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METHODOLOGY FOR ASSESSMENT OF PRECLOSURE SAFETY FOR YUCCA MOUNTAIN PROJECT

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Introduction

The proposed geologic repository at Yucca Mountain (YM) will be designed for the permanent disposal of about 70,000 MTU of spent nuclear fuel and high-level nuclear waste (HLW). During the preclosure period, the facility will receive and handle casks containing the waste in sealed disposal canisters or in the form of spent nuclear fuel assemblies. Using a series of remote operations, the waste will be transferred into disposal waste packages (WP) and transported underground for emplacement into drifts. As part of its application for a license to construct a HLW geologic repository at YM, the U.S. Department of Energy (DOE) must conduct and present a Preclosure Safety Analysis (PCSA) of the proposed geologic repository operations area (GROA) for the period until permanent closure to demonstrate compliance with the preclosure performance objectives outlined in the proposed 10 CFR Part 63. The NRC has adopted a risk-informed performance-based (RIPB) approach in developing and implementing its regulations and focuses its review on structures, systems, and components (SSCs) important to safety.

The main hazards associated with the preclosure phase of this project stem from (i) the large inventory of radioactive wastes that will be progressively accumulated on site; (ii) the large number

of surface processing operations that will have to be performed, many in parallel, to repackage the waste; and (iii) the subsurface operations involving transportation and emplacement of WPs in the underground drifts. The purpose of the PCSA is to ensure that all relevant hazards that could result in an unacceptable radiological consequence have been evaluated and appropriate protective measures identified that meet the requirements specified in the proposed 10CFR63.112, and to demonstrate compliance with the preclosure performance objectives outlined in the proposed 10CFR63.111. The PCSA accomplishes this by identifying the SSCs that are important-to-safety and demonstrate with reasonable assurance that the GROA complies with the preclosure performance objectives.

This paper describes the development of a risk-informed, performance-based review methodology and a preclosure safety analysis software tool (PCSAT) that can be used by the U.S. Nuclear Regulatory Commission (NRC) to assess, through independent analysis of critical parts of DOE PCSA, that the identification of SSCs important-to-safety and calculation of dose consequences to workers and the public by the DOE are acceptable.

Requirements of Proposed 10CFR Part 63

The PCSA addresses complience with the performance objectives of the GROA for the preclosure period. As defined in the proposed 10 CFR 63.2 and 63.102, the PCSA constitutes a systematic examination of the site; the design; and the potential hazards, initiating events, event sequences, and dose consequences to workers and the public. An objective of the analysis is to identify SSCs important to safety. The definition of SSCs important-to-safety as given in the proposed 10 CFR 63.2 are those engineered features of the GROA whose function is to (i) provide reasonable assurance that HLW can be received, handled, packaged, stored, emplaced, and retrieved without exceeding the requirements of the proposed10 CFR 63.111(b)(1) for Category 1 event sequences; or (ii) prevent or mitigate Category 2 event sequences that could result in doses equal to or greater than the values

specified in the proposed 10 CFR 63.111(b)(2) to any individual located on or beyond any point at the boundary of the site.

The flow chart shown in figure 1, describes the PCSA process. The steps involved in the PCSA are: (1) Identification of naturally occurring and human-induced events external to the facility that may initiate events inside the facility, (2) Description of the process activities at the GROA and equipment associated with SSCs, (3) Identification of human-induced events in the facility by systematic analysis of the hazards, (4) Identification of potential event sequences, (5) Categorization of the event sequences based on Category 1 and Category 2 event frequencies stipulated in the proposed 10 CFR 63.2, (6) Evaluation of radiological dose consequences to the public and to workers for Category 1 and Category 2 event sequences and identification of those event sequences that do not meet the dose requirements of 10 CFR Part 20 and the proposed 10 CFR 63.111(a) and (b), and (7) Identification of SSCs important-to-safety on the basis of each SSC's contribution to meeting the dose requirements of the previous step.

Methodology for Independent Review of DOE PCSA

The Center for Nuclear Waste Regulatory Analyses (CNWRA) is currently developing a software named PCSAT[1] to be used to review DOE PCSA[2]. The PCSAT is a review tool intended to keep track (book keeping) of all the phases of review activity from system description to the consequence analyses. Further, the tool can be applied to review all or selected components of the DOE's safety analysis, such as hazard analysis, event tree, fault tree analyses, or consequence analyses.

The PCSAT will use the review methods and applicable Acceptance Criteria from the Yucca Mountain Review Plan, which is currently under development. The PCSAT consists of seven modules as shown in figure 2. Each of the module stores data and results of review of the items selected for review by the staff. Results of the review will be abstracted, as appropriate, for use in other modules

of this tool. This abstraction and input to next module is not automatic, but the information is fed in manually which will enable the staff to tailor their review to the importance. The modules are briefly described in the following paragraphs.

Functional area or process module: The facility and operations in the GROA can be divided into functional areas by specific function, physical area of the facility, or process. For the selected functional area, design information such as system description, process flow diagram, mechanical flow diagram, and conceptual description of the operations in the functional area will be used for the safety analysis.

Identification of naturally occurring and human-induced external events module: The naturally occurring events, such as seismic, tornado, wind, or flood, and human induced external events, such as aircraft crash, or fire, are addressed in this module. The data on geologic, seismologic, hydrologic, and meteorologic characteristic of the site, and specialized calculations to determine frequency of occurrence of these events will be reviewed and documented in this module. A screening process is developed in the software to identify the credible events.

Identification of human-induced internal events module: This module constitutes a major portion of the PCSAT and consists of two submodules: system description and hazard analysis. In addition, the failure rate and failure check list database are adjunct submodules that provide inputs to this module. Each of the submodules is further described next.

- System Description: Information required for safety analysis is compiled in this submodule. Descriptions include the functions of the SSCs within the system, detailed operation sequences, and human interactions. The inventories of cask and canisters handled in this part of the operations are also documented.
- Hazard Analysis: Hazard analysis is performed in this submodule using either What-If

Analysis or Failure Modes and Effects Analysis (FMEA). The What-If Analysis focuses on human error analysis, whereas the FMEA analyzes the hardware and equipment failures that may result in radiological consequences.

- Failure Rate and Failure Mode Database: The failure rate database is a comprehensive database of equipment failure rates from actuarial data and are used to determine the probability of failure of the SSCs during the preclosure period. A failure mode list database library, containing the equipment failure modes, is used to assist in hazard analysis.

This module identifies the internal events that may lead to potential radiological dose to the public and workers.

Identification of event sequence module: Event scenarios are postulated based on the hazard analysis, and the initiating event and subsequent event sequences are identified for further analysis using event tree and fault tree analysis. Event trees and fault trees are used to estimate the frequencies for the event sequences and the results are documented in this module.

Categorization of events module: Event sequences are categorized in this module as Category 1 or Category 2 events, as defined in the proposed 10 CFR 63.2. Category 1 event sequences are those event sequences that have a frequency of occurrence greater than or equal to 10^{-2}/yr. Category 2 event sequences are other event sequences that have a frequency of occurrence less than 10^{-2}/yr but greater than or equal to 10^{-6}/yr.

Analysis of consequence module: The consequence analysis module evaluates the radiological dose to the public and workers. The PCSAT allows dose calculations for the pathways of inhalation, ingestion, ground surface exposure, and air submersion. The dose calculation requires parameters such as the inventory of radionuclides released, meteorological data, and receptor information.

Compilation and interpretation of results module: The final step in performing the PCSA is to integrate the data obtained in the various modules and interpret the results. Event sequence frequencies and dose consequences are tabulated and analyzed to determine the category of the event sequence and the dose. The data in this module can be used to identify SSCs important-to-safety and their safety significance. This information may further be used in categorization of SSCs important-to-safety for QA purpose.

Conclusions and Discussions

The power of the PCSAT software lies in its ability to enable the user to keep track of the review performed, and document independent and confirmatory analyses of the DOE PCSA, for the entire system or a component of the system, in a quick and systematic manner. This tool will enable the NRC to perform an expeditious and thorough review of the DOE PCSA. Further, the tool will enable the NRC to update the model as the DOE design evolves and carry forward the review from the Construction Authorization (CA) to the Receive and Possess Waste (R&PW) phase of licensing.

Acknowledgment

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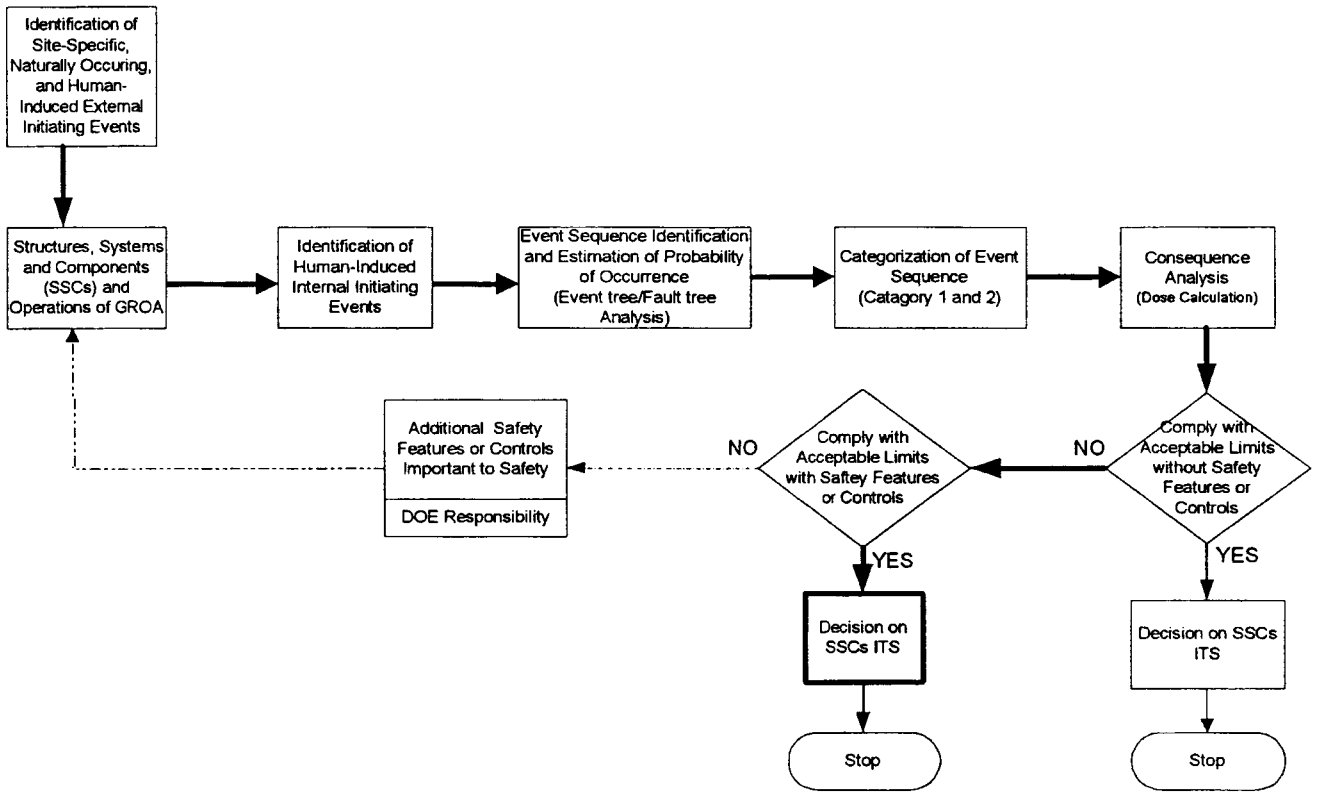

Figure 1. Preclosure safety analysis methodology flow chart

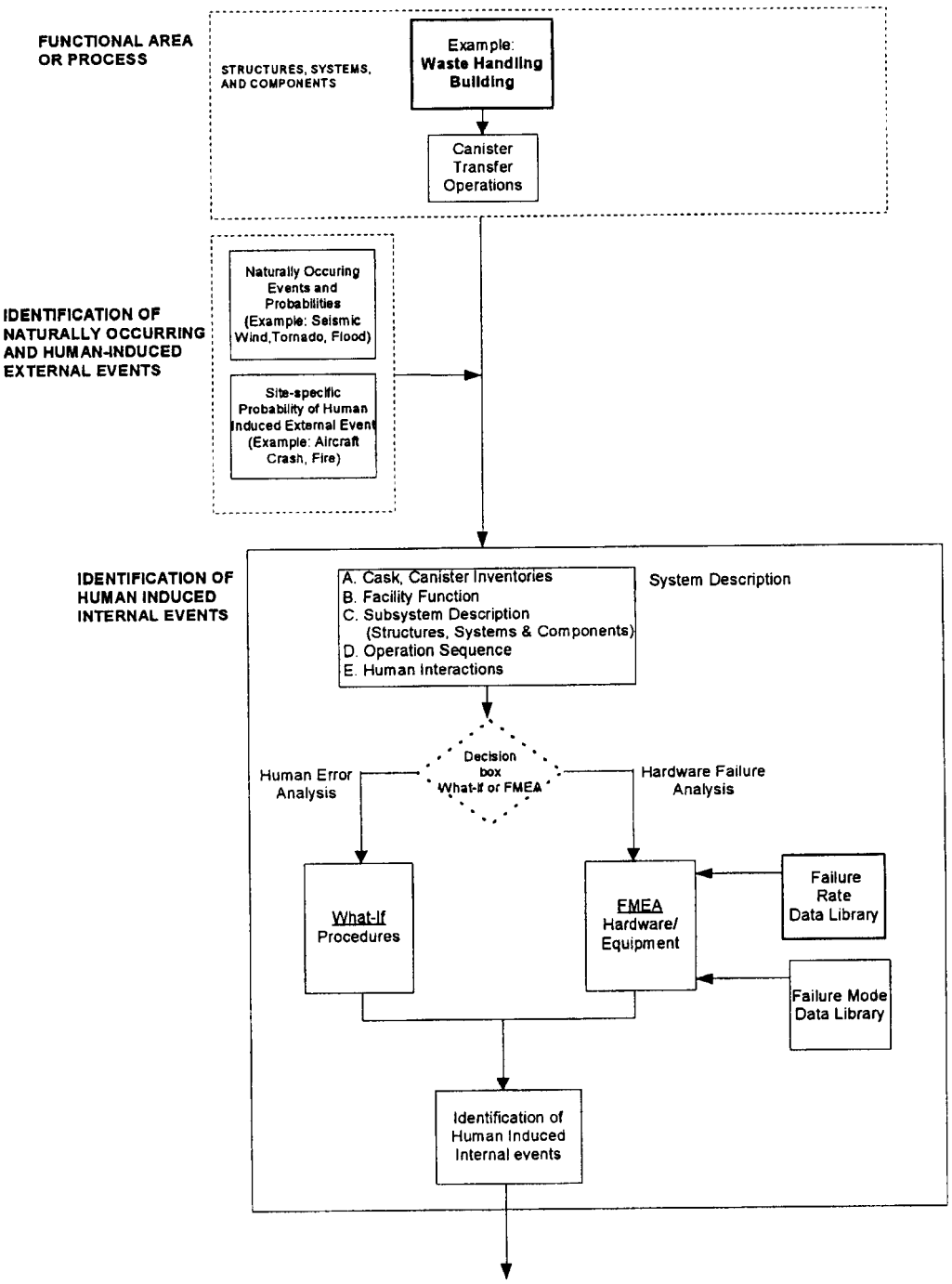

Figure 2. Preclosure safety analysis tool structure and modules

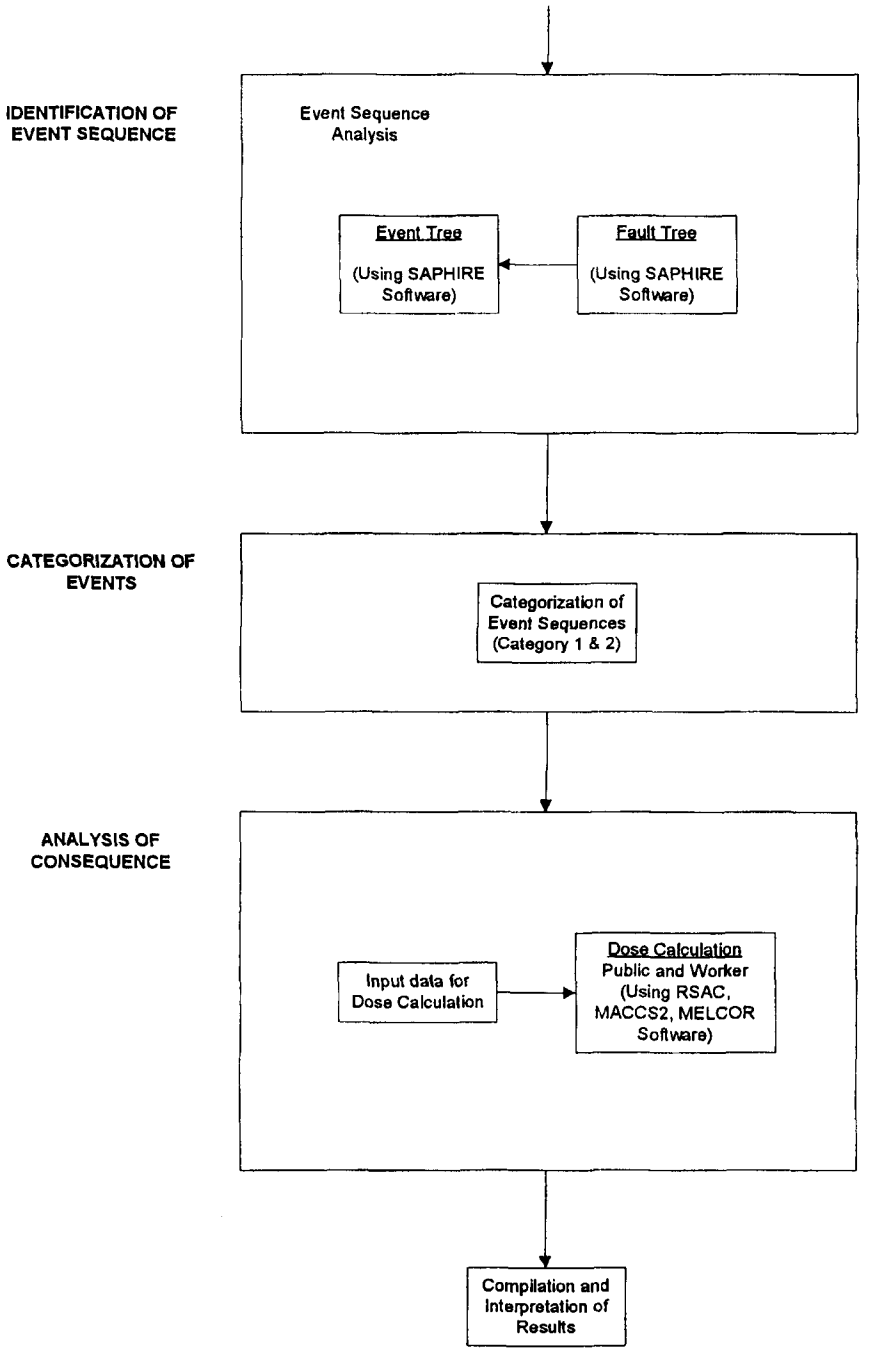

Figure 2. Preclosure safety analysis tool structure and modules (contd.)