

Status of the Standardized Plant Analysis Risk Models

1.0 Background

The objective of the U.S. Nuclear Regulatory Commission's (NRC's) Standardized Plant Analysis Risk (SPAR) Model Program is to develop standardized risk analysis models and tools for staff analysts to support various regulatory activities, including the Accident Sequence Precursor (ASP) Program and Phase 3 of the Significance Determination Process (SDP). The SPAR models have evolved from two sets of simplified event trees initially used to perform precursor analyses in the early 1980s. Today's SPAR models for internal events are far more comprehensive than their predecessors. For example, the revised SPAR models include improved loss of offsite power (LOOP) and station blackout modules; an improved reactor coolant pump seal failure model; new support system initiating event models; and updated estimates of accident initiator frequencies and equipment reliability based on recent operating experience data.

The SPAR models consist of a standardized, plant-specific set of risk models that use the event-tree and fault-tree linking methodology. They employ a standard approach for event-tree development, as well as a standard approach for input data for initiating event frequencies, equipment performance, and human performance. These input data can be modified to be more plant- and event-specific, when needed. SPAR standardization is needed to allow agency risk analysts to efficiently use SPAR models for a wide variety of nuclear plants without having to relearn modeling conventions and basic assumptions. The system fault trees contained in the SPAR models generally are not as detailed as those in licensee probabilistic risk assessments (PRAs), although, in some cases, SPAR models may contain more sophisticated modeling for common cause failure, support systems, and loss of offsite power modeling. To date, the staff has completed 80 SPAR models representing all 104 commercial nuclear power units. All SPAR models are developed under a comprehensive quality assurance program and have been benchmarked against licensee PRAs through either onsite quality assurance reviews or information changes with the licensee.

The staff initiated the Risk Assessment Standardization Project (RASP) in 2004. A primary focus of RASP was to standardize risk analyses performed in SDP Phase 3, ASP, and Management Directive (MD) 8.3, "NRC Incident Investigation Program." Under this project, the staff initiated the following activities:

- Enhance SPAR models to be more plant specific and improve the Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) code used to manipulate the SPAR models.
- Document consistent methods and guidelines for risk assessments of internal events during power operations; internal fires and floods; external hazards (e.g., seismic events and tornadoes); and internal events during low-power and shutdown (LPSD) operations.
- Provide on-call technical support for staff involved with licensing and inspection issues.

2.0 SPAR Model Program Status

The SPAR Model Program continues to play an integral role in the ASP analysis of operating events. Many other agency activities, such as the SDP analyses and MD 8.3 evaluations,

involve the use of SPAR models. The NRC is developing new SPAR modules in response to staff needs for assessing plant risk for external hazards and for assessing accident progression to the plant damage state level.

The staff has completed the following activities in model and method development since the previous status report (SECY-12-0133, "Status of the Accident Sequence Precursor Program and the Standardized Plant Analysis Risk Models," dated October 4, 2012), as described below.

Technical Adequacy of SPAR Models

The staff implemented a Quality Assurance (QA) Plan covering the SPAR models in 2006. The SPAR QA plan was updated in fiscal year (FY) 2013. The main objective of this plan is to ensure that the SPAR models continue to represent the as-built, as-operated nuclear plants and be of sufficient quality for performing event assessments of operational events in support of the staff's risk-informed activities. The staff has processes in place to verify, validate, and benchmark these models according to the guidelines and standards established by the SPAR Model Program. As part of this process, the staff performs reviews of the SPAR models and results against the licensee PRA models, when applicable. The staff also has processes in place for the proper use of these models in agency programs such as the ASP Program, the SDP, and the MD 8.3 process. These processes are documented in the RASP handbook, which serves as a desktop guidance document for agency risk analysts.

In addition, in 2010 the staff (with the cooperation of industry experts) performed a peer review of a representative boiling-water reactor (BWR) SPAR model and pressurized-water (PWR) reactor SPAR model in accordance with American Society of Mechanical Engineers (ASME)/American Nuclear Society (ANS) RA-S-2008, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," and Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities." The staff has reviewed the peer review comments and has initiated projects to address these comments, where appropriate. Activities in progress to address these peer review items include structuring the SPAR model documentation to more closely align with the structure of the PRA standard, incorporation of improved LOOP modeling, and addressing the high priority items for the BWR models. These activities have been conducted at a significantly reduced pace during FY 2013 because of sequestration-related budget cuts. However, pending the availability of sufficient resources, the staff is planning to continue resolution of peer review items in FY 2014, including documentation enhancements, model updates, and high priority BWR peer review items. Resolution of PWR peer review issues have been deferred until sufficient funding becomes available.

Routine SPAR Model Updates

Existing SPAR models need to be updated regularly as a result of any significant plant changes that may affect the risk profile of the plant. As the SPAR model is updated, its documentation (i.e., model and plant risk information eBook summary reports) is also updated to represent the latest PRA information included in the SPAR model. Although the goal is to update approximately 12 models per year, because of budget constraints, the effort was reduced to six model updates for FY 2013.

In FY 2013, the staff updated the SPAR models for the Byron, Braidwood, Turkey Point, Monticello, Duane Arnold and Watts Bar plants. The staff is currently working on identifying the next set of SPAR models to be updated in FY 2014.

SPAR Models for the Analysis of All Hazards (External Events)

Development of SPAR All HaZard (SPAR-AHZ) models that contain accident scenarios from all hazard categories applicable to a given site, has continued during FY 2013, although at a lower intensity because of budgetary constraints and conflicts with other high priority work, such as the Level 3 PRA project for the Vogtle site. Two SPAR-AHZ models, which include internal fire models extracted from National Fire Protection Association (NFPA)-compliant fire models for the Shearon Harris and D.C. Cook plants, have been constructed and placed in the SPAR model library for use by NRC risk analysts. The NRC has also initiated additional external hazard models for the V.C. Summer and the Vogtle operating nuclear plant SPAR models.

Development of these models includes licensee site visits to gather information and discuss modeling assumptions and results. Because the licensee-developed NFPA 805-compliant fire PRA models contain thousands of quantified sequences, a significant focus of the SPAR-AHZ effort was combining similar sequences to enhance model usability while maintaining the ability to retain the resolution contained in the licensee models. Currently, the NRC Office of Nuclear Regulatory Research (RES) and the NRC Office of Nuclear Reactor Regulation (NRR) are working together to identify ways to increase the pace of SPAR-AHZ model development, given expected resource constraints in FY 2014 and beyond.

New Reactor SPAR Models

Before new plant operation, the staff may perform risk assessments to inform potential risk-informed applications for Combined Licenses (COLs), focus construction inspection scope, or assess the significance of construction inspection findings. Once the plants begin operation, the results from licensee PRAs or independent assessments using SPAR models may be used by the staff for the evaluation of operational findings and events similar to the assessments performed for current operating reactors.

There are currently five new reactor internal hazard SPAR models. These include one model for the AP1000, two Advanced Boiling-Water Reactor (ABWR) models (one for the Toshiba design and one for the General Electric-Hitachi design), and one model for the U.S. Advanced Pressurized-Water Reactor (US-APWR). In addition to these internal events models, there is a seismic model for the AP1000 and a low power and shutdown model for the Toshiba ABWR. In FY 2013, the staff completed the development of the SPAR model for the U.S. Evolutionary Power Reactor (U.S. EPR) and the requisite supporting documentation for the model. The staff also started to develop a SPAR-AHZ model for the AP1000 reactor design. The first module completed included the incorporation of internal flooding. The staff plans to continue building additional modules to include internal fire and low power and shutdown models.

The staff plans to continue developing new reactor SPAR models, including external hazards and low power and shutdown models, as needed, to support licensing and oversight activities. Because design standardization is a key aspect of the new plants, it should only be necessary to develop one internal events SPAR model for each of the new designs.

MELCOR Thermal Hydraulic Analysis for SPAR Model Success Criteria

The staff continues to perform MELCOR analyses to investigate success criteria associated with specific Level 1 PRA sequences. In some cases, these analyses confirm the existing technical basis and in other cases they support modifications that can be made to increase the realism of the agency's SPAR models. The latest round of activity is documented in two reports: (1) an

upcoming NUREG report to be issued for public comment entitled, “Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Byron,” and (2) a final NUREG/CR report to be issued later in calendar year (CY) 2013 entitled, “Compendium of Analyses to Investigate Select Level 1 Probabilistic Risk Assessment End-State Definition and Success Criteria Modeling Issues.” The results of these studies will be used to confirm specific success criteria for a suite of four-loop Westinghouse plants, which are similar to Byron, with appropriate consideration of the design and operational differences of these plants. They also will be used to support application-specific consultation on the use of the SPAR models.

This effort directly supports the agency’s goal of using state-of-the-art tools that promote effectiveness and realism. The NRC is communicating the project plans and results to internal and external stakeholders through mechanisms such as the Regulatory Information Conference and the industry’s Modular Accident Analysis Program Users’ Group.

3.0 Additional Activities

SAPHIRE Maintenance and Improvements

In FY 2013, new features and capabilities have been implemented in SAPHIRE to better support NRC regulatory activities. A new cutset editor tool is being incorporated into SAPHIRE. The cutset editor will allow users to efficiently review cutset results, quickly apply changes and sensitivity cases, and recalculate the results. The work on this tool is expected to be completed this calendar year. In an effort to improve calculation speed, SAPHIRE includes a new feature to automatically adjust the model truncation level to permit more efficient solution convergences.

In addition, the SAPHIRE developers continue to explore advanced quantification techniques that can improve accuracy and solving speeds. A Binary Decision Diagram (BDD) solving tool has been incorporated into SAPHIRE and other solving options are being considered. Binary Decision Diagram-based methods quantify the overall probability directly from the logic model and avoid truncation and the use of approximations seen in cutset-based methods. The implementation of advanced quantification techniques, such as BDDs, can help to support: (1) consistency with the PRA practices and tools that are used throughout the nuclear industry and (2) quantification challenges associated with the expanded scope and complexity of the SPAR models that may include external hazards, low power and shutdown, or other accident scenarios. Other SAPHIRE enhancements have focused on improving flexibility for Level 2 PRA modeling. New SAPHIRE features support a Level 2 model quantification process similar to what is routinely used in the Level 1 SPAR models, and the ability to utilize decomposition event trees.

The SAPHIRE developers have also completed transitioning the SAPHIRE legacy source code to a new programming language for the purpose of improving long-term maintenance and support of the software. All of these improvements to SAPHIRE have been performed in accordance with the SAPHIRE software QA program. A set of software QA documents has been developed for SAPHIRE. These documents cover topics such as the software development plan, configuration management, software requirements tracking, and software testing and acceptance. The NRC project manager performs an annual audit of the SAPHIRE software quality assurance program. The most recent audit was completed on December 13, 2012 and no significant issues were identified. The NRC Project Manager confirmed that the maintenance and implementation of the SAPHIRE software quality assurance program is

consistent with the guidance contained in NUREG/BR-0167, "Software Quality Assurance Program and Guidelines."

Cooperative Research for PRA

The staff has executed an addendum to the memorandum of understanding (MOU) with Electric Power Research Institute (EPRI) to conduct cooperative nuclear safety research for PRA. Several of the initiatives included in the addendum are intended to help resolve technical issues that account for the key differences between NRC SPAR models and licensee PRA models.

During FY 2013, significant efforts have been made in implementing PRA methodologies for support system initiating event (SSIE) analysis and treatment of LOOP in PRAs. These methodologies are being implemented in the SPAR models as one of the activities associated with addressing the peer review comments. To date, 40 models have been enhanced with the improved SSIE modeling methodology and 66 models have been enhanced with the improved LOOP methodology. The staff plans to continue these cooperative efforts with EPRI and other stakeholders to address the remaining issues over the next several years.

Integrated Modeling

The Office of Nuclear Regulatory Research continues to enhance SAPHIRE and the SPAR models to support development of integrated models. To this end, RES recently completed an integrated model for Peach Bottom Unit 2 containing state-of-the-practice SPAR models for Level 1 internal events at-power, shutdown, other hazards, and Level 2. This effort included the incorporation of other ongoing modeling initiatives (e.g., modeling of SSIEs), use of modeling features new to SAPHIRE8 (e.g., decomposition event trees), and further validation of the Level 2 PRA model. This work directly benefits the RES Vogtle site Level 3 PRA project (SRM SECY 11-0089) by guiding the approach to Level 2 and integrated hazard modeling.