U.S. DEPARTMENT OF ENERGY | Nuclear Energy

@ 3.5 Years

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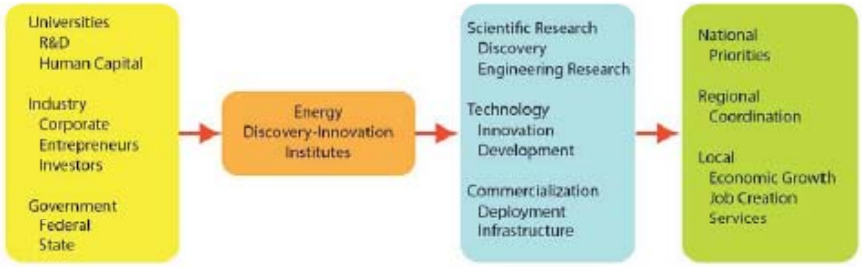
Energy Innovation Hub Concept

Energy Discover-Innovation Institutes, February 2009

Authors:
James Duderstadt, Gary Was, Robert McGrath, Mark Muro, Michael Corradini, Linda Katehi, Rick Shangraw, and Andrea Sarzynski

Energy discovery-innovation institutes would draw from a diverse support network, conduct widespread activities, and be oriented towards achieving important social goals



"When you think of the Hubs, think of large, mission-oriented research efforts such as the Manhattan Project at Los Alamos or America's great industrial laboratories in their heyday. This type of research at AT&T's Bell Laboratories gave us the transistor that powers modern electronics."

Secretary Steven Chu letter to Rep. Peter J. Visclosky dated March 24, 2010

SEAB Task Force currently in process of validating & improving the original Hub concept

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Vision for CASL (as originally proposed)

Adapt, Apply, and Develop (only where needed) Advanced Modeling and Simulation Tools and a Multi-physics Coupling Environment to Create a "Virtual Reactor" that Addresses Industry Defined Challenge Problems

TVA Watts Bar #1

	Development	Innovation	Validation
Operational			
CRUD-induced power shift (CIPS)			
CRUD-induced localized corrosion (CILC)			
Grid-to-rod fretting failure (GTRF)			
Pellet-clad interaction (PCI)			
Fuel assembly distortion (FAD)			
Safety			
Departure from nucleate boiling (DNB)			
Cladding integrity during (LOCA)			
Cladding integrity during (RIA)			
Reactor vessel integrity			
Reactor internals integrity			

End of Year 3 Status

Significant Progress	Planning & Scoping
Good Progress	Not Started

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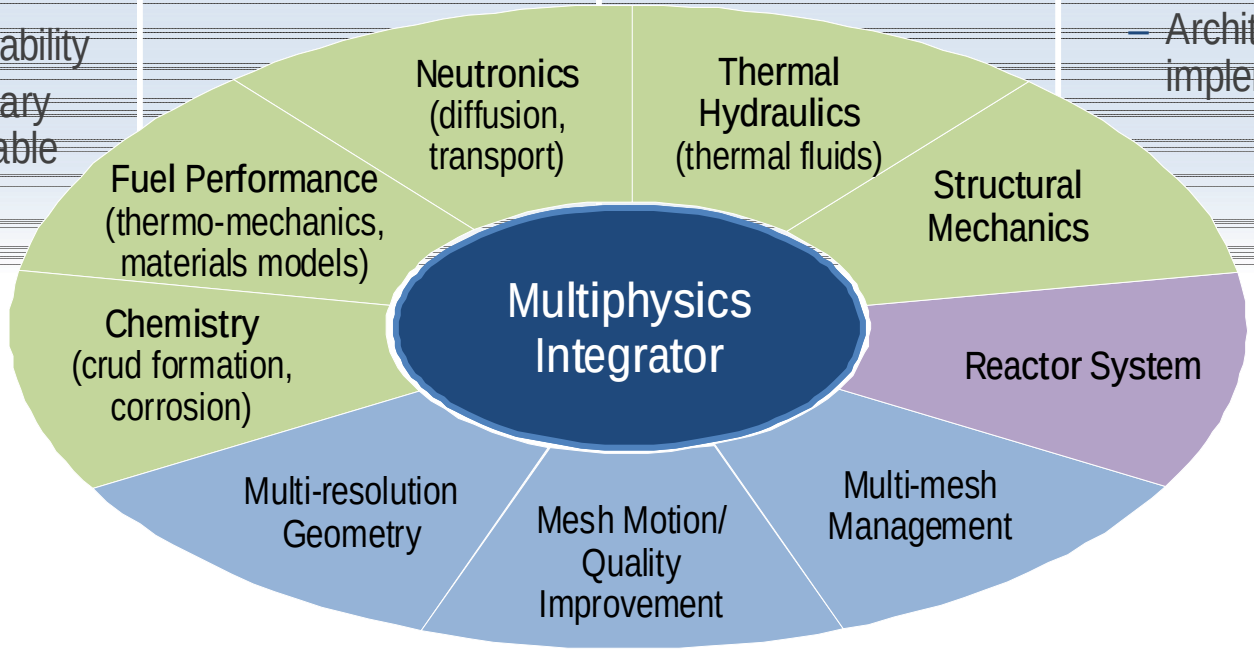
Features of the Virtual Reactor (as originally proposed)

- Flexible coupling of physics components
- Toolkit of components
  - Not a single executable
  - Both legacy and new capability
  - Both proprietary and distributable

- Attention to usability
- Rigorous software processes
- Fundamental focus on V&V and UQ

- Development guided by relevant challenge problems
- Broad applicability

- Scalable from industry class clusters to existing and future HPC platforms
  - Diversity of models, approximations, algorithms
  - Architecture-aware implementations



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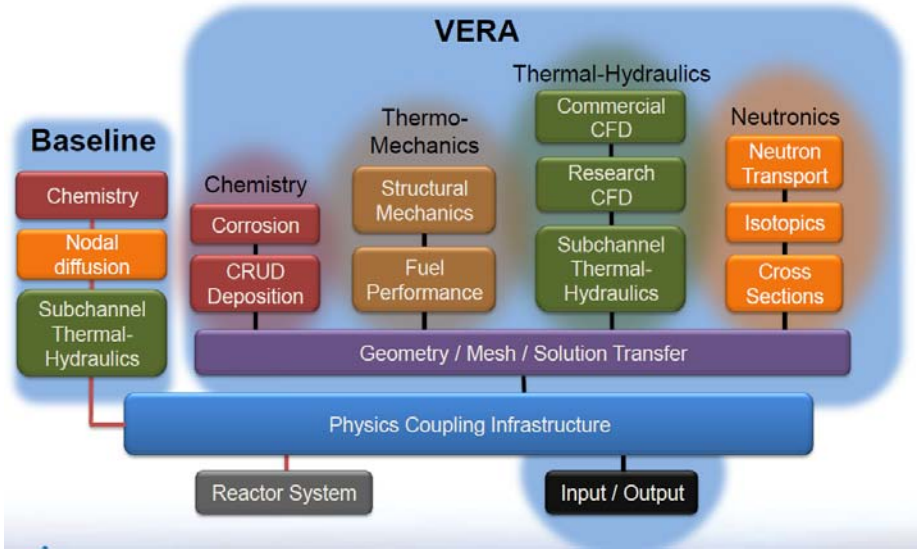
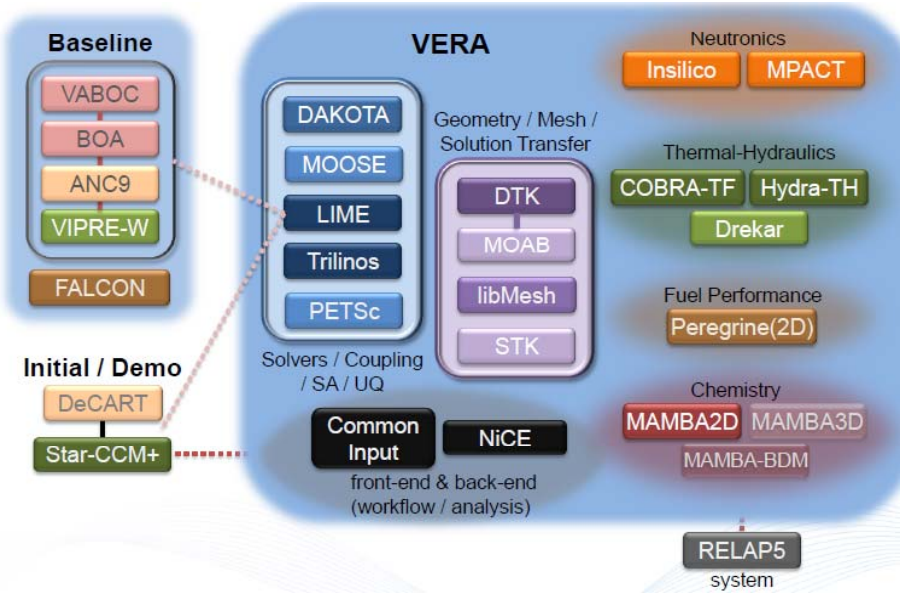
Virtual Environment for Reactor Applications (VERA)

Built to be flexible to allow modules to be activated as needed to address specific challenge problems

Target Architecture



Integrated Components as of July 2013



When Needed – 3D, High Resolution, Built-in UQ, Based on 1st Principle Physics, Running on Leadership to Industry Class HPC

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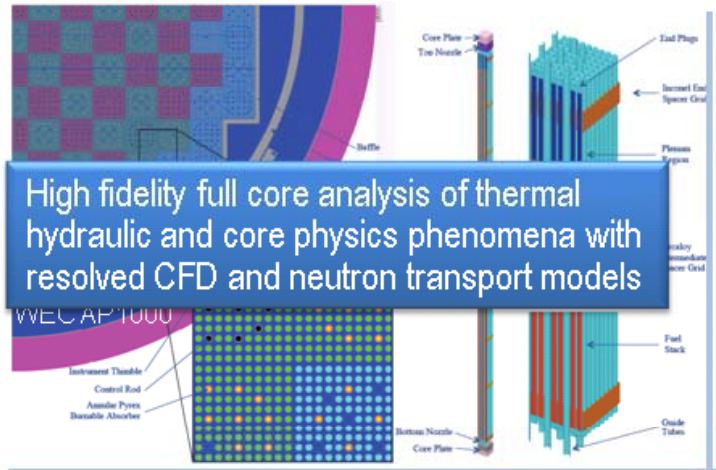
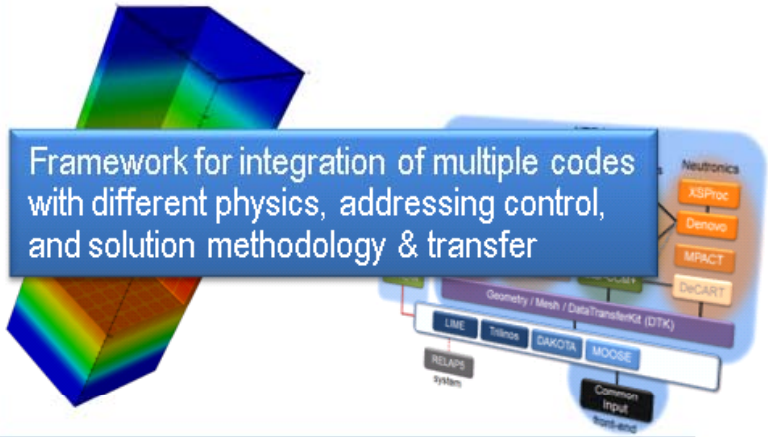
CASL Technical Innovations

Advanced Modeling Applications



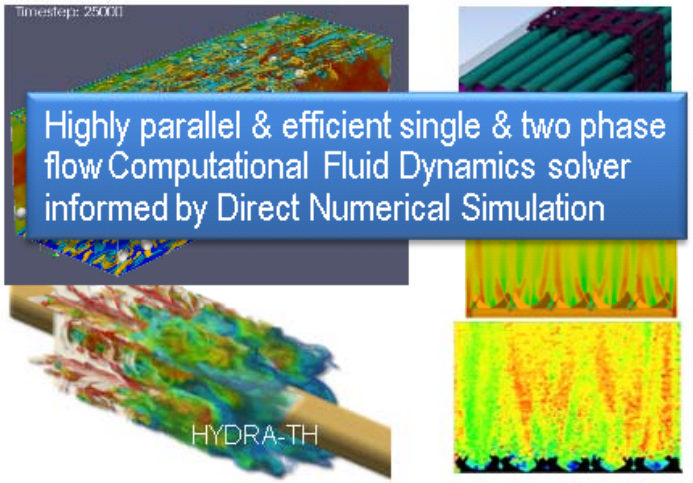
High fidelity full core analysis of thermal hydraulic and core physics phenomena with resolved CFD and neutron transport models

Physics Integration



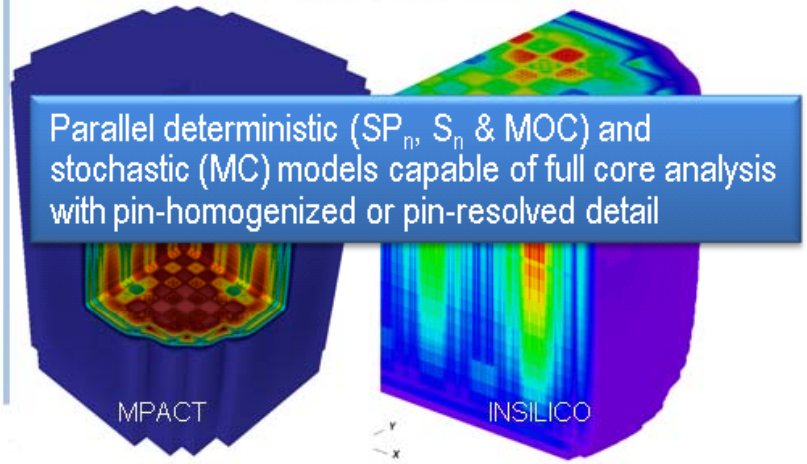
Framework for integration of multiple codes with different physics, addressing control, and solution methodology & transfer

Thermal Hydraulic Methods



Highly parallel & efficient single & two phase flow Computational Fluid Dynamics solver informed by Direct Numerical Simulation

Radiation Transport Methods



Parallel deterministic (SP_n, S_n & MOC) and stochastic (MC) models capable of full core analysis with pin-homogenized or pin-resolved detail

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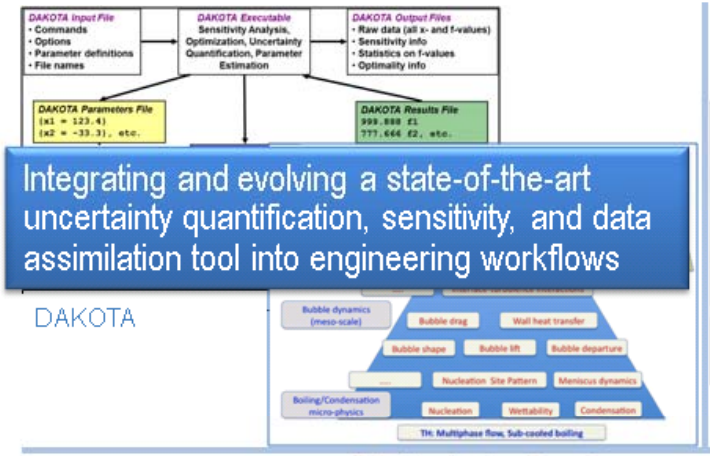
CASL Technology Innovations

Validation & Uncertainty Quantification



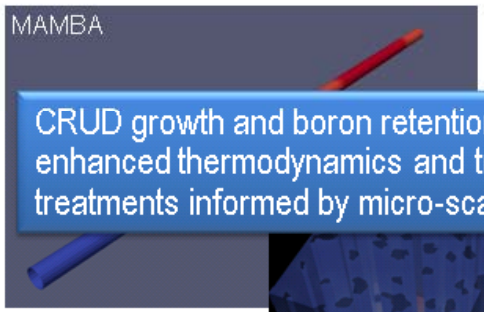
Integrating and evolving a state-of-the-art uncertainty quantification, sensitivity, and data assimilation tool into engineering workflows

DAKOTA

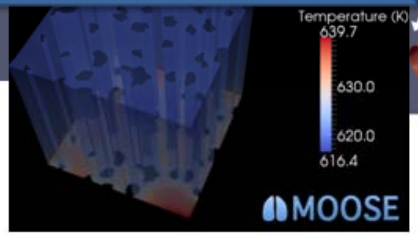
VOCC

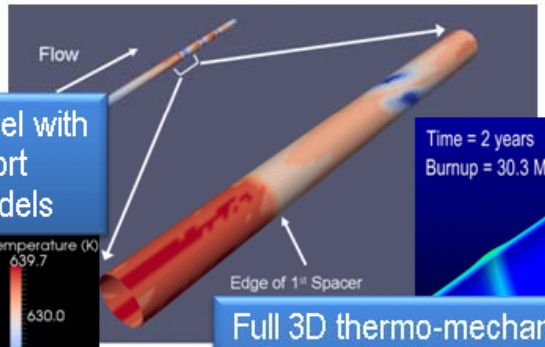
Bringing together local ("physical") and geographically distributed ("virtual") contributors in a meaningful and productive way

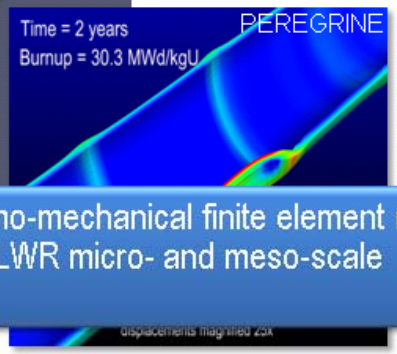
Materials Performance and Optimization



CRUD growth and boron retention model with enhanced thermodynamics and transport treatments informed by micro-scale models







Full 3D thermo-mechanical finite element model informed by LWR micro- and meso-scale models

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CASL R&D Business Enterprise Innovations

CASL Continues to Plan and Execute With our Evolving Plan of Record (PoR) Process

We have finished PoR-1 thru PoR-7, and are in the midst of PoR-8

- CASL is planned and executed in a series of 6-month periods known as the *Plan of Record* (PoR)
- PoR is a documented implementation plan of L1-L3 milestones, tasks, and risks ("who does what when")
- Each PoR is a living document describing expectations for the next six months
  - Senior Leadership Team (SLT) defines/refines L1 milestones with DOE concurrence
  - Extended Leadership Team (ELT) [Focus Area Leads + Challenge Problem Integrators] meets to discuss L1 and proposed supporting L2 and L3 milestones
  - Focus Area (FA) Leads work with staff and enter milestone information into project management database (Trac)
  - SLT iterates with FA Leads on milestones to finalize
  - Trac and PoR document finalized; baseline established and under change control

A structured continuously improving process to plan, execute and deliver results.
84+ milestones delivered to date in FY13 (since 10/01/12): 3 L1s, 8 L2s, 73 L3s

Guided and reviewed by an independent science council

Scientific Output thru Year 3

- Virtual Reactor M&S technology integrated, under active development and assessment, and deployed for beta testing
- 81+ journal articles
- 328 conference papers
- 28 technical reports
- 51+ invited talks
- 382 milestone reports
- 216 programmatic reports

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CASL Technology Deployment

Code Releases and Industry Tech Stands

- **Limited Public Releases**: Done through RSICC
- **Test Stands**: Early deployment to industry for rapid and enhanced testing, use, and ultimate adoption of VERA to support real-world LWR applications
  - **Westinghouse:** 6/13; focus on VERA simulation of AP1000 1st core startup
  - **EPRI:** 11/13; new EPRI computing capabilities will be utilized to test VERA fuel performance
  - **TVA:** Planned for Spring/Summer 2014; focus currently targeted for lower plenum flow anomaly

Industry Council

- Assure that CASL solutions are "useful and used" by industry and that CASL provides effective leadership advancing the M&S state-of-the-art.

Owner/ Operators of Nuclear Plants	Fuel and/or SMR Vendors	Engineering Design, Service Providers, R&D	Independent Software Vendor	Computer Technology Companies	Ex-Officio
Dominion	AREVA	Battelle	ANSYS	Cray	BOD
Duke Energy	GNF	Bettis /NNPP	CD-adapco	IBM	DOE
EDF	mPower	EPRI	GSE Systems	NVIDIA	
Exelon	NuScale	Rolls Royce			
TVA	WEC	Studsvik Scandpower			

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CASL @ 5.0+ Years (Approach to Phase 2 Scope)

CASL Phase 1 Results

Broaden

Other Reactors Scope

- Other PWR fuel forms
- BWRs
- New PWRs
- SMRs
- More . . . ?

Deepen

Phase 1 Reactors Scope

- Improve modeling and simulation products to better address existing challenge problems
- Extend modeling and simulation products to other PWR challenge problems
- Improve usability
- Extend and improve deployment
- More . . . ?

As in Phase 1 – CASL will be expected to define the details of the:

- » Exact problems and their expected impact
- » Approach
- » Team