MODULE T

SIGNIFICANCE DETERMINATION PROCESS (SDP)

Significance Determination Process (SDP)

- **Purpose: To acquaint students with the purpose of the SDP, the PRA basis underlying SDP, and how the SDP principles are consistent with PRA principles and practices.**
- **Objectives: Students will be able to explain;**
  - **the purpose and objectives of the SDP**
  - **the PRA basis behind the SDP Tables 1 through 5 in IMC 0609, Appendix A, Attachment 1, how these tables are used and how these five table are incorporated into the Pre-Solved Tables**
  - **how SDP is consistent with PRA principles and practices**
- **Reference: NRC Inspection Manual Chapter (IMC) 0609, Significance Determination Process**

Significance Determination Process (SDP) Purpose and Objectives

- **SDP Purpose**
  - Use risk insights, where appropriate, to help NRC inspectors and staff determine the safety significance of findings.
  - SDP determinations for inspection findings and the Performance Indicator (PI) information are combined for use in assessing licensee performance in accordance with guidance provided in IMC 0305, "Operating Reactor Assessment Program."
- **SDP Objectives**
  - Characterize significance of inspection findings for the Reactor Oversight Process (ROP), using risk insights as appropriate.
  - Provide all stakeholders an objective and common framework for communicating the potential safety significance of inspection findings.
  - Provide a basis for timely assessment and/or enforcement actions associated with an inspection finding.
  - Provide inspectors with plant-specific risk information for use in risk-informing the inspection program.

Selection of Initiating Event(s) to Evaluate

- **Site specific risk-informed inspection notebook**
  - **Table 2 - Initiators and System Dependency**
    - **Affected Systems**
    - **Major Components**
    - **Support Systems**
    - **Initiating Event Scenarios**
  - **For affected system(s), identify which initiating events need to be evaluated**

Estimating Initiating Event Likelihood During Degraded Period

- PRA uses constant (time-independent) frequencies for various initiating events
- Each core damage sequence starts with initiating event
- CDF for sequence is frequency of initiating event multiplied by probability of failure of mitigating systems and/or operator responses, given initiating event
- Probability of initiating event occurring between t_1 and t_2 is approximately

$$\Pr(IE\ between\ t_1\ and\ t_2) \approx \lambda_{IE}(t_2 - t_1)$$

Estimating Initiating Event Likelihood During Degraded Period

- Site specific risk-informed inspection notebook
  - Table 1 - Categories for Initiating Events
    - Rows in Table 1 correspond to different frequency ranges for different IEs

      Most frequent IEs at top, least frequent at bottom

      Row I > 0.1 per year

      Row II 0.1 – 0.01 per year

      Row III 0.01 – 0.001 per year, etc.
    - Right hand columns in Table 1 correspond to duration of degraded condition

      > 30 days (upper bound duration of 1 year)

      3 - 30 days (upper bound duration of 0.1 year)

      < 3 days (upper bound duration of 0.01 year)
    - Estimated initiating event likelihood is product of IE frequency (lower bound) and duration (upper bound) of degraded condition

      Initiating Event Likelihood = $-\log_{10}$[IE Frequency (lower bound) * duration]

      - Example: An IE with frequency in Row I with an exposure duration of >30 days

        0.1 per year (lower bound) * 1 year (upper bound) = 0.1

        Initiating Event Likelihood = $-\log_{10}[0.1] = 1$

      Note: Each initiating event to be assessed for a finding will use the same duration column, but each assessed IE will have frequency corresponding to its respective row.

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Summary of Estimated Initiating Event Likelihood

- **Result from Table 1 represents <u>probability</u> of having IE occur during degraded condition**
- **X = $-\log_{10}$[IE Frequency (lower bound) * duration (upper bound)]**
  - **1 $\leftrightarrow$ 10^{0} to 10^{-1}**
  - **2 $\leftrightarrow$ 10^{-1} to 10^{-2}**
  - **3 $\leftrightarrow$ 10^{-2} to 10^{-3}**
  - **4 $\leftrightarrow$ 10^{-3} to 10^{-4}**
  - **5 $\leftrightarrow$ 10^{-4} to 10^{-5}**
  - **6 $\leftrightarrow$ 10^{-5} to 10^{-6}**
  - **7 $\leftrightarrow$ 10^{-6} to 10^{-7}**
  - **8 $\leftrightarrow$ $\leq 10^{-7}$**

Summary of Estimated Initiating Event Likelihood

- **Note the uncertainty in IE frequencies shown in Table 1 (order of magnitude in each row)**
- **IE frequency will impact final risk significance, can adjust upward (subjectively) if degraded condition can increase IE frequency**
  - **Examples provided in IMC 0609, App. A, Att. 2**

SDP Worksheets for Initiating Event(s) Evaluation and Remaining Mitigation Capability

- Table 3 site specific risk-informed inspection notebook
  - For IE Scenarios identified in Table 2 – Initiators and System Dependency, complete just the affected Table 3 SDP Worksheet and just the row with the affected function
    - Circle the affected functions in each row
      - Number in parenthesis in each row indicate corresponding sequences with at least those systems indicated (minimal cut set at sequence logic level)
        - Example: Table 3.XX row 1 TRAN – PCS – CHR – CV (5, 9); on the Transient event tree sequence 5 and 9 represent failures of the indicated systems, with sequence 9 have the indicated systems plus one or more other system failures. Only need to assess contribution from the highest contributing sequence

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SDP Worksheets for Initiating Event(s) Evaluation and Remaining Mitigation Capability

- For IE Scenarios identified in Table 2 – Initiators and System Dependency, complete just the affected Table 3 SDP Worksheet and just the row with the affected function
  - From Table 1 – Categories of Initiating Events, assign the identified initiating event likelihood (IEL) for that IE
  - Assign remaining mitigation capability rating for all other functions in each row that had a circled affected function
  - Assess and assign remaining mitigation capability rating for the circled affected function
    - Example: If LPI function affected in Table 3.XX, IMC 0609, App A, Att 1, but only LPCI mode affected; then the full mitigation capability (LPCI of 3 + LPCS of 3 = 6) for the evaluation would be LPCI of 0 + LPCS of 3 = 3.
  - Assign recovery of affected (failed) train if applicable (see Table 4).
  - Add all assigned values for each circle affected row in Table 3 and enter the result in the Results column (right most column of Table 3)

Remaining Mitigation Capability

- Table 4 is not site specific and assigns probabilities of failure to different means of mitigation (systems, operator actions, and recovery of failed systems) based on past PRA experience
  - Recovery of failed train: 0.1
  - One automatic steam-driven (ASD) train: 0.1
  - One train (not steam-driven): 0.01
  - One multi-train system: 0.001 (system of two or more trains that are considered susceptible to common cause failures)
  - Two diverse trains: 0.0001 (system of two trains that are not considered susceptible to common cause failures; one train * one train = 0.01 * 0.01 = 0.0001)
  - Operator action credit:
    - 0.1 (failure probability between 0.5 and 0.05)
    - 0.01 (failure probability between 0.05 and 0.005)
    - 0.001 (failure probability between 0.005 and 0.0005)

Remaining Mitigation Capability

- **Remaining Mitigation Capability Credit = X = -log10[failure probability], thus**
  - **Recovery of failed train: 1**
  - **One automatic steam-driven (ASD) train: 1**
  - **One train: 2**
  - **One multi-train system: 3**
  - **Two diverse trains: 4**
  - **Operator action credit: 1, 2, or 3**

Estimation of Risk Significance of Inspection Finding

- Determine final risk significance by completing Table 5 – Counting Rule Worksheet
- For each affected row for each Table 3 SDP Worksheet completed (IE assessed), count the total number of rows with a specific risk significance level equal to;
  - Number of rows with 9 =
  - Number of rows with 8 =
  - Number of rows with 7 =
  - etc. for each significance level to a 4
- Complete Table 5 - Counting Rule Worksheet
  - A "Step" in Table 5 that divides a risk significance level by 3 and rounds down is producing a higher risk significance from contributing lower risk significance; Three sequences of less risk significance are equal to one sequence of greater risk significance
    - Example: Three sequences with risk significance 9 equals one risk significance 8 sequence

Estimation of Risk Significance of Inspection Finding

- Result of Table 5 – Counting Rule Worksheet indicates risk significance of inspection finding
  - Red – highest safety significance
    - at least one sequence with a 4, which is equal to 1E-4
  - Yellow – at least substantial safety significance
    - at least one sequence with a 5, which is equal to 1E-5
  - White – at least low to moderate safety significance
    - at least one sequence with a 6, which is equal to 1E-6
  - Green – very low safety significance
    - at least one sequence with a 7, which is equal to 1E-7

Final Risk Significance of Inspection Finding

- **Note:**
  - Cannot assess impact of degraded equipment reliability
  - SDP set up to analyze conditions that exist for a period of time, not set up for initiating event assessments (IE has occurred)
    - Initiating event assessment results in CCDP “spike,” which is different type of assessment than the SDP assessment
- **Note that result of SDP is a probability: the probability of core damage, given a degraded condition of specified duration and probability of an IE during that condition**
  - Called conditional core damage probability (CCDP)
- **Problems with using CCDP as risk metric**
  - PI program uses ΔCDF, as does R.G. 1.174
  - NRC has no criteria for using CCDP

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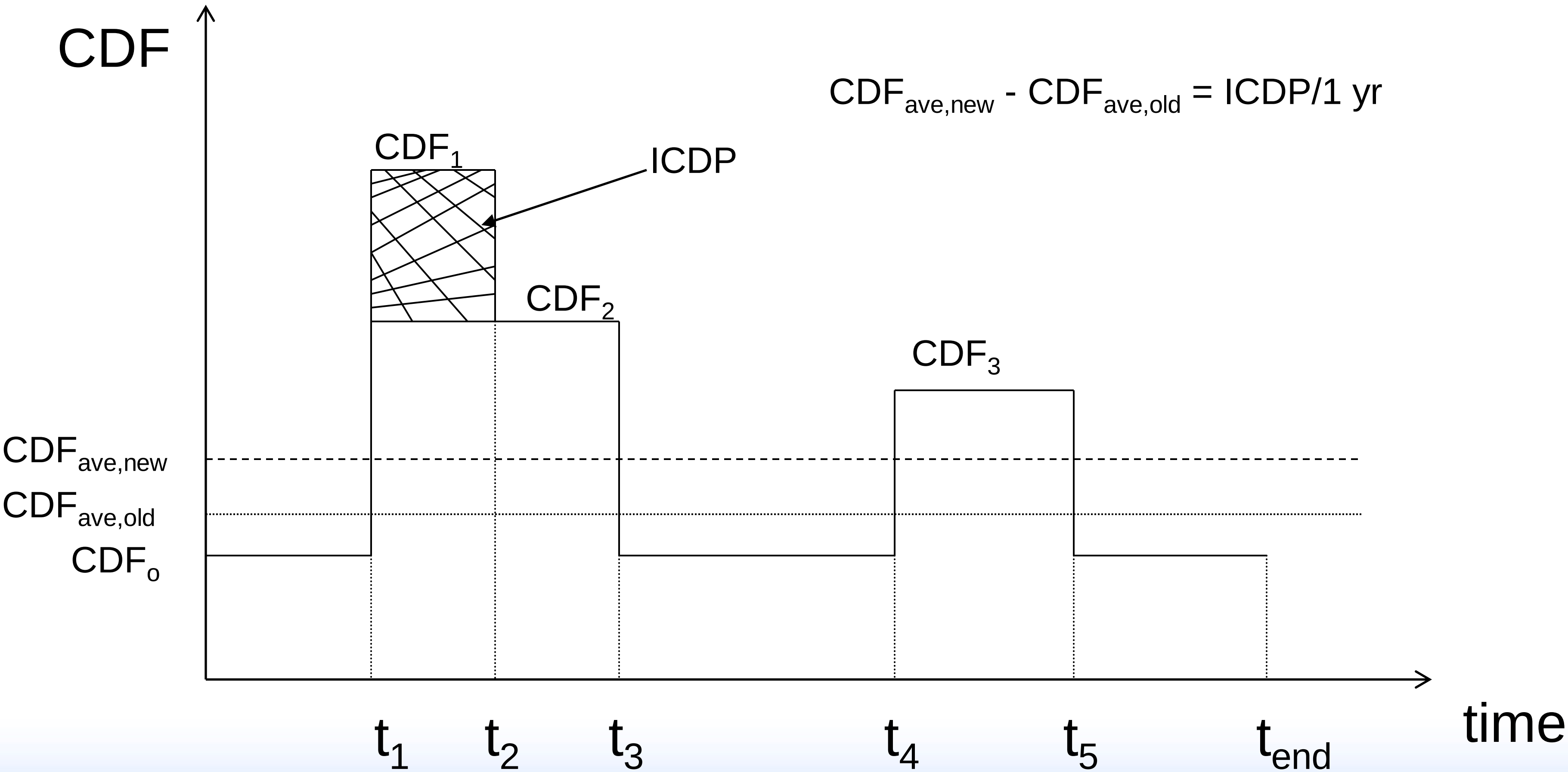
Final Risk Significance of Inspection Finding

- SDP estimates risk significance of licensee performance problems
  - Does not include equipment out of service for test or maintenance, unless related specifically to performance problem
  - Therefore, final result is increase in CCDP, or incremental CCDP, caused by the performance problem (see following graph for illustration)
  - It turns out (see algebra following graph) that, numerically, the incremental CCDP is equal to the increase in the time-weighted average CDF, if the averaging is done for a period of one year
    - So result from SDP can be compared to color criteria for PIs
- What the colors in Table 5 mean in terms of increase in annual time-averaged CDF
  - Red: Increase is ≥ 10^{-4}/yr
  - Yellow: Increase is between 10^{-5}/yr and 10^{-4}/yr
  - White: Increase is between 10^{-6}/yr and 10^{-5}/yr
  - Green: Increase is < 10^{-6}/yr

Illustrative CDF Profile



Algebra for CDF Profile (optional)

$$CDF_{ave,old} = \frac{CDF_o(t_1 + t_4 - t_3 + t_{end} - t_5)}{t_{end}} + \frac{CDF_2(t_3 - t_1)}{t_{end}} + \frac{CDF_3(t_5 - t_4)}{t_{end}}$$

$$CDF_{ave,new} = \frac{CDF_o(t_1 + t_4 - t_3 + t_{end} - t_5)}{t_{end}} + \frac{CDF_1(t_2 - t_1)}{t_{end}} + \frac{CDF_2(t_3 - t_2)}{T_{end}} + \frac{CDF_3(t_5 - t_4)}{t_{end}}$$

Algebra for CDF Profile

$$CDF_{ave,new} - CDF_{ave,old} = \frac{CDF_1 t_2 - CDF_1 t_1 + CDF_2 t_3 - CDF_2 t_2 - CDF_2 t_3 + CDF_2 t_1}{t_{end}}$$

$$= \frac{CDF_1(t_2 - t_1) - CDF_2(t_2 - t_1)}{t_{end}} = \frac{(CDF_1 - CDF_2)(t_2 - t_1)}{t_{end}} = \frac{ICDP}{t_{end}}$$

If t_{end} = 1 yr, then numerically ΔCDF_{ave} = ICDP, as claimed

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SDP for External Initiators

- SDP treats only fires and floods (internal and external), because licensee performance cannot impact frequency of other external events, such as earthquakes and severe weather
- External events treated in separate PRA analysis (see External Events Module)
  - IPEEE did not require <u>PRA </u>for external events
  - If PRA performed, separate accident sequences generated that start with fire, flood, etc.
  - Core damage requires external IE and failure of one or more systems and/or operator actions

SDP for External Initiators (cont.)

- SDP Phase 1 screens findings for events that increase likelihood of external IEs
  - Such events are analyzed by risk analyst in Phase 3 (not covered by Phase 2 SDP)
- Inspector may be able to identify external event sequences for analysis in Phase 3, using IPEEE or other licensee analysis
- If finding affects fire barrier or fire suppression feature, Appendix F is used by inspector for Phase 1 screening analysis

SDP for Containment Integrity

- IMC 0609, App. H contains draft guidance which is currently being evaluated by NRR
- Significance criteria for ΔLERF are order of magnitude less than for ΔCDF
  - Red: increase ≥ 10^{-5}/yr
  - Yellow: increase between 10^{-6}/yr and 10^{-5}/yr
  - White: increase between 10^{-7}/yr and 10^{-6}/yr
  - Green: increase < 10^{-7}/yr
- Finding that is "Green" for ΔCDF could by "White" for ΔLERF

SDP for Containment Integrity (cont.)

- Only some core damage sequences have significant LERF potential
  - ISLOCA
  - SGTR
  - Sequences where reactor vessel fails at high pressure
- Bear in mind that a "large early release" is one likely to cause acute fatalities offsite
  - Well in excess of 10 CFR 100 release

SDP for Containment Integrity (cont.)

- **SDP considers two types of findings, Type A and Type B**
- **Type A findings**
  - **Findings that affect CDF; CDF SDP performed**
  - **LERF considerations may adjust final risk significance**
  - **Use Appendix H, Table 2**
- **Type B findings**
  - **Findings that do not affect CDF; CDF SDP not performed**
  - **Appendix H, Table 3 gives results based on ΔLERF**
    - **Baseline CDF assumed to produce Table 3**
      - **PWRs: 10^{-4}/yr**
      - **BWRs: 10^{-5}/yr**

SDP for Shutdown Conditions

- Monitors five safety functions defined in NUMARC 91-06
  - Core decay heat removal
  - RCS inventory control
  - Power availability
  - Containment control
  - Reactivity control

SDP for Shutdown Conditions (cont.)

- **Phase 1 checklists are specific to plant operating state, as requirements vary among states, and states are not of equal risk significance**
- **Items screening to Phase 2 require more detailed analysis**

Significance Determination Process (SDP) Principles

- **Key Points of Section:**
  - SDP Purpose: To use risk insights to help NRC inspectors and staff determine the safety significance of findings. These findings are combined with the Performance Indicator information in assessing licensee performance.
  - SDP Objectives: To characterize the significance of inspection findings, to provide a common framework communicating tool, provide a basis for timely assessment and enforcement actions, and to provide inspectors with plant-specific risk information for use in risk-informing the inspection program.
  - SDP consists of 5 major tables:
    - Table 1- Categories for Initiating Events
    - Table 2- Initiators and System Dependency
    - Table 3- Site specific risk-informed inspection notebook
    - Table 4- (not site specific) Assigns probabilities of failure to different means of mitigation.
    - Table 5- Counting Rule Worksheet
  - Final Risk Significance of Inspection Finding
    - Red
    - Yellow
    - White
    - Green