U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

NUREG/CR-6850 FIRE PRA METHODOLOGY

Module 1

Internal Event, At-Power Probabilistic Risk Assessment Model for SNPP

Task 15: Uncertainty and Sensitivity Analysis

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Fire PRA Workshop
June 24, 2019 – June 28, 2019
Rockville, MD U.S. NRC HQ

Task 15:Uncertainty and Sensitivity Analysis
Purpose (per 6850/1011989)

- Purpose: Provide a process for identifying and treating uncertainties in the Fire PRA, and identifying sensitivity analysis cases
  - Many of the inputs to the Fire PRA are uncertain
  - Important to identify sources of uncertainty and assumptions that have the strongest influence on the final results
  - Fire risk can be quantified without explicit quantification of uncertainties, but the risk results cannot be considered as complete without it
  - Sensitivity analysis is an important complement to uncertainty assessment

Task 15:Uncertainty and Sensitivity Analysis
Scope

- Scope of Task 15 includes:
  - Background information on uncertainty
  - Classification of the types of uncertainty
  - A general approach on treating uncertainties in Fire PRA

Uncertainty and Sensitivity Analysis - Corresponding PRA Standard Element

- Primary match is to element UNC – Uncertainty and Sensitivity Analysis
- UNC Objectives (as stated in the PRA standard):

  "(a) identify sources of analysis uncertainty

  (b) characterize these uncertainties

  (c) assess their potential impact on the CDF and LERF estimates"

Uncertainty and Sensitivity Analysis
HLRs (per the PRA Standard)

- HLR-UNC-A: The Fire PRA shall identify sources of CDF and LERF uncertainties and related assumptions, and modeling approximations. These uncertainties shall be characterized such that their potential impacts on the results are understood.

Task 15:Uncertainty and Sensitivity Analysis
Types of Uncertainty

- Distinction between aleatory and epistemic uncertainty:
  - "Aleatory" - From the Latin alea (dice), of or relating to random or stochastic phenomena. Also called "random uncertainty or variability"
    - Reflected in the Fire PRA models as a set of interacting random processes involving a fire-induced transient, response of mitigating systems, and corresponding human actions
  - "Epistemic" - Of, relating to, or involving knowledge; cognitive. (From Greek episteme, knowledge.) Also called "state-of-knowledge uncertainty"
    - Reflects uncertainty in the parameter values and models (including completeness) used in the Fire PRA – Addressed in this Task

Task 15:Uncertainty and Sensitivity Analysis
Inputs and Outputs

- Inputs from other Tasks:
  - Identification of sources of epistemic uncertainties from Tasks 1 through 13 worthy of uncertainty/sensitivity analysis (i.e., key uncertainties)
  - Quantification results from Task 14 including risk drivers used to help determine key uncertainties
  - Proposed approach for addressing each of the identified uncertainties including sensitivity analyses
- Outputs to other Tasks:
  - Sensitivity analyses performed in Task 14
  - Results of uncertainty and sensitivity analysis are reflected in documentation of Fire PRA (Task 16)

Task 15:Uncertainty and Sensitivity Analysis
General Procedure (per 6850/1011989)

- Addresses a process to be followed rather than a pre-defined list of epistemic uncertainties and sensitivity analyses, since these could be plant specific
  - Step 1: Identify uncertainties associated with each task
  - Step 2: Develop strategies for addressing uncertainties
  - Step 3: Review uncertainties to decide which uncertainties to address and how
  - Step 4: Perform uncertainty and sensitivity analyses
  - Step 5: Include results of uncertainty and sensitivity analyses in Fire PRA documentation

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details

See Appendix U to NUREG/CR-6850 for background on uncertainty analysis. See Appendix V for details for each task.

- Step 1: Identify epistemic uncertainties for each task
  - Initial assessment of uncertainties to be treated is provided in Appendix V to NUREG/CR-6850 (but consider plant specific analysis for other uncertainties such as specific assumptions)
  - From a practical standpoint, characterize uncertainties as modeling and data uncertainties
  - Outcome is a list of issues, by task, leading to potentially important uncertainties (both modeling and data uncertainty)
  - Related SRs:
    - PRM-A4, FQ-F1, IGN-A10, IGN-B5, FSS-E3, FSS-E4, FSS-H5, FSS-H9, and CF-A2 for sources of uncertainty

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details (Cont.)

- Step 2: Develop strategies for addressing uncertainties
  - Strategy can range from no action to explicit quantitative modeling
  - Each task analyst is expected to provide suggested strategies
  - Possible strategies include propagation of data uncertainties, developing multiple models, addressing uncertainties qualitatively, quality review process, and basis for excluding some uncertainties
  - Basis for strategy should be noted and may include importance of uncertainty on overall results, effects on future applications, resource and schedule constraints

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details (Cont.)

- Step 3: Review uncertainties to decide which uncertainties to address and how
  - Review carried out by team of analysts familiar with issues, perhaps meeting more than once
  - Review has multiple objectives:
    - Identify uncertainties that will not be addressed and reasons why
    - Identify uncertainties to be addressed and strategies to be used
    - Identify uncertainties to be grouped into single assessment
    - Identify issues to be treated via sensitivity analysis
    - Instruct task analysts who perform the analyses

Task 15:Uncertainty and Sensitivity Analysis
Sensitivity Analysis

- Sensitivity analysis can provide a perspective that cannot be obtained from a review of significant risk contributors
  - Each task analyst can provide a list of parameters that had the strongest influence in their part of the analysis
  - Experiment with modified parameters to demonstrate impact on the final risk results
  - Modeling uncertainties can be demonstrated through sensitivity analysis
  - Sensitivities should be performed for individual uncertainties, as well as for appropriate logical groups of uncertainties

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details

- Step 4: Perform uncertainty and sensitivity analyses
  - Uncertainty analyses may involve:
    - Quantitative sampling of parameter distributions
    - Manipulation of models to perform sensitivity analyses
    - Qualitative evaluation of uncertainty
  - Following items should be made explicit:
    - Uncertainties being addressed
    - Strategy being followed
    - Specific methods, references, computer programs, etc. being used (to allow traceability)
    - Results of analyses, including conclusions relative to overall results of Fire PRA
    - Potential impacts on anticipated applications of results

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details (Cont.)

- Step 5: Include results in PRA documentation
  - Adequate documentation of uncertainties and sensitivities is as important as documentation of baseline results
  - Adequate documentation leads to improved decision-making
  - Documentation covered more fully under Task 16

Task 15:Uncertainty and Sensitivity Analysis *Expectations*

- Minimum set of uncertainties expected to have a formal treatment:
  - Fire PRA model structure itself, representing the uncertainty with regard to how fires could result in core damage and/or large early release outcomes (Tasks 5/7)
  - Uncertainty in each significant fire ignition frequency (Task 6)
  - Uncertainty in each significant circuit failure mode probability (Task 10)
  - Uncertainty in each significant target failure probability (Task 11)
    - Heat release rate
    - Suppression failure model and failure rate
    - Position of the target set vs. ignition sources
  - Uncertainty in each significant human error probability (Task 12)
  - Uncertainty in each core damage and large early release sequence frequency based on the above inputs as well as uncertainties for other significant equipment failures/modes (Task 14)

Task 15:Uncertainty and Sensitivity Analysis
Expectations (Cont.)

- Other uncertainties may be relevant to address
  - Other activities related to uncertainty are underway
  - You might need to consult other resources for information (e.g., NUREG-1855, EPRI TR 1016737)
- Sensitivity analyses should be performed where important to show robustness in results (i.e., demonstrate where results are / are not sensitive to reasonable changes in the inputs)
- While not really a source of uncertainty, per se, technical quality issues and recommended reviews are also addressed

Mapping HLRs & SRs for the UNC Technical Element to NUREG/CR-6850, EPRI TR 1011989

Technical Element	HLR	SR	6850/101198 9 section that covers SR	Comments
	A	**The Fire PRA shall identify sources of CDF and LERF uncertainties and related assumptions and modeling approximations. These uncertainties shall be characterized such that their potential impacts on the results are understood**		
		1	15.5.1	
		2	15.5.5	Documentation is discussed in Section 16.5 of 6850/101198