

Status of the Standardized Plant Analysis Risk Models

1.0 Background

The objective of the Standardized Plant Analysis Risk (SPAR) Model Program is to develop standardized risk analysis models and tools that staff analysts use in many 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 a new, improved loss of offsite power (LOOP)/station blackout module; an improved reactor coolant pump seal failure model; and updated estimates of accident initiator frequencies and equipment reliability based on more recent operating experience data.

The SPAR models consist of a standardized, plant-specific set of risk models that use the event-tree/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. The system fault trees contained in the SPAR models generally are not as detailed as those contained in licensee probabilistic risk assessments (PRAs). To date, the staff has completed 78 SPAR models representing all 104 commercial operating units and benchmarked them against licensee PRAs during the onsite quality assurance reviews of these models.

The staff initiated the risk assessment standardization project (RASP) in February 2004. The primary focus of RASP is to standardize risk analyses in SDP Phase 3, ASP, and Management Directive (MD) 8.3, "NRC Incident Investigation Program." Under this project, the staff initiated the following activities:

- Enhancing SPAR models to be more plant specific and enhancing the codes used to manipulate the SPAR models.
- Documenting consistent methods and guidelines for risk assessments of internal events during power operations; internal fires and floods, external events (e.g., seismic events and tornadoes); and internal events during shutdown operations.
- Providing 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, MD 8.3 evaluations, and the Mitigating Systems Performance Index involve the use of SPAR models. New SPAR models are under development in response to staff needs for assessing plant risk during shutdown operations and external events 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-10-0125, "Status of the Accident Sequence Precursor Program

and the Development of Standardized Plant Analysis Risk Models,” dated September 29, 2010) as described below.

Technical Adequacy of SPAR Models

The staff implemented an updated SPAR Model Quality Assurance Plan covering the SPAR models in 2006. The main objective of this plan is to ensure the SPAR models continue to 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. 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.

In addition, the staff (with the cooperation of industry experts) performed a peer review of a representative boiling-water reactor (BWR) SPAR model and pressurized-water reactor SPAR model in accordance with American National Standard, ASME RA-S-2002, “Standard for 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. This effort is planned to be completed in 2013.

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

Currently, 16 SPAR models have all-hazard scenarios (previously labeled as “external event” scenarios) as well as internal event scenarios. Based on a user need from the Office of Nuclear Reactor Regulations (NRR) to the Office of Nuclear Regulatory Research (RES), further work is in progress to add more models, and update the current ones. One significant ongoing activity is the incorporation of internal fire scenarios from the National Fire Protection Association 805, “NFPA-805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,” for one of the pilot applications into the SPAR models. Existence of SPAR models with fire and external hazard capabilities allows the U.S. Nuclear Regulatory Commission (NRC) risk analysts to estimate the overall risk from a range of initiating events, including (i) fire risk based on up-to-date NFPA-805 considerations, and (ii) extremely low frequency but high consequence scenarios, such as non-recoverable station blackout scenarios that could arise from seismic events and external floods.

SPAR Models for Analysis of Internal Initiating Events during Shutdown Operation

The staff places a priority on creating methods and guidance for the risk assessment of shutdown events, with emphasis on SDP Phase 3 analyses. For this purpose, seven SPAR models that contain selected shutdown event scenarios, as well as internal event scenarios, have been developed. These models are supported by a handbook for the analysts, a model maker’s guideline for the construction of other models and scenarios, an event tree template library, and a human error probability library. Currently, there are no plans to make further SPAR shutdown models after quality assurance reviews for the eighth and final model are completed. Currently available models, together with the supporting documents can be used to support SDP Phase 3 evaluations of shutdown events and degraded conditions for other plants, by generating further models from the existing templates.

MELCOR Thermal Hydraulic Analysis for SPAR Model Success Criteria

The staff has performed MELCOR analyses, using input decks developed under the State-of-the-Art Reactor Consequence Analysis Project, 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.

To date, calculations have been performed for a number of sequences for the Peach Bottom and Surry plants. These results have been incorporated in the technical bases supporting the Surry and Peach Bottom SPAR models. The results have been extended to include an additional 19 BWR SPAR models and 8 pressurized-water reactor (PWR) SPAR models. RES is continuing to pursue opportunities for broadening the scope of this effort in terms of the types of sequences being investigated, as well as the applicability of the work to more plants. This includes the planned development of additional MELCOR input models; the investigation of Level-1 PRA end-state characterization (e.g., realism of core damage surrogates); and planned interactions with the Electric Power Research Institute (EPRI).

This effort directly supports the agency's goal of using state-of-the-art tools that promote effectiveness and realism. Project plans and results are being communicated to internal and external stakeholders via mechanisms such as the Regulatory Information Conference and the industry's Modular Accident Analysis Program Users' Group.

3.0 Additional SPAR Model Activities

SAPHIRE Version 8 Maintenance and Improvements

The staff continues to maintain and improve the SAPHIRE Version 8 software to support the SPAR Model Program. The SAPHIRE Version 8 software is periodically reviewed and tested for the purposes of making it more efficient, reliable, and maintainable. Many of the software error fixes and modifications are developed in response to user requests, and user feedback will continue to be addressed. All SAPHIRE Version 8 maintenance activities, modifications, and improvements are performed in accordance with the documented SAPHIRE software quality assurance practices.

In fiscal year (FY) 2011, new features and capabilities have been implemented in SAPHIRE Version 8 to better support NRC regulatory activities. SAPHIRE Version 8 has been modified to run on multicore (multiple processors internal to a single computer) computers. The effective use of multicore computers has decreased the overall analysis time needed to quantify SPAR model results. SAPHIRE Version 8 also has been modified to better support its use in SDP Phase 2 analyses and inspection planning activities. SAPHIRE Version 8 now includes user-friendly links to SPAR model documentation and new risk insights reports, which summarize a plants' risk information for NRC resident inspectors. The staff has also provided training on SAPHIRE Version 8 to those resident inspectors that are participating in the piloting of a new process for significance determination process (SDP) Phase 2 analyses using SPAR models.

Companion documentation for the SAPHIRE Version 8 software has recently been completed and has been published as NUREG/CR-7039, Volumes 1 through 7, in FY 2011. The documentation includes an overview of SAPHIRE Version 8 features, a tutorial, a users' guide, and a technical reference. The completion of the SAPHIRE Version 8 documentation provides a valuable resource for the software users.

On September 19, 2011, the Office of the Inspector General (OIG) issued audit report OIG-11-A-18, "Memorandum Report: Audit of NRC's SAPHIRE 8 System." Although the OIG concluded that SAPHIRE 8 meets its operational capabilities and there is limited security risk to the software, the OIG recommended several additional measures relating to software distribution policies and website access controls to ensure that the software was properly managed. The staff is currently evaluating corrective actions for the three recommendations identified by the OIG in the audit report.

Evaluation of Extensive Damage Mitigation Strategies and Guidance

This project is in support of Staff Requirements Memorandum COMGBJ-06-0004 "Potential Closure of the Issues Surrounding the February 25, 2002, Security Orders to Nuclear Power Plants", dated April 14, 2006. The objective of this project is to evaluate the change in risk of the 104 NRC-licensed commercial nuclear power plants (NPPs) based on the implementation of extensive damage mitigation strategies and guidance required by 10 CFR 50.54(hh) if those strategies and guidance are used by the licensee to mitigate reactor accidents typically modeled in the SPAR models. An evaluation of the 78 SPAR models was completed in October 2010. The results of this study, which are designated as Official Use Only – Security Related Information and have not been publically released, were forwarded to the Office of Nuclear Reactor Regulation to support an assessment of the effectiveness of the 10 CFR 50.54(hh) security enhancements implemented by licensees and the potential credit of these enhancements in the Significance Determination Process.

New Reactor SPAR Models

Prior to new plant operation, the staff may need to perform risk assessments to confirm PRA results provided in licensing submittals or to evaluate risk-informed applications. Once the plants begin operation, the results from licensee PRAs or independent assessments using SPAR models may be used by the NRC staff for the evaluation of operational findings and events similar to the assessments performed for current operating reactors.

During FY 2011, the staff developed two design-specific internal events SPAR models for the Advanced Boiling Water Reactor (ABWR)—one for the ABWR/Toshiba reactor design and one for the ABWR/GE design. As part of the SPAR model development, the requisite supporting documentation also was completed. The first draft of the ABWR/Toshiba model was provided to the Office of New Reactors (NRO) for review and comments are being resolved. The ABWR/GE SPAR model has been completed and will be transitioned to a routine maintenance status.

The staff also has initiated work on developing a design-specific internal events SPAR model for the U.S. Advanced Pressurized-Water Reactor (U.S. APWR). The SPAR model fault tree and event tree development for the U.S APWR is in progress.

Although the AP1000 model was completed in February 2010, a modification was made to the SPAR model to include an external events seismic model. This modification has been completed and will be submitted to NRO for review.

The staff plans to continue developing new reactor SPAR models including external events 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.

Cooperative Research for PRA

The staff has executed an addendum to the memorandum of understanding (MOU) with 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. The staff also continues to work with the National Aeronautical and Space Administration to address PRA issues of mutual interest. In addition, NRC has used the cooperative agreement and grant program to establish collaborative PRA research projects with the University of Maryland and the Massachusetts Institute of Technology. The objective of this effort is to work with the broader PRA community to facilitate resolution of PRA issues and to develop PRA methods, tools, data, and technical information useful to both NRC and industry.

Initial cooperative efforts under the EPRI MOU have focused on the following:

- Support system initiating event analysis.
- Treatment of LOOP in PRAs.
- Treatment of uncertainty in risk analyses.
- Standard approach for injection following BWR containment failure.
- Standard approach for containment sump recirculation during small and very small loss-of-coolant accidents.
- Human reliability analysis.
- Digital instrumentation and control risk methods.
- Advanced PRA methods.
- Advanced reactor PRA methods.

Significant efforts have been made in the past year in the areas of support system initiating event analysis, treatment of LOOP in PRAs, and treatment of uncertainty in risk analysis. For example, in the area of support system initiating event analysis, the staff and industry have come to agreement on a common approach to modeling support system initiators and worked together to resolve common cause issues that significantly affect model quantification results. The staff plans to use the support system initiating event methodology and the improved treatment of LOOP events to further enhance the realism and accuracy of the SPAR models. These methodologies are planned to be implemented in the SPAR models as one of the activities associated with addressing the peer review comments. The staff plans to continue these cooperative efforts with EPRI and other stakeholders to address the remaining issues over the next several years.