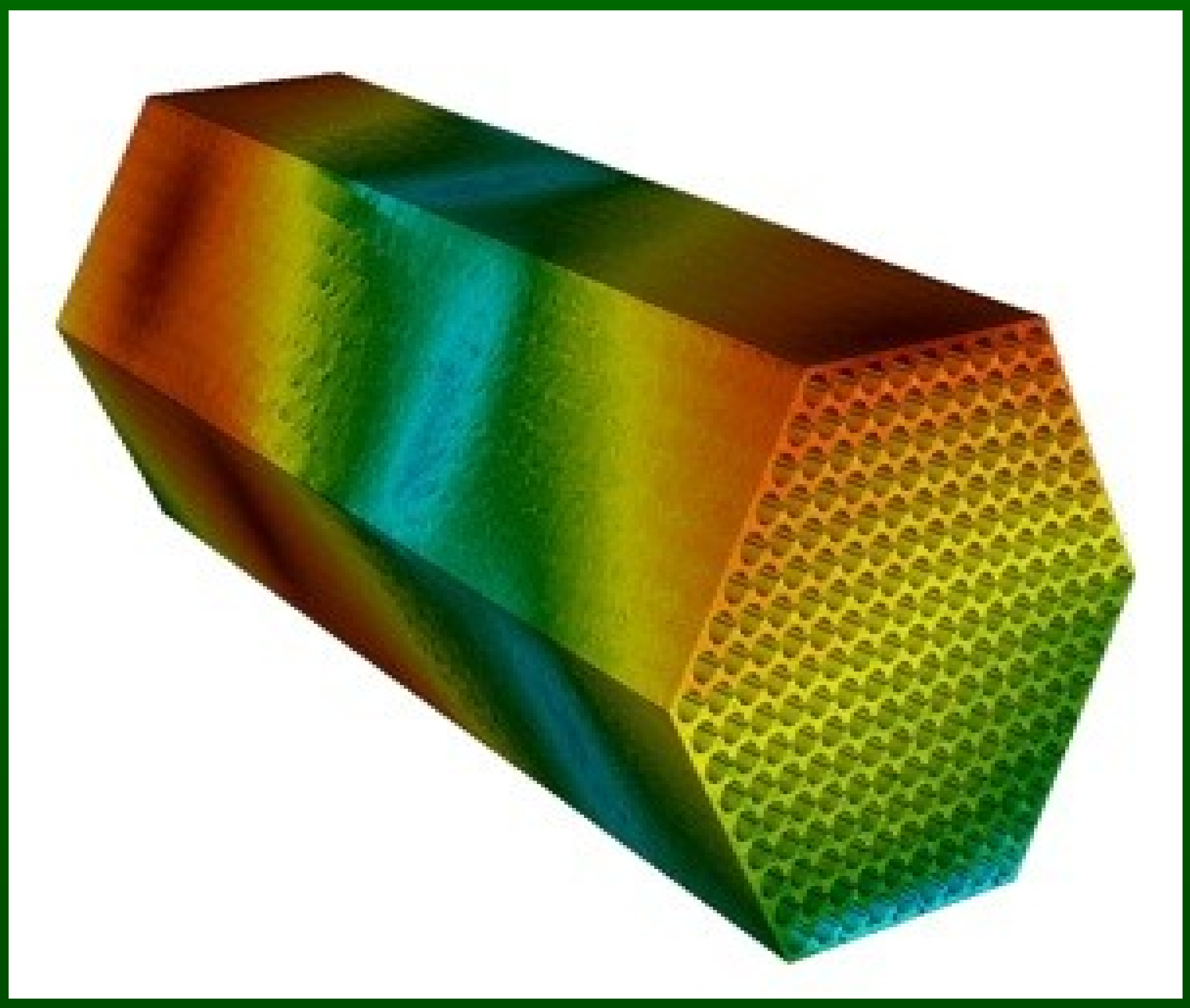
CESAR

Center for Exascale Modeling of Advanced Reactors

Next-Generation Nuclear Reactor Modeling



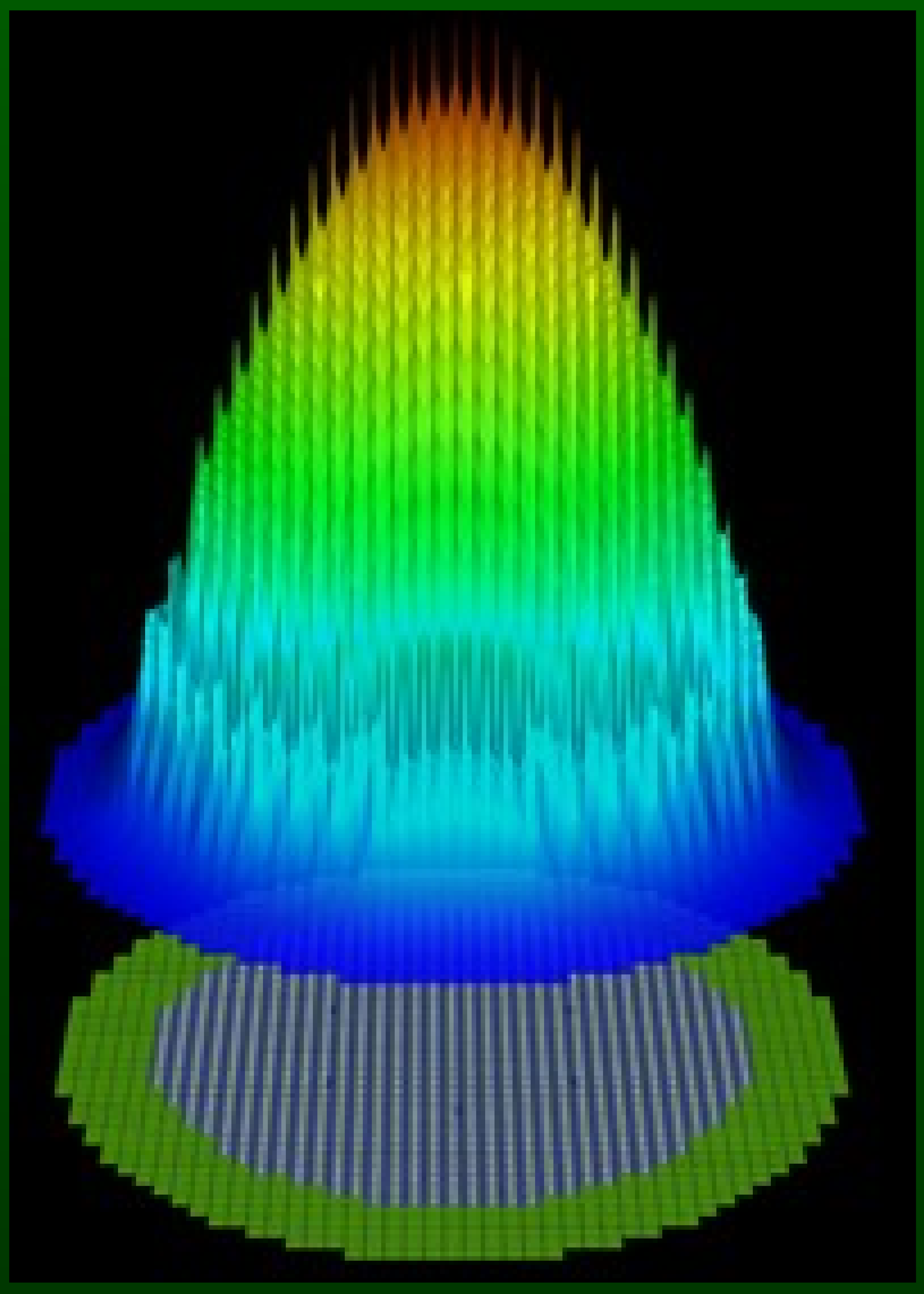
Coolant heat flow in 217-pin Fuel bundle, color coded for velocity

Background

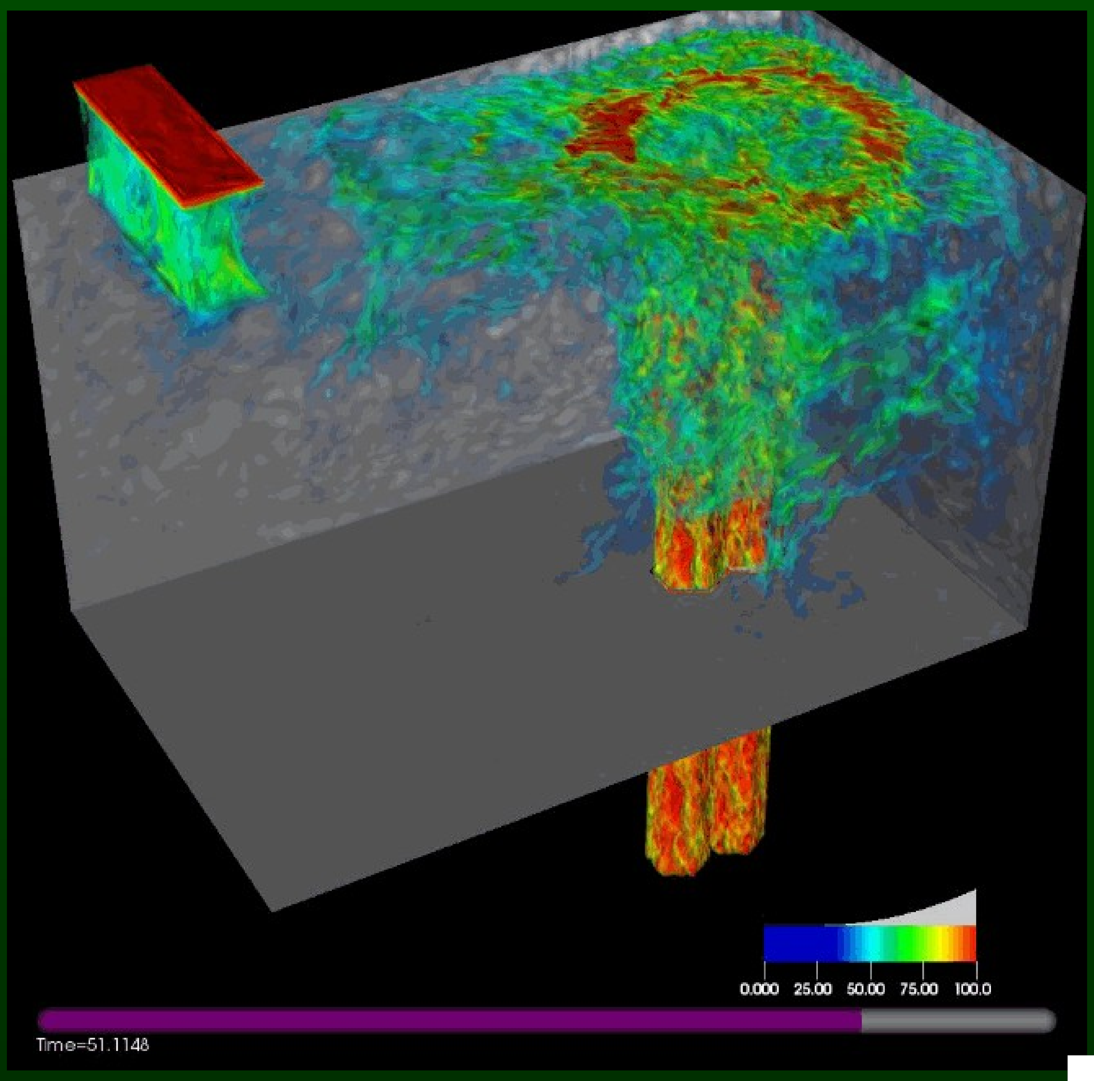
- The need for energy technologies that both avoid further contributions to global warming and serve as reliable energy sources has led to renewed interest in nuclear power.
- But current codes – though highly tuned and calibrated for commercial light-water reactors – lack the physics fidelity to seamlessly carry over to new reactor classes with significantly different design characteristics.
- CESAR (Center for Exascale Simulation of Advanced Reactors) seeks to address this problem.

The Team

- Labs: ANL, LLNL, LANL, PNNL
- Universities: Texas A&M, Rice
- Computer vendor: IBM
- Industry software: Studsvik, Inc.
- Reactor vendors: AREVA, Terrapower, General atomics, Nuscale



Neutron Transport in UNIC



Visualizing Coolant Flow

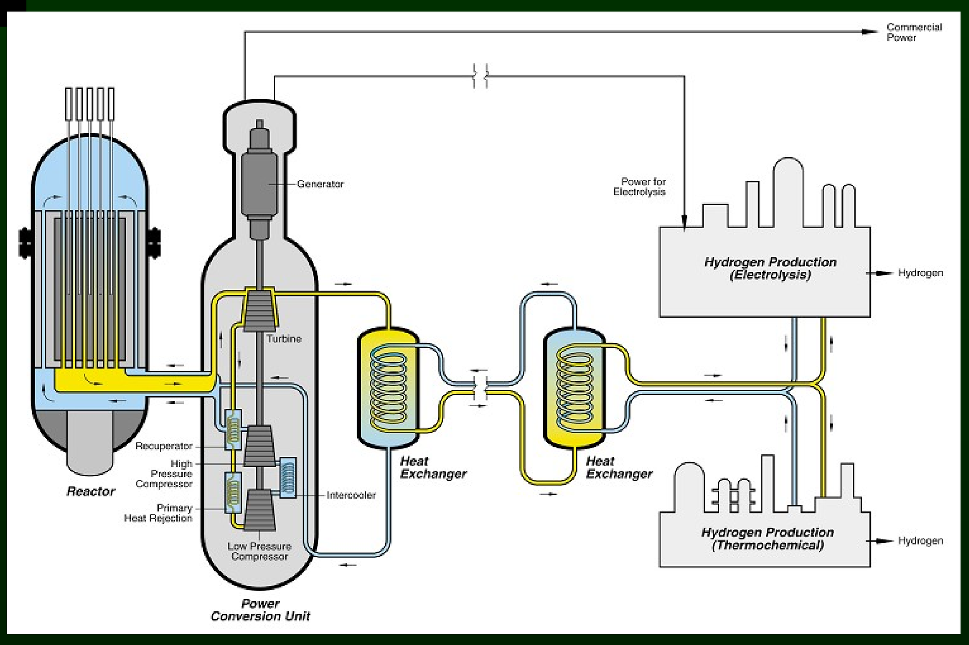
Approach

- **Start with existing petascale codes for thermo-hydraulics (NEK) , neutronics (UNIC), structures (DIABLO)**
- **Couple codes and evolve into TRIDENT, an exascale code capable of high-fidelity modeling of real states of advanced reactors**
- **Be guided by advanced reactor vendors, solving problems they pose**
- **Co-design with computer vendors and system software developers**

Benefits

Simulating a complete nuclear power system in fine detail will fundamentally change the paradigm of how nuclear reactors are built, tested and operated.

- Every step of the nuclear regulatory timeline can be compressed by guiding expensive experiment efforts.
- New designs can be rapidly prototyped, accident scenarios can be studied in detail, material properties can be discovered, and design margins can be dramatically narrowed.
- Scientists can analyze problems for a wide range of novel reactor systems.

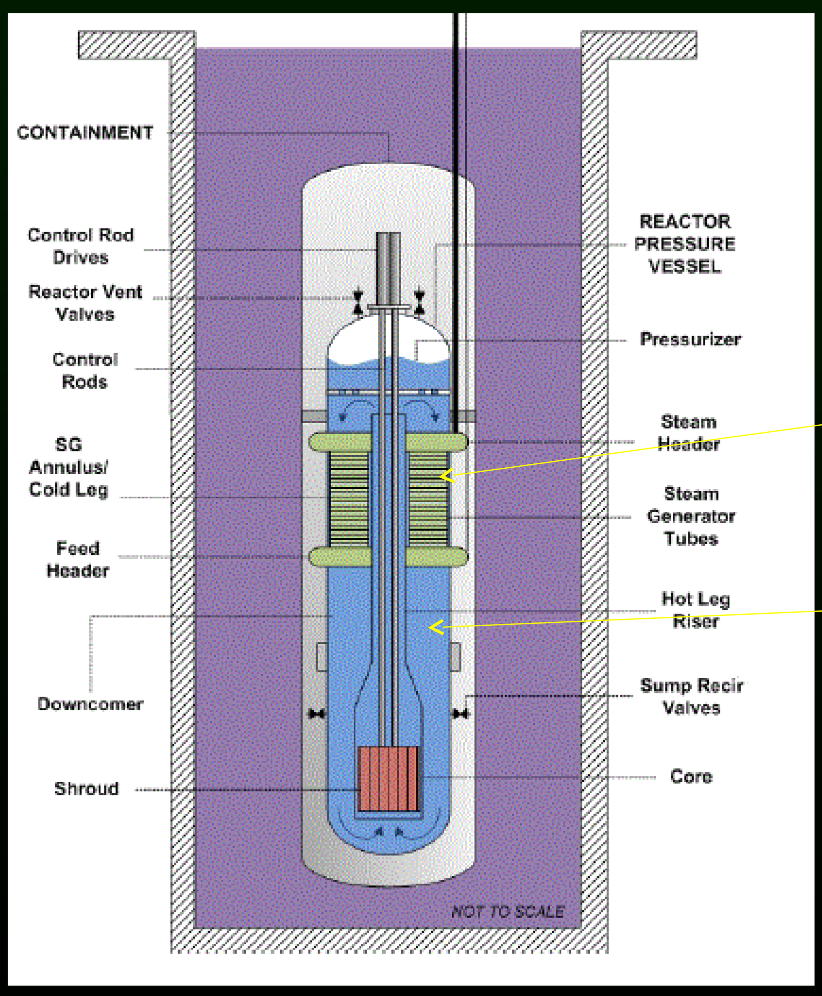


Very High Temperature Gas-Cooled Reactor (VHTR)

Computer Science in CESAR

- **Performance Modeling:** Aligning algorithms with future hardware
- **Programming models:** E.g. integrating MPI with multithreaded programming
- **Scalable I/O, data analysis, and visualization:** Data reduction, volume preserving mesh transformations, raped extraction of key features from massive datasets
- **Uncertainty quantification:** Much more detailed treatment of data/method uncertainties for breed/burn concepts

Advanced Concept Reactors



Nuscale Small

Modular Reactor

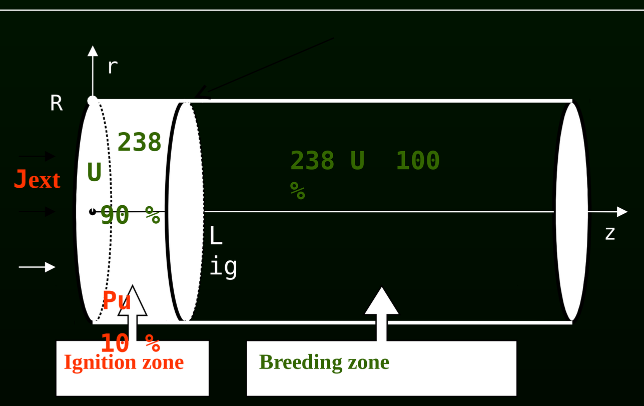
Pressure drop across helical Steam generators?

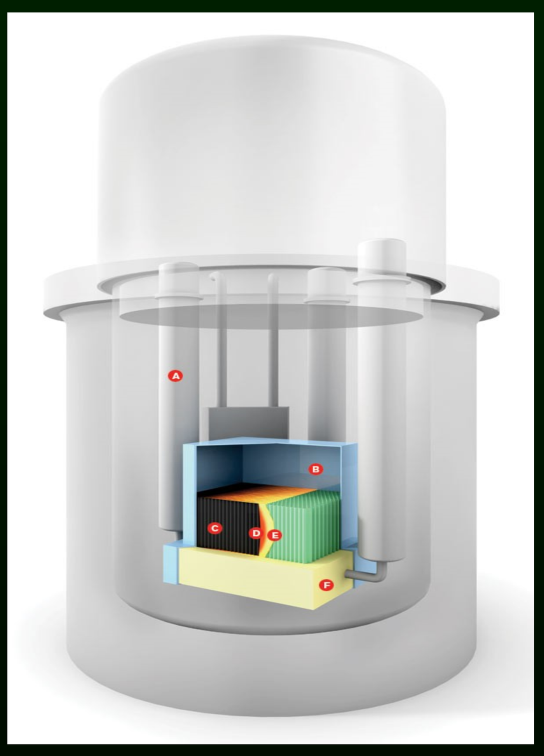
Peak temperatures reached during incipient free convection at startup?

Breed-burn concepts

Terrapower's Traveling Wave Reactor

- New regime for neutronics codes – power profiles change with time
- Highly detailed neutronics necessary with careful treatment of uncertainties in breeding zone





A. Coolant Pumps
B. Expansion area for fission gases
C. Fuel – depleted uranium inside hexagonal pillars
D. Fission wave (red)
E. Breeding wave (yellow)
F. Liquid sodium coolant