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

TSPA Analyses and Results

Presented to:
Nuclear Waste Technical Review Board

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Outline

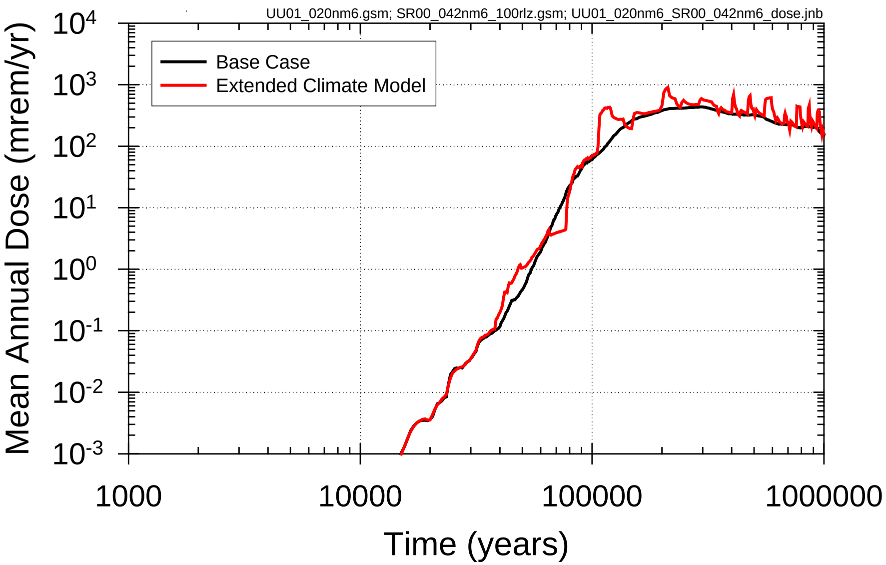
- Total System Performance Assessment-Site Recommendation (TSPA-SR) Base Case Model
- Sensitivity analyses with the Base Case Model
- TSPA-SR supplemental model
- Dose results for nominal scenario
- Subsystem results for nominal scenario

TSPA-SR Base Case Model

- **Documented in TSPA-SR technical report**
  - **TDR-WIS-PA-000001 REV 00 ICN 01, December 2000**
- **Two scenarios considered**
  - **Nominal**
  - **Igneous disruption (not discussed in this talk)**
- **Model and submodels are based on work documented in the process model and analysis model reports**
- **Uncertainty addressed by means of conservative assumptions in some submodels**
- **Temperatures above boiling for hundreds of years**

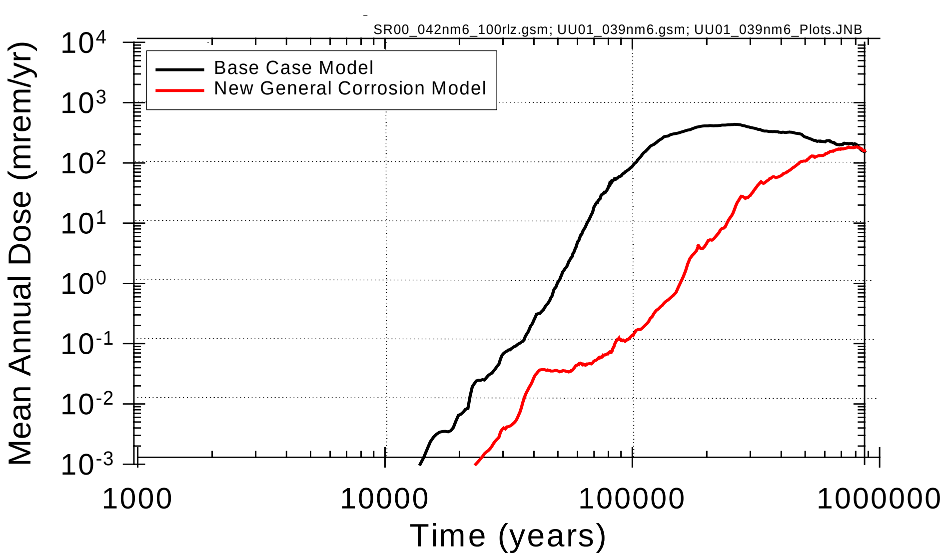
Sensitivity Analyses with the TSPA-SR Base Case Model

Effect of Extended Climate Submodel



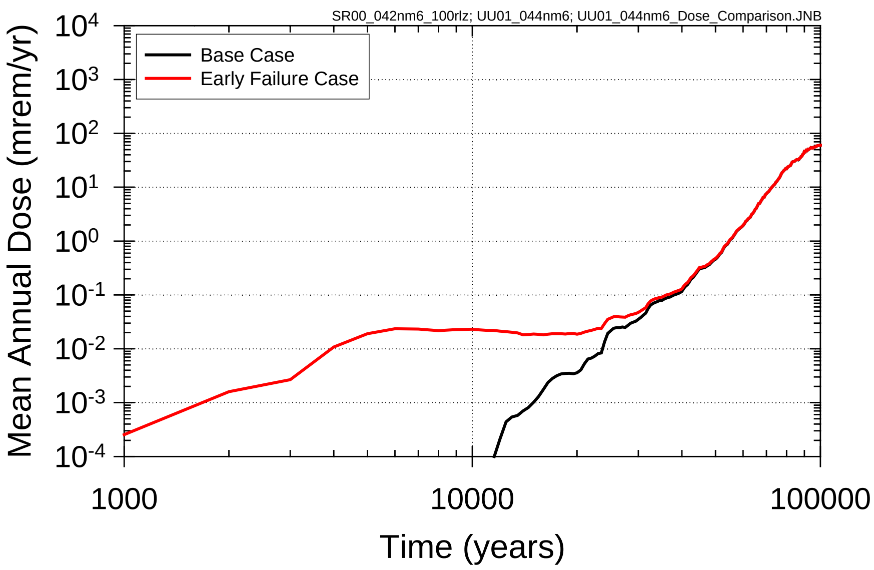
- **TSPA-SR base-case model has no climate changes after 2000 years in the future**
- **An extended climate submodel was developed that includes more realistic glacial cycles**
- **The first glacial climate in the model occurs at 38,000 years in the future**
- **On average, the model has glacial periods every 90,000 years after that**

Effect of Temperature Dependence on Waste Package Corrosion



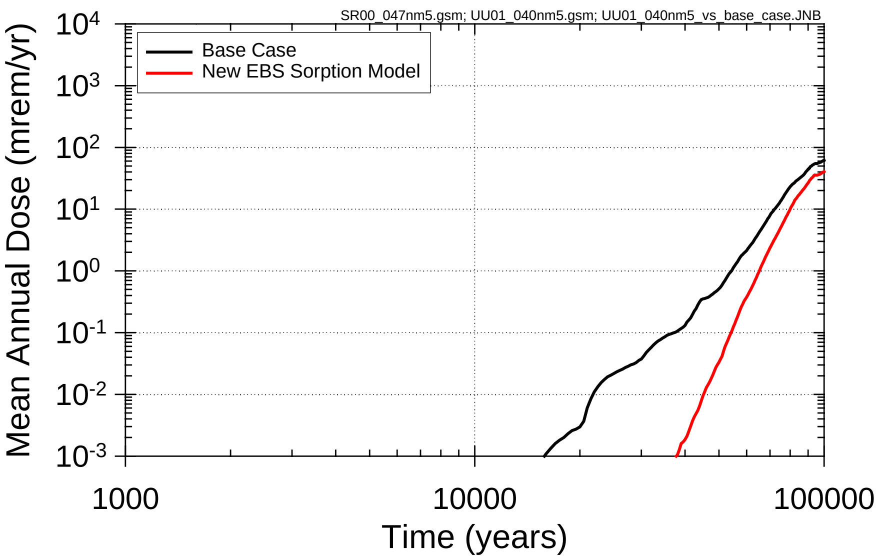
- **TSPA-SR base-case model has no temperature dependence of corrosion**
- **Temperature dependence of corrosion rates was developed from cyclic polarization test results**
- **Above 60°C, corrosion rates are higher than the base case; below 60°C, corrosion rates are lower**
- **Modeled corrosion rates are lower in this analysis after about 10,000 years, leading to later waste-package failures**

Effect of Higher Probability of Early Waste Package Failures



- TSPA-SR base-case model has no waste package (WP) failures before 10,000 years; lack of early failures based on reliability studies in the literature
- Further analysis considered possible effects of improper heat treatment of the waste packages
- This analysis led to a higher estimate of the probability of early failures

Effect of Radionuclide Sorption in the Engineered Barrier System



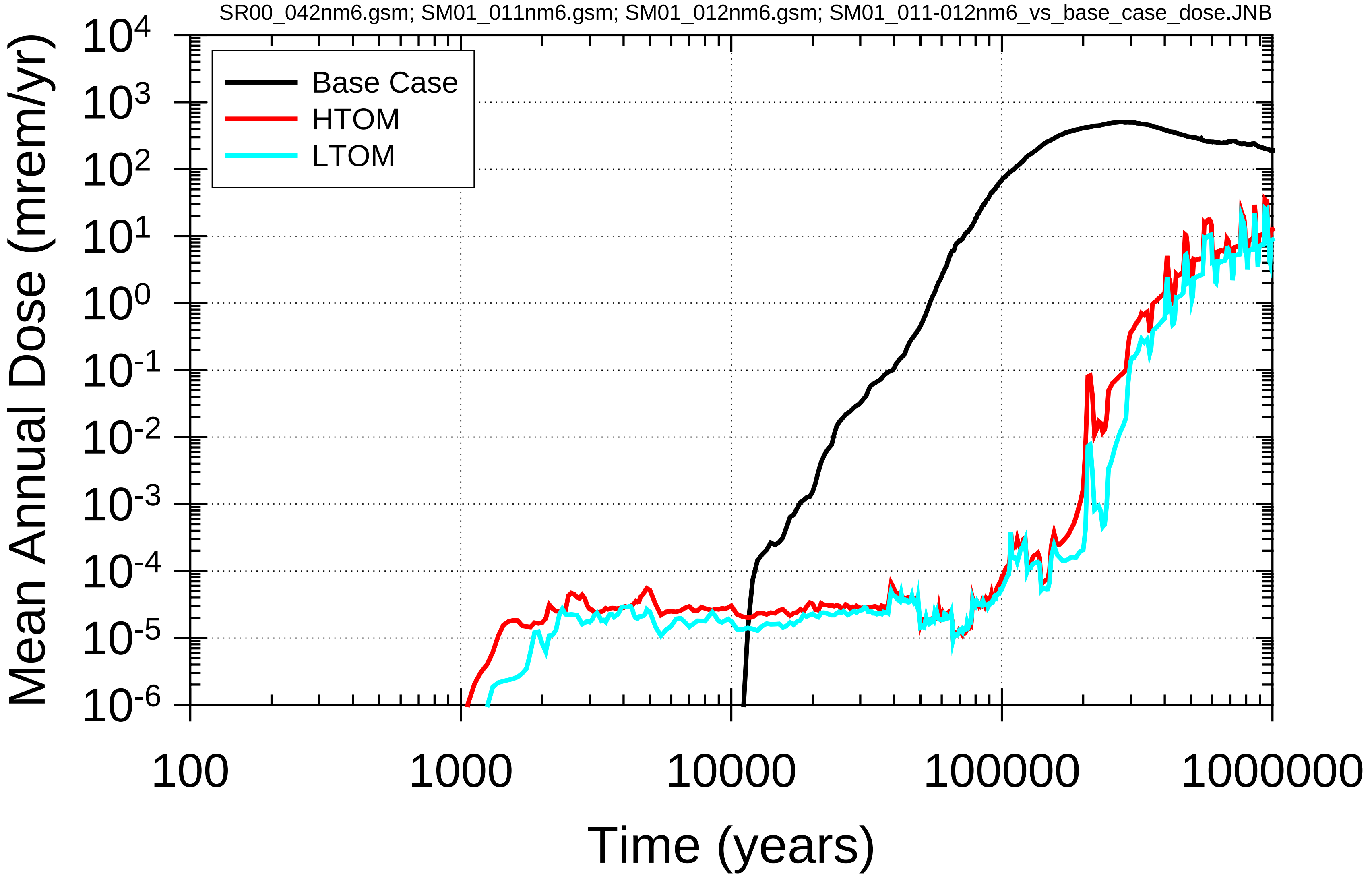
- **TSPA-SR base-case model includes no sorption in the WP or invert**
- **Further analysis developed estimates of effective sorption coefficients**
- **The most important effect is reduction of source concentration because of sorption onto corrosion products within the WP**

TSPA-SR Supplemental Model

- Documented in Supplemental Science and Performance Analyses (SSPA) Report, Volume 2
- Same two scenarios considered
- Many submodels are modified, based on work documented in SSPA Report, Volume 1
- Some modifications make the model more realistic, others improve the quantification of uncertainty
- Range of thermal possibilities represented by two repository operating modes
  - High-temperature operating mode (HTOM), nearly the same as the design assumptions in the TSPA-SR base case
  - Low-temperature operating mode (LTOM), chosen to keep WP temperatures below 85°C

Dose Results for Nominal Scenario

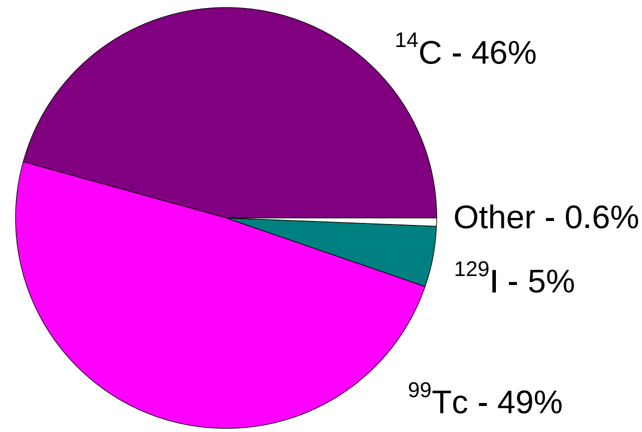
Mean Annual Dose Comparison



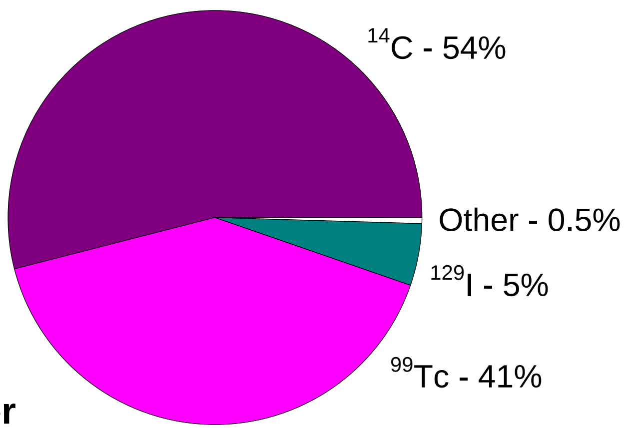
Major Radionuclides at 10,000 Years

Base Case

LTOM



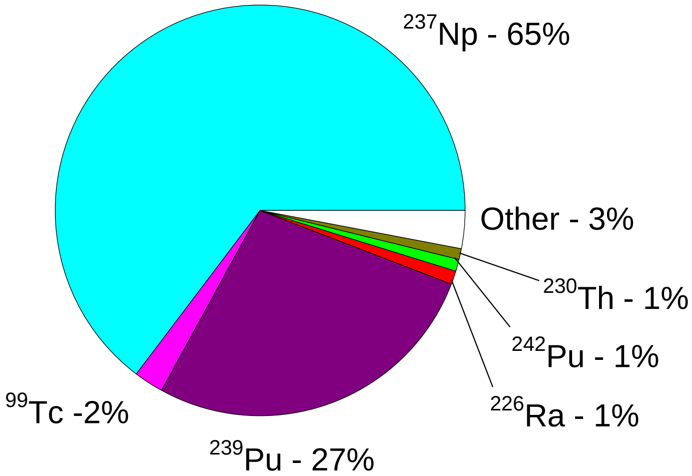
HTOM



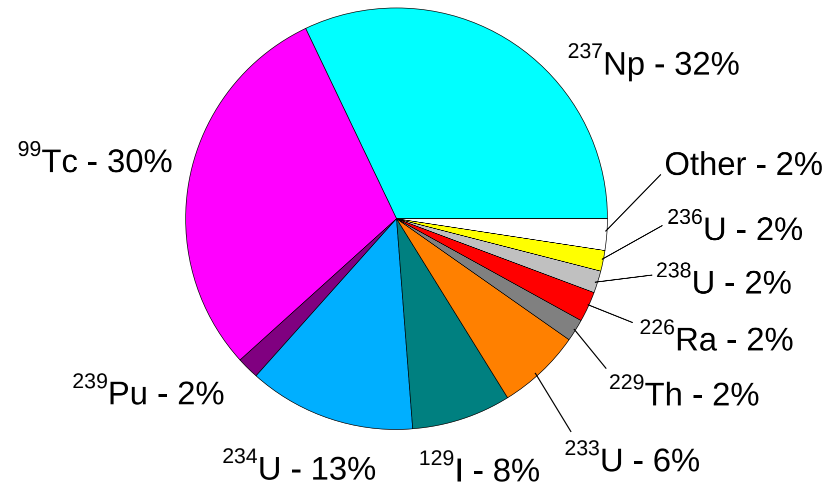
Note: Radionuclides with smaller contributions are lumped together as “other”

Major Radionuclides at 100,000 Years

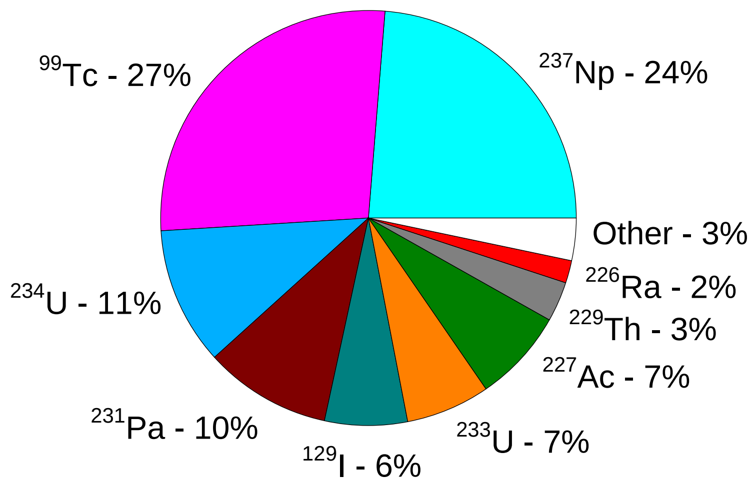
Base Case



LTOM



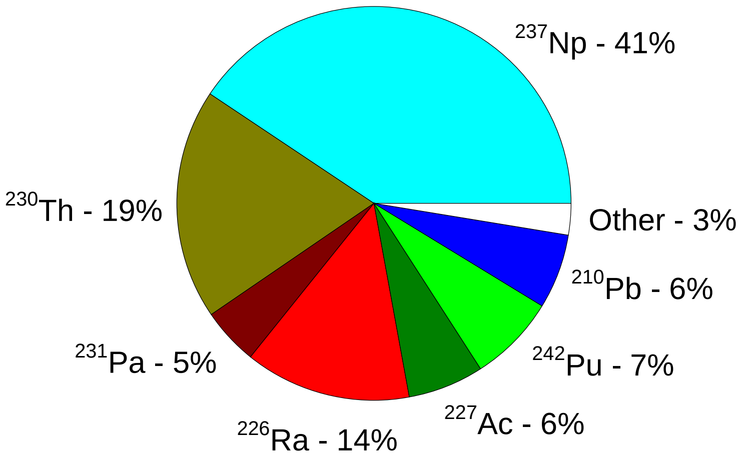
HTOM



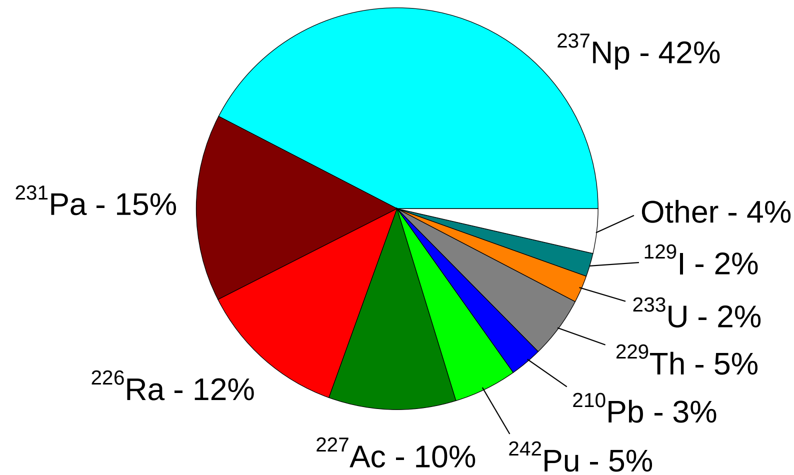
Note: Radionuclides with smaller contributions are lumped together as "other"

Major Radionuclides at 1,000,000 Years

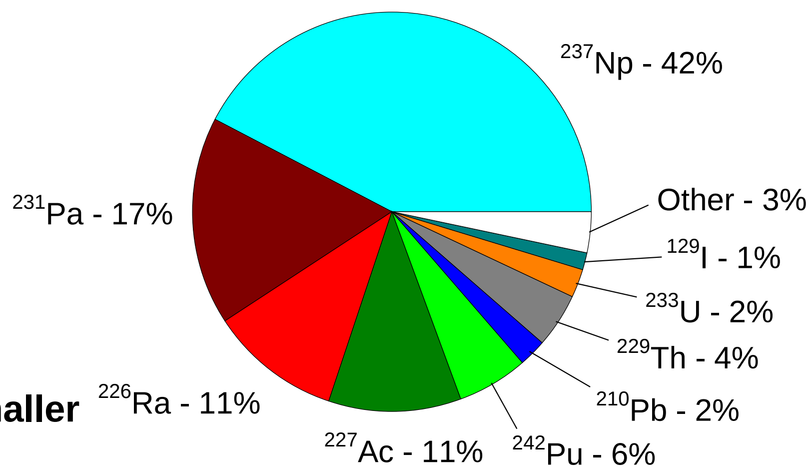
Base Case



LTOM



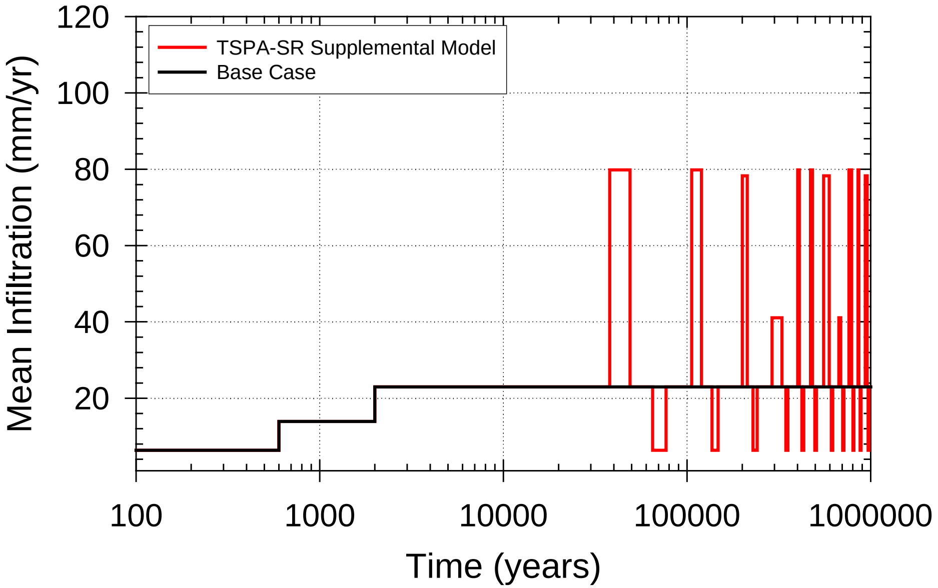
HTOM



Note: Radionuclides with smaller contributions are lumped together as "other"

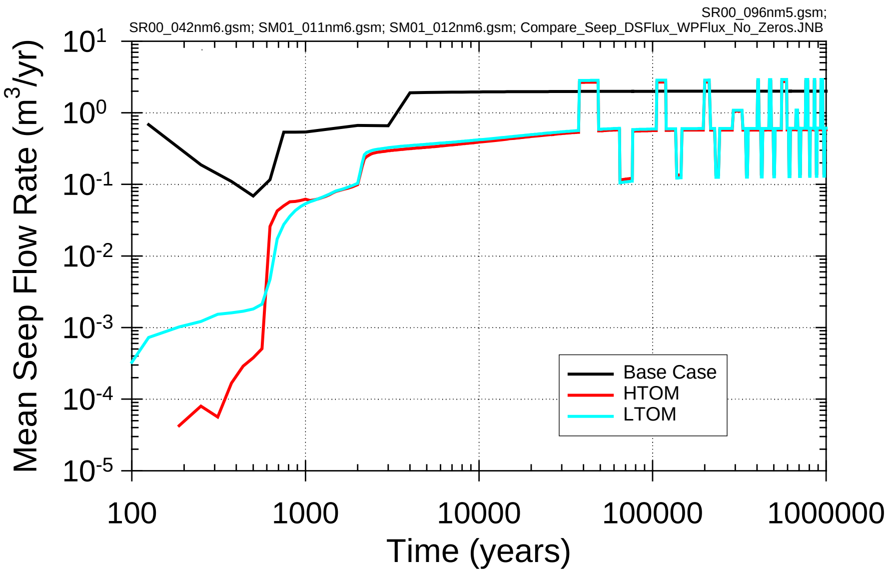
Subsystem Results for Nominal Scenario

Net Infiltration



- Curves show infiltration averaged over repository area and averaged over TSPA realizations
- Climate and infiltration are the same for HTOM and LTOM
- The high-infiltration spikes are glacial periods
- The low-infiltration spikes are interglacial periods
- Intermediate climate periods are the same in all three models

Seep Flow Rate into Drift

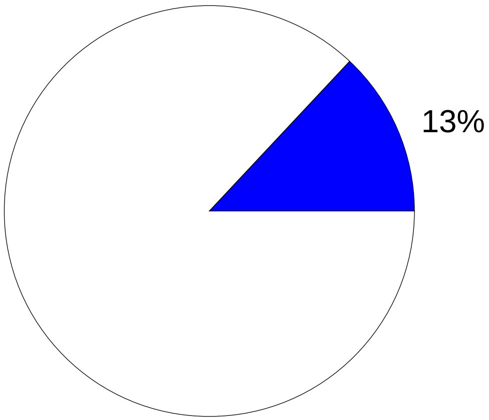


Note: The HTOM and LTOM curves are also reduced by an estimate of the amount of in-drift evaporation

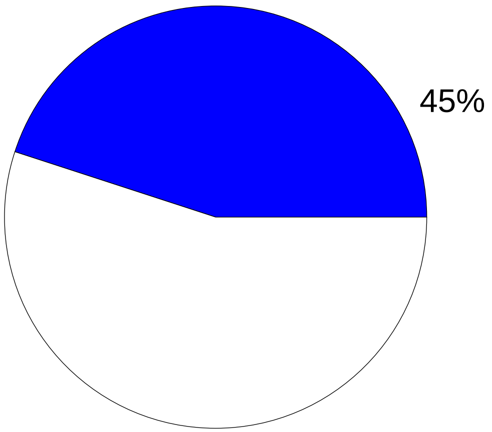
- **Curves show seep flow rate for commercial spent nuclear fuel (CSNF) WPs, averaged over locations where glacial-transition infiltration is between 20 and 60 mm/yr (i.e., relatively high) and averaged over TSPA realizations**
- **HTOM seepage is reduced by repository heat for the first few hundred years**
- **Seepage-submodel updates cause seepage in more locations (next slide), but reduced flow at those locations**

Mean Fraction of Waste Packages with Seepage

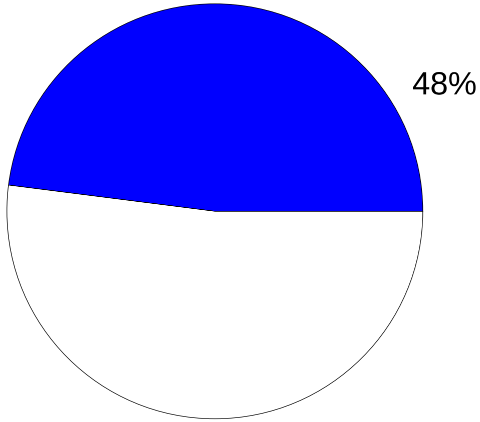
Base Case



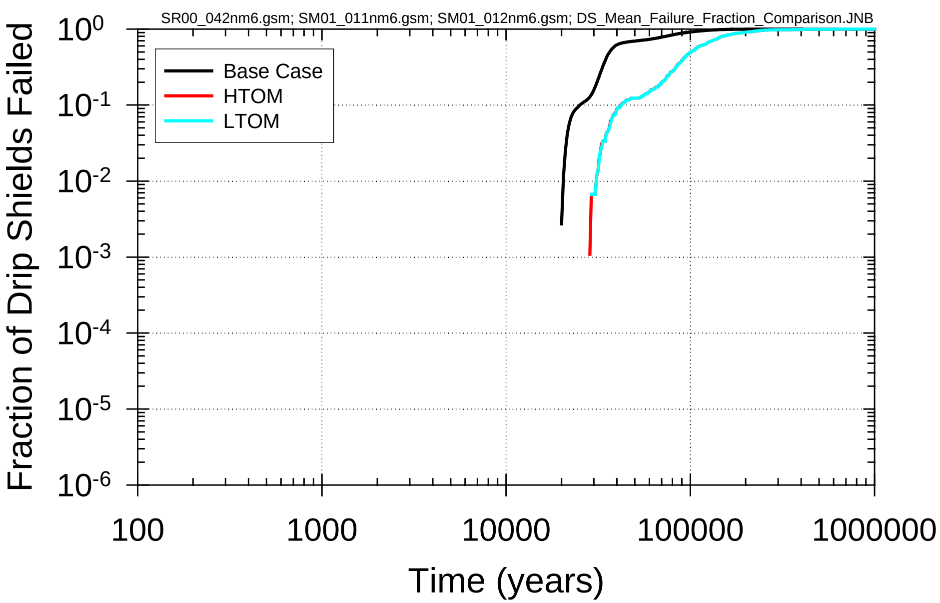
LTOM



HTOM

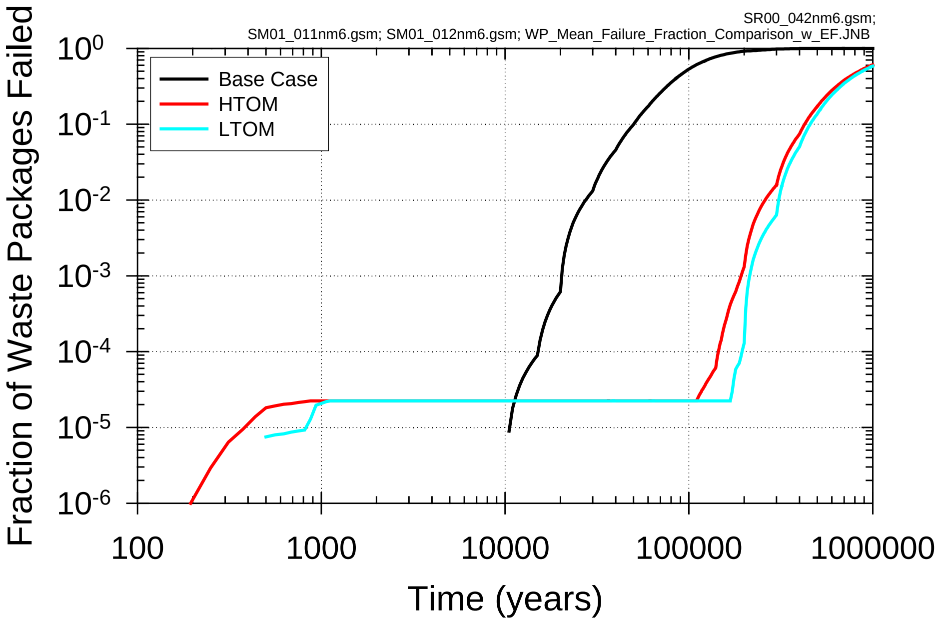


Drip Shield Failure Distribution



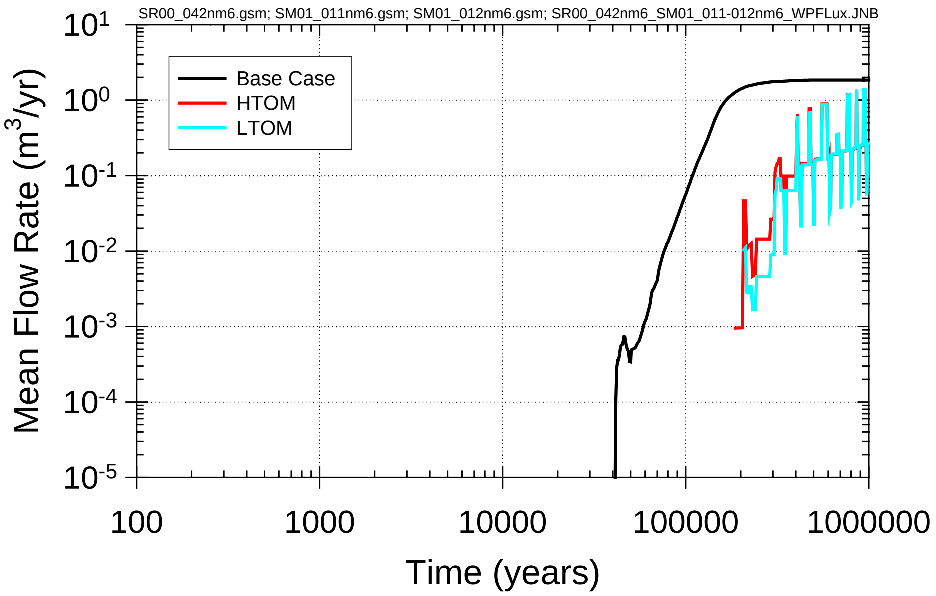
- Curves show mean distribution of first failure, averaged over TSPA realizations
- Failures are later in the supplemental model as compared to the base case, primarily because uncertainty and spatial variability are included differently in the supplemental model as compared to the base case
- Essentially no difference between HTOM and LTOM

Waste Package Failure Distribution



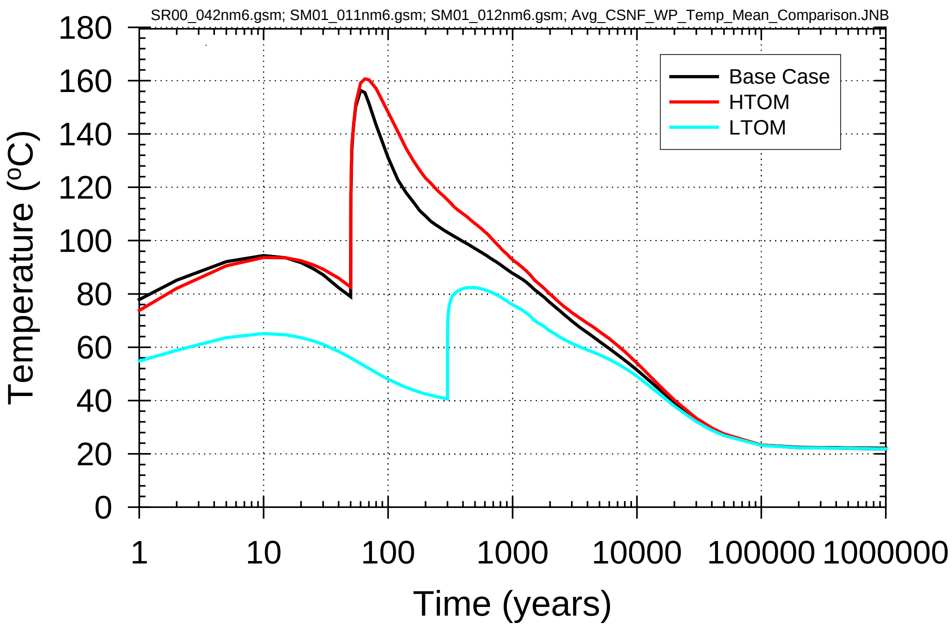
- **Curves show mean distribution of first failure, averaged over TSPA realizations**
- **The supplemental model has a small fraction of earlier failures, but most failures are much later than in the base case**
- **Failures in LTOM are a little later than in HTOM because of the corrosion temperature dependence**

Water Flow into Waste Package



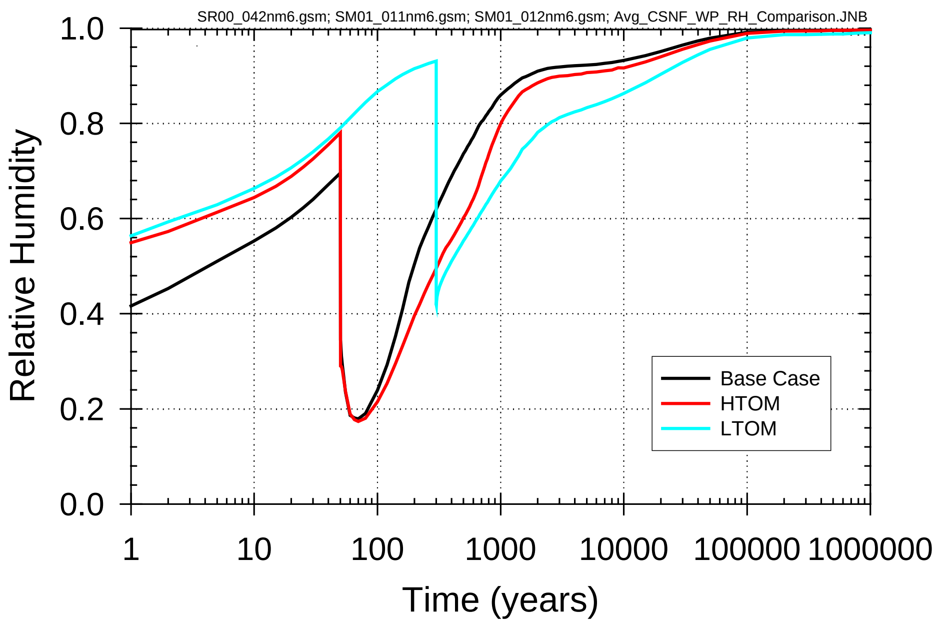
- Curves show flow rate for CSNF WPs, averaged over locations where glacial-transition infiltration is between 20 and 60 mm/yr (i.e., relatively high) and averaged over TSPA realizations
- Modeled flow through drip shield (DS) and WP depends on opening area (patches only; cracks are assumed not to transmit water)

Waste Package Temperature



- **Curves show temperature for CSNF WPs, averaged over repository locations for realizations with medium infiltration**
- **Main difference between HTOM and Base Case is updated estimate of thermal conductivity for lithophysal hydrogeologic units**
- **HTOM and Base Case have ventilation for 50 years; LTOM has ventilation for 300 years**

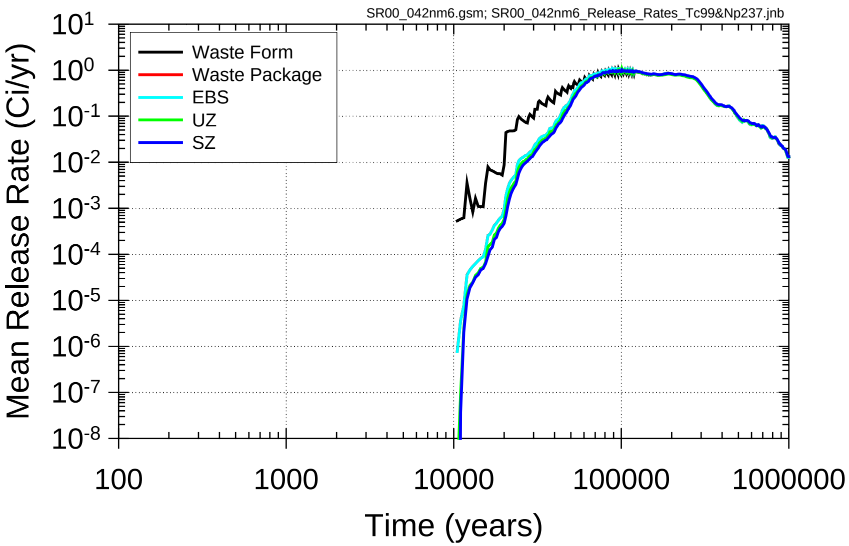
Waste Package Relative Humidity



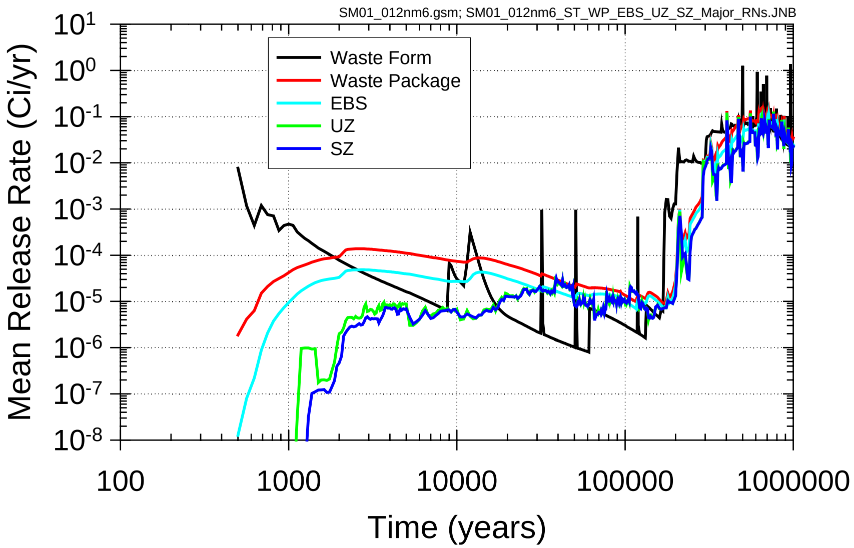
- Curves show relative humidity for CSNF WPs, averaged over repository locations for realizations with medium infiltration
- Relative humidity (RH) during ventilated period is not realistic, as the model does not include the effect of moisture removal by ventilation
- After closure, LTOM has lower RH as well as lower temperature (previous slide)

Tc-99 Release Rates

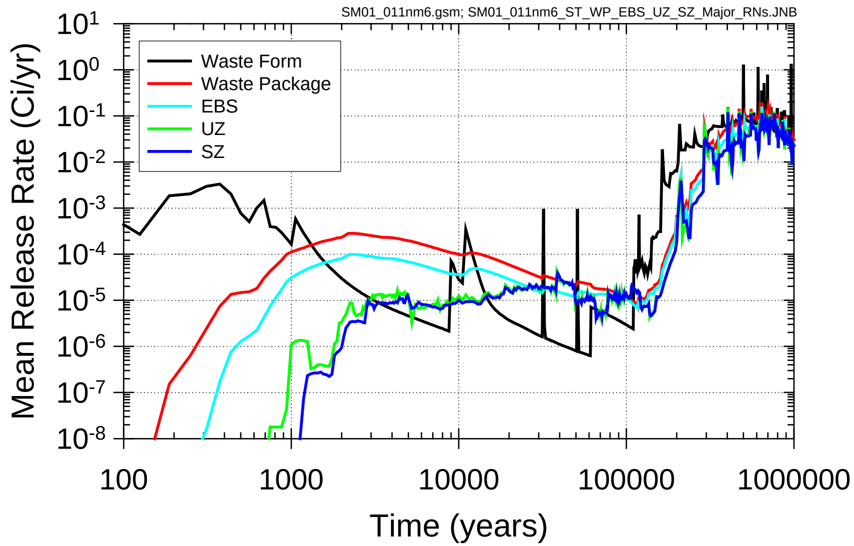
Base Case



LTOM

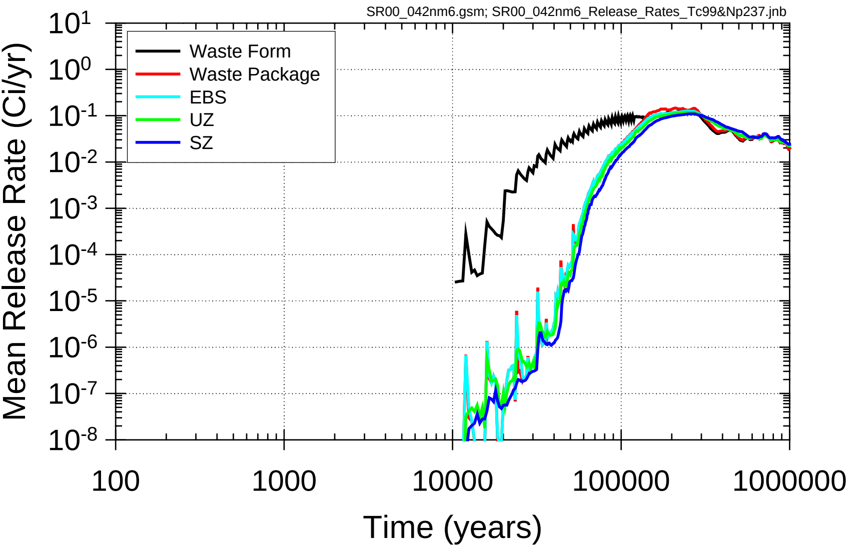


HTOM

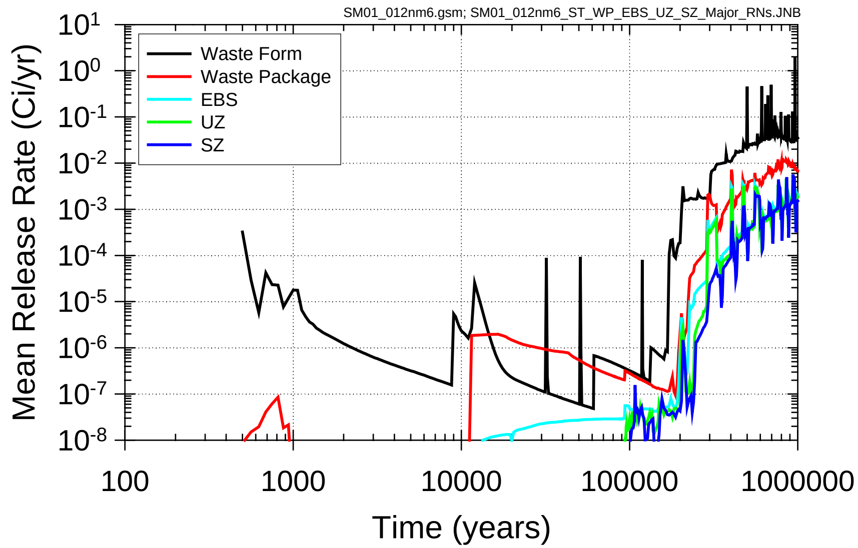


Np-237 Release Rates

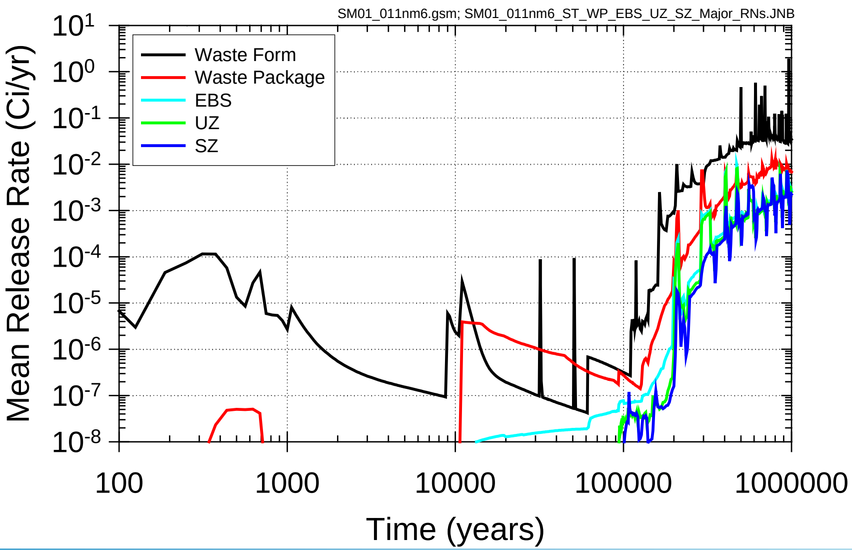
Base Case



LTOM

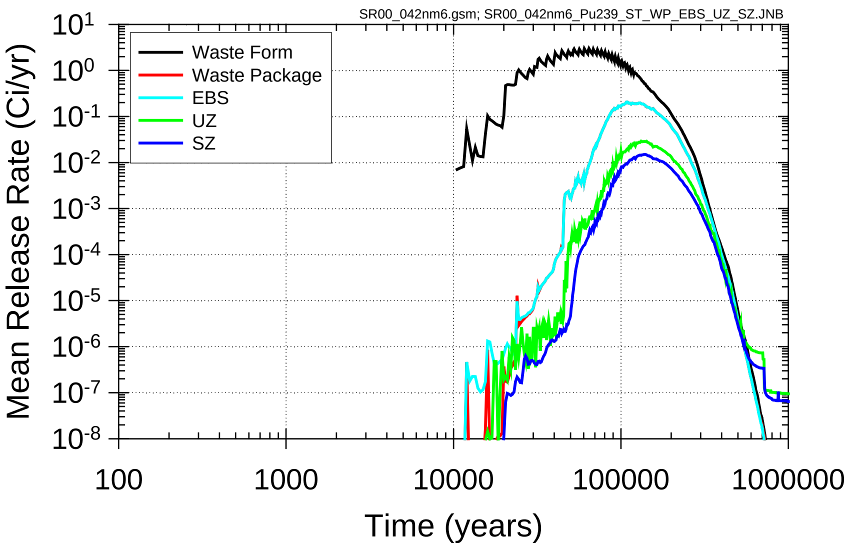


HTOM

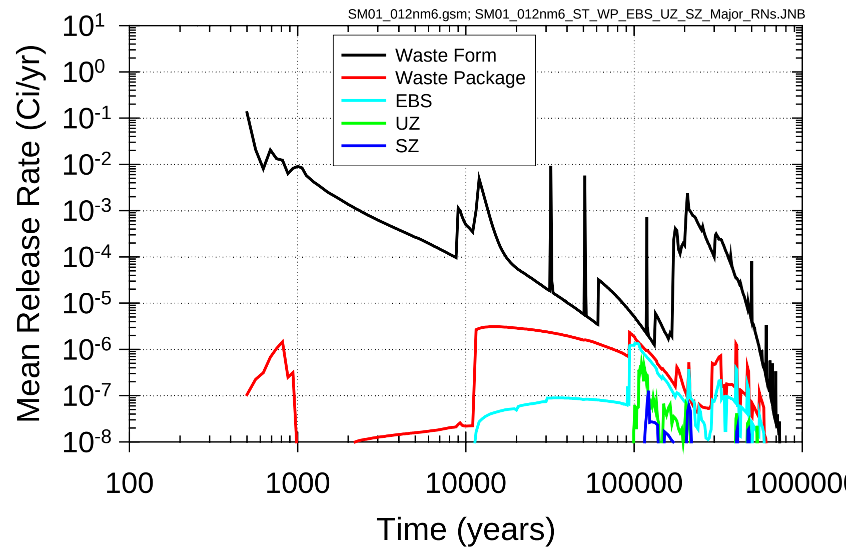


Pu-239 Release Rates

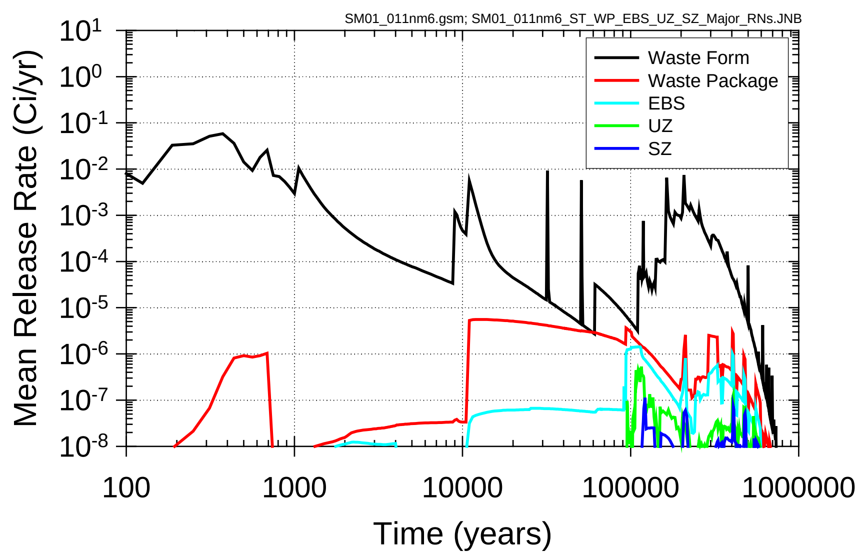
Base Case



LTOM



HTOM



Summary

- **Differences between the supplemental-model results and the base-case results for the nominal scenario are driven primarily by differences in WP failure**
  - **Small fraction of earlier failures**
  - **Most failures much later**
- **Only minor differences between HTOM and LTOM results**
  - **Significant differences in temperature and RH for 1000 years or so translate to small differences in calculated dose**
- **Conclusions regarding uncertainty and its quantification will be discussed in Kevin Coppersmith's talk**