U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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COMPREHENSIVE SITE LEVEL 3 PROBABILISTIC RISK ASSESSMENT

Office of Nuclear Regulatory Research

I. Introduction

In March 2010, following an Office of Nuclear Regulatory Research (RES) briefing on the proposal for a comprehensive site Level 3 probabilistic risk assessment (PRA), the Commission directed the U.S. Nuclear Regulatory Commission (NRC) staff to continue internal coordination efforts and engage external stakeholders in formulating a plan and scope for future Level 3 PRA activities.

In response, the RES Division of Risk Analysis initiated a scoping study to identify options for the following aspects of a proposed comprehensive site Level 3 PRA pilot study:

- Scope of the analysis and PRA technology to be used
- Perspectives on future uses of results
- Site selection attributes
- Resource estimates

II. Background

RISK-INFORMED REGULATION, RISK, AND PRA

In the NRC's risk-informed and performance-based regulatory process, risk information is used in conjunction with more traditional engineering methods to inform regulatory decision-making to ensure safety.

What is risk? **Risk = Likelihood x Consequences**

PRA is a systematic analysis tool consisting of specific technical elements that provide both qualitative insights and a quantitative estimate of risk by addressing three questions, commonly referred to as the "risk triplet."

In this way, PRA results can be used in the identification, prioritization, and mitigation of significant risk contributors to improve nuclear power plant safety.

NUCLEAR POWER PLANT PRA SCOPING OPTIONS

PRAs for nuclear power plants can vary in scope, depending on their intended use. The scope of a PRA is defined by the options included in the analysis for each of the five factors identified in the following table:

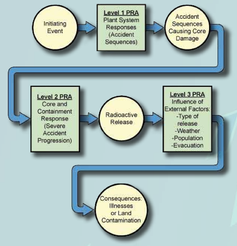
Factor	Scoping Options for Nuclear Power Plants
Radiological hazards	Reactor core Spent fuel Other Radioactive Sources
Population exposed to hazards	Onsite population Offsite population
Plant operating states	At-Power Low Power/Shutdown
Initiating event hazards	Internal events • Traditional internal events (transients, loss-of-coolant accidents) • Internal floods • Internal fires External events • Seismic events (earthquakes) • High winds • Other external hazards
Level of risk characterization	Level 1 PRA: Core damage frequency (CDF) Level 2 PRA: e.g. Large early-release frequency (LERF) / Large release frequency (LRF) Level 3 PRA: Early fatality risk Latent cancer fatality risk

THE IMPORTANCE OF LEVEL 3 PRAs

PRAs for nuclear power plants can estimate risk measures at three different levels of characterization, using sequential analyses in which the output from one level serves as a conditional input to the next.

The three sequential levels of risk characterization include the folowing:

- Level 1 PRA: Estimated frequencies for all severe accident sequences leading to core damage are summed to calculate the total core damage frequency (CDF) for the analyzed nuclear power plant.
- Level 2 PRA: Severe accident progression analysis examines system and containment response to estimate the frequency (e.g., large early-release frequency (LERF)), type, amount, timing, and energy content of the radioactivity released to the environment—also known as "source term" characteristics.
- Level 3 PRA: Using Level 2 PRA source term characteristics, severe accident consequence analysis models the release and transport of radioactive material in a severe accident and estimates the health and economic impact in terms of various consequence measures (i.e., early fatalities and injuries, latent cancer fatalities, and economic costs).



Combining the results of the Level 1 and Level 2 PRAs with the results of the consequence analysis, **only the Level 3 PRA estimates the integrated risk (likelihood x consequences) from all hazards to the public for an analyzed nuclear power plant**.

PRIOR NRC USE OF LEVEL 3 PRAs: THE NUREG-1150 STUDY

Although Level 3 PRAs are required to directly estimate the integrated risk to the public from nuclear power plant accidents, the NRC does not yet routinely use them in its risk-informed regulatory process. Instead, the NRC ensures safety primarily by using results obtained from less expensive Level 1 and limited Level 2 PRAs and how they relate to subsidiary safety goals based on the CDF and LERF metrics to risk-inform regulatory decisionmaking.

In fact, the last NRC-sponsored Level 3 PRAs were conducted over 20 years ago and were documented in a collection of NUREG/CR reports and a single corresponding summary document, NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," issued December 1990.

The NUREG-1150 PRAs were conducted on five nuclear power plants of different major reactor and containment designs. The reactor and containment design for the sites involved, as well as the scope of initiating event hazards analyzed in each PRA, are shown in the following table:

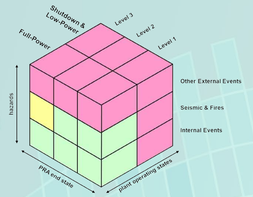
Reactor/Containment Design	Level 1 PRA Scope	Level 2 PRA Scope	Level 3 PRA Scope
Surry-1 • Westinghouse 3-loop • Subatmospheric	Internal Events Fires Seismic	Internal Events Fires Seismic	Internal Events Fires
Zion-1 • Westinghouse 4-loop • Large dry	Internal Events	Internal Events	Internal Events
Sequoyah-1 • Westinghouse 4-loop • Ice condenser	Internal Events	Internal Events	Internal Events
Peach Bottom-2 • BWR-4 • Mark I	Internal Events Fires Seismic	Internal Events Fires Seismic	Internal Events Fires
Grand Gulf-1 • BWR-6 • Mark III	Internal Events	Internal Events	Internal Events

The NRC has used the landmark NUREG-1150 results and perspectives in a variety of regulatory applications, including development of PRA policy statements, support of risk-informed rulemaking, and prioritization of generic issues and research.

III. Project Basis

There are several compelling reasons for conducting a comprehensive site Level 3 PRA. The following list is not intended to be all-inclusive:

- There have been substantial developments that may affect the results and risk perspectives that have influenced many regulatory applications in the two decades since NUREG-1150 was published:
  - Plant modifications affecting risk (e.g., safety system improvements, changes to technical specifications)
  - Implementation of risk-informed regulations to improve safety (e.g., Station Blackout Rule, Maintenance Rule)
  - Significant advances in PRA technology
- The NUREG-1150 PRAs were limited in scope, thereby limiting the potential usefulness of the results and perspectives gained. The "Reactor Accident Risk Cube" illustrates the scope of a complete reactor accident risk analysis. As shown by the green and yellow shaded regions, the NUREG-1150 PRAs were limited to the assessment of accidents initiated primarily by internal events occurring during full-power operations, with a partial coverage of seismic and fire hazards in Level 3 PRA space for two of the five analyzed nuclear power plants.



IV. Project Objectives

The NRC staff has identified the following three potential objectives for a proposed comprehensive site Level 3 PRA pilot study:

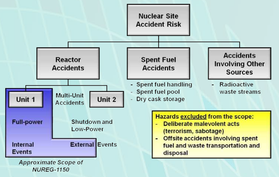
1. Update and improve staff understanding of nuclear site accident risk to support risk-informed decisionmaking by:
   - Incorporating nuclear power plant safety improvements and advances in PRA technology that have occurred in the two decades since NUREG-1150
   - Using an integrated and consistent approach to enable a meaningful comparison and relative ranking of risk contributors associated with different radiological and initiating event hazards
2. Enhance PRA capability by:
   - Identifying gaps and upgrading existing NRC risk analysis tools to enable the completion of an integrated site Level 3 PRA
   - Developing risk analysis expertise

V. Envisioned Project Scope

To accomplish these project objectives, the NRC is considering evaluating reactor accidents that might occur during any plant operating state, that are initiated by all possible initiating event hazards, and that may simultaneously affect multiple units per site.

To enable a meaningful comparison and ranking of risk contributors to focus the NRC's safety mission, the NRC is further considering analyzing the integrated risk from additional site radiological hazards, such as spent fuel and radioactive waste streams.

The originally envisioned scope of the proposed comprehensive site Level 3 PRA pilot study is illustrated in the below figure, with the approximate scope of the NUREG-1150 PRAs captured by the blue-shaded region.



VI. The Path Forward

The NRC staff is scheduled to present the results of the scoping study, along with a specific recommendation for proceeding with Level 3 PRA activities, to the Commission for consideration in July 2011.

NOTE: The information in this presentation is current as of January 10, 2011. For additional information and up-to-date details, please see the corresponding presentation on the computer monitor adjacent to this display on the tabletop.

VII. Contact Information

If you have any questions, comments, or concerns related to this project, please contact either or both of the following individuals:

NRC Project Manager: Dan Hudson, RES/DRA, at 301-251-7919 or Daniel.Hudson@nrc.gov.

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