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NRC PERFORMANCE ASSESSMENT STRATEGY FOR A HIGH LEVEL NUCLEAR WASTE REPOSITORY

In its broadest sense, any qualitative or quantitative estimation of the isolation capability (pre- and post-closure) of the high-level nuclear waste repository constitutes a performance assessment (PA). In this paper, however, performance assessment is restricted to mean only quantitative post-closure estimates of the repository's isolation capability. Furthermore, the quantitative estimates are restricted to those that are called for in relevant regulations, primarily 10 CFR Part 60 and 40 CFR Part 191.

The U. S. Department of Energy (DOE) is mandated, by regulations, to provide a comprehensive performance assessment in its license application. The law requires the U. S. Nuclear Regulatory Commission (NRC) to review the license application prior to granting, or denying, construction authorization. As a part of the review process, the NRC may, if it determines that it is necessary and appropriate to do so, form its own estimates of the potential performance of the repository described in the license application. It should be understood that performance assessment is only one input, albeit important, into NRC's decision process as will be made clear in the much broader License Application Review Strategy (LARS) that is currently under development. It is also worth noting that at no time during the life cycle of the repository is the NRC to carry out its own site investigations or perform any engineering design. It can, however, provide guidance to the DOE on both site characterization and engineering design.

The general question considered in this paper is what role should the NRC take in the conduct of performance assessments of a proposed geologic repository. This breaks down to the following issues: Should the NRC perform its own performance assessments? If so, why? And what should be the NRC's performance assessment strategy, taking into account its mission and resource availability.

REGULATORY BASIS FOR PERFORMANCE ASSESSMENT

The Regulatory requirements for the geologic repository are codified in 40 CFR Part 191 (EPA) and 10 CFR Part 60 (NRC) - two complementary, but independent regulations. Part 191, the "generally applicable standards for protection of the general environment from off-site releases from radioactive material in repositories" (NWPA, Sec. 121) is concerned solely with the acceptable level of performance of the overall repository system. It specifies three broad quantitative performance objectives: (1) limiting the cumulative release at the accessible environment boundary over 10,000 years; (2) individual protection objectives for the first 1,000 years; and (3) requirements for protection of special sources of ground water for the first 1,000 years. While it is stated that a repository system be comprised of multiple barriers, no specific performance objectives for individual barriers are specified in Part 191.

In contrast, Part 60, the "Disposal of High-Level Radioactive Wastes in Geologic Repositories" is more comprehensive in its scope. The generally applicable portions of Part 191 are incorporated into Part 60 by reference. In addition, following the mandate of the Nuclear Waste Policy Act as amended

(NWPA), Part 60 makes it explicit that a repository include a system of multiple barriers. This concept of multiple barriers is enforced by establishing three minimum sub-system performance objectives, namely, the substantially complete containment performance objective for the waste package; the release rate performance objective for the engineered barriers; and the ground water travel time performance objective for the site. In addition to performance objectives, siting and design criteria (for waste package and engineered barriers) are also specified in Part 60. However, the subsystem performance objectives of Part 60 apply only with respect to the "anticipated processes and events." An additional flexibility with respect to the subsystem standards is included in Part 60. So long as the total system performance objective is met for anticipated events and processes, the NRC can approve variance from any of the subsystem performance requirements. No such variance is available for the EPA standard.

With regard to judging compliance with these objectives (including the EPA standard) and criteria, Part 60 states: "Proof of the future performance of engineered barrier systems and the geologic setting over time periods of many hundreds or many thousands of years is not to be had in the ordinary sense of the word. For such long-term objectives and criteria, what is required is reasonable assurance, making allowance for the time period, hazards, and uncertainties involved, that the outcome will be in conformance with those objectives and criteria."

In NUREG-0804 Part C, an evaluation of the extent to which compliance with the three subsystem performance objectives increases the likelihood of compliance with EPA's overall system performance criteria is provided. Thus, the subsystem performance objectives of Part 60 are meant to provide confidence in meeting the overall system performance objective. The technical support for Part 60 (NUREG-0804) was prepared prior to promulgation of Part 191. An early working draft of Part 191 was used to carry out the evaluation mentioned above. EPA is currently in the process of reissuing Part 191, and changes from the earlier working draft and the remanded final version are certain. A performance assessment capability will allow the NRC to not only re-evaluate the extent to which the subsystem performance objectives will provide additional confidence of compliance with the EPA's standards, but it will also identify refinements to the subsystem objectives that might be appropriate.

Because of the long time frames (>10,000 years) and large space scales (>10 km^3), the future subsystem and total system performance of the repository are expected to be projected by way of mathematical models. Direct performance testing of either the total system or its subsystems over such scales is not possible. The DOE has the responsibility to develop, validate, and implement, to the degree appropriate, these models and to provide a complete description of the performance assessments in its license application. The NRC, on the other hand, has the responsibility of assuring that the licensed repository will adequately protect public health and safety. In performing its regulatory function, the NRC has the choice of simply reviewing the DOE analyses or doing independent verification through conduct of performance assessments of all or appropriately selected parts of the analyses. For reasons discussed below, the NRC will adopt the strategy of developing its own performance assessment capability.

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NEED FOR THE NRC'S PERFORMANCE ASSESSMENTS

Many relatively complex technical issues of multi-disciplinary nature are involved in assessing the future performance of the geologic repository. To meet the NRC mission of protecting public health and safety, the NRC staff must, during the licensing process, make determinations on the potential performance of the repository. In addition, the NRC will comment on and provide guidance to the DOE on the completeness and adequacy of the site characterization program and engineering design, as well as on the DOE's plans to construct, operate and close the repository. Thus, the NRC has a definite role to play throughout the life cycle of the repository.

It is conceivable that the NRC staff can form an opinion about the performance of the repository without independent analyses. However, due to the complexity of the system and in the absence of accumulated historical experience, such an opinion will not be sufficiently well founded to support licensing decisions. The NRC, therefore, should conduct its own performance assessments. Current NRC policy does not support development of complete and fully independent performance assessments. Therefore, the NRC must devise a plan based on this strategy to select critical portions of the performance assessments for intensive review that it would conduct by independent analyses. This strategy should also help the NRC in meeting its obligations to provide guidance to the DOE during site characterization, construction, operation and closure. This strategy will be implemented by all of the NRC organizations involved in performance assessment aspects of the High Level Waste Program and their contractors.

STRATEGY FOR PERFORMANCE ASSESSMENT

The key features of NRC's performance assessment strategy are derived from a few basic considerations: the complex and inter-disciplinary nature of PA; its potential use in both the reactive and proactive programs; the top down approach to guide resource utilization by identifying components important to repository performance; the integration of technical work performed in the subsystems; and to keep the NRC staff knowledgeable in PA methodology. These features are discussed below.

General Program

Assessing performance of a geologic repository requires execution of a number of steps. These include conceptualizing the system in terms of its identifiable components, the formulation of mathematical models representing all important processes, the translation of the mathematical models into computer programs, the verification and to the extent possible validation of the models, the analyzing of field and laboratory data to extract model parameter values, the executing of computer programs, performing sensitivity and uncertainty analyses, and, finally, analyzing outputs to draw conclusions.

While all parts of the performance assessments presented by DOE will be reviewed at some level, critical parts will be selected for in-depth review (see License Application Review Strategy for definitions of various review levels). In reviewing DOE's performance assessments, the NRC staff will not need to duplicate the work done by the DOE. The DOE will perform these calculations

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under an auditable QA program. As part of the NRC's reactive program, the NRC will conduct audits as needed. The NRC staff will perform, at least at a rudimentary level, a calculation to check all of the DOE estimates of performance. In addition, the NRC staff will use independent calculations to evaluate the significance of key assumptions regarding conceptual models, process models, and parameter values included in DOE's performance assessments. This evaluation will draw heavily from the proactive work described below. Other applications of PA in the oversight of DOE's program will include determination of the adequacy of performance allocations and other facets of the DOE's site characterization program. Particular attention will be given to evaluating DOE's evolving iterative performance assessment program. Auxiliary analyses done as part of independent performance assessments will also provide a technical foundation for evaluating alternatives with respect to conceptual models, process models, parameter values, and sensitivity analyses presented by DOE, and to identify those that may not be adequately considered in the DOE's work. Such work will provide technical credibility to recommendations that the NRC will make to the DOE for its investigations. The NRC research will produce a program that will generate scientific information to support determination of whether alternatives have been adequately explored by the DOE.

Special attention will be paid to uncertainties involving the assumptions that form the basis of models, future states of nature, and estimation of parameter values that are fed into performance assessment computer programs. Again, one may assume that the DOE's raw data will be collected under an approved QA program. The interpretation of these data leading to model parameter values will not only be spot checked, but the NRC itself will interpret selected data sets for critical parameters. It is in the interpretation of these data that alternate hypotheses may be identified that were not adequately considered by the DOE.

The primary aim of the NRC's proactive performance assessment program will be to evaluate its regulations, develop sound technical guidance, train and keep its staff current, and develop appropriate technical review procedures. The NRC will use the DOE developed computer codes, if available, and provided that these codes have enough flexibility to allow investigation of conditions that may have public health and safety implications. Otherwise, the NRC will develop its own codes or modify existing codes to suit its purpose. The proactive program will be also supported through research. Performance assessment issues that are related directly to NRC's regulatory function of technical review will be addressed through research. Such issues will include techniques for probability estimation, numerical schemes, and assessing reliability of long-term mathematical predictions.

Because performance assessment of nuclear waste repositories is a relatively new field and because it is interdisciplinary in nature, very few formal educational opportunities exist to train staff in this aspect. Learning through experience, by conducting limited performance assessments, is the best and most efficient method for training of the NRC and contractor staff. Insights gained by NRC staff will allow development of meaningful regulatory guidance and review procedures. Together with the Systematic Regulatory Analysis (SRA), performance assessment modeling will also help in evaluating current regulations

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regarding their interrelationships, completeness, and sufficiency in providing assurances that public health and safety will be protected.

Integration of Subsystems

As stated previously, the EPA standard states that the total repository system should include engineered and natural barriers. The NRC standard mandates that each of several barriers attain a certain performance objective. Therefore, these subsystem performance objectives have an important role in assuring that the multiple barrier concept is maintained and thereby provide additional confidence that public health and safety goals are met. In view of this, the DOE is expected to develop a repository system that will be comprised of engineered and natural barriers. Due to potential complex interactions between these barriers under future environmental states, the net impact of individual barriers on the total system performance is not known a priori. Therefore, it is natural and necessary to account for all of these barriers in conducting performance assessments of the total system.

As discussed previously, there is a need to reevaluate the relationship between the subsystem performance requirements of 10 CFR Part 60 and the EPA standard. This reevaluation will examine the extent to which meeting subsystem requirements of 10 CFR 60.113 provide reasonable assurance to the determination of protecting public health and safety. The data and analyses needed for compliance determination with requirements of Section 60.113 will also be examined.

The relative contribution of each barrier in meeting the total system performance objective can be determined only after such an assessment is conducted. Therefore, from the performance assessment view, there is no natural hierarchy to subsystems, that is, all subsystems will be considered during performance assessments of the total system. Depending on their relative importance, which will be determined during initial iterations, eventually and for certain purposes (e.g., sensitivity analyses) some subsystems may be treated in more detail than others.

Irrespective of the relative importance of any barrier in meeting the EPA standard for the total system performance, subsystem performance assessments will be conducted to judge whether the subsystem performance objectives of Part 60 are complied with. As stated before, the subsystems do not perform independently of each other; that is, the performance of the engineered barriers is determined by the site conditions and vice versa. Also, due to large time and space scales inherent in the subsystem performance objectives, like the total system, the subsystem performance assessments will also require mathematical modeling. In view of the above, it is possible that the assessments of the subsystems can become a part of the total system performance assessments. However, it is also possible to investigate the performance of these subsystems in greater detail by isolating them within properly selected boundaries. Initially, both options will be followed by the NRC staff. However, the subsystem performance assessment efforts and the total system performance efforts will be thoroughly integrated. This will be done by implementing an 'inter-disciplinary team approach' in conducting the performance assessments. The members of the various teams will be drawn from various NRC branches involved with the HLW program and its

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subcontractors. Suitable management controls will be designed and implemented for the success of the team approach.

Timing and Iterative Nature of Assessments

There are two different approaches to decide upon the right time to carry out a performance assessment. In the first approach, one waits until the computational tools are fully developed and the collection of site-specific data is complete before attempting a performance assessment. In the second approach, iterative performance assessments are carried forward with the help of available data at a given time with computational tools available at that time. From a regulatory perspective, the second approach should receive the highest priority by the NRC staff. This approach should apply to both the subsystem and the total system performance assessments.

Performance assessment of geologic repositories, including engineering barriers, is inherently iterative in nature. This is because different conceptual models must be explored, the effect of various simplifications must be assessed, and uneven and sparse data must be dealt with. The selection of the iterative performance assessments as the primary NRC staff approach is based on the axiom that complete scientific understanding of processes, fully validated computational tools, and complete and unambiguous site-specific data are objects to be strived for, but are unable to be achieved. Therefore, it is taken as a fact that licensing decisions will be made under conditions of substantial uncertainty and that it is necessary to learn to use less than perfect computational tools and incomplete data sets.

There are a number of other reasons why the iterative performance assessment approach will be followed. Iterations will be invaluable in pointing out the shortcomings in existing models and data, and will also indicate topics in need of further investigations or applied research. Incremental improvements in understanding of processes, computational tools, and data will be strived for in each iteration. It is also imperative that the iterative performance assessment perform a technical integration function by being truly interdisciplinary. Thus, the concepts developed for the engineered subsystem and the natural subsystem must be brought together in each iteration of the performance assessment.

Top Down Approach to Resource Allocation

It becomes important to optimize the utilization of limited resources. Iterative performance assessment will provide an important input to deciding priorities on work in both NMSS and Research. This input will be in the form of problems identified during iterative performance assessments that need a solution. In addition to identification of problems, iterative performance assessment, especially sensitivity and uncertainty analyses, will show which unresolved problems contribute most to uncertainties in performance. Obviously, priorities indicated by PA should be considered in conjunction with needs identified by other means.

Training of Staff

Iterative performance assessments combined with participation in international performance assessment programs will keep the NRC staff current on pertinent methodologies. This is an essential step in providing assurance that the staff will have at its disposal the needed skills to critically review DOE's performance assessments at the time of license application review. Of equal importance, it will provide the staff with needed tools for developing regulatory guidance and additional reactive work, such as review of prelicense submittals including site characterization data and interactions with the DOE, State, and affected parties.

PROGRAMMATIC PRIORITIES

Highest priority in the near term will be given to developing staff and contractor technical capabilities in the conduct of performance assessments. Progress has already been made as indicated by the recently released staff report entitled, "Phase I Demonstration of the Nuclear Regulatory Commission's Capability to Conduct a Performance Assessment for a HLW Repository" (April, 1990). The second phase of this effort has been initiated and is intended primarily to combine the knowledge of specialized technical disciplines (engineering and earth sciences) with those of the system modelers to produce integrated performance assessments. Special attention will be directed toward improvements in methodology for scenario identification and screening, retardation phenomena, mechanistic treatment of source term and near-field coupled effects, disruptive consequences, and alternative sensitivity and uncertainty analysis methods. Of equal importance in this effort is a planned evaluation of the effects of the NRC subsystem requirements on EPA Standard compliance.

Skills acquired in the Phase-I development exercise and the planned second phase will have immediate applicability to the other two principal areas of performance assessment work: support to the DOE program review and the development of regulatory guidance for use by the staff and DOE. The staff Phase I effort has already had substantial influence in dealings with DOE in its site characterization activities and led to the staff's first formal technical exchange with DOE on performance assessment (November 27-29, 1990). Immediate benefits also accrue to the regulatory guidance efforts under the Systematic Regulatory Analysis (SRA) program, which is investigating technical uncertainties related to model validation, scenario identification, data uncertainty, and use of expert judgment. Depending on SRA program results, rulemaking may also be warranted.

In the future iterations, high priority will be given to integration of the subsystem performance assessment work with the total system performance assessment. In the present organizational structure, important work on the subsystems, including compliance determination with respect to the siting and design criteria, is being funded separately. Irrespective of the funding mechanisms, a plan to implement a team approach for integration of work with respect to each one of the subsystem performance assessments will be developed. To be successful, each team must be comprised of experts from different disciplines interested in a particular subsystem and the total system. The

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compositions of the teams, the responsibilities of the team leader, relation of the teams to line management, and funding of the work of the teams will be the subject of the "NRC Performance Assessment Implementation Plan."

UPDATING OF STRATEGY

The NRC performance assessment strategy will be reviewed periodically (once a year) and updated based on possible program redirection. This applies especially to the updating of programmatic priorities stated in the last section. The proportion of reactive and proactive performance assessment work may also change from year to year depending upon the extent and nature of DOE's pre-license submittals.