POLICY ISSUE
INFORMATION

October 4, 2012 SECY-12-0133

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 of the Accident Sequence Precursor (ASP) Program, provide the annual quantitative ASP results, and 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. In SECY-02-0041, "Status of Accident Sequence Precursor and SPAR Model Development Programs," the staff expanded the annual ASP SECY paper to include: (1) the evaluation of precursor data trends and (2) the development of associated risk models (e.g., SPAR models). The ASP Program systematically evaluates U.S. nuclear power plant (NPP) operating experience to identify, document, and rank the operating events most likely to lead to inadequate core cooling and severe core damage (precursors). The ASP Program provides insights into the NRC's risk-informed and performance-based regulatory programs and monitors performance against safety measures established in the agency's Congressional Budget Justification (see NUREG-1100, Volume 28, "Congressional Budget Justification: Fiscal Year 2013," issued February 2012). The SPAR Model Program develops and maintains independent risk-analysis tools and capabilities to support the use of probabilistic risk assessment (PRA) across a broad range of the agency's risk-informed regulatory activities.

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The staff uses SPAR models to support the Reactor Oversight Program's Significance Determination Process (SDP), the ASP Program, Management Directive (MD) 8.3, "NRC Incident Investigation Program," event assessment process, and MD 6.4, "Generic Issues Program," resolution process. In addition, the staff uses SPAR models to risk inform licensing and inspection activities.

DISCUSSION:

This section summarizes the status, accomplishments, and results of the ASP Program and SPAR Model Program since the previous status report, SECY-11-0138, "Status of the Accident Sequence Precursor Program and the Standardized Plant Analysis Risk Models," dated September 30, 2011.

ASP Program

The staff continues to review plant events from licensee event reports and inspection reports. Each event analyzed by the ASP Program is thoroughly inspected by regional and, if necessary, headquarters staff to ensure it is understood and that appropriate corrective action is taken by licensees. The staff has completed the analyses of all precursor events that were identified in fiscal year (FY) 2011 (22 precursors). Precursors are events with a conditional core damage probability (CCDP) for initiating event analyses or an increase in core damage probability (ΔCDP) for equipment deemed unavailable or degraded that is greater than or equal to 1×10^{-6}. In addition, the staff has completed the screening of FY 2012 events for *significant* precursors. *Significant* precursors have a CCDP or ΔCDP greater than or equal to 1×10^{-3}. No *significant* precursors were identified in FY 2011, and no *significant* precursors have been identified in FY 2012, to date. However, the staff has identified a potential *significant* precursor involving the loss of offsite power and subsequent station blackout that occurred at Byron Station, Unit 2, on January 30, 2012. The staff will continue to evaluate this event and other ongoing analyses and inform the Commission if *significant* precursors are identified.

The staff evaluated precursor data during the period of FY 2002 through FY 2011 to identify statistically significant adverse trends for the Industry Trends Program (ITP). The staff detected no statistically significant trend for all precursors during this 10-year period. The ASP Program results are trended in the ITP to provide an input to the agency's safety performance measure of no significant adverse trend in industry safety performance.

In addition to the trend analysis of all precursors, the staff performs trend analyses on precursor subgroups. These subgroups include precursors with a high safety significance (i.e., CCDP or ΔCDP greater than or equal to 1×10^{-4}), initiating events, degraded conditions, loss of offsite power initiating events, precursors at boiling-water reactors (BWRs), and precursors at pressurized-water reactors (PWRs). The staff observed no statistically significant trends in these precursor subgroups. Enclosure 1 provides additional details on results and trends of the ASP Program.

SPAR Model Program

The staff continued to maintain and update the 79 SPAR models representing the 104 operating commercial nuclear power reactors during FY 2012. The staff completed the development of new Plant Risk Information e-Books for all SPAR models. These reports provide summary information about systems and components important to nuclear plant risk and will support use

of the Systems Analysis Program for Hands-On Integrated Reliability Evaluations (SAPHIRE) computer code platform[1] by a wider range of Regional inspection staff. In addition, the staff continued to expand the SPAR model capability beyond internal events at full-power operation. Currently, a total of 18 SPAR all-hazard models exist (these models include hazards such as fires, floods, and seismic events). The staff also incorporated internal fire scenarios from the 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 pilot application. The Office of Nuclear Regulatory Research staff continues to work with the Office of Nuclear Reactor Regulation and the Office of New Reactors to identify future enhancements to the SPAR all-hazard models.

The staff has completed the development and enhancement of the shutdown template models, resulting in a total of eight shutdown SPAR models available to support the Reactor Oversight Process evaluations of shutdown events and degraded conditions during shutdown conditions. The staff also developed new reactor SPAR models for the AP1000, Advanced BWR (for both the Toshiba and General Electric designs), and the U.S. Advanced PWR. In addition, the staff initiated the development of a SPAR model for the U.S. Evolutionary Power Reactor. The staff continues to expand the capability of some of these models to include seismic hazards and shutdown conditions. These new reactor SPAR models allow confirmation of PRA results presented in licensing submittals, evaluation of risk-informed license applications prior to plant operation, and assessment of operational findings and events once operation commences. In addition, the SPAR models for the AP1000 and Advanced BWR were used extensively to support staff recommendations in SECY-12-0081, "Risk-Informed Regulatory Framework for New Reactors," dated June 6, 2012.

In FY 2010, the staff, with the cooperation of industry experts, completed peer reviews of a representative BWR SPAR model and PWR SPAR model, in accordance with American Society of Mechanical Engineers (ASME) RA-S-2008, "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 peer review teams concluded that, within the constraints of the program, the SPAR models provide an appropriate tool to conduct an independent check on the technical adequacy of utility PRAs. The teams also made a number of observations regarding improvements that could be made to the SPAR Models and supporting documentation. The staff has reviewed the peer review comments and has initiated projects to address these comments, where appropriate. Major activities undertaken to address these peer review items in FY 2012 include the following:

- Structuring the SPAR model documentation to more closely align with the structure of PRA standard.

- Incorporating improved loss of offsite power modeling.

- Addressing the high priority items for the BWR SPAR models.

[1] SAPHIRE is the Agency's primary tool for conducting Probabilistic Risk Assessments. SAPHIRE uses logical event and fault tree models to quantify the frequencies and probabilities associated with events of interest, such as core damage. SAPHIRE is also capable of performing uncertainty calculations and risk importance measures.

These activities have been delayed approximately 1 year because of higher priority Reactor Oversight Process support and activities related to the events at Fukushima Dai-ichi, in Japan. The staff plans to complete these efforts in 2014.

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 to perform analyses with SPAR Models. During FY 2012, the new features, capabilities, and user support activities that have been implemented for SAPHIRE include:

- An improved common-cause failure calculation module.

- Oversight of the SAPHIRE software quality assurance program, including an audit of software quality assurance activities, tools, and documents.

- An update to the SAPHIRE Web site design and user support features, including an automatic password retrieval system to assist active users in maintaining access to the secure site.

- Research on advanced quantification methods to overcome limitations of the approximation methods that are typically used in PRA software.

Enclosure 2 provides a detailed status of SPAR models and related activities.

Planned Activities

- The staff will continue the screening, review, and analysis (preliminary and final) of potential precursors for FY 2012 and FY 2013 events to support the agency's safety measures.

- The staff will continue to implement enhancements to the internal event SPAR models for full-power operations. Enhancements include incorporating new models for support-system initiators and revised success criteria based on insights from thermal-hydraulic analyses. The staff also is working with industry representatives through a memorandum of understanding with the Electric Power Research Institute (EPRI) to resolve other PRA technical issues common to both licensee PRAs and NRC SPAR models. The memorandum of understanding addendum on PRA with EPRI extends through 2016.

- The staff has reviewed the SPAR model peer review comments and developed a project plan to address them, where appropriate. These activities have been delayed approximately 1 year because of higher priority Reactor Oversight Process support and activities related to Fukushima Dai-ichi. The staff is planning to complete this effort in FY 2014. The effort's main objective is to ensure the SPAR models continue to be of sufficient quality for performing SDP, ASP, and MD 8.3 event assessments in support of the staff's risk-informed activities.

- The staff will use information obtained as part of the NFPA 805 application process to create new SPAR fire models with updated fire scenarios.

- The staff will continue to evaluate the need for additional SPAR model capability (beyond full-power internal events) based on experience gained from SDP, ASP, and MD 8.3 event assessments, and Safety Risk Assessments conducted for the Generic Issues Program under MD 6.4.

- The staff will continue the development of SPAR models for new reactors to allow confirmation of PRA results presented in licensing submittals, evaluation of risk-informed applications prior to plant operation, and assessment of operational findings and events once operation commences.

- The staff will develop approximately one new all-hazards model per year, and plans to perform validation activities for existing all-hazards models.

- The staff will continue to maintain and improve the SAPHIRE software to support the SPAR Model Program.

- The staff will use SAPHIRE and the Units 1 and 2 Vogtle SPAR model as primary tools for developing the Level 1 and Level 2 portions of the full-scope site Level 3 PRA project, which is being conducted per the staff requirements memorandum to SECY-11-0089, “Options for Proceeding with Future Level 3 Probabilistic Risk Assessment Activities.”

- As noted in SECY 11-0137, “Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned,” the staff acknowledged that additional SPAR model updates could be identified as a result of Tier 1 related inspection activities. The RES staff will continue to monitor the status of these Fukushima follow-up activities and will perform additional SPAR model update activities, as appropriate.

SUMMARY:

The ASP Program 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 2012; however, a potentially *significant* precursor has been identified for an operational event that occurred at Byron Station, Unit 2. The analysis of the event is ongoing. No statistically significant trend was detected for all precursors during the FY 2002 through FY 2011 period. 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/

Brian W. Sheron, Director
Office of Nuclear Regulatory Research

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

Results, Trends, and Insights of the Accident Sequence Precursor Program

1.0 Introduction

This enclosure discusses the results of accident sequence precursor (ASP) analyses conducted by the staff as they relate to events that occurred during fiscal years (FYs) 2011 and 2012. Based on those results, this document also discusses the staff's analysis of historical ASP trends and the evaluation of the related insights.

2.0 Background

The U.S. Nuclear Regulatory Commission (NRC) established the ASP Program in 1979 in response to recommendations made in NUREG/CR-0400, "Risk Assessment Review Group Report," issued September 1978. The ASP Program systematically evaluates U.S. nuclear power plant (NPP) operating experience to identify, document, and rank the operating events most likely to lead to inadequate core cooling and severe core damage (precursors).

To identify potential precursors, the staff reviews plant events, including the impact of external events (i.e., fires, floods, and seismic events) from licensee event reports (LERs) and inspection reports (IRs) on a unit basis (i.e., a single event that affects a multiunit site is counted as a precursor for each unit). The staff then analyzes any identified potential precursors by calculating the probability of an event leading to a core damage state. A plant event can be one of two types—either (1) an occurrence of an initiating event, such as a reactor trip or a loss of offsite power (LOOP), with or without any subsequent equipment unavailability or degradation, or (2) a degraded plant condition depicted by the unavailability or degradation of equipment without the occurrence of an initiating event.

For the first type, the staff calculates a conditional core damage probability (CCDP). This metric represents a conditional probability that a core damage state is reached given an occurrence of an initiating event (and any subsequent equipment failure or degradation).

For the second type, the staff calculates an increase in core damage probability (ΔCDP). This metric represents the increase in core damage probability for a time period that a piece or multiple pieces of equipment are deemed unavailable or degraded.

The ASP Program considers an event with a CCDP or a ΔCDP greater than or equal to 1×10^{-6} to be a precursor.[1] The ASP Program defines a *significant* precursor as an event with a CCDP or ΔCDP greater than or equal to 1×10^{-3}.

Figure 1 provides a flowchart showing the complete ASP analysis process.

[1] For initiating event analyses, the precursor threshold is a CCDP greater than or equal to 1×10^{-6} or the plant-specific CCDP for a non-recoverable loss of balance-of-plant systems, whichever is greater. This initiating event precursor threshold prevents reactor trips, with no losses of safety system equipment, from being precursors.

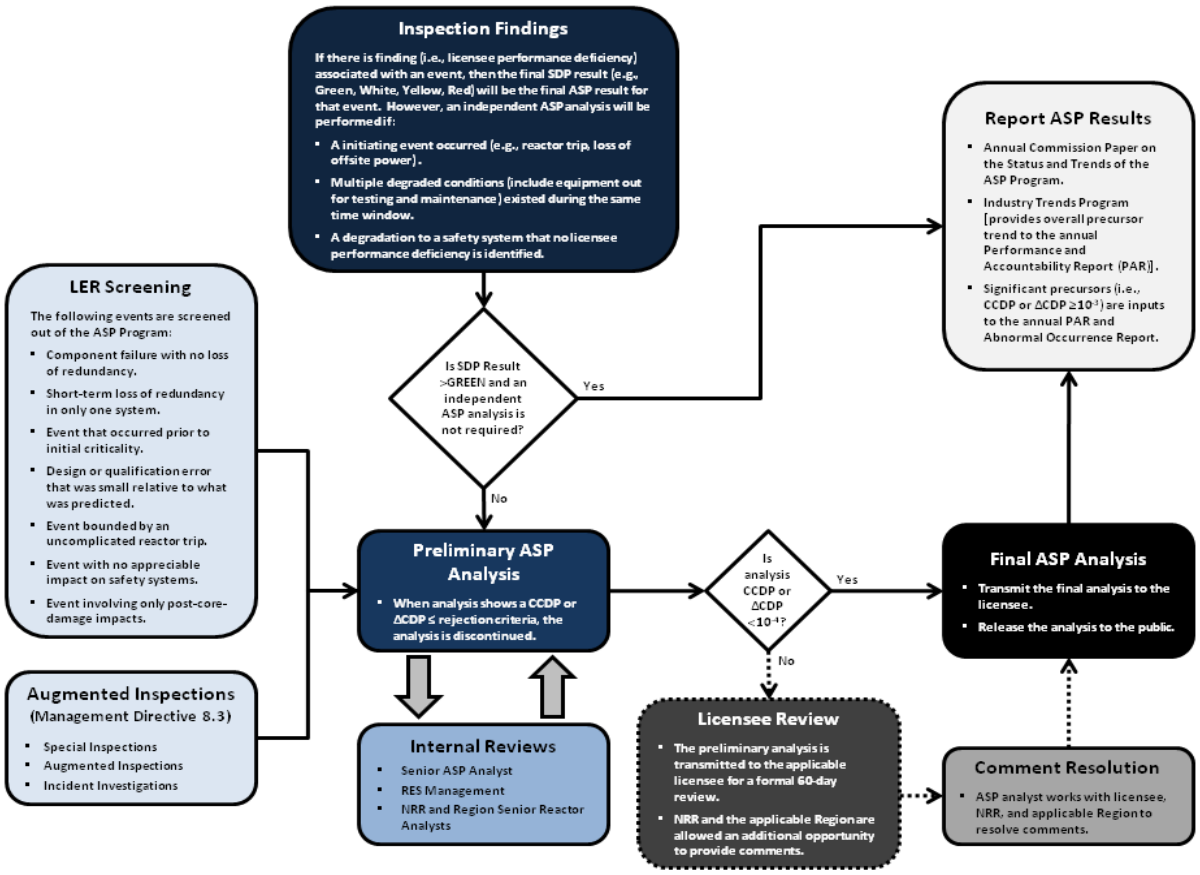

Figure 1. ASP process diagram

Program Objectives. The ASP Program has the following objectives:

- Provide a comprehensive, risk-informed view of NPP operating experience and a measure for trending core damage risk.
- Provide a partial validation of the current state of practice in risk assessment.
- Provide feedback to regulatory activities.

The NRC also uses the ASP Program as a means to monitor performance against the safety measures established in the agency's Congressional Budget Justification (Ref. 1), which was formulated to support the agency's safety and security strategic goals and objectives.[2] Specifically, the program provides input to the following safety measures:

- Zero events per year identified as a *significant* precursor of a nuclear reactor accident.
- Less than one significant adverse trend in industry safety performance (determination principally made from the Industry Trends Program (ITP) but partially supported by ASP results).

[2] The performance measures involving precursor data (i.e., number of *significant* precursors and trend of all precursors) are the same for FYs 2009–2012.

Program Scope. The ASP Program is one of three agency programs that assess the risk significance of events. The other two programs are the Significance Determination Process (SDP) and the event response evaluation process, as defined in Management Directive (MD) 8.3, "NRC Incident Investigation Program." The SDP evaluates the risk significance of licensee performance deficiencies, while assessments performed under MD 8.3 are used to determine the appropriate level of reactive inspection in response to a significant event. Compared to the other two programs, the ASP Program assesses an additional scope of operating experience at U.S. NPPs. For example, the ASP Program analyzes initiating events as well as degraded conditions where no identified deficiency occurred in the licensee's performance. The ASP Program scope also includes events with concurrent, multiple degraded conditions.

3.0 ASP Program Status

The following subsections summarize the status and results of the ASP Program as of September 30, 2012.

FY 2011 Analyses. The ASP analyses for FY 2011 identified 22 precursors. All 22 precursors occurred while the plants were at power. The staff used the SDP to identify and assess 15 of the 22 precursors. In these cases, only the SDP significance category (i.e., the "color" of the finding) is reported in the ASP Program.

The CCDP for one FY 2011 analysis exceeded 1×10^{-4} (North Anna, Unit 1 precursor event that occurred on August 23, 2011); therefore, the analysis was sent for a formal 60-day review to the licensee, Region II, and the Office of Nuclear Reactor Regulation. All of the other ASP analyses were issued as final after completion of internal reviews in accordance with the ASP review process (see Ref. 2 and Figure 1).

In SECY-11-0138, "Status of the Accident Sequence Precursor Program and the Standardized Plant Analysis Risk Models," dated September 30, 2011, the staff committed to evaluate the flooding event at Fort Calhoun Station and the LOOP event caused by an earthquake at North Anna Nuclear Power Station, and to inform the Commission if *significant* precursors were identified. The ASP analysis of the North Anna event was completed on September 1, 2012. The final analysis results determined that precursors were not significant (i.e., the CCDPs were less than 1×10^{-3}). The final ASP results for the event at North Anna are provided in Table 1.

The staff also reviewed the plant information for Fort Calhoun Station during elevated Missouri River water levels that existed from June 2011 through August 2011 to determine if a separate ASP analysis was needed. The staff determined that a separate ASP analysis was not needed because of the following reasons. (1) The ASP Program analyzes the conditional risk of plant conditions caused by actual initiating events. As the Missouri river water level rose, the plant operators took actions in accordance with their procedures to maintain it in a safe condition. This was considered normal plant operations and not an "event". An external flooding that causes a plant upset (e.g. plant trip or loss of shutdown safety system) could be considered for ASP analysis. (2) The staff discussed the possibility of additional rain creating a more severe flood condition. However; the ASP program does not evaluate the hypothetical risk of initiating events that might have been more severe than the actual event. (3) An SDP analysis was conducted for the July 7th breaker fire which occurred during the flood condition and this was accepted by the ASP Program. (4) The plant entered the Inspection Manual Chapter 0350, "Oversight of Reactor Facilities in a Shutdown Condition Due to Significant Performance and/or

Operational Concerns," on December 13, 2011, which would address any additional risk-significant issues that were identified at Fort Calhoun Station.

Table 1 presents the results of the staff's ASP analyses for FY 2011 precursors that involved initiating events. Table 2 presents the analysis results for FY 2011 precursors that involved degraded conditions.

Table 1. FY 2011 precursors involving initiating events

Event Date	Plant	Description	CCDP
4/16/11	Surry 1	Dual unit loss of offsite power because of switchyard damage caused by a tornado. **LER 280/11-001**	9×10^{-5}
4/16/11	Surry 2	Dual unit loss of offsite power because of switchyard damage caused by a tornado. **LER 280/11-001**	7×10^{-5}
4/27/11	Browns Ferry 1	Extended loss of offsite power because of a tornado with an emergency diesel generator (EDG) unavailable due to test and maintenance. A subsequent loss of shutdown cooling occurred because of an EDG failure while the plant was in cold shutdown. **LER 259/11-001**	1×10^{-5}
4/27/11	Browns Ferry 2	Extended loss of offsite power because of a tornado with an emergency diesel generator (EDG) unavailable due to test and maintenance. A subsequent loss of shutdown cooling occurred because of an EDG failure while the plant was in cold shutdown. **LER 259/11-001**	1×10^{-5}
4/27/11	Browns Ferry 3	Extended loss of offsite power because of a tornado, with an EDG unavailable due to test and maintenance. **LER 259/11-001**	1×10^{-5}
5/10/11	Pilgrim	Failure to effectively implement operations and reactivity control standards and procedures during a reactor startup caused an unrecognized subcriticality and return to criticality with a subsequent reactor scram. ***Enforcement Action (EA)-11-174***	WHITE[3]
8/23/11	North Anna 1	Dual unit loss of offsite power caused by earthquake that coincided with the Unit 1 turbine-driven auxiliary feedwater (AFW) pump being out-of-service because of testing and the subsequent failure of a Unit 2 EDG. **LER 338/11-003**	2×10^{-4}
8/23/11	North Anna 2	Dual unit loss of offsite power caused by earthquake that coincided with the Unit 1 turbine-driven AFW pump being out-of-service because of testing and the subsequent failure of a Unit 2 EDG. **LER 338/11-003**	4×10^{-5}
9/25/11	Palisades	Inadequate work instructions led to the loss of a 125-volt, direct-current train and subsequent reactor trip. ***EA-11-243***	YELLOW[4]

[3] A WHITE finding corresponds to a licensee performance deficiency of substantial safety significance and has an increase in core damage frequency in the range of 10^{-6} to 10^{-5}.

[4] A YELLOW finding corresponds to a licensee performance deficiency of substantial safety significance and has an increase in core damage frequency in the range of 10^{-5} to 10^{-4}.

Table 2. FY 2011 precursors involving degraded conditions

Condition Duration	Plant	Description	ΔCDP/ SDP Color
15 years	Prairie Island 1	Battery chargers potentially inoperable because of an under-voltage condition. ***EA-11-110***	WHITE
19 months	Browns Ferry 1	Failure to establish adequate design control and perform adequate maintenance causes valve failure that led to a residual heat removal loop being unavailable. ***EA-11-018***	RED[5]
13 years	Cooper	Deficient emergency procedures could lead to operators failing to position valves necessary for core cooling during a postulated fire. ***EA-11-024***	WHITE
10 months	Byron 2	Failure to ensure that a flange connection on the EDG lube oil cooler was correctly torqued following maintenance. ***EA-11-014***	WHITE
33 years	Millstone 2	Inadequate procedures and operator errors caused unplanned reactivity additions during main turbine control valve testing. ***EA-11-047***	WHITE
1 day	Brunswick	Penetrations in exterior wall of EDG fuel oil structure could lead to failure of the EDGs during postulated flooding. ***EA-11-251***	WHITE
193 days	Palisades	Turbine-driven AFW pump unavailable because of greasing of the wrong component in the pump. ***EA-11-227***	WHITE
30 days	Limerick 2	Reactor core isolation cooling (RCIC) inoperable because of main feedwater valve failures diverting RCIC flow to the main condenser. ***EA-11-221***	WHITE
28 years	Oconee 1	Failure to maintain design control of the Standby Shutdown Facility (SSF) pressurizer heater breakers. ***EA-11-226***	YELLOW
28 years	Oconee 2	Failure to maintain design control of the SSF pressurizer heater breakers. ***EA-11-226***	YELLOW
28 years	Oconee 3	Failure to maintain design control of the SSF pressurizer heater breakers. ***EA-11-226***	YELLOW
19 months	Fort Calhoun	Fire in safety-related 480-volt electrical breaker because of deficient design controls during breaker modifications. Eight other breakers were susceptible to similar fires. ***EA-12-023***	RED
3 years	Palisades	Failure of a service water pump because of coupling failure. ***EA-11-241***	WHITE

FY 2012 Analyses. The staff immediately performs an initial review of events to determine if they have the potential to be *significant* precursors. Specifically, the staff reviews a combination of LERs (per Title 10 of the *Code of Federal Regulations* (10 CFR) 50.73, "Licensee Event Report System," and daily event notification reports (per 10 CFR 50.72, "Immediate Notification Requirements for Operating Nuclear Power Reactors") to identify potential *significant* precursors. The staff has completed the review of FY 2012 events and one potentially *significant* precursor was identified for loss of offsite power event and subsequent station blackout that occurred at Byron Station, Unit 2, on January 30, 2012. The ASP analysis of this event in underway. In addition, the evaluations of other FY 2012 events are ongoing. The staff will inform the Commission if *significant* precursors are identified. The staff will perform full ASP

[5] A RED finding corresponds to a licensee performance deficiency of substantial safety significance and has an increase in core damage frequency greater than or equal to 10^{-4}.

analyses of applicable events after the licensee and the NRC complete their follow-up actions, such as inspection and condition reporting.

4.0 Industry Trends

This section discusses the results of trending analyses for all precursors and *significant* precursors.

Statistically Significant Trend. Statistically significant is defined in terms of the "p-value." A p-value is a probability indicating whether to accept or reject the null hypothesis that no trend exists in the data. P-values of less than or equal to 0.05 indicate that there is 95 percent confidence that a trend exists in the data (i.e., reject the null hypothesis of no trend).

Data Coverage. The data period for the ASP trending analyses is a rolling 10-year period in alignment with the ITP. The following exception applies to the data coverage of *significant* precursors.

- The data for *significant* precursors includes events that occurred during FY 2012. The results for FY 2012 are based on the staff's screening and review of a combination of LERs and daily event notification reports (as of September 30, 2012). The staff analyzes all potential *significant* precursors (an event that has a probability of at least 1 in 1,000 of leading to a reactor accident) immediately.

4.1 Occurrence Rate of All Precursors

The NRC's ITP provides the basis for addressing the agency's safety-performance measure on the "number of statistically significant adverse trends in industry safety performance" (one measure associated with the safety goal established in the NRC's Strategic Plan). The mean occurrence rate of all precursors identified by the ASP Program is one indicator used by the ITP to assess industry performance.[6]

Results. A review of the data for that period reveals the following insights:

- The mean occurrence rate of all precursors does not exhibit a trend that is statistically significant (p-value = 0.99) for the period from FY 2002–2011 (see Figure 2).

- In addition, the mean occurrence rate of precursors with a CCDP or ΔCDP greater than or equal to 1×10^{-4} does not exhibit a statistically significant (p-value = 0.74) trend during this same period (see Figure 3).

    - There is an apparent increase of precursors in this subgroup in the past two years (one precursor in FY 2010 and three precursors in FY 2011) after no events were identified in the previous six years. These precursors involved different types of operational events (e.g., LOOP, failure of containment suction valve, and degraded electrical breakers) at different plants. The staff will continue to monitor this precursor subgroup to determine if any insights can be gained into the increase of these higher-risk events.

[6] The occurrence rate is calculated by dividing the number of precursors by the number of reactor years.

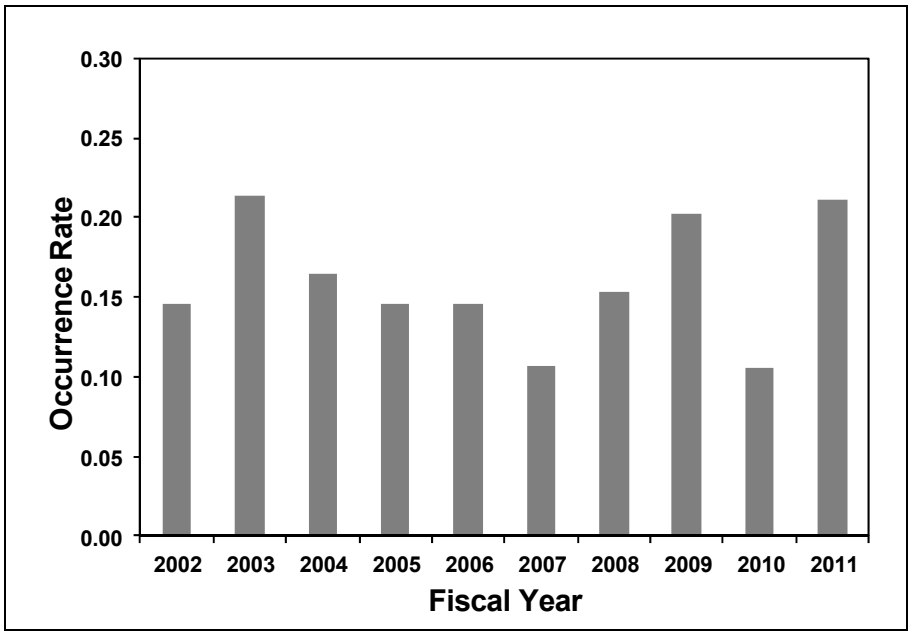

Figure 2. Total precursors

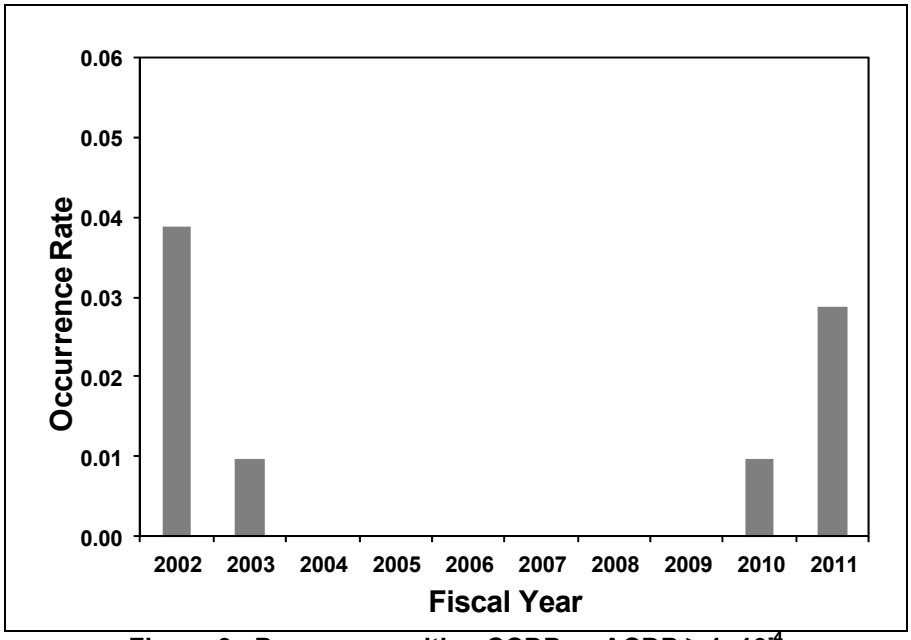

Figure 3. Precursors with a CCDP or ΔCDP ≥ 1×10^{-4}

4.2 *Significant* Precursors

The ASP Program provides the basis for the safety measure of zero "number of significant accident sequence precursors of a nuclear reactor accident" (one measure associated with the safety goal established in the NRC's Congressional Budget Justification (Ref. 1). Specifically, a *significant* precursor is an event that has a probability of at least 1 in 1,000 (i.e., greater than or equal to 1×10^{-3}) of leading to a reactor accident.

Results. A review of the data for that period reveals the following insights:

- Over the past 15 years, one *significant* precursor has been identified.[7] In FY 2002, the staff identified a *significant* precursor involving concurrent, multiple-degraded conditions at Davis-Besse.

5.0 Insights and Other Trends

The following sections provide additional ASP trends and insights for the period from FY 2002–2011.

5.1 Initiating Event and Degraded Condition Precursor Subgroup Trends

A review of the data for FY 2002–2011 yields insights described below.

Initiating Events

- The mean occurrence rate of precursors involving initiating events does not exhibit a trend that is statistically significant (p-value = 0.81) for the period from FY 2002–2011, as shown in Figure 4.

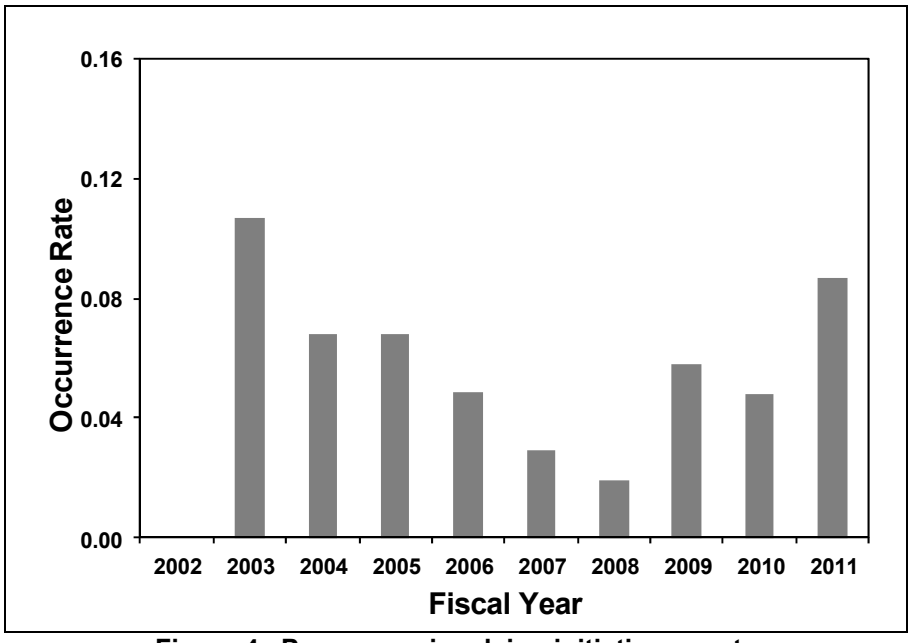

Figure 4. Precursors involving initiating events

- The apparent increase of precursors in this subgroup is largely attributed to the three LOOP events which resulted in seven FY 2011 precursors caused by external events (i.e., lightning strikes, tornadoes, and earthquake).

- Of the 55 precursors involving initiating events during FY 2002–2011, 56 percent were LOOP events. This is expected because uncomplicated transients typically do not exceed the threshold, while essentially all LOOPs do exceed the threshold. While the

[7] Reference 3 provides a complete list of all *significant* precursors from 1969–2011.

frequency of complicated transients is about the same as the frequency of LOOPs, the risk estimates for LOOPs are somewhat higher.

Degraded Conditions

- The mean occurrence rate of precursors involving degraded conditions does not exhibit a trend that is statistically significant (p-value = 0.81) during FY 2002–2011, as shown in Figure 5.

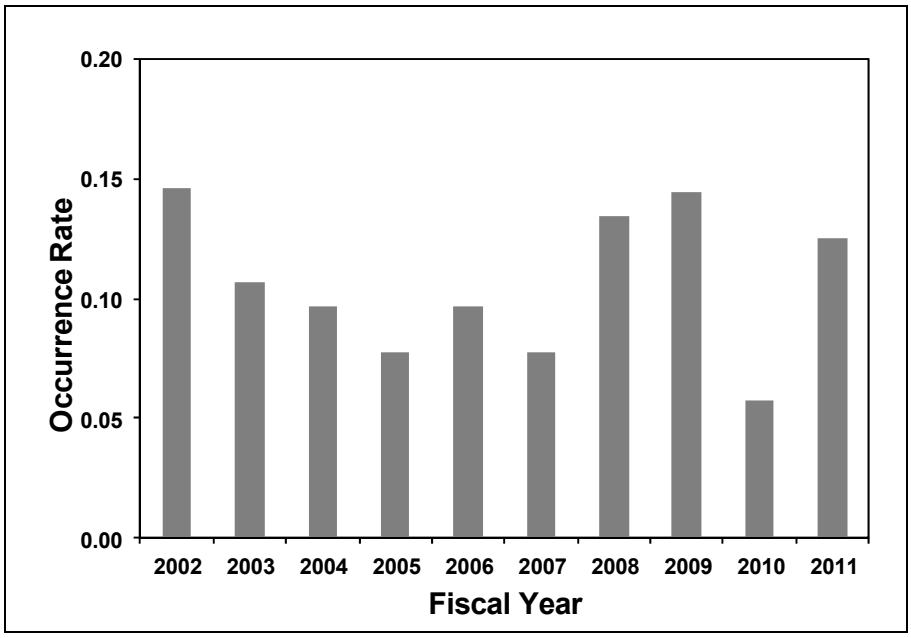

Figure 5. Precursors involving degraded conditions

- Over the past 10 years, precursors involving degraded conditions outnumbered initiating events two-to-one.

- From FY 2002–2011, 26 percent of precursors involved degraded conditions existing for a decade or longer.[8] Of these precursors, half involved degraded conditions dating back to initial plant construction.

5.2 Precursors Involving a Complete Loss of Offsite Power Initiating Events

In FY 2011, three LOOP events (resulting in seven precursors) were caused by external events (e.g., lightning strikes, hurricanes, tornadoes, and earthquake). Specifically, the LOOPs at Surry and Browns Ferry were caused by tornadoes and the LOOP at North Anna was caused by an earthquake. Typically, all complete LOOP events meet the precursor threshold.

Results. A review of the data for FY 2002–2011 leads to the following insights:

- The mean occurrence rate of precursors resulting from a LOOP does not exhibit a trend that is statistically significant (p-value = 0.65) for the period from FY 2002–2011, as shown in Figure 6.

[8] Note that although these degraded conditions lasted for many years, ASP analyses limit the exposure period to 1 year.

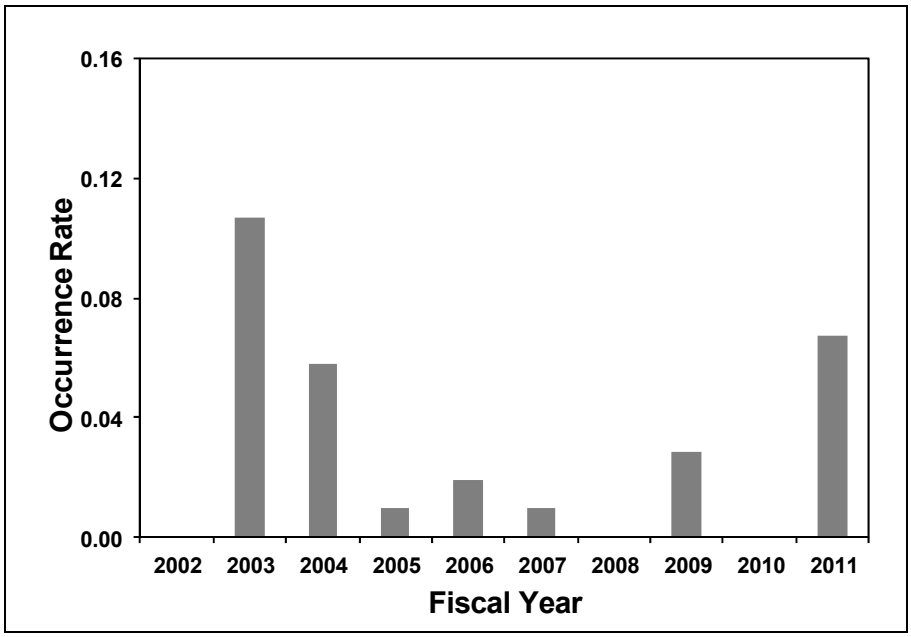

Figure 6. Precursors involving LOOP events

- Of the 31 LOOP precursors that occurred during FY 2002–2011, 39 percent resulted from external events and 35 percent resulted from a degraded electrical grid outside of the NPP boundary.
  - Eight of the 11 grid-related LOOP precursors were the result of the 2003 Northeast Blackout.
  - Seven of the 12 LOOP precursors that were caused by external events occurred in FY 2011. This is unusual and unprecedented, but there is no indication of a trend of these events.

- Four of the 31 LOOP precursor events during FY 2002–2011 involved a simultaneous unavailability of an emergency power system train.

5.3 Precursors at Boiling-Water Reactors and Pressurized-Water Reactors Subgroup Trends

A review of the data for FY 2002–2011 reveals the results for boiling-water reactors (BWRs) and pressurized-water reactors (PWRs) described below.

BWRs

- The mean occurrence rate of precursors that occurred at BWRs does not exhibit a trend that is statistically significant (p-value = 0.56) for FY 2002–2011, as shown in Figure 7.

- LOOP events contributed to 62 percent of precursors involving initiating events at BWRs.

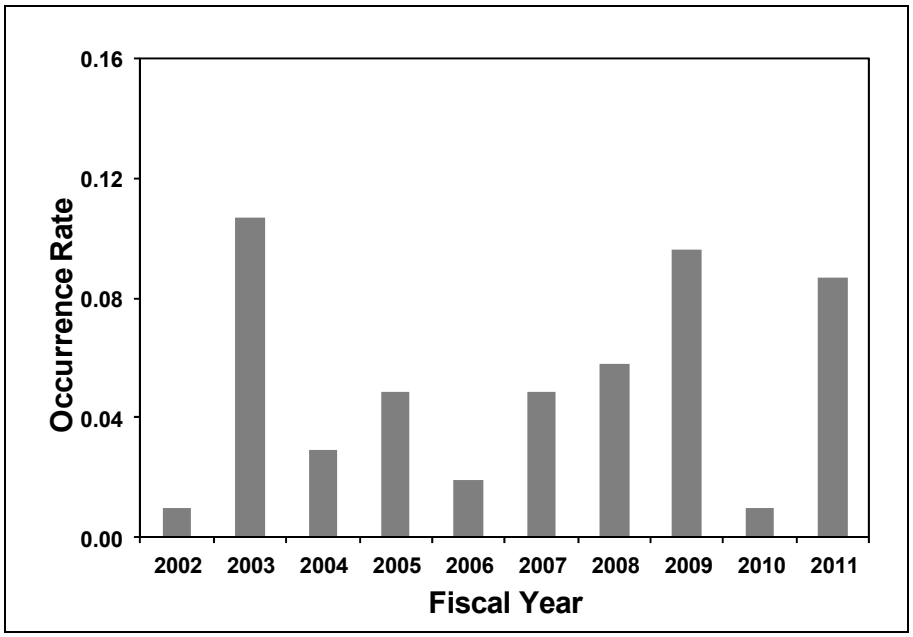

Figure 7. Precursors involving BWRs

- Of the 32 precursors involving the unavailability of safety-related equipment that occurred at BWRs during FY 2002–2011, most were caused by failures in the emergency power system (38 percent), emergency core cooling systems (25 percent), safety-related cooling water systems (13 percent), or electrical distribution system (9 percent).

PWRs

- The mean occurrence rate of precursors that occurred at PWRs does not exhibit a trend that is statistically significant (p-value = 0.39) for FY 2002–2011, as shown in Figure 8.

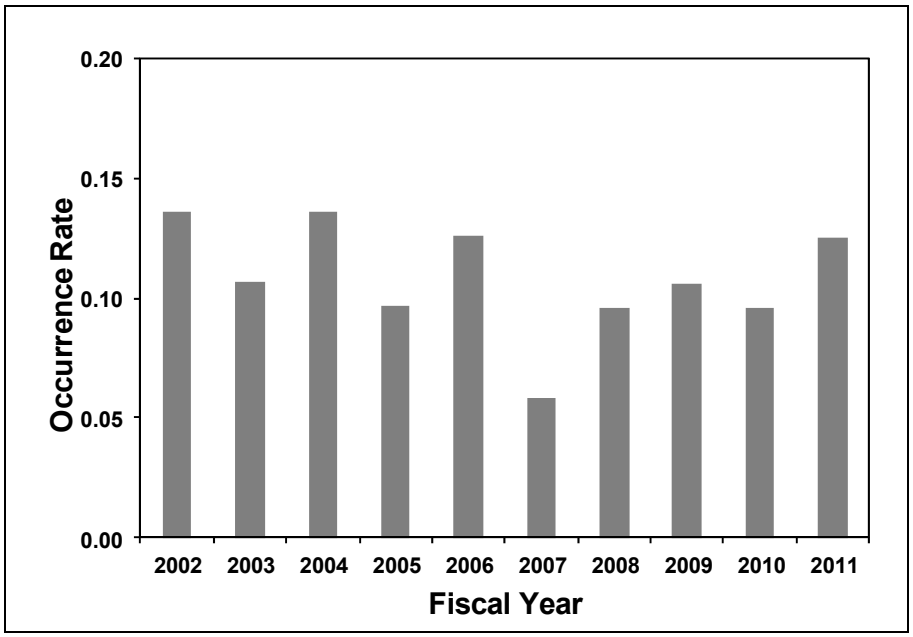

Figure 8. Precursors involving PWRs

- LOOP events contribute to 53 percent of precursors involving initiating events at PWRs.

- Of the 78 precursors involving the unavailability of safety-related equipment that occurred at PWRs during FY 2002–2011, most were caused by failures in the emergency power system (23 percent), emergency core cooling systems (22 percent), auxiliary feedwater system (19 percent), safety-related cooling water systems (13 percent), or electrical distribution system (13 percent).
  - Of the 17 precursors involving failures in the emergency core cooling systems, 13 precursors (76 percent) were because of conditions affecting sump recirculation during postulated loss-of-coolant accidents of varying break sizes. Design errors were the cause of most of these precursors (85 percent).
  - Of the 15 precursors involving failures of the auxiliary feedwater system, random hardware failures (47 percent) and design errors (53 percent) were the largest failure contributors. Thirteen of the 15 precursors (87 percent) involved the unavailability of the turbine-driven auxiliary feedwater pump train.
  - Of the 18 precursors involving failures of the emergency power system, 15 precursors (83 percent) were from hardware failures.
  - Design errors contributed 46 percent of all precursors involving the unavailability of safety-related equipment that occurred at PWRs during FY 2002–2011.

5.4 Integrated ASP Index

The staff derives the integrated ASP index for order-of-magnitude comparisons with industry-average core damage frequency (CDF) estimates derived from probabilistic risk assessments (PRAs) and the NRC's standardized plant analysis risk (SPAR) models. The index or CDF from precursors for a given fiscal year is the sum of CCDPs and ΔCDPs in the fiscal year divided by the number of reactor-operating years in the fiscal year.

The integrated ASP index includes the risk contribution of a precursor for the entire duration of the degraded condition (i.e., the risk contribution is included in each fiscal year that the condition exists). The risk contributions from precursors involving initiating events are included in the fiscal year that the event occurred.

Examples. A precursor involving a degraded condition is identified in FY 2011 and has a ΔCDP of 5×10^{-6}. A review of the LER reveals that the degraded condition has existed since a design modification that was performed in FY 2007. In the integrated ASP index, the ΔCDP of 5×10^{-6} is included in FYs 2007, 2008, 2009, 2010, and 2011 and is not prorated for any portion of the year that this condition existed but rather implemented for the entire year, which conservatively estimates the risk contribution during the first and last year. For an initiating event occurring in FY 2011, only FY 2011 includes the CCDP from this precursor.

Results. Figure 9 depicts the integrated ASP indices for FY 2002–2011. A review of the ASP indices leads to the following insights:

- Based on the order of magnitude (10^{-5}), the average integrated ASP index for the period from FY 2002–2011 is consistent with the CDF estimates from the SPAR models and industry PRAs.

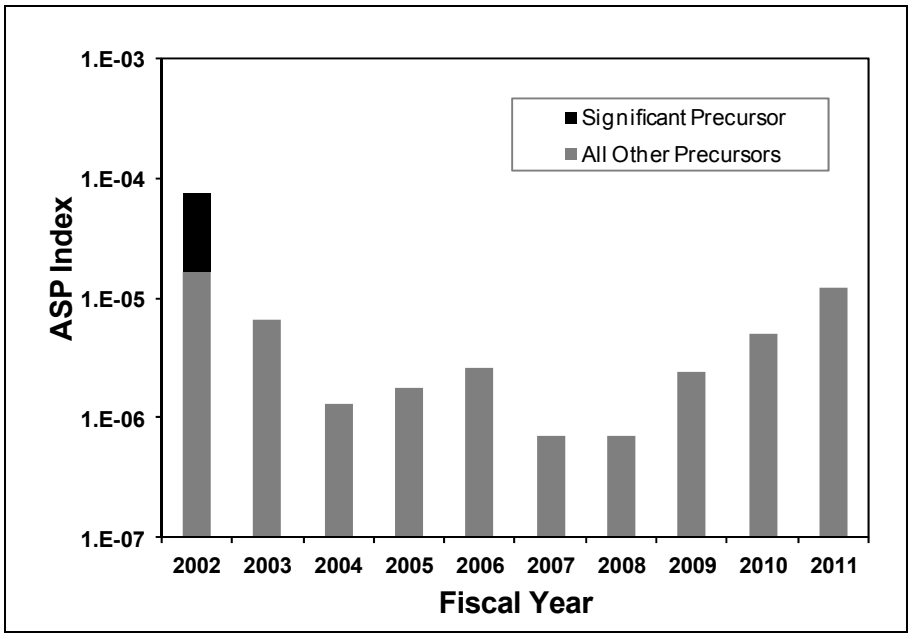

Figure 9. Integrated ASP index

- Precursors over the FY 2002–2011 period made the following contributions to the average integrated ASP index:
  - One *significant* precursor (i.e., CCDP or ΔCDP greater than or equal to 1×10^{-3}) contributed to 60 percent of the average integrated ASP index. The *significant* precursor (Davis-Besse, FY 2002) existed for 1 year.
  - The remaining 40 percent of the average integrated ASP index resulted from contributions from the 164 precursors.
  - The occurrence of three LOOP events (resulting in seven precursors) caused by external events led to a somewhat higher than usual value of this index in FY 2011. These events were mitigated without serious problems; therefore, the increase is not viewed to be significant.

Limitations. Using CCDPs and ΔCDPs from ASP results to estimate CDF is difficult because (1) the mathematical relationship between CCDPs, ΔCDPs, and CDF requires a significant level of detail, (2) statistics for frequency of occurrence of specific precursor events are sparse, and (3) the assessment also must account for events and conditions that did not meet the ASP precursor criteria.

The integrated ASP index provides the contribution of risk (per fiscal year) resulting from precursors and cannot be used for direct trending purposes because the discovery of precursors involving longer-term degraded conditions in future years may change the cumulative risk from the previous year(s).

5.5 Operating Experience Insights Feedback for PRA Standards and Guidance

A secondary objective of the ASP Program is to provide a partial validation of the current state of practice in risk assessment. ASP events from this fiscal year were reviewed against the approaches to PRA described in the American Society of Mechanical Engineers (ASME) RA-S-2008, "Standard for Probabilistic Risk Assessment for Nuclear Power Plant Applications,"

(Ref. 4), as endorsed in Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," (Ref. 5). None of the events indicated an inadequacy in the state of PRA practice as described in ASME RA-S-2008.

6.0 Summary

This section summarizes the ASP results, trends, and insights:

- ***Significant Precursors.*** The staff identified no *significant* precursors (i.e., CCDP or ΔCDP greater than or equal to 1×10^{-3}) in FY 2011. The staff identified one potentially *significant* precursor in FY 2012. The staff will continue the analysis of the event that occurred at Byron, Unit 2. The ASP Program provides the basis for the safety-performance measure goal of zero "number of significant accident sequence precursors of a nuclear reactor accident." The final results will be provided in the FY 2012 Performance and Accountability Report.

- ***Occurrence Rate of All Precursors.*** The occurrence rate of all precursors does not exhibit a trend that is statistically significant during FY 2002–2011. The trend of all precursors is one input into the ITP to assess industry performance and is part of the input into the adverse trends safety measure. These results will be provided in the FY 2012 Performance and Accountability Report.

- ***Additional Trend Results.*** During the same period, no trends were observed in other precursor subgroups.

7.0 References

1. U.S. Nuclear Regulatory Commission, "Performance Budget: Fiscal Year 2013," NUREG-1100, Vol. 28, February 2012.

2. U.S. Nuclear Regulatory Commission, "Revised Review and Transmittal Process for Accident Sequence Precursor Analyses," Regulatory Issue Summary 2006-24, December 2006.

3. U.S. Nuclear Regulatory Commission, "Status of the Accident Sequence Precursor Program and the Standardized Plant Analysis Risk Models," Commission Paper SECY-11-0138, September 30, 2011.

4. American Society of Mechanical Engineers, "Standard for Probabilistic Risk Assessment for Nuclear Power Plant Applications," Revision 1, RA-S-2002, New York, NY, April 2008.

5. U.S. Nuclear Regulatory Commission, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," Regulatory Guide 1.200, Revision 2, March 2009.

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 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) and 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 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. 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 79 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:

- 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 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 models 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-11-0138, "Status of the Accident Sequence Precursor Program

and the Standardized Plant Analysis Risk Models," dated September 30, 2011) as described below.

Technical Adequacy of SPAR Models

The staff implemented a SPAR Model Quality Assurance Plan covering the SPAR models in 2006, which was recently updated. 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 (PWR) reactor SPAR model in accordance with American Society of Mechanical Engineers (ASME) RA-S-2008, "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. 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 loss of offsite power modeling, and addressing the high priority items for the BWR models. These activities have been delayed approximately 1 year because of higher priority Reactor Oversight Process support and activities related to the Fukushima Dai ichi event in Japan. The staff is planning to complete this effort in 2014.

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

A SPAR all-hazards model was completed for Shearon Harris Nuclear Power Plant that is available in the SPAR models library for use by NRC risk analysts. Currently, 18 SPAR models have all-hazard scenarios (previously labeled as "external event" scenarios), as well as "internal event" scenarios. The Shearon Harris all-hazards model also incorporated internal fire scenarios from the National Fire Protection Association (NFPA) 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," pilot application. Based on a request from the Office of Nuclear Reactor Regulations to the Office of Nuclear Regulatory Research (RES), the NRC is conducting further work to add more models and update current models. The existing all-hazards SPAR models allow 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, eight SPAR models that contain selected shutdown event scenarios, as well as internal event scenarios, have been developed. A handbook for 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 all support these models. Currently, the NRC has no plans to make further SPAR shutdown models. Available models, together with the supporting documents, can be used to support SDP Phase 3 evaluations of LPSD events and degraded conditions for other plants, by generating further models from the existing templates.

New Reactor SPAR Models

Before 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 staff for the evaluation of operational findings and events similar to the assessments performed for current operating reactors.

The staff has 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/General Electric design. As part of the SPAR model development, the staff also completed the requisite supporting documentation. Although the SPAR model for the ABWR/Toshiba reactor design has been completed, the staff is currently working on a modification to incorporate a LPSD model. Work on this matter is progressing, and the model will soon be posted for internal review and comments.

The staff also has developed a design-specific internal events SPAR model for the U.S. Advanced PWR. The staff has initiated work on developing a design-specific internal events SPAR Model for the U.S. Evolutionary Power Reactor (EPR). The SPAR model fault tree and event tree development for the U.S EPR is in progress.

Although the staff completed the AP1000 SPAR model in February 2010, a modification was made to the SPAR model to include an external events seismic model. This modification has been completed and submitted to the Office of New Reactors for review, and comments are being resolved.

The staff plans to continue to develop 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.

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. The results of these analyses, which are documented in NUREG-1953, "Confirmatory Thermal-Hydraulic Analysis to Support Specific Success Criteria in the Standardized Plant Analysis Risk Models—Surry and Peach Bottom," 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 eight PWR SPAR models. RES is currently performing similar analyses for the Byron plant, and plans to use these results 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.

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.

SPAR Models Plant Risk Information e-Books

The staff completed the development of new Plant Risk Information e-Books (PRIBs) for all 79 SPAR models. The PRIB reports identify risk significant systems, structures, and components and provide summary risk information for each operating nuclear power plant. These reports will support the transition of the SDP from the use of Phase 2 notebooks to the Systems Analysis Program for Hands-On Integrated Reliability Evaluations (SAPHIRE) computer code platform.

3.0 Additional Activities

SAPHIRE Maintenance and Improvements

In fiscal year (FY) 2012, new features and capabilities have been implemented in SAPHIRE to better support NRC regulatory activities. SAPHIRE includes a new common-cause failure (CCF) probability calculation module. The module provides greater transparency of the CCF terms and calculation details to the users. SAPHIRE also has been modified to automatically adjust the applicable CCF probabilities when performing event and condition assessments. This is an improvement on previous versions of SAPHIRE, which required the user to make manual adjustments to achieve the correct CCF calculations. SAPHIRE also includes a new module for analyzing convoluted probability distributions. This type of analysis is used for modeling recovery from station blackout conditions (e.g., recovery of any available emergency diesel generator during a specified time window). In addition, the SAPHIRE developers are exploring new quantification techniques that can improve upon the approximation and truncation methods that are commonly used in PRA software. One method that has been explored is the use of binary decision diagrams (BDDs). A new BDD quantification tool is being incorporated into SAPHIRE. The work on this tool is expected to be competed in FY 2012. All of these improvements to SAPHIRE have been performed in accordance with the SAPHIRE software quality assurance program. A set of software quality assurance 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 February 1, 2012.

Another aspect of the ongoing review and improvement of SAPHIRE during FY 2012 was the staff's response to an audit by the Office of the Inspector General (OIG), which is documented in the audit report OIG-11-A-18. The results of the audit found that SAPHIRE met its operational capabilities, but there were additional measures the NRC should take to ensure SAPHIRE is properly managed. Several improvements were made to the management of the SAPHIRE program in response to the recommendations in the audit report. The staff developed formal guidelines for granting access to SAPHIRE and implemented a process to annually review individual users to determine if access to SAPHIRE is still required. In addition, the staff redesigned the SAPHIRE Web site and implemented improved access controls. The new

web site design incorporates user support features, including an automatic password retrieval system to assist active users in maintaining access to the secure site. The OIG found the staff's response to the audit acceptable, and all recommendations were closed on April 12, 2012.

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. The staff also continues to work with the National Aeronautical and Space Administration to address PRA issues of mutual interest. In addition, during FY 2012, the NRC used the cooperative agreement and grant program to establish collaborative PRA research projects with the University of Maryland and Ohio State University. 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 the 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, and
- 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 (SSIE) 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 SSIE methodology and the improved treatment of LOOP events to further enhance the realism and accuracy of the SPAR models. These methodologies will be implemented in the SPAR models as one of the activities associated with addressing the peer review comments. To date, 37 models have been enhanced with the improved SSIE modeling methodology and 57 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

RES continues to enhance SAPHIRE and the SPAR models to support development of integrated models. To this end, RES is developing an integrated model for Peach Bottom Unit 2 containing state-of-the-practice SPAR models for Level 1 internal events at-power, shutdown,

external hazards, and Level 2. This effort includes the incorporation of other ongoing modeling initiatives (e.g., modeling of SSIEs, use of modeling features new to SAPHIRE (e.g., phases), and further development of the Level 2 PRA model. This work is scheduled for completion at the end of the calendar year and is expected to directly benefit the RES Vogtle site Level 3 PRA project.