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Nuclear Energy Modeling and Simulation Energy Innovation Hub

Year One Results

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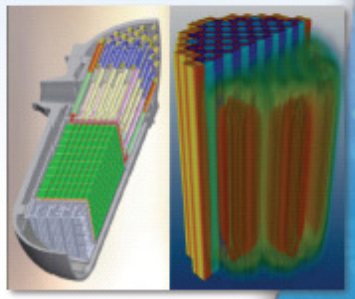
Can an advanced "Virtual Reactor" be developed and applied to proactively address critical performance goals for nuclear power?

1. **Reduce capital and operating costs** per unit energy by:
   - Power uprates
   - Lifetime extension

2. **Reduce nuclear waste** volume generated by enabling higher fuel burnups

3. **Assure nuclear safety** by enabling high-fidelity predictive capability for component and system performance from beginning of life through failure



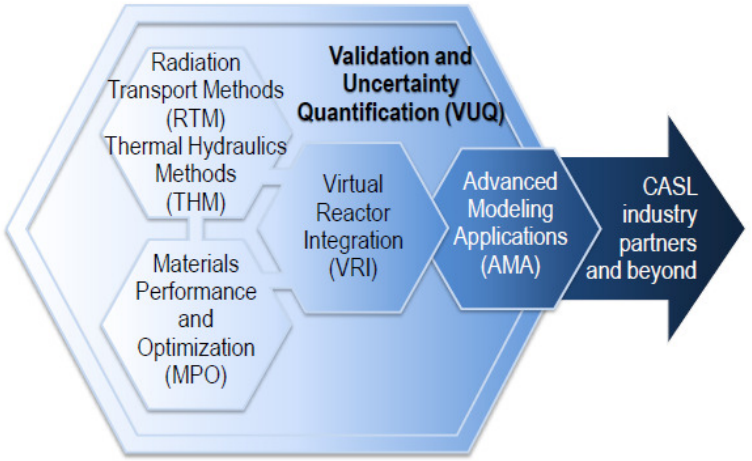
Each reactor performance improvement goal brings benefits **and** concerns

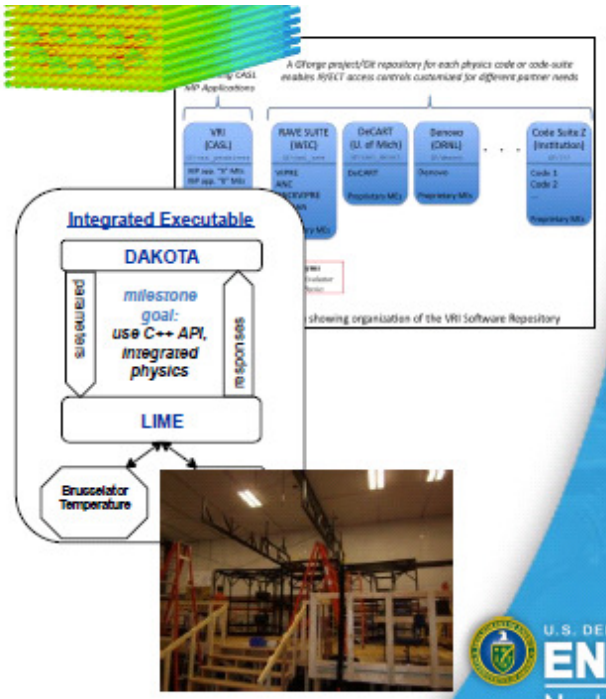
Power uprates	Lifetime extension	Higher burnup
• 5–7 GWe delivered at ~20% of new reactor cost • Advances in M&S needed to enable further uprates (up to 20 GWe) • **Key concerns:** – Damage to structures, systems, and components (SSC) – Fuel and steam generator integrity – Violation of safety limits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

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

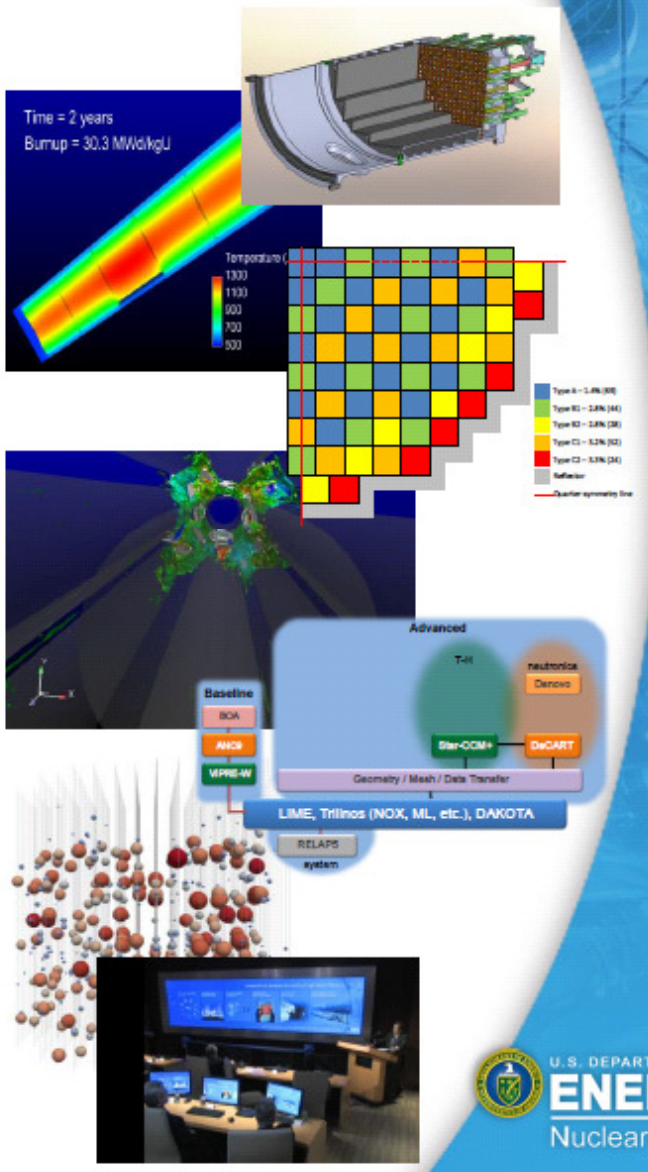




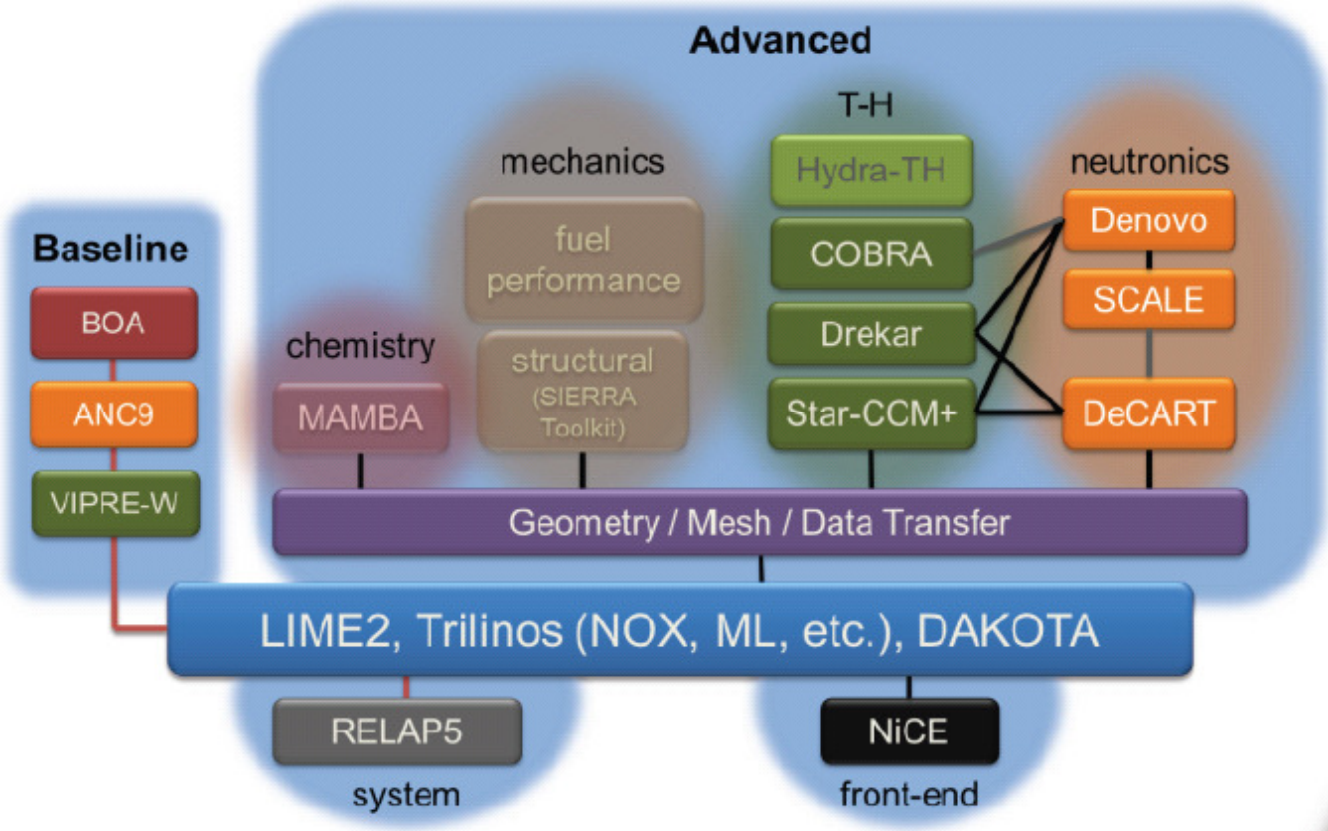
Second Period Plan of Record Highlights

PoR-2: Dec – 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.



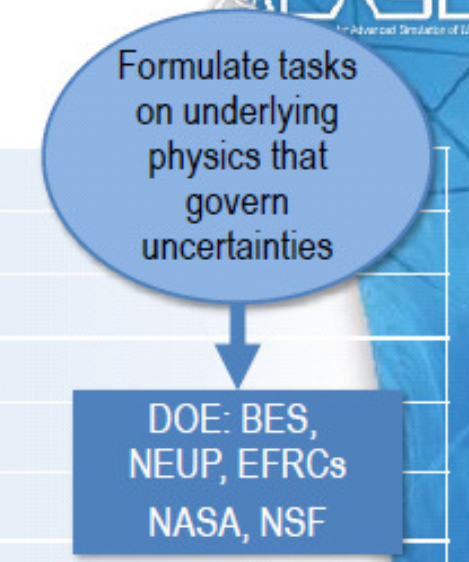
VERA Baseline and Advanced Tools will be used to Address Challenge Problems

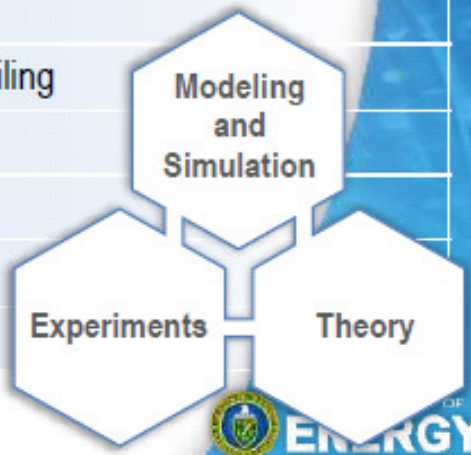


New versions of VERA will be developed and released to support achieving future CASL goals

Validation data sources

Plant and in-core diagnostics	TVA	Plant operational data
	EPRI	Fleet-wide fuel reliability and failure data
	Westinghouse	Fuel manufacturing, properties, testing
PIE of used fuels	ORNL	PIE of used fuel cladding
	INL	PIE, crud characterization
	EPRI	Industry database (U.S. & International)
In- and out-of-pile testing of prototypic fuels	ORNL	HFIR
	INL	ATR NSUF, TREAT (transient fuel testing), Halden Reactor (LWRS)
	CASL	Database of past tests
	MIT	Boiling heat transfer
Separate-effect tests	TAMU	Crud deposition, PIV flow imaging in subcooled boiling
	INL	Corrosion (LWR-S)
Integral effect tests	Westinghouse	Fuel assembly mock-ups
	Oregon State	APEX test facility for system dynamics (LWR-S)
	INL	CFD database





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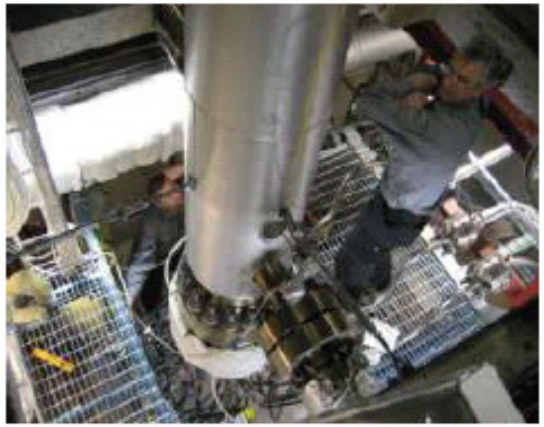
Westinghouse Test Facilities will Support Validation But more data is always needed

VISTA Loop 5x5 testing
pressure drop & vibration

FACTS Loop Single Assembly
Pressure drop and vibration

VIPER Loop Dual Assemblies
Rod Vibration and Wear



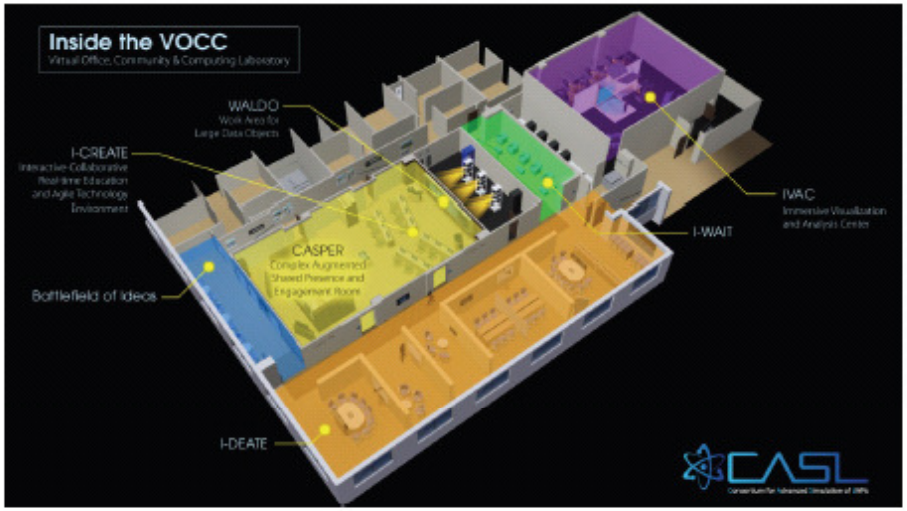
Oden Loop 5x5 and 6x6
DNB and Mixing tests

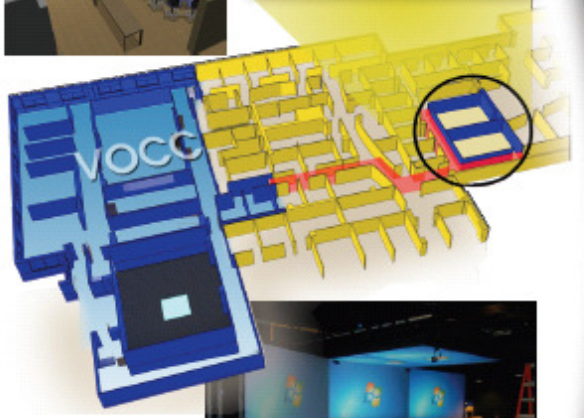
WALT Loop single rod
CRUD and thermal testing

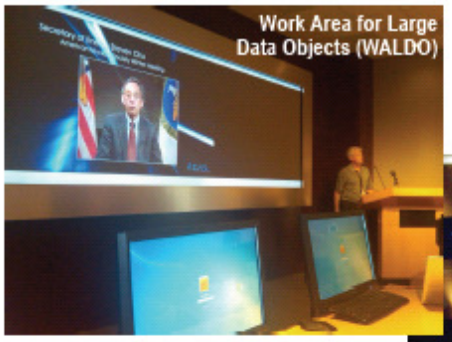
Mechanical Assembly Test
Forced Vibration & Seismic/LOCA

The CASL One-Roof Facility is Operational

Complete with its integrated virtual collaboration & data analysis venues







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DOE Annual Review Findings

- The Hub is doing very well and is adhering to management plans as described in their proposal.
- Therefore, and in keeping with the "light federal touch" philosophy for the Hubs, the Hub management structure meets all the DOE oversight obligations as described in the OMB Circulars and DOE Orders.
- The review team had no major recommendations for changes to the current CASL structure or technical work.

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Review Team Suggestions

- **The Review Team Provided Four Suggestions to the CASL Management**
  - Continued vigilance for financial issues as CASL moves out of startup phase to longer term operations
  - Work to fully integrate the outputs of all six Functional Areas into the CASL products
  - Further define the "test stands" proposed by CASL to deploy early versions of the virtual reactor to industry
  - Spend time defining the path for CASL developed products out of the Hub to allow broader impact of U.S. energy security

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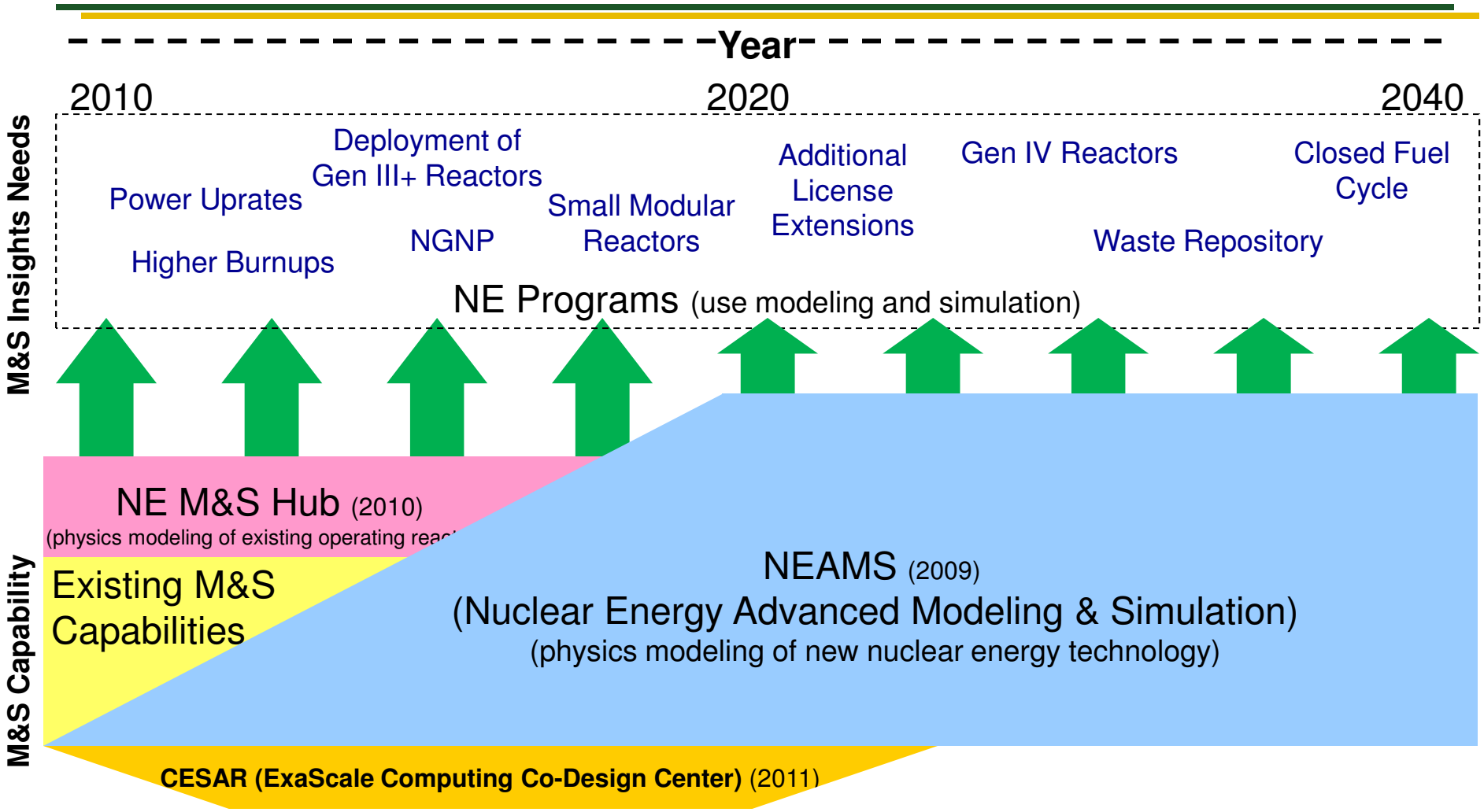
CASL Relationships Have Matured



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Distinctions

	CASL	NEAMS (Nuclear Energy Advanced Modeling and Simulation)	CESAR (Center for ExaScale Simulation of Advanced Reactors)
Funded by	Office of Nuclear Energy	Office of Nuclear Energy	Office of Science
Primary Focus	Deploy ModSim capabilities to impact existing, operating reactors	Support for NE R&D Program	ExaScale computing
Funding Level	$25M/year	$22M/ year	$4M/year
Relationship	**Air gap** – aware of each other, may use products produced by the others, but success not dependent on the others	**Air gap** – aware of each other, may use products produced by the others, but success not dependent on the others	**Air gap** – aware of each other, may use products produced by the others, but success not dependent on the others

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CASL is One Part of DOE's Applied Program Modeling and Simulation

- Hub Workshop Held in January 2011
- Applied Technology Programs User Group Meeting Held in June 2011