Idaho National Laboratory

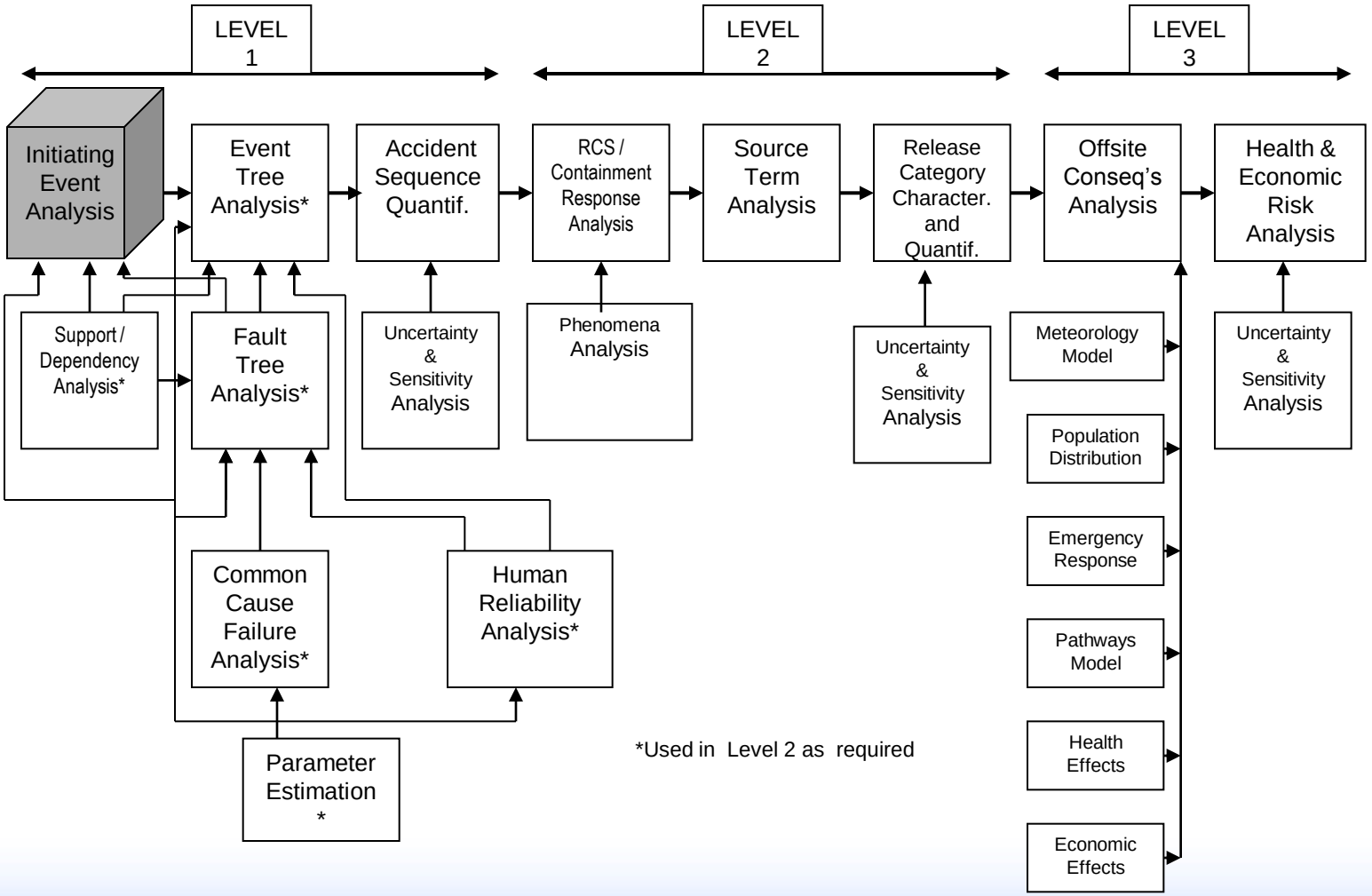
MODULE D

ACCIDENT SEQUENCE INITIATING EVENTS

Accident Sequence Initiating Events

- **Purpose: Students will learn how initiating events (IEs) are identified and grouped. Students will be exposed to the methods used to estimate initiating event frequencies and to sources of generic data for initiating events.**
- **Objectives:**
  - **Understand the relationship between initiating event identification and other PRA related tasks.**
  - **Become familiar with the various ways to identify initiating events.**
  - **Understand how initiating events are grouped and quantified.**
  - **Understand the relationship between PRA "initiators" and "challenges" in a traditional safety analysis report (SAR).**

Principal Steps in PRA



Initiating Events

- **Definition - Any potential occurrence that could disrupt plant operations. Initiating events are quantified in terms of their frequency of occurrence (i.e., number of events per year).**
- **Can occur while reactor is: at full power, at low power, at shutdown**
- **PRAs typically examine full power only**
- **Broad categories include: LOCAs and Transients (both from "internal“ and "external" events)**
- **Initiating event identification consists of**
  - **identifying comprehensive list of potential initiators that could upset plant operations**
  - **grouping initiating events into categories based on their impact on plant accident response systems**
  - **quantifying applicable initiating event category frequencies**

Illustrative List of Events and Frequencies (from North Anna IPE)

Category	Initiating Event	Frequency (per Rx Yr)	Return Period (Rx Yr)
T1	Loss of offsite power	0.11	9.1
T2	Transient w/nonrecoverable loss of MFW	0.05	20
T2A	Transient w/recoverable loss of MFW	0.55	1.8
T3	Transient w/MFW available initially	1.35	0.75
T4	Loss of RCP seal cooling	6.0E-7	1,600,000
T5	Nonrecoverable loss of DC bus	0.006	167
T6	Loss of service water	6.3E-6	158,730

Illustrative List of Events and Frequencies (from North Anna IPE) cont

Category	Initiating Event	Frequency (per Rx Yr)	Return Period (Rx Yr)
T7	Steam generator tube rupture	0.01	100
T8	Loss of emergency switchgear room cooling	0.0066	152
T9	Loss of 4.1 kV emergency buses	0.018	56
A	Large LOCA	5.0E-4	2,000
S1	Medium LOCA	0.001	1,000
S2	Small LOCA	0.02	50
V	Interfacing system LOCA	1.6E-6	625,000

Illustrative List of Initiating Events and Frequencies (from North Anna IPE) (cont.)

- Some possible initiating events may not be modeled explicitly
  - Frequency is very low (e.g., unisolated feedwater line break)
  - Effect is slow, easily identified, and recoverable (e.g., loss of control room HVAC)
  - Effect covered by existing initiating event category and frequency accounted for (e.g., loss of instrument air under T2)
  - Effect does not cause an automatic or immediate administrative demand for shutdown (e.g., waste treatment failure)

Role of Initiating Events in PRA

- **Identifying initiating events is the first step in the development of accident sequences (i.e., what can go wrong and how often can it go wrong?).**
- **Accident sequences can be conceptually thought of as:**
  - **an initiating event, which triggers a series of plant and/or operator responses, and then the initiating event in combination of success and/or failure of the plant and/or operator responses that result in some core damage state.**
- **Initiating event identification is an iterative process that requires feedback from other PRA processes for completeness.**
  - **Support/dependency analysis**
  - **Review of plant experience and data**

Example Categories of Initiating Events (SAR compared with PRA)

In SAR	In PRA
•Increase in secondary system heat removal	
•Increase in FW flow	
•Opening of SG relief valve	•T3 - transient w/MFW available
•Balance-of-plant upsets	•T2A - transient w/MFW recoverable
•Decrease in secondary system heat removal	
•Turbine trip	•T3 - transient w/MFW available
•MSIV closure	•T3 - transient w/MFW available
•Loss of FW flow	•T2 - transient w/MFW not recoverable
•Decrease in RCS flow rate	
•RCP trip	•T3 - transient w/MFW available
•Power anomalies	
•Uncontrolled rod withdrawal	•T3 - transient w/MFW available
•Boron dilution	•T3 - transient w/MFW available
•Decrease in RCS inventory	
•SGTR	•SGTR
•LOCAs	•LOCAs

Sources Used to Identify Initiating Events

- Review of Existing PRAs
- Review of Plant Experience and Procedures
- Feedback from other PRA Tasks
- Generic Databases
- Various NRC and Industry Sponsored Studies
- It should be noted that PRA initiators:
  - encompass all SAR initiators plus others
  - individual events grouped into categories for similar plant responses

Initiating Event Grouping

- **For each identified initiating event:**
  - **identify the safety functions required to prevent core damage**
  - **identify the plant systems that can provide the required safety functions**
- **Group initiating events into categories that require the same plant response**
- **This is an iterative process, closely associated with the event tree construction task (see Module E). It ensures the following:**
  - **all functionally distinct accident sequences will be included**
  - **overlapping of similar accident sequences will be prevented**
  - **a single event tree can be used for all IEs in a category (group)**

Initiating Event Grouping Example

Table 3.3.1: Success Criteria Of Front Line Equipment For Core Damage Mitigation Functions						
Initiator Class	Reactivity Control	RCS Inventory Control	RCS Pressure Boundary Integrity	RCS and Core Heat Removal		
				Primary-Secondary Heat Removal	Feed and Bleed Cooling	Long Term RCS Cooling/Inventory Control
Transients	RPS, or EB for RPS signal failure	Not needed if RCS is Intact	(SDBC, or PORVs/SRVs) and (PORVs and SRVs reclose)	(1 MFW or 1 AFW **) and (SDBC or ADV or MSSV)	1 PORV, *** and 1 HPSI	Continued Primary/Secondary Heat Removal or SDC or 1/3 HPR if feed & bleed in Initiated
Small LOCA	RPS, or Manual for RPS signal failure	1/3 HPSI ***	N/A	(1 AFW **) and (SDBC or ADV or MSSV)	1 PORV ***	1/3 HPR or SDC
Medium LOCA	N/A	1/3 HPSI	N/A	N/A	N/A	1/3 HPR
Large LOCA	N/A	1/3 HPSI & 3/4 SIT or * 1/2 LPSI & 2/4 SIT	N/A	N/A	N/A	1/3 HPR or 1/2 LPR (Cold Leg Recirculation)
SGTR	RPS, or Manual for RPS signal failure	1/3 HPSI ***	(SDBC or ADV or MSSV)	(1 MFW or 1 AFW **) and (SDBC or ADV or MSSV)	1 PORV***	Continued RCS Inventory makeup or SDC
ISLOCA	RPS, or Manual for RPS signal failure	1/3 HPSI	(SDBC or ADV or MSSV) or Low Pressure System Intact	(1 MFW or 1 AFW **) and (SDBC or ADV or MSSV)	N/A	Continued RCS Inventory makeup or SDC

* Large LOCA success criteria based on calculations performed for (< 3 ft^2 equivalent area) credible pipe break, and realistic post-accident thermal hydraulic system performance.

** If AFW is not initially available, the time available for recovery is 1 hour.

*** Feed-and-Bleed is required in conjunction with a total loss of feedwater. The inventory control aspect is provided by 1 of 3 HPSI pumps. Pressure control is provided by the PORV.

Initiating Event Quantification

- **Use values based on type and frequency of events industry-wide (useful for rare events not expected to occur during the life of the plant)**
- **Use plant-specific data to update generic values when such data is available**
- **Modeling and/or analysis techniques (useful for very rare events)**
- **All of the above are used in a typical PRA**

Exercise: Initiating Event Frequency

- **Calculate a transient initiating event frequency based on the following information:**
  - **A plant has 10 years of data, and the plant's capacity factor was 85% over that 10 year period. Transients over that 10 year period;**

Year	Number of Transients
2000	2
2001	0
2002	1
2003	0
2004	1
2005	0
2006	2
2007	0
2008	0
2009	1

Generic Initiating Event Frequencies

- Generic initiating event frequencies can be obtained from the following sources.
  - NUREG/CR-4550, Vol.1 Methods and Data for NUREG-1150
  - NUREG/CR-3862, Development of Transient Initiating Event Frequencies (pre-1986)
  - NUREG/CR-5750, Rates of Initiating Events at U.S. Nuclear Power Plants: 1987-1995
  - NUREG/CR-6365, Steam Generator Tube Failures
  - NUREG/CR-6890, Reevaluation of Station Blackout Risk at Nuclear Power Plants: 1986 - 2004
  - NUREG/CR-4407, Pipe Break Frequency Estimation for Nuclear Power Plants
  - NUREG-1829, Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process
  - NSAC-154, ISLOCA Evaluation Guidelines
  - EPRI TR-100380, Pipe Failures in U.S. Commercial Nuclear Power Plants
  - EPRI TR-1003113, An Analysis of Loss of Decay Heat Removal Trends and Initiating Event Frequencies (1989 – 2000)
  - NUREG/CR-6850, EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Plants
  - NUREG/CR-6928, Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants
- Note that the above cite industry-wide yearly averages. Plant-to-plant differences can and do exist, and on any given day can be dependent on existing plant configuration and environmental conditions. Therefore....

A Cautionary Note

- **Plant PRA initiating event frequencies should**
  - **reflect unique plant characteristics**
  - **may not be appropriate in a specific operational condition or environment**
- **For example**
  - **Generic loss of offsite power frequency is 0.05/yr**
  - **Plant X is located in "tornado alley"**
  - **Possible questions to consider:**
    - **Does the loss of offsite power frequency for this plant reflect its location?**
    - **Should plant configuration control decisions be made during the peak of tornado season using the generic frequency?**

Student Exercise

Given the following PRA results:

IE	IE Frequency (per yr)	% Contribution to CDF by IE	CDF Contribution by IE (per year)	New CDF Contribution by IE (per year)
LLOCA	5E-5	3%	2.1E-6	
MLOCA	1E-4	10%	7E-6	
SLOCA	1E-3	15%	1.05E-5	
ISLOCA	2E-6	1%	7E-7	
All Others	NA	71%	4.97E-5	
		Total Internal CDF = 7E-5		New Total Internal CDF =

The licensee finds that a number of RCS instrument lines are experiencing excessive mechanical fatigue due to lack of proper supports. Estimate the change in CDF if the IE frequency of SLOCA increases by a factor of 2 as a result of this condition.

Student Exercise

- **Answer the following from your plant's IPE/PRA**
  - **What are the transient initiator groups used in the analysis?**
  - **If more than one group is used,**
    - **What are the transient group frequencies?**
    - **Which transient group has the highest frequency?**
    - **Does the way in which transients have been grouped seem reasonable?**