CASL Industry Council Meeting
August 23 – 24, 2011 – Oak Ridge, TN

Minutes

The third meeting of the Industry Council (IC) for the Consortium for Advanced Simulation of Light Water Reactors (CASL) was held on August 23 until noon on August 24, 2011, at Oak Ridge National Laboratories (ORNL), Oak Ridge, Tennessee. The meeting was chaired by John Gaertner of EPRI.

The agenda, meeting attendees, and IC member organizations are included in Attachment 1 to these minutes.

Attendance was by invitation only. Fifteen representatives from 13 of the 19 member organizations attended. In addition, members of the CASL project team participated in the meetings as indicated on the agenda.

After the introduction of each participant, John Gaertner previewed the agenda and the objectives of the meeting: 1) update IC members on CASL project status including plans for Intellectual Property access and Quality Assurance, 2) discuss IC activity to communicate Analysis Workflow information to CASL, 3) discuss with IC recommendations on virtual reactor (VERA) Deployment , 4) discuss anticipated early applications of VERA beyond the scheduled Challenge Problems, 5) tour the CASL "One Roof" Facility, and 6) review status and update IC Action Items.

The CASL staff presented an update of CASL activities. Doug Kothe, CASL Director, offered an overview of the CASL project. He reviewed the Challenge Problems that drive the advances in technology, development of VERA, and applications of the technology. He reviewed the CASL partners and the organization of CASL which is structured around six technical Focus Areas and the external Councils. He discussed the elements of the project which establish its cadence – three to six month Periods of Record with clear milestones and deliverables. He previewed the CASL "One Roof" facility which opened in May. He summarized the status and structure of VERA. Finally, he reviewed significant achievements in the first year of CASL and the challenges which will be addressed in the next six months. Doug's presentation is Attachment 2.

For each of the six Technical Focus Areas, a member of the CASL staff -- Doug Kothe, Ronaldo Szilard, Jess Gehin, or John Turner -- summarized Focus Area objectives and significant milestones during the first year of the project. All actions created during the discussion are in the Action Items section of these minutes below. The presentations are Attachment 3.

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John Gaertner summarized the status of IC Action Items. Minutes of the January/February IC Meetings had been approved during a May 9 Industry Council Webcast. Remaining Action Items and the status of each is presented below:

- VRI to consider a larger context for specifying "Workflow Management" than currently in the VRI focus area plan.
- CASL to create list of "use-case types" and define the attributes that will require differences in the VERA physics simulation suite.

Status: Defining the path forward for the two items above is the objective of the "Workflow Project" agenda item of this meeting to follow.

- VRI to investigate potential collaboration with EDF and Rolls-Royce on mesh generation strategy.
- THM to investigate use and collaboration on open-source or other accessible turbulent flow models; e.g., with EDF.

Status: EDF and Rolls-Royce have engaged CASL staff on these collaboration opportunities and work is continuing.

- CASL to transfer the following technical items to the IC:
  - more information on the LIME integration environment
  - access to technical specs for Challenge Problems
  - CASL report on verification and validation data.

Status: CASL commits to develop a technology transfer process for communication with IC, as well as to inform the IC of publicly available papers and reports produced by CASL. This action is to be complete before next IC Meeting.

Andrew Godfrey of the CASL AMA staff then led a discussion of the proposed Workflow Project among the IC and the AMA and VRA Focus Areas. The intent is to select several high-level analyses performed by industry, develop detailed workflow for these analyses, and use these workflows to guide the development of VERA. The prioritization of analyses for detailed consideration and the development of workflows will be based on information collected from interviews and discussions with selected IC members. The purpose of this session is to receive input from IC members on 1) the desired end product of this activity, 2) the process for collecting information from the IC members, and 3) the schedule for the activities.

Andrew achieved consensus on the use and definition of the terms "analysis", "workflow", and "simulation" for this activity. He proposed a process for conducting the information gathering and synthesis by CASL staff. He proposed a set of analyses and a sample of Workflow Questions for use in interaction with IC members. Andrew's presentation is Attachment 4.

IC members offered suggestions on the potential analyses for consideration and on Workflow Questions. Six members expressed interest to provide Workflow feedback to CASL – Duke Energy, AREVA, GSE, Westinghouse, EDF, Rolls Royce and TVA. The CASL staff committed to work with members to develop a complete list of participants. It was proposed that member interactions would occur by October 31, 2011; a draft CASL white paper on Analyses and Workflows would be produced before the end of the year; and it would be a topic for the next CASL IC meeting (tentatively in January 2012). An action to plan and perform this activity is included in the Action Item list below.

Matt Sieger, CASL Quality Manager, then presented the CASL approach to quality assurance for the entire CASL product landscape; that is, Software, Communications (including Technology Transfer), Services, People, and Intellectual Property. He explained that specific quality procedures from DOE, ISO, and NRC formed the foundation for CASL quality assurance. For VERA development, this foundation together with the formal Agile Development and Automated Testing process employed by the VRI Focus Area, ensures quality assurance compliance. All actions created during the discussion are in the Action Items section of these minutes below. Matt's presentation is Attachment 5.

Ronaldo Szilard then presented the CASL FY12 Programmatic Drivers. This presentation displayed, as a matrix of specific activities by Challenge Problem and by fiscal year, activities that CASL is contractually obligated to perform for DOE. This matrix is a resource for use in the next session, discussion of VERA Deployment Strategies. The matrix is included as Attachment 6.

John Turner, Lead of the VRI Focus Area, then conducted the session on VERA Deployment Strategies. He presented the VERA Roadmap: the specific functional modules which are expected to comprise VERA versions 0.5, 1.0, and 2.0 (by the end of FY12) that will be available for internal CASL use. This roadmap addresses the Programmatic Drivers described in the previous session, and it represents an evolution toward greater modeling capability, higher resolution, better physical representation, optional modules for some functions, enhanced coupling of code modules, integrated treatment of uncertainties, and better representation of results. In light of this roadmap, John asked for the opinion of IC members "Which should be the CASL priority"…

1. Release VERA 2.0 for use by IC members or apply VERA 2.0 one or more important generic industry problems to demonstrate value added?
2. Design VERA 2.0 and beyond for 1) generally available platforms and operating systems (such as PCs and Windows), 2) high end workstations (such as Linux and cluster machines), or 3) HPC with web-based access?
3. Replace early modules with new VERA-specific capability that will continue to evolve or develop VERA as a modular environment?

Significant discussion ensued. For question 1, there was more interest in "apply VERA 2.0 to important industry problems" to demonstrate value added than "release VERA 2.0 for use by IC members", but there was also interest the other way. A number of members recommended a detailed evaluation of CIPS demonstrating real benefits (financial and operational) for core reload design—using VERA. For question 2 above, there was interest expressed in "high end workstations (such as Linux and cluster machines)" and consideration of "web-based access". For question 3, there was interest expressed to "develop VERA as a modular environment". The roadmap allows for both CASL-specific development and modularity on a case-by-case basis as appropriate. John's presentation is Attachment 7.

Jeff Cornett, Chairman of the CASL IP and Commercialization Council, then presented the CASL vision for Management of IP in CASL Products. He presented a hierarchy of considerations and a commitment to have an effective and fair process in place as CASL products became available. Jeff's presentation is Attachment 8.

The meeting attendees then reconvened at the CASL "One Roof" facility for a tour. The tour included IVAC - Cave, CASPER, Ideate Stations, and the Huddles.

Steve Hess then facilitated a discussion on Applications of VERA beyond Challenge Problems. The purpose of the discussion was to identify likely "first uses" of VERA so that these applications can be accommodated in the VERA design and V&V to increase the likelihood of successful and efficient applications after the Challenge Problems. He identified a potential set of applications for consideration by the IC members. These include:

- Corresponding CASL capabilities for other PWR fuel vendors
- Evaluation of BWR operational issues
  - Pellet / clad interaction (PCI)
  - Channel bow
  - Fuel preconditioning / start-up ramps
  - Core stability
- Evaluation of NPP safety issues post-Fukushima (PWR / BWR)
  - Behavior during severe accident conditions

– Issues related to spent fuel pool / dry cask storage
- Evaluation of changes in NPP operation
  - Load following operation (PWR and BWR)
  - "Real-time" tracking of fuel / core performance
- Design / licensing / operation of SMRs.

Several candidates were offered by IC members. B&W plant operators suggested investigation of grid to baffle wear problems including baffle swelling. BWR plants might evaluate effects of off-normal chemistry and chemical transients during startup. PWR plants proposed application to post-LOCA issues associated with boron precipitation and fiber suspension that can lead to blockage of flow in the vessel, especially for cold-leg LOCAs. It was reported that BWRs are susceptible to the same issue. BWRs might also apply VERA to vibration issues with jet pumps and reactor internals. Applications to channel bow for BWRs can address shutdown capability and testing requirements during operation. VERA could evaluate use of SiC channels for BWRs. BWR core stability issues can be investigated, particularly operational restrictions and impacts of transients. In the post-Fukushima environment, VERA could model the effect of brief dry-out of cores then recovery on fuel integrity. Steve's presentation is Attachment 9.

The next session was a "round robin", allowing each IC member to summarize his or her significant suggestions, concerns, or comments about the meeting agenda items. Comments are captured by the list below:

Chiu --

1. DOE would benefit from attending IC meetings (they typically do, but not this time).
2. CASL should prepare for a role evaluating SMRs, probably in second 5 years.
3. Platforms for VERA release have not been adequately discussed by IC.

Copestake --

4. Although pilot studies to show benefits are important, CASL must also produce a VERA tool with enhanced capabilities.
5. Transient capabilities in VERA should be accelerated. They are a critical need.
6. Integration of system tools (e.g., RELAP) should be accelerated.

Schwarz --

7. VERA must be open for commercially available modules to interface (e.g., ANSYS). ANSYS is willing to work on model evaluators to facilitate this interface.

8. Attention to detail on the QA program is essential – capture of (non-evident) Class 3 errors, document record of analysis, embed best practices in documentation.
9. What is CASL's opinion on ASME Standard 20 for V&V; what is the user experience?
10. CASL needs to consider the impact of CASL on end users – level of effort, GUI, and efficiency of use.

Wang --

11. GSE is seeking way for simulation vendor to best participate in CASL and the IC. GSE is evolving to production of engineering simulators and inclusion of beyond design basis conditions. Also, they are moving to a data-centered simulation with trace capability from source to end.

Walker --

12. Rollout of the CASL code is important beyond FY12; not just the focus on beneficial applications. Test stands are a good mechanism to facilitate rollout for early releases.

Ray --

13. It is important to focus on one significant VERA success demonstrating industry benefits as early as possible. CIPS is an excellent candidate for VERA in FY12.

Thomas --

14. IC Workflow Project will be beneficial to both CASL and to IC members.
15. CAS priority should be to advance science and perform beneficial applications – code release is less important. Duke would participate in CIPS pilot study. Validation plan for CIPS 3x3 model issuggested for next IC meeting.

Stout --

16. CASL should focus on applications that demonstrate operational improvements (e.g., burnup efficiency and spent fuel reduction). CIPS pilot study would show VERA value.
17. CASL should accelerate modeling of transients – these are limiting conditions for utilities, and they could drive model coupling capabilities.

Marchand --

18. EDF reiterates the importance of transient modeling and system modeling.
19. CASL should document best practices for configuring analyses and for choosing among module options.

Berthou --

20. Validation plans should be integral with VERA development. Validation of modules before coupling is important. VERA results should be continually compared against a baseline representing current technology.

21. CASL must address distribution of technology beyond the U.S.
22. CASL must have a clear plan for enabling modularization as VERA is developed.

Lewis --

23. CASL must maintain its focus and avoid dilution as new opportunities and issues arise. For utilities, focus is to quantify financial benefits. For vendors focus is to reduce need for testing. Although CASL should foresee safety related applications, non-safety related applications have near term value to industry.

The following Action items were identified as a result of this meeting:

1. Establish communications and technology transfer processes with IC
   - provide more information on the LIME integration environment
   - send the report on CASL validation data requirement
   - arrange access to technical specs for Challenge Problems
   - Provide CASL published papers and reports
2. Acquire Analysis and Workflow information from Industry Council members. Based on this information, CASL will select a prioritized set of analyses to represent the associated workflow.
3. Verify that CASL compliance with NQA-1 will assure compliance with Part 50 App B. Ensure that NRC NRR is knowledgeable about CASL development and potential regulatory applications.
4. Summarize input from VERA Deployment discussion. Investigate CIPS pilot applications that demonstrate benefits (such as improved margin for core reload) of advanced technology. For VERA releases, consider high end workstations, Linux OS, and web-based interface.
5. Clarify and focus the “round robin” comments by reviewing with individual IC members. Consolidate these comments and generate appropriate IC actions.

The meeting was adjourned at approximately 12:00 noon on August 24.

Prepared: September 1, 2011
By John Gaertner, Industry Council Chairman

Attachments

Attachment 1
CASL Industry Council Meeting Agenda
CASL Industry Council Meeting Attendees
IC Member Organizations

Attachment 2
CASL Refresher and Overview

Attachment 3
Focus Area Reports

Attachment 4
Workflow Project

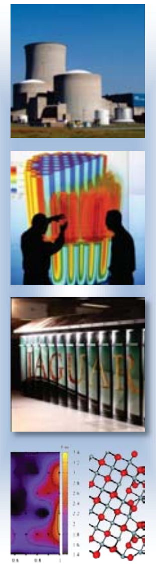
Attachment 5
CASL Quality Assurance

Attachment 6
Review of VERA Requirements Document

Attachment 7
Virtual Reactor Integration

Attachment 8
CASL IP

Attachment 9
Industry Issues Beyond CASL Challenge Problems



CASL Industry Council

Welcome!

August 23-24, 2011

The Cabin at Oak Ridge National Laboratory

Agenda

Tuesday, August 23, 2011		
8:00 am – 8:30 am	Registration and Coffee	
8:30 am – 8:45 am	Welcome and Introductions	*John Gaertner*
8:45 am – 10:15 am	Update CASL Activities/Plans since May	*CASL Team*
10:15 am – 10:45 am	Break	
10:45 am – 11:45 am	Workflow Project	*Andrew Godfrey*
11:45 pm – 12:45 pm	Logistics of Workflow Project, *working lunch*	*All*
12:45 pm – 1:15 pm	Management of IP in CASL Products	*Jeff Cornett*
1:15 pm – 1:45 pm	CASL FY12 Programmatic Drivers	*Ronaldo Szilard*
1:45 pm – 3:00 pm	VERA Deployment Strategies • Platform, Functionality, Test Stand Uses, IC Review	*John Turner*
3:00 pm – 3:30 pm	Break	
3:30 pm – 4:00 pm	CASL Quality Assurance	*Matt Sieger*
4:00 pm – 5:30 pm	Tour of CASL facilities • IVAC - Cave, CASPER, Ideate Station, Huddle	*John Shaw*
5:30 pm	Adjourn	
6:30 pm	Dinner	*At Turkey Creek*

Agenda

Wednesday, August 24, 2011		
8:00 am – 8:30 am	Coffee	
8:30 am – 10:00 am	Applications of VERA Beyond Challenge Problems	*Steve Hess*
10:00 am – 10:15 am	Break	
10:15 am – 11:30 am	Round Table: What's good, bad, missing?	*John Gaertner*
11:30 pm – 12:00 pm	Action Items and Wrap up	*John Gaertner*
	Adjourn	

Membership

EPRI
Battelle

AREVA
Westinghouse (WEC)
Global Nuclear Fuels (GNF)

Rolls Royce
Bettis
Boeing
Studsvik Scandpower

Dominion
Duke Energy
EDF
TVA

ANSYS
GSE Simulators

IBM
Cray Computing
DOE
CASL BOD (ex-officio)

Attendees

Gaertner, John	EPRI
Alan Copestake	Rolls Royce
Christopher Lewis	AREVA
Daniel Stout	TVA
George Chiu	IBM
Jean-Yves Berthou	EDF
Olivier Marchand	EDF
Russell Stachowski	GNF
Scott Thomas	Duke
Sumit Ray	WEC
Walter Schwarz	ANSYS
William Andrews	Battelle

Paul Michael Scott	Battelle
Rhonda Walker	GSE
Zen Wang	GSE
Douglas B. Kothe	CASL
John Turner	CASL
Sieger, Matt T.	CASL
Cornett, Jeffrey B.	CASL
Hess, Stephen	CASL
Ronaldo H Szilard	CASL
Andrew Godfrey	CASL
Rose Montgomery	CASL
Jess Gehin	CASL

CASL First Year Summary

Douglas B. Kothe, CASL Director

Industry Council Meeting
Oak Ridge National Laboratory
August 23, 2011

CASL Partners

Core partners

- Oak Ridge National Laboratory, HQ
- 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
- Notre Dame University
- Rensselaer Polytechnic Institute
- Southern States Energy Board
- Texas A&M University
- University of Florida
- University of Tennessee
- University of Wisconsin

CASL targets key limiting phenomena that are barriers to improved reactor performance

	Power uprate	High burnup	Life extension
Operational "Challenge Problems"			
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 "Challenge Problems"			
Departure from Nucleate Boiling (DNB)	✖		
Cladding Integrity during Loss of Coolant Accidents (LOCA)	✖	✖	
Cladding Integrity during Reactivity Insertion Accidents (RIA)	✖	✖	
Reactor Vessel Integrity	✖		✖
Reactor Internals Integrity	✖		✖

Full Scope-Current Focus	Full Scope-Future Focus	Partial Scope-Future Focus

The CASL Challenge Problems Do Address Many Key Industry Needs

- CRUD (CIPS & CILC)
  - In-depth phenomenological understanding is sorely needed as reactors move to higher power densities, or change chemistry programs
- Grid-to-Rod Fretting (GTRF)
  - Key understanding will enable faster prototype fuel development and enable more advanced fuel designs
    - Modelling of the complex area around the baffle would be a plus
      - These are the areas most susceptible to GTRF
- Pellet Clad Interaction (PCI)
  - Accurate models will provide a much better understanding of margins
    - Can provide operator guidance, and reduce overly conservative restrictions that currently exist for power maneuvers
    - Can provide insights into better pellet designs
- Fuel Assembly Distortion (FAD)
  - Better understanding would remove semi empirical methods that are in use today
  - Overly conservative assumptions in place today limit burnup
    - Better knowledge of key phenomenon will allow more reactor operating margins and potentially better fuel designs
- Departure From Nucleate Boiling (DNB)
  - Current empirical correlations do not allow for any extrapolation
  - New fuel designs cannot be developed without a DNB test
  - Phenomenological understanding will open up many new possibilities for higher reactor operating margins
- Cladding integrity during LOCA
  - NRC about to impose restrictions based on research done to date
  - These restrictions impact fuel cycle economics and reduce allowable burnup

Each reactor performance improvement goal brings benefits **and** concerns

Power uprates

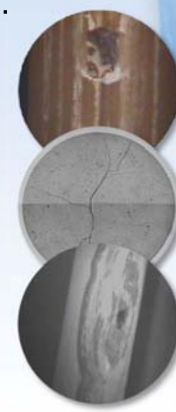
- 5–7 GWe delivered at ~20% of new reactor cost
- Advances in M&S needed to enable further uprates (up to 20 GWe)
- Key concerns:
  - Damage to structures, systems, and components (SSC)
  - Fuel and steam generator integrity
  - Violation of safety limits

Lifetime extension

- Reduces cost of electricity
- Essentially expands existing nuclear power fleet
- Requires ability to predict SSC degradation
- Key concerns:
  - Effects of increased radiation and aging on integrity of reactor vessel and internals
  - Ex-vessel performance (effects of aging on containment and piping)

Higher burnup

- Supports reduction in amount of used nuclear fuel
- Supports uprates by avoiding need for additional fuel
- Key concerns:
  - Cladding integrity
  - Fretting
  - Corrosion/ CRUD
  - Hydriding
  - Creep
  - Fuel-cladding mechanical interactions



CASL scope: Develop and apply the VR to assess fuel design, operation, and safety criteria

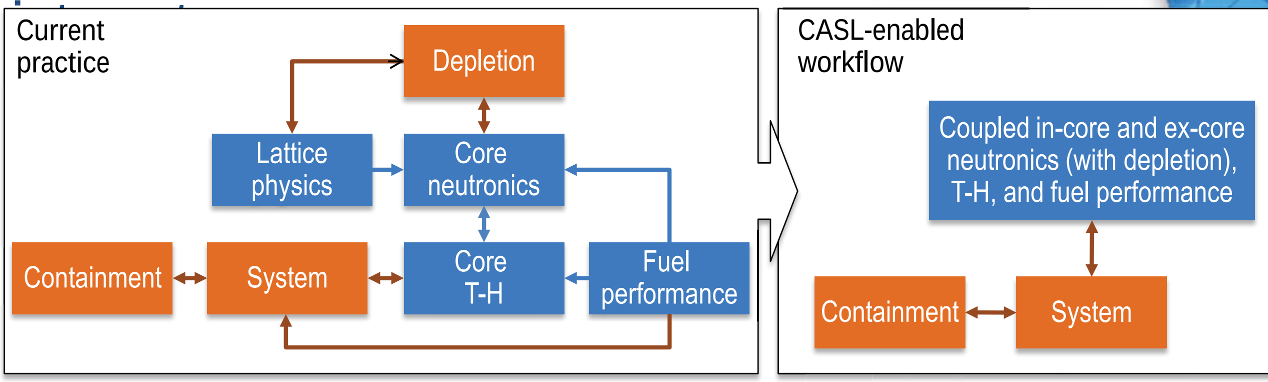
Near-term priorities (years 1–5)

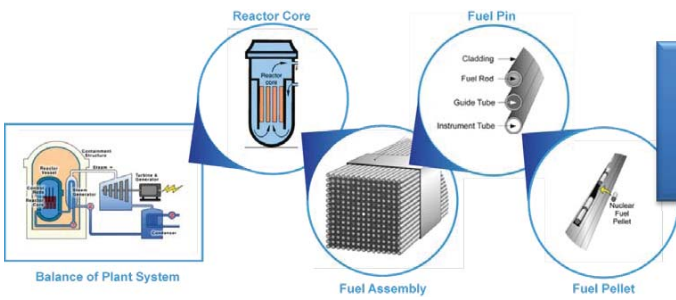
- Deliver improved predictive simulation of PWR core, internals, and vessel
  - Couple VR to evolving out-of-vessel simulation capability
  - Maintain applicability to other NPP types
- Execute work in 5 technical focus areas to:
  - Equip the VR with necessary physical models and multiphysics integrators
  - Build the VR with a comprehensive, usable, and extensible software system
  - Validate and assess the VR models with self-consistent quantified uncertainties

Longer-term priorities (years 6–10)

- Expand activities to include structures, systems, and components beyond the reactor vessel
- Established a focused effort on BWRs and SMRs
- Continue focus on delivering a useful VR to:
  - Reactor designers
  - NPP operators
  - Nuclear regulators
  - New generation of nuclear energy professionals

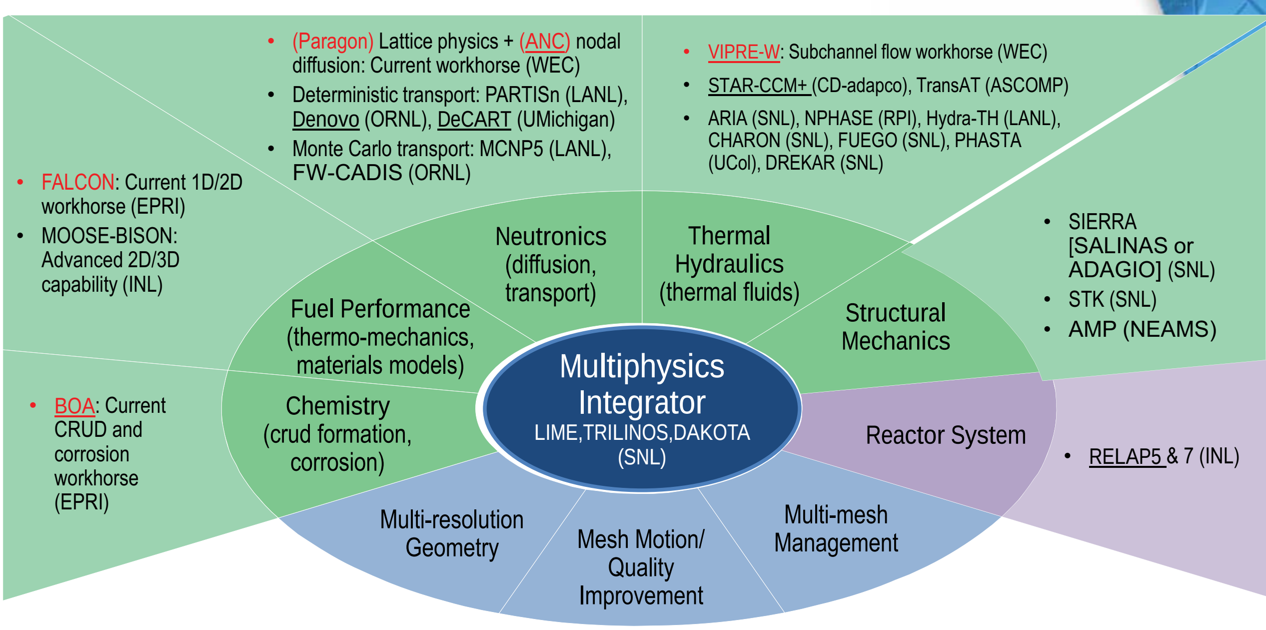
The CASL Virtual Reactor is at the heart of the plan and is the science and technology





Suite of advanced yet usable M&S tools and methods, integrated within a common software infrastructure for predictive simulation of LWRs

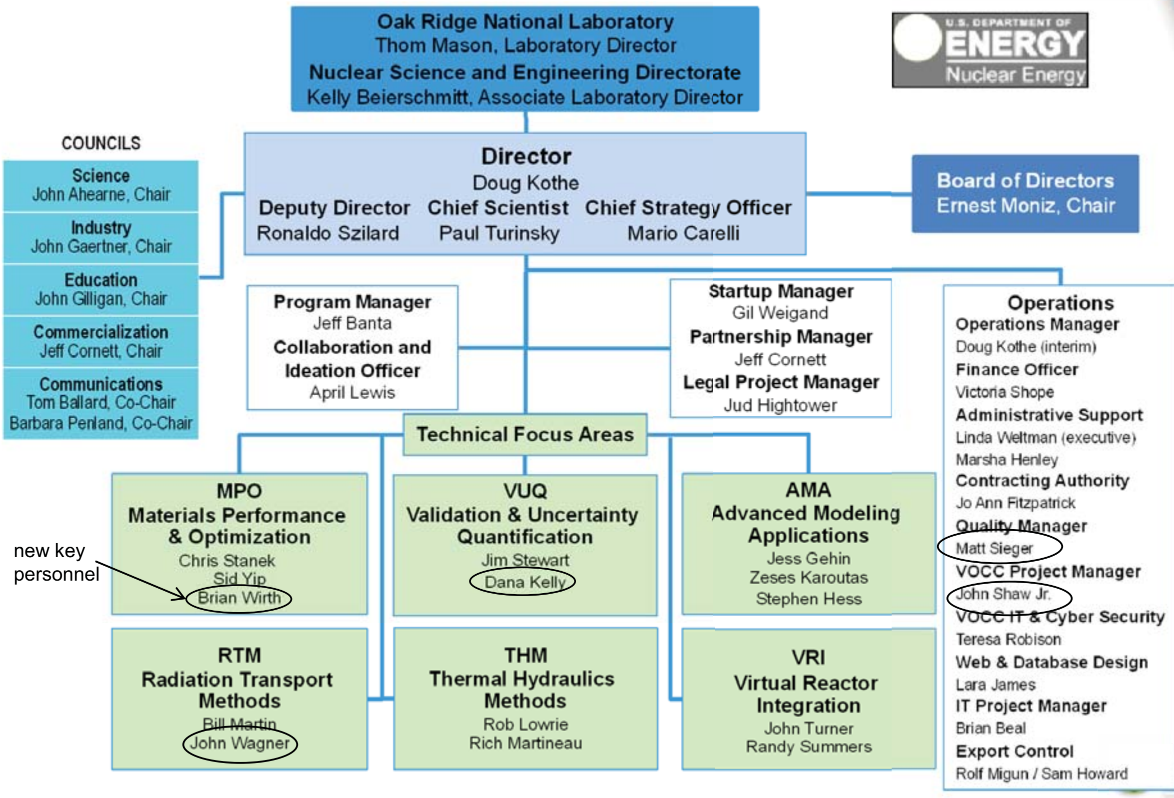
VERA builds on a foundation of mature, validated, and widely used software



Reference M&S capability built upon WEC capabilities, transitioning to existing advanced capabilities, finalizing to existing and new capabilities as required.

CASL Organization: key personnel

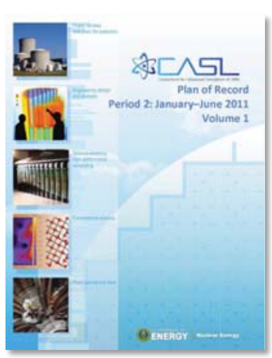
Structure at Year 1 (Aug 2011)



We are Finding a CASL Cadence

- CASL is executing per 6-month *Plan of Record (PoR)* tasks, deliverables, and milestones
  - Imposes more agility and flexibility in our plan and actions
- We would like to release our virtual reactor (VERA) regularly and follow an evolutionary delivery life cycle
  - Place our M&S products into hands of users early and often
  - Follow quarterly "treadmills": science delivery, release, assessment, solution

Period 1: Jul – Dec 2010



Period 2: Jan – Jun 2011

Period 3: Jul – Sep 2011

More details about how CASL develops a PoR in Paul Turinsky's presentation

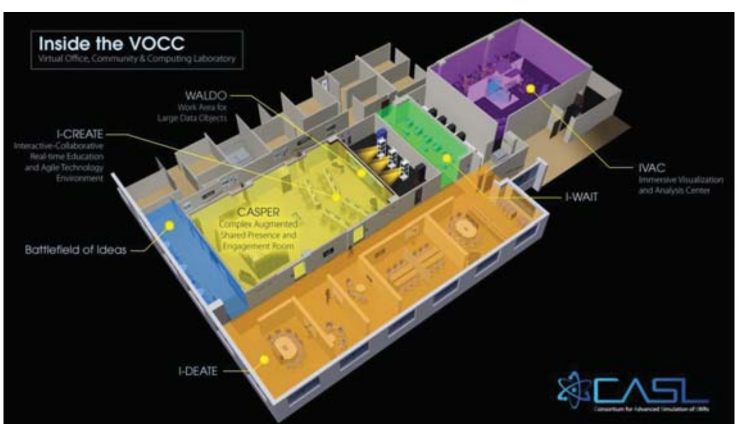
Executing within the CASL "One Roof"

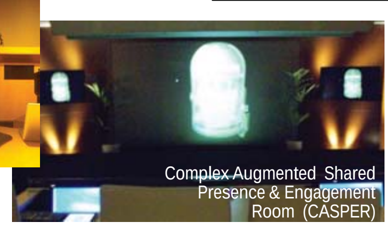
Under which CASL staff are physically and virtually collocated

- Collocation: significant collection of CASL partners in one physical location for the purpose of executing CASL goals
  - Single physical setting with CASL staff gathered to conduct technical work
  - Often this physical location will be at the anchor CASL facility.
  - Could be at a partner member site or a significant staff gathering at a technical conference, workshop, or working meeting
- With virtual collaboration among CASL staff, & the amount of effort expended by CASL partners in working and interacting in these virtual modes, such time is considered to be collocation, albeit at a reduced rate
- Collocation fraction: percent of "CASL time" spent collocated

The CASL One-Roof Facility is Operational

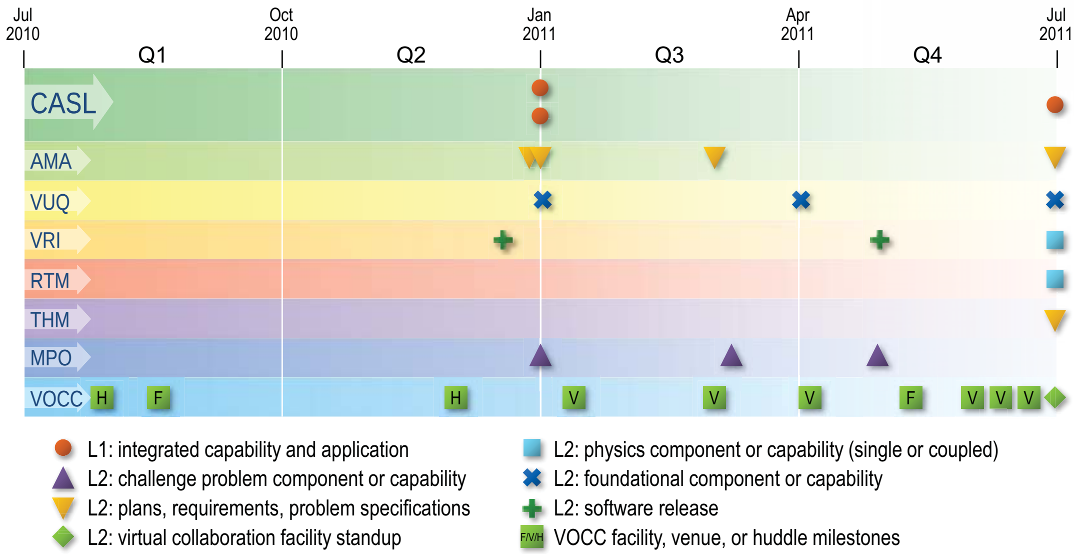
Complete with its integrated VOCC collaboration & data analysis venues





CASL Year One

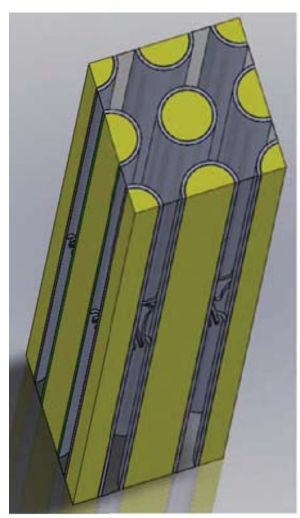
Summary of delivered L1 and L2 milestones

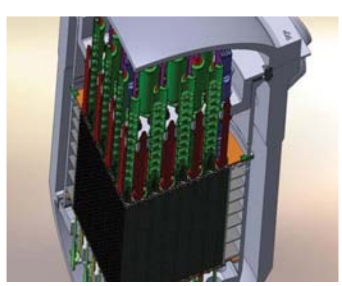


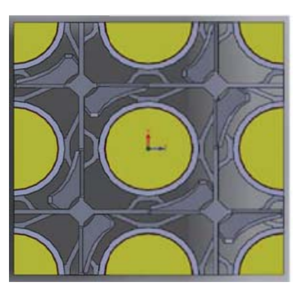
- Overall direction guided by GTRF & CRUD challenge problems (L1 milestones) per proposal
- Executed/planned 3/4 L1 and 15/17 L2 technical milestones (relative to 2 L1 & 12 L2 Y1 proposed milestones) – key technical decisions & directions in proposal remain valid
- Designed, constructed, and outfitted new CASL one-roof facility @ ORNL
- Designed, installed, and integrated VOCC Project collaboration & core data analysis venues at the CASL one-roof facility – 6 partners (+ DOE) now connected via telepresence huddles

Process for Addressing Challenge Problems

- Perform analysis of challenge problems using current tools (REF)
- Couple existing tools
- Utilize coupled existing tools to help developed advanced ones
- Start development of advanced tools with 3x3 multi-physics pin modeling then scale up to larger geometries (e.g. 17x17 & Vessel)
- Develop test problems/data packages to validate tools used for challenge problems
- Apply coupled existing and advanced tools to challenge problems for Watts Bar 1 reactor
- Utilize the Predictive Capability Maturity Model (PCMM) to summarize benefits of coupled and advanced tools and better understand safety margins



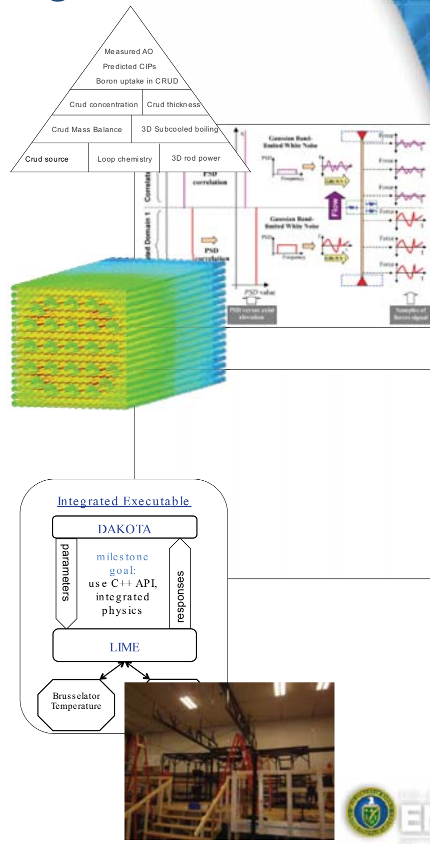




First Period Plan of Record Highlights

PoR-1: Jul – Dec 2010

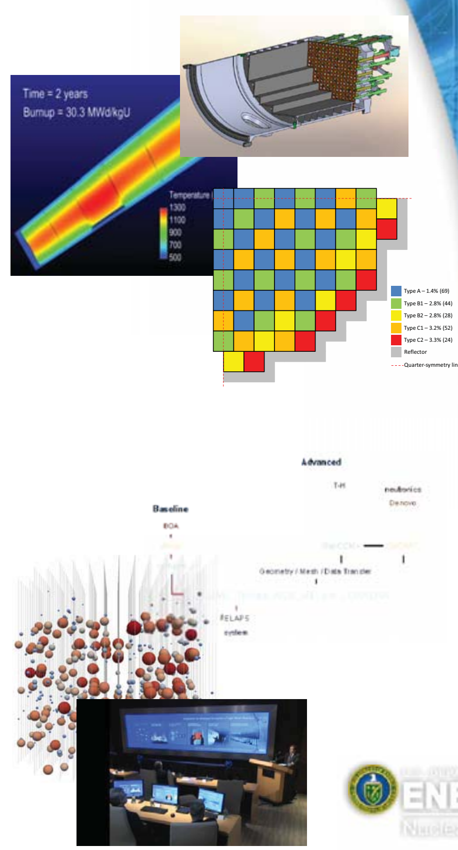
AMA	Development of requirements and validation plan to support and guide CASL virtual reactor development
MPO	Comprehensive plan developed for upscaling fundamental and improved fuel, materials science, & coolant chemistry R&D efforts
RTM	Application of radiation transport & CFD in VERA to an operational PWR sub-core scenario to demonstrate feedback coupling and contrast predictions with WEC coupled tool predictions.
THM	Initial thermal hydraulics plan
VRI	First release of Version 0.5 of VERA to CASL partners
VUQ	State-of-the-art sensitivity and optimization capability (DAKOTA) integrated within VERA
VOCC	Requirements collected, competitive technology analyzed, facility design complete and construction started, venue designs complete, telepresence procured



Second Period Plan of Record Highlights

PoR-2: Jul – Dec 2010

AMA	Developed QA Plan, VERA Validation Plan and Requirements, Challenge Problem specifications and model development, initial core model for TVA Watts Bar Plant
MPO	Delivered modeling frameworks for selected aspects of the CRUD, GTRF, and PCI Challenge Problems
RTM	Coupling of CFD to full core neutronics, state-of-the-art full-core pin-homogenized Sn transport capability, new MC code framework for hybrid capability development
THM	Identified 2 open HPC codes for further development, each with unique capabilities, defined ITM test cases and performed initial simulations of turbulent flows with wall-attached bubbles
VRI	Released Version 1.0 of the CASL Virtual Reactor (VERA)
VUQ	Completed SA, Calibration/Validation, and UQ study on Crud/CIPS application, developed VUQ procedures and workflows, performed CFD solution verification study, interfaced Percept verification library to VERA, performed initial validation data review
VOCC	Completed design and construction of the CASL one-roof facility at ORNL and installation of the collaboration and core data analysis venues. CASL staff assumed occupancy in Jun 2010.



Focus Area Reports

Industry Council Meeting
August 2011

Doug Kothe
Director, CASL

Ronaldo Szilard
Deputy Director, CASL

Jess Gehin
Advanced Modeling Applications Lead

Consortium for Advanced Simulation of LWRs

U.S. DEPARTMENT OF ENERGY Nuclear Energy

OAK RIDGE National Laboratory

Radiation Transport Methods (RTM)

Bill Martin
RTM Lead, CASL
University of Michigan

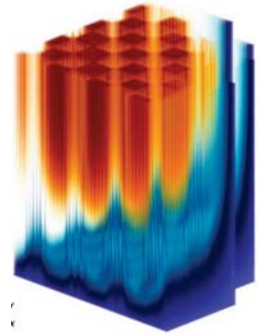
John Wagner
RTO Deputy Lead, CASL

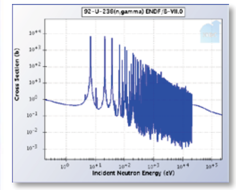
U.S. DEPARTMENT OF ENERGY Nuclear Energy

Radiation Transport Methods (RTM)

Objectives and Strategies

- Objective: Deliver next-generation, non-proprietary, scalable radiation transport simulation tools to VERA, incorporating the latest VUQ technologies
- Strategy: develop and deploy three independent methodologies for 3D pin-resolved transport to provide increasing levels of fidelity and capability for different applications





Requirements Drivers

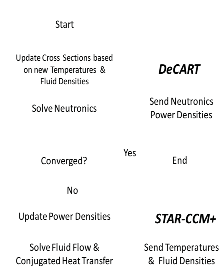
- Pin-resolved 3D full-core transport with depletion including radial, azimuthal, and axial pin power distributions
- Accommodate tight coupling to CFD (including conjugate heat transfer), structural analysis, and fuel performance models
- Common cross section processing
- Integrated within LIME

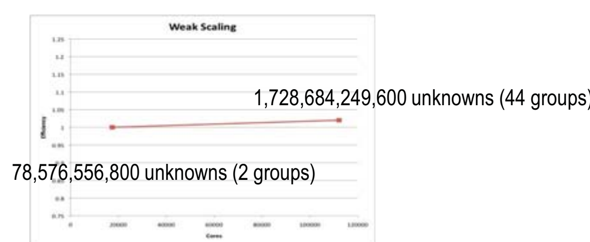
Outcomes and Impact

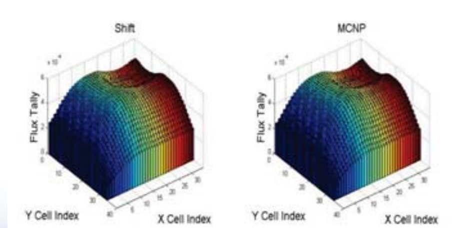
- Outcomes: development of radiation transport capabilities for VERA that contribute to meeting the L1/L2 milestones and challenge problems
- Advanced radiation transport capabilities will have impact:
  - Benefit many other DOE needs/missions
  - Advance the next generation expertise in computational radiation transport
  - Pin-resolved transport capabilities is needed to meet CASL CRUD, GTRF, and PCI milestones

RTM Highlights

- Coupling of CFD to full core neutronics – the production CFD code Star-CCM+ was coupled to the 3D transport/diffusion code DeCART and successfully applied to a full-core reactor configuration.
- The 3D transport code Denovo was applied to a huge configuration with 1.7 trillion space-energy-angle unknowns and using > 100,000 processors on Jaguar.
- A Monte Carlo code (Shift) has been developed within the Denovo framework and has been tested on standard benchmark configurations. Shift will be the platform for CASL hybrid Monte Carlo capability.







Thermal Hydraulic Methods (THM)

Robert Lowry
THM Lead, CASL
Los Alamos National Laboratory

Richard Matineau
THM Deputy Lead, CASL
Idaho National Laboratory

CASL

Thermal Hydraulic Methods

Delivers thermal-hydraulic simulation tools to VERA

Objectives and Strategies

- Deliver next-generation T-H simulation tools to VERA, interfaced with the latest VUQ technologies, and accommodate tight coupling with other physics
- Computational Fluid Dynamics (CFD) Project: Deliver to VERA non-proprietary, scalable, verified and validated component-scale CFD tools
- Interface Tracking Methods (ITM) Project: Generate microscale simulation results and experimental data for CFD closure models and validation

Requirements Drivers

- Advances in THM needed to attain the mesh and physics fidelity required for detailed investigation of CASL Challenge Problems
- Key requirements:
  - Scalable implicit algorithms for turbulent multiphase flow, from microscale through component length scales
  - Ability to mesh and analyze quickly complex geometries
  - Subgrid models that are focused on specifics of Challenge Problems
- Leverage capabilities from NE, Office of Science, NNSA, and others

Outcomes and Impact

- VERA will have the following CFD capability:
  - single- and multiphase
  - subgrid models, tuned to PWRs
  - coupled with and targeted towards specific reactor physics
- Primary success metric: Using the capabilities developed to gain new insight into the CASL Challenge Problems
- The new code, results, and experimental knowledge base will
  - lead to a greater understanding of T-H issues in reactor problems
  - form a repository for future open research and development

CASL

THM Highlights

- Identified 2 non-proprietary HPC codes for further development, each with unique capabilities
  - SNL's Drekar code computed turbulent CFD excitation forces for 3x3 GTRF problem. Contributed to GTRF L1 milestone.
- Defined ITM test cases and performed initial simulations of turbulent flows with wall-attached bubbles
- Published sensitivity study of CFD to multiphase / boiling parameters
- CASL special session at NURETH-14, the premier T-H conference, with 9 papers on advanced thermal hydraulics
- Recently hired former Director for CFD Technology of SIMULIA (leading commercial code)
  - Author of Hydra-TH code, a basis that will accelerate CFD development

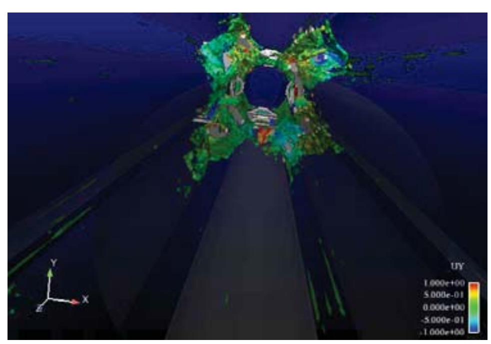
CASL

SNL's Drekar Computed Turbulent CFD Excitation Forces for 3x3 GTRF Problem

L3 THM.CFD.P2.04

- SNL Staff: J. Shadid, T. Smith, R. Pawlowski, E. Cyr, P. Weber, and D. Turner
- Targeted the Grid-to-Rod Fretting (GTRF) Challenge Problem: Fluid/Structure Vibration Wearing of Pin Cladding.
- WEC Benchmark with experimental data for validation.
- Demonstration of a scalable higher-order accurate CFD 3x3 pin capability will:
  - Increase accuracy over current CFD simulations
  - Enable VUQ assessment of CFD and vibration analysis
  - Reduce the margins of uncertainty, allowing for power up-rates, life extensions and future reactor design.
  - Build connections THM – VRI - VUQ and transfer technology within CASL partnership
- Published at NURETH-14

PWR Grid Spacer



Drekar parallel LES Simulation

CFD plays a critical role in majority of Challenge problems

CASL

Materials Performance and Optimization (MPO)

Chris Stanik
MPO Lead, CASL
Los Alamos National Laboratory

Brian Wirth
MPO Deputy Lead, CASL
University of Tennessee

Sidney Yip
MPO Deputy Lead, CASL
Massachusetts Institute of Technology

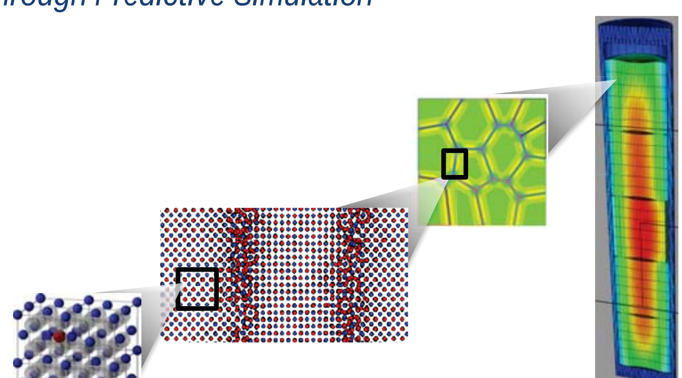
OAK RIDGE National Laboratory

Materials Performance Optimization (MPO)

Enabling Improved Fuel Performance through Predictive Simulation

Objectives and Strategies

- Provide physics-based materials models of fuel/clad/internals property evolution to enable predictive modeling of CRUD, GTRF and PCI within 3D, multi-physics, virtual reactor simulator
- Improved physics and chemistry insight delivered via constitutive relations
- MPO is comprised of a diverse group of computational materials scientists with a wide range of capabilities



Challenging, multiscale processes impact nuclear fuel performance

Requirements Drivers

- MPO enables solutions to CASL challenge problems by delivering a multiphysics, multiscale materials M&S capability to the CASL virtual reactor
- For success, MPO requires:
  - Guidance of MPO activities from industrial experience of three challenge problems
  - Experimental data, both full scale reactor tests and unit mechanisms
  - External program leverage, e.g. EFRCs, FCRD, etc.

Outcomes and Impact

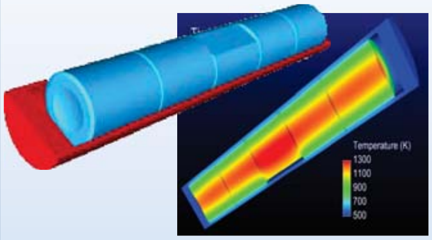
- Predictive models of fuel failure, that quantitatively define operating margins & lifetime limits
- Validated predictions of fuel failure conditions
- Power uprates & increased fuel utilization

CASL

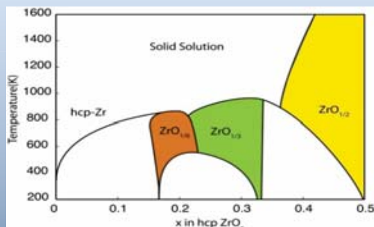
MPO delivers materials physics-based constitutive models to the VERA for CASL challenge problems

For CRUD, GTRF and PCI, identify 3-D, high resolution coupled physics simulation capability for interface with virtual reactor;

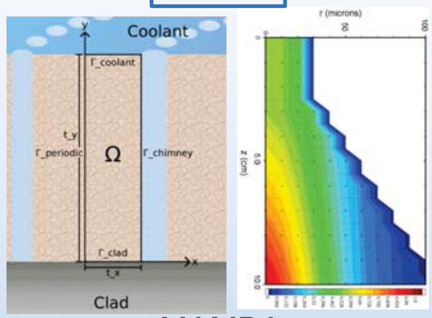
PCI



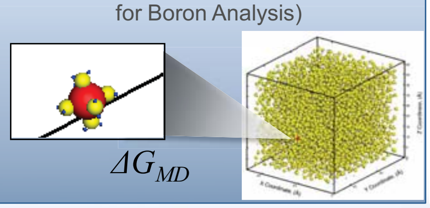
Peregrine
(Fuel Performance)



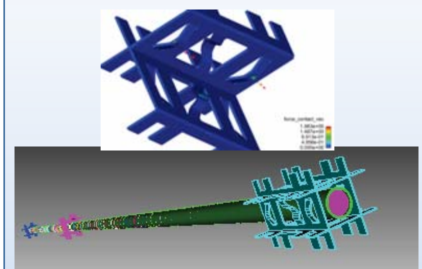
CRUD



MAMBA
(MPO Advanced Model for Boron Analysis)



GTRF



Sierra
(Structural Mechanics)

$$\bar{\dot{\varepsilon}} = \overline{M} : \bar{\sigma} + \bar{\dot{\varepsilon}}_0$$

Initiate a series of microscale activities to provide mechanistic/physical insight into complex degradation phenomena

Virtual Reactor Integration

John Turner (ORNL), Lead
Randy Summers (SNL), Deputy Lead
Rich Martineau (INL), Deputy Lead

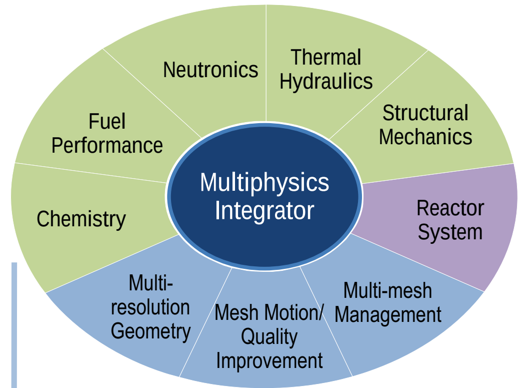
DOE Annual Review
Oak Ridge National Laboratory
August 18, 2011

Virtual Reactor Integration (VRI)

Bridging the gap between research and engineering.

Objectives and Strategies

- VRI will deliver a suite of robust, verified, and usable tools within a common multi-physics environment for the design and analysis of nuclear reactor cores, with quantified uncertainties.
- three projects combine to form the VRI focus area:
  - VERA: Virtual Environment for Reactor Applications
  - VERA Physics Simulation Suite (PSS)
  - Challenge Problem Integration (formerly Coupled Mechanics)
- Agile software development processes and partner strengths in large-scale code development are key to meeting VRI challenges



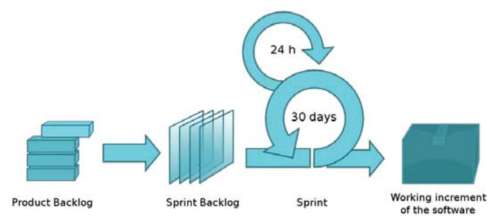
Requirements Drivers

- VRI is the conduit between targeted research and engineering analysis
  - guided by current and future simulation and workflow requirements developed with AMA
  - in collaboration with VUQ on improved tools and methodologies for quantification of uncertainties,
  - research, development, and Integration of advanced capabilities with the MPO and MNM focus areas.
- VRI depends on several external programs such as DOE/NE NEAMS for key capabilities

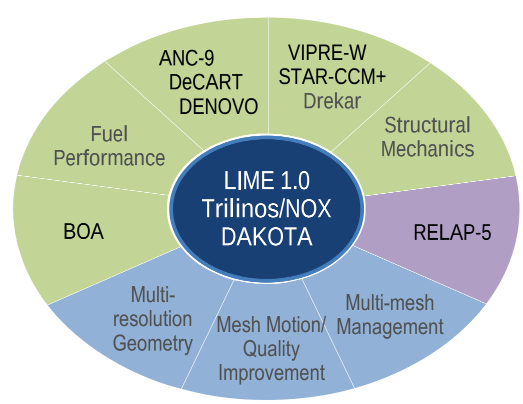
Outcomes and Impact

- VRI will deliver the environment described above, portions of which will be openly-available.
- VRI success can be measured by
  - measurable use of VERA by industry partners in understanding and mitigating key issues
  - downloads of the open portion(s) of VERA
- VRI success will transform industry analysis, bringing tightly-coupled, high-fidelity simulation into daily engineering workflows.

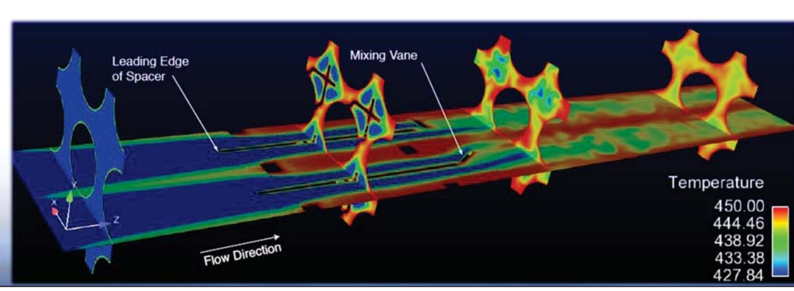
VRI Highlights



- Process
  - team was productive very quickly
  - using Scrum-ban process (combination of Scrum and Kanban methodologies)
  - desktop collaboration software essential
- Foundation
  - VERA Release 1.0 (3/31/2011)
    - Virtual Environment for Reactor Analysis
  - software framework for physics capability integration
  - baseline industry capability with improved coupling
  - initial advanced capability
    - National Lab, University, and Commercial components
  - initial coupling to reactor system capability



- Application
  - Grid-to-Rod Fretting (GTRF)
  - using PWR 3x3 geometry
  - demonstrated advanced structural dynamics and CFD capabilities
  - initial coupling demonstration



Validation and Uncertainty Quantification (VUQ)

Jim Stewart (SNL)
Dana Kelly (INL)

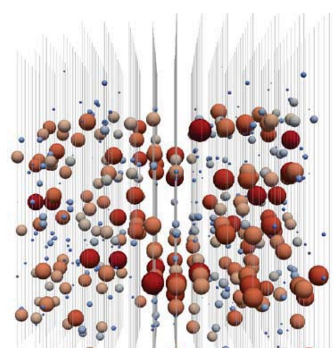
1st Annual CASL Roundtable Meeting
North Carolina State University
August 9-11, 2011

Validation and Uncertainty Quantification (VUQ)

Achieving credible, science-based predictive simulation capabilities

Objectives and Strategies

- VUQ is dedicated to developing overall V&V approach
- VUQ will provide CASL with
  - Best-estimate *predictive capabilities* with reduced uncertainties
  - Quantified *predictive maturity* assessments
- The Sensitivity Analysis & UQ process will guide CASL R&D investments, and aid in designing future experiments



Computed boiling rates and uncertainties for CIPS application

Requirements Drivers

- V&V and UQ methodologies and tools are needed by every Focus Area
- VUQ is the CASL "integrator;" we need:
  - Access to software and underlying math models
  - Validation data (at all physical scales)
  - Partnerships with other Focus Areas to implement uniform VUQ practices

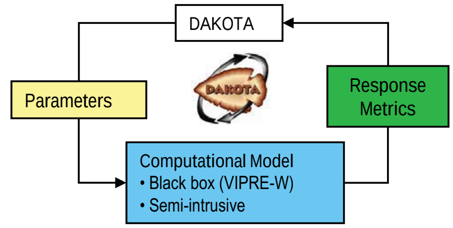
Outcomes and Impact

- Continuous evolution towards *transformational, predictive computational simulation*
- Capability to quantify and reduce uncertainties for the CASL challenge problems
- New ways for experiments and simulations to work together, leading to predictions *with quantified confidence* of scenarios for which experimental data is not directly available

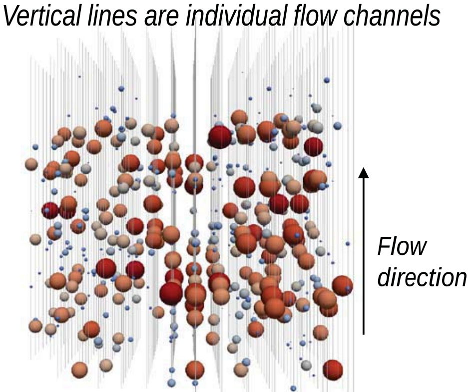
VUQ Accomplishment Highlight

Milestone VUQ.P2.03 (Enable SA/UQ Demonstrations in VERA)

- Strategy: Integrate SNL's *DAKOTA* UQ Toolkit with Westinghouse's VIPRE-W subchannel T/H simulator
- Demonstration for Crud/CIPS problem (quarter-core geometry): Assess influence of core operating parameters on mass evaporation rate
- Results: Affirmed well-known sensitivity (of mass evap. rate) to temperature and exposed sensitivity to pressure. Boiling model uncertainty is a key contributor.



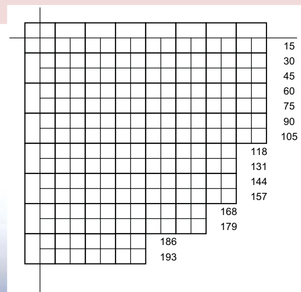
Vertical lines are individual flow channels



View inside the reactor core

Spheres denote locations where boiling occurs
- Size correlates to uncertainty
- Color correlates to mean boiling rate (*red is higher*)

VIPRE-W quarter-core geometry and axial layout *(with 193 flow channels shown, 93 nodes in axial direction (not shown))*



CASL

Advanced Modeling Applications (AMA)

Jess Gehin (ORNL)
Steve Hess (EPRI)
Zeses Karoutas (WEC)

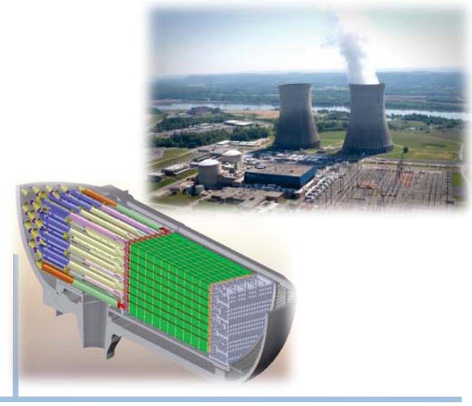
DOE Annual Review
Oak Ridge National Laboratory
August 18, 2011

Advanced Modeling Applications (AMA)

Driving development of VR to support real-world applications

Objectives and Strategies

- Establish CASL's M&S needs for achieving plant power uprates, life extension, and higher burnup fuels
- Ensure that CASL research and development (R&D) meets the needs and requirements of the stakeholders
- Engagement with regulatory authorities to enable future application of the results
- Leverage industry contribution to include en users in the development and evaluation process



Requirements Drivers

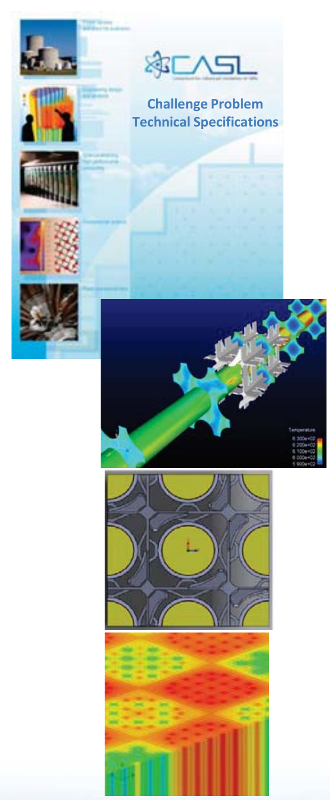
- Connect end uses with CASL R&D by:
  - Providing a conduit for end-user input
  - Defining requirements for and performing capability assessments of the Virtual Reactor
  - Integrating with other DOE and NRC programs that support improvements in light water reactors
- Simulating operational and safety challenge problems and physical nuclear reactors

Outcomes and Impact

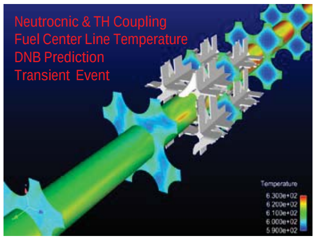
- AMA will demonstrate the applicability of VERA's capabilities to current industry challenges through successful application to the CASL challenge problems
- VERA will be benchmarked with operational data from commercial reactors
- AMA will provide early deployment for industry partners through CASL test stands.

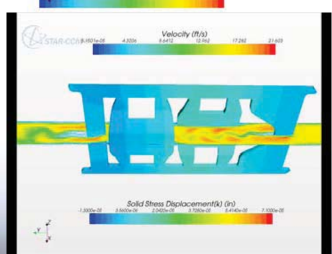
AMA Highlights

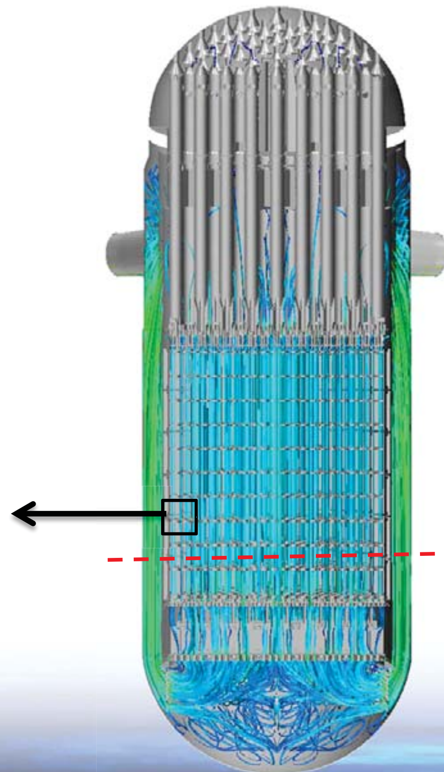
- VERA Requirements and Plans
  - SLT-approved VERA requirements established
  - Developed initial validation & QA plan for CASL
- Challenge problem specifications and simulations
  - Detailed challenge problem technical specifications developed
  - Developed scale up sequence from 3x3 pin multiphysics model to full vessel
  - Advancing state of the art by including boron feedback in neutronics for crud challenge problem
  - Developed process to calculate turbulent rod excitation force to predict rod vibration and wear (GTRF challenge problem) with Star-CCM+ (VERA "initial advanced' capability)
- Modeling and Simulation of Physical Reactors
  - Obtaining plant data for model development and validation
  - Full vessel CFD modeling (CE plant and Watts Bar Unit 1)
  - Demonstrated large-scale 3D full-core neutronics simulation on Jaguar scaling up to 260,000 cores



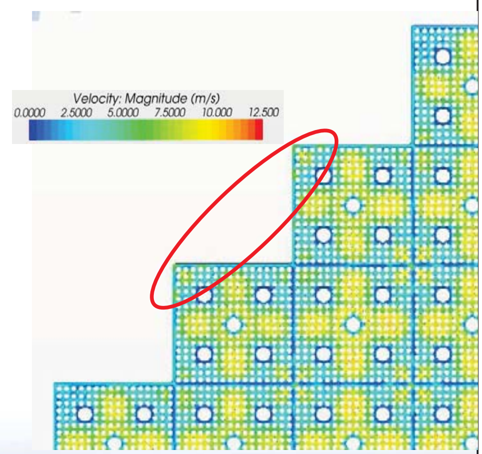
Key Highlight –From 3x3 Pin Multi-physics to Vessel CFD Model







Vessel CFD provides overall flow and temperature distributions. It also provides key indicators for GTRF, hot spot, crud deposition under normal and transient conditions.



Workflow Project

Andrew Godfrey, AMA

Industry Council Meeting
August 23rd, 2011

Purpose of Presentation

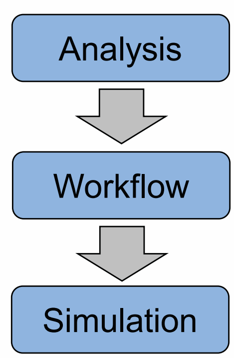
- Initiate discussion between IC / AMA / VRI for project planning and kickoff
- Brainstorm plans for:
  - Selection of several high-level analyses performed by industry
  - Development of detailed workflow for selections
  - Communication of workflow to CASL
- Discuss project logistics and schedule

Purpose of Project

- Get input from Industry Council on how VERA might be integrated into industry processes
- Highlight analyses and activities which are important to IC members
- Provide detailed workflow of important activities to AMA & VRI for development purposes

Terms

- Analysis = a high-level description of a set of engineering calculations and evaluations resulting in a prediction or better understanding of the state of a nuclear system
  - Specifically avoid the term 'use case' due to confusion with software development principles
- Workflow = the sequence of connected steps performed by an engineer as a piece of an Analysis process or procedure
- Simulation = an individual execution of software, representing the system or one of its components, as one piece of the Workflow for a particular Analysis



Sample Analyses

- Fuel or Reactor Vendor User
  - Reload analyses
  - New fuel design analysis
  - New reactor analyses
  - SFP analyses
  - Uprate analyses
  - Life extension analyses
  - Operational effects analyses (CIPS,CRUD, CILC, GTRF, PCI, etc)
  - Root cause and apparent cause investigations
  - Development of manufacturing and procurement specifications
- Utility User
  - Reload analyses
  - Uprate analyses
  - Life extension analyses
  - Operational effects analyses (CIPS,CRUD, CILC, GTRF, PCI, etc)
  - Reactor operations and core follow (startup, maneuvering, failed fuel id, etc)
  - SFP analysis & dry cask storage
- Lab User
  - Advanced fuel design analyses
  - Advanced reactor design
  - Support for PIE
  - Methods development
- Regulatory User
  - AOO and Accident scenario evaluations
  - Regulatory criteria development
  - LTA / LUA performance
  - Review of advanced fuel or reactor proposals
  - RCA and ACA
- University User
  - Education on how reactors work
  - Researching new methods and advanced designs
- Simulator/Training User
  - Simulating scenarios for reactor control

Sample Analysis: CIPS Risk Evaluation

Primary Analysts

- Core Design Engineer
- Chemistry / Materials Engineer

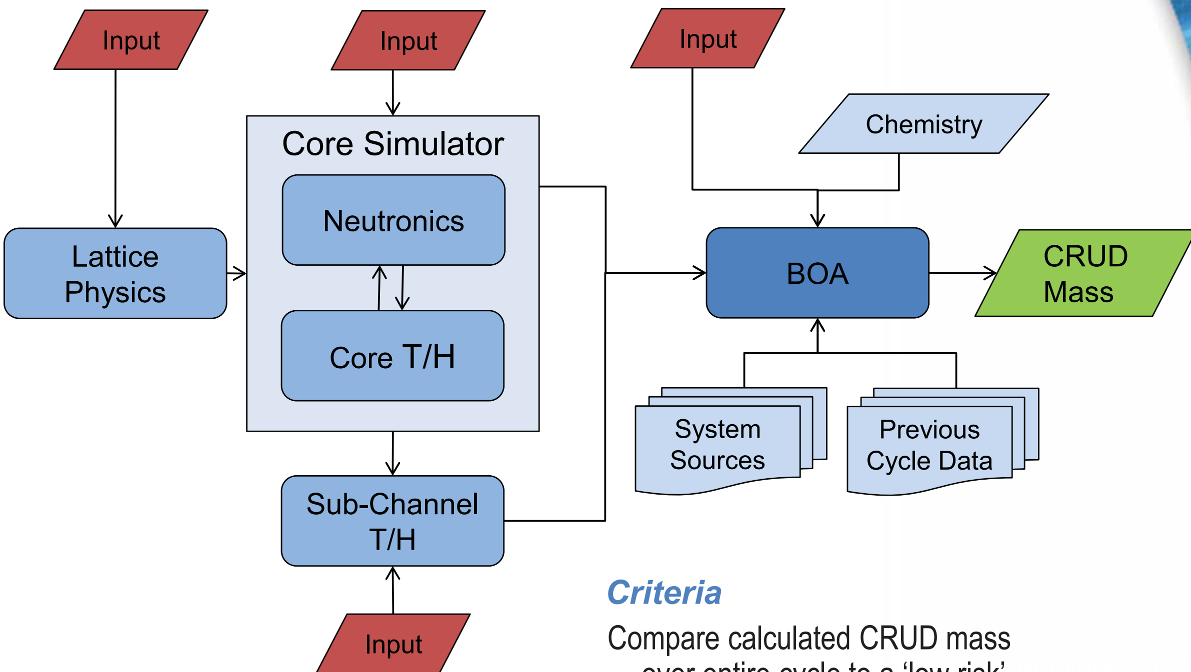
Objective

Evaluate a given cycle design for risk of developing Crud Induced Power Shift (CIPS)

Workflow Summary

- Current approach requires benchmarking of CRUD sources based on known previous cycle CIPS behavior
  - Sources adjusted to match known cycle boron deposition in CRUD
  - Adjustment to end of previous cycle fuel CRUD distribution is made to account for CRUD removal during refueling shutdown chemistry as well as for ultra-sonic fuel cleaning (if used)
- Assembly powers obtained from 3D core simulator code and provided as input to finer mesh thermal-hydraulic analysis
- Burnup dependent thermal-hydraulic conditions input to BOA code along with plant chemistry (B, Li, H2) and corrosion sources
- Execute BOA to calculate the mass of crud and boron deposited on the fuel over the cycle
- Calculated boron mass is used to determine CIPS risk
- CRUD thickness is also used to determine CILC risk

Sample Workflow – CIPS Risk Evaluation



Criteria

Compare calculated CRUD mass over entire cycle to a 'low risk' threshold = X lbs Boron

Proposed Process

- Develop a set of 3-5 analyses that you believe VERA and CASL capabilities could provide substantial benefit
- For each of the analyses each organization will identify workflows that are performed to support these activities.
- CASL staff will interact with each organization and discuss how they view the analyses and their priority. The organization can add any additional organization-specific priorities that they have for the CASL tools/VERA.
- During the interaction the organization staff will also discuss their workflows through sample interview questions (following slide)
- CASL staff will organize information from interactions into a summary report to be used as input for the VERA requirements and VERA product implementation plan.

Sample Workflow Questions

- Describe how the analysis is currently performed.
- What computer codes are used?
- How are the codes coupled and/or data transferred?
- How much staff time is needed, how much computer time is needed?
- What computer resources are available/planned?
- Over what schedule must the analysis be performed?
- Do the analyses include sensitivity studies, determination of uncertainties?
- Do the analyses support safety case, operation, business decisions?
- What issues do you have with the current analysis tools and workflows?
- How could workflow be improved with improved capabilities?
- What additional capabilities and features would be most useful?

Wrap it up

- Discussion…
- Decisions…
- Schedule for Interaction
  - 60 days ?
- Thank you!

Appendix: More Detailed Analyses

Possible Industry Analyses – Reload Work

- Fuel cycle design / optimization
- Fuel cycle economics evaluation
- Core follow / Exposure accounting
- Prediction of cycle length or power / temperature coastdown conditions
- Maximum fuel rod / assembly exposure
- Maximum fuel corrosion
- Maximum fuel rod pressure
- Maximum cycle boron concentration
- Minimum shutdown margin
- Physics parameters: Temperature coefficients, rod worths, etc.
- Input to site reactivity computer
- Margin to centerline fuel melt (CFM)
- Margin to departure from nucleate boiling (DNB)
- Margin to Dryout (CPR)
- Fuel assembly liftoff
- Incore detector lifetime
- Control blade lifetime
- Excessive quadrant power tilt mitigation
- Fuel assembly distortion / bow (FAD) risk mitigation (also IRI)
- Control rod / blade movement analyses (PCI risk mitigation)
- AOA / CIPS risk mitigation
- GTRF / baffle jetting risk mitigation
- CRUD deposition / CILC risk mitigation
- Evaluation of changes in primary chemistry for CRUD source terms
- Mixed core mechanical and T/H interactions
- Determination of site alarm / trip setpoints
- Determination of rod insertion limits
- Reduction of statistical uncertainty factors
- Quantification of existing margin

Possible Industry Analyses – Operations Support

- Startup Predictions (ITC, critical boron, rod positions, etc.)
- Reactor surveillance – reactivity and power distribution
- Reduce/eliminate exclusion zone
- Power asymmetry evaluations
- Power maneuver planning
- Local ramp rate prediction
- Failed fuel (leaker) identification
- Excore detector response prediction / calibration
- Fuel Shuffling planning (FAD impact mitigation)
- Ultra-sonic cleaning planning
- Flow predictions for RCP startup sequence
- Support of unusual evolutions (dropped rod recovery, dropped rodlet)
- Support for operational issues (CIPS, Tilts, reactivity anomalies, etc.)
- On-line monitoring

Possible Industry Analyses – Safety Analysis

- LOCA
- Sump strainer analysis
- Steam Line Break
- Containment pressure response
- Rod Ejection
- Best Estimate vs. Conservative approaches
- Other Chapter 15 accidents
- Evaluation of severe accident progression / core melt

Possible Industry Analyses – Spent Fuel

- Isotopics Inventory
- Assembly Burnup Profiles
- Reduce uncertainty in isotopics and/or burnup of record
- Source term for SFP wall gamma heating analysis
- Decay Heat

Possible Industry Analyses – New Product Design & Optimization

- Lattice design / optimization
- Spacer grid optimization
- Nozzle / Filter design
- Materials optimization
- Advanced fuel forms
- Develop new BA materials / patterns

Possible Industry Analyses – Other

- Other Analyses Supporting Power Uprates
- Other Analyses Supporting Lifetime Extension
  - Vessel fluence
  - Reactor internals fluence
  - Instrument Thimble fluence
- Other Analyses Supporting Higher Burnups

CASL Quality Assurance

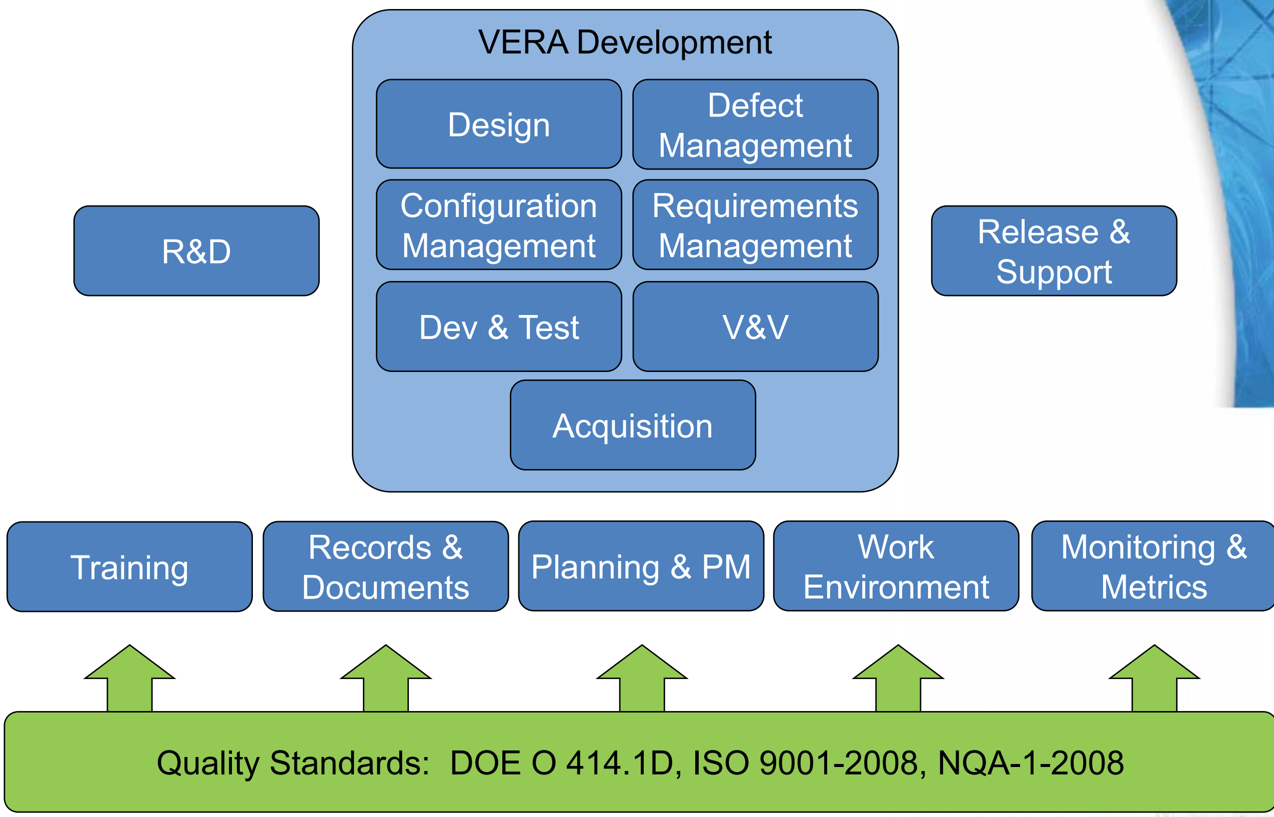
Matt Sieger
Quality Manager

The CASL Product Landscape

- Software
  - VERA SKUs
- Communications
  - Papers
  - Presentations
  - Technical Reports
  - Project Reports
  - Documentation
- Services
  - Training
  - Support
  - Consulting
- People
  - Members
  - Students
  - Networks

The CASL QA Program promotes customer satisfaction across all of our product lines

The CASL Business Process Landscape



The CASL Quality Management System

- More than just Verification & Validation
- Integrates three major QA standards
  - DOE O 414.1C
  - ISO 9001-2008
  - NQA-1-2008 & Part II Subpart 2.7
- Is supported by a dedicated Quality Manager who reports to the consortium Director
- Is documented in a Quality Manual, continually revised and published yearly
- Will be reviewed yearly for continuing suitability

Parsing the Quality Standards

- CASL has cross-walked the Quality standards to our internal processes to understand the requirements
- The Quality Manager works with process owners to ensure proper implementation, documentation, and monitoring

Standard	Requirement No	Section	Requirement	Applicable?	Implementing CASL Process	Subprocess
DOE	DOE 15	6.a	Design items and processes using sound engineering/scientific principles and appropriate standards.	Yes	Design	General
DOE	DOE 16	6.b	Incorporate applicable requirements and design bases in design work and design changes.	Yes	Design	Inputs
DOE	DOE 17	6.c	Identify and control design interfaces.	Yes	Design	General
DOE	DOE 18	6.d	Verify or validate the adequacy of design products using individuals or groups other than those who performed the work.	Yes	Design	V&V
DOE	DOE 19	6.e	Verify or validate work before approval and implementation of the design.	Yes	Design	V&V
NQA	NQA 9	3.100	The design shall be defined, controlled, and verified.	Yes	Design	General
NQA	NQA 10	3.100	Design inputs shall be specified on a timely basis and translated into design documents.	Yes	Design	Inputs
NQA	NQA 11	3.100	Design interfaces shall be identified and controlled.	Yes	Design	General
NQA	NQA 12	3.100	Design adequacy shall be verified by individuals other than those who designed the item or computer program.	Yes	Design	V&V
NQA	NQA 13	3.100	Design changes shall be governed by control measures commensurate with those applied to the original design.	Yes	Design	Change Control
NQA	NQA 24	3.400	Design analyses shall be sufficiently detailed such that a	Yes	Design	Review

Process Maturity Levels

The requirements of the standards are implemented by Processes. Processes are graded according to their maturity using a scale similar to that used by the CMM system.

Level 1 (Initial)
- Undocumented
- Constantly changing
- Driven by personal heroics

Level 2 (Repeatable)
- Established process, but inconsistent
- No rigorous discipline

Level 3 (Defined)
- Documented
- Standardized
- Improving with time

Level 4 (Managed)
- Measureable
- Controlled using metrics

Level 5 (Optimizing)
- Focus is on continuous improvement

QA Program Strategy

1. Identify the requirements of the quality standards ✓
2. Identify the CASL processes that implement those requirements ✓
3. Implement the requirements ←
4. Biannually assess the maturity of those processes ←
5. Identify areas for improvement, fold initiatives into POR cycle ←

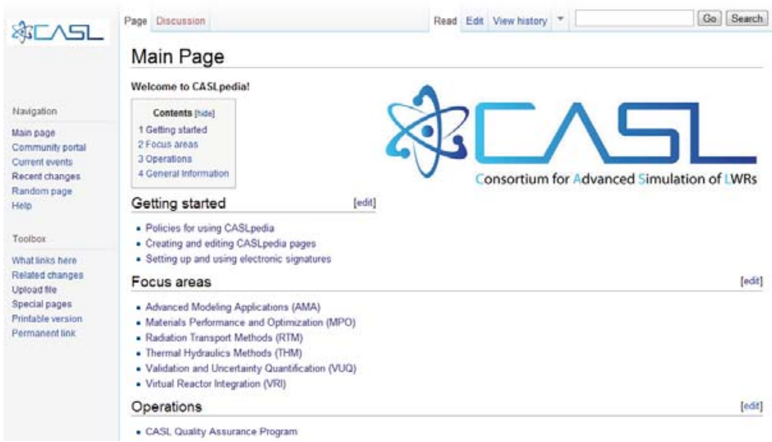
CASL Process	Maturity Level (May 2011)
Assessment	1
Communication	1
Configuration Management	2
Defect Management	1
Design	1
Documents & Records	2
Infrastructure Management	1
Monitoring & Metrics	1
Planning	2
Procurement	3
Project Management	2
Quality Management	1
Release Management	1
Requirements Management	2
Software Acquisition	1
Training	1
Test, Verification & Validation	2
Work Processes	2

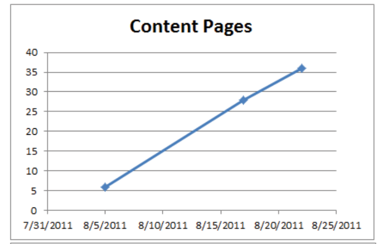
QMS Status

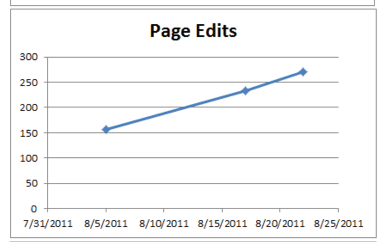
- Initial review of CASL processes identified several areas for improvement:
  - Software acquisition
    - Documented process needed to inspect & gather QA provenance of imported codes
  - Design
    - VRI.VERA.P3.02 milestone created to drive this effort
  - Defect management
    - Defined process needed to specify how defects are reported, assessed, tracked, and documented
  - Training
    - Records of staff qualifications are being gathered, processes for new staff established
- Much process definition and documentation remains to be done
  - CASLpedia Wiki platform has been set up to support this effort

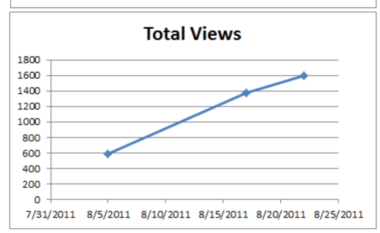
The CASLpedia Wiki

- Provides a collaborative home for process documentation
- Is based on the engine that drives Wikipedia









NRC Licensing Support

- CASL does not intend to submit VERA to NRC for licensing
- But CASL will support licensing efforts by customers using VERA, by
  - adhering to the NQA-1-2008 standard, and Part II Subpart 2.7 therein,
  - providing documented verification & validation reports,
  - providing documented, auditable software development and test methods,
  - providing validated benchmark suites, and
  - providing expertise and support.

CASL's Verification & Validation Plan directly supports customer licensing efforts

VERA capability roadmap

Capability	Year 1	Year 2	Year 3	Year 4	Year 5
Neutron Transport	• Full core 3D homogeneous pin cell Sn transport • Full core 2D/1D resolved pin cell MOC transport with T-H coupling	• Full-core 3D homogeneous pin cell Sn transport with T-H coupling	• Full-core 3D pin-resolved transport – both Sn and MOC • Prototype transient 3D transport capability – Sn and/or MOC	• Full-core 3D pin-resolved transport – both Sn and MOC – with T-H coupling • Prototype 3D hybrid Monte Carlo transport	• Transient full-core 3D pin-resolved transport – Sn and/or MOC – with T-H coupling • Full-core 3D hybrid Monte Carlo transport with T-H coupling
Thermal Fluids with Conjugate Heat Transfer	• Subchannel legacy and commercial CFD • Continuum and interface tracking method (ITM) multiphase benchmarks	• Next-generation sub-cooled boiling capability • Subgrid single-phase models informed by ITM	• Next-generation multiphase flow capability • Subgrid multiphase models informed by ITM	• Evaluate multiphase flow capability against benchmarks & exps • Improved numerical methods & coupling	• Refined multiphase flow capability • Targeted methods & coupling advances
Fuel & Clad Performance	• 1.5D legacy capability • Phenomenological models and properties	• Initial fuel mesoscale models for FG release, swelling, μ-structural evolution • Initial corrosion models	• Clad mesoscale μ-structural evolution • Fuel chemistry evolution	• Clad corrosion & refined μ-structural evolution • SCC & fatigue crack propagation	• Full upscale model for fuel/clad performance and life extension predictions
Coolant Chemistry	• Legacy capability	• CRUD source terms and formation and growth model	• Boron uptake in CRUD	• CRUD formation	• CRUD formation & induced corrosion
Structural Thermo Mechanics	• Assess and integrate existing capability with contact	• Loosely coupled structural vibrations • Initial radiation creep & hardening models	• Fully coupled structural vibration for fretting	• Implicit nonlinear fretting models • Improved radiation damage models	• Coupled and formally assessed structural vibration capability
Physics Coupling	• Legacy capabilities coupled via LIME • Subchannel transport & single-phase CFD	• Homogeneous cell transport & CFD • Initial fluid-structure interaction (FSI)	• Improved FSI • Homogeneous cell transport, CFD, fuel, & chemistry	• Pin-resolved transport & CFD	• Full-core transport, CFD, fuel, chemistry, thermo mechanics • Core + physical plant
Validation and Uncertainty Quantification	• DAKOTA interfaced for scoping UQ	• Time-dependent data assimilation for parameters and responses • Model V&V procedures	• Sensitivity and UQ capabilities for coupled components • Model V&V procedures and tools for selected	• Data assimilation with reduced-order modeling • Model V&V procedures and tools for selected	• High-order data assimilation including errors and uncertainties • Model V&V procedures and tools for coupled

FY12 Expected Accomplishments

VERA Release 2.0:

- Neutron transport
  - Full core transport: pin-homogenized 3D Sn and pin-resolved 2D/1D MOC with conjugate heat transfer T-H feedback
- Thermal fluids with conjugate heat transfer
  - Initial single phase capability with subgrid models informed by ITM
- Fuel & clad performance
  - Initial mesoscale models for FG release, swelling, and microstructural evolution
- Coolant chemistry
  - CRUD source terms (from industry models) with initial formation/growth model; upscaling plan in place
- Structural thermo-mechanics
  - Initial structural mechanics code framework; loosely coupled vibrations
- Physics coupling
  - Pin-resolved 2D/1D transport & CFD with conjugate heat transfer; initial fluid-structure interaction
- Validation and uncertainty quantification
  - Data assimilation of parameters using time-dependent responses

FY12 Milestones

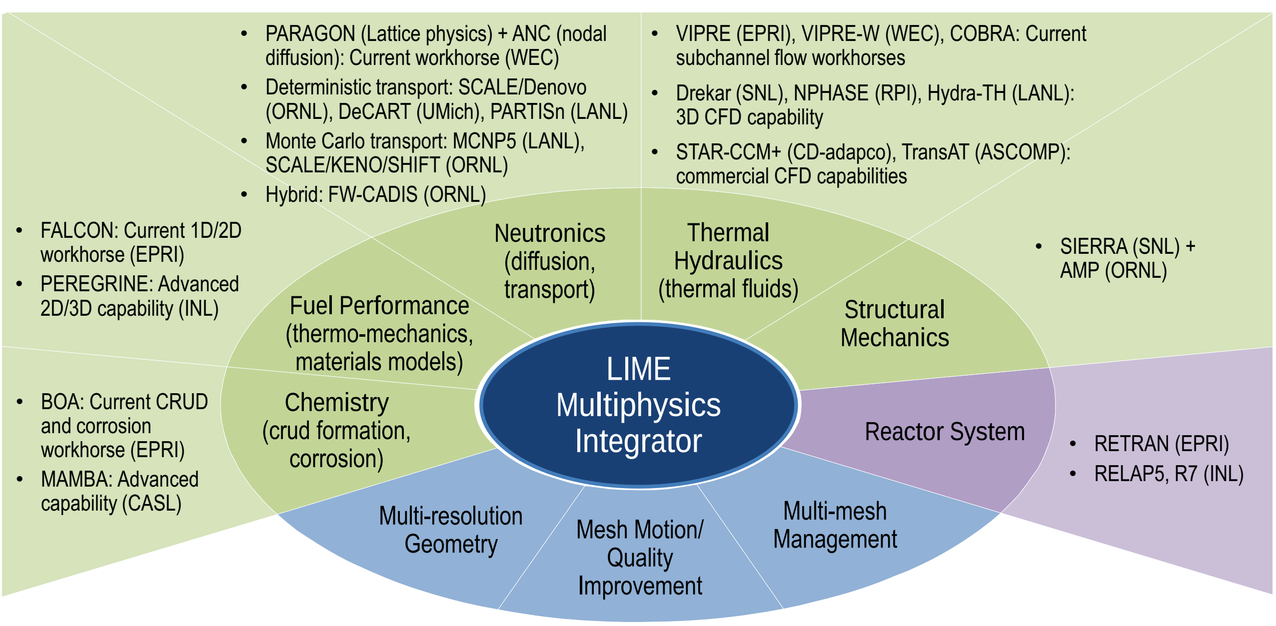
- CRUD Challenge Problem
  - Model CRUD source terms, localized pin subcooled boiling, initiation of CRUD deposition, and CRUD thickness based on best available industry and CASL capabilities
- GTRF/FAD Challenge Problem
  - Model interaction of fluid flow distribution with fuel rods to calculate dynamic forces that may lead to fuel rod vibration
- Advanced Fuels
- Operational Reactor

Virtual Reactor Integration

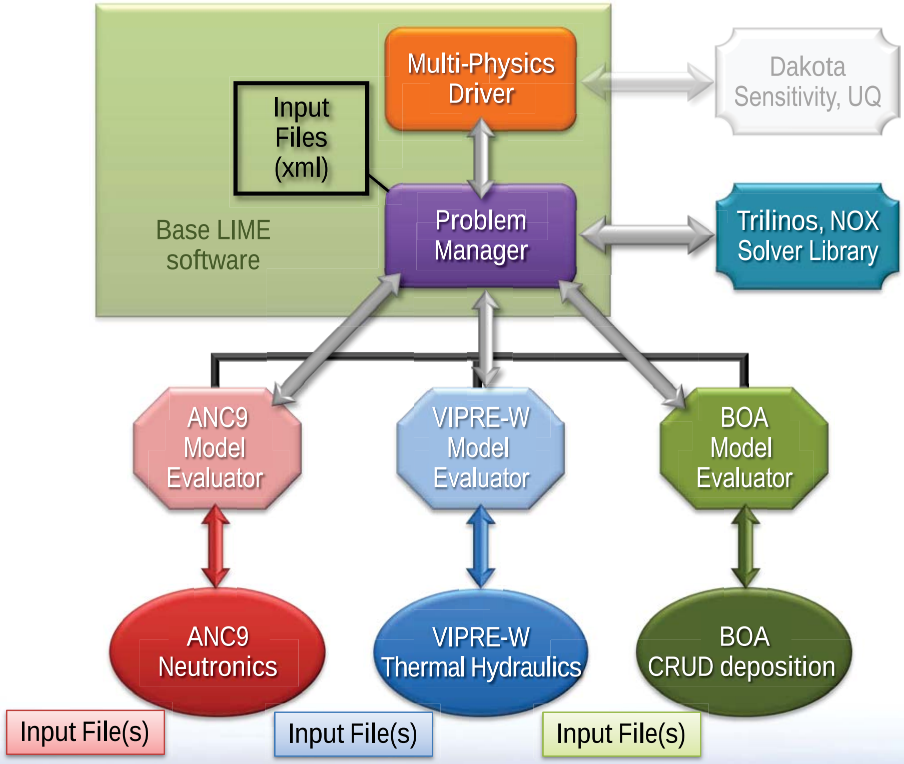
John Turner (ORNL), Lead
Randy Summers (SNL), Deputy Lead

Industry Council
Oak Ridge National Laboratory
August 23, 2011

VERA (Virtual Environment for Reactor Applications) combines advanced capabilities with mature, validated, widely-used codes.



LIME-based coupling diagram for ANC-VIPRE-BOA



CASL

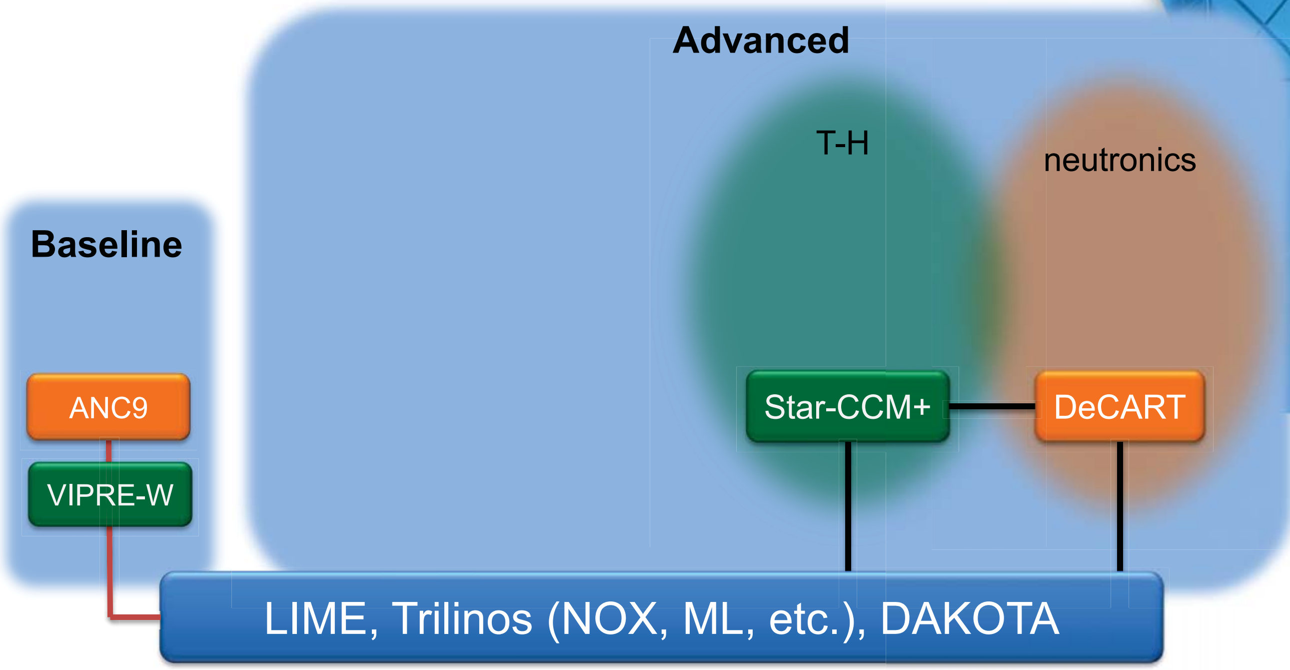
Evolution of VERA Capability

CASL

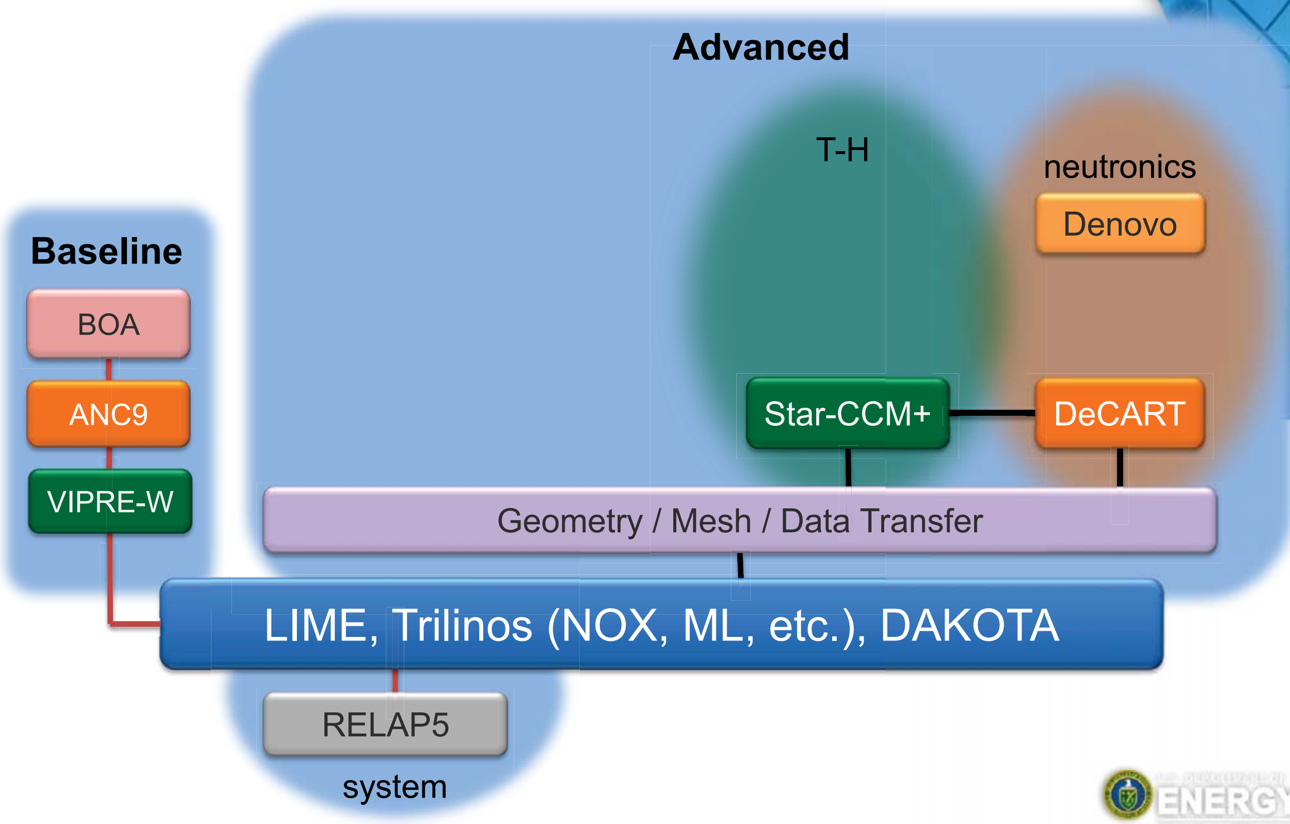
- next 5 slides depict the evolution of VERA capability through version 2.0
  - 0.5 (12/2010)
  - 1.0 (03/2011)
  - 1.1 (09/2011)
  - 1.2 (12/2011)
  - 2.0 (03/2012)

U.S. DEPARTMENT OF ENERGY Nuclear Energy

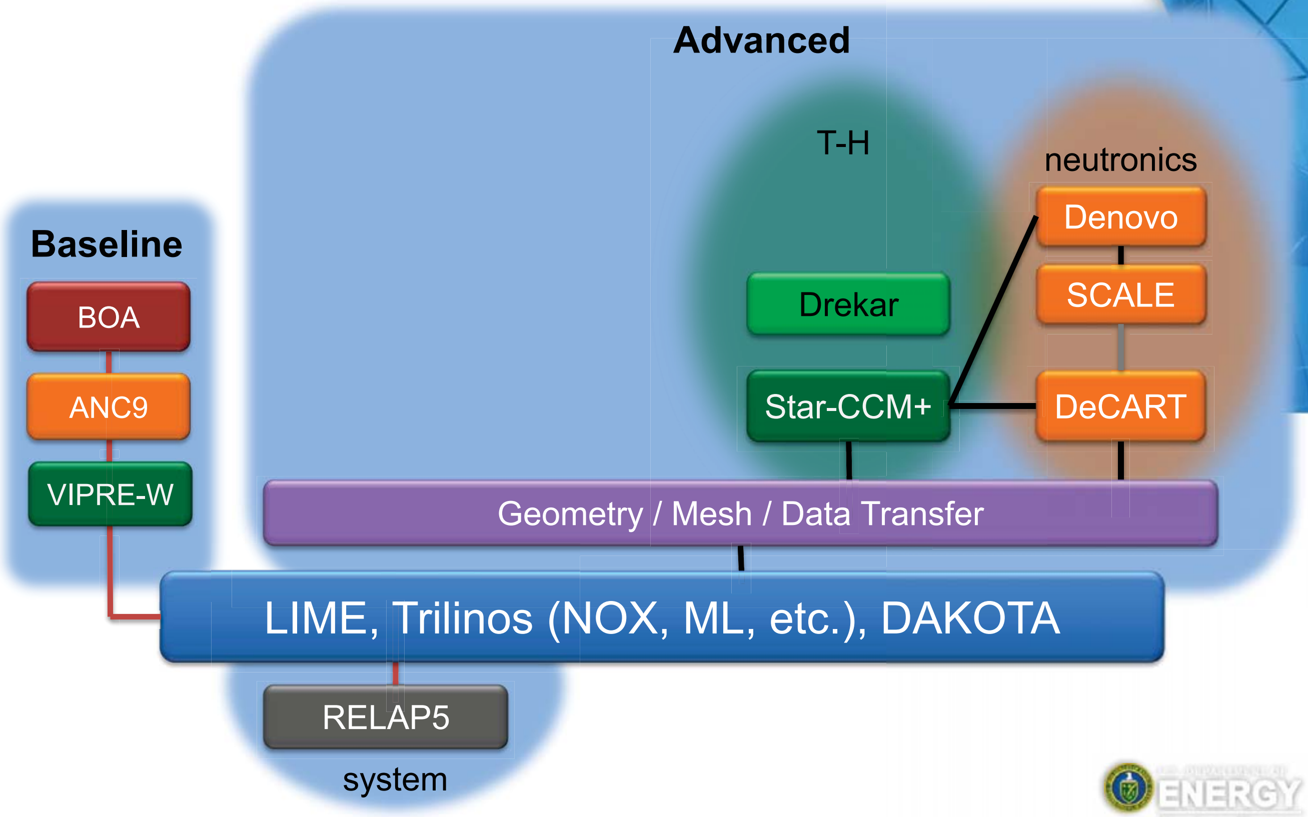
VERA 0.5 (12/2010)



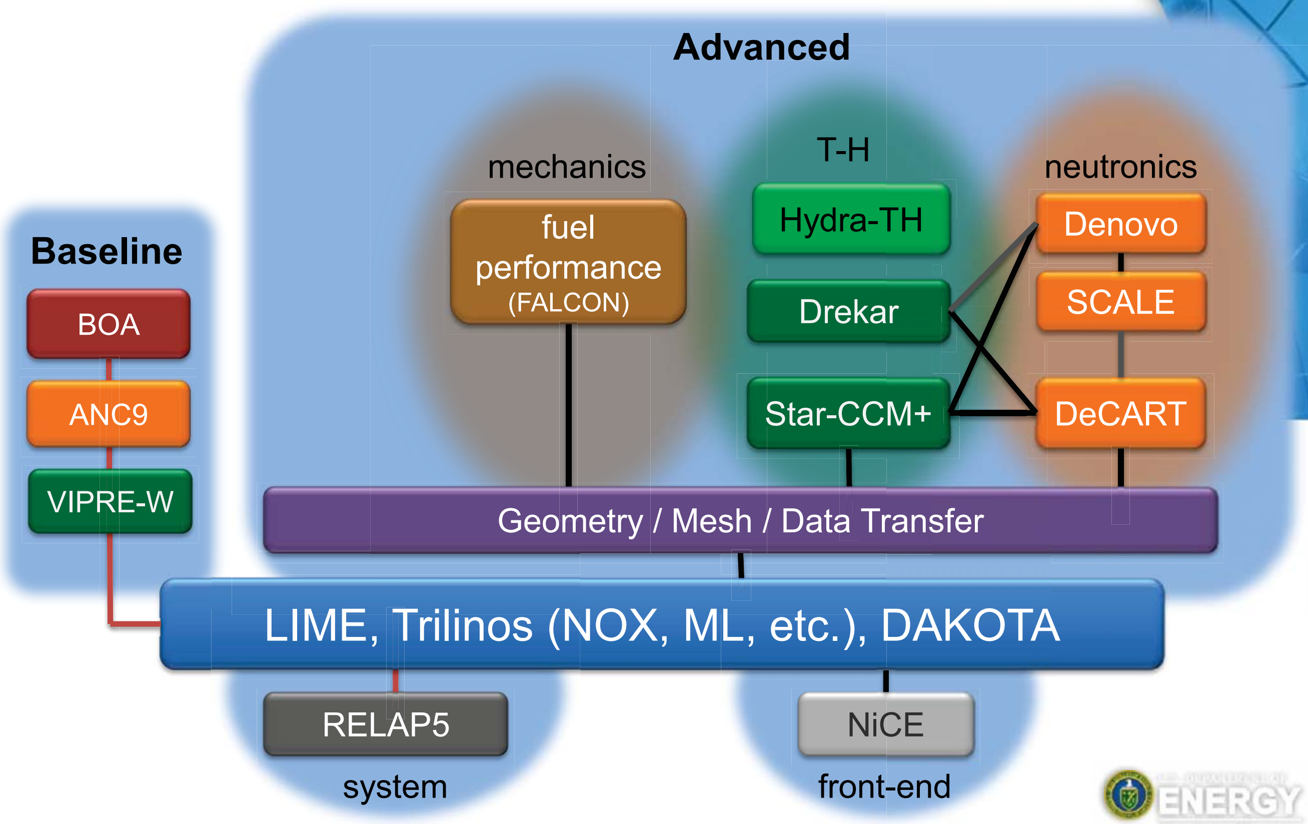
VERA 1.0 (03/2011)



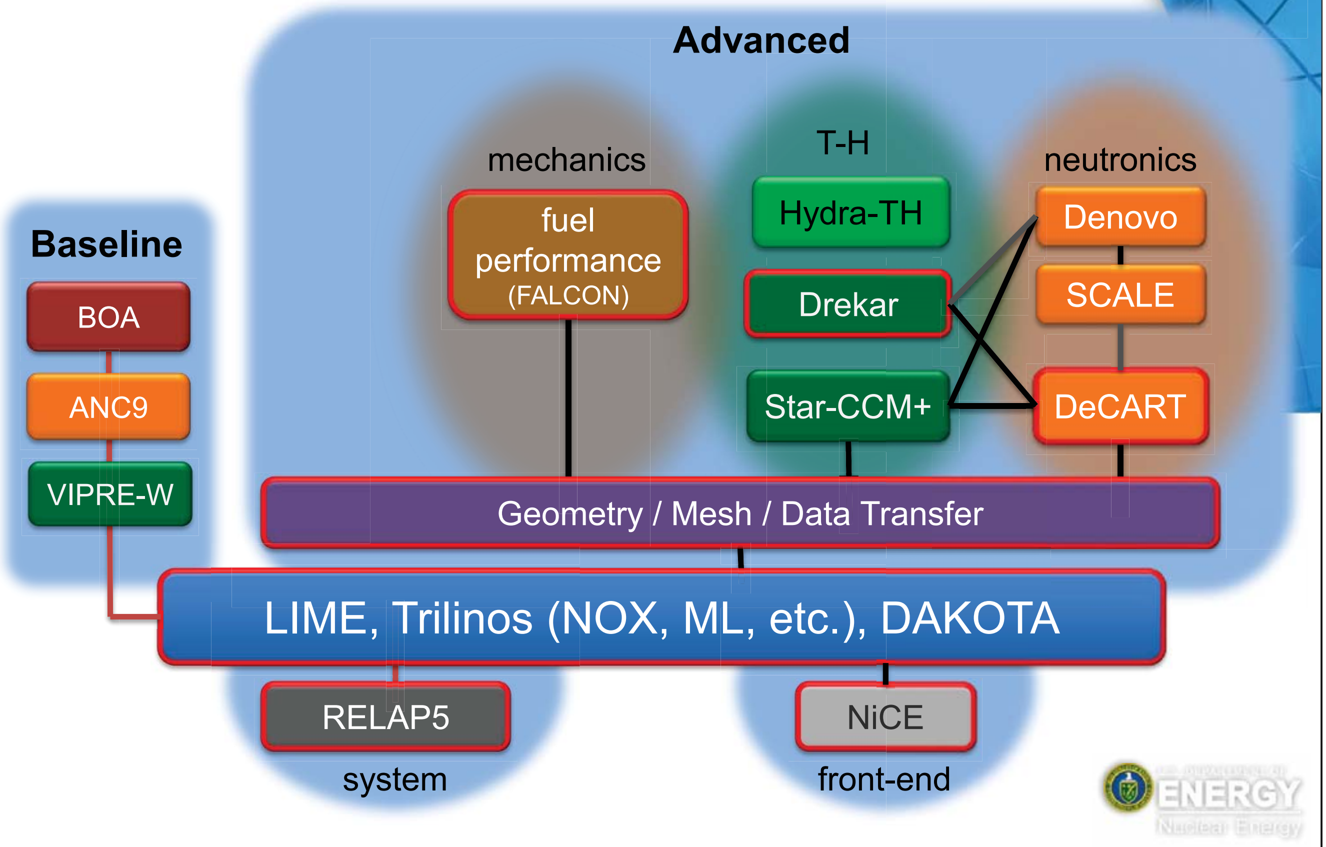
VERA 1.1 (09/2011) - planned



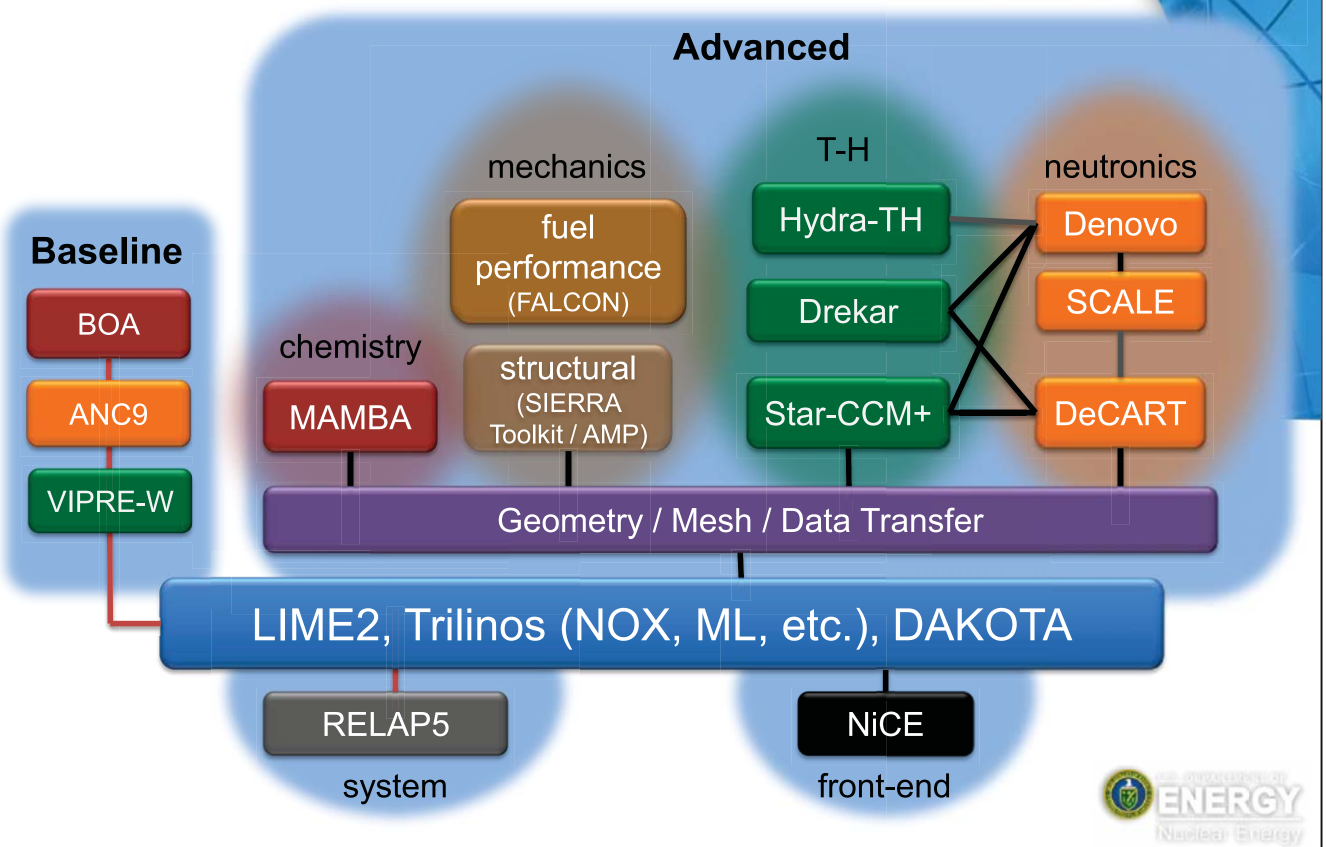
VERA 1.2 (12/2011) – projected



VERA 1.2 (12/2011) – “Early Advanced”



VERA 2.0 (03/2012) - notional



Missing…

- geometry
  - goal is a common geometry database, but long way to go
- material properties
  - similar to geometry goal/status
- mesh generation
  - looking at multiple options
- common input / user interface
  - reactor-aware, data-aware
- analysis / design / optimization

Deployment Strategy considerations

- FY12 programmatic drivers
  - internal release in March (CASL L2 milestone)
  - more open release end of July (DOE milestone)
- on-going tensions
  - usable tool vs. demonstration simulations
  - complete tool vs. infrastructure/framework
- user classes
  - see slide from Andrew's presentation
  - who are CASL's target users?
    - CASL partners, IC members, broad industry, undergrads, grad students, etc.

Deployment Strategy considerations

- platform options
  - current laptops, workstations, clusters vs. future
  - current HPC platforms vs. future
  - includes software ecosystem (OS, compiler(s), etc.)
    - Linux, Windows, Mac
- deployment mechanisms
  - source code
    - IP/export control
    - platform support
  - libraries/executables
    - can reduce both IP/export control and platform support issues
  - application server(s)
    - web-based interface
    - further reduces IP/export control and platform support issues
    - can provide access to larger-scale systems
    - many issues/questions, but worth thinking about?

CASL IP

Jeff Cornett, Chair
Commercialization Council

Industry Council Meeting

August 23, 2011

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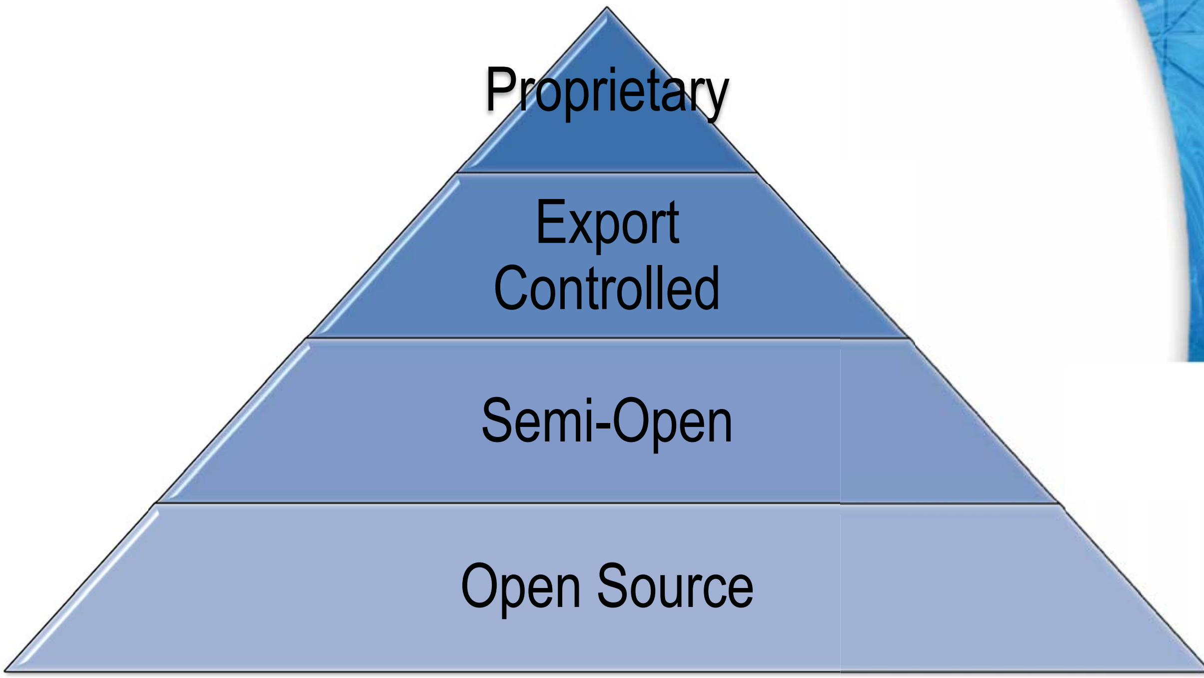
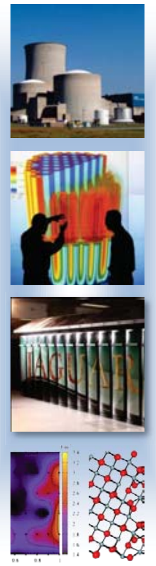
Virtual Reactor (VERA)





Industry Issues Beyond CASL Challenge Problems

Stephen M. Hess
AMA Deputy Focus Area Lead
CASL Industry Council
Oak Ridge National Laboratory
Oak Ridge, TN
22 - 23 August 2011

CASL Consortium for Advanced Simulation of LWRs

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Oak Ridge National Laboratory

Critical Elements for M&S Integration into Nuclear Energy Decision-Making

Acceptance by user community	• Address real problems in a manner that is more cost-effective than current technology • Meet needs of utility owner-operators, reactor vendors, fuel suppliers, engineering providers, and national laboratories
Acceptance by regulatory authority	• Address issues that could impact public safety • Deliver accurate and verifiable results
Acceptance of outcomes by public	• Provide outcomes that ensure high levels of plant safety and performance

Industry Council serves critical function to help CASL meet these objectives

CASL

Oak Ridge National Laboratory

CASL Financial and Technical Drivers

- Industry economic / operational goals will challenge fuel and plant performance:
  - Power uprates
  - Higher burnup
  - Life extension
- Challenge Problems based on analysis of safety, operating, and design criteria to determine key phenomena that could limit reactor performance

Initial CASL Objective:
Develop advanced M&S methods and investigate new fuel designs to address challenge problems

CASL

OAK RIDGE National Laboratory

CASL Challenge Problems

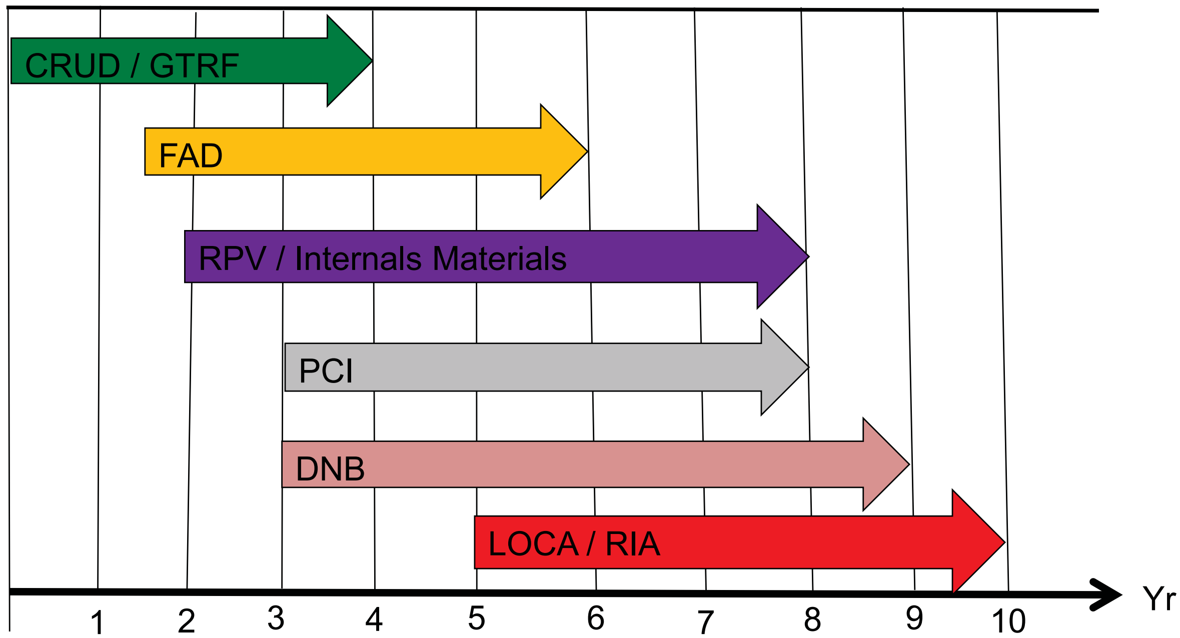
	Power uprate	High burnup	Life extension
Operational			
CRUD-induced power shift (CIPS)	×	×	
CRUD-induced localized corrosion (CILC)	×	×	
Grid-to-rod fretting failure (GTRF)		×	
Pellet-clad interaction (PCI)	×	×	
Fuel assembly distortion (FAD)	×	×	
Safety			
Departure from nucleate boiling (DNB)	×		
Cladding integrity during loss of coolant accidents (LOCA)	×	×	
Cladding integrity during reactivity insertion accidents (RIA)	×	×	
Reactor vessel integrity	×		×
Reactor internals integrity	×		×

Initial CASL development focus on non-safety related issues associated with PWR operation / performance

CASL

OAK RIDGE National Laboratory

Challenge Problem Timeline



Desire to obtain Industry Council input / confirmation of issues and timeline

Potential Issues for CASL Investigation

- Corresponding CASL capabilities for other PWR fuel vendors
- Evaluation of BWR operational issues
  - Pellet / clad interaction (PCI)
  - Channel bow
  - Fuel preconditioning / start-up ramps
  - Core stability
- Evaluation of NPP safety issues post-Fukushima (PWR / BWR)
  - Behavior during severe accident conditions
  - Issues related to spent fuel pool / dry cask storage
- Evaluation of changes in NPP operation
  - Load following operation (PWR and BWR)
  - "Real-time" tracking of fuel / core performance
- Design / licensing / operation of SMRs

Industry Council Session Objective:

Identify / discuss / prioritize critical elements for CASL consideration beyond initial set of identified challenge problems