

CASL Update

Jess Gehin (ORNL), Director

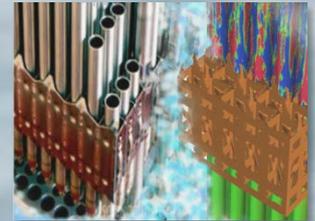
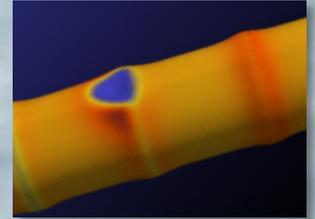
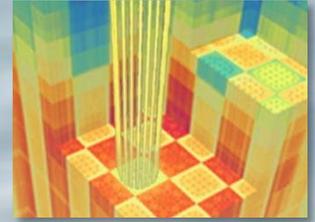
Doug Burns (INL), Deputy Director

Dave Kropaczek (NCSU), Chief Scientist

CASL Industry Council Meeting

Greeneville, South Carolina

April 13, 2016



The Consortium for Advanced
Simulation of LWRs
A DOE Energy Innovation Hub

CASL-U-2016-1081-000



U.S. DEPARTMENT OF
ENERGY

CASL's Mission is to Provide Leading-Edge M&S Capabilities to Improve the Performance of Operating LWRs

VISION

Predict, with confidence, the performance and assured safety of nuclear reactors, through comprehensive, science-based M&S technology deployed and applied broadly by the U.S. nuclear energy industry

GOALS

- Develop and effectively apply modern virtual reactor technology
- Provide more understanding of safety margins while addressing operational and design challenges
- Engage the nuclear energy community through M&S
- Deploy new partnership and collaboration paradigms

The CASL Industry Council is Crucial to our success!

- The mission of the Industry Council is to ensure that CASL solutions are “used and useful”, and that CASL provides effective leadership advancing the Modeling and Simulation state-of-the art in the nuclear industry.
- This meeting provides an opportunity for the exchange of information about CASL’s research and activities to:
 - Provide an opportunity for engagement between industry stakeholders and CASL researchers.
 - Present and seek feedback on the progress on CASL’s R&D activities and plans.
 - Discuss CASL and industry priorities to ensure that they are aligned.
 - Identify strategic collaborations between industry and CASL Focus Areas.

**Thank You for Your Participation and
Support of CASL!**

Dr. Pete Lyons Accepts CASL Board Chair Position



Jim Duderstadt

Outstanding leadership and guidance as our 3rd Board Chair!



Pete Lyons

Brings Considerable Nuclear Energy Experience to the Board Chair Position

Tansel Selekler appointed CASL's DOE Federal Manger

- Appointment effective January 1, 2016
- Previously responsible for the DOE/NE Nuclear Energy Advanced Modeling (NEAMS) and Simulation Program
- Dual reporting to John Kotek, Assistant Secretary for Nuclear Energy and Shane Johnson, Deputy Assistant Secretary for Science and Innovation



Dave Kropaczek Named CASL Chief Scientist

Thanks to Paul Turinsky for the many years of outstanding service to CASL!



Welcome to Dave Kropaczek!

- Duke Energy Endowed Professor of Nuclear Engineering at NCSU
- Formerly, President and CEO of Studsvik Scandpower, Inc.
- Strong technical background in LWR methods and applications!



More Organization Changes!

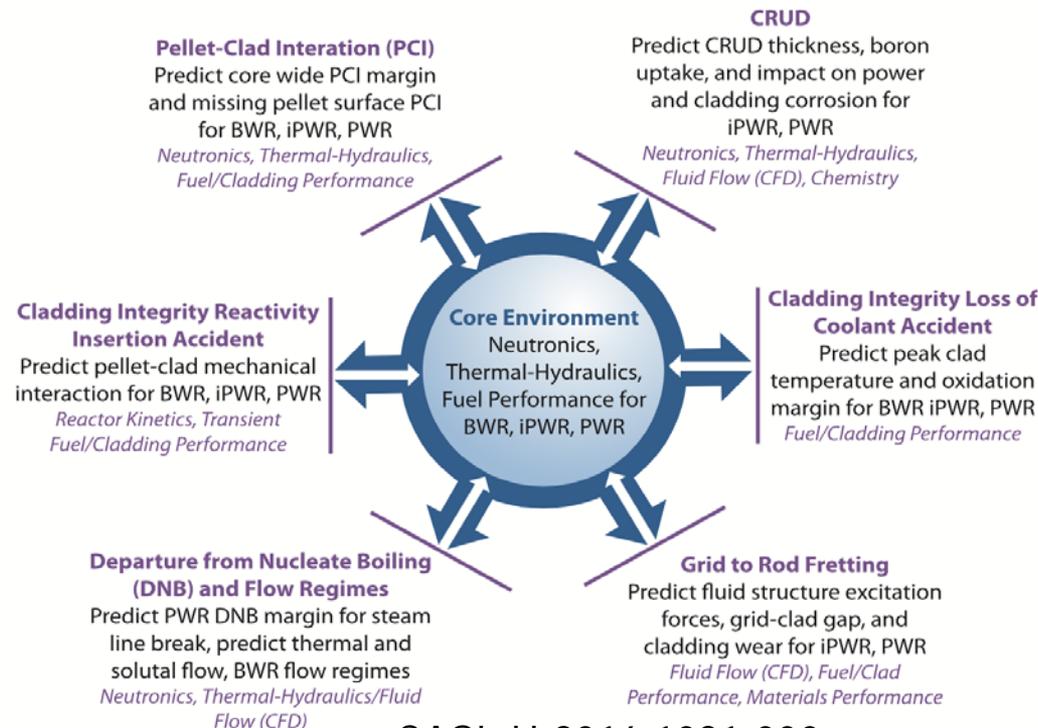
- **Industry Council Executive Director**
 - Position filled by Erik Mader of EPRI
 - Previously held by Dennis Hussey (EPRI)
- **Physics Integration (PHI)**
 - Deputy Lead Scott Palmtag (LANL) stepped down to focus on technical work – Replacement being finalized
- **Technology Deployment & Outreach (TDO)**
 - Lead Dennis Hussey (EPRI) being reassigned by EPRI and has left CASL & Deputy Lead Rose Montgomery left TVA to join ORNL in non-CASL role
 - New Lead not yet assigned since need to reevaluate and finalize responsibilities of TDO
 - Doug Burns serving as interim TDO lead

All FY16 DOE-reportable milestones are on schedule

Milestone ID	Milestone Description	Finish Date
FY16.CASL.001	Develop and test subchannel thermal hydraulics to support modeling of BWR operating conditions	Completed On Time
FY16.CASL.002	Demonstrate Uncertainty Quantification and Data Assimilation for Watts Bar Unit 1 Cycle 1	Completed On Time
FY16.CASL.003	Identify fuel performance capabilities needed for analysis of Reactivity Insertion Accidents (RIA) and complete initial implementation	May 2016
FY16.CASL.004	Initiate VERA working group by holding first meeting	April 2016
FY16.CASL.005	Complete VERA integrated Verification and Validation (V&V) requirements and planning and update V&V manuals for individual codes	June 2016
FY16.CASL.006	Define post CASL sustainability strategy	July 2016
FY16.CASL.007	Demonstrate VERA Core Simulator performance improvements	August 2016
FY16.CASL.008	Implement VERA transient capability with internal heat conduction feedback for PWRs for analysis of Reactivity Insertion Accidents (RIA)	September 2016
FY16.CASL.009	Demonstrate DNB analysis methods using CFD for Non-Mixing Vane and V5H grid spacers	September 2016
FY16.CASL.010	Assess the analysis capability for core-wide PWR Pellet-Clad Interaction (PCI) screening and demonstrate detailed 3-D analysis on selected subregion	September 2016
FY16.CASL.011	Qualify CFD-based PWR Crud Induced Localized Corrosion (CILC) capability to identify high-risk fuel rods	September 2016

Challenge Problems Progress

- The following Challenge Problems are being focused upon in FY16:
 - CRUD Induced Power Shift (CIPS) and CRUD Induced Localized Corrosion (CILC)
 - Pellet-Clad *Mechanical* Interaction (PCMI)
 - Departure from Nuclear Boiling (DNB)
 - Transient behavior during Reactivity Insertion Accident (RIA)

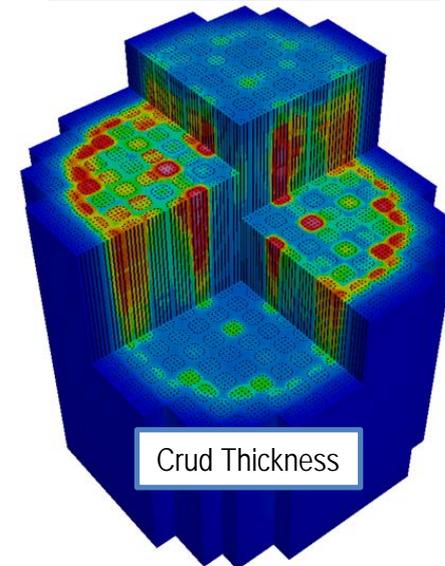


CASL-U-2016-1081-000

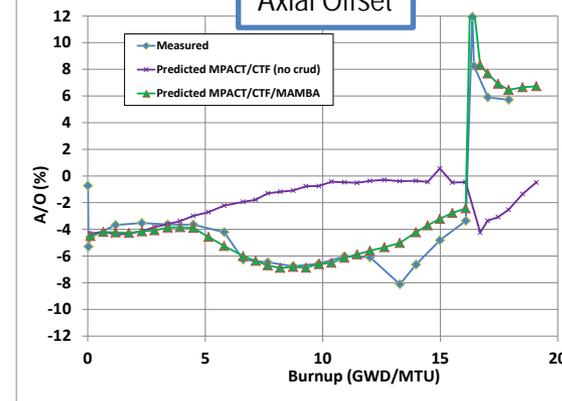
CIPS Challenge Problem Status

- First CASL successful integration CIPS calculation marked significant achievement in FY15
- Based on this effort, further development needs identified and included in FY16 work scope:
 - Cobra-TF/Mamba-1D needs to be compared with Star-CCM+/Mamba-3D to understand needs for tuning of Mamba-1D parameters
 - Coupling of Star-CCM+ with Mamba-1D and Mamba-3D is needed to understand differences
 - Improvements needed in Cobra-TF based CRUD erosion models
 - Investigate consistency of Cobra-TF, Star-CCM+ and MAMBA sub-cooled boiling models
 - Need to focus on development CRUD source models and CRUD mass balance models
 - Consider modeling additional plants with more data (Seabrook was suggested)
- FY16 DOE Reportable Milestone on CIPS UQ

Watts Bar 1 Cycle 7



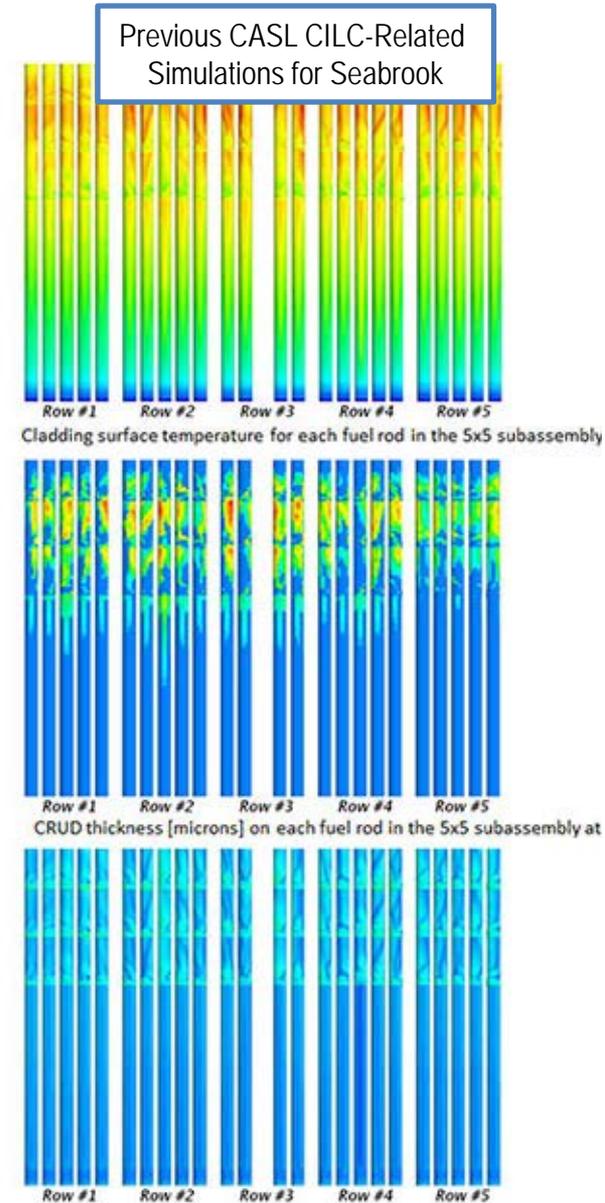
Axial Offset



CASL-U-2016-1081-000

CILC Challenge Problem Status

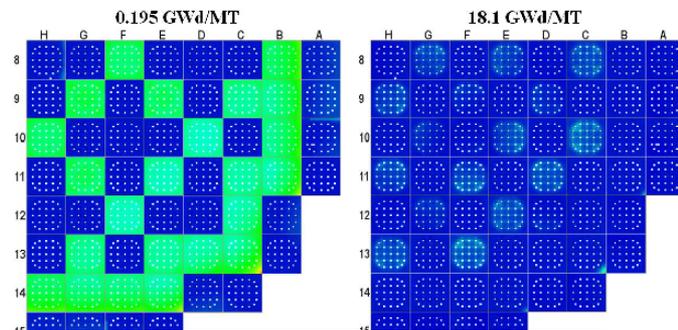
- Extends work performed for CIPS to simulate CILC
- Approach for CILC:
 - VERA-CS/MAMBA1D is used identify fuel rods that would be concern for CILC failures (e.g. high CRUD thicknesses)
 - Perform localized Star-CCM+ MAMBA3D to analyze potential for CILC on rods of interest
 - Highly leverages work being performed for CIPS
- Areas of work in FY16
 - Integration of Star-CCM+ and MAMBA-3D
 - Development of cladding corrosion models and integration with BISON
 - Simulate Seabrook cycles with CILC failures
- FY16 DOE Reportable Milestone on CFD-based CILC analysis for PWRs



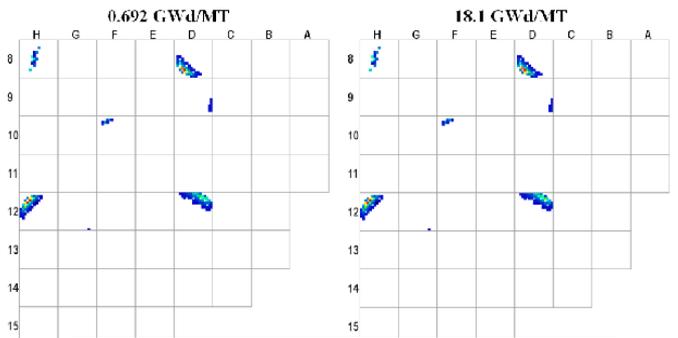
PCI Challenge Problem Status

- Goal is contribute toward validation of PCI prediction capability using nuclear power plant data
- Approach for PCMI:
 - Integration of VERA-CS and BISON (2D) to identify limiting rods for the entire core (start with one-way coupling rather than full coupling)
 - Perform BISON (3D) to identify potential for PCI on limiting fuel rods
- Areas of work in FY16
 - Continue development of BISON models to support PCI analysis
 - Investigate improved indicators of PCI failures
 - Coupling of VERA-CS/BISON for full core simulations
 - Analysis of Watts Bar Cycle 6 and 7 PCI failures
- FY16 DOE-reportable milestone on core-wide PCI analysis

VERA-CS/Bison
Simulations of Watts Bar Cycle 3



Minimum pellet-clad gap thickness



Cumulative damage index

Progress on BWR Simulation

- CASL's goal is to be able to model core subregions to support challenge problem analysis
- Radiation Transport
 - Previously demonstrated extension of capability of MPACT code to simulate BWR lattice geometries – represents an initial capability
 - Revealed need to improve cross section library, which is now in progress
- Subchannel Thermal-Hydraulics
 - CTF has capability to model BWR conditions – Fidelity being validated
 - VERAIn extended to handle BWR geometries
 - CTF extended to complete core-wide BWR analysis, necessitating adding inlet flow redistribution capability

COBRA-TF Full BWR Core Simulations

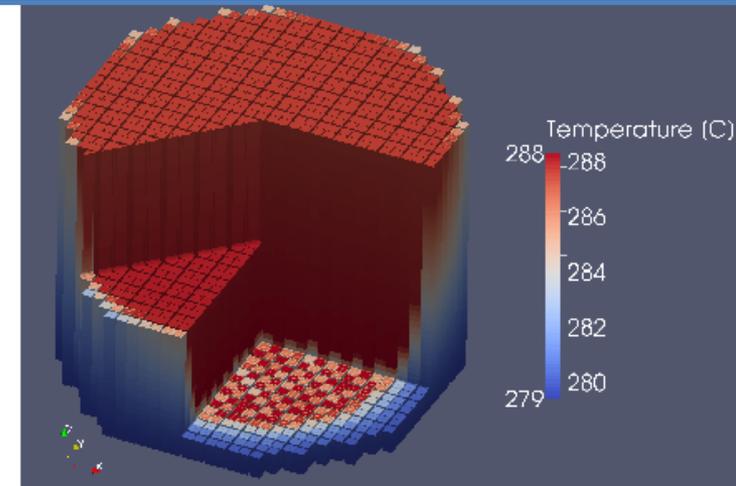


Figure 12. Isometric view of core mixture temperature distribution

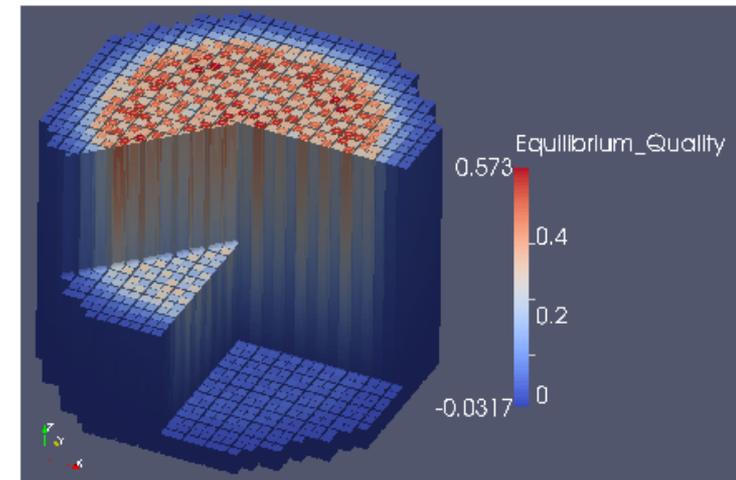
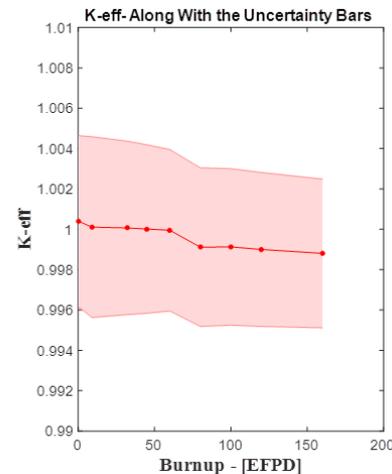


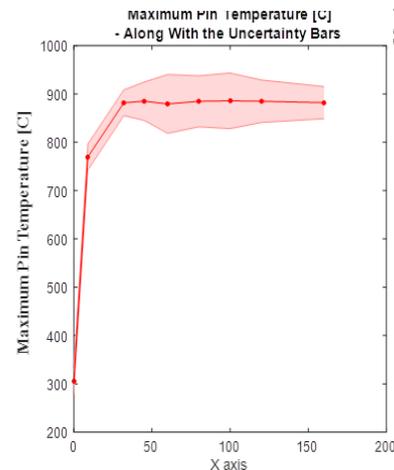
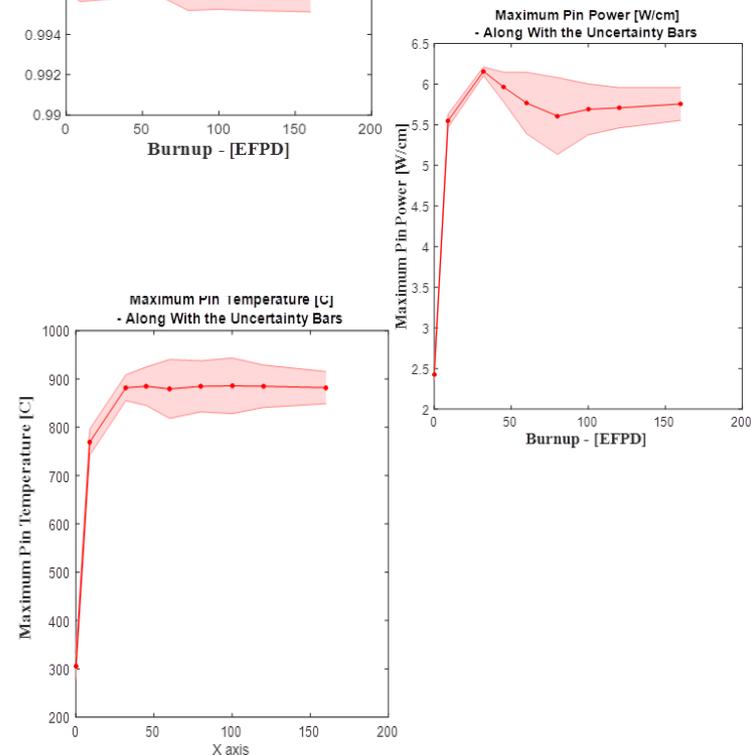
Figure 13. Isometric view of core equilibrium quality distribution

Progress on Core-Wide Uncertainty Quantification & Data Assimilation (L2:VMA.P12.01)

- March 2016 DOE reportable milestone completed on core-wide uncertainty quantification (UQ) & data assimilation (DA) using VERA-CS core simulator
 - Uncertainty in cross section and several thermal-hydraulic parameters considered
- Capability developed lays foundation for completing UQ & DA for Challenge Problems dependent upon VERA-CS, e.g. CIPS
- Concern remains of large computational resource requirements without further progress on methodology
 - This work was for a portion of the cycle (200 EFPD) and used ~2.5M core hours on ORNL and the UT-Austin TACC computer system

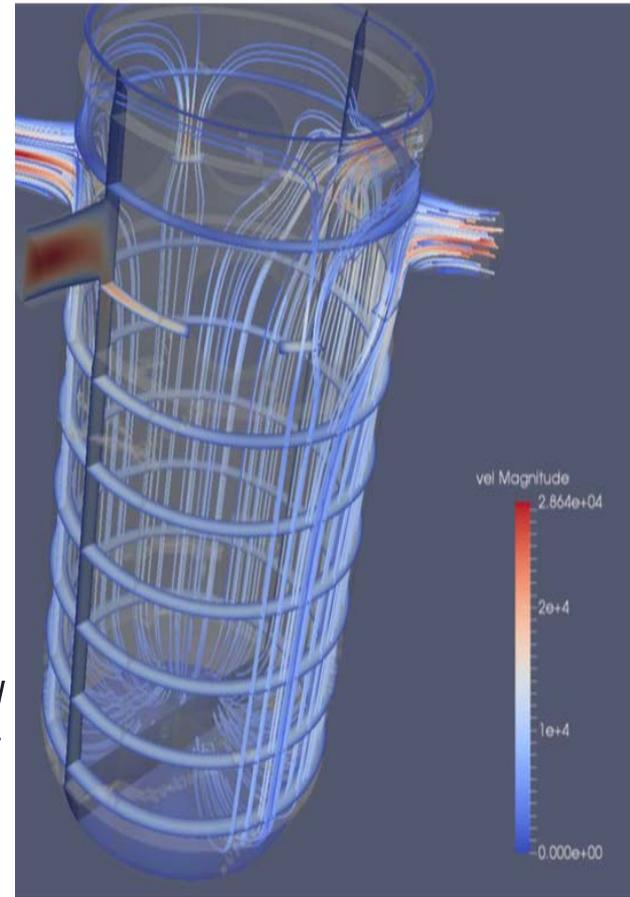


Demonstration of UQ/DA
For Portion of Watts Bar
Cycle 1



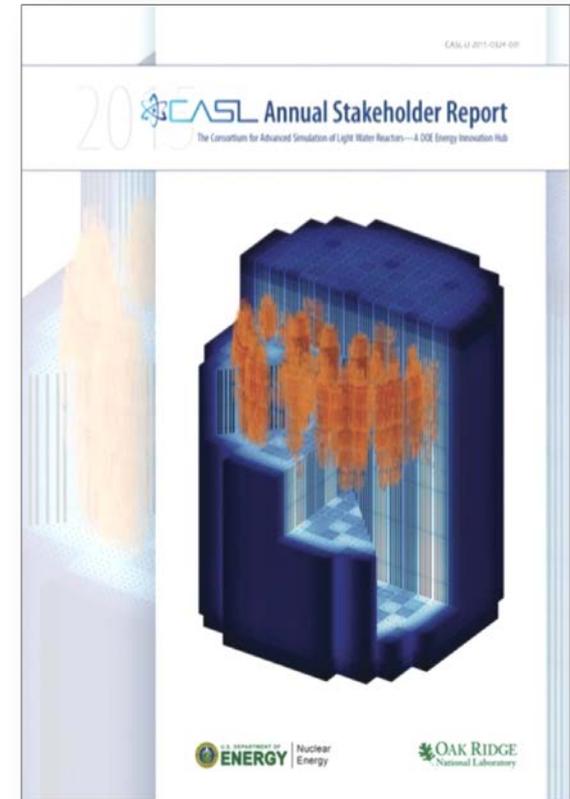
Status of Test Stands – Moving forward with external test stands

- Three test stands have been completed:
 - ✓ WEC: VERA-CS core simulator – 2015
 - ✓ EPRI: BISON fuel performance code for PCI application – 2015
 - ✓ TVA: Hydra-TH CFD for lower plenum anomaly – 2016
- Two external test stands are being established
 - AREVA: VERA-CS core simulator (with embedded MAMBA CRUD code) for modeling core flow and CRUD formation completing validation using Davis Besse Cycle 15 plant data and fuel examinations
 - University of Illinois: VERA-CS core simulator + BISON fuel performance for evaluating fuel duty under load follow conditions as relates to PCI in cooperation with Exelon for Byron NPPs



CASL prepared its first stakeholder report for 2015

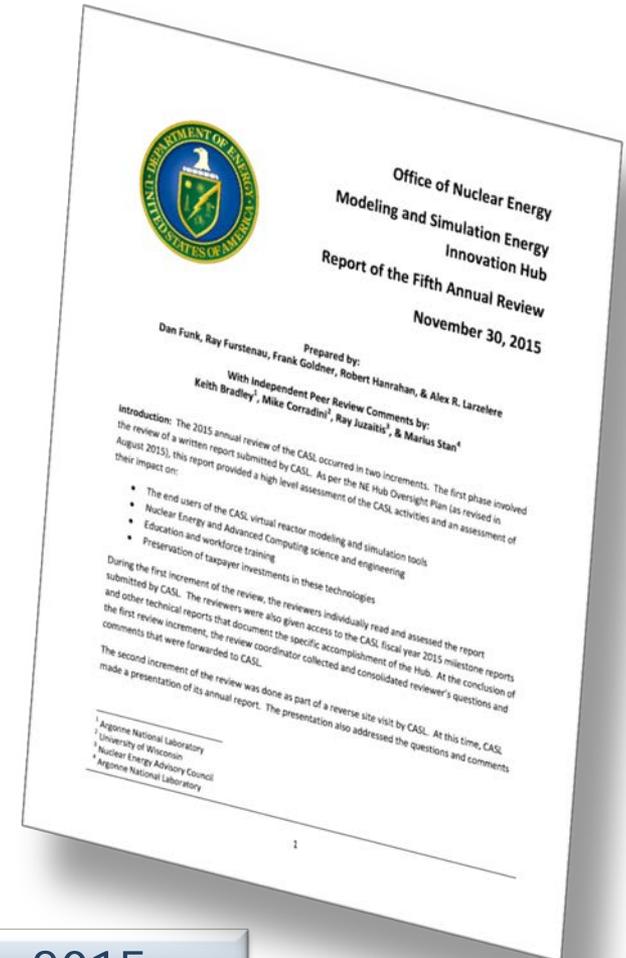
- Intention to look more like an annual report for a Board of Directors, etc.
- Included DOE request for “certifications”
 - Science Council, Industry Council, ORNL site office
- Has sections that address each of DOE’s questions.
- Submitted to DOE on October 16, 2015
- A polished glossy version created for distribution to stakeholders



Stakeholder report was well received with about 300 copies distributed to date

DOE's 2015 review provides very positive outcome for the annual review

- "Overall the review team believes that CASL has done an outstanding job this year and has successfully completed its first annual review of its second phase"
- "The review process used by NE this year ... 'raises the bar' for CASL"
- "For this review ... CASL is being asked to show the impact of its products and why the taxpayer investors should care about them – CASL did an excellent job presenting that information."



CASL Successfully Completes 2015
Annual Review!

CASL-U-2016-1081-000

Impact on End Users of the Virtual Reactor

Overall, the federal review team was very impressed with the work CASL is doing to ensure that the virtual reactor tools ... will have a significant impact

Primary Recommendations:

- Continue to develop and refine work for impact addressing problems faced by energy innovators and useful in their normal work environments
- Create a legal structure that will allow successful transfer of technologies
- Create the motivation by end users to make the necessary investments to implement use of the tools

Other Recommendations:

- Consider adding more end user feedback or testimonials to report
- Provide information about major reactor operational issues that could be avoided
- Include information on impact that CASL education and workforce training activities will have on end users

Impact on Science and Engineering

The Federal review team found that CASL is having good impact on science and engineering for nuclear engineering and modeling and simulation in general

Recommendations:

- Continue to seek opportunities to showcase CASL capabilities and accomplishments – particularly emphasizing publications in archival journals
- Do more to publicize and demonstrate how CASL is contributing to advanced computing – particularly in multi-physics coupling and VVUQ
- Also, look for opportunities to talk about the success of CASL as an energy innovation hub

Impact on Education and Workforce Training

The federal review team finds that CASL is having a good impact on nuclear energy education and workforce training, but suggest that their efforts are at just a starting point

Recommendations:

- CASL should continue its efforts to integrate the virtual reactor tool set into university curricula
- Target getting a larger number of students engaged in CASL research activities.
- Consider finding ways to involve companies on the Industry Council in the CASL educational activities.

Impact on Preserving Taxpayer Investments

The federal review team finds that CASL is off to a good start in this area, but considerable work will be needed to determine and implement the actions needed to preserve the taxpayer investment in CASL

Recommendations:

- The work in this area is just at a beginning stage, CASL needs to continue to put emphasis on this important area
- Find new/additional ways to engage with the NRC and the NE light water reactor sustainability program
- Some issues may be beyond CASL's ability to solve – in those cases engage with its Board and NE program manager.

Market Analysis Completed

CASL-U-2016-1081-000

- A VERA market analysis has been developed by a team from the Accelerated Commercialization of Technology (ACT) Program at NCSU
- Objectives of the study included:
 - Identification of existing and future market opportunities for VERA
 - Development of a viable commercialization strategy that will support creation of a self-sustaining VERA support organization
- Research included 235 contacts and 65 interviews with nuclear power industry stakeholders
 - Interviews were conducted with fuel vendors, electric utilities, national labs, computing/sim software companies, academia, and government personnel
- Two viable business models were identified:
 - Non-profit organization operated by ORNL
 - For profit organization spun out of ORNL
 - Both options will require government funding and a “champion”

Thank you for providing input!

IC Agenda

Tuesday, April 12

8:30	Welcome, Meeting Objectives and Introductions	Scott Thomas
9:00	CASL Update	Jess Gehin
10:00	Break	
10:15	IC Member Overviews	Scott Thomas
11:15	VERA Core Simulator Development Progress	Scott Palmtag
11:45	Working Lunch – Delivering the Promise Presentation	Erik Mader
1:00	Application of VERA-CS to Watts Bar and other plants	Andrew Godfrey
2:00	CIPS Simulation Progress and Path forward	Brian Kendrick
2:45	DNB Steamline Break Analysis Challenge Problem Progress	Yixing Sung
3:30	Break	
3:45	PCI Capability Development and Challenge Problem Progress	Joe Rashid
4:30	V&V Applications and Approaches for Challenge Problems	Vince Mousseau
5:30	Adjourn	

Wednesday, April 13

8:30	Update on Bison Development and V&V Plan	Rich Williamson
9:30	Progress in modeling BWRs for PCI Challenge Problem	Kevin Clarno
10:00	Break	
10:15	CASL Education Program and Summer Institute	Mike Doster
10:45	Industry Council Member Comments/Input	Scott Thomas
11:45	Wrap up - Action items and next meeting	Erik Mader
12:00	Adjourn	

We are establishing the VERA Working Group at this meeting (Wednesday PM)

- The VERA working group is envisioned to provide an open forum for discussion and exchange of information on the use of CASL technology including updates on VERA development, discussion of applications, coordination of training, development of the VERA user and support base.
- This first meeting of the VERA working group will focus on the development of the definition of the working group.
- Specific objectives
 - Discuss the need, roles, and activities of the VERA working group.
 - Define the structure and operation of the working group.
 - Develop a VERA working group charter.

