U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Addressing Uncertainty at Yucca Mountain: Overview

Presented to:
Nuclear Waste Technical Review Board (NWTRB)

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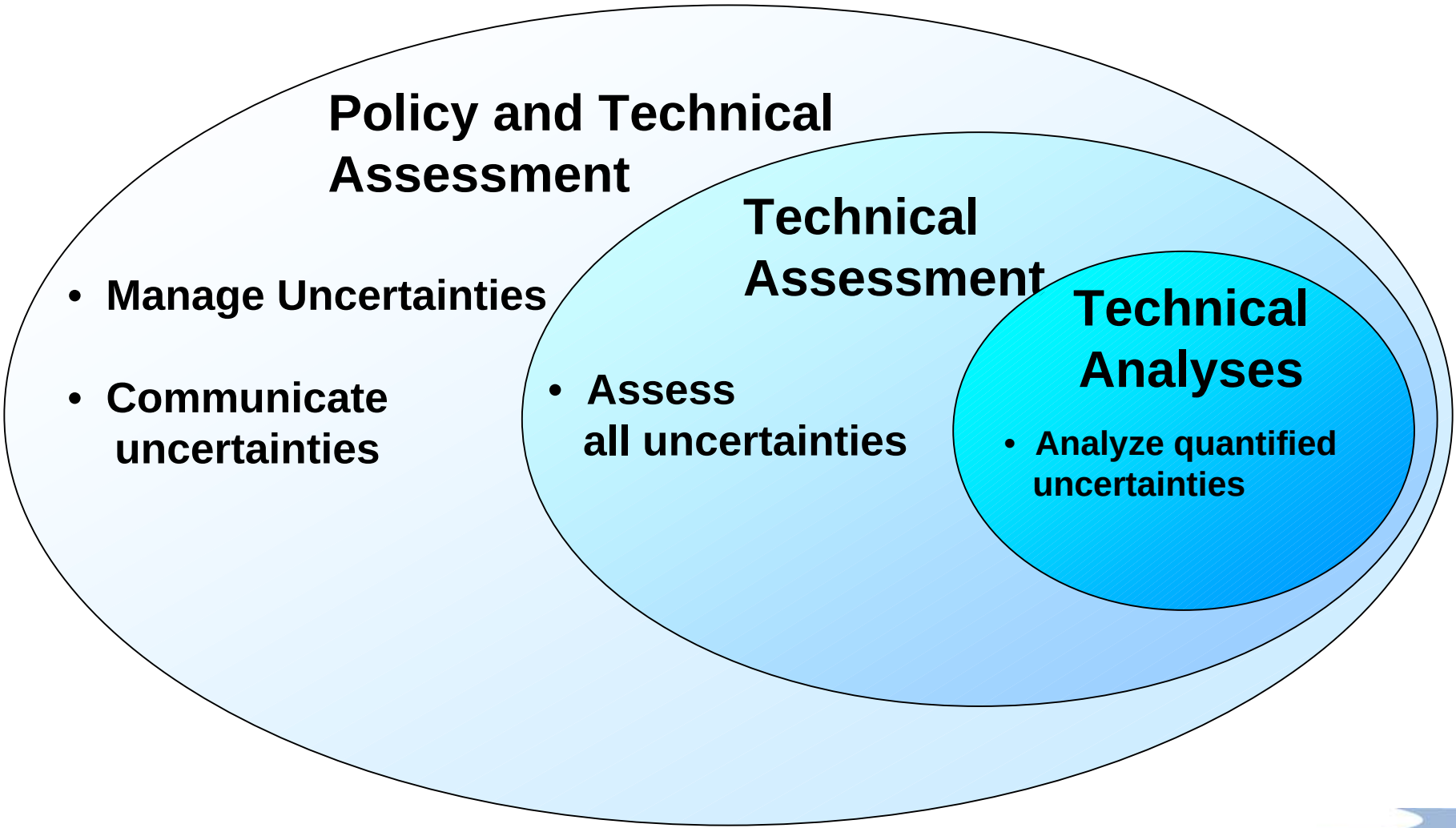
YUCCA MOUNTAIN PROJECT

Decision-Making in the Face of Uncertainty

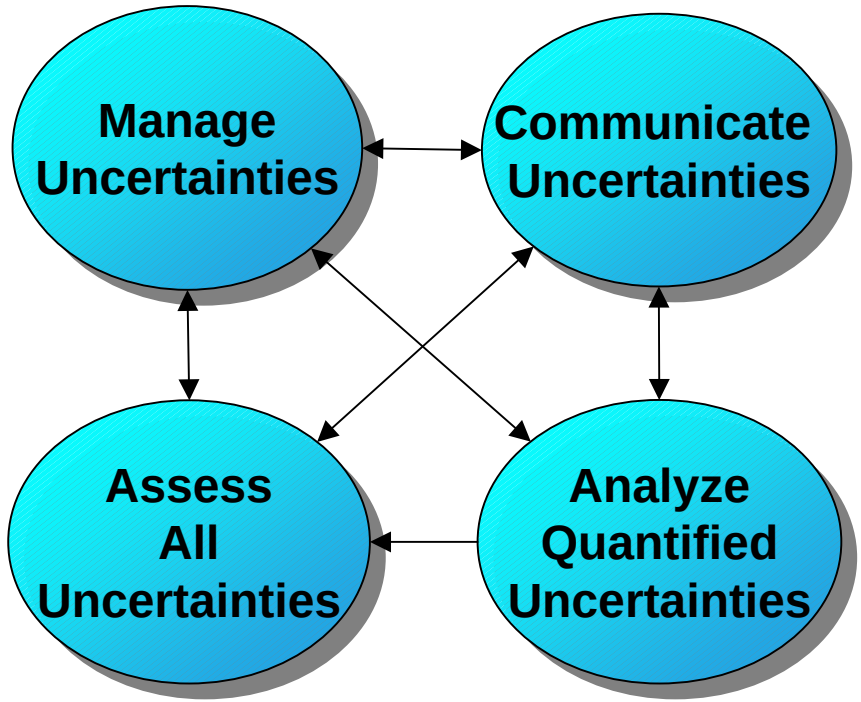


Uncertainties Affecting Postclosure Safety at Yucca Mountain

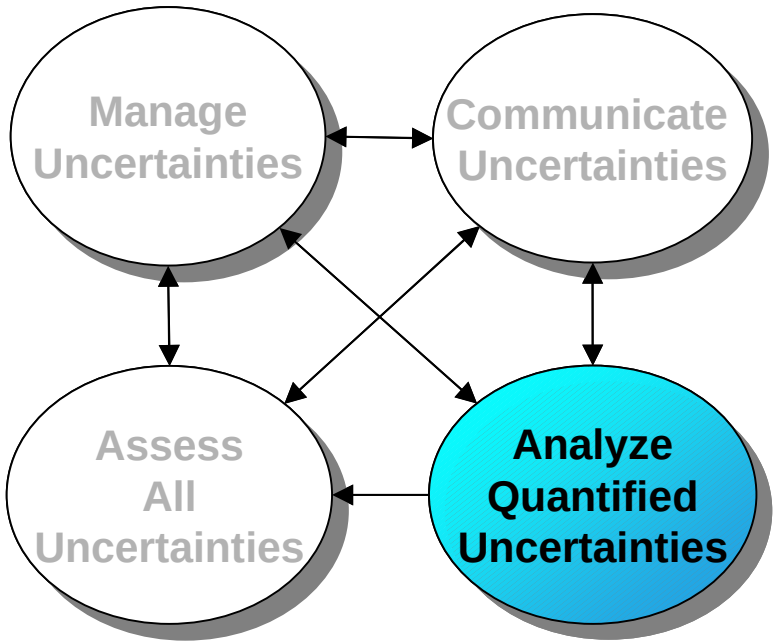
- **These uncertainties arise, for example, from**
  - **Complexity of processes**
  - **Variability and parameter uncertainty**
  - **Unanticipated failure mechanisms**
  - **Potential system evolution**
- **To support decision-making, DOE must**
  - **Identify sources of uncertainty and estimate their importance**
  - **Reduce or mitigate critical uncertainties**
  - **Assess effects of residual uncertainties**
- **The purpose here is to**
  - **Describe the DOE's approach to uncertainty**
  - **Show this approach involves not only evaluating expected performance, but also explaining the uncertainties**

DOE's Approach to Uncertainty

- The structure shown here illustrates the specific steps DOE takes in decision-making with regard to uncertainty
- These steps address both quantified and unquantified uncertainties
- The steps are iterative and began with the Yucca Mountain SCP and its Issue Resolution Strategy



Analyze Quantified Uncertainties



- **Analyses provide input to general assessment of uncertainties**
- **Through iteration, analyses are modified as a result of changes in strategy and feedback**
- **Analyses include**
  - **Explicit treatment of quantified uncertainties in TSPA**
  - **Sensitivity and importance analysis**

Explicit Treatment of Quantified Uncertainties in TSPA

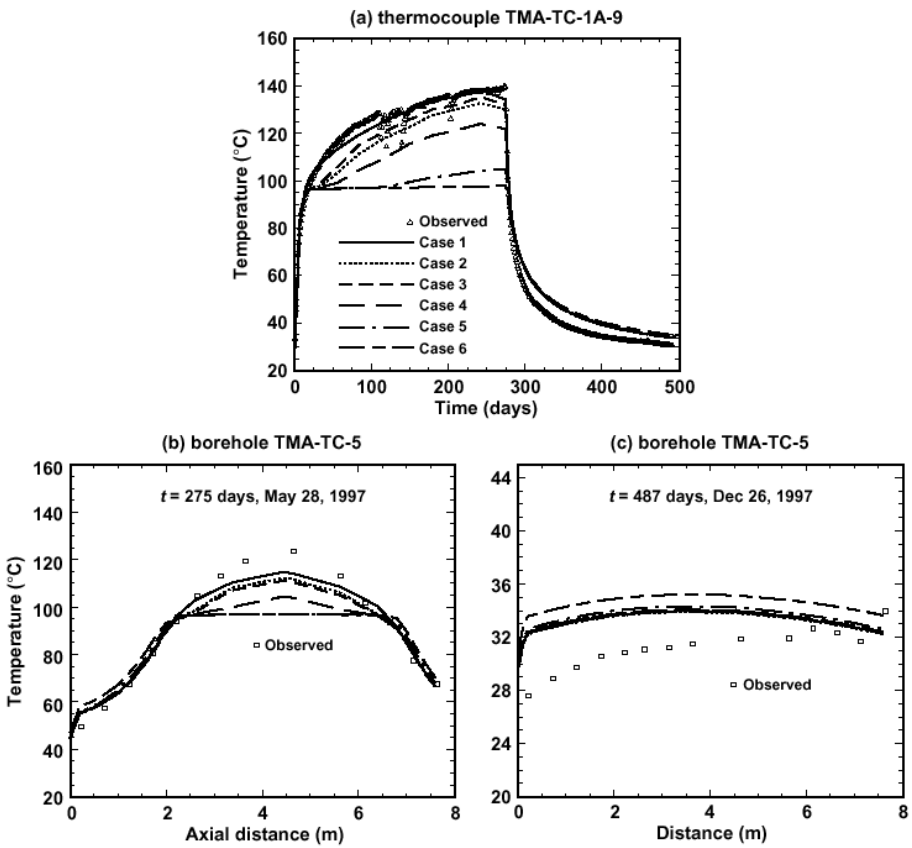
- **Uncertainties quantified and treated in TSPA**
  - **Process model complexity (e.g., conceptual and mathematical model uncertainty)**
  - **Variability and parameter uncertainty**
  - **Unanticipated failure mechanisms (e.g., potentially disruptive events)**
  - **Evolution of the system (e.g., uncertainty in future states of the system)**
- **This approach captures what is known--recognizes there are limits to the analysis**

Treating Conceptual and Mathematical Model Uncertainty

- **Test consistency of the mathematical model (e.g., compare mathematical model results against trends observed in process models)**
- **Reduce model uncertainty by testing alternative models against additional data**
- **Conduct analyses for alternate models to provide perspective on any choice of a preferred model**

Example: Test Alternative Models Against Additional Data

Single Heater Test

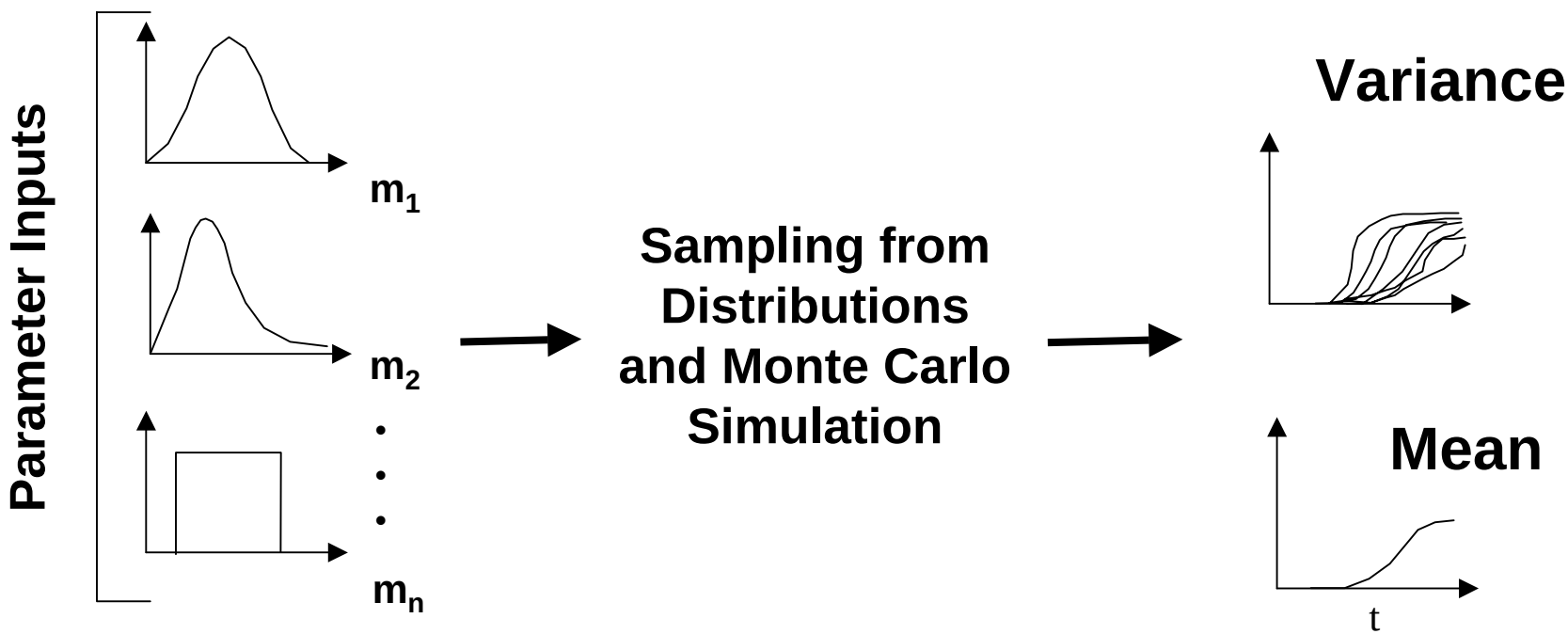


- **Note variation in results for different models (cases 1-6)**
- **Compare results of different models and parametrizations against specific experimental data**
- **Consider multiple tests to ensure model spans the full range of conditions**

Treating Input Parameter Uncertainty and Variability

- **Represent uncertainties in parameters (e.g., through probability distributions)**
- **Propagate these uncertainties through TSPA (e.g., Monte Carlo techniques)**
- **Assess impact of parameter uncertainty on the performance measure (i.e., annual dose) in terms of both expected (mean) and range (variance) of values**

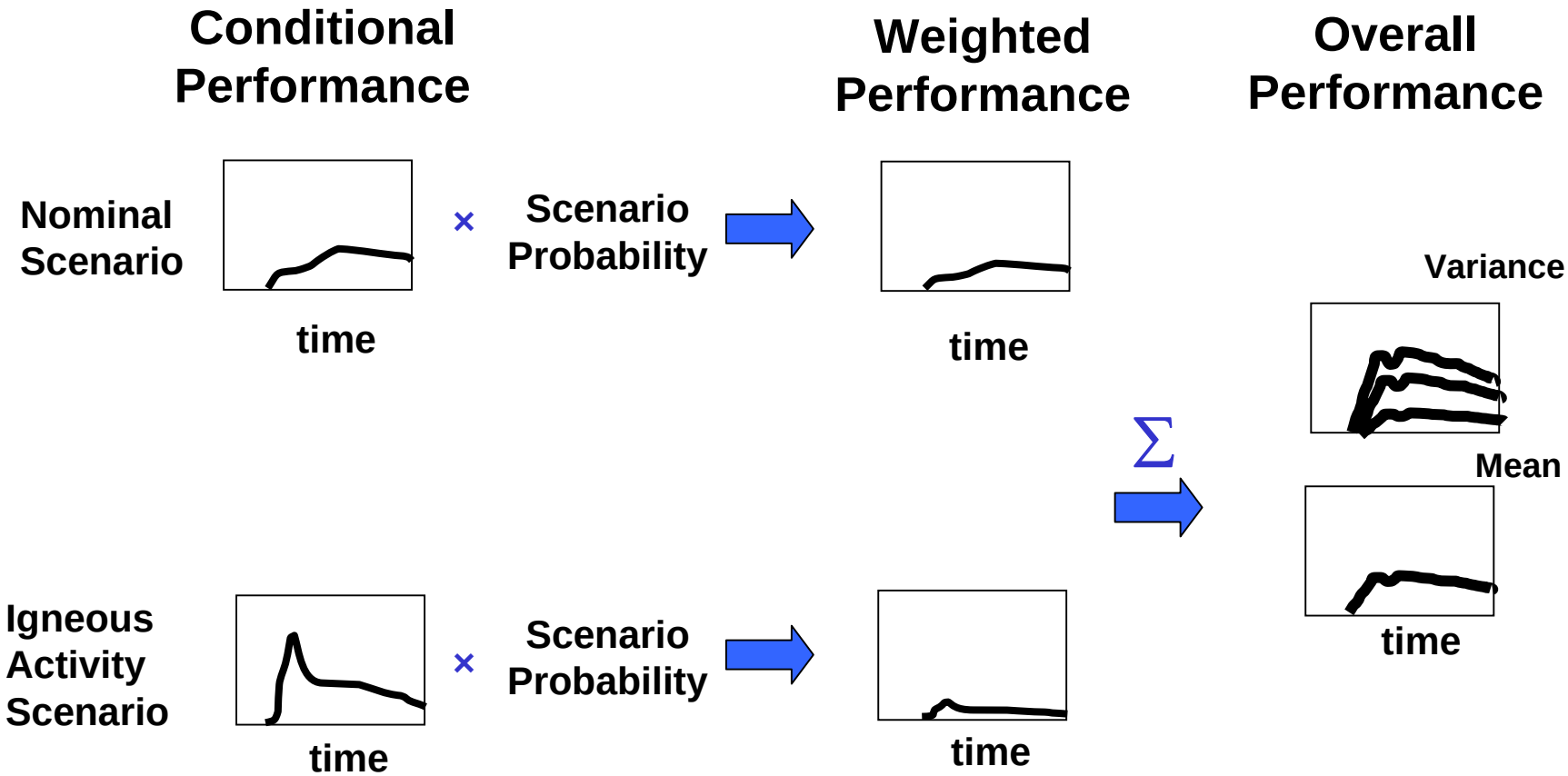
Example: Treatment of Input Parameter Uncertainty



Treating Potentially Disruptive Events and Future States Uncertainty

- **Identify relevant Features, Events, and Processes (FEPs)**
- **Screen FEPs and develop scenarios**
  - **Formulate nominal scenario and associated models and estimate scenario probability**
  - **Formulate disruptive events scenarios and associated models and estimate scenario probabilities**
- **Perform Monte Carlo simulation for individual scenarios and combine results into overall probability distribution**
- **Scenarios not constructed to represent all possibilities, but sufficient to evaluate significance**

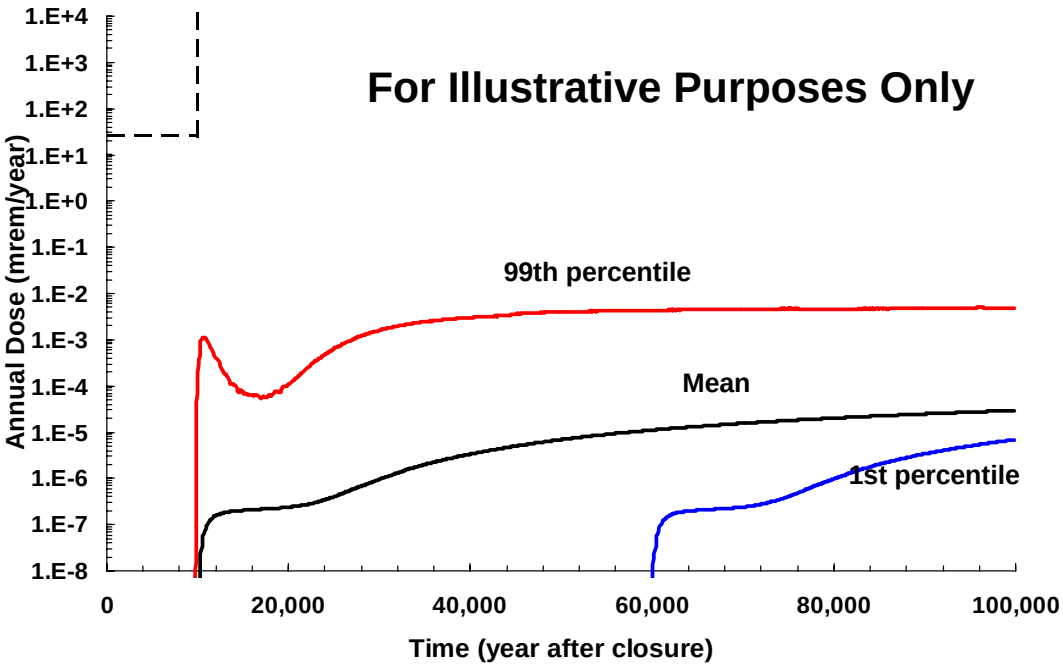
Example: Treatment of Potentially Disruptive Events Uncertainty



Sensitivity and Importance Analyses

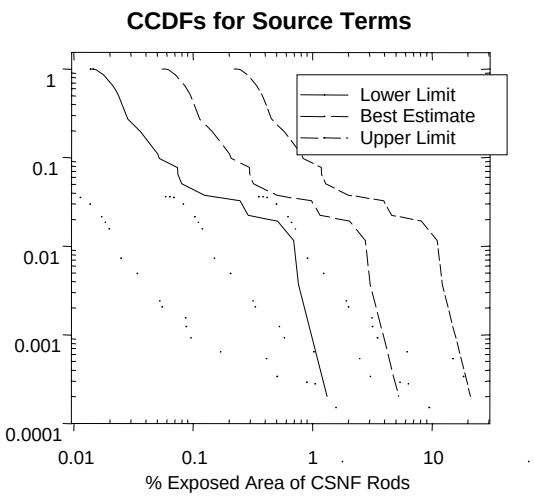
- **In addition to incorporating uncertainties quantitatively and propagating them through TSPA, insight and perspective are given through additional analyses that include**
  - **Analysis of variance in estimates of postclosure performance**
  - **Parameter sensitivity analysis to examine the effect of specific values**
  - **Trend analysis to examine when and where uncertainties accounted for in TSPA are important**
  - **Barriers importance analysis to examine specific contribution of individual barriers to TSPA results**

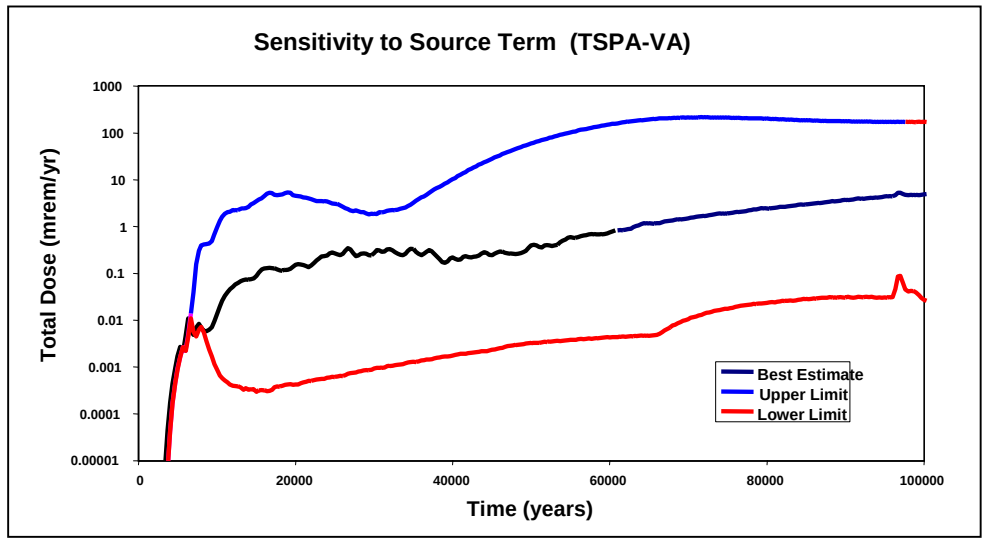
Example: Variance Analysis



- **Conduct analyses that span the range of uncertainty**
- **Review range of calculations**
- **Compare range against standards**

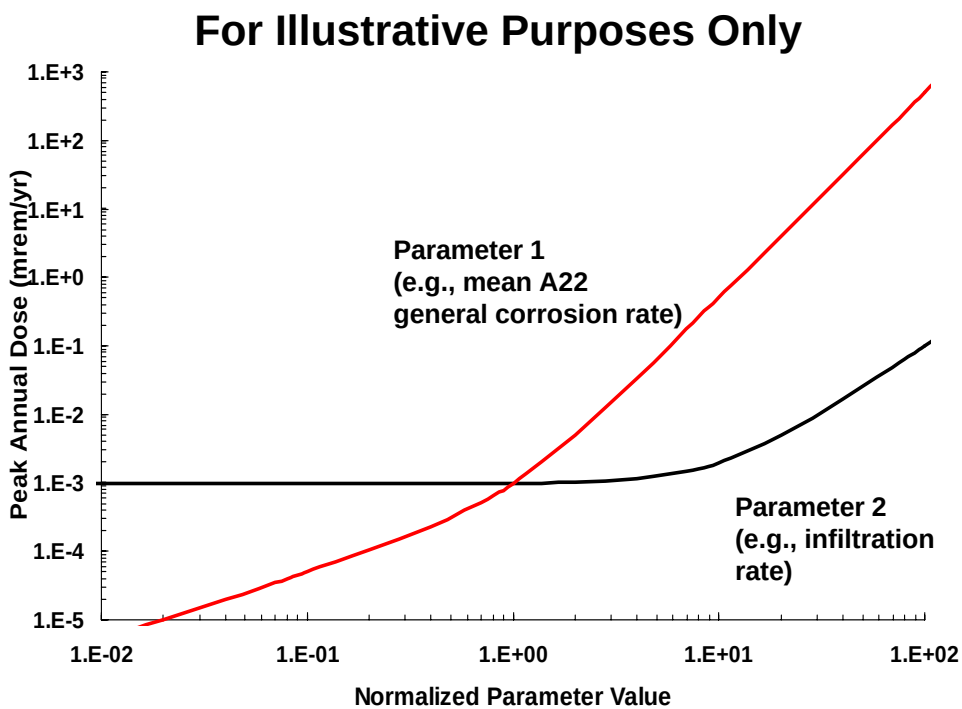
Example: Parameter Sensitivity Analysis





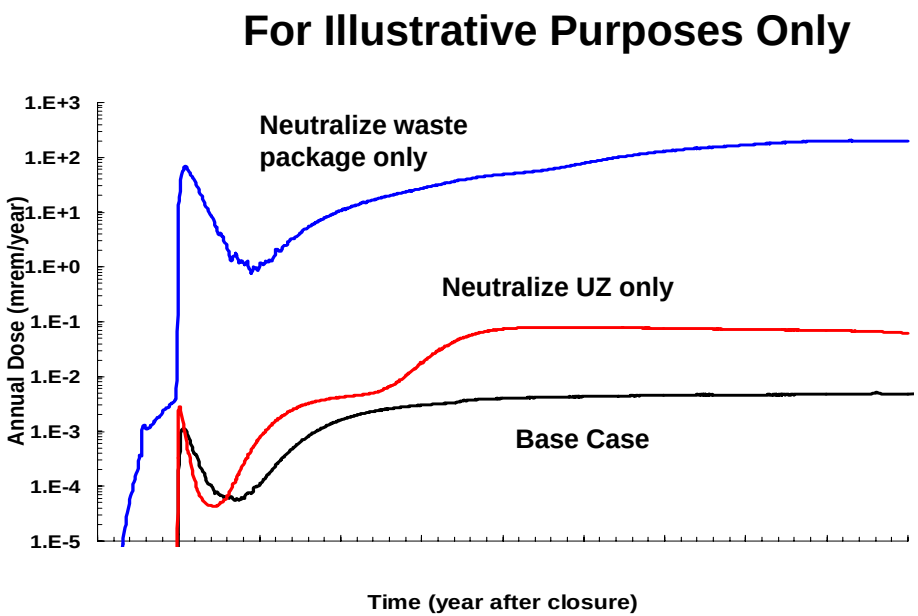
- **This is a specific example from VA--variances for each case not shown here**
- **Approach**
  - **Consider possible range of conditions**
  - **Evaluate set of specific conditions in that range**
  - **Consider "what-ifs" and evaluate specific cases**

Example: Trend Analysis



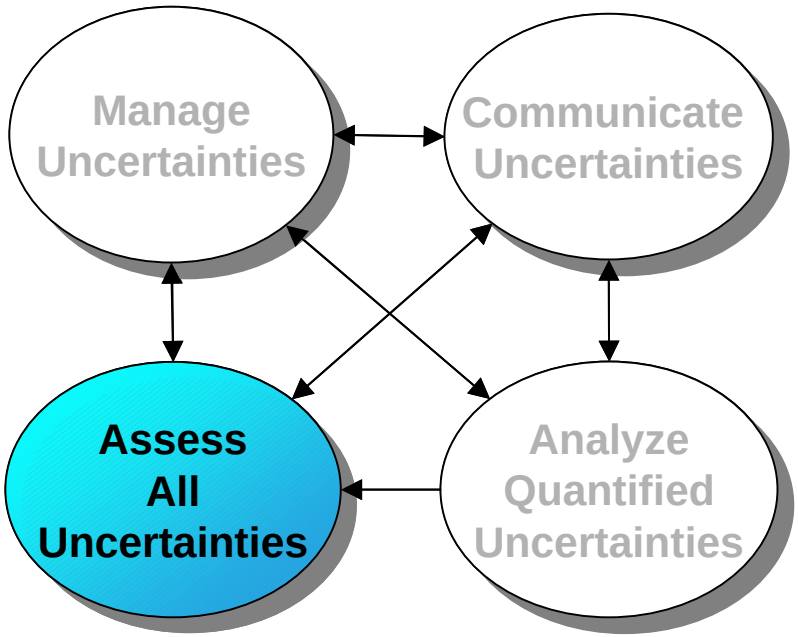
- **Consider range of uncertainty and compare to trend results**
- **Identify ranges where specific uncertainties may be important**
- **Also consider variations for parameters not at mean values**

Example: Barriers Importance Analysis



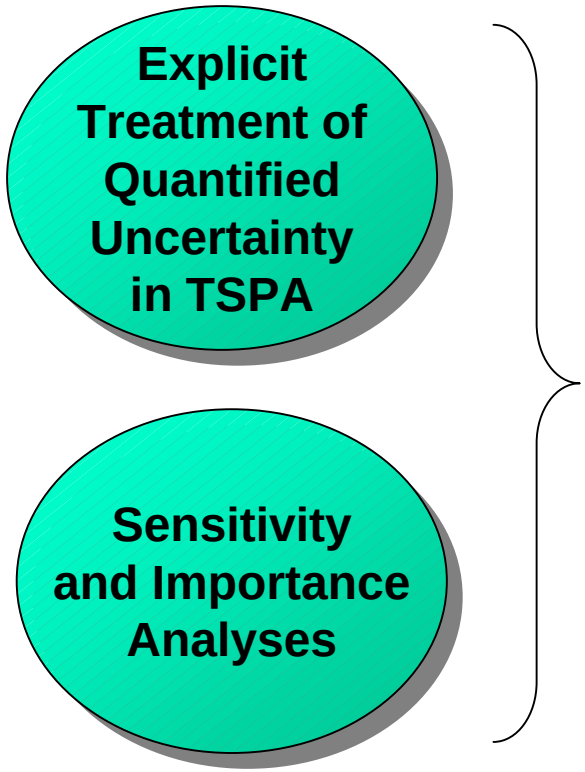
- **Barrier neutralization is only one approach**
- **Analyses will take into account variance in results**
- **General approach**
  - **Evaluate contribution of specific barriers to TSPA calculation**
  - **Identify barriers for which uncertainty may be important**
  - **Assess the specific sources of uncertainty for those barriers**

Assess All Uncertainties



- **Objective is to provide information to support uncertainty management strategy**
- **Key inputs include results of quantitative TSPA assessment and feedback**
- **Assessment includes**
  - **Evaluation of limits to TSPA analyses**
  - **Analysis of other (unquantified) uncertainties**

Assess TSPA Information and Limits to TSPA

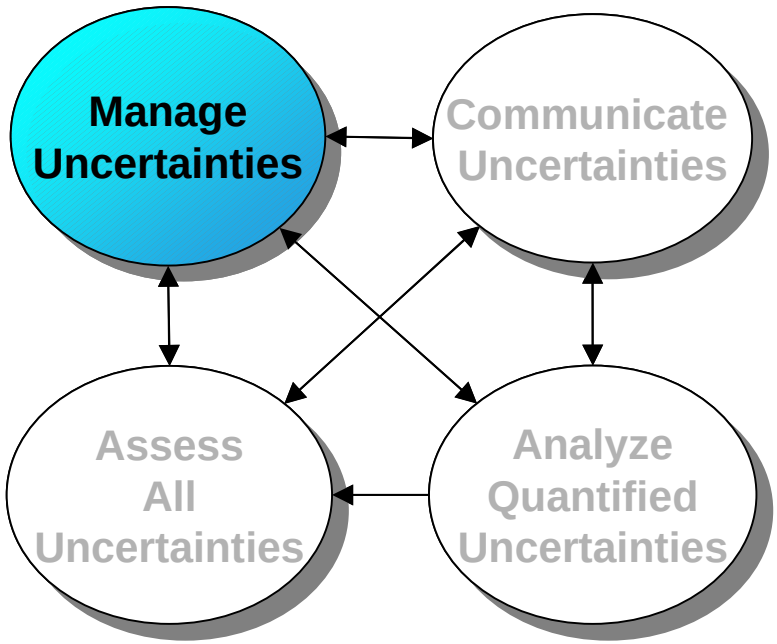


- **Synthesize and assess TSPA results**
- **Assess limits in the analyses (e.g., limits in models, probability estimates, scenario representations, etc.)**
- **Assess confidence in the models used in the analyses and importance of the uncertainties with respect to conclusions**

Assess Potential Importance of Other Uncertainties

- **Known, but unincorporated, uncertainties, e.g.,**
  - **Centimeter-scale heterogeneity**
  - **Nonlinear friction forces in flow and transport**
- **Potential for unknown unknowns, e.g.,**
  - **Unknown failure modes**
  - **Future evolution of the system**
- **Potential for surprises, e.g.,**
  - **New findings about site characteristics, materials behavior**
  - **Changes to representation of waste or conceptual design**

Manage Uncertainties



- **Objective is to determine the strategy for addressing uncertainties**
- **The strategy relies on the results of the uncertainty assessments**
- **It focuses on the Principal Factors**
- **It identifies the critical uncertainties and the the approach to reducing or mitigating them**

Evaluate Options for Addressing Uncertainties

- **Identify areas where uncertainties are not critical**
- **Identify options for reducing or mitigating uncertainties that are critical**
- **Evaluate combinations of such options to address all critical uncertainties against such factors as**
  - **Magnitude and importance of uncertainties**
  - **Introduction of new problems/uncertainties**
  - **Feasibility of the options**
  - **Effectiveness in addressing the uncertainties**
  - **Demonstrability**
  - **Cost for each option**

Identifying Options to Address Uncertainties

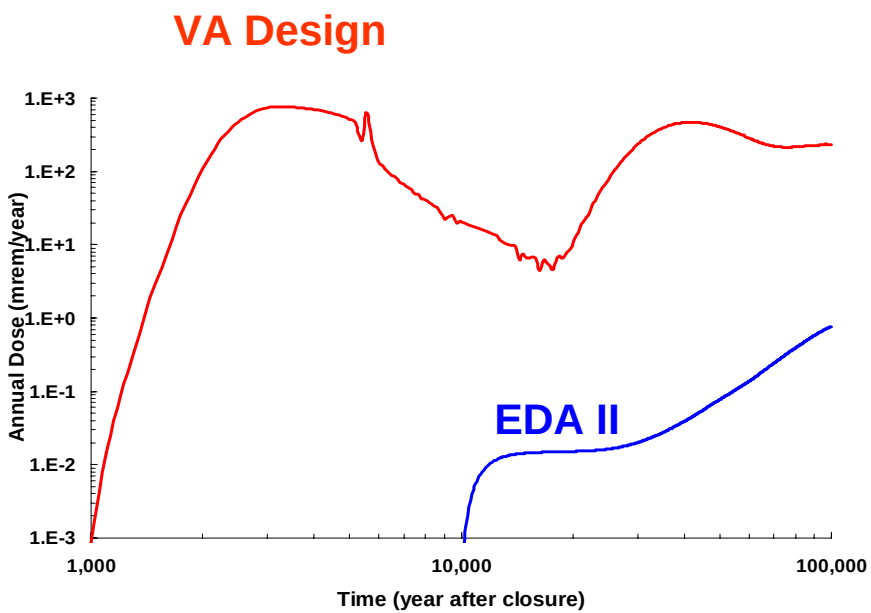
- **Options for reducing or mitigating uncertainty**
  - **Additional information**
  - **Credit/conservatism in the analyses**
  - **Design enhancement to reduce sources of uncertainty or increase safety margin and defense-in-depth**
- **Other measures to build confidence**
  - **Explicit discussion of key disruptive events**
  - **Insights from natural analogues**
  - **Commitment to specific future confirmation tests**
- **Select sets of options and identify principal factors for each one**

Examples

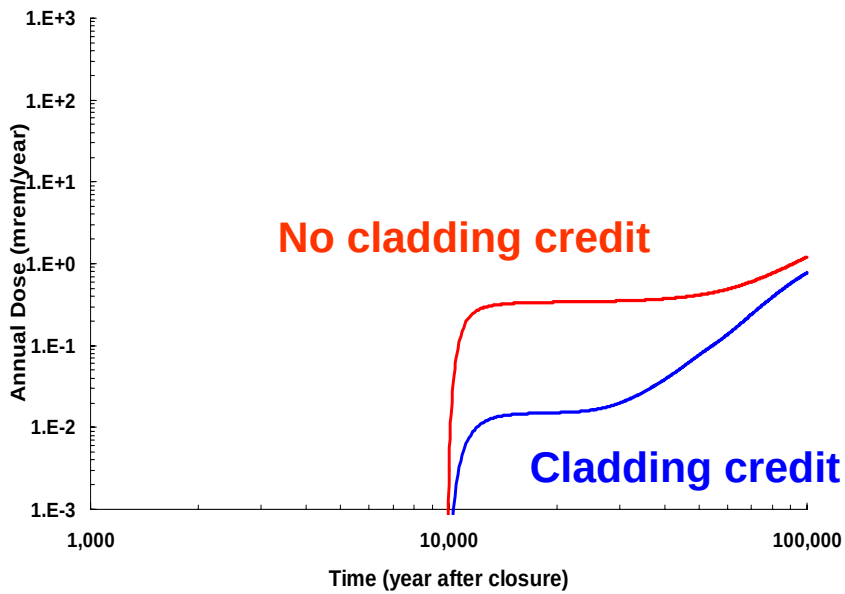
- **Option 1**
  - Cladding credit
  - Waste package + drip shield
  - Dilution in UZ and SZ
- **Option 2**
  - No cladding credit
  - Waste package only
  - Retardation in valley fill alluvium
- **Considerations**
  - Benefits of cladding vs uncertainties in condition at receipt and localized corrosion for pH < 6 and cost to acquire additional needed data
  - Defense-in-depth benefits of drip shield vs cost and additional uncertainties introduced
  - Benefits of credit for dilution, retardation vs. adequacy of data to defend models and cost to acquire additional needed data

Selection of the Strategy Involves Analyses to Confirm Effectiveness of Approach

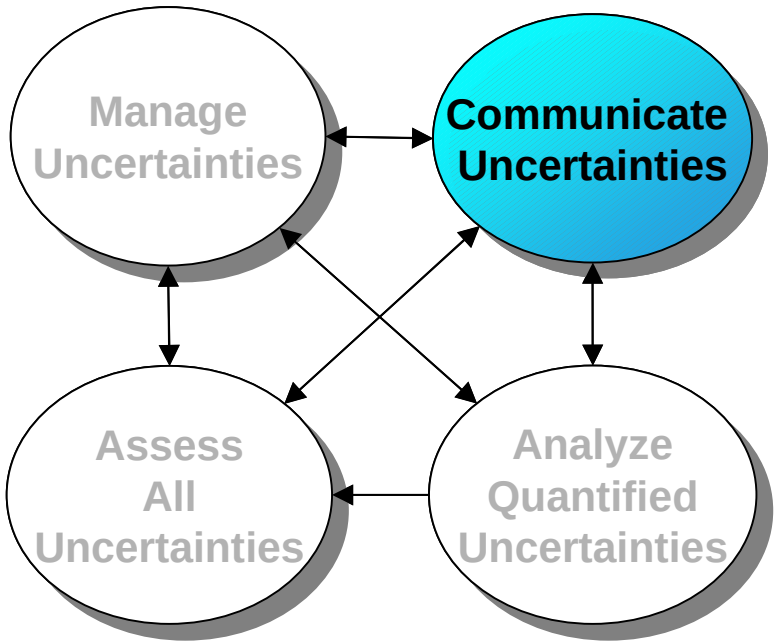
Example: Examine degree of reliance on waste package by neutralizing all waste packages



Example: Evaluate benefits of cladding credit



Communicate Uncertainties



- **Objective is communicate the results of the uncertainty assessment and the approach to uncertainty management to decision makers and other interested parties**
- **Objective is also to get feedback**
- **Communicate in a variety of ways and to a variety of audiences**

Communicating the Uncertainty Assessment and the Uncertainty Strategy

- **Identify sources of uncertainty, magnitudes, potential impacts on postclosure performance**
  - **Quantitative assessment results**
  - **Comprehensive assessment results**
- **Provide information regarding**
  - **Credit/conservatism in TSPA**
  - **Safety margin and defense-in-depth**
  - **Explicit treatment of potentially disruptive processes and events**
  - **Natural analogues**
  - **Performance confirmation**

Formats for Communicating Uncertainty

- **Formal documentation**
  - **AMRs--uncertainties in individual models**
  - **PMRs--roll-up of uncertainties in process models**
  - **TSPA-SR report--treatment of quantified uncertainty in TSPA**
  - **RSS--uncertainty assessment and uncertainty strategy**
- **Specific plans for providing information to decision-makers as well as other interested parties (e.g., State and local leaders and Nevada citizens)**
- **Communications with NWTRB, review groups, field trips, Appendix 7 meetings with NRC staff, etc.**
- **We continue to explore means of communicating with technical and non-technical audiences**

Summary

- **We are evaluating uncertainties and are getting more comprehensive about it over time**
- **We will evaluate not only expected performance, but also uncertainties in that performance, including both quantified and unquantified uncertainties**
- **We will explain the uncertainties and what we are doing about them to audiences at many levels**
- **We recognize the approach to uncertainty must be adequate to build confidence that the system will protect public health and safety despite that uncertainty**