

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 initiated 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 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 (MD) 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), and internal events during shutdown operations.
- 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, Management Directive (MD) 8.3, "NRC Incident Investigation Program," evaluations, 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 shutdown operations, external initiating events, and for assessing accident progression to the plant damage state level.

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-08-0145, "Status of the Accident Sequence Precursor Program and the Development of Standardized Plant Analysis Risk Models," dated October 1, 2008) 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 the enhancement of the 77 Revision 3 SPAR models representing the 104 operating commercial nuclear power plants.

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 multi-unit sites. To address these plant differences, four SPAR models have been split into single-unit models. The staff has developed single-unit SPAR models for all units at Peach Bottom, Brunswick, Calvert Cliffs, and Susquehanna sites.

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 2-year time period. One significant upcoming activity is the incorporation of internal fire scenarios from the National Fire Protection Association 805 PRA studies into the SPAR models.

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. In FY 2009, the staff developed a detailed shutdown model maker guideline document to provide consistent guidance for the construction of shutdown SPAR models. Two SPAR models were developed using the modeling guidelines, resulting in a total of six shutdown SPAR models available to support SDP

Phase 3 analyses. The staff plans to complete three additional shutdown SPAR models in FY 2010.

MELCOR Thermohydraulic Analysis for SPAR Model Success Criteria

The staff is currently performing 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 both the Peach Bottom and Surry plants. These results will be incorporated in to the technical basis supporting the Surry and Peach Bottom SPAR models, and some results can be readily extended to other plants. The Office of Nuclear Regulatory Research (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 effort directly supports the agency's goal of using state-of-the-art tools that promote effectiveness and realism.

3.0 Additional SPAR Model Activities

SAPHIRE Version 8 Development

SAPHIRE Version 8, currently under development, 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.
- Condition assessments for SDP Phase 3 and ASP analyses, and MD 8.3 evaluations.
- Initiating event assessments for ASP analyses and MD 8.3 evaluations.
- Other types of PRA analyses requiring more significant modeling or data revisions.

Features and capabilities also have been improved for SPAR model development and use. Enhanced SPAR models for internal events during power operations have been developed to use the new SDP Phase 2 analysis interface. A new data input method and code improvements to develop and run the external events SPAR models was developed. 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 interface layout has been made more user-friendly.

Version 8 is currently in beta testing. In addition to beta testing, quality assurance activities include an independent verification and validation, an NRC internal peer review, and NRC software quality assurance audits. SAPHIRE Version 8 is anticipated to be ready for general use by April 2010.

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. The SPAR Model Quality Assurance Plan ensures that the SPAR models represent the as-built, as-operated plants. Idaho National Laboratory has implemented a Revision Control System to maintain configuration control of SAPHIRE.

In follow-up discussions on recommendation 3, 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 recommended improvements to the SAPHIRE Version 8 project software verification and validation. These recommendations were based on a comparison of the SAPHIRE testing, verification and validation to 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 is implementing these four recommendations and the code is being tested. OIG considers this issue resolved, and the issue will be closed with the release of SAPHIRE Version 8. SAPHIRE Version 8 is scheduled for release in April 2010.

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. In addition, the staff, with the cooperation of industry experts, performed a peer review of a representative boiling-water reactor (BWR) 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." A peer review

of a representative pressurized-water reactor SPAR model is scheduled to be completed October 2009.

Evaluation of B.5.b Strategies to Mitigate Severe Accidents

This project is in support of Staff Requirements - COMGBJ-06-0004, dated April 14, 2006. The objective of this project is to establish the change in risk of the 104 NRC licensed commercial nuclear power plants based on the implementation of mitigation strategies required by Section B.5.b of Commission Order EA-02-026, dated February 25, 2002, if those mitigation strategies are used by the licensee to mitigate reactor accidents typically modeled in the SPAR models. An evaluation of 26 SPAR models has been completed as part of Phase 1 of this project. Two follow-on phases will result in the evaluation of the remaining SPAR models. This project is scheduled to be completed in October 2010.

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.

The main objective of this work during FY 2009 was the development of a design-specific internal events SPAR model for the AP1000 reactor design. As part of the SPAR model development, the requisite supporting documentation also will be developed. During FY 2010, the staff plans to initiate development of a SPAR model for the Advanced Boiling-Water Reactor design. Because design standardization is a key aspect of the new plants, it should only be necessary to develop one SPAR model for each of the new designs.

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 RES, 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 (BWRs).

- 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 two years.