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Introduction to Nuclear Safety

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What is risk?

- Arises from a “Danger” or “Hazard”
- Always associated with undesired event
- Involves both:
  - likelihood of undesired event
  - severity (magnitude) of the consequences

Risk Definition

- **Risk - the frequency with which a given consequence occurs**

$$\text{Risk}\left[\frac{\text{Consequence Magnitude}}{\text{Unit of Time}}\right] =$$

$$\text{Frequency}\left[\frac{\text{Events}}{\text{Unit of Time}}\right] \times \text{Consequences}\left[\frac{\text{Magnitude}}{\text{Event}}\right]$$

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Risk Example: Deaths Due to Accidents

- Societal Risk = 117,809 accidental-deaths/year (USA)
- (based on Center for Disease Control actuarial data)
- Average Individual Risk
- = (93,000 Deaths/Year)/304,000,000 Total U.S. Pop.
- = 3.9 x10-4 Deaths/Person-Year
- 1/2500 Deaths/Person-Year
- In any given year, approximately 1 out of every 2,500 people in the entire U.S. population will suffer an accidental death

Risk Example: Deaths Due to Cancer

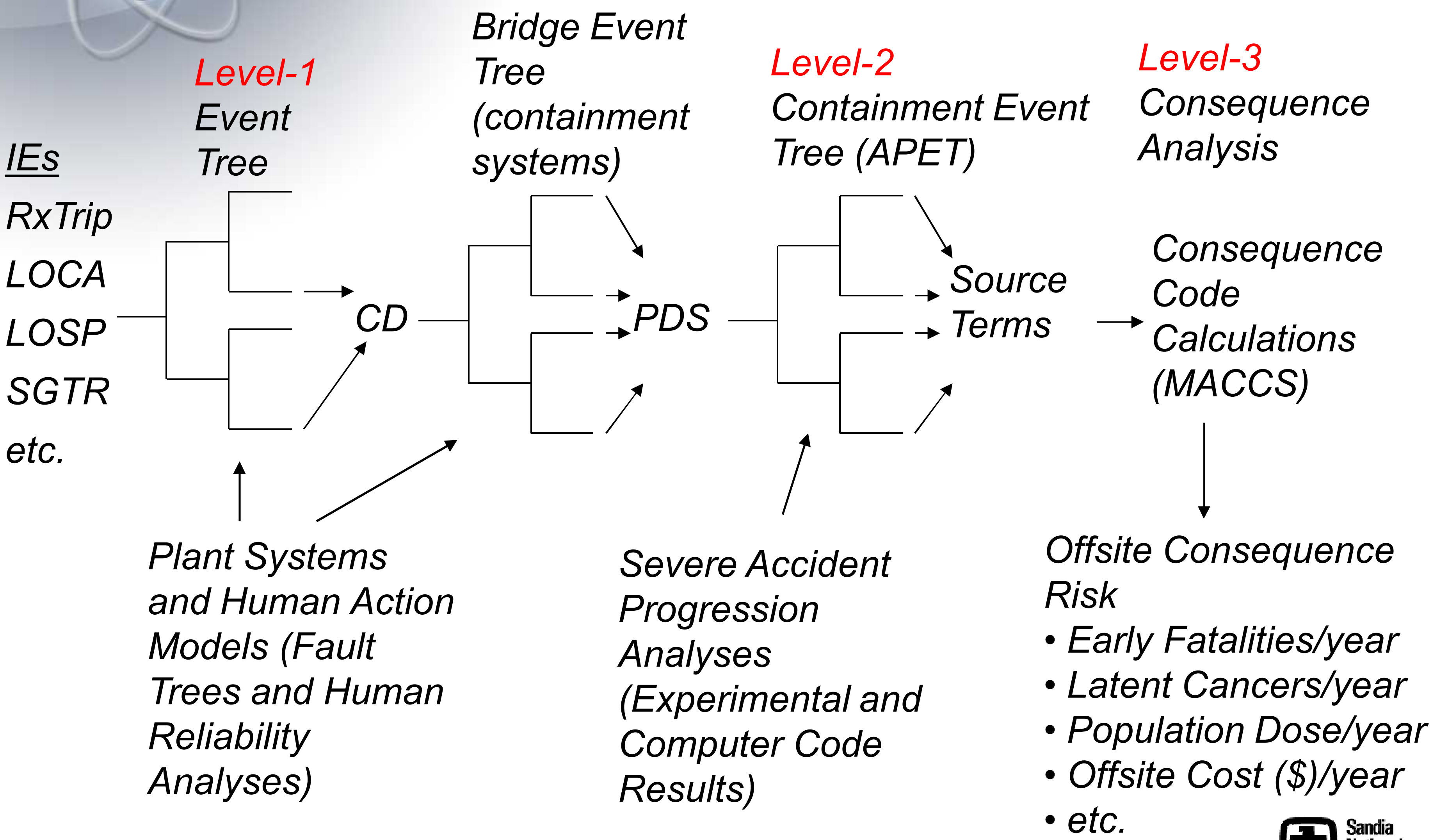
- Societal Risk = 538,000 cancer-deaths/year
- (based on Center for Disease Control actuarial data)
- Average Individual Risk
- = (538,000 Cancer-Deaths/Year)/250,000,000 Total U.S. Pop.
- = 1.7x10-3 Cancer-Deaths/Person-Year
- 1/550 Cancer-Deaths/Person-Year
- In any given year, approximately 1 person out of every 550 people in the entire U.S. population will die from cancer

Overview of PRA Process

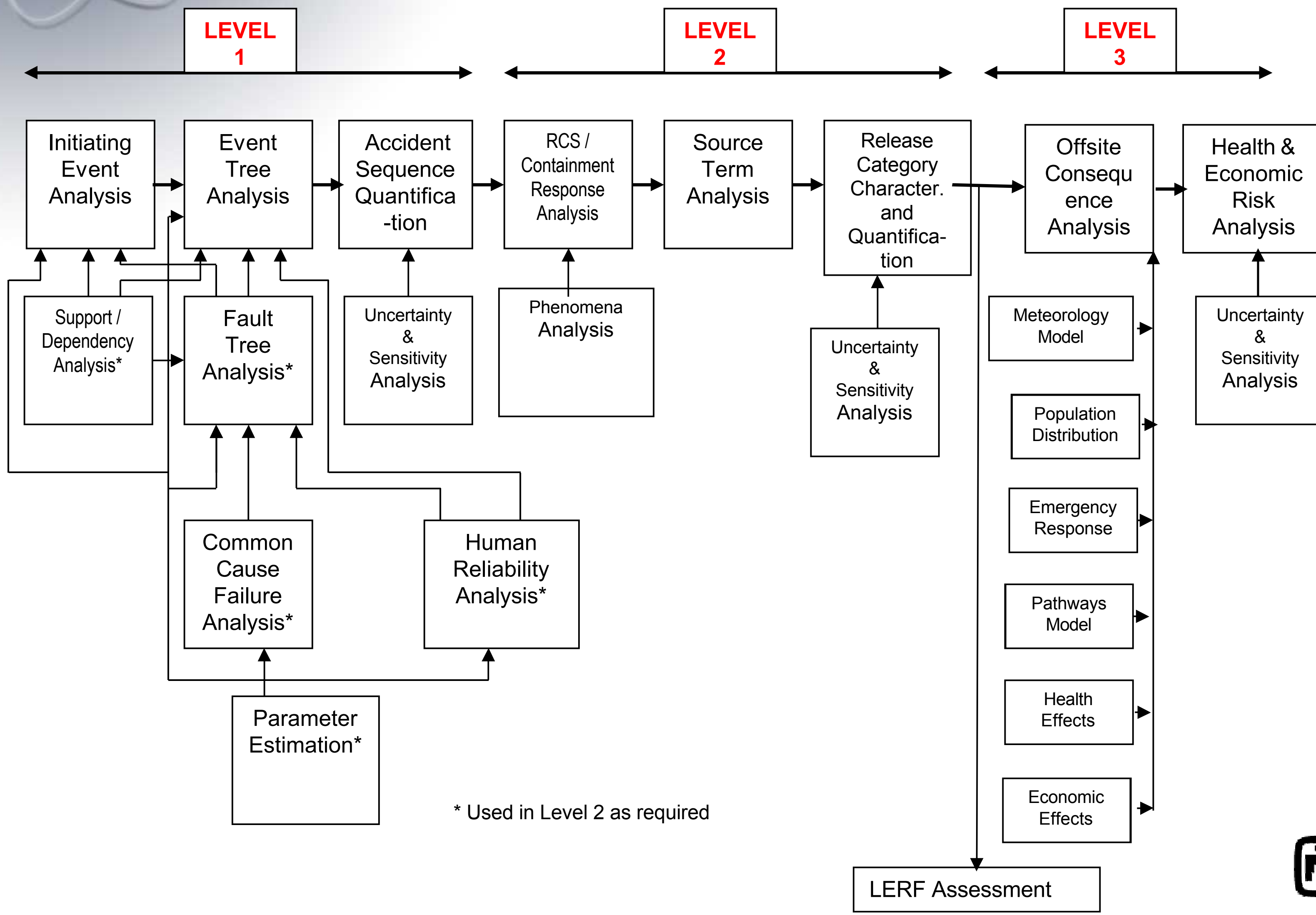
- **PRAs are performed to find severe accident weaknesses and provide quantitative results to support decision-making. Three levels of PRA have evolved:**

Level	An Assessment of:	Result
1 (Systems Analysis)	Plant accident initiators and systems'/operators' response	Core damage frequency & contributors
2 (Containment Analysis)	Frequency and modes of containment failure	Categorization & frequencies of containment releases
3 (Consequence Assessment)	Public health consequences	Estimation of public & economic risks

Overview of Level-1/2/3 PRA



Principal Steps in PRA



* Used in Level 2 as required

PRA Analyzes Risk from Various Perspectives

- The type of Initiating events, or the nature of potential insults to the plant
  - Internal Initiating Events
    - Loss of Coolant Accidents (LOCAs)
    - fire events
    - internal flooding (e.g., pipe breaks within the plant)
    - loss-of-offsite power
    - Plant transients
  - External Initiating Events
  - risk from external events. Includes:
    - seismic events,
    - external flooding (rivers, lakes, burst dams, etc.)
    - high winds and tornadoes,
    - airplane crashes,
    - lightning, hurricanes, sandstorms, etc.
  - Dependent on the physical location of the plant.
- Operational mode of Plant
  - Full Power – accidents initiated while plant is operating at power
  - Low Power and Shutdown (LP/SD) – accidents initiated while plant is at low power or shutdown

Risk Insights Gained from PRA

PRA has shown that:

- **Plants are fundamentally safe – when operated well.**
- **Many events must occur for an undesirable consequence to take place.**
  - **Level I**
    - Initiating event must occur, which is actually a common occurrence.
    - Numerous plant safety functions must fail
    - Redundant & diverse safety systems must fail to protect the core
    - Operators must fail to detect, diagnose, & correct accident conditions and system failures.
  - **Level II**
    - Additional safety systems must fail to mitigate the accident conditions.
    - Containment integrity must be compromised.
  - **Level III**
    - Severity of dispersion of source term dependent on:
      - Weather
      - Emergency Response

Risk Insights (Cont.)

PRA has caused regulatory and operational practices to change over time:

- **Current generation of reactors were designed against large LOCA accidents**
- **PRA showed that transient accidents were a bigger threat to safety**
  - **High dependence on lots of active components (e.g., pumps, valves)**
- **PRA showed that external events (e.g., seismic) were a significant threat to safety**
- **Regulations have changed to address this shift in risk perspectives**
  - **Seismic safety redesigned into existing plants**
  - **"Back-fits" to many plants address transient issues (e.g., better emergency AC power supplies)**
- **Licensees use PRA to review proposed design and operational changes**

Principal Limitations of PRA

- Inadequacy of available data
- Lack of understanding of physical processes
- High sensitivity of results to assumptions
- Constraints on modeling effort (limited resources)
  - simplifying assumptions
  - truncation of results during quantification
- PRA is typically a snapshot in time
  - this limitation may be addressed by having a “living” PRA
    - plant changes (e.g., hardware, procedures and operating practices) reflected in PRA model
    - temporary system configuration changes (e.g., out of service for maintenance) reflected in PRA model
- Lack of completeness (e.g., human errors of commission typically not considered)