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

YUCCA MOUNTAIN PROJECT

Update on Uncertainty Analyses

Presented to:
Nuclear Waste Technical Review Board

Presented by:
William J. Boyle
U.S. Department of Energy
Yucca Mountain Site Characterization Office

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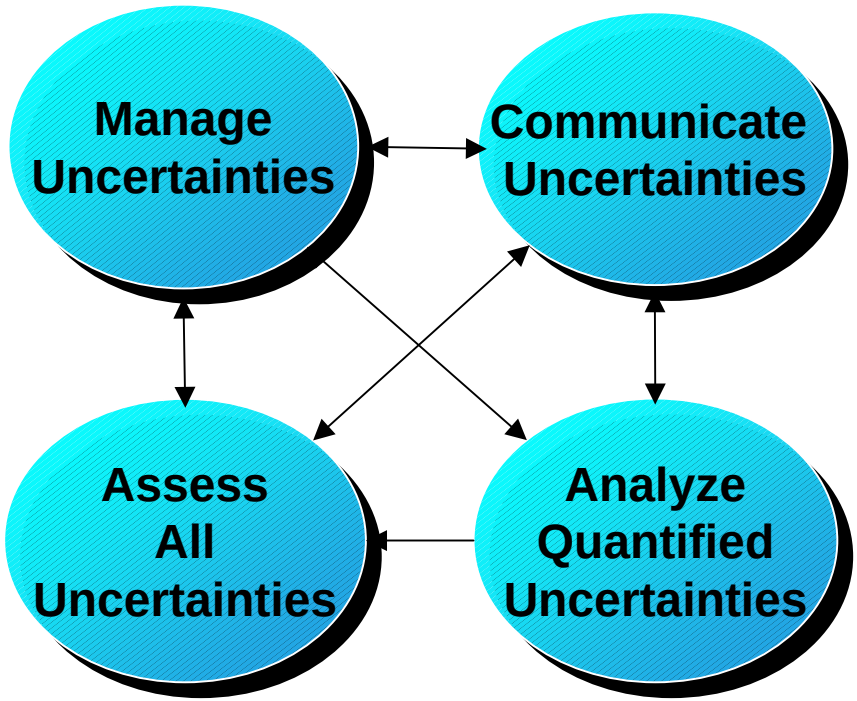
Las Vegas, Nevada

Objectives
Uncertainty Analyses

- **What was the original concern**
- **What we said we would do**
- **What we did**
- **What we will do**

Managing Uncertainties for the LA
(from A. Van Luik presentation to NWTRB January, 2000)

- **Uncertainty strategy will be aligned with licensing approach**
- **Implement DOE's overall approach to dealing with uncertainties**
- **Manage quantified and unquantified uncertainties**
- **Communicate uncertainty treatment, significance of uncertainties to make a defensible safety argument**



NWTRB Position Regarding Uncertainties in Performance Estimates

March 20, 2000 Letter from J. Cohon to I. Itkin

"The Board believes that meaningful quantification of the uncertainties associated with performance, clearly and understandably presented, is an essential element of performance characterization."

"The Board is concerned that the PA approach now envisioned by the DOE could deprive decision-makers of critical information on possible trade-offs between projected performance and the uncertainty in those projections. For example, one policy-maker might be willing to accept development of a repository that would release half the permitted dose, with only a 1 in 1,000 chance of exceeding that permitted dose. However, that same policy-maker might decline to develop a repository that is expected to release only a tenth of the permitted dose, but has a 1 in 4 chance of exceeding that permitted dose. Another policy-maker's preferences might be the opposite. Because the uncertainties about repository system performance may be substantial, estimates of uncertainty about doses are at least as important as estimates of performance."

NWTRB Priority Areas

March 30, 2001 Letter from J. Cohon to L. Barrett

"The Board has recommended that DOE focus significant attention on four priority areas dealing with managing uncertainty and coupled processes, which, the the Board's view, are essential elements of any DOE site recommendation.

- ***Meaningful quantification of conservatisms and uncertainties in DOE's performance assessments***
- ***Progress in understanding the underlying fundamental processes involved in predicting the rate of waste package corrosion***
- ***An evaluation and comparison of the base-case repository design with a low-temperature design***
- ***Development of multiple lines of evidence to support the safety case of the proposed repository…"***

PORB Position Papers

- **PORB approval to plan uncertainties task - 5/3/00**
- **Initial plan approved by Project Operations Review Board (PORB) - 5/31/00**
- **Revised plan for expanded task on unquantified uncertainties approved by PORB - 10/4/00**

History of Uncertainty Activities and Updates to NWTRB

- 1/00 A. Van Luik presentation to Board on DOE's approach to addressing uncertainty
- 5/00, 10/00 PORB actions to institute uncertainty review and unquantified uncertainty analyses
- 8/00 A. Van Luik summary to Board of treatment of uncertainties in Total System Performance Assessment - Site Recommendation (TSPA-SR)
- 11/00 Draft report to Undersecretary Moniz summarizing importance and preliminary results of uncertainty analyses (referred to in Board's 12/13/00 letter)
- 1/01 W. Boyle summary of unquantified uncertainty evaluations

History of Uncertainty Activities and Updates to NWTRB

(Continued)

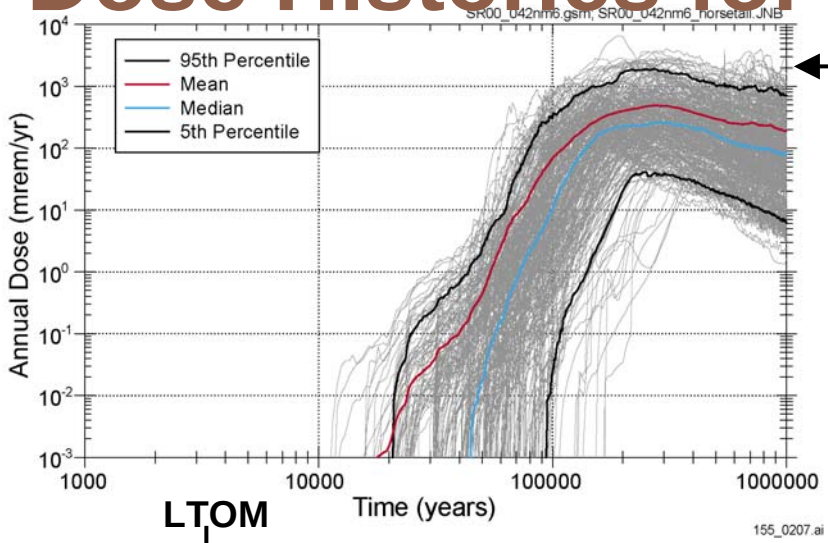
- **3/01 Concept of Supplemental Science and Performance Assessment (SSPA) develops, changing course of uncertainty analyses**
- **5/01 Management and Technical Support (MTS) review of uncertainty analyses in technical documents supporting TSPA-SR is documented**
- **5/01 W. Boyle presentation to board summarizing unquantified uncertainty analyses**
- **6/01 K. Coppersmith presentation to panel on uncertainty analyses in SSPA**
- **7/01 SSPA released with unquantified uncertainty analyses and assessments of conservatism in TSPA-SR**
- **11/01 Uncertainty Analysis report**

Supplemental Science and Performance Analyses — Content

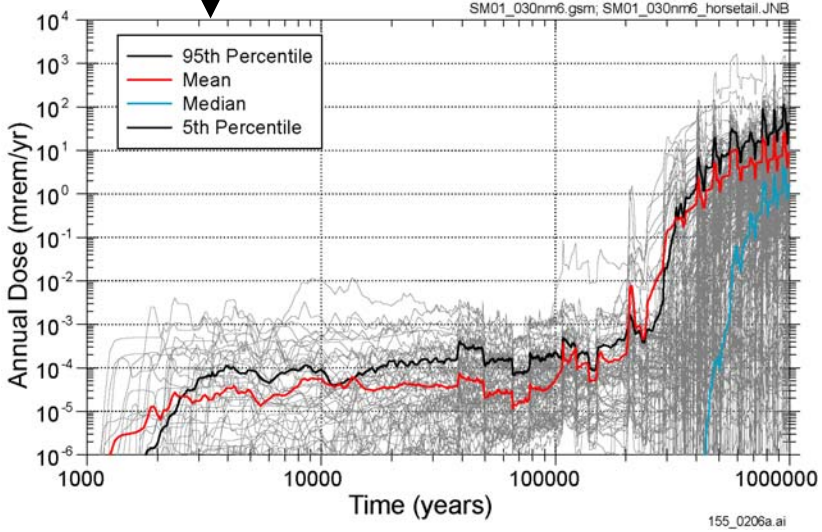
- **Supplemental Science and Performance Analyses Volume 1**
  - **Unquantified uncertainty analysis**
  - **Update in scientific information**
    - **New data, analyses and models**
  - **Cooler thermal operating mode analysis**
- **Supplemental Science and Performance Analyses Volume 2**
  - **Performance assessment sensitivity analyses**
  - **Supplemental Total System Performance Assessment (TSPA) model**
    - **High Temperature Operating Mode (HTOM)**
    - **Low Temperature Operating Mode (LTOM)**

300 Realizations of Million-Year Annual Dose Histories for Nominal Performance

TSPA-SR

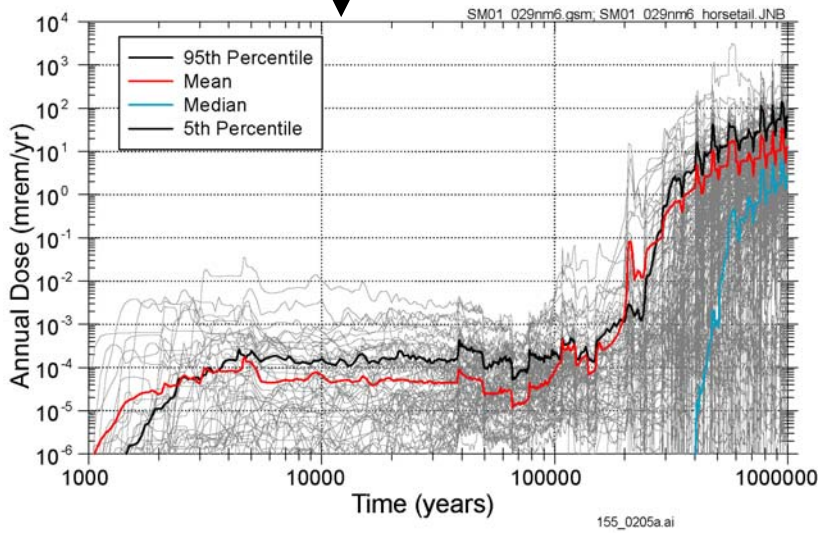


LTOM



Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-3.

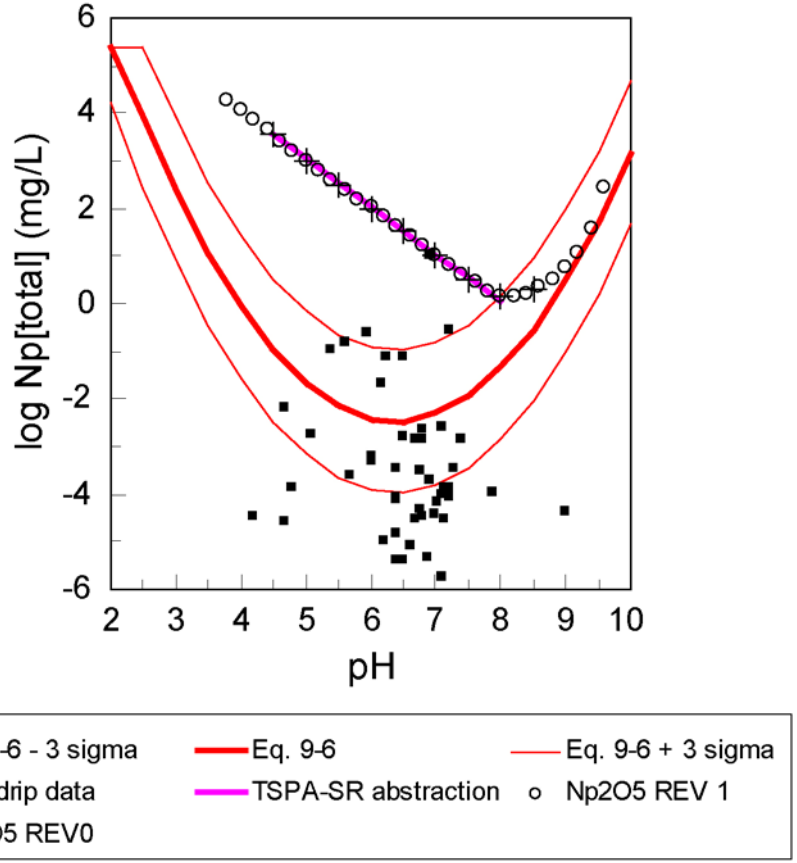
HTOM



Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-2.

Neptunium Solubility Model in Total System Performance Assessment- Site Recommendation Rev. 00

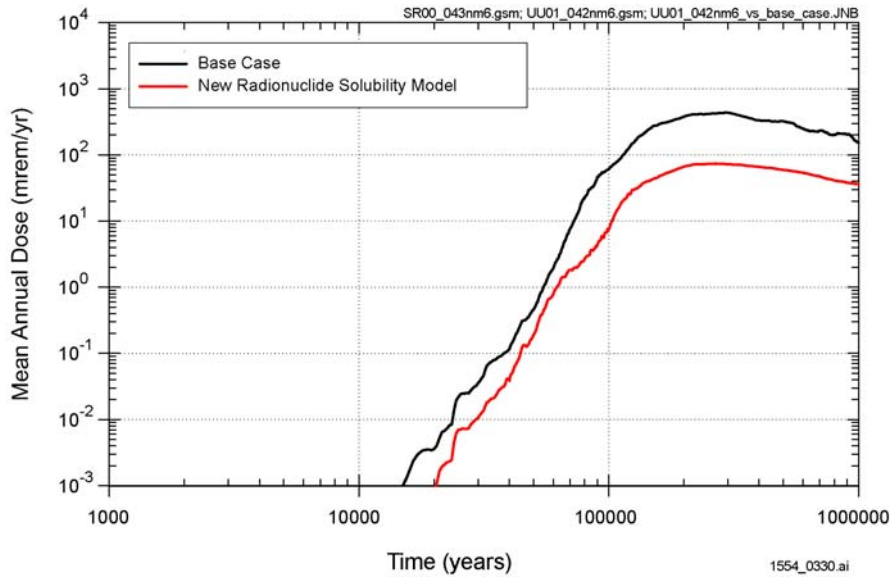
- **TSPA-SR Rev. 00 assessment of dissolved Np concentration based on conservative assumptions**
  - **Uses bounding chemistries**
  - **Pure phases (Np_2O_5) assumed to control concentrations**
  - **Np solubility is a function of pH and f_{CO2}**
- **Np_2O_5 solubility curve (as a function of pH) bounds laboratory measured Np concentrations from Argonne National Laboratory drip tests**
- **TSPA-SR Rev. 00 model, which is based on Np_2O_5 solubility, does not explain the large spread (uncertainty) in measurements of Np concentration**



Source: Supplemental Science and Performance Analyses, Volume 1, Figure 9-6b.

Comparison of Mean Annual Dose Estimates for Results Including New Radionuclide Solubility Models and Results of TSPA-SR Base-Case Models

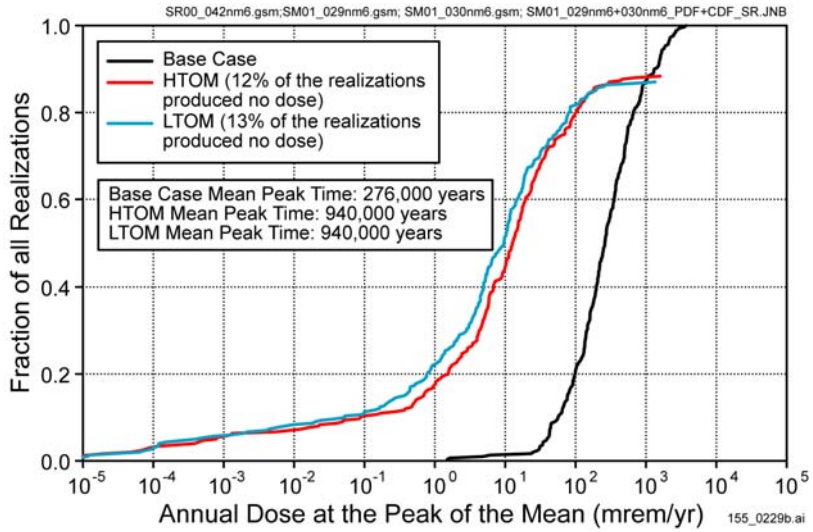
- **The decrease in the mean annual dose estimate is controlled by the revised model and uncertainty distribution for Neptunium-237**
- **The revised model for NP-237 is a preliminary secondary phase representation to address unquantified uncertainties**



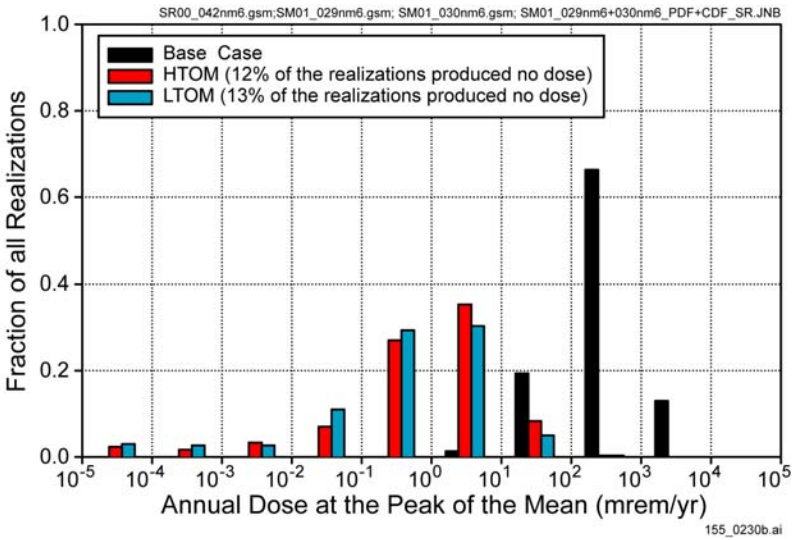
Source: Supplemental Science and Performance Analyses, Volume 2, Figure 3.2.7.3-1(a).

Doses at Particular Times: Peak dose

Cumulative distribution function of fraction of realizations



Histogram of fraction of realizations

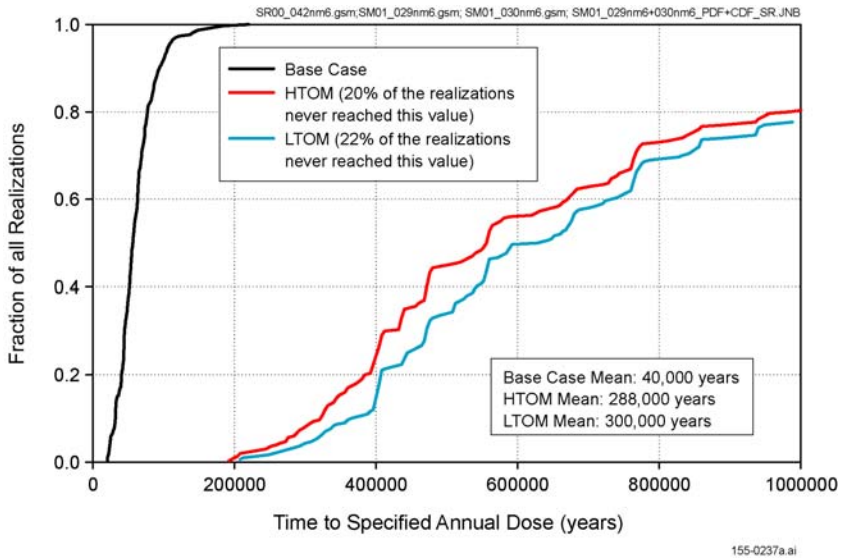


Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-11(a) (b).

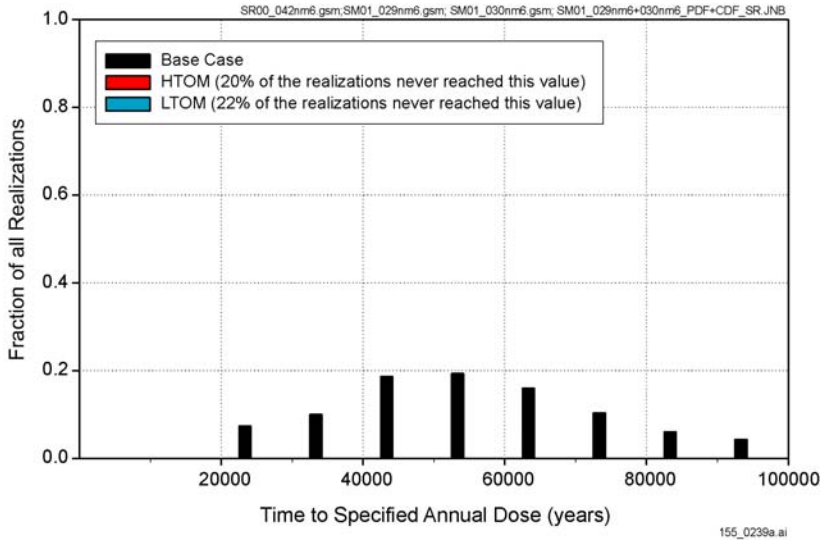
- Peak dose occurs at about 275,00 yrs for base; about 1,000,000 yrs for supplemental model
- Median (50th percentile) and mean doses for supplemental model are about one order of magnitude less than base case
- Additional quantified uncertainties and updated models lead to a reduction in the peak dose at this time, but also a broader spread in the range of dose rates
- Differences due primarily to revised solubility models, which have lower mean solubility and broader range of uncertainty

Time to Particular Doses: 0.1 mrem/yr

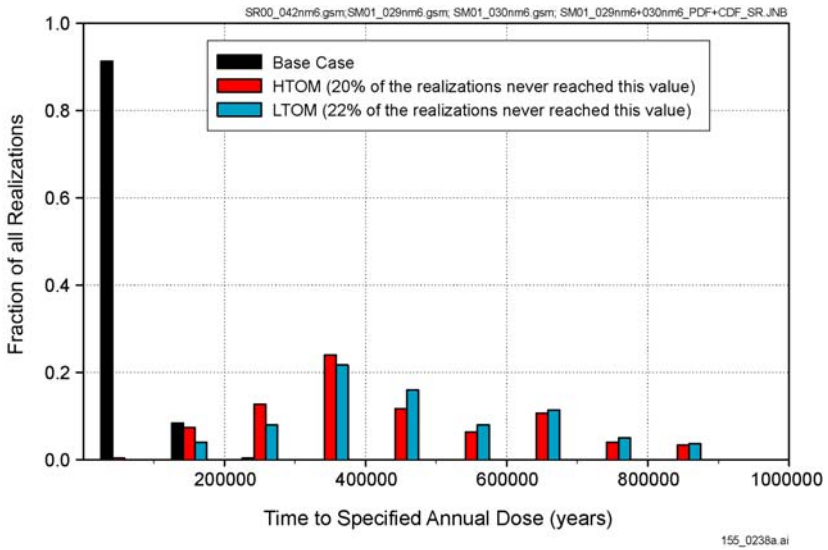
Cumulative distribution function of time to dose rate of 10^{-1} mrem/yr.



Histogram of time to dose rate of 10^{-1} mrem/yr (to 100,000 years).



Histogram of time to dose rate of 10^{-1} mrem/yr (to 1,000,000 years).



Source: Supplemental Science and Performance Analyses, Volume 2, Figure 4.1-14 (a), (b), and (c).

- **About one order of magnitude difference in time to reach 0.1 mrem/yr between base case and supplemental model at 50th percentile**
- **Broadening in timing due to additional quantified uncertainties**
- **Related to removal of conservatisms, particularly in Waste Package and solubility models**
- **Delay in reaching dose by lower temperature operating mode; due to temperature dependence in general corrosion rate**

Conclusions Regarding Uncertainties and Conservatism at System Level

- **Supplemental model shows significantly wider ranges of doses at a given time and times to reach given doses**
  - **Represented quantitatively by the distribution of realizations at particular dose rates and particular times**
  - **Broader range is a result of the additional uncertainties and updated models that have been incorporated into the supplemental model**
  - **Simplified or "bounding" models have been replaced with more physically representative models that include quantified uncertainties in their parameters**
  - **Examples are waste package degradation modes, diffusive pathways in Waste Package, Np solubility, and saturated zone transport**
  - **The low temperature and high temperature operating modes show similar effects of incorporation of uncertainties**

Conclusions Regarding Uncertainties and Conservatism at System Level

(Continued)

- **After the first 10,000 years, the base case model appears to be conservative with respect to the supplemental model:**
  - **The magnitude of the dose is less for the supplemental model and it occurs later in time**
  - **Mean estimates provide insight into the magnitude of the conservatism**
    - **At 30,000 years, the difference between the mean estimates of dose rate is about three orders of magnitude, and at time of peak mean dose the difference is about one order of magnitude**
    - **The mean delay in reaching 0.1 mrem/yr in the supplemental model is about 200,000 years, and in reaching 10 mrem/yr is over 400,000 years**

Conclusions Regarding Uncertainties and Conservatism at System Level

(Continued)

- **During the period prior to 10,000 years, the base case model appears to be slightly non-conservative with respect to the supplemental model**
  - **Base case model results in no dose and the supplemental model results in finite, but very low, dose**

Conceptual Model Uncertainty

- **Conceptual model uncertainty: Defined in SSPA as uncertainty associated with simplifying and representing a complex physical system; distinct from parameter uncertainty**
- **Conceptual models developed by technical PI's based on available data and information**
- **Where there are multiple viable conceptual models, the general approach is to pick one, and document basis in Analysis and Model Reports**

Conceptual Model Uncertainty
(Continued)

- The chosen conceptual model is usually the most "defensible" in light of available data and/or a conservative representation
- Including multiple, weighted conceptual models is computationally difficult
- In SSPA, alternative representations, which are usually more physically realistic, were developed
- One-off sensitivity analyses and total-system comparisons were made to evaluate the significance of the alternative representations (SSPA, Vol. 2, Sec. 3 and 4)

Example NRC/DOE Agreements Regarding Uncertainties

Subissue Title	Number	Example Preliminary NRC/DOE Agreements
System description and demonstration of multiple barriers	TSPAI.1.01	Provide discussion of capabilities of individual barriers in light of existing parameter uncertainty and model uncertainty
Model abstraction within the total system performance assessment methodology	TSPAI.3.01	Propagate significant sources of uncertainty into projections of waste package and drip shield performance included in future performance assessments, including: measurement uncertainty, alternative explanations for decrease in corrosion rate with time, limited numbers of samples, confidence in upper corrosion rate limit, and alternative statistical representations of empirical rates.
"	TSPAI.3.05	Provide technical basis for representation of uncertainty/variability in general corrosion rates
"	TSPAI.3.32	Provide the technical basis that the representation of uncertainty in the saturated zone as essentially all lack-of-knowledge uncertainty (as opposed to real sample variability) does not result in an underestimation of risk when propagated to the performance assessment
"	TSPAI.3.38	Develop written guidance in the model abstraction process for model developers so that (1) the abstraction process, (2) the selection of conservatism in components, and (3) representation of uncertainty, are systematic across the TSPA model. These guidelines will address: (1) evaluation of non-linear models when conservatism is being utilized to address uncertainty, and (2) utilization of decisions based on technical judgment in a complex system.

Example NEA-IAEA Peer Review Questions Related to Uncertainty

- **Reasonable expectation vs. reasonable assurance approaches; implications to uncertainty quantification**
- **“Expected dose” measure for a conservative or a realistic performance assessment**
- **Conservatism in input parameters vs. conservatism in results**
- **Sampling strategies for stability and to represent low-probability scenarios**
- **Basis for assigning pdf’s to uncertain parameters**

Uncertainty Analysis Report

- **Introduction**
- **Evaluation of Impact of Uncertainties**
  - **2.1 Summary of significance of uncertainties to total system and conservatism/non-conservatism**
  - **2.2 Examples of subsystem level results and significance**
  - **2.3 Impact of thermal operating mode on uncertainties**
  - **2.4 Conclusions regarding significance of uncertainties at the total system and subsystem level**

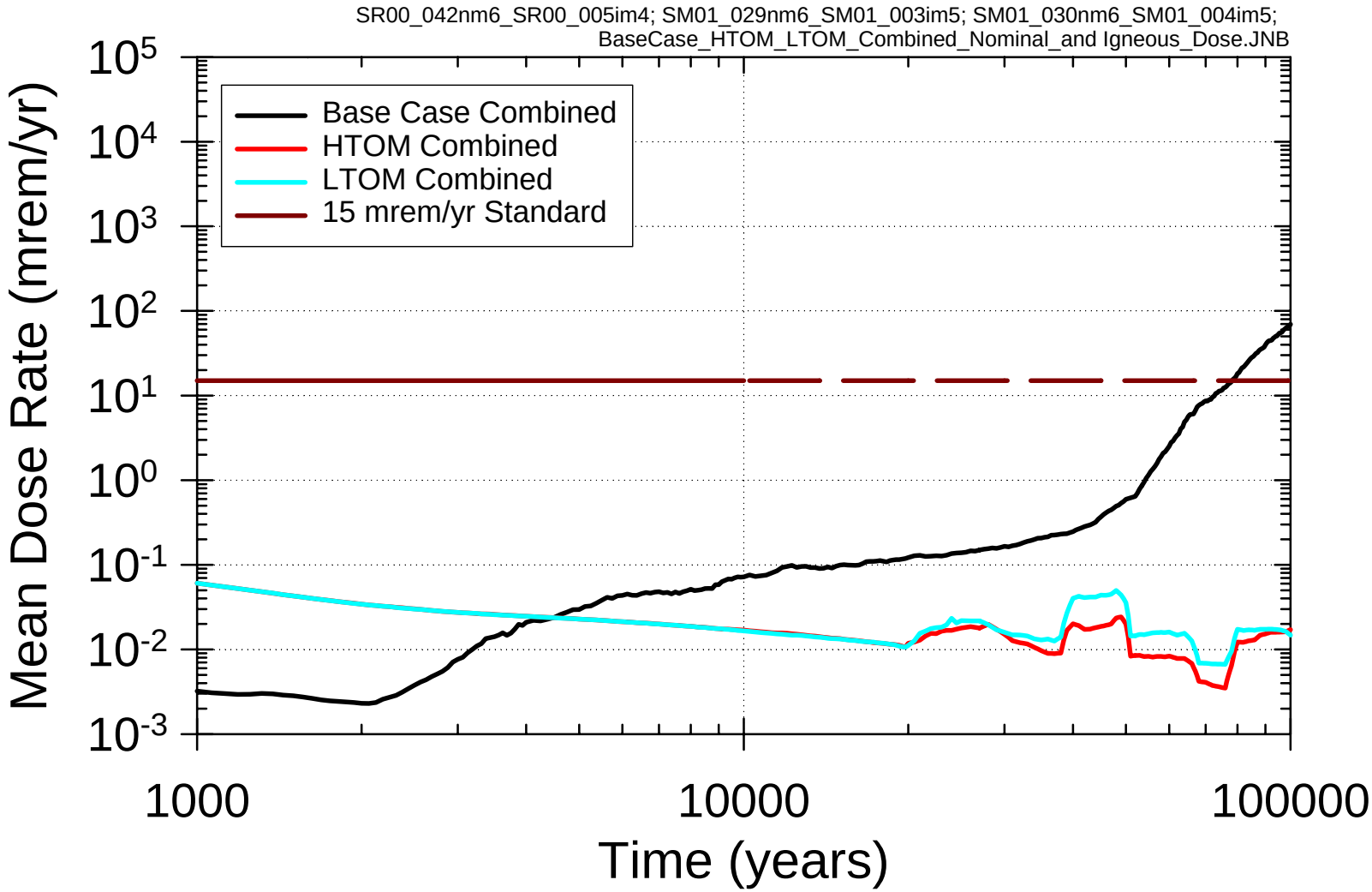
Uncertainty Analysis Report
(Continued)

- **Guidance for future treatment of uncertainties**
  - **3.1 Lessons learned from uncertainty review of TSPA-SR**
  - **3.2 Guidance consistent with License Application strategy (e.g., quantification of uncertainties, conservative bounds)**
  - **3.3 Provide guidance on**
    - **Instances where uncertainties should be quantified**
    - **Approaches to quantifying uncertainties**
    - **Approaches to handling conceptual model uncertainties**
    - **Probabilistic and statistical tools for developing probability distributions**
    - **Definitions of “bounds” and conservative estimates**
    - **Documentation of uncertainty characterization**

Uncertainty Analysis Report
(Continued)

- **Communication and management of uncertainties**
  - **4.1 Need to clearly express knowledge and uncertainties in TSPA**
  - **4.2 Examples of approaches for communicating with decision-makers and public on significance of uncertainties (e.g., simple figures and plots)**
  - **4.3 Use of uncertainty description in decision-making and prioritization**

Dose Rate Means
Combined Nominal and Igneous Scenarios



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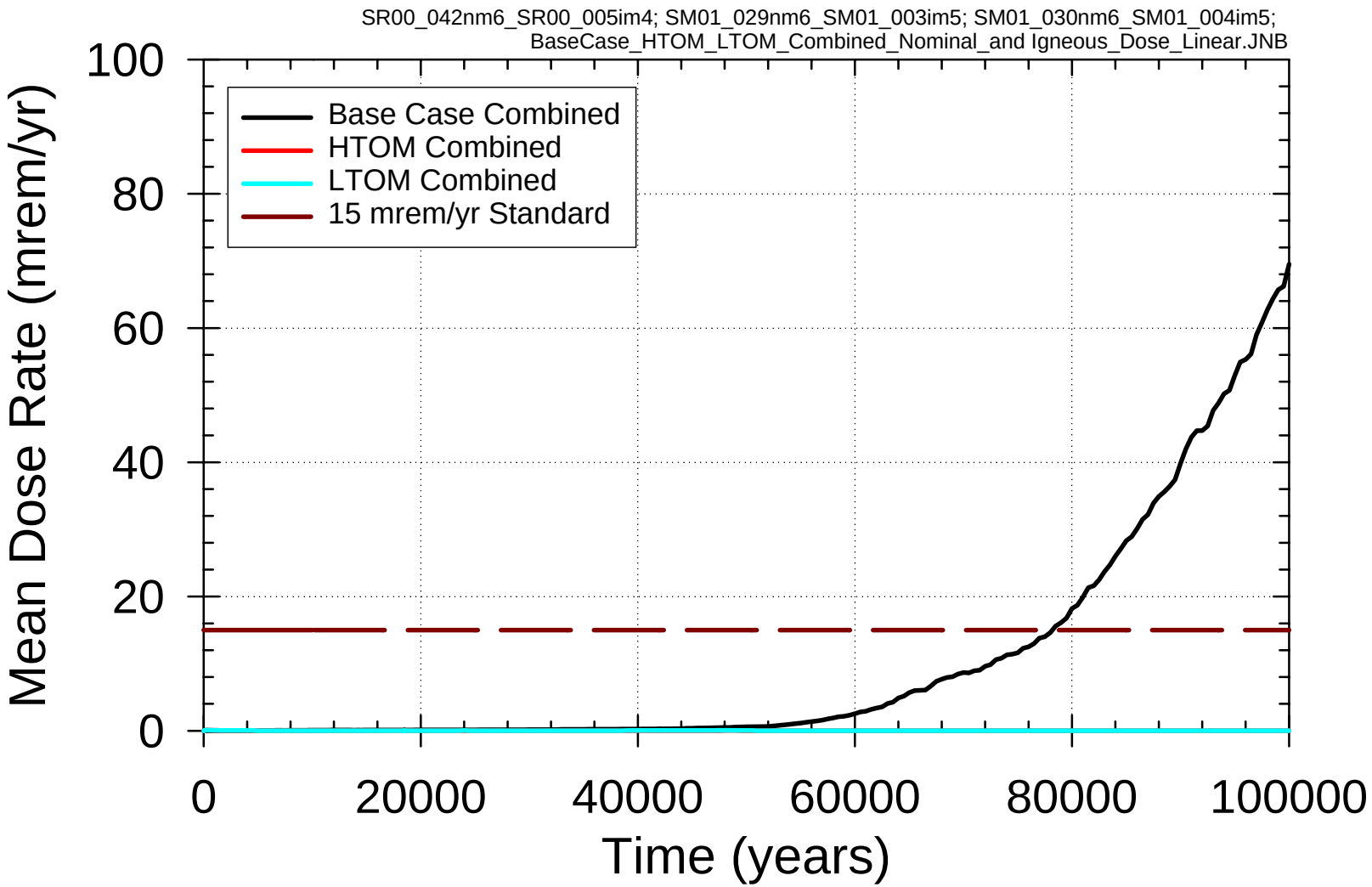

Update on Uncertainty Analyses Summary

- **Quantification, analysis, and management of uncertainties have been recognized by DOE as important activities**
- **Over the past year, DOE has focused efforts to evaluate the significance of uncertainties in TSPA, including conservatisms/non-conservatisms in TSPA-SR**
- **These efforts are documented in the SSPA and will be documented in the Uncertainty Analysis report**
- **Guidance is being developed for the future treatment and communication of uncertainties**