Neutronics for VHTR Technology Development, Deep Burn, AHTR Systems

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From Yesterday (Petti)

- The VHTR is a helium-cooled, graphite moderated reactor with a core outlet temperature between 750 and 850°C with a long-term goal of achieving an outlet temperature of 950°C.
- The reactor is well suited for the co-generation of process heat and electricity and for the production of hydrogen from water for industrial applications in the chemical and petrochemical sectors.

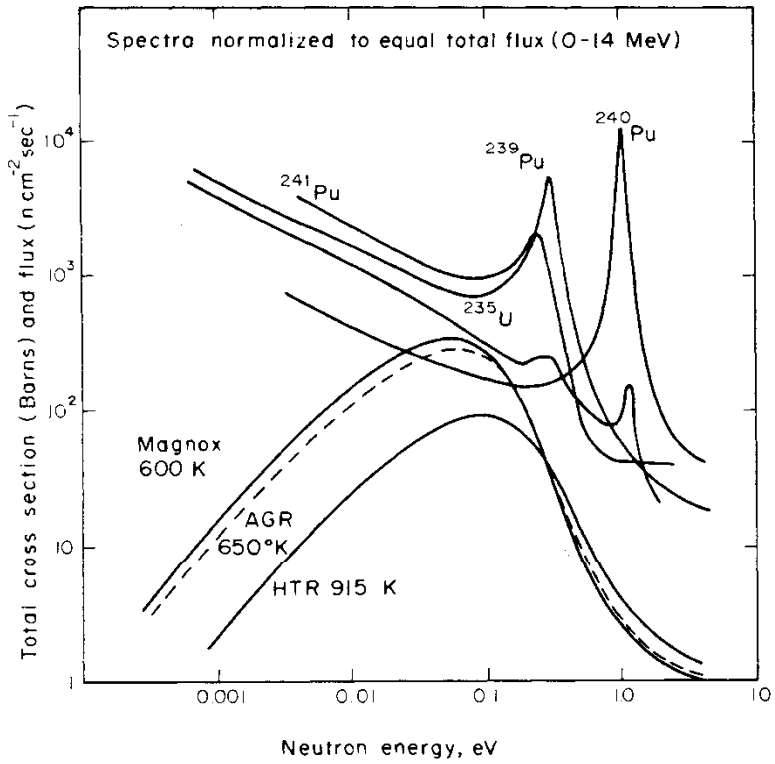
- Large R&D program planned to qualify fuel, graphite, high temperature materials and methods for NGNP which also supports many of the longer range high temperature reactor concepts.
- Smaller programs in Deep Burn, AHTR, SFR and SMR also have needs (often complementary)

Reactor Analysis Methods

- **In the area of *core simulation*, proposals are sought that address:**
  - Modeling and simulation of core phenomena such as:
    - Reactivity transient effects on fuel considering coupled fuel performance, neutronic, and thermal fluid simulation and simulation of transient fuel performance experiments
    - Mechanical-neutronic-thermal fluid interactions such as fully coupled simulations of graphite dimensional changes under irradiation with thermal and neutronic feedback
    - Fuel Management techniques that enable fuel cycle optimization in prismatic HTRs for enhanced performance and deep burn reduction of spent fuel heavy metal inventory
    - Core temperature and flux measurement/reconstruction techniques for VHTR/HTGRs
    - Nuclear data including cross section measurement and validation in high burnup fuel (experimental)

Neutronics Support

- Nuclear Data – uncertainties in cross sections at high burnup, scattering laws in graphite and heavy metals
- Rapid yet accurate lattice calculations to support online cross section generation for depletion and transient analysis
- Fast but accurate (nodal) depletion method support fuel management and fuel cycle optimization
- Propagation of neutronic and other uncertainties through to safety parameters i coupled core calculations



Capabilities and Simulations Required to Support Experiments and Licensing

- Design of tests using scaling laws
- Single physics tests and benchmarks (CFD, neutronics)
- Simulation of slow system transients (Load-follow) and lower dimension ATWS (turbine trips)
- BOL, EOL power profiles and decay trajectories

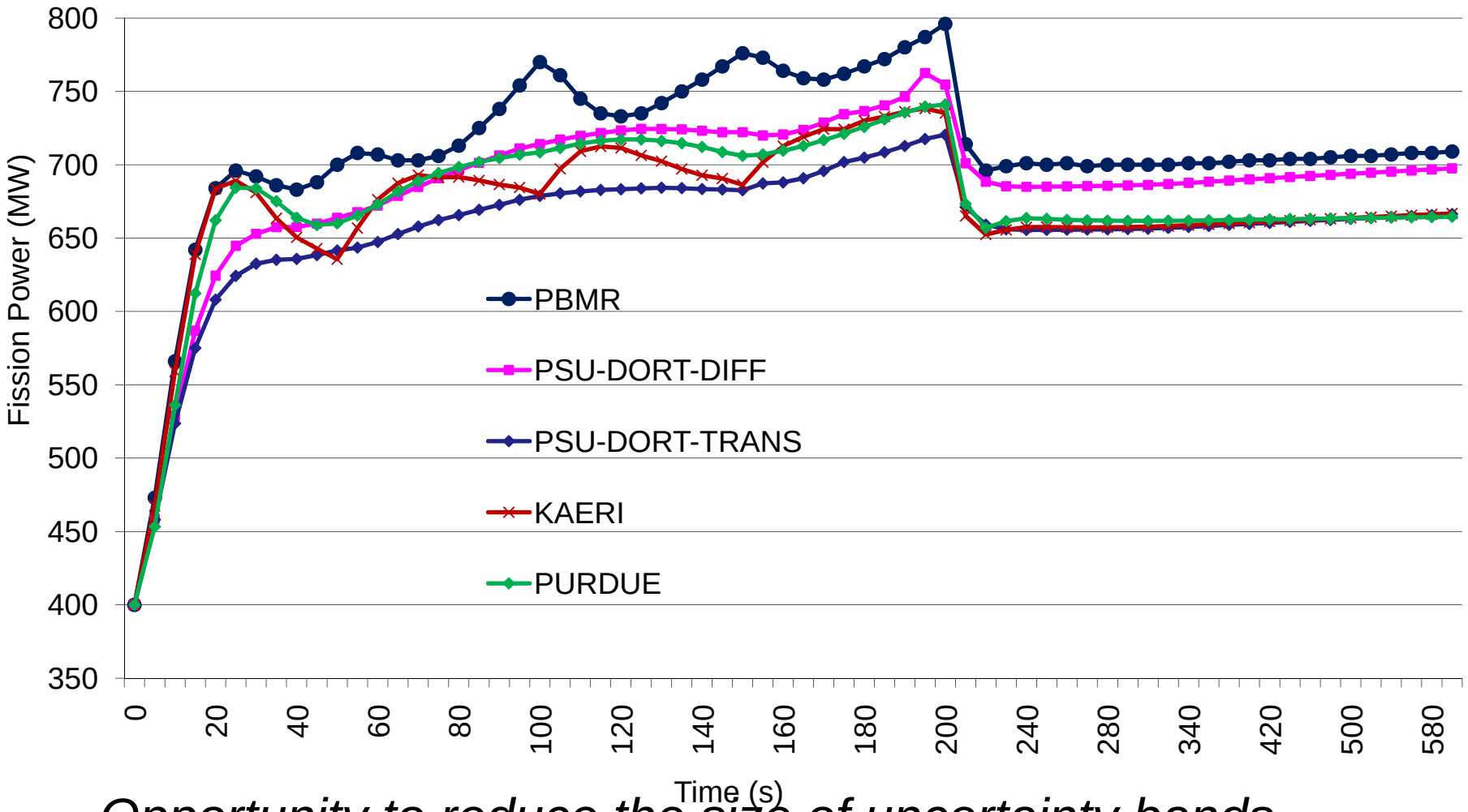
Single physics modules run separately or coupled in a plant simulator

We've got this covered.

- **Pipe breaks and blowdown, re-criticality**
- **Power and temperature profiles at pebble bed boundary**
- **Air ingress and graphite oxidation**
- **Water ingress**
- **Graphite deformation and LOFC-induced annealing**

High fidelity, high resolution transient multiphysics analyses

The Need for High Fidelity Confirmatory Analysis



Opportunity to reduce the size of uncertainty bands

Summary of Needs to Support NGNP/VHTR

- ***DON'T propose to model the VHTR with your nth –order transport code. It's already being done and doesn't buy you much (over nodal diffusion)***
- ***DO look at uncertainties in nuclear data and basic nuclear physics employed in simulation codes – propagate and assess effects on safety parameters***
- ***Look at speeding up cross section generation (lattice calcs) to support high fidelity transients and sensitivity studies***
- ***Link your methods with the other physics (T/H, thermo-mechanical) and justify it by showing the reduction in uncertainties in safety parameters***