

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

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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



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

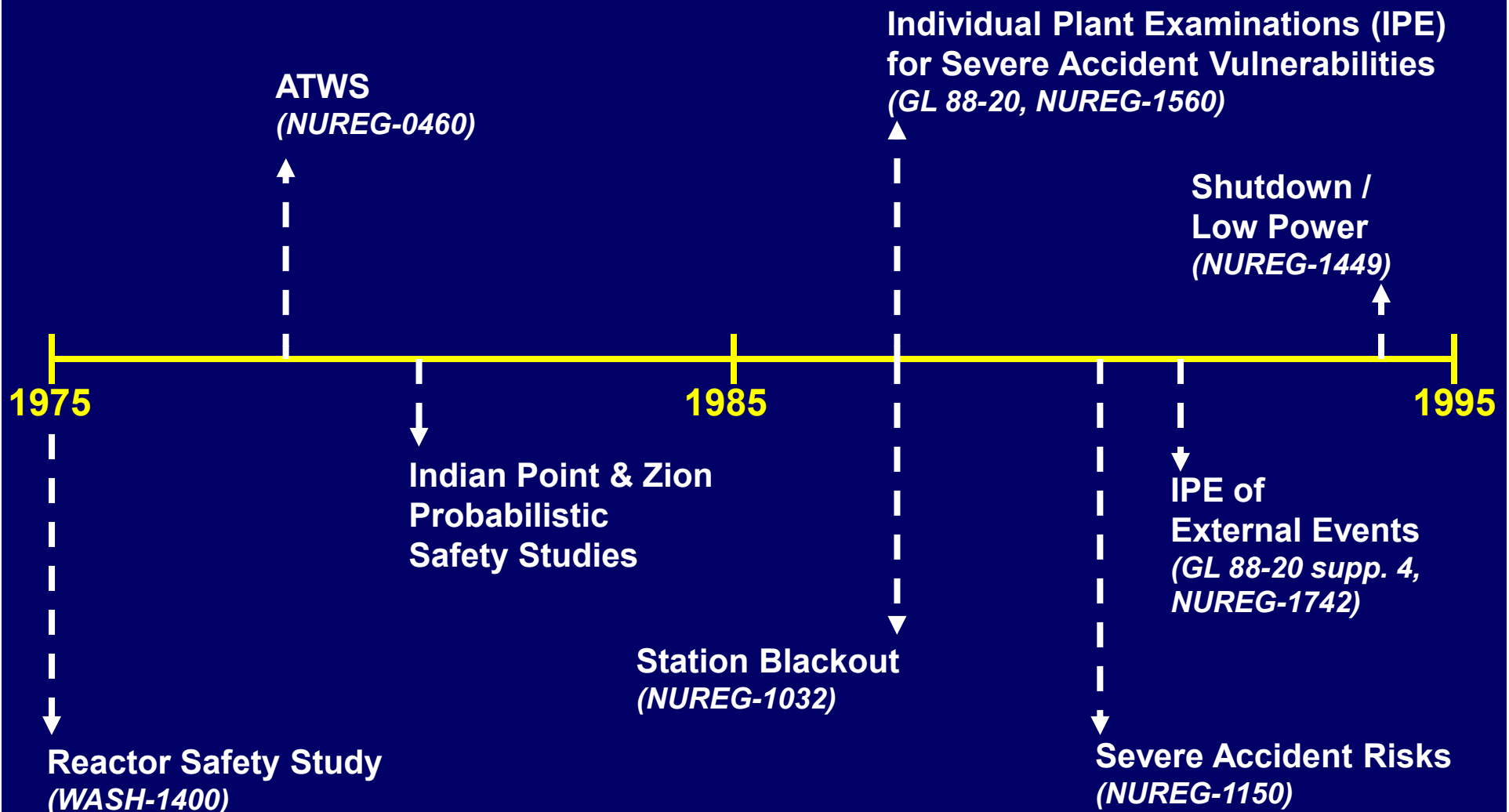
How is risk addressed in the regulatory framework?

- 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**

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

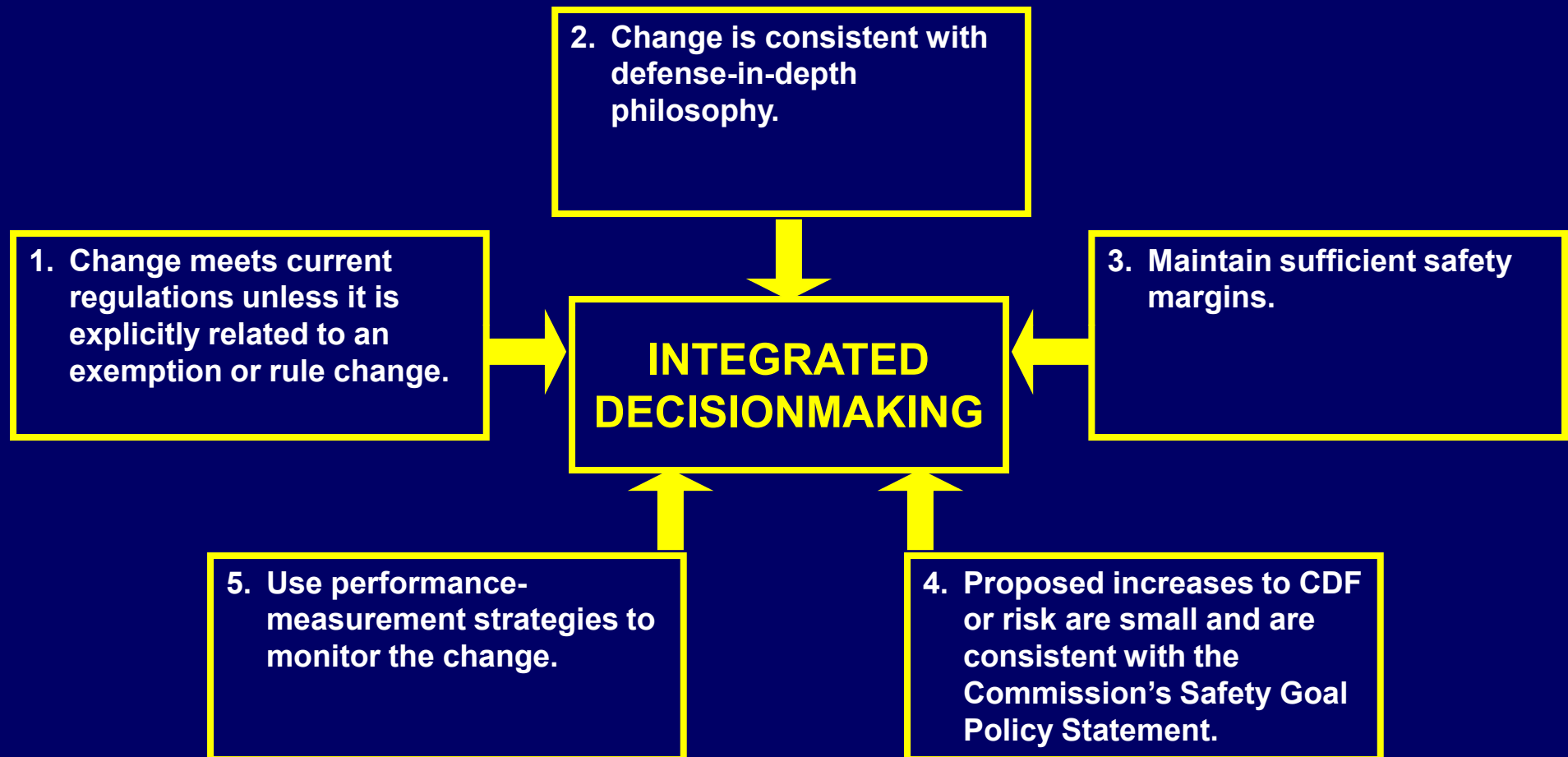
* 8/16/95

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?*



* **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-based?

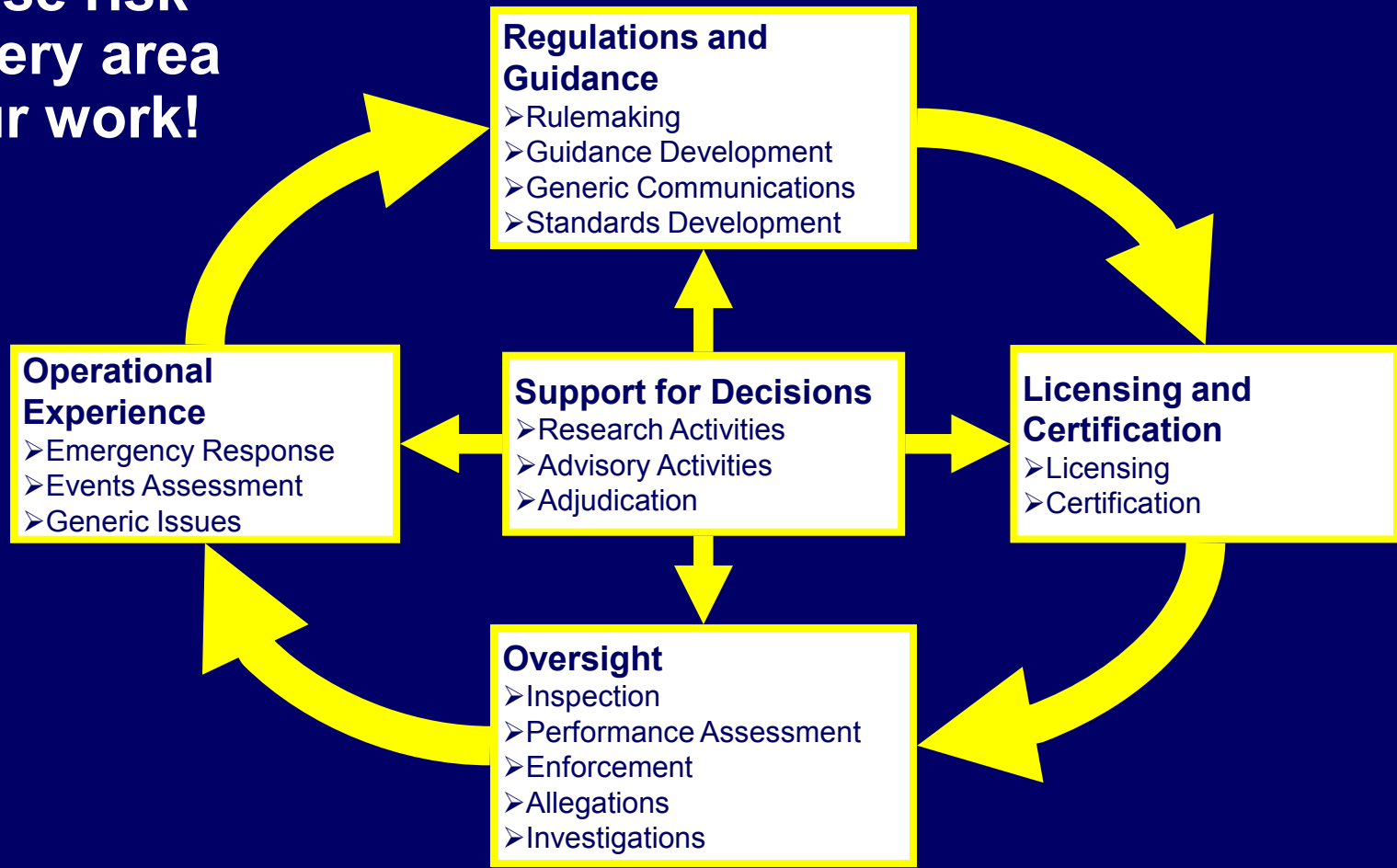
- “Risk-based” would mean we decide using only the numerical results and insights of a risk assessment – if risk assessments are so helpful, why not?
 - We can't measure risk – we have to evaluate it using models
 - The models should address all contributors but do so with varying degrees of rigor and 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 models are incomplete, 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?

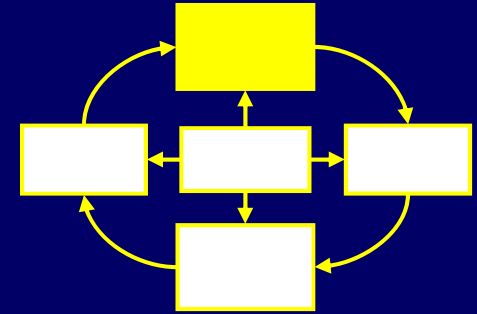


Where do we use risk-informed approaches?

- We use risk in every area of our work!

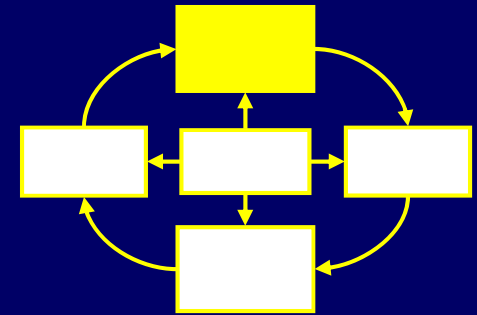


Regulations & Guidance

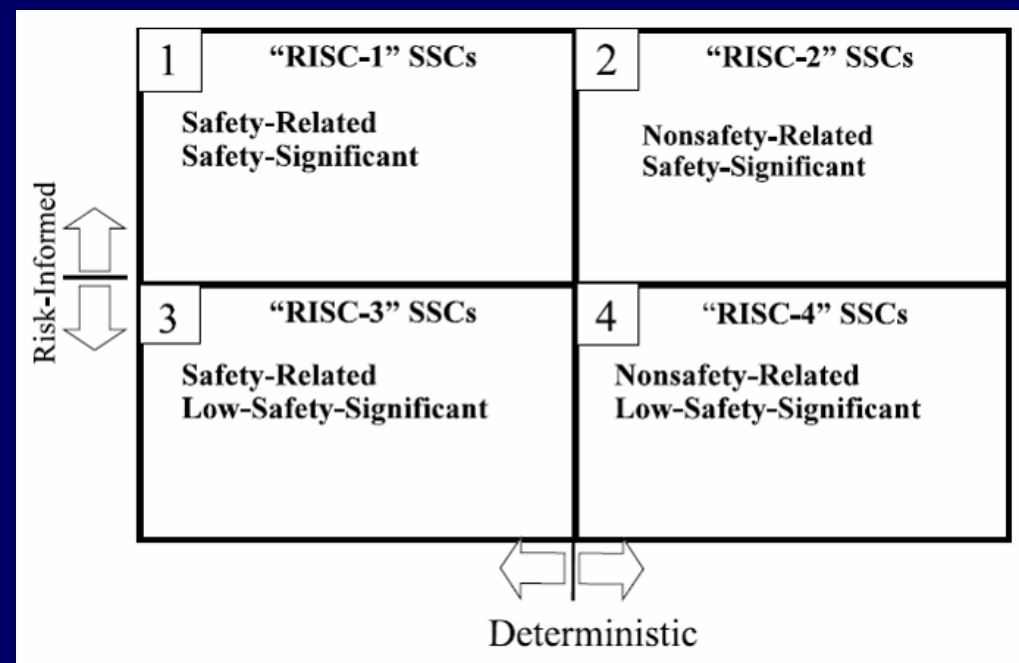


10 CFR	Subject	Year
50.44	Combustible Gas Control	2003
50.48(c)	Risk-Informed Fire Protection Requirements	2004
50.62	Anticipated Transient Without Scram	1984
50.63	Station Blackout	1988
50.65(a)(4)	Assessment of Maintenance Risk (Maintenance Rule)	1999
50.69	Risk-Informed Special Treatment Requirements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

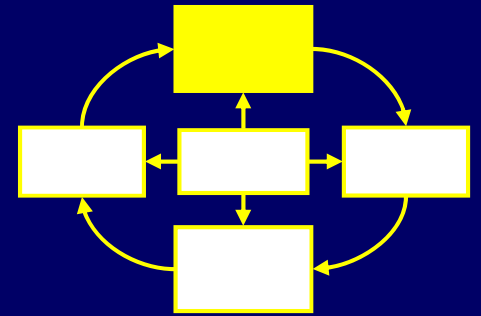
Regulations & Guidance



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



Regulations & Guidance



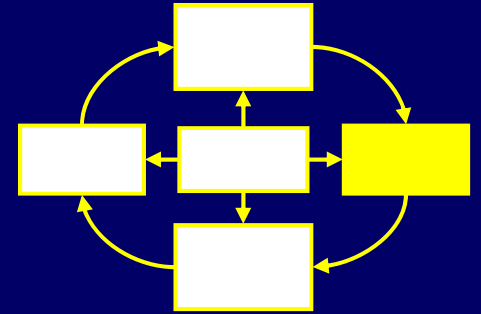
- **Example – new reactor design certification and combined licenses**
 - NRC reviews a description of the design-specific or plant-specific PRA and its results*
 - PRAs referencing a design certification must account for site information and design changes**
 - Combined license holders must maintain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

* 52.47(a)(27) and 52.79(a)(46)

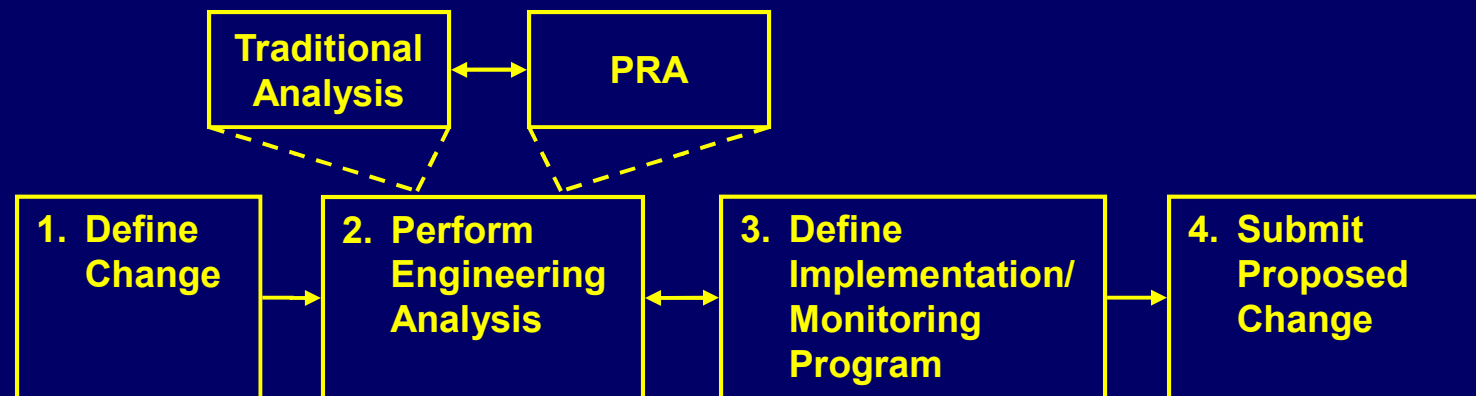
** 52.79(d)(1)

*** 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)

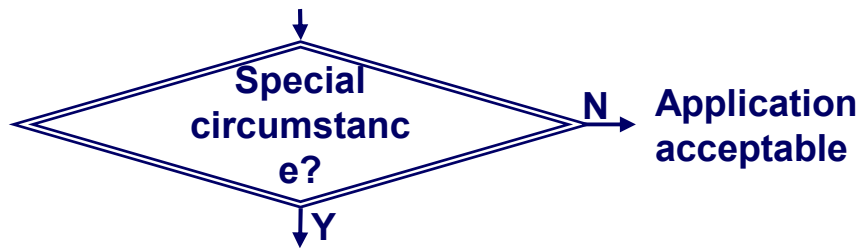


- NRC staff can **request risk information**** for non-risk-informed licensing actions in a **“special circumstance”**

* RG 1.174, 11/02

** SRP 19.2, App. D
29

Meets deterministic requirements



Inform licensee & management of risk concern



Request & review risk information



Assess in depth (adequate protection question)

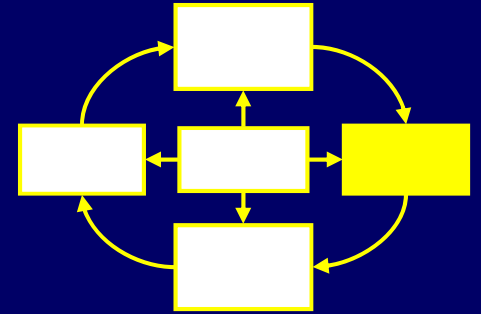


Reject application on the basis of adequate protection

“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**.

Licensing & Certification

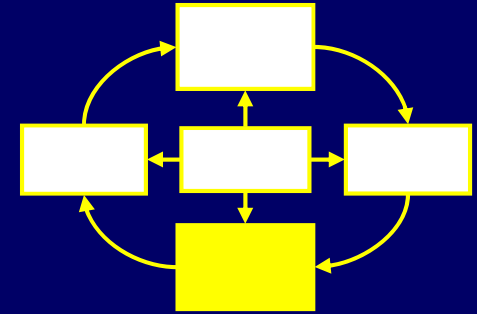


- **Regulatory treatment of non-safety systems (RTNSS)**

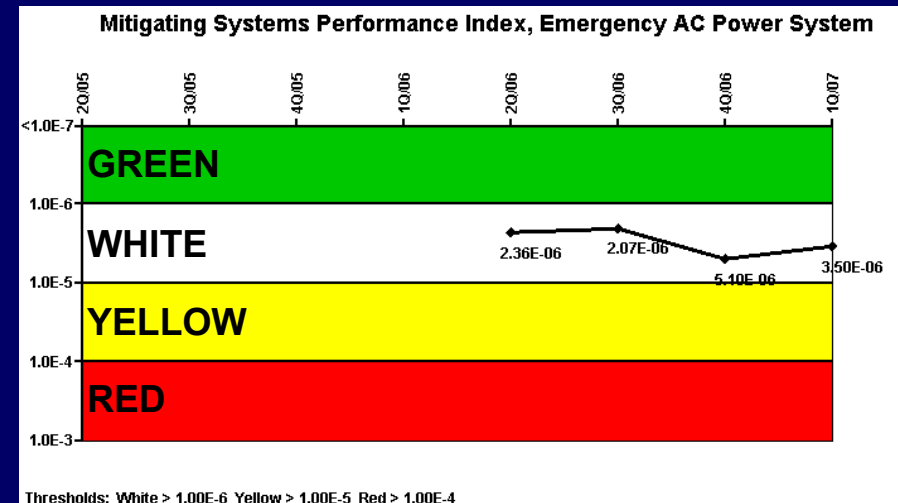
- Used in review of new reactor designs
- Applies to non-safety-related systems, structures, and components needed to:
 - Meet NRC performance requirements (ATWS, station blackout)
 - Ensure safety 72+ hours after an accident or after an earthquake
 - Meet CDF and LRF guidelines at power and during shutdown
 - 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



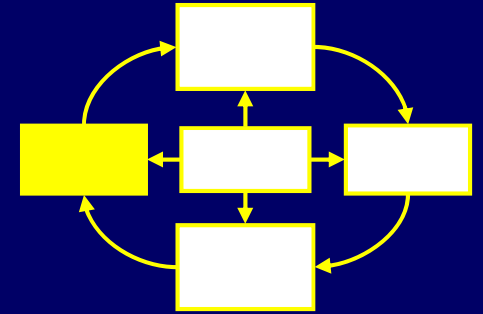
- **Notice of Enforcement Discretion (NOED)***
 - Non-compliance with a technical specification or license condition
 - Risk argument for avoiding unnecessary plant transient, inappropriate test/inspection, or unjustified delay in startup
- **Reactor Oversight Process**
 - Risk-informed performance indicators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



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?

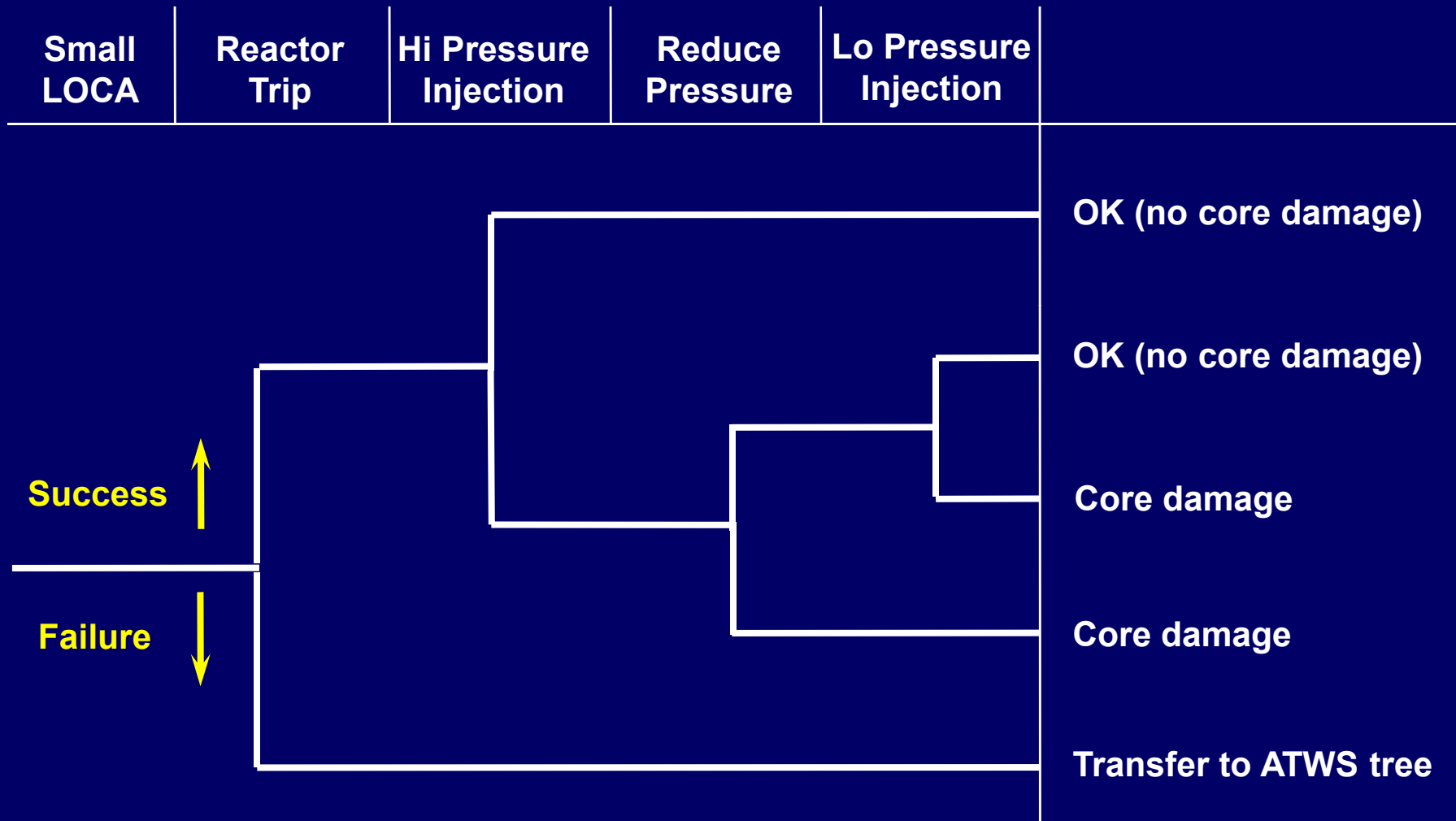
- PRA models use
 - Event trees to model the sequence of events from an initiating event to an end state
 - Fault trees to model failure of mitigating functions, including equipment dependencies to function as required
 - Frequency and probability estimates for model elements (e.g., initiating events,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

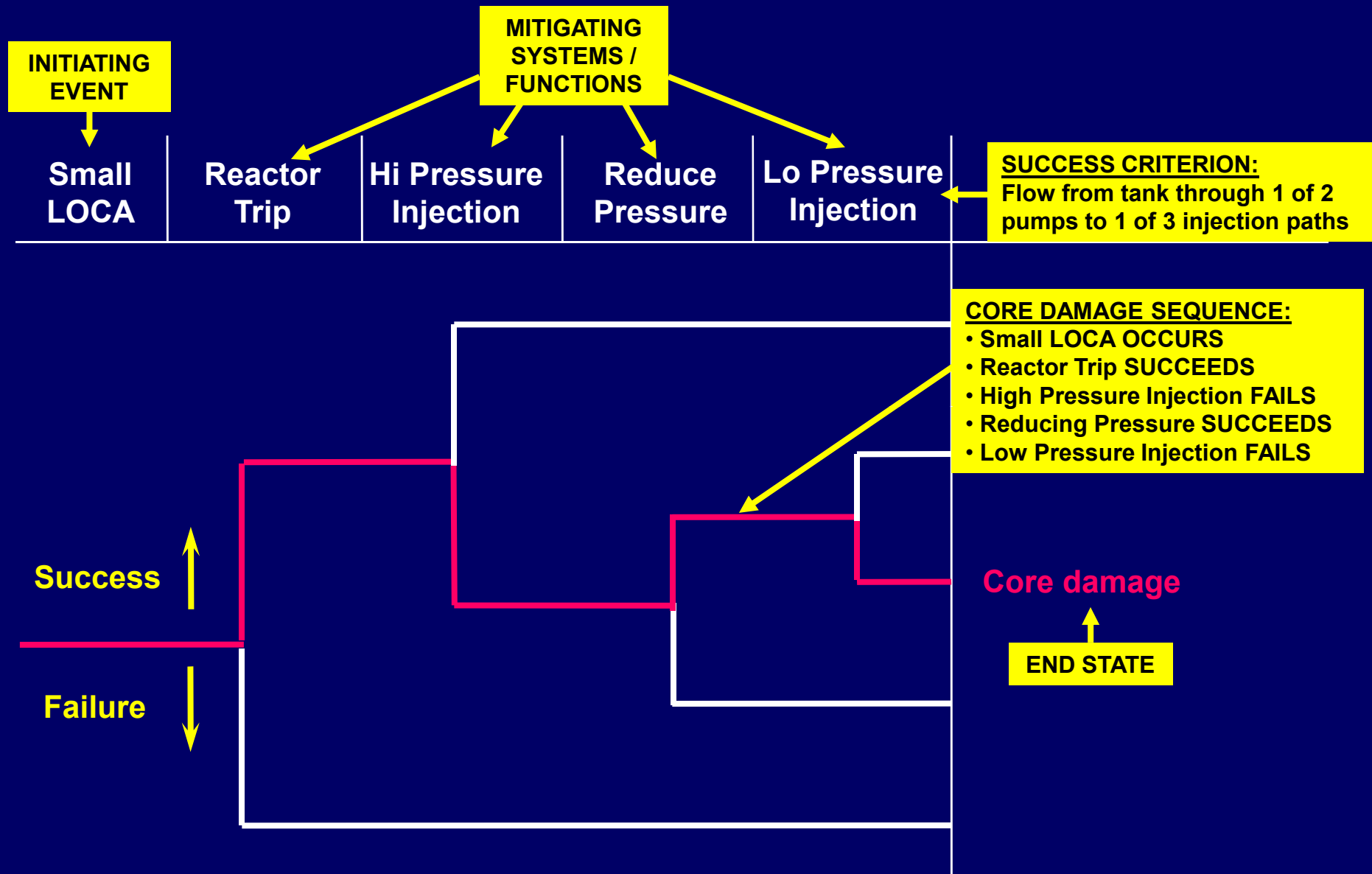
- **Core damage occurs when**
 - **Safety functions** are not met
 - Such as removal of decay heat, control of reactivity, or control of inventory
 - Engineering models show that core parameters exceed certain pre-determined limits
- **Large early release occurs when**
 - Core damage with **containment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



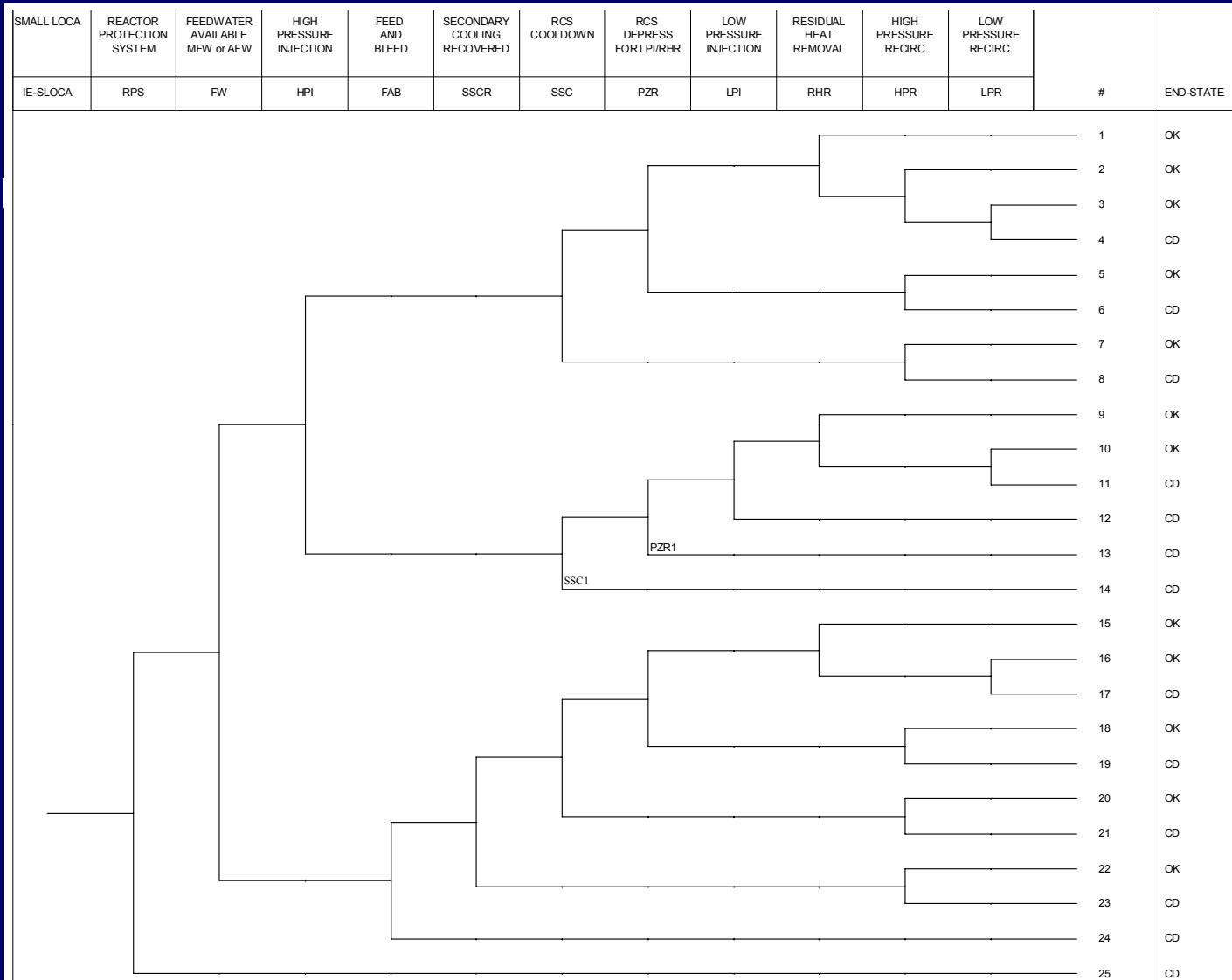
What is an event tree?



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:

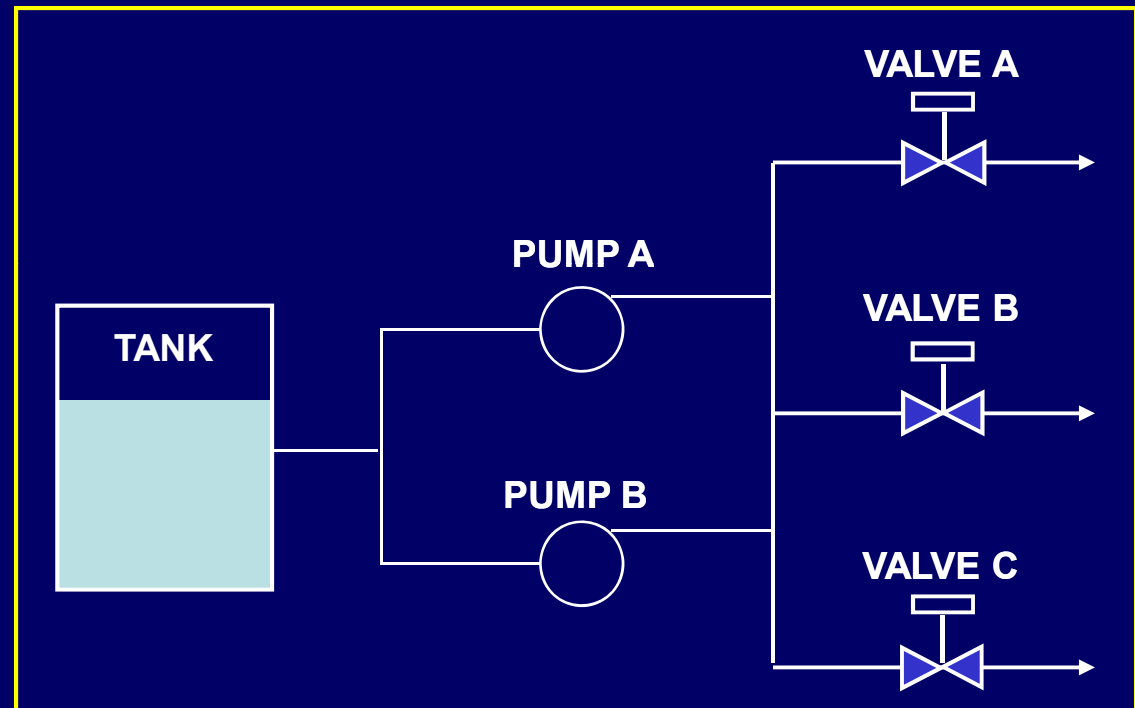
No flow from tank

OR

No flow from pumps

OR

No flow through injection paths

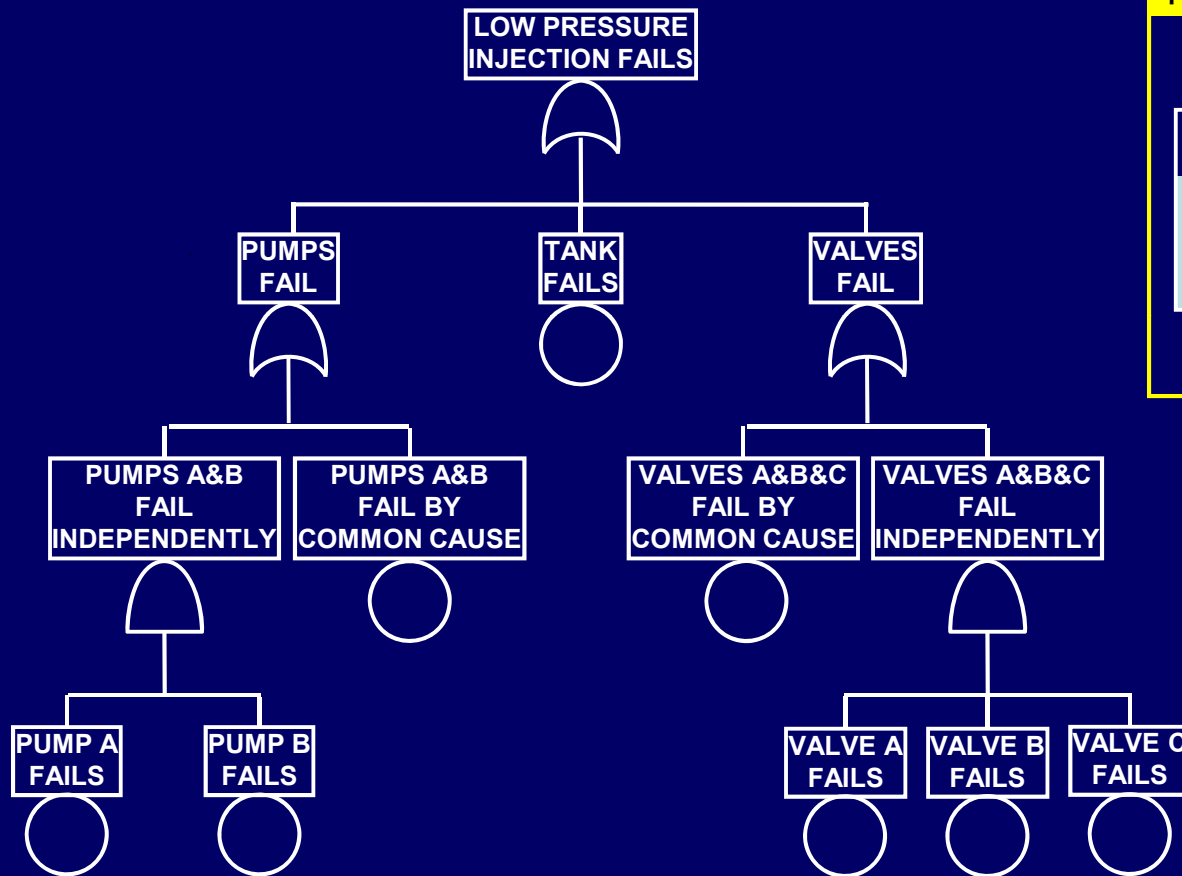


What is a fault tree?

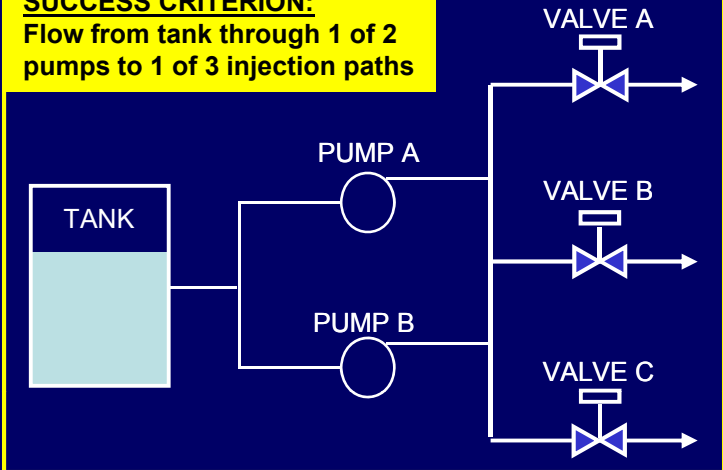
- **Developing fault trees**

- 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**

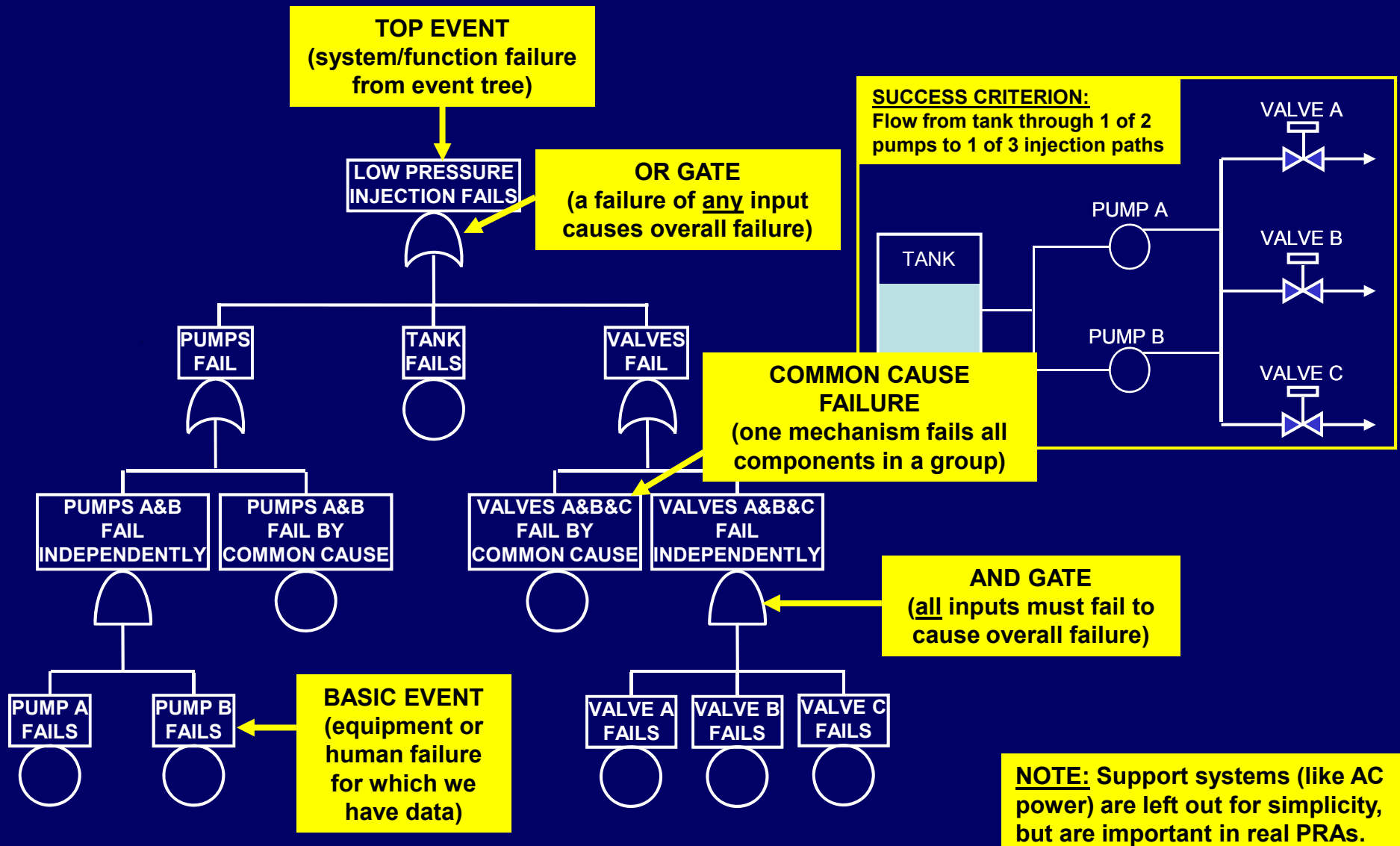
What is a fault tree?



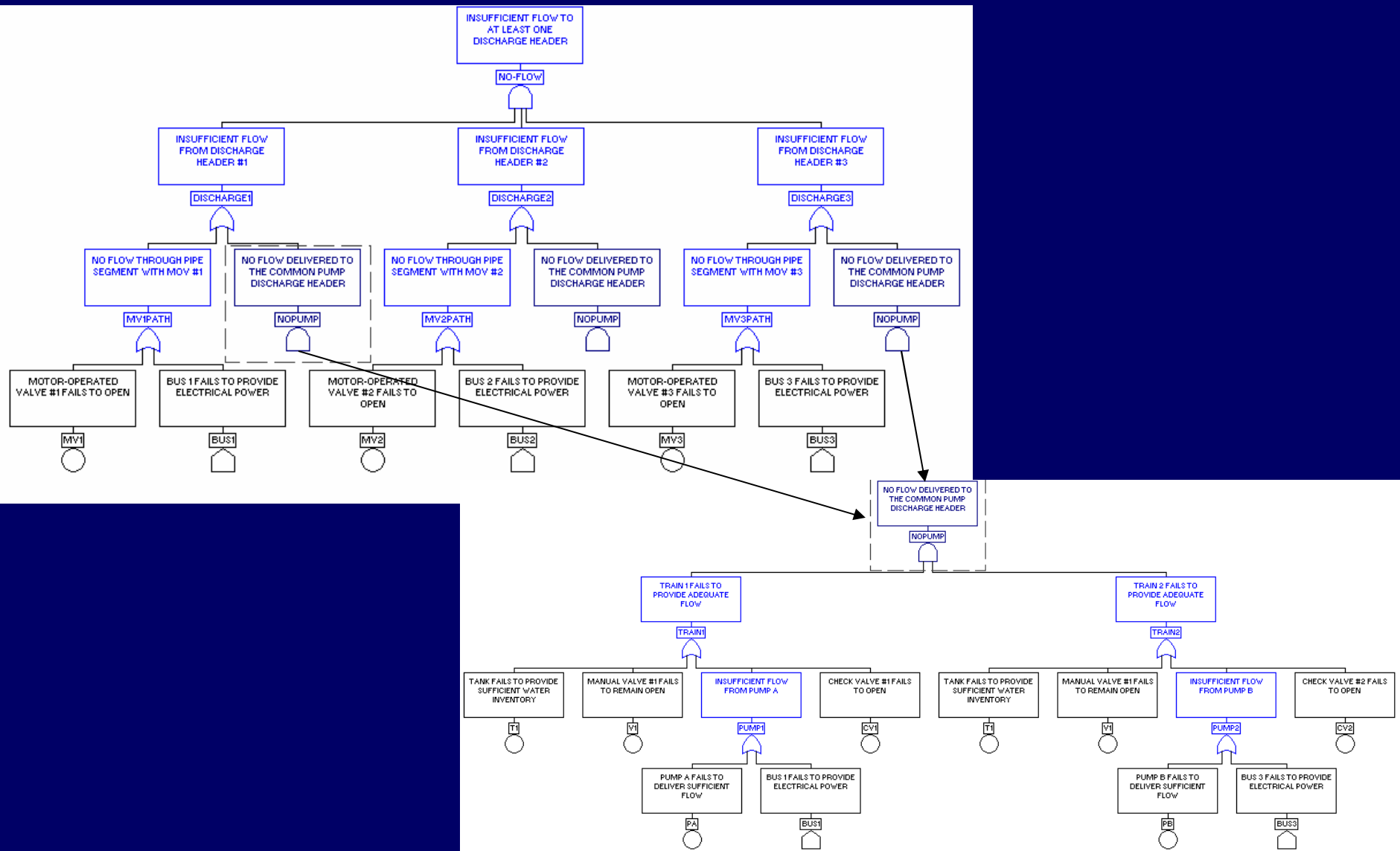
SUCCESS CRITERION:
Flow from tank through 1 of 2 pumps to 1 of 3 injection paths



What is a fault tree?

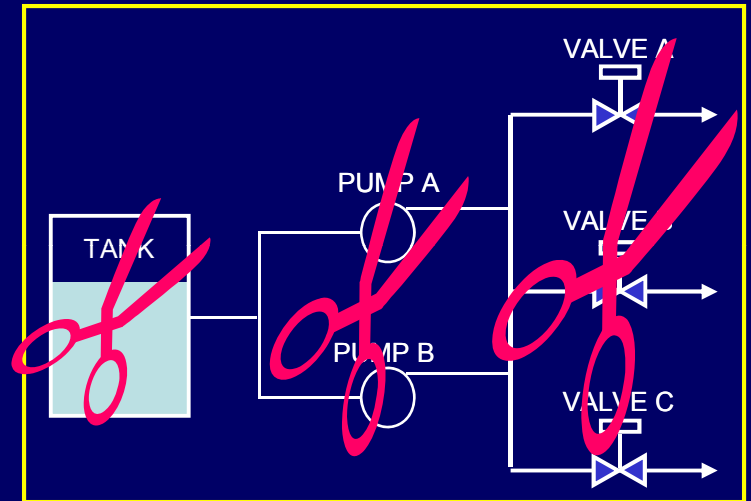


More Complex Fault Tree



How do we solve fault trees?

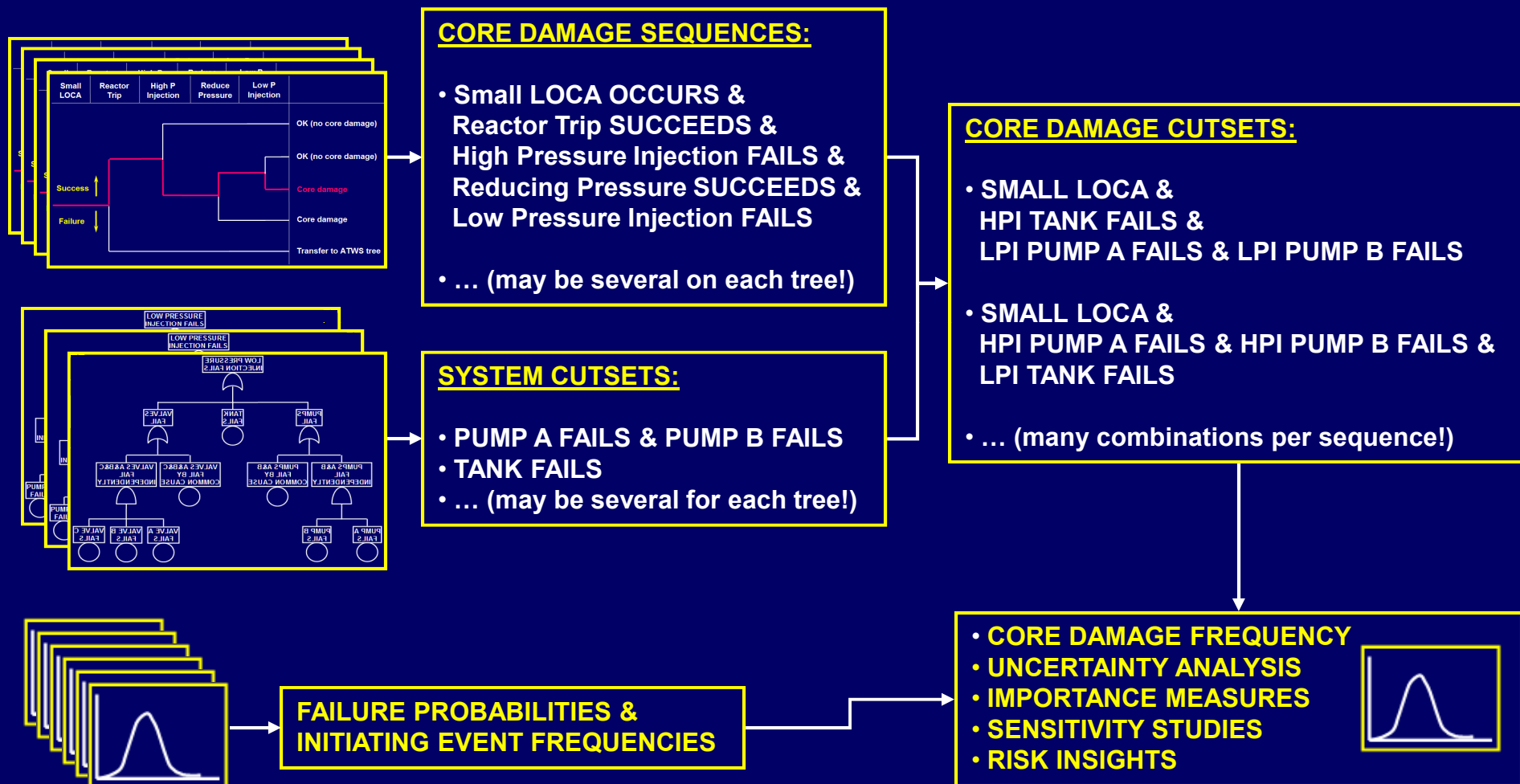
- Reducing the logic in a fault tree gives:
 - **Cutsets**, sets of failures that result in overall failure
 - PUMP A FAILS and PUMP B FAILS
 - Independently or by common cause
 - VALVE A FAILS and VALVE B FAILS and VALVE C FAILS
 - Independently or by common cause
 - TANK FAILS
 - **Probability that the function will fail**, 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?



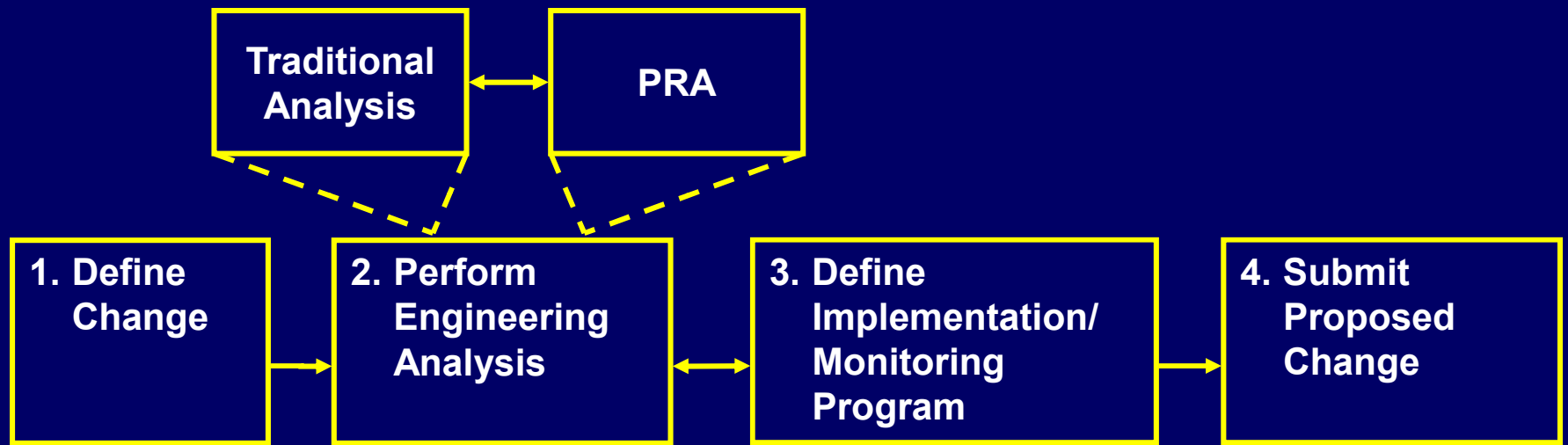
How do we use PRA in risk-informed regulation?



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?



From RG 1.174

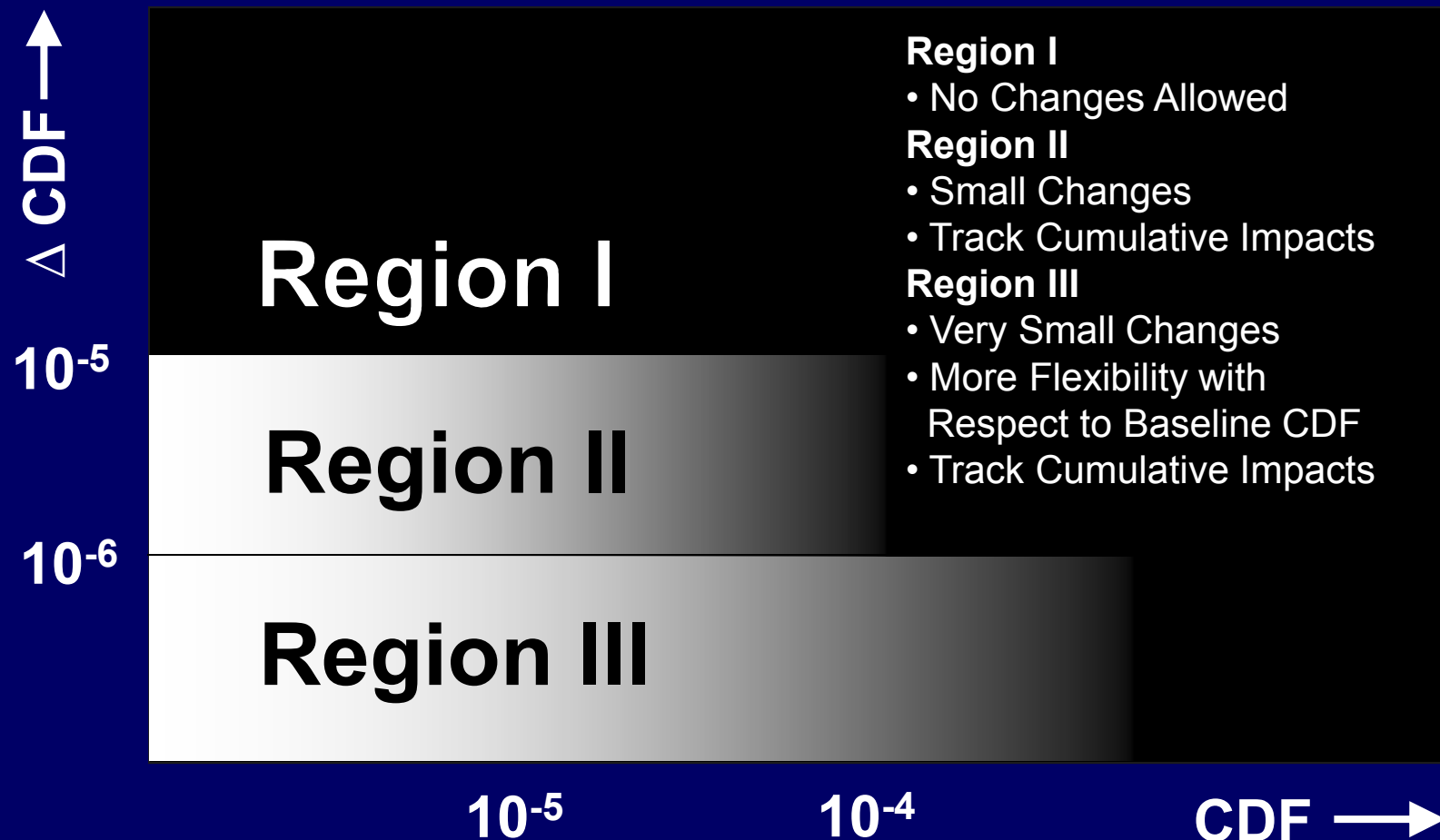


Figure 3. Acceptance Guidelines for Core Damage Frequency (CDF)

From RG 1.174

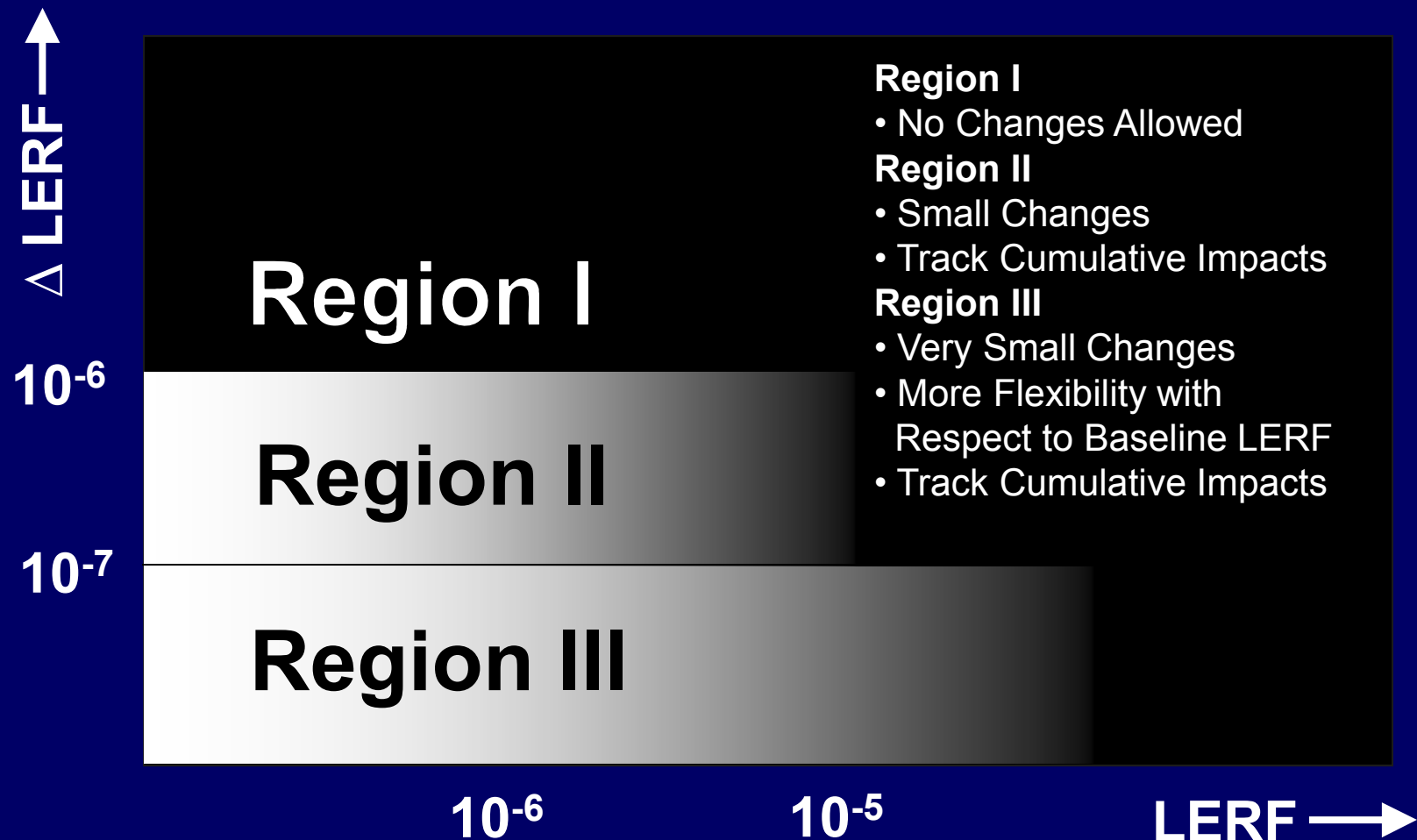


Figure 4. Acceptance Guidelines for Large Early Release Frequency (LERF)

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



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 widely-accepted good practices
- 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 NRC's vehicle for endorsing the consensus standards
 - Only the Level 1/LERF standard for internal initiating events at power 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 December 31, 2008

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 always be met
- Technical requirements must be met to the extent needed 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

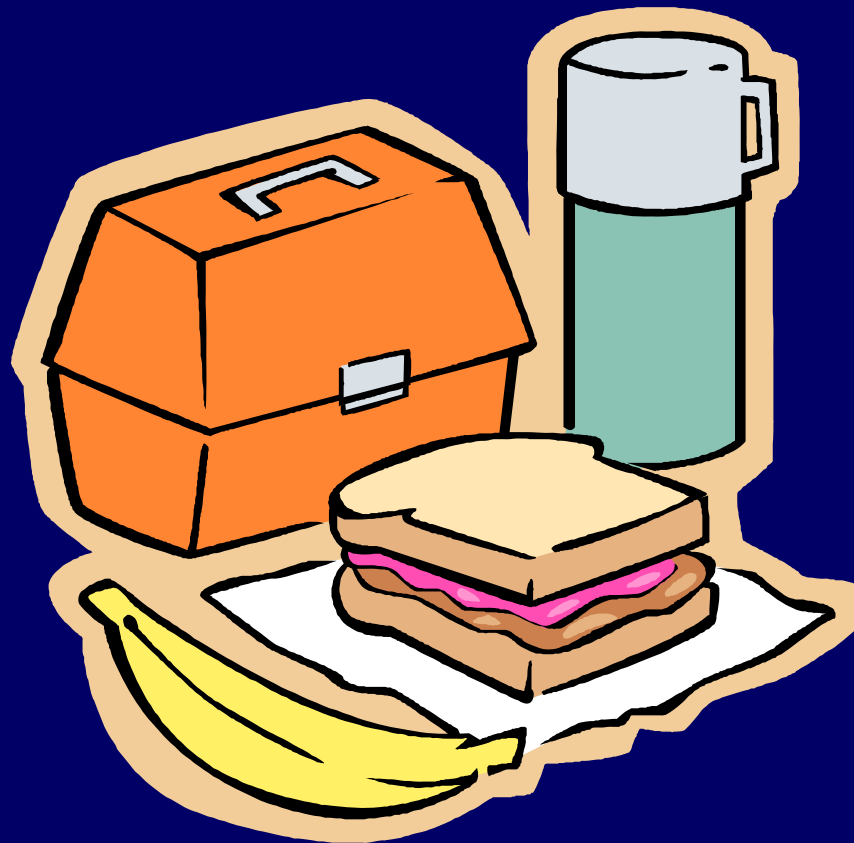
** SECY-04-0118, 7/13/04

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?

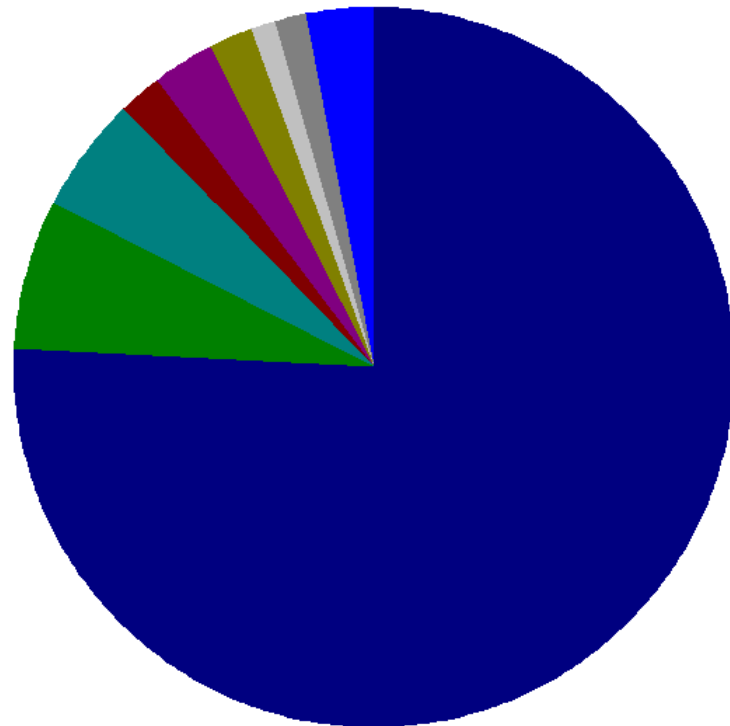


What can we learn from PRA results?

- 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*

Initiator Distribution, CDF = $1.81\text{E-}5$

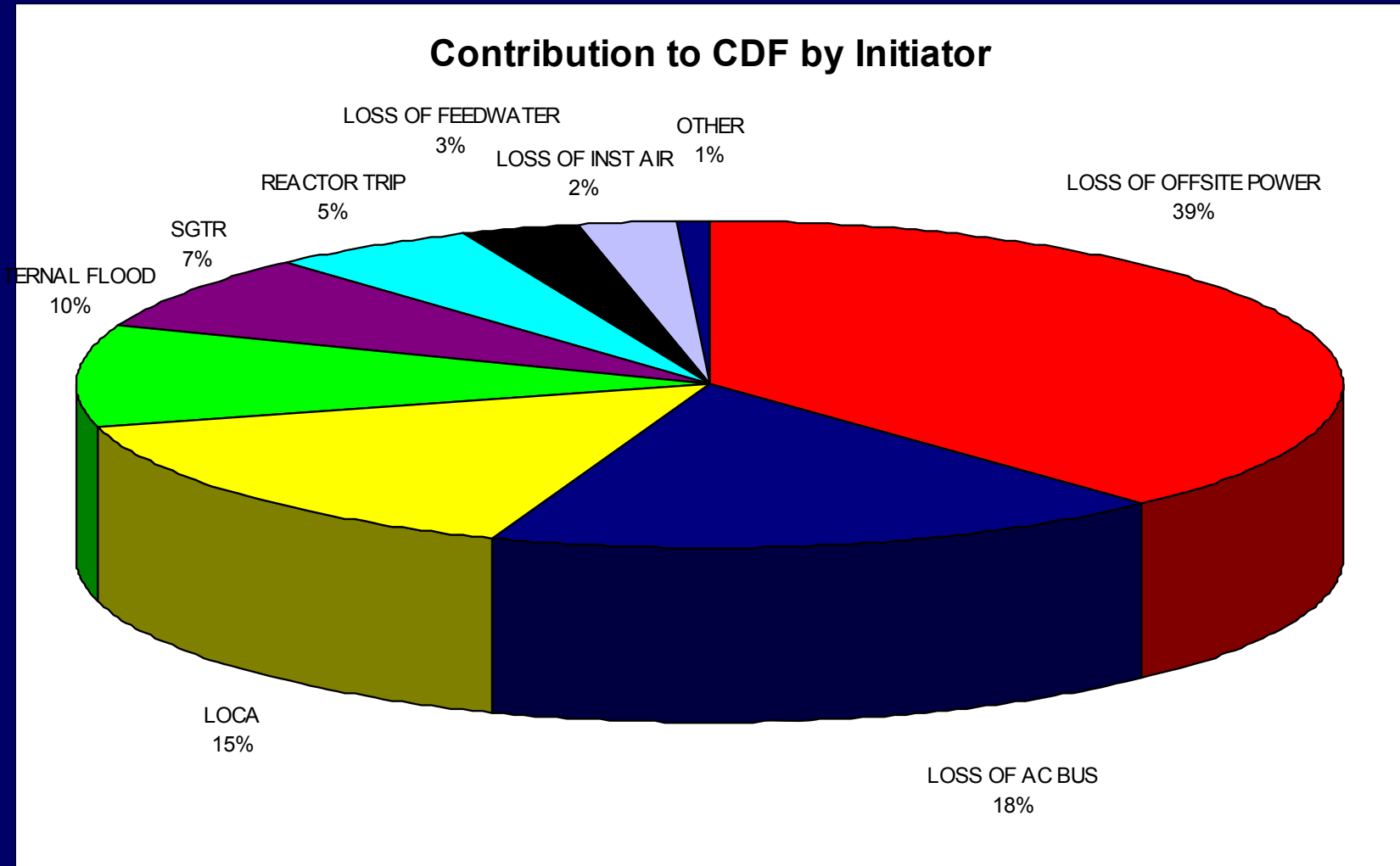


- IE-LOOP (75.9%)
- IE-LOSWWS (6.6%)
- IE-ISL-RHR (5.2%)
- IE-VSLOCA (2.0%)
- IE-SLBOC (2.8%)
- IE-TRANS (1.9%)
- IE-SLOCA (1.2%)
- IE-LODCB2 (1.2%)
- Other (3.2%)

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



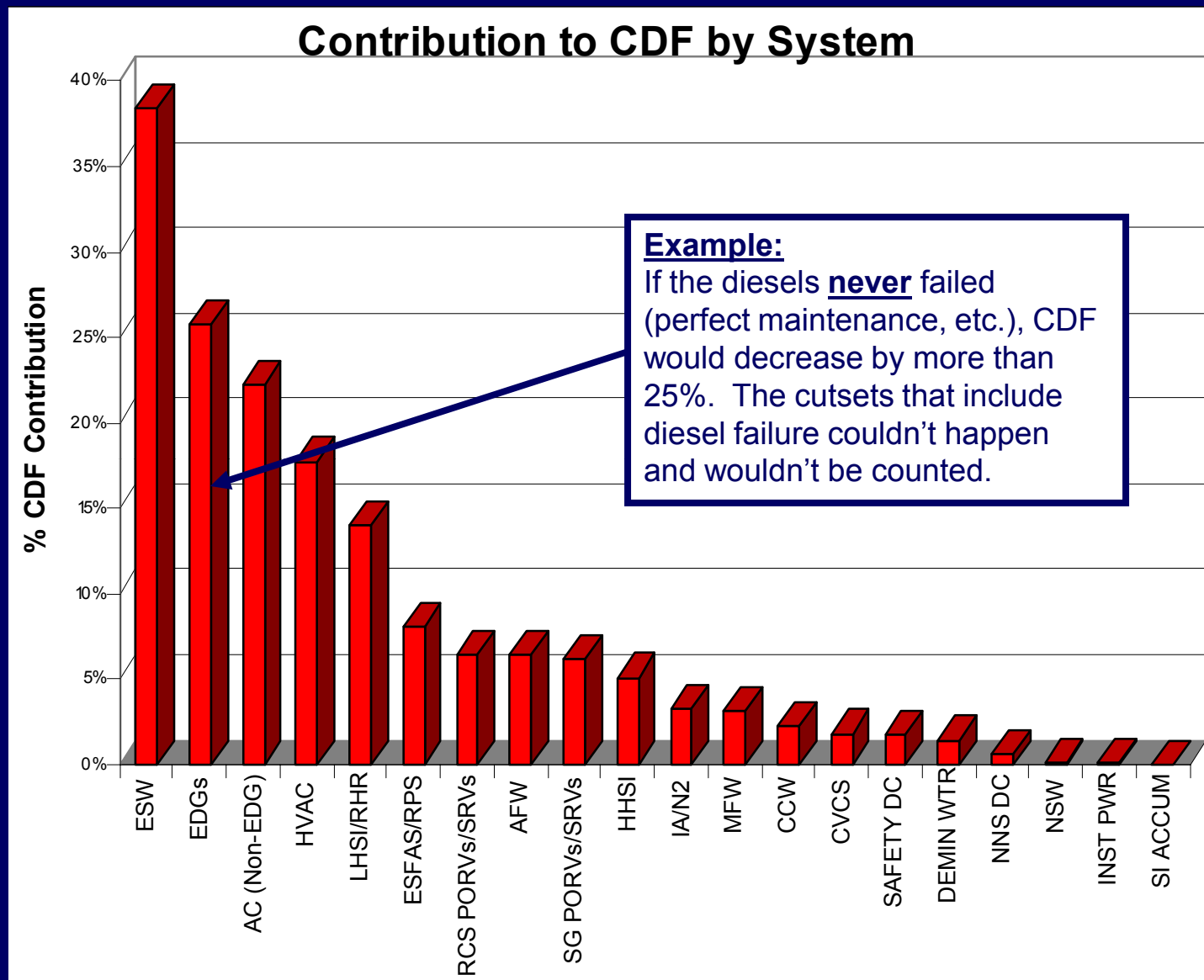
Importance Measures

- 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)

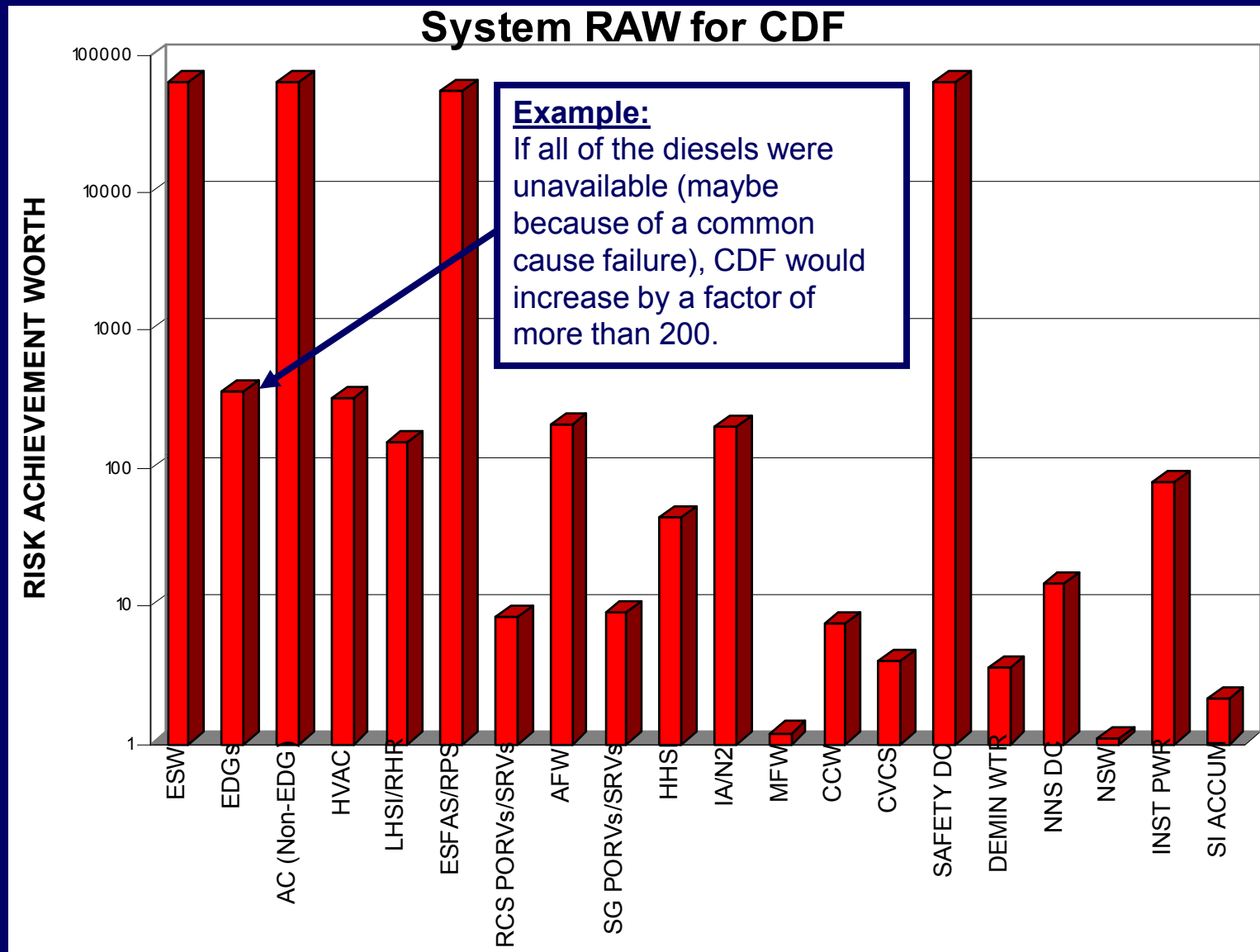
System Contribution to CDF (FV)



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)



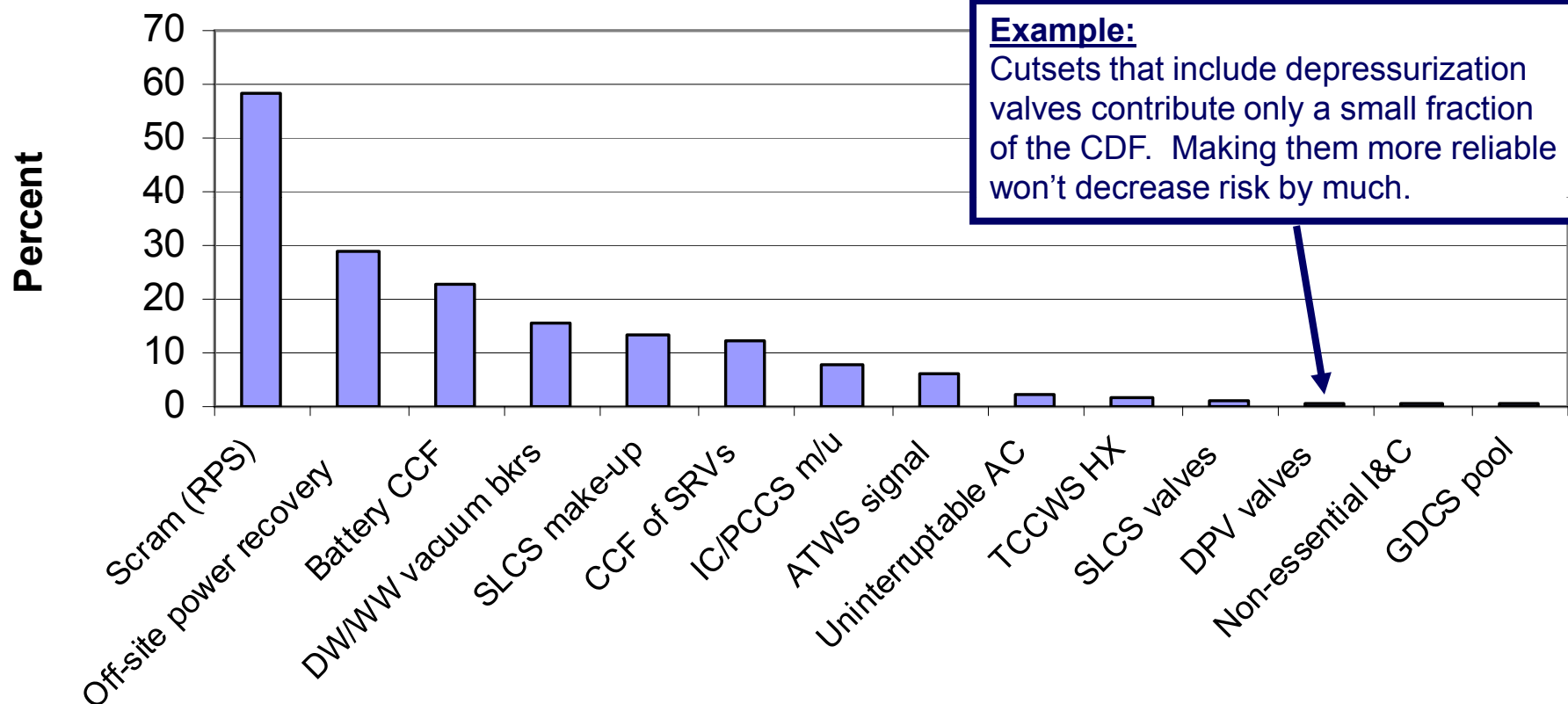
Importance Measures Example: ESBWR

- 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 GDCCS pool discharge line valves	0.44	149

System Contribution to CDF (Fussell-Vesely)

Contribution to Core Damage Frequency



System Importance to CDF (RAW)

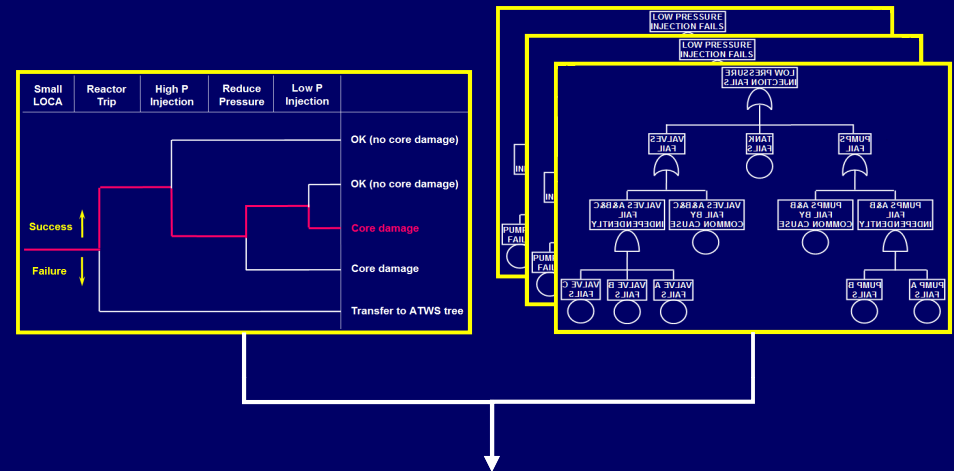


Plant Vulnerabilities

- 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

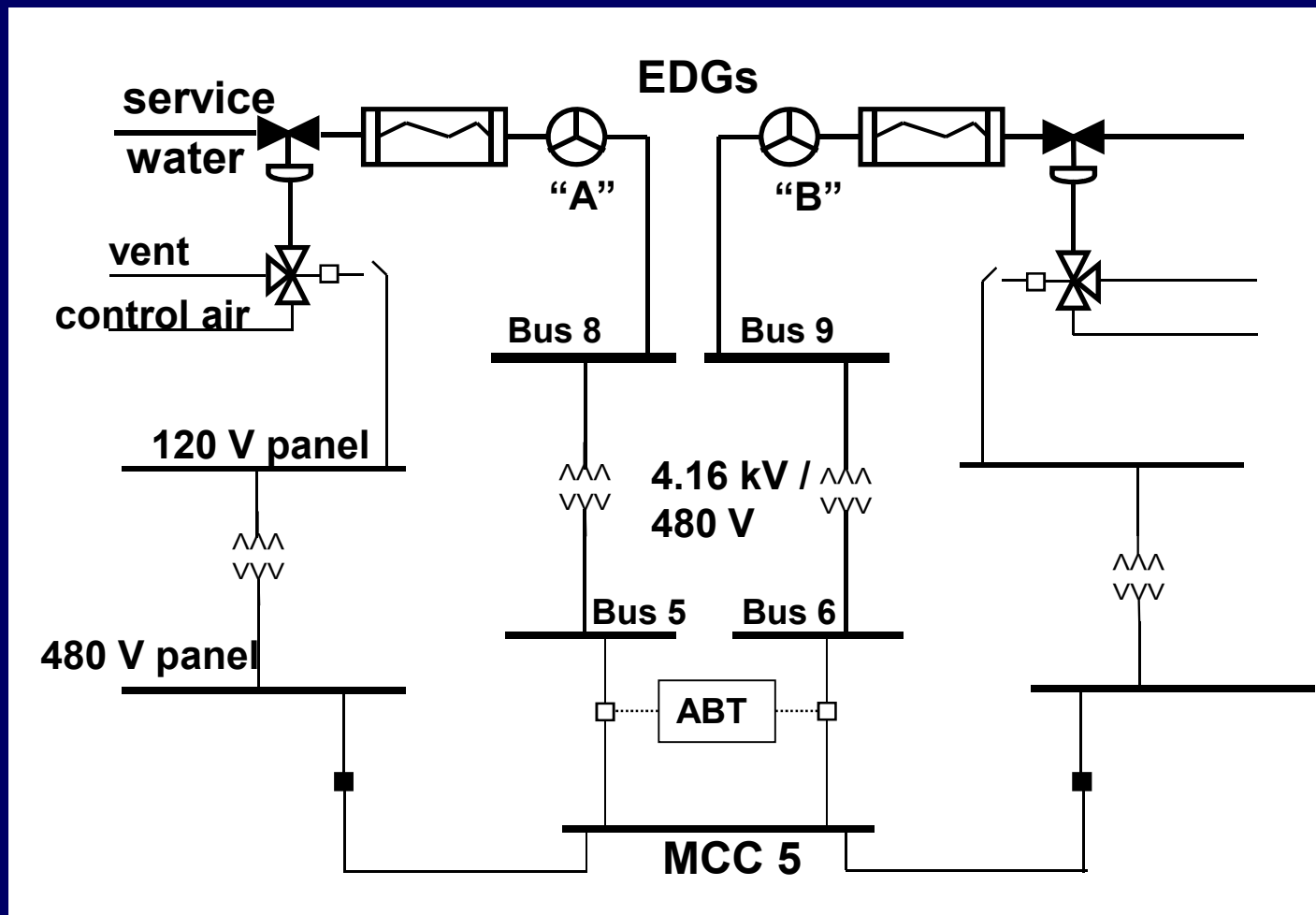
- Core damage cutsets (as opposed to system cutsets) are the **combinations of events** that result in core damage or large radioactive release
- A **measure of design robustness**, i.e., number of barriers to core damage or large release
- May indicate plant vulnerability or unexpected reliance on support system



CORE DAMAGE CUTSETS:

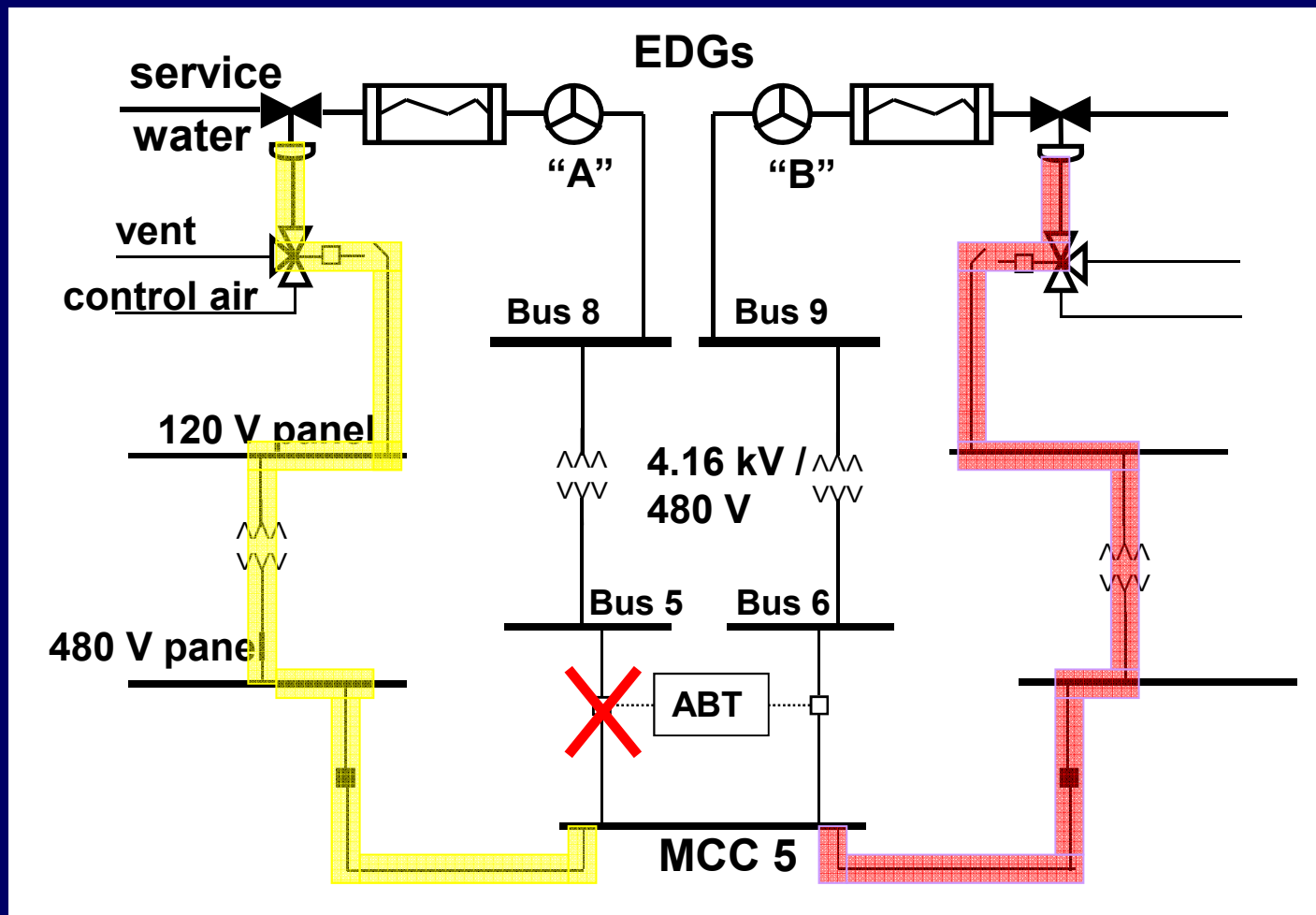
- SMALL LOCA & HPI TANK FAILS & LPI PUMP A FAILS & LPI PUMP B FAILS
- SMALL LOCA & HPI PUMP A FAILS & HPI PUMP B FAILS & LPI TANK FAILS
- ... (many combinations per sequence!)

1: Plant Vulnerability Discovered in 1980s PRA



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

1: Plant Vulnerability Discovered in 1980s PRA



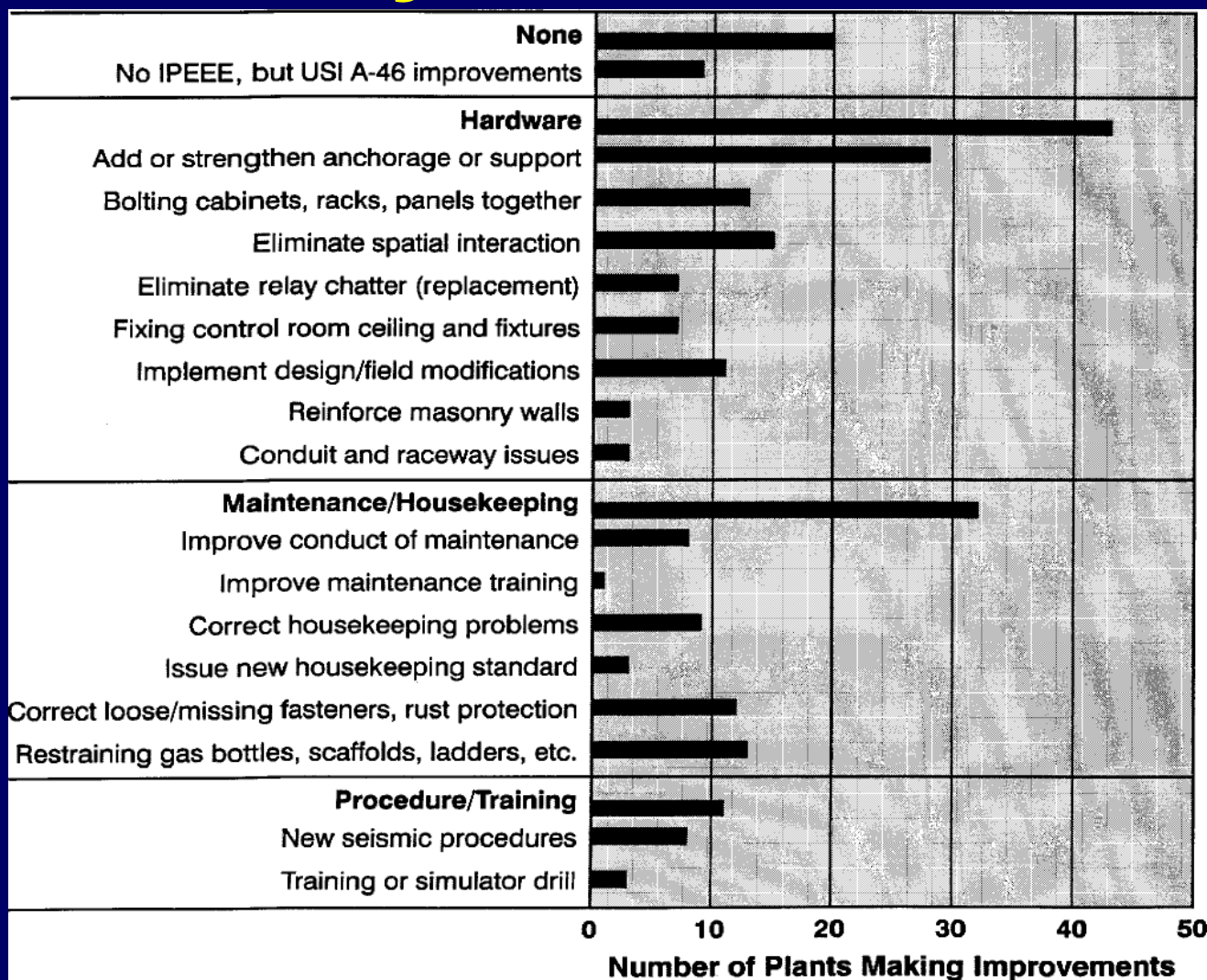
* LERs 50-213/85-029 and 94-004

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*

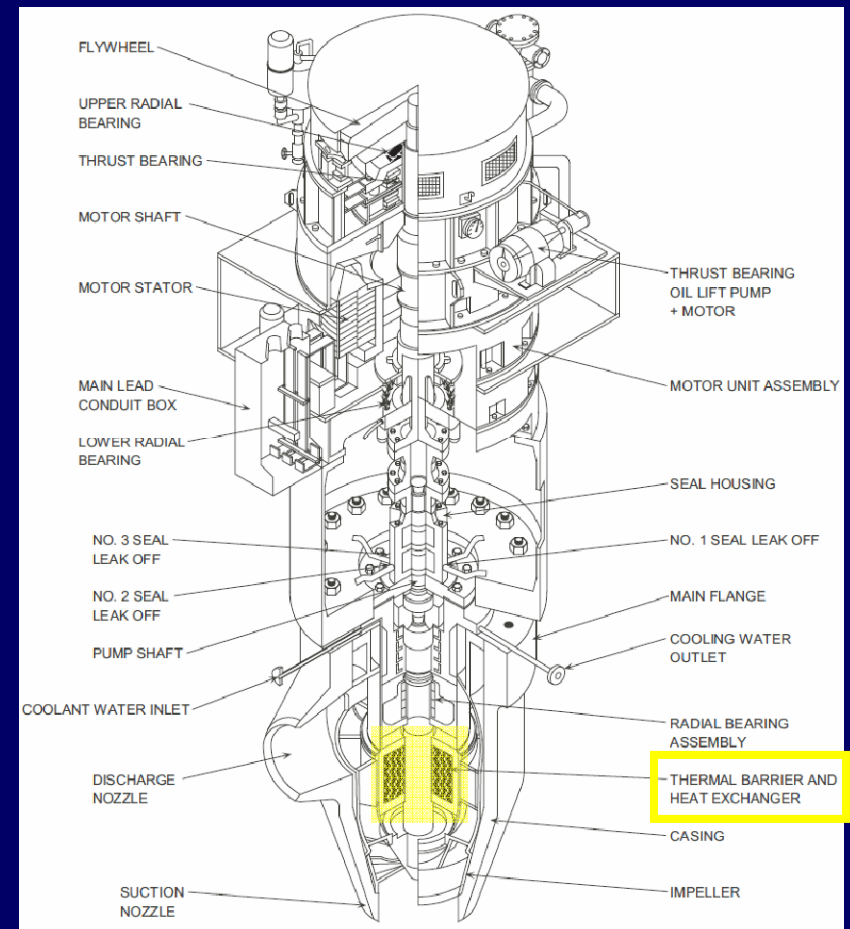


4: Improvements from IPEEE Fire Study*

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

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***



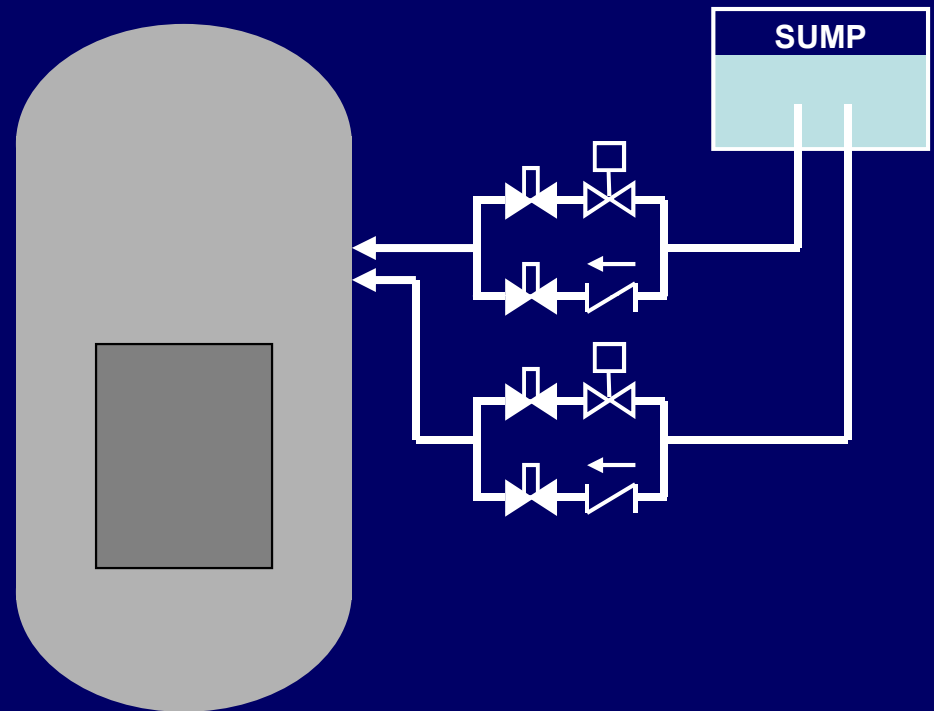
* NUREG-0933, Issue 105

** 50.72 Report, Event #15625

*** Info. Notice 89-54

6: AP1000 Design Improvements from PRA*

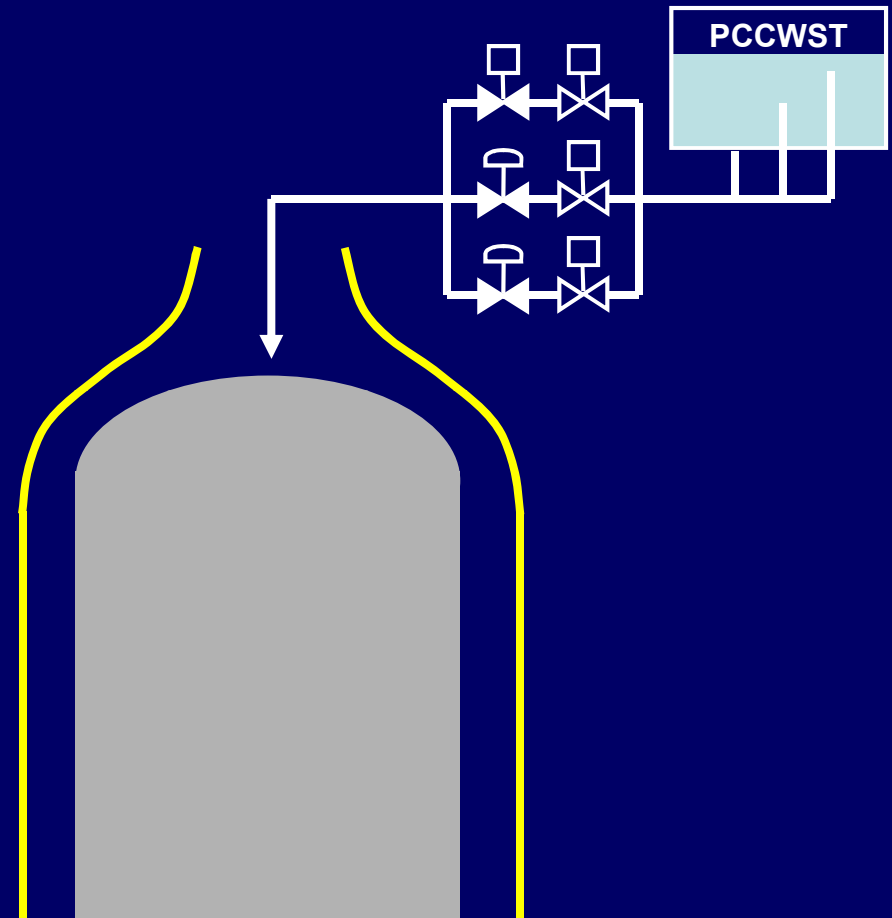
- **Recirculation – Sump to Direct Vessel Injection**
 - **Two** recirculation lines, **each** containing **2 parallel paths**:
 - Motor-operated valve and squib valve in series
 - Check valve and squib valve in series
 - **Diverse squib valves** to resist common-cause failure
 - Motor operated valve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



* *ML053460410, Section 19.1.6.2*

6: AP1000 Design Improvements from PRA*

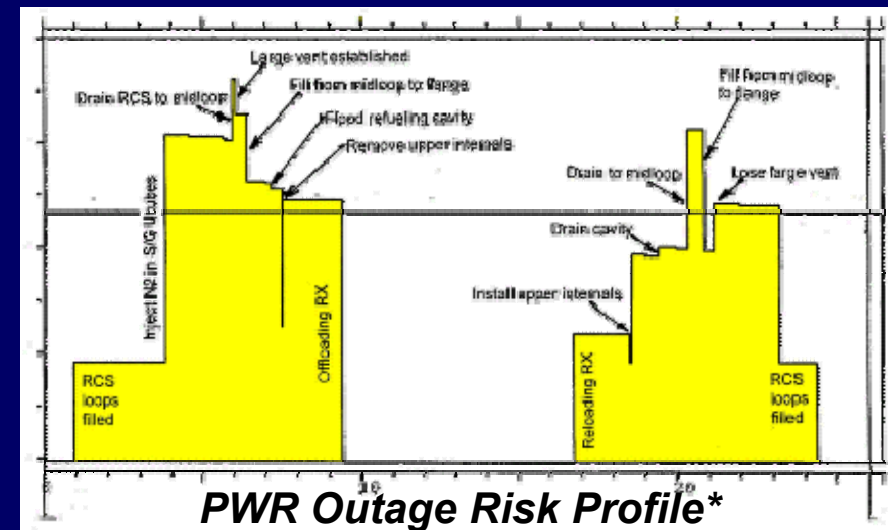
- **Containment Cooling**
 - **Three** parallel supply lines from passive containment cooling water storage tank to containment shell
 - **Diverse actuation** with motor-operated valves in one path



* *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”



* 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



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?***



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



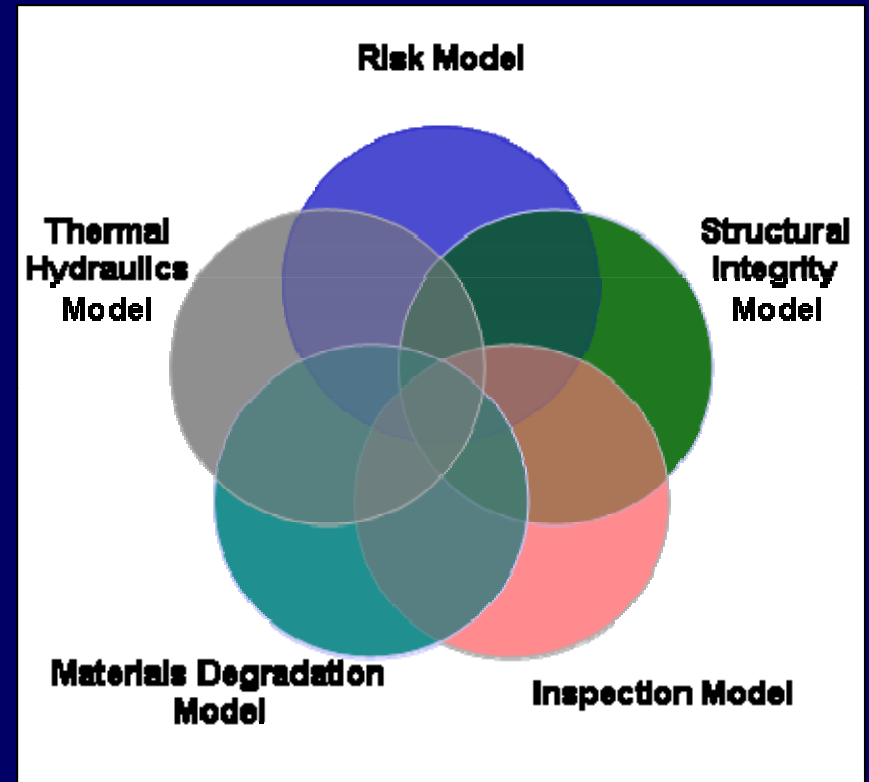
Good Decisions Require Good Input

- **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)

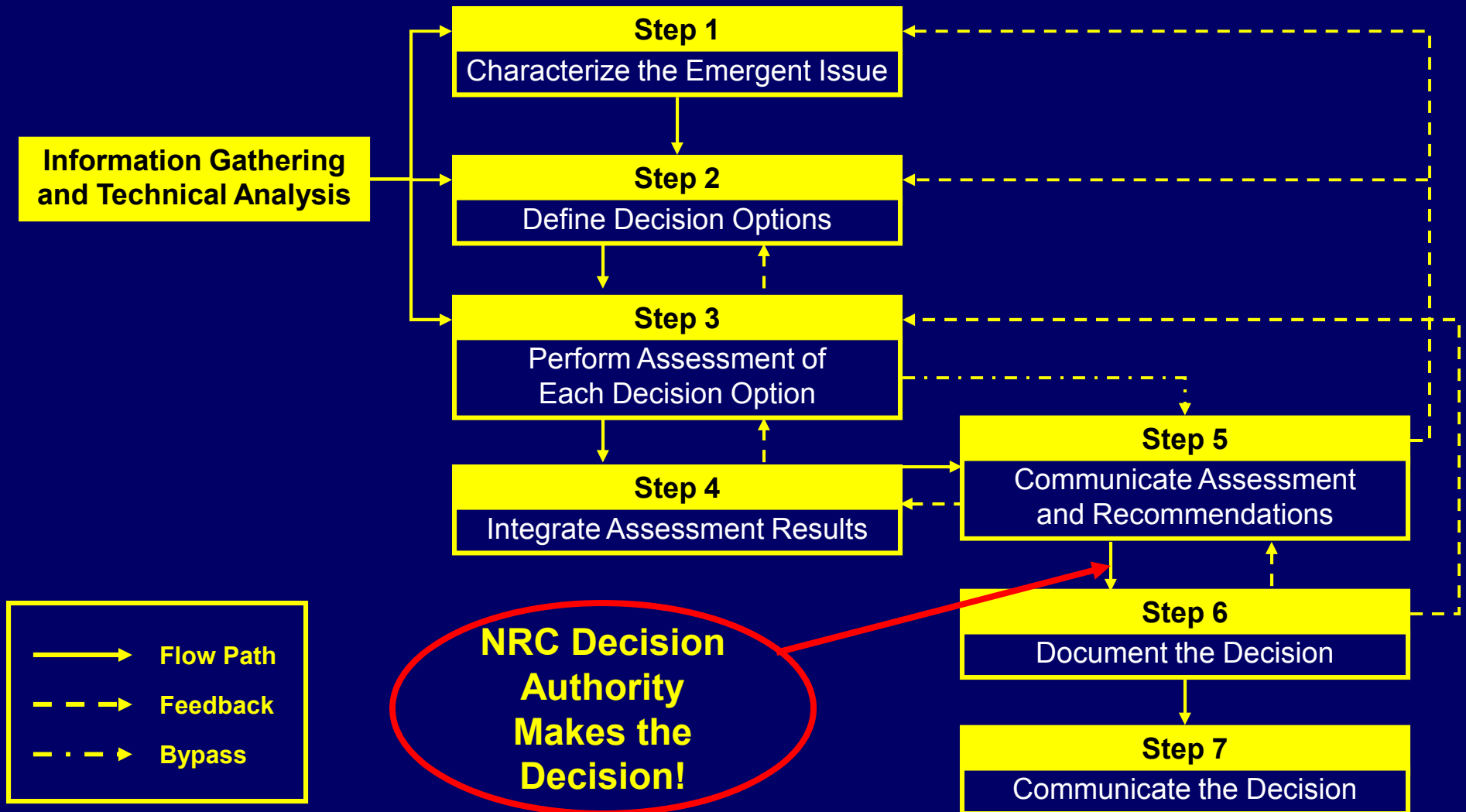
Note: Resources to invoke LIC-504 could be significant!

LIC-504 Process

Technical Activities

Risk-Informed Activities

Communication Activities



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



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 external stakeholders about topics that cause concern about health, safety, security or the environment
- Communicating amongst ourselves 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

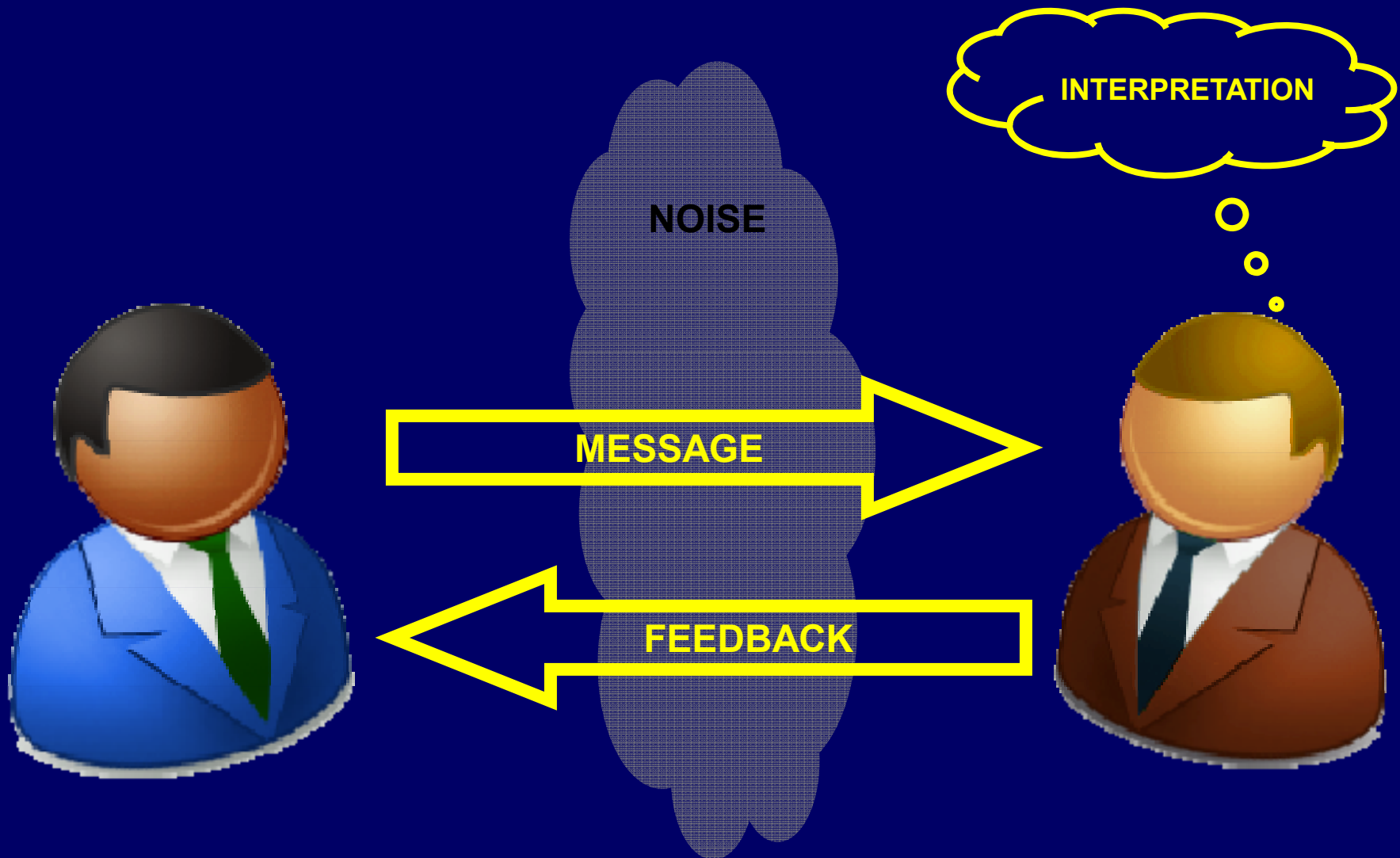
3: Building Trust & Credibility Internally

- **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

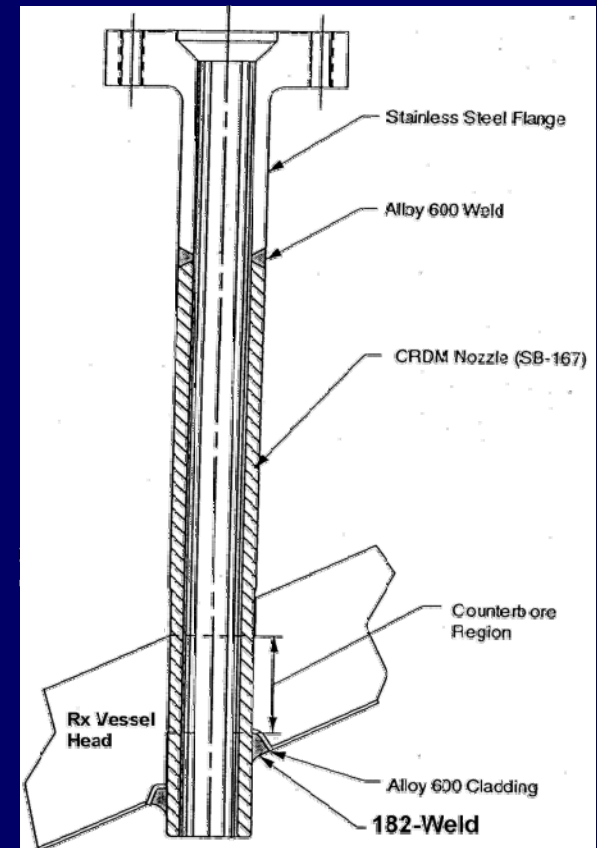
- We'll address this step with a final exercise related to the LIC-504 process of developing and communicating options
 - Discuss the scenario as a class
 - Get into 4 groups
 - Each group will organize information related to one of the options
 - Work for 30 minutes on this task
 - Appoint a leader 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



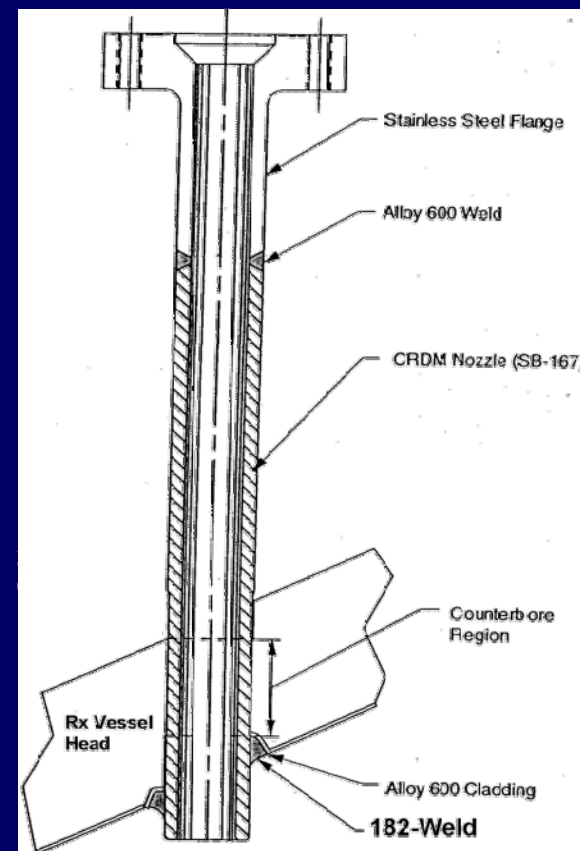
Background

- 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



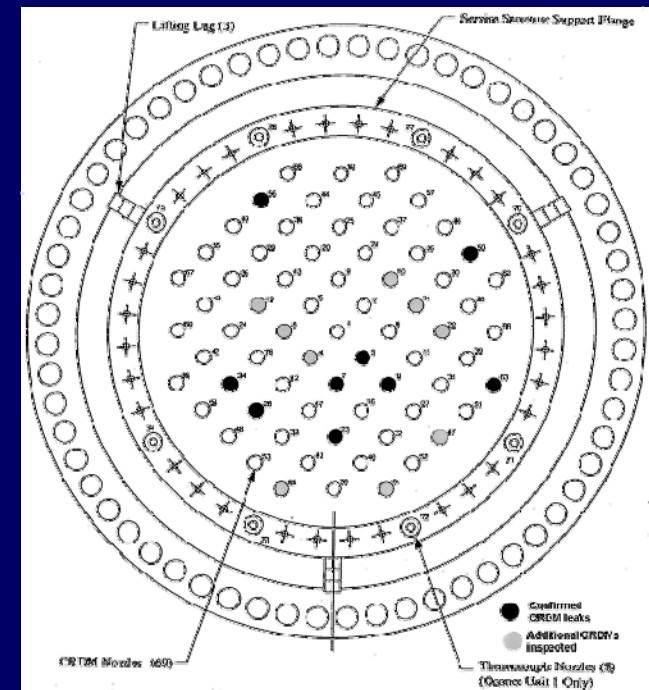
NRC Issues

- **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°**



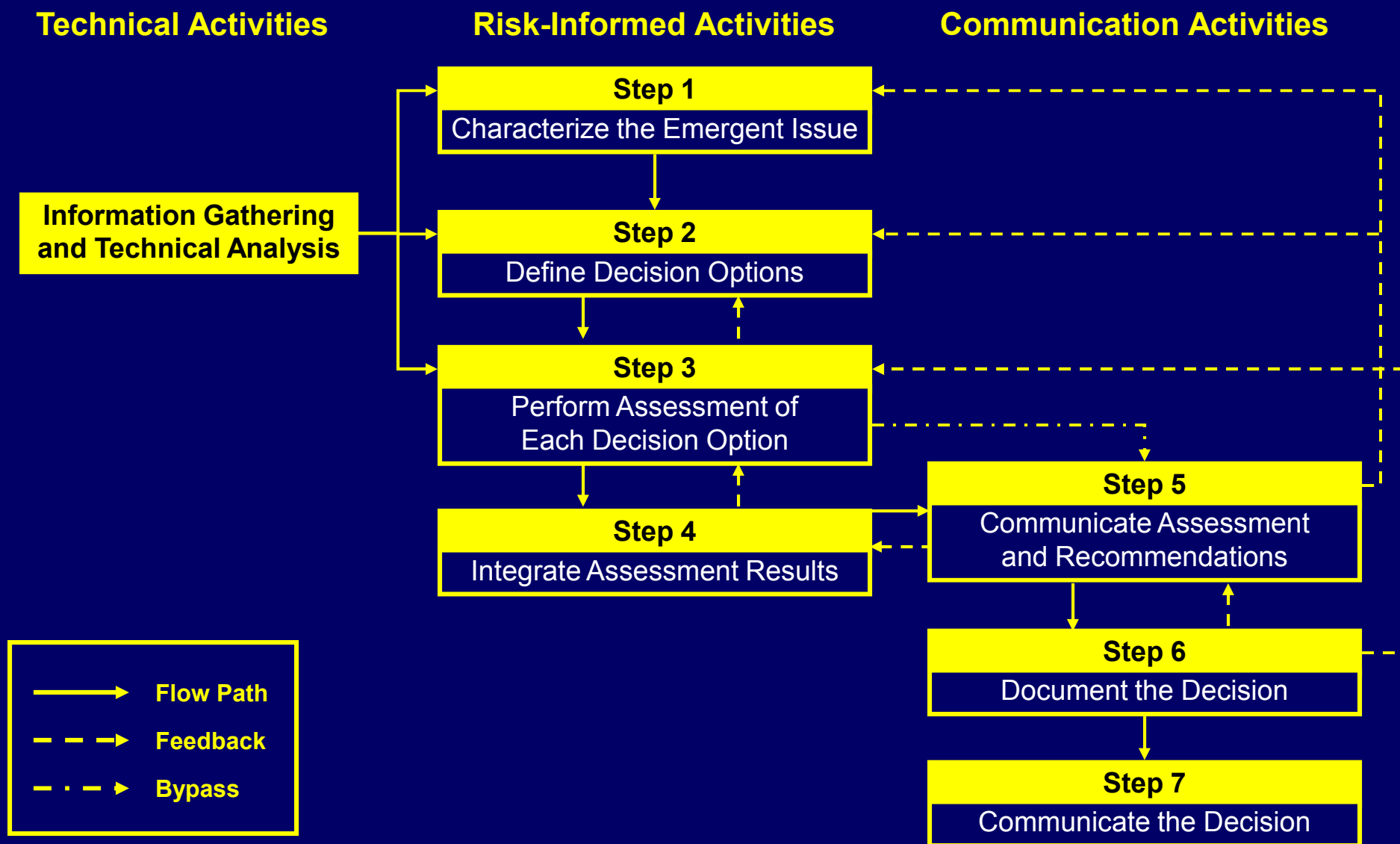
Licensee Response

- 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 <u>on-site</u> UT equipment <u>before returning to power</u> .	No	Yes	ASAP	Current
2 Require licensee to test all nozzles with <u>enhanced</u> UT equipment <u>before returning to power</u> .	No	Yes	~1 mo.	Enhanced
3 Allow licensee to <u>restart</u> , but <u>shut down ASAP</u> to test all nozzles with <u>enhanced</u> UT test equipment.	Yes	Yes	~1 mo.	Enhanced
4 Allow licensee to <u>return to service</u> 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



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
 Δ CDF = change in core damage frequency
 Δ LERF = 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)
GDSC = 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



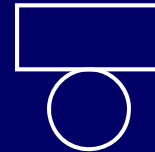
check valve



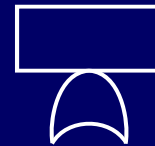
pump



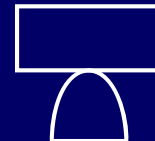
heat exchanger



basic event



OR gate



AND gate