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Advanced Mod-Sim within the DOE-NE NEAMS Program

NEAMS NUCLEAR ENERGY ADVANCED MODELING & SIMULATION PROGRAM

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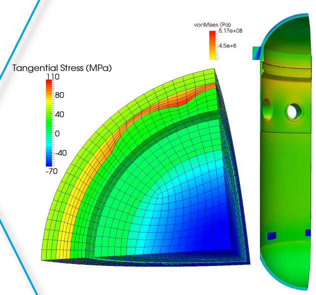
DOE-NE NEAMS Program Overview

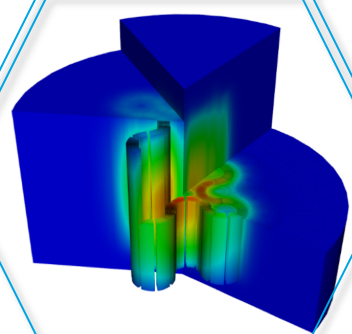
"Advanced Mod-Sim" definition

The NEAMS program is a multilab team effort that aims to develop and deploy predictive computer methods for the analysis and design of advanced nuclear reactors.

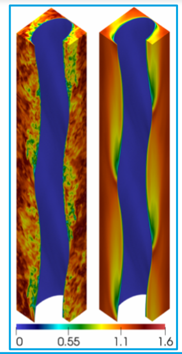
NEAMS core competencies:



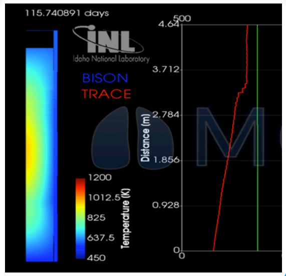
Multiscale fuel performance and structural materials degradation modeling: BISON, GRIZZLY



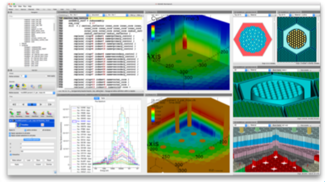
Reactor Physics: PROTEUS, MAMMOTH



Multiscale thermal fluids: SAM, PRONGHORN, Sockeye, Nek5000



Multiphysics: MOOSE

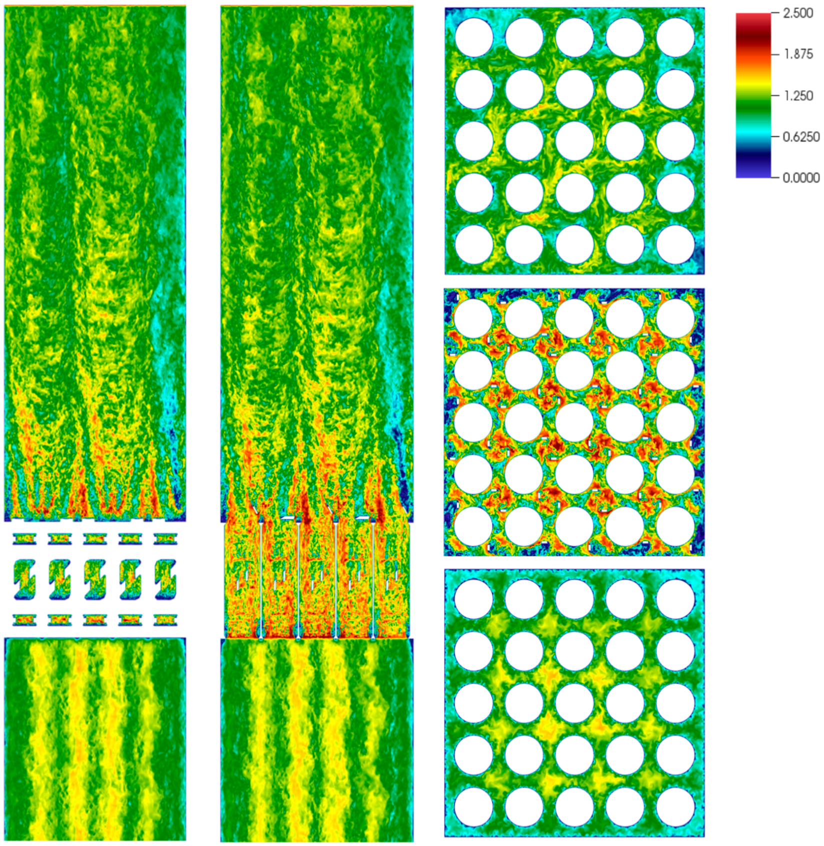


Workflow Management: Workbench

Hallmarks of **advanced mod-sim** are *"multiscale"* and *"multiphysics"* – with the specific goal to be *predictive* through mechanistic insight. Especially important for data poor regimes.

Preferred use of advanced mod-sim is in concert with experiments to solve challenging problems.

Reduced cost example 1:
LWR spacer grids



Nek5000 (LES) simulation of the flow in a 5x5 spacer grid experiment (TAMU). Instantaneous Velocity magnitude [m/s].

CFD of spacer grid designs can be used to inform design choices and reduce the number of experiments.

- Single phase CFD can provide reasonably accurate results (validation against PIV and LDV data).
- Recent NEA Benchmark (MatiS-H). NEAMS codes ranked very well (top in turbulence predictions)

Vendors use CFD to down-select grid designs before testing (including CHF).

- CFD analysis for two-phase pressure drop and CHF has still limitations.

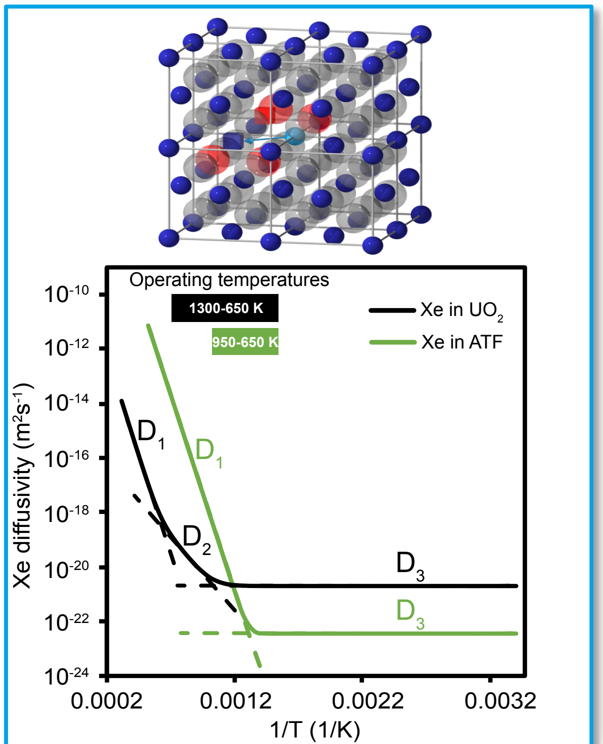
Relevant experiments range from \$100Ks to >\$1M

Reduced cost example 2:
Predictions of ATF performance

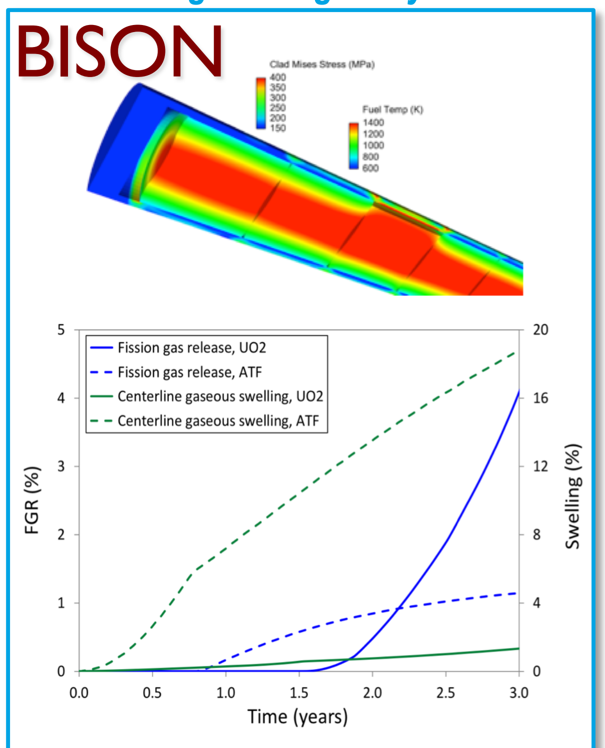
Modeling retention/release of fission gases is important for assessing fuel performance. For certain Accident Tolerant Fuel (ATF) concepts, ***no experimental information available for gas diffusivity or resolution rate.***

Given lack of data, employ atomic and mesoscale simulations to derive the diffusion and resolution rates of gas atoms in an ATF fuel candidate.

Mechanistic modeling



Engineering analysis



Diffusion rates are predicted to be higher(/lower) than UO_2 at high T(/low T) and the resolution rate lower (see left frame).

Mechanistic models pragmatically implemented in Bison fuel performance code to simulate gas release and swelling during a representative ATF experimental irradiation (see right frame).

Prediction enables more sophisticated experiment design and analysis.

Application to Advanced Reactors

- Deployment of the current LWR fleet has benefited from large experimental programs and many years of operational experience. Similar foundation less existent for advanced (non-LWR) reactors.
- **If advanced reactors are going to be *efficiently* deployed, it is critical that advanced modeling and simulation play a significant role.**
- In addition to lack of experimental data for advanced reactors, significantly different interdependence of neutronics, fuel response, and thermo-structural-fluids phenomena also pose unique multiphysics mod-sim challenges.
- **Therefore, in absence of extensive experimental data and given physics interdependence, more mechanistic/predictive and multiphysics advanced M&S capabilities are essential for these concepts.**
- Ideally, “advanced” mod-sim should also be “flexible” mod -sim, where a similar set of tools can be used for initial "low res" scoping/reactor design, and then the same framework applied to optimization using "high res"/mechanistic adv mod sim – and integrated within innovative experimental testing program.

NEAMS program is committed to working with NRC and vendors to assist the accelerated deployment of advanced reactors.