Nuclear Data, Validation Methods, and Integral Needs

Dr. Bradley T. Rearden
Director of Engineering, Xe-Mobile

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Novel Applications of Microreactors

**Defense & forward bases**
As the US Military prepares for “near-peer” adversaries of the future, highly portable power with a high energy density will be a game-changing technology.

**Highly Portable Power**

**Disaster Relief**
The ability to transport flexible electricity solutions that do not require fueling for months or years provides critical infrastructure to get railroads, water purification facilities, and hospitals powered again – within one week.

**Be powered again – within one week**

**Remote Communities**
Arid, Island and Alaskan/Canadian communities often use government-subsidized petroleum fuel deliveries to maintain their power. If their deliveries are disrupted, the impact can be significant.

**Maintain Power**
Space Nuclear Applications

Fission Surface Power System

Nuclear Electric Propulsion

Nuclear Thermal Propulsion

Images: NASA
Executive Actions and Appropriations

- **Promoting Small Modular Reactors for National Defense and Space Exploration** (Executive Order 13972, January 2021)
  - Demonstration of Commercial Reactors to Enhance Energy Flexibility at a Defense Installation
  - Defense Capabilities
  - Space Exploration
  - Domestic Fuel Supply
  - Common Technology Roadmap

- **Launch of Spacecraft Containing Space Nuclear Systems** (National Security Presidential Memorandum-20, August 2017)
  - Safety prescribed in terms of Total Effective Dose to population

- **DOE-NE** Advanced Reactor Demonstration Program ~$200M/yr, operational reactors 2027-2030s
- **DOD** Mobile Microreactor $70M FY21, demonstration unit in 2024
- **DARPA/DRACO** – ??
- **NASA NTP** ~$100M FY21
- **NASA FSP** – Launch ready 10 kWe, 10-year lifetime, 3500 kg power plant by 2026
- **NASA NEP** – Studies resuming in 2021
Nuclear data provide a foundation for performance and safety analysis.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Tool/Model</th>
<th>Analysis Type</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core neutronics</td>
<td>SCALE/KENO/ORIGEN</td>
<td>Steady-state Monte Carlo neutron transport and transmutation</td>
<td>Power Profiles, Core life, Burnable poison design, Temperature and control element reactivity</td>
</tr>
<tr>
<td>Cross section generation</td>
<td>Serpent</td>
<td>Steady-state Monte Carlo neutron transport</td>
<td>Generated few-group cross sections for AGREE-Xe and verified reactivity results from SCALE and MCNP</td>
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<tr>
<td>Photon/Neutron Transport</td>
<td>MCNP</td>
<td>Steady-state Monte Carlo neutron and photon transport</td>
<td>Ex-core heating rates</td>
</tr>
<tr>
<td>Reactor Thermo-fluid Analysis</td>
<td>StarCCM+</td>
<td>High fidelity heat conduction and thermo-fluid dynamic behavior</td>
<td>Spatially resolved temperatures and coolant flow rates</td>
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<tr>
<td>Coupled neutronic-thermal fluid analysis</td>
<td>AGREE-Xe</td>
<td>Steady-state and time-dependent neutron diffusion/heat conduction/ subchannel fluid behavior</td>
<td>Peak and average temperatures of structures during transient scenarios</td>
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<tr>
<td>Plant Dynamics</td>
<td>Flownex</td>
<td>Steady-state and time-dependent analysis of plant-wide behavior</td>
<td>Plant/Reactor response to perturbations and fault conditions. Startup, shutdown, and critical power maneuvers</td>
</tr>
<tr>
<td>Shielding</td>
<td>SCALE/MAVRIC/ORIGEN</td>
<td>Steady-state neutron and gamma transport, activation, decay</td>
<td>Ex-vessel dose and activation rates</td>
</tr>
<tr>
<td>Structural Dynamics</td>
<td>NASTRAN</td>
<td>Dynamic Finite Element Analysis</td>
<td>Static-equivalent accelerations to be used for stress analysis, Load Isolation System evaluation</td>
</tr>
<tr>
<td>Mechanical and thermal stress</td>
<td>Abaqus</td>
<td>Steady-state Finite Element Analysis</td>
<td>FEA-calculated stresses, to be compared against material allowables to determine if the parts meet design requirements</td>
</tr>
<tr>
<td>Instrumentation &amp; Controls</td>
<td>PSCAD</td>
<td>Simulation of electric power conversion</td>
<td>Power Balance of EPCS with a notional load bank at steady state response of system to various load transients, including abnormal loads and fault conditions</td>
</tr>
<tr>
<td>Hazards Analysis (Fire, chemical, mechanical, electrical, etc.)</td>
<td>Abaqus</td>
<td>Identification of hazards associated with assembly, transport, and disassembly operations</td>
<td>Design requirements for hazard mitigation systems (e.g., Fire Detection and Suppression)</td>
</tr>
</tbody>
</table>
Concerns with changes in ENDF/V-III.0 without consideration for reactor applications
Validated Nuclear Data Needs

• **Small and precise reactors require optimized power and lifetime predictions**
  - Power distribution
  - Reactivity control and shutdown margin
  - Fission product inventories

• **Close proximity to public and need for low mass solutions require precise source term and shielding data**
  - Prompt neutrons and gammas from fission
  - Gamma emissions from fission product decay
  - Material activation and decay
  - Neutron and gamma attenuation

• **Thermal scattering law data**
  - Advanced moderators/reflectors are needed for small HA-LEU cores
  - YHₓ is of interest for lower temperature applications
  - NTP systems approach 3000 K for fuel and structural materials with H₂ as internal propellant

• **Irradiation damage assessment is needed for wide range of materials**
  - Damage cross sections should be included in ENDF libraries