SIP-PA-2

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Scientific Investigation Plan

for

Waste Package Performance Assessment Activities

Conceptual Design Cycle

WBS 1.2.1.4.2

Lawrence Livermore National Laboratory

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WBS 1.2.1.4.2

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1.0 Introduction

Performance assessment is a major constituent of the program being conducted by the Office of Civilian Radioactive Waste Management Program of the U.S. Department of Energy (DOE) to develop a geologic repository.

The Yucca Mountain Project (YMP) of the U.S. DOE is currently evaluating the suitability of Yucca Mountain in southern Nevada as a repository site. The development of a geologic repository must include evaluations to determine whether the repository and waste package subsystems can satisfy the regulatory requirements for preclosure and postclosure periods. The Project includes performance assessments as part of these evaluations and to guide the development of the repository and waste package designs and the site characterization program. The performance assessments must focus on developing and applying methods to determine the waste isolation potential of the unsaturated tuff at Yucca Mountain. The methods must be based on an understanding of the fundamental concepts of the protective features of the unsaturated environment and of the mechanisms controlling release of radionuclides from the waste package, radionuclide transport, and fluid flow in unsaturated, fractured rock. They must be capable of addressing both expected conditions and unexpected potentially disruptive conditions that might exist during the required isolation periods. In addition, the performance assessment methods must be computationally efficient enough to accommodate numerous parameters and their associated uncertainties as models are developed to demonstrate compliance with regulatory criteria governing radionuclide release to the appropriate regulatory boundaries for the preclosure and postclosure periods. The existing methods are based on the current characterization information about the site, repository and waste package design concepts, waste forms, container materials, near-field geochemistry and transport phenomena, but will ultimately be supported by new data obtained during the period of site characterization.

The repository program is very complex, and performance assessments have an important role in that program. This role requires interactions with many other parts of the program. It is important that those who conduct performance assessments, those who supply information for the assessments, and those who receive guidance from the assessments have a common understanding of the general strategy and methodology for those assessments.

The Nuclear Regulatory Commission (NRC) has set long-term performance requirements on the total geologic repository system [see the Code of Federal Regulations (CFR) section 10CFR60.112] and on the engineered barrier system (EBS) (see 10CFR60.113 and 10CFR60.135). The radionuclide release rate from the EBS is taken as the source term in the larger-scale total system performance assessment.

The waste packages constitute the central elements of the EBS in the present conceptual design of the repository system. Other elements, such as the air gap in the borehole and possibly a borehole liner, serve to shelter the waste package from its environment and, secondarily in some instances, also to catch or delay released radionuclides. Assessment of the performance of the set of waste packages includes other EBS elements and is in fact assessment of the performance of the EBS.

1.1 Objectives and Scope

End Goals

The objectives of Waste Package (WP) Performance Assessment (PA) are to:

1. Provide the source term to be used in a total system performance assessment (Nuclear Regulatory Commission, NRC, Code 10CFR60.112, DOE Issue 1.1). Source term refers to the radionuclide release rate from the overall waste package system.
2. Evaluate engineered barrier system (EBS) designs for compliance to license requirements, recommend design and site characterization improvements, and demonstrate that the final EBS design complies with the long-term performance criteria of 10CFR60.113 (DOE Issues 1.4, 1.5).
3. Help demonstrate compliance with 10CFR60.135(a) (DOE Issue 1.10).
4. Assess impacts on the EBS of both favorable and potentially adverse site conditions listed by the NRC in 10CFR60.122 (DOE Issue 1.8).
5. Support the findings specified by the DOE in 10CFR960 should that regulation be determined to be applicable to the Yucca Mountain site (DOE Issue 1.9).

Performance assessment activities include developing system models of the engineered barrier system that incorporate all relevant processes and events and assessing the long-term performance of the EBS and waste package systems, which includes all waste packages in the repository.

A listing of the issues and information needs addressed in this Scientific Investigation Plan (SIP) are described in Appendix A.

Iteration Goals

The Site Characterization Plan (SCP) describes a long-duration, and in some respects sequential or iterative, process of site characterization leading to the basis for a decision on site suitability and, if suitable, for a construction license application (confirmatory investigations and testing continue after license application). The SCP recognizes that changes in the characterization plan and in the performance allocation may be appropriate as more data about the site are acquired and as iterative performance assessments are completed.

The design effort for a mined geologic disposal system (MGDS), including the waste package, comprises several cycles before the final procurement and construction design is issued, as required by the federal government for major, first-of-a-kind systems. For the MGDS, these cycles are conceptual design (CD), advanced conceptual design (ACD), license application design (LAD), and final procurement construction design (FPCD). Currently, the CD has been established and the application of the lessons learned to the information base for the start of ACD is in progress.

Performance assessment plays a critical role in the design cycles and the site characterization. It supports each design cycle and provides:

1. Guidance to the design requirements and design strategy;
2. Feedback during the design process;
3. Assessment of each completed design.

Performance assessments also identify information required from site characterization activities as well as materials, waste form, and near-field environment testing interaction investigations and provide feedback to guide SCP activities and the R&D testing investigations. As the interdependence between site and design evolves, periodic PAs will provide feedback concerning the sufficiency of the site information to support safety analysis and licensing. Performance assessments integrate the different areas of waste form, container materials, and near-field environment technical developments in terms of overall performance and identify needed changes to the CD-phase performance allocations initially described in the SCP.

1.2 Factors Important to SIP Activities

The models and assessments of PA require concept and data inputs from other SCP activities, which are being performed by LLNL to address DOE Issues 1.1, 1.4, 1.5, and 1.10. (See Fig. 1). The final models and assessment analyses depend on the final and validated information from these SCP activities. Interim models and assessments depend on interim data and models from supporting scientific activities to attain the best available scientific quality at each phase in the process leading toward licensing assessments. Where information is unavailable, sensitivity analyses will be performed to evaluate the importance of the information that is to be developed in supporting activities.

The activities in this SIP are planned to be consistent with the Lawrence Livermore National Laboratory (LLNL) YMP long-range planning networks on the basis of a goal-oriented sequence culminating in a license application for the YMP. The PA information flow among the key YMP participants is summarized in Fig. 2. Consistent with long-range planning, this SIP is based on the assumption of adequate budgets and resources.

1.3. Nature and Structure of Performance Assessments

Performance assessment model developments are planned to correspond to the major design cycles in three major cycles—CD, ACD, and LAD. The schedule may need to be further structured to provide timely information on the design effort.

Three types of assessments will be developed and applied during each iterative phase. The models and assessments for each of these three types—single waste package, source term, and reliability—build on the results of preceding model assessments. In the first type, we assess the performance of a single waste package under the different near-field environments. In the second type, we assess how the overall waste package system, which includes all waste packages in the repository, performs with respect to the NRC performance requirements assigned to the EBS (10CFR60.113) and as a source term for total system transport. In the third type of assessment, we characterize the reliability of the predictions made by the first two assessments (or conversely, their uncertainty).

The following waste package PA SIP activities already have been completed or partly implemented, as noted:

I-20-5: Development of the first version of single waste package model, PANDORA-1.

I-20-6: Partial verification of PANDORA-1.

I-20-7: Example application of PANDORA-1 to CD waste package assessment.

I-20-14: Development and evaluation of uncertainty assessment and ensemble integration methodologies.

This SIP addresses planned activities during the CD cycle. These activities also will support the information base for the start of the ACD cycle. The interfaces of these activities and their relationship to the FY90 products are depicted in Fig. 3. Future SIPs will be prepared to address performance activities that will be performed to support the ACD and LAD cycles, respectively. Several activities identified in this SIP are intended to be continued by a subsequent iteration through the ACD and LAD phases. The PA activities that will be implemented in the ACD and LAD cycles are listed Appendix B.

The activities planned in this SIP are grouped in the three major categories: (1) model and conceptual development; (2) application; and (3) advanced studies.

1. Model and Conceptual Development

I-20-22: Extend system model PANDORA-1 to version PANDORA-1.1 for applications before the start of ACD.

I-20-20: Identify, categorize, and quantitatively describe scenarios.

I-20-23: For source-term model version 1, develop models of parameter variation across the repository and among waste packages and select a method (e.g., analytical or numerical) for integrating PANDORA-1.1-assessed waste package performances to source term and regulatory

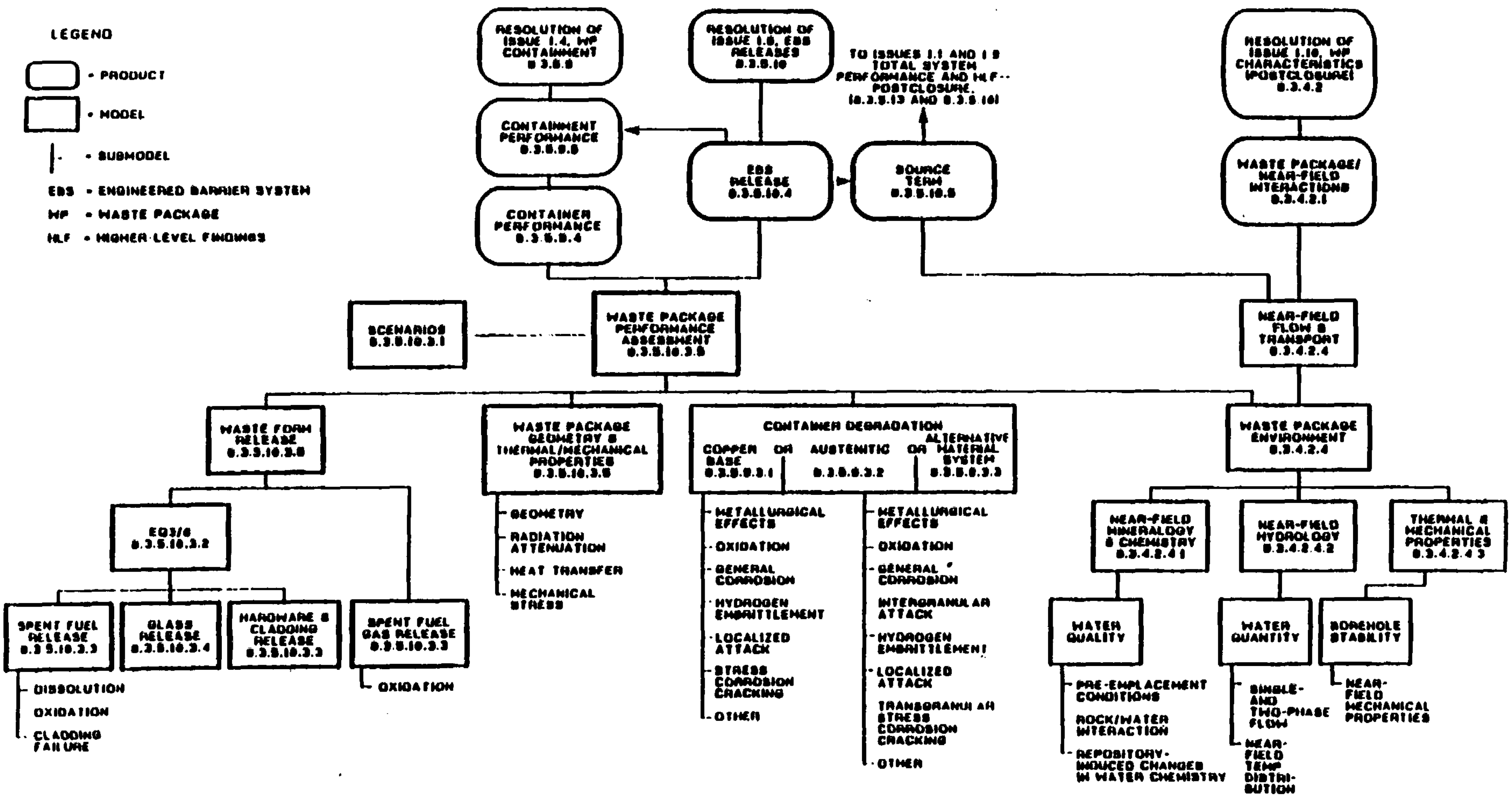

Figure 1. Model hierarchy for DOE Issues 1.4,1.5, and the postclosure aspects of 1.10. The figure is taken from the SCP (DOE, December 1988), Fig. 8.3.5.10.1.

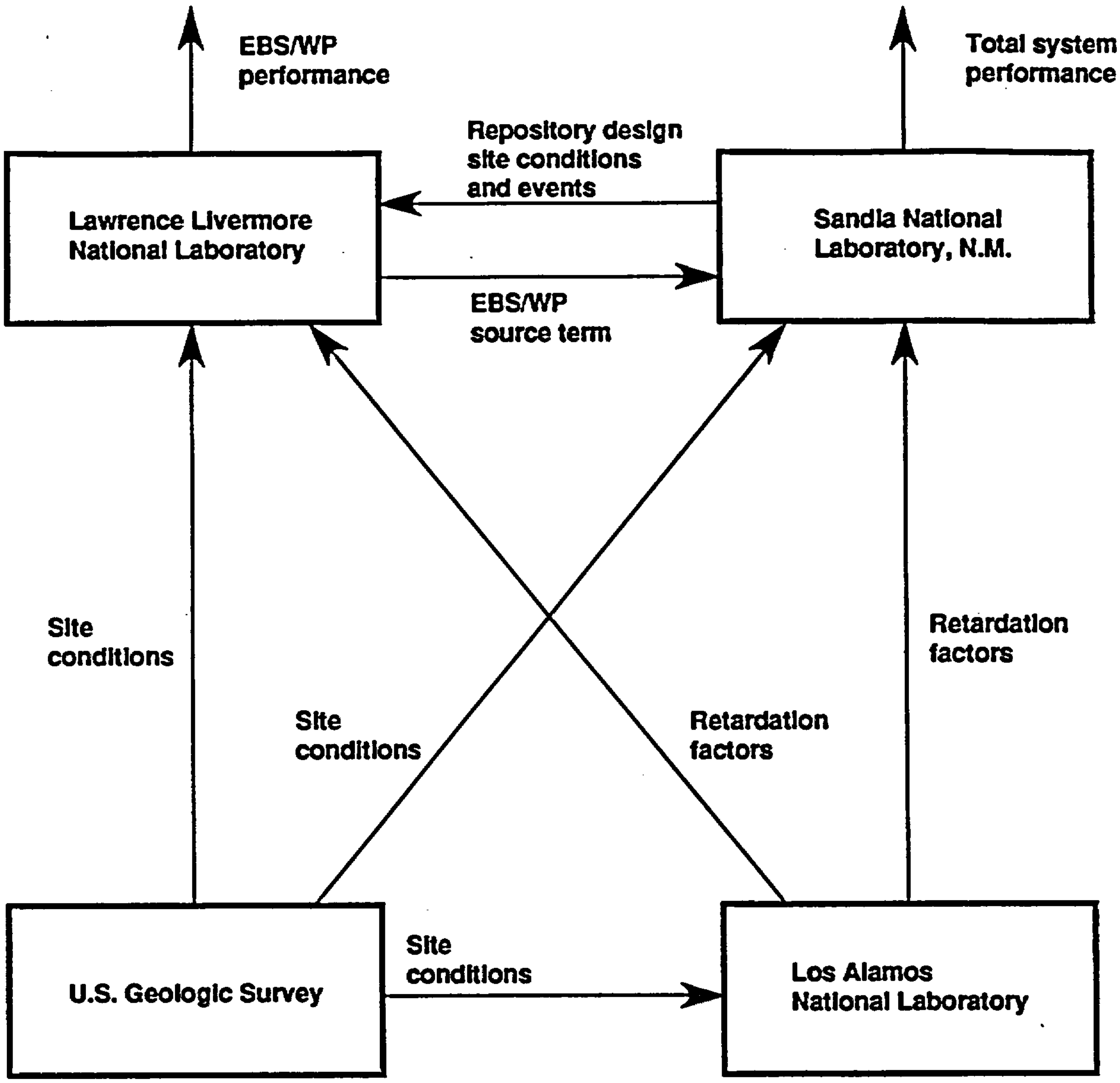

Figure 2. Summary view of the required information flow between the major scientific participants in the YMP. This diagram helps to place into perspective the efforts described in this SIP, and how LLNL will help provide the basis for LAD specifications and data.

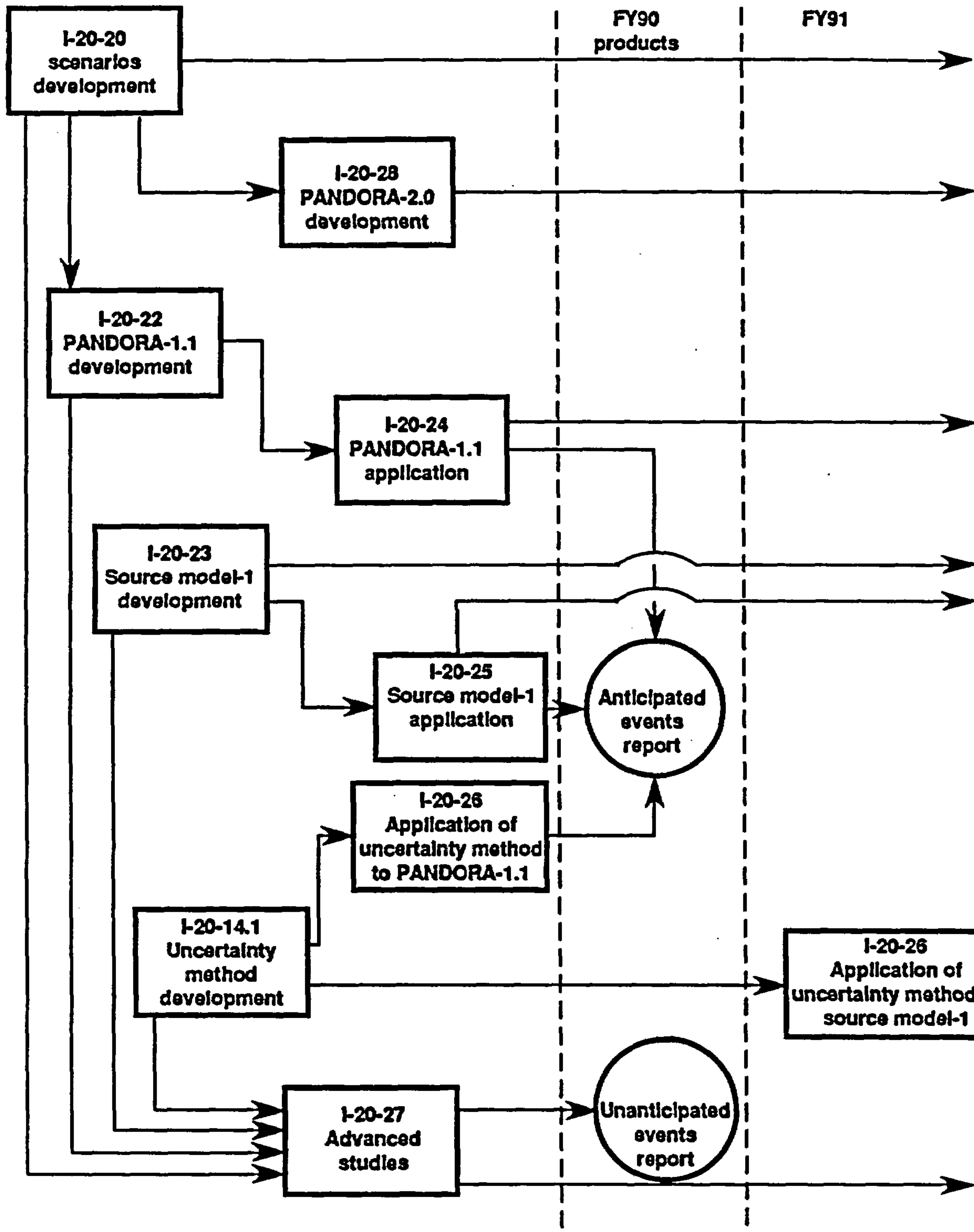

Figure 3. Summary view of the activities described in this SIP, their main relationships in terms of information flow, and the FY90 products that we expect to derive from them. There are ten activities altogether. The two primary products for FY90 are identified as two reports, one each on waste package performance under anticipated and unanticipated conditions/events. The list of FY91 Interactions and Products is incomplete. Activities which have products that may be delivered in FY91 or beyond are shown with arrows passing through the FY91 Products column.

performance. The resulting package of models and method, including a computer code if necessary, constitutes source-term model version 1.

I-20-14.1: Complete development and further evaluate uncertainty methodologies.

I-20-28: Develop and verify PANDORA-2 analysis of waste package designs at quality assurance level 1 (QAL-1) for use in anticipated processes and events and selected unanticipated processes and events. The analysis will include capability for model extension to assess ACD designs as they develop.

2. Application

I-20-24: Perform assessments and sensitivity studies with PANDORA-1.1.

I-20-25: Source Term Model Applications—CD Phase.

I-20-26: Uncertainty Method Applications—CD Phase.

Note: Activities I-20-24, I-20-25, and relevant elements of I-20-26 will generate the inputs for the LLNL WP Conceptual Design PA Report. This report will be used to guide the ACD design and the strategy to demonstrate regulatory compliance of the waste packages and EBS.

3. Advanced Studies

I-20-27: Advanced and prototype studies will be performed to determine the impacts on the EBS of specific scenarios and of special or potential problems, e.g., magma intrusion, or fault block movement intersecting portions of the EBS.

2.0 Rationale

2.1 Introduction

The technical rationale for each listed activity is presented in this section. The section organization corresponds to the three areas of study listed in Section 1.3. A corresponding description of each activity is given in Sec. 3. Quality assurance level assignment sheets for each activity are provided in Appendix C.

2.2 Model and Conceptual Development

2.2.1 Activity I-20-22: Extend PANDORA-1, the Deterministic Single Waste Package System Model, to PANDORA-1.1

This deterministic, single waste package system model has several purposes. First, it integrates in one computer program the various physical process models independently developed in the LLNL-YMP scientific investigations that are being performed to characterize phenomena affecting waste package post-closure performance. In this role, the model functionally integrates the various modeling activities and assures the use of consistent assumptions and inputs among them. Also, waste package performance models not addressed within process investigations are identified within the system model as new/additional information needs.

Second, the single package model assesses the net performance of waste package designs, considering the dependencies and coupling among the physical processes. These assessments provide feedback to the design process. Although regulatory compliance cannot be demonstrated with individual waste package analysis alone, the information gained by analyzing individual packages is beneficial in assessing design options.

Third, to demonstrate regulatory compliance, we must assess the collective "ensemble" of waste packages within the repository. Therefore, we must do analyses that account for variations in environmental conditions, waste package characteristics, and waste forms. These analyses will use the deterministic single waste package model as a kernel for determining the performance of individual packages under each particular set of conditions and then will combine or integrate the individual performances to assess the ensemble performance.

We will extend PANDORA-1 to version 1.1 to incorporate models and data that have been developed recently or that have been identified as next steps during the development of PANDORA-1. This extension will provide a usable model on a timely basis for CD applications, Activity I-20-24, and for use as the kernel in the source-term model development, Activity I-20-23. Thus, useful and timely feedback to site characterization, materials and interactions testing programs, design alternatives assessment, and design basis for ACD can be produced while the more extensive PANDORA-2 is being developed.

2.2.2 Activity I-20-20: Scenario Identification, Categorization, and Quantitative Description

This activity (I-20-20) clearly and inclusively defines the set of anticipated and unanticipated event sequences of the near field and EBS that will establish the range of cases for which waste package performance must be predicted. Repository scenarios compiled for the SCP must be reconsidered so as not to exclude any scenarios significant to waste package releases, and new scenarios that are relevant to near-field processes must be developed. Acceptable decision criteria for classification and delineation as anticipated or unanticipated scenarios are to be developed . The concept of "scenarios" encompasses three categories:

1. Site or repository-scale scenarios, such as climate change or fault movement inpacting the EBS, and near-field environment events, such as key block slippage or contact;

2. Near-field environment consequences of site and repository scenarios, including the expected variations of these near-field environment descriptions among the waste packages;

3. Local time histories of paths to an altered and waste-releasing state, including changes in engineered barrier and waste package components.

The specific scenario parameters influencing waste package environment interactions are required for PA. These parameters are needed for anticipated conditions for the waste package PA as well as for anticipated and unanticipated processes for the source term PA. Finally, the adequacy of the waste package design must be determined as anticipated waste package scenarios are specifically identified, quantified, and assessed. The work in this activity is performed under QAL-1.

The key outputs of this activity are to:

1. Identify all scenarios to be screened for classification as anticipated or unanticipated;

2. Develop decision criteria to separate processes and events into anticipated or unanticipated categories and develop the data and bounding estimates required by the criterion;

3. Develop and assemble the critical near-field and waste package parameters that describe the anticipated scenarios; and

4. Confirm the waste package design envelope or identify the range of conditions to be considered in design and testing.

These outputs are iterative and will continue throughout the design life cycle of the package and repository. To some degree, confirmatory work will continue through closure and the period of retrievability. Outputs 1, 2, and 4 will be directly used for the waste package and source term PA models. Output 3 will be transferred to information need 1.10.4, where the waste packages and their environment will be evaluated for the provided scenarios.

2.2.3 Activity I-20-23: Develop Source Term Model—CD Phase

The waste package PA outputs are the source term for PA of the total systems and the performance of the collective "ensemble" of waste packages in units of the NRC's performance measures for the EBS subsystem (i.e., substantially complete containment and limited release rate). These outputs require the sum over the individual waste package performances. This summation analysis must consider variations in environmental conditions, waste package characteristics, and waste forms.

Indeed these variations in conditions are an essential part of the performance allocation for meeting the EBS performance requirements, as described in the SCP, Sections 8.3.5.9 and 8.3.5.10. Some, but not all, waste packages may be exposed to liquid groundwater. The times of initial breaches or wetting of containers or both are expected to be distributed over time. These and other variabilities must be determined by specialized investigations and their relevance to regulatory performance determined by PA. One of the tasks of PA is to find interconnections among processes, including those that moderate the net performance summed over waste packages.

The source term modeling activity will have to identify and model the important variations in environmental and waste package properties, determine the performance of a waste package under each set of properties (using PANDORA as a basis), and sum over the individual performances. The sum or integration may use sampling as its technique; see Activity I-20-14.

Interim assessments of the source term and regulatory performance are needed for the same general reasons as the interim assessments of single waste packages: guidance to strategy feedback to design, site characterization, laboratory testing, and model development; activities and assessments of designs and of current information.

The source term assessments provide different information for feedback than do the single waste package assessments. The source term assessments are in units of the regulatory requirements and evaluate the EBS design in the full repository environment, including its trends and local variations.

2.2.4 Activity I-20-14.1: Complete Development and Further Evaluate Uncertainty Methods

Uncertainty assessment techniques will be used to describe the uncertainty in the predictions from the source-term model. To obtain a positive finding, the NRC must be able to assert "reasonable assurance" that the performance requirements will be met. Toward this end, the source-term model will provide a prediction of performance. But a description of the uncertainty of these predictions is also required. Uncertainty in the predicted output arises from at least four sources: uncertainties in the completeness of scenarios, modeling uncertainties, numerical method uncertainties, and uncertainties in the input parameters. At first, our uncertainty methods will address only the effects of parameter uncertainties.

Sampling represents the most widely used technique for estimating uncertainties in model outputs that are due to uncertainties in the input variables. (Sampling is also an effective method for numerical integration when the number of dimensions or variables is large. Thus, we expect the sampling method to be useful as the integration technique in the source-term model, Activity I-20-23.) Many sampling methods are available. They differ largely in the methods used to reduce the variance in the statistical estimates extracted from their output samples. Some methods work effectively for some modeling conditions but not for all (O'Connel, Lappa, and Thatcher, 1989; and O'Connell, in prepration). We have investigated sampling methods that can address the special modeling conditions that are anticipated for the source-term model. These investigations led us to design a new sampling method for this purpose that combines beneficial features of several existing methods.

We need a sampling method that is designed for the special modeling conditions that we anticipate for the PA task. These modeling conditions can be summarized as follows:

1. The sampled model will likely require a lot of computer time for a single evaluation. Thus, sample sizes must be limited.
2. Accuracy in the estimate of the cumulative distribution function (i.e., fractile values) is of importance at all potential values of the random variables of the underlying output.
3. The source term models will be complex as well as large, and no "prior knowledge" about output distributions will be available before any samples are evaluated.

We have studied existing sampling methods, including simple random, stratified, and Latin Hypercube sampling, and have concluded that none would produce low-variance estimates of fractiles and means of outputs, consistently, under these modeling conditions.

Initial tests of our new controlled sampling (CS) method indicate beneficial and robust performance (O'Connell, Lappa, and Thatcher, 1989). Confirmatory tests are needed to establish acceptance of the method.

We need to couple the selected uncertainty method to the waste packages source term problem. The complete need is to model or describe the input uncertainties affecting the source term, couple them to the source-term model, and proceed to the output uncertainties.

2.2.5 Activity I-20-28: Develop PANDORA-2, a QAL-1 Deterministic, Single Waste Package System Model

We have two primary reasons for developing an entirely new version of the PANDORA model. First, to qualify analyses to be used in QAL-1 decisions and for our analyses to be used for licensing, we must develop a QAL-1 theoretical model and software implementation of that model.

Second, significant developments in modeling the physical processes affecting waste package post-closure performance require a fresh evaluation of software approach and program structure. The development of scenarios (Activity I-20-20) and the modeling of container failure may introduce a new approach and a new structuring into submodels. Modeling of near-field interactions and of waste transport through the near-field zone are needed. Also, because we must assess the performance for unanticipated processes, we will require additional modeling for PANDORA.

Finally, the development of the source term (ensemble) model of the waste packages will undoubtedly lead to additional requirements for PANDORA, which serves as a kernel to source term calculations.

The products of this activity will be part of the QAL-1 PANDORA-2 model with the software-related products to develop that model, e.g., requirements, test plans, and source code.

2.3 Application

2.3.1 Activity I-20-24: Conduct Performance Assessment and Sensitivity Studies Using PANDORA-1.1

This activity uses PANDORA-1.1, the product of activity I-20-22. The first major application in this activity will be to assess single waste package post-closure performance under anticipated and, possibly, unanticipated conditions. These assessments help guide the model development activities, indicate areas in which too little or too great a level of performance margin has been incorporated, and provide information for feedback to site characterization, testing and design The need for timely feedback leads us to plan a fixed-time report, i.e., during FY90, to include information developed during FY90. Continuing applications to round out the types of needed information will be developed for a follow-on report.

The second major application of PANDORA-1.1 will be to conduct sensitivity analyses of input parameters for the model. Knowledge about the sensitivity to input parameters is useful in conducting the uncertainty analyses of single packages and of the ensemble of waste packages, and it provides timely feedback for site characterization, and design, testing, and model development.

2.3.2 Activity I-20-25: Apply Source Term Model—CD Phase

In the CD phase we expect to do some initial assessments on site suitability and we are preparing the information base for the start of the ACD phase.

A source term PA using existing information will provide some initial indication as to the outlook for site suitability for anticipated-conditions performance and for potentially disqualifying conditions, when the site is paired with the prototype or conceptual design. The PA will indicate what inferences or bounding statements can be made on the strength of the existing information. Some contributing activity to the advanced studies activity, I-20-27, for unanticipated events is also planned.

In preparation for the planned site characterization and design activities, initial source terms are needed to:

1. Indicate the types of site, near field, design and interaction information (concepts and data) needed;
2. Confirm or guide the waste package regulatory-compliance strategy, including performance allocation and design requirements, and testing strategy;
3. Redirect model development and material R&D testing.

The performance allocation given in the SCP can be checked or alterations guided by source term PAs. For example, the performance allocation as written has an open issue: during the controlled release rate period, there is an allocation of a factor of ten reduction in release rate from the waste packages, assigned to "mass transfer resistance." But the source of mass transfer resistance is not established; four potential contributing phenomena are listed in the SCP, page 8.3.5.10–15. Preliminary studies of the detailed phenomena coupled to a source term assessment can evaluate some of the contributing phenomena and their effectiveness. Other phenomena contributing to a release rate reduction can be investigated; one such is that the environmental temperature continues to decline toward ambient, and the spent fuel matrix alteration rate declines strongly as the temperature declines (about a factor of ten when temperature declines from 85 to 25°C).

Other elements or assumptions of the performance allocation can be checked or made more specific by source term assessments. The performance allocation has different allocations for the first time period, when substantially complete containment is required, and the later time period, when a limit on the release rate is required. There is a similar material shift of the set of waste packages from a "substantially complete containment" behavior to a non-containment but controlled-release-rate system configuration. Schematic but thorough source term PAs using allocated behaviors and existing data can provide more detailed understanding or confirmation of whether the set of waste packages will meet their performance goals during the transition period from a containing to non-containing configuration.

2.3.3 Activity I-20-26: Apply Uncertainty Method—CD Phase

In addition to developing an uncertainty modeling capability for the source-term model, it will be useful to apply the controlled sampling method to single waste package evaluations. For example, further insight in the source-term model development of activity I-20-23 might be gained from sensitivity and uncertainty studies on PANDORA inputs.

Application of the uncertainty method to the source-term model for the CD will be a prototype of the final required licensing assessments and will provide early feedback.

The uncertainty assessments of conceptual designs are performed to:

1. Provide feedback to other tasks as to the most important factors that affect the performance and the current uncertainty in the performance of the waste package system.
2. Test and guide improvements in PA methodology.
3. Develop the formats for describing the stochastic source term over the time history of the waste package.

2.3.4 Activity I-20-21: Provide Guidance for Waste Package Information Data Base

LLNL will develop waste package data base information to provide environmental, waste form, and waste package data to the design process. This information will include data from several technical disciplines spanning a broad range of issues that affect waste package design.

A waste package performance complying with regulatory criteria is the ultimate goal of the design efforts. Because LLNL has the lead responsibility for determining the adequacy of waste package designs with respect to regulatory requirements, the LLNL PA group must be actively involved in identifying and assessing the adequacy of information categories and accuracies planned for inclusion in the data base.

This activity provides guidance for, but not development of the data base.

2.4 Advanced Studies, Activity I-20-27: Conduct Prototype Study of the Impact of Specific Unanticipated Events

To facilitate rapid response to potential problems identified by the project and the DOE-HQ, a special activity has been designated to assess these problems using current tools and data. As shown in Fig. 3, this activity will draw from the longer term tasks yet cause minimal interference on those tasks.

The intent covers goals of scoping and prototyping. First, scoping studies will identify the potential scope of selected problems and the availability of models and data. The goal of such studies is not just to help us resolve and eliminate problems where possible, but also to shed light on those problems that warrant further analysis. Second, prototype studies will identify data and modeling needs, and will outline the framework and potential approaches for needed modeling. The goal is to show the process for assessment and specify more clearly the needs, rather than to solve the problems all in one step. A single study may serve both scoping and prototype needs.

Initially, two unanticipated event scenarios will be addressed: fault displacement and magma intrusion impacting on the EBS.

3.0 Description of Tests, Analyses, and Previous Work

3.1 Introduction

Plans for the activities covered by this SIP are given in Sections 3.2 through 3.4. Where appropriate, dependencies among the activities are described. When previous work has been done, a summary of that work is given. All QAL-1 activities will be planned, controlled, and implemented in accordance with the LLNL YMP Quality Assurance (QA) Plan, including, as applicable: the sequence of events in an activity; how the relevant QA procedures will be implemented; applicable Technical Implementing Procedures (033-YMP-QP-5.0); scientific notebooks used to document work (033-YMP-QP-3.4); peer and technical reviews (0.33-YMP-QP-2.2 and 0.33-YMP-QP-2.4); and hold points. Quality assurance program controls for work conducted by a subcontractor also will identify, as necessary: the QA specification issued to the subcontractor; technical interfaces; materials or equipment to be provided to the subcontractor; and deliverables.

Scientific notebook control will be implemented on all QAL-1 and -2 activities, except for repetitive administrative processes, to document analysis and to support software QA plans. Scientific notebook control is warranted because of the high degree of professional judgment required in PA technology.

Control methods to be applied to development of QAL 1 and 2 computer programs will be addressed in individual software QA plans, which may include use of scientific notebook controls.

3.2 Model and Conceptual Development

3.2.1 Activity I-20-22: Extend PANDORA-1, the Deterministic, Single Waste Package System Model, to PANDORA-1.1

From late FY86 through FY89, LLNL developed the first version of the deterministic, single waste package system model, PANDORA-1. A preliminary specification was published (O'Connell and Drach, 1986). The current version of the PANDORA-1 model and results from preliminary analyses of it are described in a report by Lappa and Hardenbrook that is currently in review.

PANDORA-1 has been developed with limited resources. Several submodels can be improved over their current state by incorporating models and data that have been developed more recently or that have been identified as next steps during development of PANDORA-1.

We will extend PANDORA-1 to version 1.1 to incorporate available models and data. This extension will allow us to conduct PAs and sensitivity studies using PANDORA-1.1, as described in Activity I-20-24. Also, the insights gained from bringing PANDORA-1 more in line with the state-of-the-art models will prove useful in developing the QAL-1 PANDORA-2 computer program, activity I-20-28. For QA program transition, see Section 5 of this report.

Intended products from this SIP for FY90 are as follows:

1. An unverified and unvalidated PANDORA-1.1, which will be an extension of PANDORA-1.
2. Additional documentation of the source code for implementing PANDORA-1/1.1.

3.2.2 Activity I-20-20: Scenario Identification, Categorization, and Quantification

Identifying, categorizing, and quantifying both near-field scenarios and near-field impacts of far-field scenarios to evaluate the waste package performance represents one of six key input activities to the waste package PA model. The other five activities are developing: (1) the geochemical speciation and reaction model; (2) the spent-fuel release models; (3) the glass waste-form release models, (4) the container degradation model, and (5) the rock-water interaction and hydrology model. It is vital to the design as well as the licensing process that the scenarios at the near-field and waste package level be rigorously delineated. To date, broad boundary conditions have been assumed. These bounding conditions are not sufficient for waste package design. In addition, specific guidance on waste form and waste package environment testing can be provided by rigorous examination of scenarios. The guidance is likely to include the types of testing as well as the degree of confidence required in that testing.

The scenario identification process requires the acceptance of credible scenarios for the far-field assessment, the reassessment of far-field scenarios previously excluded on the basis of consequence, and the identification of new scenarios relevant to the waste package and near field. A basic-systems approach will be used in assembling the information, e.g., a failure modes and effect analysis (FMEA). Preliminary test data and expert interview techniques will be used to reassess scenarios in regard to waste package consequences.

Scenarios will be developed and documented in consideration of techniques previously used for repository scenario development. The three basic techniques (Monte Carlo simulation, event trees, and expert opinion) will be evaluated with the expected outcome of using expert opinion. Various expert opinion techniques will be evaluated in regard to the appropriateness for this specific subactivity, i.e., identifying processes and events affecting the waste package. We anticipate that experts in the various subjects, within and outside LLNL, will participate in these evaluations.

To separate scenarios into anticipated and unanticipated categories, we must develop and document the decision criteria and the concurrent data for the criteria. Initially, we expect that the scenarios will be classed discrete-state probability and frequency-magnitude-relation types. Decision criteria techniques for quantitative and qualitative determination will be reviewed and used as appropriate. In addition to considering the appropriateness of the criteria in regard to the data and end user (PA), the need of independence from Issue 1.1 scenario delineation and the need for simplicity will be considered. Independence is necessary because of the different systems affected and because of the NRC's focus on "anticipated processes and events" for the subsystem requirements basis. Simplicity refers to how easily the key players, including intervenors, comprehend the principle of the decision criteria.

In developing the parameters to define the scenarios, we will describe the far-field influence in the near field, design-dependent parameters, and the evolution of waste package near-field parameters at the waste package scale. Parameters will be developed for both anticipated and unanticipated scenarios for a given set of waste package configurations. The configuration will specify waste form and container material type. Alternative waste package and EBS design configurations will be considered. The next step is to identify the relevant parameters. The physical test data, preliminary performance model outputs, scientific knowledge, and expert opinion will be used to develop and quantify the set of parameters. Quantification will include point estimates and probabilistic characterizations. Because the system is a dynamic environment, the data will be developed for specified appropriate time intervals.

To determine the adequacy of the design envelope, we must confirm or adjust that envelope. Near-field conditions resulting from anticipated scenarios established above will be examined in making this determination. Furthermore, the determination will be based on scientific knowledge and, where appropriate, expert opinion. The adequacy of these determinations will be assessed singularly and collectively. The envelope must be valid for design and testing bases.

The primary outputs of this activity will be a series of reports and, as appropriate, a data base of the scenarios and parameters.

3.2.3 Activity I-20-23: Develop Source Term Model—CD Phase

The source-term model version 1 is for the conceptual design waste packages. Source-term model development is expected to continue through the successive design cycles.

The source term for the total systems performance assessment is the summed performance of all waste packages in the repository. The CD version of the source-term model will include a method of integrating over the single-package assessments produced by the PANDORA model. The result will consist of a single value for each source term output parameter. (For output performance probability distributions, see activity I-20-14.1.) The following subactivities will be included in I-20-23:

Subactivity 1: Develop a Base-Case Repository Load. Develop a base load of waste packages for the repository. The base load will describe the base repository system whose performance is to be assessed. Variations of the base load will also be developed.

Scenario activity I-20-20 will provide much of the base load data. Other YMP tasks will also be consulted as necessary.

Subactivity 2: Establish a Repository Temperature Prediction (RTP) Model. Existing technology and reports will be used to establish an RTP model. The model will predict temperatures throughout the repository as a function of time, from a specified repository load. In particular, with respect to individual waste packages, the capability of predicting canister temperatures over time as a function of their contents and location will be developed. Other YMP tasks will be consulted for information about current technology for producing or obtaining an RTP model.

Subactivity 3: Determine Other Source Term Parameters. The need to develop the values and variability of other input parameters for predicting the source term is anticipated. Important input parameters are expected to include water flux and contact modes, water chemistry, rock wall condition, container properties, and details of waste contents.

Subactivity 4: Develop an Integration Method. Develop a method that links the single package modeling capability of PANDORA with source term parameters and integrates to predict the source term. The first version of the source-term model version 1 will use PANDORA-1.1 An improved version of the source-term model will be developed and will use PANDORA-2. This is a steady progression and is being planned under this activity; but depending on schedules for PANDORA-2 and ACD, parts of this activity may be replanned and executed under the PA SIP for the ACD phase of work.

3.2.4: Activity I-20-14.1: Complete Development and Further Evaluate Uncertainty Methods

Subactivity 1: Select a Sampling Method for Uncertainty Analysis. Finish programming and verify the controlled sampling test system (CSTS). Compare the controlled sampling method with existing sampling methods, such as simple random, stratified, and Latin Hypercube sampling.

The main program in the CSTS is the CONTROL program, which performs the controlled sampling method. The CSTS operates CONTROL and can compare the performance of the controlled sampling method with that of other sampling methods on the same models.

Two draft volumes by R. Thatcher, entitled "Modeling Uncertainty with Limited Sample Size" have been written. Volume I is subtitled "The Controlled Sampling Method," which describes the mathematical theory behind the new sampling method. Volume II is subtitled "The Controlled Sampling Test System (CSTS)." This volume describes the CSTS computer program.

CONTROL is completed but needs verification. About 75% of CSTS has been completed and implemented. After it has been verified, final comparison tests of the controlled sampling method will be conducted. CSTS tests will be the basis for selecting the sampling method for modeling performance analysis uncertainty.

Subactivity 2: Modeling the Uncertainties in the Single Waste Package Model (PANDORA-1.1). The input random variables generating uncertainty in the single-waste-package predictions will be studied. The coupling of the uncertainty method to PANDORA-1.1 will proceed coordinated with the source term integration method coupling to PANDORA-1.1. These are similar in method, but differ in the types of input variability.

Subactivity 3: Modeling Approach to Uncertainties in the Source Term Model. After the source term models have been established, the structure of the random variables input to the model will be studied and described. Issues, such as the existence of correlations, spatial autocorrelations, and relative variable importances will be resolved. These issues will determine procedures for sampling and propagating inputs, or for modeling output uncertainties by other methods.

As an example, uncertainties in the estimated temperatures of individual waste packages at specified times will be sources of input uncertainty. The source-term model will generate and use spatially dependent "expected" temperatures, but the true temperatures still have some uncertainty. This subactivity will account for the joint distribution of package temperatures throughout the repository as a function of time.

First Steps in Waste Package Uncertainty Modeling. Initial uncertainty model development will target some near-term studies. Methods for determining probability distributions for single-package evaluations by PANDORA will be developed. Methods for other parameter variations in the source-term model will be developed. The development of uncertainty methods for the overall source-term model will follow after the source-term model has developed sufficiently.

3.2.5 Activity I-20-28: Develop PANDORA-2, a QAL-1 Deterministic, Single Waste Package System Model

The first step is to develop the theoretical understanding of the waste package and EBS system and of its interacting processes. First we will survey the state of knowledge in the specialized areas feeding information to PA. In parallel we will examine the interactions among them and the degradation pathways for the waste package system, while making use of the failure modes and effects analysis (FMEA) work in Activity I-20-20, Scenarios. Then we will determine the overall concepts and structure the functional system into submodels (or processes). The submodels will be from the general topics of near-field environment, metal barrier degradation and breach, waste form alteration, waste form release, and waste transport through the near-field zone.

From these concepts, we will develop a specification of the model's overall input-to-output functions and of its functional structuring into submodels. Then, within each of the parallel submodel activities, the next step is to complete an up-to-date, detailed, and highly scrutable theoretical specification for the physical process submodel.

When these specifications are developed, we will follow a complete and highly effective software life cycle to control the development of requirements, designs, test plans, and source code and user's manuals for the software implementation of the model, in keeping with good professional software development practices and in accordance with the prescriptions of our individual software plan. The work will likely progress on several fronts at once, i.e., we may be developing the theoretical specifications for one submodel while simultaneously testing the source code implementation of another submodel. Such parallel activity is essential if we are to make effective use of our resources and achieve a product in a timely manner.

The specifics of modeling improvements beyond PANDORA 1.1 that we plan to make are for the most part, to be determined by the activity. However, preliminary plans include the following, or similar, changes to the theoretical specifications and/or software implementation of PANDORA:

Radiation Submodel

- Complete and implement the work begun in the Waste Package Performance Assessment report by O'Connell and Drach.

Thermal Submodel

- Use a more sophisticated treatment of the borehole wall boundary temperature.
- Improve the model of radial heat transport in spent fuel packages for peak temperatures and for temperatures out to 10,000 years.

Environmental Submodel

- Model the atmospheric humidity of the borehole.
- Couple the submodel to the radiation submodel to account for radiolytic effects on water chemistry.
- Implement variations in groundwater flow rates.
- Include a diffusive mode for groundwater contact with the metal barrier and waste forms.
- Model the infilling of the package-borehole air gap with particulate tuff.

Corrosion Submodel

- Expand the model of uniform oxidation and corrosion; implement a model of the initiation and propagation of pitting corrosion, the initiation and propagation of stress corrosion cracks, and the effects of crevice corrosion.

Global

- Include a base-case data base and user option to input data when different from that of the base case.
- Consider splitting PANDORA-1 into two separate models, one for glass-based waste and one for spent fuel. The geometric, mechanical, and chemical differences between these waste forms lead to parallel but different process submodels.
- Accumulate calculated data and modify the output routines to enhance the interface with PANGRAPH, a recently developed graphics post-processor for PANDORA.

3.3 Applications

3.3.1 Activity I-20-24: Conduct Performance Assessment and Sensitivity Studies Using PANDORA-1.1

The primary product of this activity, in conjunction with other activities within this SIP, is a report on conceptual design waste package post-closure performance under anticipated conditions. The initial task will be to develop a clear specification of the scope and extent of that report.

Another product of this activity will be documentation of the results of sensitivity analyses carried out using the PANDORA-1.1 model. We expect at a minimum to provide discussion about the sensitivity of key performance measures to some of the more basic parameters within the PANDORA-1.1 model. These sensitivities may prove useful in the ensemble/uncertainty work being carried out in other activities (e.g., I-20-23 and I-20-14.1).

3.3.2 Activity I-20-25: Apply Source Term Model—CD Phase

This activity will be our central effort to integrate all of the information that is currently available from all YMP tasks. The source-term model will use PANDORA-1.1 for all single waste package assessments (see activity I-20-23). Outputs of source term amplitudes and of regulatory performance measures will be "best estimates." Some sensitivity studies or large-step variations of inputs may be performed.

The first near-term product will be a source term PA for anticipated conditions of the conceptual design, using the conceptual source-term model version 1, PANDORA version 1.1, parameter descriptions across the repository and among waste packages, and simplified calculational techniques to apply the source-term model. The assessment will examine what we can predict about containment and release rate performance; what we can't predict and why that is the current status of knowledge; and what concepts, understanding of processes, and data are needed to do adequate assessments of containment and release rate performance.

This first product is intended to provide such preliminary results as can be available in a fixed time period, intended to be one year from start of the activity. Continued work after this time period will improve the content of the models and assessments.

Longer-term products during the CD phase will be further source term performance assessments using iteratively improved versions of the source-term model version 1, and addressing further design questions arising during the conceptual design phase.

In parallel with this activity, some uncertainty analyses on single waste packages that pertain to this application are planned. These are described in activity I-20-26.

3.3.3 Activity I-20-26: Apply Uncertainty Method—CD Phase

Application of the controlled sampling method on the PANDORA-1.1 model will be conducted to demonstrate our capability of applying uncertainty and sensitivity analyses to single waste package output variables produced by PANDORA-1.1 and to provide insights useful in the development of the source-term model. Some numerical tests will be based on single package PANDORA-1.1 runs that will be performed for initial source-term model applications, described by activity I-20-25.

The uncertainty method will be applied to the computer-based implementation of the source-term model when available. We will identify and quantify by estimates the sources of uncertainty in the source term, and then propagate these uncertainties through the source-term model using our uncertainty method.

3.3.4 Activity I-20-21: Provide Guidance for the Waste Package Information Data Base

In this activity we will describe the data category needs for PAs identified during the development of PANDORA-1 and during the ongoing activities for this SIP. We will also review the categories of information as they have been developed by other sources, commenting on the need for and sufficiency of those categories, and providing inputs based on the results of iterative analysis to assure convergence to a licensable design.

3.4 Advanced Studies Activity I-20-27: Conduct Prototype Study of the Impacts of Specific Unanticipated Events

The state of information available on specific unanticipated events will be surveyed. This will include literature searches and solicitation of expert opinions. It is expected that the techniques and information developed under the scenario activity I-20-20 will be used.

Conceptual models will be developed from data available, filling in with engineering judgements where data are lacking or unavailable, or documenting their absence and their need to be developed. A range of models or model parameters will be used to provide a sensitivity analysis to indicate the possible magnitude of suggested processes and effects for each unanticipated event. Results from the PANDORA 1.1 source term and uncertainty models activities will be applied as appropriate.

Two unanticipated events will be considered initially. These events are generally described as fault displacement and magma intrusion involving the EBS. This activity will include a more specific and relevant description of the events as well as an indication of what parameters at what magnitude are significant to the EBS performance. The activity will also include a description of the EBS performance under these conditions. A report will document the study.

3.5 Interfaces

3.5.1 Interface Identification

Performance assessment needs data, models, and evaluated concepts for models from activities in other technical areas in LLNL-YMP; design information from the design organization; site scenario information and a description of source term needs from the Total System Performance Assessment activity. Performance assessment transfers site scenario information to LLNL-YMP's near-field Environment technical area, which determines and transfers back the near-field environment descriptions resulting from those site scenarios.

Performance assessment provides results, evaluated information, and descriptions of further needs to the site and site-material interaction activities, mostly within other technical areas of LLNL-YMP and possibly also in external organizations. Performance assessment provides results and evaluated information to the design organization, and provides source term description to the Total System Performance Assessment. Performance assessment provides results and evaluated information in the form of technical reports to the licensing organization in the DOE Program.

3.5.2 Interface Control

All interfaces with other technical areas in LLNL-YMP and with other organizations external to LLNL-YMP will be controlled.

Data and models produced by LLNL activities outside performance assessment that are intended for use in PA shall be designated with a status of "preliminary" or "final," in accordance with quality procedures and technical implementing procedure. The data or models will be transmitted to PA via the document control center, which shall keep logs of all transmittals, including the date and status of the transmittal.

Performance assessment data and models that are required by others shall be transmitted to the document control center and shall be designated with a status of "preliminary" or final," in accordance with the quality procedures and technical implementing procedures. Preliminary data or models input to the PA process will result in preliminary PA products. Note that although all input to the PA process may be designated as final, the resultant PA products may be preliminary pending qualification of PA computer models.

Data and models exchanged with organizations outside LLNL will proceed under controls and documentation determined by procedures.

4.0 Application of Results

Performance assessment scientific investigations will integrate and coordinate the experimental data and analytical models being developed by LLNL from the waste package container material studies, geochemical modeling, package near-field environment characteristics, and waste form release rates to address Issues 1.1, 1.4, 1.5, and 1.10. These issues and related information needs are listed in Appendix A.

The results of the models and computer programs designed for these scientific investigation activities will be analyzed to:

1. Provide guidance to the advanced conceptual design phase of the YMP waste package and repository.
2. Generate ensemble source terms for use in assessing the total system performance for the geologic repository.
3. Broaden the knowledge of scenarios affecting licensing and focus future design and analysis on the most critical scenario parameters.
4. Confirm the analysis performed with analytical models and computer programs developed prior to application of an NRC qualified project QA program.
5. Guide the development of improved analytical methods, models, and computer programs for use in future safety analysis and licensing.

5.0 QA Program Transition

Work performed before implementation of the YMP QA plan that was reviewed and accepted by the Nuclear Regulatory Commission requires additional consideration for future use and qualification.

The early performance assessment analysis addressed by this SIP will require the use of assumptions and either inputs, models, or computer programs developed before approval of the LLNL YMP QA Program Plan, which implements NNWSI 88/9, Revision 2. Methods for status control and distribution of results, pending qualification and acceptance of input not generated under control of the LLNL YMP QA Program Plan will be implemented.

Formal analysis performed will be controlled and documented in accordance with quality procedures and technical implementing procedures and classified as "preliminary" pending verification of assumptions and qualifications. The individual software QA plans for computer programs to be qualified will address the interim use, modification, and the qualification process for computer programs to be used in the licensing application.

PANDORA 1 will be upgraded to 1.1 by use of the most recent models and data available, and will be designated unqualified for use in licensing application until superseded by PANDORA 2 which will be developed in parallel. Preliminary analysis performed with PANDORA 1.1 will be finalized or superseded when PANDORA 2 and input data qualified under the LLNL YMP QA Program Plan are available.

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Appendix A.
Issues and Information Needs Addressed by Performance Assessment

The DOE has developed a hierarchy of issues that address the technical criteria of 10CFR60 as well as other requirements of the regulations that apply to the repository. This issues hierarchy provides an important focus for the performance assessments. The key issues and the performance and design issues associated with each key issue are listed in Table A-1.

The relevant key issues addressed in this SIP are:

Issue 1.1: Will the mined geologic disposal system meet the system performance objective for limiting radionuclides released to the accessible environment, as required by 10CFR60.112 and 40CRF191?

- 1.1.3 Calculational models for predicting releases to the accessible environment attending realizations of the anticipated and unanticipated release-scenario classes.
- 1.1.4 Determination of the radionuclide releases to the accessible environment associated with the realizations of the anticipated and unanticipated release-scenario classes.

Issue 1.4: Will the waste package meet the performance objective for containment as required by 40CFR191 and 10CFR60.112?

- 1.4.3 Scenarios and models needed to predict the time to loss of containment and the ensuing degradation of the containment barrier.
- 1.4.4 Estimates of the rates and mechanisms of containment barrier degradation in the repository environment for anticipated and unanticipated processes and events.
- 1.4.5 Determination of the time to loss of substantially complete containment of the waste packages for anticipated processes and events.

Issue 1.5: Will the waste package and repository engineered barriers meet the performance objective for radionuclide release rates as required by 10CFR60.113?

- 1.5.3 Scenarios and models needed to predict the rate of radionuclide release from the waste package and EBS.
- 1.5.4 Determination of the release rates of radionuclides from the EBS for anticipated and unanticipated processes and events.
- 1.5.5 Determination of the amount of the radionuclides leaving the near-field environment of the waste package.

Issue 1.10: Have the characteristics and configurations of the waste packages been adequately established to (a) show compliance with the post closure design criteria of 10CFR60.135 and (b) provide information to support resolution of the performance issues?

- 1.10.4 Description of the post-emplacement near-field environment of the waste packages, including the expected range of environmental characteristics under conditions appropriate for the reference emplacement configuration.

Table A-1. Key DOE issues

KEY ISSUE 1.	POSTCLOSURE PERFORMANCE
Issue 1.1	Radionuclide releases to accessible environment
Issue 1.2	Individual doses in accessible environment
Issue 1.3	Protection of special sources of ground water
Issue 1.4	Waste-package containment
Issue 1.5	Rates of radionuclide release from engineered-barrier system
Issue 1.6	Pre-waste-emplacement ground-water travel time (GWTT)
Issue 1.7	Performance-confirmation program
Issue 1.8	Demonstrations for favorable and potentially adverse conditions
Issue 1.9	Postclosure siting guidelines
Issue 1.10	Waste-package design effects on predicted performance
Issue 1.11	Repository and engineered-barrier design effects on predicted performance
Issue 1.12	Seal design effects on predicted performance
KEY ISSUE 2.	POSTCLOSURE RADIOLOGICAL SAFETY
Issue 2.1	Dose to members of the public during normal operations
Issue 2.2	Radiation safety of workers during normal operations
Issue 2.3	Radiation exposures of the public and workers during credible accidents
Issue 2.4	Preservation of waste-retrieval option
Issue 2.5	Preclosure siting guidelines
Issue 2.6	Waste-package design effects on predicted performance
Issue 2.7	Repository design effects on predicted performance
KEY ISSUE 3.	ENVIRONMENTAL PROTECTION DURING REPOSITORY AND TRANSPORTATION ACTIVITIES AND PROTECTION OF PUBLIC HEALTH AND SAFETY DURING TRANSPORTATION
KEY ISSUE 4.	FEASIBILITY REPOSITORY BASED ON REASONABLY AVAILABLE TECHNOLOGY AT REASONABLE COST
Issue 4.1	Siting guidelines on cost and feasibility
Issue 4.2	Effects of repository design and operating procedures on nonradiological health and safety of workers
Issue 4.3	Adequacy of waste-package production technologies
Issue 4.4	Adequacy of repository technologies
Issue 4.5	Adequacy of waste-package and repository cost estimates

Appendix B.

Future SIP activities for ACD and LAD cycles.

Advanced Conceptual Design Performance Assessment

The following activities will be included in the SIP for this:

I-20-28.2: Complete the development (includes verification) of system model 2 for analysis of ACD waste package designs for anticipated processes and events and for selected unanticipated processes and events.

I-20-29: Validation studies for system model 2.

I-20-30: Development of source-term model version 2, using system model version 2 as a kernel; includes code development and verification.

I-20-31: Validation studies for source-term model version 2.

I-20-32: Selection of uncertainty methodology or source-term model version 2 using system and source term models version 2 as kernel or referent.

I-20-33: Validation studies for uncertainty methodology version 2.

I-20-34: Analyses of ACD waste packages, including final analyses using system model 2.

I-20-35: Analyses of ACD waste package source term, regulatory performance, and sensitivity investigations, including final analyses using source-term model version 2 (includes source term for Draft EIS).

I-20-36: Analyses of ACD waste package uncertainty and reliability issues including sensitivity of uncertainty, and including final analyses using source-term model version 2.

I-20-37: Advanced Topics

License Application Design Performance Assessment

The following activities will be included in the SIP for this:

I-20-38: Development (includes verification) of system model 3 to include unanticipated processes and events and for analysis of LAD waste package designs.

I-20-39: Validation of system model 3.

I-20-40: Development of source-term model version 3, using System Model as a kernel; includes code development and verification.

I-20-41: Validation of source-term model version 3.

I-20-42: Selection of uncertainty methodology or source-term model version 3 using system and source term models version 3 as kernel or referent.

I-20-43 Validation of uncertainty methodology version 3.

I-20-44: Analyses of LAD waste packages, including final analyses using system model 3.

I-20-45: Analyses of LAD waste package source term, regulatory performance, and sensitivity investigations, including final analyses using source-term model version 3 (includes source term for Final EIS).

I-20-46: Analyses of LAD waste package uncertainty and reliability issues including sensitivity of uncertainty, and including final analyses using source-term model version 3.

I-20-47: Assessment for NRCs (10CFR60.122) list of favorable and potentially adverse conditions (WBS 1.2.1.4.4.2, DOE Issue 1.8), especially those conditions where the NRC notes potential impacts on the performance of the EBS.

I-20-48: Assessment for DOE (10CFR960) higher level findings on suitability of the site (WBS 1.2.1.4.4.3, DOE Issue 1.9).

I-20-49: Assessment to support establishment of the Performance Confirmation Program (WBS 1.2.1.4.8, DOE Issue 1.7).

Appendix C.
Quality Assurance Level Assignment Sheets

Appendix D. Glossary

barrier: Any material or structure that prevents or substantially delays the movements of water or radionuclides.
containment: The confinement of radioactive waste within a designated boundary.
design: The act of developing designs for construction or of analyzing the performance or repository-engineered structures, systems, components, and natural barriers.
engineered barrier system: The waste package and the underground facility.
isolation: Inhibiting the transport of radioactive materials so that amounts and concentrations of this material entering the accessible environment will be kept within prescribed limits.
quality assurance: All those planned and systematic actions that are necessary to provide adequate confidence that the geologic repository and its subsystems or subcomponents will perform satisfactorily in service.
performance allocation: A systematic process of assigning confidence levels and performance goals for the mined geologic disposal systems, subsystems, and components.
performance assessment: The process of quantitatively evaluating component and system behavior, relative to containment and isolation of radioactive waste, to determine compliance with the numerical criteria associated with 10CFR60.
radioactive waste: High-Level Waste (HLW) and other radioactive materials that are received for emplacement in a geologic repository.
scenario: An account or sequence of a projected course of action or event, or process.
scientific investigation: Any research, experiment, test, study, or activity that is performed for the purpose of investigating the natural barriers or the man-made aspects of the geologic repository, including the overall design of the facilities and the waste package.
scientific notebook: A document that may be used to provide a written record of the results of scientific investigations and experiments when the work involves a high degree of professional judgement or trial and error methods, or both.
source term: The release from the overall waste package system. This system includes the EBS and all waste packages in the repository.
waste package: The waste form and any containers, shielding, packing, and other absorbent materials immediately surrounding an individual waste container.