Nuclear Energy Advanced Modeling and Simulation

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Overview for NEAC Review Meeting
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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.
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

Positive Impact on NE technology
# Modeling and Simulation Budgets

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<th>FY-08</th>
<th>FY-09</th>
<th>FY-10</th>
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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

- **Multiphysics Object-Oriented Simulation Environment**
  - Simulation framework allowing rapid development of FEM-based applications
Reactor Product Line Multiphysics/Multiscale Development Roadmap

Neutronics
Thermo Mechanics
Fluid Mechanics
Structural Mechanics
System Response

Applications and Usability
Validation and UQ
Supporting Elements

SQA including Verification
Reactor Product Line
Multiphysics/Multiscale Development Roadmap

PROTEUS
Nek5000 & Star-CCM+
Diablo
RELAP-7

Applications and Usability
Validation and UQ

MOOSE, CouPÉ, MOAB, MBCoupler, NiCE, MeshKit, VisIT

SQA including Verification
NEAMS Toolkit Component Map

NiCE, w/ VisIt

Coupé

Nek5000
- Fluid Dynamics
- Thermo Mechanics

PROTEUS
- Transport Solver
- Cross-Section Tools
- Reactor Kinetics
- Isotopic Depletion

Diablo
- Structural Mechanics
- Seismic Analysis

NEAMS Framework

RAVEN
- LWR, SFR and VHTR Properties and Correlations
- LWR, SFR and VHTR Safety Modules

RELAP7

Fuels Product Line
- BISON
- MARMOT

SHARP ToolKit
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
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**
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
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
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
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.
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.
Collaboration with Halden Reactor Project

- Several Halden experiments considered in our existing validation suite; raw data are available

- Validation to 3D experiment

- 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