

Analysis as part of simulation workflow

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Virtual Reactor Integration (VRI) Lead

SOS17 Panel:
The State of HPC Data Analysis Software
Jekyll Island, GA
March 27, 2013



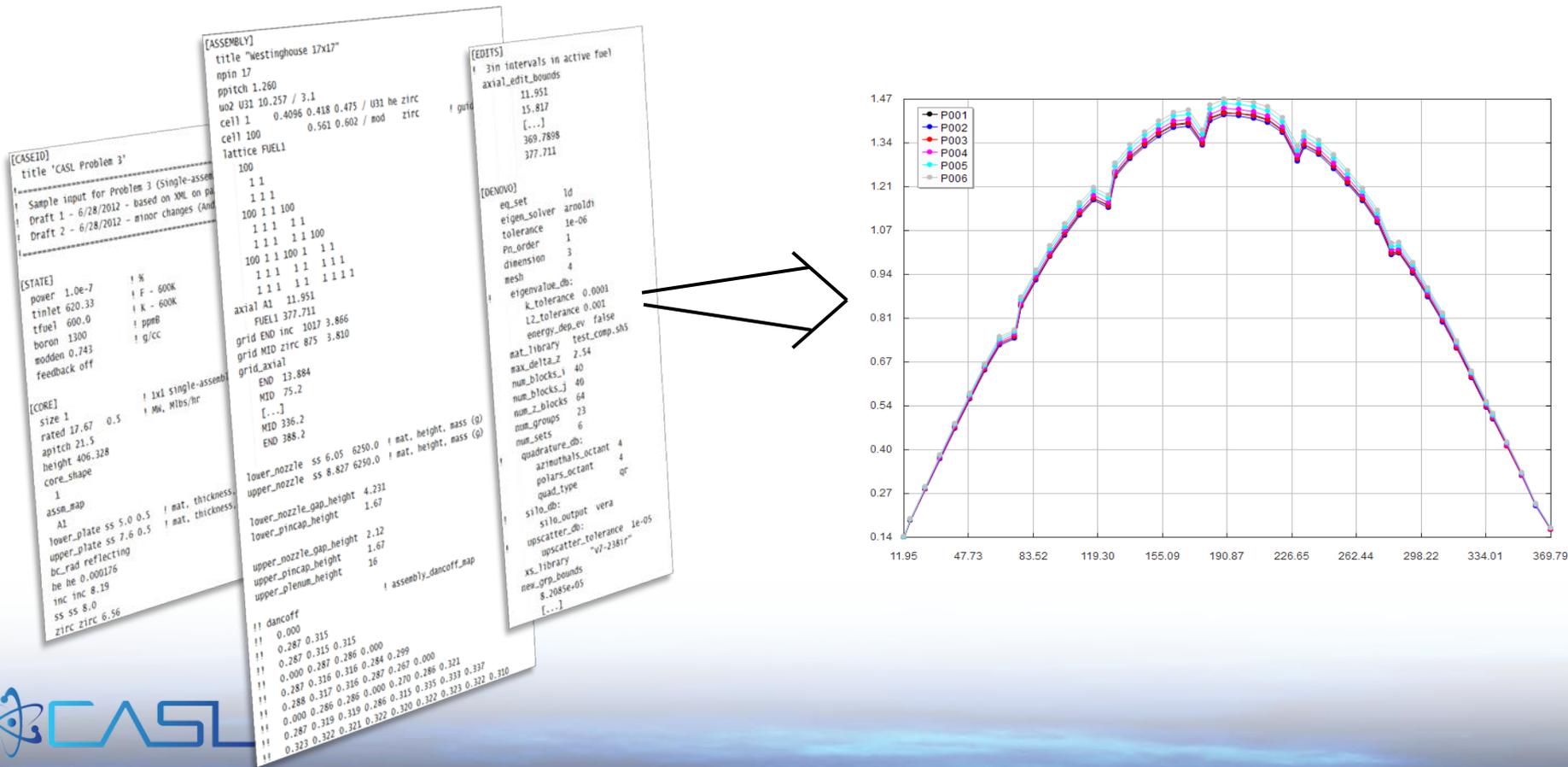
U.S. DEPARTMENT OF
ENERGY

Nuclear
Energy

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



Individual contributors

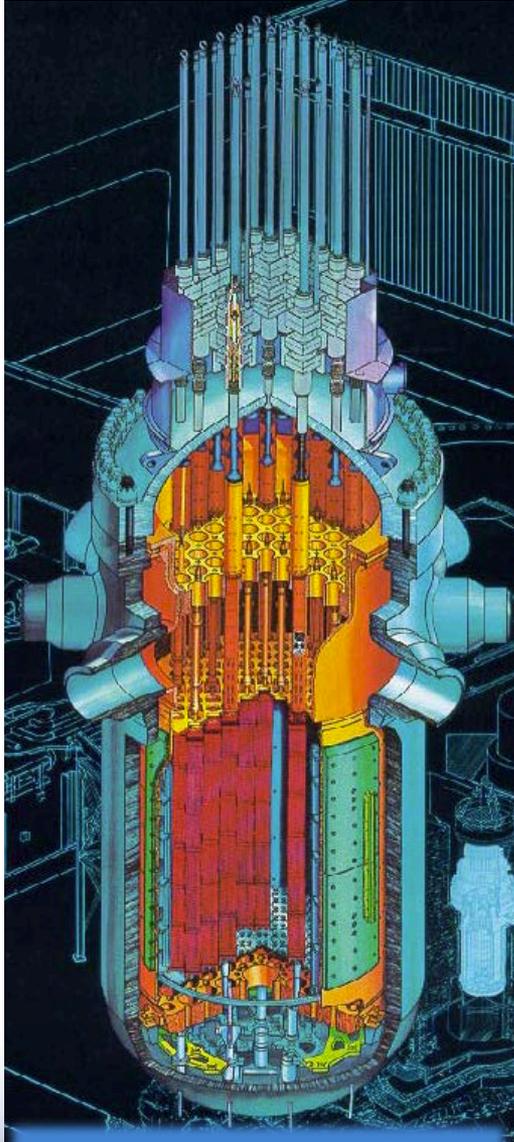
ASCOMP GmbH
CD-adapco, Inc.
City University of New York
Florida State University
Imperial College London
Rensselaer Polytechnic Institute
Southern States Energy Board
Texas A&M University
University of Florida
University of Tennessee
University of Wisconsin
Worcester Polytechnic Institute

Challenges

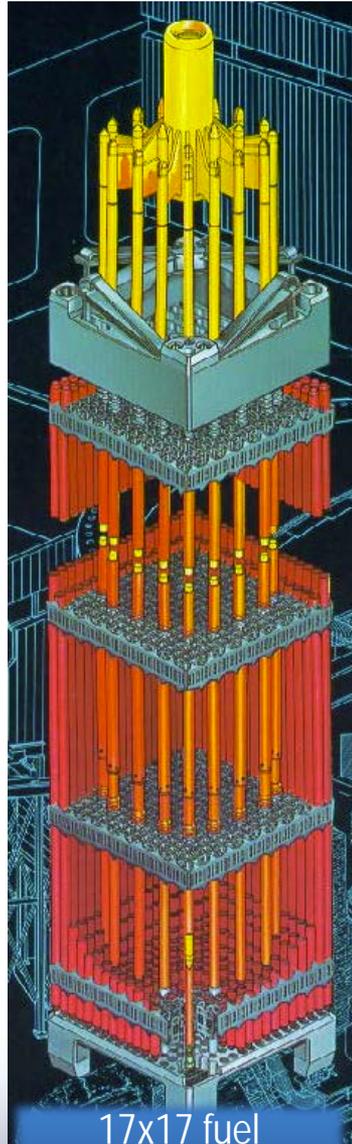
- High visibility
- Geographically-dispersed
- Diversity of experience
- Wide range of motivation / priorities
- Proprietary codes and data
- Role of commercial codes
- Export control

Anatomy of a Nuclear Reactor

Example: Westinghouse 4-Loop Pressurized Water Reactor (PWR)



reactor vessel and internals



17x17 fuel assembly

Fuel Specs

Core

- 11.1' diameter x 12' high
- 193 fuel assemblies
- 107.7 tons of UO_2 (~3-5% U_{235})

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

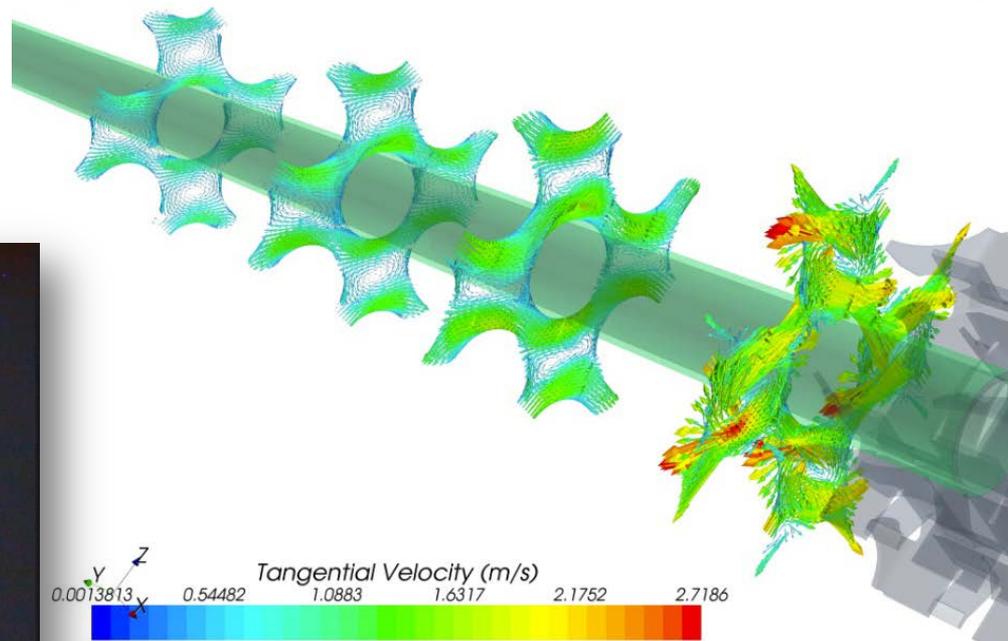
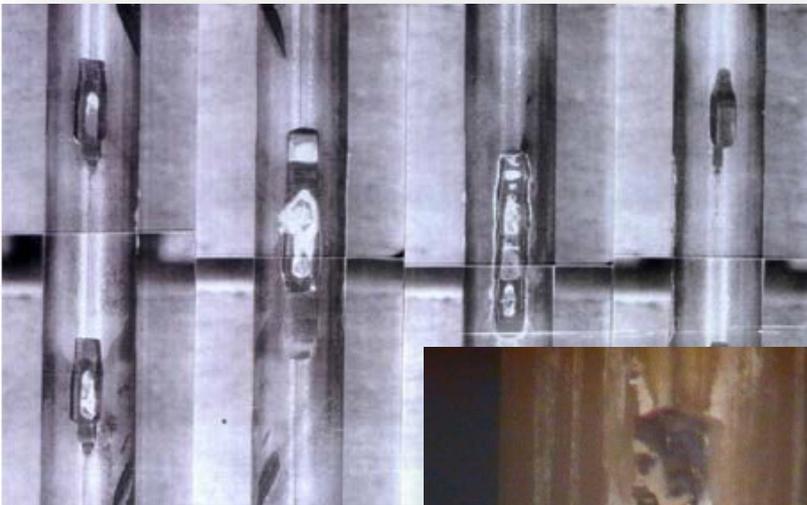
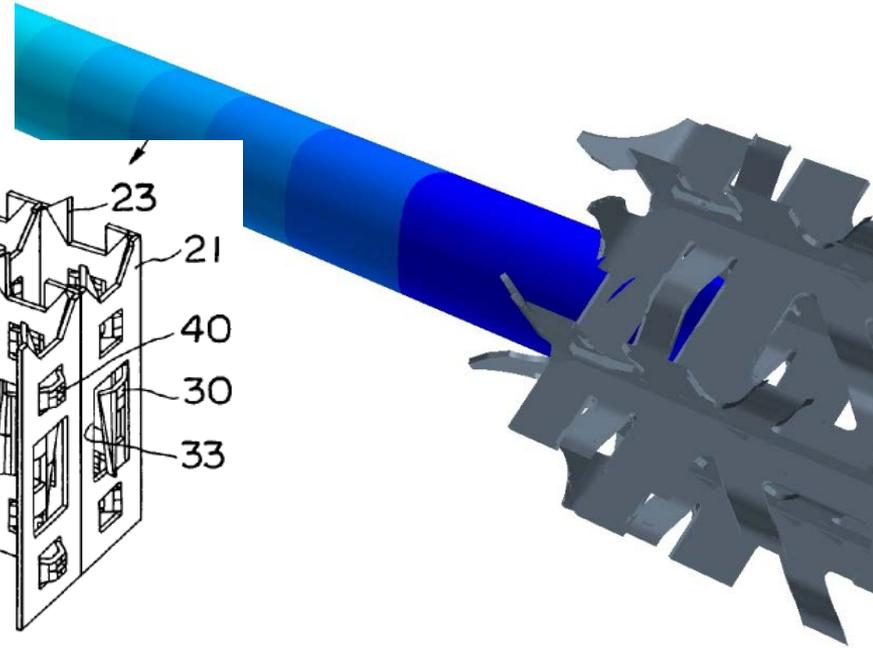
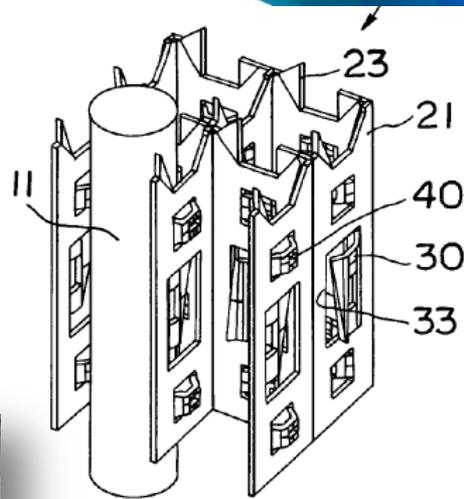
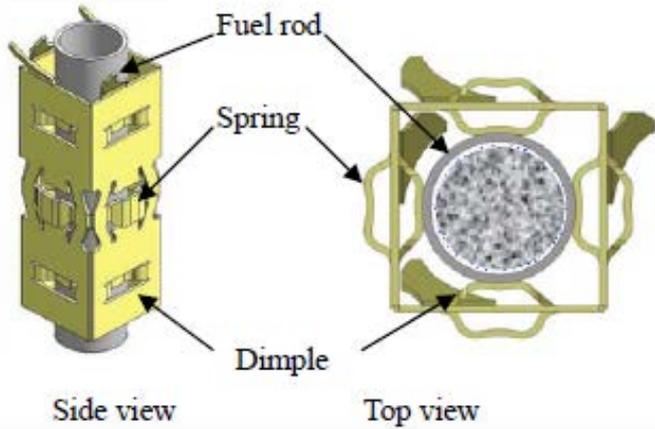
Physics Model	Industry Practice	VERA-CS (in progress)
Neutron Transport	3-D diffusion (core) 2 energy groups (core) 2-D transport on single assy	3-D transport 23+ energy groups
Power Distribution	nodal average with pin-power reconstruction methods	explicit pin-by-pin(*)
Thermal-Hydraulics	nodal average (1-D)	subchannel (w/crossflow)
Fuel Temperatures	nodal average	pin-by-pin(*)
Xenon/Samarium	nodal average w/correction	pin-by-pin(*)
Depletion	infinite-medium cross sections quadratic burnup correction history corrections spectral corrections reconstructed pin exposures	pin-by-pin(*) with actual core conditions
Reflector Models	1-D cross section models	actual 3-D geometry
Target Platforms	workstation (single-core)	1,000 – 300,000 cores



(*) pin-homogenized or pin-resolved depending on application

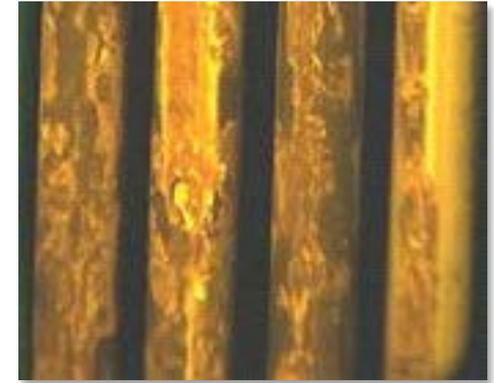
Grid-to-Rod-Fretting (GTRF)

Spacer Grid with Springs/Dimples

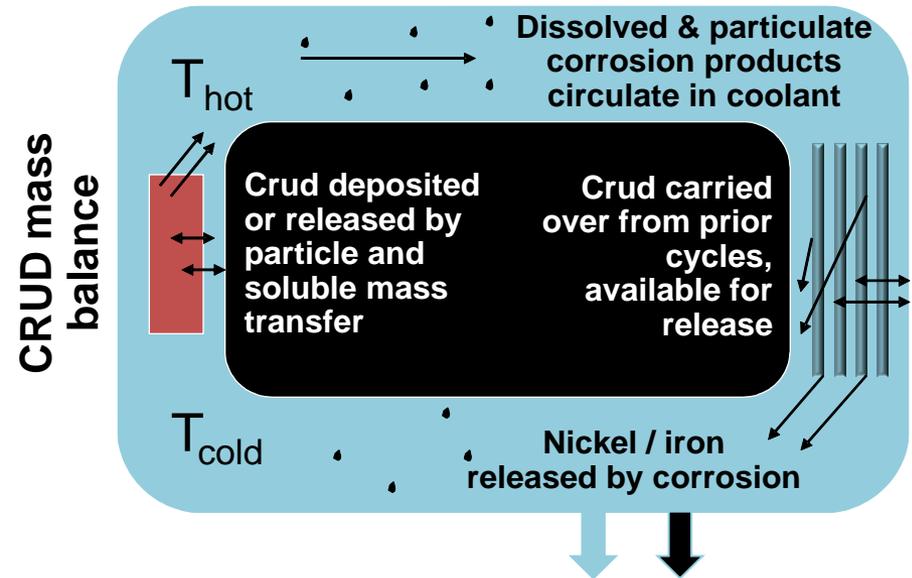
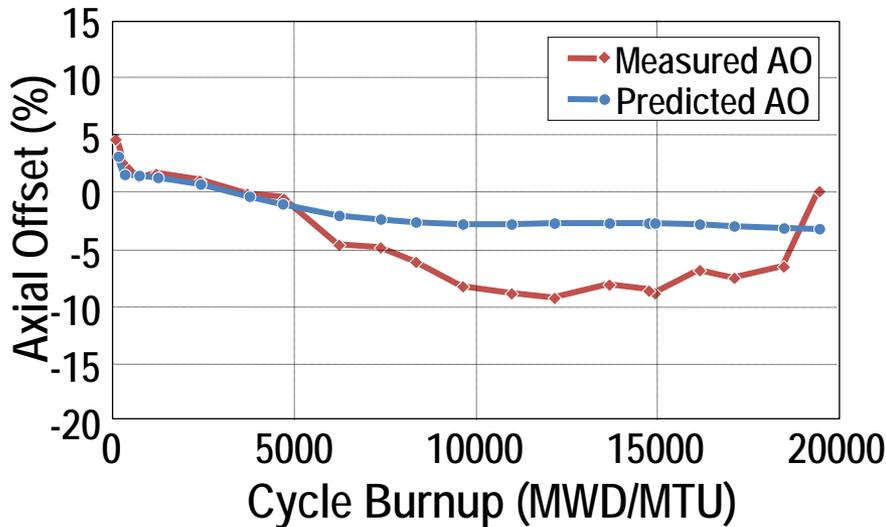


CRUD-induced power shift (CIPS)

- 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

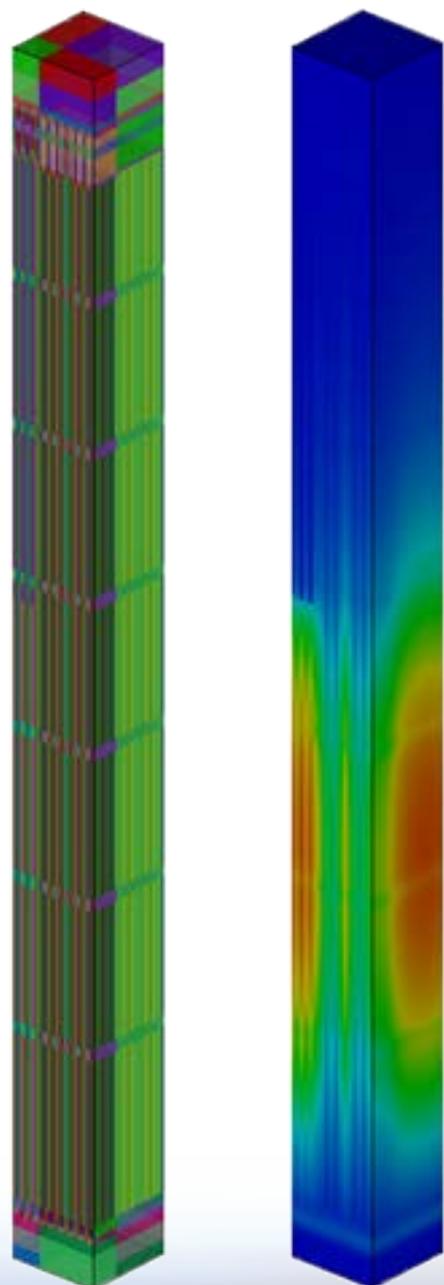
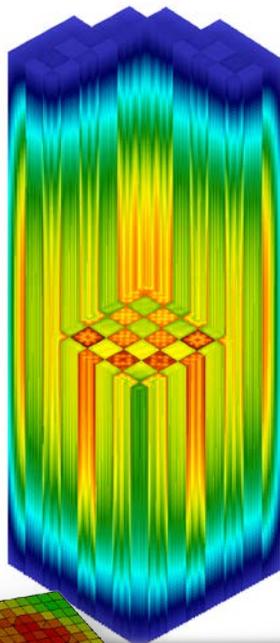
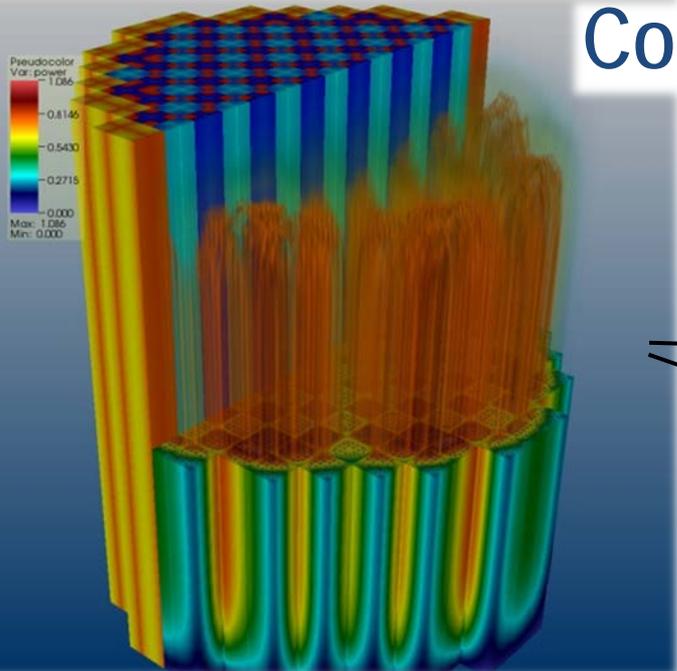


CRUD deposits

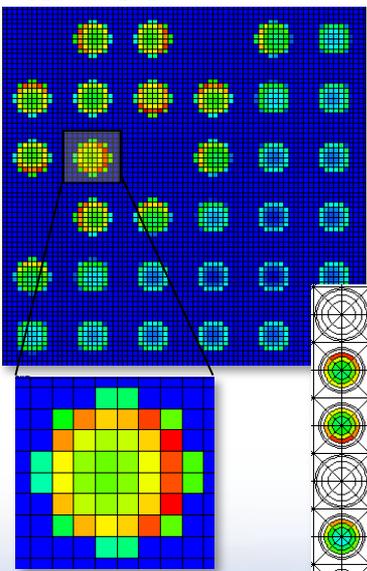


Need: Multi-physics chemistry, flow, and neutronics model to predict CRUD growth

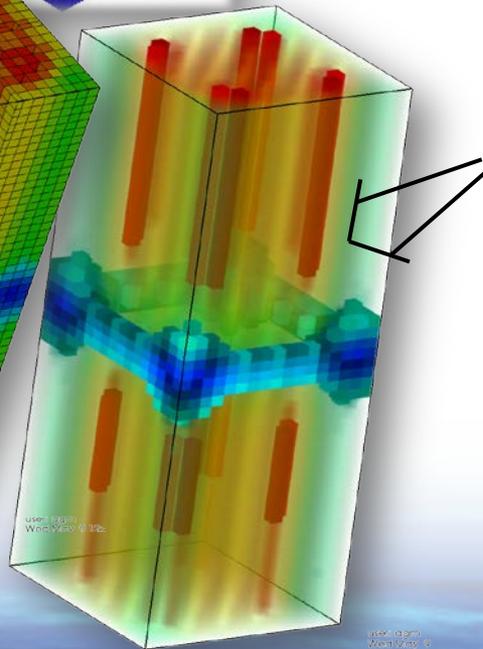
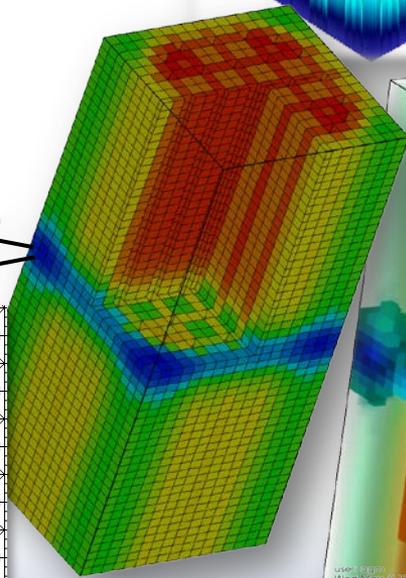
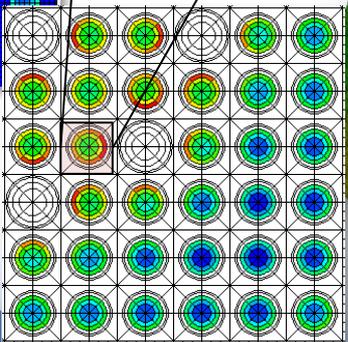
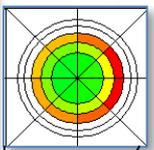
Core -> Assembly -> Pin



DENOVO 12x12

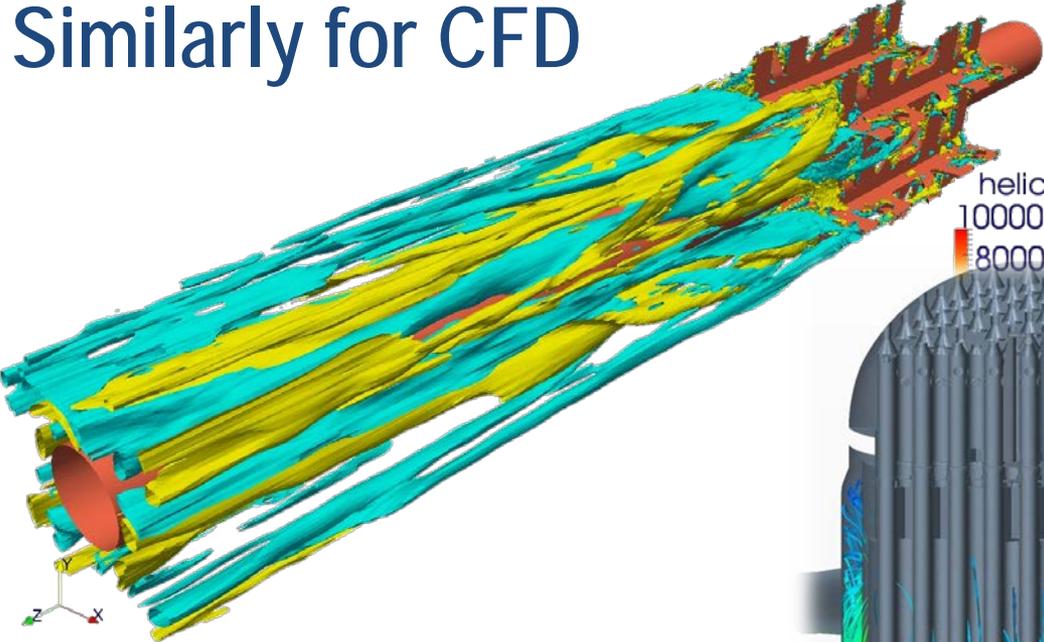


DeCART

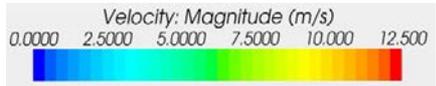
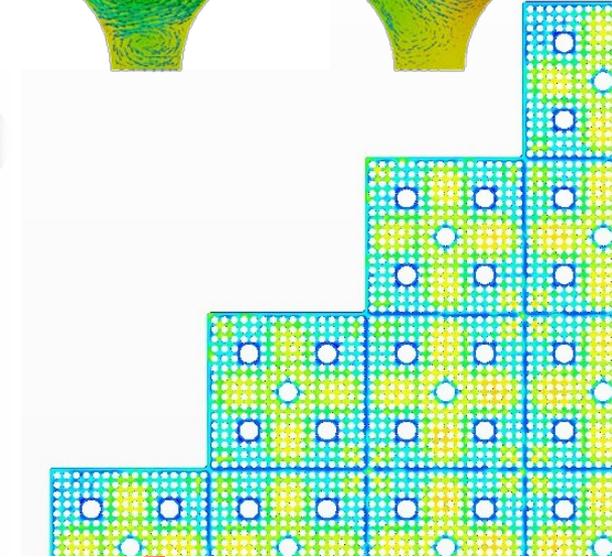
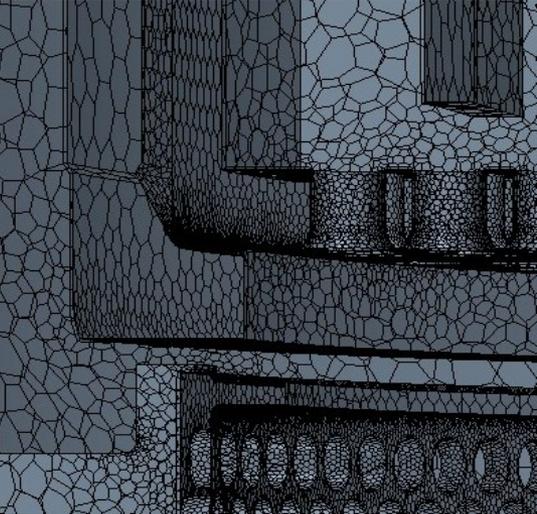
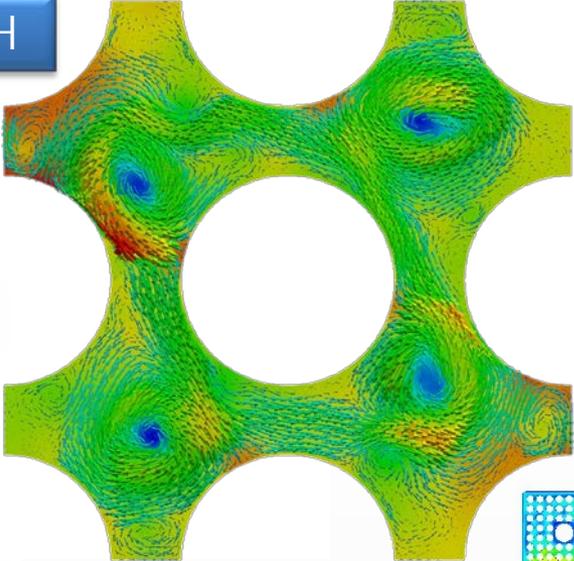


Insilico/Denovo

Similarly for CFD



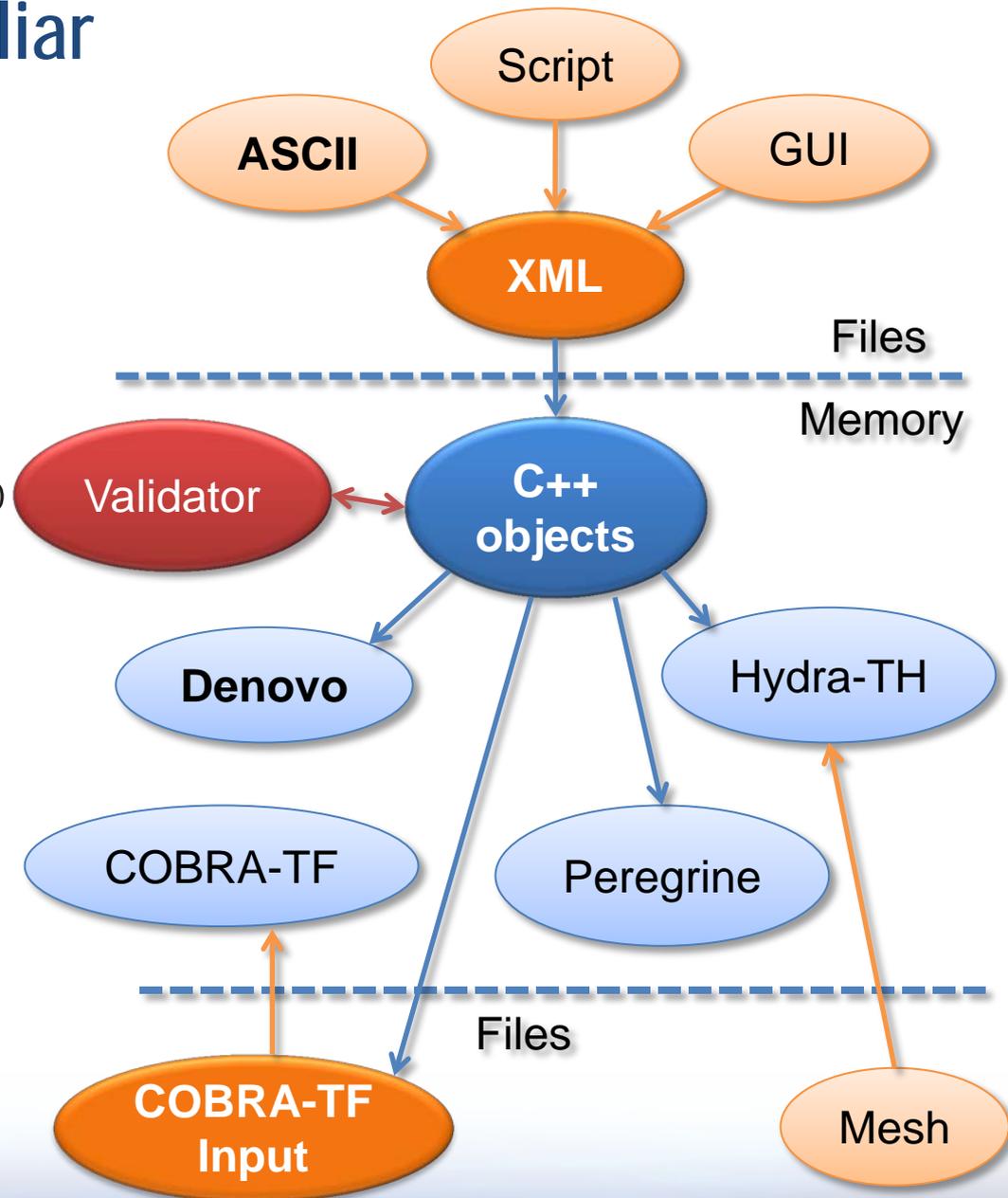
Hydra-TH



Star-CCM+

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”

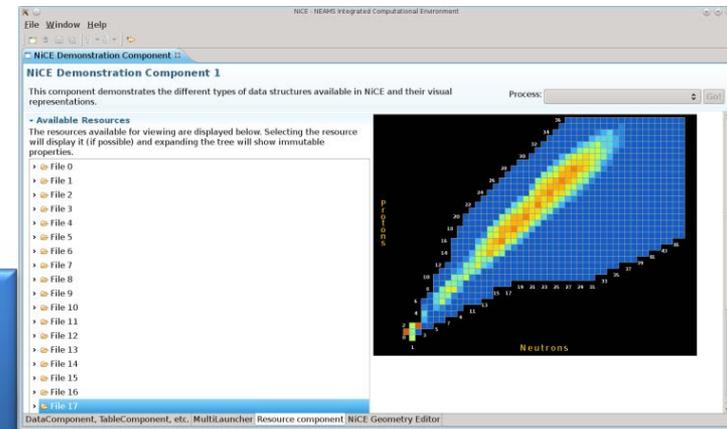
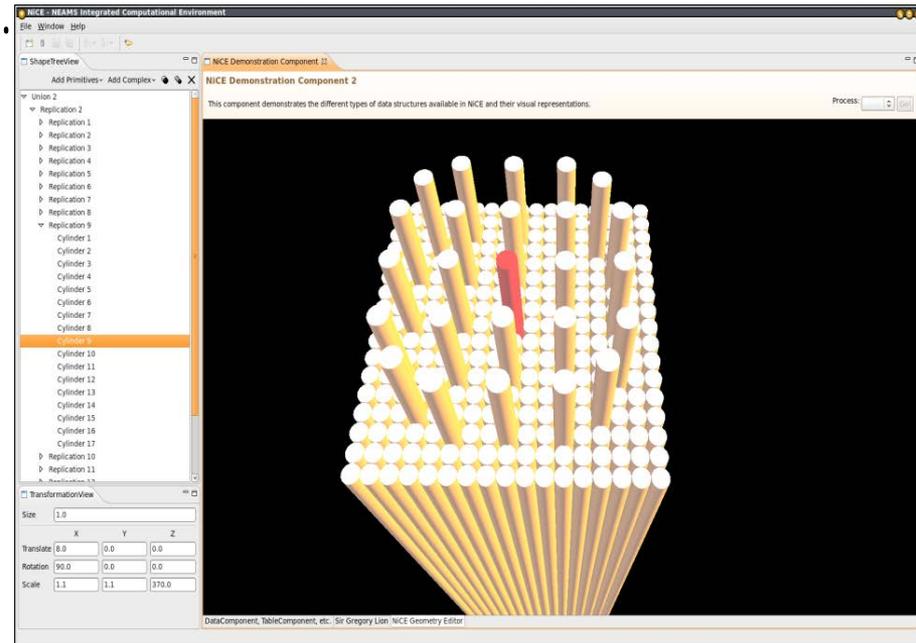
Insilico/Denovo
fission rate for full
assembly, generated
SILO file and VisIt



CASL is leveraging NiCE for analysis workflow.

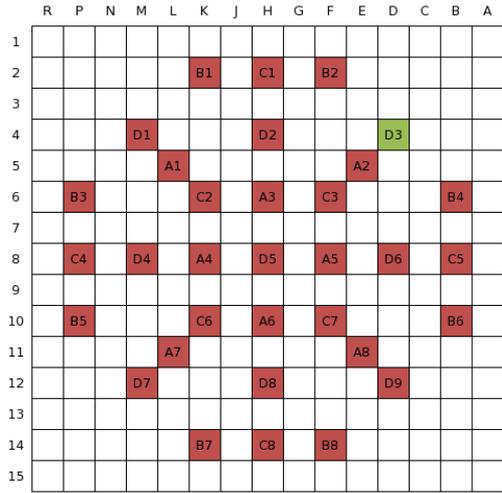
The NEAMS Integrated Computational Environment (NiCE) helps with difficult chores for non-expert users...

- 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



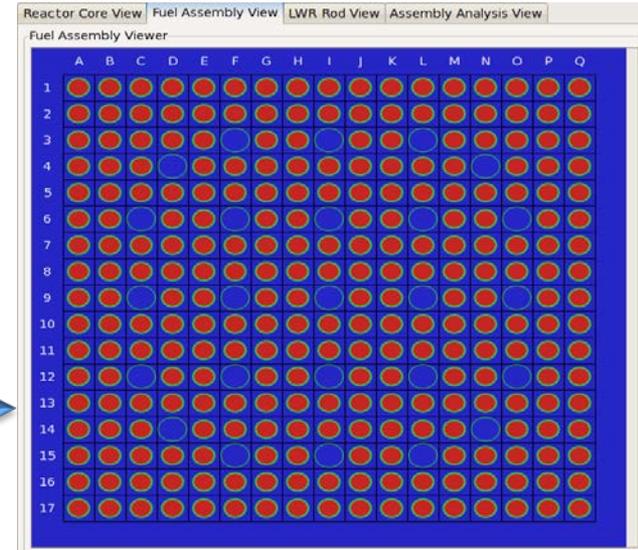
100% Free and Open Source, Eclipse-based
<https://niceproject.sourceforge.net>

Nuclear Reactor "Views" in NiCE



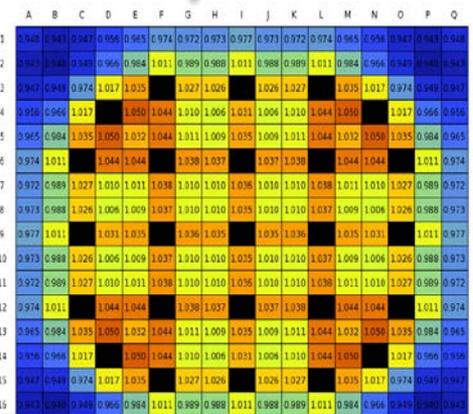
Step 1: Load and select data from an Hierarchical Data Format file (HDF5)

Step 2: Check out pin map for obvious problems 



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

Step 3: Look at "power map" of fuels pins



Adding anomaly detection and direct reference comparisons.

Step 4: Graph pin powers against each other

