POLICY ISSUE
INFORMATION

March 8, 2002 SECY-02-0041

FOR: The Commissioners

FROM: William D. Travers
Executive Director for Operations

SUBJECT: STATUS OF ACCIDENT SEQUENCE PRECURSOR AND SPAR MODEL DEVELOPMENT PROGRAMS

PURPOSE:

To inform the Commission of the status of the Accident Sequence Precursor (ASP) Program and the development of the Standardized Plant Analysis Risk (SPAR) models that support this programs.

SUMMARY:

In an April 24, 1992, memorandum to the Chairman, the staff committed to report periodically to the Commission on the status of efforts to improve the ASP Program. In SECY-94-268, dated October 31, 1994, two changes were made to the report. First, the staff committed to provide the report annually, and second, the staff began providing annual quantitative ASP results.

Since the last status report, SECY-00-034, dated March 1, 2001, the staff has:

- Completed evaluating Fiscal Year (FY) 1999 events for precursors; completed preliminary analyses of FY 2000 precursors; and continued analyzing FY 2001 events.
- Evaluated trends in the precursor data.
- Continued developing SPAR models.

BACKGROUND:

The discussion below provides a brief background of the ASP and SPAR Model Development Programs and their uses.

CONTACTS: Don Marksberry, RES, 301-415-6378 (ASP Program)
Patrick O'Reilly, RES, 301-415-7570 (SPAR models)

***ASP Program*.** The ASP Program was established by the NRC in 1979 in response to the Risk Assessment Review Group report (see NUREG/CR-0400, September 1978). The primary objective of the ASP Program is to systematically evaluate U.S. nuclear plant operating experience to identify, document, and rank operating events most likely to lead to inadequate core cooling and severe core damage (precursors), if additional failures had occurred.

The secondary objectives of the ASP Program are

- To categorize the precursors by their plant-specific and generic implications,

- To provide a measure for trending nuclear plant core damage risk, and

- To provide a partial check on probabilistic risk assessment (PRA)-predicted dominant core damage scenarios.

The program is also used to monitor the agency's performance against the following Strategic Plan performance goals in the Reactor Safety arena for maintaining safety (see Volume 2, Part 1, of NUREG-1614, September 2000):

> No more than one event per year identified as a significant precursor (i.e., conditional core damage probability or importance $\geq 1 \times 10^{-3}$) of a nuclear reactor accident.
>
> No statistically significant adverse industry trends in safety performance.[1]

Events and conditions from licensee event reports, inspection reports, and special requests from NRC staff are reviewed for potential precursors. These potential precursors are analyzed, and a conditional core damage probability (CCDP) is calculated by mapping failures observed during the event onto accident sequences in risk models. An event with a CCDP or a condition with a change in core damage probability (ΔCDP or importance) greater than or equal to 1.0×10^{-6} is considered a precursor in the ASP Program.

Current ASP analyses do not explicitly include uncertainties for calculating CCDPs. Revision 3 of the SPAR models includes uncertainty analysis capability for future ASP analyses. Sensitivity analyses are used to assess the impact of uncertainties in key parameters that could influence the characterization of an event as a precursor (CCDP or ΔCDP $\geq 1.0 \times 10^{-6}$), important precursor (CCDP or ΔCDP $\geq 1.0 \times 10^{-4}$) or significant precursor (CCDP or ΔCDP $\geq 1.0 \times 10^{-3}$).

***SPAR Model Development Program*.** SPAR models are the analysis tool used by staff analysts in many regulatory activities, including the ASP Program and Phase 3 of the Significance Determination Process (SDP). The SPAR models have evolved from two sets of simplified event trees that were used initially to perform precursor analyses in the early 1980s. One set of event trees was used for boiling-water reactors (BWRs) and one set for pressurized-water reactors (PWRs) to model plant response to the same set of initiating events. In 1985, the models were improved to better reflect the operating plant population by

[1]One industry trend indicator used in this performance measure was provided by the ASP Program for FY 2000. The Industry Trends Program is discussed in SECY-01-0111, "Development of an Industry Trends Program for Operating Power Reactors."

using eight plant classes of event trees that reflected differences among the plant designs. In 1992, the staff conducted a workshop of internal and external stakeholders to discuss the methods, models, and data needs of the program to better meet the program's objectives. The results and recommendations generated at this meeting were documented in NUREG/CP-0124 (June 1992). In response to the recommendations, the staff prepared the Integrated ASP Program Plan (Enclosure 1 to SECY-94-076, March 22, 1994) for improving the models used for ASP analyses. Among the improvements identified was the development of Level 1, Revision 1 SPAR models, which included plant-specific fault trees and other improvements to the existing event tree-based models. Another improvement was the development of feasibility studies for specialized models, such as low power or shutdown, external events, and Level 2 models. In 1998, Revision "2QA" SPAR models were issued that more closely reflected plant-specific risk based on comments generated by peer reviews of precursor analyses and models.

In 1999, the SPAR Model Users Group (SMUG) assumed coordination of model development efforts that support the ASP Program and other risk-informed regulatory processes. This group is comprised of representatives from the Offices of Nuclear Reactor Regulation and Nuclear Regulatory Research, and regional offices that use reactor plant risk models in regulatory activities. In August 2000, the SMUG completed the SPAR Model Development Plan, which conforms to the modeling needs identified by SMUG members and their management for performing risk-informed regulatory activities. The following models are addressed in this plan:

- Level 1: Internal events during full power operation
- Level 1: Internal events during low-power and shutdown operations
- Level 1: External events (including fires, floods, seismic events)
- Level 2: Large early release frequency (LERF).

Uses. The NRC staff uses the ASP methodology, SPAR models, and results of ASP analyses to perform the following risk-informed regulatory activities:

(1) Promptly assess the risk significance of operational events to support regulatory decisions by senior management.

(2) Evaluate the significance of inspection findings as part of the agency's reactor oversight process (ROP), in Phase 3 of the significance determination process (SDP).

(3) Establish plant-specific, risk-informed thresholds to support the development of enhanced performance indicators for the ROP.

(4) Develop risk-informed thresholds for industry-level indicators in the Industry Trends Program.

(5) Evaluate the change in risk associated with licensing amendments submitted by licensees requesting changes in surveillance frequencies or allowed outage times.

(6) Support decisions to develop generic communications.

(7) Systematically screen, review, and analyze operational experience data for accident sequence precursors.

(8) Evaluate the generic implications of precursors; trend industry performance; and compare results against PRAs.
(9) Perform regulatory analyses to resolve generic issues.

DISCUSSION:

This section provides summaries of historical trends and insights, documentation and issuance of ASP results, and status of SPAR model development.

Historical Trends and Insights

A review of the ASP analyses[2] for FYs 1999, 2000, and 2001 and a comparison with analyses from previous years for insights and trends are summarized in the Attachment. The ASP results used to monitor the agency's performance against the two Strategic Plan goals are as follows:

Significant Precursors. The Strategic Plan performance goal is "No more than one event per year identified as a *significant* precursor of a nuclear accident." A *significant* precursor is defined in the Strategic Plan as an event that has a 1/1000 (10^{-3}) or greater probability of leading to a reactor accident.

No *significant* precursors were identified during FYs 1999, 2000, and 2001[3] with a CCDP or $\Delta CDP \geq 1.0 \times 10^{-3}$. *Significant* precursors have occurred, on the average, about once every 4 to 5 years. The events in the *significant* precursor group involve differing failure modes, causes, and systems.

Industry Trends. The occurrence rate of precursors has exhibited a decreasing trend that is almost statistically significant during the 1993–2000 period (see Figure 1 of the Attachment). The occurrence rate of precursors has decreased over the period by about a factor of 2.

Documentation and Issuance of ASP Results

There are 17 reports in the NUREG/CR series documenting the results of the ASP Program covering the years 1969–1998. The precursor report for FY 1999 was completed and sent to publications in September 2001. However, the report was subsequently withdrawn from distribution because of the agency's heightened awareness of the release of sensitive information to the public following the September 11th terrorist attacks. In addition, preliminary and final precursor analyses are not yet being issued to licensees or released to the public pending Agency guidance (in response to the Staff Requirements Memorandum, "Staff Requirements - COMSECY-01-0030 - Guidance to the Staff on Release of Information to the Public," dated January 25, 2002) and office procedures for classifying and transmitting sensitive information involving results of risk analyses. Staff is working to resolve this issue as soon as possible.

---

[2]Results for FY 1999 are based on final analyses. Results for FY 2000 are based on a combination of final and preliminary analyses. The preliminary analysis of events in FY 2001 is ongoing.

[3]Although, preliminary analyses of events in FY 2001 are ongoing, the screening and review of FY 2001 events for potential significant precursors were completed.

Trends in ASP events are also displayed on the NRC web page maintained by NRR for the industry trends program. The ASP trends on this page will be updated after this status report is issued.

SPAR Model Development

The SPAR Model Users Group (SMUG) is comprised of representatives from each of the organizations within the agency's program and regional offices that use risk models in regulatory activities. The SMUG meets on a regular basis to provide technical guidance for the SPAR Model Development Program consistent with the approved Integrated SPAR Model Development Plan. This plan conforms to the modeling needs identified by the SMUG members and their management for performing risk-informed regulatory activities.

In the last year, the staff completed the following activities in model and methods development:

Level 1: Internal events during full power operation

- Maintained Revision 2QA SPAR models on an as-needed basis (e.g., add plant features not previously modeled, correct a deficiency). These models are currently used by the staff to perform risk-informed regulatory activities.

- Completed 19 Revision 3i SPAR models (the "i" stands for interim; most of these models have not undergone an onsite QA review). To date, 60 Revision 3i SPAR models out of a total of 70 have been produced.

- Completed the onsite QA review of ten Revision 3i SPAR models. These onsite reviews were performed in conjunction with NRR's benchmarking of the SDP Plant Notebooks. A total of 20 of the 60 Revision 3i models have undergone onsite review.

Level 1: Internal events during low-power and shutdown operations

- Completed preliminary templates for developing low-power/shutdown models for all pressurized-water reactors and for boiling-water reactor models for BWR 4 and BWR 5/6 designs.

Level 2: Large early release frequency (LERF)

- Began evaluation of the current capabilities to model Level 2/LERF sequences for risk-informed staff activities and to plan future development work.

/RA/

William D. Travers
Executive Director
for Operations

Attachment: Results, Trends, and Insights from the ASP Program

SECY PAPER DATED: / /02

SUBJECT: STATUS OF ACCIDENT SEQUENCE PRECURSOR AND SPAR MODEL DEVELOPMENT PROGRAMS

Distribution (w/attch):

OERAB RF
DRAA RF
OEDO RF
(WITS NO 9200101)
Public
File Center
MCunningham, RES
MMayfield, RES
FEltawila, RES
JFlack, RES
BSheron, NRR
GHolahan, NRR
RWBorchardt, NRR
WDean, NRR
DMatthews, NRR
LMarsh, NRR
MJohnson, NRR
DCoe, NRR
ECobey, NRR
RBarrett, NRR
PWilson, NRR
WLanning, RI
JShedlosky, RI
JTrapp, RI
CCasto, RII
RBernhard, RII
WRogers, RII
JGrobe, RIII
MParker, RIII
SBurgess, RIII
AHowell, RIV
TPruett, RIV
DO'Neal, NRR
MFields, NRR
PO'Reilly, RES
TBoyce, NRR
DRasmuson, RES
ELois, RES
JRidgely, RES
VHodge, NRR
HVanderMolen, RES

DOCUMENT: A:SP02-0041.wpd

***See previous concurrence**

To receive a copy of this document, indicate in the box "C" copy w/o attach/encl "E" copy w/attach/encl "N" no copy

OFFICE	OERAB*	E	OERAB*	E	OERAB*	E	DRAA*	E
NAME	DMarksberry		SMays		PBaranowsky		SNewberry	
DATE	2/9/02		12/05/01		12/05/01		12/11/01	
OFFICE	NRR*	E	RES*	E	DEDR		EDO	
NAME	SCollins		AThadani		CPaperiello		WTravers	
DATE	12/28/01		1/18/02		03/07/02		03/08/02	

OFFICIAL RECORD COPY

OAR in ADAMS? (Y or N)		**Publicly Available? (Y or N)**	

Template Number: RES-006 Accession Number: ML020420319 RES File Code: 2C-3

Results, Trends, and Insights from the ASP Program

This section describes the status of Accident Sequence Precursor (ASP) analysis of Fiscal Year (FY) 1999, 2000, and 2001 events, the analysis of historical Accident Sequence Precursor (ASP) trends, and the evaluation of insights.

1.0 ASP Event Analyses

The status of analyses is provided in Table 1. The results are summarized below.

FY 1999 analyses. The final analyses of events in FY 1999 were completed in September 2001. Peer review comments were received from the respective licensee and NRC staff and incorporated into the final analysis. Seven of the initiating events and conditions that occurred during FY 1999 had a conditional core damage probability (CCDP) or a change in core damage probability (ΔCDP or importance) $\geq 1 \times 10^{-6}$. Of these seven precursors, all were at-power precursors.

The results of final ASP analyses for FY 1999 are presented in Table 2 for precursors involving initiating events and Table 3 for precursors involving conditions.

FY 2000 analyses. The screening, review, and preliminary analysis of events in FY 2000 were completed in February 2002. The final analysis of four precursors were completed. The issuance of preliminary analyses for licensee peer review was delayed because of the agency's heightened awareness of the release of sensitive information to the public following the September 11th terrorist attacks. This will delay the completion of the remaining final analyses.

The ASP analyses identified 14 precursors for FY 2000 (4 precursors based on final analyses, 10 precursors based on preliminary analyses). Of these 14 precursors, all were at-power precursors.

The results of ASP analyses for FY 2000 are presented in Table 4 for precursors involving initiating events and Table 5 for precursors involving conditions.

FY 2001 analyses. The screening and review of licensee event reports (LERs) of events in FY 2001 were completed in January 2002. The preliminary analyses are ongoing.

A combination of LERs and daily event notification reports (10 CFR 50.72) were reviewed to identify potential significant precursors (CCDP or ΔCDP $\geq 1 \times 10^{-3}$). No such events were identified for FY 2001.

2.0 Overall Industry Trends

This section provides the results of trending analyses for all precursors and for precursors grouped by the order of magnitude of their CCDP or ΔCDP (called CCDP bins).

Note: The trending results cover the FY 1993–2000 period. Although most of the results for FY 2000 are preliminary, all preliminary analyses have undergone in-house review. However, FY 2000 results are subject to change when they become finalized. Results for FY 2001 are not included in the trends because the preliminary analyses of all events are not complete.

2.1 Occurrence Rate of Precursors

The 1993–2000 occurrence rate of all ASP precursors are trended by fiscal year. The trend plot is shown in Figure 1.

The mean occurrence rate of precursors has exhibited a decreasing trend that is almost statistically significant. The occurrence rate of precursors has decreased over the period by a factor of 2.

2.2 Occurrence Rate of Precursors by CCDP Bins

In addition to the occurrence rate of all precursors, the data were analyzed to determine whether trends exist in the occurrence rate of precursors with CCDP of different orders of magnitude. The analysis method is based on a staff technical paper reported in Reference 1.

The objective of this analysis was to determine whether a trend exists in the ASP precursor bin data. The results of the trending analysis of the four probability bins ($\geq 10^{-3}$, 10^{-4}, 10^{-5}, 10^{-6}) for the FY 1993–2000 period are as follows:

CCDP Bin	Trend (FY 1993–2000[a])
$\geq 10^{-3}$	No statistically significant trend
10^{-4}	Decreasing–statistically significant
10^{-5}	Decreasing–statistically significant
10^{-6}	No statistically significant trend

a. Results for FY 2000 are preliminary

A histogram of the occurrence rate as a function of fiscal year for each probability bin is provided in Figures 2a-d. The trend line of the mean occurrence rate (with the 90% confidence band) is shown in the two figures with statistically significant trends. No trend line is shown when a statistically significant trend was not detected.

3.0 Insights

The number of *significant* precursors presented in Section 3.1 cover the FY 1993–2001 period. The result for FY 2001 is based on the screening and review of a combination of LERs and daily event notification reports (10 CFR 50.72).

The insights presented in the remaining sections cover the FY 1993–2000 period. Although most of the results for FY 2000 are preliminary, all preliminary analyses have undergone in-house review. However, FY 2000 results are subject to change when they become finalized.

3.1 Significant Precursors

The ASP Program is used to monitor the agency's performance against the following Strategic Plan performance goal: "No more than one event per year identified as a significant precursor of a nuclear accident." A *significant* precursor is defined in the Strategic Plan as an event that has a 1/1000 (10^{-3}) or greater probability of leading to a reactor accident (Ref. 2).

No *significant* precursors were identified during FYs 1999, 2000, and 2001 with a CCDP or ΔCDP $\geq 1.0 \times 10^{-3}$. *Significant* precursors have occurred, on the average, about once every 4 to 5 years. The events in this group involve differing failure modes, causes, and systems.

Two precursors with a CCDP $\geq 1.0 \times 10^{-3}$ have occurred since 1991—the Wolf Creek event involving a reactor coolant system draindown to the refueling water storage tank during hot shutdown (1994) and the Catawba 2 event involving an extended plant-centered loss of offsite power with an emergency diesel generator out of service for maintenance (1996).

3.2 Important Precursors

Precursors with a CCDP or ΔCDP $\geq 1.0 \times 10^{-4}$ are considered *important* in the ASP Program. There were no *important* precursors in FY 1999. Two *important* precursors were identified in FY 2000—the Cook 1 and 2 conditions involving potential high-energy line breaks.

The review of the ASP data reveals the following:

- The mean occurrence rate of *important* precursors has exhibited a decreasing trend that is statistically significant during the FY 1993–2000 period (Fig. 3). The mean occurrence rate of precursors decreased over this period by a factor of 6.

- During the FY 1993–2000 period, 16 *important* precursors have occurred. Of these, 38% involved a loss of offsite power initiating event.

3.3 Initiating Events vs. Conditions

A precursor can be the result of an operational event involving an actual *initiating event* (e.g., loss of offsite power) or a precursor can be a *condition* found during a test, inspection, or engineering evaluation. A *condition* involves a reduction in safety system reliability or function for a specific duration (and no initiator actually occurred during this time).

Five of the seven precursors in FY 1999 involved *conditions* (unavailability of equipment); two involved *initiating events*. In FY 2000, 12 of the 14 precursors involved *conditions*; two involved *initiating events*.

A review of the data reveals the following:

- The results for FY 1999 and FY 2000 are consistent with the FY 1993–2000 results. Historically, *conditions* (64%) outnumbered *initiating events* (36%). In FY 1999, *conditions* contributed to 71% of the precursors. In FY 2000, *conditions* contributed to 86%. This indicates that risk-significant conditions are being identified prior to unplanned demands of the degraded safety systems.

- The mean occurrence rate of precursors involving *initiating events* has exhibited a decreasing trend that is statistically significant during the FY 1993–2000 period (Fig. 4). The occurrence rate of precursors decreased over this period by a factor of 5.

- No trend that was statistically significant was detected for precursors involving conditions (Fig. 5).

3.4 Precursors Involving Loss of Offsite Power Initiating Events

One precursor involving a loss of offsite power (LOOP) initiating event occurred in both FY 1999 and FY 2000—the Indian Point 2 loss of offsite power to safety-related buses following a reactor trip (1999) and the Diablo Canyon 1 extended loss of offsite power (2000).

The review of the ASP data reveals the following:

- The mean occurrence rate of LOOP precursor events exhibited a decreasing trend that is almost statistically significant during the FY 1993–2000 period (Fig. 6). The occurrence rate of precursors decreased over this period by a factor of 4.
- Over one-third (38%) of the LOOP precursor events that occurred during FYs 1993–2000 are considered *important* precursors (CCDP $\geq 1.0 \times 10^{-4}$) in the ASP Program.

- A simultaneous unavailability of an emergency power system train and a LOOP were also involved in 3 of the 15 LOOP precursor events during the FY 1993–2000 period. Two of the precursors involving a LOOP event and an emergency power train unavailability had a CCDP $\geq 1\times10^{-4}$.

- None of the precursors since 1989 have involved a grid-related LOOP event.

3.5 Precursors at BWRs vs. PWRs

None of the precursors in FY 1999 and FY 2000 occurred at a boiling-water reactor (BWR); there has been only one such precursor since 1996. A review of the data for BWRs and pressurized-water reactors (PWRs) during the FY 1993–2000 period reveals the following:

- *BWRs.* The mean occurrence rate of precursors at BWRs has exhibited a decreasing trend that is statistically significant during the FY 1993–2000 period (Fig. 7). The mean occurrence rate of precursors has decreased during this period by a factor of 17.

- *PWRs.* No trend that was statistically significant was detected for the mean occurrence rate of precursors at PWRs (Fig. 8). Historically, precursors occur at a PWR on an average of 10 per year. Results for FY 1999 (7 precursors) are consistent with the historical average.

  The slight increase in the number of precursors in FY 2000 (14 precursors) over the historical average was attributed in part to conditions related to design-basis issues affecting multi-unit plants—one condition affecting all three units at Oconee and two conditions affecting both units at Cook.

According to the staff's review of individual plant examinations (NUREG-1560, Ref. 3), the core damage frequencies estimated in the individual plant examinations were generally lower for BWRs than for PWRs. NUREG-1560 attributed the difference to the larger number of injection systems in the BWR design along with the ability to rapidly depressurize to allow the use of low-pressure injection systems. This may explain, in part, the lower number of precursors at BWRs.

3.6 Precursors Caused by Unavailability of Safety-Related Equipment

Most precursors involve the unavailability of safety-related equipment. These events occur during periods of extended unavailability of equipment without a reactor trip, or in combination with a reactor trip in which a risk-important component is unable to perform its safety function due to an unavailability condition.

A review of the ASP data during the FY 1993–2000 time period produced the following insights about the unavailability of safety-related equipment.

Equipment unavailabilities in BWRs

- Only 11 precursors occurred in BWRs during the FY1993–2000 period. There were too few events to detect trends in equipment unavailabilities.

Emergency core cooling systems (ECCS)

- An unavailability of safety-related high- and/or low-pressure injection trains contributed to 64% of all precursors in PWRs.

  Most of these unavailabilities were caused by failures in the ECCS (33%), emergency power source (27%), and design-basis issues of other systems/structures impacting the ECCS or an ECCS support system (25%).

- Of the 17 precursors that involved a failure in an ECCS train:

  - Sixteen precursors involved a conditional unavailability found during testing, inspection, or engineering reviews. This indicates that conditions are being identified prior to unplanned demand of the degraded ECCS.

  - Eleven precursors involved a condition affecting sump recirculation during postulated loss-of-coolant accidents of varying break sizes.

Auxiliary/emergency feedwater systems (AFW/EFW)

- The unavailability of AFW/EFW trains contributed to 43% of all precursors in PWRs.

  Most of these unavailabilities were caused by failures in the AFW/EFW system (29%), emergency power source (43%), and design-basis issues of other systems/structures impacting AFW/EFW or an AFW/EFW support system (26%).

- Of the 10 precursors that involved a failure in an AFW/EFW train:

  - Five of the train failures occurred following a reactor trip.

- Eight of the precursors involved the unavailability of the turbine-driven AFW/EFW pump train.

Emergency power sources in PWRs

- The unavailability of emergency power sources, such as emergency diesel generators (EDGs) and hydroelectric generators (at Oconee), contributed to 25% of all precursors in PWRs.

  Most of these unavailabilities were caused by failures in the emergency power system (75%).

- A simultaneous EDG unavailability and a LOOP were also involved in three of the LOOP-related precursors. Two of the precursors involving a LOOP event and EDG unavailability had a CCDP $\geq 1.0 \times 10^{-4}$. The third of these precursors was less risk significant because restoration of the EDG and/or offsite power were more likely resulting in a lower CCDP.

3.7 Annual ASP Index

The annual ASP Index is derived for order of magnitude comparisons with industry average core damage frequency (CDF) estimates derived from probabilistic risk assessments (PRAs) and individual plant examinations (IPEs). The index for a fiscal year is the sum of the conditional core damage probabilities (CCDPs) divided by the number of reactor years (RYs).

Limitations. Using CCDPs from ASP results to estimate CDF is difficult because (1) the mathematical relationship requires a great level of detail, (2) statistics for frequency of occurrence of specific precursor events are sparse, and (3) events and conditions that did meet ASP precursor criteria also need to be accounted for in the assessment.

The ASP models and process do not explicitly cover all core damage frequency scenarios, such as fires, flooding, and external events, and are therefore incomplete for estimating total CDF. Also, using CCDP to estimate CDF can overestimate the frequency because of double counting.

Because of these and other limitations, the CCDPs have been used primarily as a relative trending indication. Despite these limitations, ASP results can be linked to CDF by using an Annual ASP Index. The IPEs also give incomplete estimates of total CDF, but IPEs are reasonably similar in scope to the current ASP Program.

Results. For the last eight fiscal years, the annual ASP index is as follows:

Fiscal Year	**Annual ASP Index (per RY)**
1993	1.4×10^{-5}
1994	3.1×10^{-5}
1995	2.1×10^{-6}
1996	2.9×10^{-5}
1997	4.5×10^{-7}
1998	5.9×10^{-6}
1999	9.6×10^{-7}
2000[a]	1.1×10^{-5}
Average	1.2×10^{-5}

a. Result for FY 2000 is preliminary

The estimated CDFs in the IPEs range from 1.2×10^{-6}/RY to 3.7×10^{-4}/RY, with an average value of 6.2×10^{-5}/RY. On an order of magnitude basis, the ASP Index over the last eight fiscal years is consistent with the order of magnitude of estimates of CDFs from the IPEs. However, because of the limitations discussed above, the ASP results are not sufficient to verify the IPE results.

3.8 Consistency with PRAs/IPEs

Most of the precursor events are consistent with failure combinations identified in probabilistic risk assessments (PRAs) and individual plant examinations (IPEs). A review of the precursor events for the period 1994–2000 shows that 19% of the precursors involved event initiators or conditional availability of equipment not typically modeled in PRAs or IPEs.

Precursors not typically modeled in PRAs and IPEs are listed in Table 6.

4.0 References

1. Rasmuson, D.M., and P.D. O'Reilly. "Analysis of Annual Accident Sequence Precursor Occurrence Rates for 1984–94," in *Proceeding of the International Topical Meeting on Probabilistic Safety Assessment*. American Nuclear Society (ANS), Park City, Utah. 29 September–3 October 1996. Vol. III, pp. 1645-1652. ANS: LaGrange Park, Illinois. 1994.

2. U.S. Nuclear Regulatory Commission. NUREG–1614, Vol. 2, Part 1, "Strategic Plan, Fiscal Year 2000 - Fiscal Year 2005." NRC: Washington, D.C. September 2001.

3. U.S. Nuclear Regulatory Commission. NUREG–1560, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance, Summary Report." NRC: Washington, D.C. October 1996.

Table 1. Status of ASP analysis as of 02/02/02.

Precursor analysis status	FY 1999	FY 2000	FY 2001
Final analysis issued	7	4	0
Preliminary analyses completed	0	10	3
Preliminary analysis underway (includes events that will be rejected as precursors)	0	0	18

Table 2. FY 1999 at-power precursors involving initiating events.

Plant	Description/Event Identifier	Plant type	Event date	CCDP	Event type
Davis - Besse	Manual reactor trip while recovering from a component cooling system leak and de-energization of safety-related bus D1 and non-safety bus D2 (LER 346/98-011)	PWR	10/14/98	1.4×10^{-5}	Transient
Indian Point 2	Loss of offsite power to safety-related buses following a reactor trip and an emergency diesel generator output breaker trip (LER 247/99-015)	PWR	08/31/99	2.8×10^{-6}	Loss of offsite power

Table 3. FY 1999 at-power precursors involving conditional unavailabilities.

Plant	Description/Event identifier	Plant type	Event date	CCDP	Importance (CCDP – CDP)	Event type
Oconee 1, 2, and 3 [a]	Postulated high-energy line leaks or breaks leading to failure of safety-related 4 kV switchgear (LER 269-99-001)	PWR	2/24/99	Unit 1 3.4×10^{-5}	8.2×10^{-6}	Unavail-ability
				Unit 2 3.2×10^{-5}	5.6×10^{-6}	
				Unit 3 3.1×10^{-5}	5.2×10^{-6}	
Cook 1 and 2 [a]	Lack of capability to operate emergency service water following a seismic event (NRC Inspection reports 50-315/316/97-024 and 50-315/316/99-010)	PWR	6/11/99	5.2×10^{-5}	3.2×10^{-5}	Unavail-ability

Note:
a. Multiple precursors—one for each unit.

Table 4. FY 2000 at-power precursors involving initiating events as of 02/02/02. *(Preliminary results are subject to change.)*

Plant	Description/Event Identifier	Plant type	Event date	CCDP	Event type
Indian Point 2	Manual reactor trip following a steam generator tube failure (LER 247/00-001)	PWR	2/15/00	8.0×10^{-5} (Preliminary)	Steam Generator Tube Rupture
Diablo Canyon 1	Extended loss of offsite power to safety-related buses due to 12-kV bus fault (LER 275/00-04)	PWR	5/15/00	9.7×10^{-5} (Preliminary)	LOOP

Table 5. FY 2000 at-power precursors involving conditional unavailabilities as of 02/02/02. *(Preliminary results are subject to change.)*

Plant	Description/Event identifier	Plant type	Event date	CCDP	Importance (CCDP – CDP)	Event type
Cook 1 and 2 [a]	Potential high-energy line break conditions affecting the operability of mitigating systems (LER 315/99-026)	PWR	10/22/99	4.5×10^{-4}	4.3×10^{-4}	Unavail-ability
Salem 2	Degraded CO2 fire suppression system in the 4160Vac switchgear room (LER 272/99-011)	PWR	11/15/99	4.1×10^{-6} (Preliminary)	3.7×10^{-6} (Preliminary)	Unavail-ability
Cook 1 and 2 [a]	Valves required to operate post-accident could fail to open due to pressure-locking/thermal binding (LER 315/99-031)	PWR	12/30/99	5.7×10^{-5}	3.7×10^{-5}	Unavail-ability
Oconee 1, 2, and 3 [a]	Potential inoperability of a HPI pump following a tornado of F3, F4, or F5 severity (NRC Inspection Report 269/00-11)	PWR	4/1/00	Unit 1 4.2×10^{-5} (Preliminary)	5.0×10^{-6} (Preliminary)	Unavail-ability
				Units 2, 3 2.8×10^{-5} (Preliminary)	3.0×10^{-6} (Preliminary)	
Harris	Degraded fire barriers and inadequate fire brigade practice for switchgear room B (NRC Inspection Report 400/00-16)	PWR	6/26/00	3.3×10^{-6} (Preliminary)	3.0×10^{-6} (Preliminary)	Unavail-ability
Harris	Charging/SI Pump "C" inoperable for a time in excess of the TS LCO action statement requirements (LER 400/00-007)	PWR	9/4/00	7.7×10^{-6} (Preliminary)	4.2×10^{-6} (Preliminary)	Unavail-ability

Table 5. (Continued)

Plant	Description/Event identifier	Plant type	Event date	CCDP	Importance (CCDP – CDP)	Event type
Summer	Discharge valve to turbine-driven auxiliary feedwater pump locked closed for 48 days (LER 395/00-006)	PWR	9/21/00	5.1×10^{-6} (Preliminary)	4.2×10^{-6} (Preliminary)	Unavail-ability
Millstone 2	Failure of turbine-driven auxiliary feedwater pump during testing (NRC Inspection Report 336/00-11)	PWR	9/20/00	7.9×10^{-6} (Preliminary)	7.2×10^{-6} (Preliminary)	Unavail-ability

Note:
a. Multiple precursors---one for each unit.

Table 6. Precursors not typically modeled in PRAs or IPEs.

Year	Plant(s)	Event description
1994	Wolf Creek	Blowdown of the reactor coolant system to the refueling water storage tank during hot shutdown
1996	Wolf Creek	Reactor trip with the loss of one train of emergency service water due to the formation of frazil ice on the circulating water traveling screens and the unavailability of the turbine-driven auxiliary feedwater pump
1996	LaSalle 1 and 2	Fouling of the cooling water systems due to concrete sealant injected into the service water tunnel
1996	Haddam Neck	Potentially inadequate residual heat removal pump net positive suction head following a large- or medium-break loss-of-coolant accident due to design errors
1998	Oconee 1, 2, and 3	Incorrect calibration of the borated water storage tank (BWST) level instruments resulted in a situation where the emergency operating procedure (EOP) requirements for BWST-to-reactor building emergency sump transfer would never have been met; operators would be working outside the EOP
1998	Cook 2	Potential failure of all component cooling water pumps due to steam intrusion resulting from a postulated high-energy line break
1999	Oconee 1, 2, and 3	Postulated high-energy line leaks or breaks in turbine building leading to failure of safety-related 4 kV switchgear
1999	Cook 1 and 2	Postulated high-energy line leaks or breaks in turbine building leading to failure of multiple safety-related equipment

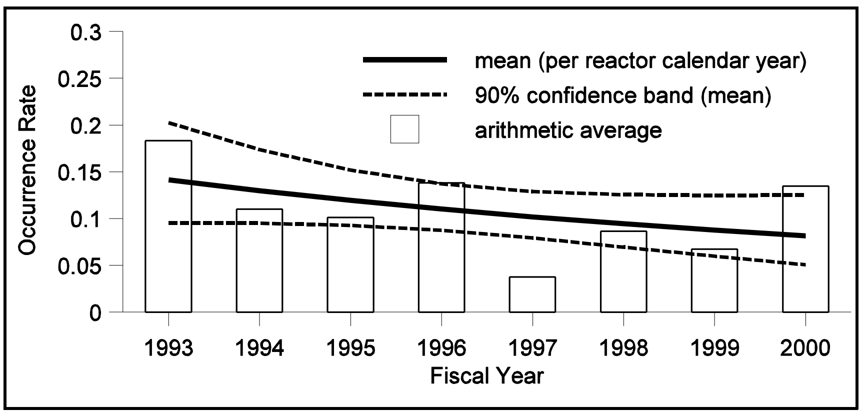

Figure 1. ***All precursors***—occurrence rate, by fiscal year. The decreasing trend is almost statistically significant (p-value[1] = 0.083). The result for FY 2000 is preliminary.

[1] The p-value is the probability of observing a trend as a result of chance alone. A p-value is considered statistically significant if the p-value is smaller than 0.05.

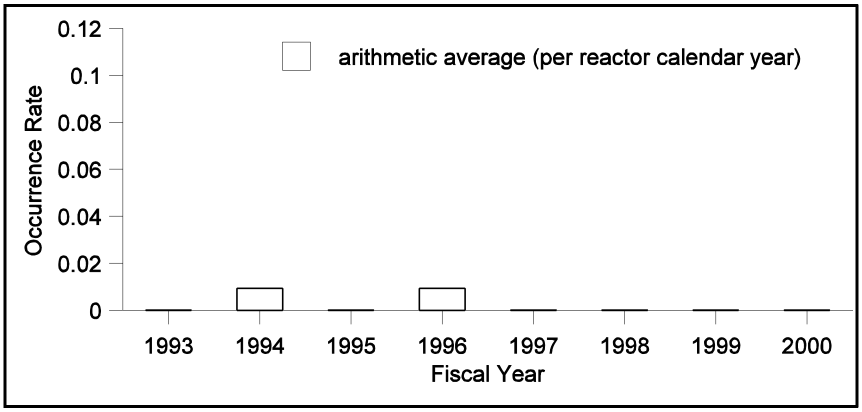

Figure 2a. ***Precursors in CCDP bin 10^{-3}***—occurrence rate, by fiscal year. No trend line shown because no trend detected that is statistically significant (p-value = 0.3556). The result for FY 2000 is preliminary.

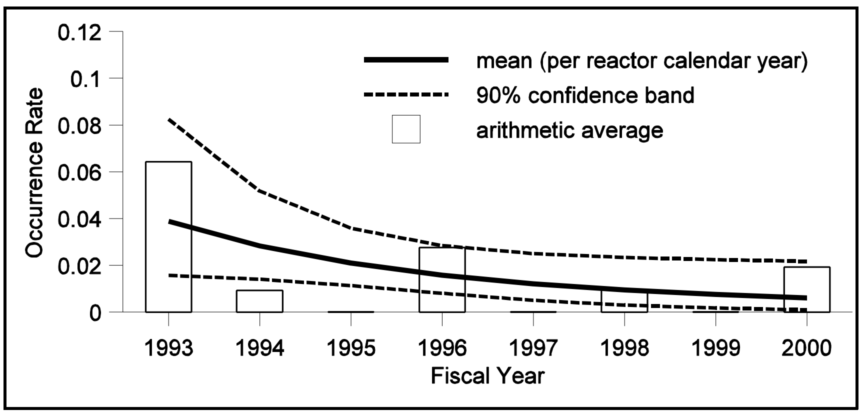

Figure 2b. ***Precursors in CCDP bin 10^{-4}***—occurrence rate, by fiscal year. The decreasing trend is statistically significant (p-value = 0.0204). The result for FY 2000 is preliminary.

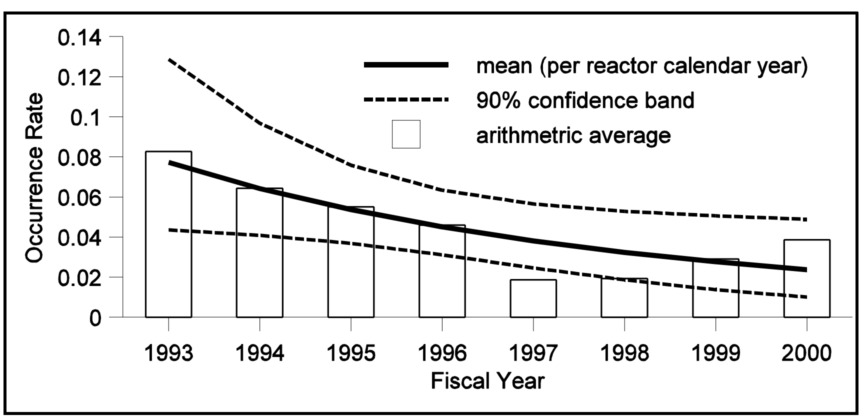

Figure 2c. ***Precursors in CCDP bin 10^{-5}***—occurrence rate, by fiscal year. The decreasing trend is statistically significant (p-value = 0.0170). The result for FY 2000 is preliminary.

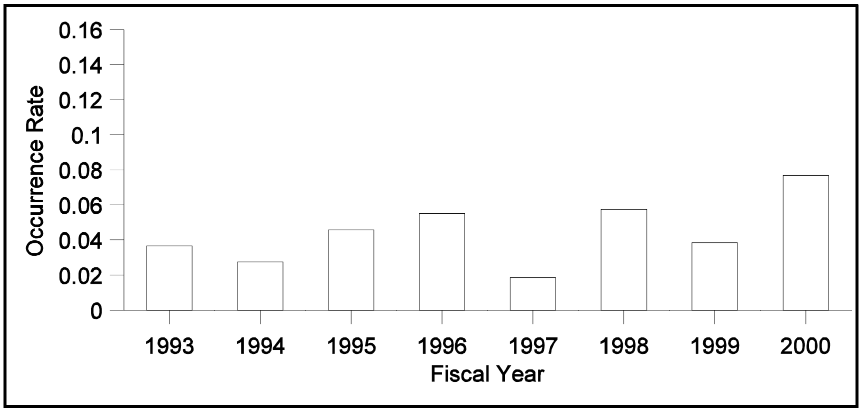

Figure 2d. ***Precursors in CCDP bin 10^{-6}***—occurrence rate, by fiscal year. No trend line shown because no trend detected that is statistically significant (p-value = 0.2091). The result for FY 2000 is preliminary.

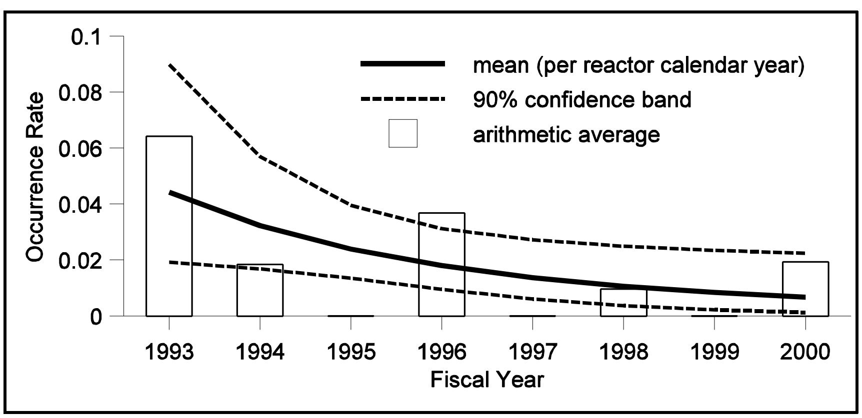

Figure 3. ***"Important" precursors (CCDP $\geq 10^{-4}$)***—occurrence rate, by fiscal year. The decreasing trend is statistically significant (p-value = 0.0126). The result for FY 2000 is preliminary.

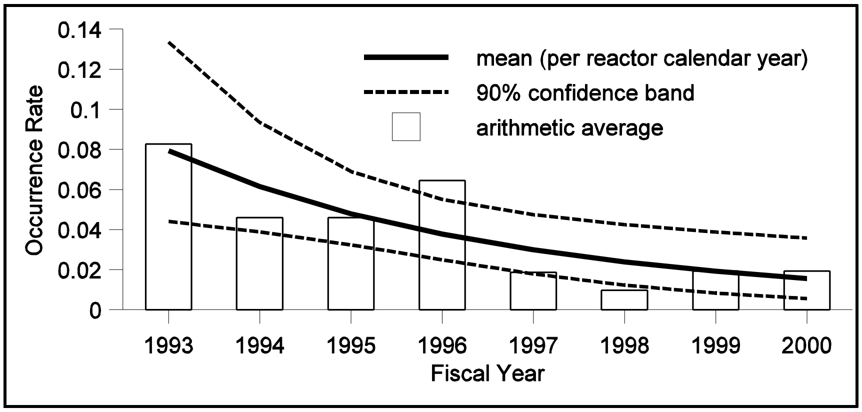

Figure 4. ***Precursors involving initiating events***—occurrence rate, by fiscal year. The decreasing trend is statistically significant (p-value = 0.0025). The result for FY 2000 is preliminary.

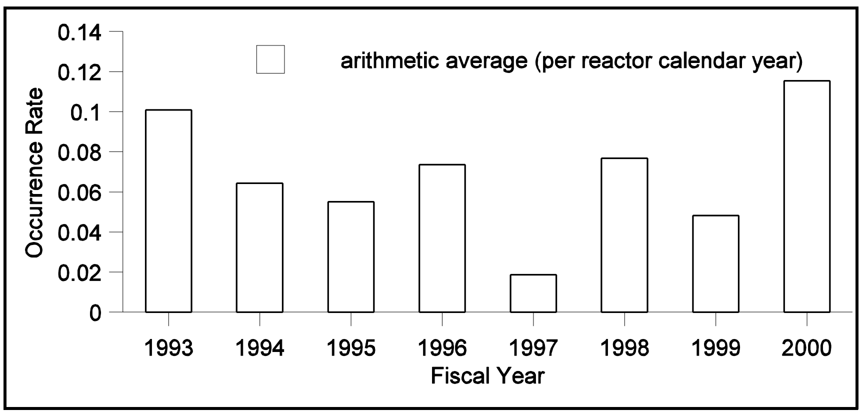

Figure 5. ***Precursors involving conditional unavailability of equipment***—occurrence rate, by fiscal year. No trend line shown because no trend detected that is statistically significant (p-value = 0.9495). The result for FY 2000 is preliminary.

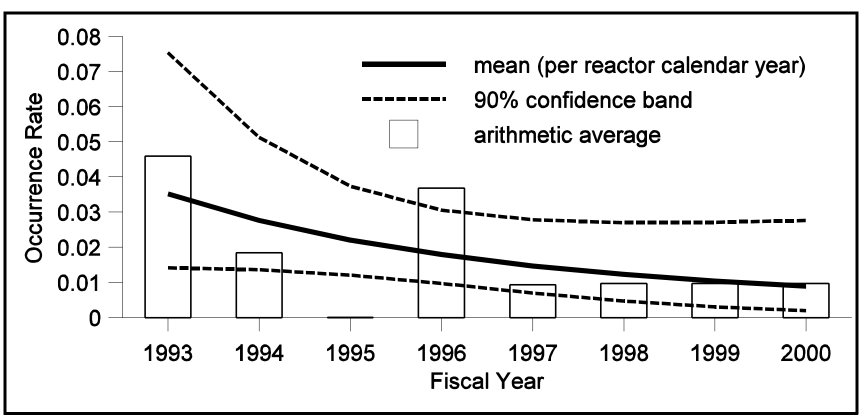

Figure 6. ***Precursors involving loss of offsite power initiating events***— occurrence rate, by fiscal year. The decreasing trend is almost statistically significant (p-value = 0.0699). Result for FY 2000 is preliminary.

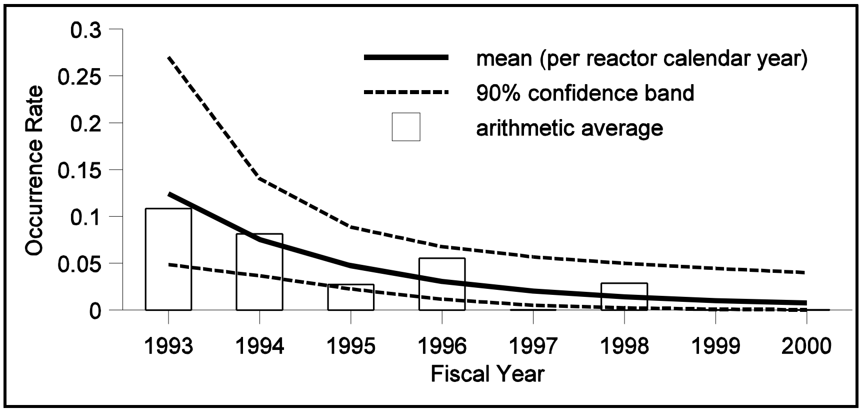

Figure 7. ***Precursors involving BWRs***—occurrence rate, by fiscal year. The decreasing trend is statistically significant (p-value = 0.0024). Result for FY 2000 is preliminary.

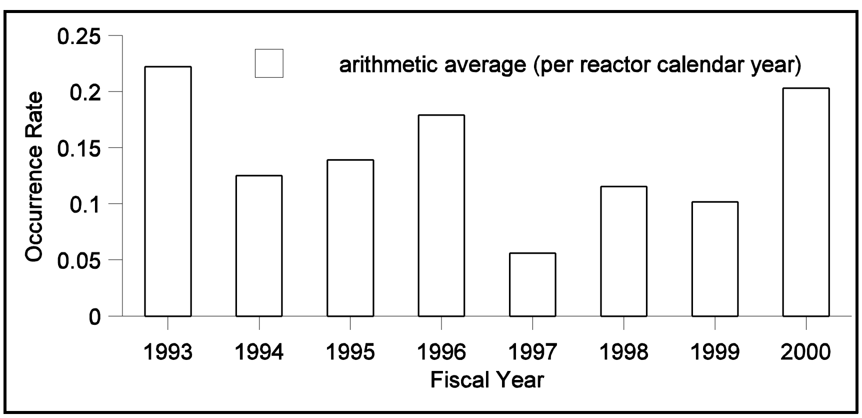

Figure 8. ***Precursors involving PWRs***—occurrence rate, by fiscal year. No trend line shown because no trend detected that is statistically significant (p-value = 0.4295). The result for FY 2000 is preliminary.