CASL
A DOE Energy Innovation Hub

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Consortium for Advanced Simulation of Light Water Reactors

The Consortium for Advanced Simulation of Light Water Reactors (CASL) is an Energy Innovation Hub established by the US Department of Energy in 2010 to advance the development and application of modeling and simulation (MODSIM) technologies for nuclear reactors. CASL's mission is to provide a step change in computational capabilities to the nuclear energy industry—one that enables more accurate prediction of the key phenomena defining the operational and safety performance of light water reactors (LWRs).

Through CASL, experts from national laboratories, universities, and industry are developing and deploying CASL's Virtual Environment for Reactor Applications (VERA), a "virtual reactor" designed to accurately simulate the physical processes inside a reactor at unprecedented levels of detail. These processes include neutron transport, thermal hydraulics, nuclear fuel performance, and corrosion and surface chemistry. VERA relies on the latest science-based physical models for nuclear reactor phenomena, advanced numerical methods for solution of these models, modern computational science and engineering techniques for imparting these methods into the VERA software, tools for estimating uncertainties and sensitivities of the VERA simulations, and validation against data from operating reactors and other pertinent experiments.

CASL Achievements and Plans

CASL is meeting an aggressive set of milestones and delivering technologies that address industry issues. VERA has been deployed through "test stands" (prototype installations in actual engineering and design environments) and used to match actual startup data for a Generation 2 reactor on the grid (the Tennessee Valley Authority's Watts Bar Unit 1 Plant). VERA has also been used to predict startup data for a Generation 3+ reactor design, the Westinghouse AP1000®, that is the basis for eight reactors now under construction. The CASL team has shown that a subset of VERA, the VERA Core Simulator, can follow reactor operations through a single refueling cycle and is now working on demonstrating this for multiple refueling cycles.

CASL addresses three critical areas of performance for nuclear power plants (NPPs): (1) reducing capital and operating costs by supporting the analysis justification for permitting power uprates; (2) reducing nuclear waste volume by enabling higher fuel burnup, and (3) assuring nuclear safety by enabling high-fidelity predictive capability for component performance through the onset of failure.

Extending CASL for a second five-year term enables enhanced development of VERA for applications beyond pressurized water reactors —that comprise approximately 2/3 of the U.S. fleet—to boiling water reactors (the remainder of the U.S. fleet) and next-generation reactor designs such as small modular reactors. Increasing the breadth and depth of technologies in the VERA Core Simulator provides the nuclear industry with powerful tools for exploring operational and design challenges such as:

- current and next generation nuclear fuel cladding performance under operational and accident conditions,
- chemically induced corrosive interactions between nuclear and nonnuclear materials and coolants, and
- fluid dynamics and heat transfer, fully coupled to neutronics behavior, of both operational and transient scenarios for pressurized, boiling, and small modular reactors.

CASL Founding Partners

CASL Strategic Goals

1. Develop and apply contemporary modeling and simulation (MODSIM) practices for design, operational, and safety challenges for light water reactors.
2. Engage the nuclear community (government, academia, and industry) in the research, development, and deployment process, in order to set scope and priorities and ensure outcomes of value.
3. Deploy advanced MODSIM technology via a "Virtual Environment for Reactor Applications" (VERA) to customers, clients, and users.
4. Advance nuclear technology by deploying new capabilities for predicting the performance of commercial nuclear power plants and supporting progress toward key nuclear industry goals:
   - higher power ratings
   - greater fuel burnup
   - next-generation designs

CASL Mission

Provide modern analysis tools that reliably model the effects of multiple processes occurring simultaneously inside reactor cores, thereby predicting core behavior and helping to improve operational/safety performance in light water reactors

Achievements to Date
(FY 2010–FY 2014)

Year 1 . . .
- Technical roadmaps established for addressing high-priority Challenge Problems
- First high-resolution reactor core model for TVA Watts Bar plant
- First-of-a-kind three-dimensional (3D) assessment of fuel pellet-to-cladding interaction
- **VERA 1.0** established with infrastructure and basic industry Core Simulator
- Established methods for placing computer-based tools in industrial environments for real-life testing

Year 2 . . .
- **VERA 2.0:** Initiated neutronics simulation (prediction of changing core power distribution in reactor core)
- Expanded the neutronics capability to unprecedented details on the distribution of neutrons in a reactor core (demonstrated how to model the individual performance of thousands of fuel pins in an entire reactor)

Year 3 . . .
- **VERA 3.1** internal release: Core neutronics + thermal hydraulics + fuel performance
- Demonstrated the application of VERA tools to improve understanding of fuel-to-cladding interactions and the corrosion-induced power losses that result (reducing corrosion prevents power losses).
- Increased VERA accuracy using statistical methods and probability analysis [uncertainty quantification (UQ) and sensitivity analysis (SA)]

Year 4 . . .
- **VERA 4.0** limited external release: Refinements to prior capabilities + corrosion and surface chemistry
- Completion and validation of VERA Core Simulator

Year 5 . . .
- **VERA 5.0** broad external release: Refinements to prior capabilities + unique physics problem analysis + integrated UQ/SA

Key Goals for 2nd Five-Year Term
(FY 2015–FY 2019)

1. Continue expanding **VERA** to solve more problems that limit nuclear power plant performance:
   - Fuel performance under accident conditions →further assure safety of plants
   - Chemical and corrosion interactions between materials and coolants →often a gating factor for improving fuel cycle economics
   - Two-phase thermal hydraulics for operational and transient reactor scenarios →more efficient plant performance
   - Expand to other types of reactors and reactors of the future →achieve industry-wide performance improvements
2. Maintain VERA Core Simulator in pace with the state of the art in contemporary MODSIM technology → maximize value
3. Establish a self-sustaining organization, drawing from the CASL Industry Council, that is dedicated to the advancement and industry-wide deployment of VERA MODSIM technologies

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