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

Review of Uncertainty in the Models Supporting the TSPA-SR: Status Report

Presented to:
Nuclear Waste Technical Review Board

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August 2, 2000

YUCCA MOUNTAIN PROJECT

Decision-Making in the Face of Uncertainty

- Decision-making in the face of uncertainty is a worldwide challenge (Nuclear Energy Agency:"Geologic Disposal of Radioactive Waste, Review of Developments in the Last Decade," 1999, Paris, p. 20):
  - "It is appreciated that decision making requires only that the technical arguments, including performance assessment and arguments that give confidence in its findings, are adequate to support the decision at hand, and that an efficient strategy exists to deal at future stages with uncertainties that may compromise feasibility and long-term safety."

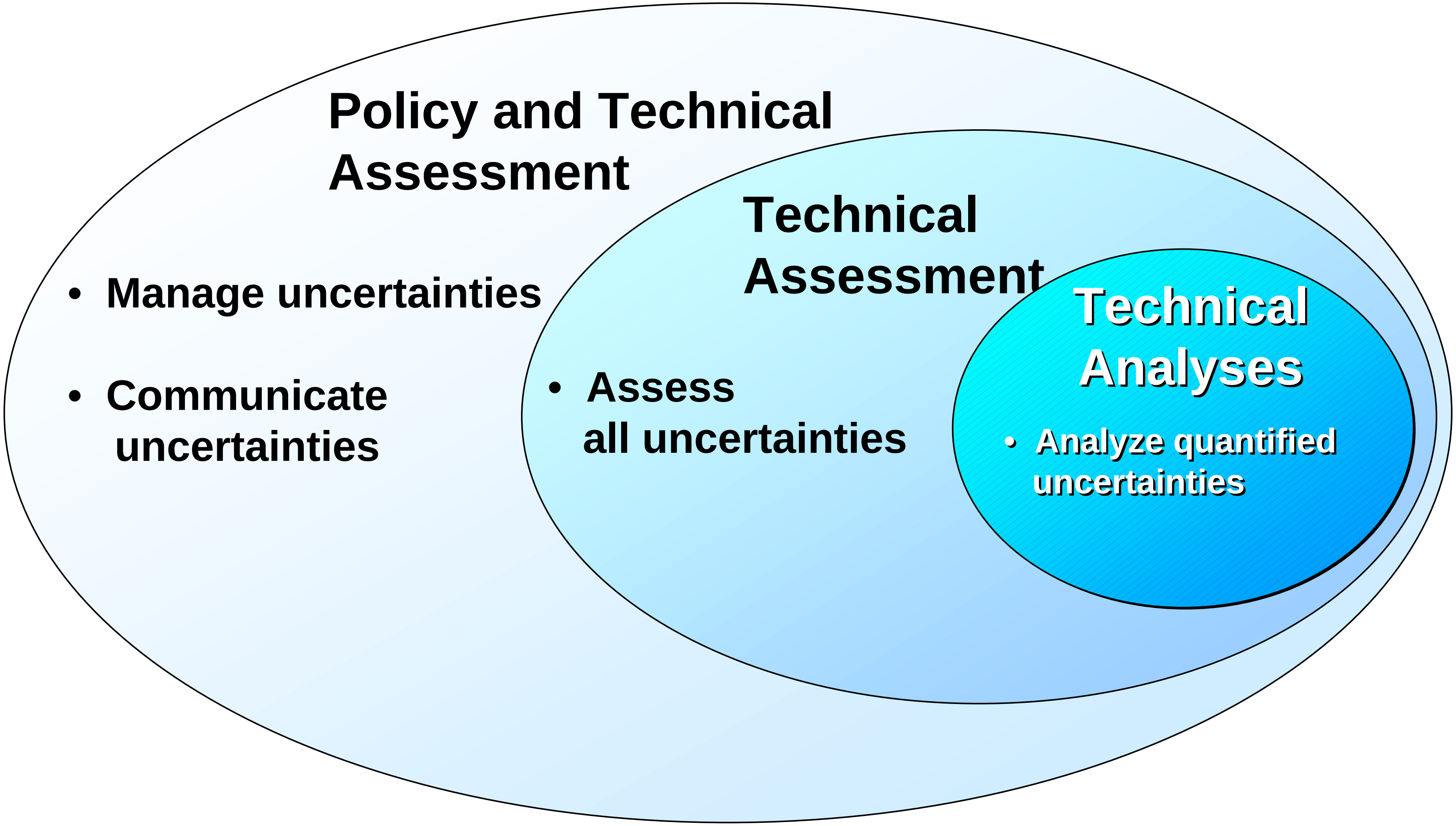
Decision-Making in the Face of Uncertainty

(Continued)

- DOE is following this logic in the construction of its SR
  - System performance is being estimated
  - Quantified uncertainties are being evaluated
- A Repository Safety Strategy that discusses confidence and steps forward is being updated

Decision-Making in the Face of Uncertainty

Focus of This Presentation is On Technical Analyses



Overview of Uncertainty Treatment

- In January 2000, DOE outlined our uncertainty approach
  - Identify sources of uncertainty; and treat quantitatively, qualitatively, or with conservative bounds
  - Manage uncertainties, considering their impact and importance
  - Reduce or mitigate critical uncertainties
  - Assess effects of residual uncertainties
- DOE, MTS, and M&O are examining the implementation and effectiveness of this approach
  - Identify where uncertainties and variability have been included in overall performance assessment (see previous presentations)
  - Identify how all uncertainties have been treated at the process model and abstraction level : September, 2000
  - Evaluate uncertainty treatment and develop recommendations : November, 2000

Overview of Uncertainty Treatment
(Continued)

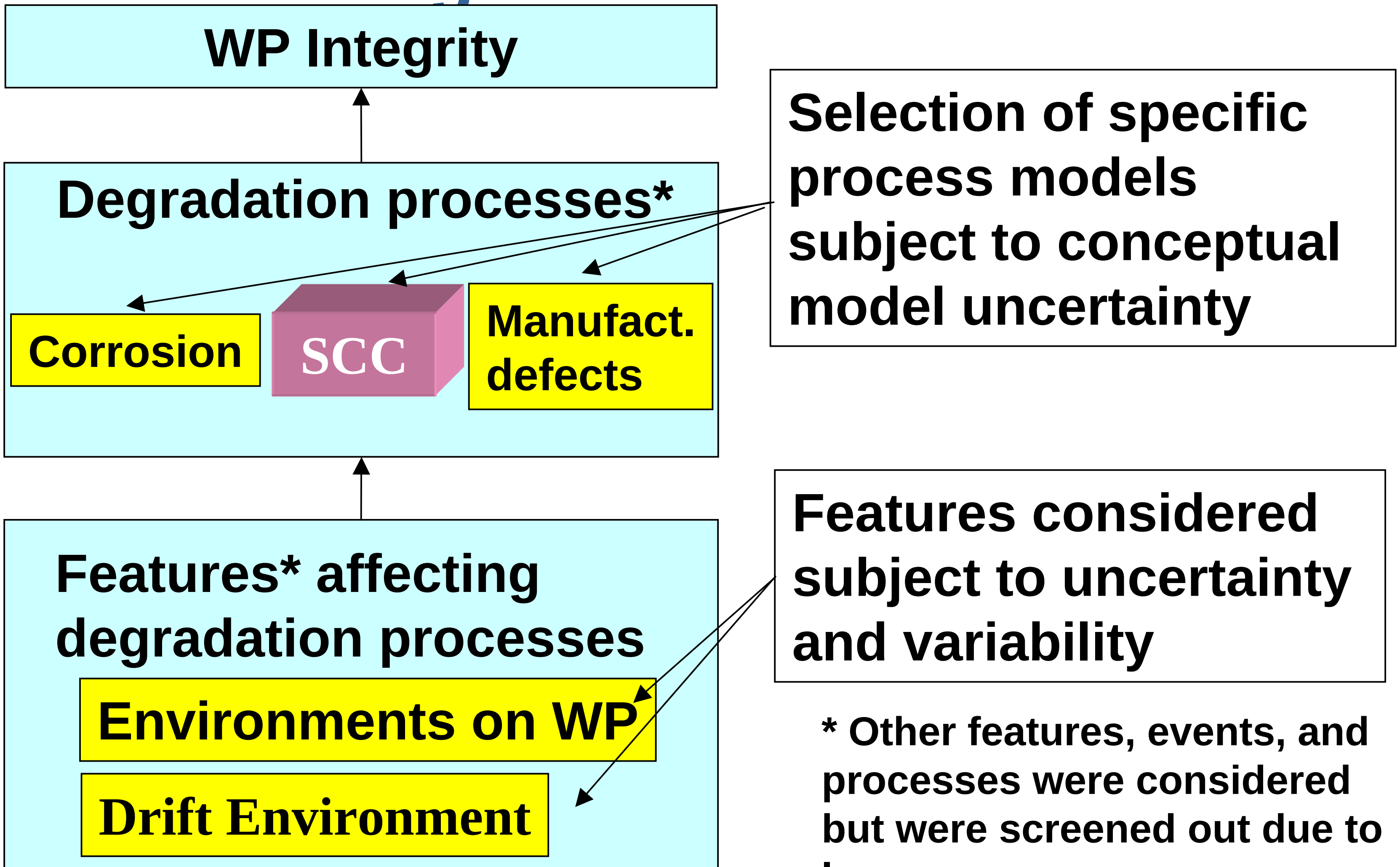
- **A bottoms-up approach is being used to evaluate uncertainty treatment in the process models and abstractions, including:**
  - **Alternative conceptual models: choice of a preferred model using physical arguments, or through comparisons with test data**
  - **Parameter distributions using Project data or published data**
  - **Spatial-extrapolation/time-scale issues (e.g., correlations between measured data and needed data)**
  - **Partitioning of variability and uncertainty**

Overview of Uncertainty Treatment
(Continued)

- Temporal and spatial boundary conditions
- Assumptions/judgments
- Use of data bounds
- Use of conservative estimates
- FEPs (features, events, and processes) screening of low probability/low consequence scenarios

- **Current review includes both quantified and unquantified uncertainties**
- **This presentation is a status report focusing on two detailed examples of the treatment of uncertainties**

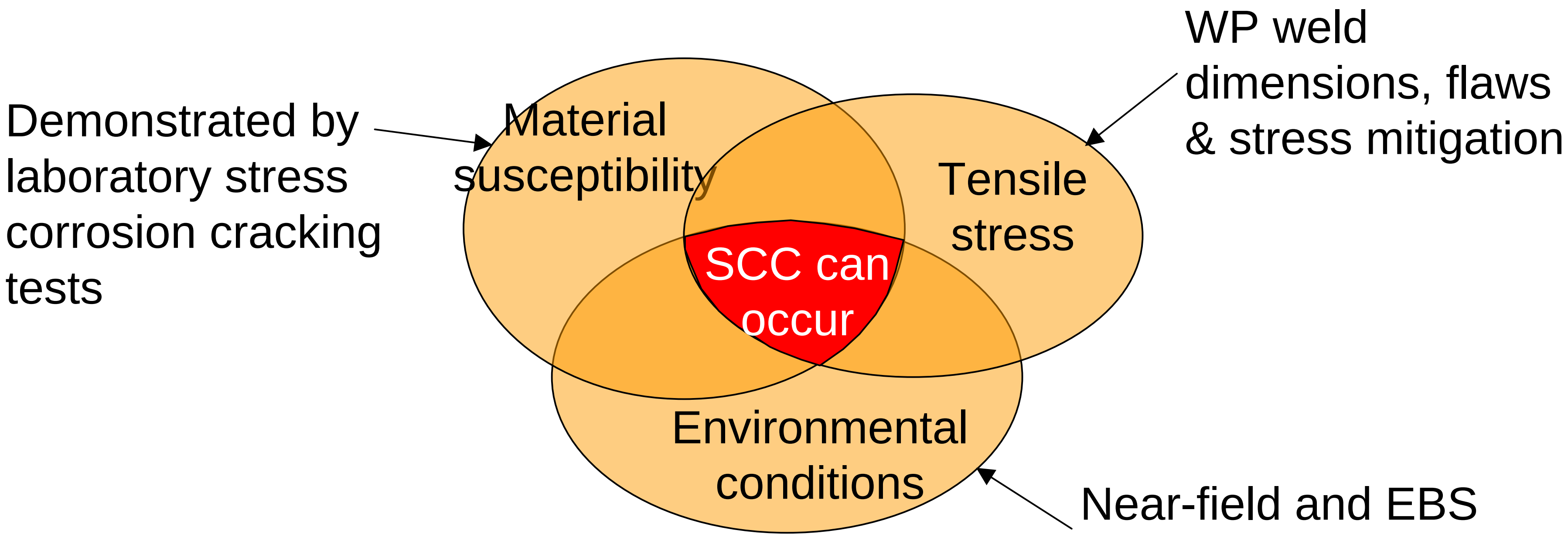
Example 1: Uncertainties in WP Degradation Processes



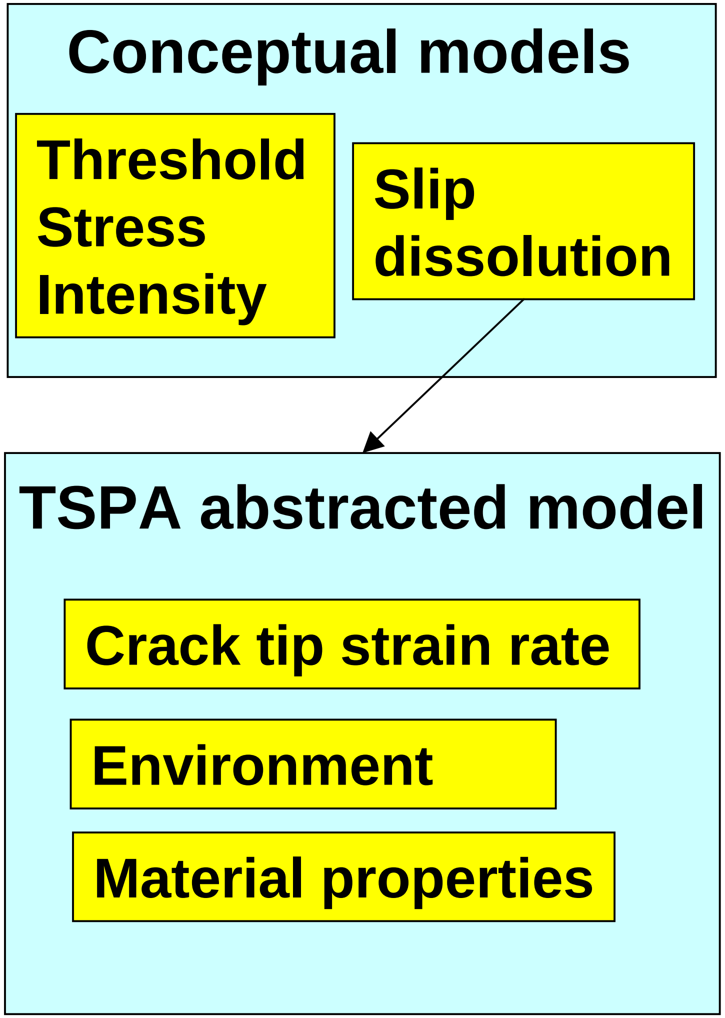
* Other features, events, and processes were considered but were screened out due to low consequences or probability

Process Model Uncertainty: Stress Corrosion Cracking (SCC)

- **SCC is the most significant failure mechanism for the WP**
- **SCC requires an overlap of three conditions**
  - **Inputs from NFE model, manufacturing defects model**



Evaluation of Alternative Conceptual Models for Crack Growth



Model 1: Threshold stress intensity

- Cracks propagate when stress intensity is above a threshold

Model 2: Slip dissolution

- SCC occurs when passive film on material repetitively slips, ruptures, and reforms due to applied strain in underlying matrix

Slip dissolution model used in abstraction

- Advisors suggest this model is more defensible for 10K year time frame
- Significance of the model is dependent on the degree of stress mitigation

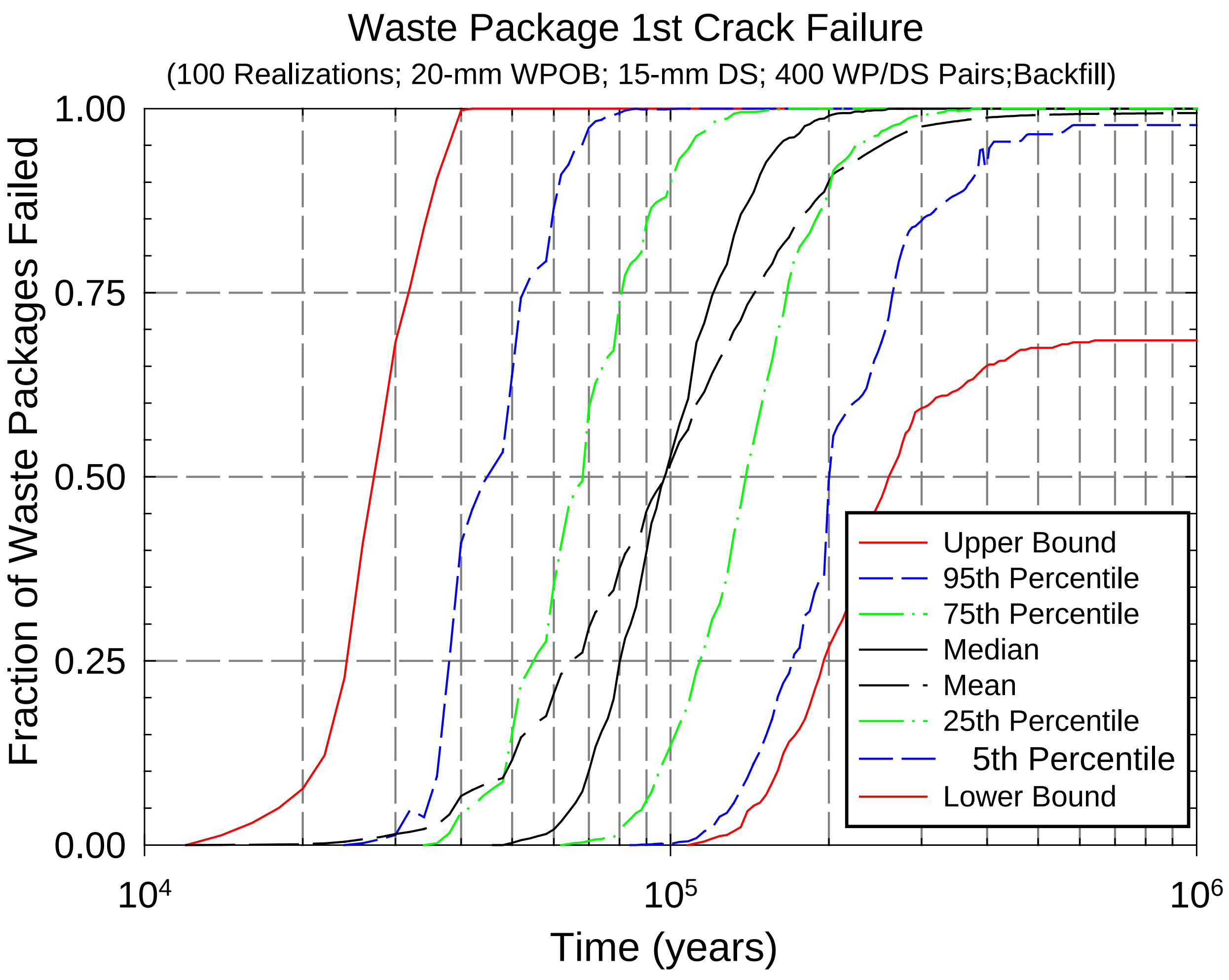
Uncertainty Treatment in Stress Corrosion Cracking Model: Example Assessments

Treatment	Topic	Range	Basis
Uncertainty	Initiation stress threshold	Uniform 10-40% of yield strength	Published data on A-22 yield strength; published data on susceptible stainless steels
Alternative conceptual models	SCC propagation	Threshold stress intensity; Slip dissolution	Judged more defensible for long time periods
Uncertainty	Residual stress range after mitigation	± 5% to ± 30% of yield strength	Published data on carbon steel and Incoloy; judged control of weld stress mitigation process
Uncertainty	Repassivation potential slope	Uniform 0.75-0.84	Published data on resistant SS; Project data on A-22
Variability	Flaw size	Lognormal	Fit to data from NRC research; checked with published data on piping and vessel welds
Uncertainty and variability	Probability of non-detect	Lognormal	Published data on inspection reliability for SS
Uncertainty	Fraction of flaws that are surface breaking	Uniform 0.13%-0.49%	Published data

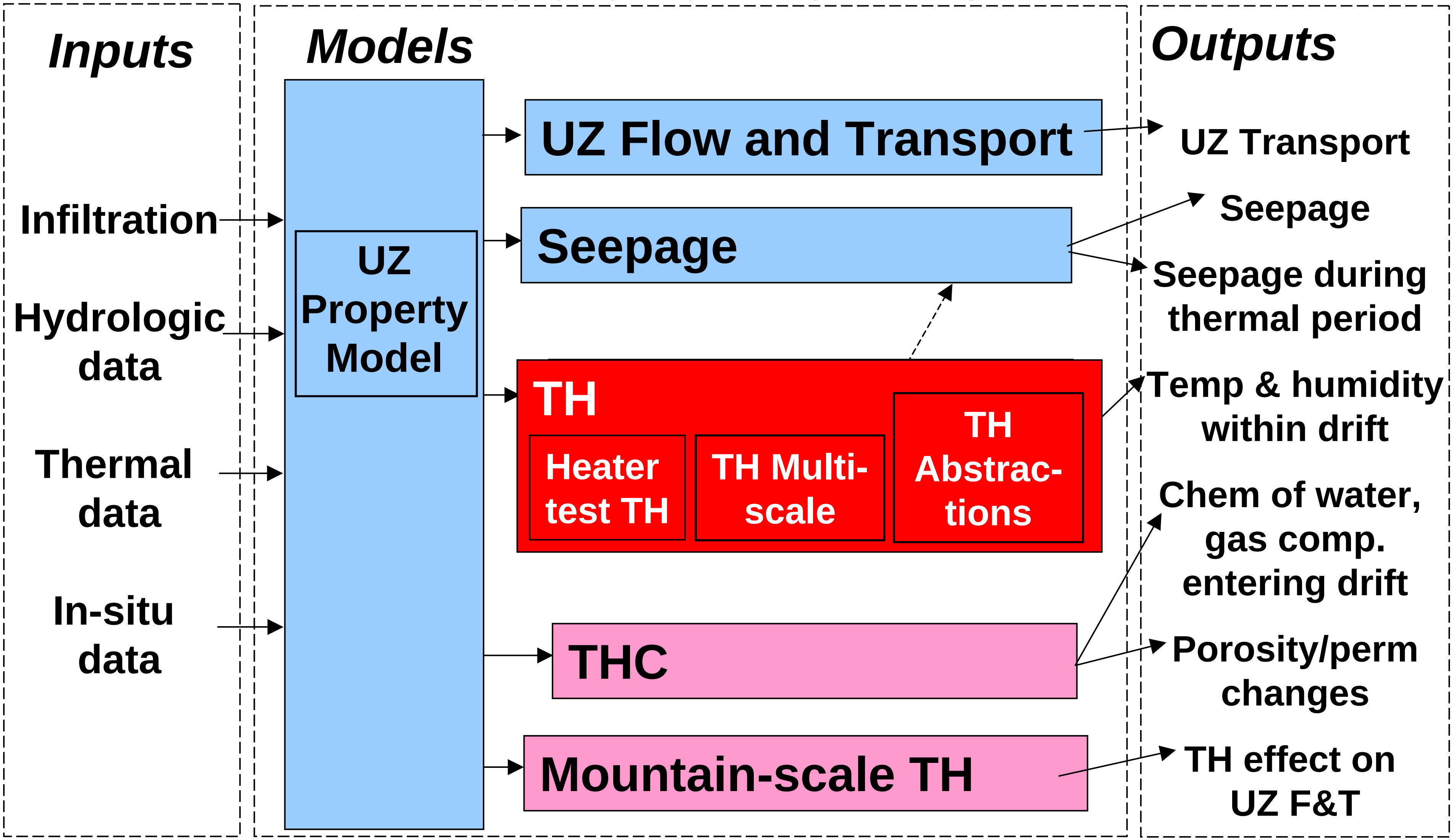
Example of Use of Conservatism: Number of Flaws Considered for SCC

- **Abstraction introduces additional conservatisms:**
  - **Orientation of flaws not included:**
    - **Only radial flaws have sufficient stress intensity to propagate to through-wall cracks**
    - **Process model results and literature indicate that less than 1% of flaws have radial orientation**
    - **Conservative assumption is that all flaws are subject to SCC**
  - **Considered surface-breaking flaws and all embedded flaws in outer 25% of depth of weld**

Quantified Uncertainties in Model Outputs: Time to First Crack Failure Distribution



Example 2: Thermal-hydrologic Models for TSPA-SR



Use of UZ Properties Model to Define Parameter Uncertainties

- **Purpose is to develop a best-estimate hydrologic property set that is most consistent with measurements and their uncertainties**
- **Matrix and fracture parameters for use in UZ flow and transport, drift seepage, drift-scale and mountain-scale coupled process models**
- **Calibration process uses data inversion to compare and adjust the modeled parameters and the data**
- **ITOUGH2 computer code considers uncertainties in input data, analysis, and output parameters and their sensitivities**

Property Set Calibration

- **Data inverted:**
  - **Matrix saturation**
  - **Matric potential**
  - **Pneumatic pressure in fractures**
- **Parameters estimated (for the high, mean, low infiltration cases):**
  - **Fracture and matrix permeability**
  - **Fracture and matrix van Genuchten parameters: ∝ and m**
  - **Fracture activity parameter**
- **Parameter uncertainties for 31 model layers, assumed to have uniform properties within each layer**
- **Spatial variability in infiltration incorporated using a 200m radius average around boreholes**

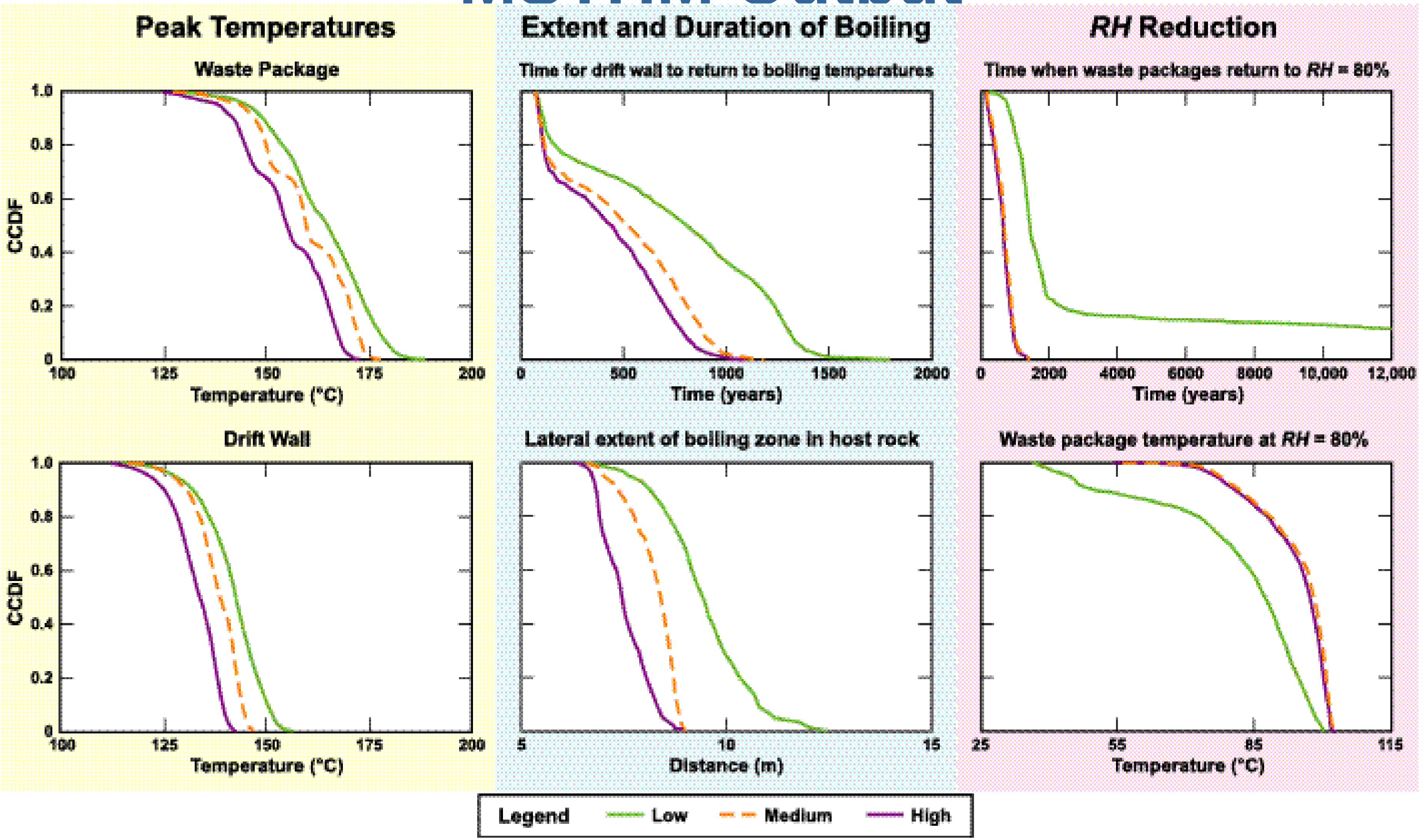
Evaluation of Ambient Property Sets for Use as TH Property Sets

- **Predictions made for single heater test using properties from**
  - **TSPA-VA**
  - **Drift Scale Property Set (TSPA-SR base case)**
  - **Single Heater Test Property Set (median bulk permeability)**
- **Considered two forms of the dual permeability model (DKM)**
  - **Constant value reduction factor between matrix/fracture**
  - **Active fracture model**
- **Predicted temperatures using property sets and conceptual flow models are compared to measured temperature data**
- **Evaluated statistically, but not a calibration (no adjustment of parameter values)**
- **Concluded that ambient drift scale property set and active fracture DKM are suitable for use in TH models for SR**

Uncertainty Treatment Multi-Scale Thermal Hydrologic Model: Example Assessments

Treatment	Topic	Range	Basis
Uncertainty	Infiltration	High, mean, low rates	Project data and interpretation
Spatial variability	Infiltration	Estimates at over 600 points across repository	Project data and interpretation
Temporal variability	Infiltration	Present day, monsoon, glacial transition climate states	Project data and interpretion
Variability	Thermal hydrologic properties	Mean properties for each hydrologic unit, infiltration flux, climate state	Property set calibration, lab measurements, and property correlations
Variability	Heated repository footprint	Center/ edge effects, rep host unit, topography	Thermal modeling
Spatial and temporal variability	WP heat-generation histories for different waste package types	Eight WP types fixed y % representation in repository	Modeling of heat generation for waste inventory
Spatial variability	Boundary temperatures and pressures at surface and water table	Vary based on elevation	Project data and modeling

Uncertainty and Variability in MSTHM Output



Influence of three possible infiltration states evaluated

Summary

- DOE's approach to uncertainties recognizes the need to assess, quantify, manage and communicate uncertainties
- Uncertainties, variability, and conservatisms are being identified in all process models providing input to the TSPA
- We are in the process of examining the current implementation -- focus to date has been on understanding the details of what has been done and how adequately it is documented

Next steps

- Complete the detailed review of uncertainty treatment and how uncertainties are reflected in the TSPA-SR
- Assess where we need to improve the characterization and/or documentation of uncertainty
- Develop recommendations to be used in future uncertainty treatment, including:
  - Assuring consistent definitions and methods for treating quantified uncertainties
  - Improving importance analyses of quantified uncertainties
  - Suggesting approaches for evaluating key unquantified uncertainties in terms of their implications to TSPA dose uncertainties