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

Total System Performance Assessment - Site Recommendation

Presented to:
NRC/DOE 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			
TSPA Documentation Style, Structure, and Organization			
T1) Documents and reports are complete, clear, and consistent.	All PMRs, TSPA-SR	Largely Resolved	The TSPA-SR is currently being performed. For this acceptance criteria to be closed, the TSPA-SR Technical Report and supporting PMRs and AMRs will need to be reviewed by the NRC.
T2) Information is amply cross referenced.	All PMRs, TSPA-SR	Largely Resolved	The TSPA-SR is currently being performed. For this acceptance criteria to be closed, the TSPA-SR Technical Report and supporting PMRs and AMRs will need to be reviewed by the NRC.

Objectives of Briefing

- Overview of Presentations
- Messages
  - iteration on TSPA
  - traceability (documentation hierarchy)
  - improvements
  - resolving issues
- Reference Design
- TSPA-SR process
- Schedule
- Summary

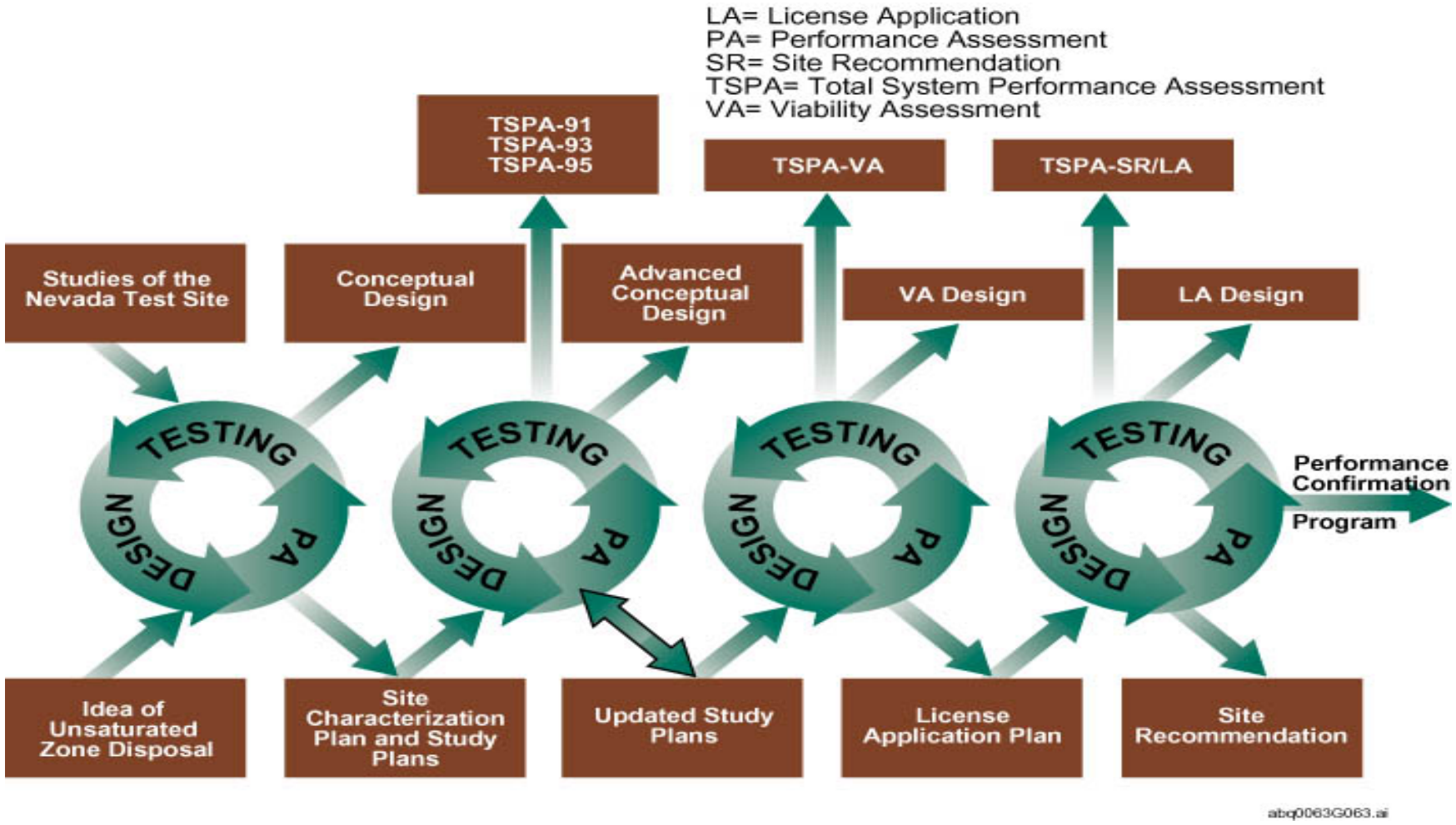
Overview of Presentations

- Overall Approach
- Features, Events and Processes (FEPs) Approach
- FEPs Details
- TSPA Subsystem Component Models
- Integrated TSPA Model
- Sensitivity and Uncertainty Analyses
- Human Intrusion Analysis
- Progress on Meeting TSPA&I Requirements

Overall Messages

- **Iteration on Previous TSPA**
- **Improvements from TSPA-VA**
- **Improved Traceability (documentation hierarchy)**
- **Resolving Issues**

TSPA Iterations



TSPA-SR Major Improvements

Technical Improvements

- Iteration of Viability Assessment
- Improve models to address review comments of VA
- Improved models include:
  - Climate and seepage
  - Coupled thermal processes
  - Waste package degradation
    - Stress corrosion cracking
    - Initial defects/weld flaws
  - Saturated zone transport
  - Volcanism
- TSPA approach modified to address NRC and EPA requirements

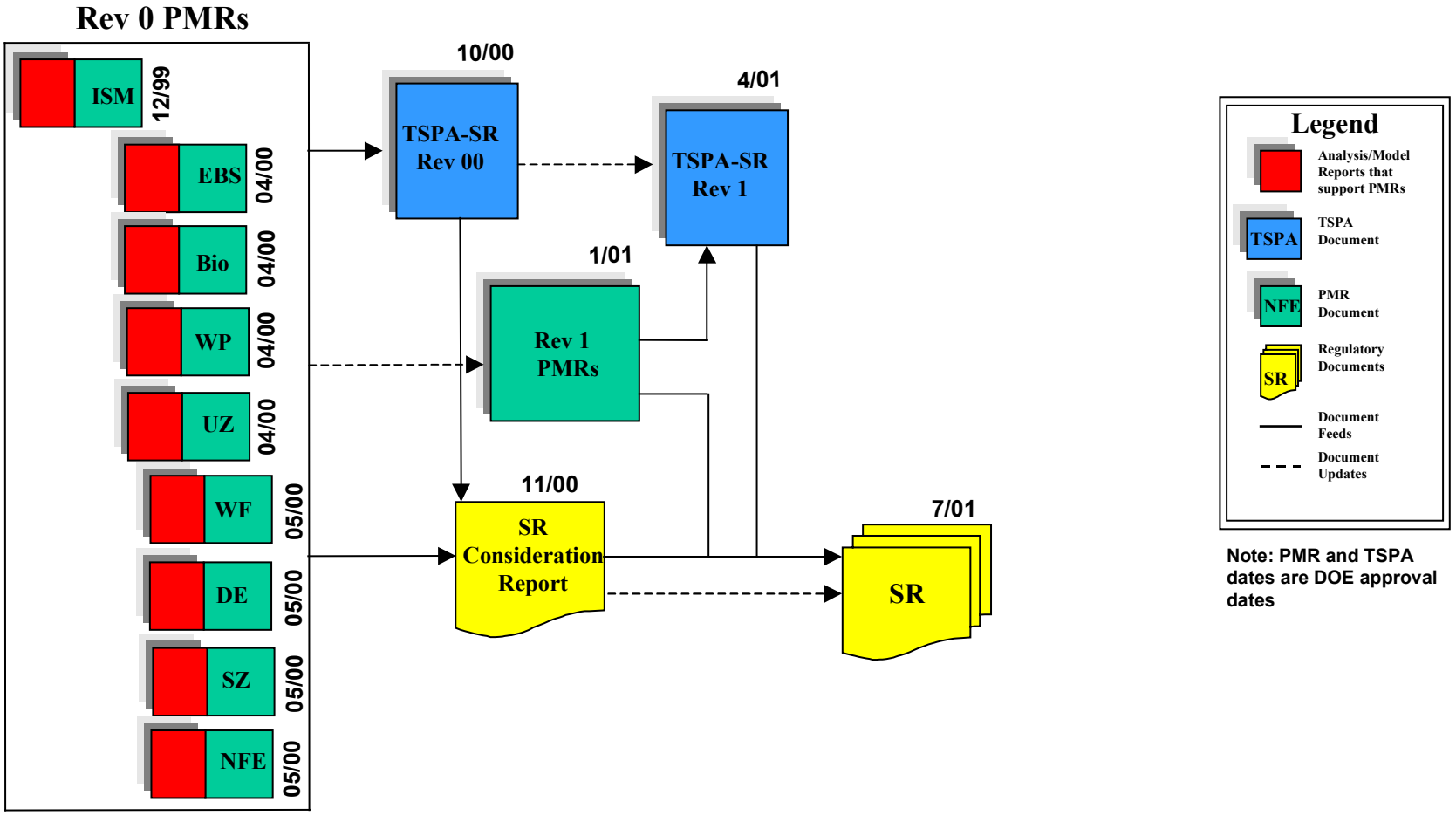
Process Improvements

- All analyses, models, data, software controlled under common procedures
- TSPA-SR model developed to assure traceable data sets are used
- Q-status of all data, models, software is tracked

TSPA-SR Documentation Hierarchy

- **Based on Analysis/Model Reports (AMR's) and Process Model Reports (PMR's)**
- **Preliminary information from data transmittals**
- **Feed information to SRCR**
- **Provides traceability back to models and data from TSPA model**

TSPA-SR Documentation Hierarchy



Resolving Issues

- **Issue: System Description/Demonstration of Multiple Barriers**
  - **Transparency/traceability through process modeling, supporting analyses, and back to the data**
  - **Consistency from TSPA through supporting documentation**
  - **Numerous multiple barrier analyses to be conducted and documented in TSPA-SR**
- **Issue: Scenario Analysis**
  - **Identify FEPs, screening rationale, defend use of intermediate performance measures for screening**

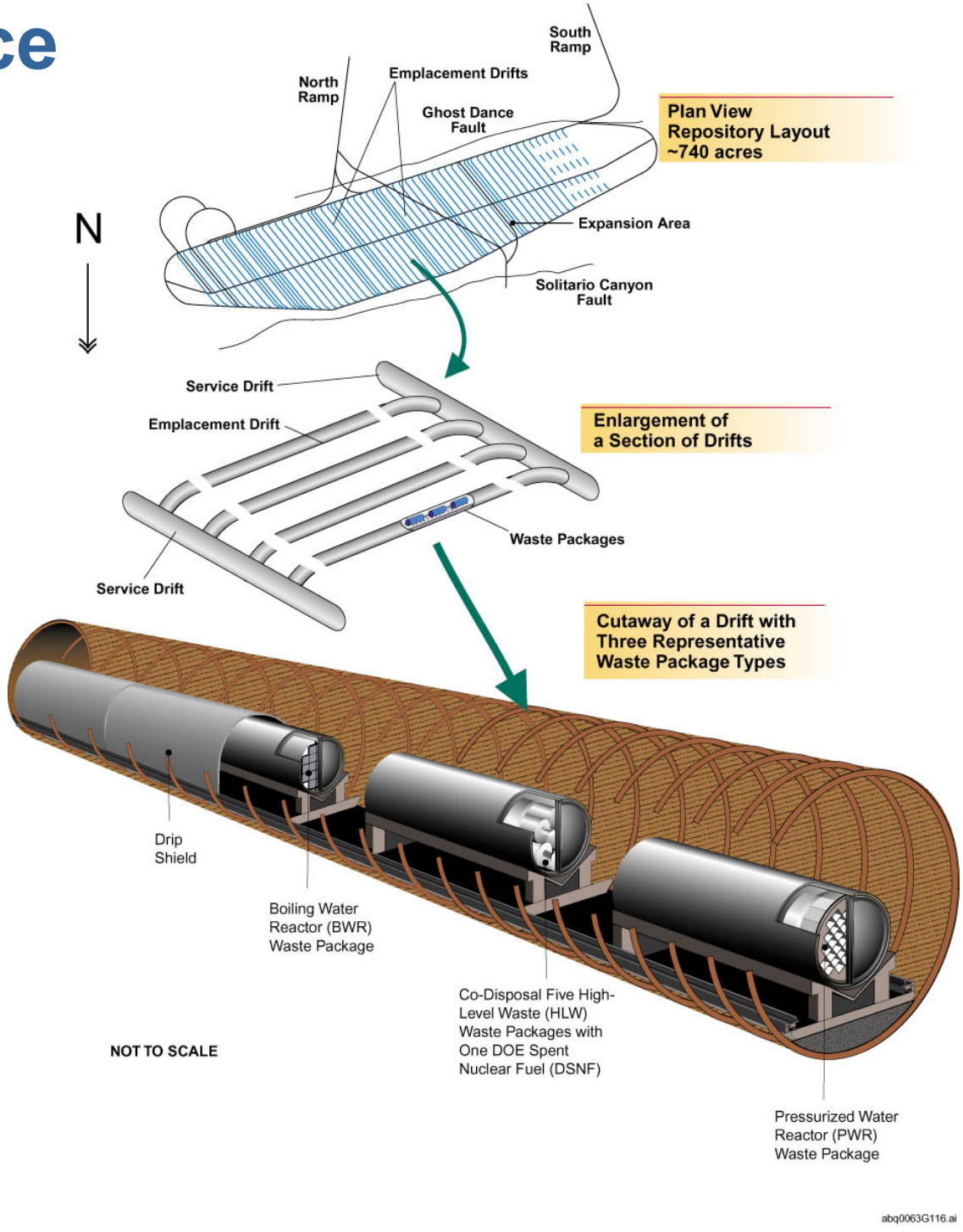
Resolving Issues (continued)

- **Issue: Model Abstraction**
  - **Integration of FEPs into TSPA-SR**
  - **Integrated model components to improve coupling**
- **Issue: Overall Performance Objective**
  - **Use TSPA-SR model to demonstrate performance objectives have been met**

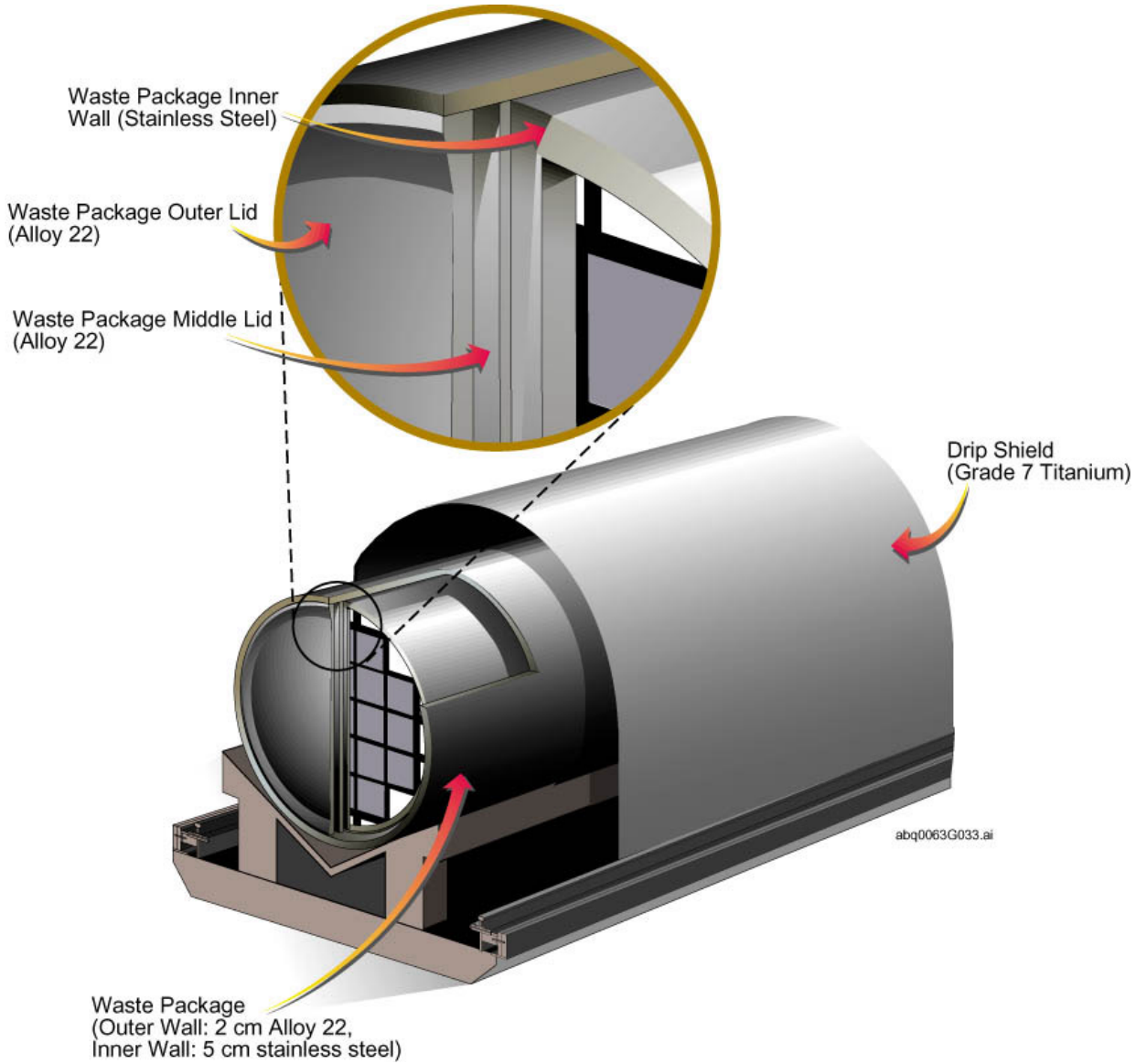
Reference Design for TSPA-SR

- **TSPA-SR is based on the Site Recommendation Design**
- **Repository design**
  - **Average thermal load of ~ 62 MTHM/acre (lower than VA)**
  - **50 years of ventilation**
  - **Blending of fuel at surface to level thermal load**
- **Engineered barrier system design**
  - **Titanium drip shield placed over waste packages**
  - **No backfill**
  - **Waste packages placed end-to-end average (line load of ~ 1.4 kW/m)**
- **Waste package design**
  - **Waste packages for CSNF (21-PWR/44-BWR) and co-disposed DSNF and HLW**
  - **Outer layer of corrosion resistant Alloy 22 (20 mm) and inner layer of stainless steel (100 mm)**
  - **Dual-lid closure weld, outer lid closure weld stress mitigated by solution annealing, inner lid closure weld stress mitigated by laser peening**

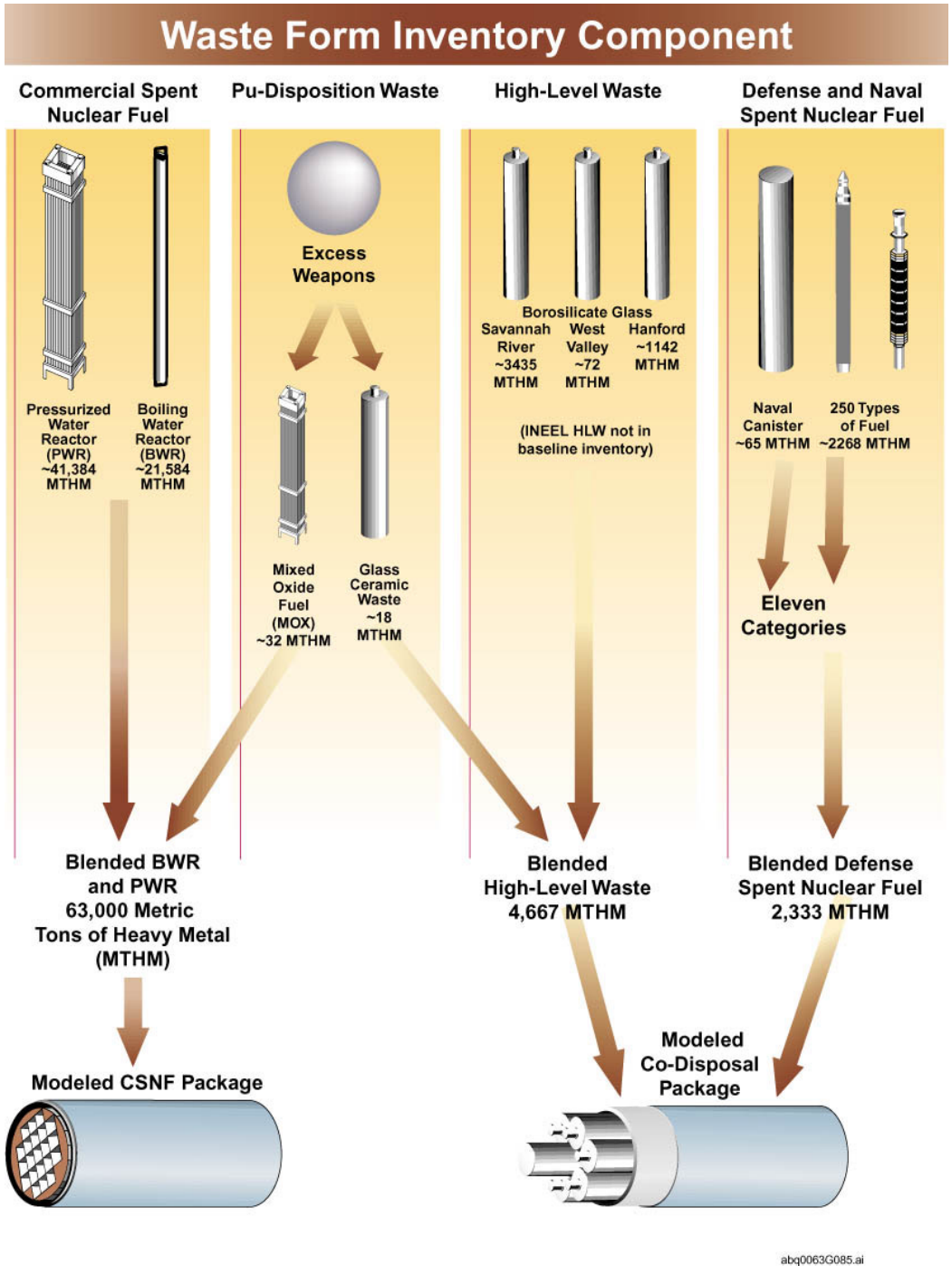
Reference Design



Reference Design - Waste Package



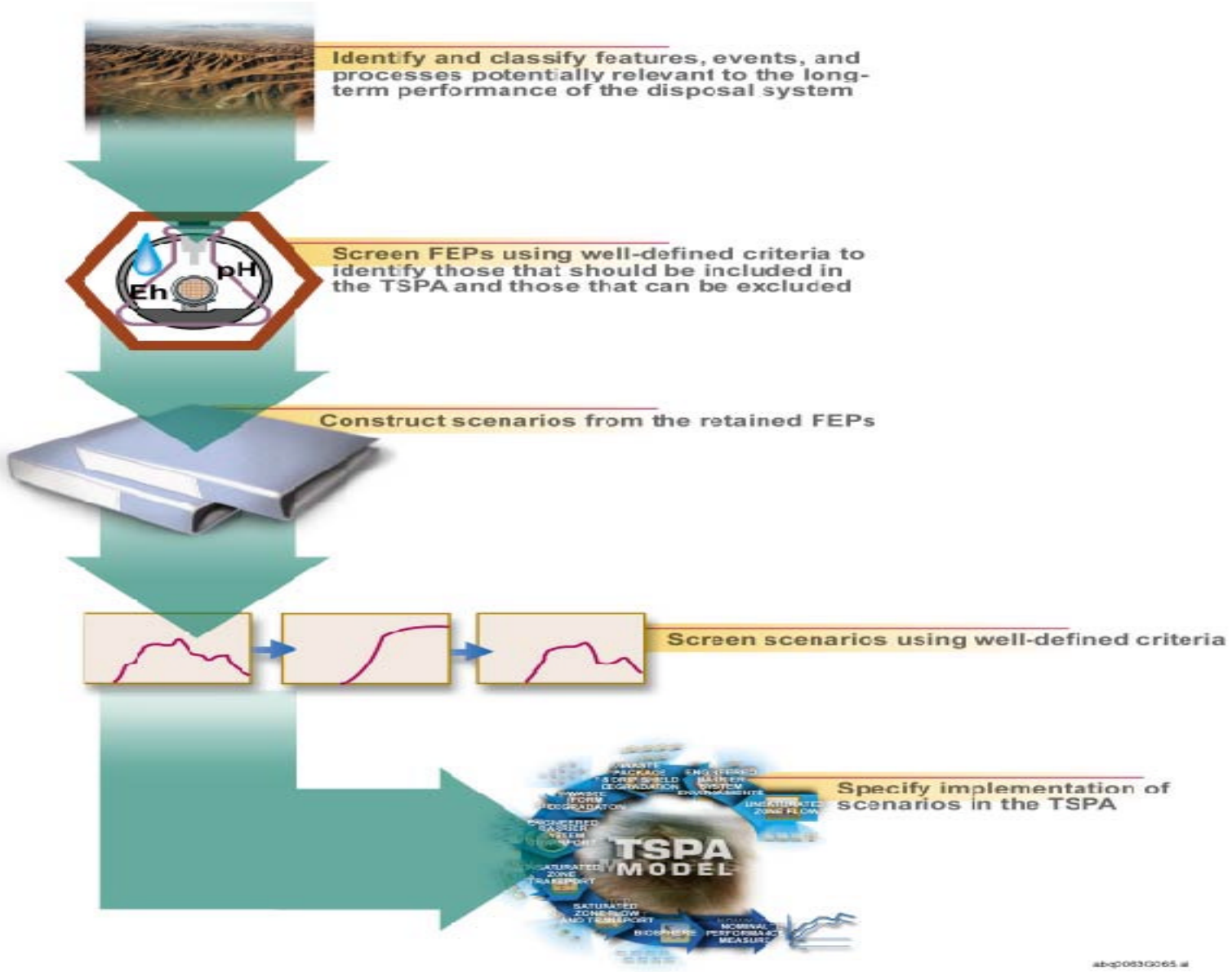
Reference Design - Waste Form



Introduction – TSPA-SR Process

- Screen features, events and processes to determine those that must be retained in performance assessment
- Develop models, along with their scientific basis, for each process included in TSPA
- Identify uncertainty in models and parameters
- Construct integrated TSPA model using all retained processes
  - "Nominal" performance model contains all features, events and processes likely to occur
  - "Disruptive event" performance model contains low probability events (e.g., volcanism)
- Evaluate total system performance (individual dose and groundwater protection) and significance of uncertainty

TSPA-SR Process



TSPA-SR Process

Oversight

NRC Technical Exchanges, Appendix 7 Meetings

NWTRB Panel Meetings, Reports to Congress

State of Nevada; Affected Units of Local Government

Public

Prior TSPAs

DOE TSPA-91, 93, 95, VA

NRC IPA-1, -2, -3

EPRI TSPA Phases 1, 2, and 3

Process Model Abstraction

Unsaturated Zone Flow

Engineered Barrier System Environments

Waste Package & Drip Shield Degradation

Waste Form Degradation

Engineered Barrier System Transport

Unsaturated Zone Transport

Saturated Zone Flow and Transport

Disruptive Events

Biosphere

Process Models

Unsaturated Zone Flow Model

Seepage Model

In-Drift Environment Model

Waste Package and Drip Shield Corrosion Model

Unsaturated Zone Transport Model

Saturated Zone Flow and Transport Model

Volcanic Eruption Model

Site and Design Information

Site Description Document

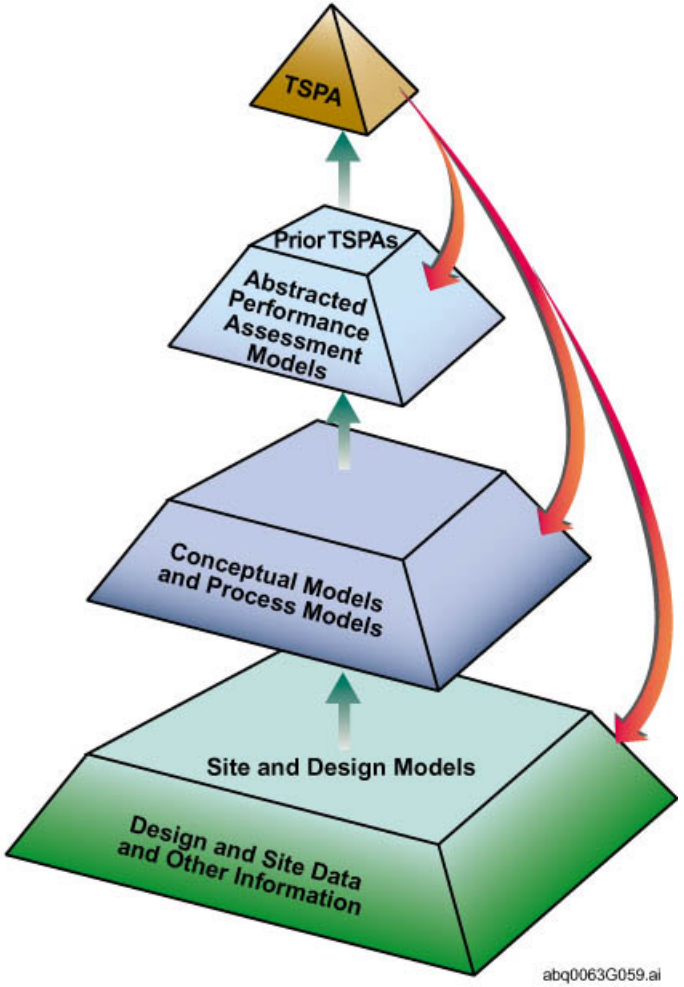
Repository Design

Waste Package Design

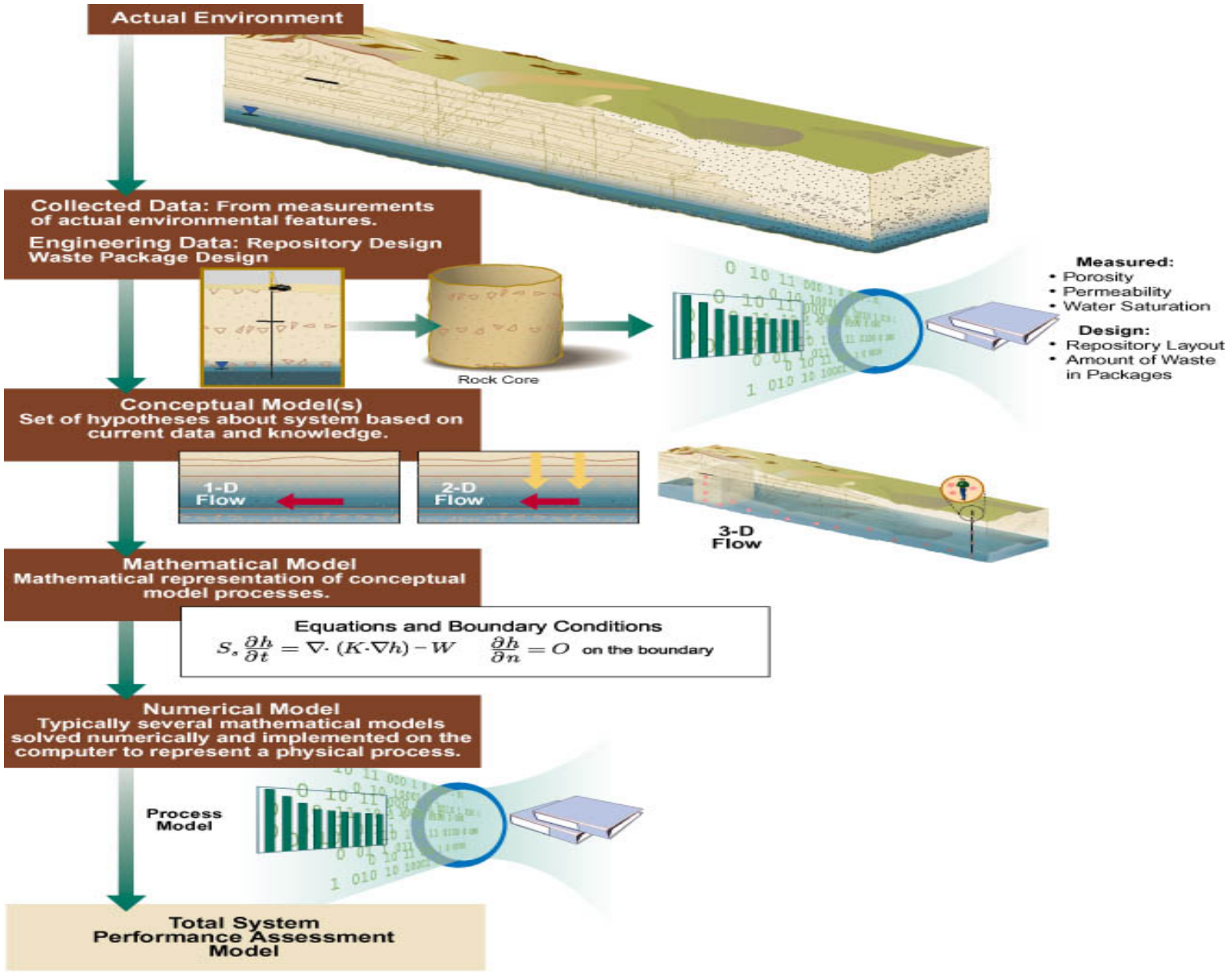
Laboratory Data

In-Situ Data

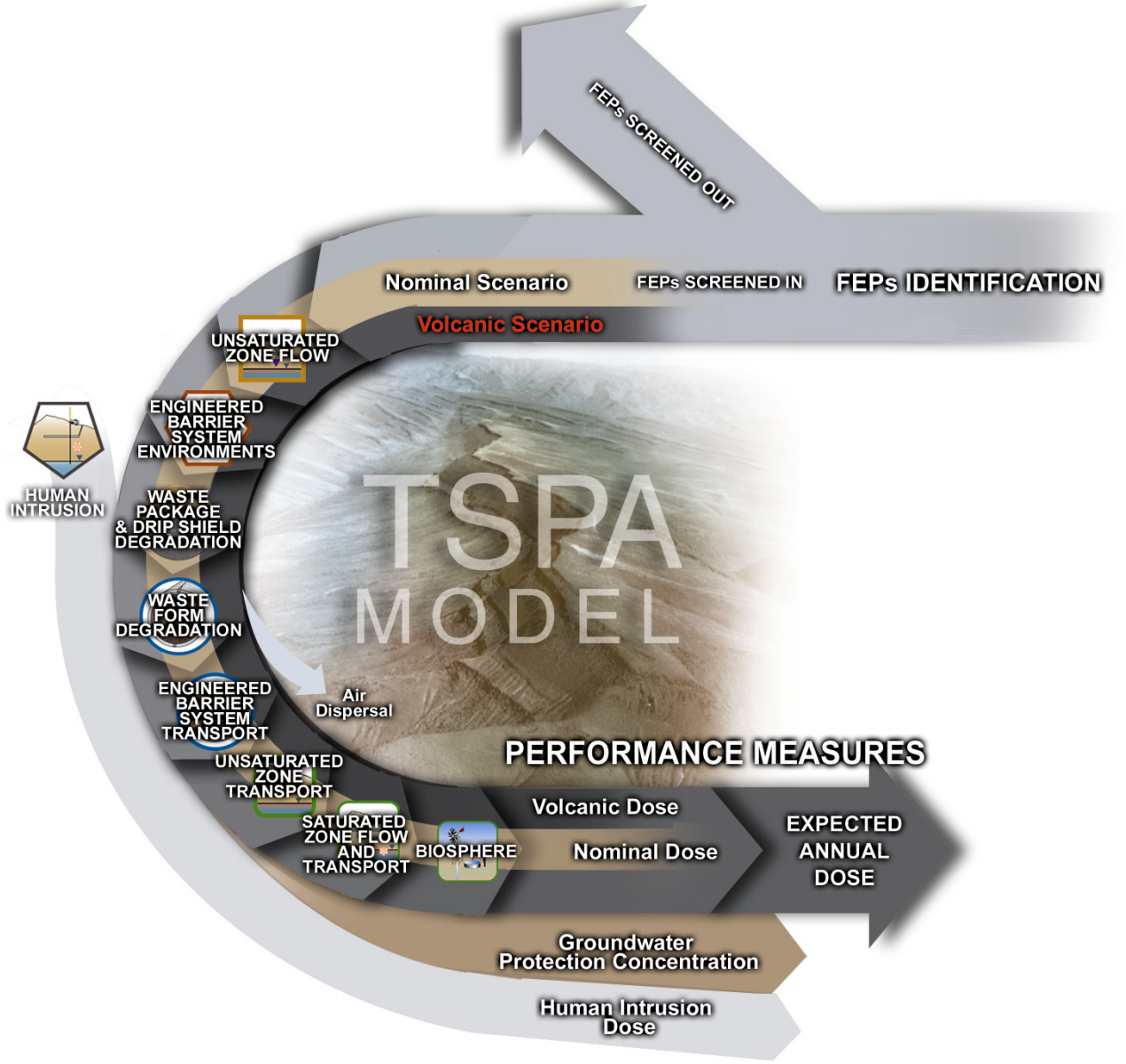
Analog Data



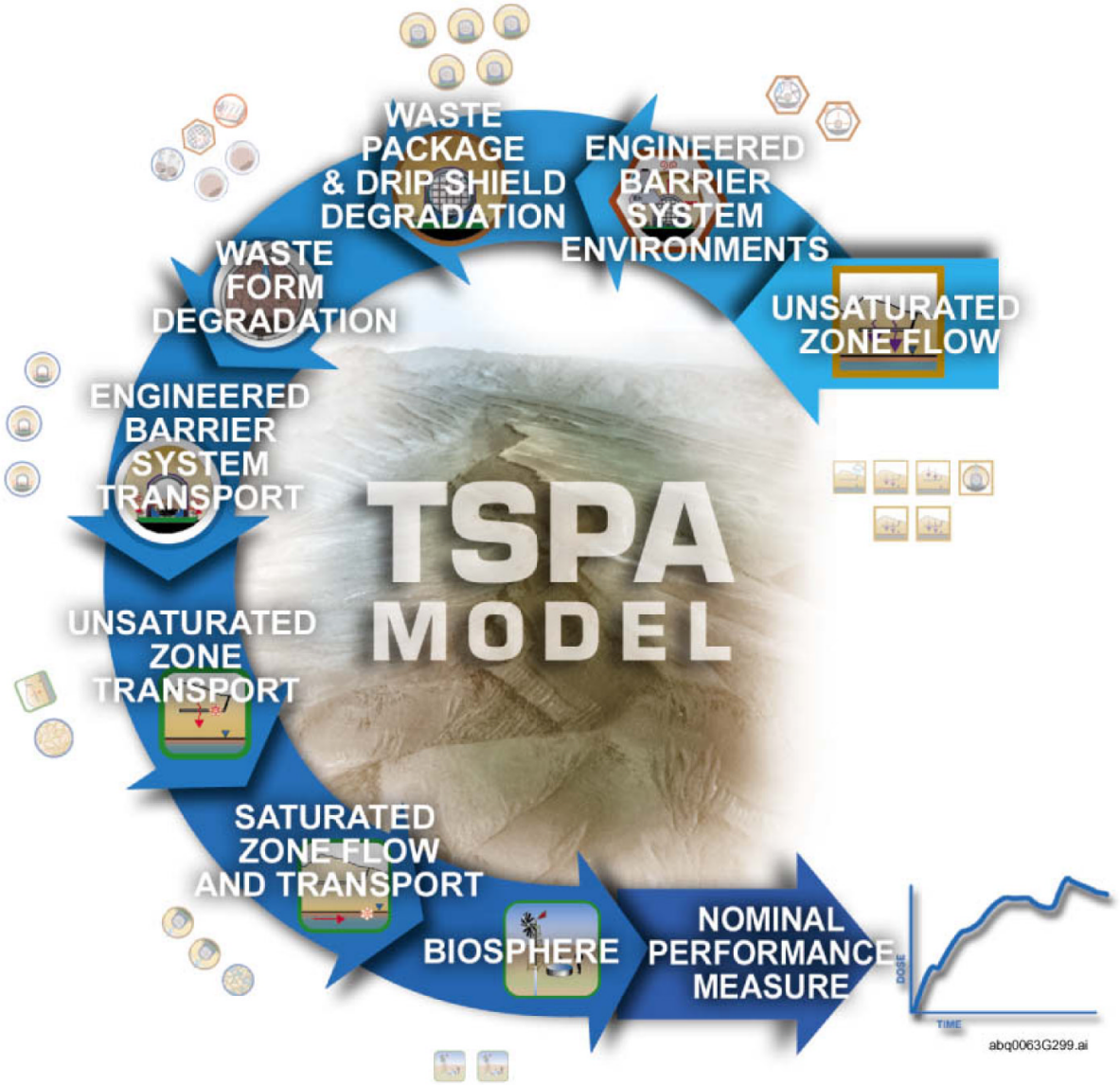
TSPA-SR Process



TSPA-SR Model Analyses

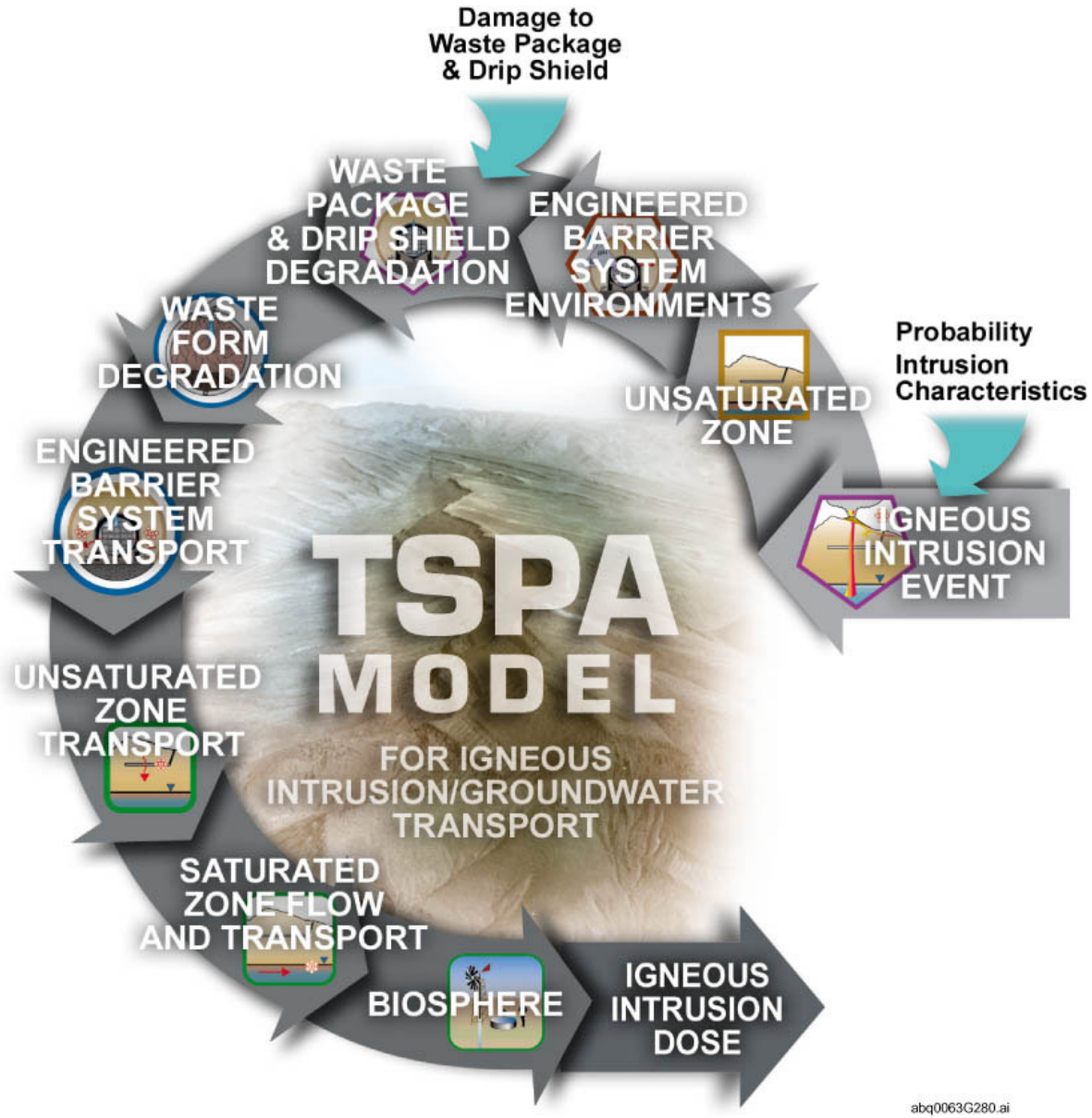


TSPA-SR Nominal Scenario

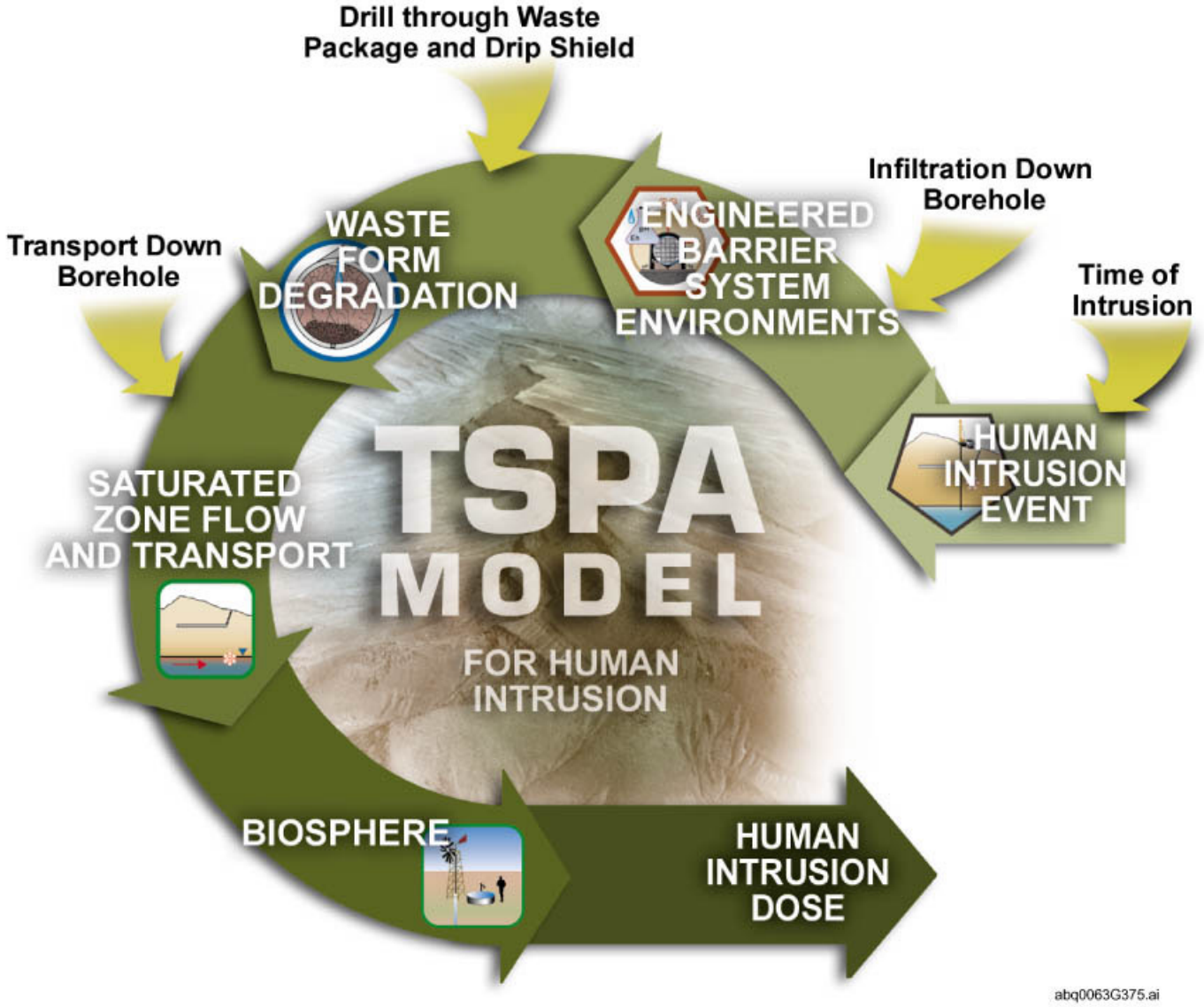


TSPA-SR Disruptive Events Scenario
(Volcanic Eruption)

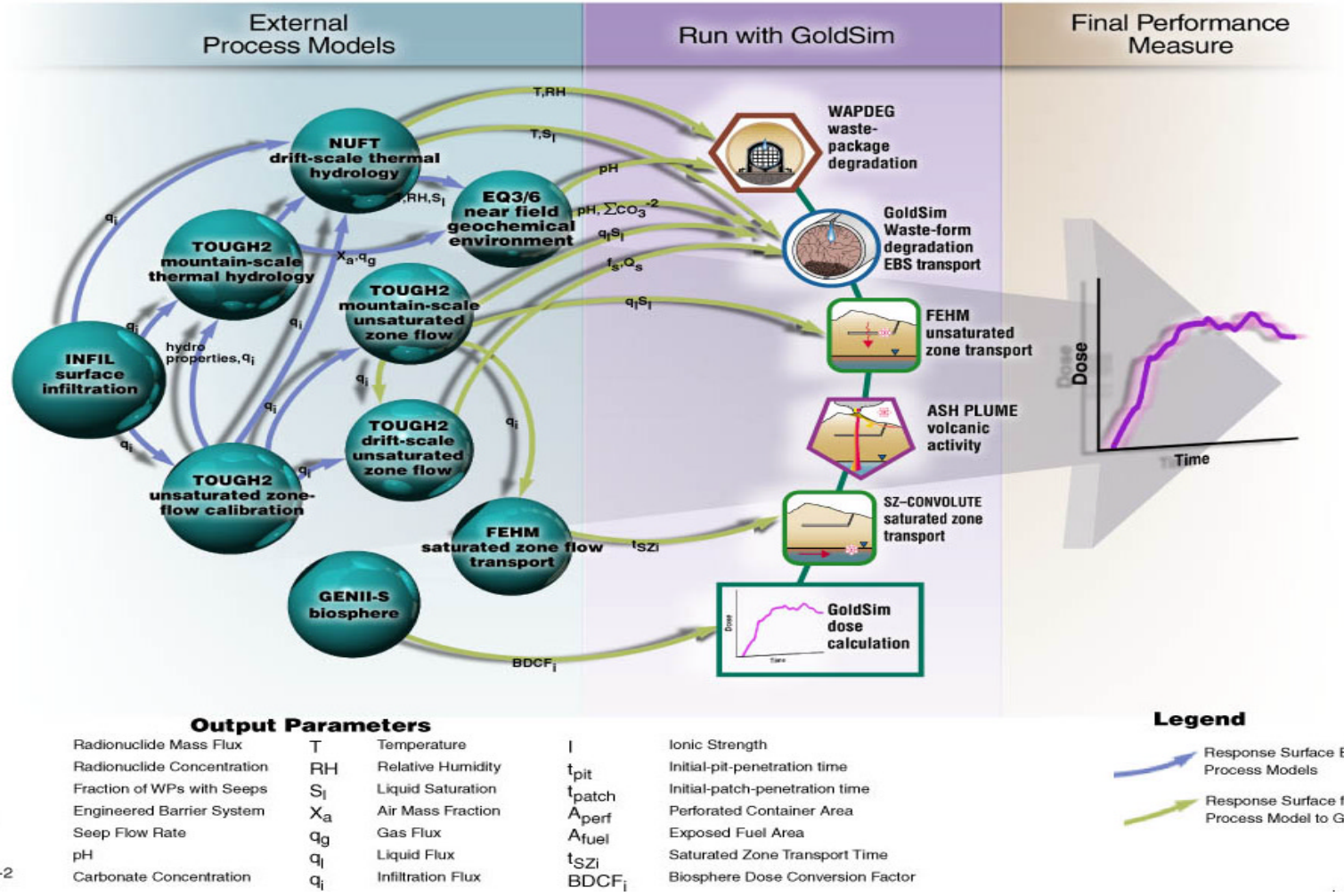
TSPA-SR Disruptive Events Scenario
(Igneous Intrusion/Groundwater Transport)



TSPA-SR Disruptive Events Scenario
(Human Intrusion)



TSPA-SR Model: Configuration/Information Flow



Output Parameters

M_i	Radionuclide Mass Flux	T	Temperature	I	Ionic Strength
C_i	Radionuclide Concentration	RH	Relative Humidity	t_{pit}	Initial-pit-penetration time
f_S	Fraction of WPs with Seeps	S_l	Liquid Saturation	t_{patch}	Initial-patch-penetration time
EBS	Engineered Barrier System	X_a	Air Mass Fraction	A_{perf}	Perforated Container Area
Q_S	Seep Flow Rate	q_g	Gas Flux	A_{fuel}	Exposed Fuel Area
pH	pH	q_l	Liquid Flux	t_{SZi}	Saturated Zone Transport Time
ΣCO_3^{-2}	Carbonate Concentration	q_i	Infiltration Flux	$BDCF_i$	Biosphere Dose Conversion Factor

Legend

Response Surface Between Process Models

Response Surface from Process Model to GOLDSIM

TSPA-SR Significance Analyses to Support Safety Case and 10 CFR 963 Compliance

- **Uncertainty analyses**
  - **> 100 parameters in nominal performance scenario are represented with an uncertainty range**
  - **regression analysis, discriminant analysis, partial correlations and regression trees will be used to identify the most significant parameters**
  - **parameter importance will be quantified**
- **Sensitivity analyses**
  - **specific analyses will fix individual key parameters at their 5th and/or 95th percentile to illustrate contribution to performance of individual process model factors**

TSPA-SR Significance Analyses to Support Safety Case and 10 CFR 963 Compliance
(continued)

- **Barrier Importance analyses**
  - **specific analyses fixing groups of key parameters at their 5th or 95th percentile (depending on which leads to more conservative performance) will be used to illustrate contribution to performance of combined process model factors or barriers**

TSPA-SR Schedule

- Process models and analyses supporting TSPA-SR are essentially complete
- Process Model Reports (Rev 00) are being reviewed by DOE
- TSPA-SR model is complete, documentation underway
- TSPA-SR Technical Report (similar to VA Volume 3) is being developed, expect delivery to DOE in late August
- TSPA-SR sensitivity analyses and barrier importance analyses to support compliance evaluation and safety case are to be underway in June/July
- Draft Site Recommendation Consideration Report scheduled for DOE review in September

Summary of Technical Improvements for TSPA-SR

- Have addressed a number of issues raised by reviewers of VA, including DOE Peer Review, NWTRB, NRC, USGS, M&O TSPA-VA Peer Review, Clark County
- Major process model revisions to address issues include:
  - Climate and seepage
  - Coupled thermal-hydro-chemical processes
  - Waste package degradation (especially stress corrosion cracking)
  - Saturated zone transport
  - Igneous activity
- TSPA approach modified to address NRC and EPA requirements:
  - Explicit screening of features, events and processes in construction of model
  - "Expected" annual dose to reasonably maximally exposed individual
  - Groundwater protection of representative volume of aquifer
  - Stylized human intrusion scenario

Summary of Process Improvements for TSPA-SR

- All process models, abstraction models, analyses and calculations used to support TSPA-SR are being controlled under a set of procedures common to all participants
- Documented "validation" of process models developed in accordance with NUREG-1636 guidance
- All data sets, parameters and models/analyses inputs and outputs are being tracked and controlled to ensure traceability
- TSPA-SR model developed to ensure only traceable data sets are used as input
- Q-status of all data, developed or acquired, is tracked to identify qualification need, including software

Summary of Remaining Work for TSPA-SR

- **Complete analyses modifying conditions for no-backfill design**
- **Complete uncertainty, sensitivity and barrier importance analyses**
- **Complete documentation**
- **Complete contributions to Site Recommendation Consideration Report**
  - **Volume 1 – Technical Basis for Site Recommendation Consideration**
  - **Volume 2 – Compliance Evaluation**