Idaho National Laboratory

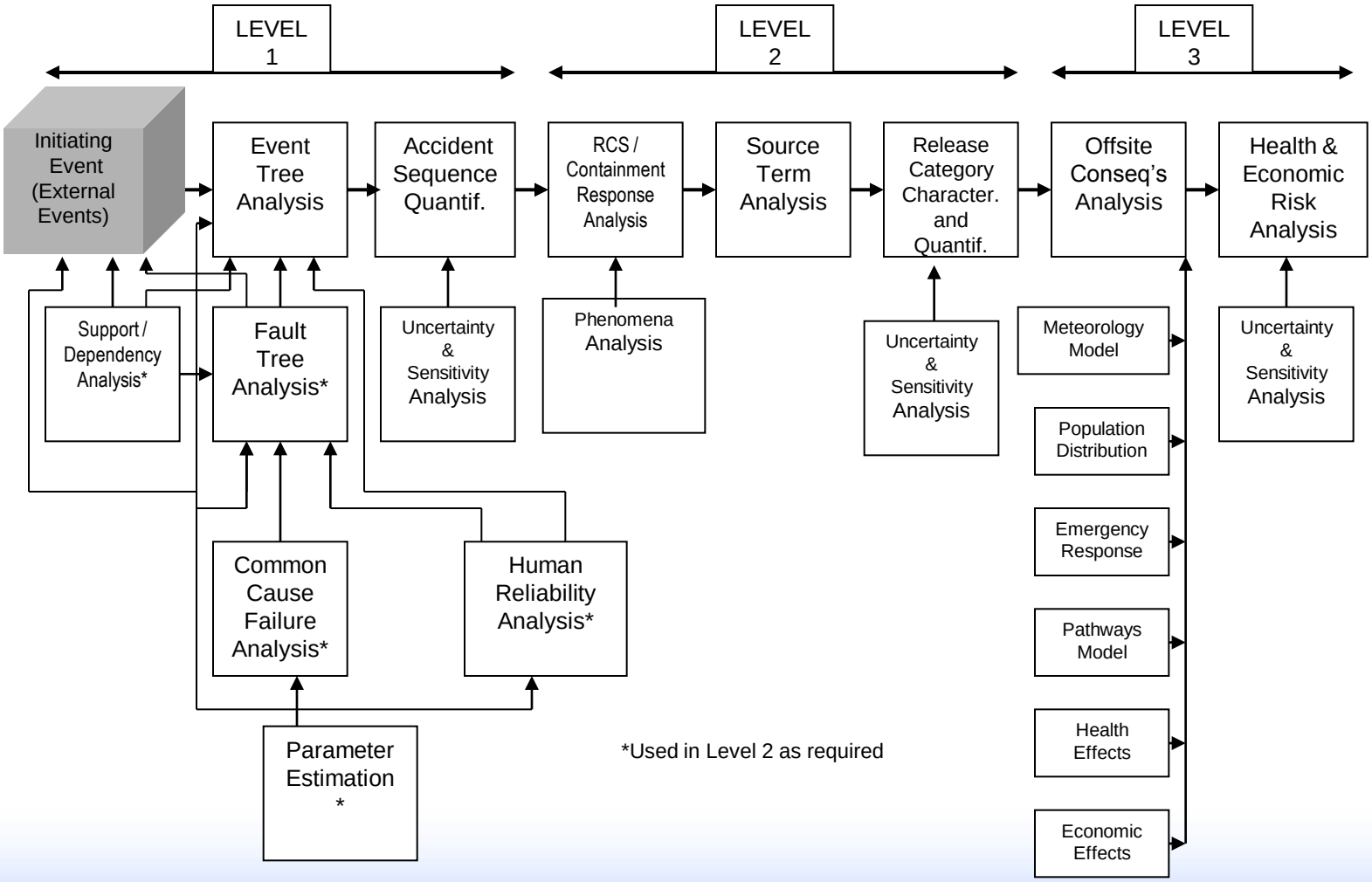
MODULE K

EXTERNAL EVENTS

External Events

- **Purpose: This topic will acquaint students with the definition of external events and the IPEEEs.**
- **Objectives:**
  - **Define external events and understand how they differ from internal events**
  - **List several of the more significant external events, including those analyzed in the IPEEEs**
  - **Know acceptable approaches for seismic events and fires to meet objectives of the IPEEE**
  - **Explain the ways in which external events may be evaluated and how this evaluation is related to the overall PRA task flow.**
- **References:**
  1. **ANSI/ANS Std. 58.21-2007 (External Events PRA Standard)**
  2. **NUREG/CR-6850 (fire PRA methodology)**

Principal Steps in PRA



Overview of External Events Analysis

- External Events (EE) refers to those events that are external to system being analyzed
  - Examples: fires, floods, earthquakes
    - Includes on-site events such as flooding of various rooms within plant
- External Events (EE) are important and are of concern due to their dependent nature, that is EE can both;
  - Initiate a potential core damage accident
  - Fail or compromise the safety systems and/or procedures used to prevent or mitigate core damage accidents and consequences
- General approach
  - Identify hazard and its intensity
  - Estimate conditional failure probability of plant SSCs
  - Assess overall plant response to event

Initial List of Potential External Event Hazards (1 of 2)

- Aircraft
- Avalanche
- *Earthquake
- *Fire in plant
- Fire outside plant but on site
- Fire off site
- Flammable fluid release
- Fog
- *Flooding, external (including seiche, storm surge, dam failure, and tsunami)
- **Flooding, internal
- *High winds (including tornadoes)
- Hurricane
- Ice
- Industrial or military accident offsite
- Landslide

*** Included in IPE*

** Included in IPEEE*

Initial List of Potential External Event Hazards (2 of 2)

- Lightning
- Meteorite impact
- Pipeline accident
- Sabotage
- Ship impact
- Toxic gas release
- Transportation accident
- Turbine missile
- Volcanic activity
- Blizzard/Snow
- Drought
- Erosion
- Hail
- Heavy rain
- High temperature
- Low Temperature
- River diversion or change in lake level
- War

History of External Events PRA in U.S.

- **1975 - WASH-1400 used logic models to analyze risks to public from two nuclear power plants; external events omitted from quantitative results**
- **1980s - Nuclear industry-sponsored studies of commercial nuclear plants first included assessments of external events**
  - **Oyster Creek - 1979 (first seismic PRA study)**
  - **HTGR - 1979 (first fire PRA study)**
  - **Big Rock Point - 1981 (included external events)**
  - **Zion/Indian Point - 1982 (included external events)**
  - **Browns Ferry (1983), Oconee (1984), Midland (1984), Shoreham (1986, 1988), Three Mile Island (1987), South Texas Project (1989)**

History of External Events PRA in U.S. (cont.)

- NRC/industry-sponsored PRA Procedures Guide (NUREG/CR- 2300) includes methods for analyzing external events - 1983
- Extensive research sponsored by NRC and EPRI on methods for analyzing external events
- GL 88-20 issued - 1988, includes requirements for assessing vulnerabilities to internal floods
- NUREG-1150 - 1989, contains analyses of external events for Peach Bottom and Surry
- GL 88-20, Supplement 4 - 1991, contains IPEEE requirements for other external events
- NUREG-1407 issued containing IPEEE submittal guidance - 1991
- Originally requested IPEEE submittal date was June 1994
- GL 88-20, Supplement 5 revised IPEEE seismic requirements - 1995

Most Hazards Excluded for Various Reasons

- **IPEEE required analysis of hazards believed to dominate external event risk**
  - **Seismic**
  - **Internal fires**
  - **High winds and tornadoes**
  - **External floods (internal flood analysis required in IPE)**
  - **Transportation and nearby facility accidents**
  - **Any known plant-unique hazards**

External Events Analyses Performed at Various Levels of Detail

- **Seismic**
  - **Seismic PRA**
    - **Required for high-seismicity sites**
  - **Seismic margin assessment (calculates HCLPF - high confidence of low probability of failure)**
- **Fire**
  - **Fire PRA**
  - **Fire-Induced Vulnerability Evaluation (FIVE)**
- **Other**
  - **External Event PRA**
  - **Screening analysis**

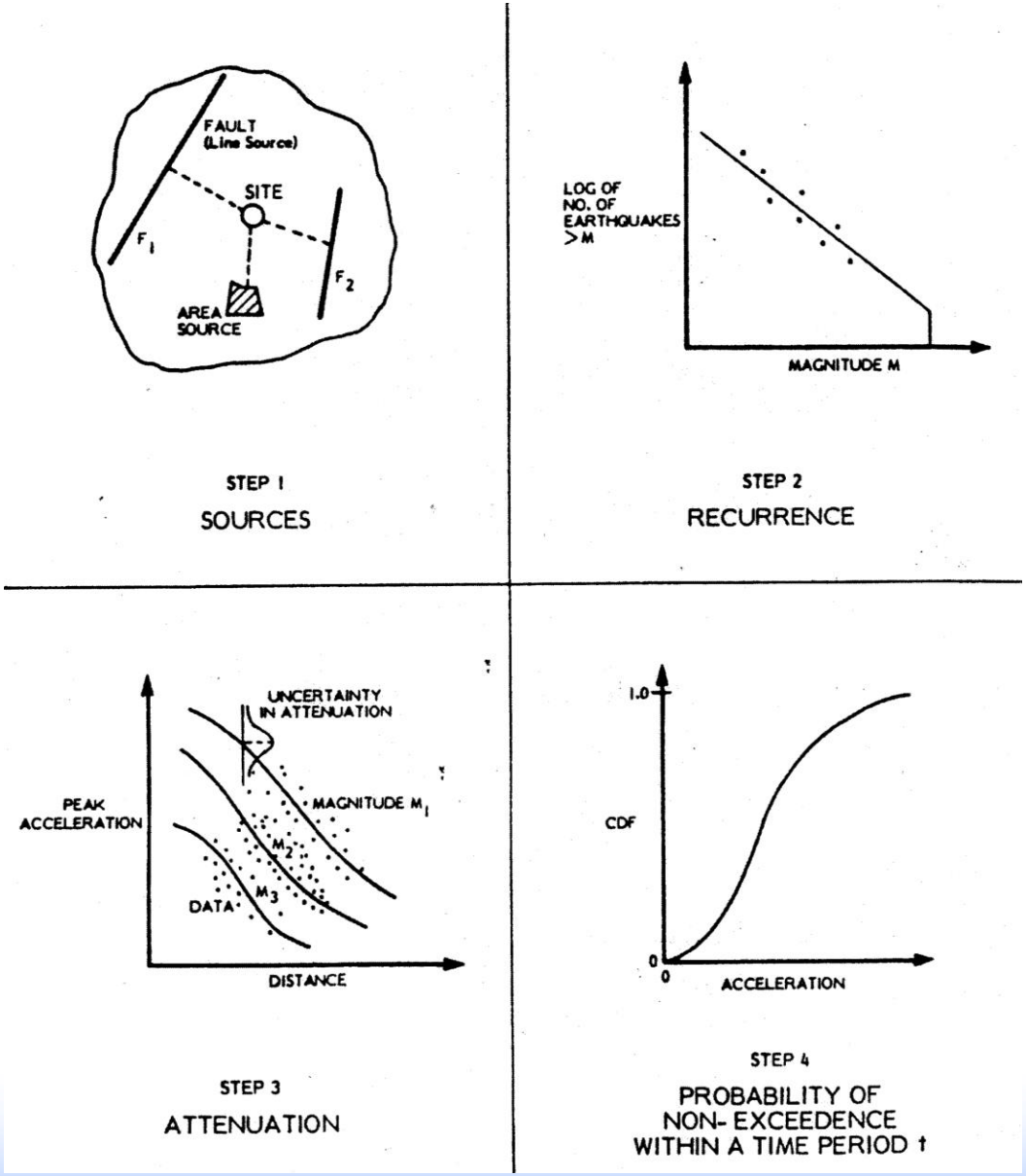
Seismic Hazard PRA - 3 Basic Steps

- **Hazard analysis (frequency-magnitude relationship for earthquakes)**
  - **Location-specific hazard curves produced by NRC (LLNL) and EPRI**
- **Fragility analysis ("strength" of component)**
  - **Conditional probability of failure given a specific earthquake severity**
- **Accident sequence analysis**

Analysis process briefly looked at in following slides

Four Steps in Seismic Hazard Curve Development

1. Identify seismic sources
2. Develop frequency-magnitude model for each source
3. Develop ground motion model for each source
4. Integrate over sources



Frequencies Estimated for Various Ground Acceleration Levels

- Frequency of 0.1g, 0.2g, 0.3g, etc. earthquake estimated
- Each g-level earthquake analyzed separately (i.e., as a separate and unique event)
- Failure probabilities of plant SSCs calculated based on g-level and fragility of SSC
- Internal events PRA re-evaluated using “new” seismic failure probabilities

Seismic Fragility Expressed in Terms of Peak Ground Acceleration

- **Fragility (A) = A_m β_R β_U (lognormal model assumed)**
  - **A_m = median ground acceleration capacity of SSC**
  - **β_R β_U = Measure of the uncertainty in median fragility due to randomness and confidence, respectively (can also be labeled aleatory and epistemic, respectively).**
  - **A_m derived from various safety and response factors ($F_c F_{RE} F_{RS} A_{SSE}$), in turn are products of other factors**
    - **F_C - Capacity Factor**
    - **F_{RE} - Response factor for equipment**
    - **F_{RS} - Response factor for structure**
    - **A_{SSE} - Safe Shutdown Earthquake acceleration**

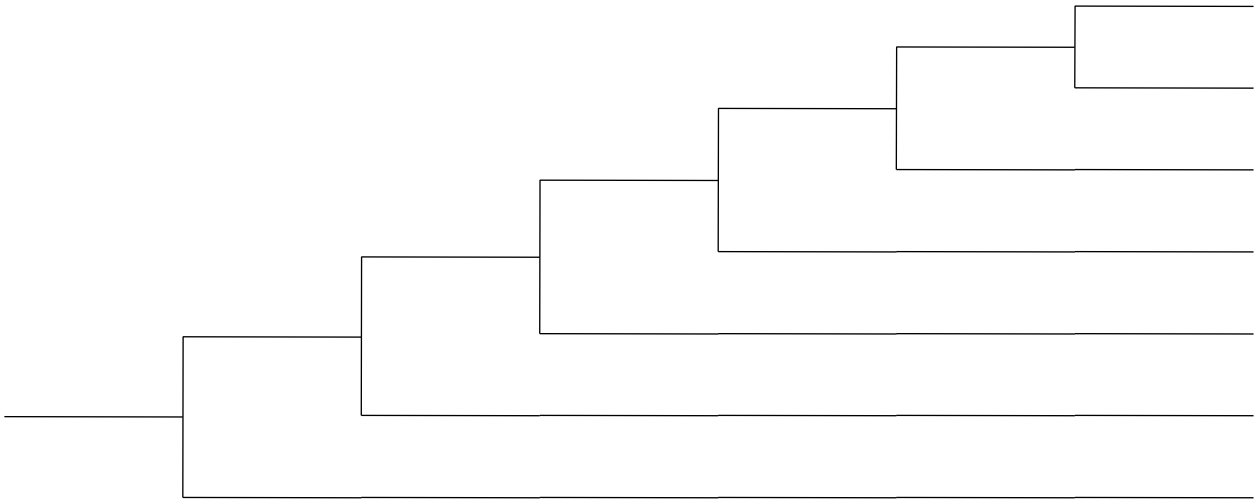
Range of Seismic Fragilities for Selected Components*

Componenent/Structure	*Dominant Failure Mode*	*Median Fragility Range (g)*
Concrete containment building	*Shear failure*	*2.50-9.20*
Reactor Pressure Vessel	*Anchor bolt*	*1.04-5.70*
Flat-bottom tank	*Shell wall buckling*	*0.20-1.00*
Batteries and racks	*Cases and plates*	*0.90-5.95*
Motor control centers	*Chattering*	*0.06-4.20*
Diesel generator	*Anchor bolt*	*0.70-3.89*
Offsite power	*Ceramic insulators*	*0.20-0.62*

* *Y. J. Park, et al, Survey of Seismic Fragilities Using in PRA Studies of Nuclear Power Plants, Reliability Engineering and System Safety, Vol. 62, pages 185-195, 1998.*

Probability of “Initiating Events” Estimated Given Occurrence of EE (Provides Link to Sequence Analysis)

Seismic Event Occurs	*Reactor Vessel Rupture*	*Large LOCA*	*Medium LOCA*	*Small LOCA*	*Loss of Off-Site Power*	*Rx-Trip with FW nominally available*	
EQ	*RVR*	*LLOCA*	*MLOCA*	*SLOCA*	*LOSP*	*T*	



Fire Analysis Follows Phased Approach

- **Qualitative Screening**
  - **Fire in area does not cause a demand for reactor trip**
  - **Fire area does not contain safety-related equipment**
  - **Fire area does not have credible fire source or combustibles**
- **Quantitative Screening**
  - **Utilized existing internal events PRA**
  - **Estimate fire frequency for area and assume all equipment in fire area failed by fire, calculate CDF**
- **Detailed Analysis**

Detailed Fire Analysis Includes

- **Fire occurrence frequency assessment**
  - **Either location-based or component-based**
  - **Generic data updated with plant-specific experience**
- **Fire growth and propagation analysis**
  - **Considers: Combustible loading, fire barriers, and fire suppression**
  - **Modeled with specialized computer codes (COMPBRN IIIe)**
- **Component fragilities and failure mode evaluation**
- **Fire detection and suppression modeling**
- **Detailed fire scenarios analyzed using transient ET**

Fire-Induced Vulnerability Evaluation (FIVE)

- Developed by EPRI as an alternative to a fire PRA for satisfying IPEEE requirements
- Equivalent to a fire-area screening analysis
  - Worksheet-based systematic evaluation using information from Appendix R implementation
  - Does not produce detailed quantification of fire CDF
- Most FIVE users (IPEEE) also quantified fire CDF of unscreened areas

Current Activities in External Events PRA

- NFPA Std. 805 issued
- Many plants updating fire PRAs to meet NFPA standard
  - Risk-informing 10 CFR 50, App. R
- NUREG/CR-6850 documents updated fire PRA guidance
- Research ongoing for outstanding issues
  - Multiple spurious actuations
  - Hot shorts of cabling
- NRC expanding SPAR models to include external events

Other External Events Analyzed Using Structured Screening Process

- **IPEEE Guidance - Progressive Screening approach (see Figure 5.1 of NUREG-1407)**
  - **Review plant-specific hazard data and licensing basis (FSAR)**
  - **Identify significant changes, if any, since operating license issuance**
  - **Does plant/facility design meet 1975 SRP criteria (via quick screening & confirmatory walkdown)**
    - **If yes, no further analysis is needed**
    - **If no, continue analysis (next slide)**

Examples of SRP Non-Conformance

- **Flood**
  - **Probable Maximum Precipitation (PMP) at site based on old National Weather Service data**
- **High-Wind/Tornado**
  - **Design basis tornado missile spectrum different from that specified in SRP**

If 1975 SRP Criteria Not Met

- **Is Hazard Frequency Acceptably Low (<1E-5/yr)?**

If Not:

- **Does bounding analysis estimate CDF <1E-6/yr?**

If Not:

- **Perform detailed PRA**
  - **Details of analysis are tailored to particular hazard**