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Methodology Development for Passive Component Reliability Modeling in a Multi-Physics Simulation Environment

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ABSTRACT

Reduction in safety margin can be expected as passive structures and components that cannot be readily replaced undergo degradation with time. Limitations in the traditional probabilistic risk assessment (PRA) methodology constrain its value as an effective tool to address the impact of aging effects on risk and for quantifying the effectiveness of aging management strategies in maintaining safety margins. The objective of this project is to develop methodology to address multiple aging mechanisms involving large numbers of components (with possibly statistically dependent failures) in a computationally feasible manner, where the sequencing of events is conditioned on the physical conditions predicted in a simulation environment, such as being developed under the New Generation System Code program (also known as R-7).

A methodology will be developed for the identification of risk-significant passive component failure modes. Using surrogates, this methodology will need to take account of the extent to which the affected structures and components are currently modeled in the PRA, the importance of components and systems (using Risk Achievement Worth, as well as other importance measures) for the current plant state, anticipated rates of degradation, and the effectiveness of surveillance in identifying degradation. Where the component failure has no identifiable surrogate, it will be added to the model for the purposes of the importance analysis using dynamic PRA techniques, such as the ADAPT methodology which uses DETs coupled to a system code (e.g. R-7) to model possible differences in system evolution due to uncertainties. Both epistemic and aleatory uncertainties can be accounted for within the same phenomenological framework. The DETs are similar to conventional event trees expect that the order of the events is not prespecified by the user but rather determined through the system code. Maintenance can be accounted for in a coherent fashion. Hybrid component reliability models that have physics-based prior structures but allow the use of service data (flaw identification, leaks, ruptures) will be developed for the estimation of the model parameters in a Bayesian framework. Such a hybrid would be able to take advantage of both physics models/data and operational service data. The framework developed will accommodate the prospective impacts of various intervention strategies such as testing, maintenance, and refurbishment. A methodology will be developed for the incorporation of component aging models into the R-7 environment. This integration will be structured to conform to the epistemic/aleatory sampling structure of R-7 which would partly include the ADAPT approach to the quantification of some of the modeling uncertainties.