SAND2009-6267C

Treatment of Model Uncertainty

Final Annual PAMINA Workshop
Sept 28-30, 2009
Hohenkammer, Germany

Clifford W. Hansen

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline

- Definitions
  - Models, model uncertainty
- Approach for evaluating model uncertainty
- Conclusions

Hierarchy of Models

- Conceptual – set of assumptions used to describe a system
- Mathematical – set of equations designed to represent the conceptual model
- Computational – code or other tools to evaluate mathematical model

Definition – Model Uncertainty

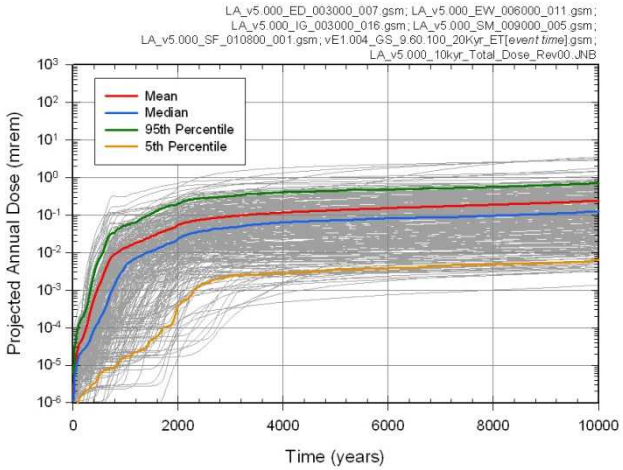
- **Model Uncertainty arises from:**
  - **an incomplete knowledge of the behaviour of engineered systems, physical processes, or site characteristics,**
  - **representation of features, events and processes using simplified models and computer codes.**
- **Embodied by assumptions associated with:**
  - **the formulation of process models,**
  - **the reduction of complex "process" models to simplified or stylised conceptual models for PA purposes,**
  - **the representation of conceptual models in mathematical form,**
  - **the inexact implementation of mathematical models in numerical form and in computer codes.**
- **Includes conservatisms**

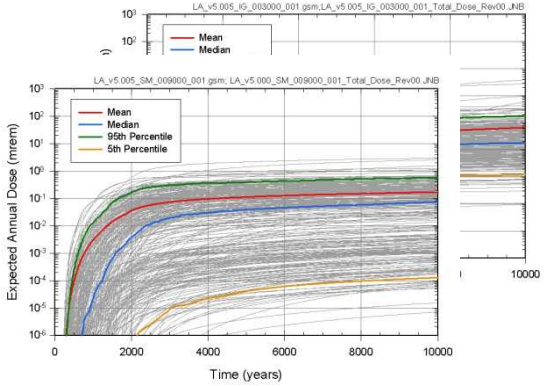
Other Uncertainties

- Model Uncertainty distinguished from
- Parameter Uncertainty
  - Uncertainties associated with the values of the parameters that are used in the implemented models
- Scenario Uncertainty
  - Uncertainties associated with significant changes or events that may occur over time
- Yucca Mountain Example
  - Occurrence of an igneous event – scenario uncertainty
  - Effect of magma on engineered barriers – model uncertainty
  - Solubility of uranium in waters percolating through cooled magma – parameter uncertainty

Constraints on Evaluation of Model Uncertainty

- Parameter uncertainty can be propagated numerically
- Scenario uncertainty managed by various techniques
- Evaluation of model uncertainty presents a significant challenge
  - Quantitative evaluation entails developing and calculating alternate models
  - Limited by practical considerations





Sandia National Laboratories

Proposed Approach

- Screening approach to reduce scope
- Identify and characterize model uncertainty in the safety case
  - Catalog sources of model uncertainty
  - Identify reasonable alternative assumptions
  - Identify key model uncertainties
  - During development of the performance assessment
- Evaluate key model uncertainties
  - Part of analysis of the performance assessment

Catalog sources of model uncertainty

- Assumptions inherent in
  - Conceptual models
    - E.g. flow is steady-state through a porous media
  - Mathematical models
    - E.g. Darcy's law
  - Computational models
    - E.g. implement Darcy's law on a 1D grid
- Assumptions inherent in linkages between models
  - Independent vs. coupled processes
- Assumptions made by the use of conservatisms

Identify reasonable alternative assumptions

- A reasonable alternative assumption is one that has a technical basis at least as sound as the baseline assumption
  - Consistent with available data and observations
- Techniques to identify reasonable alternative assumptions
  - Model comparison studies
  - Peer or regulator review
- Model uncertainty is present only when reasonable alternative assumptions are identified

Identify key model uncertainties

- A model uncertainty is key when use of reasonable alternative assumptions has the potential to have a significant effect
- Effects are judged in the context of the model's use
  - Estimating performance measures
    - key if contributes to magnitude or uncertainty
  - Judgments about safety
    - key if significant to the decision being considered
    - Particularly important for conservatisms

Identify and Evaluate key model uncertainties

- Some type of analysis is needed to:
  - Identify key model uncertainties
  - Evaluate the effects of key model uncertainties
- Quantitative methods
  - Develop and compare alternate models
  - Represent alternate models with uncertain parameter(s), then apply parameter sensitivity methods
  - “Level-of-detail” and convergence studies
  - Various schemes for combining results across alternate models
- Qualitative methods
  - Influence diagrams, reasoned arguments
  - Informed by sensitivity analyses of PA results

Conservatisms

- Conservatisms are assumptions made to simplify PA models in such a way that system performance is not over-estimated (i.e. risk is not under-estimated)
- Judicious use of conservatisms enhances confidence in the safety case, but
- May also obscure understanding of the physical processes that contribute to system performance
- Conservatisms should be acknowledged and, where reasonable to do so, their effects evaluated

Conclusion

- Screening approach to reduce scope
- Identify and characterize model uncertainty in the safety case
  - During development of the performance assessment
- Evaluate key model uncertainties
  - Part of analysis of the performance assessment
- Address conservatisms
- Unproven process