PSA Level 1-2-3 uncertainty propagation

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Abstract: This paper proposes a methodology for the uncertainty propagation in Level 1 and Level 2 PSA and studies the effects of the source terms frequency uncertainty in the conditional risk as an outcome of Level 3 PSA. This involves identifying uncertain parameters, quantifying uncertainties through probability distributions, conducting sensitivity analyses, and employing Monte Carlo simulations to refine assessment iteratively. In Level 2, it is proposed to quantify the uncertainty by integrating the uncertainty of thermohydraulic models in the study using software tools such as RAVEN and MELCOR. An exercise of uncertainty propagation of source terms uncertainty from the Level 1 & 2 coupled model to the Level 3 PSA conditional risk is presented.

Keywords: PSA, Uncertainty, Monte Carlo, RAVEN, MELCOR

1) INTRODUCTION

Within the domain of Probabilistic Safety Assessment (PSA) for nuclear facilities, elucidating the uncertainty within the outcomes is crucial. This not only adds clarity to the results but also enhances the confidence level associated with them. Most techniques used to conduct uncertainty analyses on a model entail the propagation of uncertainties in the model's input parameters through the model.

One of the interests of uncertainty analysis is the quantification of uncertainties in the system outputs propagated from uncertain inputs, known as uncertainty propagation [1]. This process aims to quantify the resulting uncertainty in the model responses (outputs) that are of interest. These approaches can be broadly classified into two categories: statistical and deterministic [2]. This process entails tracing the impact of uncertainties in diverse input parameters as they traverse through the successive stages of a PSA model, ultimately shaping the outcome uncertainties.

Figure 1 illustrates the procedural flow of an extensive PSA application for nuclear facilities and uncertainty propagation. The analysis incorporates uncertainties related to thermohydraulic behaviour, failure frequencies, and the model itself. To give an idea of the degree of knowledge or confidence in the available data, these frequencies are usually represented with uncertainty bounds or probability density functions (pdf).

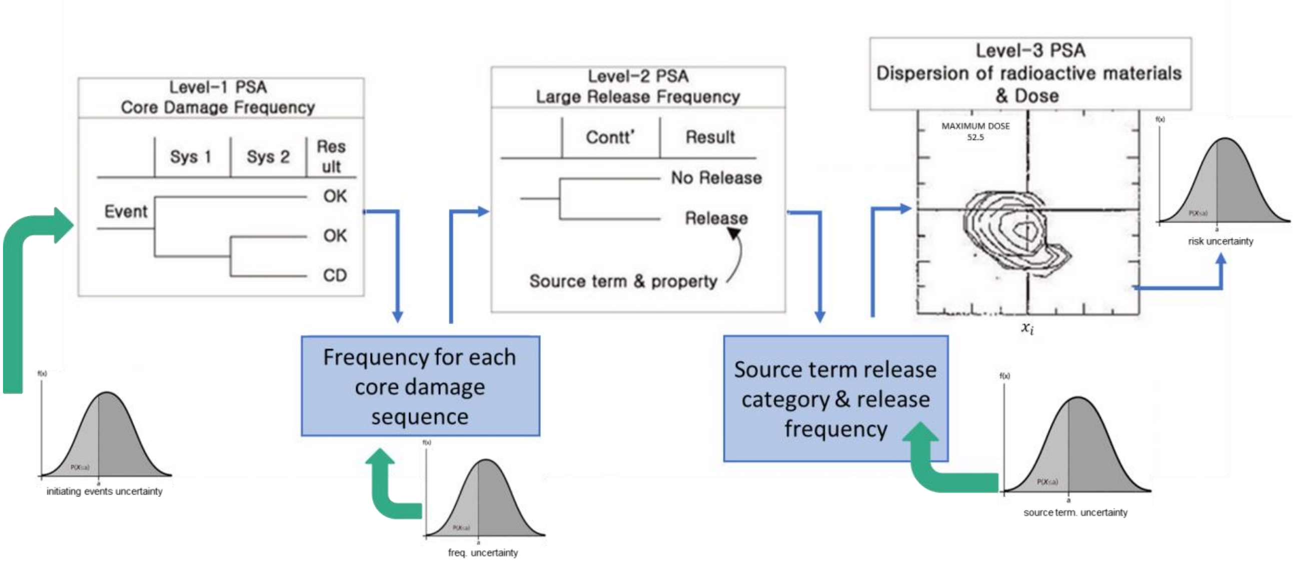

Figure 1. Uncertainties propagation between Level 1-2-3 PSA [3]

In the context of PSA, three hierarchical levels of analysis are distinguished: Level 1, Level 2, and Level 3. Level 1 PSA focuses on appraising plant failures leading to code damage (CD) and determining the core damage frequency (CDF) or when a Level 2 analysis will follow an assessment of plant damage state frequencies. Building upon Level 1 plant damage state frequencies, Level 2 PSA delves into assessing containment response, contributing to the determination of release magnitudes and frequencies [4].

The scope of Level 2 analysis extends to accident progression, containment performance, and radiological release frequency analysis. Level 3 PSA takes a broader perspective, evaluating the off-site consequences of those releases to estimate the risk to the public, incorporating results from Level 2 analysis and including off-site radiological consequence analysis.

Compliance with defined risk acceptance criteria is paramount [5], encompassing the probability of individual fatalities due to beyond-design basis accidents (BDBA) and the potential for direct fatalities within specific timeframes. Additionally, societal risk, considering the actual population distribution around the installation, is a key criterion.

This article investigates how the uncertainties of input probabilities can be propagated through the distinct levels of PSA models to produce the output uncertainty in the Level 3 PSA [6]. A methodology to quantify and propagate the uncertainty in the context of PSA is proposed. The ultimate goal of PSA results is to enhance system safety by identifying and mitigating the plant's vulnerabilities.

The article is organised as follows: Section 2 addresses the uncertainty quantification issue related to Level 1, Level 2, and level 3 PSA. Section 3 delineates a methodology for propagating uncertainties from Level 1 to Level 2 PSA. Section 4 demonstrates the uncertainty propagation from Level 1 to Level 2 PSA by using a benchmark coupled model. Finally, the conclusions and remarks are given.

2) UNCERTAINTY QUANTIFICATION

2.1. Sources of uncertainty in Level 1 PSA

In Level 1 PSA [7], several sources of uncertainty contribute to the overall uncertainty in risk estimates. These uncertainties can be broadly categorised into diverse types [8]:

1) Initiating event uncertainties:
    a) Frequency estimation: The occurrence frequency of initiating events may be uncertain due to limited historical data, changes in plant operation, and evolving technology.
    b) Data quality: Reliability of data sources, completeness of event records, and the accuracy of event classification.
    c) Modelling assumptions: Assumptions made in modelling initiating events, especially for rare events.
2) Human reliability:
    a) Error rates: Human error probabilities are uncertain and may vary based on the complexity of tasks, training effectiveness, and other human factors.
    b) Task dependency: The dependency between tasks and the human reliability model.
3) Component failure uncertainties:
    a) Failure data: The availability and quality of failure data for safety-critical components can vary.
    b) Ageing and degradation: Uncertain nature of component ageing and degradation over time affects failure probabilities.
    c) Modelling assumptions: Simplifications and assumptions made in the modelling of component failure modes.
4) Common cause failure uncertainties:
    a) Modelling dependencies: Modelling dependencies between components and systems for common cause failures.
    b) Data limitations: Limited data on common cause failures may result in uncertainties in modelling their occurrence.
5) Modelling assumptions and simplifications:
    a) Event tree and fault tree modelling: Assumptions made in constructing event trees and fault trees, such as the independence of events.
    b) Failure mode aggregation: Combining failure modes or events for simplification introduces uncertainty regarding the accuracy of the aggregation.

6) External events:
    a) Natural hazards: Inherent uncertainty of frequency and intensity of natural hazards (earthquakes, floods, strong wind, etc.) predictions.
    b) Human-induced external events: Uncertainties in predicting human-induced external events, such as aircraft crashes or intentional acts.
7) Model parameter uncertainties:
    a) Parameters in risk models: Uncertainties in parameters used in risk models, such as conditional probabilities and consequence assessments.
    b) Expert judgment: Subjective judgments and expert opinions used in model parameters.
8) Plant-specific factors:
    a) Design changes: Changes in plant design or modifications over time.
    b) Operating practices: Variability in plant operation and maintenance practices.
9) External environment changes:
    a) Regulatory changes: Changes in regulatory requirements and standards over time.
10) Data variability over time:
    a) Temporal changes: The variability of risk-related data over time, including changes in equipment performance, maintenance practices, and operational conditions.

Understanding and quantifying these sources of uncertainty is crucial for providing a realistic and comprehensive assessment of the risks associated. Methods such as sensitivity analysis and uncertainty quantification techniques are employed to address and communicate these uncertainties in Level 1 PSA.

2.2. Sources of uncertainty in Level 2 PSA

In Level 2 PSA [4], the focus shifts from the accident sequences that lead to core damage (CD) (Level 1) to the identification of potential releases once CD has happened. Level 2 PSA involves the detailed modelling of accident progression, from core damage to the release of radioactive materials (content and frequency). The uncertainty has two distinct terms: uncertainty in the frequency of the releases and uncertainty in the magnitude/content of them.

The sources of uncertainty are partly comparable with those in Level 1, i.e., the functional behaviour of mitigating systems and operator actions needed after CD, and can be categorised as follows:

1) Accident progression modelling:
    a) Code dependent: The selection of models and parameters within the code.
    b) Model assumptions: Assumptions about the behaviour of reactor systems, structures, and components during accident progression.
2) Uncertainty in source term analysis:
    a) Source term models: Uncertainties exist in predicting the release and transport of radioactive materials during an accident.
    b) Radioactive inventory: Estimation of the radioactive inventory within the reactor core and its release pathways.
3) Parameter uncertainties in Level 2 PSA models:
    a) Model parameters: Parameters such as decay heat, thermal-hydraulic properties, and material properties are crucial for accurate accident progression modelling.
4) Severe accident management strategies:
    a) Operator actions: Uncertainties in predicting the effectiveness of operator actions and severe accident management strategies.
    b) Timing and success of mitigation measures: Uncertainties in the timing and success of measures taken to mitigate severe accidents.
5) Common cause failure modelling:
    a) Modelling dependencies: Dependencies between systems and components during severe accidents and assessing common cause failure probabilities and their impact on accident progression.
6) Integration of external events:
    a) External hazards: The potential impact of external events, such as fires, floods, or earthquakes, on accident progression.
    b) Timing and magnitude: Uncertainties in predicting the timing and magnitude of external events.

7) 7. Data limitations:
    a) Limited data for severe accidents: Modelling and parameter estimation with limited operational experience and data for severe accidents contribute.
    b) Validation data: The availability and quality of data for validating severe accident progression models.
8) Expert judgment:
    a) Expert input: Expert opinions and judgments bias play a significant part in developing severe accident progression models.
9) Dynamic interaction between systems:
    a) System dynamics: The dynamic interactions between various systems and components during severe accidents introduce uncertainties. These interactions may not be fully understood or predictable.
10) Feedback effects:
    a) Feedback mechanisms: Identifying and modelling feedback effects, such as thermal-hydraulic feedback and core-melt feedback.

Several specialised codes can deal with uncertainty quantification on Level 2 PSA, such as MELCOR [9], MAAP [10], and SPECTRA [11], among others.

Quantifying and managing these uncertainties in Level 2 PSA helps to increase the understanding of the potential consequences of severe accidents.

2.3. Source of uncertainty in Level 3 PSA

In the context of Level 3 PSA, which focuses on the consequences of severe accidents and their impact on public health and the environment, there are several key sources of uncertainty:

1) Model uncertainty:
    a) Simplifications and assumptions: The models used to simulate accident progression and release of radioactive materials often involve simplifications and assumptions.
    b) Parameterization: The selection of parameters and their values can be uncertain, affecting the model outputs.
2) Data uncertainty:
    a) Limited historical data: There may be a lack of historical data on severe accidents, leading to uncertainties in frequency and severity estimates.
    b) Measurement errors: Errors in the measurement of parameters and environmental data can propagate through the analysis.
3) Scenario uncertainty:
    a) Accident scenarios: The range of potential accident scenarios considered may not cover all possible events, leading to incomplete analysis.
    b) Human actions: Uncertainties regarding human actions and interventions during an accident can affect outcomes.
4) Environmental and meteorological conditions:
    a) Variability in weather conditions: Weather conditions, which influence the dispersion of radioactive materials, are inherently variable.
    b) Environmental response: The interaction of released materials with the environment (e.g., deposition, resuspension) can be complex and uncertain.
5) Health impact modelling:
    a) Dose-response relationships: The relationship between radiation dose and health effects can be uncertain, particularly for low doses and long-term impacts.
    b) Population distribution and behaviour: Assumptions about population distribution, evacuation effectiveness, and public behaviour during an accident can introduce uncertainties in estimating health impacts.
6) Regulatory and methodological uncertainty:
    a) Changes in regulations: Evolving safety standards and regulatory requirements can lead to uncertainties in the assumptions and criteria used in the analysis.
    b) Methodological approaches: Different methodological approaches and the use of various computational tools can yield different results.

3. METHODOLOGY

3.1. Uncertainty propagation in Level 1 PSA

The methodology for uncertainty propagation in Level 1 PSA involves assessing and quantifying uncertainties associated with various components and parameters in the analysis. Uncertainty propagation aims to understand how uncertainties in input parameters propagate through the PSA model, influencing the results [8]. Here is a step-by-step explanation of the methodology:

i. Identify uncertain parameters: Identify the parameters and data inputs in the Level 1 PSA that have inherent uncertainties, see subsection 2.1.
ii. Quantify uncertainties: Assign probability distributions or uncertainty ranges to the identified uncertain parameters. This step involves capturing the range of potential values for each parameter, considering factors such as variability and lack of precise data.
iii. Sensitivity analysis: Conduct sensitivity analysis to identify which uncertain parameters have the most significant impact on the results. This helps prioritize further data collection efforts and provides insights into the critical factors driving uncertainty.
iv. Monte Carlo simulation: Use Monte Carlo simulation, randomly sampling values from the assigned probability distributions for each uncertain parameter and running the PSA model for each set of sampled values. Perform multiple iterations of the simulation to obtain a statistical distribution of the PSA results.
v. Calculate key metrics: Calculate the key risk metrics of interest, such as core damage frequency for Level 1, and plant damage states (PDS) frequencies as intermediate metrics between Level 1 and Level 2.

Collect and analyse the results to understand the range of possible outcomes and the likelihood of different risk levels. This methodology gives a comprehensive understanding of the uncertainties inherent in Level 1 PSA results. The Monte Carlo simulation provides a powerful tool for exploring a wide range of possible scenarios and their associated risks, considering the uncertainties in the input parameters.

3.2. Uncertainty propagation in Level 2 PSA

For Level 2 PSA, a methodology can be formulated to quantify uncertainty similarly to the approach outlined for Level 1 PSA. This may encompass the following stages:

i. Identify sources of uncertainty: Enumerate and categorize the various sources of uncertainty in the Level 2 PSA, see subsection 2.2.
ii. Quantify parameter uncertainties: For each parameter in the Level 2 PSA model, assess the degree of uncertainty by using statistical methods, expert judgment, or historical data to quantify uncertainties associated with each parameter.
iii. Sensitivity analysis: Conduct sensitivity analyses to identify which parameters have the most significant impact on the Level 2 PSA results.
iv. Probabilistic modelling: Use probabilistic methods, such as Monte Carlo simulations or Latin Hypercube Sampling, to incorporate parameter uncertainties into the Level 2 PSA model.
v. Scenario uncertainty analysis: Examine the uncertainties associated with different initiating events and sequences. Consider variations in event frequencies, probabilities, and consequences. Assess how uncertainties propagate through the analysis.

Uncertainty quantification in Level 2 can be split into two parts, one part related to the frequency and the other related to the source term content for specific accident progression sequences. The frequency part can be covered by using fault trees and event trees, similar to Level 1 PSA. Whereas the uncertainty assessment of the source term content as outlined in steps ii to iv can be performed by using computational tools, for example, RAVEN [9] that handle the statistical sampling and iterations of the deterministic severe accident codes, such as MELCOR [12], MAAP [10], and RELAP [13], among others. This part of the study is not completed yet. The uncertainty assessment of the sources term on the risk is therefore for the moment limited to the frequency part.

An example of how to propagate the uncertainty of the source term frequency will be given.

3.3. Uncertainty of source term frequencies

The methodologies outlined in section 3 are applicable when Levels 1 and Level 2 of a PSA fault tree are represented as separate models, and the Level 3 PSA generally uses other software simulation tools. There exists although, a method to integrate Levels 1 & 2 into a unified model, such as depicted in [14], offering the advantage of inherently propagating uncertainties for source term frequencies by using, for instance, Monte Carlo simulations.

The propagation of uncertainties, on source term frequencies, between Level 1 and Level 2 can be achieved using tools like RiskSpectrum [15]. To illustrate this, a coupled Level 1 & 2 model of a nuclear unit is used to compute the distribution probabilities of the source terms' frequencies.

4. SOURCE TERMS FREQUENCIES UNCERTAINTY QUANTIFICATION

This section focuses on unravelling the results of the source term frequencies of a benchmark Level 1 & 2 coupled model and employing the RiskSpectrum software for the analyses, as such as developed in [16]. The source term is a critical factor in assessing the potential consequences of nuclear accidents.

In Level 2 PSA, the source term represents the quantity and type of radioactivity release given the accident progression after core damage (the end point of the Level 1 PSA) and the safety barriers functionality.

The benchmark coupled model uses lognormal distributions to model the uncertainties. The Level 2 PSA end points are clustered in 5 source terms (ST) in the model based on similarities incident progression and containment behaviour This example will illustrate how this uncertainty would impact the Level 3 PSA outcome, i.e. the conditional risk.

4.1. Source term 1 (ST1)

This source term encompasses releases that originate from external hazards that lead to a complete loss of containment and direct core damage. Not surprisingly the uncertainty is therefore determined fully by the frequency of aircraft crash and extreme external flooding hazards.
The cumulative density function is presented in Figure 2. It can be observed that the uncertainty range between the 5th and 95th percentiles span a range of two decades.

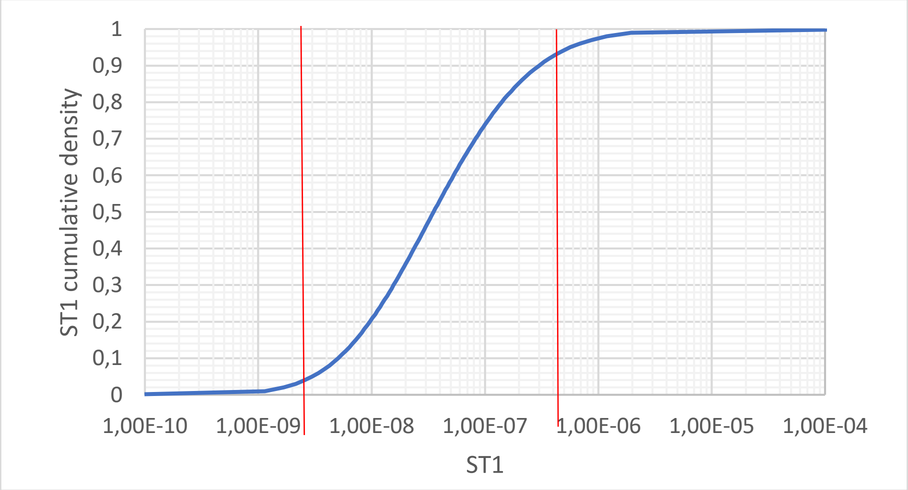

Figure 2. "ST1" cumulative density function

4.2. Source term 2 (ST2)

ST 2 is the source term that encompasses accidents that originate from a LOCA inside containment in combination with a failure to isolate the containment building.

The results indicate as expected a high sensitivity for the “and “LOCA” initiating events frequencies. Next to this, a “common cognitive error of the operators failing to diagnose the need for Decay Heat Removal (DHR)” and the failure of specific air operated isolation valve to close” play an important role. The combination of IE and failure to start DHR leads to core damage; the valve failure leads to the release.

For the ST2 frequency the percentiles 5th and 95th uncertainty spans 2 decades in Figure 3.

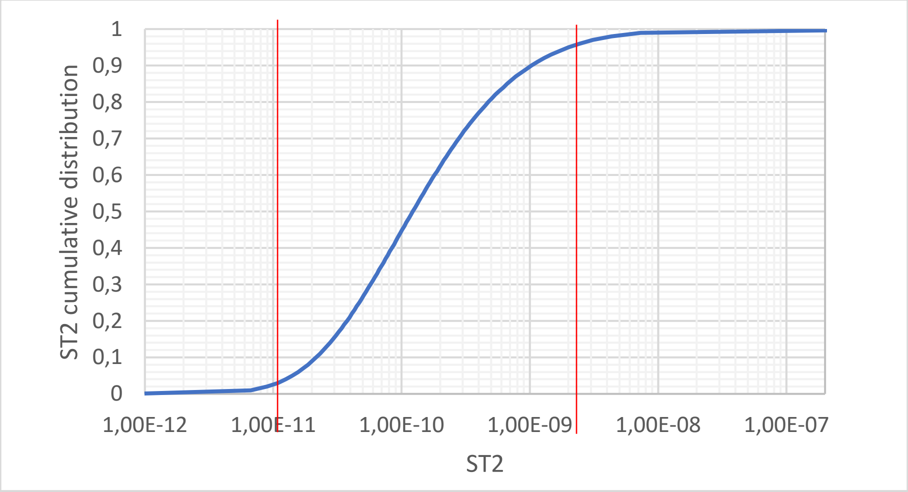

Figure 3. ST2 cumulative density function.

4.3. Source term 3 (ST3)

ST 3 contains the same initiators as ST 2 (LOCAs). The difference is that in this case the containment is successfully isolated. The result is most sensitive to the initiator frequency and failures related to isolating the LOCA and establishing DHR.

In Figure 4 the uncertainty ranges from the 5th to the 95th percentile for the source term frequency ST3 extends over two decades.

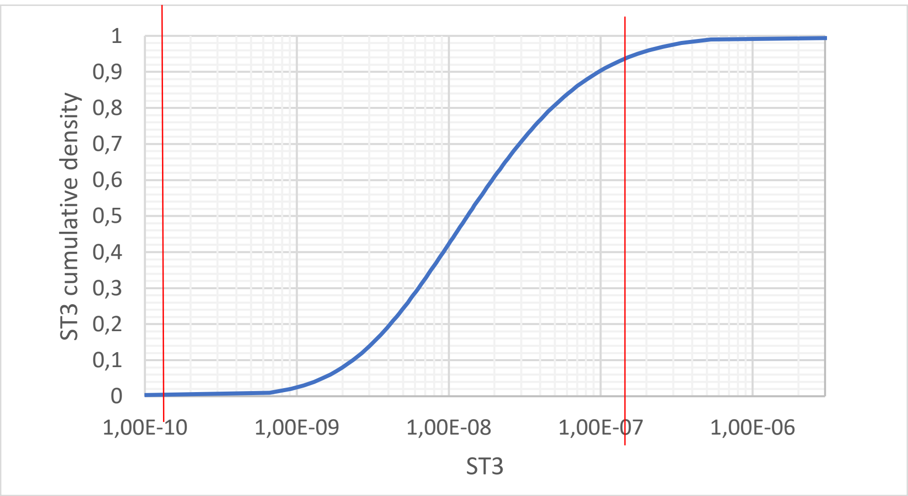

Figure 4. ST3 cumulative density function.

4.4. Source term (ST4)

ST4 is the source term assigned to LOCAs that originate outside containment. The containment function has failed in this case by definition. As expected, the outcome of the analysis is most sensitive for the same events as ST 3: the IE frequency, LOCA isolation and DHR.

Figure 5 depicts the cumulative density, indicating a span of roughly two decades between the 5th and 95th percentiles.

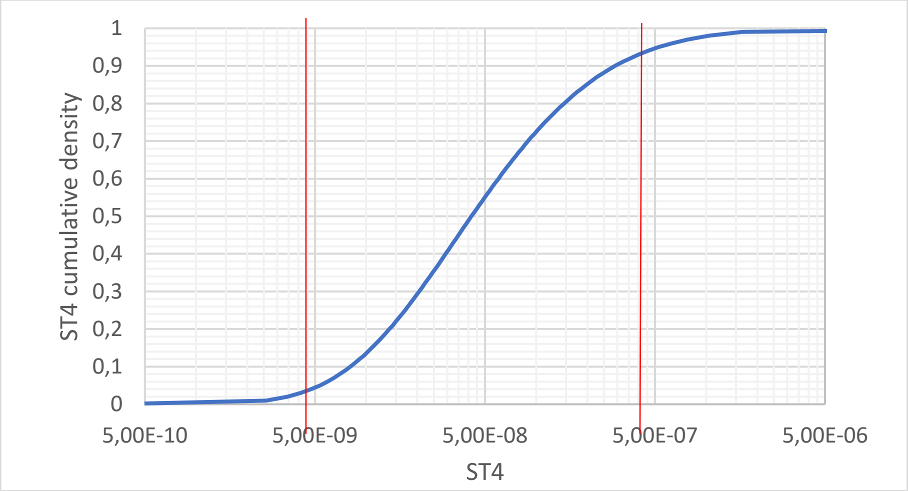

Figure 5. ST4 cumulative density function.

4.5. Source term (ST5)

ST5 is reserved for reactivity insertion accidents, like control rod withdrawal, start-up accidents resembling loss of primary cooling. Next to initiator frequencies, the events “Failure to scram because of not de-energising the control rod or because of mechanical failure” display high sensitivity.

Figure 6 displays the cumulative density function, indicating an approximate span of two decades between the 5th and 95th percentiles.

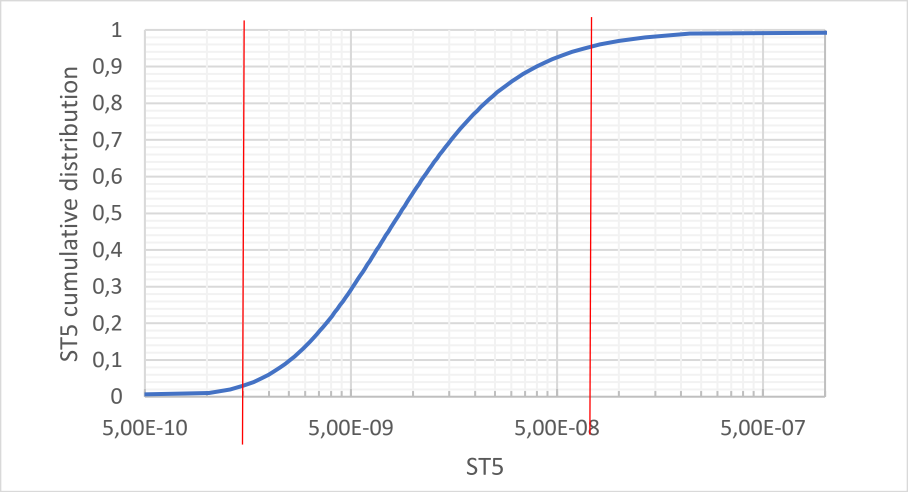

Figure 6. ST5 cumulative density function.

Table 1 presents a summary of uncertainty in source term frequencies. The table includes the mean, median, and the 5th and 95th percentiles. In all accident scenarios, there is an approximate two-decade difference between the 5th and 95th percentiles, indicating an uncertainty range of two orders of magnitude for the frequency of source terms.

Table 1. Source terms uncertainty quantification results.

Source term	**Mean**	**Median**	**5th Percentile**	**95th Percentile**
ST1	1.53E-07	3.52E-08	3.00E-09	5.66E-07
ST2	5.74E-10	1.22E-10	1.41E-11	2.00E-09
ST3	4.64E-08	1.33E-08	1.49E-09	1.74E-07
ST4	1.41E-07	4.16E-08	5.34E-09	5.27E-07
ST5	2.28E-08	8.64E-09	1.85E-09	6.82E-08

5. LEVEL 3 PSA RISK UNCERTAINTY

In Level 3 PSA, it is important to assess the impact of uncertainties in source term frequencies on the conditional risk. Level 3 PSA specifically focuses on risk, defined as individual risk as well as group or societal risk [17].

In the context of PSA Level 3, "risk" refers to the likelihood and consequences of potential accidents. Individual risk pertains to the impact of a hazardous event on an individual within the vicinity of the facility. It is often expressed as the probability of a specified level of harm (such as fatality) occurring to an individual because of an accident. There are 2 kinds, individual risk for children and adults. This accounts not only for immediate fatalities (so called early or deterministic effects) but also for posterior fatalities (late or probabilistic) due to exposure and future cancer development.

Group or societal risk extends beyond the impact on individual members and considers the cumulative impact on a larger population or community. It considers the potential for harm to groups of people, including only immediate effects, and is often expressed in terms of the potential for multiple fatalities or injuries within a given population. The risk is given by:

$$Risk = Probability \times Consequences \tag{1}$$

Where probability is the frequency of the source term release given the event (Level 2 PSA outcome), and consequences are given by Level 3 PSA calculations. A Level 3 PSA consequence code (for instance Nudos2 [18], COSYMA (CODE SYSTEM from MARIA [19]), MACCS (MELCOR Accident Consequence Code System [20])) typically uses the outcome of the Level 2 PSA source term frequency and the magnitude of the source term from a severe accident analysis code, like MECOR or MAAP as input for the risk assessment. The Level 3 PSA codes combine dispersion model with radiation health impact models or other consequence models.

In Level 3 PSA, there are therefore other sources of uncertainty to consider, such as the source term content, dispersion parameters, weather conditions, and heat release, among others. Such uncertainties should be quantified in Level 3 PSA calculations. This phase of the project is focused on the uncertainties of the source term frequencies.

Table 2 presents the comparison of uncertainties in risks for each event based on the uncertainty values of source term frequencies derived from the 5th and 95th percentiles. Note no group risk is achieved except for ST1 due to the fact that the risk for these source terms is not calculated because the release leads to exposures that under the threshold for deterministic effects., and that ST2 and ST5 have been merged due to the similar nature of the accidents involved.

Table 2. Level 3 PSA outcome, risk of fatalities per year.

Source term		**Individual risk for children**		**Individual risk for adults**		**Group risk**
		20 m	**100 m**	**20 m**	**100 m**	**10 people (freq.)**
ST1	Mean	5.51E-08	2.95E-08	9.56E-08	3.42E-08	8.16E-08
	Median	1.27E-08	6.79E-09	2.20E-08	7.87E-09	1.88E-08
	5th Percentile	1.08E-09	5.78E-10	1.87E-09	6.70E-10	1.60E-09
	95th percentile	2.04E-07	1.09E-07	3.54E-07	1.26E-07	3.02E-07
ST2 + ST5	Mean	2.34E-08	3.02E-10	2.34E-08	1.27E-09	n/a
	Median	8.76E-09	1.13E-10	8.76E-09	4.76E-10	n/a
	5th Percentile	1.86E-09	2.40E-11	1.86E-09	1.01E-10	n/a
	95th percentile	7.02E-08	9.06E-10	7.02E-08	3.81E-09	n/a
ST3	Mean	4.64E-08	3.72E-09	4.64E-08	4.64E-08	n/a
	Median	1.33E-08	1.06E-09	1.33E-08	1.33E-08	n/a
	5th Percentile	1.49E-09	1.19E-10	1.49E-09	1.49E-09	n/a
	95th percentile	1.74E-07	1.40E-08	1.74E-07	1.74E-07	n/a
ST4	Mean	3.46E-08	1.73E-08	8.78E-08	2.05E-08	n/a
	Median	1.02E-08	5.08E-09	2.59E-08	6.04E-09	n/a
	5th Percentile	1.31E-09	6.51E-10	3.32E-09	7.74E-10	n/a
	95th percentile	1.29E-07	6.43E-08	3.27E-07	7.64E-08	n/a

The risk uncertainty, considering only the uncertainty in source term frequencies, has a range of about 1 or 2 orders of magnitude. Moreover, the maximum factor between the 5th and the 95th is 189.

The uncertainty of the total risk for Level 3 PSA can be computed by adding up the risk contribution of each of the source terms, i.e., ST1 to ST5. In the case of independent distribution, this is a straightforward computation, nevertheless, if there is dependency, the sum up of these distributions is a more complex task.

6. CONCLUSION

Comprehensive methodologies for propagating uncertainty in both Level 1, Level 2, and Level 3 PSA were proposed, encompassing the incorporation of specialized software applications in the analysis.

The probability distributions of source term frequencies exhibit a right skewness, signifying that the predominant grouping of data tends to concentrate towards the left side of the distribution, indicating a prevalence of lower frequency values.

The importance analysis revealed the events in Level 1 PSA that exert a more significant influence on source term frequencies. Specifically, for ST1 (aircraft crash), the uncertainties are primarily driven by the uncertainties in aircraft crashes within the reactor building frequency, along with uncertainties in external flooding leading to core damage frequency.

In the case of ST2 (LLOCA without containment isolation), the analysis determined that the uncertainty in the source term is influenced by uncertainties in LOCA within the reactor building frequency and uncertainties in medium LOCA frequency.

In the scenario of ST3 (LLOCA with containment isolation), the analysis identified that the primary contributors to the uncertainty in the source term are the uncertainties in LOCA frequency within the reactor building and the uncertainty in medium LOCA frequency.

In the case of ST4 (LLOCA in the primary pump building), the analysis showed that the key factors influencing the uncertainty in the source term are the uncertainties in LOCA frequency outside the reactor building and the frequency of medium LOCA.

In the case of ST5 (loss of primary cooling without containment isolation), the primary factors contributing to the uncertainty are the uncertainties in the frequency of the event "failure to SCRAM due to mechanical failure of control rods" and the frequency of accidents during startup.

The uncertainty quantification of source terms frequencies shows a range, containing the 5th and 95th percentiles, spanning two decades. This represents a variation of two orders of magnitude for the frequency in the source terms. An uncertainty range spanning two orders of magnitude in source term frequency has a proportional impact on the uncertainties associated with the Level 3 PSA outcome, specifically the conditional risk.

One effective approach to minimize uncertainty in the overall outcome involves mitigating the uncertainties associated with the identified event frequencies in Level 1 PSA. It is still to study the other sources of uncertainty on Level 3 PSA.

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