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

www.ocrwm.doe.gov

Addressing Public Confidence in the Case for Yucca Mountain Safety

Presented to:

American Nuclear Society International High-Level Radioactive Waste Management Conference

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Outline

- **Background and status of Yucca Mountain repository program**
- **Preclosure Safety Analysis (PCSA)**
- **Postclosure Total System Performance Assessment (TSPA)**
- **Communicating the basis for confidence in the TSPA**

Background and Status of the Yucca Mountain Repository Program

- **Nations with nuclear power programs pursue the geologic disposal option**
- **Yucca Mountain location**
- **Nuclear power history in the US**
- **Selecting the Yucca Mountain site**
- **Licensing is the next step**

The United States is One of Many Countries Pursuing Geologic Repositories

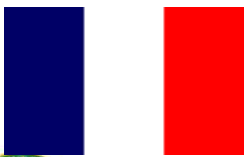
United States
Yucca Mt site approved 2002; site characterization complete; license application to NRC in June 2008; repository operation TBD

Belgium
URL at Mol (Boom clay); 2002 SAFIR-2 site feasibility report favorable; repository by 2035

Canada
"Adaptive Phased Management" approach agreed Nov. 2005; siting to use public input; repository operations by 2035

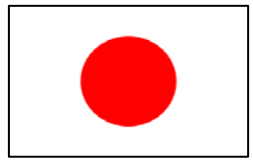
China
Beishan granitic site near Gansu in Gobi Desert under study since 2001; site characterization thru 2010URL and disposal demos thru 2025

Finland
Olkiluoto granite site ratified 2001; "Onkalo" URL confirmatory tests since 2004; repository construction permit by 2012, operations by 2020



France
Bure clay site feasibility published 2005; June 2006 Act calls for 2025 repository

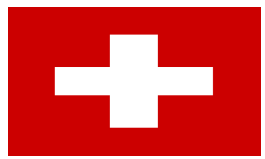
Germany
Moratorium on Gorleben site; 2002 siting criteria being debated; could lead to two new sites by 2010 – possibly Konrad iron mine



Japan
URLs at Horonobe & Mizunami; NUMO voluntary siting shortlist by 2007; site selection by 2025

Spain
Central SNF storage by 2010; generic repository design; no siting work before 2010

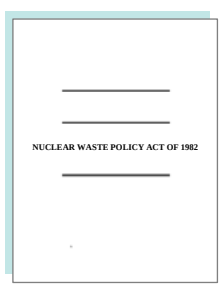
Sweden
Osthammar & Oskarshamn crystalline site studies since 2002; LA by 2008; SNF canister facility permit application LA submitted Nov. 2006; operations test at Aspo URL



Switzerland
URLs at Grimsel (granite) & Mt. Terri (clay); Opalinus clay site feasibility approved June 2006; siting procedures soon

United Kingdom
CoRWM's final recommendation for repository disposal accepted October 2006; interim storage for now; siting process under development

U.S. Nuclear Waste Policy and Yucca Mountain



1983 — Office of Civilian Radioactive Waste Management

1982 — Congress passes Nuclear Waste Policy Act (NWPA)

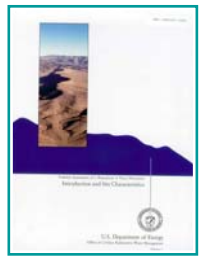
1970s — Nat'l screening & search for potential repositories

1957 — National Academies of Science (NAS) supports deep geologic disposal

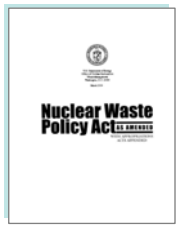
U.S. Nuclear Waste Policy and Yucca Mountain

Yucca Mountain Site Selection

2002



1998 DOE issues **Viability Assessment of Yucca Mountain**



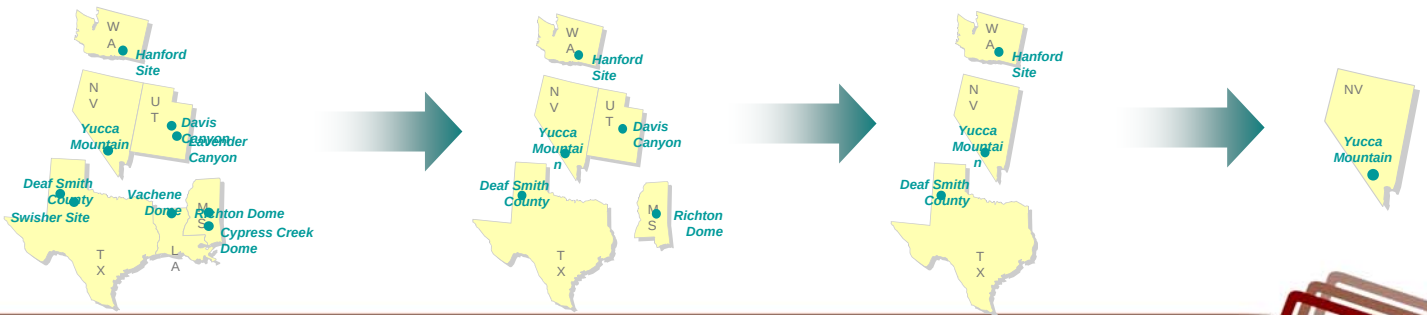
1992 EPA to set radiation protection standard

1987 NWPA Amended: Act mandates ONE SITE for characterization

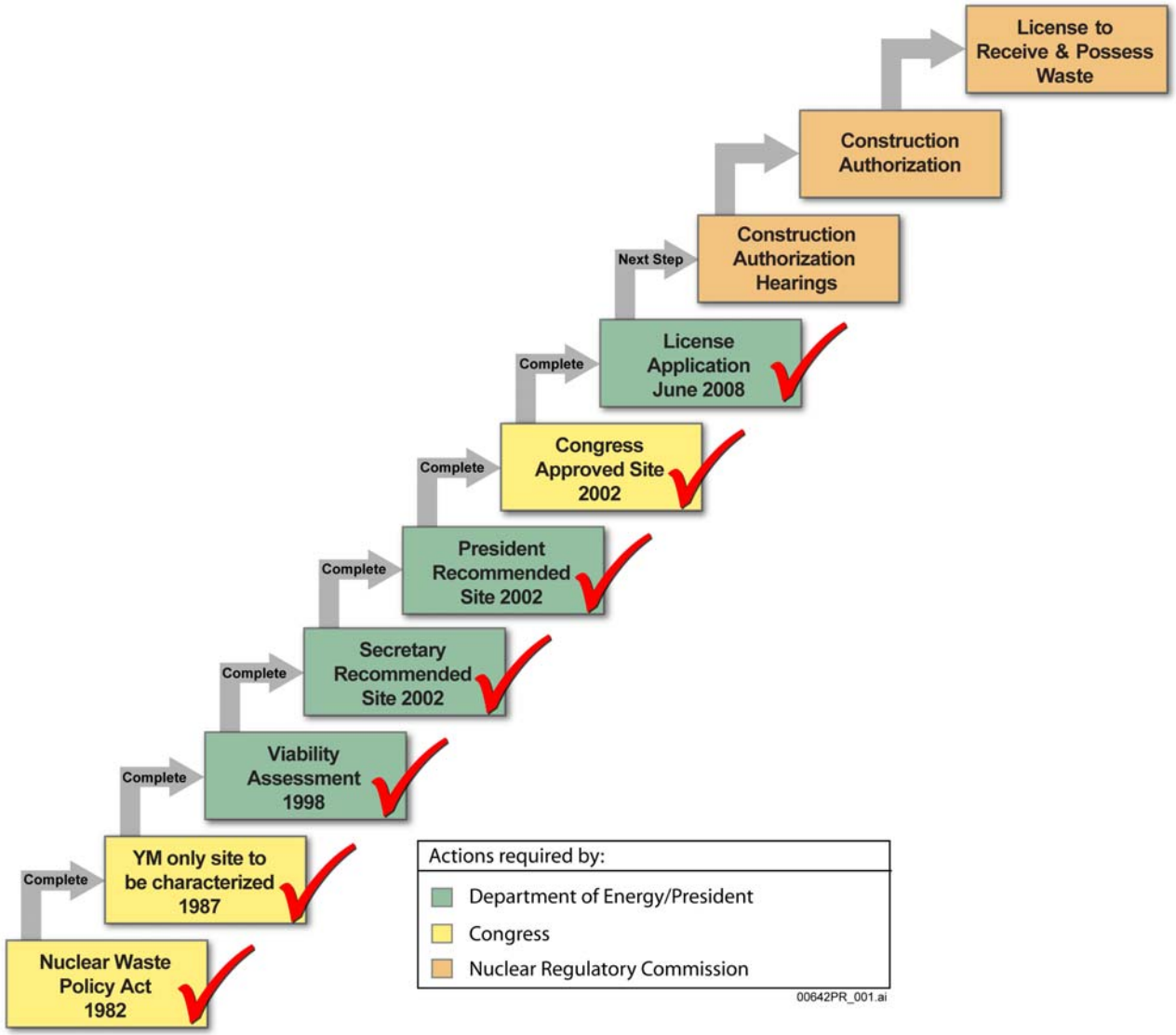
1986 3 SITES Approved for Further Study

Secretary of Energy NOMINATES 5 SITES

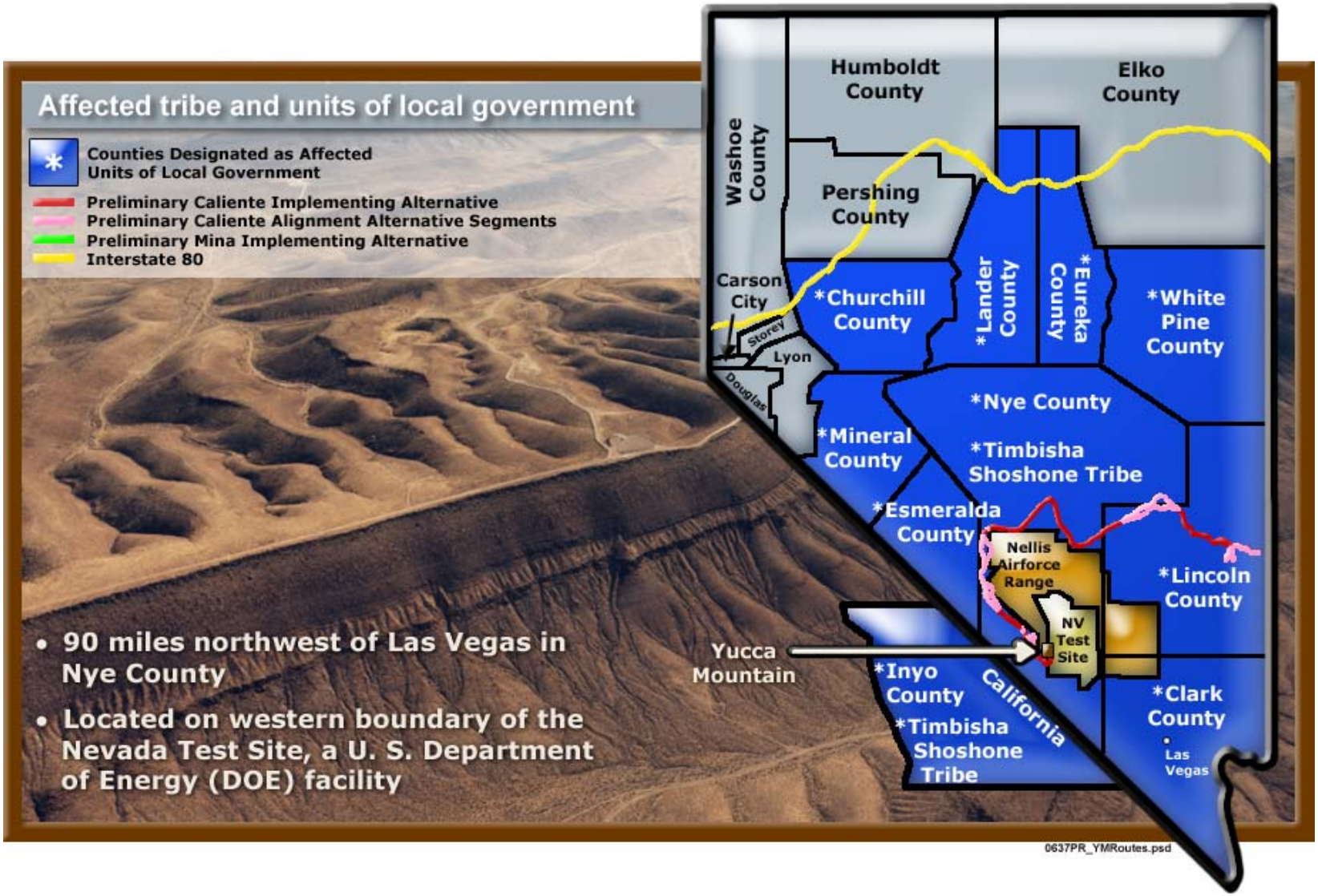
1983 DOE identifies 9 POTENTIAL SITES



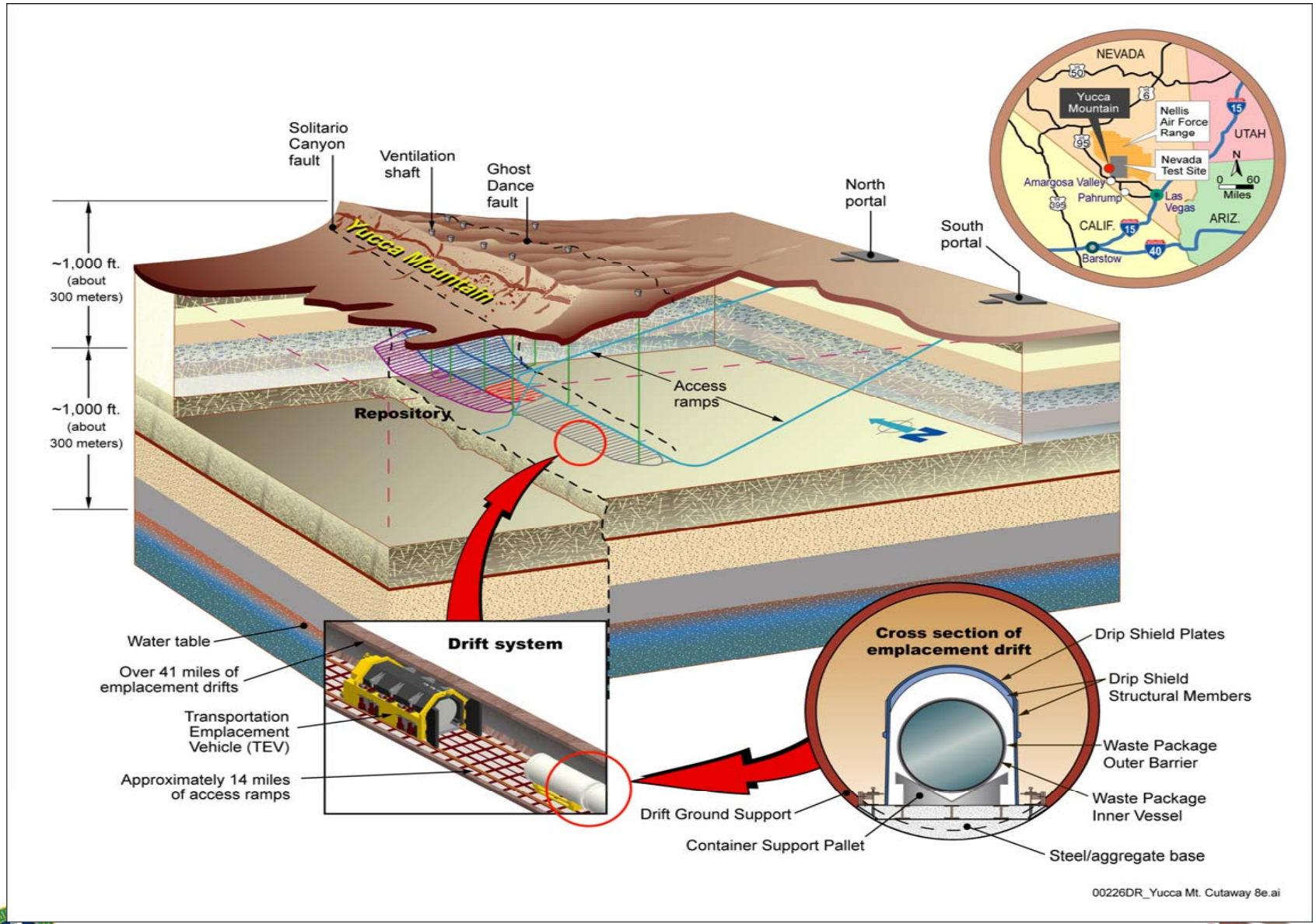
Repository program steps



Yucca Mountain, Nevada



Proposed Repository at Yucca Mountain

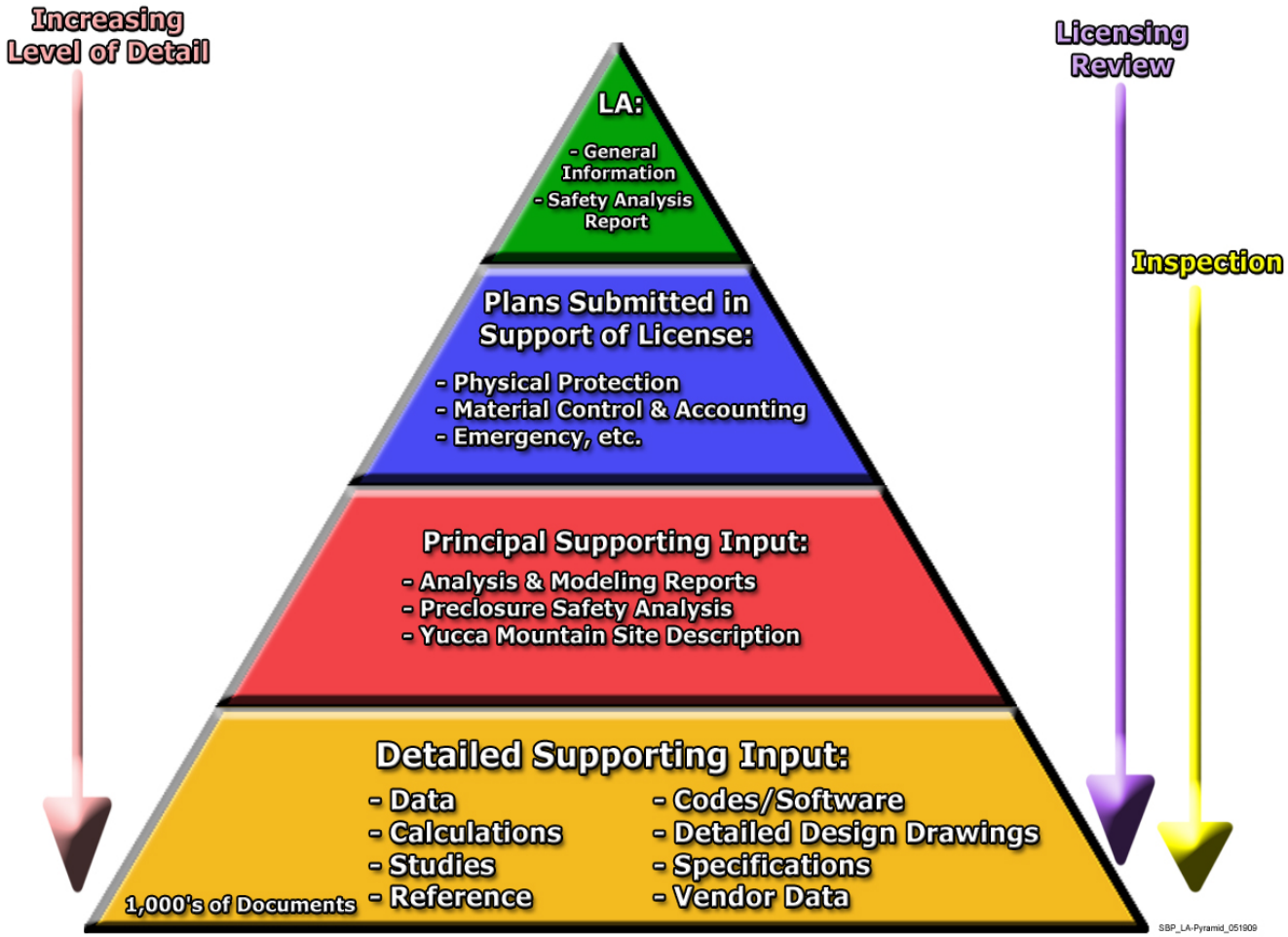


Safety Evaluations and the License Application

- **Preclosure Safety Analysis (PCSA)**
- **Postclosure Total System Performance Assessment (TSPA)**

License Application Content

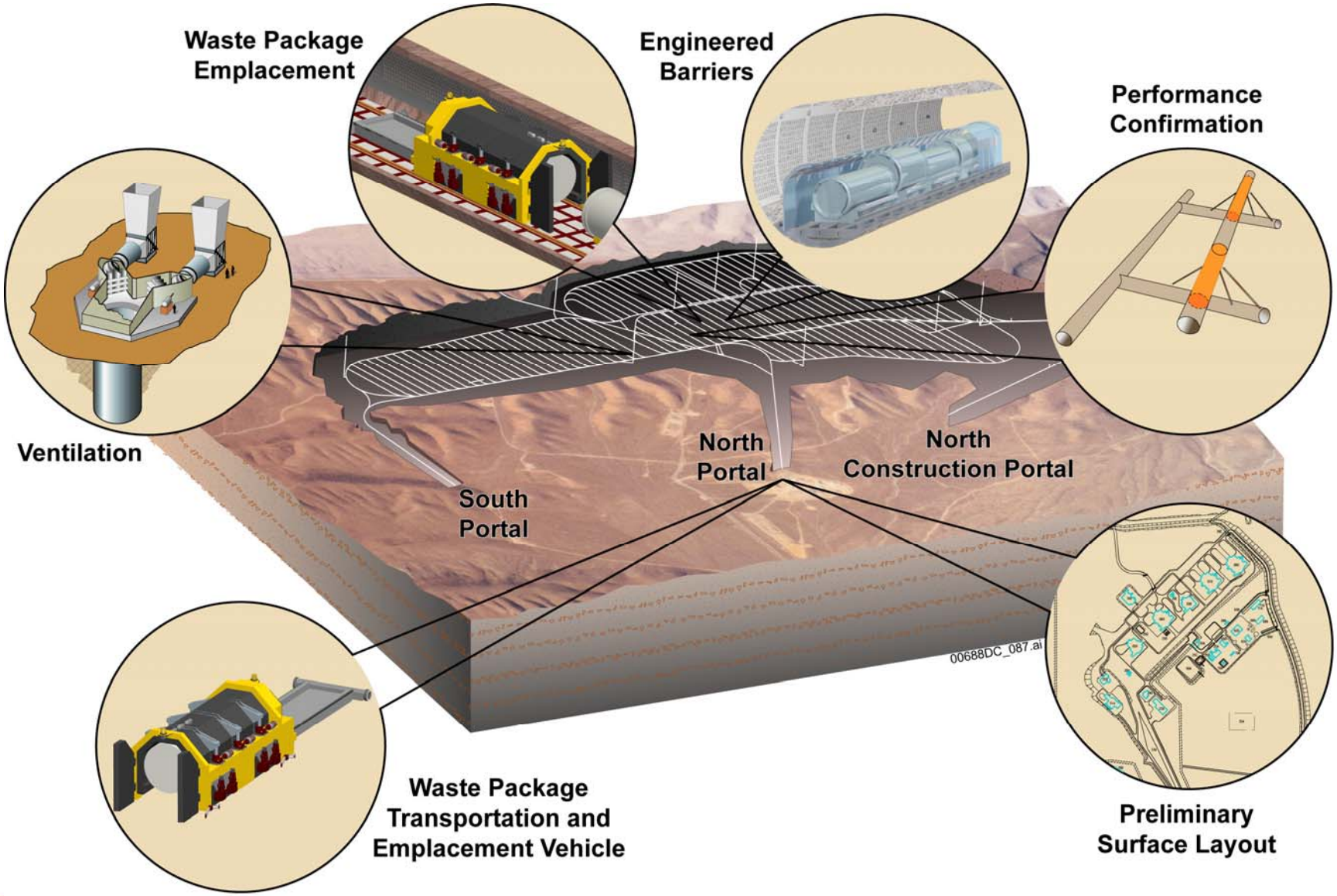
- **General Information (GI)**
  - General Description
  - Proposed Schedules for Construction, Receipt and Emplacement of Waste
  - Physical Protection Plan
  - Material Control and Accounting Program
  - Site Characterization
- **Safety Analysis Report (SAR)**
  - Repository Safety Before Permanent Closure
  - Repository Safety After Permanent Closure
  - Research and Development Program to Resolve Safety Questions
  - Performance Confirmation Program
  - Administrative and Programmatic Requirements



Elements of the Safety Case

- **Postclosure Safety Case**
  - Total system performance assessment (TSPA)
  - Comprehensive analyses and defense-in-depth
  - Evaluation of uncertainty
  - Analysis of potentially disruptive events
  - Insights from natural analogues
  - Performance confirmation
- **Preclosure Safety Case**
  - Preclosure safety analysis - event sequences categorized by frequency (PCSA)
  - Safety margin and defense in-depth
  - Analysis of Category 1 & 2 event sequences
  - Industry precedent and experience
  - Licensing specifications and surveillance

Preclosure Safety Analysis Domain



Preclosure vs. Postclosure Safety Analyses

- **Preclosure Safety Analysis (PCSA) Uses Probabilistic Risk Assessment (PRA) Technology**
  - **PCSA uses industry-standard and largely proven methods**
  - **The operational phase of the repository will be closely monitored, giving feedback on the PCSA as the repository is loaded, based on experience**
- **This feedback from monitoring separates the PCSA from the postclosure TSPA**
  - **Only very limited monitoring can be done to address a million-year projection of potential safety**
- **Therefore, providing arguments for postclosure safety to a non-specialist audience is likely more challenging for the postclosure safety evaluations than the preclosure (operational) safety evaluations**

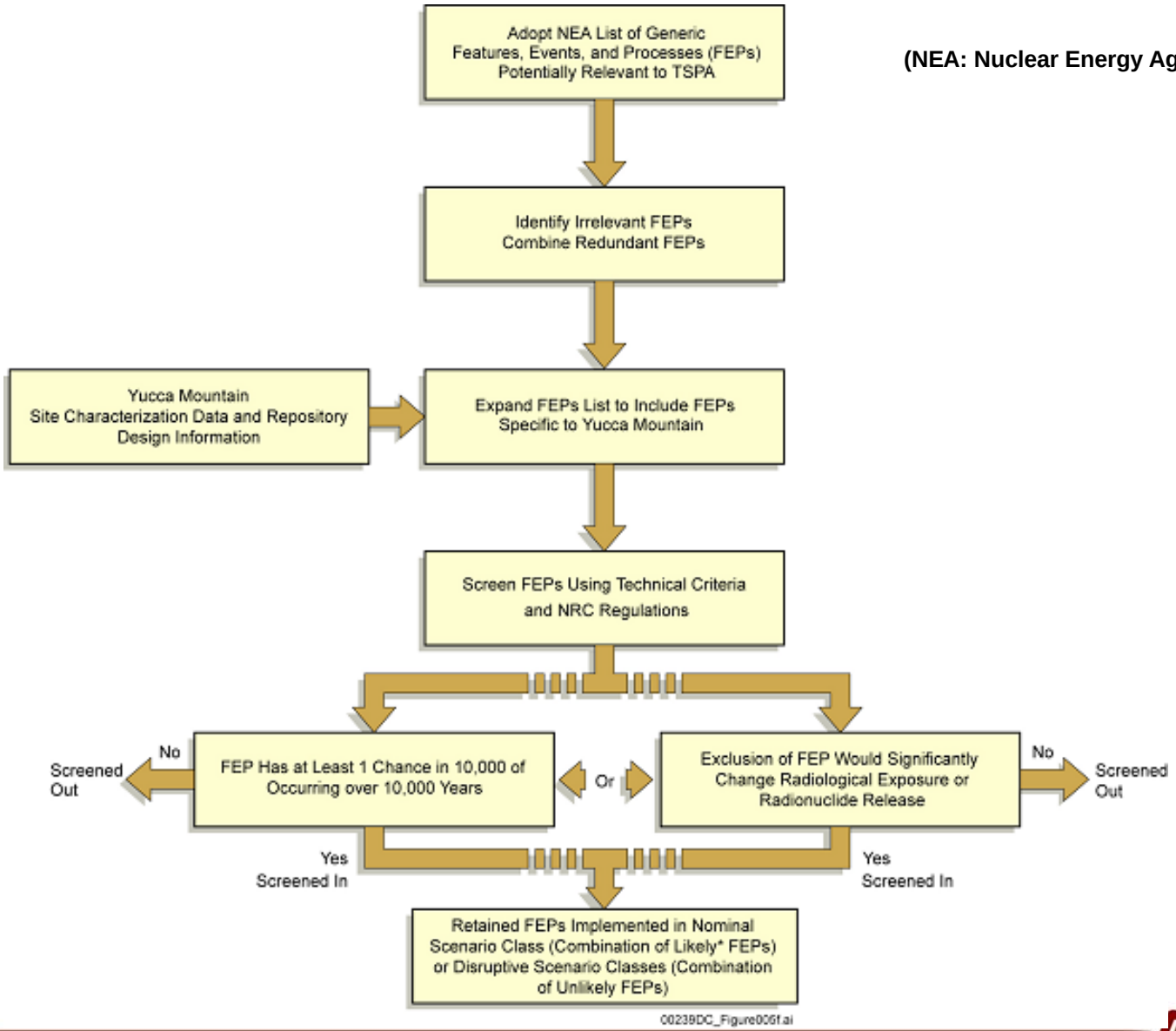
Postclosure Total System Performance Assessment (TSPA)

- **TSPA is a method for providing quantitative estimates of future system performance, considering uncertainties**
  - **Defined by NRC and EPA regulations**
- **Key aspects include**
  - **Weight consequences by probability (i.e., regulate on risk)**
  - **Account for uncertainties (regulate on mean risk, display uncertainty)**
- **Basic approach**
  - **Monte Carlo uncertainty analysis of scenarios**

TSPA Model Architecture

- **TSPA Models address scenario classes**
  - **Nominal Scenario Class**
  - **Early Failure Scenario Class**
    - **Early failure of a statistically determined number of dripshields or waste packages**
  - **Igneous Scenario Class**
    - **Volcanic eruption and/or igneous intrusion**
  - **Seismic Scenario Class**
- **Each scenario class has a separate TSPA model**
- **Each model component has information flow logic diagrams**
- **Each model component has an integrated set of inputs and outputs**
- **Each model abstraction has a conceptual basis**

Features, Events and Processes (FEPs) Evaluation

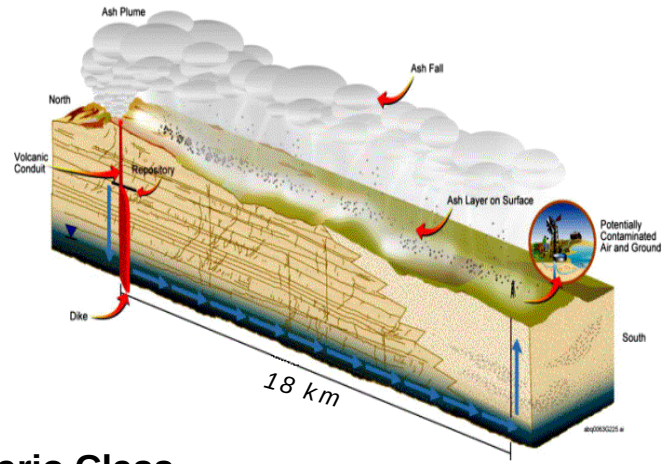


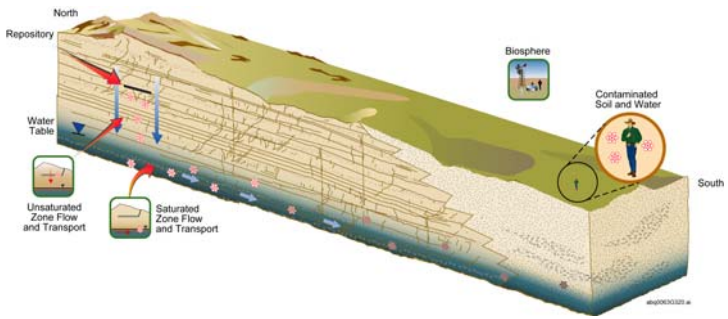
(NEA: Nuclear Energy Agency, Paris)

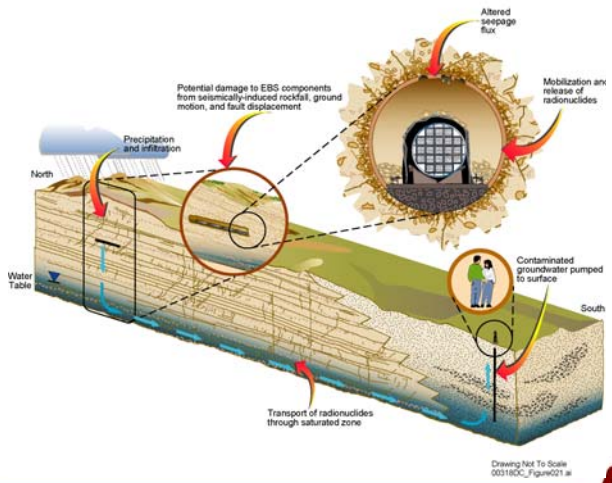
TSPA-LA Scenarios

Four scenario classes divided into seven modeling cases

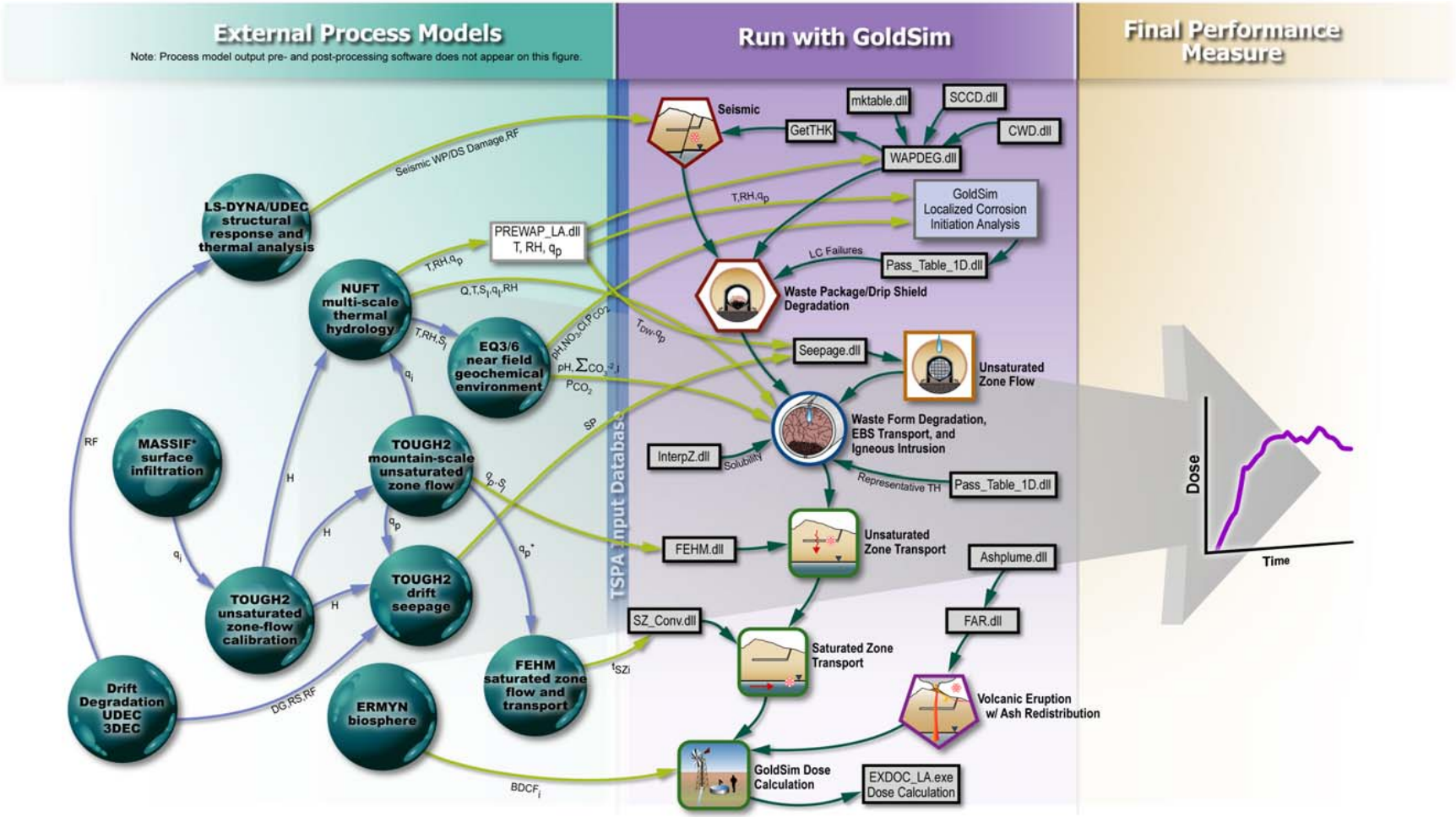
- Nominal Scenario Class
  - Nominal Modeling Case
- Early Failure Scenario Class
  - Waste Package Modeling Case
  - Drip Shield Modeling Case
- Igneous Scenario Class
  - Intrusion Modeling Case
  - Eruption Modeling Case
- Seismic Scenario Class
  - Ground Motion Modeling Case
  - Fault Displacement Modeling Case







TSPA Software Architecture



Output Parameters

f_S	Fraction of WPs with Seeps	q_p	Percolation Flux	q_i	Infiltration Flux	H	Hydrologic Properties
EBS	Engineered Barrier System	NO_3	Nitrate Concentration	DG	Drift Geometry	SP	Seepage Parameters
Q_S	Seep Flow Rate	T	Temperature	Cl	Chloride Concentration	RS	Rock Strength
Q	Evaporation Rate	RH	Relative Humidity	I	Ionic Strength	RF	Rockfall Size and Number
pH	pH	S_l	Liquid Saturation	t_{SZi}	Saturated Zone Transport Time		
ΣCO_3^{-2}	Carbonate Concentration	X_a	Air Mass Fraction	$BDCF_i$	Biosphere Dose Conversion Factor		
P_{CO_2}	Partial Pressure of CO_2	q_l	Liquid Flux	q_g	Gas Flux		

*Note: q_p derived from INFIL model

Legend

Response Surface between Process Models
Response Surface from Process Model to GoldSim
Connection in GoldSim
Preprocessor
TSPA Model DLL

00817DC_0093a.ai

Contributions of Evaluated Scenarios to Million-Year System Performance

LA_v5.005_ED_003000_000.gsm; LA_v5.005_EW_006000_000.gsm ;
LA_v5.005_IG_003000_000.gsm; LA_v5.005_SM_009000_003.gsm;
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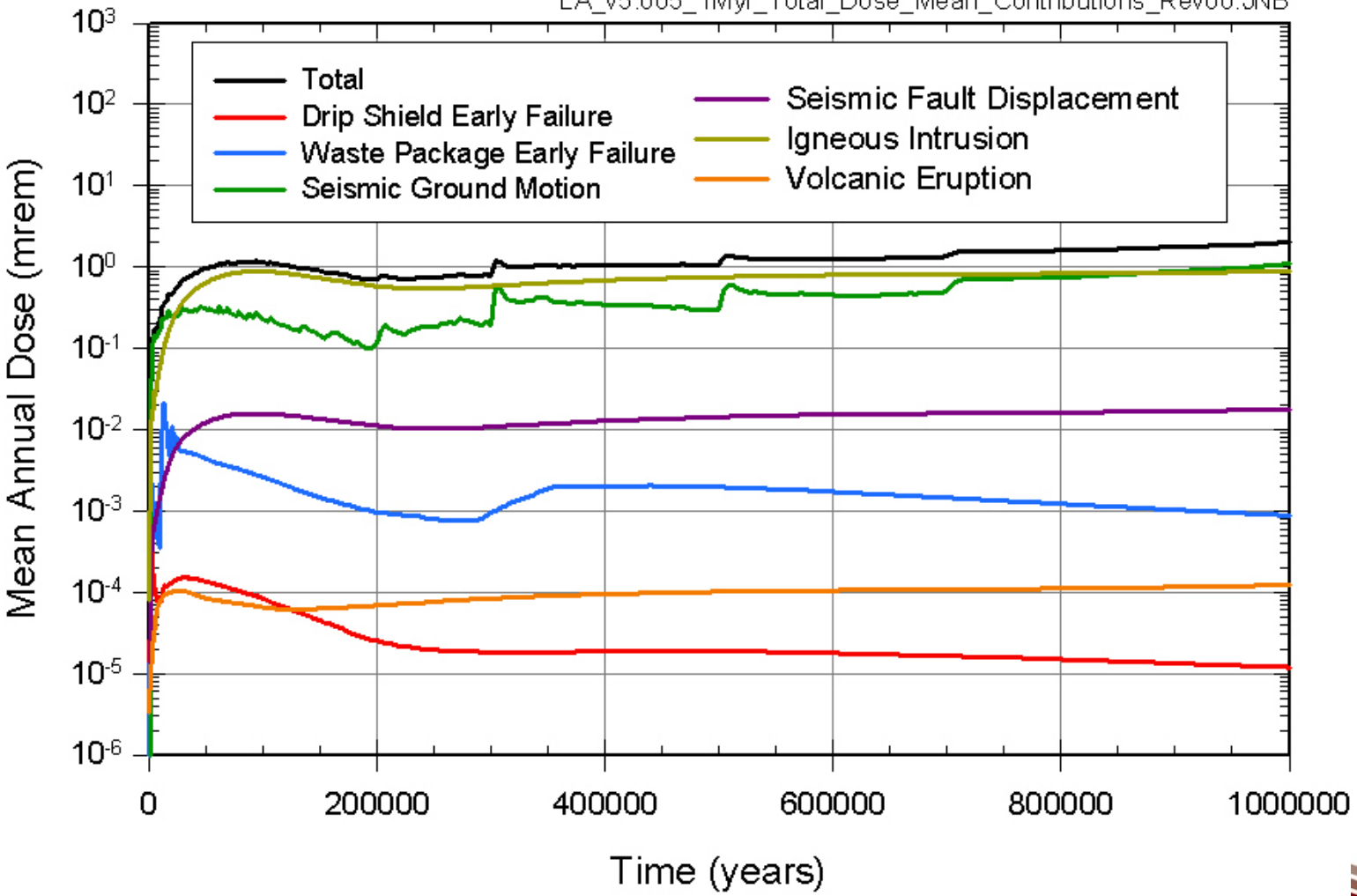
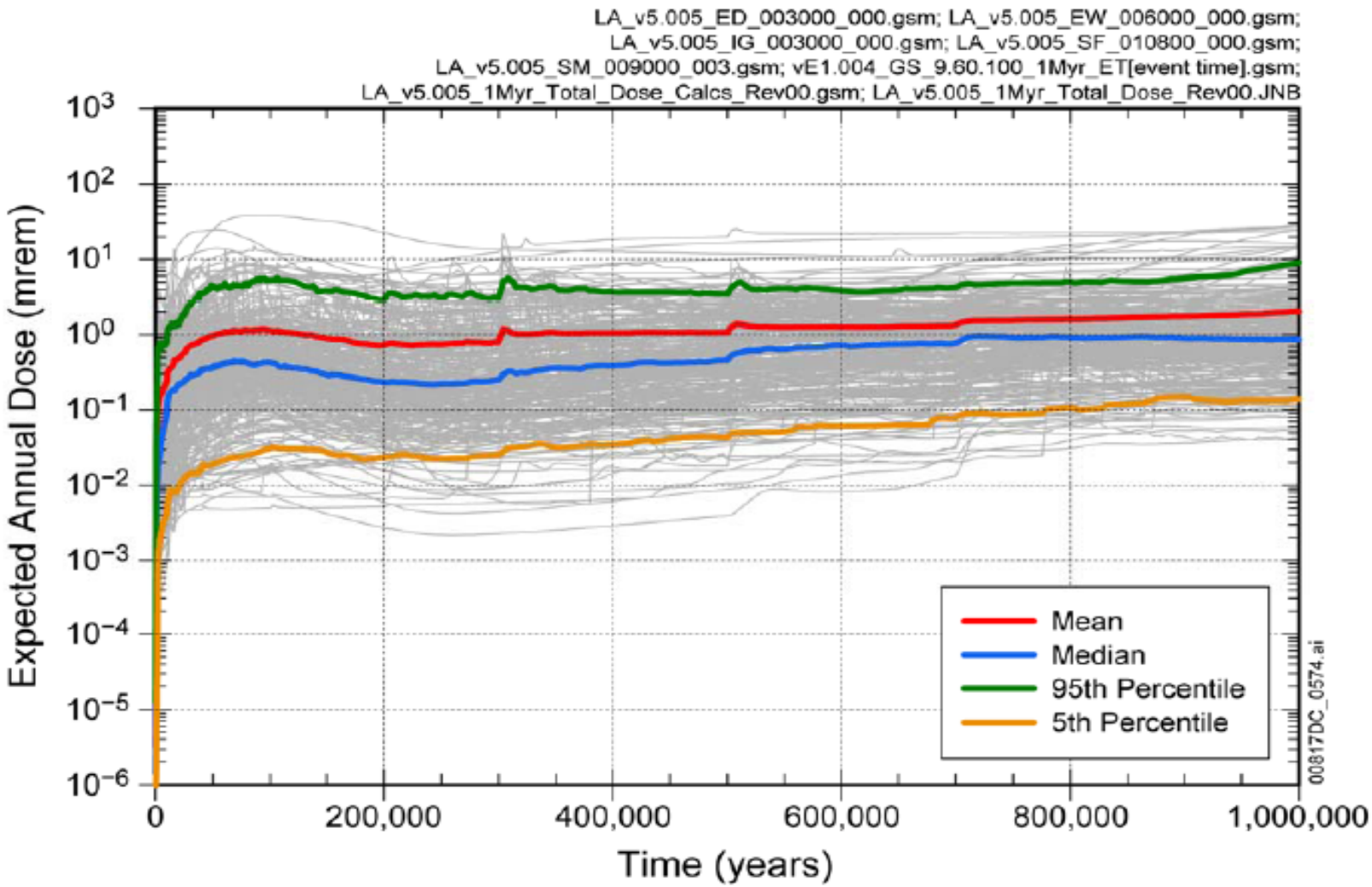
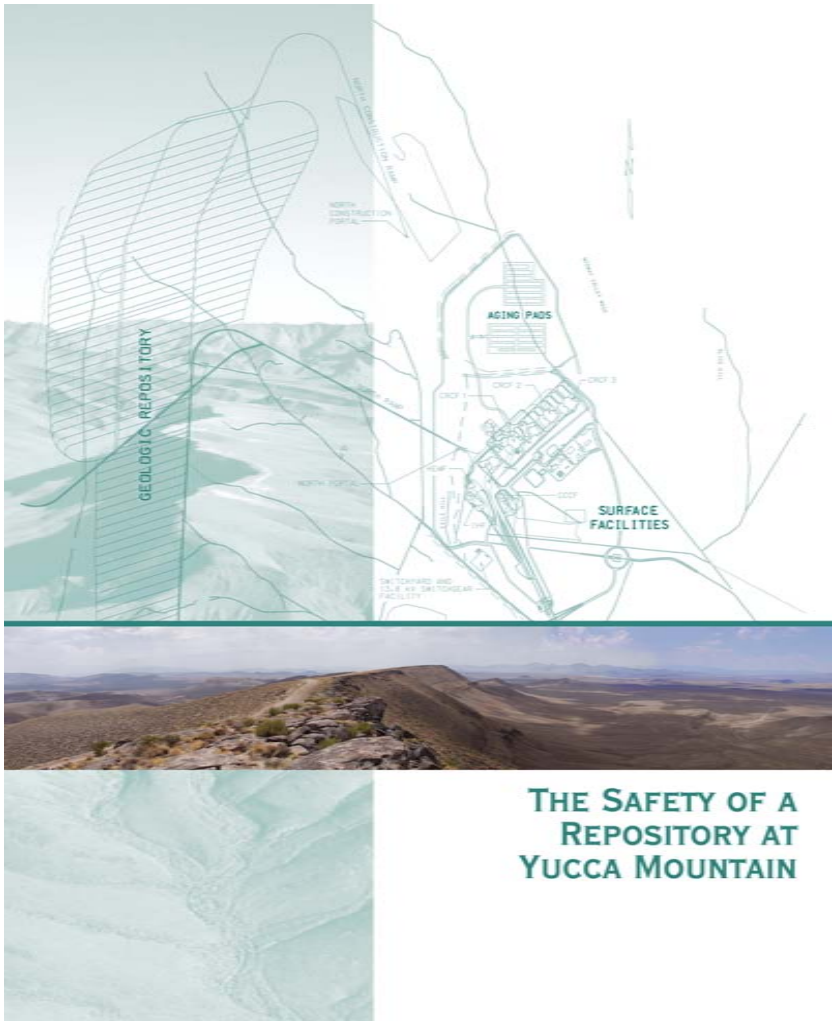


Example TSPA 2008 Dose-History Results 300 Realizations -- All Scenarios



The Safety of a Repository at Yucca Mountain



Available on the internet at:
http://www.ocrwm.doe.gov/ym_repository/license/docs/Safety_of_a_repository.pdf

Communicating the Basis for Postclosure Safety

- **It is difficult to obtain a complete understanding of the PCSA and TSPA without a background in various engineering and science disciplines**
- **However, it is important for persons without such specialized backgrounds to also understand how DOE has concluded that it is safe to dispose spent nuclear fuel in the Yucca Mountain repository**
- **DOE has prepared a brochure entitled "The Safety of a Repository at Yucca Mountain," written in plain language with illustrations of various aspects of the repository to aid in this understanding**

Confidence and uncertainty in TSPA results

- There is a inherent uncertainty in predictions of how complex systems perform over extremely long periods of time
- DOE is required to evaluate uncertainty and the NRC will assess DOE's performance assessment against a "reasonable expectation" of safety standard
- Accounting for uncertainty does not detract from having confidence in the overall expectation of safety for the repository system
  - Evaluation of uncertainty gives an indication of what the more likely range of outcomes may be
  - A mean or median value presented in the context of overall uncertainty gives a more comprehensive view of likely repository safety than a single calculated value with no insight into its likelihood

Conclusion

- **In its License Application submitted to the Nuclear Regulatory Commission on June 3, 2008**
  - **The DOE believes that its licensing documents provide a sufficient basis for finding the proposed system to be safe to allow the repository project to move into its next phase: construction**
  - **The licensing process, with its thorough technical review and hearings, will permit the regulatory authority to judge the DOE case for Yucca Mountain repository safety**
- **The TSPA and PCSA are complex and not easily understood by persons without a specialized technical background**
  - **DOE's plain-language safety case brochure is intended to convey the bases for its confidence in safety of the Yucca Mountain repository**
  - **The brochure can be downloaded at:**

http://www.ocrwm.doe.gov/ym_repository/license/docs/Safety_of_a_repository.pdf