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Improved Hybrid Modeling of Used Fuel Storage Facilities

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ABSTRACT:

We propose to develop a variance reduction method for computational transport that will use enhanced modeling and simulation to improve the ability to design and operate monitoring systems for interim used fuel installations. With these new tools we will demonstrate that modeling calculations can be done more accurately in less time than with current tools and we will perform studies characterizing how changes in material, cask configurations, and number of casks could impact monitoring systems. These innovative analysis tools will enable next generation nuclear material management for existing and future U.S. nuclear fuel cycles, minimizing proliferation and terrorism risk.

Accurately modeling radiation coming from used fuel cask arrays is integral to safeguarding and monitoring used fuel storage installations. Modern radiation transport codes offer variance reduction capabilities that employ an importance map—a measure of how important a particular particle in a Monte Carlo simulation is to the tally being computed—but they are only a function of space and energy. For problems with very *strong anisotropies in the particle flux*, such as the streaming found near the air vents of an individual cask or in between casks stored in an array pattern, the importance map developed using the space/energy treatment does represent the real importance well enough to sufficiently accelerate Monte Carlo calculations for effective use in material control and accountability.

To do fast, accurate transport for used fuel monitoring, we need an importance map generated quickly using deterministic methods that captures the impact of angle in the importance information. We propose to develop such a method, which will provide importance values that more accurately reflect the average importance of particles that will be transported in the final Monte Carlo calculation, yielding faster Monte Carlo run times. We will characterize the ability of this new tool to predict and detect material control and accountability issues in order to minimize proliferation and terrorism risk.

Specifically, this tool has the potential to: inform the design of used fuel storage monitoring systems such that they are more sensitive to material accountability concerns; inform the strategy for cask spacing and fuel aging to enhance material accountability; predict the expected change in monitoring system readings before a cask is added to a fuel storage site; and be available to assess potential implications of a monitoring response that is different from prediction. Any shielding problem containing strong angular anisotropies will also benefit from the ability to include angular influence in variance reduction.

Several scientific innovations will also result from this work. The ability to handle and integrate the multiple-gigabyte-sized angular flux from the forward and adjoint deterministic calculations will be an important challenge to overcome. This work may also require innovations related to the sensitivity of the new importance map capability to angular discretization. Most importantly, this work will result in innovations related to interim used fuel storage facilities. This modeling tool will significantly assist in designing and operating systems to safeguard and monitor interim used fuel storage facilities, enabling next generation nuclear material management for existing and future U.S. nuclear fuel cycles and minimizing proliferation and terrorism risk