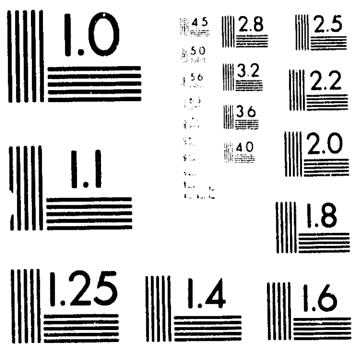
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93-1109C
Conf-9309228--1

An Approach to Validation of Thermomechanical Models

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All papers must include the following statement:
This work performed at Sandia National Laboratories is supported by the U.S. Department of Energy under contract DE-AC04-76DP00789.

Abstract

Thermomechanical models are being developed to support the design of an Exploratory Studies Facility (ESF) and a potential high-level nuclear waste repository at Yucca Mountain, Nevada. These models are used for preclosure design of underground openings, such as access drifts, emplacement drifts, and waste emplacement boreholes; and in support of postclosure issue resolution relating to waste canister performance, disturbance of the hydrological properties of the host rock, and overall system performance assessment. For both design and performance assessment, the purpose of using models in analyses is to better understand and quantify some phenomenon or process. Therefore, validation is an important process that must be pursued in conjunction with the development and application of models. The Site Characterization Plan (SCP) addressed some general aspects of model validation, but no specific approach has, as yet, been developed for either design or performance assessment models. This paper will discuss a proposed process for thermomechanical model validation and will focus on the use of laboratory and in situ experiments as part of the validation process. The process may be generic enough in nature that it could be applied to the validation of other types of models, for example, models of unsaturated hydrologic flow.

Because of the limitations and uncertainties in characterizing rock properties, geology, hydrology, and other factors that affect the behavior of the rock mass, the approach to validation must be somewhat different than the classical approach developed for "engineered" materials and structures. Even under the best circumstances, repository design and performance analyses will be conducted in a very "data-limited" environment[1].

That is, there will never be enough known about the rock mass that it can be modeled unambiguously. This is a common situation in engineering practice in general and in practical rock mechanics problems. Thus, using thermomechanical models to make absolute predictions, which are then compared to test results (a more classical form of validation), is unlikely to produce meaningful results and could lead to disqualification of useful analytical tools. Instead, validation is to be considered a process of developing sufficient confidence in the models that they can be used to explore and evaluate potential trade-offs and alternatives. Figure 1 shows the generalized validation process for thermomechanical models. Validation must be targeted at demonstrating that the key phenomena, processes and properties are incorporated in the simulation and that the accuracy of the results are sufficient to meet the design or performance assessment needs. It may take considerable modeling and characterization effort to determine what key elements must be part of the validation process.

The validation process itself is viewed as having three main components: peer review, evaluation relative to empirical evidence and case histories (including natural analogues), and evaluation relative to experimental data obtained from in situ and laboratory tests. Depending on the particular model, one or more of these components may be applied. For most thermomechanical models, the focus will be on comparisons with the results of specific laboratory and in situ experiments. Validation of a model, however, cannot rely completely on what can be obtained from one or more experiments. The model has to have been judged adequate by past experience in design or scientific studies in related or similar circumstances or, to add credibility to its adequacy, used to back-analyze well-documented case studies.

Because of the data-limited environment, a large part of the validation process involves the application of judgment to determine the adequacy of the model, and the limitations and uncertainties associated with its use. These judgments must be tempered by the context in which the models are applied. In addition, the validation process must be adaptive and evolutionary with the process resulting in improvements in the model to enhance confidence in the model. Model validation may never be strictly complete, but if a decision is made to proceed to license application, sufficient evidence must be available to support a claim that the models are valid for the specific applications used to support the license application.

For thermomechanical models, a major emphasis in the model validation process will be in the evaluation of models relative to results from laboratory and in situ experiments. Figure 2 provides a detailed description of the process. Model validation was used in the SCP as partial justification for a number of thermomechanical in situ and laboratory tests. However, at the time the SCP was published, there was only a limited understanding of the key processes affecting thermomechanical behavior of the rock mass. Therefore, little indication was provided of what the needs for model validation might be. Now in the development of study plans and experimental procedures, the model validation needs for each in situ test must be integrated with other objectives of these tests. In situ thermomechanical tests are designed to provide in situ rock mass properties, to provide demonstrations of adequate performance of repository system components (such as drift stability and ground support) under expected thermal loads, and to provide data for model validation. In some cases these objectives may be conflicting, thereby requiring some compromise in the test objectives or expansion of the suite of thermomechanical tests to accommodate all objectives.

By way of illustration, the paper will describe several thermomechanical models in use for repository design, the status of model validation of those models, and the in situ thermomechanical tests planned in the ESF to support model validation. The suite of thermomechanical tests is consistent with those outlined in the SCP, but differs in detail to accommodate the multiple objectives of each test and changes in repository construction methods. Finally, some thoughts on how to make meaningful comparisons of model and test results will be presented.

References

1. Starfield, A. M. and P. A. Cundall, Int. J. Rock Mech. Min. Sci. & Geomech. Abstr., Vol. 25, No. 3, pp. 99-106, 1988.

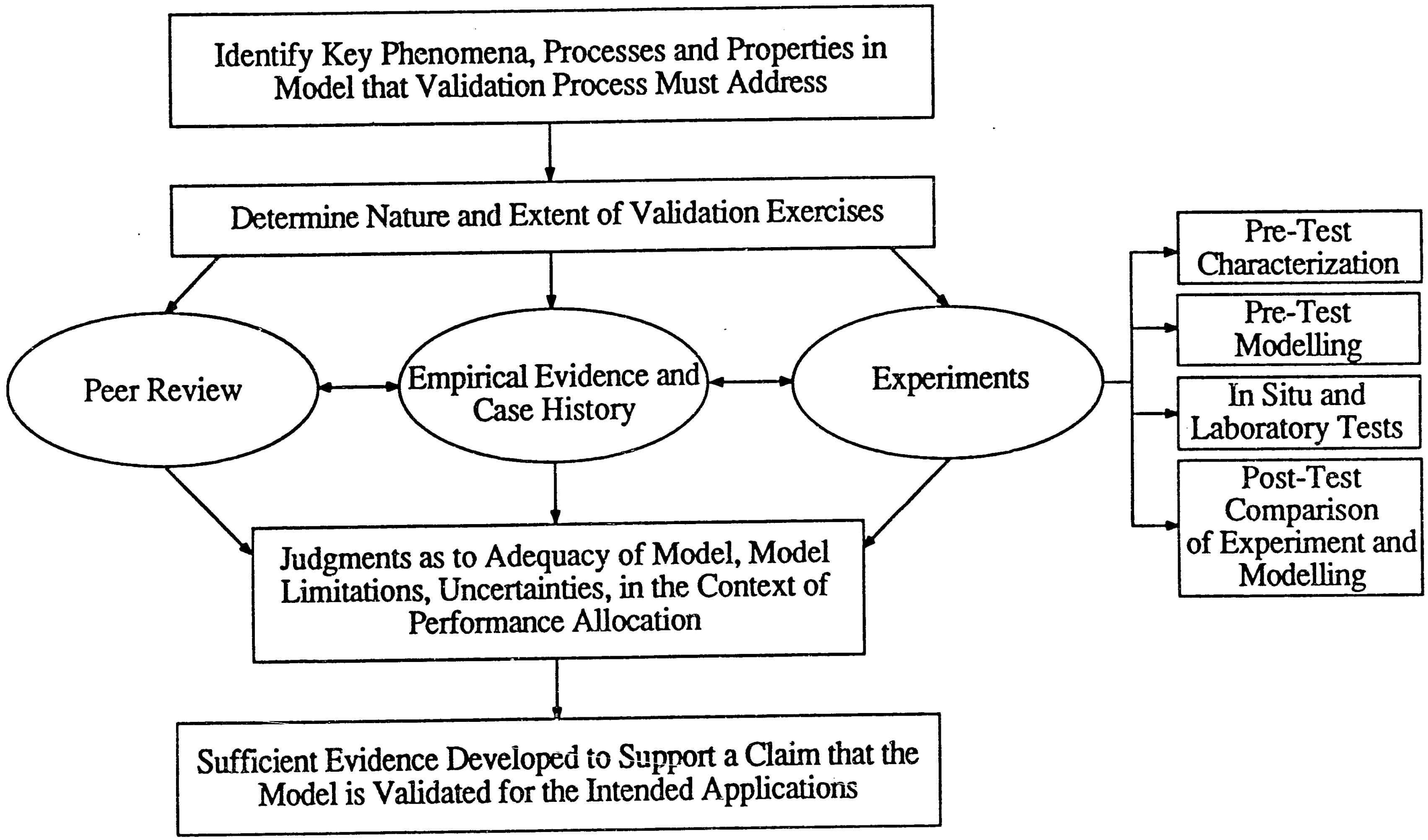

Figure 1. Generalized Validation Process.

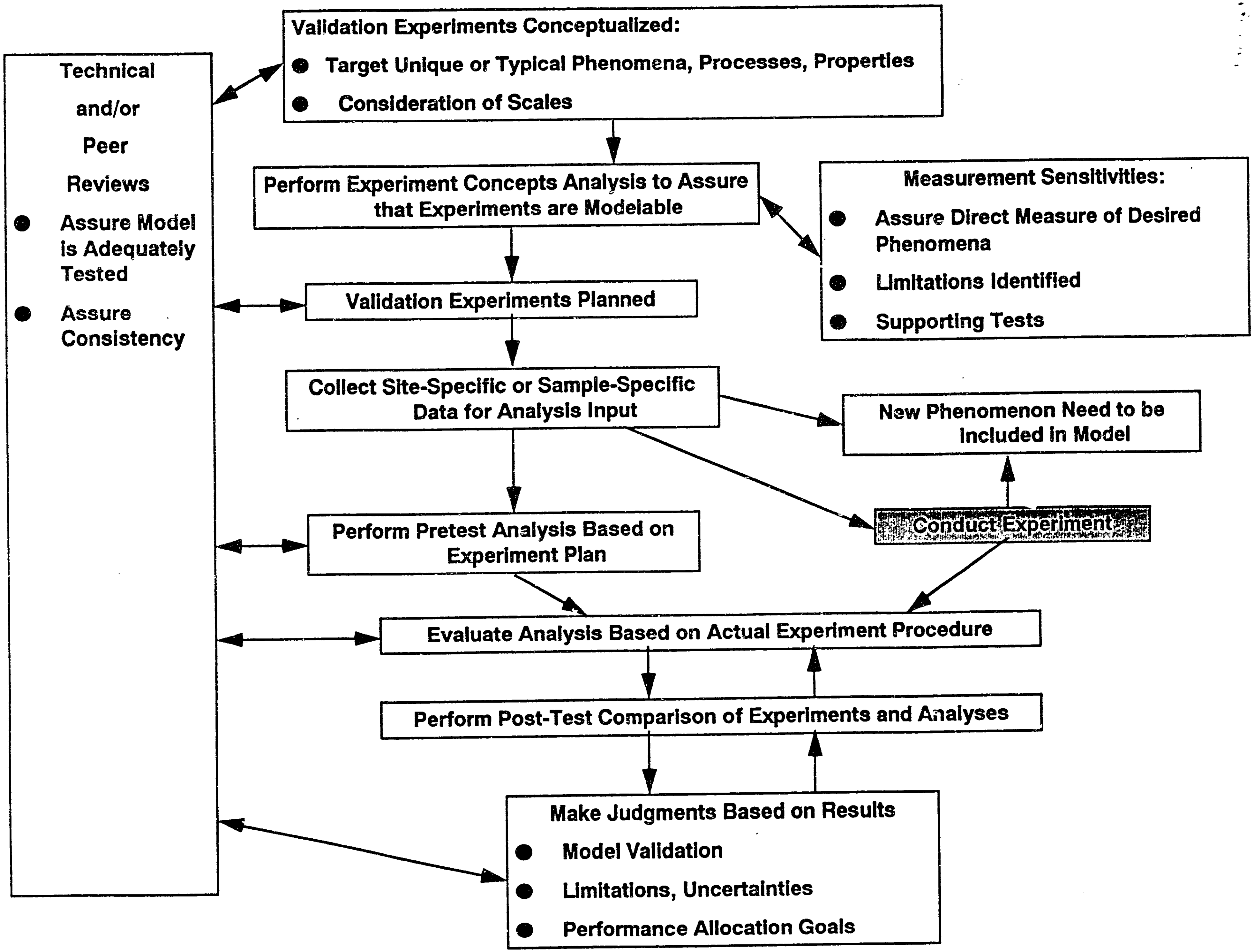

Figure 2. Depiction of a Validation Exercise with Experiments.

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