SAND2014-4749C

Used Fuel Disposition Campaign

Mathematical Characterization of the uncertainty in Gaps

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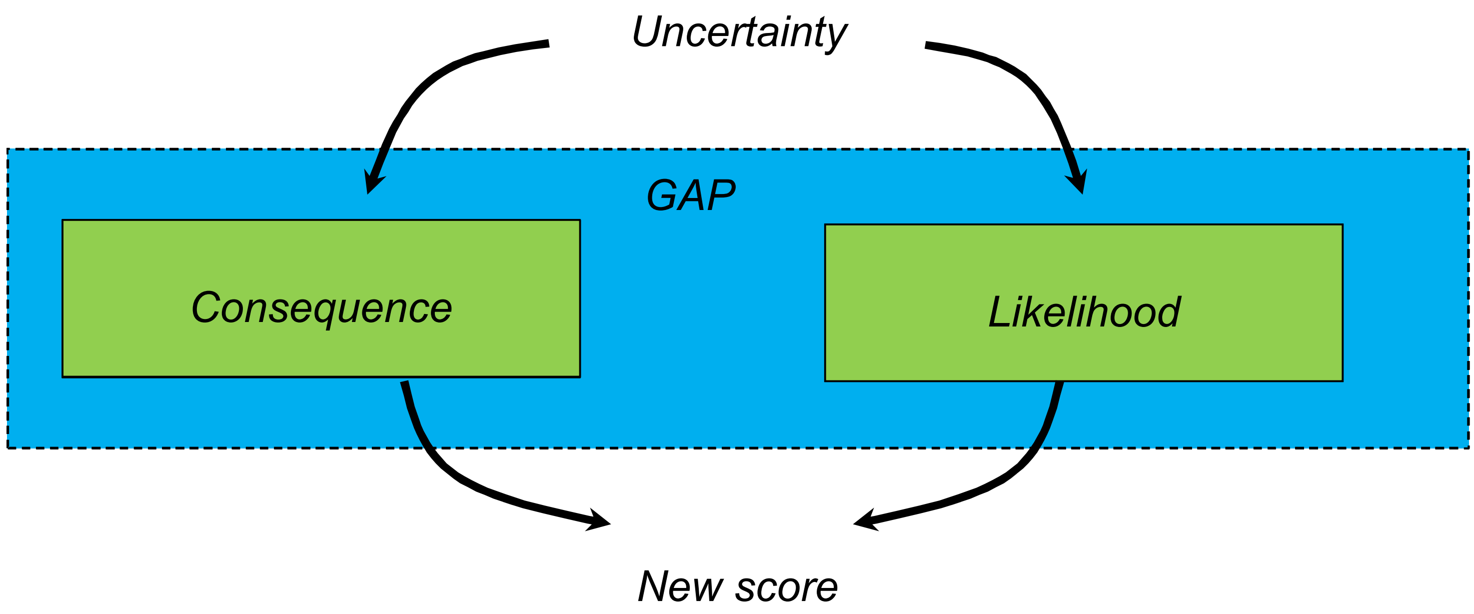
Plan of the presentation

- **Uncertainty – Concept and purpose**
- **Application to this project**
- **Separation of problem into three steps**
  - Consequence
  - Likelihood
  - Model
- **Cross-cutting gap**
- **Conclusion**

Global Concept

- **Inclusion of uncertainty in GAPs to better understand their influence and compare them to each other.**



Purpose of uncertainty

- **Uncertainty does not intend to make user's life harder**
- **It gives a framework to characterize the unknown**
- **If you're not sure of something, it's hard to give a value and it's taking the risk of being wrong. A range of value is a way to tell "I'm not sure what value would be the most appropriate"**
- **Defining bounds may not be as hard a setting a value. A approach can be to try to answer the following questions:**
  - What could be the worse case ?
  - What could be the best condition if it still occurs
- **If there is a reason to have more preference in a certain value within the range, it's OK to indicate so. If not, it's OK not to**

Project’s approach

- **Existing information:**
  - Gap Analysis to Support Extended Storage of Used Nuclear Fuel (FCRD-USED-2011-000136 Rev. 0 PNNL-20509)
    “This report documents the initial gap analysis performed to identify data and modeling needs to develop the desired technical bases to enable the extended storage of UNF”
  - Used Nuclear Fuel Storage and Transportation Data Gap Prioritization (FCRD-USED-2012-000109 PNNL-21360)
    “The primary purpose of this report is to document the methodology and results of a more quantitative analysis used to prioritize the Medium and High priority data gaps from the initial Gap Analysis”
  - Review of Used Nuclear Fuel Storage and Transportation Technical Gap Analyses (FCRD-USED-2012-000215 PNNL-21596)
    “In order to verify that the UFDC identified all of the technical gaps and properly prioritized them, this report was commissioned to compare the UFDC Gap Analysis and UFDC Gap Prioritization reports to those recently published by others…”
- **We do not plan to redo everything but build on what’s existing to develop new insights**
- **The purpose is NOT to criticize previous work**

Information that will be used from the existing reports

GAP Analysis

- *Selection of the gap of interest*

GAP prioritization report

- *Scoring of gaps for consequence*
- *Scoring of gaps for likelihood*
- *Rationale for the scoring*

GAP comparison

- *Range in the importance of the GAP (help building uncertainty over gaps consequence and likelihood)*

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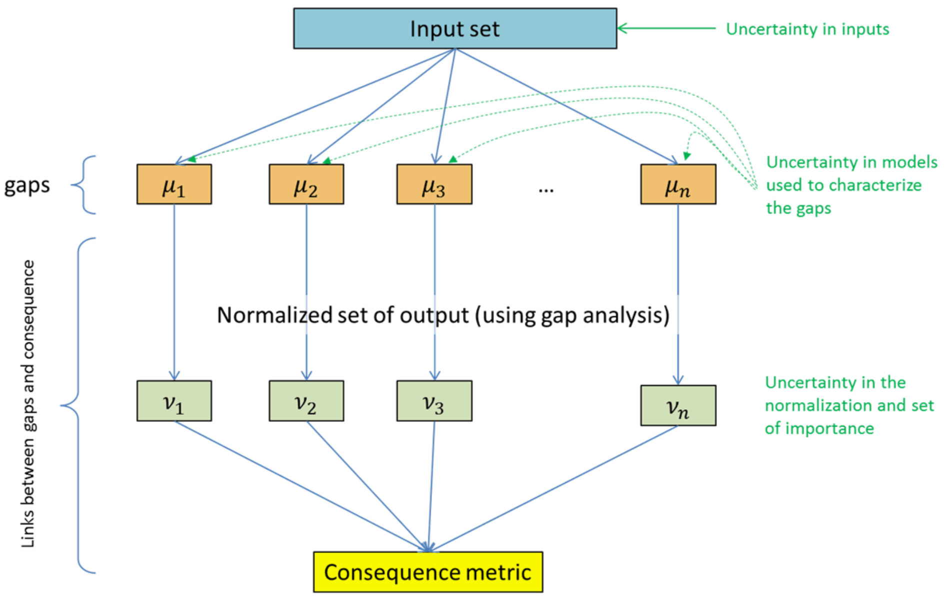
Dissociating the different steps

In this analysis, each gap is representing via three separate elements, each of them having potentially its own uncertainty :

- **Consequence**
- **Likelihood**
- **Model**



Consequence and model are not the same: the model estimates a physical output. The consequence reflects how serious an output may be

Likelihood represents the likelihood to have the necessary conditions such as the gap may occur. The model will be run conditional on this assumption.

Consequence (1/3) - structure

- **Consequence will be set on a scale of 1 to 10.**
- **Why changing from 1-4 ?**
  - First because usually people can relate better with a scale of 1 to 10 and have a better idea of what a number means within this scale
  - Furthermore, it will be easier to set up a range to represent uncertainty (short or large)
- **Nominal value will be based on GAP prioritization (for specific gaps) by simple scaling**
- **An example of approach could be as follow :**
  - Value of 1. default range [1-2.5] – nominal value 1.25
  - Value of 2 . Default range [2.5-5] – nominal value 3.75
  - Value of 3 . Default range [5-7.5] – nominal value 6.25
  - Value of 4. Default range [7.5-10] – nominal value 8.75
  - This is just a proposed approach. We can use another one if one seems more appropriate

Consequence (2/3) - rationale

- **One question people may ask : *Choosing a number (e.g., 3 out of 4) may look easy sometimes than representing a full range. Especially we may not be able to say one gap is [1-1.5] and another [1.5-2].***

- **We could reply to this question with another one. *How confident are we when we set a value of 3 ?***

- **The purpose at this stage is not to go into neaty greaty details and spend hours discussing whether a gap is slightly more serious than another one (although if we could, it would be nice).**

- **One can simply use the range proposed in the previous slide and see if he/she is happy with this range. The purpose is to make you feel comfortable with the range of consequence that this gap may produce**

- **AND, it is easy to change the range to work on a "what-if" scenario. This is one advantage of dissociating results and consequences.**

Consequence (3/3)

Example for welded canister atmospheric conditions

- **Reported consequence score : 4**

A breach of the canister results in a loss of the primary confinement. This could result in ingress of air and water and release of radionuclides, potentially exposing workers and the public.

- **Information from gap comparison document:**
  - The description of atmospheric corrosion is consistent in all the gap reports that discuss it.
  - All organizations that prioritize, and all countries that use welded canisters for long-term storage, assign a high priority to additional research

Priority	UFDC	NWTRB	NRC	EPRI	IAEA
	VH	X	H1	H	

Note: Here an analysis of each document to understand how the consequence are evaluated would be more appropriate

- **How to interpret these results:**
  - All analyses agree that this gap is highly important and could have serious consequence. It would then make sense to set the maximum score a value of 10.
  - The minimum score depends on how serious could be considered the lowest results of the analysis. An approach could be to decide the lower bound once the model results are available
  - For the purpose of illustration, we will set the minimum value with a score of 6
- **Example of possible range**

Bolted Casks (Atmospheric Corrosion)	SG	1	2	3	4	5	6	7	8	9	10

Likelihood (1/2) - Approach

- **Distinction between likelihood of certain consequences and likelihood of conditions to have a gap**

- **We are only interested here in checking that the conditions are met for a gap to be considered**

  – Because it makes the models more efficient, concentrating on conditional gap (we know that the conditions are met)

  – Furthermore the likelihood of seriousness will be included in the model (when uncertainty is included) and it should not be counted twice

Likelihood (2/2)

Example for welded canister atmospheric conditions

- **Reported likelihood score (near term) : 4**

If conditions on the surface of the container are sufficiently aggressive to support the initiation of atmospheric corrosion, there is the potential for SCC of the container closure weld region. Data from Shirai et al (2011a) suggest that salt deposition in marine environments is sufficient to cause SCC. Industrial pollutants, including concentrates from power plant cooling towers, may also deposit and result in SCC. Based on the results of Shirai et al. (2011a), the likelihood of sufficient salt deposition is very high, even over short times.

- **More details will be given in follow-up presentation (Charles Bryan).**

- **Conclusion is this will be site specific, going from very unlikely ($p=10^{-4}$ per canister?) for inland sites, to almost certain (p~1.0 per canister) for a western coast site such as Diablo's Canyon**

- **Separation of likelihood of condition to modelization (conditional) has the advantage to reduce the problem to one conditional analysis on which the likelihood will be changed depending on the site.**

Performance Requirement - linking model output to consequence
(work performed by C. Stockman)

- **Requirements outlined in 10 CFR 72**

"*Confinement systems* means those systems, including ventilation, that act as barriers between areas containing radioactive substances and the environment."

"Specifications must be provided for the spent fuel to be stored in the spent fuel storage cask, such as, ...the inerting atmosphere requirements."

- **Regulatory guidance is provided in NUREG-1536 and NUREG-1567.**

The application should specify the maximum allowed leakage rates for the total primary confinement boundary and redundant seals... the allowable leakage rate must be evaluated for its radiological consequences and its effect on maintaining an inert atmosphere within the cask. However, the analyses discussed below are unnecessary for storage casks including its closure lid that are designed and tested to be "leak tight" as defined in … ANSI N14.5-1997."

- **Welded storage canisters are designed and tested to be "leak tight", with all of the newer canisters using the ANSI N14.5-1997 definition of "leak tight" (leak rate ≤1.0×10^{-7} reference cm^3/s).**
- **A SCC crack in a canister could result in a leak rate significantly higher than the 1.0×10^{-7} reference cm^3/s or 1.0×10^{-4} $atm \cdot cm^3/s$ limits**
- **Conclusion: if a through-wall stress corrosion crack is detected in a canister, the leak rate limit licensing condition cannot be assured and action is required. The canister must be returned to a safe analyzed condition.**

Model

- **To be consistent with the concepts presented for consequence and likelihood, the model needs**
  - To be conditional on the right conditions to be met for the gap to be considered
  - To arrive with a result that can be interpreted in term of consequences. For instance the consequence range for the SCC specific gap is set to [xxx,xxx]. The outputs of the model should be mapped to this range (simple linear map or more complex)

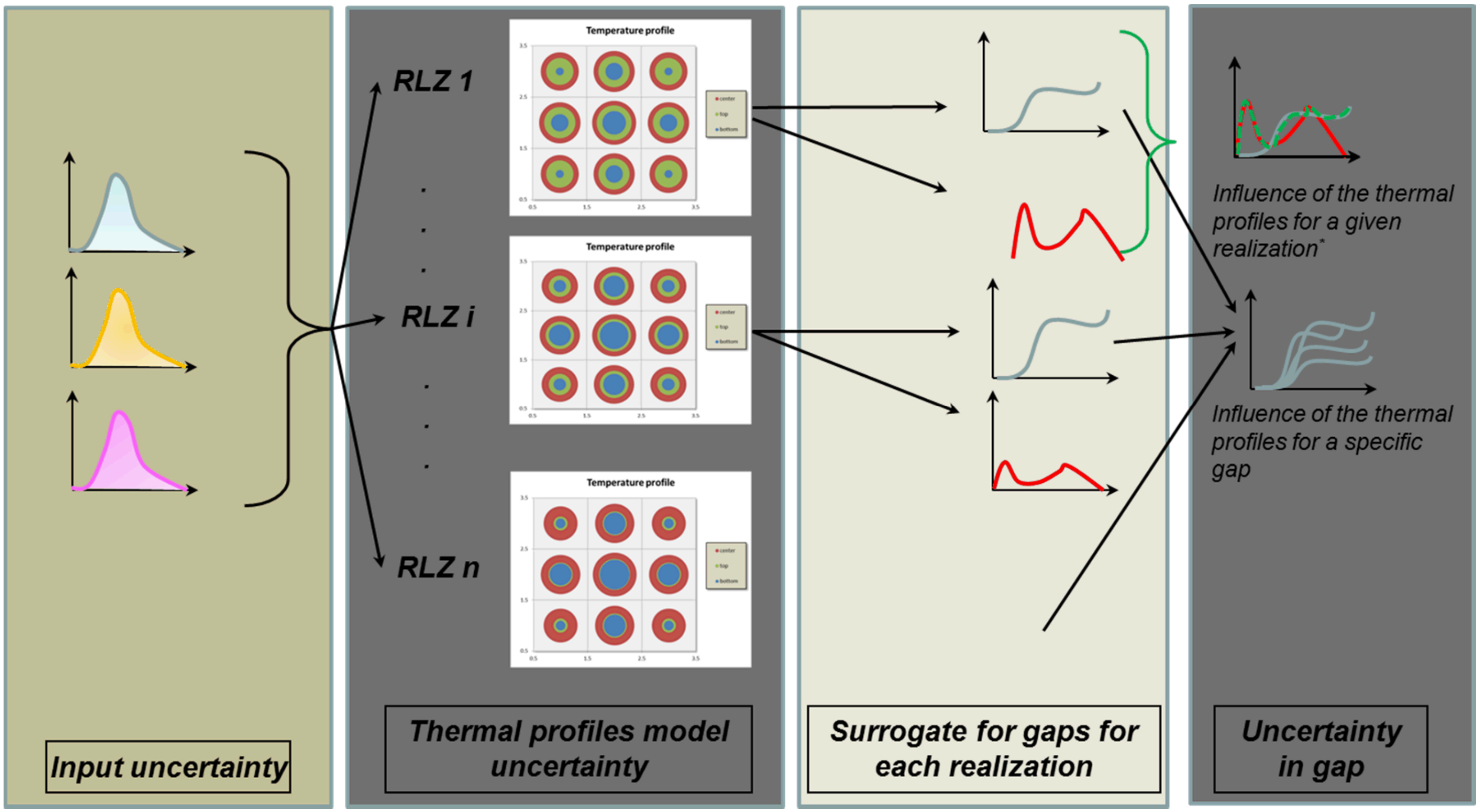
- **Furthermore, the model should**
  - Include any input uncertainty
  - Include model uncertainty with parameter uncertainty and/or several models
  - Not being conservative or optimistic if possible.

- **Example of model presented by Charles Bryan for SCC**

Cross Cutting Gap (1/3)

- **Question : How can we apply this approach to cross-cutting gap while they are only intermediate results ?**
- **By default, they will be considered as important if they are mandatory to the specific gap calculations**
- **However sensitivity analysis can be used to estimate their effect and rank them**
- **Example follows for Thermal maps**
- **Because of time and budget constraints – the thermal maps approach will be simplified in this pilot study.**

Cross cutting gap (2/3)
Thermal Profile graphical representation



*: illustration. It may not necessarily be the maximum over time

Cross cutting gap (3/3)

Thermal profiles example

- **Uncertainty is applied to the thermal profiles**
- **Each result is propagated to the specific gap**
- **Sensitivity Analysis will tell us how much the uncertainty in the thermal profile affect the uncertainty in the output result.**
- **Furthermore, each result for specific gap using the cross cutting gap can be associated with a consequence value. As a result, for each cross cutting gap result, a maximum effect amongst the gaps can be estimated. This can then be translated to see the cross cutting gap importance distribution.**

Conclusion

- **Purpose of uncertainty : represent our current state of knowledge and allow to mathematically characterize the lack of information**
- **Problem separated into three parts : Consequence, Likelihood and model. Such approach should reduce computational cost and allow to test different scenarios ("what if" approach)**
- **Method developed mainly with Specific gaps in mind, but sensitivity analysis can be used to extend it to cross cutting gap.**
- **Methodology can only be applied if some knowledge is available. Which means we need (1) the information gathered in the different gap reports and (2) the help from the authors of these reports to benefit from their experience.**