POLICY ISSUE
(Information)

October 5, 2015 SECY-15-0124

FOR: The Commissioners

FROM: Brian W. Sheron, Director
Office of Nuclear Regulatory Research

SUBJECT: STATUS OF THE ACCIDENT SEQUENCE PRECURSOR PROGRAM AND THE STANDARDIZED PLANT ANALYSIS RISK MODELS

PURPOSE:

To inform the Commission of the status, accomplishments, and results of the Accident Sequence Precursor (ASP) Program, including quantitative ASP results, and to communicate the status of the development and maintenance of the Standardized Plant Analysis Risk (SPAR) models. This paper does not address any new commitments or resource implications.

BACKGROUND:

In a memorandum to the Chairman dated April 24, 1992, the staff of the U.S. Nuclear Regulatory Commission (NRC) committed to report periodically to the Commission on the status of the ASP Program. Subsequently, in SECY-02-0041, "Status of Accident Sequence Precursor and SPAR Model Development Programs," dated March 8, 2002, the staff expanded the annual ASP status report to include: (1) an expanded evaluation of precursor data trends and insights, and (2) the development of associated probabilistic risk assessment (PRA) models (e.g., SPAR models).

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The ASP Program systematically evaluates U.S. nuclear power plant (NPP) operating experience to identify, document, and rank the operating events that had the highest conditional probability to lead to inadequate reactor core cooling and severe core damage (i.e., precursors).[1] The ASP Program provides a comprehensive and integrated assessment of plant risk associated with operating events. The ASP Program provides insights into the NRC's risk-informed and performance-based regulatory programs; evaluates performance against performance indicators in the agency's Congressional Budget Justification[2] and Industry Trends Program;[3] and reports to Congress events of high safety significance in accordance with "abnormal occurrence" criteria.[4] As part of the rebaselining work being conducted under the Project AIM 2020 initiative, the staff plans to evaluate the different programs and determine how best to further reduce the duplication of effort and potentially propose to the Commission modifications to the criteria used in the Congressional Budget Justification as a means of improving efficiency.

Under the SPAR Model Program, the staff develops and maintains independent risk-analysis tools and capabilities to support NPP-related risk-informed regulatory activities. The staff uses SPAR models for the Reactor Oversight Process (ROP) Significance Determination Process (SDP); the ASP Program; the Management Directive (MD) 8.3, "NRC Incident Investigation Program," event assessment process; and the MD 6.4, "Generic Issues Program," resolution process. In addition, the staff uses the SPAR models to risk inform NRC inspection activities, to gain risk insights in support of reactor-related rulemaking, and to support other risk assessment studies, such as system and component reliability studies.

DISCUSSION:

This section summarizes the status, accomplishments, and results of the ASP Program and SPAR Model Program since the previous status report, SECY-14-0107, "Status of the Accident Sequence Precursor Program and the Standardized Plant Analysis Risk Models," dated October 6, 2014.

ASP Program

Program Scope. The ASP Program is one of three agency programs that assess the risk significance of events. The other two programs are the SDP and the event-response evaluation process, as defined in MD 8.3. Currently, the ASP Program provides integrated analyses of complex operating events not evaluated by the SDP or finalized by MD 8.3 evaluations. The SDP evaluates the risk significance of a single licensee performance deficiency, while risk assessments performed under MD 8.3 are used to determine, in part, the appropriate level of reactive inspection in response to an event. An SDP assessment has the benefit of information obtained from the inspection, whereas the MD 8.3 assessment is expected to be performed within a day or two after the event notification. In contrast to the other two programs, a

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1 Enclosure 1 provides background on the process used by the staff to identify precursors.

2 See NUREG-1100, Volume 31, "2016 Congressional Budget Justification," issued January 2015.

3 See SECY-15-0061, "Fiscal Year 2014 Results of the Industry Trends Program for Operating Power Reactors," dated April 8, 2015.

4 See Appendix A of NUREG-0090, Volume 37, "Report to Congress on Abnormal Occurrences—Fiscal Year 2014," issued May 2015.

comprehensive and integrated risk analysis under the ASP Program includes all anomalies[5] observed at the time of the event or discovered after the event.

There are similarities in the risk assessments conducted by the three programs. All programs use SPAR models, the same documented methods and guidance, and similar analysis assumptions, except where program objectives deviate from one another. To minimize overlap and improve efficiency, since 2006, SDP results have been used in lieu of independent ASP analyses to the extent practical and consistent with the overall objectives of both programs. Typically the SDP analyses are used in the ASP Program when the analysis performed addresses the major contributors to risk for the event based on a review conducted by an ASP Program risk analyst. Typically for initiating events, many of the modeling assumptions made for MD 8.3 analyses can be adopted by ASP analyses. However, some modeling assumptions are revised as detailed information about the event becomes available when inspection activities are completed. These key similarities provide opportunities for significant ASP Program efficiencies. For a potential *significant* precursor (defined below), analysts from the three programs work together to provide a timely determination of plant risk. As such, duplication between programs is minimized to the extent practical within program objectives.

Status and Results. The staff continues to review operational events from licensee event reports (LERs) and NRC inspection reports (IRs) to identify potential precursors to a reactor core damage event. The results of these reviews are used to identify areas requiring additional evaluation to determine the appropriate regulatory response in activities like the Generic Issues Program and Reactor Oversight Program. The evaluations identify trends in causal factors that may contribute to increased risk to the safety of operating reactors. The results also provide input to the Abnormal Occurrence Report to Congress and input to Agency Performance Monitoring as part of the NRC's Congressional Budget Justification. Operational events that exceed the ASP thresholds, mentioned in the Background section of Enclosure 1, are considered precursors in the ASP Program. *Significant* precursors have a conditional core damage probability (CCDP)[6] or a change in core damage probability (ΔCDP)[7] greater than or equal to 1×10^{-3}. The staff has identified 16 precursor events for fiscal year (FY) 2014. The staff did not identify any *significant* precursors for FY 2014 and has not identified any potentially *significant* precursors for FY 2015 to date, although the reporting of FY 2015 events in LERs and NRC IRs are still in progress.

In addition to the identification of precursor events, the staff performs trend analyses on precursors for additional insights. Trend analyses are performed on the following precursor groups:

- all precursors
- precursors with a CCDP or ΔCDP greater than or equal to 1×10^{-4}

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5 These anomalies or conditions may include unavailable and degraded plant structures, systems, and components (SSCs); human errors; and an initiating event (reactor trip). In addition, an unavailable or degraded SSC does not have to be a performance deficiency or an analyzed condition in the plant's licensed design basis.

6 The term CCDP is the probability of the occurrence of core damage given that an initiating event has occurred.

7 The term ΔCDP is the increase in probability of core damage (from the baseline core damage probability) due to a failure of plant equipment or an identified deficiency during the time the failure or deficiency existed.

- precursors involving an initiating event
- precursors involving degraded conditions
- precursors involving a complete loss of offsite power (LOOP)
- precursors that occurred at boiling-water reactors (BWRs)
- precursors that occurred at pressurized-water reactors (PWRs)

For the period of FY 2005 through FY 2014, the staff found a statistically significant increasing trend in the mean occurrence rate of precursors resulting from a LOOP initiating event. This increasing trend resulted from the occurrence of 20 LOOP precursor events in the last 4 years after 7 precursor occurrences in the previous 6 years.

In the FY 2012 and FY 2013 annual report, statistically significant increasing trends were identified in the mean occurrence rate of precursors with a CCDP or ΔCDP greater than or equal to 1×10^{-4}. However, with no additional precursor observed in this group in FY 2013 and FY 2014, the trend is no longer statistically significant. As reported in last year's status report (SECY-14-0107), six of the seven precursors in this group were caused by multiple electrical failures during a 3-year period. Based, in part, on the observed increases in electrical- and LOOP-related precursors over the past few years, the staff initiated a detailed study in FY 2014 to better understand the contribution of electrical system and associated component failures on risk at NPPs. Results for this study should be available in FY 2017.

The staff found no statistically significant trends for any of the other precursor groups during the FY 2005 through FY 2014 period. Enclosure 1, "Results, Trends, and Insights of the Accident Sequence Precursor Program," provides additional details on results and trends of the ASP Program.

SPAR Model Program

The SPAR models provide agency risk analysts with an independent risk assessment tool to support a variety of risk-informed agency programs, including the ROP and the ASP program. SPAR models are built with a standard modeling approach, using consistent modeling conventions, that enables staff to easily use the models across a variety of U.S. NPP designs. Unlike industry PRA models, SPAR models are run on a single software platform, the Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) computer code. The staff currently maintains and updates 75 SPAR models representing 99 commercial NPPs.[8] The scope of every SPAR model includes logic modeling covering internal initiating events at power through core damage (i.e., Level-1 PRA model). In FY 2015, the staff modified all SPAR models to take advantage of new SAPHIRE features and to improve the usability of the models. In addition to these global changes, approximately 30 models were updated to support specific SDP or ASP activities. The staff also performed more comprehensive updates to selected SPAR models to reflect recent plant modifications and to incorporate significant modeling updates. In FY 2015, the staff performed significant updates to six SPAR models to reflect changes such as the addition of logic for new station blackout generators, battery charging generators, and expansion of electrical power distribution modeling. During FY 2015, the staff continued to perform a comprehensive data update to all 75 SPAR models to reflect recent operating experience and

[8] The SPAR models associated with NPPs that have recently permanently shut down (Kewaunee, San Onofre Units 2 and 3, Crystal River Unit 3, and Vermont Yankee) are no longer being updated, but remain available for agency use.

implement other enhancements to improve the usability and functionality of the models. In addition, the staff continued to expand SPAR model capability beyond internal events at full-power operation. For example, 22 of the SPAR models, representing 28 nuclear power reactors, include other hazard groups and are referred to as SPAR All-Hazard (SPAR-AHZ) models.[9] Currently, 18 of the SPAR-AHZ models include hazards such as fires, internal floods, and seismic events based on assessments conducted for Supplement 5, "Individual Plant Examination of External Events for Severe Accident Vulnerabilities," to Generic Letter 88-20, "Individual Plant Examination for Severe Accident Vulnerabilities—10 CFR 50.54(f)" (dated September 8, 1995), and other readily available information. The staff also incorporated internal fire scenarios from the fire PRAs done in compliance with National Fire Protection Association (NFPA) 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," for the Shearon Harris Nuclear Power Plant, the Donald C. Cook Nuclear Power Plant, and the Virgil C. Summer Nuclear Generating Station. In addition to more detailed fire PRA modeling, the SPAR models for these NPPs include improved external hazard modeling and model validation. The staff has also leveraged the ongoing Level-3 PRA project for the Vogtle Electric Generating Plant, Units 1 and 2, to develop improved external hazard and fire modeling for the Vogtle SPAR model. In FY 2015, a new SPAR-AHZ model for the Point Beach site was created, and the SPAR-AHZ model for the Sequoyah site underwent a major revision.

In the new reactor area, the staff has developed SPAR models for the AP1000 Advanced Boiling-Water Reactor (ABWR) (for both the Toshiba and General Electric-Hitachi designs), U.S. Advanced Pressurized-Water Reactor (US-APWR), and the U.S. Evolutionary Power Reactor (U.S. EPR). The staff has expanded the capability of the AP1000 SPAR model to include hazards such as seismic, fire, flooding, and low-power shutdown events. A post-core damage severe accident logic model (i.e., Level-2 PRA model) is also being developed for the AP1000 SPAR model.

The Office of Nuclear Regulatory Research (RES) staff continues to work with the Regions, the Office of Nuclear Reactor Regulation (NRR), and the Office of New Reactors (NRO) to identify future enhancements to the SPAR models, including continuing the development of new SPAR-AHZ models. Further, NRR is considering how it can improve the efficiency and effectiveness of the SDP process. These improvements may include pilot activities to assess the use of alternatives to the SPAR models. The use of alternatives to the SPAR models has other implications that will need to be assessed and addressed in support of any pilot activity that may be undertaken.

In FY 2010, the staff completed PRA standard-based peer reviews of a representative BWR SPAR model and a representative PWR SPAR model. It performed these peer reviews 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 peer-review teams concluded that, within the constraints of the program, the SPAR model is an efficient method to offer qualitative and quantitative insights

[9] These models were formerly named SPAR external event (SPAR-EE) models, but have been renamed SPAR-AHZ to reflect recent improvements in external hazard modeling efforts and for consistency with the ASME PRA Standard model scope.

for applications, SDP evaluations, inspections, event assessments, and model evaluations. The peer review teams also noted that the SPAR model structure was robust and well developed, model fault trees were streamlined with an appropriate level of detail for the model's intended users, and the model structure and the SAPHIRE computer software are at the state of the technology. The teams also identified a number of enhancements for the SPAR models and supporting documentation. Major activities undertaken to address the high priority peer-review items include the following:

- Structuring the SPAR model documentation to more closely align with the structure of ASME/ANS PRA standard. A majority of the peer review comments were related to documentation issues.

- Incorporating improved LOOP modeling and support system initiating events modeling into the SPAR models (e.g., loss of service water or component cooling water).

- Expanding the SAPHIRE Web site to better log and track model change requests.

The staff completed these PWR and BWR SPAR Model peer-review enhancements in August 2015.

On July 14–15, 2015, RES, in collaboration with Idaho National Laboratory staff, held a 2-day public workshop on the agency's SPAR model program. Workshop discussions included the objectives of the SPAR model program; data collection and analysis; human reliability analysis; LOOP modeling; and SPAR model maintenance and quality assurance. The workshop participants included representatives from NPPs, industry contractors, international partners, and public interest groups. In addition, NRC staff from NRR, NRO, and the Regions attended. A meeting summary of the workshop can be found in Agencywide Documents Access and Management System (ADAMS) at Accession No. ML15198A191.

The staff continues to maintain and improve the SAPHIRE software to support the SPAR Model Program. SAPHIRE is a personal-computer-based software application used to develop PRA models and perform analyses with SPAR models. During FY 2015, significant SAPHIRE activities included the following:

- Oversight of the SAPHIRE software quality-assurance program, including performance of an annual audit of software quality-assurance activities, tools, and documents in accordance with NUREG/BR-0167, "Software Quality Assurance Program and Guidelines."

- Implementation of new SAPHIRE features, including the capability to easily sort model results by their contribution to different accident sequences and improvements to the reporting functions for external hazard model results.

- Evaluation of code infrastructure improvements necessary to support a multi-user Web-based platform for SAPHIRE.

Enclosure 2, "Status of the Standardized Plant Analysis Risk Models," provides a detailed status of SPAR models and related activities.

Planned ASP and SPAR Model Activities

- The staff will continue the screening, review, and analysis (preliminary and final) of potential precursors for FY 2015 and FY 2016 events.

- The staff will continue the detailed study of electrical system and component failure contribution to the risk at operating NPPs.

- The staff will continue to implement enhancements to the internal event SPAR models for full-power operations. Planned enhancements include model updates based on insights from ongoing thermal-hydraulic analyses and a comprehensive update of all SPAR models to reflect recent operating experience.

- The staff will continue quality-assurance activities for both the agency SPAR models and the SAPHIRE code. This will ensure that agency risk tools continue to be of sufficient quality for performing SDP, ASP, and MD 8.3 event assessments in support of the staff's risk-informed regulatory activities.

- The staff will continue to evaluate the need for additional SPAR model capability (beyond full-power internal events) based on experience gained from risk assessment activities and feedback from users. In addition, the staff intends to continue to develop new external hazard capabilities with new SPAR-AHZ models.

SUMMARY:

Under the ASP Program, the staff continues to evaluate the safety significance of operating events at NPPs and to provide insights into the NRC's risk-informed and performance-based regulatory programs. The staff identified no *significant* precursors in FY 2014 and in the FY 2015 events evaluated to date. The staff identified one statistically significant increasing trend involving the occurrence rate of LOOP precursor events for the period FY 2005 through FY 2014. The SPAR Model Program is continuing to develop and improve independent risk-analysis tools and capabilities to support the use of PRA in the agency's risk-informed regulatory activities.

COORDINATION:

The Office of the General Counsel reviewed this Commission paper and has no legal objection.

/RA/

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Enclosures:
1. Results, Trends, and Insights of the ASP Program

2. Status of the SPAR Models

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Enclosures:
1. Results, Trends, and Insights of the ASP Program
2. Status of the SPAR Models

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