Progress in modeling BWRs for PCI Challenge Problem

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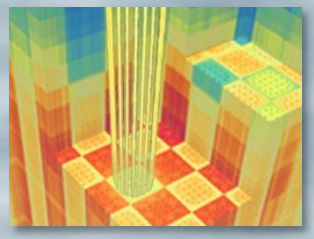
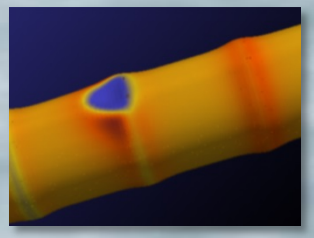
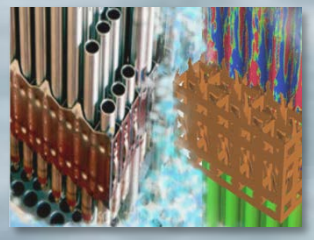






The Consortium for Advanced Simulation of LWRs
A DOE Energy Innovation Hub

CASL-U-2016-1088-000

U.S. DEPARTMENT OF ENERGY

Goal: Understand margin to PCI failure during a control blade maneuver

- In 2018, demonstrate BWR PCI capabilities:
  - Utilizing VERA-CS with Bison(2D) coupled, complete BWR core subregion depletion with maneuver to identify PCI limiting fuel rods;
  - Utilizing Bison(3D) complete PCI analysis for limiting fuel rods.

- Requirements:
  - Integrated neutronics, thermal-hydraulics, and fuel performance
  - High spatial resolution in all physics
  - Account for depletion about a control cell
    - Modeling only a sub-region of the core
  - Easily used and accurate

- Outline
  - Define path towards the goal
  - Recap MPACT capability
  - Summarize CTF capability
  - Identify key milestones

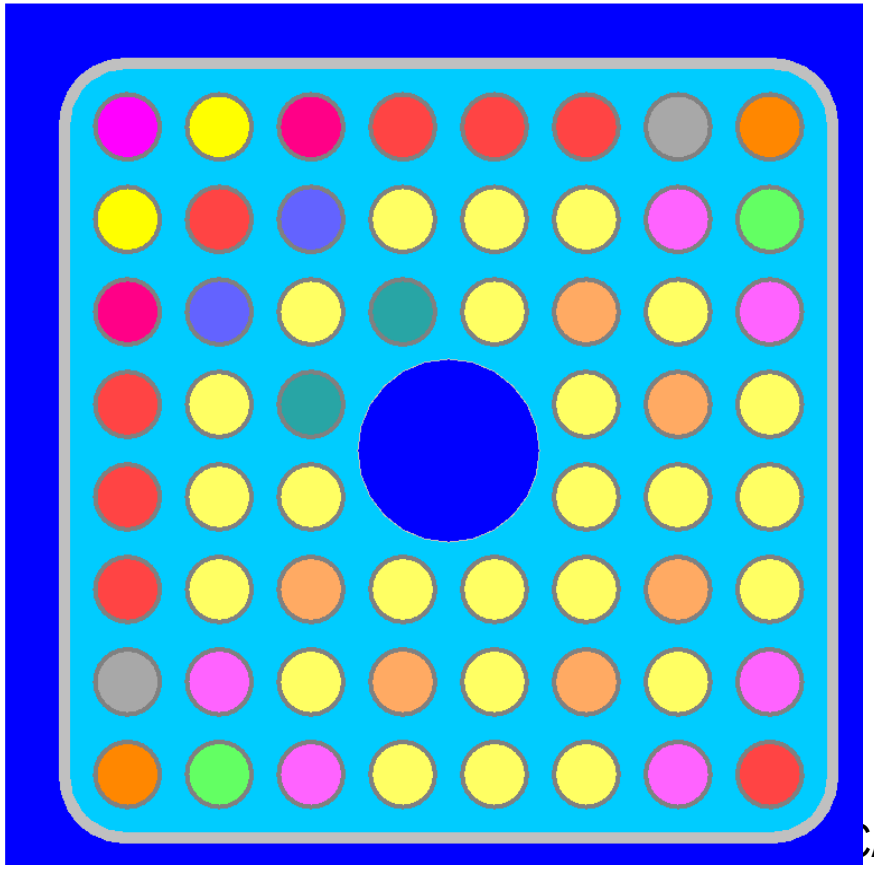
Progression of Capability

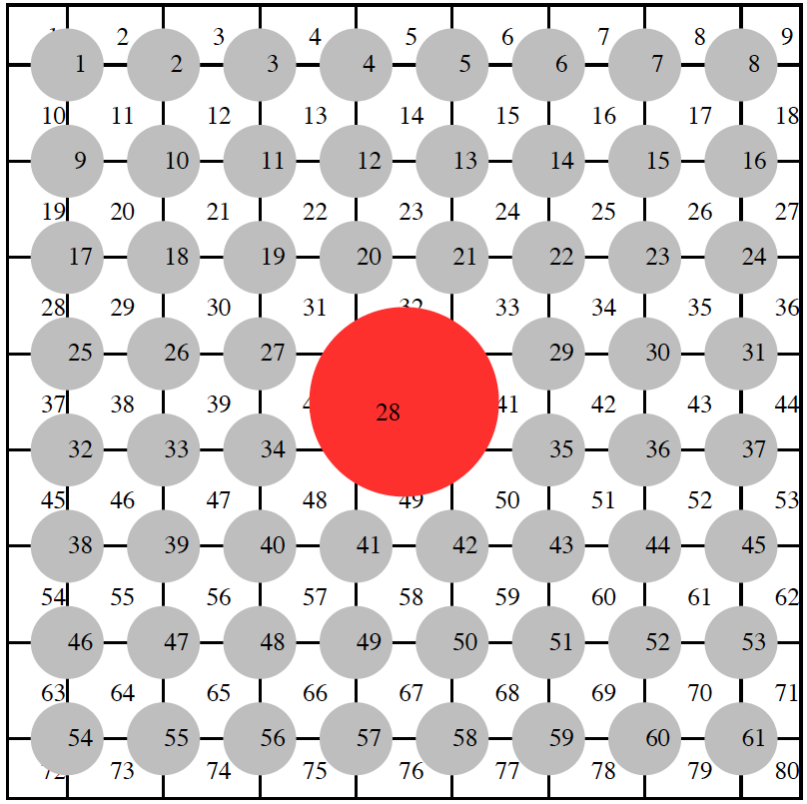
- FY 15: MPACT neutronics — RTM
  - Initial 2D geometry and evaluation of cross sections
- FY 16: CTF thermal-hydraulics — PHI
  - Initial geometry, evaluation of solvers, and V&V
  - Extensions and improvements in MPACT, including 3D
- FY 17: VERA-CS coupled physics — PHI
  - Initial coupled capability and large-scale demonstrations
  - Extensions and improvements to CTF
- FY 18: VERA-CS+Bison integrated fuel performance — FMC
  - Initial integrated PCI capability with 2D Bison
  - Extensions and improvements in VERA-CS
- FY19+: Application and validation — VMA

Goal: Understand margin to PCI failure during a control blade maneuver

Geometric Fidelity

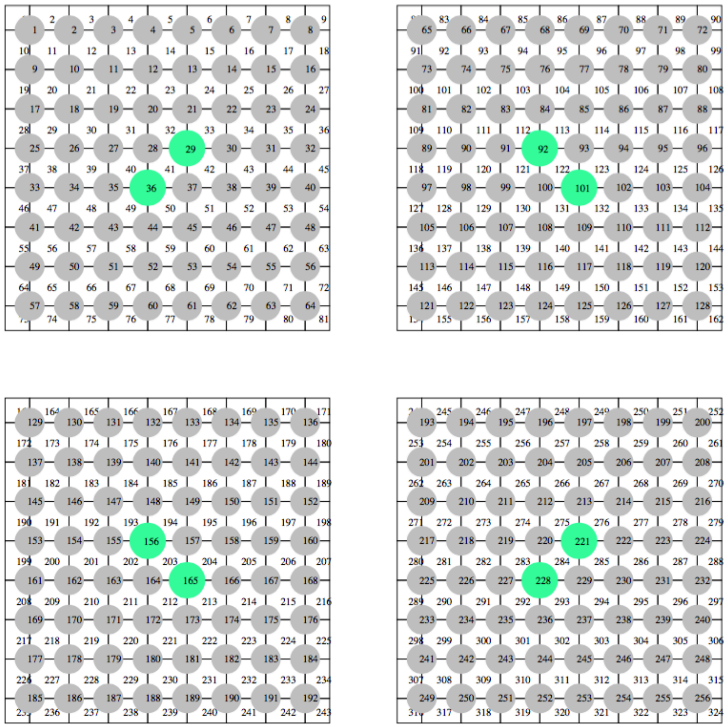
- Large water rods
  - MPACT and CTF

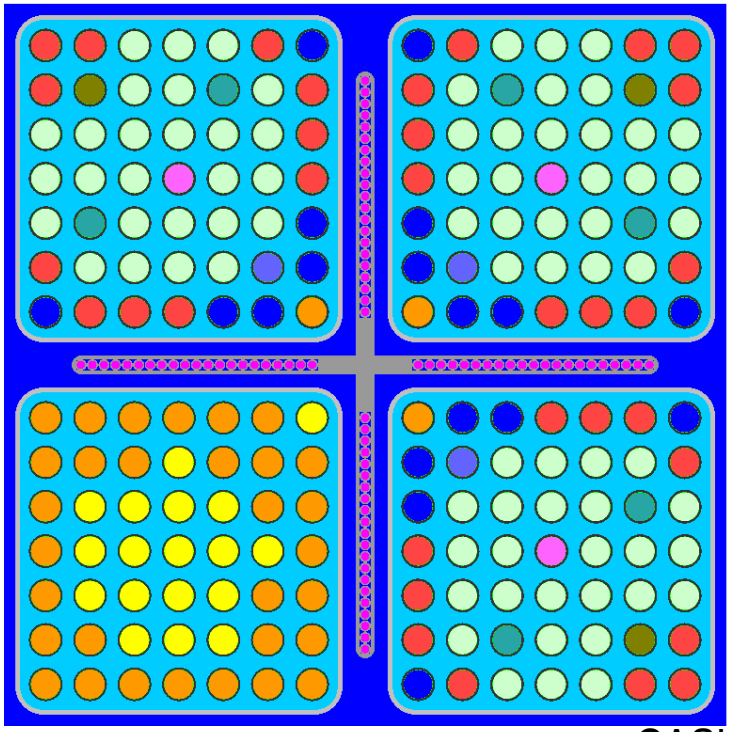


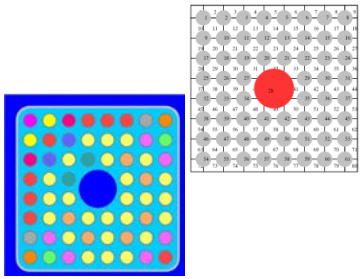


Geometric Fidelity

- Large water rods
  - MPACT and CTF
- Multiple bundles
  - MPACT and CTF







Geometric Fidelity

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  - MPACT and CTF
- 3D bundles
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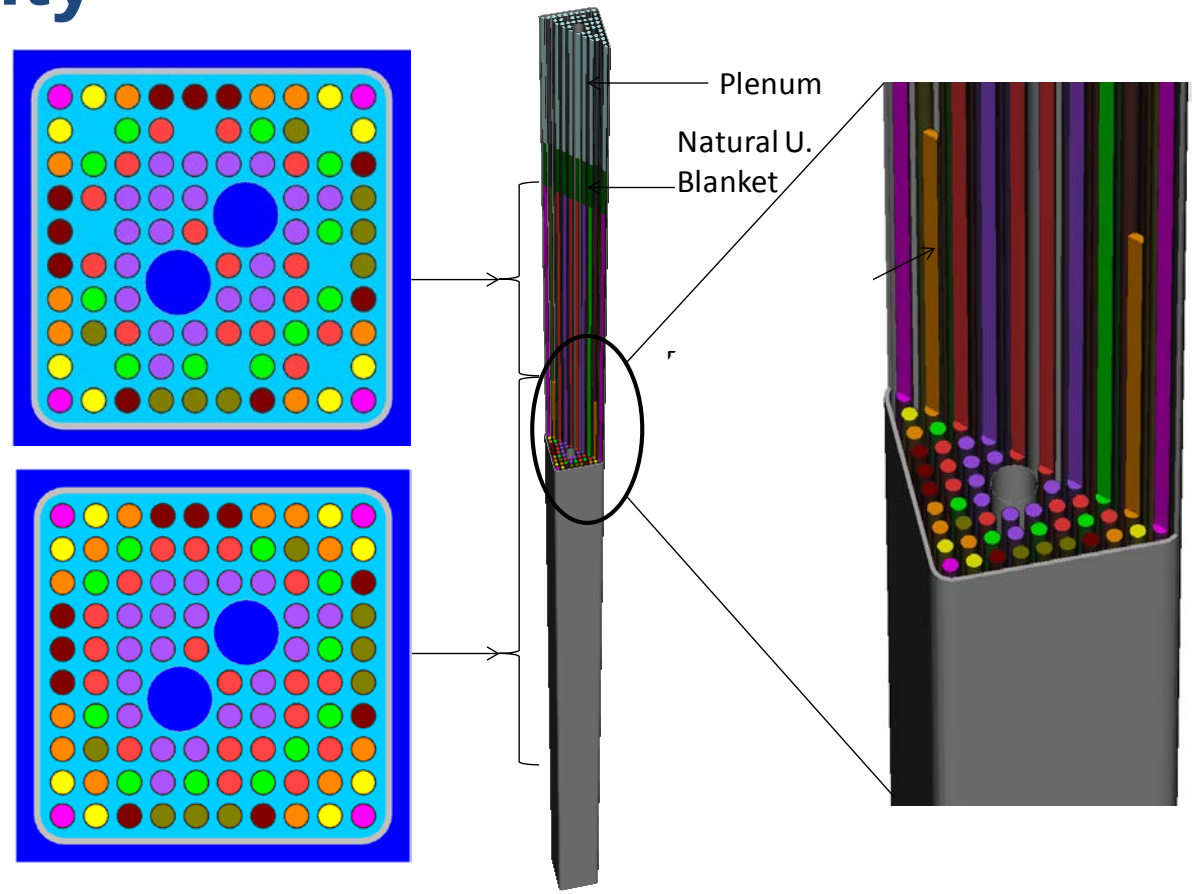
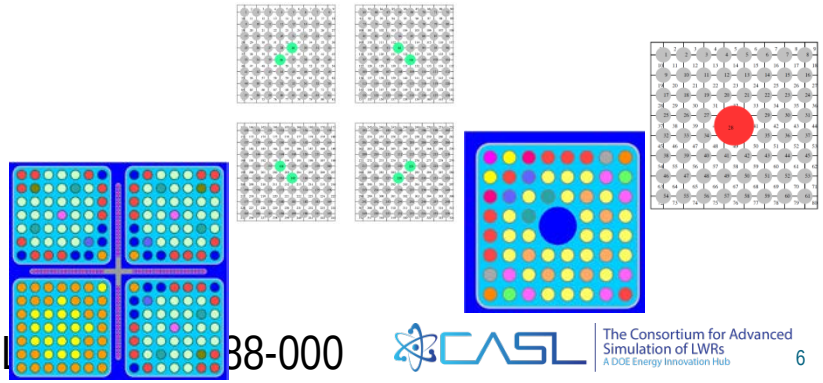
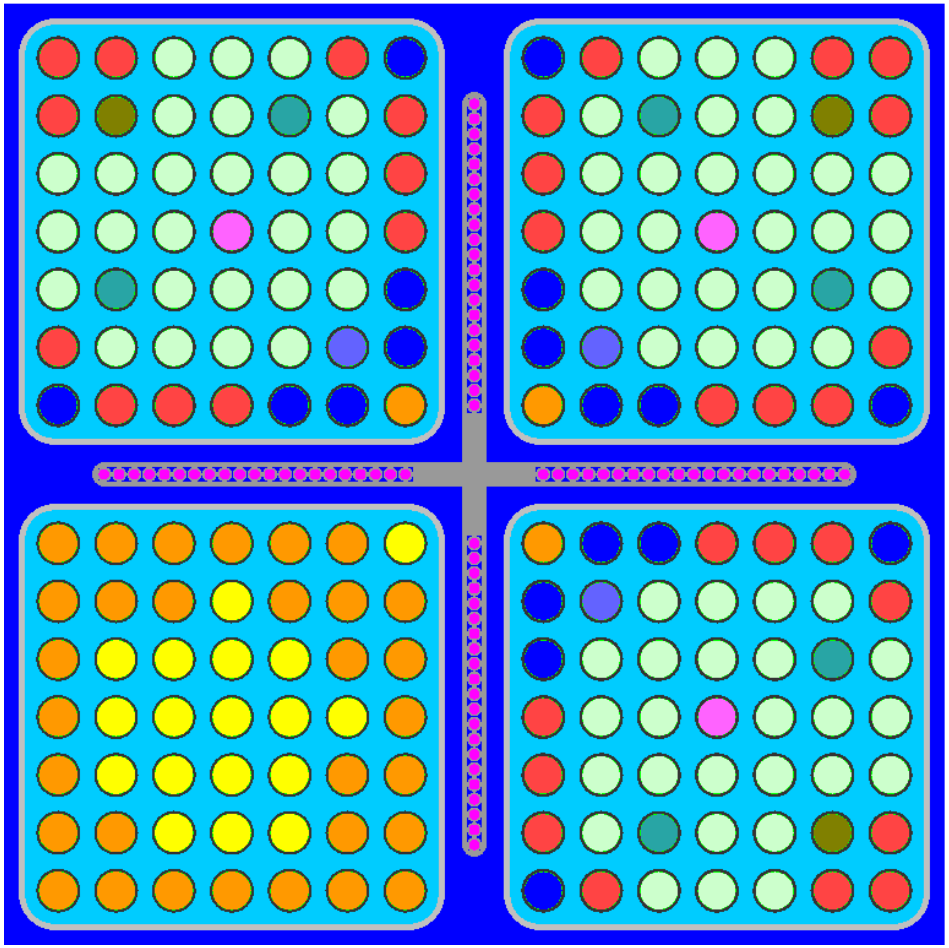
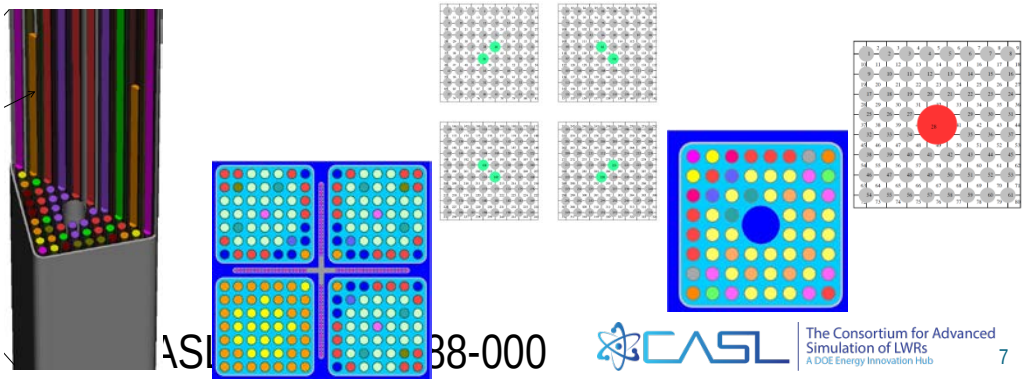




Geometric Fidelity

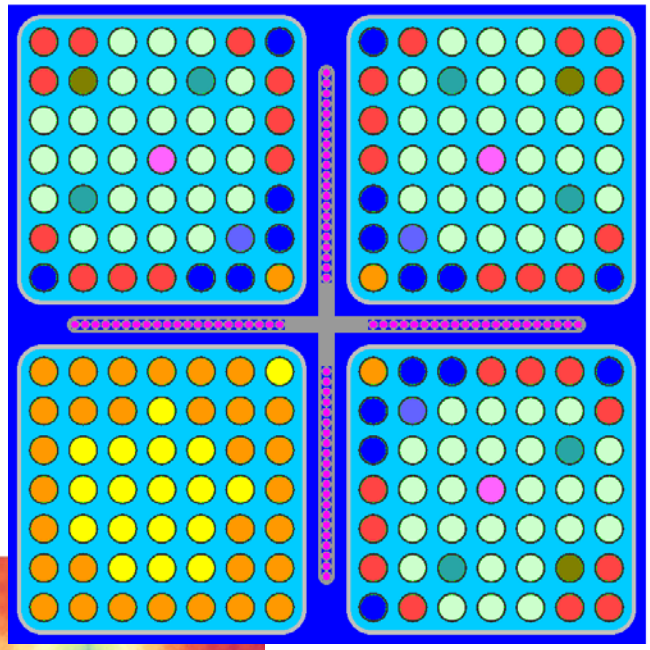
- Large water rods
  - MPACT and CTF
- Multiple bundles
  - MPACT and CTF
- 3D bundles
  - MPACT and CTF
- Control blades
  - MPACT

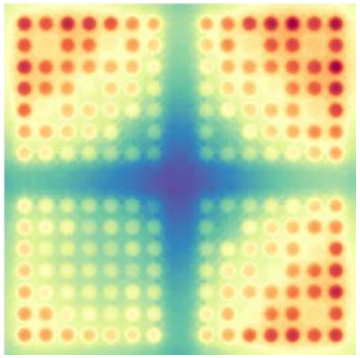




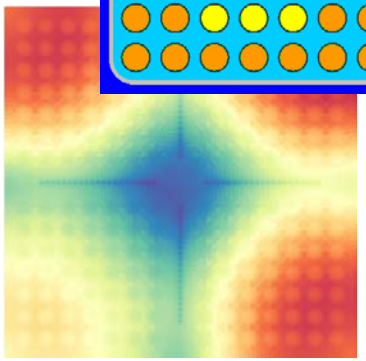
MPACT Status

- High-resolution results
  - 47 energy groups
  - Full geometric detail in 3D
  - Tracking 500 isotopes

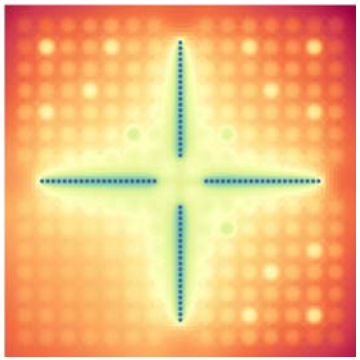




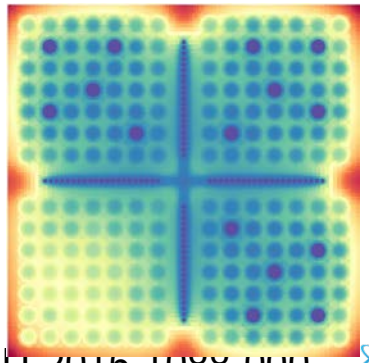
Group 1 Flux



Group 10 Flux



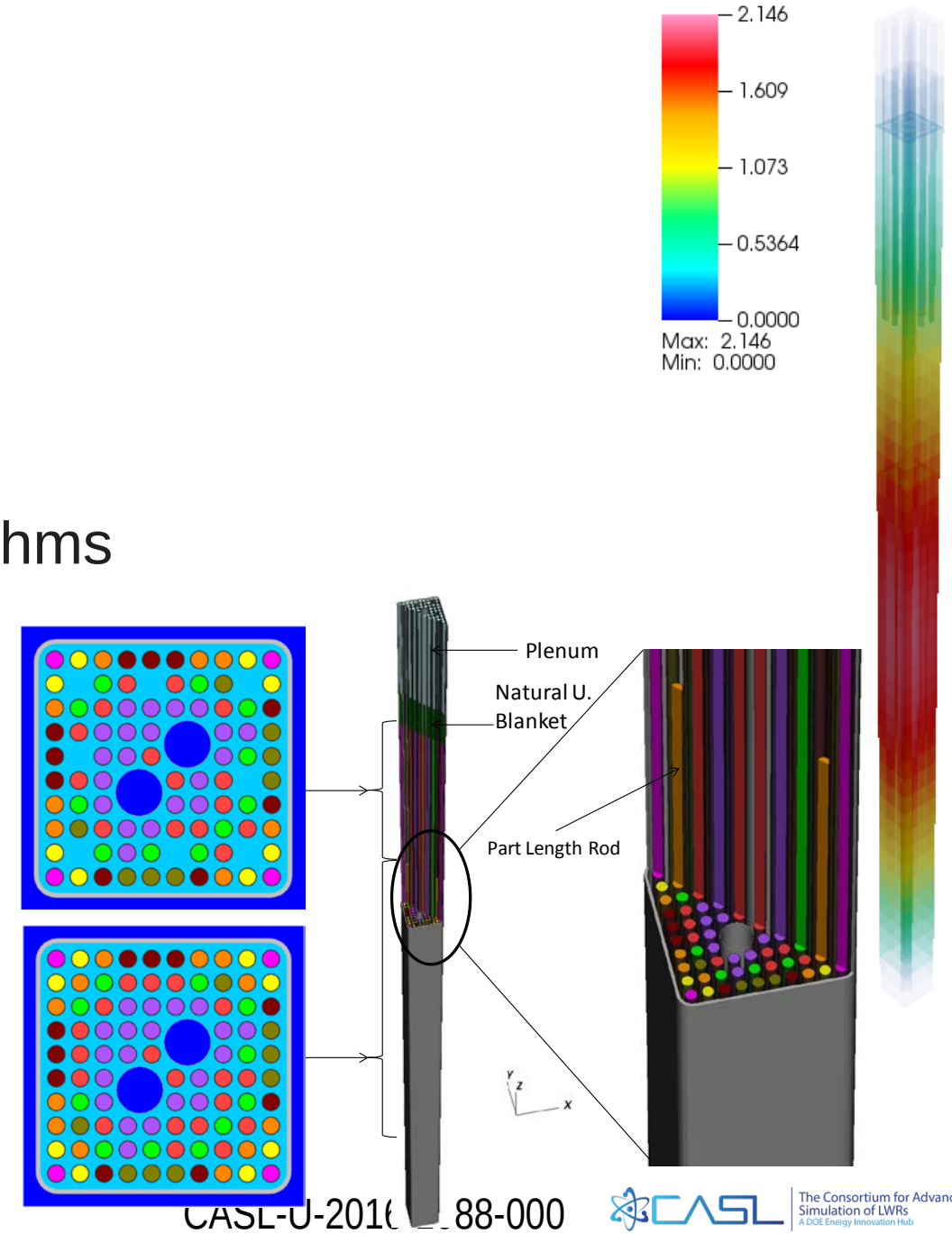
Group 37 Flux



Group 47 Flux

MPACT Status

- High-resolution results
  - 47 energy groups
  - Full geometric detail in 3D
  - Tracking 500 isotopes
- Robust, efficient algorithms
  - 3D bundle in
    - 4.8 minutes on
    - 52 processors
    - In 9 iterations



MPACT Status

- High-resolution results
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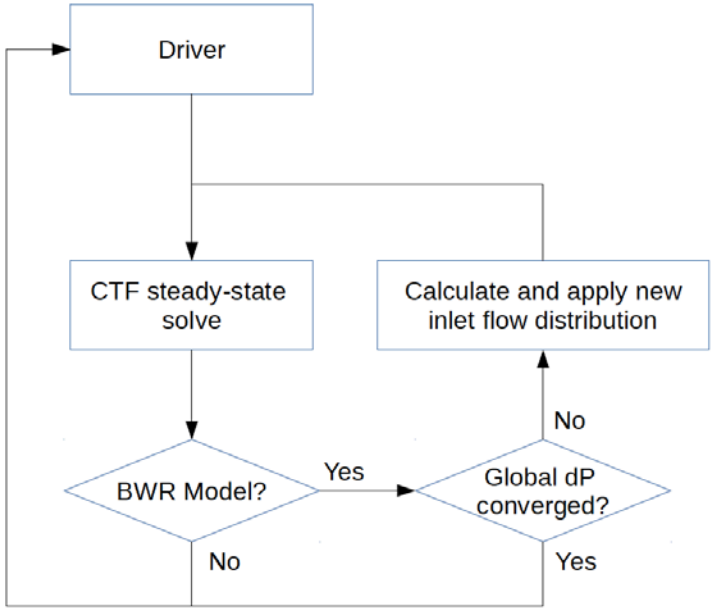
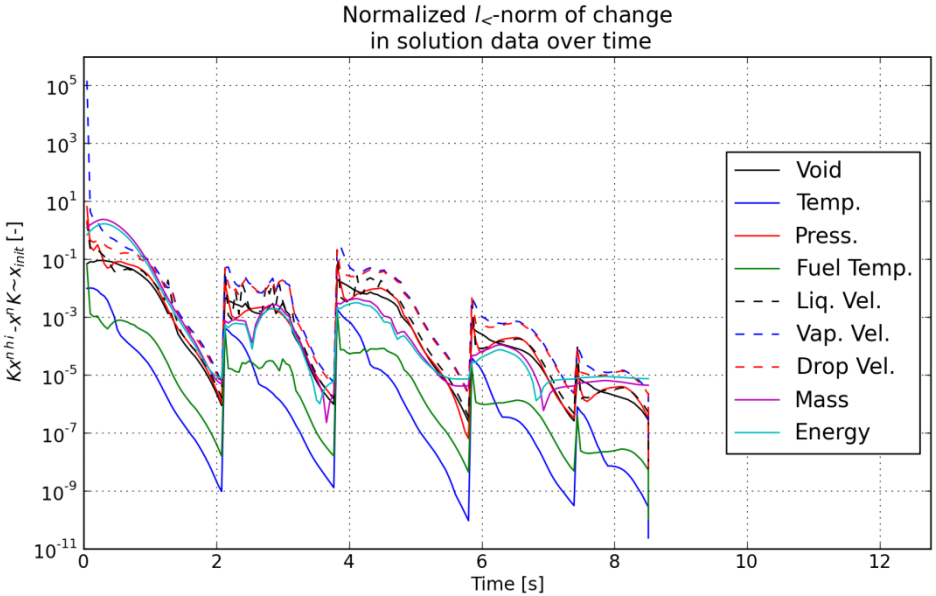
  - Tracking 500 isotopes
- Robust, efficient algorithms
  - 3D bundle in
    - 4.8 minutes on
    - 52 processors
    - In 9 iterations
- Additional work in progress or needed

- Geometric features
  - Thick channel box corners, thick-thin boxes
  - Square water rods, GE9 water rods, GE11 water rods, SVEA
  - Fuel rod connectors, grid spacers, nozzles, tie/core plates
- Modeling improvements
  - Improved convergence
  - Higher order depletion methods
  - Control rod depletion
  - Nuclear data processing
- Verification & Validation

CTF Developments in FY16

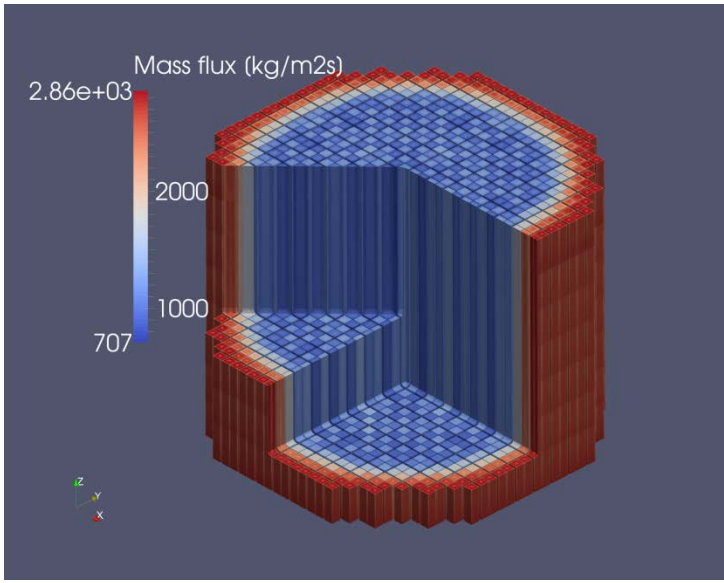
- Input and geometry processing
  - Processing VERAIn for CTF BWRs
  - Creating parallelization domains
- Developed robust iteration scheme
  - Multi-bundle pressure iteration
  - Consistent with PWR modeling
- Evaluated convergence
  - Physics-based metrics
  - Robust tolerances

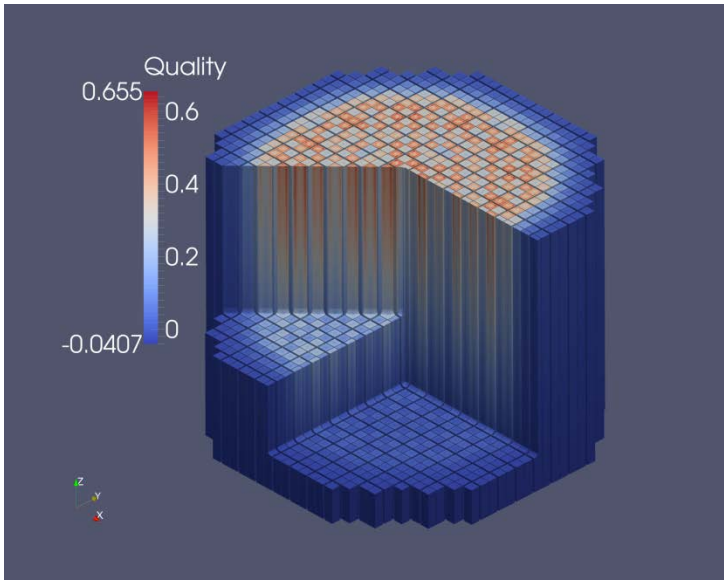




CTF Developments in FY16

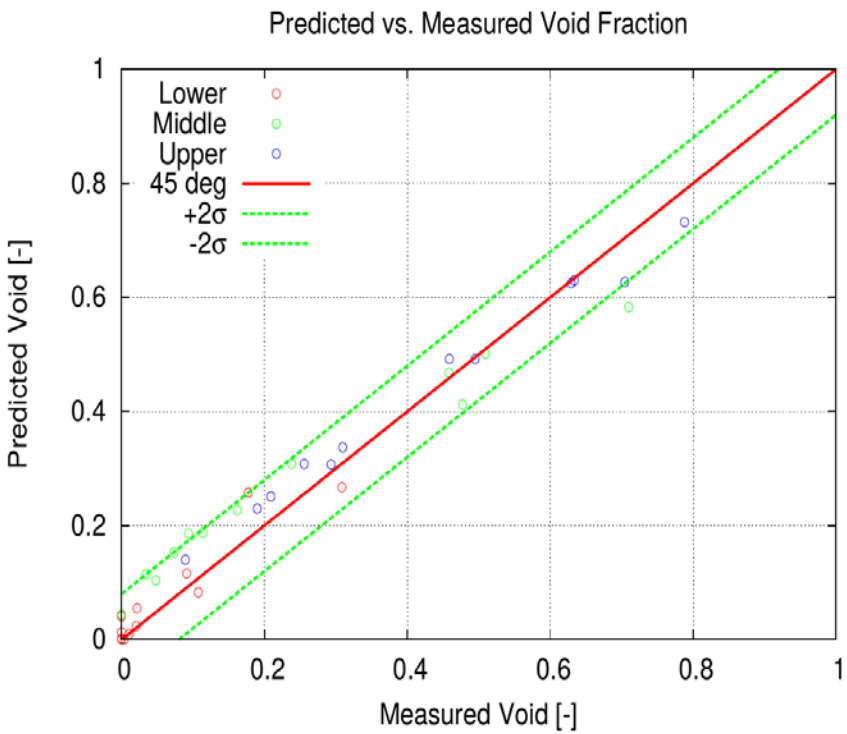
- Input and geometry processing
  - Processing VERAIn for CTF BWRs
  - Decomposing parallel domains
- Developed robust iteration scheme
  - Multi-bundle pressure iteration
  - Consistent with PWR modeling
- Evaluated convergence
  - Physics-based metrics
  - Robust tolerances
- Large-scale demonstration





CTF Validation for BWRs

- Updated CTF V&V Report
  - Developed from PIRT to define level of testing by phenomena
  - Includes data from:
    - FRIGG
    - GE 3x3
    - PSBT
    - BFBT
    - CE 5x5
    - Harwell high pressure loop
  - Current efforts focus on void drift validation



CTF prediction of center channel void at different axial locations in PSBT rod-bundle experiment

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