Proposal for Setting up an Expert Group on Uncertainty Analysis for Criticality Safety Assessment

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Outline

- Aim of the Expert Group (EG)
- Principal Actions
- Mandate for Two Years
- Deliverables
- Benchmarking: Aim, Stages
- Correlation with the Other EG Activities
General Purpose of Code Validation for Criticality Safety Assessment

Determination of the calculational biases and uncertainties due to computational method, nuclear data and technological uncertainty for a criticality safety tool

Application criticality → $k_{\text{eff}} = k_{\text{eff}}^{\text{calc}} + \Delta k$

$\Delta k_{\text{eff}} = \Delta k_m + \Delta k_{\text{nd}} + a \sqrt{\sigma_m^2 + \sigma_{\text{nd}}^2 + \sigma_t^2}$

- $\Delta k_{\text{eff}}$ - computational bias,
- $\Delta k_m$ - bias due to computational method,
- $\Delta k_{\text{nd}}$ - bias due to nuclear data,
- $\sigma_m$ - uncertainty of the bias due to computational method,
- $\sigma_{\text{nd}}$ - uncertainty of the bias due to nuclear data,
- $\sigma_t$ - technological uncertainty,
- $a$ - a multiplier.
Global Aim of the EG

- Assisting in selection or/ and development an efficient and safe methodology to establish bias and uncertainty to assist criticality safety analyst

- The technique validation through their inter-comparison

- Providing feedback from the technique employment to the national standards for nuclear criticality safety in operation with fissile materials outside reactors
Principal EG Actions

- Survey and compare the current criticality safety validation techniques and codes
- Create benchmarks aimed at cross-validation of the techniques, codes, and the initial data
- Draft lessons learned from the benchmarking
Mandate for Two Years

- Identify requirements of the existing standards for nuclear criticality safety in operation with fissionable materials outside reactors for validation of the methods and data used in nuclear criticality safety calculations.

- Survey the current methods and data available for criticality safety analysis, and their qualitative comparison.

- Draw a roadmap for the benchmarks development for validation of the existing techniques through their inter-comparison.
Deliverables

A state-of-the-art report on

1) current status of the methodologies, codes and associated initial data sets available for criticality safety validation,

2) their compliance with existing standards for nuclear criticality safety,

3) their qualitative comparison.

Drafting of the requirements to the benchmarks for verification and/or validation of the above techniques, codes, and associated initial data sets.
Deliverables (con’d)

Qualitative Comparison of the Methods and Codes:

Criteria

✓ Main characteristic
✓ Error source
✓ Basic method
✓ Specific requirements to benchmark-experiments
✓ Benchmark-experiments selection
✓ Required modification of the criticality calculations codes
✓ Validity of quality
✓ Manpower
✓ Status of development etc.
# Deliverables (2)

## Qualitative Comparison of Methods, Codes and Data Sets: an Example

<table>
<thead>
<tr>
<th>Criterion</th>
<th>MACSENS &amp; USLSTATS</th>
<th>INDECS &amp; TSURFER</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main characteristic</strong></td>
<td>Based on formal statistical approach</td>
<td>Based on the linear form of Boltzmann equation in variations (sensitivity coefficients)</td>
</tr>
<tr>
<td><strong>Supposed error source</strong></td>
<td><strong>Modelling approximation and neutron data uncertainty</strong></td>
<td>Neutron data uncertainty</td>
</tr>
</tbody>
</table>
| **Basic method**       | **MACSENS:** PCA (Principal Component Analysis), SIR (Sliced Inversed Regression), KS (Kernel smoothing method) and trending analysis  
**USLSTATS:** Trending analysis | Generalized Linear Least Squares (GLLS) Method                                      |
| **Specific requirements to benchmark-models** | **MACSENS:** None  
**USLSTATS:** Selected minimum values of $c_k$, correlation coefficient, relative to safety application sensitivities (i.e., >0.8, >0.9, >0.93) | “Simple” geometry is desirable to avoid impact of modelling |
Phases of Validation

- Bias and uncertainty prediction
  - Uncertainty propagation technique
  - Determination of similarity of application to the benchmark-configurations
  - Impact of initial data (experimental uncertainty and their correlation, sensitivity coefficients etc)
- Sensitivity coefficients computation
- Uncertainty of depletion calculation
Validation of Bias and Uncertainty Prediction

Cross-verification stages

- Algorithms verification
- Verification of uncertainty propagation technique
- Validation of both uncertainty propagation technique and the initial data suits

Initial information specification

- Analytical application object
- Set of test models with invented $k_e$ values
- Invented nuclear data parameters
- Prescribed set of experiments
- Application objects with known bias
- Set of experiments selected by the validated tool
- Prescribed applications

Benchmark for sensitivity coefficients computation?
Example of Methods Comparison (Provided by ORNL*)

Correlation with the Other EG Activities

**WPEC EG**
Methods and issues for the combined use of integral experiments and covariance data

- “Adjusted” covariance matrices of nuclear data uncertainty

**EG UAM**

**EG on uncertainty analysis for criticality safety**

- ~4000 critical experiments
- Covariance matrix of $k_{\text{eff}}^{\text{bench}}$ uncertainties for all experiments (DICE)

**ICSBEP**

- Requirements to the benchmark quality: uncertainties and their correlation
- Critical experiments need for current and innovative fuel cycle