Cask Mis-Loads Evaluation Techniques

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ABSTRACT

Currently, there is over 74,000 metric tons of used nuclear fuel (UNF) in storage in the U.S. This corresponds to more than 260,000 UNF assemblies out of which approximately 91,000 are stored in over 2,200 dry storage systems, while the rest are stored in UNF pools at the reactor sites. The UNF increases by 2,000-2,300 metric tons per year. In 2012, the U.S. Department of Energy (DOE) established the Nuclear Fuels Storage and Transportation (NFST) project to develop and begin implementation of a management plan. The main objectives of NFST are to (1) implement interim storage, (2) improve integration of storage into an overall waste management system, and (3) *prepare for large-scale transportation of UNF* and high-level waste. There are currently two tentative plans to build consolidated interim storage facilities. It is expected that the number of UNF transportation events will drastically increase in the near future. As such, it is essential to monitor the condition and stability of the transport cask internals to maintain sub-criticality of the fissile materials in the fuel during normal conditions of transport (NCT) and hypothetical accident conditions (HAC), particularly after long-term storage in dry casks or UNF pools for several decades.

The *main objective* of this integrated research project (IRP) is to develop a probabilistically-informed methodology, which involves innovative non-destructive evaluation (NDE) techniques, to determine the extent of potential damage or degradation of internal components of UNF canisters/casks during NCT or HAC. The *novelty* of the research proposed here is due to

1. Development of a *non-intrusive* and *non-destructive* inspection approach for dry canisters/casks based on three *complementary* NDE techniques that are *proven* to yield *high quality results*.
2. *Integration* of the NDE with computational modeling, proof-of-principle (mock-up) testing, burnup calculations, mis-loading and criticality evaluations, and uncertainty quantification to develop a *validated methodology* to perform a *comprehensive evaluation* of UNF transportation events.
3. *Incorporation* of all *major sources of uncertainty* including but not limited to those of the NDE, computational modeling, mock-up testing and criticality evaluations in the overall methodology to obtain a *quantitative measure* of the *risks* involved with UNF transportation events.

To address the research problems identified above, the methodology shown in Figure 1 is proposed. At the core of this methodology lies the NDE of UNF canisters/casks. Three modes of NDE that are based on different approaches will be investigated: (i) time-tagged neutron interrogation, (ii) elastodynamic waveform tomography, and (ii) non-invasive acoustic sensing. These three modes of inspection are complementary to each other with sufficient redundancy to ensure that the overall methodology will still be successful if one of the NDE modes falls short of anticipated outcomes. The NDE will be supported by various other essential components; namely, thermo-mechanical simulations, mock-up testing, burnup credit calculations, evaluation of mis-loading scenarios, uncertainty quantification, and finally criticality evaluations and risk assessment that will be collectively integrated into a *cohesive* and *comprehensive* methodology. As also indicated with color coding, the research tasks are divided into five thrust areas (TA). Specifically, TA 1: NDE, TA 2: thermo-mechanical simulations, TA 3: proof-of-principle "mock-up" testing, TA 4: mis-loading, burnup and criticality evaluations, TA 5: validation, verification and uncertainty quantification (VVUQ).

The research consortium combines the expertise of 12 investigators and their research groups from four universities, one National Laboratory and one Industry Corporation. Each of the investigators is a leading expert in their individual field of research, and the collective expertise of the research team covers all the relevant and necessary areas to develop a successful methodology for evaluating the performance of UNF casks under NCT and HAC.

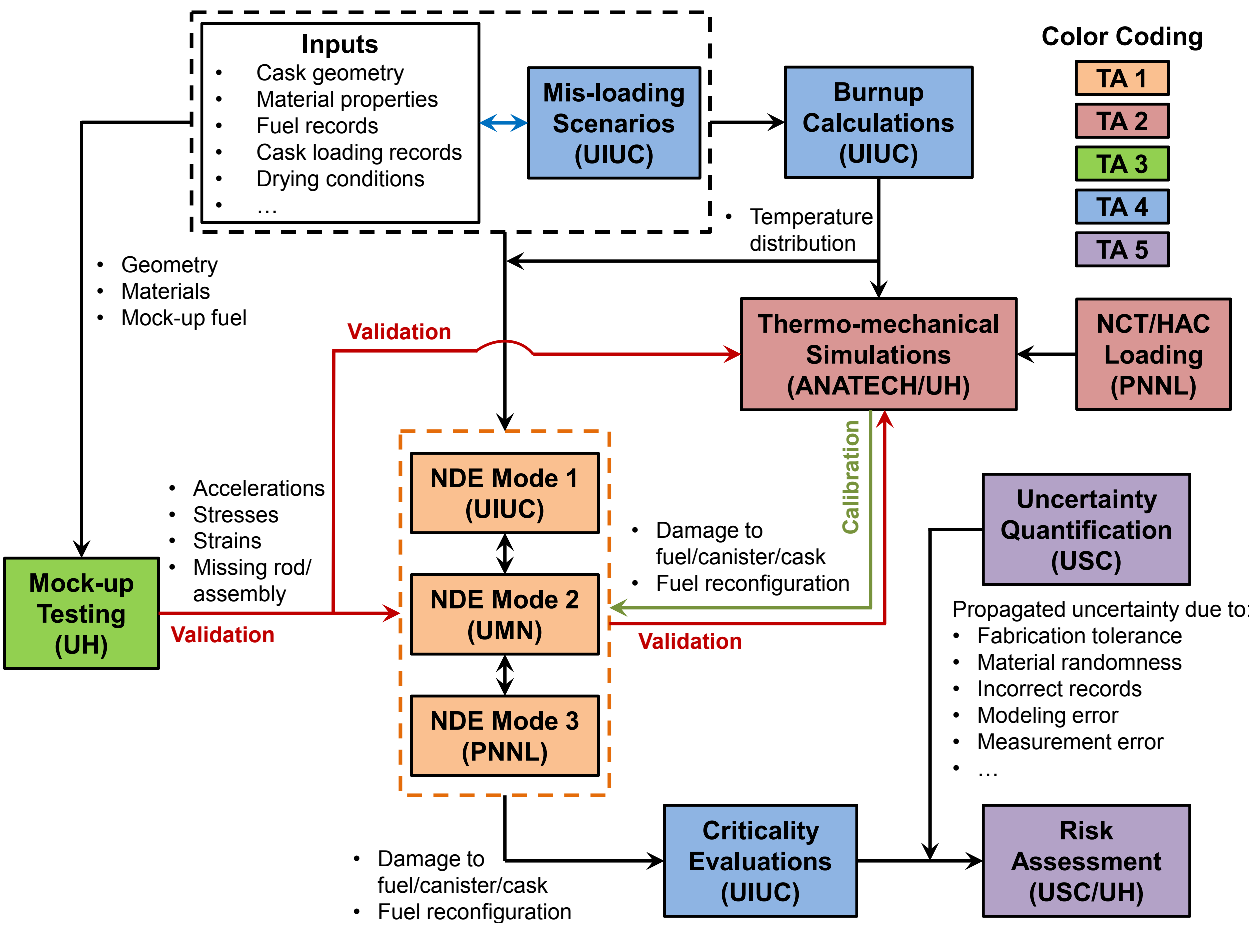

Figure 1. Proposed methodology for evaluation of UNF transportation events