CASL: The Consortium for Advanced Simulation of Light Water Reactors

A DOE Energy Innovation Hub for Modeling and Simulation of Nuclear Reactors

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Director, CASL

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

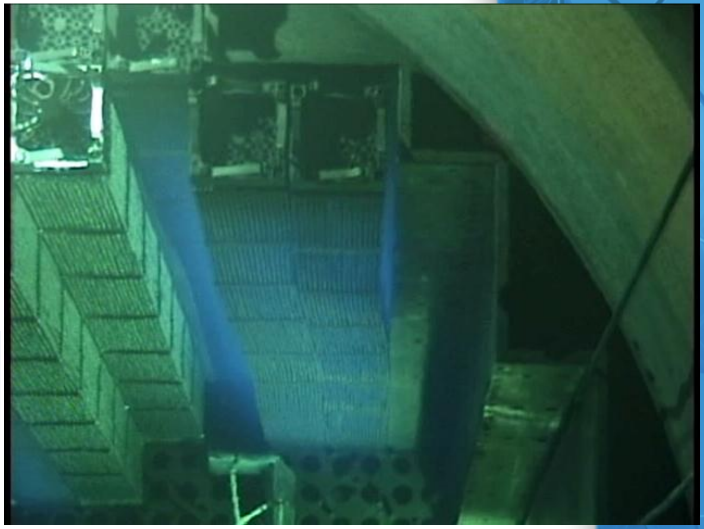
- CRUD (CIPS & CILC)
  - In-depth phenomenological understanding is sorely needed as reactors move to higher power densities, or change chemistry programs
- Grid-to-Rod Fretting (GTRF)
  - Key understanding will enable faster prototype fuel development and enable more advanced fuel designs
    - Modelling 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

Physical Reactor Application

TVA Support of CASL Mission

Objectives and Strategies

- Provide information and data from TVA's operating reactors to support validation of VERA
  - Initial data from Watts Bar
- Serve as a conduit for industry feedback (supplementary to the Industry Council)
- TVA located full-time at ORNL in support of CASL
- TVA to operate Test Stands as they become available, providing feedback to CASL regarding usability



Requirements Drivers

- Need to simulate specific phenomenon such as CRUD deposition, GTRF and PCI failures to validate VERA
- Application of quality assurance reviews of validation information to maintain potential for future licensing applications
- Early testing of VERA for industry use
- Represent the Utility User Group

Challenges and Risks

- Agreements, procedures and training for handling of non-public information
- Multiple sources for similar information

Outcomes and Impact

- Collect information and data
- Complete QA reviews
- Transmit to CASL subject to Records Management Procedure and after CASL-wide training

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CASL scope: Develop and apply a "virtual reactor" to assess fuel design, operation, and safety criteria

Near-term priorities (years 1–5)

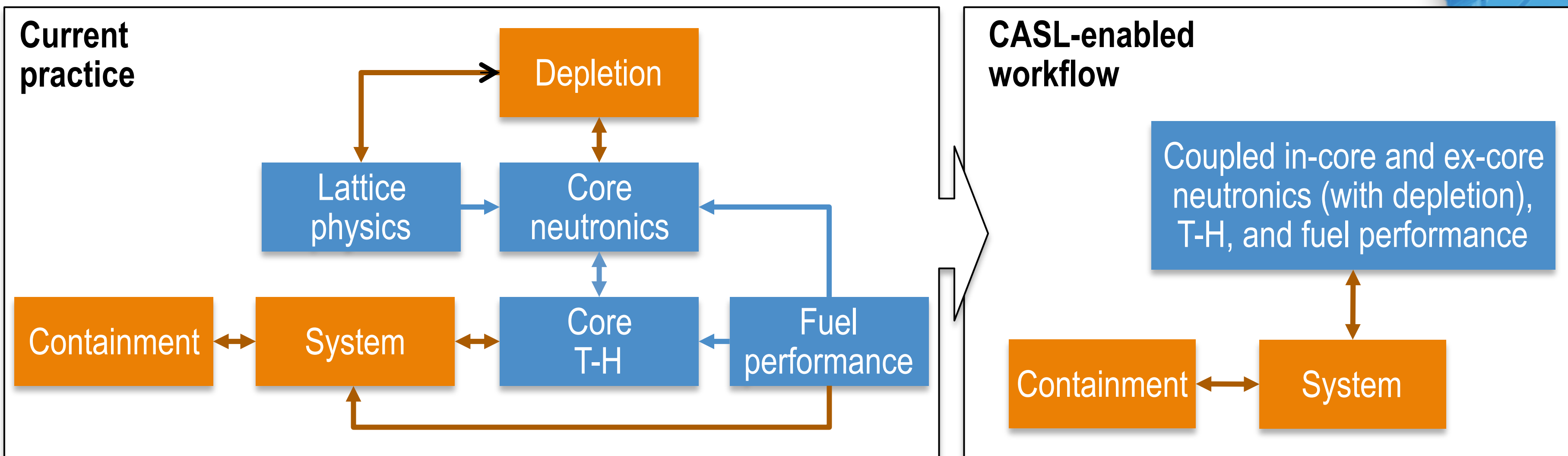
- Deliver improved predictive simulation of PWR core, internals, and vessel
  - Couple VR to evolving out-of-vessel simulation capability
  - Maintain applicability to other NPP types
- Execute work in 5 technical focus areas to:
  - Equip the VR with necessary physical models and multiphysics integrators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

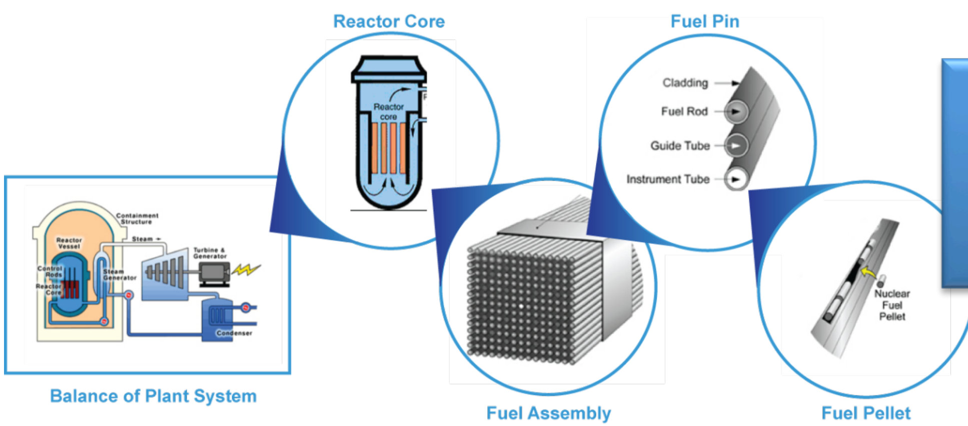
Longer-term priorities (years 6–10)

- 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

Our scope and focus on challenge problem solutions remains unchanged after one year

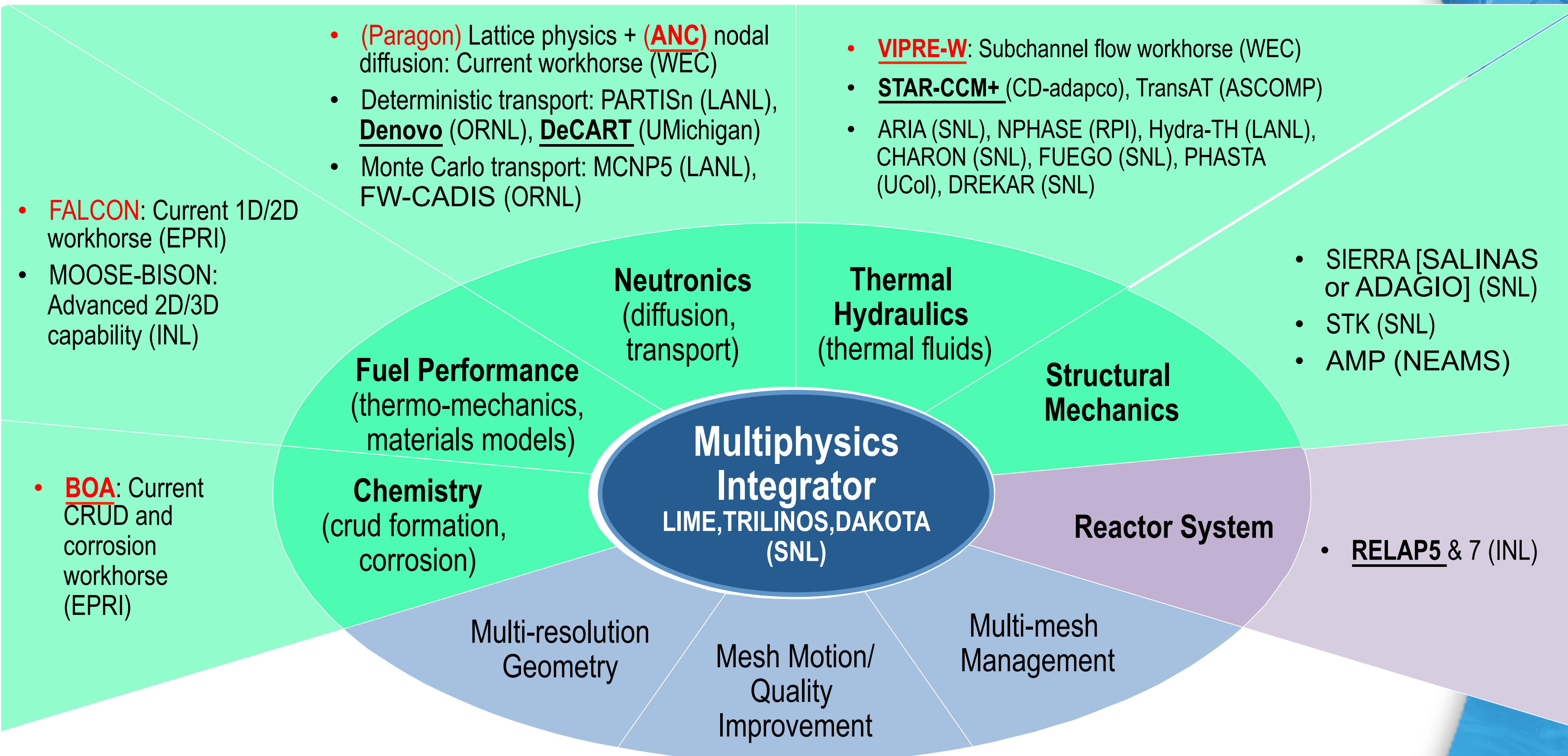
The CASL Virtual Environment Reactor is at the heart of the plan and is the science and technology integrator





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.

The CASL One-Roof Facility is Operational

Complete with its integrated VOCC collaboration & data analysis venues

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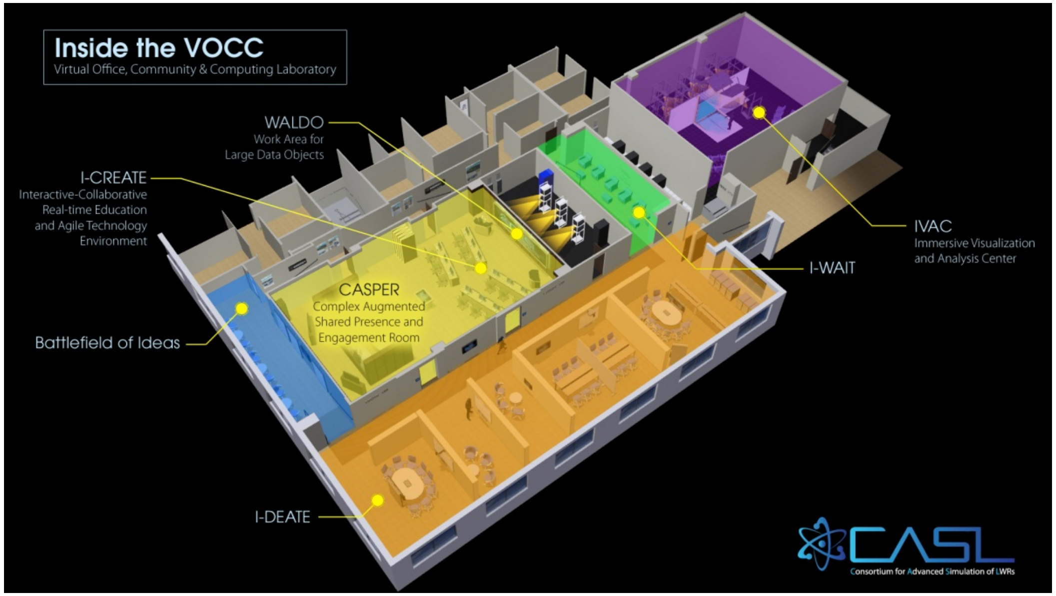

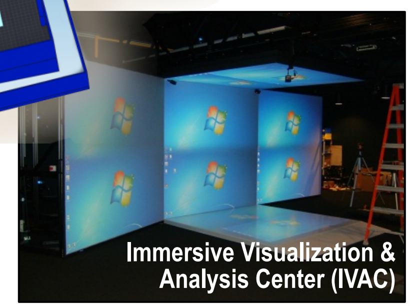

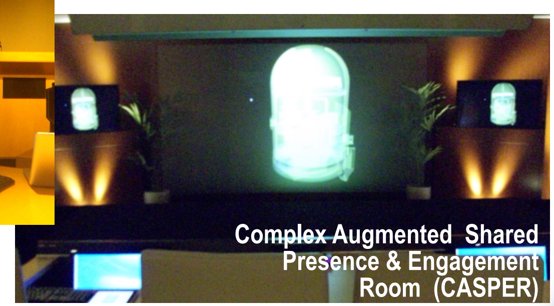

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CASL Dedication

May 3, 2011 rollout of the new CASL One-Roof Facility

CASL AGENDA

May 3, 2011

1:00 pm Welcome and Introductions Dr. Doug Kothe, CASL Director
Welcome and Remarks Dr. Thomas E. Mason, ORNL Director

Remarks
Dr. Steven Koonin, DOE Under Secretary for Science
Dr. Pete Lyons, DOE Assistant Secretary for Nuclear Energy

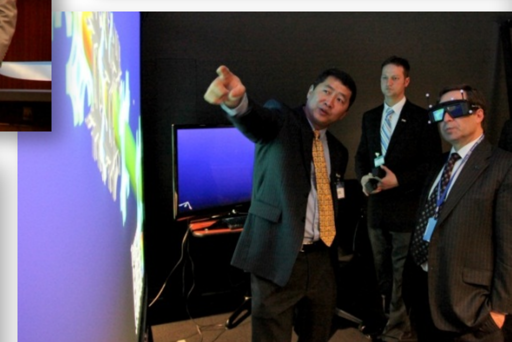
Industry Perspectives
Dr. Michael Howard, EPRI
Dr. Kate Jackson, WEC
Mr. Jack Bailey, TVA

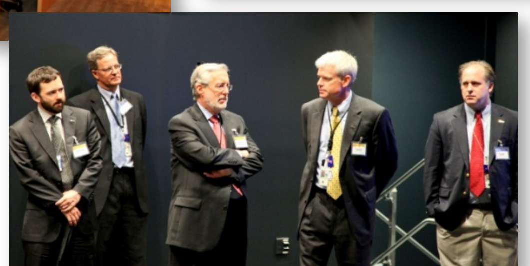
Remarks
Dr. Ernie Moniz, CASL Board Chair

Ribbon Cutting
Under Secretary Koonin, Thom Mason, Ernie Moniz

Media availability

Open House and Refreshments

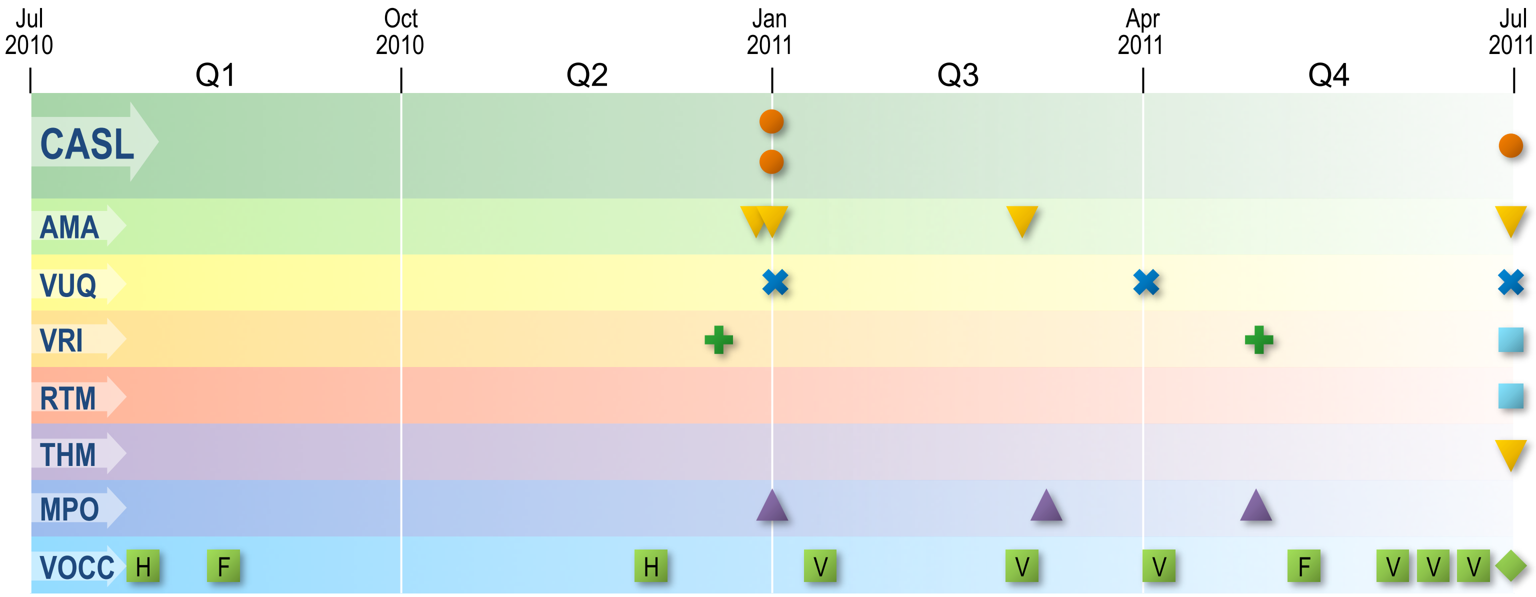




In only 10 months following its DOE Energy Innovation Hub award, CASL, under the leadership of its CIO April Lewis and with support from ORNL Senior Leadership, rolled out its new virtual one-roof facility as proposed and promised, complete with its state-of-the-art virtual collaboration and data analysis venues. Key leaders from DOE, ORNL, CASL partners, and the CASL Board of Director Chair participated in the May 3, 2011 Dedication.

CASL Year One

Summary of delivered L1 and L2 milestones



- L1: integrated capability and application
- L2: challenge problem component or capability
- L2: plans, requirements, problem specifications
- L2: virtual collaboration facility standup
- L2: physics component or capability (single or coupled)
- L2: foundational component or capability
- L2: software release
- F/V/H VOCC facility, venue, or huddle 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

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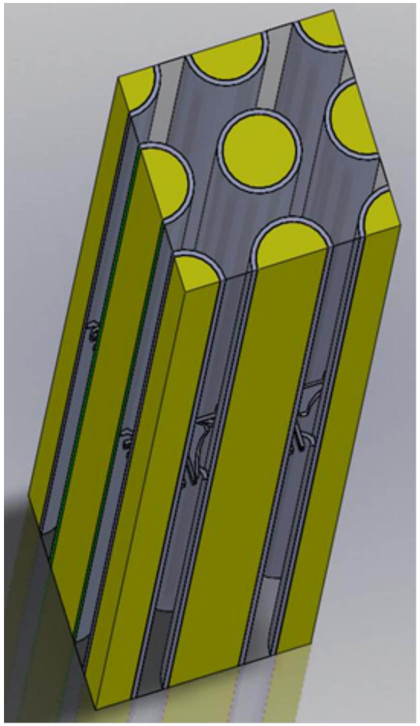
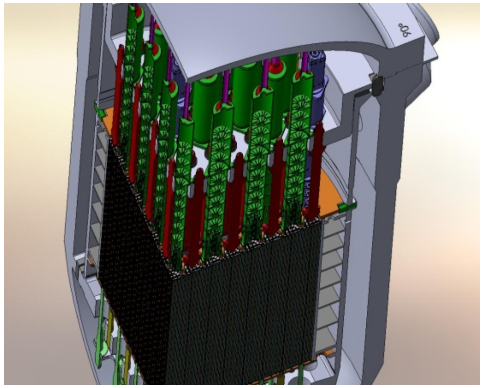
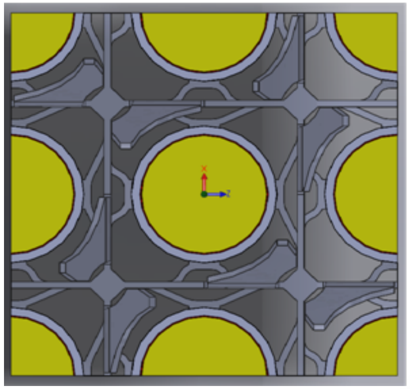
Process for Addressing Challenge Problems

- 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

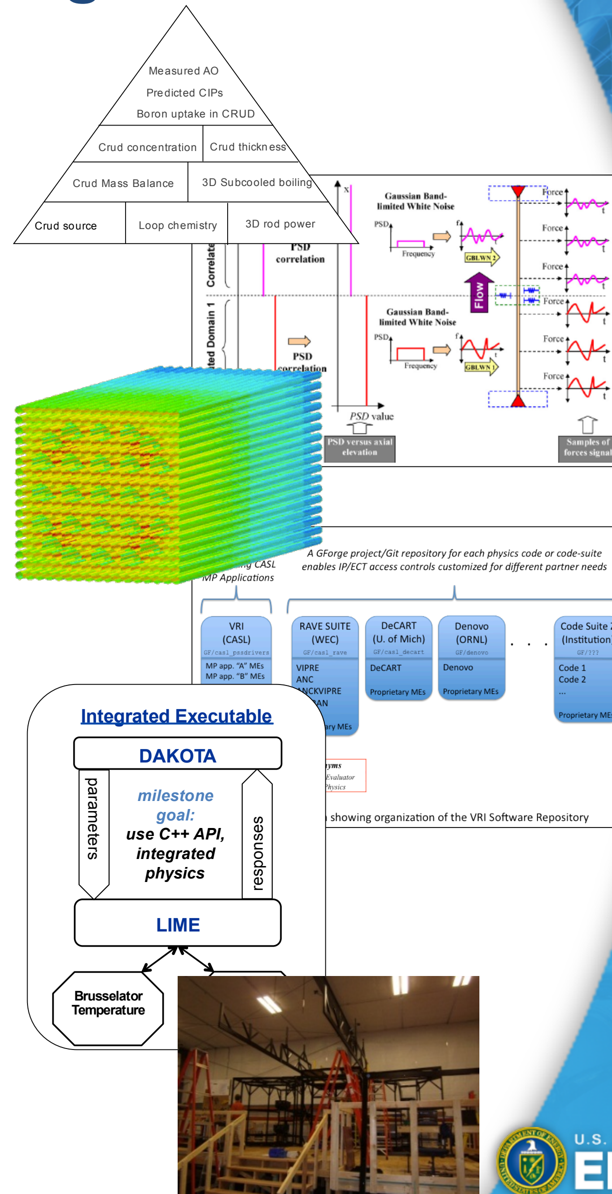




First Period Plan of Record Highlights

PoR-1: Jul – Dec 2010

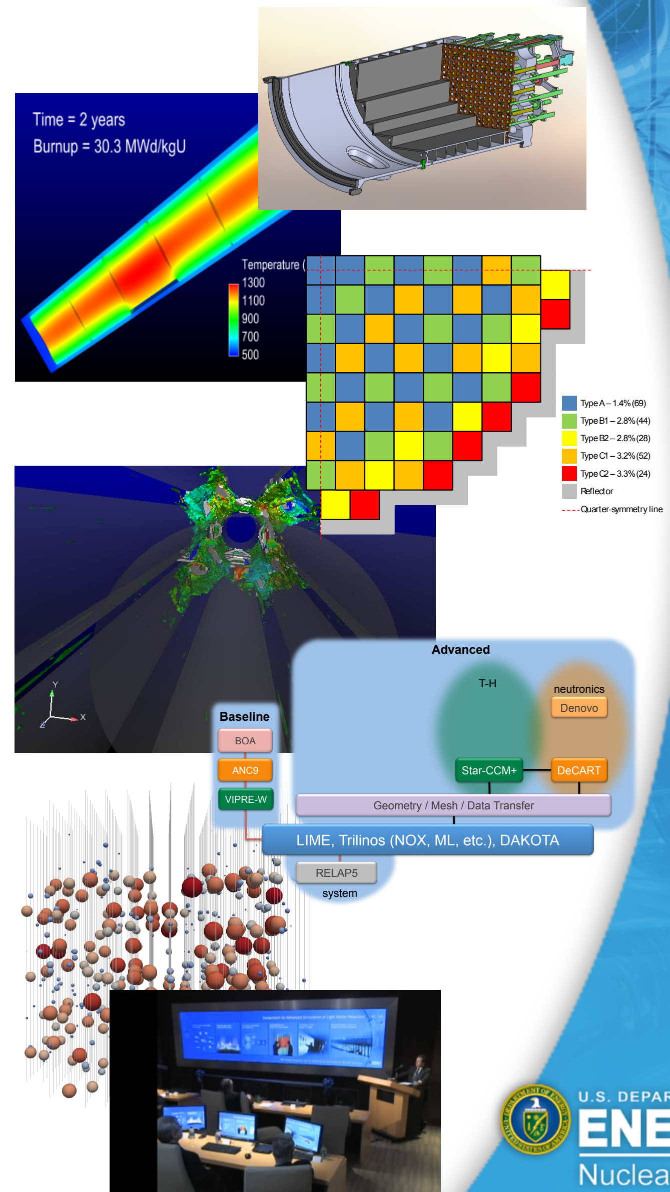
AMA	Development of requirements and validation plan to support and guide CASL virtual reactor development
MPO	Comprehensive plan developed for upscaling fundamental and improved fuel, materials science, & coolant chemistry R&D efforts
RTM	Application of radiation transport & CFD in VERA to an operational 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: Jan – Jun 2011

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.



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CASL Y1 Culminates in our First "Roundtable"

- CASL had an outstanding 1st year of science and engineering output as measured by external (non CASL programmatic) technical reports, publications, and countless invited and contributing presentations
- This output is encouraging given the deliberate head-down, milestone-driven pace and direction adopted the1st year

Latest Publication Tally: 97 total	
Jun 10 – Jul 2011	57
Aug – Oct 2011	40
2011 ANS Winter Meeting	10
Aug/Sept 2011 Issue of JoM	7
NURETH	11
Other publications	4
Submitted	8


Inaugural Annual CASL Roundtable
Aug 9-11, NCSU


Inaugural Annual CASL Knight Award
Brendan Kochunas (UM)
Most outstanding technical performer


Inaugural Annual CASL Jester Award
Rod Schmidt (SNL)
Most positive and enthusiastic performer

Long Term CASL Goals

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2015

- The CASL Virtual Reactor (VR) is released to the nuclear energy industry and demonstrates - through industry adaption – that its technology is a useful advance for the industry
- Influence analysis activities and decisions supporting core reload and new core design for one or more vendors and owners/operators through use of the CASL VR and CASL staff expertise.
- Demonstrably address, through new insights afforded by the CASL VR, key nuclear energy industry challenges to furthering power uprates, higher burnup, and/or lifetime extension while providing higher confidence in assuring nuclear safety.

2018

- The CASL VR (or portions thereof) becomes a viable nuclear energy industry modeling and simulation capability for supporting and furthering advanced nuclear steam supply system (NSSS) and nuclear fuel research, development, and deployment

2020

- Facilitate one or more nuclear energy industry licensing activities related to power uprates and/or lifetime extension through direct involvement of one or more CASL VR components.
- The CASL VR (or portions thereof) becomes one of the standard, reliant technologies in licensing by one or more nuclear energy vendors and/or owners/operators.
- Demonstrably expand the applicability of CASL VR to LWR-based SMRs and/or BWRs.

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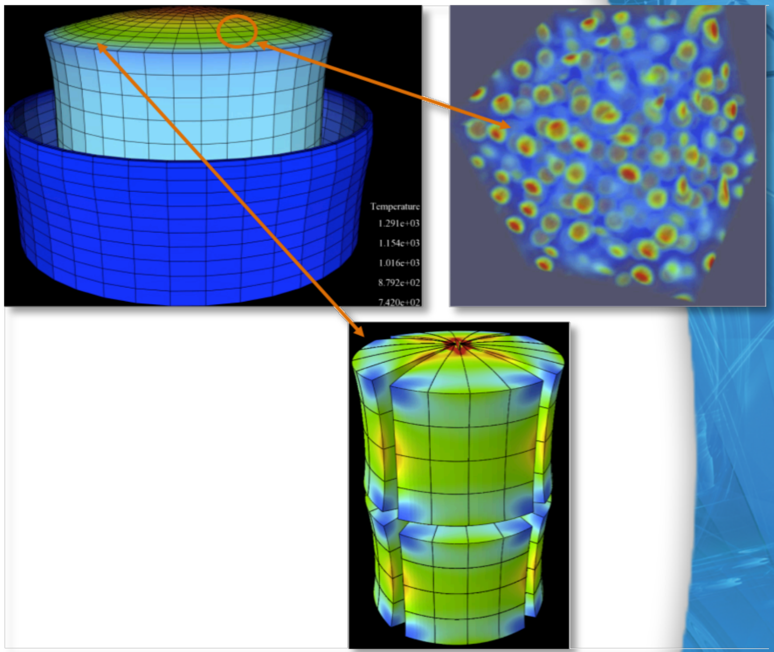
CASL legacy:
A preeminent computational science institute for nuclear energy



- CASL Virtual Reactor: Advanced M&S environment for predictive simulation of LWRs
  - Operating on current and future leadership-class computers
  - Deployed by industry (software “test stands” at EPRI and Westinghouse)
- Advanced M&S capabilities:
  - Advances in HPC algorithms and methods
  - Validated tools for advancing reactor design
- Fundamental science advances documented in peer-reviewed publications
- Innovations that contribute to U.S. economic competitiveness
- Highly skilled work force with education and training needed:
  - To sustain and enhance today’s nuclear power plants
  - To deliver next-generation systems