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RISK ASSESSMENT STANDARDIZATION PROJECT (RASP) HANDBOOK FOR RISK ASSESSMENT OF OPERATIONAL EVENTS

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ABSTRACT

This paper provides an overview of the NRC Risk Assessment Standardization Project (RASP) Handbook for risk assessment of operational events. This RASP Handbook was developed to provide consistent methods for use by NRC staff in performing risk assessments in various risk-informed regulatory applications. Currently, a RASP Handbook for risk assessment of "internal events" and "external events" conditions at U.S. nuclear power plants has been issued for use by NRC staff. The Handbook describes methods that are used in risk analysis of plant conditions for Significance Determination Process (SDP) Phase 3 analyses, and for the Accident Sequence Precursor (ASP) program and Management Directive (MD) 8.3 event assessments.

Key Words: significance determination, operational events, precursor.

1 INTRODUCTION

In the U.S. Nuclear Regulatory Commission's (NRC) Reactor Oversight Process, the NRC staff performs risk assessments of inspection findings and reactor incidents to determine their significance for appropriate regulatory response [1]. The Risk Assessment Standardization Project (RASP) was initiated to provide consistent methods for use by NRC staff in performing risk assessments in various risk-informed regulatory applications [2]. An important RASP product was the development of the RASP Handbook for guidance in risk analysis of plant conditions in the Significance Determination Process (SDP) [3] Phase 3 and Accident Sequence Precursor (ASP) [4] programs, and the risk analysis of events/conditions in ASP and event assessment programs (Management Directive 8.3) [5].

Currently, a RASP Handbook for risk assessment of "internal events" and "external events" conditions at U.S. commercial nuclear power plants has been issued for use by NRC staff. This handbook entitled: "Risk Assessment of Operational Events Handbook for SDP Phase 3, ASP, and MD 8.3," Volumes 1, 2 and 3 is in the form of a practical, "how to" handbook of methods, best practices, examples, tips and precautions for using Standardized Plant Analysis Risk (SPAR) models to evaluate the risk of reactor incidents and inspection findings. The Handbook represents best practices based on feedback and experience from the analyses of over 600 precursors in the ASP Program (since 1969) and numerous SDP Phase 3 analyses (since 2000). This paper provides an overview of the detailed contents of the RASP Handbook.

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2 RASP HANDBOOK

The primary objective of the RASP Handbook is to provide methods and guidance that NRC staff could use to achieve more consistent results when performing risk assessments of operational events and licensee performance issues. Additionally, the RASP Handbook provides best practices for risk analysts and Standardized Plant Analysis Risk (SPAR) model developers to ensure that SPAR models used in the risk analysis of operational events represent the as-built, as-operated plant to the extent needed to support the analyses. The principal users of the Handbook are NRC Senior Reactor Analysts (SRAs) and risk analysts involved with performing risk analyses of operational events.

The Handbook consists of three volumes, designed to address internal events analysis (Volume 1), external events analysis (Volume 2), and SPAR model reviews (Volume 3). The scope of each of these volumes is presented below.

2.1 Volume 1, Internal Events

This volume, "Internal Events," provides guidance on generic methods and processes to estimate the risk significance of initiating events (e.g., reactor trip, loss of offsite power) and degraded conditions (e.g., a failed high pressure injection pump, failed emergency power system) that may have occurred at a nuclear power plant. Specifically, this volume provides guidance on the following analysis methods:

1. Exposure Time Determination and Modeling;
2. Failure Determination and Modeling;
3. Mission Time Modeling;
4. Test and Maintenance Outage Modeling;
5. Recovery Modeling of Failed Equipment;
6. Multi-Unit Considerations Modeling

The section on *Exposure Time Determination and Modeling* provides definitions of exposure time, repair time, and "t" period (i.e., time interval between last successful functional operation and the unsuccessful functional operation) that could be assumed in the risk analysis of an operational event. This section also provides guidance on determining exposure time models (e.g., t + repair time, t/2 + repair) for standby or periodically operated components that fail due to a specific degradation mechanism. Guidance for determining exposure time of standby or periodically operated components that fail during their operation or run time, continuously operating components, and components under test or maintenance, is also provided. Examples are provided to demonstrate the determination of exposure time of component run failures.

The section on *Failure Determination and Modeling* provides definitions of the various types of failures (e.g., incipient, degraded, catastrophic) that may be considered in the risk analysis of an operational event. This section also provides guidance on modeling each failure type in a risk analysis. Examples are provided to illustrate how a specific failure type is modeled in the risk model for quantitative analysis. Specific guidance is also provided for modeling various failure modes (e.g., fail to start) and failure categories (e.g., independent, common cause failure) in

SPAR models for risk calculations using the SAPHIRE probabilistic risk assessment (PRA) computer codes.

The section on *Mission Time Modeling* provides a definition of the typical mission time that is assumed in the risk analysis of an operational event using the SPAR models. This section provides specific guidance on modifying mission time of components to be consistent with the time span (e.g., short term) of accident sequences in the risk model. Guidance is also provided to determine the appropriate mission time to be used in a risk analysis when modeling assumptions in the SPAR model and the licensee's PRA model appear to be different.

The section on *Test and Maintenance Outage Modeling* provides guidance on modeling test and maintenance events (T/M) in the risk analysis of an operational event. This guidance includes considerations for modeling T/M events in SPAR models, and techniques to remove mutually exclusive T/M event combinations from the risk model to avoid illogical analysis results.

The section on *Recovery Modeling of Failed Equipment* provides guidance on crediting recovery of failed equipment in the risk analysis of an operational event. Considerations for crediting recovery of an actual equipment failure are listed to help the analyst determine a supportable basis of recovery in an accident sequence. Guidance on modeling recovery actions (e.g., recovery of AC power) in a SPAR model is provided, including the preferred use of human reliability analysis (HRA) methods (e.g., SPAR-H) to model recovery of an actual failure.

The section on *Multi-Unit Considerations Modeling* provides guidance on risk analysis of an operational event that impacts one or more plant unit at a multiple unit site. Analysis rules are specified for risk assessment of plant units with shared assets (e.g., shared systems or crosstie capabilities) and operational events (e.g., loss of offsite AC power) affecting multiple plant units. Guidance is provided for modeling shared systems or crosstie capabilities in a SPAR model, and event scenarios such as loss of offsite AC power that affect more than one plant unit across the site.

In addition, Volume 1 of the RASP Handbook contains appendices that provide guidance on the process to perform risk analysis of operational events. The appendix, *Roadmap - Risk Analysis of Operational Events*, provides an overview of the risk analysis process and detailed steps on how to perform a risk analysis of an operational event. The detailed steps begin with documentation to provide a comprehensive understanding of the event, verifying the SPAR model to reflect the as-built, as-operated plant configuration for the sequences impacted by the operational event, revising the SPAR model to reflect additional details of the event (e.g., updated initiating event frequency), and modifying the SPAR model to reflect the event impact. Subsequent steps include initial quantification of the SPAR model to estimate significance of the event, reviewing the initial analysis results without recovery actions, re-quantification of SPAR model with potential recovery actions, and review final analysis results to check for inconsistencies with all available information relevant to the event. The final step is the performance of sensitivity and uncertainty analyses to evaluate the impact of influential factors, such as data variability, model inaccuracy, and modeling assumptions, on the overall risk significance of the event. Figure 1 shows the overall process for performing risk analysis of operational events.

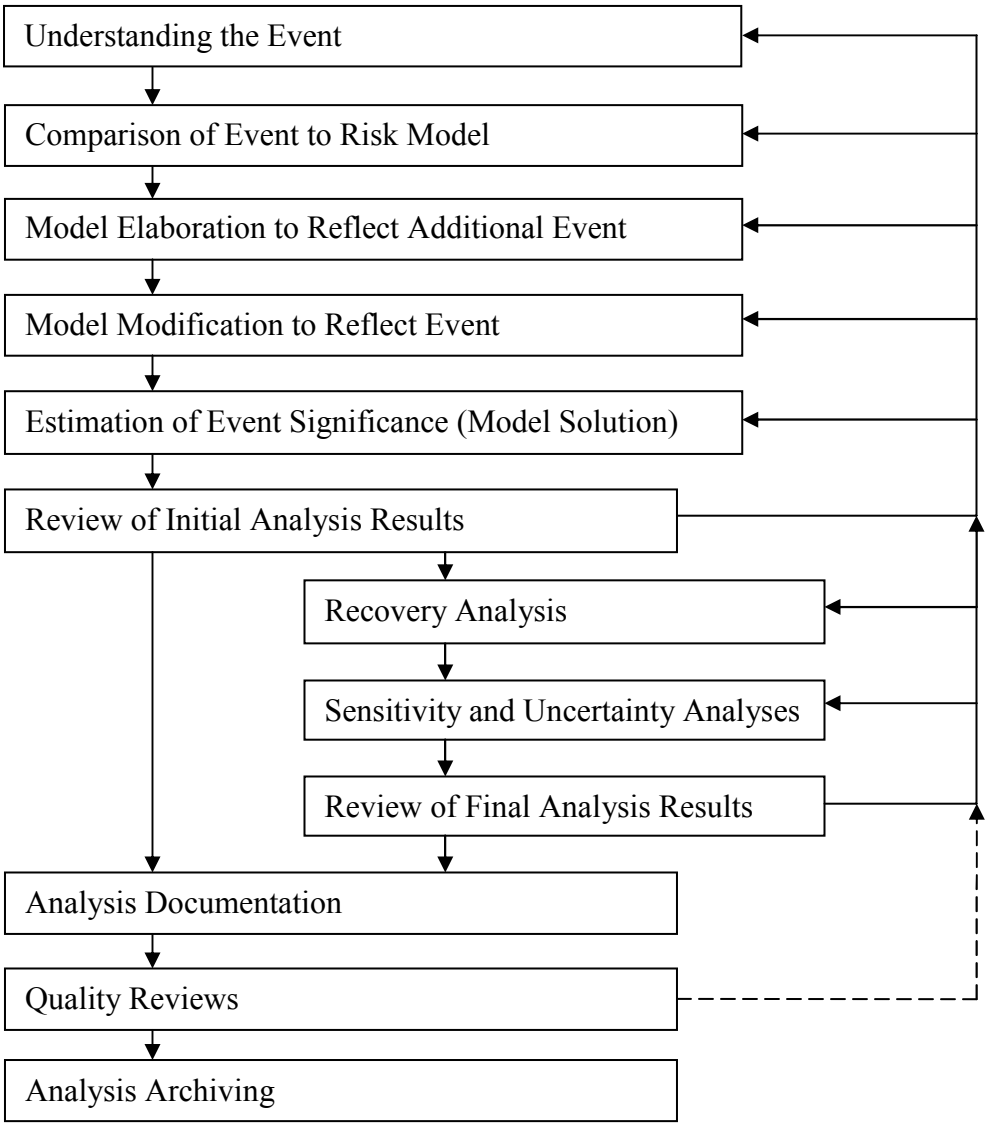

Figure 1. Risk analysis of operational events – process flow

Although guidance in Volume 1 of the Handbook focuses on methods for the analysis of internal events during at-power operations, the basic processes for risk analyses of initiating events and degraded conditions can be applied to analyzing risk contributions of external events, and operational events occurring during low-power and shutdown operations.

2.2 Volume 2, External Events

This volume, "External Events," provides methods and guidance for the risk analysis of initiating events and conditions associated with external events. External events include internal fire, internal flooding, seismic events, and other external events such as external flooding, external fire, high winds, tornado, hurricane, and other extreme weather-related events. This

volume is intended to complement Volume 1 for Internal Events. Specifically, this volume provides guidance on the following analysis methods:

1. Internal Fire Modeling and Fire Risk Quantification;
2. Internal Flood Modeling and Risk Quantification;
3. Seismic Event Modeling and Seismic Risk Quantification;
4. Other External Events Modeling and Risk Quantification

The section on *Internal Fire Modeling and Fire Risk Quantification* provides guidance for risk analysis of initiating events and conditions associated with internal plant fire scenarios. Guidance is provided for analyzing risk of (a) plant conditions related to degraded fire protection structures, systems, and components (SSCs) (e.g., fire suppression system), (b) plant conditions related to degraded SSCs other than fire protection SSCs that are affected by postulated fire scenarios, and (c) fire event initiators where a reactor trip may have been caused by fire. This guidance includes considerations for modeling fire scenarios related to potential plant fire event initiators, and quantifying their sequence frequency estimates using SPAR models and SAPHIRE software.

The section on *Internal Flood Modeling and Quantification* provides guidance for risk analysis of initiating events and conditions associated with internal plant flooding scenarios. This guidance includes considerations for modeling flooding scenarios related to potential internal plant flooding event initiators, and quantifying their sequence frequency estimates using SPAR models and SAPHIRE software. Guidance is provided to define flooding scenarios that are considered for modeling a flood event initiator or potential plant flooding condition. The types of flood scenarios are: (a) flood scenarios that can be terminated by operator action before critical flood height for equipment damage is reached, (b) flood scenarios that are not terminated early, but are limited to a single flood area, and (c) flood scenarios that are not terminated early and can propagate to additional areas. Examples are provided to illustrate the methods for analyzing the risk of an internal flooding event versus a plant condition with a degraded flood protection barrier.

The section on *Seismic Event Modeling and Seismic Risk Quantification* provides guidance for risk analysis of initiating events and conditions associated with seismic event scenarios. This guidance includes considerations for modeling seismic event scenarios during normal plant power operation, and quantifying their sequence frequency estimates using SPAR models and SAPHIRE software. Guidance is provided to define the bin of seismic event scenarios with increasing intensity that is considered for modeling a seismic event initiator. The bins of seismic event scenarios are seismic events with: (a) peak ground acceleration (pga) of 0.05-0.3g, (b) pga of 0.3-0.5g, and (c) pga greater than 0.5g.

The section on *Other External Events Modeling and Risk Quantification* provides guidance for risk analysis of initiating events and conditions associated with other external events such as external flooding and high winds/tornado events. This guidance includes considerations for modeling the specific external event scenarios during normal plant power operation, and quantifying their sequence frequency estimates using SPAR models and SAPHIRE software. Guidance is provided to define the scenarios that arise from the specific initiating event by identifying the damaged SSCs, evaluating their potential recovery (or lack of recovery), calculating the scenario frequency estimates, and transferring each scenario to an existing event

tree (e.g., loss of offsite power event tree) for final quantification. Examples are provided to illustrate the methods for analyzing the risk of a specific external event (e.g., hurricane causing loss of offsite power event) versus a plant condition with a postulated event (e.g., external flooding due to catastrophic dam failure).

2.3 Volume 3, SPAR Model Reviews

This volume 3, "SPAR Model Reviews," provides analysts and SPAR model developers with additional guidance to ensure that the SPAR models used in the risk analysis of operational events represent the as-built, as-operated plant to the extent needed to support the analyses. This volume provides checklists that can be used following modifications to SPAR models that are used to perform risk analysis of operational events. These checklists were based on the PRA Review Manual [6], the ASME PRA Standard [7], Regulatory Guide 1.200 [8], and experiences and lessons learned from SDP and ASP analyses.

In addition, this volume provides a summary of key assumptions in a SPAR model and a discussion of unresolved technical issues that may produce large uncertainties in the analysis results. The effects of these assumptions or issues depend on the sequences and cut sets that were impacted by the operational event. Guidance in this volume also provides instructions to address plant-specific assumptions and issues that may significantly affect analysis uncertainties.

3 RASP HANDBOOK REVISIONS

Revision 1 of the RASP handbook containing Volumes 1, 2 and 3 was made publicly available in January 2008. This document can be accessed from the NRC public website at the web link: http://www.nrc.gov/reactors/operating/oversight/program-documents.html.

The RASP Handbook is updated on a periodic and as-needed basis, based on user comments and insights gained from "field application" of the document. New topics will be added as needed to future revisions of the Handbook to consolidate and streamline risk analysis activities conducted by NRC staff. Specifically, future revisions of the Handbook will include additional method guides and tutorials on advanced techniques in risk analysis applications. The method guides provide guidance on the following areas:

1. Common cause failure determination and modeling;
2. SPAR-H human reliability analysis;
3. Parameter estimation and update;
4. Convolution of failure to run parameters;
5. Uncertainty analysis;
6. Simplified expert elicitation;
7. Event-specific analysis of internal events with examples

Two additional volumes of the RASP Handbook are planned in the near future for providing guidance on (a) risk analysis of low-power and shutdown events, and (b) calculation of large early release frequency (LERF) estimates for containment-related conditions.

4 CONCLUSIONS

The RASP Handbook describes methods that can be used in risk analysis of plant conditions for SDP Phase 3, ASP and MD 8.3 event assessments. This handbook is a compendium of methods, best practices, examples, tips, and precautions for using SPAR models to evaluate the risk from operational events. Specifically, the Handbook is the recommended guidance document for SDP Phase 3 assessments of risk significance of inspection findings [3]. In most cases, the use of the RASP Handbook methods (e.g., exposure time determination and modeling) in SDP Phase 3 assessments has produced consistent results with ASP analyses. The increasing use of the Handbook methods has also resulted in more timely and better quality SDP Phase 3 assessments. The Handbook will be maintained as a living document to support the agency's knowledge management and training initiatives. It will be updated based on user comments and insights gained from field use of the document.

New topics will be added to the RASP Handbook such as guides for common-cause failure modeling and analysis of low-power and shutdown events.

5 ACKNOWLEDGMENTS

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