

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 Level 1, Revision 3, 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 Level 1, Revision 3, 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 are not as detailed as those contained in licensees' probabilistic risk assessments (PRAs). To date the U.S. Nuclear Regulatory Commission (NRC) staff has completed Revision 3 SPAR models to represent all 104 commercial operating units and benchmarked them against licensee PRAs during the onsite quality-assurance reviews of these models.

In August 2000, the staff developed the SPAR model development plan to address the following models:

- Internal initiating events during full-power operation (Revision 3 SPAR models).
- Internal initiating events during low-power and shutdown operations.
- External initiating events (including fires, floods, and seismic events).
- Calculation of large early release frequency (LERF).

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 8.3. Under this project, the staff is working to complete the following activities:

- Enhance SPAR models to be more plant specific and enhance the codes 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 events (e.g., seismic events and tornadoes), internal events during low-power and shutdown operations, and LERF sequences.
- Provide on-call technical support for licensing and inspection issues.

2.0 SPAR Model Development 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, MD 8.3 evaluations, licensing actions, and the Mitigating Systems Performance Index (MSPI), involve the use of SPAR models. New SPAR models are under development in response to staff needs for modeling internal initiating events during low-power and shutdown operations, external initiating events, and for assessing accident progression to the plant damage state level.

The staff currently uses SPAR models to support the State-of-the-Art Reactor Consequence Analysis Project. The staff uses Revision 3 SPAR models for the plants selected, along with other sources of PRA information, to identify accident sequences that will be evaluated for their potential offsite consequences. The staff plans to update the SPAR models as appropriate, based on insights gained through this project.

In conformance with the SPAR model development plan, the staff has completed the following activities in model and method development since the previous status report (SECY-07-0176, "Status of the Accident Sequence Precursor Program and the Development of Standardized Plant Analysis Risk Models," dated October 3, 2007) as described below.

SPAR Models for Analysis of Internal Initiating Events During Full-Power Operation

The staff developed enhanced Revision 3 SPAR models. This effort involved (1) performing a cut-set-level review against the respective licensee's plant PRA model for each of the Revision 3 SPAR models and (2) incorporating into the Revision 3 SPAR models the resolution of the PRA modeling issues that were identified during the onsite quality assurance reviews of the Revision 3 SPAR models, during the MSPI pilot program reviews, and based on feedback from model users. The staff completed enhanced Revision 3 SPAR models for 75 of the 77 Revision 3 SPAR models.

Completion of the cut-set-level reviews at two plants (Nine Mile Point Unit 2 and Watts Bar) have been delayed because of holdups experienced by the licensees in updating their PRA and completing an American Society of Mechanical Engineers (ASME) standard peer review of their revised PRA. Nine Mile Point Unit 2 anticipates completion by February 2009. At this time, Watts Bar is unable to provide an anticipated completion date.

The staff developed a Browns Ferry Unit 1 SPAR model, which includes performing a cut-set-level review.

The staff completed updating the enhanced Revision 3 SPAR models with data published in NUREG/CR-6928, "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants," issued February 2007.

The staff has identified important plant differences at some multiunit sites. To address these plant differences, applicable SPAR models are being split into single-unit models. The staff has developed single-unit SPAR models for Peach Bottom Units 2 and 3, Brunswick Units 1 and 2, Calvert Cliffs Units 1 and 2, and Susquehanna Units 1 and 2.

In addition to the above model enhancements, the staff completed SPAR model reevaluations of the eight MSPI pilot plants and nine enhanced Revision 3 SPAR models because of changes to licensee PRAs that occurred during the implementation of MSPI.

SPAR Models for the Analysis of External Events

The staff previously completed a total of 15 SPAR external event models. The staff is developing a plan to define and direct the activities for the next 3-year time period. One significant upcoming activity is the incorporation of internal fire event scenarios from the National Fire Protection Association 805 PRA studies into the SPAR models.

SPAR Models for Analysis of Internal Initiating Events during Low-Power and Shutdown Operation

In FY 2008, the activities were completed for five second-generation SPAR low-power and shutdown models to support SDP Phase 3 analyses. The staff is developing a plan to define and direct the activities for the next 3-year time period. The staff places a priority on creating a RASP Handbook on PRA analysis of low-power and shutdown events, with emphasis on SDP Phase 3 analyses.

The staff completed one SPAR model that contains internal, external, and shutdown events. The task of integration and configuration control of various event models (internal, external, and shutdown) has been assigned a high priority to manage and control costs of these integrated models and their maintenance.

Extended SPAR Models for the Analysis of Accident Progression to the Plant Damage State Level

The staff initiated a project to develop extended Level I SPAR models covering different reactor technologies. In addition to the plant systems needed to mitigate core damage, these extended SPAR models will include containment systems that are needed to mitigate potential radionuclide release. These models will provide the capability to assess accident progression to the containment damage state level. The staff completed extended Level I SPAR models for five plants: Surry, Peach Bottom, Sequoyah, Grand Gulf, and Susquehanna. In addition, the staff completed Level II SPAR models for Surry, Peach Bottom, and Sequoyah. The staff anticipates integration of the Level II SPAR models with their respective extended Level I SPAR models to be completed in CY 2009.

This activity enhances prior NRC research that was directed at the evaluation of accident sequences to determine if they contributed to large early releases. This task also will provide the capability to further extend the models for other modes of radionuclide release should the need arise in the future.

3.0 Additional SPAR Model Activities

Audit by the NRC Office of Inspector General

The NRC Office of the Inspector General (OIG) completed an audit report, OIG-06-A-24, "Evaluation of the NRC's Use of Probabilistic Risk Assessment in Regulating the Commercial

Nuclear Power Industry,” dated September 29, 2006, which made the following three recommendations:

- (1) Develop and implement a formal, written process for maintaining PRA models that is sufficiently representative of the as-built, as-operated plant to support model uses.
- (2) Develop and implement a fully documented process to conduct and maintain configuration control of PRA software (i.e., SAPHIRE, GEM).
- (3) Conduct a full verification and validation of SAPHIRE Version 7.2 and GEM.

The corrective actions required to resolve recommendations 1 and 2 have been completed.

In follow-up discussions, OIG acknowledged that performing a full verification and validation of SAPHIRE Version 7 would not be justified at this time because of the development schedule of SAPHIRE Version 8. The staff is implementing four improvements to the SAPHIRE project software verification and validation. These improvements are consistent with the Institute of Electrical and Electronics Engineers Standard for Software Verification and Validation 1012-1998. Subsequent discussions with the OIG staff indicated that the addition of these four recommendations, combined with code testing, would satisfy full verification and validation of SAPHIRE Version 8.

The staff will implement these improvements in the SAPHIRE Version 8 statement of work and anticipates its general release date in CY 2009. OIG considers this issue resolved, and the issue will be closed with the release of SAPHIRE Version 8.

Technical Adequacy of SPAR Models

The staff implemented an updated SPAR Model Quality Assurance Plan covering the Revision 3 SPAR models in 2006. 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 Revision 3 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. The staff documented its processes in the RASP handbook.

New Reactor SPAR Models

The staff has begun the development of new reactor SPAR models. Prior to new plant operation, the staff may need to perform risk assessments to confirm PRA results provided in combined operating license (COL) submittals or to evaluate risk-informed applications after COL issuance.

The main objective of this work is to develop a design-specific internal events SPAR model for the Advanced Passive 1000 Reactor based on the SAPHIRE computer code. As part of the SPAR model development, the requisite supporting documentation also will be developed. Because design standardization is a key aspect of the new plants, it will only be necessary to develop one SPAR model for each of the new designs.

Because some of the new reactor designs rely on passive systems and components to mitigate accident scenarios, the first model will be a proof-of-concept to ensure that the necessary technical capabilities are in fact available and the state-of-the art of the SPAR models is sufficient to complete the models. Upon successful completion of the first model the remaining models will be developed.

Cooperative Research for PRA

The staff has executed an addendum to the memorandum of understanding with the 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.

The objective of this effort is to work with the broader PRA community to resolve PRA issues and to develop PRA methods, tools, data, and technical information useful to both NRC and industry. The agency has established working groups that include support from the Office of Nuclear Regulatory Research, Office of Nuclear Reactor Regulation, Office of New Reactors, and the regional offices. Initial cooperative efforts include the following:

- Support system initiating event analysis.
- Treatment of LOOP in PRAs.
- Initiating event guideline development.
- Treatment of uncertainty in risk analyses.
- Aggregation of risk metrics.
- Standard approach for injection following containment failure (boiling-water reactors).
- Standard approach for containment sump recirculation during small and very small loss-of-coolant accident.
- 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, treatment of uncertainty in risk analysis, and aggregation of risk metrics. 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 continue this cooperative effort with EPRI to address the remaining issues over the next 3 years.

SAPHIRE Version 8 Development

SAPHIRE Version 8 includes features and capabilities that are new or improved over the current Version 7 to address new requirements for risk-informed programs. User interfaces were developed for performing:

- SDP Phase 2 analyses with the SPAR models.
- Event assessments.
- Other types of PRA analyses.

Features and capabilities also have been improved for SPAR model development and use. Level 1 SPAR models were updated to run in the new SDP Phase 2 analysis interface. External events models required a new data input method and code improvements to develop and run them. New requirements for LERF models have been incorporated, including the capability to perform phase mission time analysis which also is useful for low power and shutdown modeling. In addition, SAPHIRE Version 8 has been designed with unique capabilities to use the SPAR models in an integrated manner (i.e., different model types such as internal and external events models combined into one model). Improved PRA methods also have been implemented for common cause failure modeling and for sequence solving. Finally, the software's general functionality has been enhanced, and the layout has been made more user-friendly.

Version 8 is currently in beta testing. In addition to beta testing, independent verification and validation activities and the staff's peer review are planned. SAPHIRE Version 8 is anticipated to be ready for general use by the end of CY 2009.