Risk-Informed Regulation for Technical Managers *(P-107)*

October 4, 2007

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Course Objectives

- **At the end of this course, you will be able to:**
  - Define **basic terms** related to risk-informed regulation
  - Identify **applications** of risk-informed regulation in your work area
  - Understand the **basic modeling concepts** in a probabilistic risk assessment
  - **Make risk-informed decisions** on emergent issues
  - **Communicate** risk information to internal and external stakeholders
  - Find **references** for more information in the future

Course Modules

1. **Introduction to Risk-Informed Regulation**
   – What do risk and risk-informed regulation mean?
   – Where do we use risk-informed approaches?

2. **Use of PRA Models**
   – How do we build PRA models?
   – How do we use PRA in risk-informed regulation?
   – How do we know a licensee's PRA is adequate?
   – What can we learn from PRA results?

3. **Making Risk-Informed Decisions**
   – How should we think about the issue?
   – What guidance do we use?

4. **Communicating Risk Information**
   – How do we communicate with internal stakeholders?
   – How do we communicate with external stakeholders?

5. **Resources**
   – Where can you get more information?

1. Introduction to Risk-Informed Regulation

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Module 1: Intro to Risk-Informed Regulation

- What do risk and risk-informed regulation mean?
- Where do we use risk-informed approaches?
- How do you fit in to risk-informed regulation?

What do risk and risk-informed regulation mean?

What is risk?

- **In everyday usage, "risk" is often used synonymously with the probability of a loss.**
- **In the context of evaluating risk from a nuclear power plant, risk is commonly expressed as the “risk triplet”:**
  1. What can go wrong (accident scenario)?
  2. How likely is it (frequency on a reactor year basis)?
  3. What are the consequences (impact on the plant or on people)?

How do we characterize risk?

- **We characterize risk in terms of its effect on people**

- **What is the likelihood of a nuclear accident:**
  - Causing near-term death? (prompt fatality)
  - Causing death from cancer? (latent fatality)

How do we characterize risk?

- **Our SAFETY GOALS* define the Commission's policy on "how safe is safe enough"**
  - Qualitative safety goals
  - Quantitative health objectives
  - Subsidiary objectives

**** Policy statement, 8/21/86***

How do we characterize risk?

- **Qualitative safety goals**
  - Individual members of the public bear **no significant additional risk to life and health** as a result of nuclear power
  - Societal risk should be **comparable to or less than** risks of other generation technologies

How do we characterize risk?

- **Quantitative health objectives**
  - For an average individual living near a plant:
    - The risk of **accidental death** as a result of a nuclear accident should be **less than one-tenth of a percent (1/1000)** of the total accidental death risk to which the U.S. population is exposed
  - For the population in the area of the plant:
    - The risk of **death from cancer** as a result of plant operations should be **less than one-tenth of a percent (1/1000)** of the total cancer fatality risk from all other causes

How do we characterize risk?

- **Subsidiary objectives (operating reactors)**
  - Core damage frequency (CDF) no more than about **once every 10,000 years (1E-4/year)** per plant
    - ➢Surrogate for latent cancer fatalities
  - Large early release frequency (LERF) no more than about **once every 100,000 years (1E-5/year)** per plant
    - ➢Surrogate for prompt fatalities

How do we characterize risk?

- **Metrics for new reactors**
  - Core damage frequency (CDF) no more than about **once every 10,000 years (1E-4/year)** per plant
  - Large release frequency (LRF) no more than about **once every 1,000,000 years (1E-6/year)**
  - Conditional containment failure probability (CCFP) less than approximately **0.1**

**** SRM on SECY-90-016, 6/26/90***

What tools are available to evaluate risk?

- **Probabilistic Risk Assessment (PRA) Methods**
  - PRA is a structured, analytical process for identifying potential weaknesses and strengths of a plant design in an **integrated** fashion
  - **One way** of analyzing risk in the nuclear industry
  - PRA provides a framework for explicitly addressing and presenting uncertainties (vs. making conservative assumptions to deal with uncertainty)

- **Alternate methods include:**
  - Qualitative arguments
  - Bounding analyses
  - Screening tools

How is risk addressed in the regulatory framework?

- **Traditional engineering or "design basis" approaches**
  – Implicit consideration of risk (which accidents, systems, etc. are important?)
  – Engineering judgment in determining a set of **"credible" accident categories** that require prevention/mitigation capabilities
    - You'll hear this called **"deterministic"** analysis
  – Reliance on **worst case analyses**, single failure criterion, defense-in-depth, and safety margins

How is risk addressed in the regulatory framework?

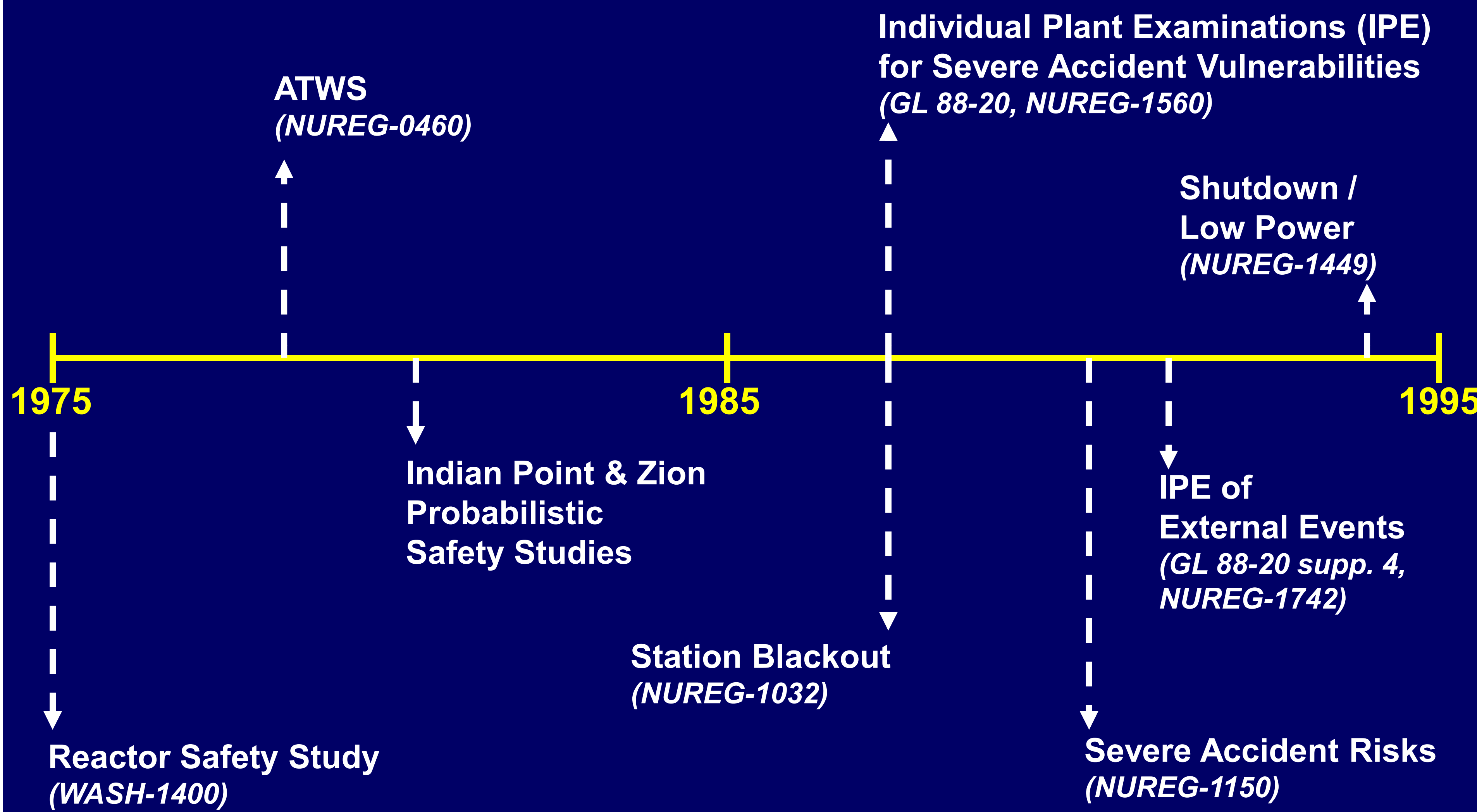
- **Risk-informed approaches**
  - Explicit consideration of risk
  - "Full picture" – scope includes **all potential accident initiators and mitigation failures** (including multiple failures)
  - Address the **possibility of releases** greater than regulatory limits

Why is risk information used?

- **WASH-1400* assessed reactor risk using PRA**
  - Revealed actual risk significant areas and interactions that were very different from the design basis events
    - Ex: **small loss of coolant accidents (LOCAs)** are significant risk contributors for pressurized water reactors
  - Demonstrated the value of an **integrated** view of risk
- **Other risk studies followed to expand on these early findings**

**** NUREG-75/014, 10/75***

What early risk studies were done?



Why is risk information used?

- **Commission's policy statement on the use of PRA* included four main statements:**

  1. **Increase use of PRA** to the extent supported by the state-of-the-art and in a way that **complements** traditional engineering approaches
  2. Use PRA both to **reduce unnecessary conservatism** in current requirements and to support proposals for **additional regulatory requirements**
  3. Be as **realistic** as practicable
  4. Consider **uncertainties** appropriately when using the Commission's safety goals and subsidiary numerical objectives

***** *8/16/95***

What is risk-informed regulation?

- A philosophy whereby risk insights are considered **together with other factors** to establish requirements that better focus licensee and regulatory attention on **design and operational issues commensurate with their importance** to health and safety.*

**** SRM on SECY-98-144, 3/1/99***

What are the principles of risk-informed regulation?*

1. Change meets current regulations unless it is explicitly related to an exemption or rule change.
2. Change is consistent with defense-in-depth philosophy.
3. Maintain sufficient safety margins.
4. Proposed increases to CDF or risk are small and are consistent with the Commission's Safety Goal Policy Statement.
5. Use performance-measurement strategies to monitor the change.

INTEGRATED DECISIONMAKING

**** RG 1.174, 11/02***

How do you fit in to risk-informed regulation?

- **YOU communicate with stakeholders on the risk of an event**
  – ASK YOURSELF: How close was the plant to losing core cooling?

- **YOU make an integrated decision based on both deterministic and risk information**
  – ASK YOURSELF: Does this change meet the principles of RG 1.174? Do I need to order the plant to shut down because of this situation?

- **YOU encourage your staff to work with the PRA group on risk-informed licensing actions**
  – ASK YOURSELF: What does the PRA group think? Are their questions and concerns the same as yours?

Why aren't our decisions risk-<u>based</u>?

- "Risk-based" would mean we decide using **<u>only the numerical results and insights</u>** of a risk assessment – if risk assessments are so helpful, why not?
  - We can't measure risk – we have to evaluate it using models
    - ➢ The models should address all contributors but do so with varying degrees of rigor and realism
    - ➢ Data on many failures or initiating events is sparse
    - ➢ Uncertainties may be large, but in principle we know how to deal with them
  - However, we cannot know everything, and therefore our **<u>models are incomplete</u>**, e.g., there could be previously unknown failure mechanisms.
- **Therefore, we still consider traditional "deterministic" concepts such as defense-in-depth and safety margins, as well as performance monitoring, to accommodate our incomplete knowledge!**

Where do we use risk-informed approaches?

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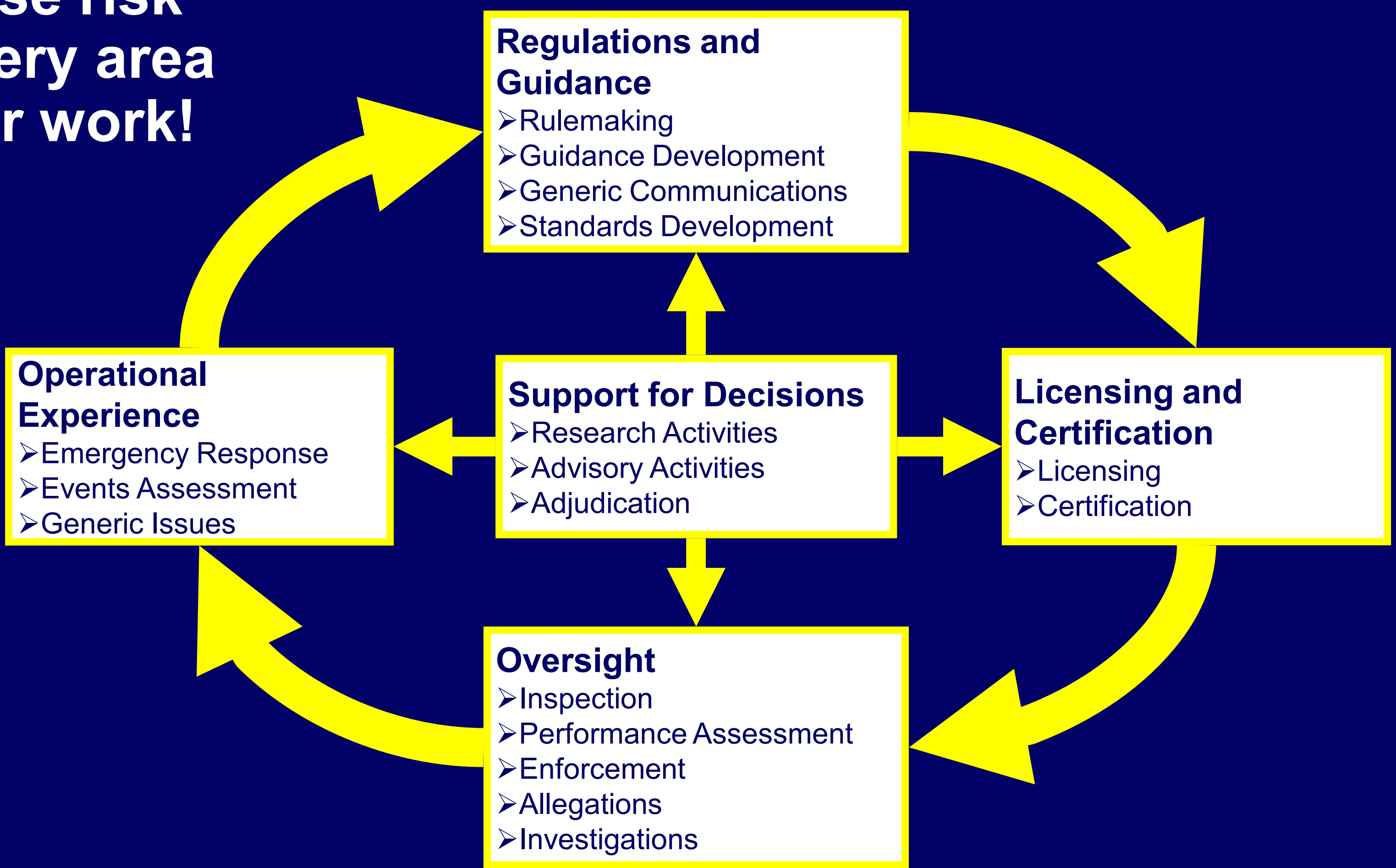
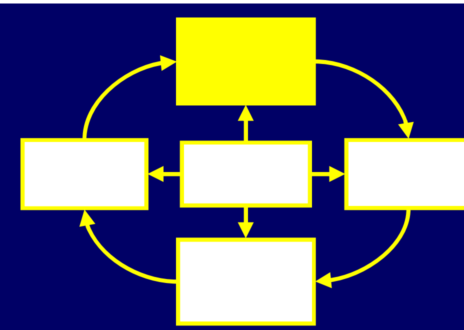
Where do we use risk-informed approaches?

- **We use risk in every area of our work!**



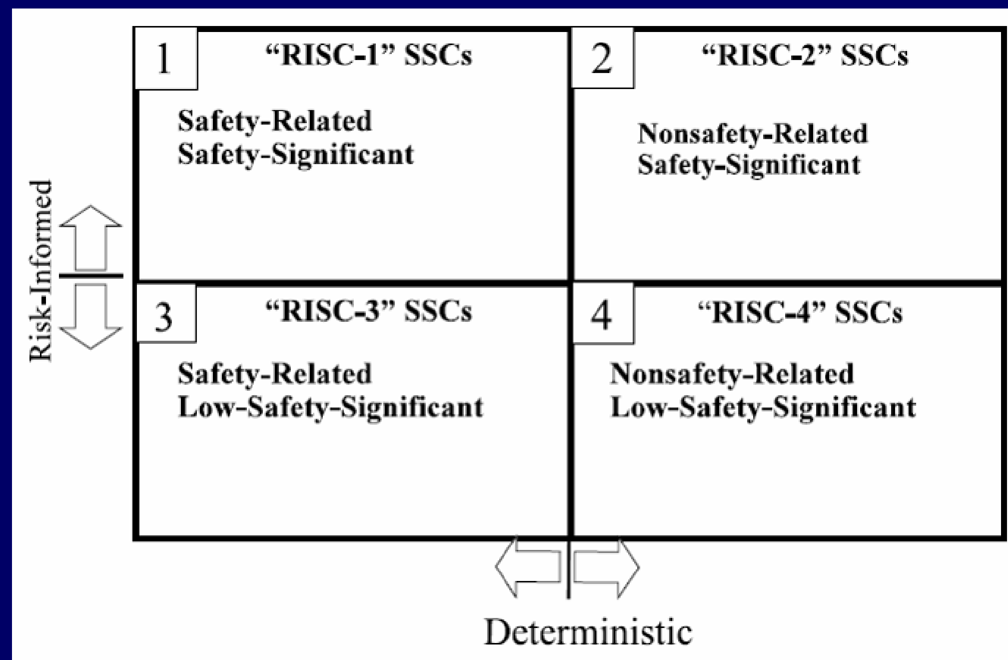
Regulations & Guidance



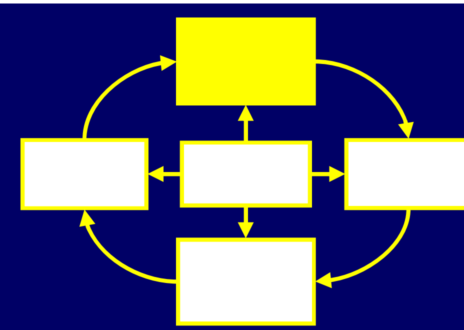
10 CFR	Subject	Year
50.44	Combustible Gas Control	2003
50.48(c)	Risk-Informed Fire Protection Requirements	2004
50.62	Anticipated Transient Without Scram	1984
50.63	Station Blackout	1988
50.65(a)(4)	Assessment of Maintenance Risk (Maintenance Rule)	1999
50.69	Risk-Informed Special Treatment Requirements	2004
50.71(h), 52.47	PRA Requirements for New Reactors	2007
50.61a	Pressurized Thermal Shock	TBD

Regulations & Guidance

- **Example – 50.69**
  - Risk-informed categorization of systems, structures, and components
  - Reduce (or increase!) testing, procurement requirements, quality assurance, etc.
  - Reduces burden on licensees <u>and</u> focuses on most risk-significant areas



Regulations & Guidance

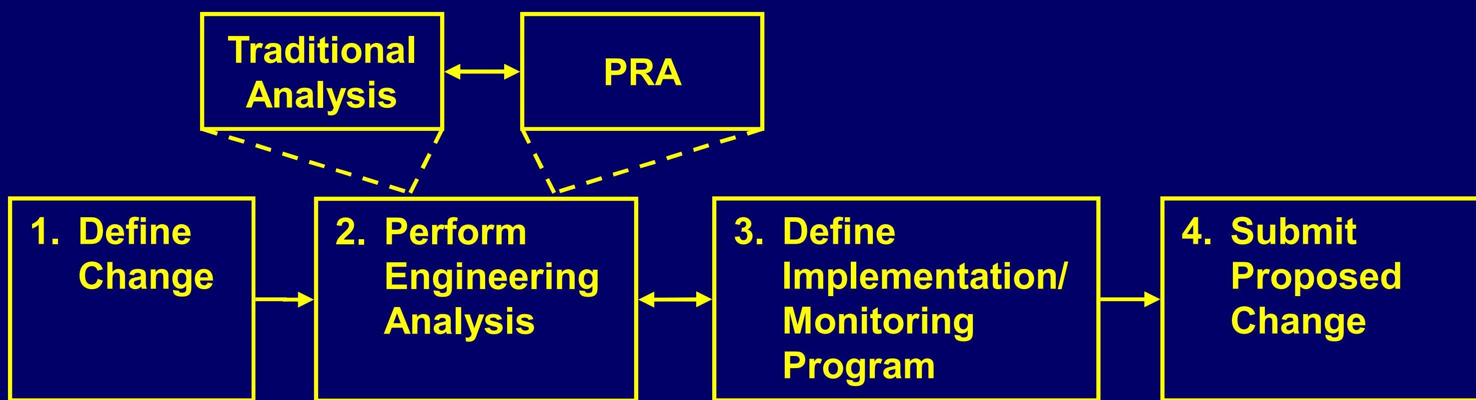


- **Example – new reactor design certification and combined licenses**
  - NRC reviews a description of the design-specific or plant-specific PRA and its results*
  - PRAs referencing a design certification must account for site information and design changes**
  - Combined license holders must maintain and upgrade their PRAs according to NRC-endorsed standards***

**** 52.47(a)(27) and 52.79(a)(46)***
***** 52.79(d)(1)***
****** 50.71(h)***

Licensing & Certification

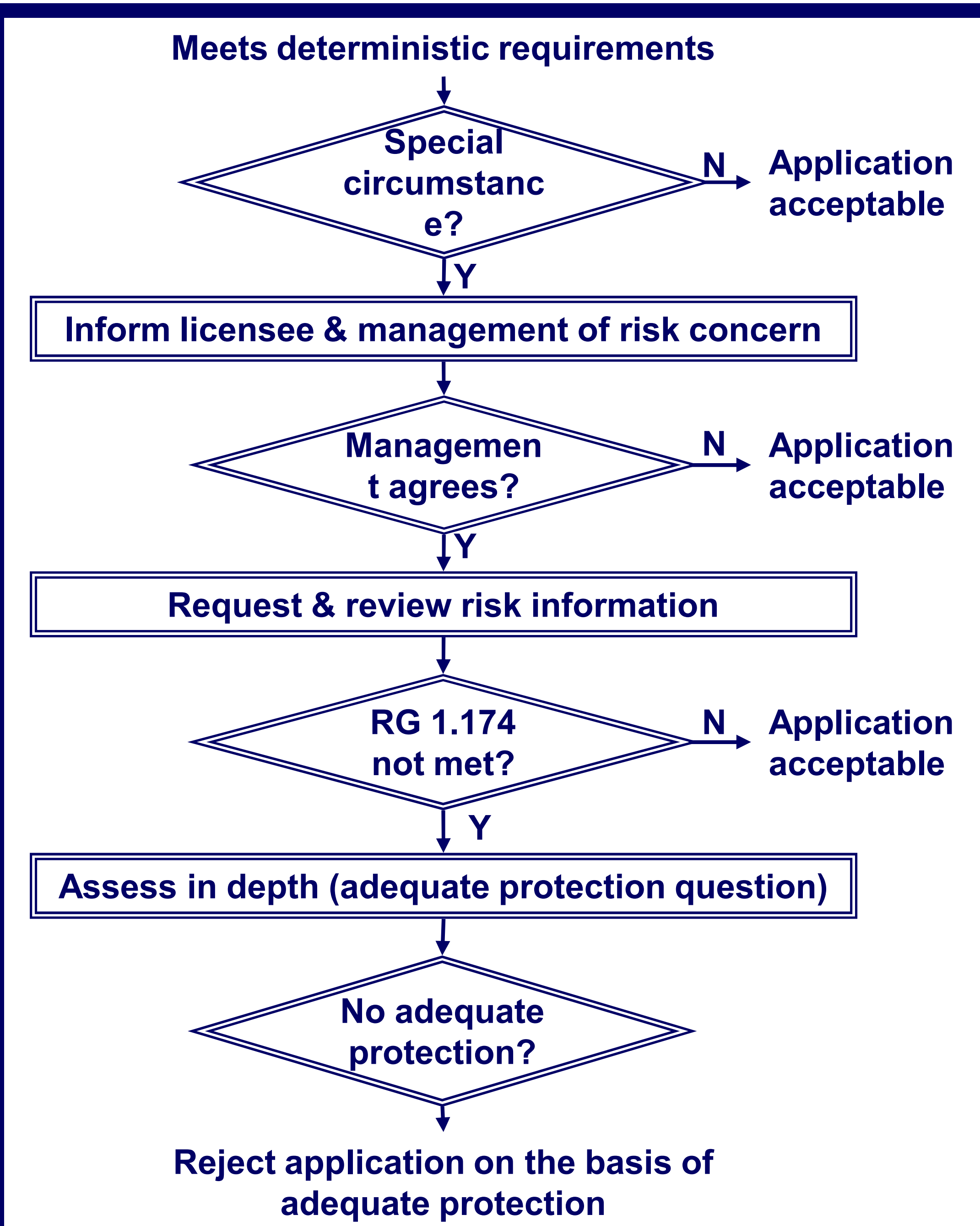
- **Voluntary risk-informed licensing basis changes***
  - Risk-informed technical specifications changes
  - Risk-informed inservice testing (pumps/valves) and inspection (pipes)



- **NRC staff can request risk information** for non-risk-informed licensing actions in a "special circumstance"**

** RG 1.174, 11/02*

*** SRP 19.2, App. D*



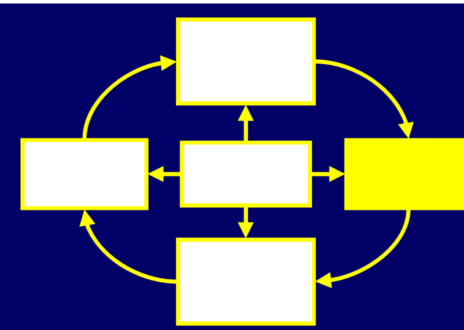
"Special circumstances" may exist if:

1. The situation was not identified or addressed in development of regulations, and could be **important enough to warrant a new regulation** if encountered on a widespread basis.

2. The reviewer has knowledge that the risk impact is not reflected by the licensing basis analysis, and has reason to believe that the risk increase would **warrant denial if the request were evaluated as a risk-informed application**.

**** SRP 19.2, App. D***

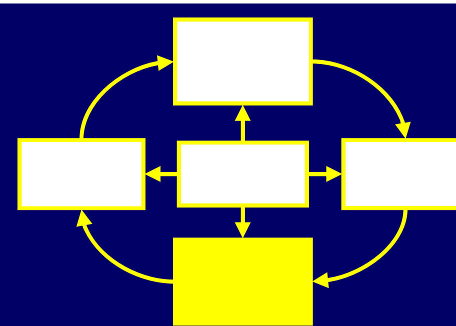
Licensing & Certification



- **Regulatory treatment of non-safety systems (RTNSS)**
  - Used in review of new reactor designs
  - Applies to non-safety-related systems, structures, and components needed to:
    - Meet NRC performance requirements (ATWS, station blackout)
    - Ensure safety 72+ hours after an accident or after an earthquake
    - Meet CDF and LRF guidelines at power and during shutdown
    - Meet the containment performance goal (CCFP) during severe accidents
    - Prevent significant adverse system interactions
  - Example: short-term availability controls on hydrogen igniters for AP1000*

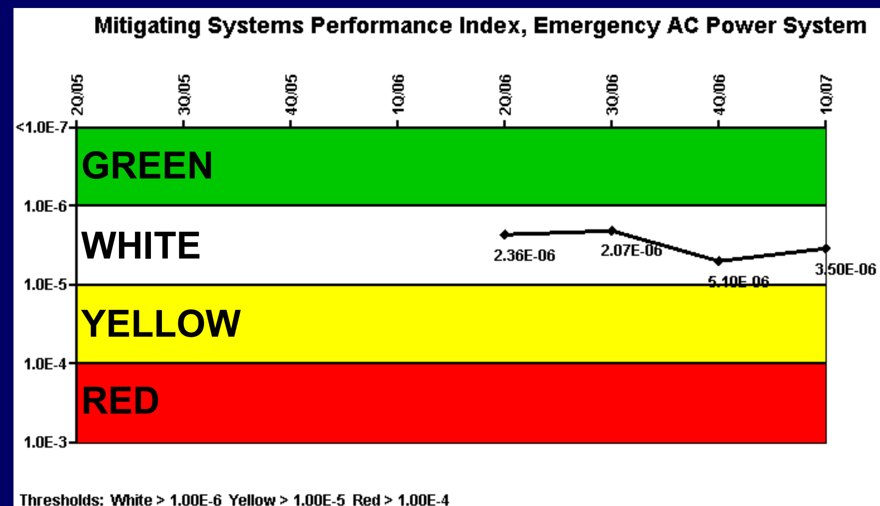
**** WCAP-15985, 9/9/03***

Oversight



- **Notice of Enforcement Discretion (NOED)***
  - Non-compliance with a technical specification or license condition
  - Risk argument for avoiding unnecessary plant transient, inappropriate test/inspection, or unjustified delay in startup

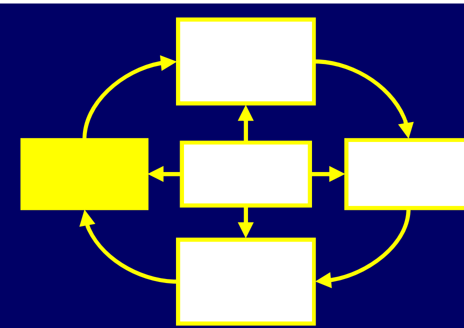
- **Reactor Oversight Process**
  - Risk-informed performance indicators
    - ➢ Mitigating System Performance Index (MSPI)**
  - Risk-informed baseline inspections
  - Significance Determination Process for inspection findings



Inspection Manual Chapter Part 9900

*** http://www.nrc.gov/NRR/OVERSIGHT/ASSESS/mspi.html***

Operational Experience



- **Incident response**
  - Follow-up inspections based on event significance*
- **Event assessment**
  - Risk-informed decision-making** (more later!)
  - Accident Sequence Precursor (ASP) program reported to Congress

Estimated Conditional Core Damage Probability (CCDP)				
CCDP < 1E-6	1E-6 – 1E-5	1E-5 – 1E-4	1E-4 – 1E-3	CCDP > 1E-3
No additional inspection				
	Special inspection			
		AIT		
			IIT	

*** Management Directive 8.3***
***** NRR Office Instruction LIC-504***

2. Use of PRA Models

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Module 2: Use of PRA Models

- How do we build PRA models?
- How do we use PRA results in risk-informed regulation?
- How do we know a licensee's PRA is adequate?
- What can we learn from PRA results?

How do we build PRA models?

What is a PRA?

- **Risk assessments include identification and analysis of…**
  - Initiating events
    - Circumstances that put a nuclear plant in an **off-normal condition**
  - Safety functions
    - Functions designed to **mitigate the initiating event**
  - Accident sequences
    - Combination of **safety function successes and failures** that describe the accident after an initiator
- **Successful response is that the plant transitions to safe, stable end-state for specified period of time**
- **We use a PRA model to look at the frequency and consequences of NOT achieving a safe, stable end-state**

What is the technical basis for the PRA model?

- **The PRA model is constructed to model the as-built, as-operated plant**
- **Multiple sources of information from the traditional engineering disciplines, including:**
  - Plant design information
  - Thermal hydraulic analyses of plant response
  - System drawings and performance criteria
  - Operating experience data
  - Emergency, abnormal, and system operating procedures
  - Maintenance practices and procedures

What is the technical basis for the PRA model?

- **Understanding the plant perturbation – "initiating event"**
  - Transient (loss of feedwater, condenser vacuum, instrument air, etc.)
  - Loss of offsite power
  - Loss of coolant accident
- **Understanding how the plant responds to the perturbation**
  - **Physical responses**
    - Neutronic
    - Thermal-hydraulic (e.g., vessel and containment pressure, temperature, water level)
  - **Automatic responses**
    - Reactor trip/turbine trip
    - Mitigating equipment actuates
  - **Operator responses** (per procedures)
    - Manual reactor trip
    - Manual switchover to sump recirculation

What is the technical basis for the PRA model?

- **This understanding is used to establish success criteria (based on engineering analyses)**
  - Definition of end states:
    - ➢ Establish the acceptance criteria for prevention of core damage, e.g., collapsed level greater than 1/3 core height
    - ➢ Establish containment capability
  - Determination of system success criteria for a given scenario:
    - ➢ Time at which system is required to prevent core damage
    - ➢ Required system performance, e.g., two out of three pumps

What are the basic components of a PRA?

- **PRA models use**
  - **Event trees** to model the sequence of events from an initiating event to an end state
  - **Fault trees** to model failure of mitigating functions, including equipment dependencies to function as required
  - **Frequency** and **probability** estimates for model elements (e.g., initiating events, component failures)

- **Outputs may include**
  - **Core damage** frequency (“Level 1” PRA)
  - **Release** frequencies (“Level 2”)
  - **Radiological consequences** to public (“Level 3”)

What are the end states of a PRA?

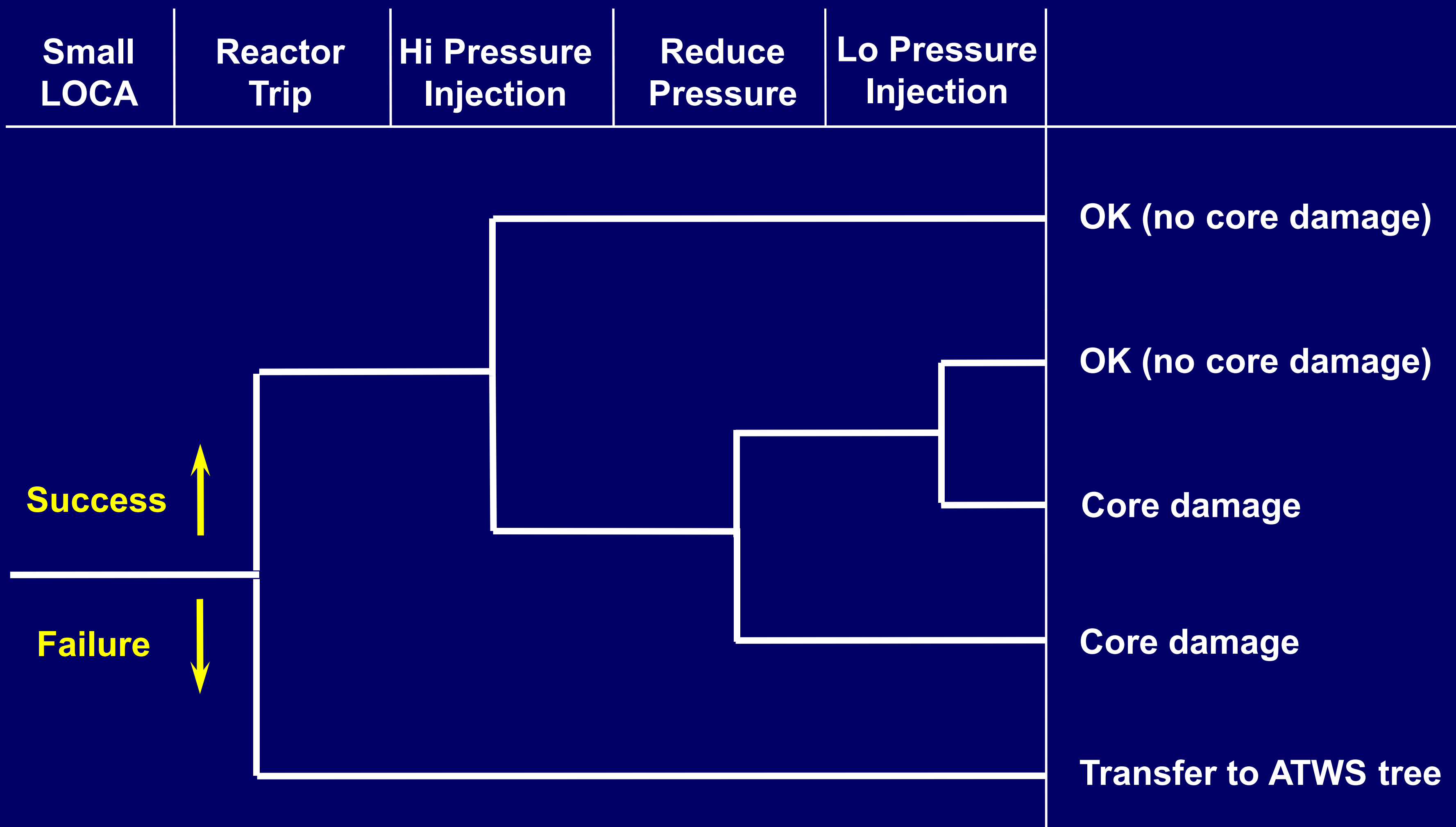
- **Core damage occurs when**
  - **Safety functions** are not met
    - Such as removal of decay heat, control of reactivity, or control of inventory
  - Engineering models show that core parameters exceed certain pre-determined limits

- **Large early release occurs when**
  - Core damage with **containment challenge**, leading to significant, **unmitigated releases prior to effective evacuation** of the close-in population

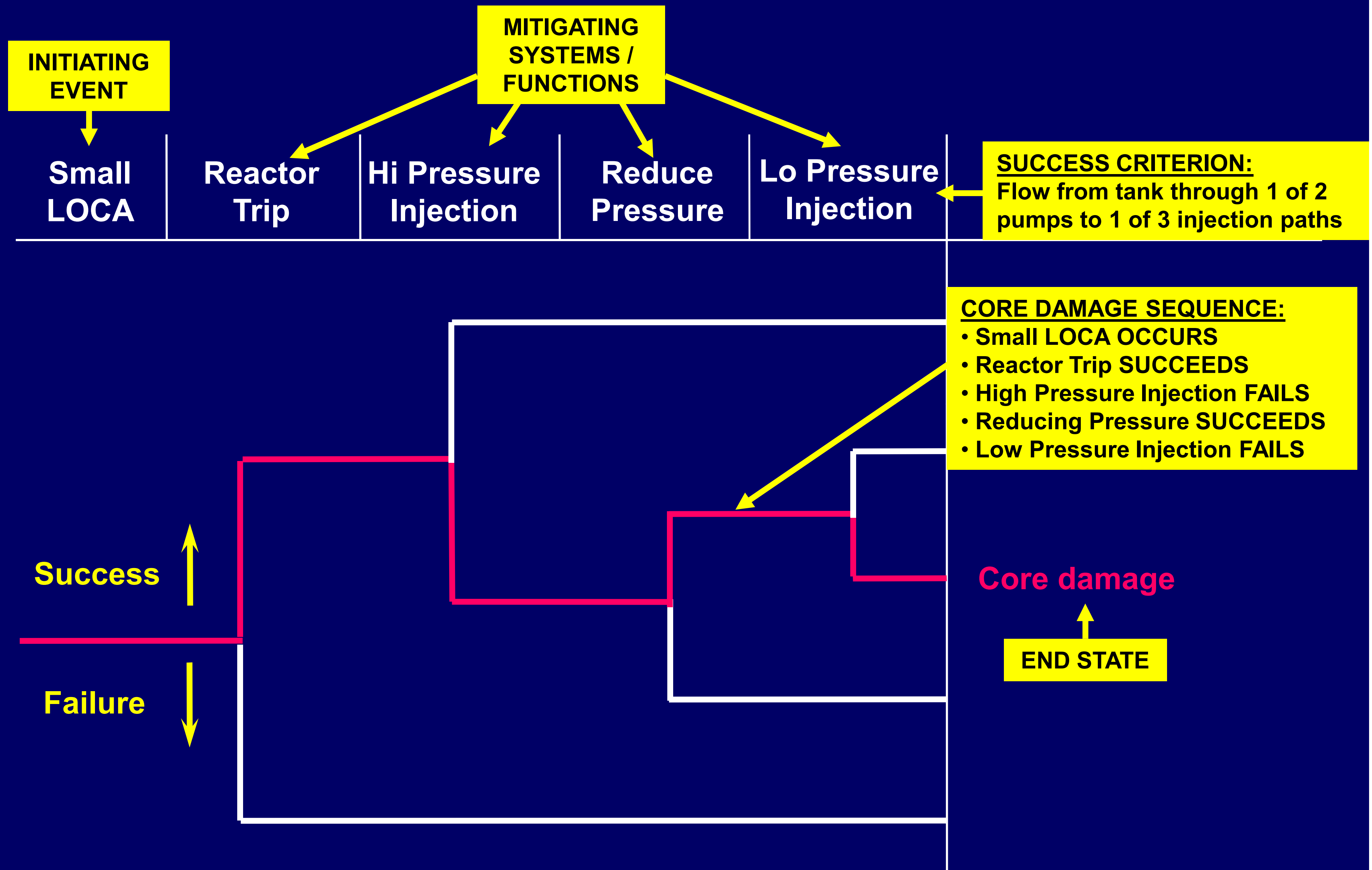
- **A limited Level 2 PRA provides insights related to core damage and large early release.**

What is an event tree?

A graphical depiction of a sequence of events



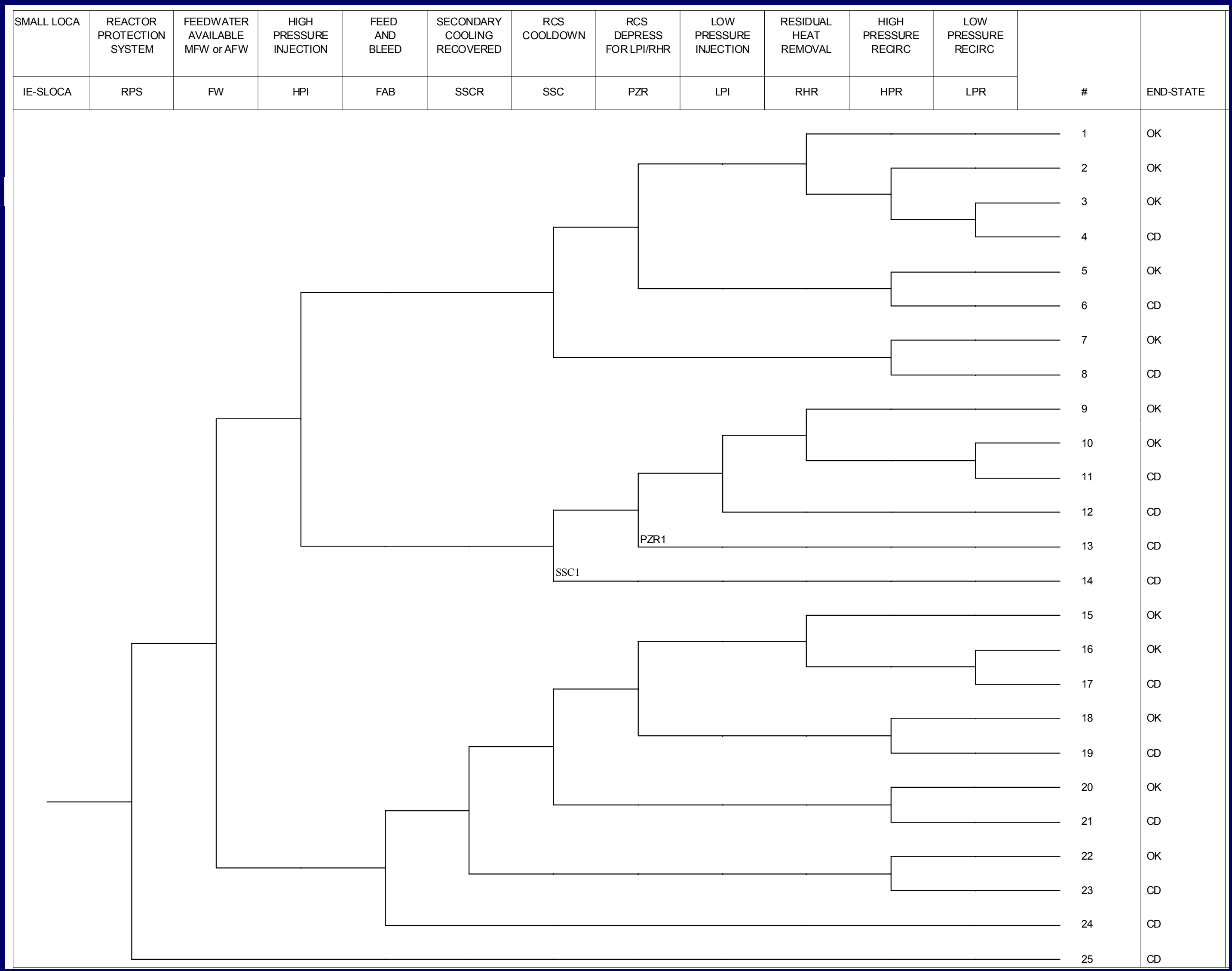
What is an event tree?



What is an event tree?

- **Event tree "top events" may represent:**
  - Functions or systems to **mitigate** core damage
  - Key **operator actions**
  - **Containment** support systems
    - Fan coolers, sprays
    - Isolation
- **Event tree also used for Level 2**
  - Use tree to model **core melt and severe accident phenomenology** that challenges containment integrity
  - **LERF is a subset of Level 2** – specific tree end states

More Complex Event Tree

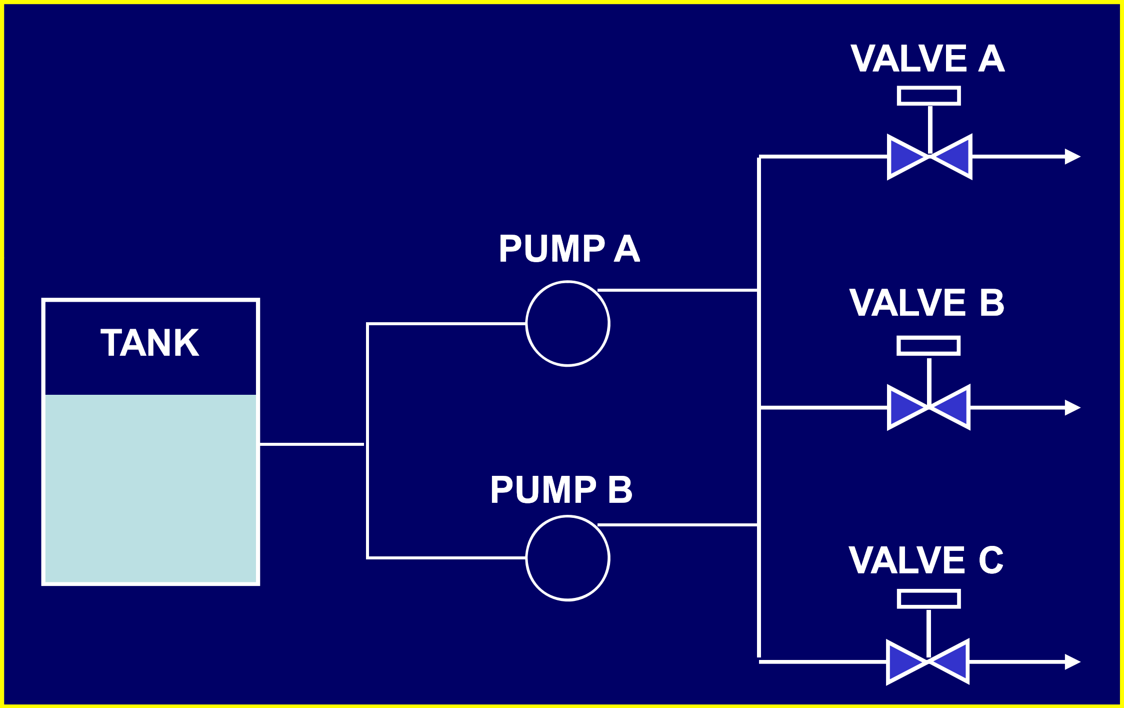


What is a fault tree?

A graphical depiction of how a system can fail

SUCCESS CRITERION:
Flow from tank through 1 of 2 pumps to 1 of 3 injection paths

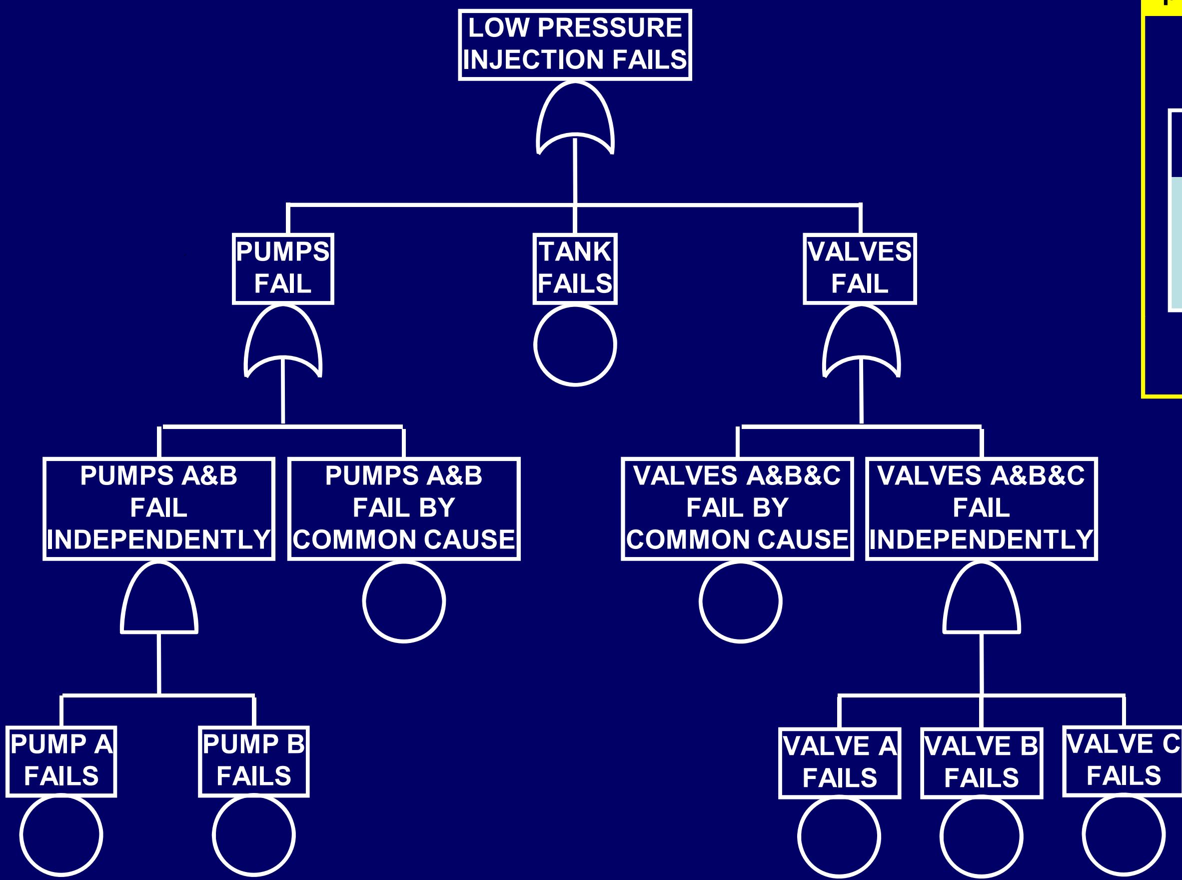
FAILURE OCCURS WHEN:
No flow from tank
OR
No flow from pumps
OR
No flow through injection paths

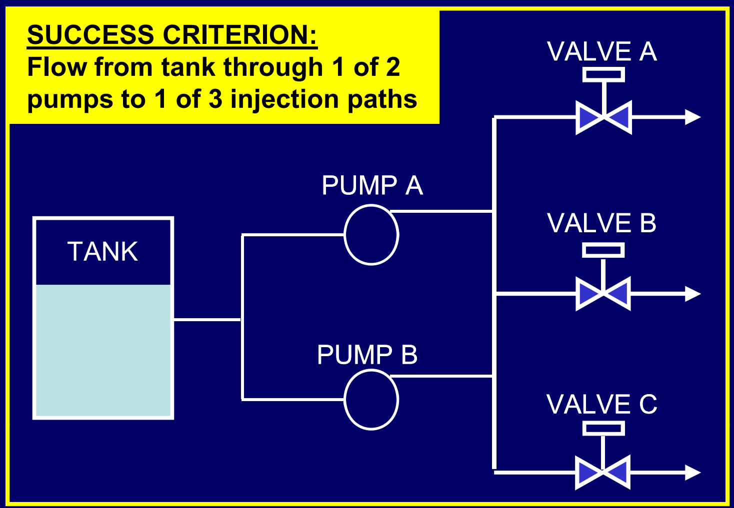


What is a fault tree?

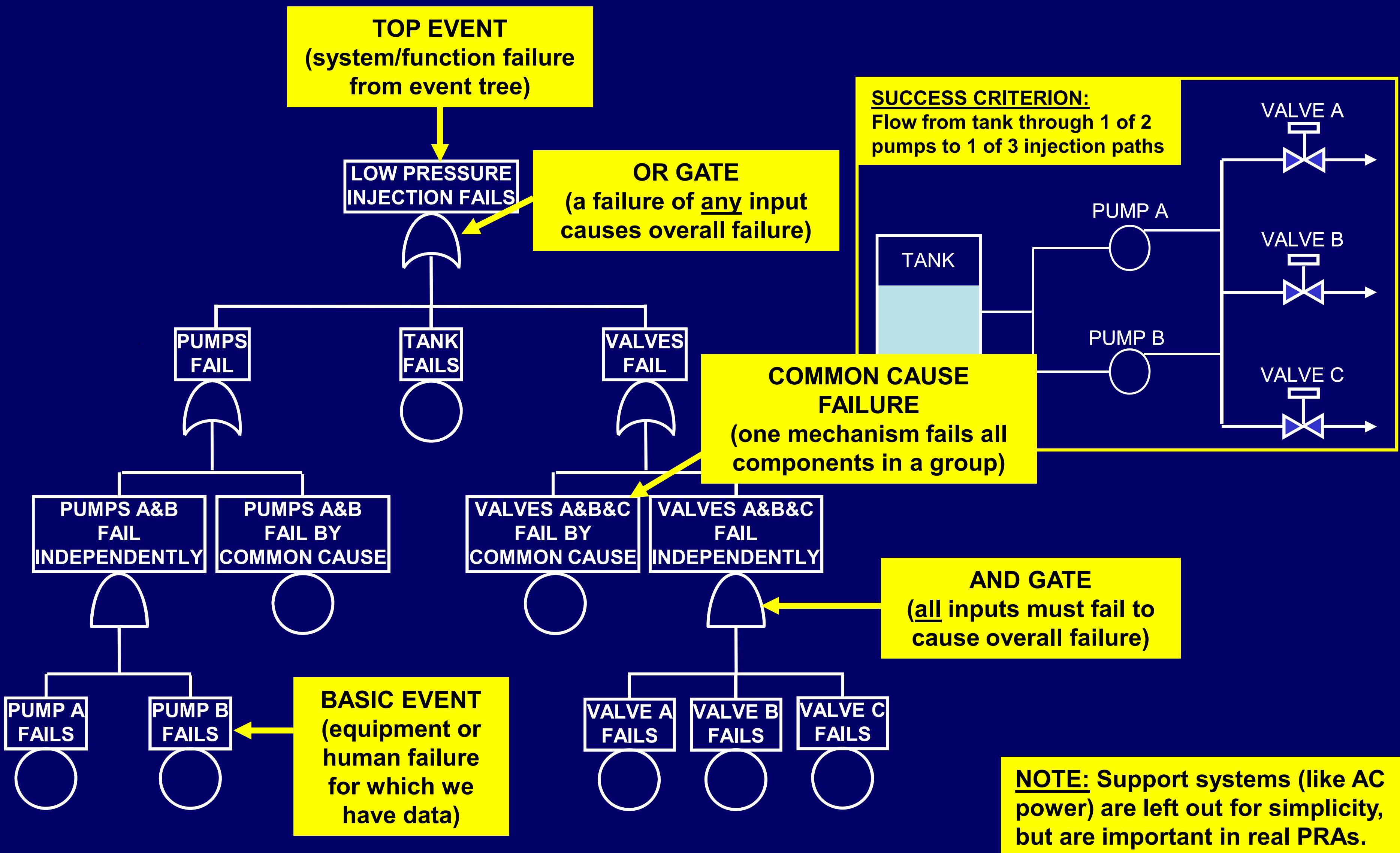
- **Developing fault trees**
  - Need for fault tree usually arises from the event tree
    - What equipment can provide the function?
    - What operator actions must take place?
  - Define **success criteria**, e.g.
    - How much flow is needed to remove decay heat?
    - How much flow is necessary to restore inventory?
    - How many valves must close to isolate containment?
  - Determine the **failure modes** to include in the tree
  - Determine supporting systems; e.g., electric power, room cooling, seal and cooling water, control power, etc.
  - Continue modeling to **basic event level**

What is a fault tree?

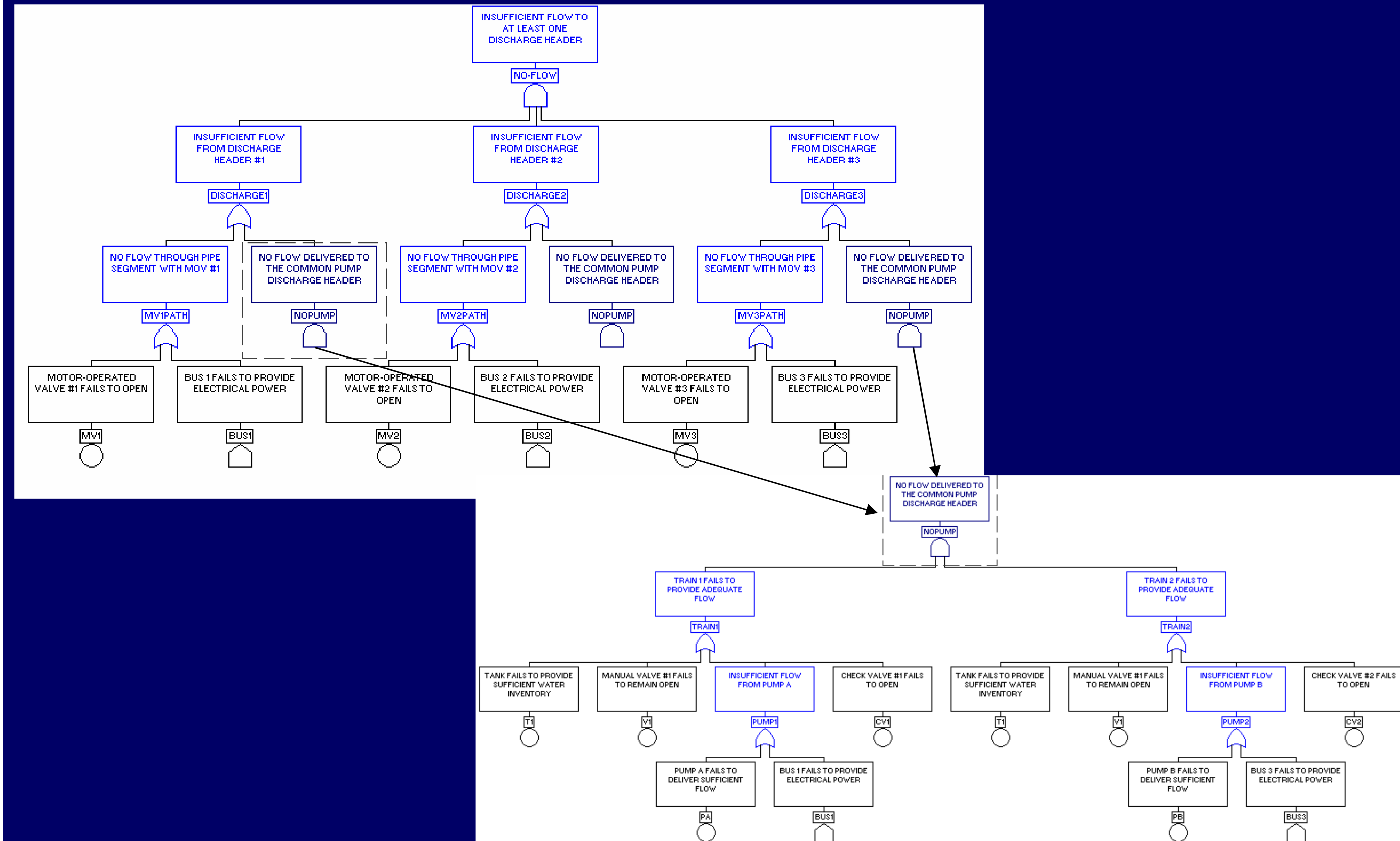




What is a fault tree?

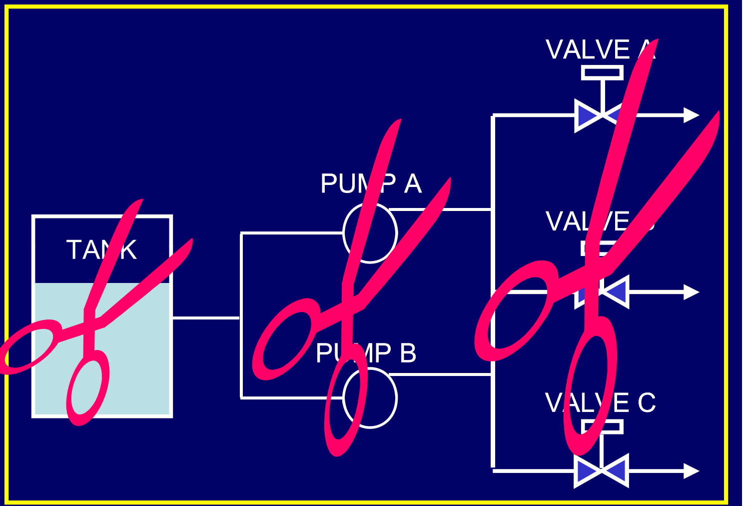


More Complex Fault Tree



How do we solve fault trees?

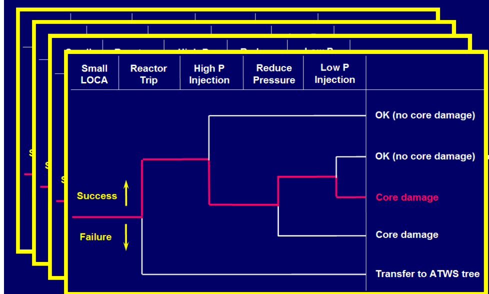
- **Reducing the logic in a fault tree gives:**
  - **<u>Cutsets</u>**, sets of failures that result in overall failure
    - PUMP A FAILS <u>and</u> PUMP B FAILS
      - Independently or by common cause
    - VALVE A FAILS <u>and</u> VALVE B FAILS <u>and</u> VALVE C FAILS
      - Independently or by common cause
    - TANK FAILS
  - **<u>Probability that the function will fail</u>**, derived from the cutsets and the failure probabilities of the basic events therein



Where do we get the numbers?

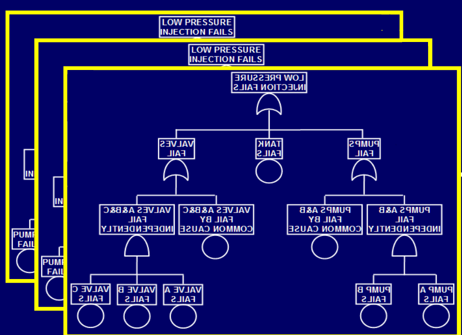
- **Operating experience data for:**
  - Frequency of many initiating events
  - Failure rates of plant equipment
  - Average availability of plant equipment
  - Probabilities of repair and recovery (e.g., restoration of offsite power)
- **Special methods:**
  - **Expert elicitation** for rare events (e.g., large LOCA frequency)
  - **Human reliability analysis** (e.g., operator fails to switch to recirculation)
  - **Common cause failure** modeling

How do we "solve" the PRA model?



CORE DAMAGE SEQUENCES:

- Small LOCA OCCURS &
  Reactor Trip SUCCEEDS &
  High Pressure Injection FAILS &
  Reducing Pressure SUCCEEDS &
  Low Pressure Injection FAILS
- … (may be several on each tree!)

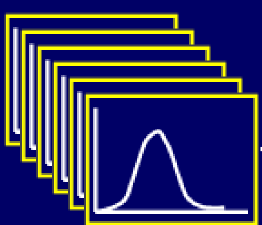


SYSTEM CUTSETS:

- PUMP A FAILS & PUMP B FAILS
- TANK FAILS
- … (may be several for each tree!)

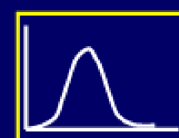
CORE DAMAGE CUTSETS:

- SMALL LOCA &
  HPI TANK FAILS &
  LPI PUMP A FAILS & LPI PUMP B FAILS
- SMALL LOCA &
  HPI PUMP A FAILS & HPI PUMP B FAILS &
  LPI TANK FAILS
- … (many combinations per sequence!)



FAILURE PROBABILITIES &
INITIATING EVENT FREQUENCIES

- CORE DAMAGE FREQUENCY
- UNCERTAINTY ANALYSIS
- IMPORTANCE MEASURES
- SENSITIVITY STUDIES
- RISK INSIGHTS

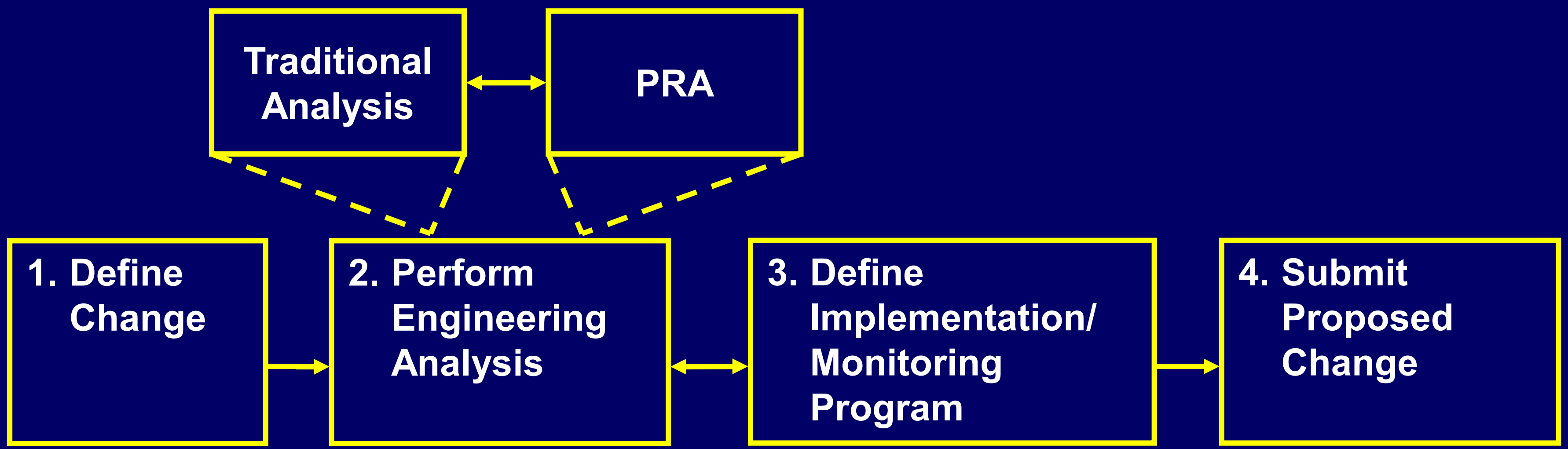


How do we use PRA in risk-informed regulation?

How do we use PRA in risk-informed regulation?

- The PRA model is used to evaluate the issue being assessed, e.g., the change in risk due to a proposed license amendment
- The risk results are compared against acceptance guidelines or criteria
- This evaluation is included as one element of an integrated risk-informed decision

How do we use PRA in risk-informed regulation?



**** RG 1.174, 11/02***

From RG 1.174

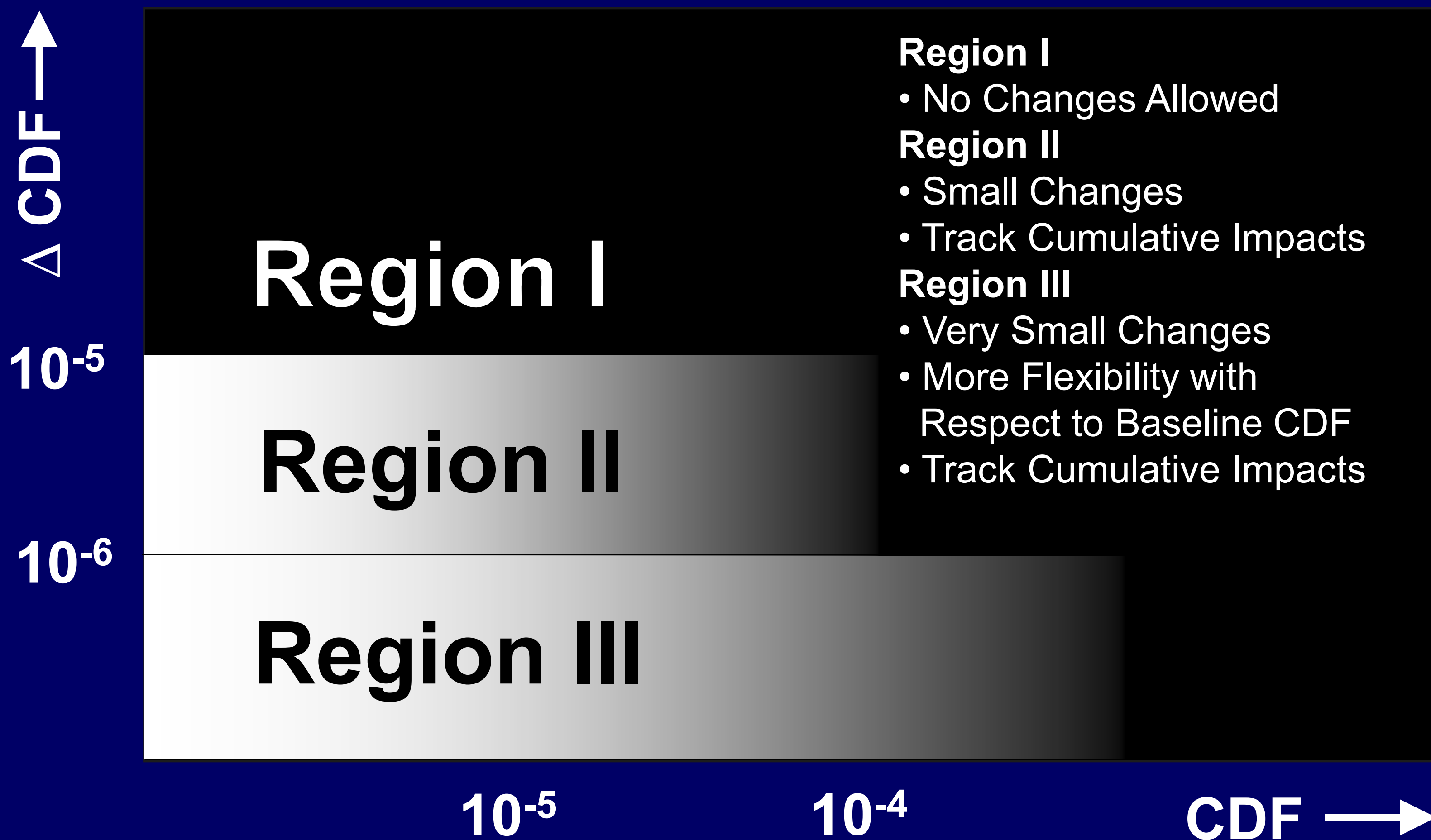


Figure 3. Acceptance Guidelines for Core Damage Frequency (CDF)

From RG 1.174

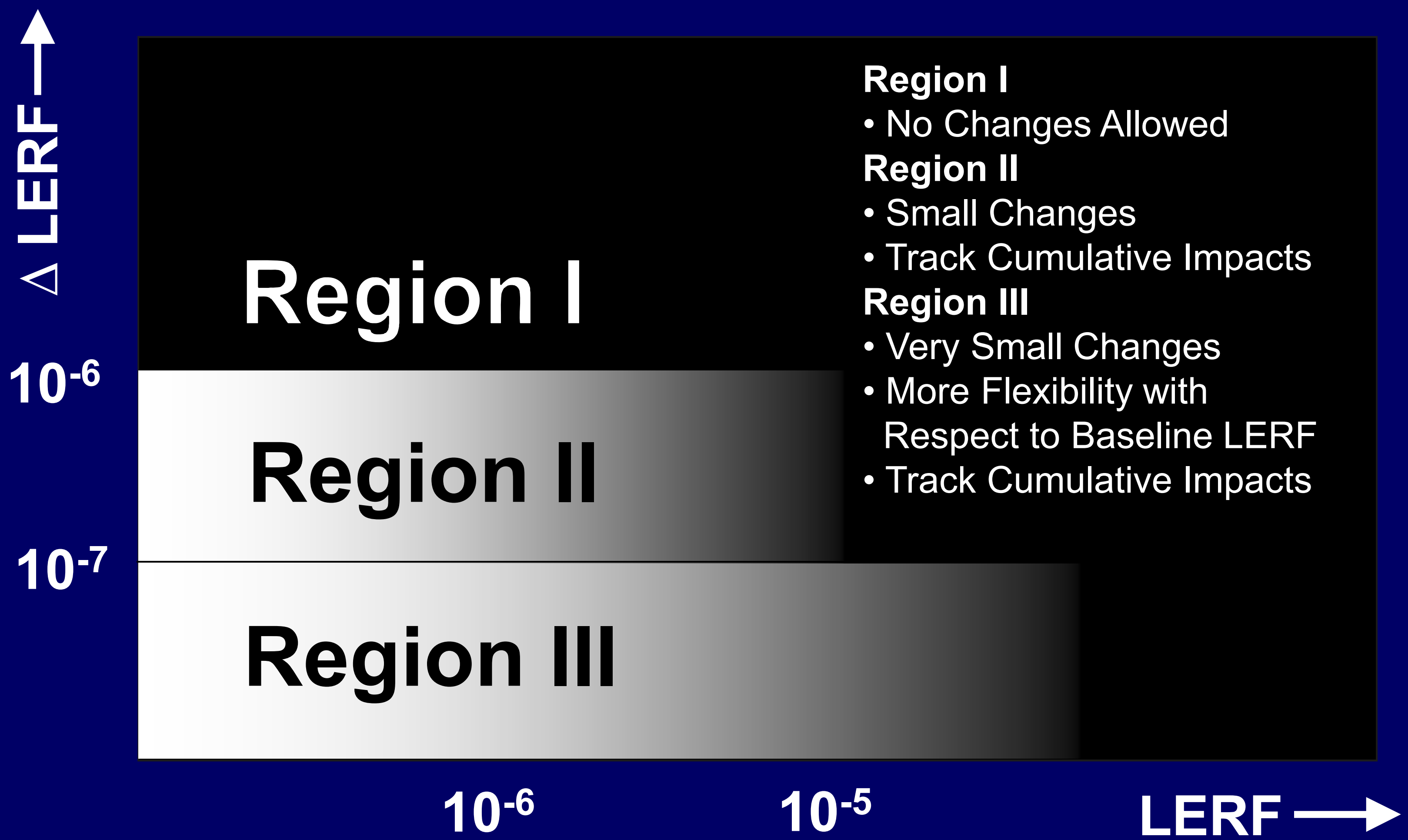


Figure 4. Acceptance Guidelines for Large Early Release Frequency (LERF)

How do we know a licensee's PRA is adequate?

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What does PRA quality mean?

- **In RG 1.174 and RG 1.200, PRA quality is described in terms of its:**

  1. **Scope** (range of risk contributors addressed)
  2. **Technical adequacy**
  3. **Level of detail**

- **The PRA must be of sufficient quality to support the application**

- **When the quality is considered adequate, the analyst can have confidence in the results of the PRA**

1: PRA Scope

- **The assessment of risk performed to support a risk-informed application must address the following contributors to risk:**
  - All credible initiating events
    - "Internal" events like reactor trip or loss of feedwater
    - Other events (fires, floods, earthquakes, etc.) that can impact multiple systems
  - Full power, low power, and shutdown modes of operation

- **Ideally, the PRA would address all the relevant scope items**
  - When the PRA does not address the full scope, the missing scope items may be addressed by showing their **impact on the decision is not significant**
  - Another approach to addressing a limited-scope risk assessment is to **limit the applicability** of the risk-informed activity to that addressed by the risk assessment

- **The PRA must provide an assessment of the metrics used to characterize risk:**
  - CDF
  - LERF/LRF

2: PRA Technical Adequacy

- **Those elements of the PRA required for an application must be performed in a technically competent manner consistent with <u>widely-accepted good practices</u>**

- **Consensus Standards**
  - PRA standards and an industry peer review process can be used to demonstrate the technical adequacy of the base PRA
  - RG 1.200, An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-informed Activities, is the **<u>NRC's vehicle for endorsing</u>** the consensus standards
    - Only the **<u>Level 1/LERF</u>** standard for **<u>internal initiating events at power</u>** is complete and endorsed in RG 1.200
    - External events, and internal fire PRA standards will be endorsed in Revision 2 to RG 1.200 by **<u>December 31, 2008</u>**

PRA Standards

- **Different in nature from other standards**
- **Two types of requirements:**
  - **Process requirements**
    - PRA maintenance and upgrade
    - Peer review
  - **Technical requirements** for each element of the PRA, e.g., initiating events, systems analysis
    - Specify "**what to do**," but not "how to do"

What does it mean to “meet the PRA standard”?

- **Process requirements must <u>always</u> be met**
- **Technical requirements must be met to the <u>extent needed</u> for the application**
- **There are different ways of meeting the technical requirements**
  - Analyses of the same plant may not be identical
    - Use of different HRA model
    - Different assumptions
  - Addressed through peer review and analysis of uncertainty on the results

3: PRA Level of Detail

- **Different applications require use of different PRA elements and different levels of detail**
  - Some use the complete PRA (e.g., categorization of structures, systems, and components by risk significance)
  - Others require only a portion of the PRA (e.g., a simple tech spec change)
- **If the PRA doesn’t model a particular system or component, you can’t justify a change to it using the PRA!**

Phased Approach to PRA Quality

- **In December 2003, the Commission issued an SRM* entitled *Stabilizing the PRA Quality Expectations and Requirements***
- **A plan developed by the staff was submitted to the Commission****
  - Defines a phased approach to achieving an appropriate quality of licensee PRAs
  - Benefits from the development of PRA standards
  - Allows **continued practical use of risk insights while progressing towards more complete and technically acceptable PRAs**

**** SRM on COMNJD-03-0002, 12/18/03***

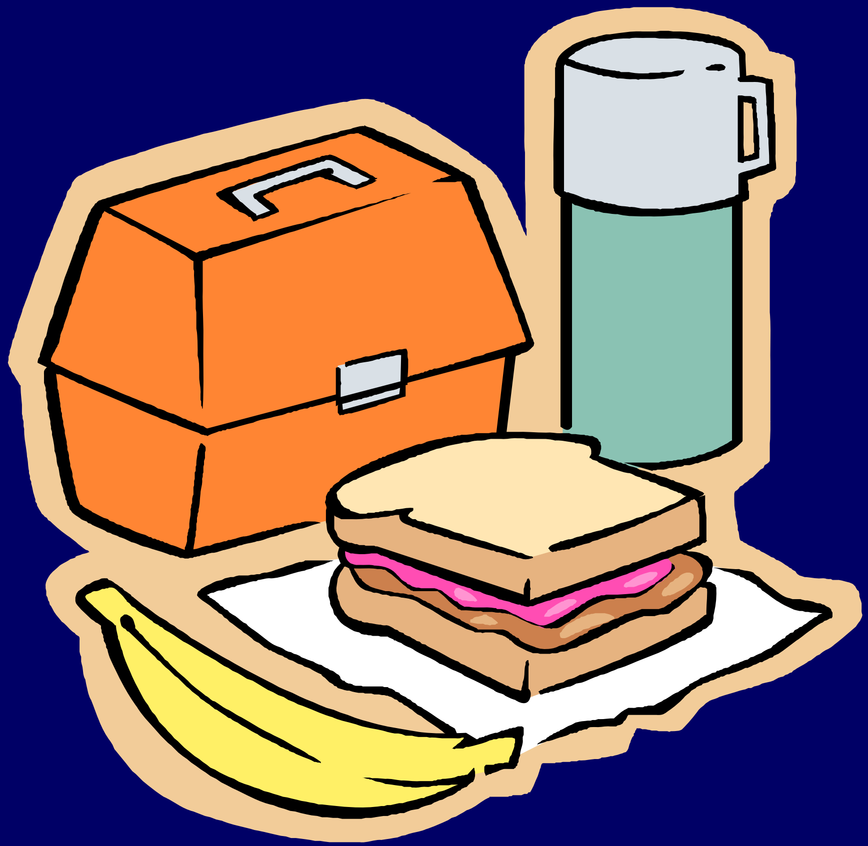
***** SECY-04-0118, 7/13/04***

Phased Approach to PRA Quality (cont.)

- **Once the NRC has endorsed a PRA standard, assessments of the risk contributor covered by the standard must be performed using a PRA if that contributor is significant to the application under consideration**
  - For example, once the fire PRA standard is endorsed, a screening approach is not acceptable if fire risk is important to the application
- **Applications not meeting endorsed standards will be given low priority or not accepted**
  - Acceptance review and prioritization process to be included in NRR Office Instruction LIC-101

Staff Review of PRAs

- **Currently, a review of the base PRA (the entire model) is required when a submittal is based on a PRA that has not been shown to meet the applicable standards**
  - Focus is on those areas of the PRA relevant to the application
- **When the base PRA complies with the standard as endorsed in RG 1.200, no review of the base PRA will be necessary**
- **However, the staff will always examine the modifications to the PRA that are made to support an application**
- **The staff will also confirm that appropriate changes are made to address an emergent issue not included in the original PRA**



Review & Discussion

- **What did we learn this morning?**
  - Define **basic terms** related to risk-informed regulation
    - Risk – What can go wrong? How likely is it? What are the consequences
    - Risk-informed regulation – traditional and risk analyses used together to focus on most safety-significant areas
  - Identify **applications** of risk-informed regulation in your work area
    - Risk-informed applications in rulemaking, licensing, oversight, and operating experience
  - Understand the **basic modeling concepts** in a probabilistic risk assessment
    - Logical event trees and fault trees
    - Based on engineering analyses, plant procedures, etc.

Review & Discussion

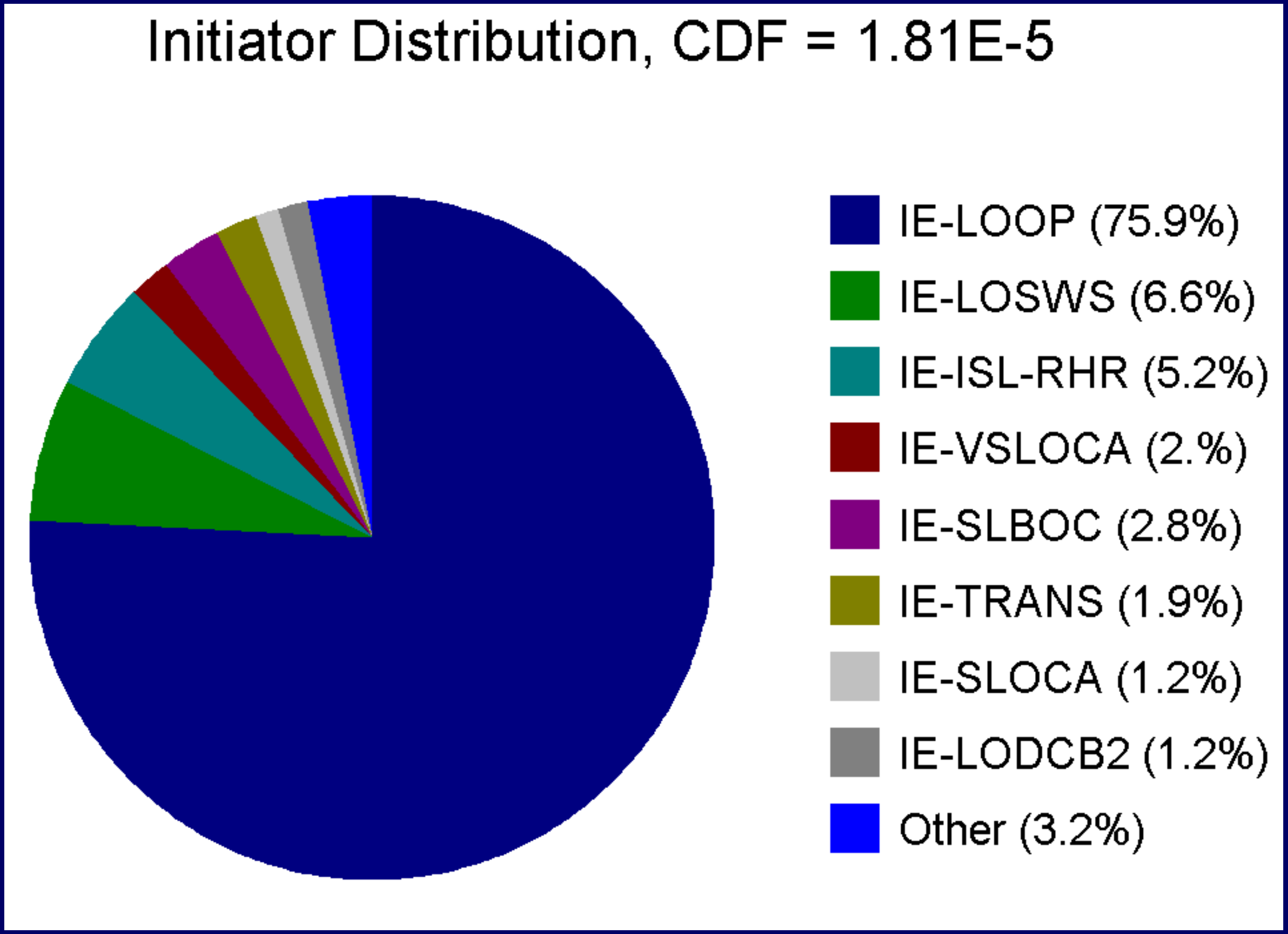
- **Thinking of the examples we discussed earlier…**
  - How could risk information **help you** do your job?
  - **Are** any aspects of your current job or reviews "risk-informed"?
  - **Could** any aspects of your current job or reviews be "risk-informed"?

What can we learn from PRA results?

What can we learn from PRA results?

- **A quantitative assessment of risk impact**
  - Core damage frequency
  - Large early release frequency
- **The significant contributors to the risk measures being used, in terms of, for example:**
  - Initiating events
  - Accident sequences
  - Systems
  - Basic events
- **A number of tools are available to extract these results and characterize their significance and the confidence we can have in them:**
  - Importance analyses
  - Uncertainty analysis
  - Sensitivity analyses
- **Qualitative and quantitative insights about plant vulnerabilities**

Core Damage Contribution by Initiating Event*



Loss of Offsite Power

Loss of Service Water

Intersystem LOCA - RHR

Very Small LOCA

Steam Line Break

General Transient

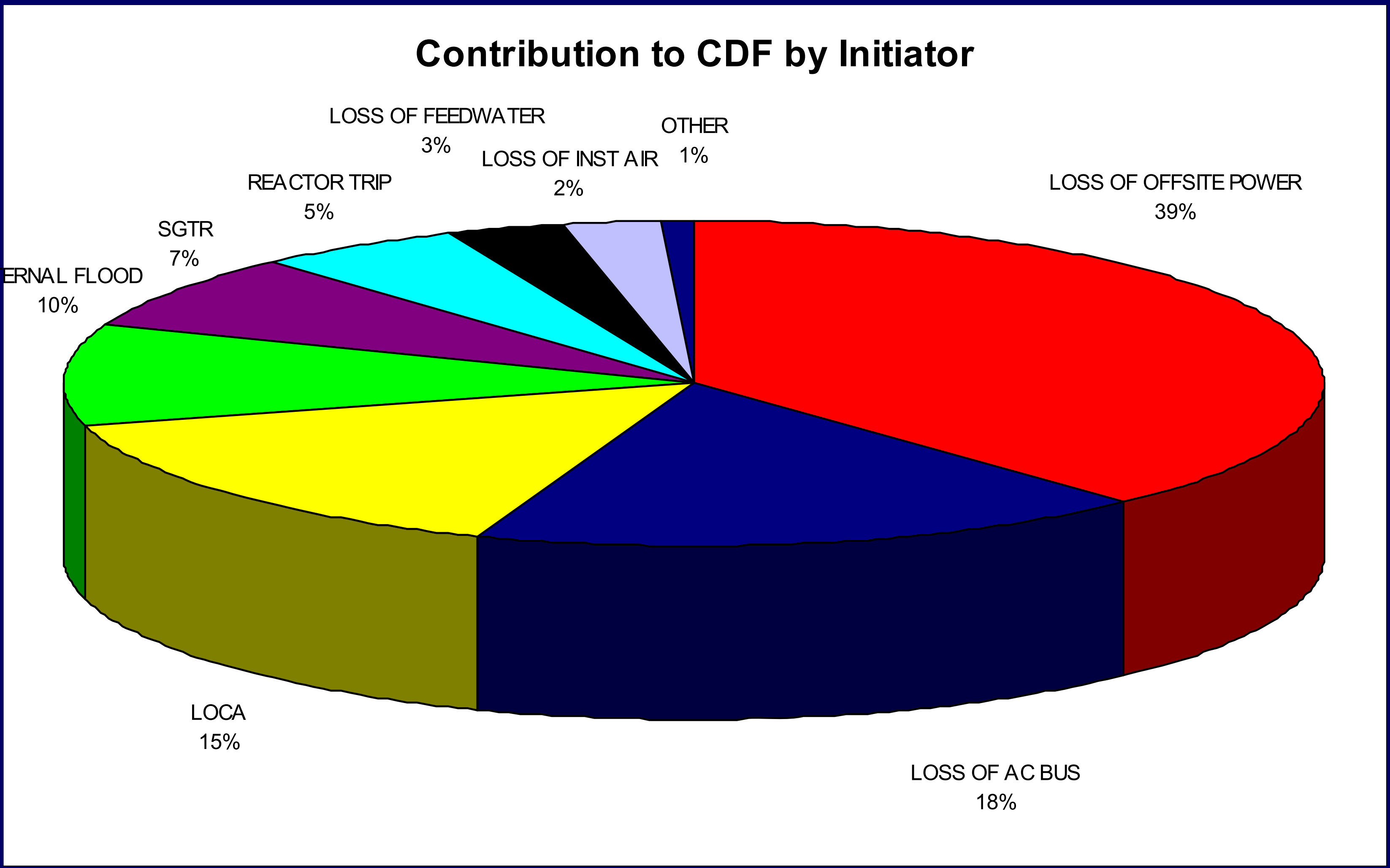
Small LOCA

Loss of DC Bus 1EB2

All Other Initiating Events

**** Comanche Peak SPAR version 3.31***

Core Damage Contribution by Initiating Event



Importance Measures

- **Provide insight into impact of basic events on overall risk**

- **Generally two types:**

  1. Risk decrease measures
     - How much the overall **risk would decrease** if the associated SSC were **less likely to fail**
     - Fussell-Vesely (FV)

  2. Risk increase measures
     - How much the overall **risk would increase** if the associated SSC were **certain to fail**
     - Risk Achievement Worth (RAW)

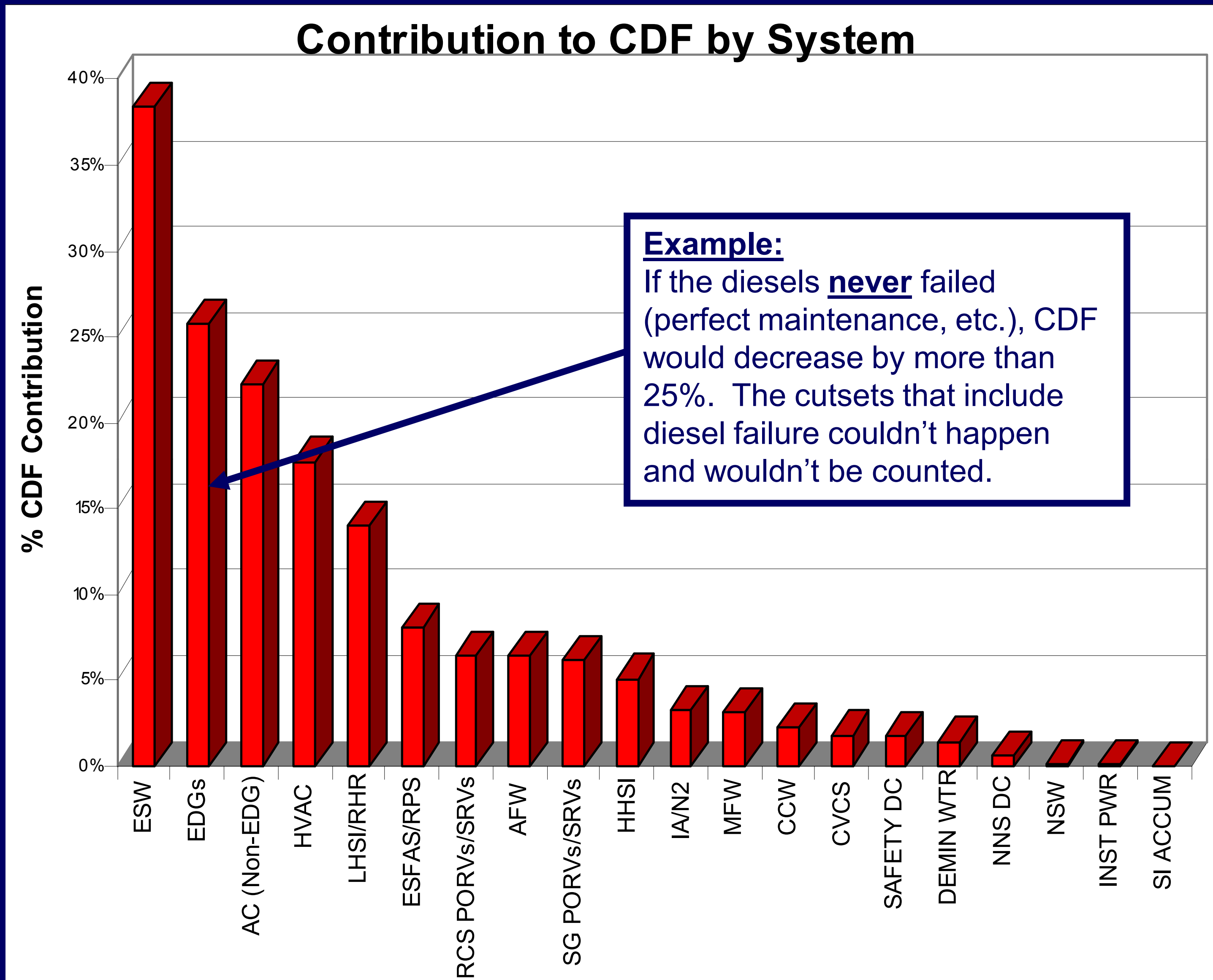
Fussell-Vesely (FV)

- **Answers the questions:**
  - What is driving **current risk**?
  - What **fraction of the total risk comes from cutsets that include a particular component**?
  - If a component were **less likely to fail** (better maintenance, etc.), would that **decrease risk a lot or a little**? (i.e., is it worth the effort?)

- **We use it to:**
  - Focus on **key initiating events, equipment, operator actions, and procedures**
  - Help decide what to inspect

- **A component needs more attention when:**
  - FV is greater than **0.005** (i.e., that event appears in cutsets that contribute to ½% of the risk)

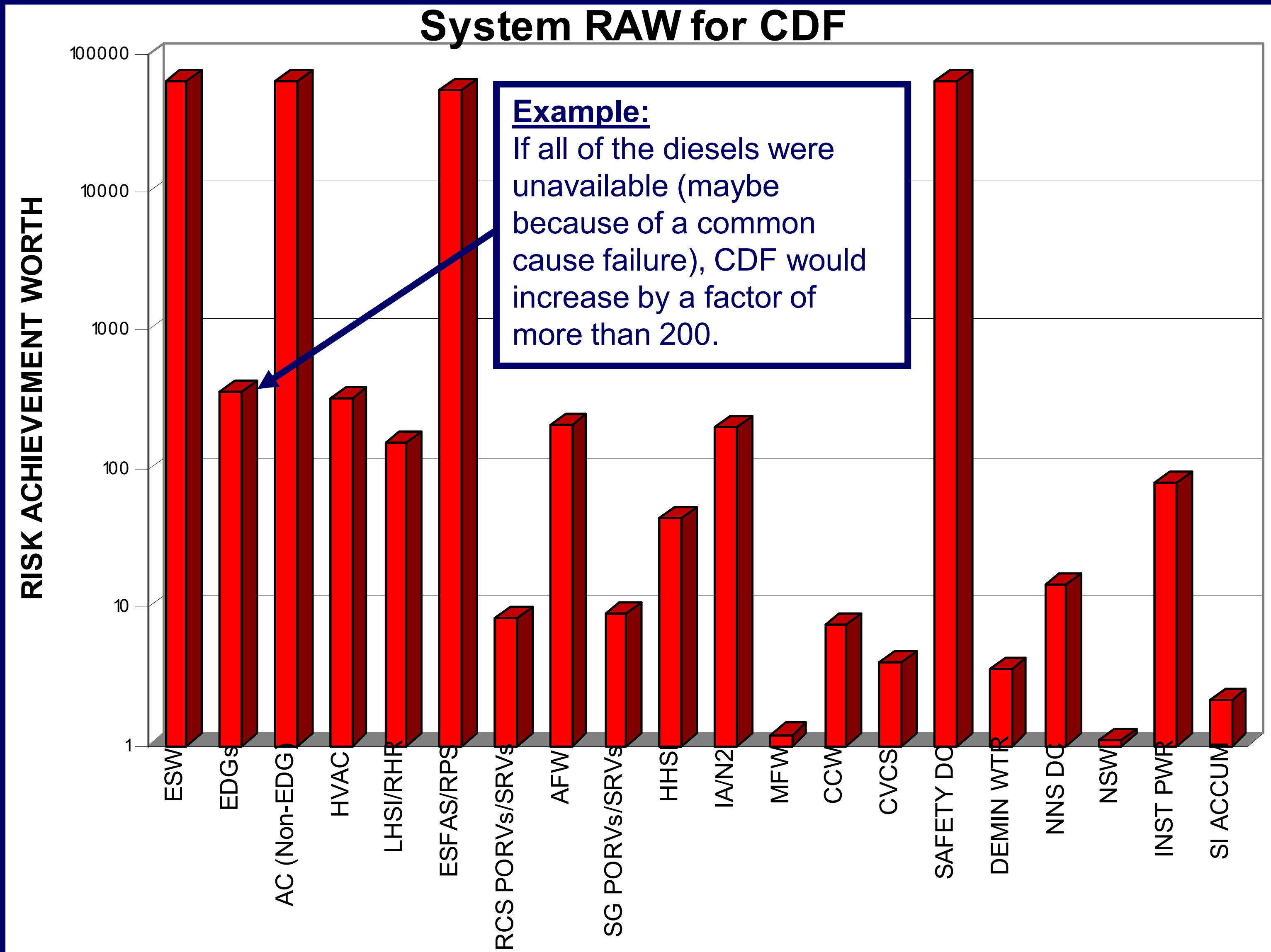
System Contribution to CDF (FV)



Risk Achievement Worth (RAW)

- **Answers the questions:**
  - If this **component were broken or unavailable**, would that **increase risk a lot or a little**?
  - How important is a component to **maintaining the current level of risk**?
- **We use it to:**
  - Help determine the **significance of inspection findings**
  - **Prioritize systems** to review
  - Identify equipment that needs **special controls** to keep it operational
- **A component is treated differently when:**
  - RAW is greater than **2** (i.e., risk doubles without that component)

System Importance to CDF (RAW)



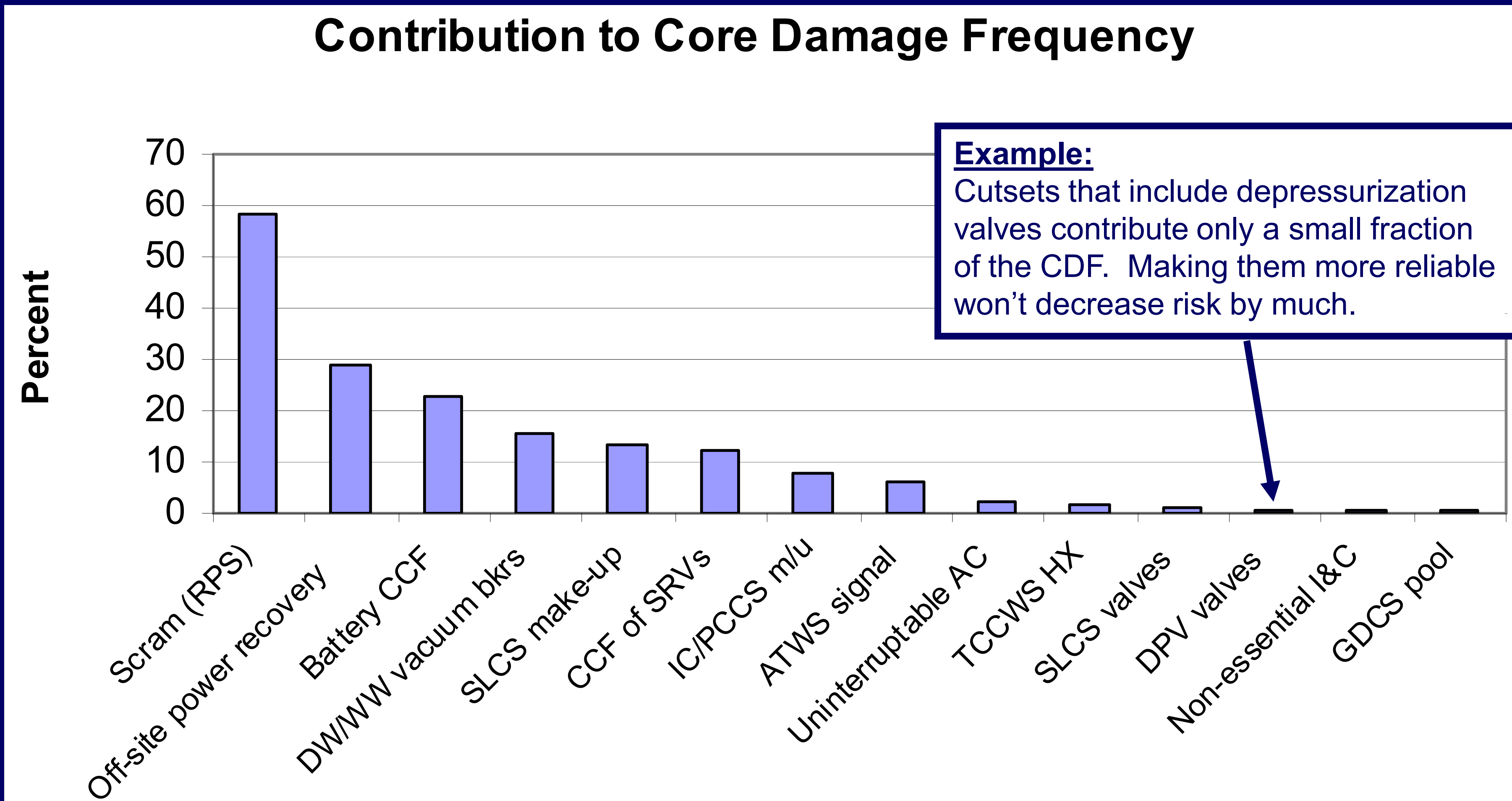
Importance Measures Example: ESBWR

- **Memo from PRA group to ESBWR design certification reviewers***
  - **RAW** → design features and assumptions that contribute to the "low risk" of the design (may need **extra requirements and maintenance**)
  - **FV** → areas where design and operational **changes could improve safety**
- **Similar insights to be developed for other new designs****

Structures, Systems and Components	Fussell-Vesely Importance (F-V) (%)	Risk Achievement Worth
Scram function of reactor protection system	58.5	1.0E+6
Off-site power recovery	28.8	1.18
CCF of batteries	22.7	2.52E+4
CCF of drywell/wetwell vacuum breakers	15.7	5.23E+4
SLCS make-up recovery	13.2	2.2
CCF of SRVs	12.5	3.0
IC/PCCS make-up from fire truck	7.87	40
CCF of APRM ATWS signal	6.22	144
AC uninterruptible power distribution failures	2.27	143
CCF of TCCWS heat exchanger regulating valve	1.52	9
CCF of SLCS valves	1.18	40
CCF of DPV valves	0.51	339
CCF of non-essential instrumentation and control (I&C) VLU and DTM components	0.50	43
CCF of GDCS pool discharge line valves	0.44	149

*** ML061040127**
**** ML072040352**

System Contribution to CDF (Fussell-Vesely)



System Importance to CDF (RAW)

Example:
However, if the DPV valves don't work, overall CDF increases by a factor of 339. Compensatory measures are needed during maintenance.

Plant Vulnerabilities

- **Key operator action or procedure appearing in many core damage sequences**
- **Safety function that needs a single piece of equipment or support system for success**
- **Degradation that could fail redundant components**
- **Unexpected and adverse system interactions**

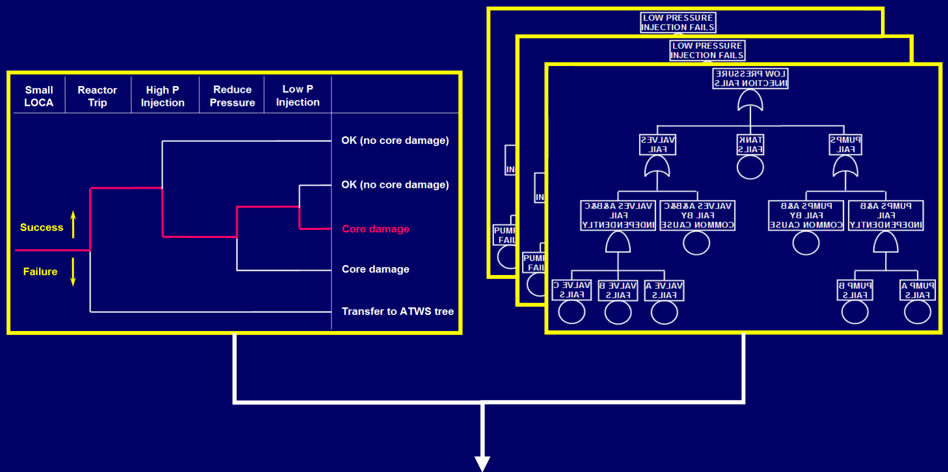
- **Next few slides: some real-life discoveries**
  – Station blackout
  – Individual Plant Examination insights
  – Seismic and fire improvements
  – AP1000 design improvements
  – Shutdown risk

Cutset Analysis

- Core damage cutsets (as opposed to system cutsets) are the <u>combinations of events</u> that result in core damage or large radioactive release

- A <u>measure of design robustness</u>, i.e., number of barriers to core damage or large release

- May indicate plant vulnerability or unexpected reliance on support system



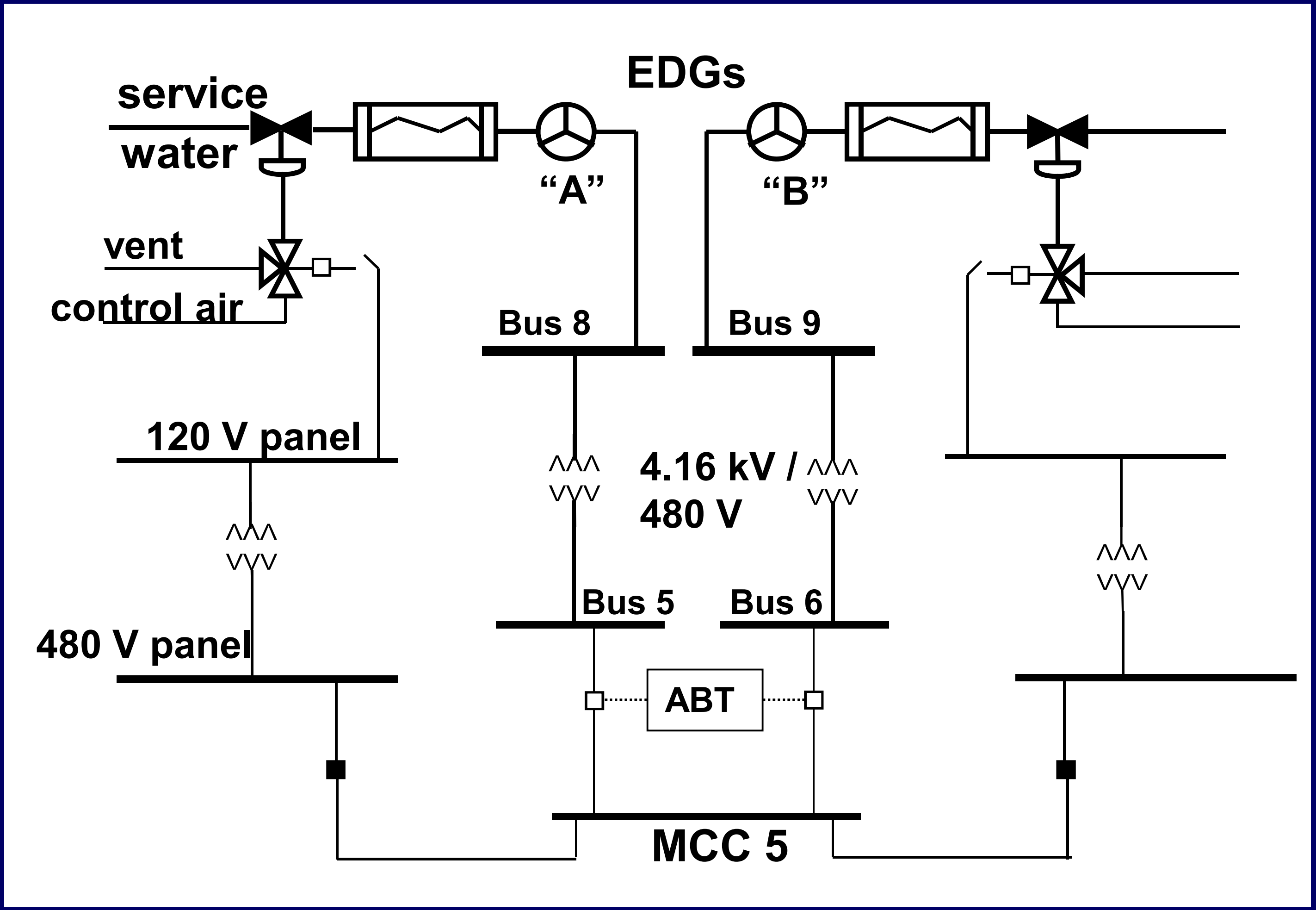
<u>CORE DAMAGE CUTSETS:</u>

- SMALL LOCA & HPI TANK FAILS & LPI PUMP A FAILS & LPI PUMP B FAILS

- SMALL LOCA & HPI PUMP A FAILS & HPI PUMP B FAILS & LPI TANK FAILS

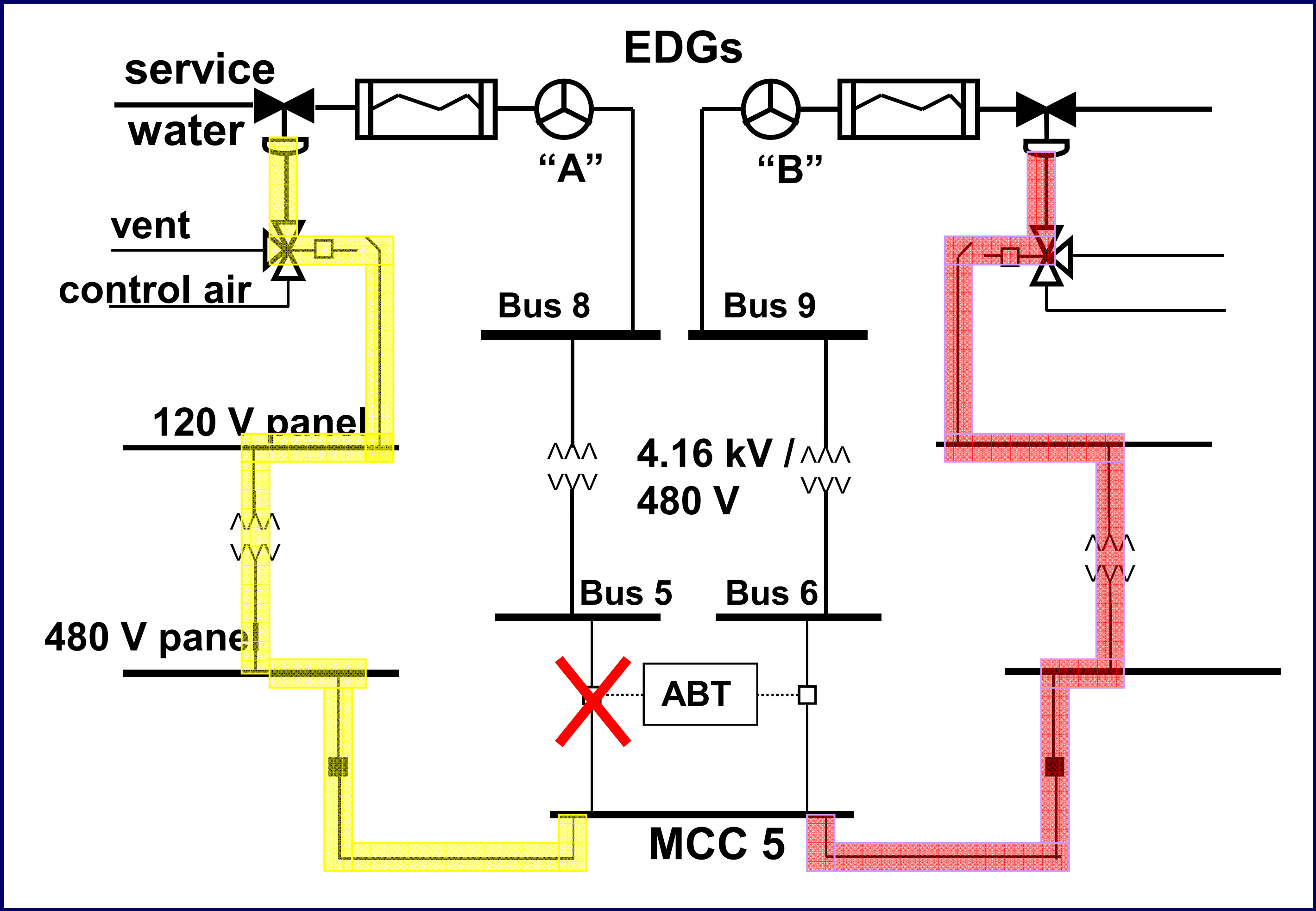
- … (many combinations per sequence!)

1: Plant Vulnerability Discovered in 1980s PRA



*** LERs 50-213/85-029 and 94-004**

1: Plant Vulnerability Discovered in 1980s PRA



**** LERs 50-213/85-029 and 94-004***

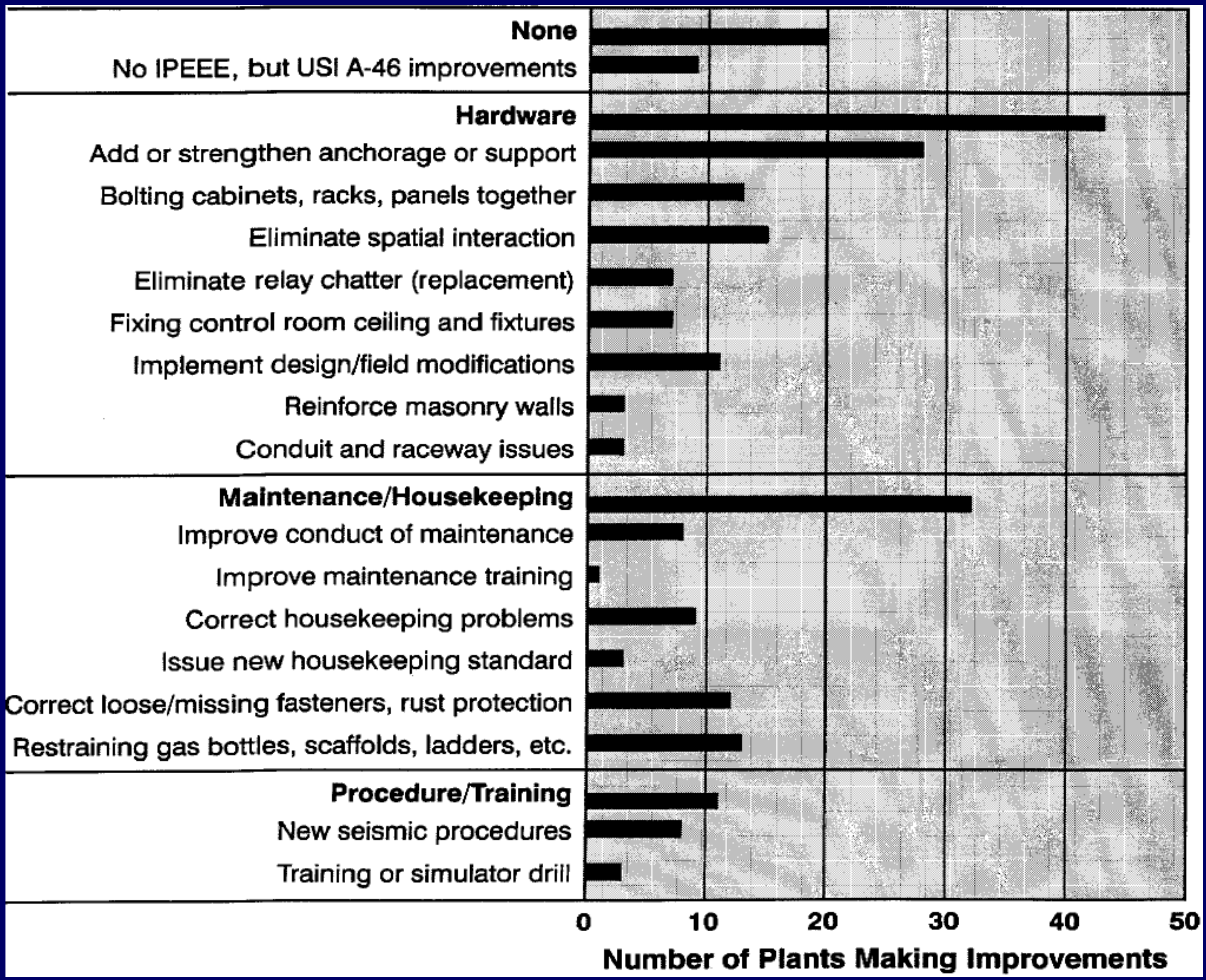
2: Individual Plant Examination Insights*

- **Westinghouse 4-Loop PWRs**
  - **Vulnerability:** Auxiliary feedwater and feed-and-bleed failures in many accident sequences
  - **Resolution:** Prioritize operator training
- **General Electric BWR 3 and 4**
  - **Vulnerability:** Lose 3 of 4 residual heat removal (RHR) loops as a result of failure of either 4.16 kV AC safety bus
  - **Resolution:** Procedures and training for manual alignment of fire water to RHR service water; considering RHR service water cross-tie, portable generator, etc.

- **Other improvements included additional power sources, air-cooled motors, water-tight doors, portable fans, and improved training and procedures.**

**** NUREG-1560, Vol. 1***

3: Improvements from IPEEE Seismic Study*



*** NUREG-1742, Vol. 1**

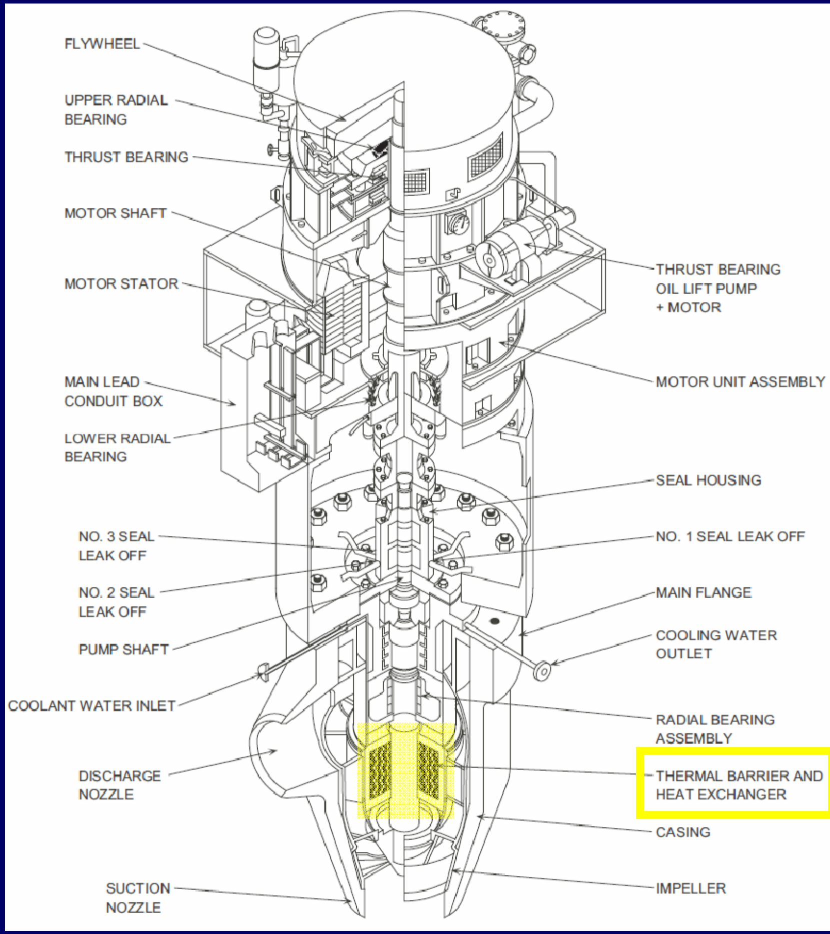
4: Improvements from IPEEE Fire Study*

Improvement Type	#	% of Category	% of Total
Operational Procedures			
Emergency Procedures	71	65	29
Operator Training	17	15	7
Fire Brigade Training	16	15	7
Other	6	5	2
Maintenance Procedures			
General Maintenance Procedures	23	82	10
Other	5	18	2
Physical Design Changes			
General Equipment Modifications	25	24	10
Relocate Equipment/Cables	17	16	7
Fire Protection System Modifications	19	18	8
Barrier Change/Upgrade	19	19	8
Plant System Design Upgrade	19	19	8
Other	5	5	2

*** NUREG-1742, Vol. 1***

5: Interfacing Systems Loss-of-Coolant Accident*

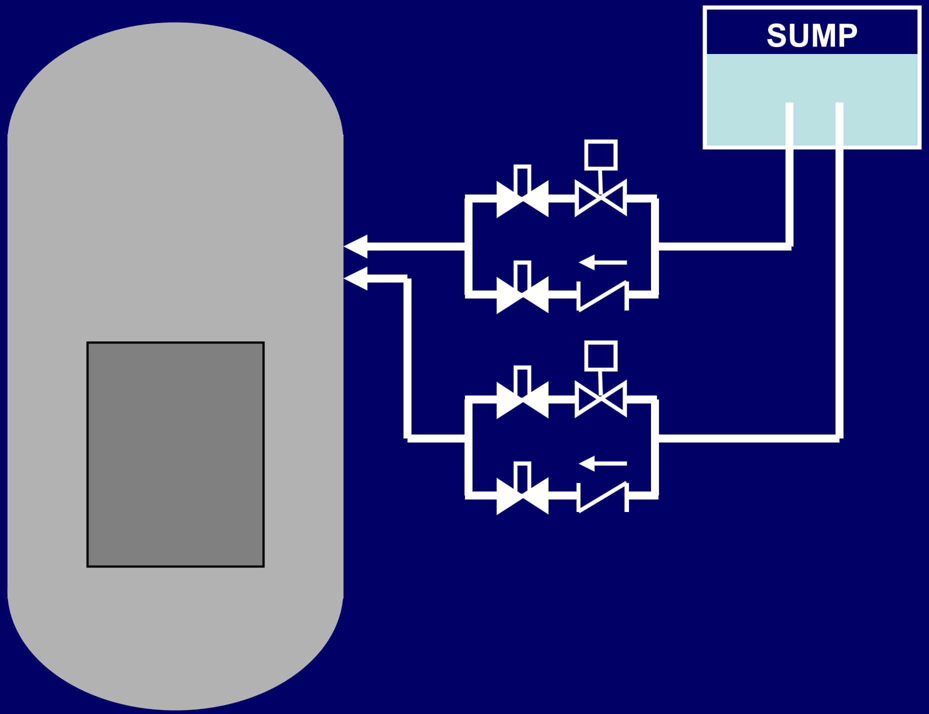
- **Leakage of reactor coolant into another system outside containment**
  - Creates a pathway for **radiation to reach the public** if core damage occurs
  - **"What are the consequences?"** from the risk triplet
- **Surry vulnerability:**
  - Reactor coolant pump **thermal barrier leak** into the component cooling water (CCW) system could **rupture CCW**
  - Unanalyzed **1400 gpm** leak into the auxiliary building**
  - Licensee installed **additional relief capacity** on the CCW lines***



** NUREG-0933, Issue 105*
*** 50.72 Report, Event #15625*
**** Info. Notice 89-54*

6: AP1000 Design Improvements from PRA*

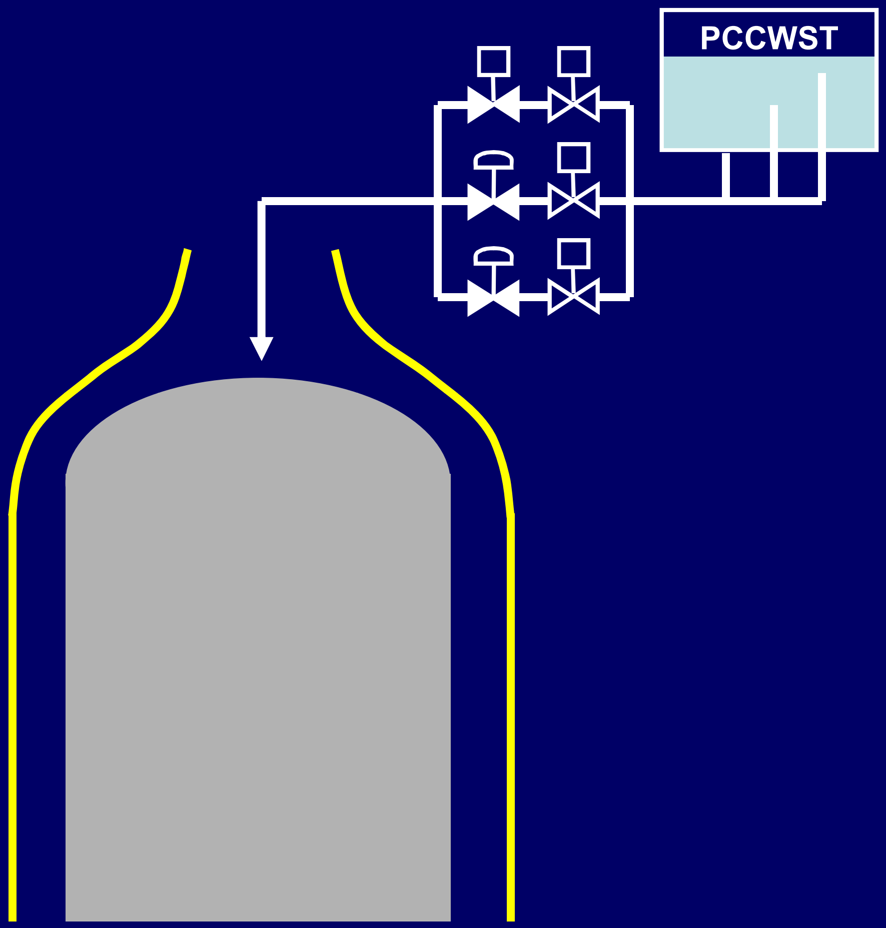
- **Recirculation – Sump to Direct Vessel Injection**
  - **Two** recirculation lines, **each** containing **2 parallel paths**:
    - ➢ Motor-operated valve and squib valve in series
    - ➢ Check valve and squib valve in series
  - **Diverse squib valves** to resist common-cause failure
  - Motor operated valve **fails open**



**** ML053460410, Section 19.1.6.2***

6: AP1000 Design Improvements from PRA*

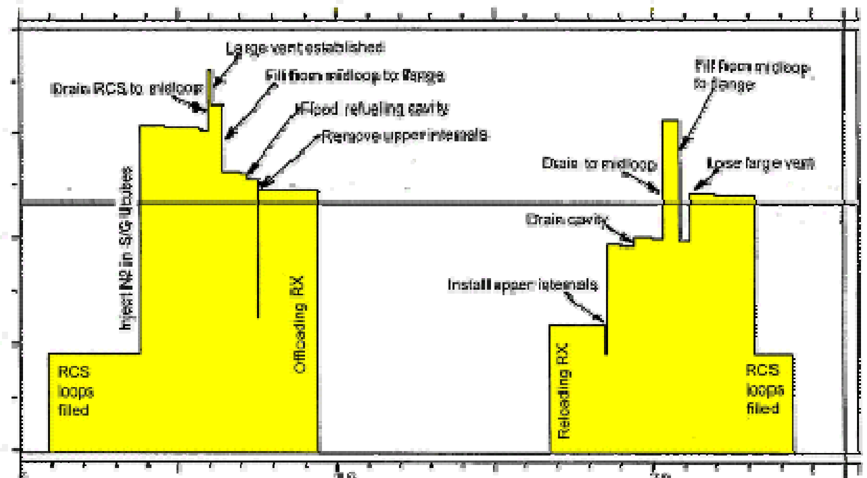
- **Containment Cooling**
  - **Three** parallel supply lines from passive containment cooling water storage tank to containment shell
  - **Diverse actuation** with motor-operated valves in one path



***** ML053460410, Section 19.1.6.2**

7: Shutdown Risk

- **Because of decay heat, risk does not go away when the plant is shut down!**
  - Maintenance unavailability and reliance on manual actuation increase probability of failure
  - Risk accumulated during shutdown can be comparable to operational risk during the rest of the year
- **Example: draining a PWR to mid-loop for steam generator maintenance – could drain too far and draw air into the RHR pumps, possibly failing the system**
- **NRC concern about shutdown risk drove the industry to develop NUMARC 91-06, "Industry Actions to Address Shutdown Management"**



*PWR Outage Risk Profile**

** Info. Notice 2000-13*

What is uncertainty?

- **You may see the following terms:**
  - **Aleatory uncertainty**: associated with the **random nature** of the events we model in a PRA
  - **Epistemic uncertainty**: associated with limitations in our **state of knowledge** about the events and their rates of occurrence
- **Aleatory uncertainty is inherent in the structure of the PRA model**
- **Epistemic uncertainty is addressed by performing an uncertainty analysis of the PRA results in relation to the decision being made**

How do we analyze epistemic uncertainty?

- **Identify sources of uncertainty**
- **Characterize the impact on the PRA model**
  - Uncertainty in parameter values (**parameter uncertainty**)
  - Uncertainty in the structure of the logic model or in the models used for basic events (**model uncertainty**)
  - Uncertainty due to incompleteness of the model (**completeness uncertainty**)
- **Assess the impact of uncertainties on the results**

Examples of Epistemic Uncertainty

- **Parameter uncertainty**
  - Statistical uncertainty associated with parameter estimates based on experience data for active components (pumps, valves) and frequent events (e.g., loss of main feedwater)
  - Uncertainty in estimates of probabilities for rare events (e.g., large loss-of-coolant accident), passive failures (tank collapse), and human errors for which data is sparse or non-existent
- **Model uncertainty (inadequate or incomplete understanding)**
  - Physical processes not fully understood (e.g., chemical effects on containment sump screen clogging)
  - Uncertainty on whether to take credit for a system due to untested performance (e.g., injection into BWR reactor vessel after containment overpressure)

Examples of Epistemic Uncertainty

- **Incompleteness**
  - Things knowingly left out of the model
    - Modeling of human errors of commission
    - Exclusion of equipment from model
    - External initiating events
  - Things we don't know
    - New failure modes (e.g., degradation mechanisms, digital I&C failure mode)
    - Unknown, but potentially important effects
- **Impact of resource constraints (not so much a source of uncertainty, as a source of bias)**
  - Simplifying assumptions in model to save effort
  - Excessive truncation of results during quantification to save time

Treatment of Epistemic Uncertainty

- **Parameter uncertainty can be dealt with analytically**
  - Use **probability distributions** to characterize the uncertainty in parameter values
  - Uncertainty on input parameters can be propagated to give a probability distribution on the numerical results (e.g., CDF)
- **Model uncertainty is typically addressed by making assumptions**
  - Its impact is analyzed by performing **sensitivity analyses** to assess potential impact of alternate, credible assumptions (e.g., alternate common-cause model or human reliability analysis model)
- **Assumptions or approximations can be made for convenience**
  - The impact on the results is assessed, and the PRA model may be refined as necessary to support a specific application

Treatment of Uncertainty (Cont.)

- **Completeness uncertainty cannot be quantitatively assessed**
  – **Known unknowns** dealt with in a number of ways, including:
    - **Limiting the scope of implementation** of the application
    - Demonstrating that the missing issues do not affect the application
  – **Unknown unknowns** addressed through the other key principles of risk-informed regulation,
    - Defense in depth
    - Safety margins
    - Performance monitoring
  – Again, we're not risk-based!

How do we make decisions given the uncertainty?

- The results obtained from the PRA are presented in the manner required for comparison with the acceptance criteria of the application
- The assessment of the acceptability of the risk associated with the application takes into account the uncertainties in the results of the risk analysis
- The purpose of the uncertainty analysis is to provide the decision-maker with confidence in the assessment of the risk input to the decision

Course Modules

1. **Introduction to Risk-Informed Regulation**
   – What do risk and risk-informed regulation mean?
   – Where do we use risk-informed approaches?

2. **Use of PRA Models**
   – How do we build PRA models?
   – How do we use PRA in risk-informed regulation?
   – How do we know a licensee's PRA is adequate?
   – What can we learn from PRA results?

3. **Making Risk-Informed Decisions**
   – How should we think about the issue?
   – What guidance do we use?

4. **Communicating Risk Information**
   – How do we communicate with internal stakeholders?
   – How do we communicate with external stakeholders?

5. **Resources**
   – Where can you get more information?

3. Making Risk-Informed Decisions

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Module 3: Making Risk-Informed Decisions

- **How should we think about the issue?**
- **What guidance do we use?**

How should we think about the issue?

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Good Decisions Require Good Input

- **Analyses need to provide basis for concluding that…**
  - Regulatory position provides reasonable assurance of adequate protection of **public health and safety**
- **All five principles of risk-informed regulation are potentially contributing support for a conclusion**
  - **Integrated approach** to decision making

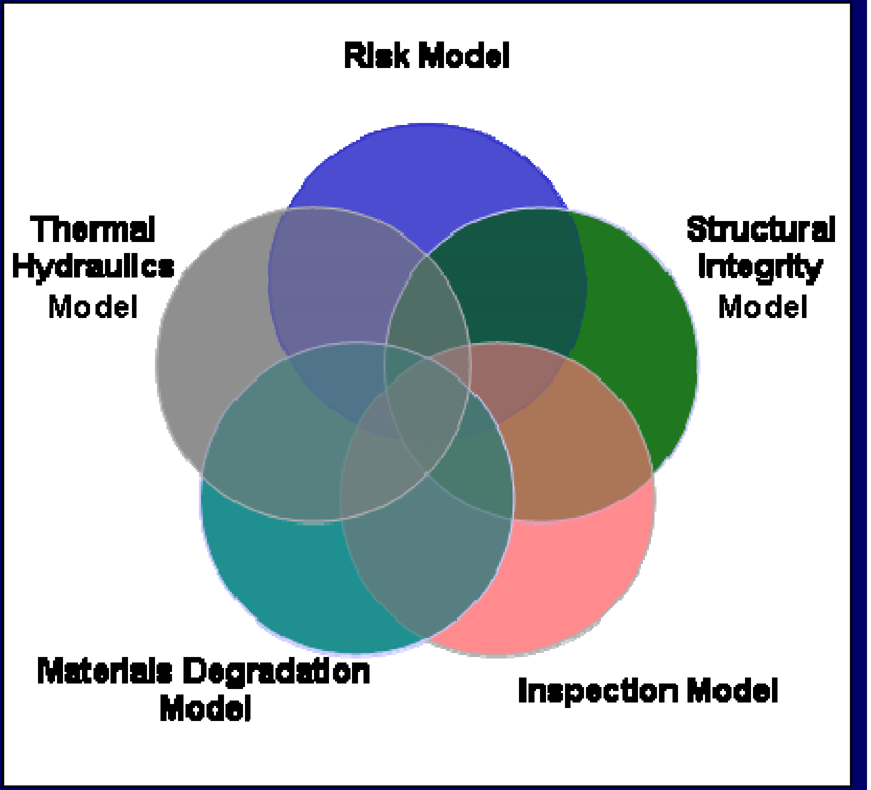
Good Decisions Require Good Input

- **Analysis results**
  - Need to be **relevant** to issue being decided
  - Need to be **clearly understood** by decision-maker
  - Need to include information on **uncertainties**
  - Need to provide assessment of **confidence** in results
- **Communication is key – expect well-defined …**
  - Characterization of problem
  - Identification of options
  - Analysis of options, including uncertainty
  - Recommendation and basis/rationale

Good Decisions Require Good Input

- **Decision-makers need to be "educated" about analyses**
  – Assumptions
  – Boundary conditions
  – Limitations
  – Uncertainties
  – Confidence in results
- **Inadequate communication/ education leads to less-than-ideal decisions**
- **You need the information to make a good decision**

ASK FOR IT! DEMAND IT!



Effective decision-making requires integration of information from many sources

Causes of Bad Decisions

- **Pressure to get the "right" answer**
- **Rush to judgment**
  - Schedule/cost pressure
- **Competing priorities**
  - Safety vs. economics
  - Missing a milestone may affect others
- **Convenient explanations**
  - New characteristics/issues attributed to existing or known causes
- **Failure to perceive a problem once it has occurred**
- **Groupthink**
- **Correctly answering the wrong question**
- **Overgeneralization**
- **Illogical reasoning**
  - Flawed thought process
  - Incorrect consideration of causal mechanisms
- **Lack of information distribution**
  - Analysis insights and recommendations do not get distributed or are ignored
- **Failure to anticipate a problem**
  - Failure to attempt to solve it after it has been perceived
- **Simple errors**

What guidance do we use?

What guidance do we use?

- **A good framework for making risk-informed decisions is found in NRR Office Instruction LIC-504, "Integrated Risk-Informed Decision Making Process for Emergent Issues"**
  - Resulted from GAO audit after Davis-Besse reactor vessel head degradation
  - Provides process for **development and documentation** of risk-informed decisions
  - Not intended to replace existing risk-informed decision-making processes:
    - RG 1.174, "An Approach for Using [PRA] in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis"
    - MD 8.3, "NRC Incident Investigation Program"
    - LIC-401, "NRR Reactor Operating Experience Program"

➔ ***Specifically developed for risk-informed decisions that are not already covered by established processes***

When to Enter LIC-504

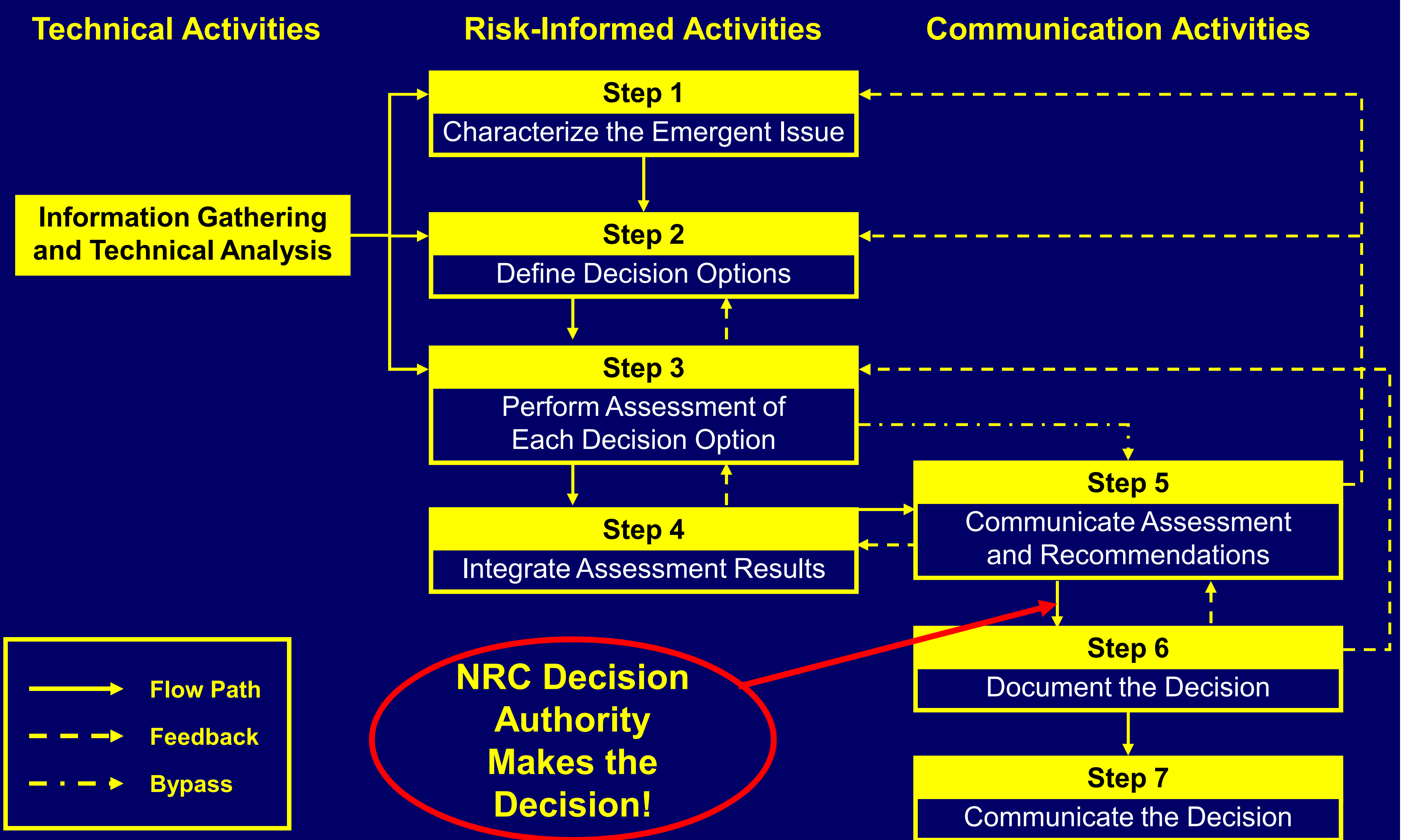
- **Decision to enter LIC-504 made by Division Director with lead responsibility for the issue**
- **LIC-504 may be used**
  - By itself when no other procedure applies
  - In conjunction with other procedures as directed by management
- **Factors that could influence the decision to implement LIC-504**
  - Potential **safety significance** of the issue
  - **Extent of condition** and generic implications
  - **Complexity** of the issue
  - Level of interest of various **stakeholders**
  - Need for scrutable and defensible **documentation** of the decision
  - **Uncertainty regarding the consequences** of the decision

LIC-504 Entry and Outputs

- **LIC-504 process should be entered when the emergent issue has potentially significant safety implications**
  - Potential for an **immediately effective order**
  - Discovery of potentially risk-significant **generic issues**
  - Significant concerns about **safety margin or defense in depth**
  - When other risk-informed processes call for **increased management attention**
- **The outputs of LIC-504 are:**
  - The **decision**
  - **Communication** of the decision
  - **Documentation of decision and basis** (in ADAMS)

Note: Resources to invoke LIC-504 could be significant!

LIC-504 Process



Invoking the LIC-504 Process

- **Identify the decision authority – who will make the decision?**
- **Name a management lead**
- **Name a technical lead**
- **Ensure an adequate technical team is formed**
  - Sufficient resources to characterize, define options, analyze and make a recommendation
  - Include a communication lead
- **Set expectations**

Conclusion on LIC-504

- **Manager's role – not only to make the decision, but …**
  - Insist on the **best input** available/practicable
  - Foster an **open atmosphere** for analysis & communication
  - Practice **critical thinking**
  - Ask the **hard questions**
- **When LIC-504 is warranted – invoke early**
  - Name management and technical leads
  - Set expectations for team
  - Ensure documentation of the entire decision process
- **We'll do an exercise on this subject later!**

4. Communicating Risk Information

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Module 4: Communicating Risk Information

- How do we communicate with internal stakeholders?
- How do we communicate with external stakeholders?

What is risk communication?

- Communicating with our <u>external stakeholders</u> about topics that cause concern about health, safety, security or the environment
- Communicating <u>amongst ourselves</u> about risk models, risk assessments and risk-informed decisions

Why is risk communication important at the NRC?

- **Provides essential links between risk analysts, risk managers (decision-makers) and internal and external stakeholders.**

- **Facilitates risk-informed decision-making**
  - GAO recommendation: improve communication of risk estimates, uncertainties and assumptions to decision-makers
  - Integrated risk-informed decision-making process developed (Office Instruction LIC-504) which addresses communication

What resources are available?

- **NUREG/BR-0308, NRC Guidelines for External Risk Communication, January 2004**
- **NUREG/BR-0318, NRC Guidelines for Internal Risk Communication, December 2004**
- **NRC Risk Communications Web Page:**

  http://www.internal.nrc.gov/communications/riskcommunication.html

Internal Risk Communication Examples

- Gathering or providing information for a risk model or risk assessment
- Providing input in support of a decision
- Providing background information
- Developing a new risk-informed regulatory approach

External Risk Communication Examples

- **Speaking to external stakeholders about safety matters**
  - meetings with licensees/applicants
  - public workshops
  - briefing outside groups
- **Preparing public documents**
  - safety evaluation reports
  - Rulemaking
  - congressional Q&A
  - Director's Decision (10 CFR 2.206)

Steps for Risk Communication

1. Determine Objectives for Communication
2. Understand the Audience
3. Establish Trust and Credibility
4. Design and Deliver Effective Messages

1: Internal Communication Objectives

- Gathering or providing information for a risk determination
- Eliciting or providing peer feedback
- Providing input in support of a decision
- Providing background information
- Conveying a decision
- Supporting communication with external stakeholders
- Developing a new risk-informed regulatory approach

1: External Communication Objectives

- Providing information
- Gathering information
- Building trust and credibility
- Seeking involvement
- Influencing behavior or perceptions about risk

2: Understanding Your Internal Audience

- **Who are they?**
  - NRC decision-makers
  - risk analysts
  - technical staff
  - non-technical staff
- **What are their needs and preferences?**
  - types of information and level of detail
  - presentation

2: Understanding Your External Audience

- **Who are they?**
  - state, federal and foreign officials
  - members of the public
  - licensees and nuclear industry representatives
  - public and private organizations
  - the media
- **What are their needs and preferences?**
  - research on the internet
  - use NRC resources (e.g., OCA, OPA)
  - review local newspapers
  - contact community leaders and local organizations
  - conduct interviews and focus groups

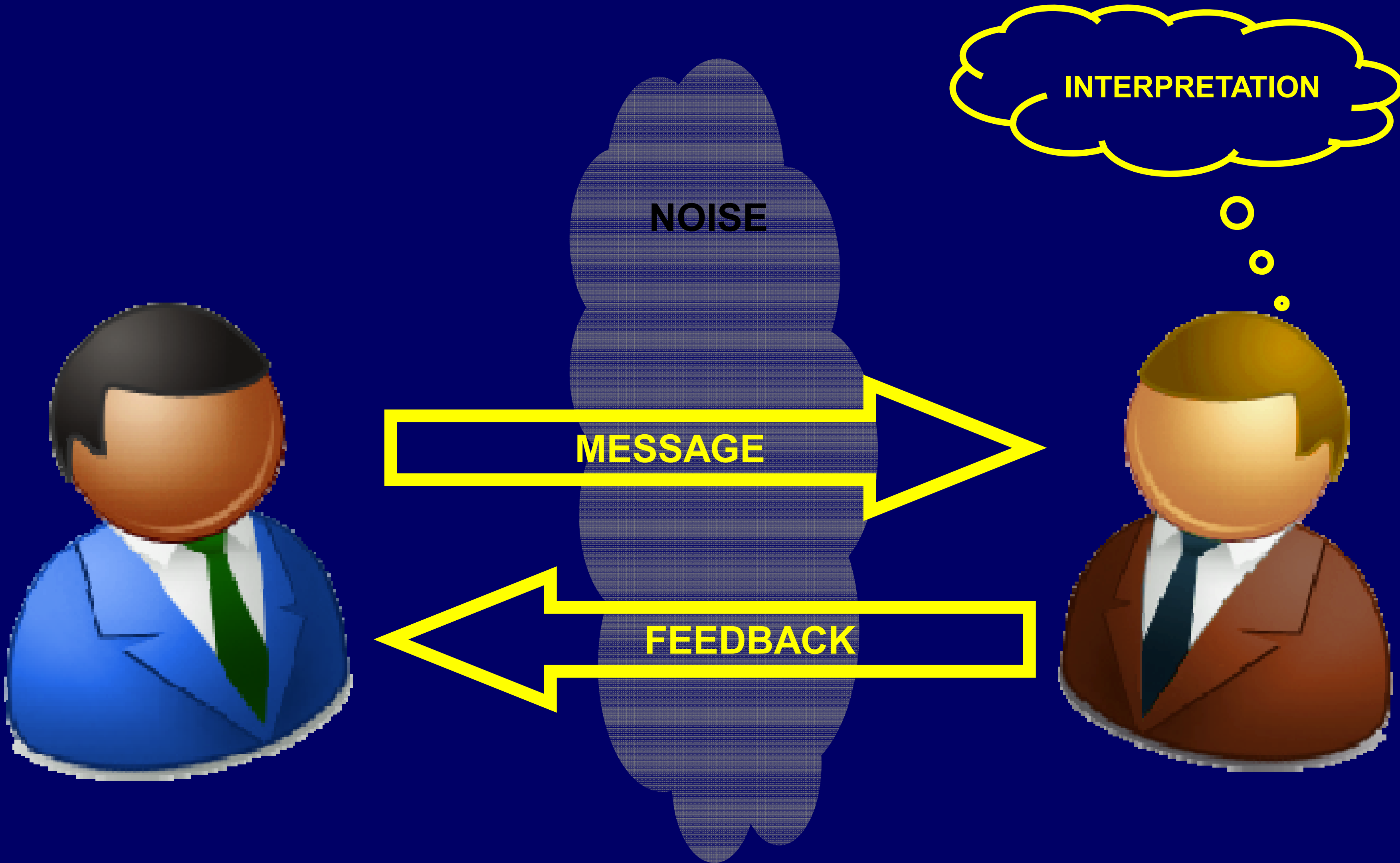
3: Building Trust & Credibility Internally

- Involve stakeholders early and often in risk assessments
- Peer review risk information and discuss the reviewer's perspective
- Discuss the strengths and limitations of risk information and how it should be used
- Explain why risk information is satisfactory for a given application or decision

3: Building Trust & Credibility Externally

- **Be open and honest**
- **Acknowledge stakeholder concerns**
- **Encourage questions when concerns are evident**
- **Build alliances with credible third parties**
- **Be organized and prepared**
- **Present technical information in a way that makes sense to stakeholders**
- **Follow through on commitments**

Implementing Two-Way Communication



Examples of two-way internal risk communication

Decision-makers *will gain a better understanding of...* • The information that is available and its quality • What form it will be in • What it means	**Noise** • Time pressures • Lack of familiarity with risk terminology and decision-making • Lack of openness due to organizational culture issues	**Risk analysts** *will gain a better understanding of...* • The decision • The non-risk-based factors that are present • Individual communication preferences
Risk analysts *will gain a better understanding of...* • Key design or operational factors • Failure rates/sources of data • Accidents to consider • Review of assumptions about a specific technical area, such as fire protection	**Noise** • Technical jargon from area of specialty • Different conceptual frameworks about safety • Lack of familiarity with risk models • Varying understandings of what "risk informed" means	**Technical staff** *will gain a better understanding of...* • Where information/expertise is included in a risk analysis • What might be missing from the model • The problems risk information can help address
Risk analysts *will gain a better understanding of...* • Concerns and values of external stakeholders • Local conditions that might influence assumptions or models • Risk perceptions	**Noise** • Time pressures • Lack of familiarity with risk terminology and decision-making • Lack of understanding of public perceptions and acceptance of risk	**Public Affairs** *will gain a better understanding of...* • What information is available • The processes used to arrive at a decision • The risks

4: Design & Deliver Effective Messages

- **We'll address this step with a final exercise related to the LIC-504 process of developing and communicating options**
  - Discuss the scenario as a class
  - Get into 4 groups
    - Each group will organize information related to one of the options
    - Work for 30 minutes on this task
    - Appoint a leader to present the option to "management"
  - As a class, we'll be "management" and ask those tough questions

Exercise: Cracking at the Sunny Valley Plant

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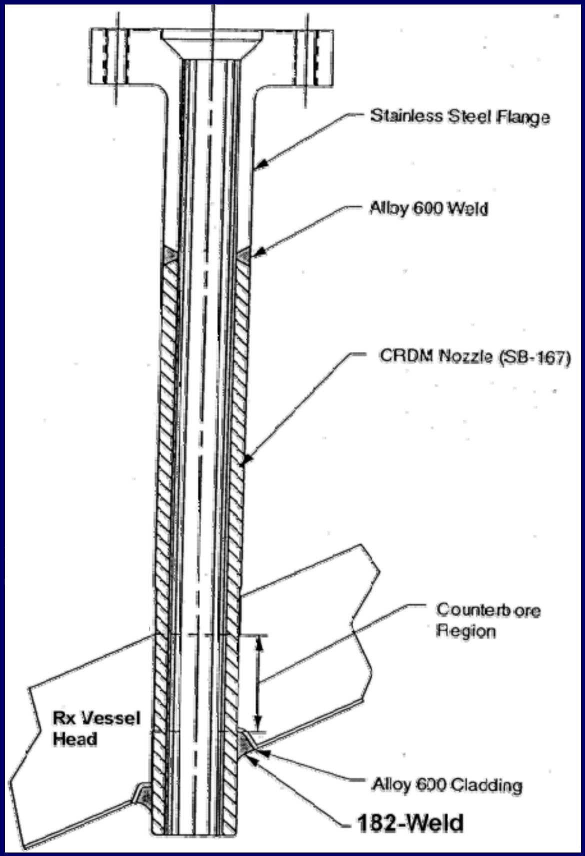
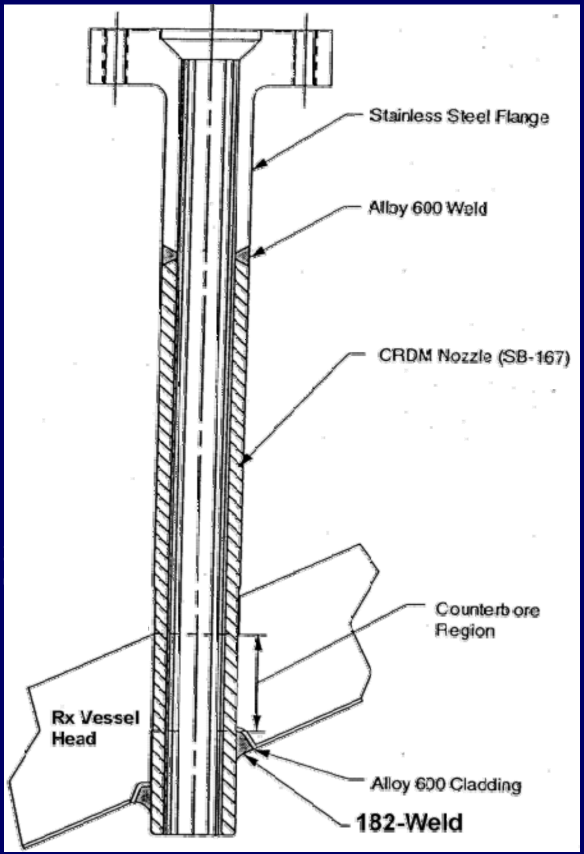
Background

- Control rod drive mechanism (CRDM) weld and nozzle cracks observed in France in ~1990
- U.S. computer models predicted **axial cracks only**
- Nozzle ejection (which would create a **medium LOCA**) not considered credible before the leak would be detected
- U.S. licensees committed to **visual inspections to look for leaks** on the head



NRC Issues

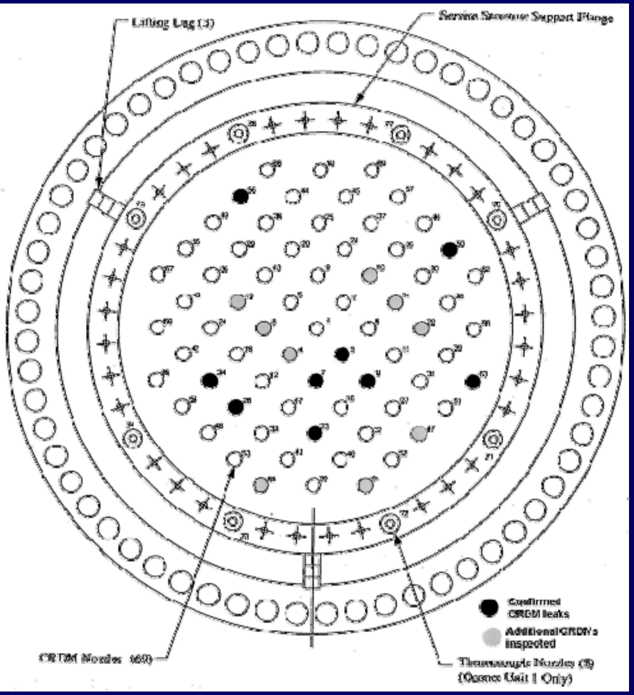
- **Regulatory Considerations**
  - Technical Specifications **prohibit pressure boundary leakage and limit unidentified leakage**
  - 10 CFR 50 Appendix B requires that licensees determine the cause and prevent repetition of **significant conditions adverse to quality** (SCAQs)



- **Risk Concern**
  - If a medium LOCA occurs, there is about a **1/1000 chance of core damage**

Inspection at the Sunny Valley Plant

- **9 leaking nozzles** found in a visual inspection of all 69 nozzles
- Leakage indications much less obvious than expected
- Ultrasonic (UT) exams performed only on 9 visibly leaking nozzles
- **Circumferential cracks** found accidentally in 3 nozzles during repair
- Circumferential cracks began on outside surface; means there was **leakage through axial cracks for years without being discovered by visual inspections**
- Physical exams showed cracks went **almost halfway around the circumference (165°); ejection predicted at 324°**



Licensee Response

- **Additional ultrasonic testing (UT) on 9 nozzles that didn't appear to be leaking (15% of remaining nozzles)**
- **No additional axial or circumferential cracks found**
- **UT was not configured to find circumferential cracks**
  - NRC expert assessment that UT configuration has reasonable probability to **detect at least part of a crack** large enough to become a structural integrity problem within 6 months
- **51 nozzles not inspected by UT**

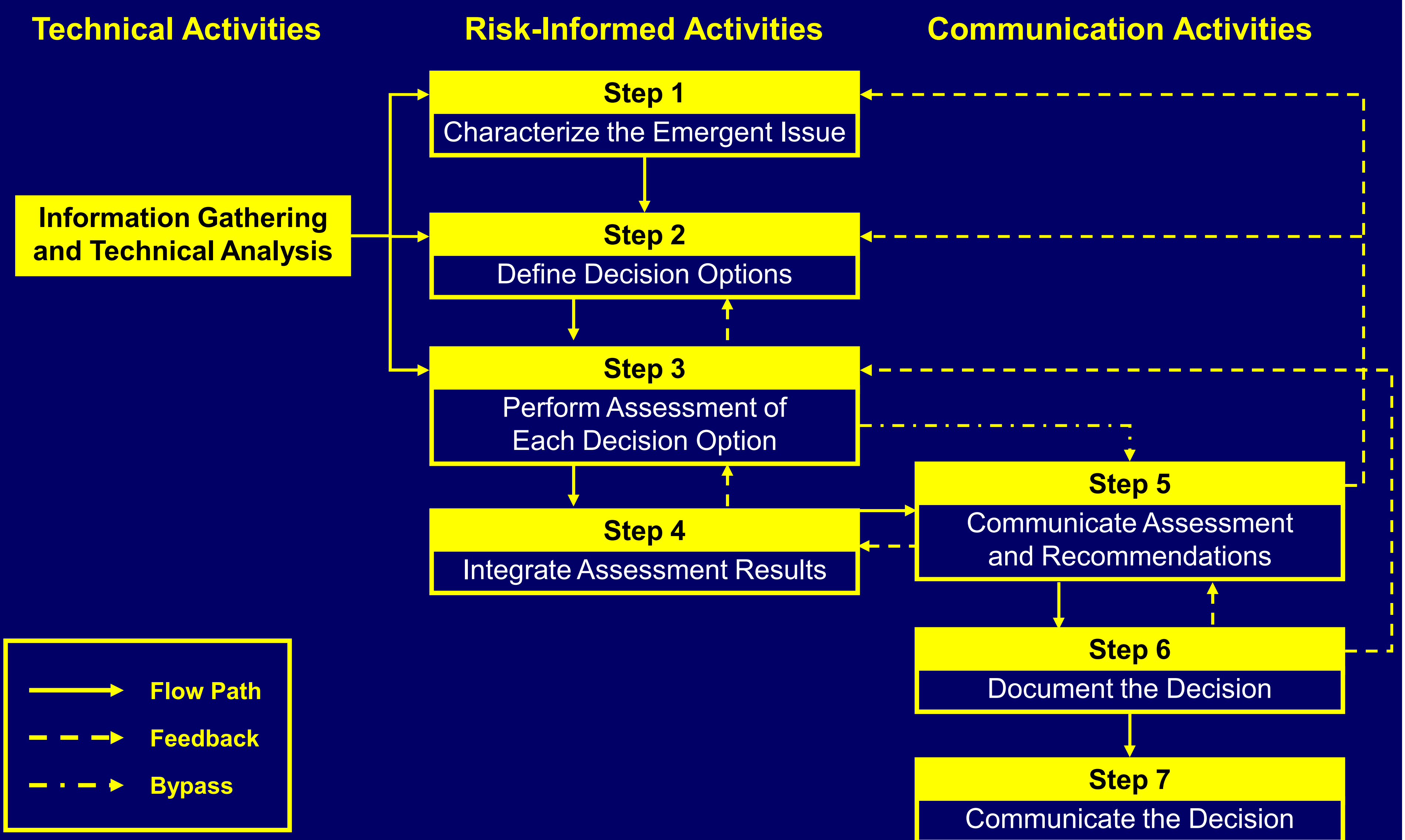
Our Decision as the Regulator

- **Should we allow the plant to start up?**

- **Should the licensee be required to complete additional testing to provide high confidence that there are no more cracks needing repair in the other 51 nozzles?**

- **Should we allow the licensee to use the current UT configuration to avoid extending their outage?**

Enter the LIC-504 Process…



Step 2 of LIC-504: Define Options

		Return to Power Before UT?	Additional UT Before Next Refueling Outage?	When Next UT?	UT Method
1	Require licensee to test all nozzles for circumferential cracks with on-site UT equipment before returning to power.	No	Yes	ASAP	Current
2	Require licensee to test all nozzles with enhanced UT equipment before returning to power.	No	Yes	~1 mo.	Enhanced
3	Allow licensee to restart, but shut down ASAP to test all nozzles with enhanced UT test equipment.	Yes	Yes	~1 mo.	Enhanced
4	Allow licensee to return to service without additional testing requirements.	Yes	No	~6 mo.	Enhanced

Now it's your turn…

- Take 5 minutes to read the handout
- We'll walk through the first option together
- Take 20 minutes, in groups, to address the other three options
- We'll reconvene to discuss the outcome

5. Resources

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Where can you get more information?

- **Web Resources**
  - NRC Public Website
    - *http://www.nrc.gov/what-we-do/regulatory/rulemaking/risk-informed.html*
  - NRR/DRA Website
    - *http://nrr10.nrc.gov/adt/dssa/spsb/webpages/spsbpage/spsbhomepageindex.html*
    - Huge document archive on risk-informed regulation
  - @Risk-InformedCommunity Web Forum
    - *http://nrr10.nrc.gov/forum/index.cfm?selectedForum=08*
    - Post questions on anything related to risk-informed regulation

- **NRC Organizations**
  - NRR/DRA
  - NRO/DSRA
  - RES/DRASP
  - Regional Senior Reactor Analysts

- **Training**
  - PRA Basics for Regulatory Applications (P-105, 3 days)
  - PRA Technology and Regulatory Perspectives (P-111, 2 weeks)
  - Advanced P-series courses
  - Model uncertainty course
  - Risk Communication Workshop

Course Objectives

- **At the end of this course, you will be able to:**
  - Define **basic terms** related to risk-informed regulation
  - Identify **applications** of risk-informed regulation in your work area
  - Understand the **basic modeling concepts** in a probabilistic risk assessment
  - **Make risk-informed decisions** on emergent issues
  - **Communicate** risk information to internal and external stakeholders
  - Find **references** for more information in the future

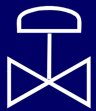
Guide to Abbreviations

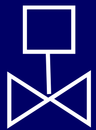
ABT = automatic bus transfer
AC = alternating current
AOT = allowed outage time
ASP = Accident Sequence Precursor program
ASME = American Society of Mechanical Engineers
ATWS = anticipated transient without scram
BWR = boiling water reactor
CCDP = conditional core damage probability
CCFP = conditional containment failure probability
CCW = component cooling water
CDF = core damage frequency
CFR = *Code of Federal Regulations*
CRDM = control rod drive mechanism
CT = completion time
CVCS = chemical and volume control system
ΔCDF = change in core damage frequency
ΔLERF = change in large early release frequency
DC = direct current
DPV = depressurization valve
EDG = emergency diesel generator
ESAS = engineered safeguards actuation signal
ESBWR = Economic Simplified Boiling Water Reactor
FV = Fussell-Vesely importance
GAO = Government Accountability Office
GDC = General Design Criteria (10 CFR 50 Appendix A)
GDCS = gravity-driven cooling system
GL = Generic Letter
GPM = gallons per minute
HHSI = high-head safety injection
HVAC = heating, ventilation, and air conditioning
IA = instrument air
IC = isolation condenser
ICCDP = incremental conditional core damage probability
ICLERP = incremental conditional large early release probability
IPE = Individual Plant Examination (for severe accident vulnerabilities)
IPEEE = Individual Plant Examination of External Events
LER = Licensee Event Report
LERF = large early release frequency
LHSI = low-head safety injection
LOCA = loss of coolant accident
LRF = large release frequency
MCC = motor control center
MFW = main feedwater
MSPI = Mitigating System Performance Index
NOED = Notice of Enforcement Discretion
PCCS = passive core cooling system
PORV = power- (or pilot-) operated relief valve
PRA = probabilistic risk assessment
PWR = pressurized water reactor
RAW = risk achievement worth
RFO = refueling outage
RG = Regulatory Guide
RHR = residual heat removal
RIS = Regulatory Issue Summary
RPP = Risk-informed Performance-based Plan (formerly RIRIP, Risk-Informed Regulation Implementation Plan)
RRW = risk reduction worth
RTNSS = regulatory treatment of non-safety systems
SBO = station blackout
SCAQ = significant condition adverse to quality
SLCS = standby liquid control system
SRAS = sump recirculation actuation signal
SRM = Staff Requirements Memorandum
SRV = safety/relief valve
SRP = Standard Review Plan (NUREG-0800)
SSC = structure, system, or component
SWS = service water system
TS = technical specifications
UFSAR = Updated Final Safety Analysis Report
UT = ultrasonic testing

Guide to Symbols

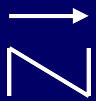

diesel generator

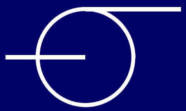

transformer

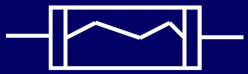

air-operated valve

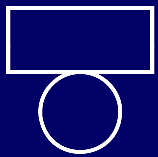

motor-operated valve

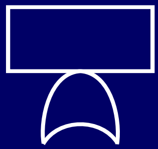

squib (explosive) valve

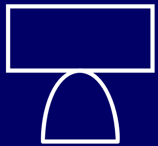

check valve


pump


heat exchanger


basic event


OR gate


AND gate