Sandia National Laboratories

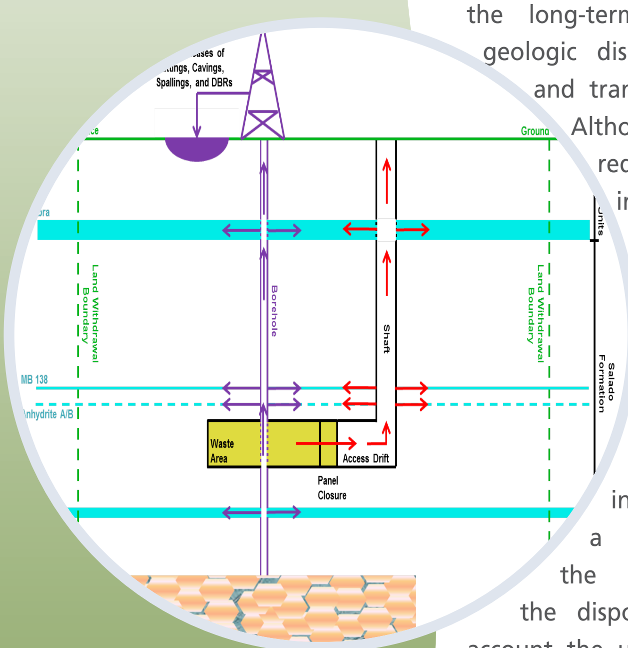
Energy, Climate, & Infrastructure Security

Performance Assessment

Sandia National Laboratories implements Performance Assessment to estimate the overall performance of deep geologic disposal sites.

Description

Performance assessment (PA) is defined in the United States by the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) regulations as a process to be used in estimating the long-term performance of deep geologic disposal sites for high-level and transuranic radioactive waste. Although specific regulatory requirements differ for individual projects (e.g., the Waste Isolation Pilot Plant and the potential repository at Yucca Mountain), the overall approach to PA is similar in repository programs both within the U.S. and internationally. PAs provide a quantitative estimate of the overall performance of the disposal concept, taking into account the uncertainty associated with the behavior of engineered and natural systems over very long periods of time. Results are compared to regulatory limits, in terms of annual radiation doses to hypothetical future humans or cumulative radionuclide releases from the site, and uncertainty in those results is evaluated as part of the decision-making process before the site is approved for operation.



All significant processes and events must be represented in the set of modeled scenarios

Capabilities

Performance assessments begin with the selection of a disposal concept (such as a mined geologic repository in a specific rock type) and the preliminary selection of one or more sites for evaluation. Physical characteristics of sites must be characterized sufficiently to allow identification of the features, events, and processes most likely to affect performance, and to support numerical modeling of important aspects of the system such as waste mobilization and groundwater flow. Early iterations of system-level modeling allow identification of areas where further data collection is needed to support more detailed analyses, and subsequent iterations throughout the process of characterizing the site allow for sensible prioritization of research activities and informed decisions regarding the suitability of the site. Ultimately, if the site is suitable, information gathered during site characterization will support a PA that will meet regulatory expectations for defensibility and traceability, and will become the cornerstone of a licensing decision.

SNL has expertise in the complete PA process that includes:

Identification of Relevant Features, Events, and Processes (FEPs). Not all potentially relevant FEPs will have a sufficient impact on performance to warrant including in computational models, and resources should be focused on those that matter. Careful identification of the relevant FEPs, screening evaluations to determine which FEPs must be included in the full modeling effort, and documentation of the technical basis for the exclusion of FEPs is a fundamental step in PA that assures confidence in the completeness of the analysis.

Scenario Selection. Pragmatically, computational models can only address a small number of the essentially infinite number of future states of the system that could be imagined. Scenarios for modeling must be selected so that they are appropriately representative of the full range of plausible future states, including the relevant FEPS, without resulting in an unworkably large number of discrete cases to be modeled.

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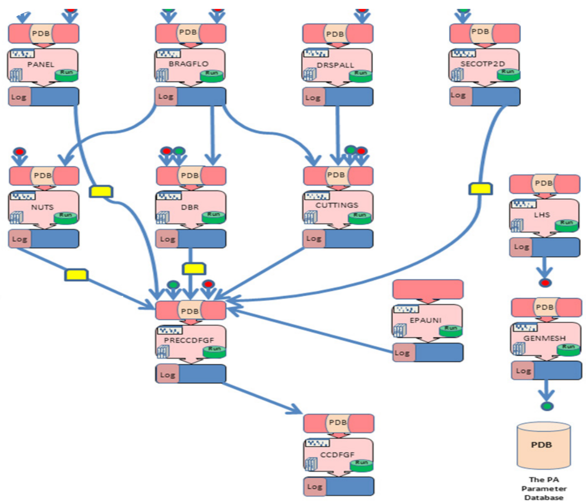
Model Development. Computational models must be developed that simulate the major components of the system, including the evolution of the engineered and geologic barriers through time. These models must capture all important uncertainties in the system, either explicitly or with defensibly bounding assumptions, they must meet the expectations of the technical review community, and they must be computationally efficient to be effective in the overall PA. Typically, PA models must represent some level of abstraction or simplification from detailed process models developed by experts working in the individual component areas because such models are rarely efficient enough to meet the demands of system-level simulation. Both detailed process models and efficient PA implementations must be developed for processes such as waste form degradation, radionuclide mobilization, groundwater flow, and radionuclide transport.

Characterization of Uncertainty in Models and Data. Site characterization and experimental programs can reduce uncertainty, but it cannot be eliminated. Uncertainty must be included in the PA, either through the consideration of alternative scenarios that can be weighted by the probability of their occurrence (e.g., human intrusion, igneous disruption), through the explicit consideration of alternative conceptual models for important processes, or through the development of probability distributions that characterize uncertainty in the data used to develop parameter values used in the models.

Code Linkage and System-Level Monte Carlo Modeling. System-level simulations require linking computer models for individual components into an overall model that allows automated data flow and fully scripted simulations of the complete system. System-level modeling must ensure traceability and reproducibility of results from the large number (hundreds to thousands) of Monte Carlo simulations used in a full uncertainty analysis.

Uncertainty and Sensitivity Analysis. Monte Carlo analyses using large numbers of simulations of system performance with different sampled values of uncertain input parameters can be analyzed using a variety of statistical techniques (e.g., stepwise linear regression analysis) to identify and rank those models and parameters to which overall performance is most sensitive. Examination of the distribution of calculated results provides a measure of the level of confidence associated with the specific performance measure (e.g., the mean) that is used for assessing regulatory performance.



Individual process model codes are linked together to form an overall computational model of the system

System Prioritization. Uncertainty and sensitivity analyses can be used to identify those aspects of the model where reductions in uncertainty will result in the greatest changes in overall performance. Information about the cost and time required for activities planned to reduce uncertainty in specific areas can be combined with results of PA sensitivity analyses to provide the basis for risk informed project management. Resources can be allocated to those experimental and field programs that will have the most significant impact on overall performance.

Demonstrating Regulatory Compliance. PAs that support a licensing decision must meet both technical and regulatory criteria for completeness, sufficiency, traceability, and reproducibility. Supporting data and models must be qualified, software must be appropriately verified and validated, and all calculations must be done in a controlled and reproducible environment.

PA Framework Evolution. In this day and age, computing hardware and the software that can utilize it become outdated at a rapid rate. Demonstration of regulatory compliance via performance assessment is typically a recurring task for a given facility, done periodically over a period of many years. The hardware and supporting software that underlie the PA computational suite can quickly become outdated, with a corresponding reduction in technical support. PA numerical codes need to be migrated to modern computing platforms occasionally in order to maintain a PA capability into the future. Code migration must be done in such a way as to maintain confidence in results obtained on the migrated system while also satisfying quality assurance requirements.