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

TSPA-SR Features, Events, and Processes Approach: Process and Methodology

Presented to:
DOE/NRC Technical Exchange on Total System Performance Assessment (TSPA) for Yucca Mountain
San Antonio, Texas

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YUCCA MOUNTAIN PROJECT

TSPAI IRSR REV. 2 ACCEPTANCE CRITERIA	PRESENTATION/ DOCUMENTATION	SELF-ASSESSMENT	PATH FORWARD TO CLOSURE
SUBISSUE 1 - System Description and Demonstration of Multiple Barriers			
Transparency and Traceability of the Analysis			
Features, Events, and Processes Identification and Screening	Peter Swift		
T1) The screening process by which FEPs were included or excluded from the TSPA is fully described.	All PMRs, FEP AMRs, TSPA-SR Section 1.6	Largely Resolved	Each TSPA-SR component will include a table of included FEPs. A table of excluded FEPs will be in an appendix to the TSPA-SR. The screening process utilized to include or exclude FEPs is described in various documentation including the TSPA-SR Technical Report and the FEP AMRs. The TSPA-SR Technical Report and supporting PMRs and AMRs will need to be reviewed by NRC to close this acceptance criteria.
T2) Relationships between relevant FEPs are fully described.	FEP AMRs, TSPA-SR Section 3	Partially Resolved	Each TSPA-SR component will include a table of included FEPs. A table of excluded FEPs will be in an appendix to the TSPA-SR. This approach needs to be reviewed by the NRC to determine if the acceptance criteria has been satisfied.

TSPAI IRSR REV. 2 ACCEPTANCE CRITERIA	PRESENTATION/ DOCUMENTATION	SELF-ASSESSMENT	PATH FORWARD TO CLOSURE
SUBISSUE 2 - Scenario Analysis			
Identification of an Initial Set of Processes and Events Data	Peter Swift/Geoff Freeze		
1) DOE has identified a comprehensive list of processes and events that: (1) are present or might occur in the Yucca Mountain region and (2) includes those processes and events that have the potential to influence repository performance.	FEP AMRs, TSPA-SR	Largely Resolved	Each TSPA-SR component will include a table of included FEPs. A table of excluded FEPs will be in an appendix to the TSPA-SR. The TSPA-SR Technical Report and supporting PMRs and FEPs AMRs will need to be reviewed for comprehensiveness by the NRC to close this acceptance criteria.
Classification of Processes and Events	Peter Swift/Geoff Freeze		
1) DOE has provided adequate documentation identifying how its initial list of processes and events has been grouped into categories.	FEP AMRs, TSPA-SR Section 1.6, TSPA-SR Section 3	Largely Resolved	The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
2) Categorization of processes and events is compatible with the use of categories during the screening of processes and events.	FEP AMRs, TSPA-SR Section 1.6, TSPA-SR Section 3	Largely Resolved	The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
Screening of Processes and Events	Peter Swift/Geoff Freeze		
1) Categories of processes and events that are not credible for the YM repository because of waste characteristics, repository design, or site characteristics are identified and sufficient justification is provided for DOE's conclusions.	FEP AMRs, TSPA-SR	Largely Resolved	A table of excluded FEPs will be in an appendix to the TSPA-SR. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
2) The probability assigned to each category of processes and events not screened based on criterion T1 or criterion T2 is consistent with site information, well documented, and appropriately considers uncertainty.	FEP AMRs, TSPA-SR	Largely Resolved	Each TSPA-SR component will include a table of included FEPs. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
3) DOE has demonstrated that processes and events screened from the PA on the basis of their probability of occurrence, have a probability of less than one chance in 10,000 of occurring over 10,000 years.	FEP AMRs, TSPA-SR	Largely Resolved	A table of excluded FEPs will be in an appendix to the TSPA-SR. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
4) DOE has demonstrated that categories of processes and events omitted from the PA on the basis that their omission would not significantly change the calculated expected annual dose, do not significantly change the calculated expected annual dose.	FEP AMRs, TSPA-SR	Largely Resolved	A table of excluded FEPs will be in an appendix to the TSPA-SR. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.

Formation of Scenarios			
1) DOE has provided adequate documentation identifying: (i) whether processes and events have been addressed through consequence model abstraction or scenario analysis and (ii) how the remaining categories of processes and events have been combined into scenario classes.	FEP AMRs, TSPA-SR	Largely Resolved	Documentation pertaining to FEPs screening is contained primarily in the FEP AMRs and the TSPA-SR Technical Report. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
2) The set of scenario classes is mutually exclusive and complete.	FEP AMRs, TSPA-SR	Largely Resolved	

Screening of Scenario Classes			
1) Scenario classes that are not credible for the YM repository because of waste characteristics, repository design, or site characteristics, individually or in combination, are identified and sufficient justification is provided for DOE's conclusions.	FEP AMRs, TSPA-SR	Largely Resolved	All scenario classes generated by the FEP screening process were retained for the TSPA-SR. Documentation pertaining to FEPs screening of scenario classes is contained primarily in the FEP AMRs and the TSPA-SR Technical Report. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
2) The probability assigned to each scenario class is consistent with site information, well documented, and appropriately considers uncertainty.	FEP AMRs, TSPA-SR	Largely Resolved	Documentation pertaining to FEPs screening is contained primarily in the FEP AMRs and the TSPA-SR Technical Report. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
3) Scenario classes that combine categories of processes and events may be screened from the PA on the basis of their probability of occurrence, provided: (i) the probability used for screening the scenario class is defined from combinations of initiating processes and events and (ii) DOE has demonstrated that they have a probability of less than one chance in 10,000 of occurring over 10,000 years.	FEP AMRs, TSPA-SR	Largely Resolved	All scenario classes generated by the FEP screening process were retained for the TSPA-SR. Documentation pertaining to FEPs screening is contained primarily in the FEP AMRs and the TSPA-SR Technical Report. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.
4) Scenario classes may be omitted from the PA on the basis that their omission would not significantly change the calculated expected annual dose, provided DOE has demonstrated that excluded categories of processes and events would not significantly change the calculated expected annual dose.	FEP AMRs, TSPA-SR	Largely Resolved	All scenario classes generated by the FEP screening process were retained for the TSPA-SR. Documentation pertaining to FEPs screening is contained primarily in the FEP AMRs and the TSPA-SR Technical Report. The TSPA-SR Technical Report, supporting PMRs, and FEPs AMRs will need to be reviewed by the NRC to close this acceptance criteria.

Outline

- KTI Subissues
- Documentation of Methodology
- Schedule
- Comprehensiveness
- Screening Arguments and Screening Criteria
- Scenario Analysis
- Status of Screening and Scenario Selection

KTI Subissues

- **Relevant TSPAI IRSR Rev. 2 Acceptance Criteria include:**
  - **Section 4.1.1.2: Features, Events, and Processes Identification and Screening**
  - **Section 4.2.3: Screening of Processes and Events**
- **Resolution of TSPAI IRSR open issues described in Open Items table**
- **Matrix of TSPAI IRSR Acceptance Criteria versus Process Model Reports provided**

Documentation of Methodology

- TSPA-SR is the first full implementation of the Features, Events, and Processes (FEPs) approach for the Yucca Mountain (YM) TSPA
- Methodology described previously
  - Disruptive Events Appendix 7 Meeting (10/1998)
  - Nuclear Energy Agency (NEA) conference paper (5/1999)
  - TSPA Technical Exchange (5/1999)
  - FEPs Appendix 7 Meeting (9/1999)
  - TSPA-SR Methods and Assumption Document (10/99)
- Methodology and TSPA-SR Implementation will be documented in the TSPA-SR Technical Report
- FEP screening arguments have been documented in FEP Analysis/Model Reports (AMRs)

Schedule

- October 1998: Project adopts FEP approach
  - NEA FEP database, existing YM FEPs from literature, TSPA workshop process, preliminary Primary/Secondary grouping
- April 1999: Technical work organized by Process Model Reports (PMRs)
- July 1999: All FEPs assigned to AMRs and appropriate subject matter experts, within PMR framework
- February-May 2000: FEP AMRs complete review, TSPA makes final scenario selection
- July 2000: FEP database updated to include screening arguments developed in FEP AMRs

Summary of Approach

- **Scenario Analysis Based on FEPs Identification and Screening**
  - **Derived from NRC approach (NUREG-1667)**
  - **Consistent with TSPA&I Issue Resolution Status Report (IRSR) Rev. 2**
    - **comparison made at 9/99 FEPs Appendix 7**
- **Five Main Steps in the NRC Process**
  - **Identification of FEPs**
  - **Classification of FEPs**
  - **Screening of FEPs**
  - **Constructing Scenario Classes from Retained FEPs**
  - **Screening Scenario Classes**

Five Steps in NRC Scenario Development

Identify features, events, and processes potentially relevant to the long-term performance of the disposal system

Classify FEPs to support evaluation of completeness and to facilitate screening

Screen FEPS using defined criteria to identify those that should be included in the TSPA and those that can be excluded

Construct scenario classes from the retained FEPS

Screen scenario classes using defined criteria

Comprehensiveness of the FEP Analysis

- Initial FEP list compiled from international NEA list and YM-specific documents
- Additional FEPs identified during TSPA-SR planning workshops in 1998 and 1999
- Additional (but relatively few) FEPs identified during AMR process
- Total of 1792 FEPs now in the database
- Best test of comprehensiveness is iterative review
  - If new FEPs are identified, they must be considered

Grouping of FEPs into Categories

- **NRC Criterion (TSPA&I IRSR Rev. 2, Section 4.2.2)**
  - **Provide adequate documentation identifying how its initial list of processes and events has been grouped into categories**
- **DOE Implementation**
  - **FEPs have been grouped into primary and secondary categories**
  - **Detailed arguments provided for primary FEPs**
    - **Redundant or narrowly defined FEPs are classed as Secondary FEPs, mapped to relevant Primary FEP**
    - **Database structure assures transparency of mapping**
  - **Documentation of grouping in FEP AMRs**

Grouping of FEPs into Categories
(continued)

- **Goal of Primary/Secondary classification**
  - reduce redundancy in initial FEP list
  - avoid excessively narrow FEP definition (as per NRC guidance)
  - simplify review of FEPs by grouping closely related FEPs
  - maintain traceability from all FEPs in the comprehensive list to the final set evaluated in the TSPA
- **Preliminary grouping of primary FEPs performed by TSPA FEP team and distributed to FEP AMR leads July 1999**
- **Review, confirmation, and revision (as needed) of grouping by FEP AMR teams**

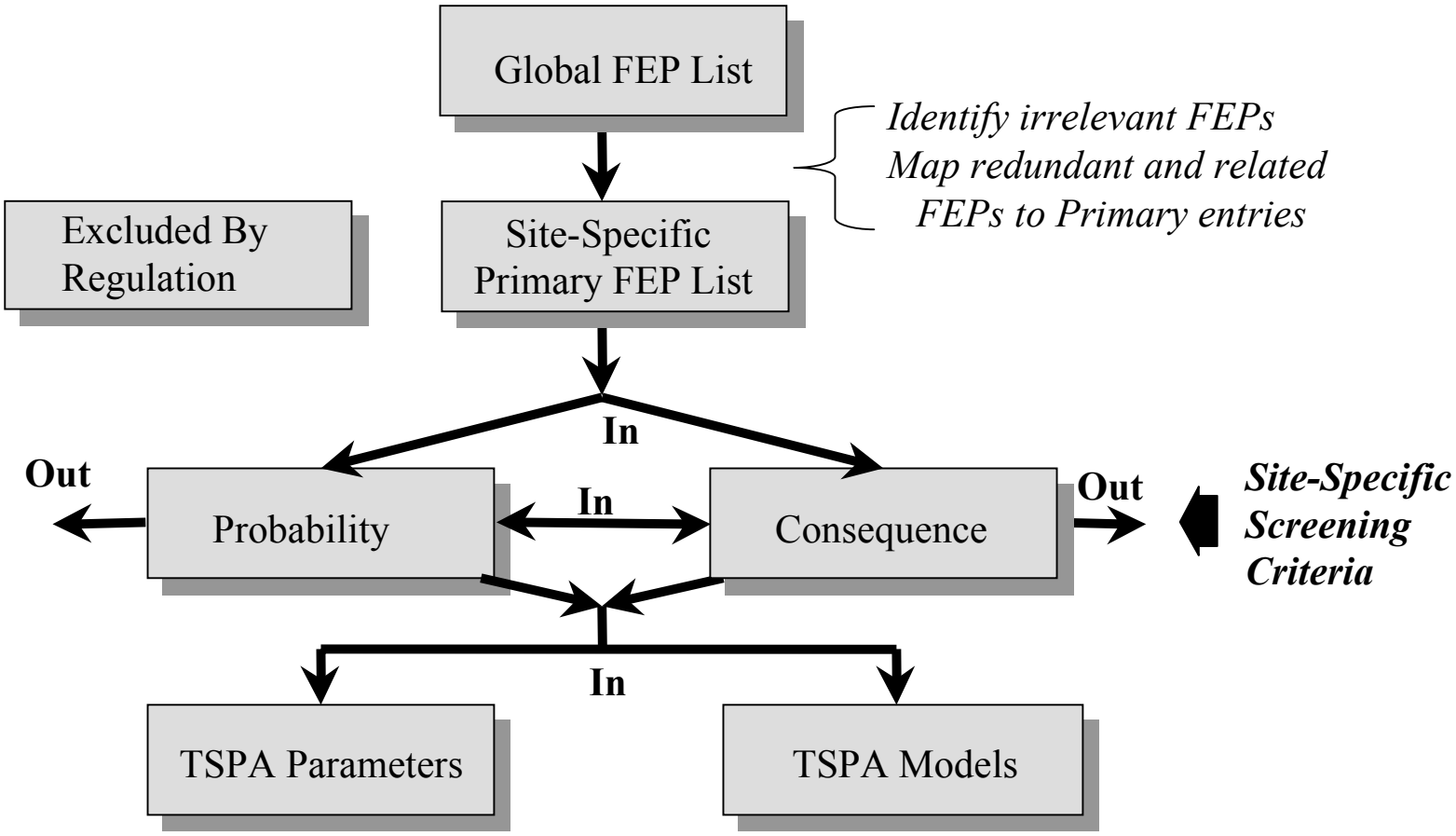
FEP Screening Criteria

- **NRC Criteria (TSPA&I IRSR Rev. 2, Sec. 4.2.3)**
  - **Criterion T1: Justify identification of categories of FEPs that are not credible for YM repository**
  - **Criterion T2: Document probability for each category of FEPs not otherwise screened**
  - **Criterion T3: Document that categories of FEPs screened out on the basis of low P have $P < 10^{-4}/10^{4}$ yr.**
  - **Criterion T4: Document that categories of FEPs screened out on the basis of low consequence would not significantly change the expected annual dose**

DOE Implementation of NRC Criteria

- **DOE treats “not credible” as a variant of “low probability”**
- **DOE uses probability and consequence criteria**

Screening Features, Events, and Processes



Examples of Screening Criteria

- **Probability Criteria**
  - **Criticality during the first 10,000 years is screened out on the basis of low probability**
- **Consequence Criteria**
  - **Rockfall and ground motion damage to drip shield and waste package are screened out on the basis of low consequence**

Examples of FEPs Excluded by Regulation

- **Human Activity**
  - **Human Intrusion FEPs other than drilling are screened out**
    - **Drilling is modeled in a stylized scenario as specified**
  - **Operational period FEPs are screened out**
    - **e.g., detectable operational errors (such as failure to seal the repository) are excluded**
- **Climate for Biosphere**
  - **Limited to Arid to Semiarid**

NRC Guidance on Consequence Screening

- **TSPA&I IRSR Rev. 2 Technical Basis for Screening of Events and Processes (Sec. 4.2.3)**
  - **Detailed calculations of the consequences is not required for screening purposes. . . . The amount of information required to support excluding categories of processes and events from the performance assessment may vary from one category to another, based on the processes and events involved.**

Examples of DOE Consequence Arguments

- Evaluate impact on intermediate performance measures
  - e.g., rockfall is shown to have no effect on drip shield lifetime, and is therefore excluded because it has no potential to affect expected annual dose
- Use deterministic and in some cases bounding analyses
  - e.g., atmospheric releases of C-14
- Use models and codes external to the TSPA
  - e.g., rockfall is excluded based on detailed analysis done outside the TSPA
- Exclude some FEPs whose only effect is beneficial (but minor)
  - e.g., improved performance of DSNF packaging and cladding is neglected

Examples of DOE Consequence Arguments
(continued)

- Consequence Arguments rely on
  - reasoned arguments based on literature
    - e.g, FEPs related to regional processes such as erosion, uplift
  - hand calculations
    - e.g., meteorite impact
  - extensive site characterization or modeling outside of TSPA
    - e.g., water-table rise due to seismicity
  - TSPA sensitivity analysis
    - e.g., disruption of groundwater flow by faulting
- TSPA-SR system-level analyses can provide confirmation
  - e.g., decision to exclude rockfall damage can be examined through barrier-importance analyses of degraded drip shields

Scenario Analysis

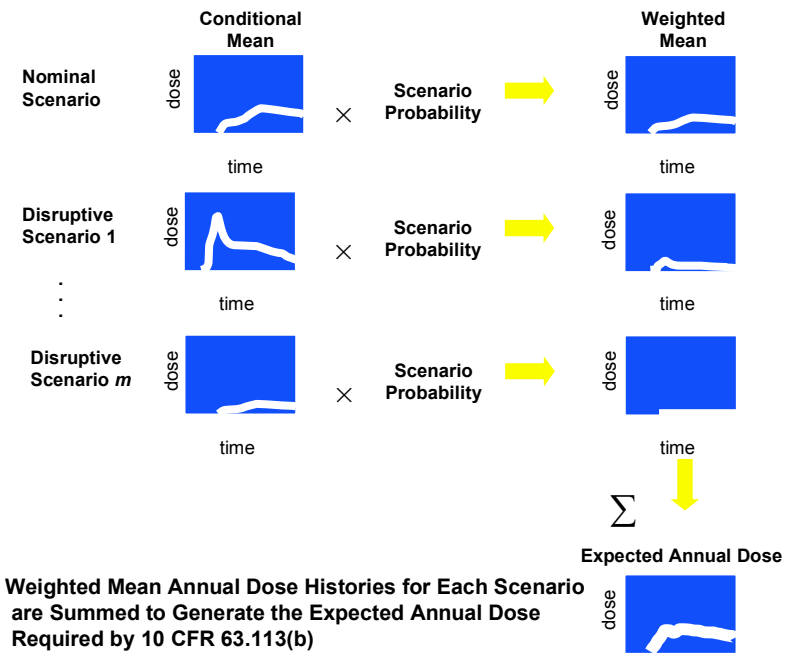
- **Scenario Classes are constructed from all retained FEPs**
  - **The nominal scenario class contains all expected FEPs (FEPs for which P=1 for the purposes of the analysis)**
  - **Disruptive scenario classes contain all expected FEPs plus all combinations of disruptive FEPs (retained FEPs with P<1)**
- **In the TSPA-SR, Igneous Activity is the only category of disruptive FEPs, and therefore Igneous Disruption is the only Disruptive Scenario Class**

Latin Square Scenario Diagram for TSPA-SR

	Igneous Disruption Occurs P = P(I)	Igneous Disruption Does Not Occur P = 1- P(I)
All Expected FEPs Occur P = 1	Igneous Disruption Scenario Class P = P(I)	Nominal Performance Scenario Class P = 1 - P(I)

Combining Scenario Results

- Implementation is more complicated than the schematic approach shown in TSPA&I IRSR Rev. 1., App. D and the TSPA-SR Methods and Assumptions Document
- Key points discussed here
- Details later, in the context of GoldSim implementation



Combining Scenario Results (continued)

- **Dose histories calculated for**
  - **Nominal performance**
  - **Two cases of the Igneous Disruption Scenario Class**
    - **Eruption/Ashfall**
    - **Groundwater transport following intrusion**
- **Eruptive dose histories evaluated for *N* realizations of eruptions every 25 years**
  - **Probability = (annual probability) X 25**
- **Igneous intrusion groundwater dose histories use sampled time of intrusion during 20,000-year period**
  - **Probability = (annual probability) X 20,000**
- **Overall Expected Annual Dose is the sum of the nominal dose history and the two igneous dose histories**

Conclusions

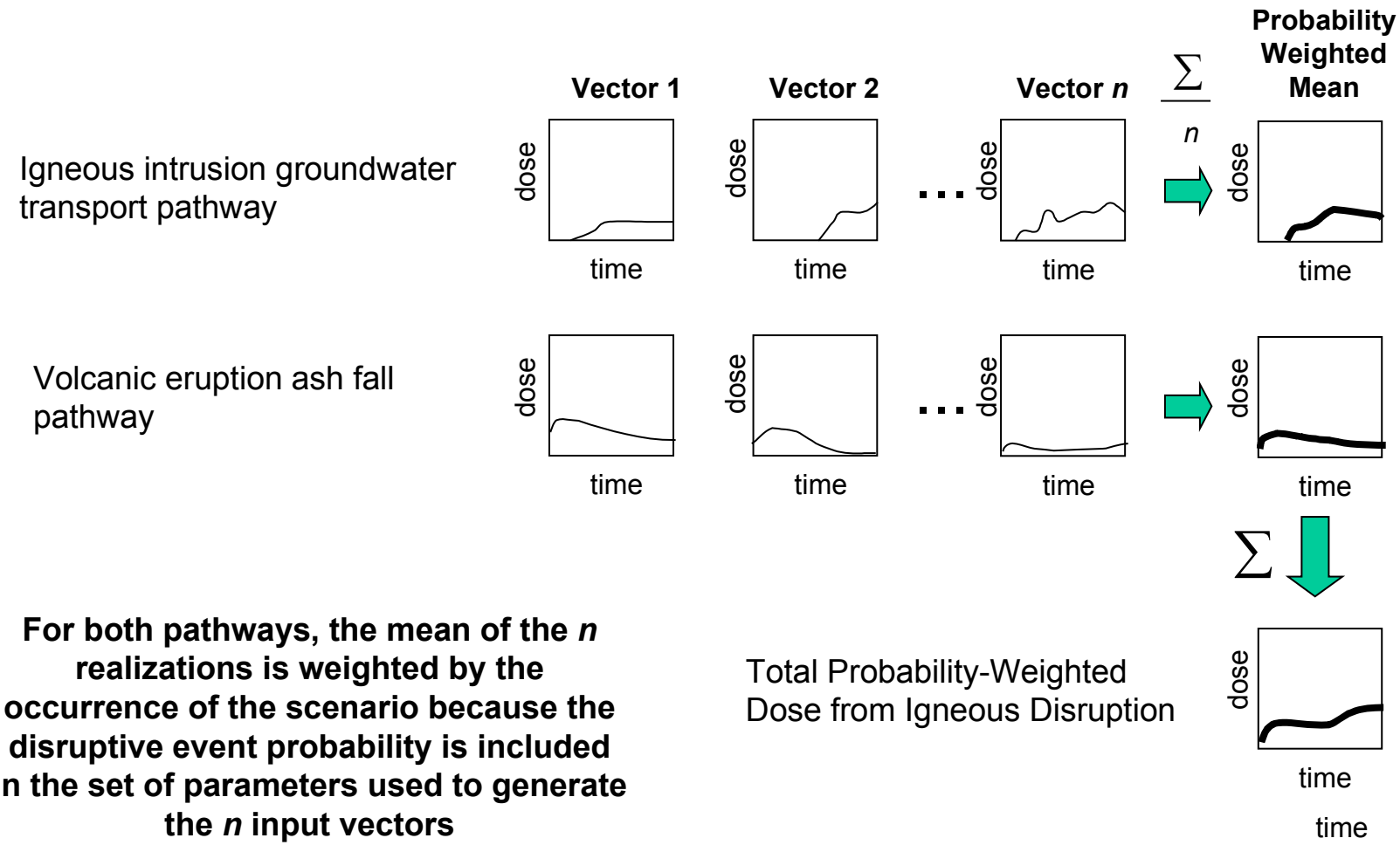
- DOE has implemented the NRC FEP approach for TSPA-SR
- Identification and screening of FEPs is the basis for DOE's demonstration of the comprehensiveness of the TSPA
- Technical basis for FEP screening documented through PMR and AMR process (in progress)
- TSPA includes nominal and igneous disruption scenario classes developed from the FEP-based scenario analysis

Backup

FEP AMRs

- BIO: Evaluation of the Applicability of Biosphere-Related Features, Events, and Processes (FEP)
- DE: Disruptive Events FEPs
- EBS: EBS FEPs/Degradation Modes Abstraction
- NFE: Features, Events, and Processes in Thermal Hydrology and Coupled Processes
- SYS: Analyses to Support Screening of System-Level Features, Events, and Processes for the Yucca Mountain Total System Performance Assessment - Site Recommendation
- SZ: Features, Events, and Processes in SZ Flow and Transport
- UZ: Features, Events, and Processes in UZ Flow and Transport
- WF: Miscellaneous Waste-Form FEPs
  - Clad Degradation – FEPs Screening Arguments
  - Waste Form Colloid-Associated Concentrations Limits: Abstraction And Summary
- WP: FEPs Screening of Processes and Issues in Drip Shield and Waste Package Degradation

Calculating the Probability-Weighted Mean Annual Dose for the Igneous Disruption Scenario

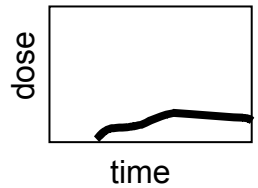


For both pathways, the mean of the *n* realizations is weighted by the occurrence of the scenario because the disruptive event probability is included in the set of parameters used to generate the *n* input vectors

Sum the Probability-Weighted Means to Yield the NRC's "Expected Annual Dose"

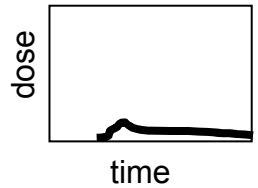
Weighted Mean

Nominal Scenario



Nominal Dose is weighted by probability = 1

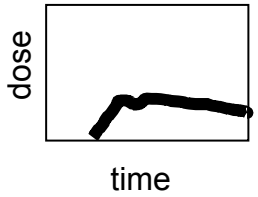
Igneous Disruption Scenario



Igneous Disruption Dose is weighted by the event probability during calculation

$\sum$

Expected Annual Dose



Combined Scenario Probability = 1

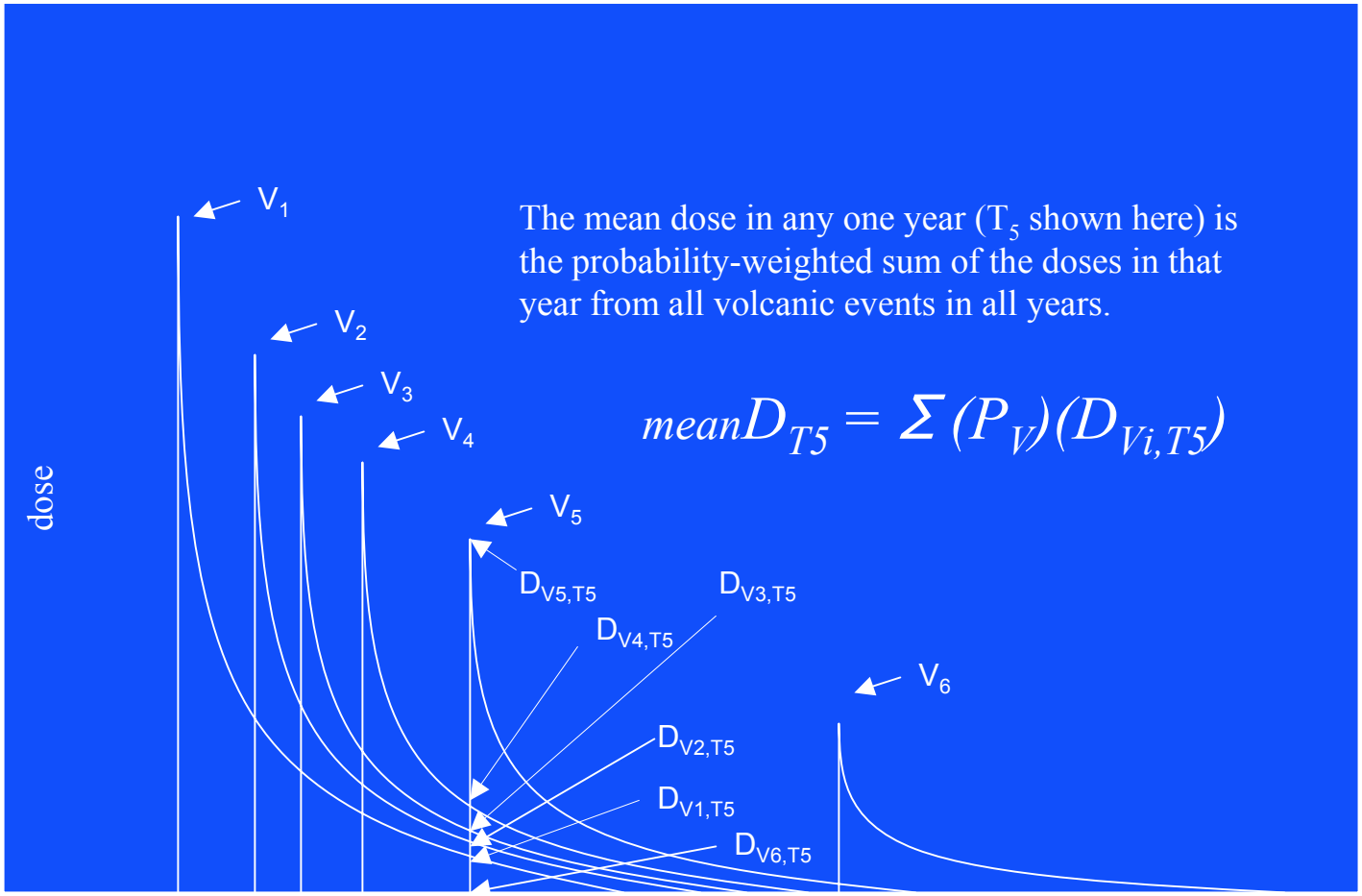
P(igneous) = P_i (a sampled parameter)
P(nominal) = $1-P_i$

Expected nominal dose (D_{ne})
$= (1- P_i)D_n$

Expected igneous dose (D_{ie})
$= (P_i)D_i + (P_i)D_n$

Expected total dose (D_{te})
$= (1-P_i)D_n + (P_i)D_i + (P_i)D_n$
$= D_n + (P_i)D_i$

The Mean Eruptive Volcanic Dose in One Year



The mean dose in any one year (T_5 shown here) is the probability-weighted sum of the doses in that year from all volcanic events in all years.

$$meanD_{T5} = \Sigma (P_V)(D_{Vi,T5})$$