



Technology-Based Licensing MSR Evaluation Models for Safety Analyses

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Scope, motivation, and modeling mission

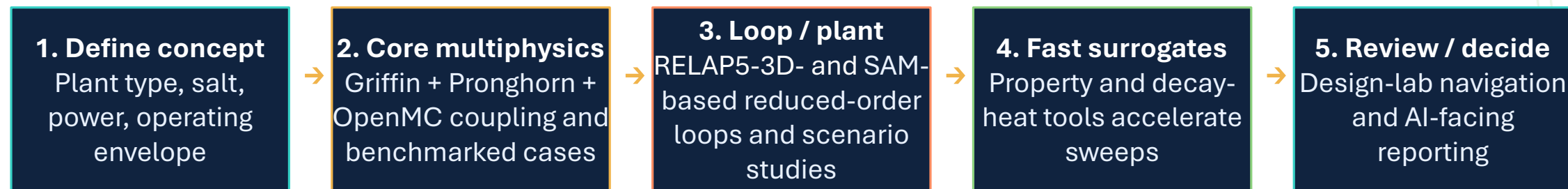
1. Rapid evaluation of molten salt reactor concepts across core, loop, and plant scales.
2. Enables consensus on safety, security, and safeguards for molten salt reactors in general.
3. Bridges benchmark models, design screening tools, and transient studies into one evaluation workflow.
4. Needed to better define experimental bounds and needs.
5. Supports both mechanistic physics models and faster surrogate layers for iteration and communication.

Key Issues

- Large variety of MSR designs (fluoride vs chloride, moderated vs fast, power production, breeder, burner, ...)
- MSR concept, key operational challenges, and safety bounds will be vary depending on the related MSR function
- There are many MSR vendors proposing different concepts with different scopes and applications
- **Solution:** Create a tool that leverages DOE-codes (NEAMS, MELCOR, etc.) to enable the development of evaluation models

Key Features of the Evaluation Model Development Tool

- The workflow moves from plant definition to traceable decisions, with high-fidelity models and lighter-weight surrogates used where they add the most value.



1. Defining the Concept: Scope Builder

- Select parameters related to mission, design, model boundaries, metrics, safety basis, controls, and validation requirements

The screenshot displays the 'Step 1: Scope Builder' interface. On the left is a dark sidebar with navigation links: 'app', 'Scope Builder' (highlighted), 'Plant Designer', 'Neutronics Kinetics', 'Thermal Hydraulics', 'Simulation Lab', 'Program Dashboard', and 'AI Copilot'. Below these are sections for 'Navigation' (with a note about Step 2-4 pages) and 'Wizard step' (listing Mission, Design, Model boundary, Metrics, Safety basis, Evidence & outputs, and Review & export, with 'Design' selected). At the bottom of the sidebar is a 'Quick Help &' link. The main content area is titled 'Step 1: Scope Builder' and includes a description: 'Define the formal scope contract that drives autonomous plant design, OpenMC-ready neutronics, thermal-hydraulic assembly, controls, and future deployment workflows.' Below this are four buttons: 'Design Trade Study', 'Circulating Liquid Fuel', '46 selected list items', and '92% complete'. The interface then shows four status boxes: 'COMPLETION' at 92% (Population of the Step 1 scope contract), 'SCHEMA ERRORS' at 0 (Blocking issues for downstream activation), 'WARNINGS' at 0 (Business-rule findings to review), and 'DOWNSTREAM STATUS' as 'Ready' (Whether the current scope can drive Step 2-4 pages). Below these are three configuration boxes: 'Variant profile' (Chloride / Thermal / Loop / 400 MWth), 'Layout mode' (graphite moderated loop), and 'Priority transients' (loss of heat sink, pump coastdown, manual trip). A 'Help & Guide for This Page' link is at the bottom of the main area. The footer of the interface is titled 'Design Variant and Plant Basis'.

2. Autonomous Plant Design

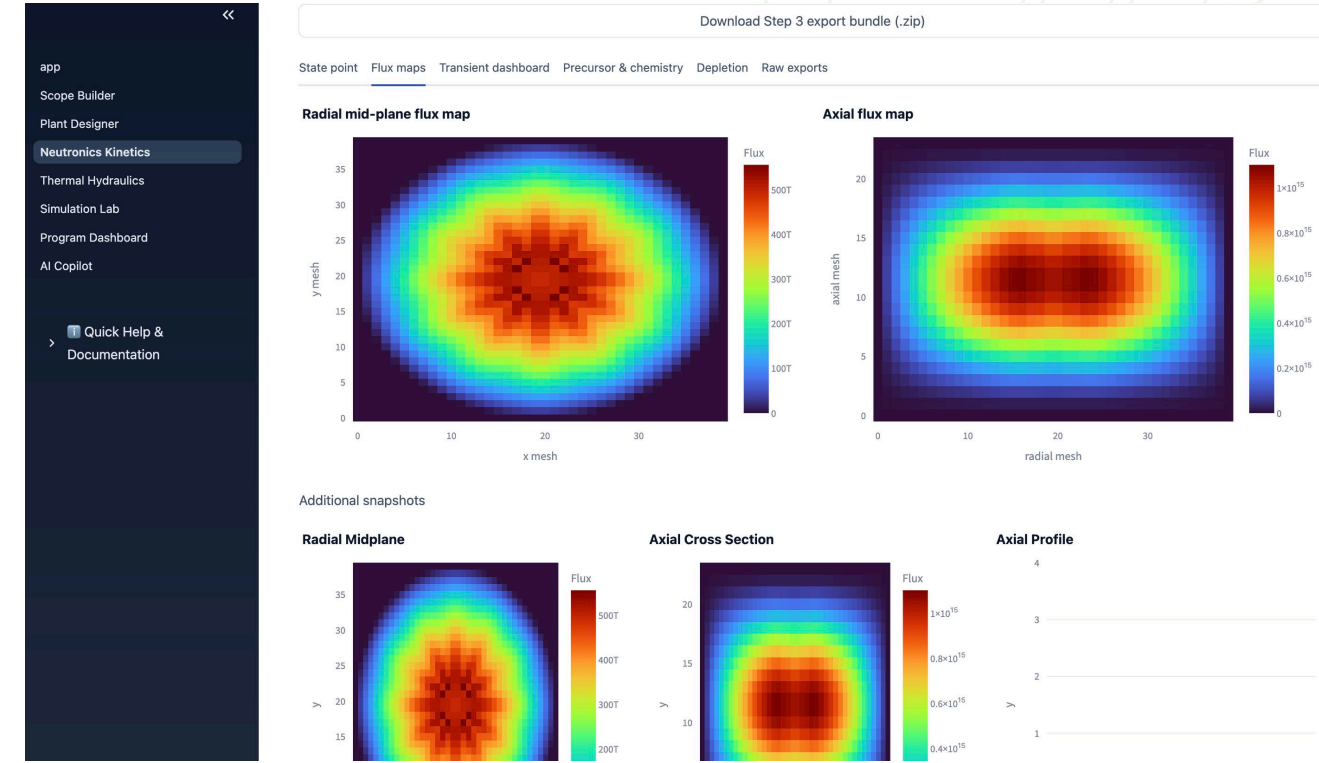
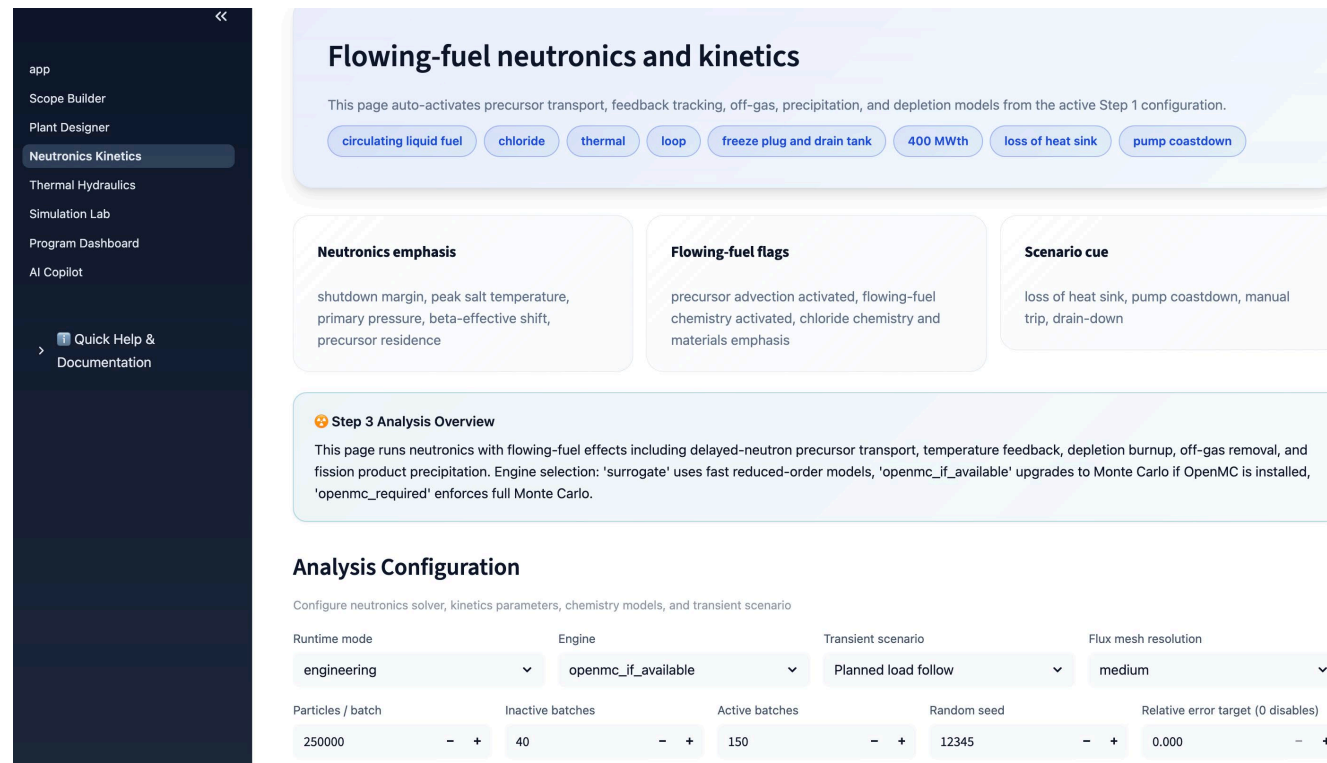
- Develops conceptual layout and BIM models, systems & controls, PFDs, P&IDs, and data tables for the plant
- User selects the required level of complexity for the evaluation model

The screenshot shows the 'Step 2: Autonomous Plant Designer' interface. On the left is a dark sidebar with navigation links: 'app', 'Scope Builder', 'Plant Designer' (highlighted), 'Neutronics Kinetics', 'Thermal Hydraulics', 'Simulation Lab', 'Program Dashboard', and 'AI Copilot'. Below these is a 'Quick Help & Documentation' link. The main content area has a light blue header 'Step 2: Autonomous Plant Designer' with a description: 'Generate the controlled plant configuration baseline, conceptual PFD/P&ID, interfaces, instrumentation, controls, and a parametric CAD-style layout directly from the active Step 1 scope.' Below this are four buttons: 'Autonomous Synthesis', 'P&ID Generation', '3D Layout', and 'Control Loops'. Further down are two input fields: 'Help & Guide for This Page' and 'Load a different Step 1 scope for this page'. A section titled 'Component Detail Level' explains that higher detail levels generate more realistic MSR designs. It offers four radio button options: 'Minimal (18-22 components, 7-12 systems) - Original behavior', 'Standard (50-80 components, 12-18 systems) - Recommended' (selected), 'Detailed (100-150 components, 18-25 systems) - Engineering detail', and 'Comprehensive (200+ components, 25+ systems) - Full plant design'. A 'Debug Info' box shows 'Detail Level: STANDARD | Components: 55 | Interfaces: 12 | Systems: 41'. At the bottom is a button labeled 'Autonomous plant baseline synthesis'.

The screenshot shows the 'Professional 3D BIM Model' interface. The sidebar is identical to the previous screenshot. The main content area has a light blue header 'Professional 3D BIM Model' with the subtitle 'Production-ready Building Information Model with realistic materials, lighting, and interactive camera controls'. Below this is a status bar: 'BIM Data - Passing to renderer: 55 components, 12 interfaces. Open browser console (F12) for detailed logs.' The central '3D BIM View' displays an isometric 3D model of a nuclear reactor system with various components labeled, such as 'CR-125', 'CR-128', 'D-700', 'FP-701', and 'EL-900'. To the right is a 'System Layers' panel with a 'Show All' button and a 'Hide All' button. It contains a list of system components with checkboxes: 'auxiliary heat removal', 'containment structure', 'cover gas supply', 'Drain Tanks', 'freeze plug system', 'fuel addition', 'intermediate hx', 'Moderator', 'normal power', 'Off-gas Treatment', 'Power Block', 'Primary Circulation', 'Primary HX', 'Control Rods', 'reactor auxiliary', 'Reactor Core', and 'salt sampling'. At the bottom left is a 'Camera Views' section.

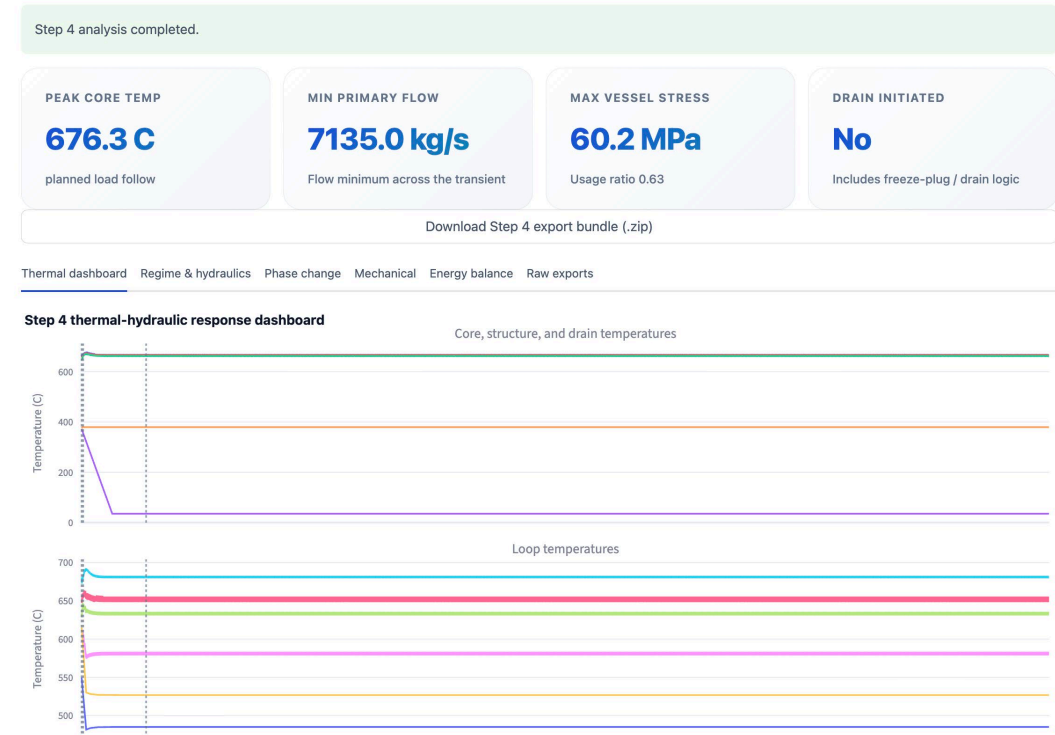
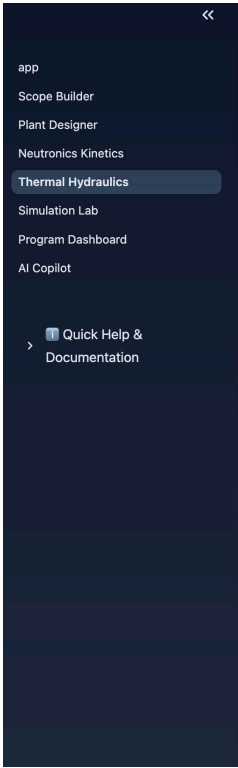
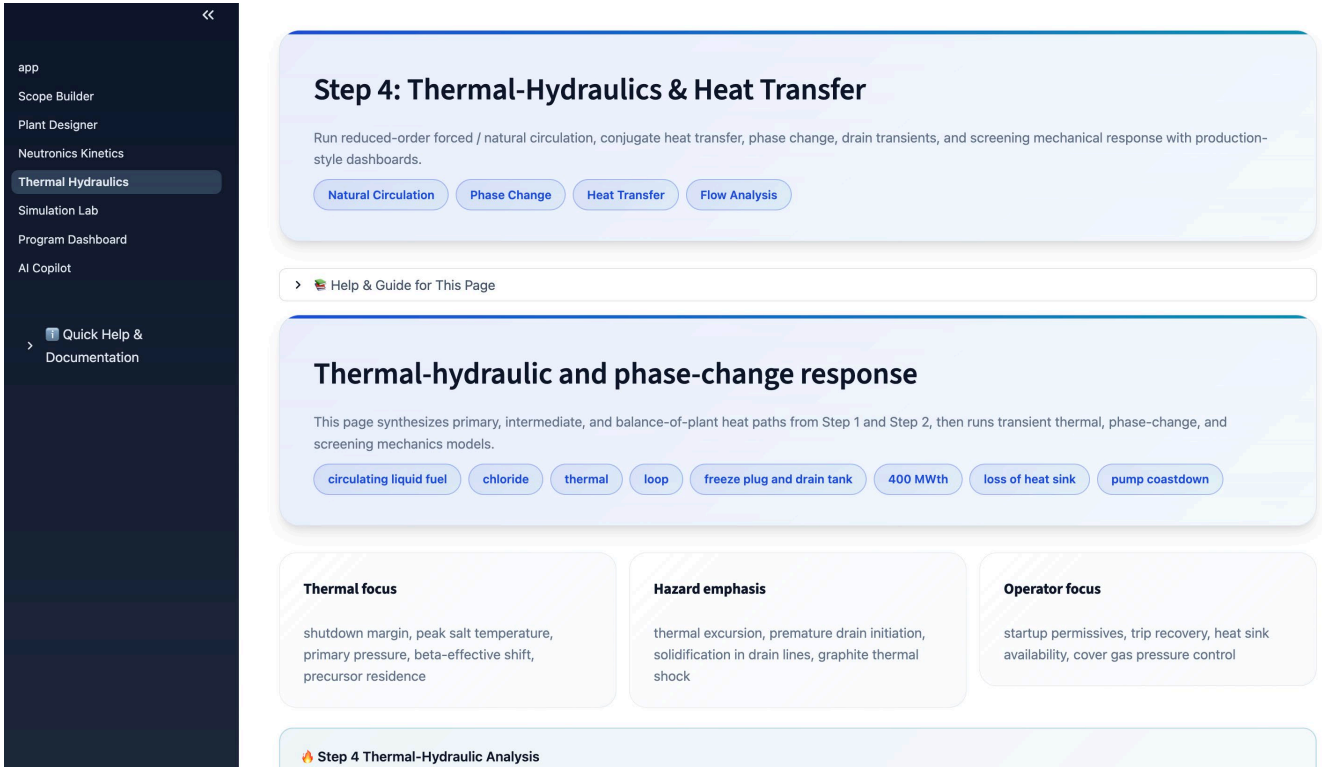
3. Neutronics and Kinetics Studies

- Creates steady-state flux maps and kinetics neutronics models for the selected configuration
- Develop flux distribution and short- and long-term transient studies including depletion and speciation



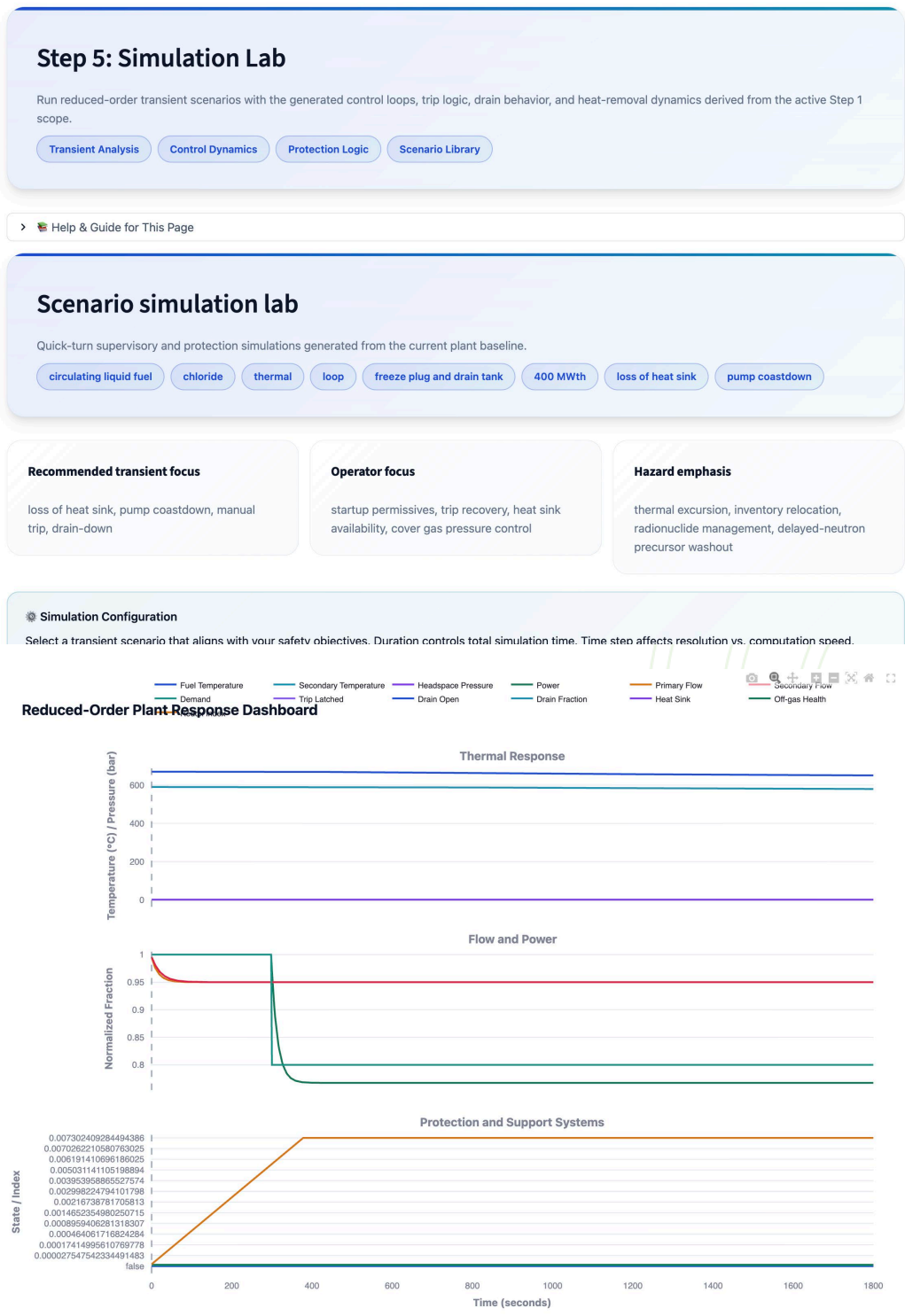
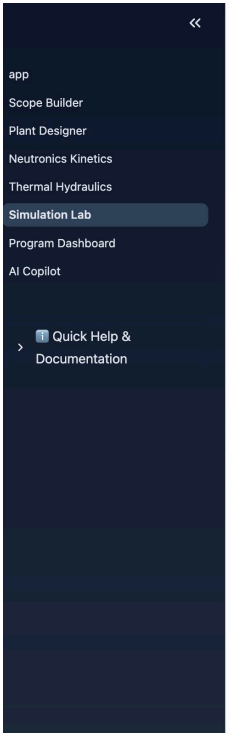
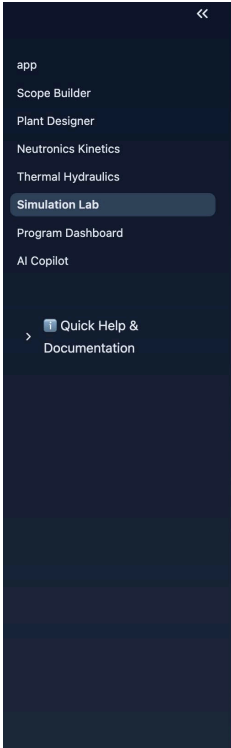
4. Thermal-Hydraulics Analyses

- Runs reduced-order plant-scale thermal-hydraulics models for the steady-state operation of the MSR model



5. Simulation Lab

- Runs reduced-order models for plant transients with incorporated trips, controls, and auxiliary systems
- Allows the user to study the plant dynamics and better understand its behavior in characteristic operational transients



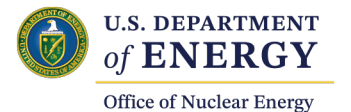
6. AI Co-Pilot

- Enables model auditing, report writing, results explanations, etc. via the integration of the platform with leading Large Language Models

The screenshot displays the AI Co-Pilot interface. On the left is a dark sidebar with a navigation menu including 'app', 'Scope Builder', 'Plant Designer', 'Neutronics Kinetics', 'Thermal Hydraulics', 'Simulation Lab', 'Program Dashboard', and 'AI Copilot' (which is highlighted). Below the menu is a 'Quick Help & Documentation' link. The main content area is light blue and titled 'Step 7: AI Copilot'. It contains a description: 'Optional provider-backed engineering review for the generated plant baseline. The autonomous synthesis, diagrams, and simulations work without any external model key.' Below this are four buttons: 'Optional', 'AI Review', 'Engineering Analysis', and 'LLM Integration'. The next section is 'Engineering copilot review', with the instruction: 'Use deterministic checks first, then optionally add OpenAI or Anthropic review for critique, gap-finding, and polish.' It features a row of buttons: 'circulating liquid fuel', 'chloride', 'thermal', 'loop', 'freeze plug and drain tank', '400 MWth', 'loss of heat sink', and 'pump coastdown'. Below this are three boxes: 'Review focus' (thermal excursion, inventory relocation, radionuclide management, delayed-neutron precursor washout), 'Likely operator focus' (startup permissives, trip recovery, heat sink availability, cover gas pressure control), and 'Plant package basis' (11 systems | 17 components | 10 interfaces). At the bottom, there is a 'Review focus' dropdown menu currently set to 'overall' and a section header 'Deterministic local review'.

Platform Demonstration

4/23/2026

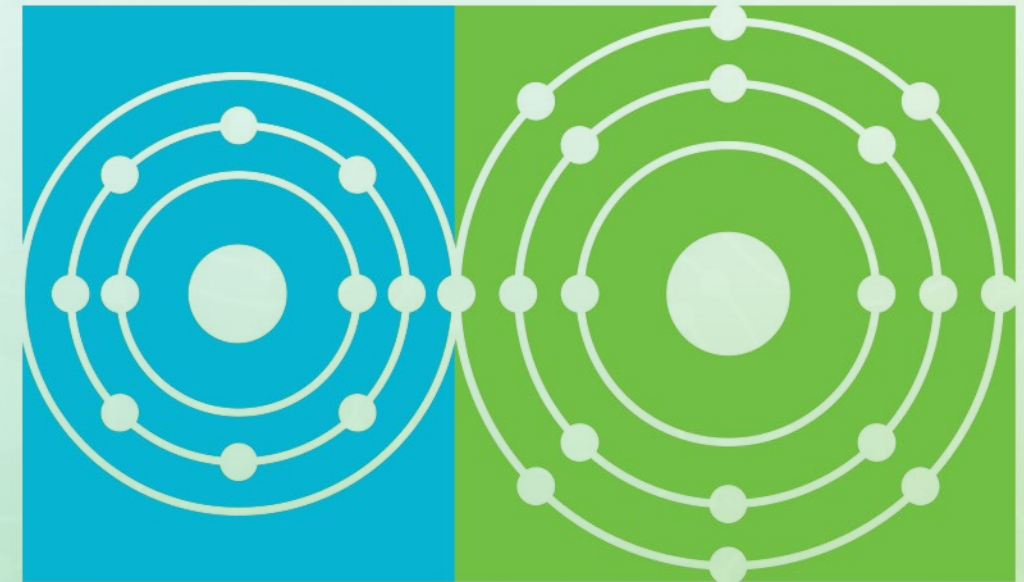


Next Steps

- New additions will include:
 - Increased transient and accident scenario evaluation sets
 - Integrated balance of plant modeling
 - Improved fidelity for corrosion and plating estimates
 - Extended model validation against MSRE and experiments
- Upcoming improvements will integrate:
 - Improved traceability to the sources of the models
 - Improved QA and configuration control
- Continue collaboration with French CEA

**Thank you for you
attention!
Questions?**

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Molten Salt Reactor
P R O G R A M