Foundational Development of an Advanced Burner Reactor Integrated Safety Code

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories

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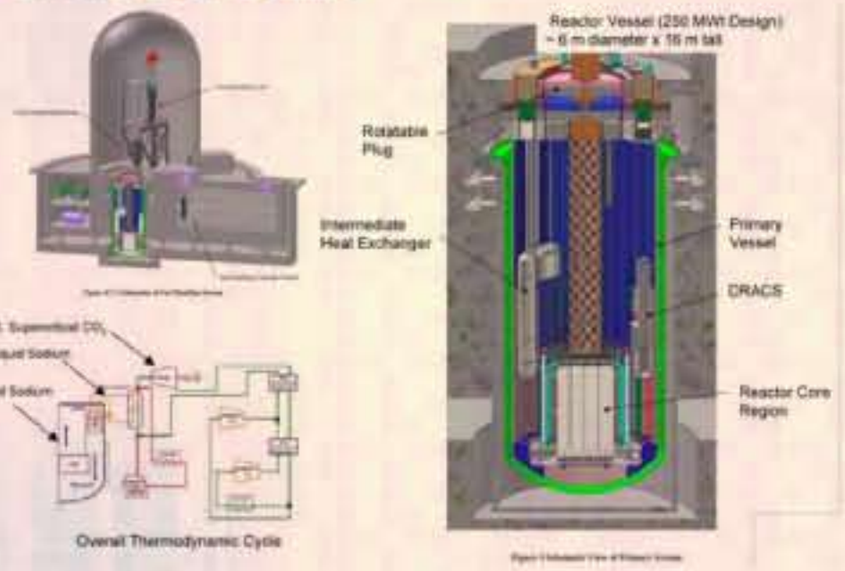
Objective: To develop and demonstrate the *foundational* aspects of a next-generation nuclear reactor safety code (BRISC) that leverages advanced computational technology.

Why: Legacy reactor safety codes are inadequate to meet future NRC & DOE needs. How to best apply advanced computational technologies to these types of problems is not clear.

How: Leverage the combined expertise and experience of staff in 1400, 1500, and 6700 (~2.5 FTEs for 3 years) to help *create a new standard for nuclear reactor safety simulation.*

Approach

An ANL Preconceptual Design Suggests What an Advanced "Burner" Reactor might look like



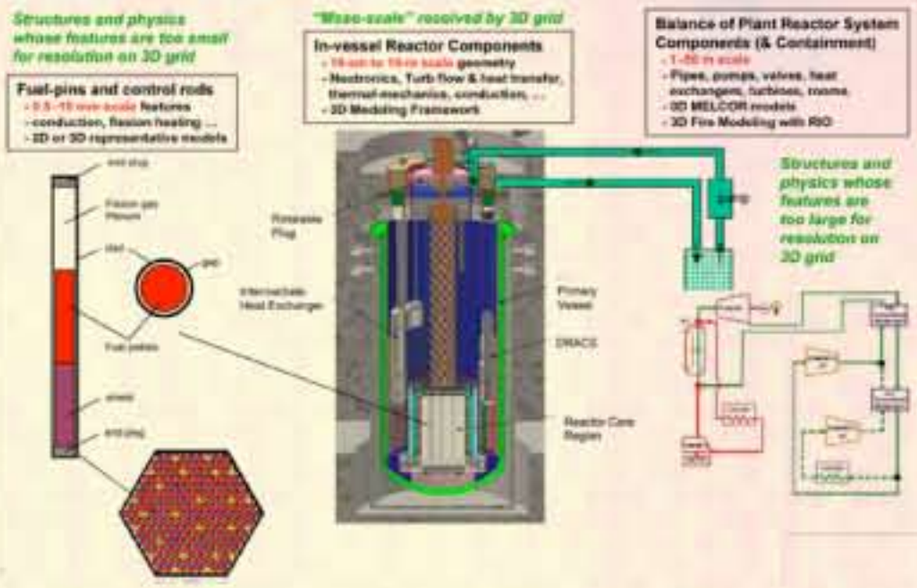
Problem

There are Four High-level Challenges

- The **"multiscale" issue**
  - Length-scales
  - Time-scales
  - Energy groups
- The **"coupled multiphysics" issue**
  - Fluid flow and heat transfer
  - Neutronics
  - Thermal mechanics
- The **"complex geometry" issue**
  - Nuclear reactors are not simple devices
- The **"uncertainty quantification" issue**
  - "without UQ (with requires V&V), results are no better than speculation, and often worse"

Approach

A 3-Tiered Multiscale Modeling Strategy



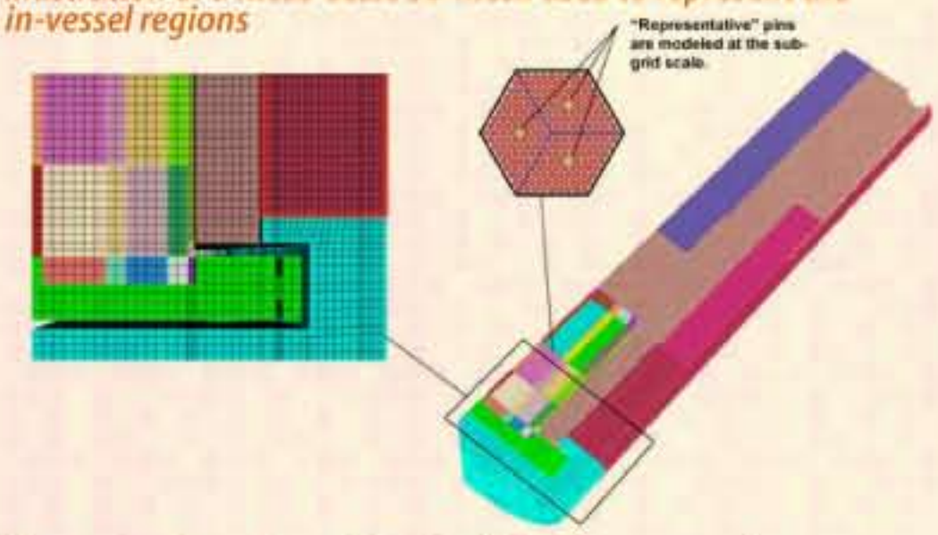
Two Approaches for Multiphysics Coupling

- **Both approaches use different codes for different physics**
  - CFD (RIO, MELCOR)
  - Neutronics - (ORNL code)
  - Thermal Mechanics (ARIA)
  - Fuel Pin heat transfer
- Loose coupling in BRISC-α using RIO for overall time integration
- Strong Coupling being developed using JFNK, orchestrated by a Multiphysics Driver/Solver Code written in Python
  - Designed to accept multiple PhysicsModules (codes).
  - Primary job of PhysicsModules is to take a complete state vector and return a partial residual.

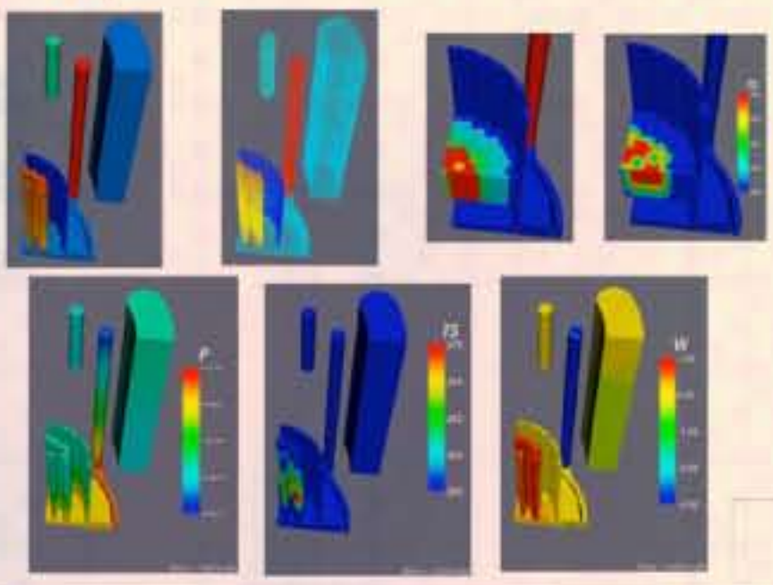
** JFNK is a Newton method that employs Krylov-based linear solves (eg. CG, GMRES) without requiring formation of the Jacobian matrix.*

Results

Illustration of a meso-scale 3D mesh used to represent the in-vessel regions



Illustrative Snapshots of 3D Model for Unprotected Loss of Flow Sequence



Significance

- A first-iteration version of our test-bed code, BRISC-α, was planned, written, evaluated/tested and reviewed. We are now working on BRISC-β
- As a stepping stone to test individual components, a CFD-centric loose-coupling approach has been implemented and tested on a full-scale reactor problem (ULOF) to test and evaluate individual components and methods.
- A prototype Multiphysics coupler leveraging JFNK has been written in Python and demonstrated on simple problems. Challenges for "wrapping" external codes with the Multiphysics driver were uncovered.
- Capabilities of the Multiphysics driver are being expanded for use with full-scale reactor simulation codes, and is an important focus of current work.

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