Implementation of Enhanced Uncertainty Analysis into Probabilistic Fitness-for-service Evaluations of Pressure Tubes in CANDU Reactors

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Outline

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- Infrastructure Development
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Introduction

- Probabilistic fitness-for-service evaluations of pressure tubes are performed according to Canadian Nuclear Standard CSA N285.8
- Probabilistic evaluations related to pressure tube flaws, as currently performed, include uncertainty analysis at baseline level
- CSA N285.8 requires that enhanced uncertainty analysis be performed when outcome of probabilistic evaluation reaches a specified level with respect to relevant acceptance criterion
- CSA Standard N285.8 provides methodology for enhanced uncertainty analysis to be incorporated into relevant probabilistic evaluations

Introduction

- ❑ Work program is underway to establish the inputs and to develop the tools required to perform enhanced uncertainty analysis for probabilistic evaluations related to pressure tube flaws
  - Work program involves five projects addressing different aspects of methodology for enhanced uncertainty analysis
  - Work program structure recognizes that probabilistic evaluations related to pressure tube flaws share a significant number of input variables
- ❑ Development of infrastructure is required for implementing enhanced uncertainty analysis

Enhanced Uncertainty Analysis

Objective

Review probabilistic evaluation using bottom-up approach focusing on:

- ❑ Identification of influential sources of uncertainty in probabilistic evaluation results
- ❑ Characterization of influential sources of uncertainty in probabilistic evaluation results
- ❑ Assessment of impact of influential sources of uncertainty on probabilistic evaluation results

Enhanced Uncertainty Analysis

Key elements

- Identification of influential input variables
- Characterization of uncertainties in influential variables
- Characterization of statistical correlations ** among influential variables
- Incorporation of uncertainty characterization results into probabilistic evaluation

** Correlations originating from shared sources of uncertainty

Enhanced Uncertainty Analysis

Identification of influential variables

Identification of influential variables allows directing greater effort towards uncertainty characterization of non-deterministic variables having greater effect on probabilistic evaluation outcome

- Approaches to identification of influential variables
  - Analysis of probabilistic evaluation outputs
  - Sensitivity analysis
  - Expert judgement

Enhanced Uncertainty Analysis

Characterization of uncertainties

Statistical assessment and expert judgement are recognized as complementary approaches, and either one may be used as the primary approach, on a case-by-case basis

Expert judgement as primary approach involves a formal process for elicitation and aggregation of expert opinions

Uncertainty components in model response: Originate from different sources in calibrated parametric models and in statistical models

Enhanced Uncertainty Analysis

Propagation of uncertainties

- Approaches to propagation of uncertainties
  - Monte Carlo simulation method
  - Other appropriate methods

Statistical correlations are to be investigated and appropriately accounted for in the probabilistic evaluation

Currently no provisions with respect to using nested or non-nested sampling for uncertainty propagation

Scope of Work

Projects

- Development of infrastructure for enhanced uncertainty analysis
- Identification of influential input variables
- Characterization of uncertainties
- Characterization of statistical correlations
- Modification of probabilistic computer codes

Iterative Approach to Inputs

- Inputs in enhanced uncertainty analysis:
  - Non-deterministic input variables considered to be influential
  - Uncertainties in influential input variables
  - Statistical correlations among influential input variables

Stage 1: Baseline inputs

Inputs used in relevant probabilistic evaluations as currently performed

Stage 2: Primary inputs

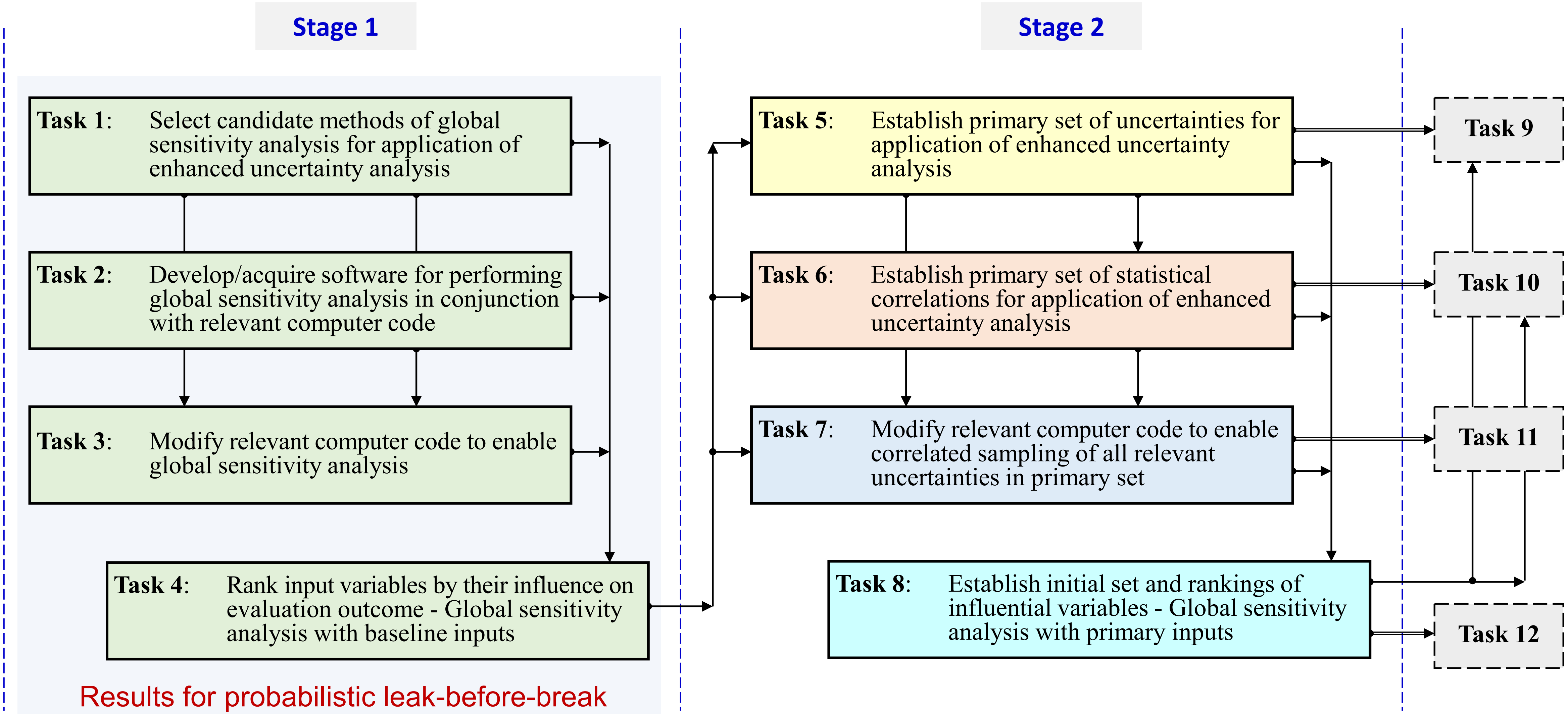
Baseline uncertainties reviewed and updated if required
Statistical correlations involving primary uncertainties

Stage 3: Additional inputs

Additional uncertainties as per guidelines of CSA N285.8
Statistical correlations involving additional uncertainties

Implementation Stages

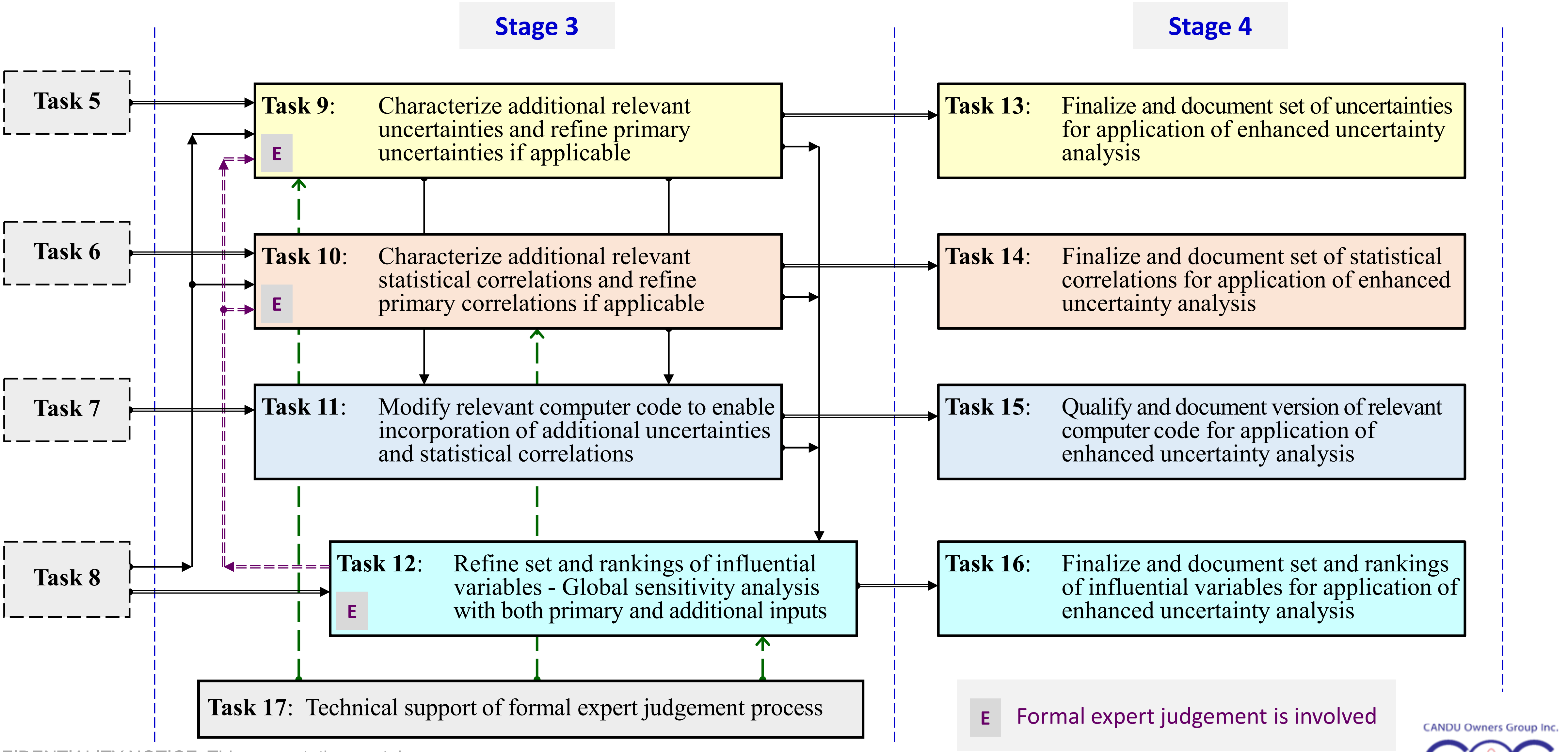
Stages 1 and 2



Results for probabilistic leak-before-break are provided in next presentation

Implementation Stages

Stages 3 and 4



Infrastructure Development

Sensitivity analysis

Local sensitivity analysis

Sensitivity analysis that determines the impact of input variables on the evaluation outcome at a reference point, without explicit consideration of uncertainties

Global sensitivity analysis

Sensitivity analysis that apportions the uncertainty in the evaluation outcome to the uncertainty in the input variables across a multi-variable evaluation domain

Infrastructure Development

Sensitivity analysis

- Global sensitivity analysis methods:
  - Provide substantially more comprehensive measures of sensitivity of the evaluation outcome to its inputs, thereby improving confidence in analysis results
  - Are substantially more efficient in assessing the impact on evaluation outcome of input uncertainties and interactions among inputs
  - Are considered more suitable for implementation into probabilistic evaluations related to pressure tube flaws
  - Require tools to be developed and used in conjunction with relevant probabilistic evaluations

Summary

- ❑ Probabilistic fitness-for-service evaluations of pressure tubes are performed according to Canadian Nuclear Standard CSA N285.8
- ❑ Probabilistic evaluations related to pressure tube flaws, as currently performed, include uncertainty analysis at baseline level
- ❑ CSA N285.8 provides methodology for enhanced uncertainty analysis to be incorporated into relevant probabilistic evaluations when required
- ❑ Key elements of enhanced uncertainty analysis as per CSA N285.8:
  - Identification of influential input variables
  - Characterization of uncertainties in influential variables
  - Characterization of statistical correlations among influential variables
  - Incorporation of uncertainty characterization results into probabilistic evaluation

Summary

- Work is in progress to implement enhanced uncertainty analysis into probabilistic evaluations related to pressure tube flaws
  - Scope of work addresses different aspects of methodology for enhanced uncertainty analysis
  - Five projects, including development of infrastructure
- Infrastructure for enhanced uncertainty analysis in probabilistic evaluations strongly relies on global sensitivity analysis
  - Next presentation describes global sensitivity analysis with baseline inputs in probabilistic evaluations of pressure tube leak-before-break
  - Same method of global sensitivity analysis is suitable for all probabilistic evaluations related to pressure tube flaws

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