8.0 Initiating Events Analyses

8.1 Objective and Scope

- ***Objective.*** This section provides guidance on the treatment of initiating events (IEs) during at-power operation in event and condition assessments (ECAs). This section discusses the treatment of IEs ~~initiating events~~ with and without availability of a structure, system, or component (SSC). In a SDP evaluation, the same performance deficiency (PD) must be the cause of an initiating event (IE) with or without concurrent SSC unavailability. ~~The cause of an observed SSC unavailability and/or observed initiating event must be associated with the same performance deficiency (PD) for a SDP evaluation.~~ The identification of a PD is not required for an ASP or MD 8.3 analyses.

  For SDP analyses, Section 8.2 of Inspection Manual Chapter (IMC) 308 Attachment 3, "Significance Determination Process Technical Basis," provides the approach of using the incremental conditional core damage probability (iCCDP) for evaluating significance of degraded conditions and IEs caused by licensee performance deficiencies. When evaluating the significance of an IE caused by deficient licensee performance, the stated approach is to calculate the conditional core damage probability (CCDP) for the event by setting the associated IE frequency to 1.0 event per year, or a probability of 1.0 in a given year with the other IEs being set to a probability of zero. The iCCDP is obtained by subtracting the baseline core damage probability (CDP) of the affected IE sequence from the CCDP. In this type of SDP evaluations, recovery of any related mitigating equipment affected by the IE from its initial effects (i.e., recovery of main feedwater, condenser heat sink, offsite AC power, etc.) should be appropriately considered in determining the iCCDP estimate.

  Guidance provided in this section ~~does not change~~ supports the guidance provided in Appendix A of this volume of the Handbook for the ASP and MD 8.3 analyses of IEs. ~~initiating events. The treatment of initiating events in SDP evaluations have been applied in the past for certain performance deficiencies associated with at-power findings, although infrequently (as expected).~~

- ***In scope.*** Treatment cases that are in the scope of this guide are summarized below.[1]
  - *Case 1– Initiating event only.* A PD causes an ~~initiating event~~ IE with subsequent reactor trip and the same PD does not cause other complications (e.g., unavailability of, or inability to recover any related mitigating equipment). **IEs involving only reactor trip events with no additional complications are not subject to SDP evaluations unless the SDP Phase 1 analysis screens such reactor trip events as potentially Greater than Green findings.**
  - *Case 2– Initiating event and mutually exclusive SSC (SDP only).*[2] A PD causes an IE

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1 The identification of a PD noted in each case below is required for a SDP analysis, but is not required for ASP and MD 8.3 analyses. ASP and MD 8.3 only requires the observation of a SSC unavailability and/or ~~reactor trip~~ initiating event.

2 This case only applies for SDP evaluations.

~~initiating event with subsequent reactor trip~~ and the same PD causes an observed unavailability of a SSC that is mutually exclusive of the ~~initiating event~~ IE (i.e., the unavailable SSC does not help to mitigate the IE that occurred).

- *Case 3– Initiating event and mutually inclusive SSC.* A PD causes an IE ~~initiating event with subsequent reactor trip~~ and the same PD causes an observed unavailability of a SSC that is mutually inclusive of the ~~initiating event~~ IE (i.e., the unavailable SSC is necessary to help mitigate the IE that occurred).
- *Case 4– SSC unavailability increases the initiating event frequency.* A PD ~~results in~~ causes a degraded or unavailable SSC that ~~could~~ increases the frequency of an IE; ~~initiating event;~~ however, no IE ~~reactor trip~~ occurred (e.g., failure of a single service water pump).

- ***Not in scope.*** The following cases below are outside the scope of this guide.
  - A PD that did not cause an IE ~~a reactor trip~~ occurrence or SSC unavailability, but created a degraded condition that could increase the frequency of an ~~initiating event~~ IE (e.g., excessive pipe wall thinning without loss of function).
  - A PD that did not cause an IE ~~a reactor trip~~, but contributed to a consequential ~~initiating event~~ IE (e.g., loss of offsite power event) given a random reactor trip. Such cases are evaluated in SDP as a condition analysis. See Appendix A of this volume of the Handbook for guidance of a condition analysis.

8.2 Case 1– Initiating Event Only

For this case, a PD causes an IE ~~initiating event~~ with subsequent reactor trip (e.g., loss of offsite AC power event). In addition, the same PD did not affect any other SSCs or cause ~~other~~ additional complications (e.g., unavailability of, or inability to recover any related mitigating equipment) during the IE. ~~initiating event.~~ This case involves one calculation — an ~~conditional core damage probability (CCDP)~~ iCCDP estimation associated with the IE only. ~~(e.g., a reactor trip with no complications. (i.e., an initiating event analysis).~~ **As stated in Section 8.1, IEs involving only reactor trip events with no additional complications are not subject to SDP evaluations unless the SDP Phase 1 analysis screens such reactor trip events as potentially Greater than Green findings.**

For ASP and MD 8.3 analyses, a PD does not have to be identified or associated with the IE. ~~initiating event.~~ As such, consider adjustments to test and maintenance (T/M) basic events.[3] A SSC that was unavailable due to T/M at the time of the IE is modeled as unavailable; therefore, the associated T/M basic event is set to TRUE. Potential recovery actions for restoring the SSC should be modeled, as appropriate. Refer to the Section 6 on modeling recovery for additional information.

- ~~***Consider adjustments to test and maintenance (T/M) basic events (ASP and MD 8.3 only).***[3] For ASP and MD 8.3 analyses, a SSC that was unavailable due to T/M at the time of the initiating event is modeled as unavailable; therefore, the associated T/M basic event is set to TRUE. Potential recovery actions for restoring the SSC should be modeled, as appropriate. Refer to the Section 6 on modeling recovery for additional information.~~

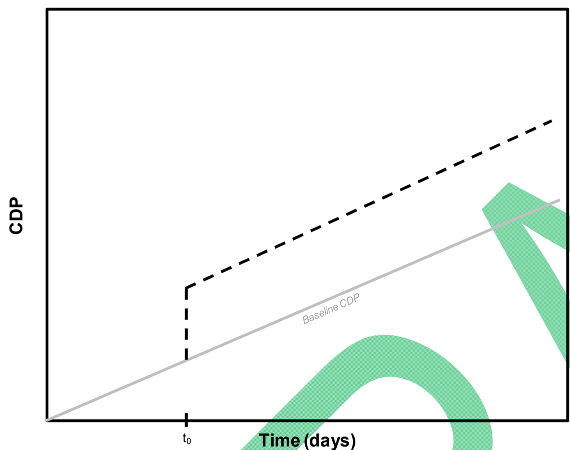
3 For SDP evaluations, the T/M basic events remain unchanged at their nominal unavailability probabilities, given that observed unavailability due to T/M was not related to the identified PD.

- ***Calculate iCCDP.*** Calculate the CCDP by setting the observed IE ~~initiating event~~ (e.g., ~~general transient, loss of main feedwater,~~ loss of vital bus transient) to 1.0 and all other initiating events to 0.0.[4] The iCCDP is obtained by subtracting the baseline CDP from the CCDP.

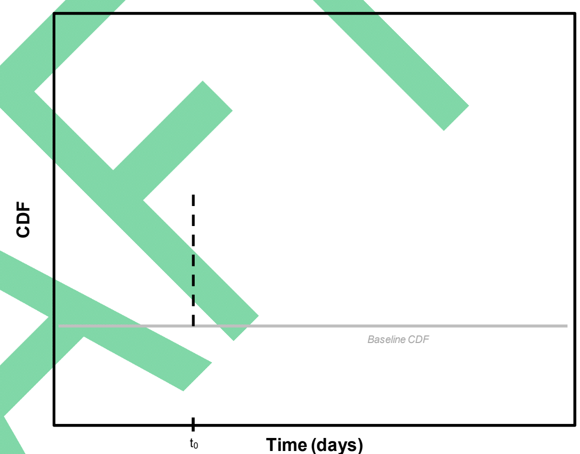
  ~~– For SDP evaluations, multiply the CCDP by one inverse year (yr^{-1}) to equate this to a change in average core damage frequency (ΔCDF_{ave}).~~

  ~~– For ASP and MD 8.3 analyses, the final metric is the CCDP.~~

~~Figures 8-1a and 8-1b provide the core damage probability (CDP) versus time and core damage frequency (CDF) versus time for Case 1.~~



~~**Figure 8-1a.** CDP vs. time for Case 1.~~



~~**Figure 8-1b.** CDF vs. time for Case 1.~~

~~The plot of CDP vs. time (Figure 8-1a) shows a line[5] representing the CDP vs. time prior to the IE initiating event, at t_0 a "spike" in CDP accumulates due to an IE initiating event with subsequent reactor trip, and then the CDP returns to the same slope as the baseline CDP following the IE initiating event (t_0).[6] A plot of CDF vs. time (Figure 8-1b) shows a horizontal line (equal to the baseline CDF), with Dirac delta function (or "spike") at t_0 when the IE reactor trip occurs. After the initiating event IE occurs, the CDF returns to equal the baseline CDF. The CDP is approximately the integral of CDF over time. At the point where the initiating event IE occurs (t_0), the integral is equal to the CCDP multiplied by the integral of the delta function, which is numerically equal to the iCCDP.~~

8.3 Case 2– Initiating Event and Mutually Exclusive SSC Unavailability (SDP Only)

For this case, a PD causes an IE to occur. ~~initiating event with subsequent reactor trip.~~ In addition, the same PD also causes an unavailability of a SSC that was mutually exclusive of the IE (i.e., the unavailable SSC is not required to help mitigate the IE that occurred). ~~initiating~~

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4 If using the SAPHIRE General Analysis Module use TRUE/FALSE instead of 1.0/0.0.

5 In the CDP vs. time plots, the slope of the line is equal to the CDF.

6 This plot assumes the reactor was returned to at-power operations at t_0; therefore, showing no change in the lower baseline CDP line. Had the reactor remained in shutdown for a given period, the slope of the baseline CDP would change during this period. The slope of the upper line would track the shutdown baseline over the shutdown period.

~~event.~~ The exposure time of the unavailable SSC may (or may not) sometimes overlap with the time of the observed IE. ~~reactor trip event. However, the unavailable SSC is not required for mitigation of any of the initiating event sequences.~~ This case only applies for SDP evaluations.[7]

Case 2 involves three calculations: (1) iCCDP estimation (~~initiating event~~ IE analysis) associated with just the IE ~~initiating event~~, (2) ΔCDP estimation (condition analysis) associated with just the SSC unavailability over the exposure time, and (3) the sum of the iCCDP and ΔCDP results.

- ***Calculate iCCDP for the IE ~~initiating event~~.*** Calculate the CCDP by setting the observed IE ~~initiating event~~ (e.g., general transient, loss of essential service water ~~main feedwater~~, loss of vital bus) to 1.0 and all other IEs ~~initiating events~~ to 0.0.[8] The iCCDP is obtained by subtracting the baseline CDP from the CCDP. ~~Numerically, this is equivalent to a change in average CDF (ΔCDF_{ave}) over one year when CCDP is divided by one year.~~

- ***Calculate ΔCDP for the SSC unavailability.*** In a condition analysis, the basic event associated with the SSC unavailability is set to TRUE and the SPAR model is solved to calculate the ΔCDP over the exposure time. Do not adjust any IE ~~initiating event~~ frequency in this step of the SDP evaluation. **Potential recovery action for restoring the SSC (see Section 6) and adjustments to T/M basic events (see Section 8.2) may be considered, as appropriate.**

  The SSC unavailability causes an increase in the CDF that lasts for a specified period of time, Δt. The ΔCDP is calculated as

$$\Delta CDP = (CDF_{new} - CDF_{base})\Delta t$$

Ensure that the units of time match with the terms in this equation. Numerically, this is equivalent to a change in average CDF (ΔCDF_{ave}) over one year when ΔCDP is divided by one year.

***Calculate total* risk (ΔCDF_{ave}).** Calculate the total ΔCDP by adding together the iCCDP for the IE ~~initiating event~~ and the ΔCDP for the SSC unavailability. The result is

$$\Delta CDP_{Total} = iCCDP + [CDF_{new} - CDF_{base}]\Delta t$$

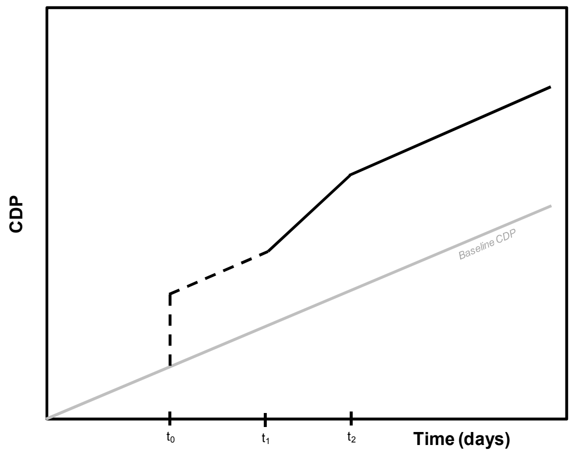
~~Multiply the ΔCDP_{Total} by one inverse year (yr^{-1}) to equate this to a change in average core damage frequency (ΔCDF_{ave}).~~

~~Figures 8-2a and 8-2b provide the CDP versus time and CDF versus time for Case 2. From t_0 to t_1 Case 2 is identical to Case 1; however, the same PD that caused an IE initiating event with subsequent reactor trip at t_0 also caused an unavailable SSC from t_1 to t_2 (i.e., Δt). The unavailable SSC is restored at t_2.~~

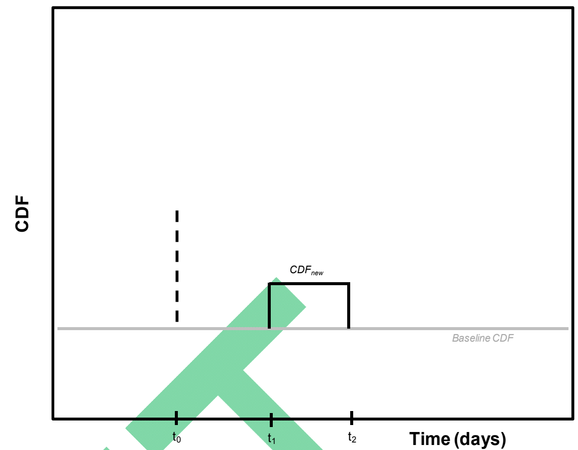
~~The plot of CDP vs. time (Figure 8-2a) shows the CDP spike at t_0 due to the IE initiating event with subsequent reactor trip and CDP returning to the same slope as the baseline CDP following the IE initiating event (as in Case 1).~~

7 This case only applies for SDP evaluations. MD 8.3 or ASP analysis requires a SSC failure to occur during (concurrent with) the initiator's PRA mission time (generally within 24 hours following the reactor trip).

8 If using the SAPHIRE General Analysis Module use TRUE/FALSE instead of 1.0/0.0.



~~**Figure 8-2a.** CDP vs. time for Case 2.~~



~~**Figure 8-2b.** CDF vs. time for Case 2.~~

~~At t_1 the PD caused the unavailability of a SSC; therefore, the CDP slope increases, and then the CDP returns to the same slope as the baseline CDP when the condition is corrected at t_2. The plot of CDF vs. time (Figure 8-2b) shows a horizontal line equal to baseline CDF (i.e., CDF_{base}) with a "spike" occurring at t_0 due to the IE. initiating event with subsequent reactor trip. The CDP then jumps to a higher horizontal line (CDF_{new}) from t_1 to t_2, due to the unavailable SSC. The ΔCDP is approximately the integral of CDF over time.~~

~~These plots show an example of Case 2 where the IE initiating event and degraded condition do not overlap, and the deficiencies associated with the IE initiating event and degraded condition were fixed at different times (t_0 and t_2, respectively). Other variations of this case are possible, such as the condition starting at a sometime before the IE reactor trip and fixed sometime after the IE occurrence. reactor trip.~~

8.4 Case 3– Initiating Event and Mutually Inclusive SSC Unavailability

For this case, a PD causes an IE ~~initiating event with subsequent reactor trip. In addition, the same PD causes an observed~~ and an unavailability of a SSC that was mutually inclusive of the IE. ~~initiating event.~~ The observed SSC unavailability must overlap with the IE ~~observed reactor trip event and~~ **AND** the unavailable SSC must be required for mitigation of any of the initiating event sequence(s).

~~For~~ ASP and MD 8.3 analyses are performed for an IE and an unavailability of a SSC that was mutually inclusive of the IE when both events are observed to overlap. However, a PD does not have to be identified or associated with the IE ~~initiating event~~ and/or SSC unavailability.

This case involves the comparison of two calculations: (1) iCCDP estimation (IE ~~initiating event~~ analysis) associated with the combined IE ~~initiating event~~ and SSC failure, and (2) ΔCDP estimation (condition analysis) associated with just the SSC unavailability over the exposure time. To avoid double counting, the highest result of the two calculations is documented for the record.

- ***Calculate iCCDP for the combined IE ~~initiating event~~ and SSC unavailability.*** The calculation of iCCDP may differ slightly between a SDP evaluation and MD 8.3 or ASP analysis. The SDP evaluation considers both the IE ~~initiating event~~ and SSC unavailability in the same IE ~~initiating event~~ analysis only if the same PD was involved. ASP and MD 8.3 analysis consider all failures that were observed during the IE ~~initiating event~~, regardless of an identified or common PD.

- For SDP evaluations, follow the same guidance in Section 8.2 to calculate the CCDP associated with the IE. ~~initiating event.~~ In the same calculation, set the basic event associated with the SSC unavailability to TRUE. The iCCDP is obtained by subtracting the baseline CDP from the CCDP. **Model potential recovery actions for restoring the SSC, as appropriate. Refer to the Section 6 on modeling recovery for additional information.**
- For ASP and MD 8.3 analysis, follow the same guidance in Section 8.2 to estimate the CCDP associated with the IE ~~initiating event.~~ In addition, set the basic event associated with the SSC unavailability to TRUE and set any other observed equipment failures to TRUE. Consider adjustments to T/M basic events as appropriate. The iCCDP is obtained by subtracting the baseline CDP from the CCDP. **Model potential recovery actions for restoring the SSC, as appropriate. Refer to the Section 6 on modeling recovery for additional information.**

- ***Calculate ΔCDP for the SSC unavailability only.*** For SDP, ASP, and MD 8.3 analyses, follow the same guidance in Section 8.3 to estimate the ΔCDP associated with the SSC unavailability over the exposure time. Do not include the IE ~~initiating event~~ in this step of the calculation. **Model potential recovery actions for restoring the SSC, as appropriate. Refer to the Section 6 on modeling recovery for additional information.**

- ***Choose the highest of the CCDP or ΔCDP result.*** Given that both calculations include the risk contribution of the SSC failure (or unavailability); only the highest result should be recorded as the final result.

8.5 Case 4– SSC Unavailability Increases the Initiating Event Frequency, but No Initiating Event Occurred

For this case, a PD results in an observed unavailability of a SSC that ~~could~~ increases the frequency of an IE ~~initiating event~~; however, no IE ~~initiating event~~ occurs. Certain equipment failures, particularly for SSCs in support systems (e.g., service water, component cooling water, instrument air) can lead to an increase in the system failure probability. If a system failure can result in an IE ~~initiating event~~, then an increase in system failure probability can increase the IE ~~initiating event~~ frequency, in addition to an increase in the overall plant risk due to the reduction in mitigation capability.

One approach to estimate the change in IE ~~initiating event~~ frequency for a degraded condition that involved the failure of an SSC but did not result in an IE ~~initiating event~~ is provided as follows. Plant-specific support system initiating event (SSIE) models in SPAR models ~~should~~ support an alternate method of handling the increase in IE ~~initiating event~~ frequency due to a failed support system SSC. Section 11 provides guidance for the use of the SSIE models in ECA.

- ***Solve the applicable fault tree in the SPAR model***. This provides an estimate of the baseline system failure probability.

- ***Calculate the system failure probability factor***. Use a change set in SAPHIRE to model the observed component failure (set the basic event to TRUE) and solve the system fault tree to obtain the modified system failure probability. Calculate the system failure probability factor (or ratio) by dividing the baseline system failure probability into the modified system failure probability.

- ***Calculate the modified initiating event frequency.*** Multiply system failure probability factor with the baseline IE ~~initiating event~~ frequency to calculate the new IE ~~initiating event~~ frequency.

- ***Consider recovery actions.*** Recovery actions to restore the loss of function due to the SSC failure may require prompt corrective actions in order to prevent an automatic or manual reactor trip. Special attention to the timing of the IE ~~initiating event~~ and complexity of the associated recovery action should be considered in the human reliability analysis of the non-recovery probability. Refer to the Section 6 on modeling recovery for additional information.

- ***Calculate ΔCDP for degraded condition.*** Solve the SPAR model with the modified IE ~~initiating event~~ frequency and the SSC unavailability (set to TRUE) to obtain the ΔCDP for the overall condition. Follow the same guidance in Section 8.3 to estimate the ΔCDP associated with the SSC unavailability over the exposure time.

8.6 Other Considerations

Additional considerations are provided below.

- In ASP and MD 8.3 analyses, all unavailable SSCs that overlap an IE ~~a reactor trip event~~ are evaluated in one risk assessment.

- In the SDP, a PD that caused an IE ~~initiating event with subsequent reactor trip~~ will be evaluated separately from other performance deficiencies revealed during the event. The guidance of Inspection Manual Chapters ~~0609 and 0308~~ 0612 and its Appendix B apply to defining PDs.

- This section does not address recovery of functions lost as a result of the IE ~~initiating event~~ such as main feedwater or service water. **Refer to the Section 6 on modeling recovery for additional information.**

- For SDP evaluations, the analyst may need to consider whether the PD that directly caused an IE ~~initiating event with subsequent reactor trip~~ also represented a degraded condition over a defined exposure period. In ~~this~~ these cases, the analyst may need to determine which analysis approach best represents the evaluation of the risk significance ~~effects~~ of the PD. ~~An alternative analysis approach can be presented as a sensitivity evaluation.~~

- A Bayesian update of the IE ~~initiating event~~ frequency using the observed IE occurrence ~~initiating event~~ over a duration time period should not be used for treatment of IEs ~~initiating events~~ in ECAs. The SDP is ~~reason is that we are trying~~ to estimate the increase in risk above the facility's baseline risk due to ~~risk significance of~~ the actual occurrence of an IE ~~event~~ caused by a PD. ~~deficiency, and~~ The Bayesian update produces a change in the initiator frequency that reflects the occurrence of the initiator over some period of time, which is a different calculation. Furthermore, a Bayesian update assumes that the prior distribution and the plant-specific data are consistent; the fact that the IE ~~initiating event~~ was caused by a PD, ~~deficiency,~~ which is assumed to cause a significant increase in the frequency of the initiator, invalidates this assumption.