Repository Safety Strategy - Introduction to Model Validation

Presentation to:
Nuclear Waste Technical Review Board (NWTRB)

Presentation by:
Robert W. Andrews
Manager, Performance Assessment Operations
Management and Operating Contractor

Alexandria, VA
September 14-15, 1999

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

Yucca Mountain Project

Outline

- Definitions of “validation”
- Regulatory and QA requirements for “validation”
- Lessons learned from international validation efforts
- Regulatory and NWTRB Perspectives
- Approaches to Develop Confidence in the
  - Repository Safety Case
  - Performance Assessment
  - Models

Validation - Some Definitions

- **"a process carried out by *comparison of model predictions with field observations and experimental measurements*"**
  - **A model is considered validated when sufficient testing has been performed to ensure an *acceptable level of predictive accuracy* over the range of conditions over which the model may be applied**
  - **Note that the *acceptable level of accuracy* is judgmental and *will vary depending on the specific problem or question to be addressed* by the model (IAEA)**
- **"a somewhat *subjective* assessment of likely suitability in the intended environment" (Oxford Dictionary of Computing)**

Regulatory Perspectives on Acceptable Level of Accuracy

- **“reasonable assurance” (Part 63)**
  - **“proof . . . is not to be had in the ordinary sense of the word”**
  - **“demonstrating compliance will involve the use of complex predictive models that are supported by limited data . . . that may be supplemented with prevalent expert judgment”**
- **“reasonable expectation” (Part 197)**
  - **“requires less than absolute proof because absolute proof is impossible to attain”**
  - **“takes into account the inherently greater uncertainties in making long-term projections of the performance”**

DOE QA Requirements Document

III.2.6 Model Development and Use

E. Models of natural phenomena shall be *validated to a level determined by the intended uses of the model.*

F. Model validation shall be accomplished by *comparing analysis results against data acquired from laboratory, field experiments, natural analogue studies, or subsequent relevant observations.*

1. When data are not available from these sources, alternative approaches shall be documented and used for model validation.

International Model Validation Efforts

- **INTRAVAL (1987 - 1993)**
  - » **International Transport Model Validation**
    - ¤ **focussed on geosphere flow and transport models**
- **CHEMVAL (1987 - 1993)**
  - » **Validation and Verification of Geochemical Models**
    - ¤ **focussed on speciation and reactive chemical transport models**
- **BIOMOVS (1986 - present)**
  - » **Biosphere Model Validation Study**
    - ¤ **focussed on environmental transfer of radionuclides models**
- **DECOVALEX (1991 - present)**
  - » **Development of Coupled Models and their Validation against Experiments**
    - ¤ **focussed on near-field T-M-H models**

Lessons Learned from International Model Validation Efforts

- **Validation is difficult**
- **Thorough understanding of processes is required**
- **Comparison with experimental results enhances confidence**
- **Integrated performance measures may be a more useful comparison between observed and predicted results**
- **Insights are gained by comparing several different conceptual models**

Model Validation - Regulatory Perspective[1]

- **Level of confidence required for a particular PA model is tied to the importance of the model to the licensing decision**
- **Exact prediction is neither expected nor required. Goals of model validation are to:**
  - **Establish adequacy of model's scientific basis**
  - **Demonstrate model is sufficiently accurate for its intended use**

[1] NRC, SKI, CNWRA, 1999. "Regulatory Perspectives on Model Validation in High-Level Radioactive Waste Management Programs: A Joint NRC/SKE White Paper (NUREG-1636)

Model Validation - Regulatory Perspective[1]

(Continued)

- **Validation strategy should consist of:**
  - **Defining compliance demonstration strategy**
  - **Determining goals for model validation**
  - **Determining existing degree of validation**
  - **Comparing goals with existing degree of validation**
  - **Deciding whether to revise compliance demonstration strategy**
  - **Obtaining additional information to support validation, if needed**

[1] NRC, SKI, CNWRA, 1999. "Regulatory Perspectives on Model Validation in High-Level Radioactive Waste Management Programs: A Joint NRC/SKE White Paper (NUREG-1636)

Comparison of NRC/SKI Model Validation Strategy and DOE's Implementation

NRC/SKI Validation Strategy	DOE's Implementation
Define compliance demonstration strategy	VA Vol 4; Repository Safety Strategy Rev 03
Determine goals for model validation	VA Vol 4; Repository Safety Strategy Rev 03; Goals depend on significance to safety case
Determine existing degree of validation	VA Vol 4; VA Technical Basis Documents; SR Process Model Reports
Compare goals with existing degree of validation	VA Vol 4
Decide whether to revise compliance demonstration strategy	Design modified; Repository Safety Strategy Rev 03
Obtain additional information to support validation	On-going testing; Revised AMRs and PMRs

Confidence Building - NWTRB Insights

- **More robust decisions can be made if**
  - **Uncertainties are fully and accurately addressed**
  - **Sensitivity studies are carried out to show the effects of different assumptions**
  - **Compliance is shown with a margin of safety**
- **Identify how the PA conclusions will be used to make decisions**
- **PA should be transparent, i.e.,**
  - **Assumptions used in analyses, their basis, and their effects are clearly and explicitly stated**
  - **Key parameters are traceable to data**
  - **TSPA has undergone an independent outside review**

Levels of Confidence in Evaluating Suitability

- **Confidence in the repository safety case**
- **Confidence in the performance assessment used within the safety case**
- **Confidence in the models used within the performance assessment**
- **Confidence in the data and information used within the models**

Approach to Develop Confidence in the Repository Safety Case

- **Robustness of the system concept**
  - **Margin of safety**
  - **Defense-in-depth/multiple barriers**
  - **Sensitivity analyses**
- **Quality of the safety assessment and reliability of the performance assessment**
  - **Well-defined PA approach that ensures transparent and traceable analyses and documentation**
  - **Component models that contribute to safety with high confidence**
  - **Relevant data, their uncertainty, and opposing views have been considered**
  - **Results are fully disclosed and subjected to QA and review**

Approach to Develop Confidence in Performance Assessment

- **Identify levels of importance of model in demonstrating compliance**
- **Identify degree of validity or confidence in component models**
  - **assure that models have been adequately tested**
- **Identify range of reasonable model alternatives (features, events and processes)**
- **Conduct subsystem or component screening of model uncertainty significance**

Approach to Develop Confidence in the Performance Assessment

(Continued)

- **Identify reasonable (or conservative) ranges of parameters**
- **Conduct subsystem or component screening of parameter uncertainty significance**
- **Evaluate robustness of system performance to uncertainties in models and parameters**
  - **determine barrier significance**
- **Document assessments in a manner suitable to assure transparency and traceability**

Developing Confidence in the TSPA

Regulatory Objectives

NRC-10 CFR Part 63
EPA-40 CFR Part 197
DOE-10 CFR Part 960

Technical Objectives/Criteria

NRC IRSR Acceptance Criteria; Observations on TSPA-VA
NWTRB Comments on VA
DOE Repository Safety Strategy
DOE and USGS Reviews of TSPA-VA
TSPA-VA Peer Review Suggestions
State of Nevada; Affected Units of Local Government
Public

Prior TSPAs

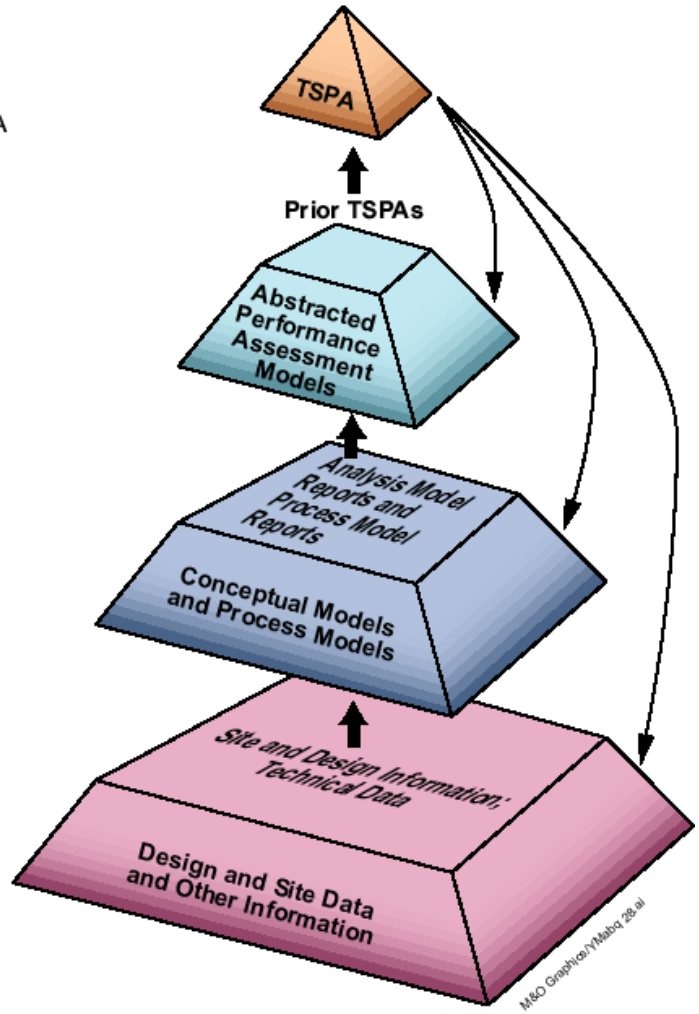
DOE TSPA-91, 93, 95, TSPA-VA, TSPA-DEIS
NRC IPA-1, -2, -3.1, -3.2
EPRI TSPA Phases 1, 2, and 3

Process Model Reports

Integrated Site Model
Unsaturated Zone Flow and Transport Model
Near-Field Enviroment Model
Engineered Barrier System Degradation Model
Waste Package Degradation Model
Waste Form Degradation Model
Saturated Zone Flow and Transport Model
Biosphere Model
Tectonics Model

Site and Design Information

Site Description Document
Repository Design
Waste Package Design
Laboratory Data
In situ Data
Analog Data



Approaches Used to Develop Confidence in Models[1]

- Identify theoretical support for models
  - May include more mechanistic models of processes
- Laboratory experiments
  - Controlled environment
  - Controlled variability
- Field tests
  - Large spatial scales
- Natural analogues
  - Large spatial and temporal scales
- Peer review

[1] Appropriateness depends on type of model

Conclusions

- **Model validation is a process of providing increasing levels of confidence commensurate with the models' importance**
- **Basic tenets of model validation approach identified in NRC white paper and NWTRB suggestions have been included in DOE's Safety Case**
- **Examples of details of implementation of validation approach for two components of TSPA-SR will be presented**
  - **Unsaturated zone flow model (Bo Bodvarsson)**
  - **Waste package corrosion models (Joe Farmer)**

Back-Up Slides

- **Regulatory Requirements**
  - **Reasonable assurance**
  - **Reasonable expectation**

Reasonable Assurance
10 CFR 63.101

(2) Although the performance objective for the geologic repository after permanent closure specified at Sec. 63.113 is generally stated in unqualified terms, it is not expected that complete assurance that the requirement will be met can be presented.

- **A reasonable assurance . . . that the performance objective will be met is the general standard that is required**

Reasonable Assurance
10 CFR 63.101
(Continued)

- **Proof that the geologic repository will be in conformance with the objective for postclosure performance is not to be had in the ordinary sense of the word because of the uncertainties inherent in the understanding of the evolution of the geologic setting, biosphere, and engineered barrier system**
- **For such long-term performance, what is required is reasonable assurance, making allowance for the time period, hazards, and uncertainties involved, that the outcome will be in conformance with the objective for postclosure performance of the geologic repository**

Reasonable Assurance
10 CFR 63.101
(Continued)

- **Demonstrating compliance will involve the use of complex predictive models that are supported by limited data from field and laboratory tests, site-specific monitoring, and natural analog studies that may be supplemented with prevalent expert judgment**
- **Further, in reaching a determination of reasonable assurance, the Commission may supplement numerical analyses with qualitative judgments including, for example, consideration of the degree of diversity among the multiple barriers as a measure of the resiliency of the geologic repository**

Reasonable Expectation
40 CFR 197.14

Reasonable expectation means that the Commission is satisfied that compliance will be achieved based upon the full record before it. Reasonable expectation:

(a) Requires less than absolute proof because absolute proof is impossible to attain for disposal due to the uncertainty of projecting long-term performance;

(b) Is less stringent than the reasonable assurance concept that NRC uses to license nuclear power plants;

Reasonable Expectation
40 CFR 197.14
(Continued)

(c) Takes into account the inherently greater uncertainties in making long-term projections of the performance of the Yucca Mountain disposal system;

(d) Does not exclude important parameters from assessments and analyses simply because they are difficult to precisely quantify to a high degree of confidence; and

(e) Focuses performance assessments and analyses upon the full range of defensible and reasonable parameter distributions rather than only upon extreme physical situations and parameter values.