sec. 15 sec. 2.75 days

soluble
sometimes soluble
insoluble
gaseous



$^{131,132}Cd \rightarrow ^{131}In \rightarrow ^{131}Sn \rightarrow ^{131}Sb \rightarrow ^{131}Te \rightarrow ^{131}I \rightarrow ^{131}Xe$

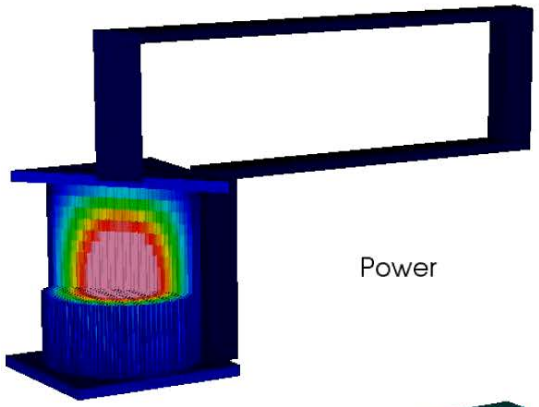
<1 sec <1 sec 1 min. 23 min. 25 min. 8 days

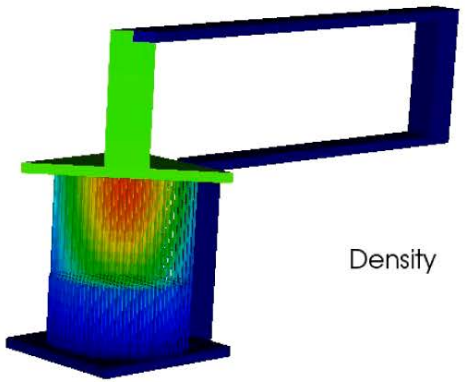
Thermochemistry

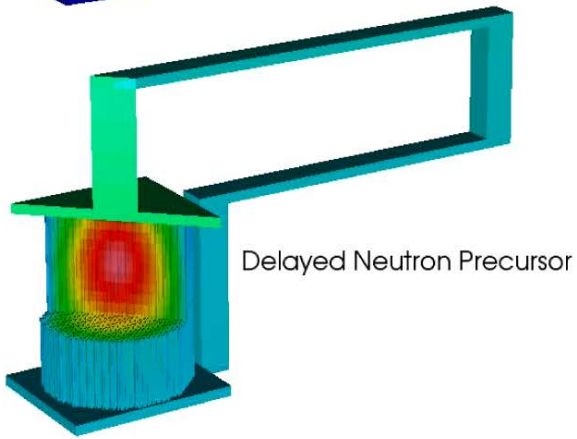
- Developing equilibrium thermochemistry code Thermochimica to add quasi-chemical model for ionic liquids
- CTF/MPACT provide local temperature, pressure, and elemental fractions
- Thermochemistry can provide
  - Phase / chemical state
  - Fluid density / specific heat

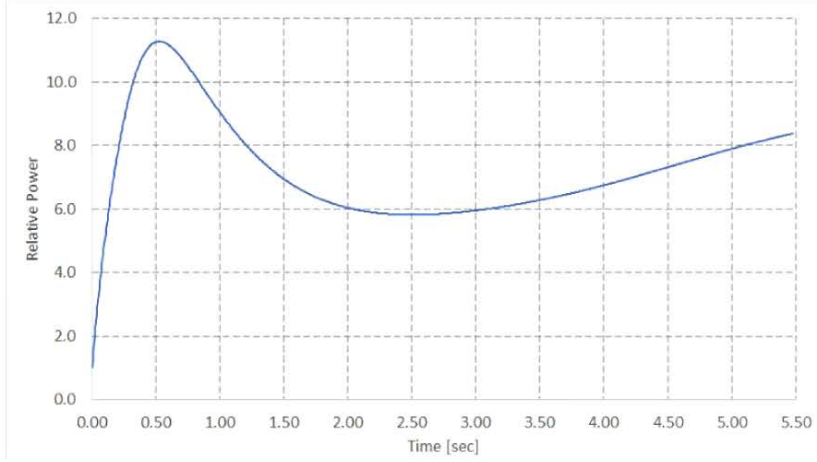
Putting it all together

- Coupled neutron transport, TH, and delayed precursor
- 20 cent reactivity insertion numerically implied at t=0

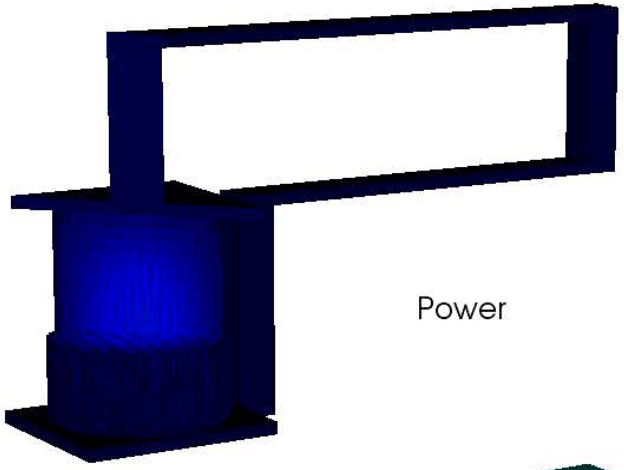




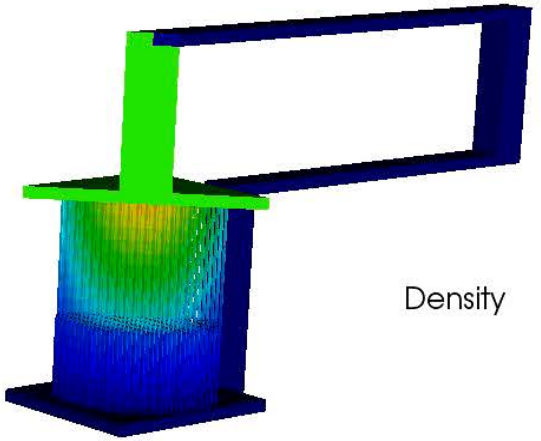




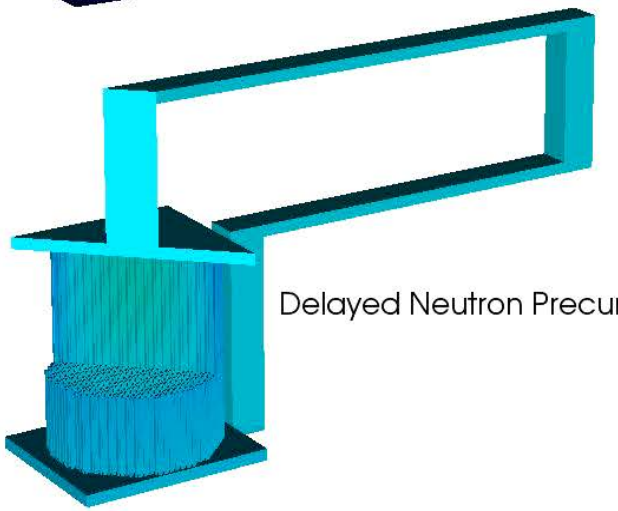
Fully coupled multiphysics transient demonstration



Power

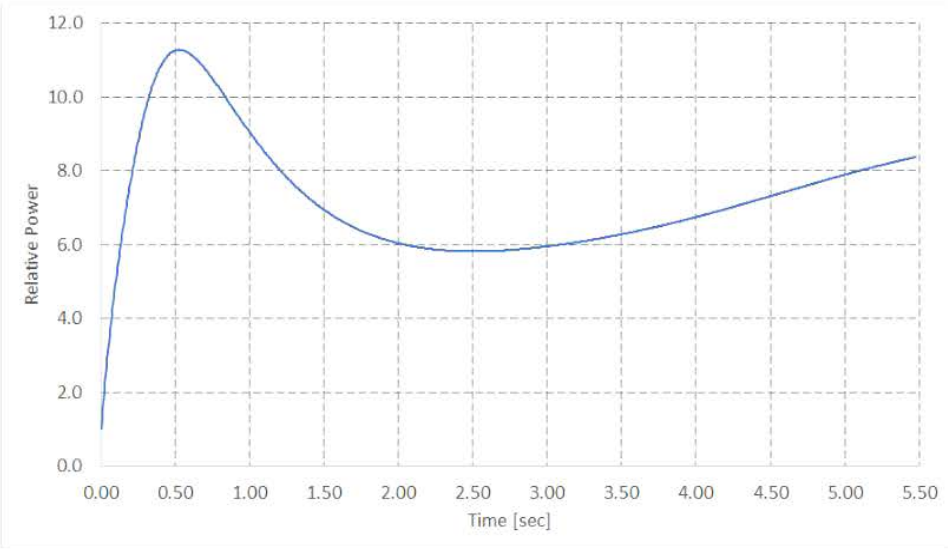


Density



Delayed Neutron Precursor

Time=0 s



Questions

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