An Integrated Open-Source Framework for Finite-Element Analysis and Probabilistic Risk Assessment

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Probabilistic risk assessment (PRA) of safety-critical structures such as nuclear power plants and dams for various external and internal hazards often requires performing finite element simulations to calculate failure probabilities of the various systems, structures, and components (SSCs). In practice, these finite-element simulations are performed separately from PRA, and the results of the finite element simulations are post processed for risk calculation. This requires transfers of large quantities of data between the finite element and the risk analysis software and conversion between different data types to maintain compatibility, resulting in a cumbersome and often error-prone process.

The Idaho National Laboratory (INL) has developed the MASTODON, an open source tool, for large-scale seismic analysis including nonlinear soil-structure interaction. MASTODON is capable of seismic PRA, including the automation of probabilistic simulations using parallelizable and memory-efficient processes, postprocessing of the results and fragility analysis, fault-tree and event-tree analysis, and calculation of seismic risk. This presentation demonstrates a full seismic probabilistic risk assessment (SPRA) of an idealized safety-related nuclear facility using MASTODON. The demonstration involves probabilistic soil-structure interaction analysis of the nuclear structure, calculation of demand distributions and fragilities of the systems, structures, and components (SSCs), and fault and event tree analysis that propagates the fragilities through various accident sequences to calculate the risk. The presentation describes the various aspects of the automated seismic PRA process, and compares the seismic risk calculated using linear and nonlinear soil-structure interaction.