EPRI Workshop on Risk-Informed Decision Making
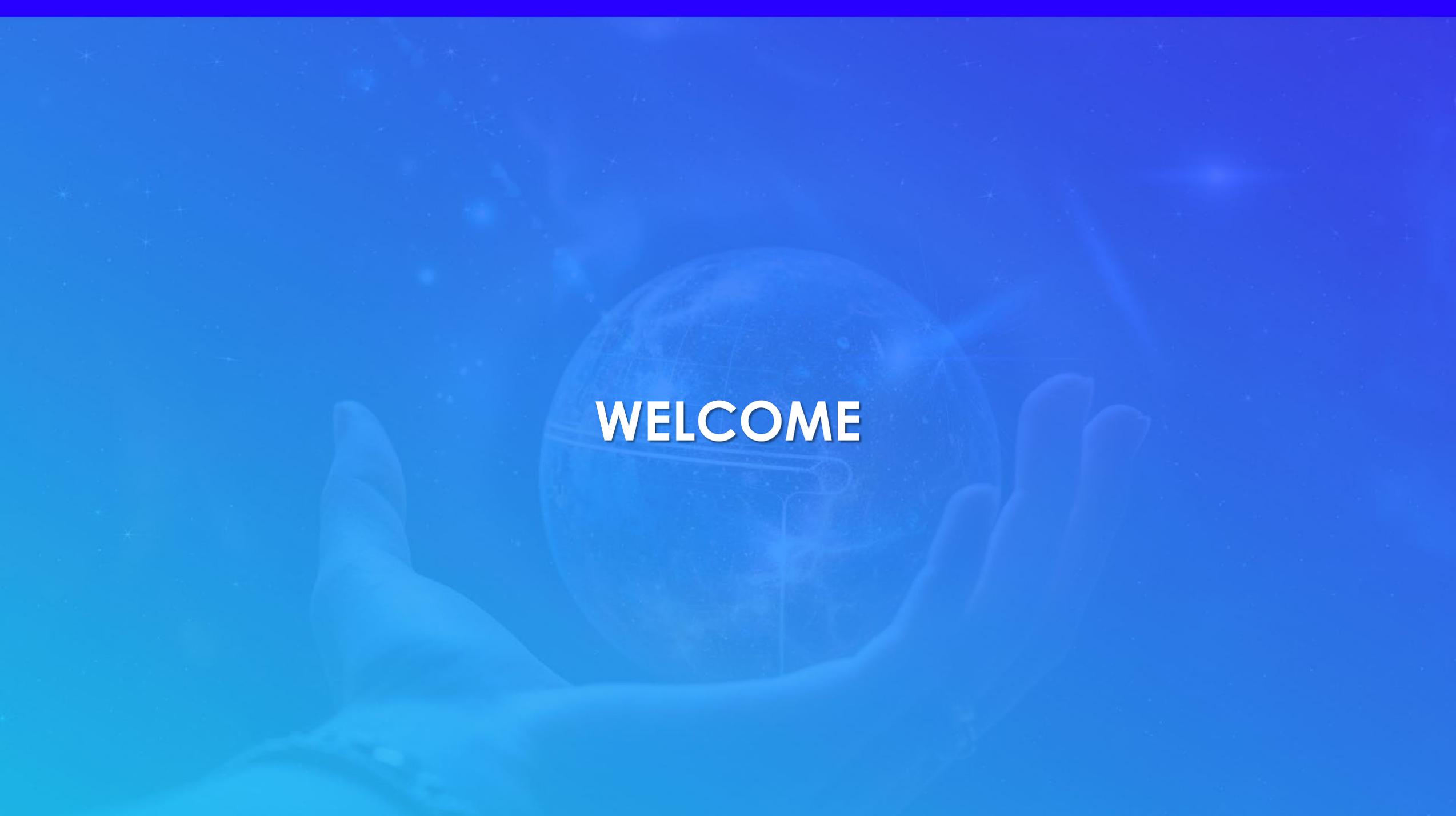
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WELCOME

EPRI and Member Benefits

Vision – To be a world leader in advancing science and technology solutions for a clean energy future

Mission – Advancing safe, reliable, affordable, and clean energy **for society** through global collaboration, science and technology innovation, and applied research.

EPRI provides independent, objective scientific research, expertise, and innovative technology to help members reduce costs, satisfy customers, and build for the future

Identify and solve critical and emerging industry issues

Stay at the forefront of Technology Innovation

Access deliverables and expertise

Collaborate and network with industry peers

Implement and **apply R&D** with support of EPRI experts

Reduce future risks of investment

Inform polices and regulations with objective scientific-based findings and facts

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Leveraging this Workshop

- We've brought together subject-matter experts— please actively engage, ask questions, and challenge ideas.

- Share your PRA experience, including what has worked well and where you've encountered challenges or frustrations.

- What are your primary concerns—technical, regulatory, organizational, or resource-related?

- Where do you see opportunities for improvement, and what support are you looking for from EPRI to help address those gaps?

- What opportunities for collaboration do you see across utilities, vendors, regulators, or industry groups?

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OVERVIEW OF RIDM

Why Risk-Informed Decision Making (RIDM)?

- Globally, risk-informed decision making <u>already</u> plays an <u>important</u> role in a wide range of activities that impact plant operations and <u>expansion of</u> risk-informing is expected

- When implementing RIDM, it is important to know how it may interface with different activities and groups within an organization that is leveraging insights for practical aspects

- <u>Your</u> input may be critical to support RIDM or you may need to interface with risk results and applications, even if your role is not directly related to risk assessment

- Awareness of RIDM basics and its role also supports improved <u>communication</u> and <u>support</u> for critical plant decisions

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What is Risk-Informed Decision-Making (RIDM)?

EXAMPLES OF DEFINITIONS:
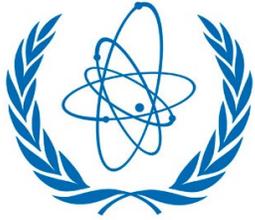
▪ **International Atomic Energy Agency (IAEA)** INSAG-25 definition of IRIDM:

"…a systematic process aimed at the integration of the major considerations influencing nuclear power plant safety…to ensure that any decision affecting nuclear safety is optimized without unduly limiting the conduct of operation…(i)t underpins nuclear safety decisions and ensures consistency with the safety goals of the Member State."

▪ **US Nuclear Regulatory Commission (USNRC)** definition of RIDM:

"An approach to regulatory decisionmaking, in which insights from probabilistic risk assessment are considered with other engineering insights."

A NON-NUCLEAR EXAMPLE:

▪ **US Federal Energy Regulatory Commission (FERC)** definition of RIDM:

"…the process of making safety decisions by evaluating if existing risks are tolerable and present risk measures are adequate, and if not, whether alternative risk reduction measures are justified."
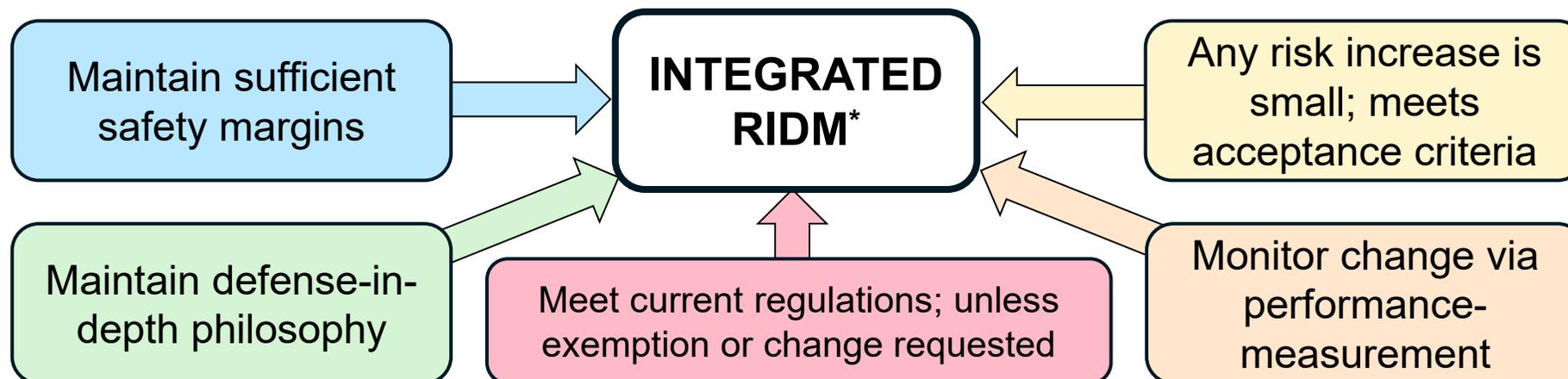
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What is Risk-Informed Decision-Making (RIDM)?

▪ At its basic level, RIDM is about considering (examples):

– <u>What decision do I need to make?</u>
  ▪ What plant modifications will reduce on-line risk the most?
  ▪ What is the risk significance of having a specific equipment out of service?

– <u>What tools do I have available?</u>
  ▪ Does my plant PRA cover a hazard that can impact the decision?
  ▪ Are the tools appropriate for the decision I need to make?
  ▪ What other insights aside from PRA results should I consider?

– <u>How much confidence do I have on the results of the tools available?</u>
  ▪ How technically adequate is my plant PRA model?
  ▪ Have I addressed uncertainty aspects such as modeling uncertainty and completeness?

– <u>What else do I need to consider before making a decision?</u>
  ▪ Is a plant modification possible given regulatory/financial constraints?

– <u>How do I communicate possible options for the decision? How do I document the decision?</u>
  ▪ What do I need to tell my supervisor/utility VP/regulator to support a decision?
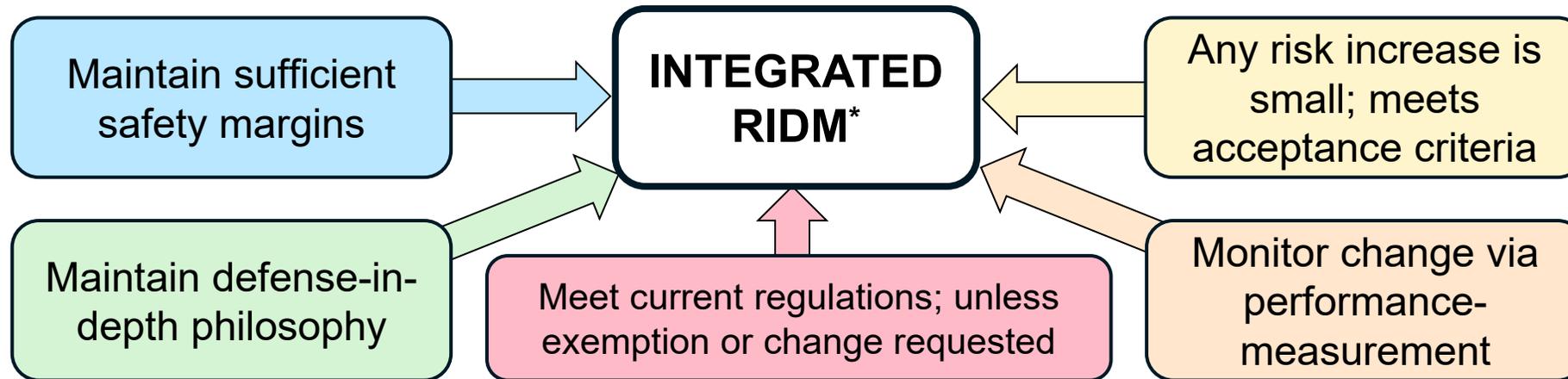
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What is Risk-Informed Decision Making?

- What is Risk-Informed Decision Making (RIDM)?
  - An approach (i.e., structured process) to decision-making in which insights from probabilistic risk assessment are considered along with other engineering insights
- RIDM integrates the strengths of multiple approaches
  - Probabilistic: includes an integrated view of plant design and operation; uses risk calculations to identify safety strengths and weaknesses
  - Other engineering insights: consider and maintain proven principles of defense-in-depth, safety margins, regulatory compliance, and performance monitoring

Maintain sufficient safety margins → INTEGRATED RIDM* ← Any risk increase is small; meets acceptance criteria

Maintain defense-in-depth philosophy → INTEGRATED RIDM* ← Monitor change via performance-measurement

Meet current regulations; unless exemption or change requested → INTEGRATED RIDM*

*Adapted from USNRC Regulatory Guide 1.174

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What is Risk-Informed Decision Making?


```
Maintain sufficient
safety margins                →
                                  ┌──────────────┐
                                  │  INTEGRATED  │    ←   Any risk increase is
Maintain defense-in-         →    │    RIDM*     │            small; meets
depth philosophy                  └──────────────┘          acceptance criteria
                                         ↑
                            Meet current regulations; unless  ←   Monitor change via
                            exemption or change requested          performance-
                                                                   measurement
```

Adapted from USNRC Regulatory Guide 1.174

IMPORTANT MESSAGES:
- "Risk-informed" is not equal to "having a PRA" (PRA is one input into a process)
- "Risk-informed" is not "risk-based" (PRA numbers should not be relied upon in isolation)
- RIDM helps to avoid pitfalls such as:
  - "Core damage will never happen, so we don't need containment" (defense in depth)
  - "I don't need to meet regulations because risk is low" (needs approved process)
  - "I don't need to meet codes/standards because the risk is low" (needs approval)
  - "I don't need to monitor performance because risk is low" (changes can happen)

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Traditional Design Basis Approach

CONSIDERATION	TRADITIONAL APPROACH (DESIGN BASIS)	RISK-INFORMED (USING PRA)
SCOPE OF EVENTS ANALYZED	• Pre-defined set of events plant should be able to cope with • Foundation for licensing/safety • Assumes design basis events are bounding	• Not constrained by pre-defined rules
FAILURE SCENARIOS INCLUDED	• Worst single active failure assumed to occur	• Unlimited number of failures considered probabilistically
COMMON CAUSE FAILURES	• Assumed to be precluded through design, testing, inspections, etc.	• Probabilistically considered for common components based on experience
HUMAN ACTIONS	• Assumed effective when proceduralized	• All human actions probabilistically considered
APPROACH TO UNCERTAINTIES	• Dependent upon bounding assumptions • Assume all other events less challenging, so they are adequately addressed by mitigation of the worst event(s)	• Focus on mean (realistic) estimate • Assess uncertainties quantitatively

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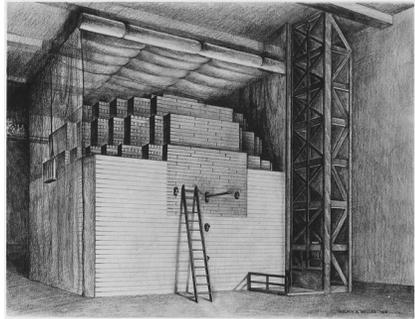# Dealing with Risk Has Always Been Necessary
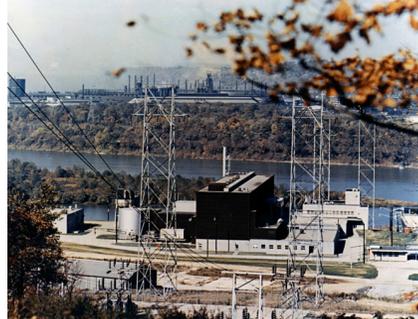
In the Beginning	The Early Years	The Growth Years	Present & Future
 Image from Public Domain, https://commons.wikimedia.org/w/index.php?curid=8147703	 Image from Public Domain, https://commons.wikimedia.org/w/index.php?curid=249584	 Image from Public Domain, https://commons.wikimedia.org/w/index.php?curid=10711268	 Image from https://www.iaea.org/newscenter/news/iaea-launches-new-version-of-advanced-reactors-database

FOCUS

REACTIVITY	**LOCA** **LOOP** **CONTAINMENT**	**ATWS SBO CCF** **FIRE TRANSIENTS** **OPERATOR ERROR** **EXTERNAL EVENTS**	**RARE EVENTS** **OLD UNCERTAINTIES** **NEW UNCERTAINTIES**

MITIGATION

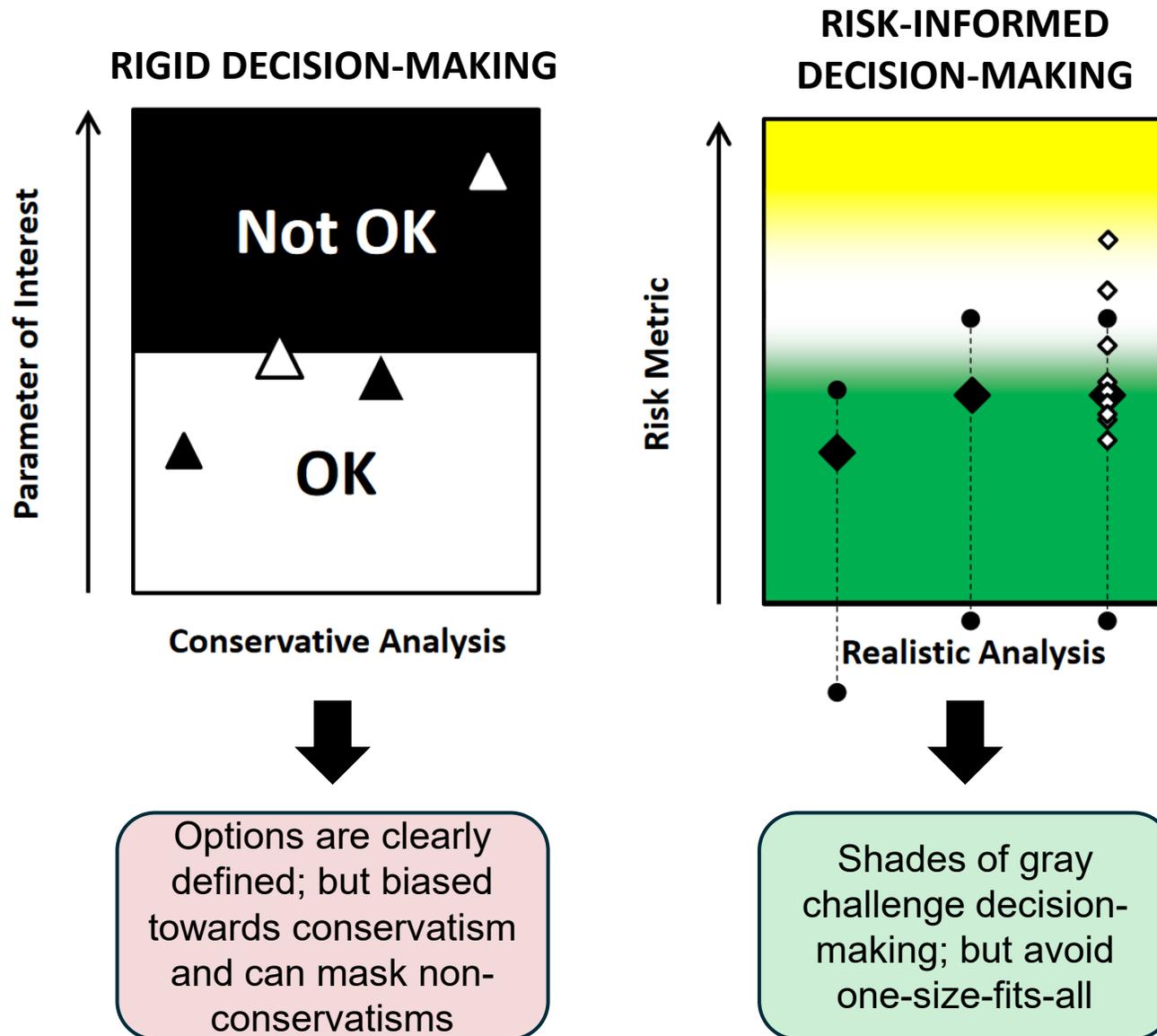|			
CONTROL RODS SCRAM ROD CHEMICAL CONTROL	GDCs DBAs ESF ECCS QA OPEX	RULES PRA EP FLEX HF ROP OPEX SEVERE ACCIDENT	PASSIVE SAFETY SYSTEMS NEW FUEL DESIGNS

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The "Deterministic versus Risk-Informed" Fallacy

RIGID DECISION-MAKING

Parameter of Interest

Not OK

OK

Conservative Analysis

Options are clearly defined; but biased towards conservatism and can mask non-conservatisms

RISK-INFORMED DECISION-MAKING

Risk Metric

Realistic Analysis

Shades of gray challenge decision-making; but avoid one-size-fits-all

- Risk-informing had to overcome a lot of skepticisms in implementation, e.g.:
  - *"Engineering is deterministic."*
  - *"PRA has too much uncertainty to be useful."*
  - *"Risk assessment does not apply to my area; it can't provide me any insights I don't know."*
  - **Understandable reactions; confidence in RIDM needs to be earned**

- RIDM may even challenge some deterministic assumptions

- But it is never a full substitute for traditional inputs!

- Ultimately, RIDM is about providing additional insights, supporting better decision-making outcomes

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EPRI 3002014783 - Framework for RIDM

DID = Defense-in-Depth
SMs = Safety Margins
PM = Performance Monitoring

RISK INFORMED DECISION MAKING (RIDM)
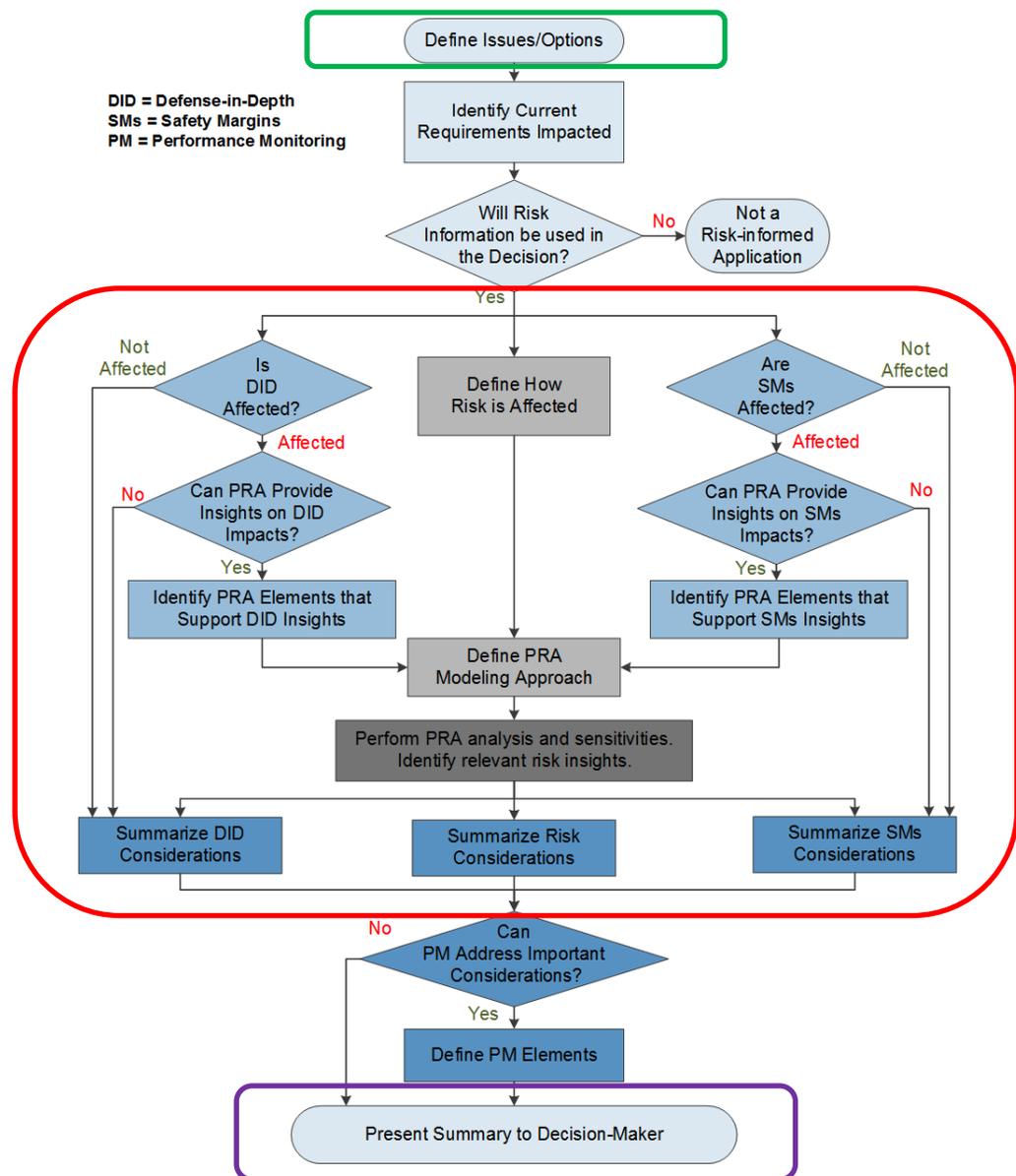
Key aspects:

1) Properly defining the issue

2) Selection of options and PRA/modeling approach

3) Communication with decision-makers

RIDM Examples

- Risk results are used by operators to assess and respond to changes in plant conditions
- In-service inspection (ISI) of piping is driven by risk-informed categorization
- Risk evaluations are performed for potentially cost-beneficial changes for license extension
- Power uprates include consideration of risk results due to expected plant changes (for example, success criteria)
- Changes to plant licenses are justified with a risk-informed basis for specific applications (for example, technical specifications)
- Risk assessments are used to determine the significance of events and performance deficiencies

Not hypothetical, these are actual benefits gained
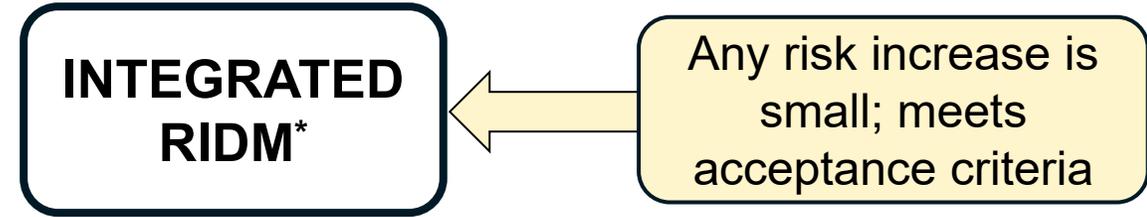
The Role of Risk Assessment in RIDM

- What about risk and PRA?
  - Risks can be expressed qualitatively
    - "This event might happen more often"
    - "This consequence would be worse"
  - For RIDM, we need a quantitative evaluation of risks

INTEGRATED RIDM*

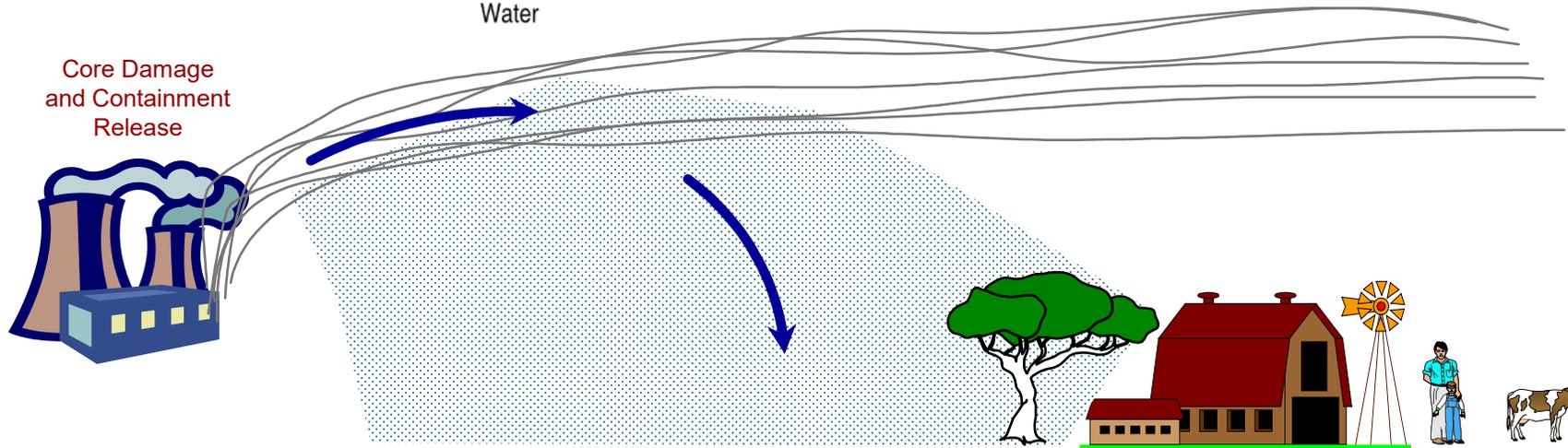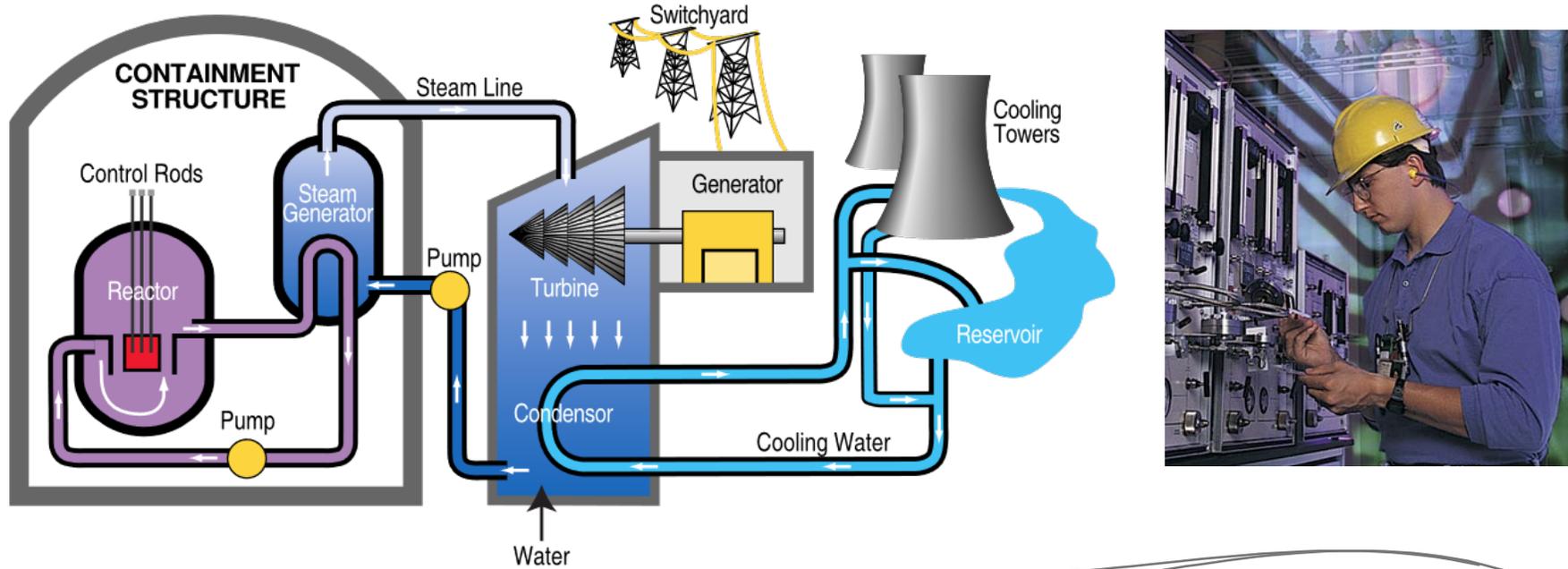Any risk increase is small; meets acceptance criteria

$$Risk = Frequency \quad X \quad Consequences$$

| Consequence Magnitude / unit of time | Events / unit of time | Magnitude/event |

In PRA, the term "risk" is:
the frequency with which a given consequence occurs

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The Role of Risk Assessment in RIDM

The goal of PRA is to focus on important safety aspects

The Role of Risk Assessment in RIDM

- An <u>integrated</u>, <u>multidisciplinary</u> engineering tool

- Models how <u>accidents</u> may progress and how systems & operators impact scenarios (including natural hazards)

- Uses probabilistic and statistical approaches as a common language for assessing risk
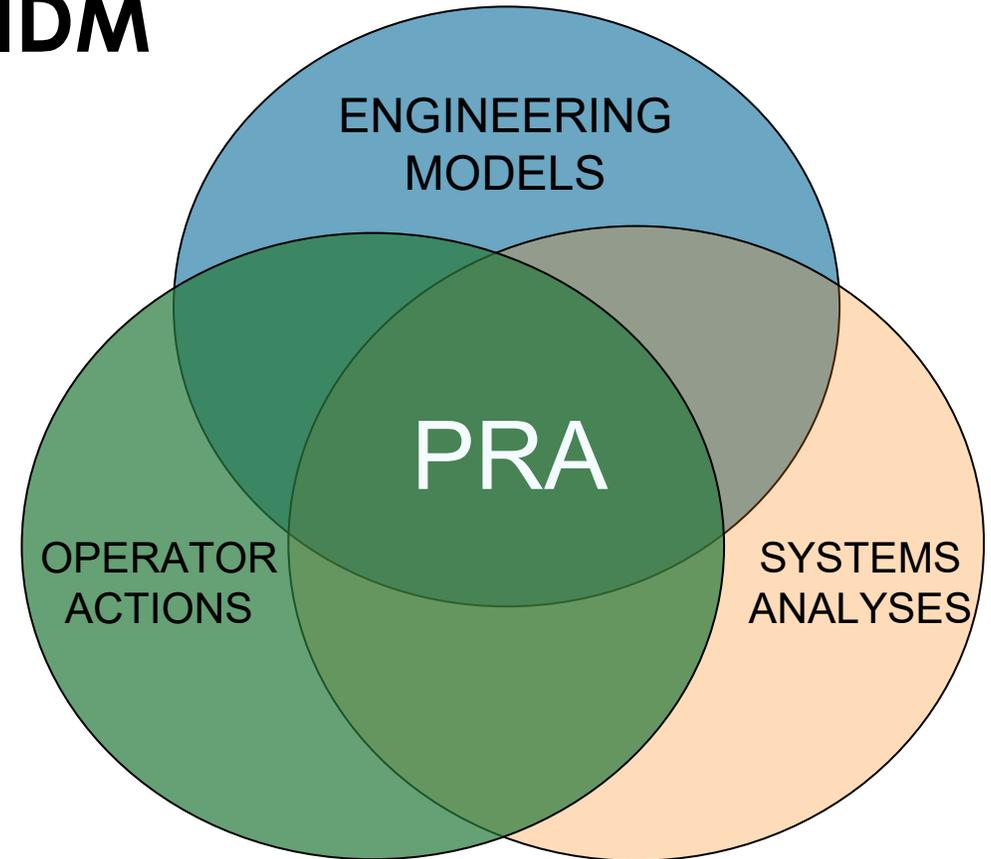
<u>IMPORTANT:</u> PRA is a systematic and comprehensive technical framework for evaluating the risk associated with nuclear power plant design and operation

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The Role of Risk Assessment in RIDM

PRA is a tool based on general risk analysis concepts that is adapted for commercial operating reactors

LESS

MORE

IMPORTANT

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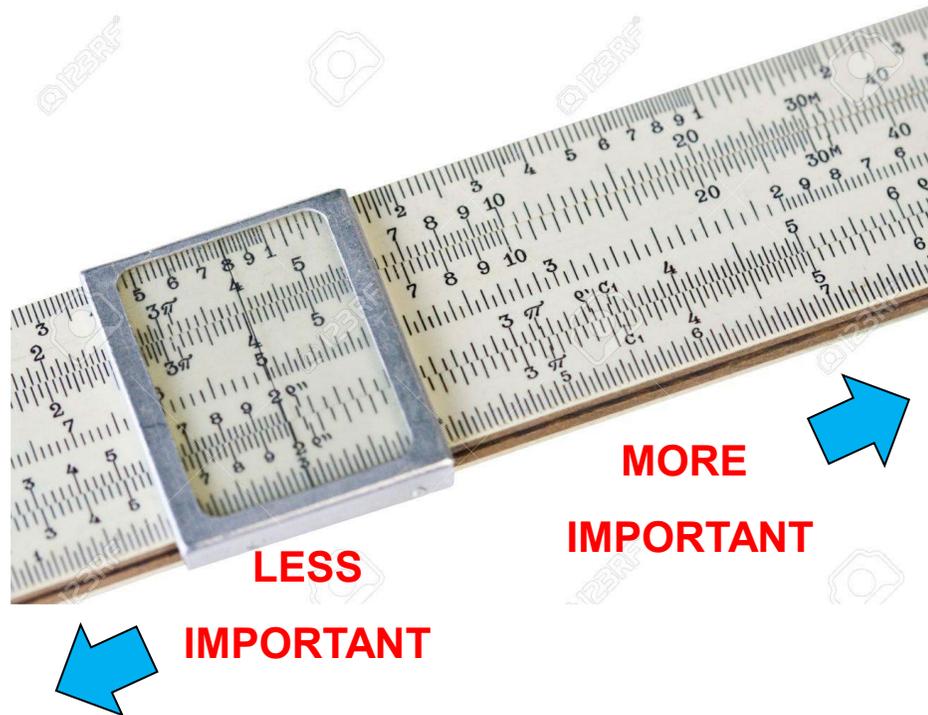
<u>Like any tool, one must ask KEY questions:</u>

– Do we have the right tool?

– Are we measuring the right outputs?

– Is the tool at the right scale?

– Do we understand what the tool is telling us?

– Do we know what to do with the "measurements" (insights) we get from the tool?

– How can the tool (or results) help me?

<u>IMPORTANT:</u> *While developers & users are familiar with the details, it is important for everyone to know how to ask informed questions*

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The Role of Risk Assessment in RIDM

The PRA models scenarios by asking the following questions

RISK TRIPLET

What Can Go Wrong?
- <u>Systematic search for challenges to plant safety</u>
  - What can upset normal operations?
  - What systems can be used to mitigate the event?
  - What operator actions impact event progression?

How Likely is it?
- <u>Logical, objective estimation of occurrence probability</u>
  - Frequency of upsets
  - Probability of equipment failure
  - Probability of equipment out of service
  - Probability of human error

What are the Consequences?
- <u>Realistic evaluation of impact on plant/public safety</u>
  - What are the possible accident progression(s)?
  - How can radionuclides be released to environment?

You are ALREADY a risk analyst – think how you apply this everyday…

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What is included in a PRA?

PRA models include most of the important structures, systems, and components (SSCs) in the as-built, as-operated plant

- A risk model is <u>not</u> meant to be a live simulation of <u>all</u> plant activities
  - Some are <u>not relevant</u> to risk
  - Some are <u>not risk-significant</u> AND can be screened out
  - Some are included with varying levels of detail and rigor
- If an SSC is not included in the PRA,
  - Was it screened out, and what was the basis?
  - Could it impact safety-related functions?
  - Is it indirectly related to a modeled SSC (a potential surrogate)?
- If an SSC was not included, it does not mean the PRA model is deficient

- **Heat Removal Systems**
  - Reactor Coolant System
  - Main Steam
- **ECCS Injection Systems**
  - Feedwater / Auxiliary Feedwater
  - PWR HPI / LPI / RHR
  - BWR HPCI / RCIC/ RHR / LPCS
- **Containment Systems**
  - Containment Isolation
  - PWR Fan Coolers / Spray
  - BWR Drywell Coolers / Spray
  - BWR Suppression Pool Cooling
- **Support Systems**
  - Actuation / RPS / Instrumentation
  - Service Water / Comp. Cooling Water
  - Instrument Air
  - AC & DC Electric Power
- **Operator Actions**

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PRA Scope To Support RIDM

Typically, a plant PRA model includes consideration of:

QUANTITATIVE, DETAILED — Internal Events 🔧🧍

QUANTITATIVE, DETAILED — Internal Floods 🚰

USUALLY QUANTITATIVE, DETAILED — Internal Fires 🔥

USUALLY QUANTITATIVE, DETAILED — Seismic Events ⬚

MOSTLY QUALITATIVE, SCREENING — High Winds ⚠️

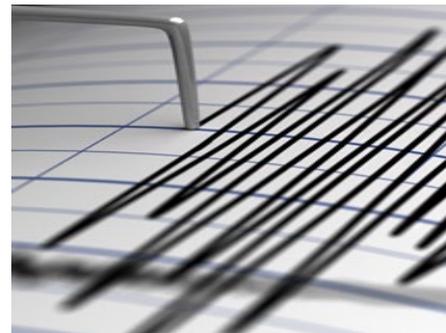MOSTLY QUALITATIVE, SCREENING — External Floods 💧

MOSTLY QUALITATIVE, SCREENING — Other External Hazards ⚠️

Not typical, but you may see/hear:

Low Power Shutdown 🛠️

Multi-unit risk 🏭

Enterprise risk 🪙🪙🪙🪙

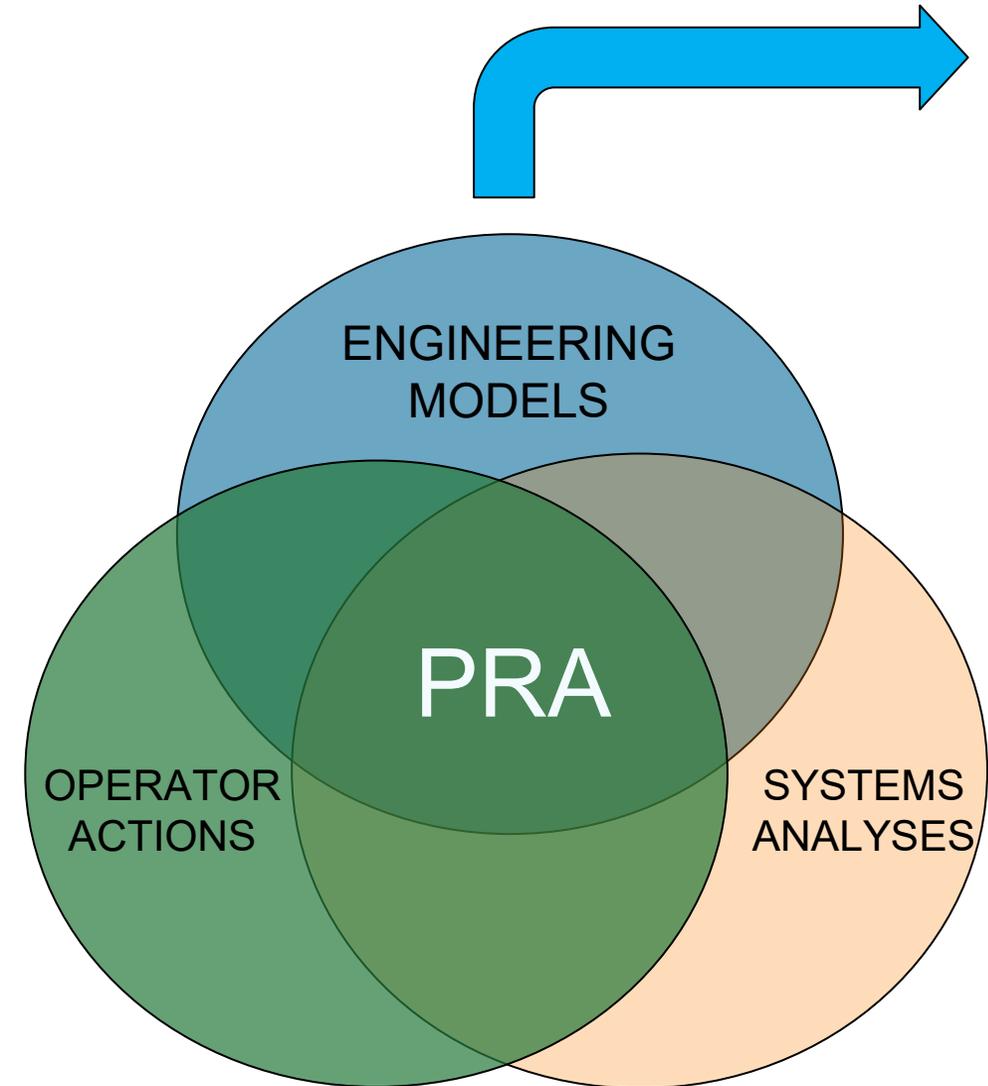**Risk has been applied to:**

Spent Fuel Pool 〰️

Dry cask storage, high level waste ⬤

Transportation aspects 🚚

Aspects of physical security 🔒

Advanced reactor designs/applications ⚛️

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What are the outputs of PRA?

Venn diagram showing PRA at the intersection of ENGINEERING MODELS, OPERATOR ACTIONS, and SYSTEMS ANALYSES.

- How likely is a scenario to reach core damage, offsite release, etc.?
- How does the probability of failures of individual SSCs/operators contribute to these scenarios?
- What combinations of failures are the most likely and/or most consequential?
- What underlying uncertainties exist on accident scenarios and contributors?
  - Uncertainties exist whether PRA is used or not
  - PRA does not create uncertainty, it highlights areas we know more or less about so that our decisions can be better informed

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Specific Strengths of PRA

- Rigorous, systematic analysis tool
- Integrates information from multiple disciplines
- Allows consideration of complex interactions
- Develops qualitative design insights
- Develops quantitative measures for comparison
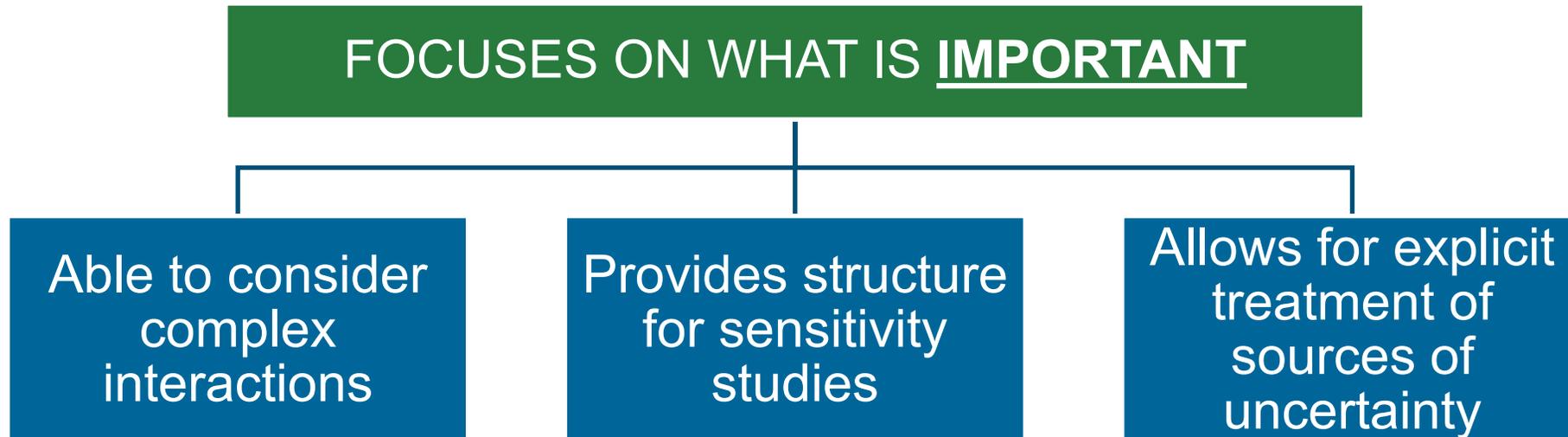- Provides a structure for sensitivity studies
- Explicitly highlights and treats principal sources of uncertainty
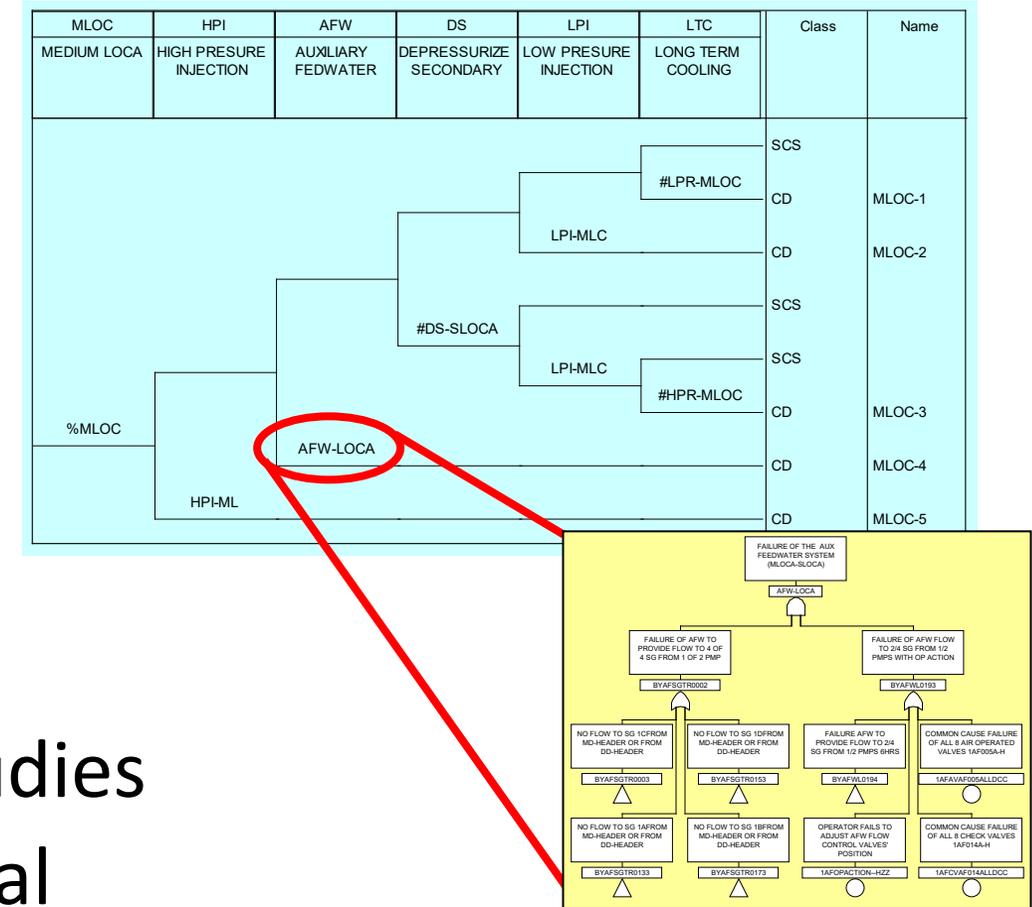
Benefits of RIDM

- An Integrated RIDM approach, including PRA, provides
  - Rigorous, systematic analysis tools to capture complex interactions
  - Multidisciplinary information concerning plant design and operating practices
  - More rational safety and regulatory decisions
  - Allocation of resources commensurate with the real safety significance, resulting in more safety at a lower cost
    - With a proven record of risk management improving plant performance!

FOCUSES ON WHAT IS **IMPORTANT**

Able to consider complex interactions	Provides structure for sensitivity studies	Allows for explicit treatment of sources of uncertainty

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Benefits of RIDM

- An Integrated RIDM approach, including PRA, also
  - Identifies weaknesses in plant design that are not always captured in deterministic evaluations alone
    - Addresses a more extensive set of scenarios
    - Considers the likelihood of different events
  - Highlights areas where plant design is extremely robust
    - Provides realistic capabilities
    - Credits all plant capabilities
  - Assesses whether new information or a performance degradation is risk significant or not
    - Prevents unnecessary use of resources if not risk significant
    - Provides a technical bases for internal and external discussions

Requirements for RIDM

- The PRA model scope and any limitations are critical to understanding the risk profile and the overall decision
  - Availability of empirical data
  - Simplifying assumptions
- At some point, a decision MUST be made
  - As in other areas, an endless debate about analysis results, the quality of modeling, etc. can lead to paralysis
  - Decisions are almost always made in the presence of uncertainty

> **IMPORTANT:** *As with any other engineering tool, PRA scope, applicability, and limitations need to be understood in order to be properly applied (not immune to "garbage in, garbage out")*

Requirements for RIDM

- The "risk-informed" aspect of RIDM requires an investment

HOW TO EFFICIENTLY BUILD THE PRA ENGINE
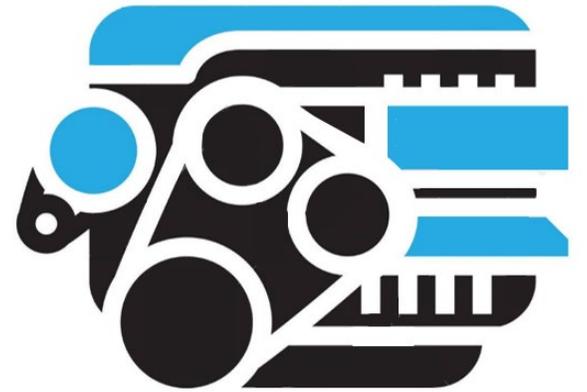
"PRA ENGINE"

HOW TO USE THE PRA ENGINE

HOW TO EFFICIENTLY MAINTAIN AND SUPPORT THE PRA ENGINE

As everything else, resources are needed to maintain the PRA

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Challenges for Decision-Making

- Limitations due to available data for rare events

- Limitations due to understanding of physical processes

- Results are sensitive to incoming assumptions

- Limitations due to available resources
  - For example, simplifying assumptions, need to truncate calculations

- A Deterministic/PRA model is typically a snapshot in time
  - This limitation may be addressed by having a "living" document approach

- Limitations due to a lack of completeness where lower likelihood events may be excluded
  - For example, human errors of commission are not typically considered

Limitations not restricted to RIDM; RIDM allows assessment of impact for key assumptions

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Dealing with Challenges for Decision-Making: Uncertainty

PRA allows uncertainty to be identified and assessed to increase confidence in results and identify gaps

Identify the sources of uncertainty

↓

Parameter Uncertainty

Modeling Uncertainty

Modeling Completeness

↓

Assess the impact of uncertainties on the results
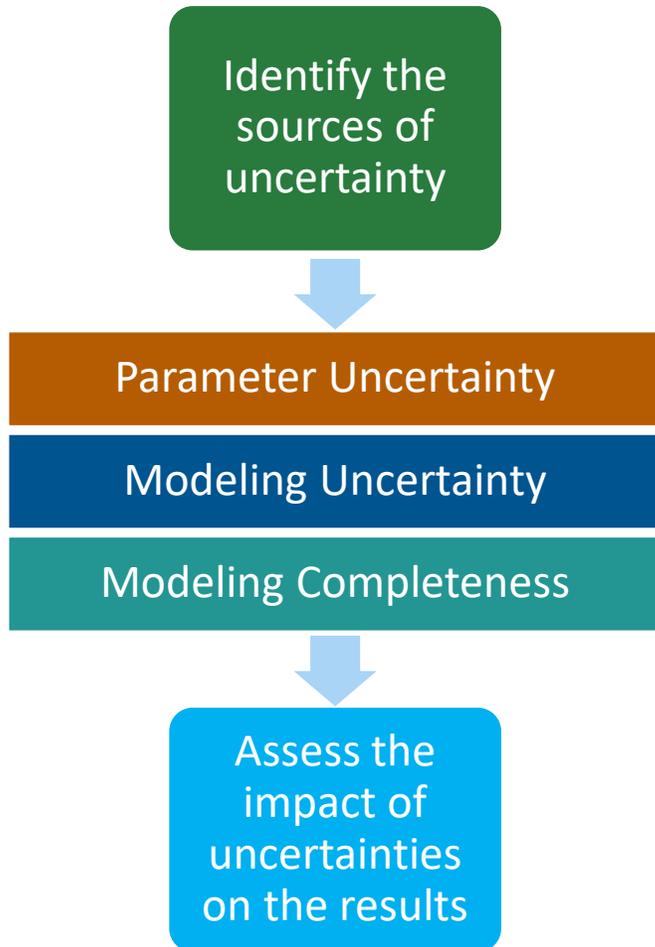
IMPORTANT

MYST: *"PRA outputs are too uncertain; they cannot be trusted"*

REALITY: Uncertainty exists whether PRA modeling is performed or not

- **Prior to the Three Mile Island accident, a core damage event was thought to be impossible**

- **Uncertainty exists on how severe core damage accidents progress**

- **Unexpected errors may be introduced by human actions or design issues**

- **The frequency and magnitude of natural hazards are challenging to estimate**

- **We have sufficient experience with PRA models to understand insights such as larger and smaller contributors and important plant operations**

RIDM for Plant Organizations

FOR A MANAGER

- Risk outputs are available to assess daily risk, compare design or operational alternatives, understand important contributors, uncertainty impacts

FOR MAINTENANCE PERSONNEL

- Risk outputs are used to compare equipment performance and to determine the importance of specific systems and components
- Risk outputs identify plant configurations where risk may be higher than usual, which may require protecting equipment
- Equipment performance feeds into the risk analysis through failure and unavailability data

FOR REGULATORY AFFAIRS

- Risk outputs help identify issues that the regulator may focus upon
- Risk outputs provide a technical basis to address concerns that may have a relatively smaller impact to the plant

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RIDM Summary

- Risk information is one of the tools in the RIDM toolbox
  - PRA should not be a separate process off to the side
- RIDM and its applications will continue to evolve as the state of practice advances and the industry continues to learn and share with each other
- We can always ask ourselves:
  - What risk information is available to bring to bear on this decision?
  - Have we framed the right question relative to nuclear safety?
  - Where is the most efficient or appropriate place in the process to utilize that information to improve safety?
  - What are others doing to advance their use and understanding of risk information and what information can I share?

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IMPLEMENTATION ASPECTS FOR RIDM

Risk-Informed Decision-Making and PRA Applications

- ## What is a RIDM application?

A RIDM (or PRA) application is the usage of PRA for a specific purpose	The PRA results are used to evaluate the risk level for acceptability	Many RIDM or PRA applications are regulatory and can be either mandated or voluntary (with requirements for the submittal)
One key application involves *a change to the licensing basis of the plant*	PRA results for voluntary PRA applications are used *to demonstrate risk is small (meets acceptance criteria)*	The purpose for many RIDM applications is to investigate safety aspects (which can include additional operational flexibility, efficiency benefits)

Some countries, like the US, have implemented an extensive use of PRA and RIDM in regulatory applications; most countries currently focus PRA on confirming overall plant safety

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Types of RIDM Applications and Types of Information

PRA OUTPUT	Total Risk Example: CDF, LERF	Change in Risk Example: ΔCDF, ΔLERF	Incremental Risk	Risk Ranking
TYPE OF RIDM APPLICATION	Comparison to Safety Goals (Is plant safe enough?)	Permanent Change to Plant Design, Operations (Is the change acceptable?)	Temporary Change to Plant Design, Operations (Is the change, duration acceptable?)	Understanding of Important Risk Contributors (Can we use a graded prioritization?)
EXAMPLE APPLICATION	Basic application to confirm safety of the plant	Plant Licensing Basis Changes	Significance Determination Process / Risk-Informed Completion Times	Risk-Informed Categorization of Components / Risk-Informed Maintenance / Performance Indicators

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Configuration Risk Management (CRM)

- CRM is a process to manage the risk associated with various plant configurations especially when structures, systems, and components (SSCs) may be out of service

| Looks at plant configuration holistically by tracking multiple combinations of SSC conditions | → | Allows for online maintenance activities to be performed while managed safely and efficiently | → | Provides information that can indicate specific actions that may be needed (compensatory measures) |

IMPORTANT: CRM is a powerful tool to assist nuclear power plant personnel in planning and executing day-to-day maintenance and operations activities
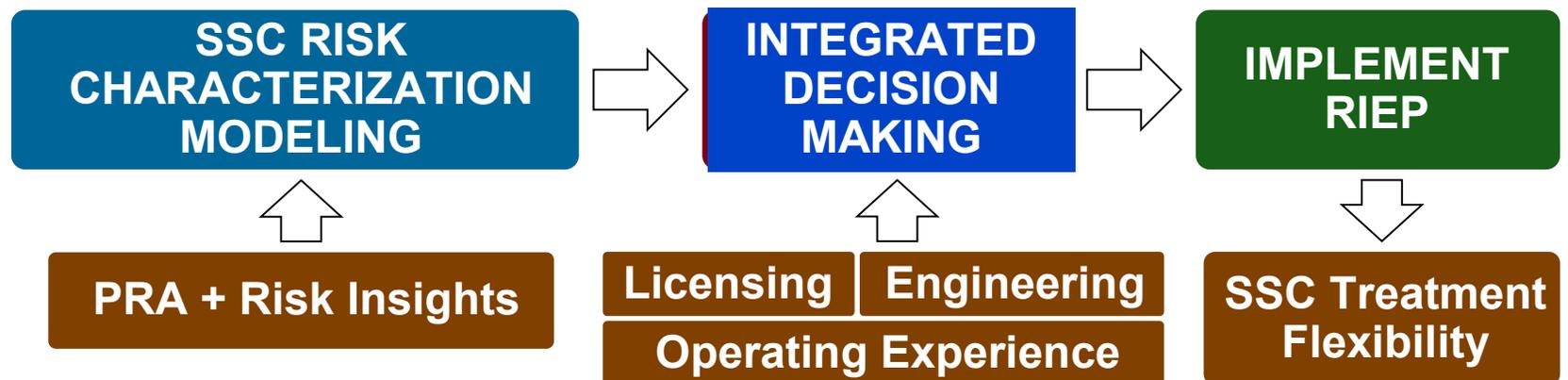
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Benefits of CRM (and other applications)

- Improves plant safety
- Supports more online maintenance & shorter outages
- Provides flexibility in maintenance & outage planning
  - Manages plant risk for configurations involving multiple SSCs being out of service for maintenance (or test) as well as for emergent work
  - Considers normal work control for low-risk configurations or risk management actions for higher-risk configurations
- Shares risk results & insights across site organizations
  - Allows for risk insights to be communicated across all activities
  - Continued use improves risk modeling as well as implementation
- Benefits both utilities as well as regulators
  - Formalizes the RIDM framework for regulatory oversight of maintenance
  - Increases safety & efficiency by focusing on the most important aspects

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Risk-Informed Engineering Programs (RIEP)

- A program that allows for specific requirements to be changed when a risk-informed categorization process is followed

  - Looks at the safety significance of SSCs in an integrated fashion

  - Categorizes SSCs according to their primary function with respect to safety and their safety significance, in a structured process

  - PRA models are one of the inputs into the process of categorizing SSCs under this risk-informed application

  - For current US plants, 50.69 allows "alternate" treatment for a safety-related component if it is categorized as having low safety significance

  - For advanced reactors, the Licensing Modernization Project performs the categorization for initial licensing, resulting in "special treatment" for non-safety-related SSCs that are important to risk or defense-in-depth

| SSC RISK CHARACTERIZATION MODELING | ⇒ | INTEGRATED DECISION MAKING | ⇒ | IMPLEMENT RIEP |

⬆ **PRA + Risk Insights**

⬆ **Licensing** | **Engineering** | **Operating Experience**

⬇ **SSC Treatment Flexibility**

EPRI

Surveillance Frequency Control Program (SFCP)

- SFCP is a risk-informed and performance-based approach providing utility control over surveillance test frequencies within an established framework

- SFCP was developed as a generic approach - each utility has the option to submit their implementation approach to the regulator

- Once approved by the regulator, the utility-selected Technical Specifications with surveillance frequencies are relocated to a utility-controlled document

- The utility applies industry guidance to examine the potential risk impact of changes to selected surveillance frequencies; if acceptable, the utility implements changes without further regulatory action

- There are no prescriptive requirements regarding which surveillance frequencies to change – it depends on plant needs and the level of effort required to implement changes on a plant-specific basis

EPRI

Risk-Informed Completion Times (RICT)

- RICT is a risk-informed application involving technical specification changes to the allowed outage time (or completion time) based on real-time risk assessments

- The RICT application is programmatic – it involves the implementation of a new process and requires culture change to implement

- RICT shares basic principles with CRM and applies them to the technical specifications
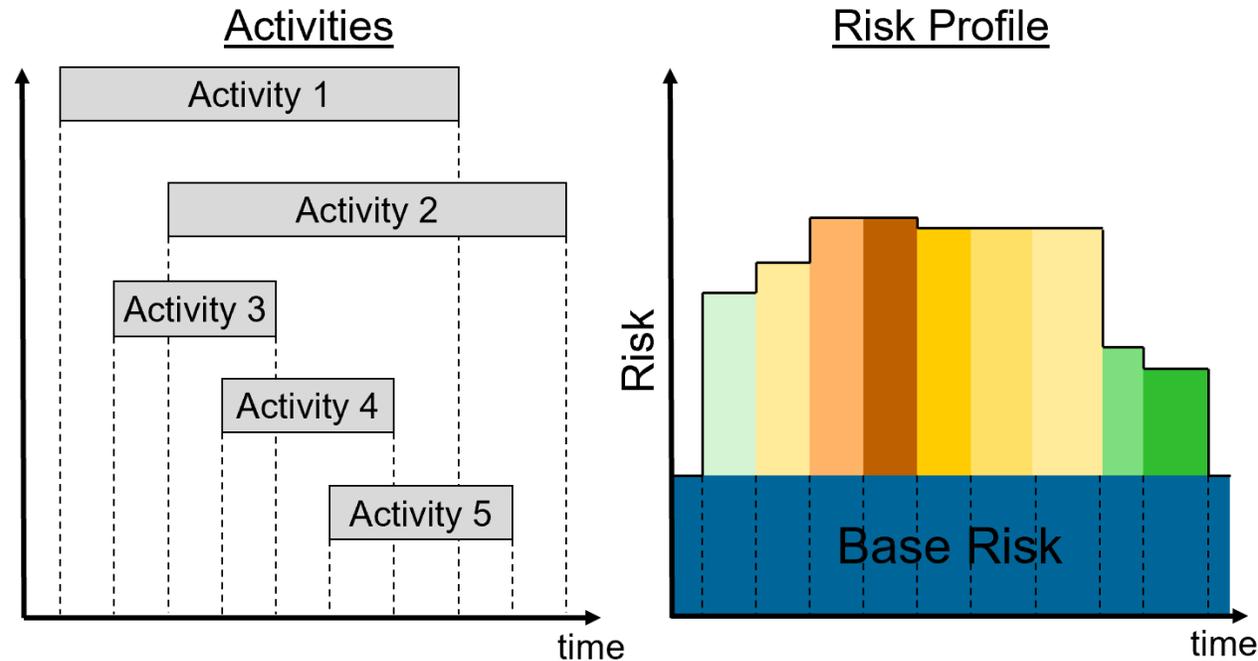
Risk-Informed Oversight Approach – US

- Revised process was to be based on the following structure:
  - Licensee performance was to be measured via quantitative criteria and inspection results in pre-defined key areas of safety ("cornerstones")
  - The quantitative criteria (PIs) were to be developed for each cornerstone to provide an objective indication of licensee performance (recognizing it may not cover all safety aspects)
  - A risk-informed "baseline" inspection program was to be developed to independently verify the PIs and to inspect those licensee performance aspects not adequately covered by PI.
  - The risk-informed baseline inspection program would establish the minimum inspection effort that all licensees would receive, regardless of their performance
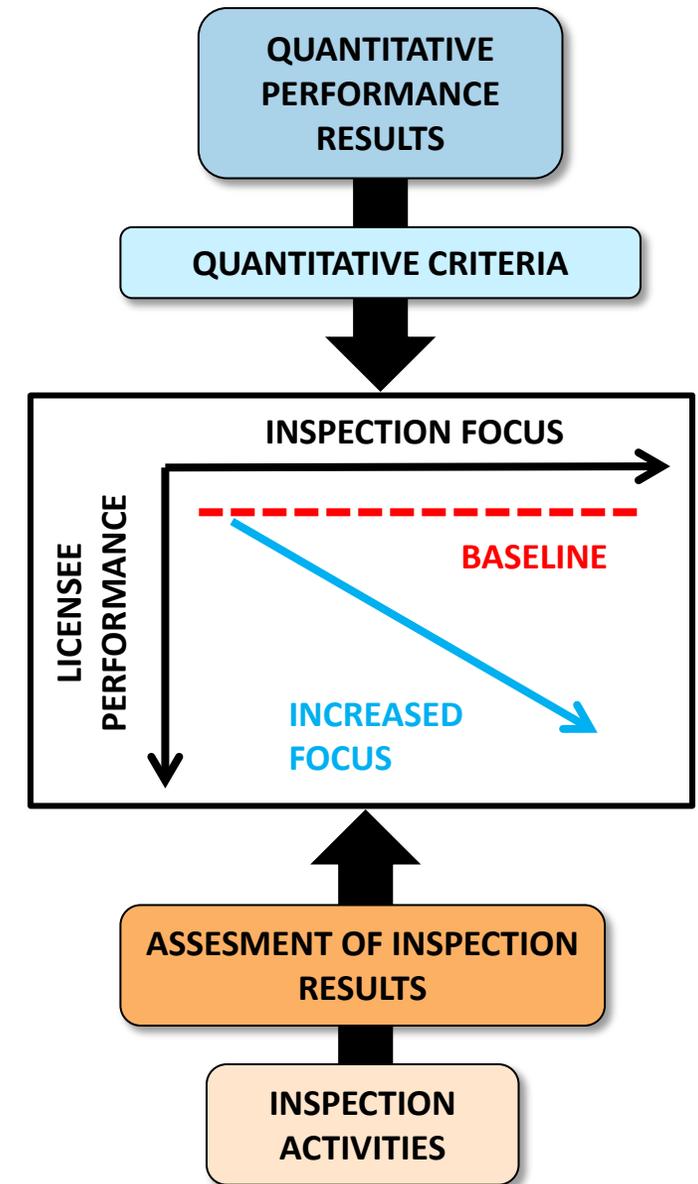
More Applications...

Air Operated Valve Risk Ranking (AOV)	Component Design Basis Inspection (CBDI)	Fire Protection (NFPA-805)	Industry Initiative on Management of Materials (NEI 03-08)
License Amendment Requests (LARs)	Missed Surveillance (LCO 3.0.3)	Mitigating System Performance Index (MSPI)	Mode Change (LCO 3.0.4b)
Motor Operated Valve Risk Ranking (MOV)	Notice of Enforcement Discretion (NOED)	Reactive Inspection (M.D. 8.3)	Risk-Informed Inservice Inspection (RI-ISI)
Risk-Informed Inservice Testing (RI-IST)	RI Repair and Replace (RI-RRA) and ASME Code Case N-752	Significance Determination Process (SDP)	Time Sensitive and Time Critical Operator Actions (TSOA/TCOA)

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More Applications…Risk-Informed Aging Management

Aging management programs (AMPs) provide the required to address aging mechanisms. See the NRC's Generic Aging Lessons Learned (GALL) and the IAEA International Generic Ageing Lessons Learned (IGALL) Reports.
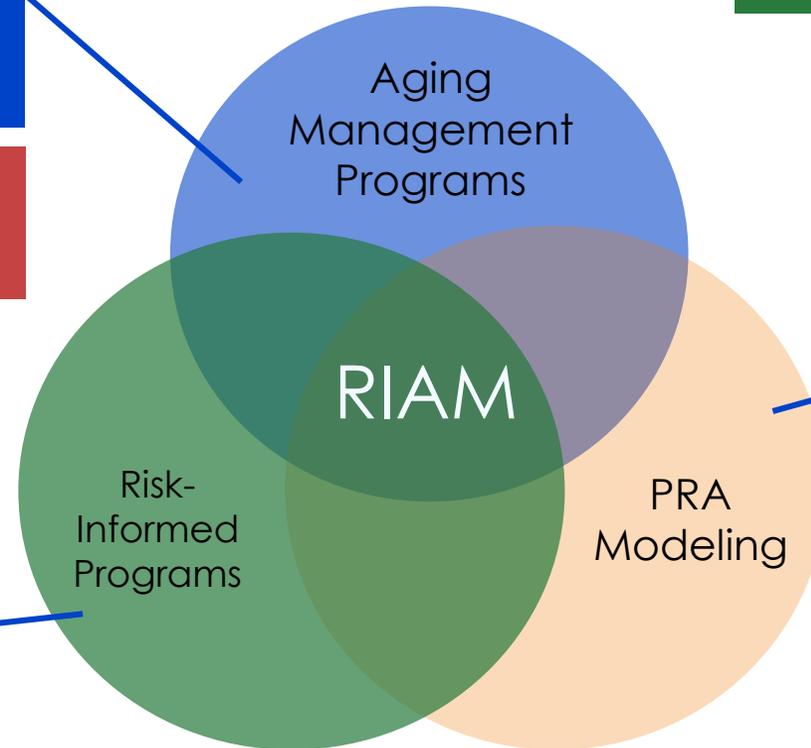
Largely developed using deterministic methods.

Leveraging risk insights provides an additional approach to optimizing aging management resources and activities while allowing a reduction of lower-value activities.

Aging Management Programs

RIAM

Risk-Informed Programs

PRA Modeling

Internal flooding PRA models consider flood sources with the potential to produce risk contributions to overall plant safety. This includes spray, floods, major floods, and high energy line breaks. Modeling also considers the capabilities for isolation and specific impacts to components (SSCs) within the flood's impact area.

Risk insights are developed using already established risk-informed applications, such as risk-informed inservice inspection (RI-ISI), risk-informed inservice testing (RI-IST) and risk-informed repair and replace (RI-RRA).

EPRI RIAM framework (3002020713) includes pilot applications on selective leaching inspections and cable testing frequencies

EPRI

Digital Engineering Guide (DEG)

- EPRI has developed a framework for designing digital I&C systems
- The Digital Engineering Guide (DEG) provides the design framework that integrates various supporting products
  - HAZCADS, DRAM, HFAM, TAM, EMCAM
- This framework uses a **Systems Engineering** approach to create an iterative design process that generates:
  - A risk-informed design that meets all stakeholders' needs
  - The correct (complete and accurate) design requirements

DEG — What I&C design meets stakeholder needs?

HAZCADS — How risky is the proposed design?

DRAM HFAM TAM EMCAM — Is the design good enough to mitigate risks?

EPRI

Risk-Informing for Advanced Reactors

OBJECTIVES

- Determine the readiness of current Risk methods and tools for use in Advanced Reactors

- Identify technical gaps that can be resolved through research

- Develop and execute a research roadmap to guide EPRI research in this area

  - Needs for new technology

  - Needs for new decisions

STATUS

- Published formal EPRI report of identified gaps and research roadmap (August 2023)

- Beginning research to resolve key challenges

- Organized stakeholder collaboration group to share common challenges and approaches to solutions

**EPRI Report 3002026495
Evaluation of Risk Analysis Methods & Tools
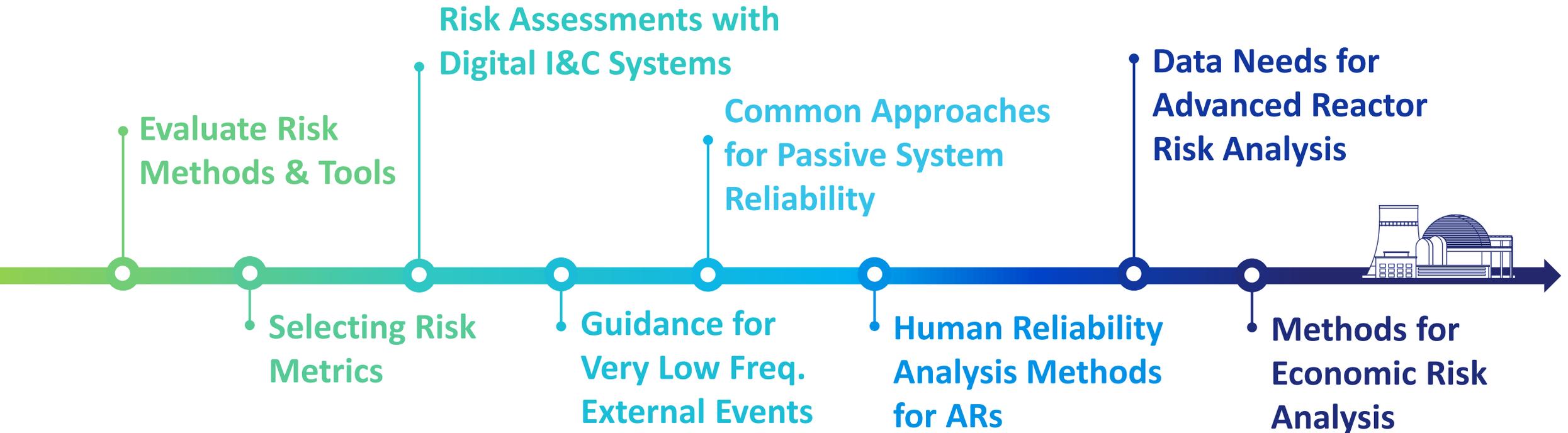for Advanced Reactors**

NEXT STEPS

- Continue monitoring & prioritizing the key challenges to assist the development and deployment of Advanced Reactors

- Planning for expanded research activities in 2024...

Risk-Informing for Advanced Reactors

Evaluate Risk Methods & Tools

Risk Assessments with Digital I&C Systems

Common Approaches for Passive System Reliability

Data Needs for Advanced Reactor Risk Analysis

Selecting Risk Metrics

Guidance for Very Low Freq. External Events

Human Reliability Analysis Methods for ARs

Methods for Economic Risk Analysis

Other Roadmap Actions Related to Risk Research:
- Develop and qualify analytical tools for advanced reactor design
- Develop enhancements to licensing process
- Reduce operating and maintenance costs to a level similar to other thermal plants
- Develop technical input to siting criteria
- Establish decoupling framework for Nuclear Beyond Electricity users
- Develop industry recommendations for regulatory guidance on operator staffing
- Develop guide on leveraging legacy reactor experience
- Provide joint recommendations to North American regulators on regulatory alignment

EPRI

Ensuring Efficient RIDM Implementation

- What do we need to have a practical, wise, and efficient RIDM approach?
  - PRA model(s) with sufficient scope & quality
    - The PRA model does not have to be omniscient
    - Hazards, modes, and level of detail must be sufficient to support the decision being made with the understanding of uncertainties
  - Efficiency increases with experience
    - Learn from others
    - Build capabilities
    - Some applications are "easier" than others – start with those

"PRA ENGINE"

LEARN   DO

DO   LEARN

EPRI
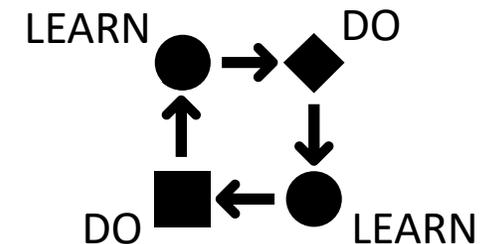
There isn't a single "correct" way to implement RIDM

LIMITED	IN-BETWEEN	EXTENSIVE

WHERE ANY INDIVIDUAL COUNTRY, UTILITY, TECHNICAL AREA IS DEPENDS ON CONTEXT

LIMITED	IN-BETWEEN	EXTENSIVE
MOSTLY USED IN RESEARCH	FOCUSED ON HOW SAFE IS INDIVIDUAL SITE/PLANT	EXTENSIVELY USED BY MULTIPLE STAKEHOLDERS
LIMITED NUMBER OF EXPERTS	NOT USED ON DAY-TO-DAY APPLICATIONS – LIMITED RIDM	WIDESPREAD USE ACROSS LARGE REACTORS GLOBALLY
FOCUSED ON LARGE FEASIBILITY STUDIES	REGULATIONS FOCUSED ON ADDITIONAL SCRUTINY	RELIED UPON FOR PRACTICAL DAY-TO-DAY APPLICATIONS
LIMITED DATA, EXPERIENCE	GUIDANCE, WORKFORCE UNDER DEVELOPMENT	WIDER BASE OF GUIDANCE, STANDARDS, TECHNICAL DOCUMENTS
LACK OF CONFIDENCE FOR WIDER USE	EVOLVING TECHNICAL ADEQUACY OF PRA MODELS	EXTENSIVE TECHNICAL ADEQUACY BASIS AND EXPERIENCE
LIMITED TO NO GUIDANCE OR STANDARDS FOR PRACTICAL USE		

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There isn't a single "correct" way to implement RIDM

- An example: US NRC's [Action Plan on a Phased Approach (~2000s)]

"The phased approach defines the <u>needed PRA quality</u> for <u>current or anticipated applications</u> and the <u>process for achieving this quality</u>, while allowing risk-informed decisions to be made <u>using currently available methods</u> until all the <u>necessary guidance documents</u> defining the PRA quality are developed and implemented."

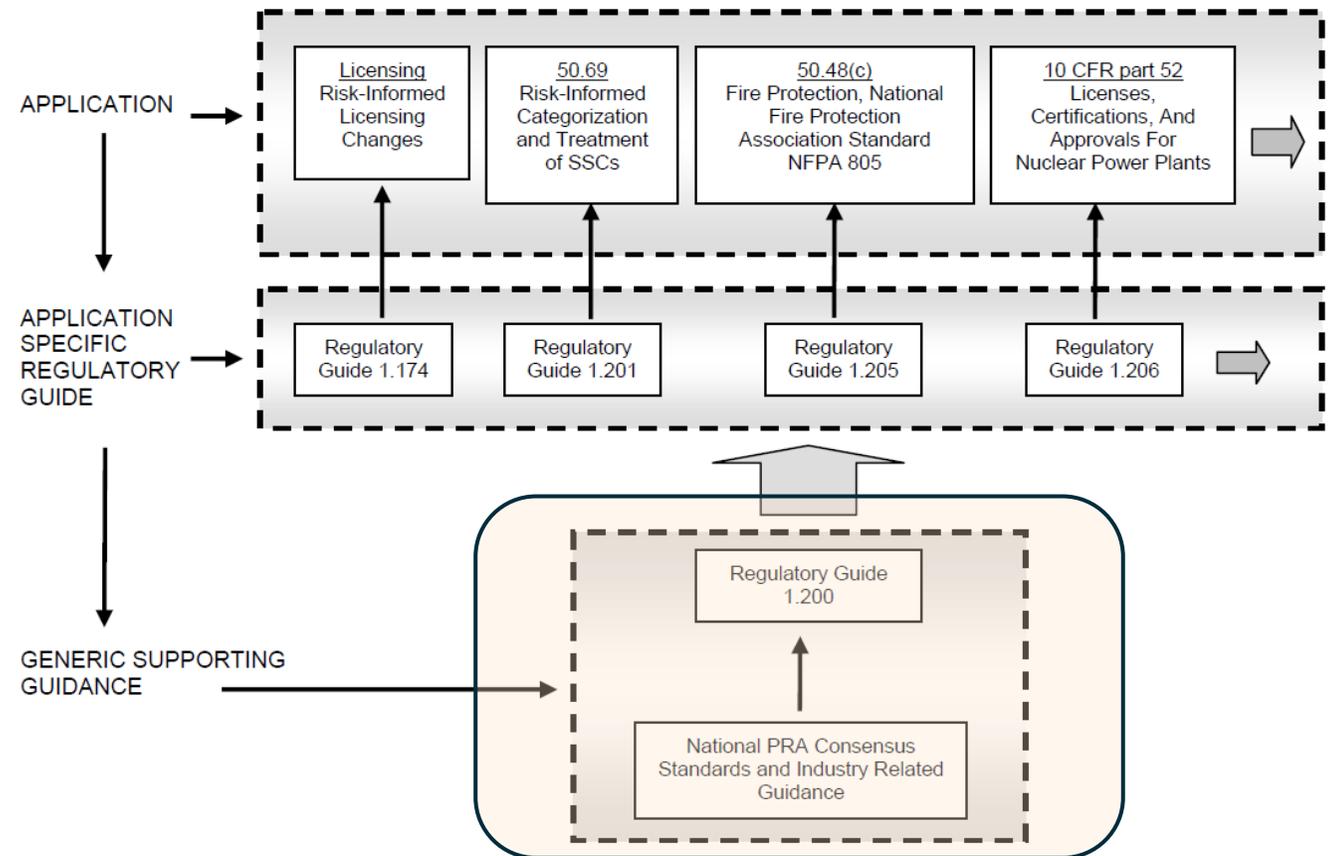| PHASE 1: An "Application-Specific" Phase of PRA Quality	PHASE 2: An "Application Type" Phase of PRA Quality	PHASE 3: An All-Applications Phase of PRA Quality

- <u>Industry movement</u> towards improved and more complete PRAs

- <u>Increased efficiencies</u> in the regulator's review of risk-informed applications

- Clarification of <u>regulatory expectations</u> (whether in rulemaking, licensing, oversight…)

- Continued <u>near-term progress</u> in enhancing safety through the use of <u>available risk-informed methods</u> while striving for <u>increased effectiveness and efficiency</u> in the <u>longer term</u>

LESSON LEARNED = Full PRA Technical Completeness is <u>not an impediment</u> to RIDM
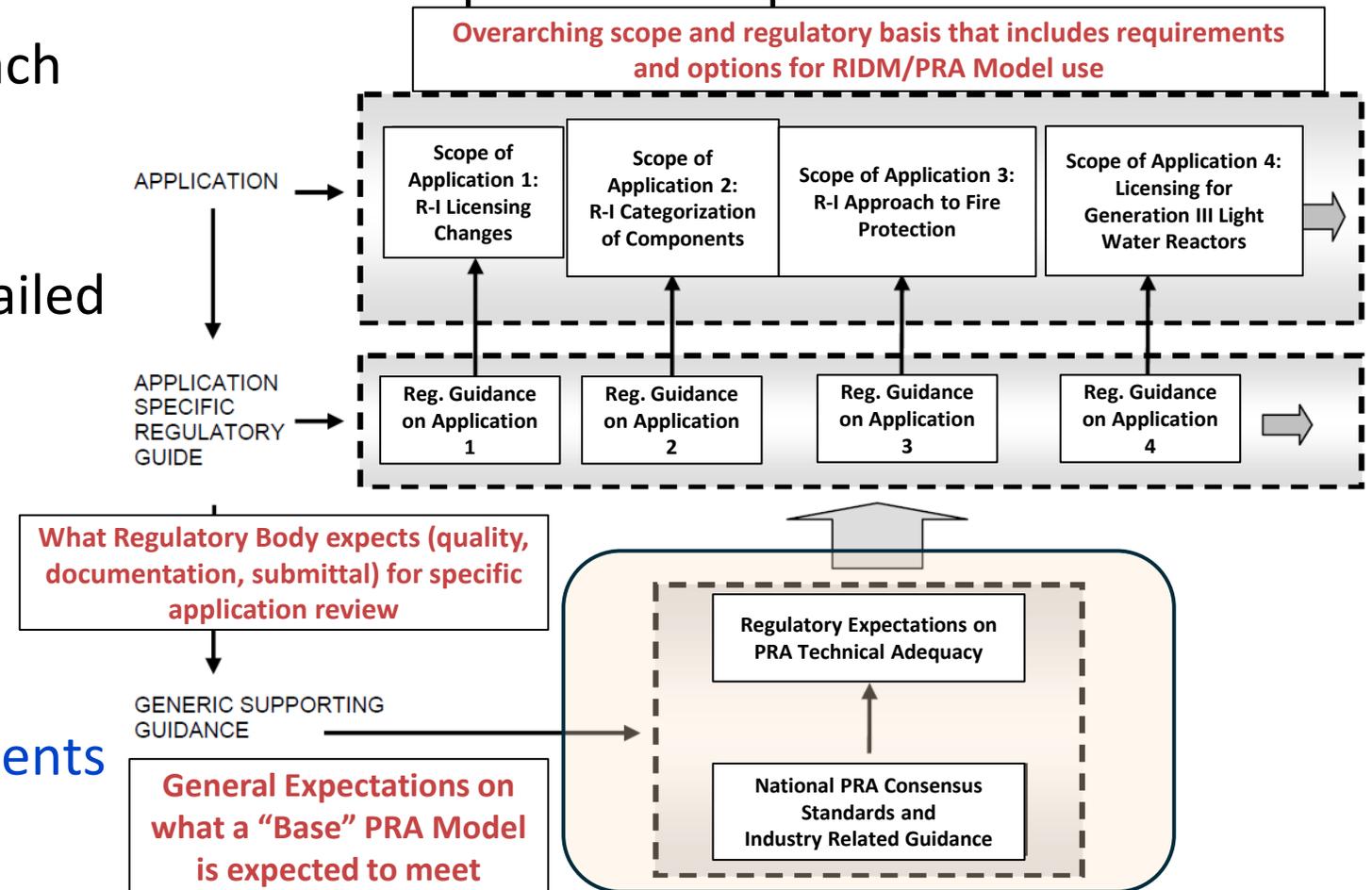
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Who Decides "How Good Does the PRA need to be"?

- Multiple documents typically focus on providing confidence in the PRA information (technical content accuracy sufficient to justify results,insights to support specific decision)

- **EXAMPLES:** regulatory position on PRA Standards and peer review process

- A PRA Standard not intended to teach about PRA modeling or how to make decisions in RIDM

- **BENEFIT:** Reduces the need for detailed review, approval of PRA model by the regulator

- Technical aspects are discussed in specific reports

- A structure with specific roles and expectations for the various documents is typically used, e.g., US →
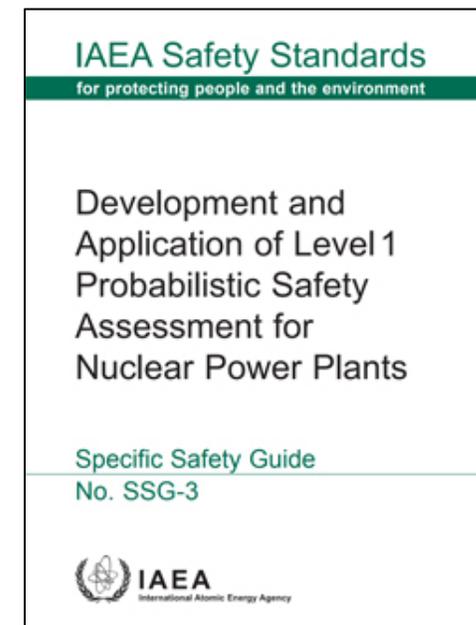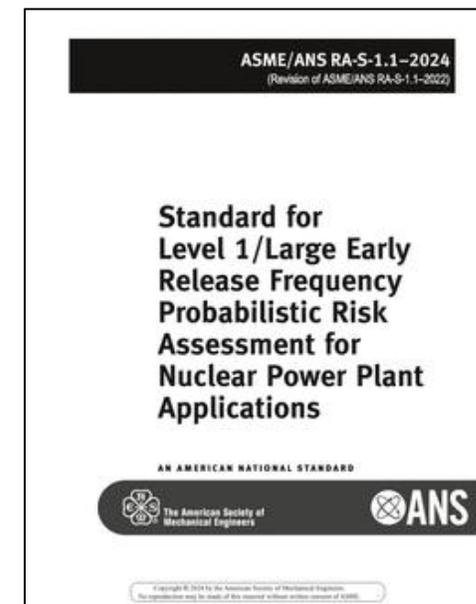

APPLICATION →
- Licensing Risk-Informed Licensing Changes
- 50.69 Risk-Informed Categorization and Treatment of SSCs
- 50.48(c) Fire Protection, National Fire Protection Association Standard NFPA 805
- 10 CFR part 52 Licenses, Certifications, And Approvals For Nuclear Power Plants

APPLICATION SPECIFIC REGULATORY GUIDE →
- Regulatory Guide 1.174
- Regulatory Guide 1.201
- Regulatory Guide 1.205
- Regulatory Guide 1.206

GENERIC SUPPORTING GUIDANCE →
- Regulatory Guide 1.200
- National PRA Consensus Standards and Industry Related Guidance

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Who Decides "How Good Does the PRA need to be"?

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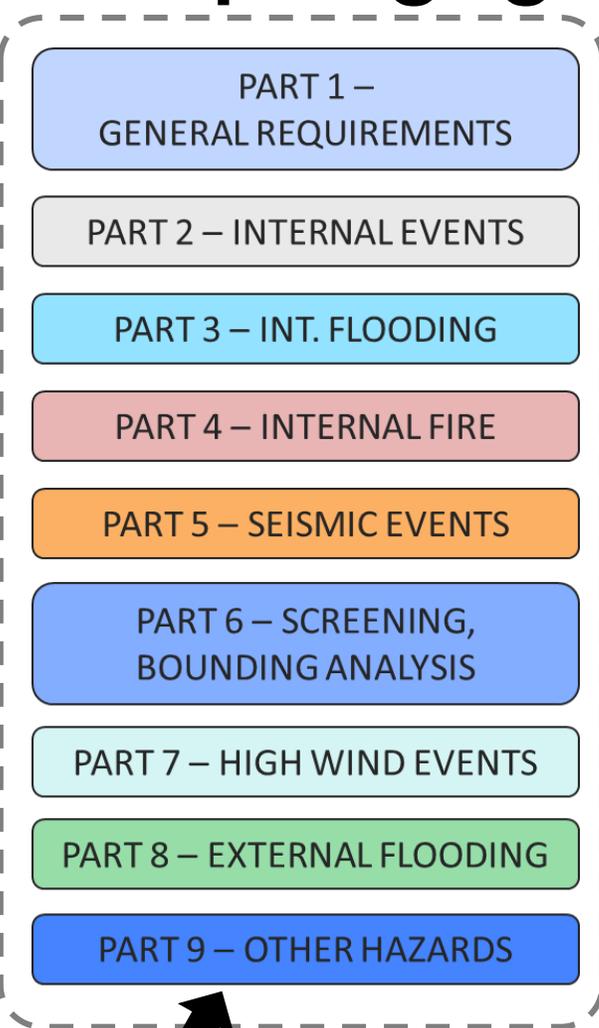
Overarching scope and regulatory basis that includes requirements and options for RIDM/PRA Model use

APPLICATION

| Scope of Application 1: R-I Licensing Changes | Scope of Application 2: R-I Categorization of Components | Scope of Application 3: R-I Approach to Fire Protection | Scope of Application 4: Licensing for Generation III Light Water Reactors |

APPLICATION SPECIFIC REGULATORY GUIDE

| Reg. Guidance on Application 1 | Reg. Guidance on Application 2 | Reg. Guidance on Application 3 | Reg. Guidance on Application 4 |

What Regulatory Body expects (quality, documentation, submittal) for specific application review

GENERIC SUPPORTING GUIDANCE

General Expectations on what a "Base" PRA Model is expected to meet

Regulatory Expectations on PRA Technical Adequacy

National PRA Consensus Standards and Industry Related Guidance

EPRI

Who Decides "How Good Does the PRA need to be"?

- In many countries, there is a consensus standard that sets requirements for using a PRA in RIDM for commercial nuclear power plants
  - Not necessary to meet all detailed technical requirements to meet the requirements for a specific application
  - IAEA Safety Series and other documents are also examples
- The standard does not describe "how to do a PRA", but what a PRA needs to have ("<u>what</u> to do")
- The final applicability of the use of the PRA is specific to each risk-informed application
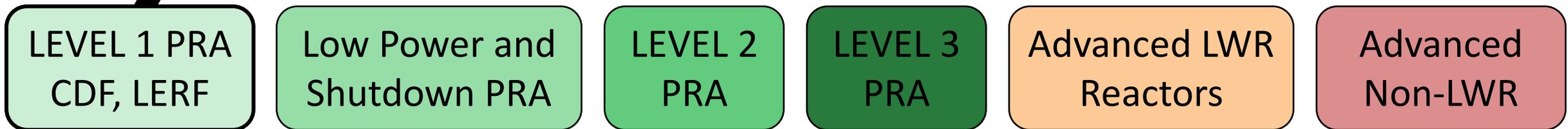 - A "graded approach" is needed as capabilities evolve

ASME/ANS RA-S-1.1–2024
(Revision of ASME/ANS RA-S-1.1–2022)

Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers — ANS

IAEA Safety Standards
for protecting people and the environment

Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants

Specific Safety Guide
No. SSG-3

IAEA
International Atomic Energy Agency

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Deep Engagement with Standard Development Orgs

PART 1 –
GENERAL REQUIREMENTS

PART 2 – INTERNAL EVENTS

PART 3 – INT. FLOODING

PART 4 – INTERNAL FIRE

PART 5 – SEISMIC EVENTS

PART 6 – SCREENING,
BOUNDING ANALYSIS

PART 7 – HIGH WIND EVENTS

PART 8 – EXTERNAL FLOODING

PART 9 – OTHER HAZARDS

- Consensus standard that sets requirements for PRA use in risk-informed decisions for commercial nuclear power plants

- Does not describe <u>how to do</u> a PRA, but <u>what</u> a PRA needs to have ("what to do")

- Final applicability of the use of PRA is specific to risk-informed application

- In the US, the Nuclear Regulatory Commission relies on the PRA Standard to assess if the PRA model is "good enough" for the specific application

- **<u>EPRI staff</u>** engaged directly in multiple aspects of standard

← *Multiple standards for different topics/designs* →

LEVEL 1 PRA
CDF, LERF

Low Power and
Shutdown PRA

LEVEL 2
PRA

LEVEL 3
PRA

Advanced LWR
Reactors

Advanced
Non-LWR

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How RIDM is Implemented is <u>Important</u>

- PRA technical adequacy is a <u>continuous</u> journey – NOT A FINAL DESTINATION

- Risk modeling should be <u>continuously exercised</u>

- Different applications have different levels of detail, scope, review

<u>REGULATORY ACCEPTABILITY</u>

Required scope, level of detail, technical robustness, and plant representation

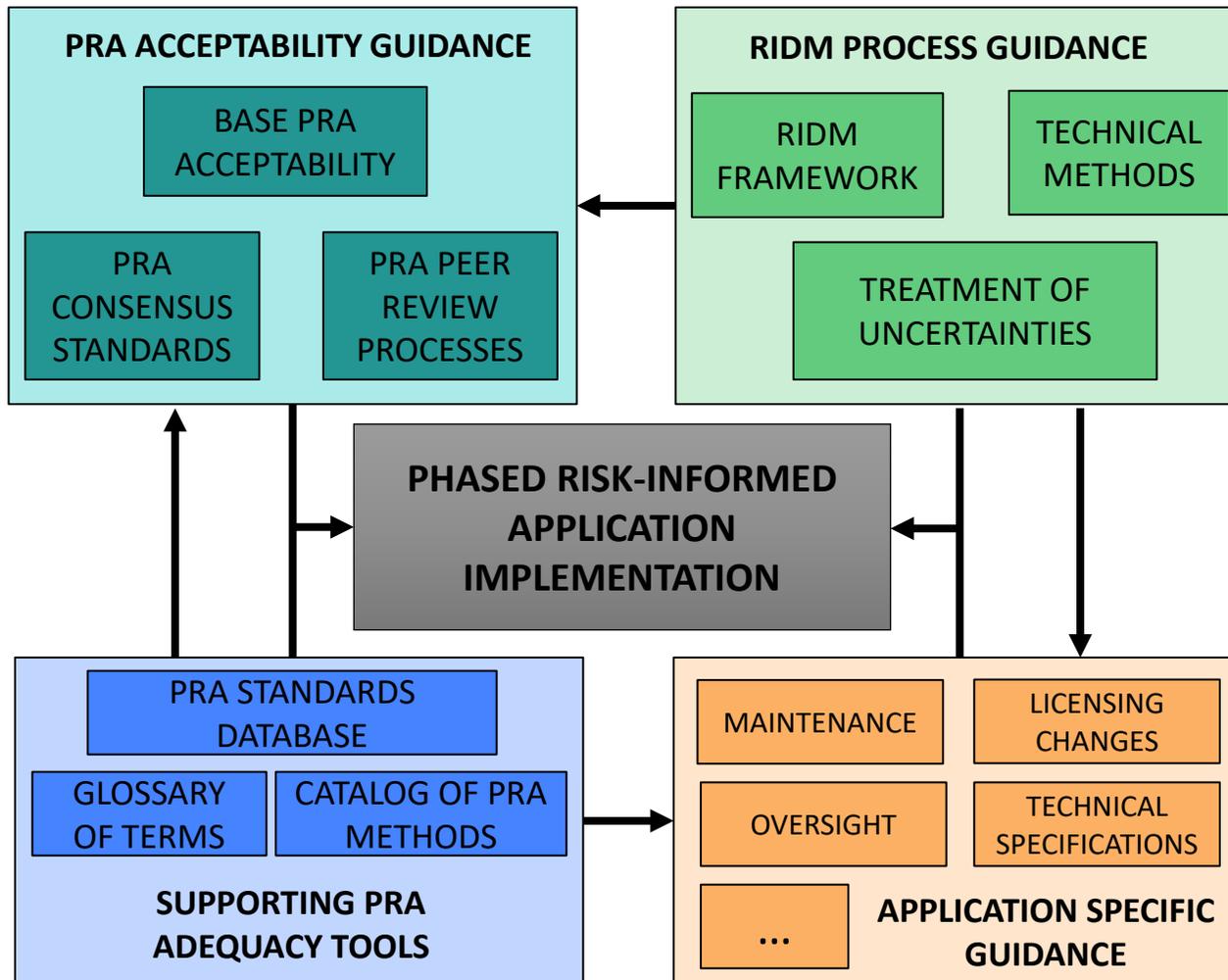**Extending Allowed Outage Time windows in Technical Specifications**

Risk-Informed Fire Protection Programs

Using alternate treatments for SSCs with low safety significance

Extending surveillance frequency intervals

Changing in-service inspection locations and/or components

SOURCE (adapted from) = Enclosure 1 - NRC Presentations on Lessons-Learned from Reviews of Risk-Informed Categorization and Treatment of Structures Systems and Components for Nuclear Power Reactors.

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How RIDM is Implemented is <u>Important</u>

PRA ACCEPTABILITY GUIDANCE
- BASE PRA ACCEPTABILITY
- PRA CONSENSUS STANDARDS
- PRA PEER REVIEW PROCESSES

RIDM PROCESS GUIDANCE
- RIDM FRAMEWORK
- TECHNICAL METHODS
- TREATMENT OF UNCERTAINTIES

PHASED RISK-INFORMED APPLICATION IMPLEMENTATION

SUPPORTING PRA ADEQUACY TOOLS
- PRA STANDARDS DATABASE
- GLOSSARY OF TERMS
- CATALOG OF PRA METHODS

APPLICATION SPECIFIC GUIDANCE
- MAINTENANCE
- LICENSING CHANGES
- OVERSIGHT
- TECHNICAL SPECIFICATIONS
- ...

Adapted from US NRC Figure in Risk-Informed Activities Technical Guidance Program | NRC.gov

Elements that provide confidence in RIDM are essential:

- A <u>living, continuously evolving</u> set of standards and guidance on specific PRA technical adequacy elements

- <u>Robust guidance</u> on the implementation aspects of RIDM

- Venues for <u>multiple stakeholders</u> to participate in the development of RIDM guidance, standards, processes

Creating a sustainable RIDM approach is key!

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Effective RIDM and PRA Practices

- Different approaches to PRA organizations can be found among nuclear utilities, but common elements include:

  - Utility responsibility: the plant "owns" the model and is responsible for its technical content and use

  - Plant-specific application of PRA
    - For voluntary applications, the plant determines which ones it needs to pursue, and how to implement the specific aspects of the application
    - The PRA organization leads the development and implementation of the applications in coordination with other plant organizations

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Effective RIDM and PRA Practices

- PRA capabilities & infrastructure
  - PRA staff are not the only ones who need these capabilities
  - Training of operators and other plant staff in PRA should be expected and become routine

- Risk communication
  - Common practice to post risk information throughout plant
  - Promotes a safety-conscious culture among employees
  - Helps to highlight specific aspects of the plant that should be protected

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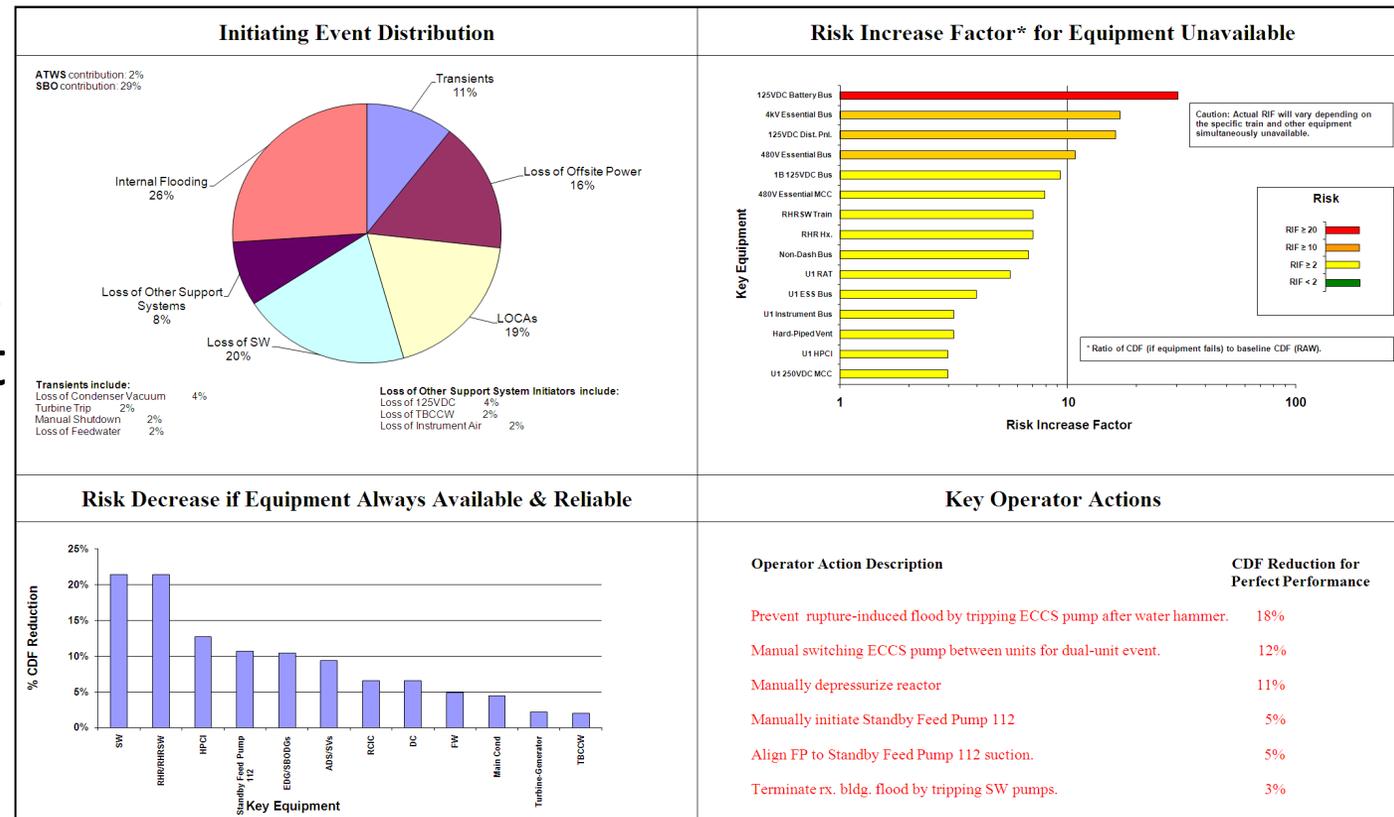
RIDM Interfaces within a Nuclear Utility
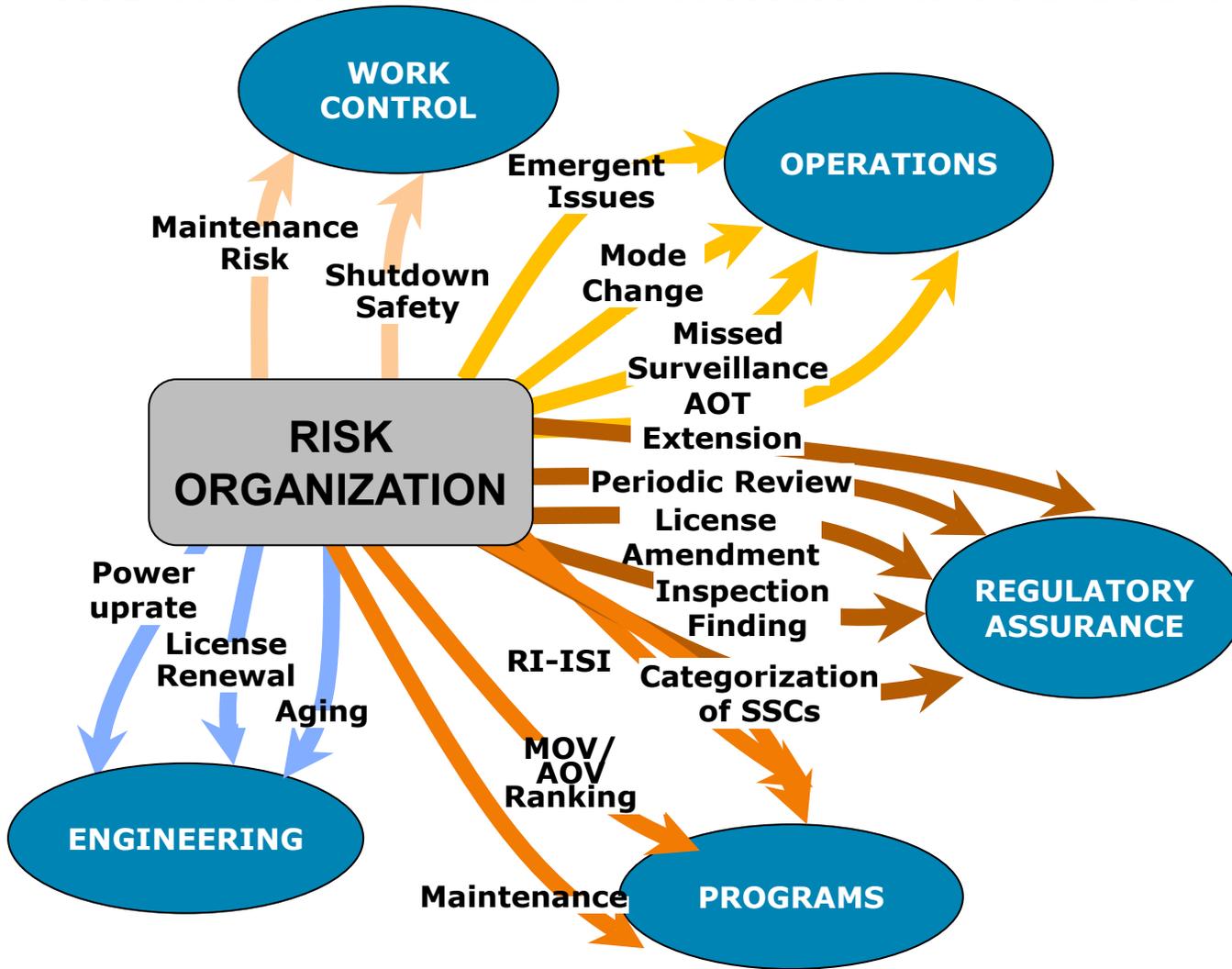
As RIDM expanded organically, there is a synergy arising from various uses

- PRA is used throughout the organization

- There are many different applications, which can require different approaches and risk criteria

- The increasing use of PRA is a major challenge to PRA organizations

Adapted from Nuclear Energy Institute's image – September 23, 2021

As RIDM Evolves, New Challenges and Opportunities Arise

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Managing PRA Use/Cost <u>Key</u> to RIDM Success

- Like many other nuclear aspects, PRA models can be highly refined and integrate large/diverse inputs
  - E.g., changes in one aspect impact the others
- With the expanding use of risk-informed applications, managed implementation is key
- Focus is on ensuring a sustainable path forward
- Leveraging global operating experience essential

"PRA ENGINE"

EPRI Report 3002020760
"EPRI PRA Maintenance Optimization: 2021 Industry Survey Results"

Publicly Available

SUMMARY – RIDM BENEFITS

- Ensures focus is on the most risk significant aspects

- Helps understand residuals risks in a way that supplements deterministic analysis

- Creates a highly skilled, well-informed workforce with an integrated understanding of operations, design, licensing, and many other aspects

- Provides inputs into challenging decision-making conversations

- Significant global implementation allows for the sharing of operating experience

A LOT OF FOCUS HERE

QUANTITATIVE RESULTS
(e.g., CDF, ΔCDF)

MOST OF THE RIDM BENEFIT IS OBTAINED HERE

RISK INSIGHTS
- Cutsets
- Relative Ranking
- Key operator actions
- Uncredited actions
- Potential Biases
- Completeness

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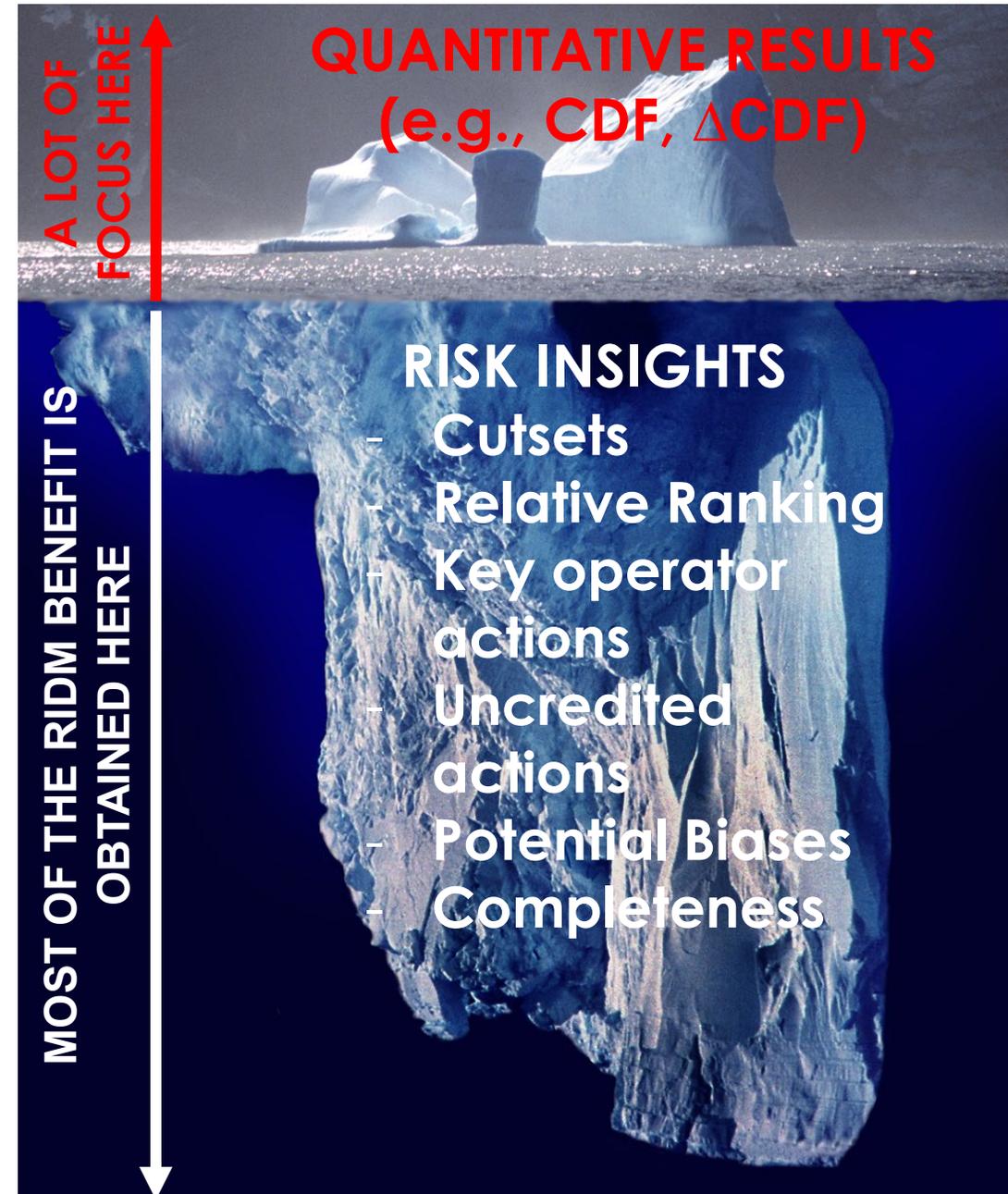
SUMMARY – IMPLEMENTING RIDM

- Implementing RIDM does require consideration of how, when, how fast, and with what resources
  - How well-refined does the PRA model itself need to be to support RIDM?
  - Common understanding between utility and regulator for RIDM implementation
  - The RIDM approach in one country does not necessarily need to be the same as in other countries (focus on key elements) – there is flexibility
  - Choosing specific applications to test RIDM use can help further expansion

A LOT OF FOCUS HERE

QUANTITATIVE RESULTS (e.g., CDF, ΔCDF)

MOST OF THE RIDM BENEFIT IS OBTAINED HERE

RISK INSIGHTS
- Cutsets
- Relative Ranking
- Key operator actions
- Uncredited actions
- Potential Biases
- Completeness

Question & Answer Time

- Questions about the presentation content?
  - RIDM overview
  - The role of risk assessment
  - Benefits of RIDM
  - Requirements for RIDM
  - RIDM applications for current and future plants
- Questions about our experiences?
  - Specific RIDM applications
  - PRA technical capabilities and requirements

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Good Questions for You to Use

- What is included in the PRA model?

- To what level of detail are seismic, high winds, & other hazards considered?

- How recently has the PRA for this hazard been updated?

- What is not modeled in the internal events PRA model?

- What are the key risk drivers in the PRA model results?

- Is the risk result based on bounding assumptions or best estimate?

- Has the PRA model been peer reviewed (such as against the PRA standard)?
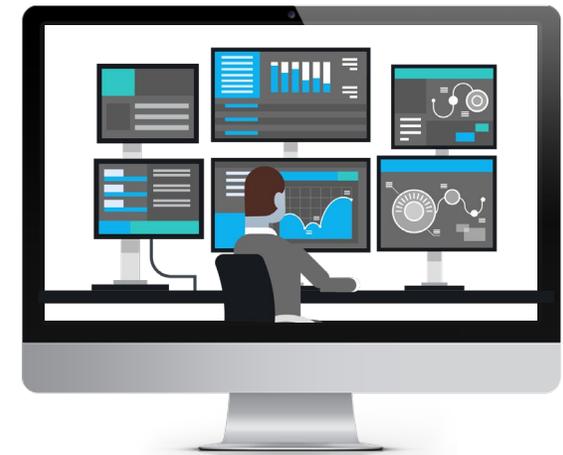
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EXPERIENCE WITH RIDM APPLICATIONS

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EPRI/RSM Work Continuously Supports RIDM

Risk Methods and Applications

- **Common Risk Technology**
  - Level 1 and Level 2 PRA Methods
  - Risk Insights and Risk-informed decisions
  - Risk-Informed applications
  - 50.69 – Voluntary Risk-Informed Engineering Regulation in the US
- **Human Reliability Analysis (HRA)**
- **Risk/resilience to climate change**
- **Generation Risk Assessment**

Hazards

- **Hazard Curve, Fragility Data and Calcs, PRA Methods**
- **Fire PRA**
  - Methods, Tools, Data for performance of Fire PRA
- **Seismic PRA**
  - Methods, Tools, Data for performance of Seismic PRA
- **Other External Hazards**
  - Focus currently is External Flooding and High Winds
- **Coincident Hazards**
- **Monitoring for Changes in External Hazards**
- **Site-specific Climate Change Hazard Data**

Items in blue text are Supplemental projects (not base)

Implementation and Tech Transfer

- **Risk Software**
  - Integrated Risk Technologies (IRT)
    - Phoenix Architect/ CAFTA (Modeling)
    - Phoenix Risk Monitor/ EOOS (Risk Monitor)
  - HRA Calculator
  - FTREX (Quantification Tool)
- **Severe Accidents and T/H**
  - MAAP Severe Accident Code
  - GOTHIC Thermal Hydraulic Code
- **Training**
  - Education of Risk Professionals (ERP)
  - PRA and non-PRA Staff Courses

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RSM Group Interconnected with other groups and programs

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Workforce Development is key for sustainable RIDM

Experience with RIDM Education and Knowledge Transfer

- **Education of Risk Professionals**
  - Program launched in 2007; provides fundamental PRA knowledge and skills for Level 1 PRA topics
  - 20 graduates in the 2023-2024 series
  - 235 graduates total; approximately 33,000 professional development hours
- **Computer Based Training** primarily for management
  - Includes an introduction to PRA, PRA fundamentals, risk-informed regulation, and risk-informed decision-making
- **Specialized PRA Courses and Training**
  - HRA Fundamentals, Fire PRA Fundamentals
  - Seismic PRA, Seismic Fragility
  - IRT and HRA User Group software training – multiple events scheduled each year
    - IRT UG collaboration website – software resources
    - HRA UG collaboration website – software resources
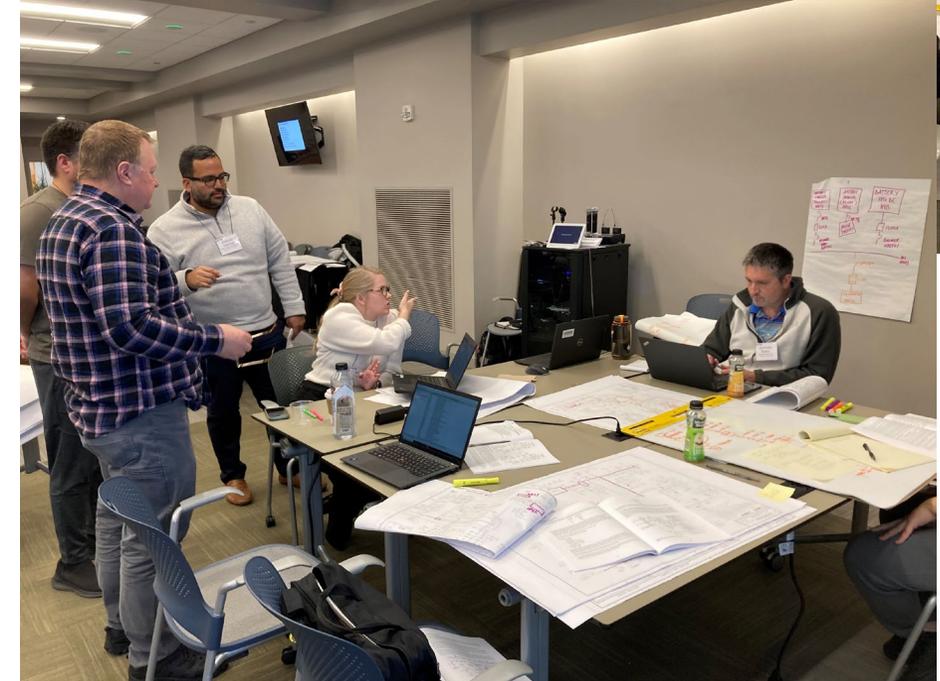
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Enhancing Safety and Efficiency Through Risk-Informed InService Inspection (RI-ISI)

Presenting the Results of a Pilot RI-ISI Study Performed on System RC – Barakah NPP
EPRI Report IR-2024-0855

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02/18/2026

Enhancing Safety and Efficiency Through RI-ISI

About Me - Andrew Ceto

EPRI Gulf – Technical Executive

UAE – Abu Dhabi

- Past Experience

  UAE – ENEC Barakah Nuclear Power Plant (9 years)

  ➤ Eng Program Head, Senior Engineering Manager

  South Africa - Eskom Koeberg NPP (18 years)

  ➤ Welding & NDE / ISI Program/ LTO / Engineering Program Manager

Enhancing Safety and Efficiency Through RI-ISI

Introduction - RI-ISI Industry Experience

- RI-ISI methodologies improve safety, reduce worker radiation exposure and prioritize inspection of locations most susceptible to Degradation.

- Has been shown to enhance plant safety compared to traditional inspection methods.

- Methodologies can lead to reduced inspection costs and minimized outage impacts.

- Quality of plant-specific Probabilistic Risk Assessments (PRAs) and available design information important.

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Enhancing Safety and Efficiency Through RI-ISI

Objectives

Pilot Study performed by EPRI to evaluate the application of RI-ISI methodologies to enhance safety and efficiency:

- Evaluate feasibility of RI-ISI implementation
- Assess plant-specific data quality (PRA, Design, Ops)
- Demonstrate safety and efficiency gains
- Align with international best practices and regulatory frameworks

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Enhancing Safety and Efficiency Through RI-ISI

Scope

- Applied to Reactor Coolant System (RCS)

- Focused on ASME Class 1 piping welds (B-F and B-J)

- 403 welds evaluated for degradation and risk significance

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Nondestructive Evaluation
Internal Report

Barakah RI-ISI Pilot Study
IR-2024-0855

Enhancing Safety and Efficiency Through RI-ISI

RI-ISI Methodologies Applied

- Traditional RI-ISI (ASME Section XI, Appendix R)

- Streamlined RI-ISI (ASME Code Case N-716)

- Both methods focus on enhancing safety by:

  - Integrating PRA and degradation mechanism analysis

  - Focus on safety significance and

  - Inspection optimization

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Enhancing Safety and Efficiency Through RI-ISI

Key Technical Findings

- Sufficient data and PRA quality exist to support RI-ISI application

- Identified Degradation Mechanisms susceptibility:

  - Thermal fatigue
  - Stress corrosion cracking
  - Flow-accelerated corrosion
  - Erosion-cavitation

- High-risk welds prioritized; low-risk welds identified for scope optimization

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Enhancing Safety and Efficiency Through RI-ISI

Risk Impact & Safety Evaluation Results

- ΔCDF and ΔLERF remained well below regulatory thresholds
- High Safety Significant (HSS) welds retained
- Low Safety Significant (LSS) welds down scoped
- Overall safety maintained or improved

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Enhancing Safety and Efficiency Through RI-ISI

Enhancement and Optimization

Inspection Scope Comparison		
Approach	Weld Inspection Locations	% Reduction vs Deterministic
Deterministic ISI	109	—
Traditional RI-ISI	34	~69%
Streamlined RI-ISI	41	~62%

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Enhancing Safety and Efficiency Through RI-ISI

Conclusion

The pilot has demonstrated that RI-ISI enhances safety, reduces unnecessary inspections, aligns with international standards, while prioritizing the inspection of locations most susceptible to degradation mechanisms and increased risk.

RI-ISI Implementation Roadmap – Key Activities

- Preparation & Capability Building
- RI-ISI Program Development
- Regulatory Approval & Stakeholder Engagement
- Implementation Confirmation
- Monitoring, Feedback & Continuous Improvement

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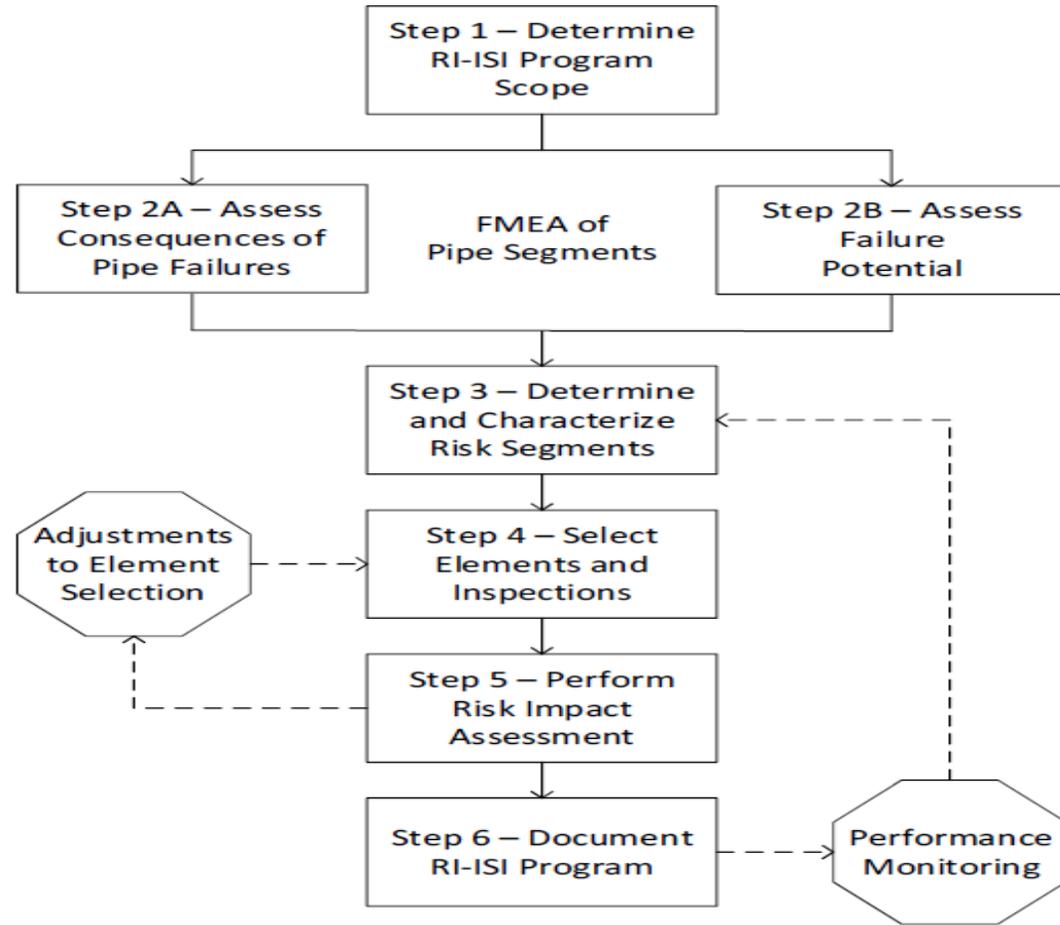
Figure 2-1: Overview of the EPRI Traditional RI-ISI Methodology

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DEVELOPING A RIDM FRAMEWORK FOR UAE

Concepts for a RIDM Framework

- Objective: Collaboratively develop a UAE framework for implementation of RIDM approaches in the nuclear industry
  - Build on the work of others, but built for UAE
    - Process requirements
    - Quality & scope requirements
    - Risk thresholds
  - Support for all organizations: ENEC, FANR, KU, etc.
  - Support for near-term issues and long-term growth
- EPRI expertise & resources
  - Unbiased technical reputation
  - Global work including with IAEA
  - Experience with practical implementation of RIDM

Key Development Questions

- What areas of the UAE nuclear industry can benefit from RIDM?

- What overall framework is needed to support the development and implementation of RIDM across the UAE industry?

- How will the interests of key UAE stakeholders be captured within the RIDM framework?

- How ready are risk analysis methods and tools to support applications of RIDM in the UAE, and what new method development is necessary?

- What training/knowledge transfer is needed to build the necessary capabilities for operators and regulators?

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Phased Approach for Framework Development

- Phase 1 – Project Launch

  - UAE project participants will identify and establish communications with key UAE stakeholders such as plant operators, regulators, and research organizations

  - EPRI will coordinate with these key stakeholders to hold workshops and meetings to gather input and ensure alignment of the project's objectives

    - At least <u>one in-person workshop</u> will be planned, supplemented with virtual meetings as needed

  - EPRI will consolidate input from key stakeholders to define the plan for the development of a UAE RIDM framework, initially focused on support for the current operating nuclear power fleet

Phased Approach for Framework Development

- Phase 2 – Process Development
  - EPRI will partner with UAE stakeholders to develop recommendations for initial modifications to regulatory and operational processes to enable RIDM, including
    - Identification of organizational responsibilities and impacts
    - Identification of technical requirements
    - Potential changes to regulations
    - Potential development of regulatory guidance
    - Identification of high-priority RIDM applications
  - EPRI will provide guidance for the development of training programs for UAE stakeholders to effectively use RIDM tools and processes
  - EPRI will provide guidance for ongoing monitoring of UAE industry and regulator performance related to risk assessment and management

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Phased Approach for Framework Development

- Phase 3 – Pilot Application(s)

  - EPRI will provide technical and programmatic support to the first RIDM application (to be selected in coordination with UAE stakeholders)

  - As needed, EPRI will provide continued technical and programmatic consultation on subsequent RIDM applications, while depending on the increasing capabilities of UAE stakeholders to lead the applications

Framework Value

- **Enhanced Safety and Reliability**
  - RIDM integrates both deterministic and probabilistic analyses, leading to more comprehensive safety evaluations that ensure that critical safety issues receive the necessary attention

- **Optimized Resource Allocation**
  - By focusing on the most significant risks, RIDM allows for more efficient use of resources that enhances overall operational efficiency for both the nuclear industry and the regulator

- **Improved Regulatory Compliance**
  - RIDM provides a structured framework for meeting regulatory requirements by supporting transparent and evidence-based decision making for better interactions with regulators

- **Increased Public Confidence**
  - A risk-informed approach demonstrates a commitment to safety and transparency, which can enhance public trust in nuclear operations

- **Team Development**
  - A collaborative approach to this project will enable the UAE stakeholders to develop their own personnel through increased awareness of risk-informed decision-making processes, improved PRA technical expertise, and strengthened communication opportunities
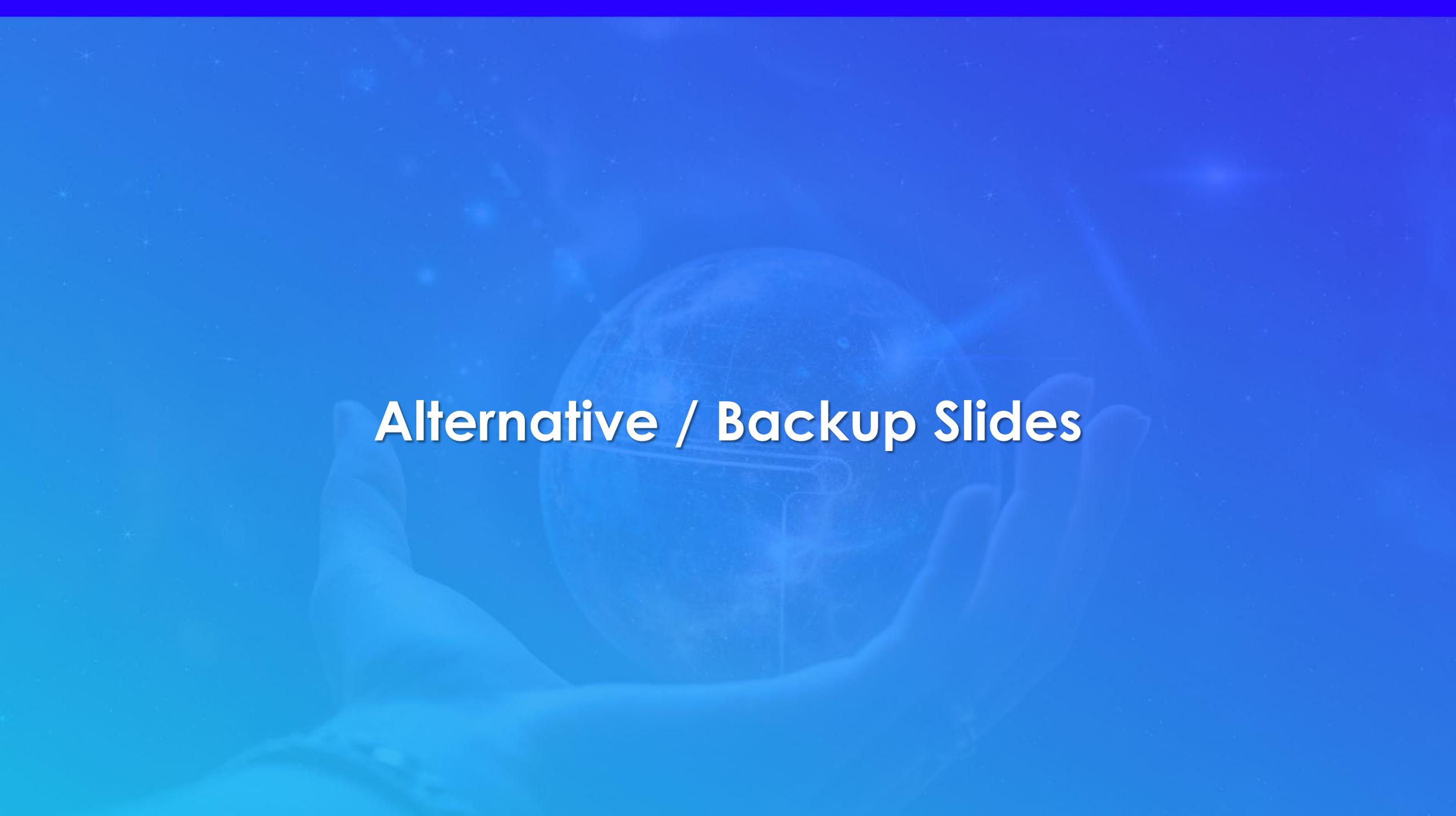
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Roundtable Discussion

- What challenges does your organization face with decision making?
  - Plant operation
  - Regulatory processes
  - Safety prioritization
- What capabilities do you need to apply a RIDM approach?
  - Technical training
  - Process guidance
- What do you want to achieve with this RIDM framework?
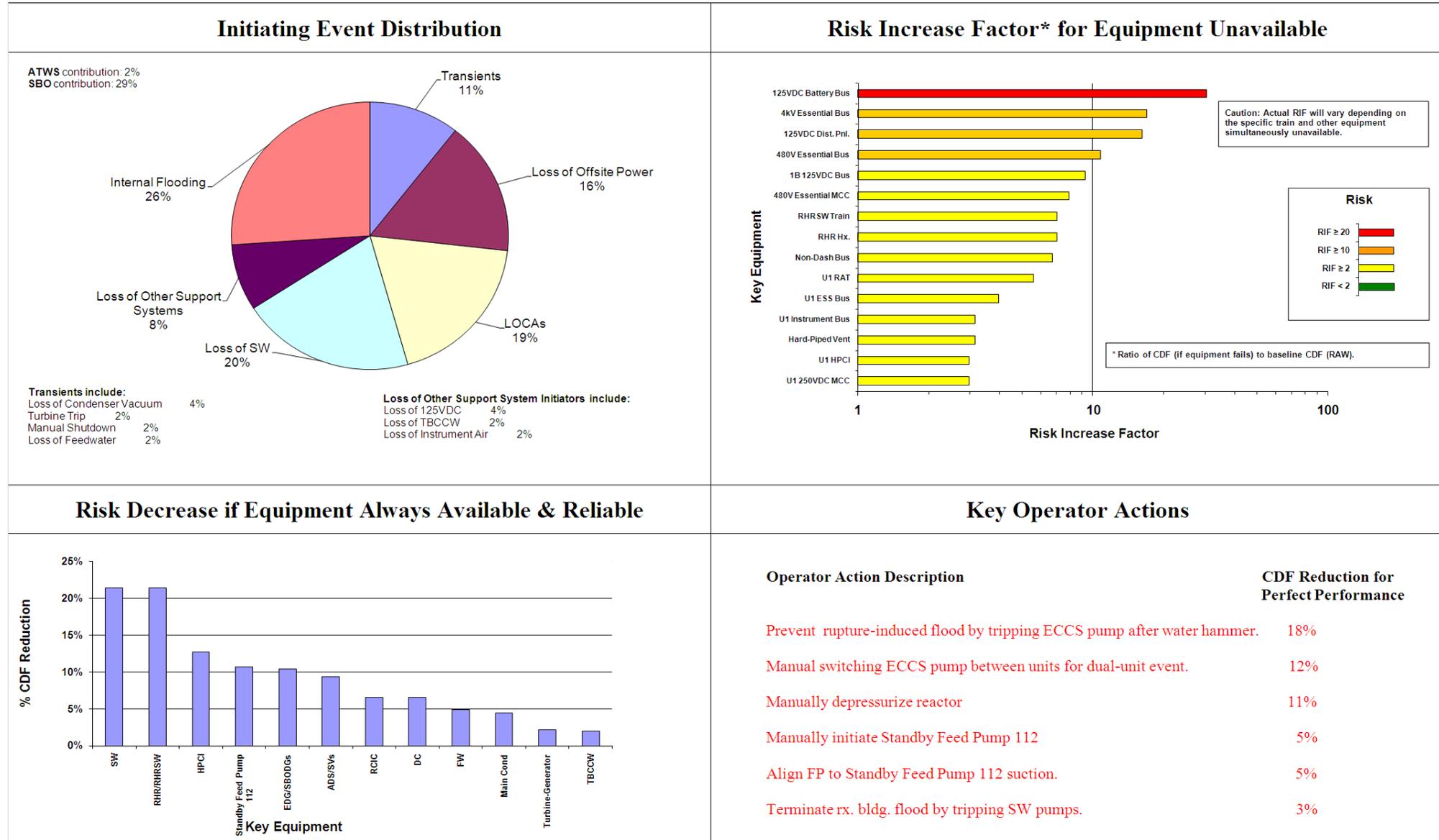
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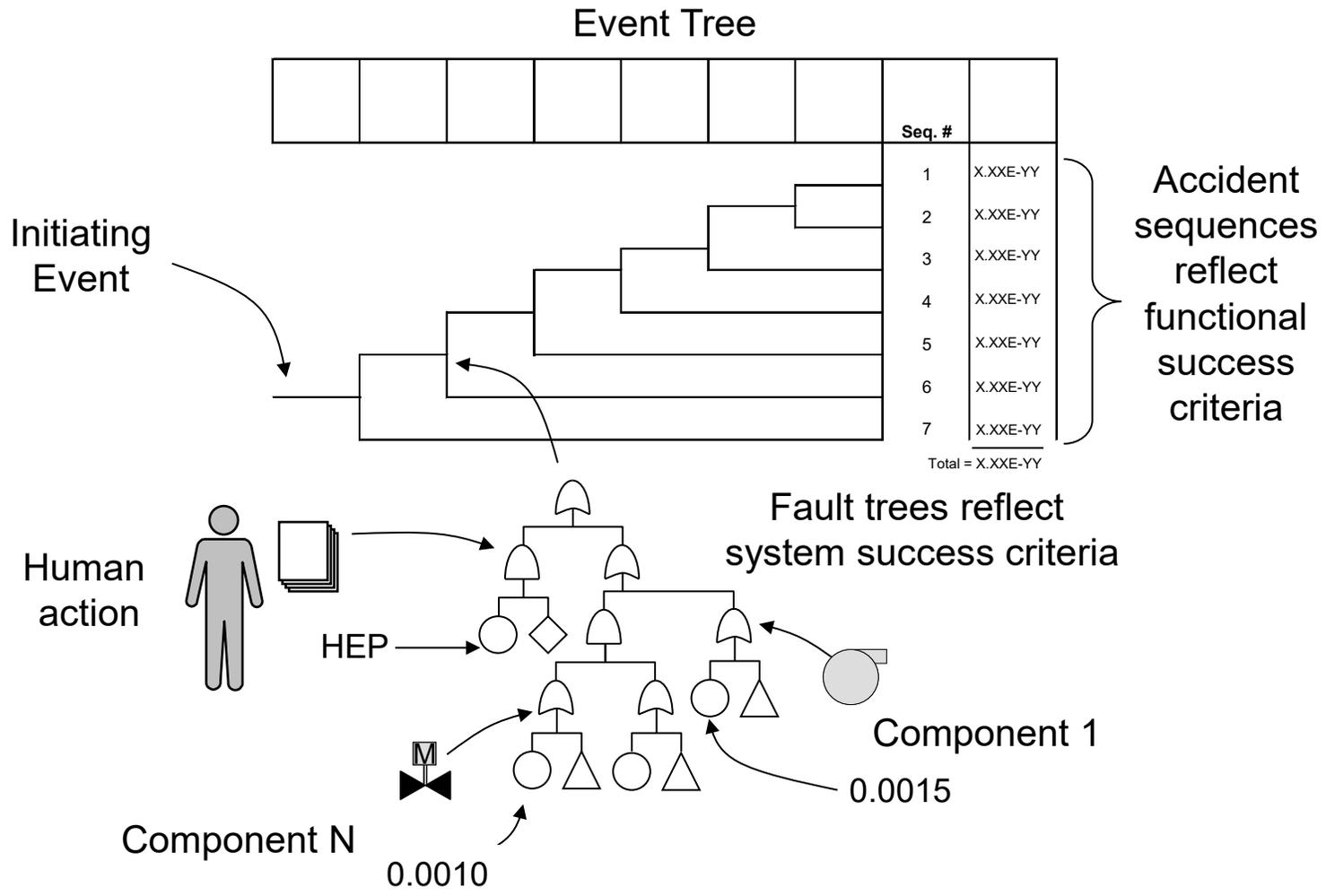
Alternative / Backup Slides

EPRI's PSA Applications Guide

- EPRI TR-105396 is an applications guide that provides technical basis for using risk results and insights

- Key elements include:
  - Application planning
  - Analysis
  - Results interpretation
  - PRA maintenance and update

- Ultimately, NRC's regulatory guides adopted similar concepts and provided NRC-specific details, but many concepts and elements are still relevant:
  - Use of importance measures
  - Use of core damage frequency (CDF) & large early release frequency (LERF) as risk metrics
  - Graded approach to quantitative acceptance guidelines

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Example PRA Outputs

Review of PRA Model Elements

Event Tree

Initiating Event

Seq. #	
1	X.XXE-YY
2	X.XXE-YY
3	X.XXE-YY
4	X.XXE-YY
5	X.XXE-YY
6	X.XXE-YY
7	X.XXE-YY
Total =	X.XXE-YY

Accident sequences reflect functional success criteria

Fault trees reflect system success criteria

Human action

HEP

Component 1

0.0015

Component N

0.0010

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Plant Risks Change Over Time

- A plant-specific PRA typically calculates annual average risk
  - For example, core damage frequency or large early release frequency
- The level of risk changes with time due to:
  - Changes in plant configurations
    - System alignment changes
    - Equipment taken out of service
      - Planned maintenance
      - Emergent maintenance
      - Testing
    - Operating mode changes
  - External plant conditions
    - Severe weather
    - Seasonal differences (for example, summer vs. winter heat loads)
  - Plant changes to design, procedures, training, etc.

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Traditional Safety Approach vs. PRA

Consideration	Traditional Approach (Design Basis)	PRA
Scope of Events Analyzed	• Pre-defined set of events • Assumes design basis events are bounding	• Not constrained by pre-defined rules
Failure Scenarios Included	• Worst single active failure assumed to occur	• Unlimited number of failures are considered probabilistically
Common Cause Failures	• Assumed to be precluded through design, testing, inspections, etc.	• Probabilistically considered for common components based on experience
Human Actions	• Assumed effective when proceduralized	• All human actions are probabilistically considered
Approach to Uncertainties	• Dependent upon bounding assumptions	• Focus on mean (realistic) estimate • Assess uncertainties quantitatively

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PRA Outputs

While the numerical PRA model results receive a lot of attention, real benefits are derived from the risk insights, for example:

- Understanding the most risk significant systems and components in your plant

- Recognizing specific human actions that may need more training than others

- Finding combinations of failures not previously known (e.g., shared dependency)

- Recognizing specific evolutions during an outage that may increase/decrease risk
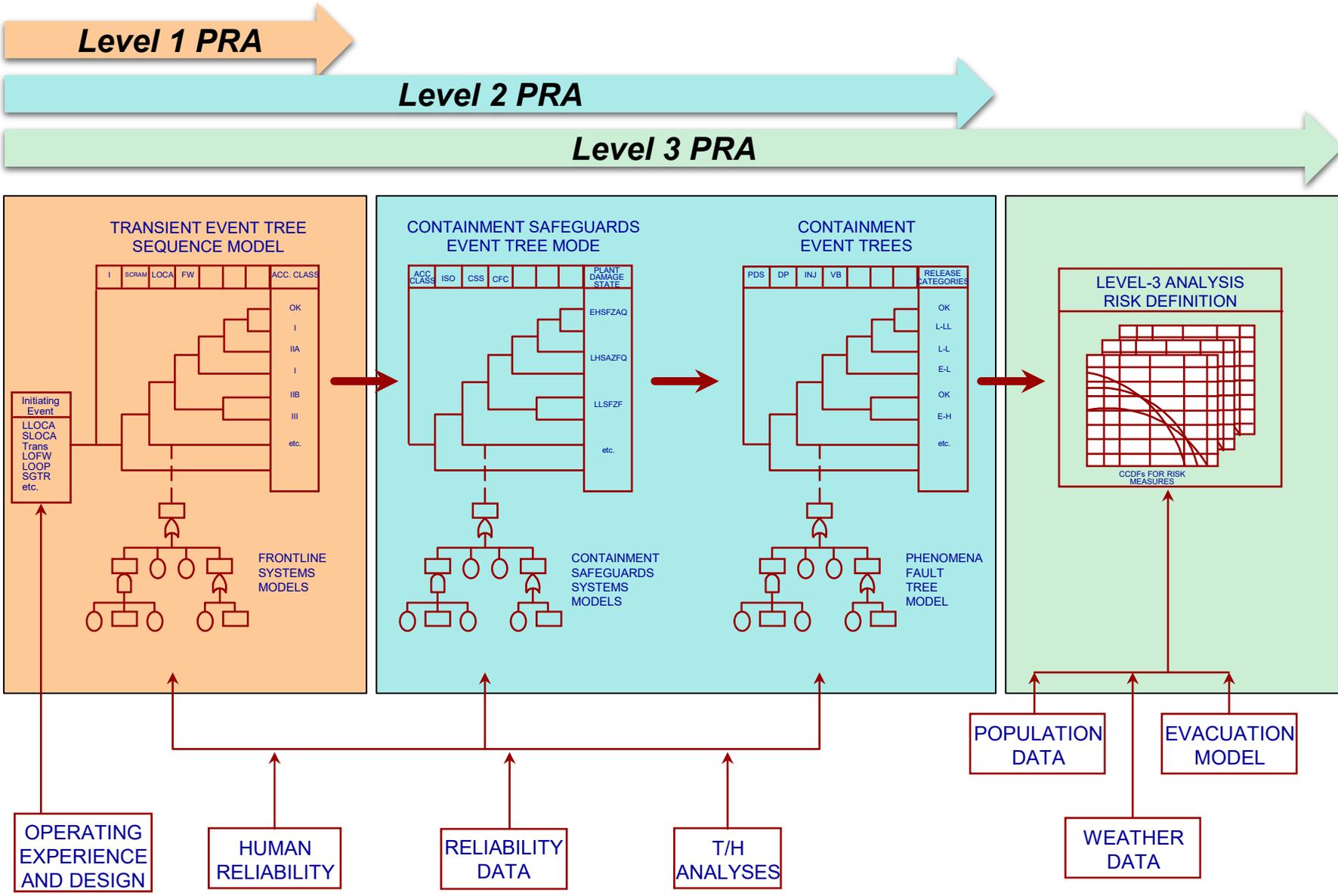
- Identifying systems or components that have very little risk contribution (e.g., reduce cost)

- Anticipate specific actions that may help reduce risk during events (e.g., weather)

RISK INSIGHT

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Basic Elements of a PRA

Summary: Need for Realism in PRA

- One of the distinct challenges in PRA is the <u>requirement</u> for realism

- Unlike traditional deterministic analysis, PRA is intended to provide a realistic quantification
  - What is the level of plant safety?
  - What are the important contributors to risk?

- Introducing conservatisms creates problems
  - Distortion of the results
  - Masking of important risk insights

EPRI research focuses on improving realism of PRA approaches

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Questions & Answers

- How do US utilities use risk information decision-making? What sort of formal processes have been used?

  - Utilities in the US generally do not use a very prescriptive process for incorporating risk information in decisions. Risk reduction is considered as one (very important) attribute in making the decision, but a formal process or mathematical model is not generally used.

- How do US utilities report risk information to their executives? How do they ensure such information is used in improving plant safety and safety culture?

  - Utility risk organizations report results at a high level to all utility management. These reports include recommendations for safety improvements. Such information is also posted prominently in the plant, such as at personnel entry portals.

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Questions & Answers

- How do US utilities account for uncertainty in making decisions regarding the use of risk information?
  - Consideration of uncertainty is very important to the use of risk information in decision-making. EPRI has developed guidance for such use, published in reports such as:
    - 1026511: Practical Guidance on the Use of Probabilistic Risk Assessment in Risk-Informed Applications with a Focus on the Treatment of Uncertainty
    - 1010068: Aggregation of Quantitative Risk Assessment Results

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Questions & Answers

- Where do the numbers in the PRA come from? Are they just made up?
  - Many inputs in the PRA are based on actual data, for example
    - The number of failures of specific SSCs
    - The rate of observed pipe breaks
    - The occurrence of observed weather conditions
  - Some inputs in the PRA, such as the frequency of extreme events, are based on expert assessment/elicitation
    - Examples: Large pipe breaks, extreme earthquakes
    - Their pedigree can vary from detailed to bounding to individual estimates
  - The overall PRA result will aggregate many sources of data, uncertainty, levels of maturity, and confidence in the inputs
  - Core damage events have occurred, but their frequency is such that the risk is low
  - What we do with insights from the PRA models is more important than "the number"

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