Embedded Monte Carlo

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ABSTRACT:

Monte Carlo methods have long been considered the standard in terms of accuracy and have seen increased use in design of small nuclear systems, however the uncertainty quantification (UQ) of desired output is often relegated to later stages of the design process. Nuclear data UQ is often performed long after the design has been set and often too late to identify critical information gaps. Additionally, the current methods are, either costly in computational time and/or memory requirements, while also being of questionable accuracy. This proposal seeks to embed nuclear data UQ in a single Monte Carlo simulation such that each desired quantity will not only provide the mean value and statistical uncertainty, but also the related nuclear data uncertainty, hence the name embedded Monte Carlo.

Embedded Monte Carlo (EMC) is a novel approach to model a stochastic process with varying cross section samples. Total Monte Carlo (TMC) is a brute force solution to this problem where we generate the ensemble or histogram of the stochastic process given multiple sets of cross-sections and the distribution of this ensemble is an indication of the nuclear data uncertainty. The embedded approach aims instead to approximate the moments of the output ensemble directly in a single Monte Carlo simulation instead of relying on multiple Monte Carlo runs each requiring some level of convergence. Prior work has developed and demonstrated the necessary tallies needed to compute the moments of this distribution in a way that nuclear data uncertainty can be separated from the stochastic uncertainty of the Monte Carlo process. EMC will work for any perturbed data set, but to make it practical, it is preferable if the data set can be represented in a compact parametric representation and this proposal will thus rely on the windowed multipole formalism for the resolved resonance range, and develop new models for the prompt fission neutron spectrum, nu-bar and the unresolved resonance range.

Verification will be performed using a continuous energy analytical benchmark that will be extended to the new data formats. For validation, this project will leverage the extensive validation suite developed by Los Alamos National Laboratory (LANL) encompassing integral responses that query nuclear data from thermal to 15 MeV in addition to the International Criticality Safety Benchmark Evaluation Project (ICSBEP) critical benchmarks and the Lawrence Livermore National Laboratory (LLNL) pulsed-sphere neutron leakage spectra and sub-critical observables.