Analysis as part of simulation workflow

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SOS17 Panel:
The State of HPC Data Analysis Software
Jekyll Island, GA
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Is the customer (user) always right? Not necessarily...

- **When?**
  - doesn’t believe something is possible
  - can’t imagine beyond incremental improvement (disruptive transition)
The Consortium for Advanced Simulation of Light Water Reactors (CASL)

Core partners
Oak Ridge National Laboratory
Electric Power Research Institute
Idaho National Laboratory
Los Alamos National Laboratory
Massachusetts Institute of Technology
North Carolina State University
Sandia National Laboratories
Tennessee Valley Authority
University of Michigan
Westinghouse Electric Company

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University of Florida
University of Tennessee
University of Wisconsin
Worcester Polytechnic Institute

Challenges
• High visibility
• Geographically-dispersed
• Diversity of experience
• Wide range of motivation / priorities
• Proprietary codes and data
• Role of commercial codes
• Export control
Anatomy of a Nuclear Reactor
Example: Westinghouse 4-Loop Pressurized Water Reactor (PWR)

Fuel Specs

Core
• 11.1' diameter x 12' high
• 193 fuel assemblies
• 107.7 tons of UO₂ (~3-5% U₂₃₅)

Fuel Assemblies
• 17x17 pin lattice (14.3 mm pitch)
• 204 pins per assembly

Fuel Pins
• ~300-400 pellets stacked within 12’ high x 0.61 mm thick Zr-4 cladding tube

Fuel Pellets
• 9.29 mm diameter x ~10.0 mm high

Fuel Temperatures
• 4140° F (max centerline)
• 657° F (max clad surface)

~51,000 fuel pins and over 16M fuel pellets in the core of a PWR!
## VERA-CS(+) vs. Industry Core Simulators

(+) Virtual Environment for Reactor Applications – Core Simulator

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<td>1,000 – 300,000 cores</td>
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(*) pin-homogenized or pin-resolved depending on application
Grid-to-Rod-Fretting (GTRF)
Spacer Grid with Springs/Dimples
CRUD-induced power shift (CIPS)

- deviation in axial power shape
  - Cause: Boron uptake in CRUD deposits in high power density regions with subcooled boiling
  - affects fuel management and thermal margin in many plants
- power uprates will increase potential for CRUD growth

Need: Multi-physics chemistry, flow, and neutronics model to predict CRUD growth
Core -> Assembly -> Pin

DENONO 12x12

DeCART

CASE

Insilico/Denovo
Similarly for CFD
VERA input is both familiar to current industry and extensible.

- provide ability to create, archive, compare, and modify input similar to current industry workflows
- provide common reactor problem setup for physics components
  - VERA-CS: assemblies, poisons, control rods, non-fuel structures, baffle, power, flow, depletion, etc.
- reduce inconsistencies between coupled physics codes through the use of a common geometry description
- doesn’t have to be all-singing, all-dancing from the outset
  - can evolve as appropriate
VERA Common Output

• fine-mesh results written to SILO files for visualization in tools such as VisIt / Paraview
• pin-by-pin distributions (from multiple codes) written to a common HDF5 format that can be post-processed to create user edits
  – 2D/3D pin distributions
  – 2D/3D assembly distributions
  – peaking factors
• recognition that industrial users need both visualization and “real numbers”
CASL is leveraging NiCE for analysis workflow.

The NEAMS Integrated Computational Environment (NiCE) helps with difficult chores for non-expert users…

- Serial, chained, simultaneous or stand-alone job launch and monitoring
- Managing inputs, geometry, materials, and meshing
- Data analysis and visualization
- “Asset” management in multiple formats (SQL, XML)
- Linux, Windows, Mac
  - soon Web and Android
- Adding new launchers to NiCE

100% Free and Open Source, Eclipse-based
https://niceproject.sourceforge.net
Nuclear Reactor “Views” in NiCE

Step 1: Load and select data from an Hierarchical Data Format file (HDF5)

Step 2: Check out pin map for obvious problems

Step 3: Look at “power map” of fuels pins

Step 4: Graph pin powers against each other

Adding anomaly detection and direct reference comparisons.

SWT(+) works exceptionally well with complicated, interactive, scientific views of data!