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Nuclear Energy Advanced Modeling and Simulation

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Overview for NEAC Review Meeting
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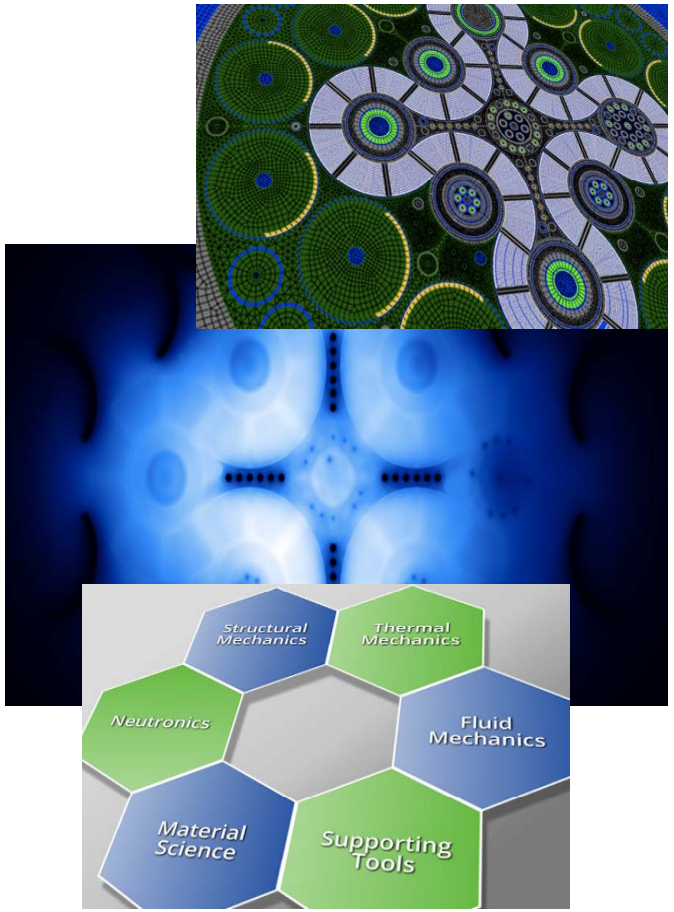
Nuclear Energy Enabling Technologies
Nuclear Energy Advanced Modeling & Simulation (NEAMS)

Why NEAMS? Why pursue advanced modeling and simulation capabilities?

- When integrated with theory and experiment, modeling & simulation **enhances opportunities for new insights into the complex phenomena occurring in the nuclear reactor**
- Advanced modeling & simulation offers the ability to improve the performance and safety of nuclear energy; **NEAMS provides new capabilities & tools** for doing so
- These advancements can be deployed as user-friendly simulation toolsets to both the R&D community and industry – **will impact existing and future reactors**



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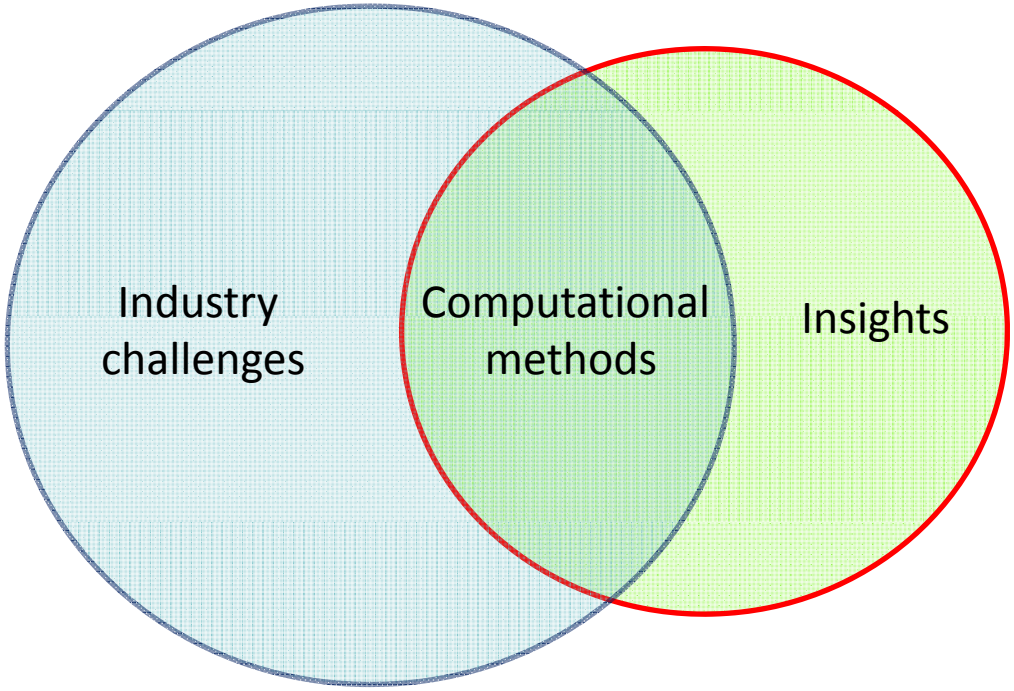
HUBS AND NEAMS – PARTNERSHIP AND COMPLEMENTARITY

- **Partnership**
  - Advance multi-scale, multi-physics computational methods for reactor simulations
  - Demonstrate positive impact of models and simulations on NE technology
- **Complementarity**
  - CASL – focus on solutions to industry defined challenges
  - NEAMS – focus on insights into performance and safety
- **"hubification" – using successful Hub R&D and business models to improve other programs**
  - Medium-long term objectives, plan
  - Independent advisory boards
  - Self-sustained user groups
  - Funding stability

CASL Consortium for Advanced Simulation of LWRs

NEAMS NUCLEAR ENERGY ADVANCED MODELING & SIMULATION PROGRAM



Positive Impact on NE technology

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Modeling and Simulation Budgets

	FY-08	FY-09	FY-10	FY-11	FY -12	FY-13	FY-14
NEAMS	7,792	20,000	26,574	40,495	15,299	17,242	9,536
HUB			22,000	22,000	23,517	24,588	24,300

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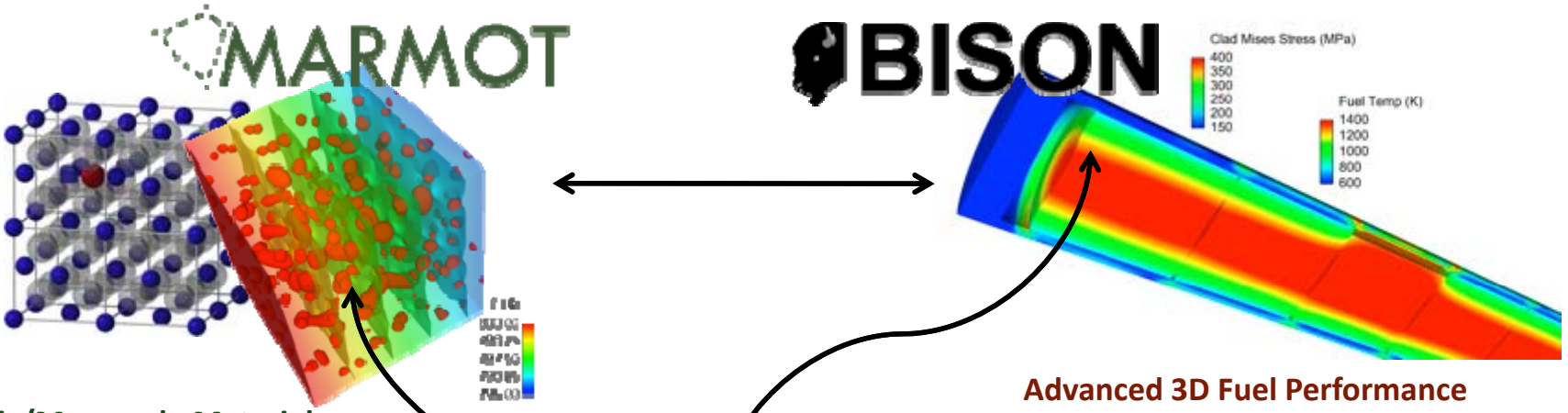
MOOSE-BISON-MARMOT – Core of the Fuels Product Line

- **The MOOSE-BISON-MARMOT codes provide an advanced, multiscale fuel performance capability**



Atomistic/Mesoscale Material Model Development

- Predicts microstructure evolution in fuel
- Used with atomistic methods to develop multiscale materials models

Advanced 3D Fuel Performance Code

- Models LWR, TRISO and metal fuels in 2D and 3D
- Steady and transient reactor operations

MOOSE

Multiphysics Object-Oriented Simulation Environment

- Simulation framework allowing rapid development of FEM-based applications

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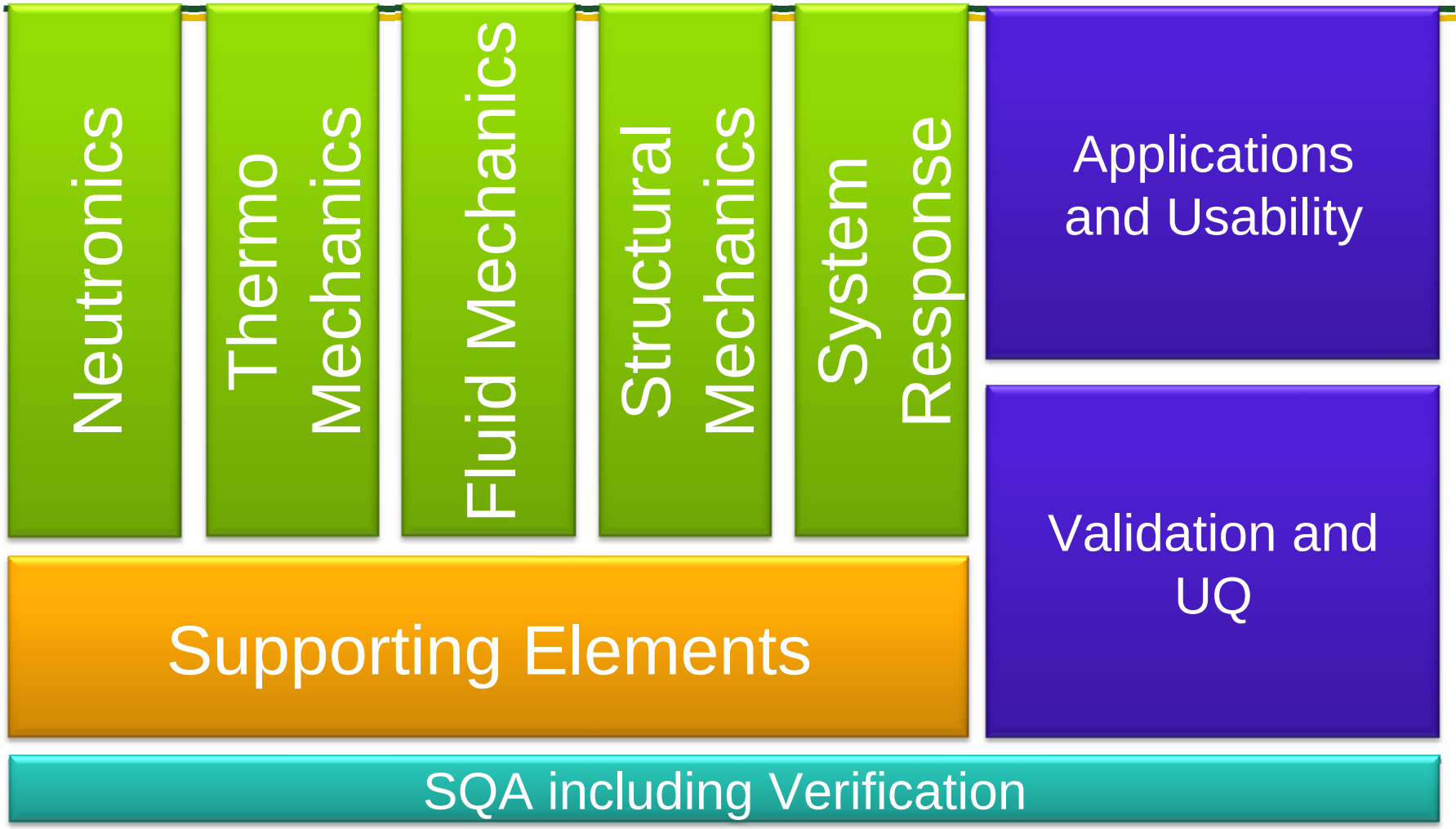
Reactor Product Line Multiphysics/Multiscale Development Roadmap



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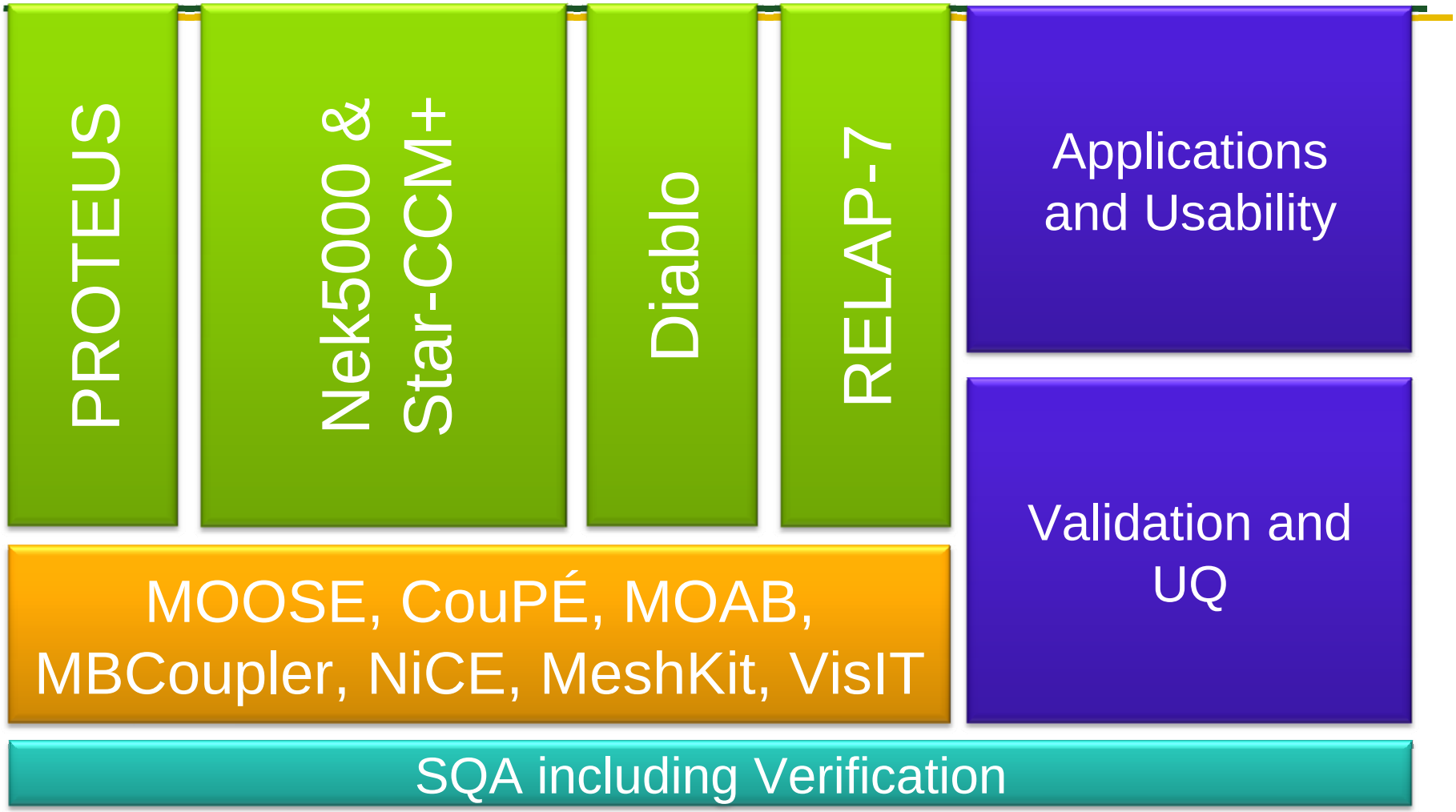
Reactor Product Line Multiphysics/Multiscale Development Roadmap



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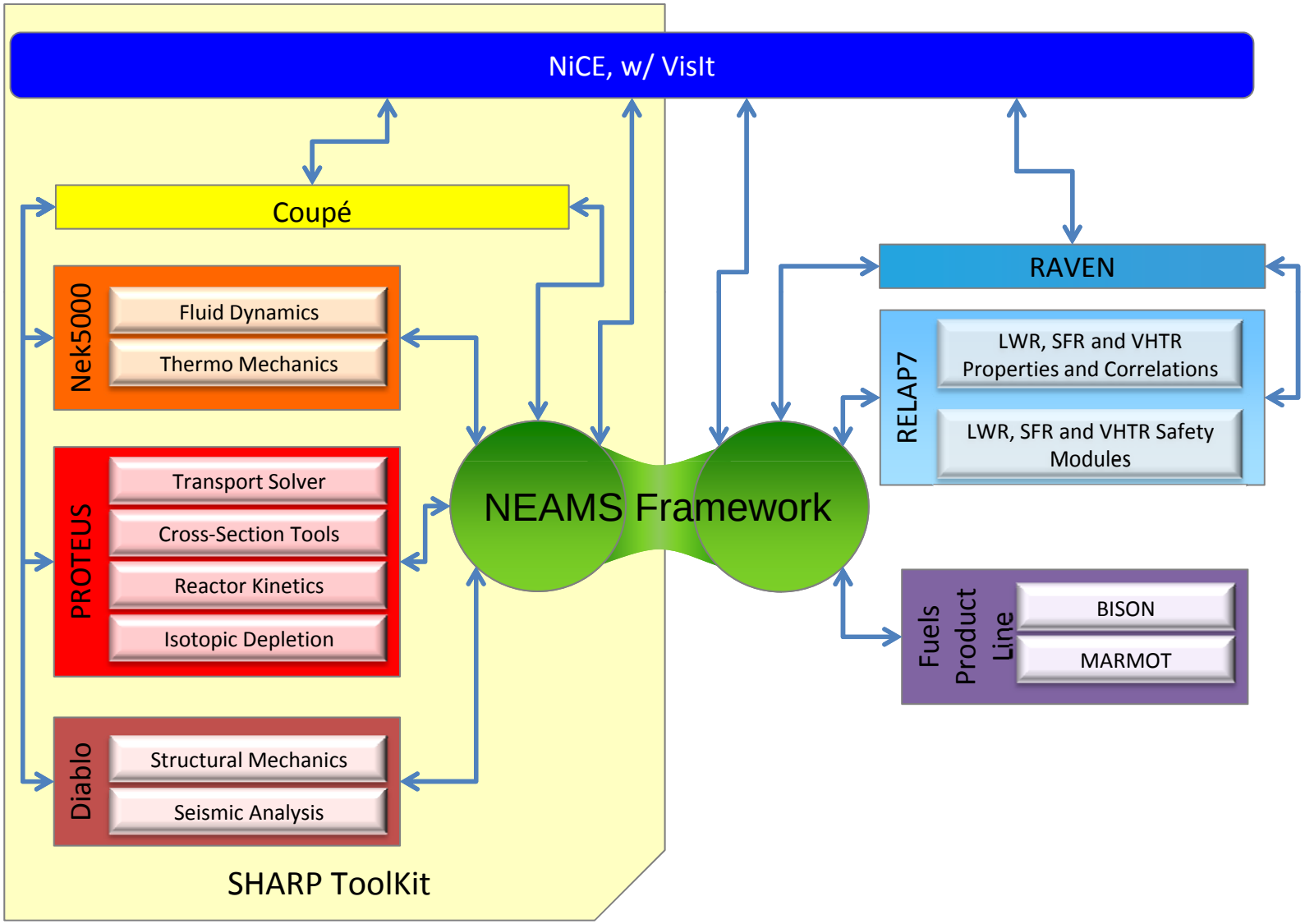
NEAMS Toolkit Component Map



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NEAMS Components and their Users

- RELAP-7 reactor safety
- Diablo structural mechanics
- PROTEUS neutron transport
- MC²-3 ultra fine cross sections
- NiCE user environment
- MOAB data backplane
- Nek5000 computational T/H
- MOOSE BISON MARMOT

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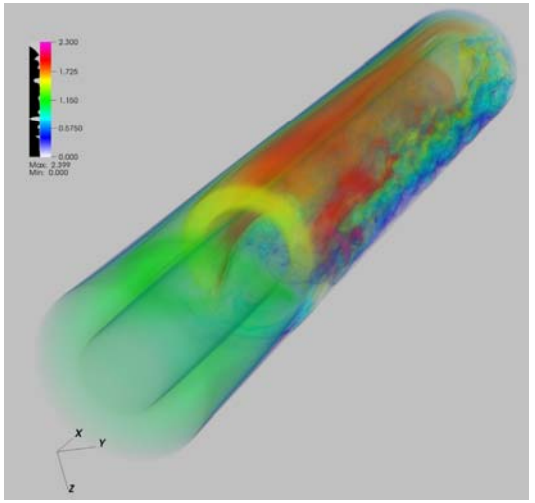
NEAMS Reactor Product Line Validation

- **NEAMS will provide baseline validation for every physics module**
  - Left to end user to execute application specific validation based on their own PIRT, GDCs and FOM
- **Have established validation plans for every physics module**
  - Neutronics – Build on DIFF3-D/Variant validation basis
  - Structural Mechanics – Build on NIKE3D validation basis
  - Thermal Fluids – Custom validation plan
    - New DOE Data – MAX, NSTF, MIR – and NEUP data
    - International Collaborations
      - Russian Federation Collaboration (IBRAE, IPPE)
      - Euratom I-NERI
      - KAERI I-NERI
    - NEAMS Validation Pathways
      - Validation data requirements
      - Uncertainty quantification expectations
  - RELAP-7
    - Custom validation plan based on EPRI collaboration



- **Will validate integrated RPL toolkit using EBR-II SHRT data**

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NEAMS Fuel Product Line Validation

- Issued Bison V&V Assessment Document 1.0
- Completed: 24 LWR cases, 13 TRISO cases
- Many more are needed; major emphasis for FY-14
  - FUMEX-II and -III priority cases
  - NNL collaboration on ENIGMA cases
- Participation in FUel Modeling under Accident Conditions (FUMAC), new IAEA Coordinated Research Project (participated in initial roundtable planning meeting)
- Develop systematic approach to frequently run all cases, compare results and update documentation
- Sensitivity analyses and UQ studies – DAKOTA and RAVEN

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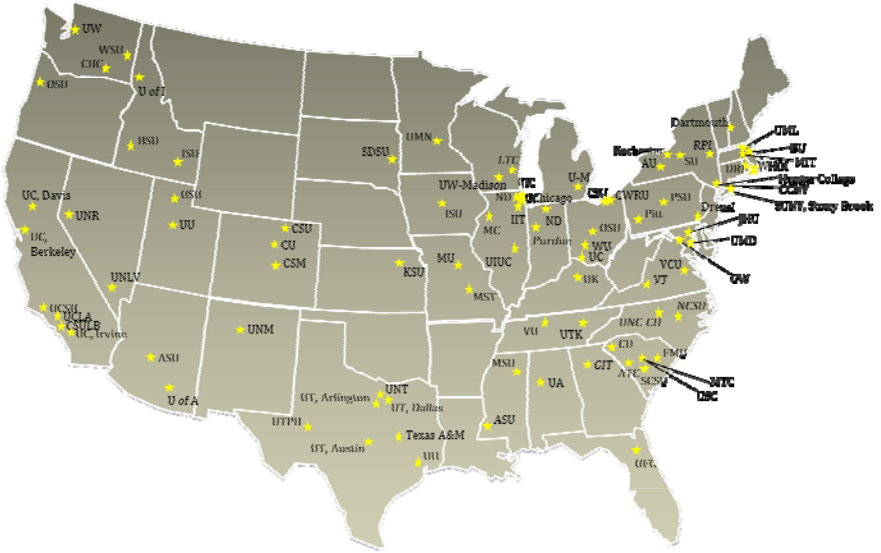
Nuclear Energy University Programs (NEUP) and NEAMS V&V

- **The Nuclear Energy University Programs (NEUP) and the Integrated University Program (IUP) have a well established competitive process for awarding R&D, infrastructure and scholarships and fellowships.**
  - NEAMS V&V included in the last two calls
  - This year 43 pre-proposals received for NEAMS V&V
  - In addition, appendix to the call included information on CASL and NEAMS data needs that might be served in response to calls from NE-5 and NE-7



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Points to Remember

- NEAMS has a robust and growing user community
- NEAMS TOOLKIT is technology neutral with capability for simulations of LWRs, SFRs, and VHTRs
- NEAMS and CASL partner and complement each other, already making a difference and promising much more for the future

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BACKGROUND

- **Next two slides give examples on International Collaboration**
  - With Halden we are doing bison runs to help design a 3d fuel experiment
  - with the National Nuclear Laboratory of the UK, we are sharing our code and they are sharing their expertise and potentially, data.

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National Nuclear Laboratory (UK) Collaboration

- INL is sharing:
  - MOOSE/BISON software
  - Experience with advanced computational modeling
- NNL is sharing:
  - extensive experience with fuel performance modeling
  - Extensive experience with code validation
  - Potentially, a large number of nonproprietary LWR validation cases (>200)
- NNL recently used BISON to study an AP1000 fuel rod. Preliminary comparisons to ENIGMA results were reported as “broadly comparable”. Further comparisons are needed.

NATIONAL NUCLEAR LABORATORY

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Collaboration with Halden Reactor Project

- Several Halden experiments considered in our existing validation suite; raw data are available
- Validation to 3D experiment
  - Invited paper - J. D. Hales, D. M. Perez, R. L. Williamson, S. R. Novascone, B. W. Spencer, and R. C. Martineau, *Validation of the BISON 3D Fuel Performance Code: Temperature Comparisons for Concentrically and Eccentrically Located Fuel Pellets*, Extended Halden Program Group Meeting, Gol, Norway, March 11-14, 2013.
- Jason Hales invited to guest lecture at the OECD-Halden Reactor Project Summer School, August 26-29, 2013
  - Topic - Special Modeling: 3D Models and their Application
- Currently simulating a unique double-encapsulated fuel thermal conductivity experiment for installation in 2014; aiding in experimental design