MODULE A

Introduction to PRA and Its Use by the NRC

Introduction to PRA and Its Use by the NRC

- **Purpose**
  - Introduce use of PRA from perspective of NRC policy
  - Introduce PRA terminology
  - Introduce NRC perspective on relationship of PRA to inspection
    - Inspection planning
    - Evaluating findings
    - Evaluating licensee use of PRA

Objectives

- Upon completion of this module, students should be able to
  - Define risk
  - List the basic questions answered by PRA
  - List three potential uses of PRA by inspectors
  - Generally describe NRC's quantitative health objectives
  - List the subsidiary numerical goals derived from the NRC's quantitative health objectives
  - List three expected outcomes of the NRC PRA Policy Statement
  - List one area explicitly precluded from PRA application
  - Describe NRC's framework for incorporating PRA into facility regulation
  - List two ways in which PRA is affecting licensing basis
  - List example PRA strengths and limitations
  - Discuss ways in which PRA limitations are addressed

Outline of Topics

- Basic terminology
- Risk definition and examples
- How PRA is being used
- NRC quantitative health objectives and subsidiary numerical goals
- NRC PRA Policy Statement
- Risk-Informed and Performance-Based Plan (RPP)
- Strengths and limitations of PRA
- How PRA limitations are addressed

Basic PRA Terminology

- **Frequency – Number of occurrences of an event per number of demands or per unit time**
  - **Parameter used in model for stochastic (aleatory) uncertainty**
  - **Time-based frequencies can be any positive value (i.e., can be greater than one)**
- **Probability – Likelihood of an event occurring**
  - **Internal measure of certainty about the truth of a proposition**
  - **Unitless value which is always conditional**
  - **Value between 0 and 1**
  - **Typically used for all events in PRA except initiating events**
- **Note: Frequency and Probability are different concepts, but sometimes numerically equal**
- **Consequence – Ultimate result of event in terms of public health impact, economic impact, etc. Intermediate consequence measures such as core damage frequency or large early release frequency are often used.**

Risk Definition

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

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

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

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Risk Example - Death Due to Accidents

- **Societal Risk = 123,706 Accidental-Deaths/year**
- **Average Individual Risk**
  = (123,706 Accidental-Deaths/Year)/301,606,770 Est. U.S. Pop.
  = 4.10E-04 Accidental-Deaths/Person-Year
  ≈ 1/2438 Accidental-Deaths/Person-Year
- **In any given year, approximately 1 out of every 2,438 people in the entire U.S. population will die from an accidental death**

Note: Figures presented above are based on the National Vital Statistics Reports, Deaths: Final Data for 2007, May 20, 2010, Volume 58, Number 19, at www.cdc.gov which is the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS) for the United States. Unintentional injuries is the preferred term to accidental deaths in the public health community. The average individual risk for accidental deaths in the 1980s was approximately 5.0E-04 Deaths/Person-year.

Risk Example - Death Due to Cancer

- **Societal Risk = 562,875 Cancer-Deaths/year**
- **Average Individual Risk**
  = (562,875 Cancer-Deaths/Year)/301,606,770 Est. U.S. Pop.
  = 1.87E-03 Cancer-Deaths/Person-Year
  ≈ 1/536 Cancer-Deaths/Person-Year
- **In any given year, approximately 1 out of every 536 people in the entire U.S. population will die from a cancer death**

Note: Figures presented above are based on the National Vital Statistics Reports, Deaths: Final Data for 2007, May 20, 2010, Volume 58, Number 19, at www.cdc.gov which is the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics (NCHS) for the United States. Unintentional injuries is the preferred term to accidental deaths in the public health community. The average individual risk for cancer deaths in the 1980s was 2.0E-03 Deaths/Person-year.

Basic PRA Terminology (cont.)

- **Probabilistic risk assessment (PRA) – an analytical tool that answers three questions:**
  - **What can go wrong?**
    - **Accident scenarios**
  - **How likely is each scenario?**
    - **Frequency, probability**
  - **What are the effects?**
    - **Consequences**
- **A fourth question, reflecting the importance of uncertainty, has also been addressed in recent PRAs**
  - **How confident are we in our answers to these three questions?**

PRA Now Widely Used by Industry and NRC

- **Use by licensees initially (during IPE) to evaluate plant severe accident potential vulnerabilities**
- **Now being used by some licensees to support submittals to NRC**
- **NRC has endorsed PRA as important element in licensing regulatory process**

NRC Applications of PRA

- Monitoring reactor operations
  - Maintenance Rule
  - Mitigating System Performance Index (MSPI)
- Value impact analysis for potential changes to licensed reactor design and operation (backfits)
- Efforts to Risk Inform – 10 CFR 50
- Licensing advanced reactor designs
- Reactor operations
  - Evaluation of changes to licensing basis
    - General guidance – R.G. 1.174
    - IST – R.G. 1.175
    - ISI – R.G. 1.178
    - Graded QA – R.G. 1.176
    - Tech. Specs. – R.G. 1.177
  - Inspections support (e.g., Senior Reactor Analysts in Region)
    - Prioritization and planning of inspections
    - Evaluation of inspection findings (e.g., SDP)
    - Evaluation of licensee use of PRA

NRC Applications of PRA (cont.)

- Resource allocation
  - Regulatory requirements (e.g., risk-informing 10 CFR 50)
  - Research (e.g., fire protection issues)
  - Regulatory analysis (e.g., generic issue resolution)
- Reactor design
  - Identify weaknesses in design
    - Risk-significant Systems, Structures, Components (SSCs)
    - Risk-significant accident scenarios
    - Risk-significant human actions
- Standardized Plant Analysis Risk (SPAR) Models
- Event analysis and risk significance
  - Accident Sequence Precursors (ASP)
  - Significance Determination Process (SDP)
- Risk Monitors
- Non-reactor issues
  - Licensing high-level waste repository
  - Sealed sources
  - Spent fuel storage
  - Medical uses of byproduct materials
  - Others

Use of PRA by Inspectors

- **Uses can be categorized broadly as**
  - **Providing risk perspective for inspection planning (focus and priorities)**
  - **Evaluating risk significance of findings and events**
  - **Evaluating licensee uses of PRA (e.g., plant configuration control)**

NRC Quantitative Health Objectives (QHOs)

- Originally known as the Probabilistic Safety Goals
  - NRC adopted two probabilistic safety goals on August 21, 1986
- High-level goal: incremental risk from nuclear power plant operation < 0.1% of all risks
  - Average individual (within 1 mile of plant) early fatality (accident) risk
    < 5E-7/year
  - Average individual (within 10 miles of plant) latent fatality (cancer) risk
    < 2E- 6/year
- Lower level subsidiary goals were derived from the high-level QHOs
  - Frequency of significant core damage (CDF)
    < 1E-4/year
  - Frequency of large early release of fission products from containment (LERF)
    < 1E-5/year
- Metrics for new reactors (SRM on SECY-90-016, 6/26/90)
  - CDF < 1E-4/year
  - Large release frequency (LRF) < 1E-6/year
  - Conditional containment failure probability (CCFP) < 0.1

NRC QHOs (cont.)

- Commission has approved guidelines for plant-specific application of QHOs and subsidiary objectives (R.G. 1.174, Module P)
- “Small” increases in risk are allowable in changing plant licensing basis (R.G. 1.174, Module P)

Purposes of Individual Plant Examinations (IPE/IPEEE)

- Systematically examine plant design, normal and emergency operation to
  - Identify plant-specific severe accident vulnerabilities
  - Develop understanding of what could possibly go wrong, accident scenarios
  - Identify and evaluate means of improving plant and containment performance during such accidents
  - Decide upon improvements to implement (if any)
- Supplement 4 to GL 88-20 requested same type of evaluation for selected external events (e.g., earth quake)
  - Known as IPEEE

IPEs (IPEEEs) Did Not Require PRA

- All utilities chose to perform a PRA to address GL 88-20
  - PRAs not performed to specified standards
  - No requirements specified for data or models
- Not all utilities used PRAs for IPEEE (external events) portion of GL 88-20
- IPE not typically full-scope PRA (only full-power operation considered)
- Estimated CDF and probability of containment failure, but not source terms and offsite consequences (typical)
- IPE/IPEEE not performed to support risk-informed, performance-based regulation

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Use of IPE/IPEEE in Risk-Informed, Performance-Based Regulation

- **Requires more detailed reviews of models and data**
  - **Initial NRC reviews done to ensure requirements of GL 88-20 met**
  - **SER (Staff Evaluation Report) issued for each plant [sometimes TER (Technical Evaluation Report) also]**
  - **Initial reviews <u>did not</u> validate modeling assumptions, data, or results**

NRC PRA Policy Statement

- **Process to allow for increased use of PRA**
- **Develop from concerns that**
  - **PRA methods not applied consistently throughout NRC**
  - **Sufficient PRA/statistics expertise not available in NRC**
  - **Commission not deriving full benefit from NRC and industry investment in PRA methods**

NRC PRA Policy Statement (cont.)

- **Policy – Expand use of PRA to extent supported by state of the art, in support of defense in depth and traditional engineering**

NRC PRA Policy Statement (cont.)

- Expected outcomes (became expected outcomes of risk-informed regulation, too)
  - Improved risk-effective decision-making
    - Staff takes consistent approach to regulatory decisions
  - More efficient use of NRC resources
  - Reduce unnecessary regulatory burden on licensees
- Initially put in place through PRA implementation Plan, then referred to as Risk-Informed Regulation Implementation Plan (RIRIP), as of April 2007 (SECY-07-0074) it is now referred to as Risk-Informed and Performance-Based Plan (RPP)

Area Currently Excluded from the PRA Application

- **Equipment operability determination (for Tech. Specs.)**

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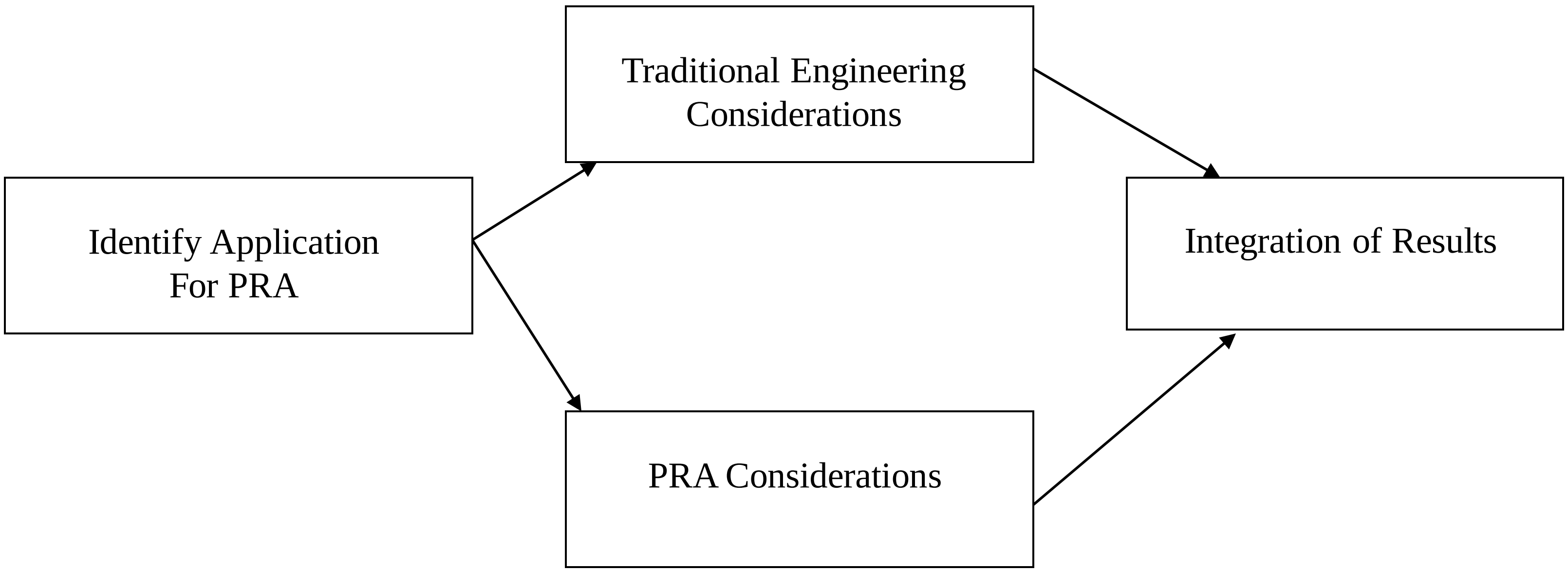
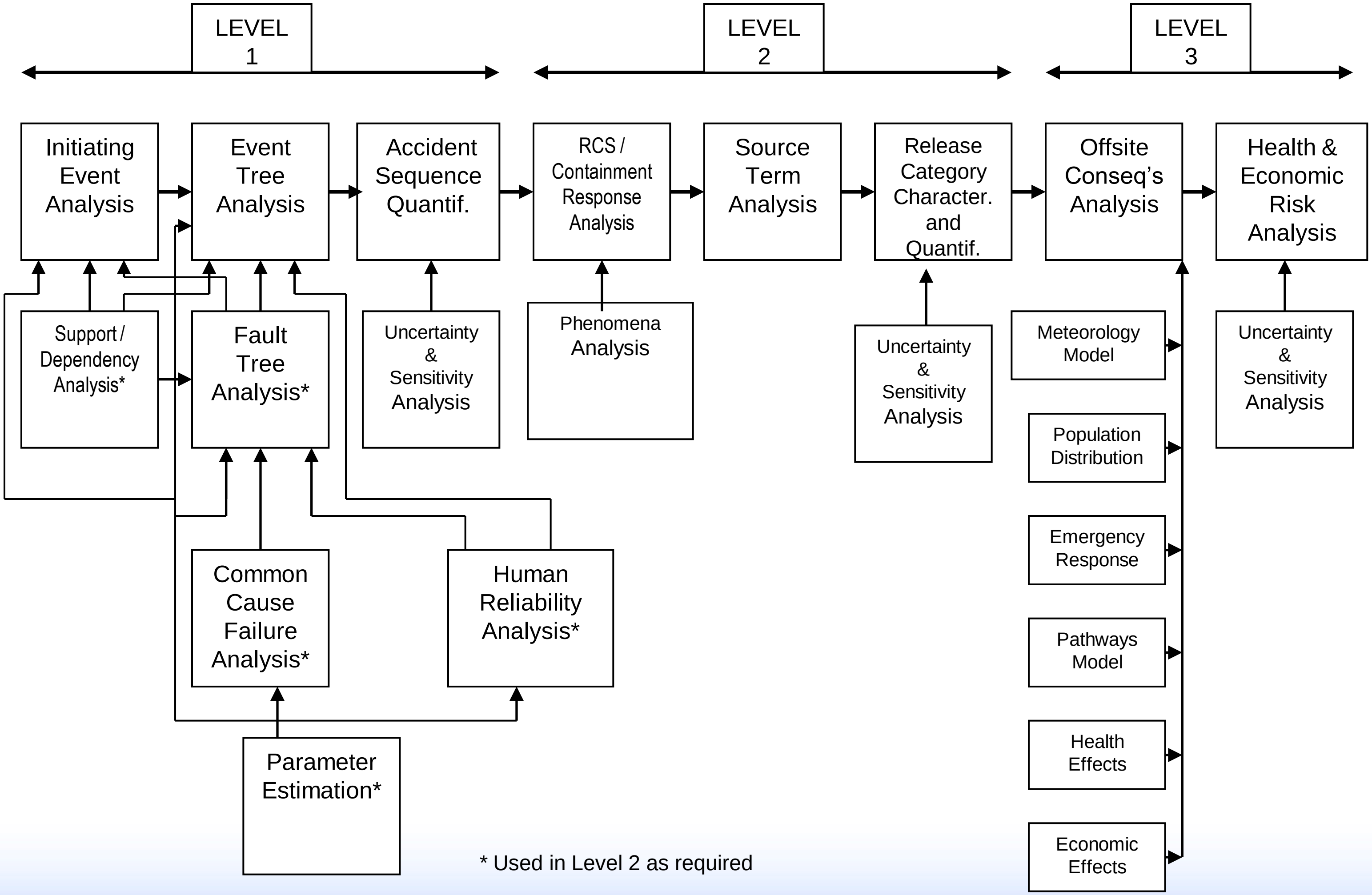
NRC Framework for Applying PRA in Reactor Regulation



PRA Is Impacting Licensing Basis

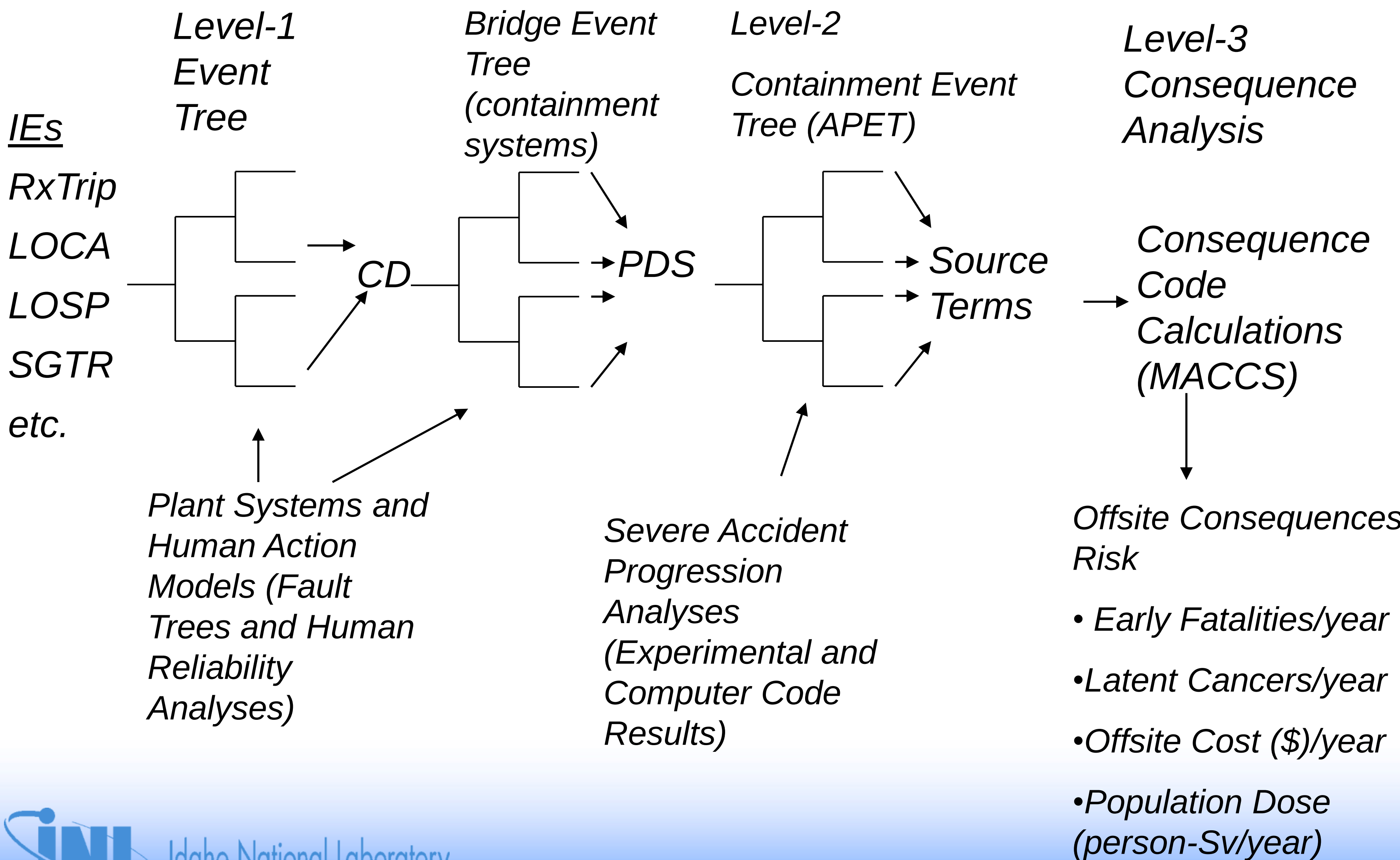
- **Examines whether risk-significant issues exist that are currently outside the licensing basis (e.g., Station-blackout rule)**
- **Examines areas within the licensing basis where current regulations are too strict or overly conservative (e.g., reduced requirements for containment leak-rate testing)**

Principal Steps in PRA



* Used in Level 2 as required

Overview of Level-1/2/3 PRA



PRA Strengths

- Rigorous, systematic tool for analyzing complex systems
- Information integration (multidisciplinary)
- Allows consideration of complex interactions
- Develops qualitative design insights
- Develops quantitative measures for decision making
- Provides a structure for sensitivity studies
- Provides a structure for uncertainty analysis of input parameter values

Principal PRA Limitations (see also Module O)

- Adequacy of data base for hardware and human performance
- Incomplete understanding of severe accident behavior
  - Results may be sensitive to analytical assumptions
- Constraints on modeling effort (limited resources)
  - Simplifying assumptions
  - Incomplete solution of models (truncation of results) during quantification
    - Less of a limitation now than in the past
- Lack of completeness
  - Less than full scope with respect to initiators and modes of operation
  - Not all scenarios included
    - Some missed by oversight
    - Some cannot be modeled at present
- PRA is typically a snapshot in time
  - This limitation may be addressed by having a "living" PRA (Note: Living PRA required for new reactor designs)
    - 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

Addressing PRA Limitations

- Sensitivity studies on data and modeling assumptions
- Use of expert judgment
- Peer review
- Use results in conjunction with traditional engineering analysis and philosophy of defense in depth (regulation is risk-informed, not risk-based)
- Basis for PRA results must be understood before using them