

# Practical Risk-Informed Decision Making Aspects for Mid-Managers

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# Practical RIDM Aspects for Mid-Managers

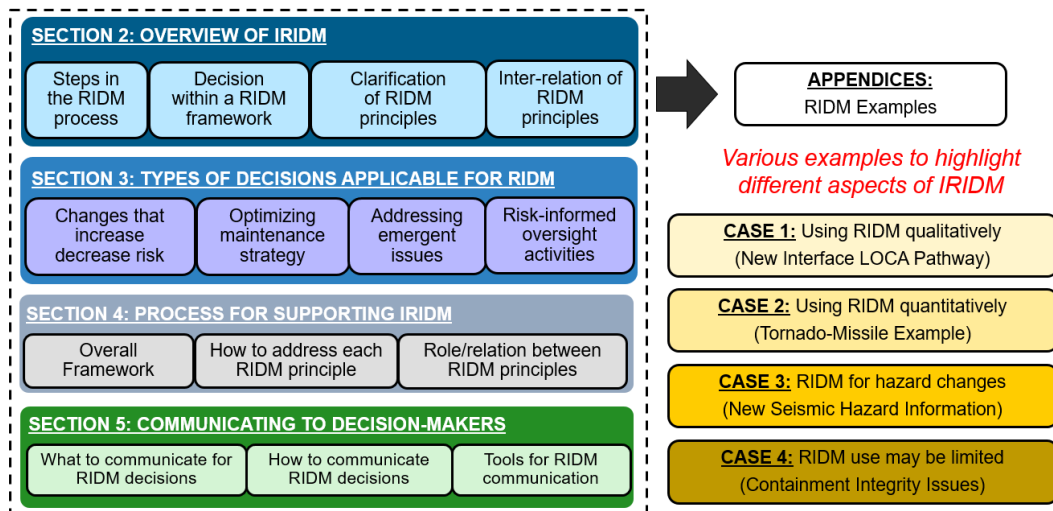
- Minimum knowledge needed on PSA
- Consuming information effectively
- Understanding and communicate risk
- Aggregating the information for decision-making
- Confidence and document the decision-making
- Cost-value aspect on the decision-making

# Practical RIDM Aspects for Mid-Managers

- Better with a structured process
- Lack of transparency or confusion is not an element of RIDM, it's often due to:
  - Poor implementation, poor communication, poor training
- It is ok to consider whether RIDM should be used (or not)
- But it should be consistently applied AND the basis and outcome should be clear
- Again, non-technical aspects critical, as much as technical



**RIDM should not look like a “Rorschach test”**



[EPRI 3002014783](#), “A Framework for Using Risk Insights in Integrated Risk-Informed Decision-Making” (2019)

# Practical RIDM Aspects for Mid-Managers - Knowledge

- The PRA Workforce in the Nuclear Industry is a complex organization supporting many industry risk initiatives in addition to supporting the day-to-day risk questions from plant operations, work week management, and other plant staff
- The PRA Workforce is growing/changing – and many new PRA engineers are recent graduates and/or new to the role or organization.

**What is the most effective way to develop RIDM organization?**

# Evolution of Minimum knowledge Needed on PSA

Initial Research

Initial Construction & Licensing

New Reactors

Advanced Designs

1960

1970

1980

1990

2000

2010

2020

EARLY PRA RESEARCH

PLANT SPECIFIC PRAs

EXPANDED USE OF PRA

INTERNAL EVENTS



OTHER HAZARDS

HRA, CCF  
LEVEL 1, 2, 3...

INTERNAL EVENTS



OTHER HAZARDS

INT.  
FIRE/FLOOD

SEISMIC

LEVEL 2/3

HRA

CCF

INTERNAL EVENTS



INT. FIRE  
+

SEISMIC  
HAZARD +

SEVERE  
ACCIDENT +

HRA +

APPLICATIONS EXPERT

PRA REGULATIONS

SOFTWARE EXPERT

STANDARDS EXPERT

INTERNAL  
FLOOD +

CIVIL/  
FRAGILITY +

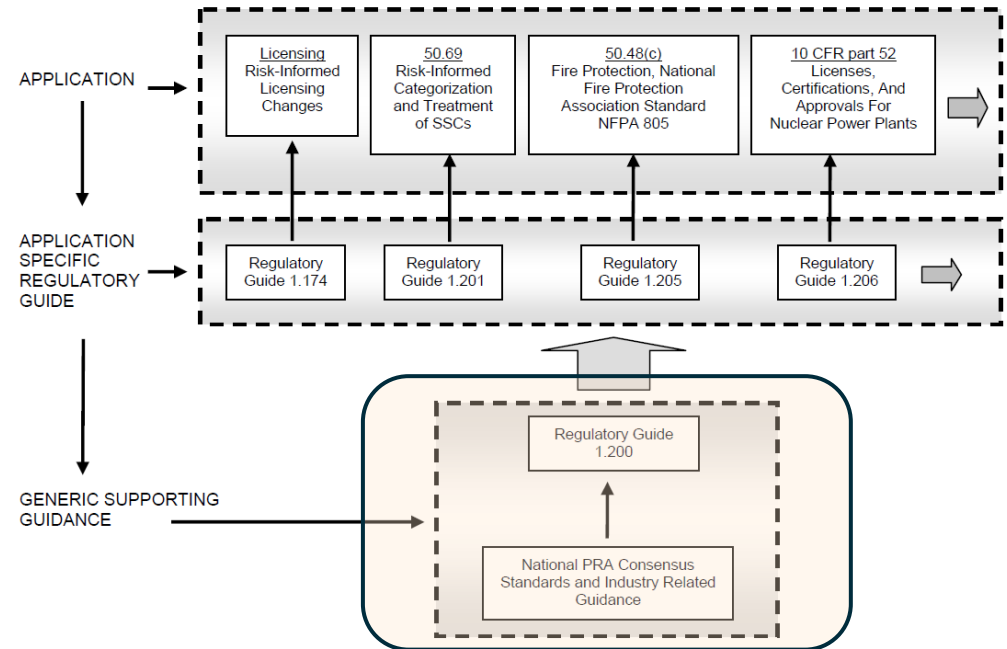
ACCIDENT  
RELEASE +

CCF +

INCREASED SPECIALIZATION/INTEGRATION

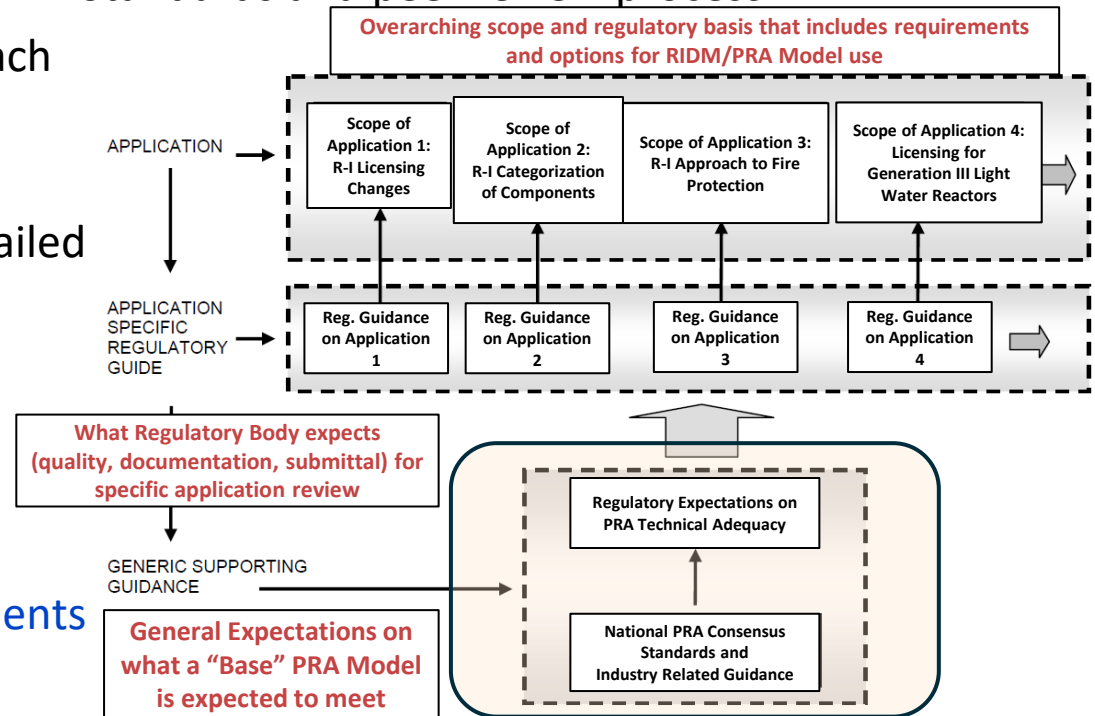
# How does the “Minimum” get defined to begin with?

- 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 ➡



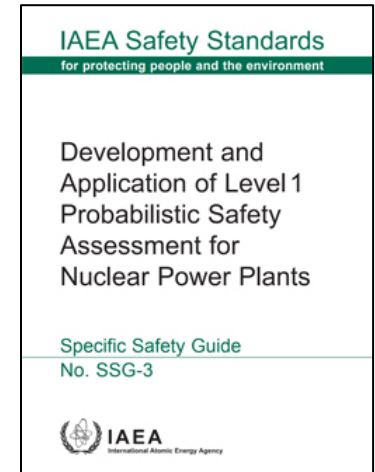
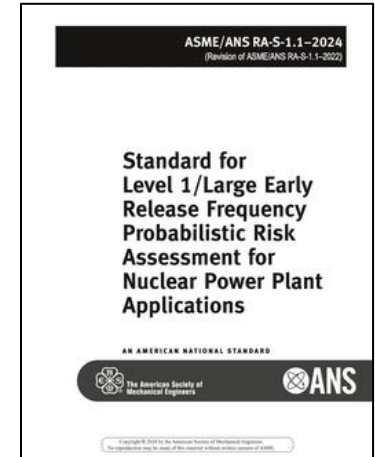
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# How does the “Minimum” get defined to begin with?

- 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 (“what 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



Knowledge needs must be supported...

# How does the “Minimum” get defined to begin with?

↑ Different requirements within a Standard ↓

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 NPPs
- Does not describe how to do a PRA, but what a PRA needs to have (“what to do”) – **varies from country to country**
- Final applicability of the use of PRA is specific to risk-informed application
- Multiple disciplines, often requiring experience in implementation, use of software, and understanding of regulatory processes involved

← 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

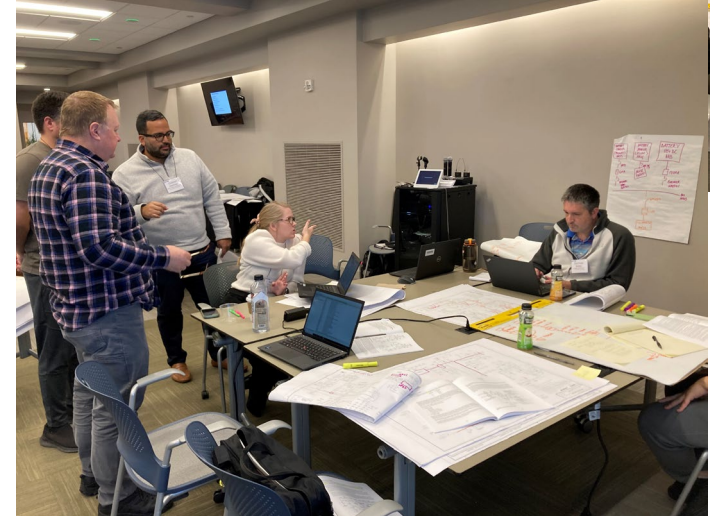
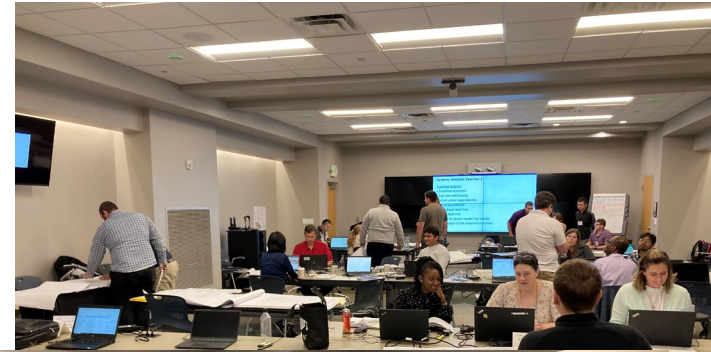
Advanced  
Non-LWR

# What should a PRA engineer know?

- In general, there are two types of PRA engineers:
  - Model Engineer – responsible for maintenance and update of the PRA model. These engineers are typically responsible for the documentation and model for the Internal Events, Flood, and Fire PRAs at a minimum.
  - Applications Engineer – responsible for direct support of the site. These engineers are typically responsible for rolling out the (a)(4) model (Phoenix RM), providing support for all applications of the PRA model (one time and recurring), and interfacing with the model engineers to be sure that feedback from the site plant personnel is incorporated during the next model updates as needed.
- These engineers have slightly different skillsets or knowledge requirements and may need different levels or types of technology transfer.

# Needed Support for RIDM Education, Knowledge Transfer

- **Basic Risk Professionals training**
  - Major programs take time and effort to developed and significant resources to support, e.g.,
  - EPRI has a program started in 2007, which has produced 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
  - Systems and HRA software training – multiple training may be needed, which may or may not be available each year



# How to Build the PRA Workforce Efficiently?

- PRA Standards and engineering experience can be used to identify the skillsets
- Skillsets to be defined for PRA Model Engineer and PRA Applications Engineer
- Does course order matter? **Yes!**
  - Taking foundational training FIRST gives a solid foundation for all other courses and topic specific training given in the future
  - A suggested curriculum outline for becoming a proficient PRA engineer is needed
- Is the PRA Engineer/Analyst fully qualified after taking training? **No!**
  - Taking these courses and following the curriculum is not a replacement for your site qualification cards
- **HOWEVER**, taking the courses and aligning the subjects expedite professional development/qualification process!

# Example of Building a PRA Workforce Curriculum



**Risk Experts Can Be in High Demand – Highly Skilled, Wide Plant Knowledge**

# Example of a PRA Workforce Development Curriculum

1 - Introduction to Probabilistic Risk Assessment (PRA)	
+ Overview of Nuclear Power and Systems Training (utility trained)	C-4
+ Overview of PRA and its importance in nuclear safety	C-3, C-4, C-5, C-6, C-7, C-8, C-9, C-10, C-11, C-12, C-13, C-14, C-15, C-16, C-17, C-18, C-19, C-20, W-3F
+ Historical context and evolution of PRA	C-13, C-15, C-17, C-18, C-20
+ Key concepts: risk, hazard, initiating events, and consequences	C-3, C-4, C-5, C-6, C-7, C-8, C-9, C-10, C-11, C-12, C-13, C-14, C-15, C-16, C-17, C-18, C-19, C-20, W-3F
2 - Regulatory Framework and Standard	
+ Overview of relevant regulations (e.g., NRC guidelines, international standards)	C-3, C-4, C-5, C-6, C-7, C-8, C-9, C-13, C-15, C-20
+ Understanding the role of consensus standards in PRA	C-3, C-4, C-5, C-6, C-7, C-8, C-9, C-13, C-15, C-20
+ Regulatory decision-making processes involving PRA	C-8

3 - Basic Principles of Risk Assessment	
+ Identifying and modeling specifying hazards	C-7, C-8, C-9, C-20, C-21, C-22, W3
+ Initiating events and their frequency	C7, C-9
+ Data Analysis and Industry Input	C-6, C-18, C-19, C-23, C-24
+ Consequence analysis	C-5
+ Risk reduction strategies	C-8
4 - Software Tools and Resources	
+ Introduction to PRA software tools (e.g., RiskSpectrum, CAFTA)	C-20, W-3B
+ Training on using these tools effectively	C-20, W-3B
+ Resources for further learning and research	C-20, W-3B
5 - Risk Assessment Methods	
+ Event Tree Analysis (ETA)	C-5
+ Fault Tree Analysis (FTA)	C-4, C-5
+ Human Reliability Analysis (HRA)	C-6, C-8, C-19, C-20, W-2
+ Use of Monte Carlo simulations	TBD

# Example of a PRA Workforce Development Curriculum

6 - Advanced PRA Techniques	
+ Detailed modeling of plant systems	C-4, C-5, C-6, C-20
+ Level 2/LERF Analysis	C-7, C-9
+ Internal Flood PRA	C-7, C-8, C-9
+ Fire PRA	C-20, W-3
+ Analysis of common-cause failures	C-6, C-23, C-24
+ Integration of deterministic and probabilistic approaches	TBD
+ Severe accident evaluation	C-7, C-9
7 - Peer Review and Validation	
+ Importance of peer review in PRA	C-3, C-4, C-5, C-6, C-7, C-8, C-9, C-13, C-15, C-20
+ Techniques for validating PRA results	C-3, C-4, C-5, C-6, C-7, C-8, C-9, C-13, C-15, C-20
+ Addressing uncertainties and assumptions	C-6, C-8

8 - Case Studies and Practical Applications	
+ Review of historical PRA case studies	TBD
+ Hands-on exercises with real-world scenarios	TBD
+ Group projects to develop PRA for hypothetical nuclear plants	TBD
9 - Ethical and Professional Considerations	
+ Ethical responsibilities in risk assessment	TBD
+ Professional standards and best practices	TBD
+ Continuous learning and professional development	TBD
10 - Final Capstone Project	
+ Comprehensive project to develop a PRA for a nuclear power plant	TBD
+ Presentation of findings and recommendations	TBD
+ Peer and instructor feedback	TBD

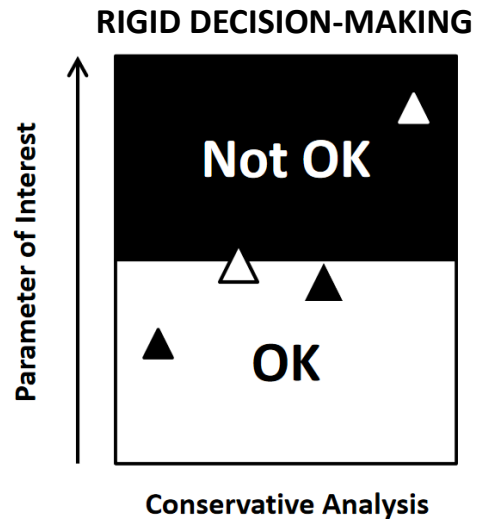
# Practical RIDM Aspects for Mid-Managers - Communication

- Risk communication is a never-ending challenge
  - If properly done: PRA continues to support key decisions for efficient, safe operation
  - If not done properly: confidence in PRA sags, use of risk insights is halted and/or diminished
- Past development of PRA technology has led to disparate tools, methods applied in different ways, to different issues
- This resulted in inefficiencies, technical challenges in integrating the results, possibly compounded with additional demands, new applications which can:
  - Limit the ability of software developers to maintain and improve the software
  - Constrain ability of end users to fully benefit from variety of methods, tools available
  - Prevent researchers from developing and applying new methods

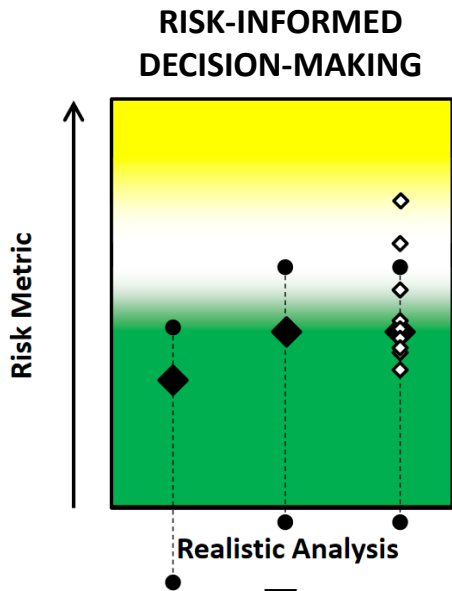
# Communication & Visualization – Who is the Audience?

LEADING AUDIENCE	TARGET AUDIENCE	TYPE OF INTERACTIONS	LEVEL OF PRA DETAIL INVOLVED	EXPECTED OUTCOME
NPP UTILITY	Regulatory Staff	License submittals, public meetings, efforts on risk-informing activities	Detailed, especially if a licensing change is involved, focus on technical issues	Efficient review of issues involved and proper documentation for approval or rejection
REGULATORY STAFF	NPP Utility/Utilities	License submittals, oversight actions, public meetings, efforts on risk-informing activities	Detailed, especially if a licensing change is involved, may include public communication needs	Understanding of regulatory expectations, prompt actions, increased public confidence
NPP UTILITY	Members of the Public	Public meetings with local communities	High level, stronger focus on clarity and key messages	Increased public confidence, transparency in NPP operations
REGULATORY STAFF	Members of the Public	Public meetings with local communities, public stakeholders	High level, stronger focus on clarity and key messages	Increased public confidence, transparency; feedback on regulations
NPP UTILITY PRA ANALYSTS	NPP Utility PRA Managers	Internal deliberations on detailed use of PRA, risk insights for experts	Very detailed, strongly focused on deep technical issues	Discussions on PRA technical adequacies, creating options for decision-makers
NPP UTILITY PRA MANAGER	NPP Utility Management	Internal deliberations on options for decision-making	Intermediate level, needs to connect with impacts to operations, strategic decision-making focused	Improved decision-making, transparency/confidence in the use of PRA and risk insights, understanding of key nuances and assumptions
NPP UTILITY PRA EXPERTS	NPP Utility non-PRA Experts	Internal deliberations on sharing of risk insights, potentially associated to implementation of risk-informed activities	Intermediate level, needs to connect with impacts to operations, practical decision-making	Improved decision-making, transparency/confidence in the use of PRA and risk insights, understanding of key nuances and assumptions

# Addressing Cultural, “Tribal” Aspects

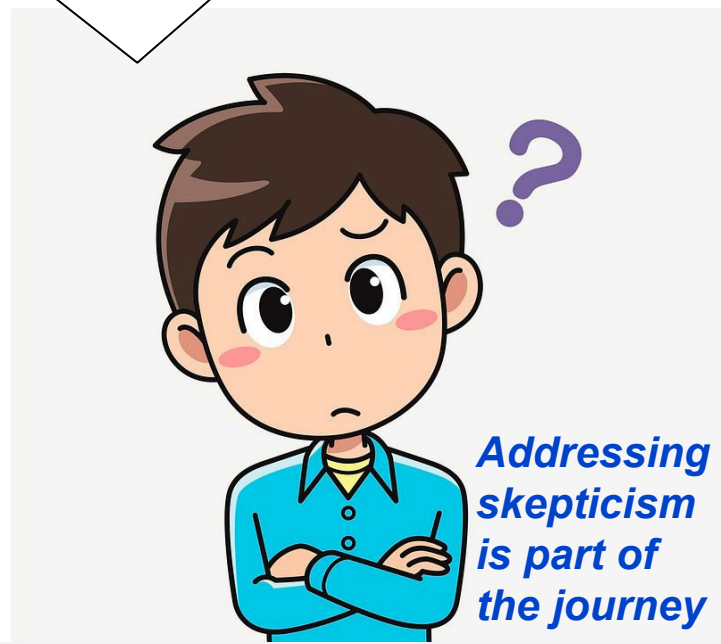


Options are clearly defined; but biased towards conservatism and can mask non-conservatisms



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

*“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.”*



# Risk Visualization & Communication – “The Numbers”

- PRA information can be challenging to present and understand

EPR1 3002023813 Enhanced Information Visualization and Communication Methods for RIDM

Name	FV 5%	FV Mean	FV 95%	RAW 5%	RAW Mean	RAW 95%	Bin 5%	Bin Mean	Bin 95%
CCBCCFCCT12	0.00000	0.00000	0.00000	1.001	1.011	1.028	0.000	0.000	0.000
CCBCCFCCT13	0.00000	0.00000	0.00000	1.001	1.012	1.028	0.000	0.000	0.000
E1MM	0.00063	0.00063	0.00245	1.048	1.619	3.011	0.000	0.001	0.001
E2MM	0.00063	0.00065	0.00247	1.048	1.627	2.995	0.000	0.001	0.001
E3MM	0.00063	0.00063	0.00226	1.048	1.627	3.004	0.000	0.001	0.001
EA1	0.00064	0.01162	0.04191	1.048	1.803	2.923	0.000	0.001	0.001
EALL	0.00000	0.00006	0.00025	1.051	1.847	3.069	0.000	0.001	0.001
EATD01DW	0.00000	0.00034	0.00160	1.048	1.627	3.013	0.000	0.001	0.001
EATD02DW	0.00000	0.00034	0.00160	1.048	1.628	2.998	0.000	0.001	0.001
EATD03DW	0.00000	0.00034	0.00161	1.048	1.628	3.005	0.000	0.001	0.001
EB1	0.00001	0.00006	0.00022	1.000	1.000	1.001	0.000	0.000	0.000
EB2	0.00077	0.00995	0.03170	1.047	1.800	2.913	0.000	0.001	0.001
EBCCA1DW	0.00191	0.07343	0.23833	75.801	686.207	1933.722	0.503	0.601	0.696
EBCCB1DW	0.00190	0.07345	0.23870	75.751	694.433	1967.158	0.504	0.601	0.695
EBCCC1DW	0.00191	0.07350	0.23982	76.793	694.430	1954.269	0.504	0.601	0.697
EBC1A	0.00018	0.00072	0.00175	1.428	1.533	1.640	0.000	0.001	0.004
EBC1B	0.00019	0.00070	0.00174	1.432	1.534	1.640	0.000	0.001	0.004
EBC1C	0.00018	0.00074	0.00182	1.429	1.532	1.636	0.000	0.001	0.004
EBS0A1DW	0.00016	0.01341	0.05904	124.744	1164.895	3301.089	0.992	0.998	1.000
EBS0B1DW	0.00016	0.01341	0.05904	124.744	1171.688	3301.089	0.992	0.998	1.000
EBS0C1DW	0.00016	0.01341	0.05904	124.744	1171.688	3301.089	0.992	0.998	1.000
EBS111DW	0.00010	0.00809	0.03579	76.407	694.274	1956.547	0.503	0.601	0.695
EBS112DW	0.00010	0.00809	0.03533	76.755	694.541	1967.171	0.504	0.601	0.695
EBS113DW	0.00010	0.00808	0.03572	76.796	694.456	1954.298	0.504	0.601	0.697
EBS690DW	0.00000	0.00000	0.00000	1.001	1.008	1.017	0.000	0.000	0.000
EBS001DW	0.00010	0.00809	0.03579	76.407	694.274	1956.547	0.503	0.601	0.695
EBS002DW	0.00010	0.00809	0.03533	76.755	694.541	1967.171	0.504	0.601	0.695

Typical PRA quantitative results

- Context for “risk numbers” matter!
  - $10^{-4}$ /year versus  $10^{-5}$ /year not small
  - Small fluctuations between similar orders of magnitude may not be statistically significant
  - Strong influence of method maturity, level of confidence in inputs, complex software implementation
  - Calibration on what “realistic” risk numbers are takes effort
  - Critical to provide a confident understanding of what PRA outputs mean
  - Value of PRA goes well beyond numbers

# Risk Visualization

- Developing the most efficient tools, content for different audiences

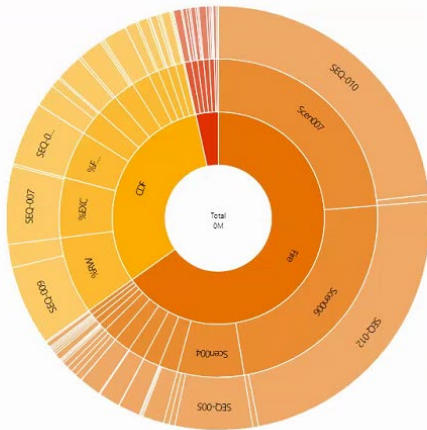
[EPRI 3002014783 A Framework for Using Risk Insights in IRIDM](#)

INTEGRATED RISK INFORMED DECISION MAKING RUBRIC - AGGREGATION		
<b>PURPOSE</b>		
Characterize the overall core damage and large early release frequency (CDF, LERF) results with respect to U.S. NRC subsidiary goals to understand risk insights, main contributors, and uncertainty impacts.		
<b>APPLICATION RISK RESULTS</b>		
<ul style="list-style-type: none"> <li>The computed CDF and LERF are both below the surrogates of 1E-4/year for CDF (1E-5/year for LERF) for the aggregated results; CDF has a margin of 1.4E-5/year and LERF has a margin of almost 4E-6/year</li> <li>Internal Fire is the highest contributor followed by seismic; both have conservatism that could be addressed</li> <li>External flooding is screened (not quantified) and conservative estimates of High Winds risk would not be expected to exceed the existing margins to the surrogate values (uncertainty is high to moderate, respectively)</li> <li>Internal fire modeling includes conservatism on fire ignition frequencies and main control board fires; additional work on these areas may reduce the overall fire CDF/LERF if implemented</li> <li>Seismic assumes low fragilities and direct core damage for several components which could be refined</li> </ul>		
<b>DEFENSE-IN-DEPTH (DID) CONSIDERATIONS</b>		
<ul style="list-style-type: none"> <li>Impacts from CCF are modeled in the baseline PRA, dependent failure mechanisms are considered</li> <li>Human failure events are modeled in the baseline PRA and no over-reliance on programmatic activities exists</li> <li>Balance between barriers is maintained with no risk significant contributors that could impact multiple barriers</li> <li>Baseline PRA includes modeling of system redundancy, independence, and diversity</li> <li>No credit is taken in the PRA for installed RCP Shutdown Seals and beyond design bases mitigative equipment</li> </ul>		
<b>SAFETY MARGIN (SM) CONSIDERATIONS</b>		
<ul style="list-style-type: none"> <li>Approved codes and standards/safety analysis acceptance criteria are currently met</li> <li>Safety limits and operating limits are met according to licensing bases</li> </ul>		
<b>PERFORMANCE MONITORING (PM) CONSIDERATIONS</b>		
<ul style="list-style-type: none"> <li>The plant performs risk-informed monitoring under the Maintenance Rule</li> <li>Explicit monitoring for fire protection systems is included under a risk-informed, performance-based program</li> </ul>		
<b>INTEGRATED RISK-INFORMED DECISION MAKING INPUTS</b>		
Additional margin to the subsidiary values is expected based on identified conservatisms in portions of the model (may be impacted by high winds, but not expected to exceed values)		
DEFENSE-IN-DEPTH	SAFETY MARGINS	PERF. MONITORING
PRA	PRA	PRA

**Example:** How can we communicate risk information better to non-risk experts?

FV Init by Haz. Scen/Init and Sequence

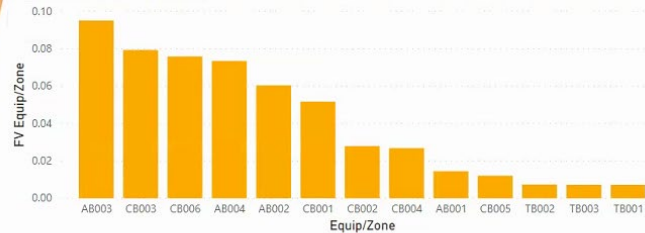
Haz. CDF Fire Seismic



FV Equip/Zone by Equip/Zone



FV Equip/Zone by Equip/Zone

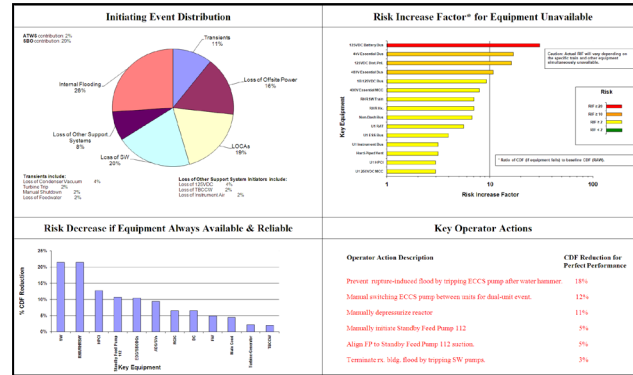


**Example:** How can we show the content of a PRA model in "one page", allow for more in-depth review?

[EPRI 3002023813 Enhanced Information Visualization and Communication Methods for RIDM](#)

# Risk Visualization

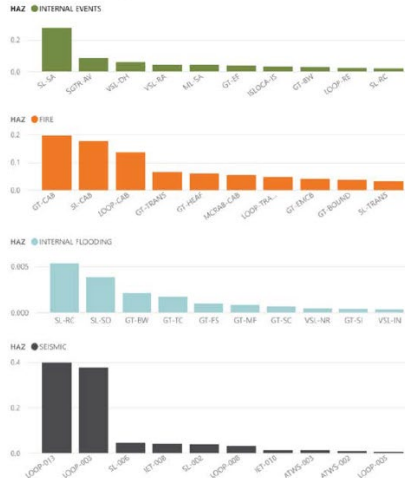
- Tools are already been used
- Better tools are possible



CDF Contribution from Hazard Types



Contribution from Sequence by Hazard



**Purpose**

Characterize the overall risk from plant operations with respect to the subsidiary safety of objective of  $CDF < 1 \times 10^{-4}/yr$ .

**Risk Information**

**Parametric Uncertainty**

- Mean values represented in results
- External Flood mean values highly uncertain

**Modeling Uncertainty**

- External flooding initiating event frequencies highly uncertain
- Fire PRA methods result in a substantial overstatement of fire CDF.

**Completeness Uncertainty**

- All relevant site hazards and operating modes considered except:
  - High winds – design basis shown to protect to 1E-7/yr

**Overall Risk Characterization**

- Computed total CDF less than subsidiary objective
- Very large uncertainties for external flood results could challenge subsidiary objective
- Non-realistic fire PRA methods are not likely to compensate for external flooding uncertainties

**Defense-in-Depth Characterization**

- No DID vulnerabilities identified. All fire scenarios confirmed to have at least one success path.
- Mitigating strategies capabilities to mitigate external flooding not included in PRA model

**Safety Margin Characterization**

- Limited available margin to address beyond design basis floods leads to potential external flooding scenarios

**Performance Monitoring**

- Annual average CDF monitoring performed as part of Maintenance Rule
- Routine PRA updates scheduled for every 4 years

**Integrated Decision-making Inputs**

Risk	Defense-in-Depth	Safety Margins	Performance Monitoring
External Flood Uncertainties	Confirmed	Limited for External Flooding	Annual Average CDF Monitoring

**Conclusion:**

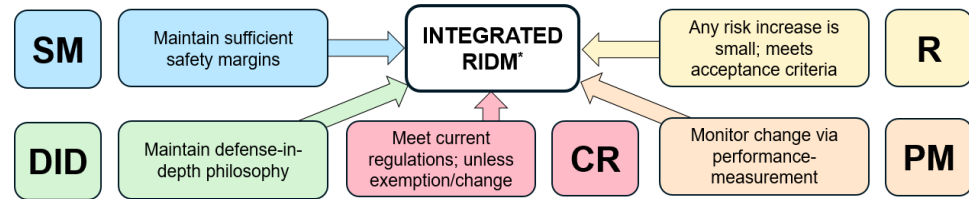
- Although the computed total CDF meets subsidiary objective with some margin, the external flooding risks are sufficiently uncertain that they do not provide confidence in the computed mean value.
- Capabilities of mitigating strategies lowers external flood risk and effectively increases safety margin
- Performance monitoring not effective for low frequency flood scenarios that drive plant risk

# Communicating the Role of PRA in RIDM, DID, and SM

## IAEA-defined DID levels

DID Level	Objective	Essential Means
Level 1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
Level 2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance feature
Level 3	Control of accidents within the design basis	Engineered safety features and accident procedure
Level 4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
Level 5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

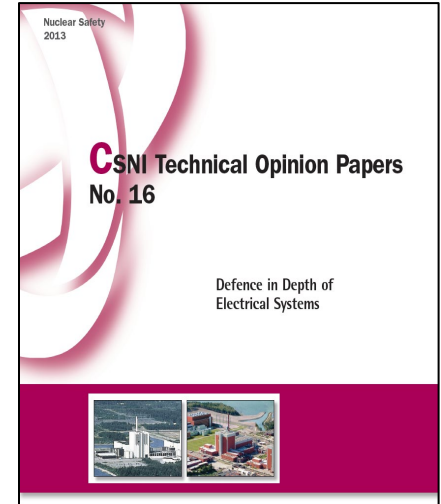
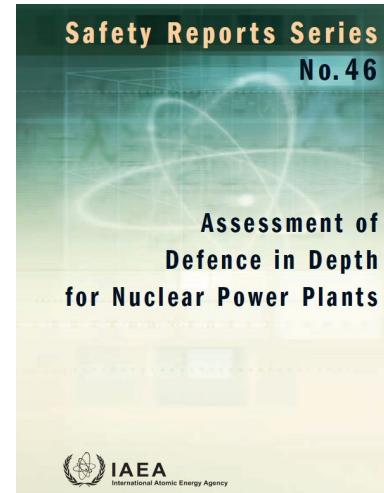
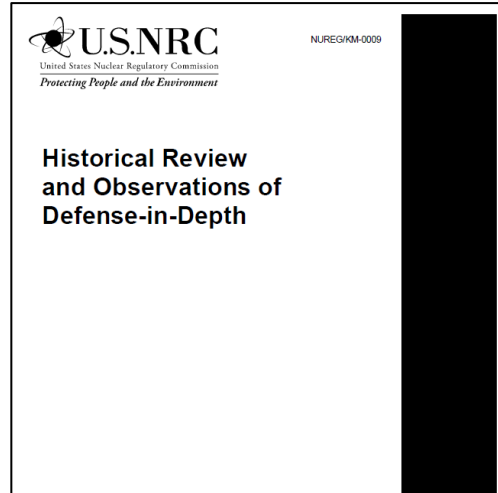
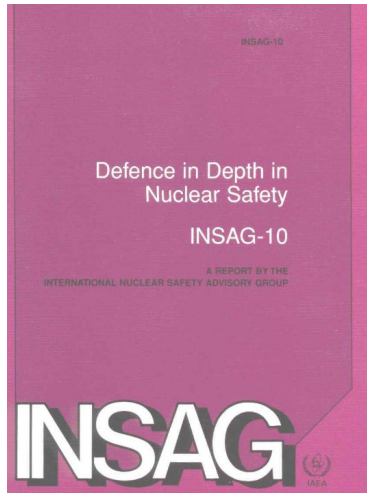
## NRC-defined DID levels according to Regulatory Guide 1.174 (for IRIDM)



- Robust plant design to survive hazards and minimize challenges that could result in an event occurring,
- Prevention of a severe accident (core damage) if an event occurs,
- Containment of the source term if a severe accident occurs,
- Protection of the public from any releases of radioactive material (e.g., through siting in low-population areas and the ability to shelter or evacuate people, if necessary).

# Communicating the Role of PRA in RIDM, DID, and SM

- View of DID/SM in RIDM has evolved through history of nuclear safety
- There are still aspects of DID/SM in RIDM that can be challenging without a proper context and a structured approach to assess them, and
- There has been significant research and proposed approaches that could drive a more efficient approach forward.



# Communicating the Role of PRA in RIDM, DID, and SM

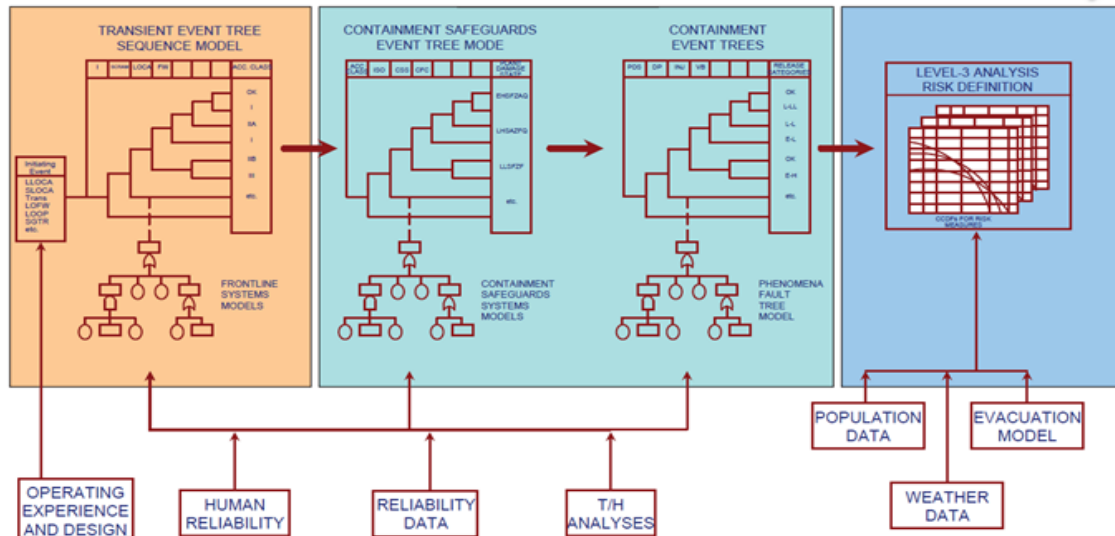
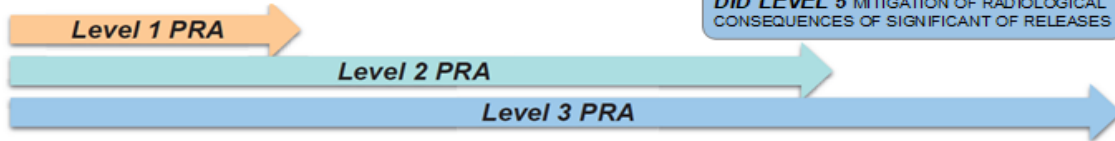
**DID LEVEL 3** CONTROL OF ACCIDENTS WITHIN DESIGN BASIS

**DID LEVEL 2** CONTROL OF ABNORMAL OPERATION & DETECTION OF FAILURES

**DID LEVEL 1** PREVENTION OF ABNORMAL OPERATION AND FAILURES

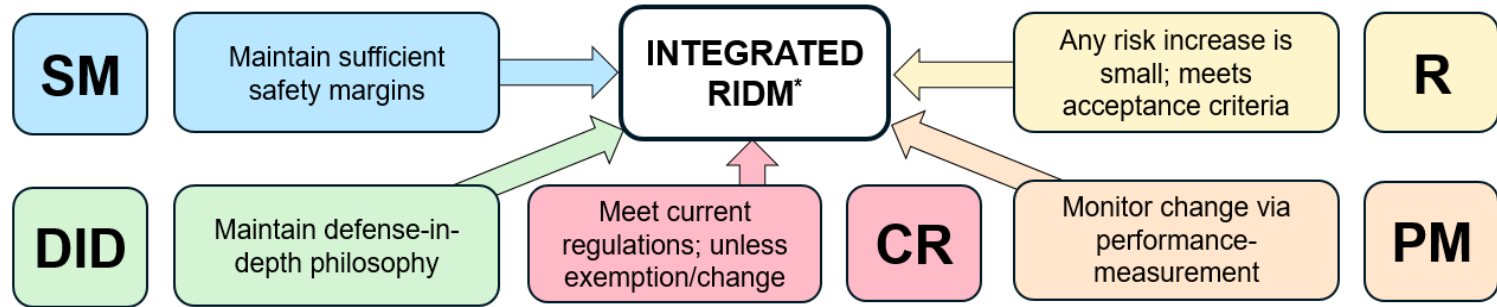
**DID LEVEL 4** PREVENTION OF ACCIDENT PROGRESSION AND MITIGATION OF THE CONSEQUENCES OF SEVERE ACCIDENTS

**DID LEVEL 5** MITIGATION OF RADIOLOGICAL CONSEQUENCES OF SIGNIFICANT OF RELEASES



- Several deterministic inputs into DID are inputs for PRA
- Key scenarios considered for DID in licensing of NPPs are part of PRA
- Hence, PRA overlaps significantly with DID and SM
- PRA can explicitly consider what we know and don't know
- But role of PRA is not to "quantify" DID
  - Using PRA only for DID would be limiting
  - But not using PRA insights would be equally limiting

# Communicating the Role of PRA in RIDM, DID, and SM



- Most of guidance in regulatory documents focuses on “meet codes/standards”
  - This is highly simplistic, incomplete, and ultimately lacking in clear guidance
- “Margin” can be deterministic or probabilistic, depending on the context
- There is no single SM that is considered in NPP applications; there are SMs met at a “localized” level, and those at a “global” level
- Fundamental insight: SM can be better leveraged as a support to DID (EPRI 3002020763 position is that is not logical to consider DID and SM separately)

# Practical RIDM Aspects for Mid-Managers

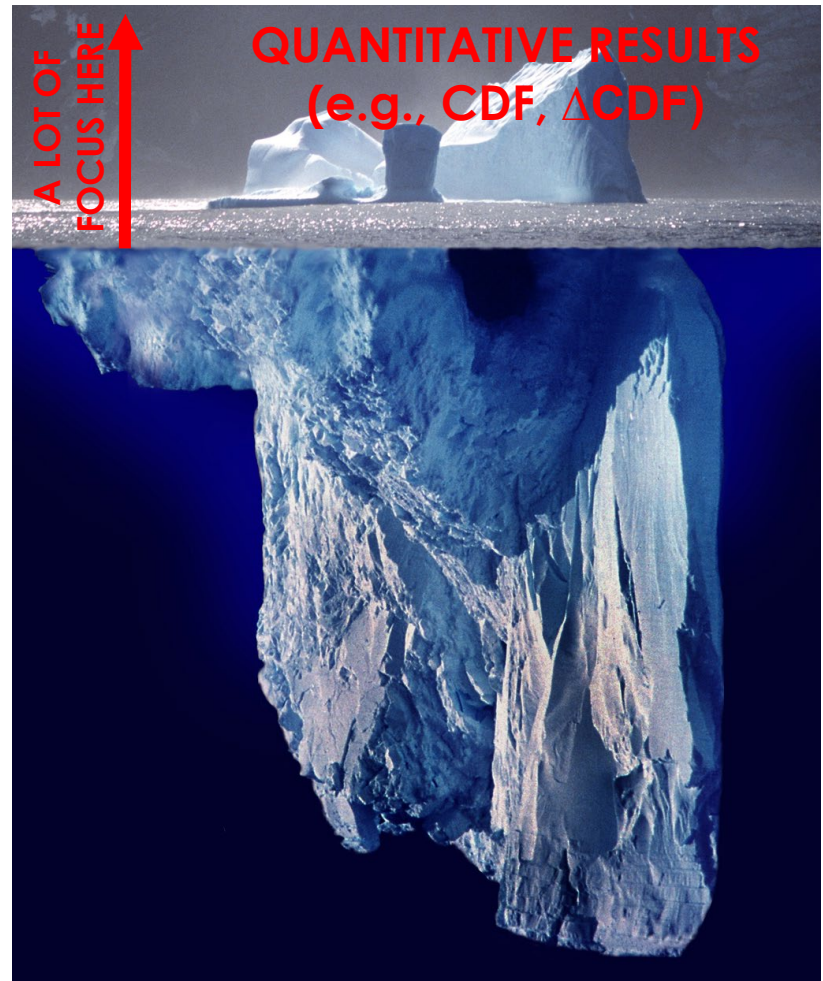
A good consumer of risk information should be able to ask key questions to probe the quality and usefulness of insights (regardless of risk expertise!):

- *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?*
- *What are the sources of uncertainty and how are they addressed?*
- *Has the PRA model been peer reviewed (such as against the PRA standard)?*
- *What is the past experience in using this risk information?*



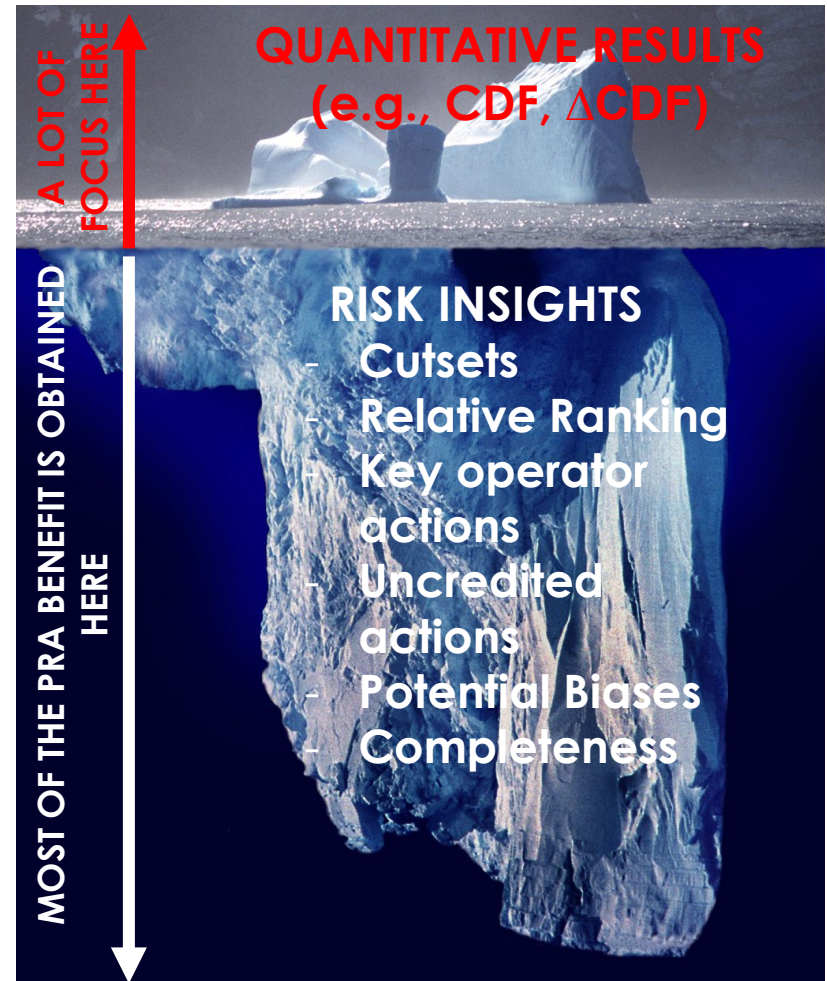
# Practical RIDM Aspects for Mid-Managers - Aggregation

- Risk aggregation not a new or unique issue; it's a core aspect of IRIDM:
  - How do we ensure the risk profile is as complete as possible?
  - How do we interpret the PRA results consistently, given what we know about the model?
  - Not all issues in IRIDM relate to risk aggregation, but risk aggregation may impact multiple applications



# Risk Aggregation – Is it an issue? If so, why?

- Risk aggregation is related to having a clear RIDM framework
  - Adding numbers = not hard to do
  - But does this make sense (enough to make a decision regarding nuclear plant safety)?
- Significant references and resources are available
  - E.g., see IAEA, EPRI guidance



# EPRI Report (2005) on Quantitative Risk Aggregation

EPRI 1010068

- Identified need to aggregate as primarily driven by desire to consider integrated quantitative risk insights
- Recognized risk-management perspective is important when measuring a proposed risk change against established guidelines or criteria
- Indicated need to aggregate is dependent on the risk-informed application type
  - Some risk-informed application types might not require or benefit from the integrated quantitative risk perspective (i.e., may not be cost-beneficial)
  - Some applications can be effective using approximate risk quantifications for some contributors (e.g., via bounding estimates or by showing small relative values in risk equation).
- Highlighted that aggregation aspects are essentially connected to the technological and resource issues associated with individual risk contributors

# EPRI Report (2015) - Challenges (Maturity/Consistency)

EPRI 3002003116

*NOTE = Despite challenges discussed in this report, significant benefits of using PRA and RIDM are also recognized (i.e., these issues are raised within the context of risk aggregation).*

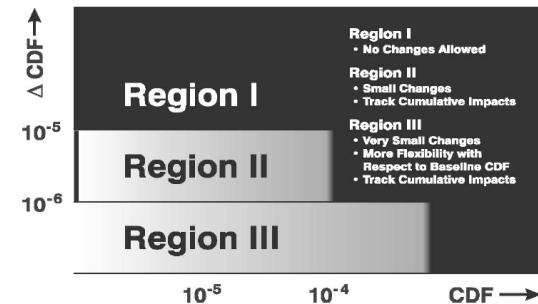
- Nature and Limitations of PRA Models
  - Discretized representation of the potential spectrum of accident sequences
  - Approximations due to limitation of analytical tools and resource limitations
  - Known conservative and non-conservative assumptions can affect decision-making
  - Unknown risk contributors
  
- Maturity and consistency are important aspects to consider in a PRA model:
  - Recognition that risk assessment of various hazards has evolved unevenly (e.g., operating experience for internal events led to calibration of quantitative results)
  - Inconsistent treatment of uncertainty across hazards (state-of-art vs state-of-practice)
  - Uncertainty of external events can overwhelm important metrics

# EPRI Report (2015) - Types of Applications & Implications on Risk Aggregation

Metric	Example Application(s)	Challenges	Ramifications
Total Risk (CDF/LERF/LRF)	Comparison to Safety Goal(s) or Subsidiary Objectives Comparison to RG 1.174 Quantitative Guidelines	Conservative methods	Overstatement of total risk
		Intentionally conservative characterizations	Typically only implemented for minor contributors or in cases where margin is very large
		Immature methods	Uncertain characterization of state of knowledge Often overstates risk
		Uncertainties due to rare environmental events	Mean value may not be meaningful measure
		Modeling uncertainties	Requires sensitivity studies
		Quantified uncertainties (parameter)	Only essential for computing mean Uncertainty bands typically not used in comparison with criteria
		Scope of model (completeness)	Risk from omitted contributors understated
		Cliff-edge effects	May not be captured in mean values

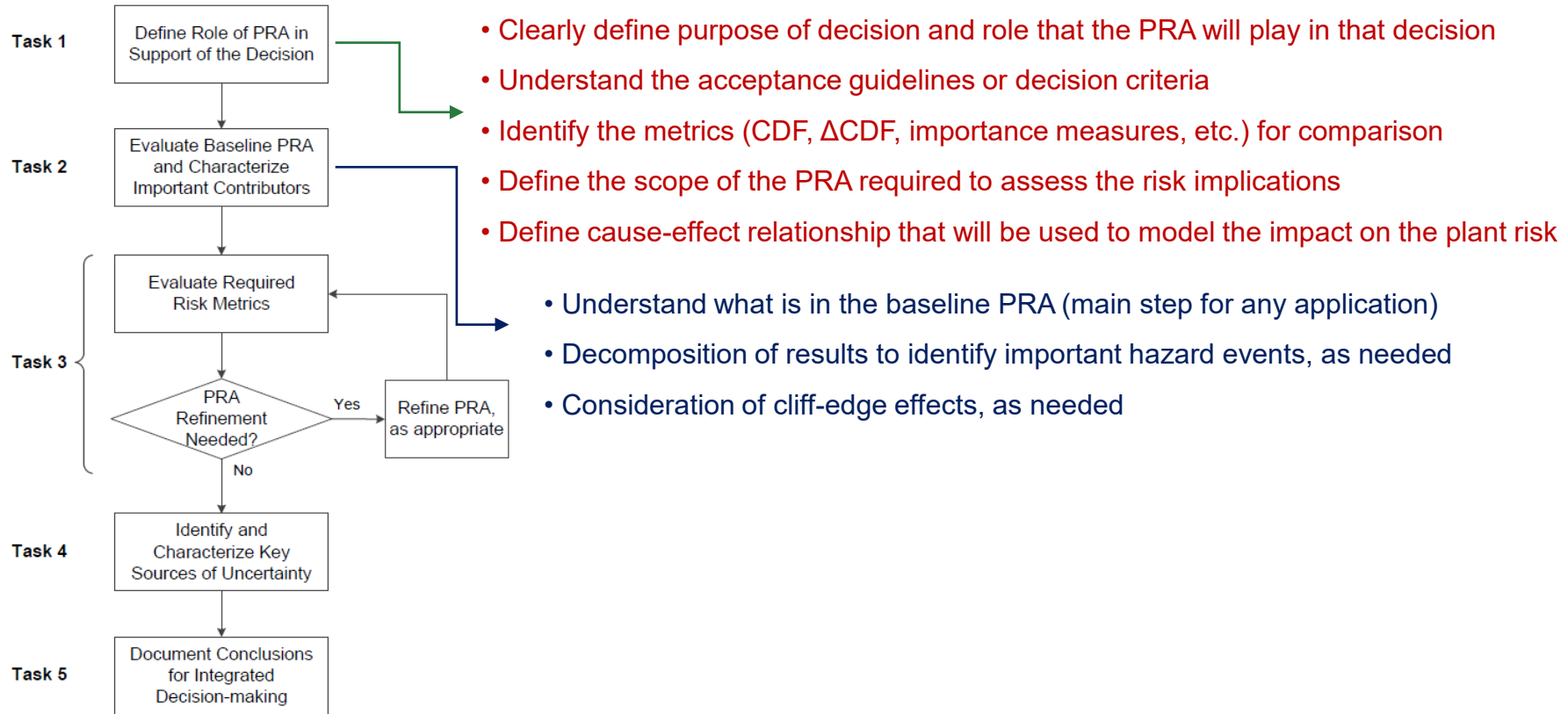
Individual challenges need to be understood within the context of the application

Effect of individual challenges may not be intuitive, e.g., conservative assumptions could lead to non-conservative decision-making

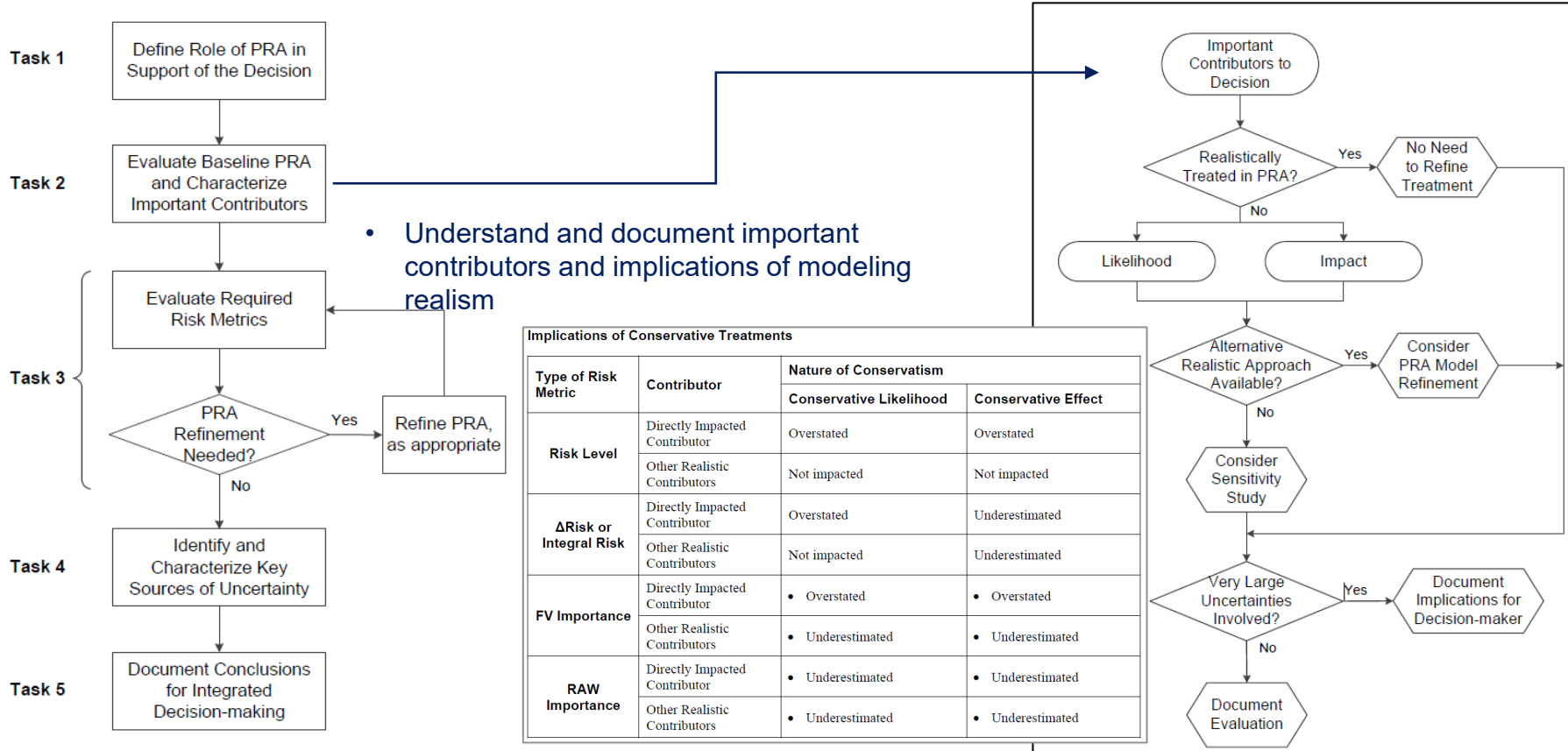


E.g. NRC's Regulatory Guide 1.174 acceptance guidelines for CDF for plant licensing bases changes

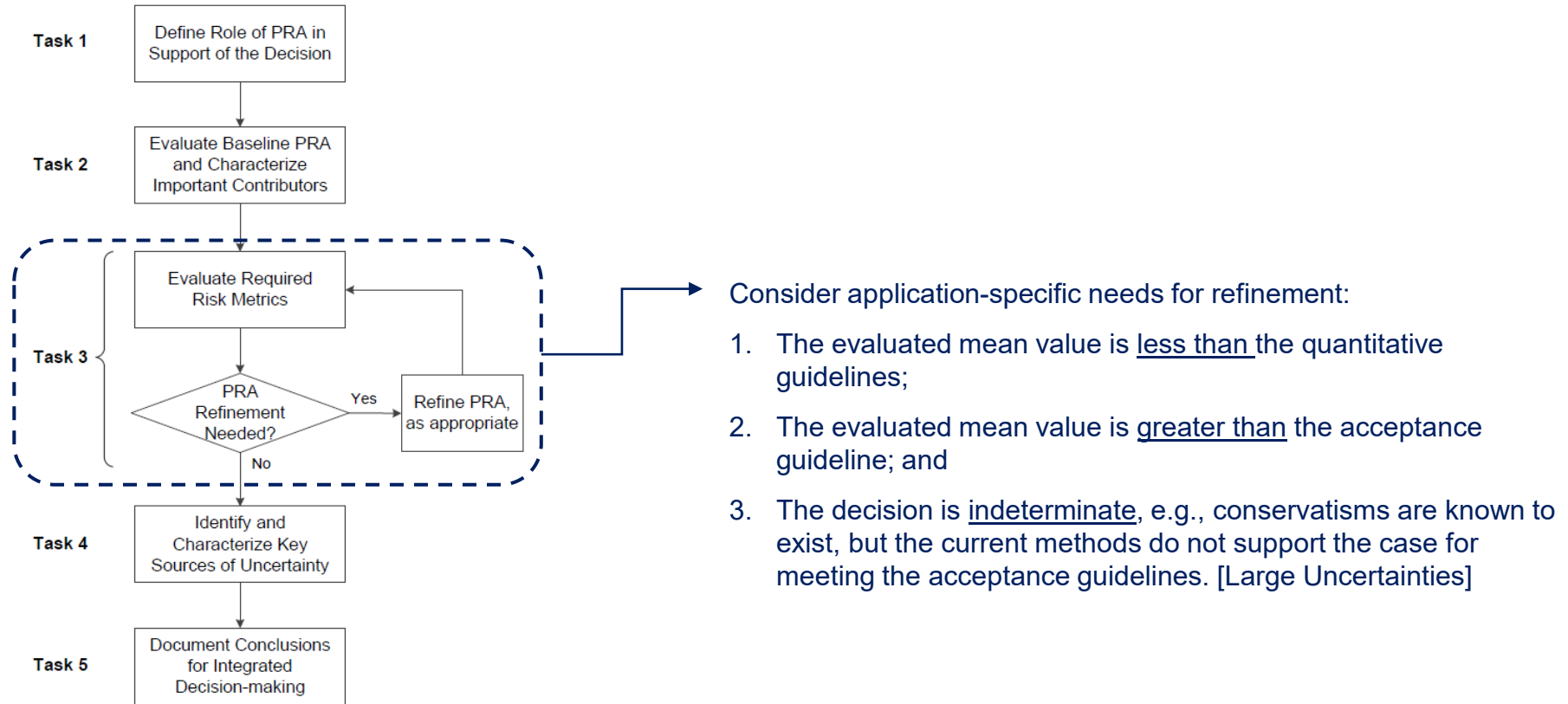
# EPRI Report (2015) – Proposed Approach & Framework



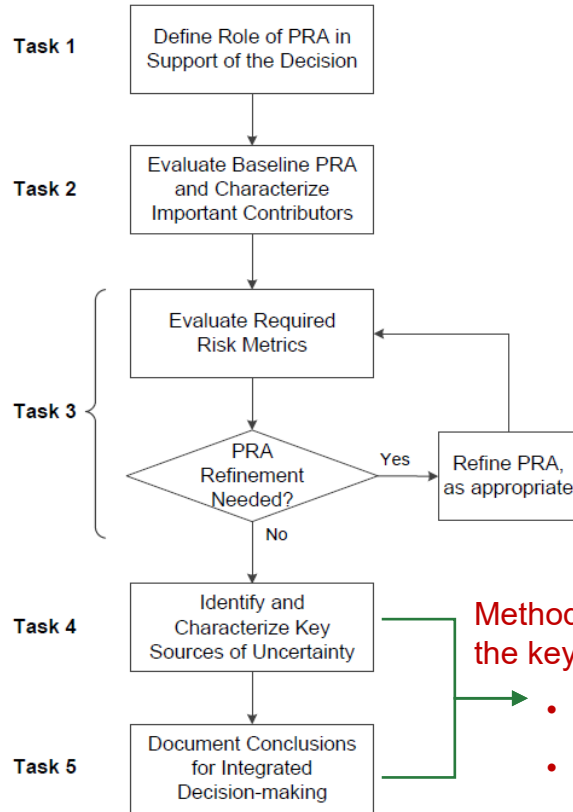
# EPRI Report (2015) – Proposed Approach & Framework



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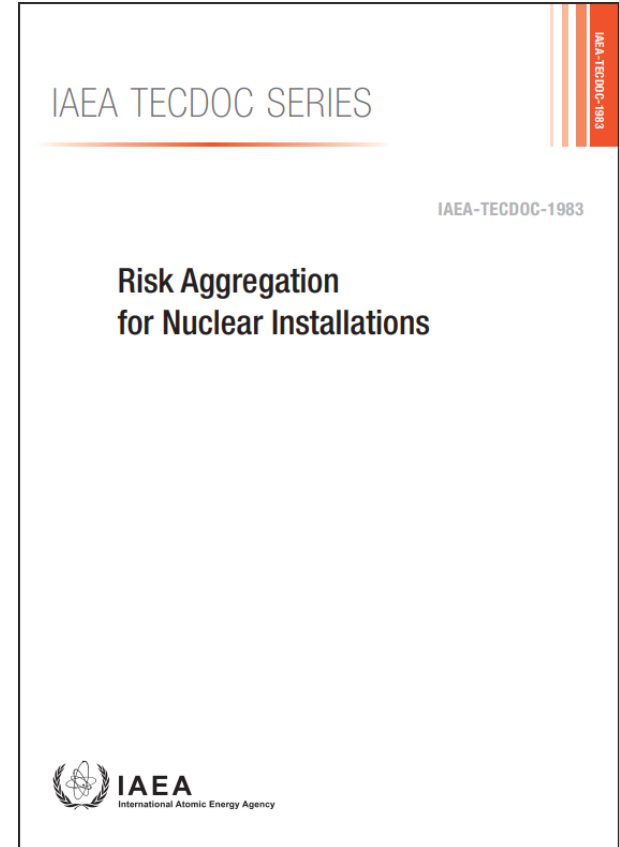


Methods for identification and characterization of the key sources of uncertainty, e.g.,

- US NRC's NUREG-1855
- EPRI 1016737
- EPRI 1026511

# IAEA Report (2021) – International Perspective

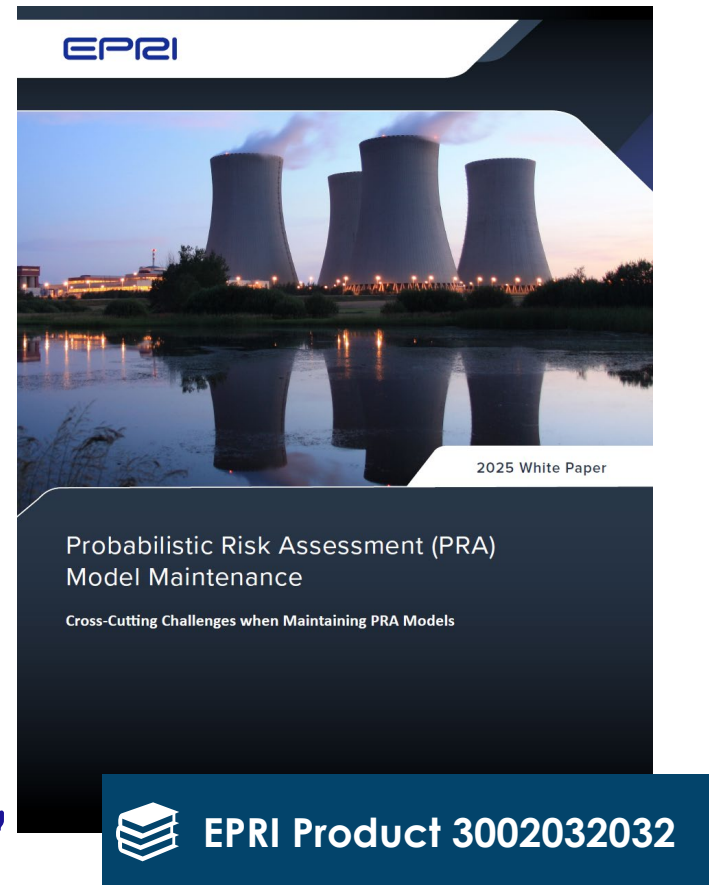
- Discussion of integrated versus separate risk models
- Multi-source integration aspects
- Integration of various operational states
- Risk Aggregation in RIDM
- Communicating risk
- Compliance with safety limits
- Aggregation and Uncertainty
- Examples from multiple member states



# Practical RIDM Aspects for Mid-Managers – Value, Confidence

Implementing RIDM comes with a significant investment of time, resources

- See EPRI 3002032032 for an investigation on the complexities and challenges of maintaining PRAs for use by the nuclear power industry.
- Focus of many countries is now shifting towards
  - Enhancing and simplifying the PRA model maintenance process,
  - Ensuring that PRA models remain accurate, reliable, and useful for risk-informed decision-making

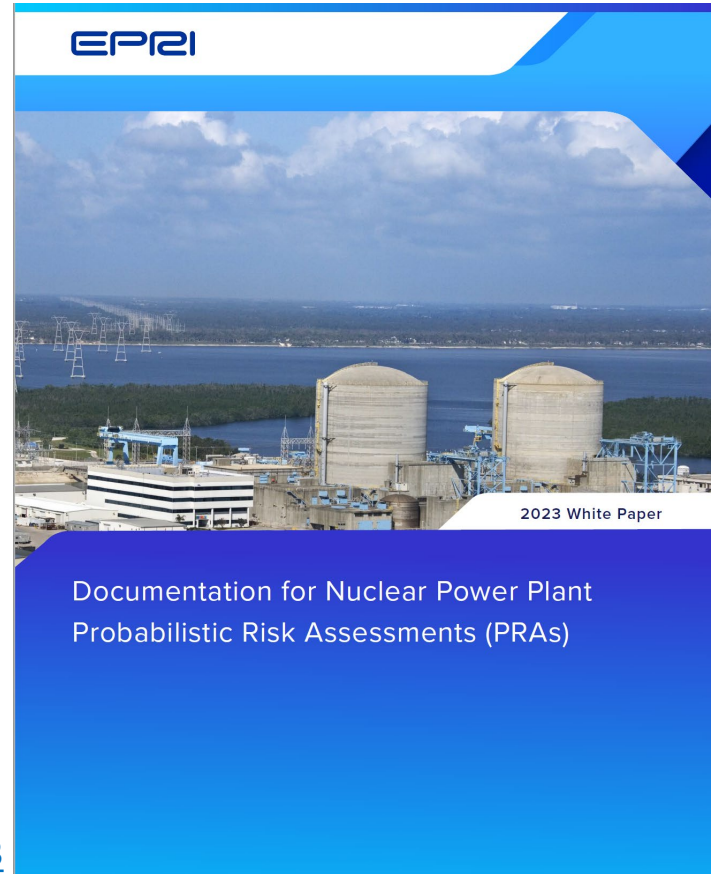


# RIDM/PRA Documentation is also a Cost to be Managed

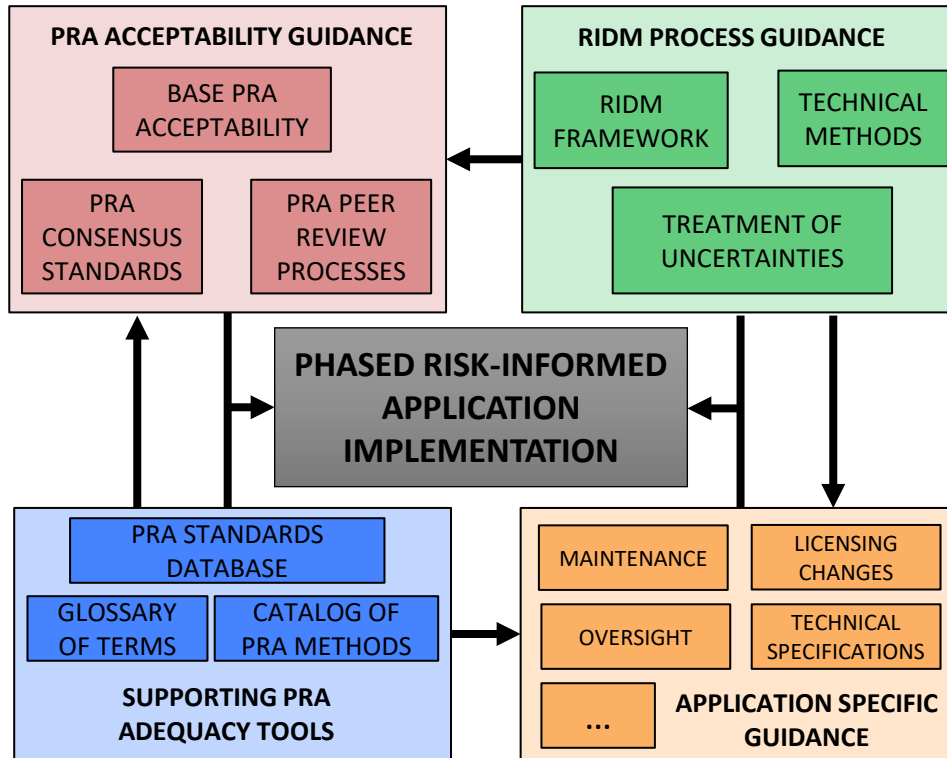
## Significant cost(s) involves documentation burden

- Characteristics of PRA documentation, e.g., system & other notebooks
- Focusing on value-added content, rather than including retrievable information in updates.
- Characteristics of PRA model updates – full or partial updates
- Current challenges, practices, and lessons-learned from industry workshops
- Demonstration of a web-based product applied to typical PRA model information
  - Interactive, automated approaches
  - Includes realistic examples
  - Version history, workflow, searching
- Interfaces: PRA software tools and Add-ins; Automation of tables and figures; PRA application interfaces
- PRA Standard Considerations

[3002026383](#)



# Practical RIDM Aspects for Mid-Managers – Confidence



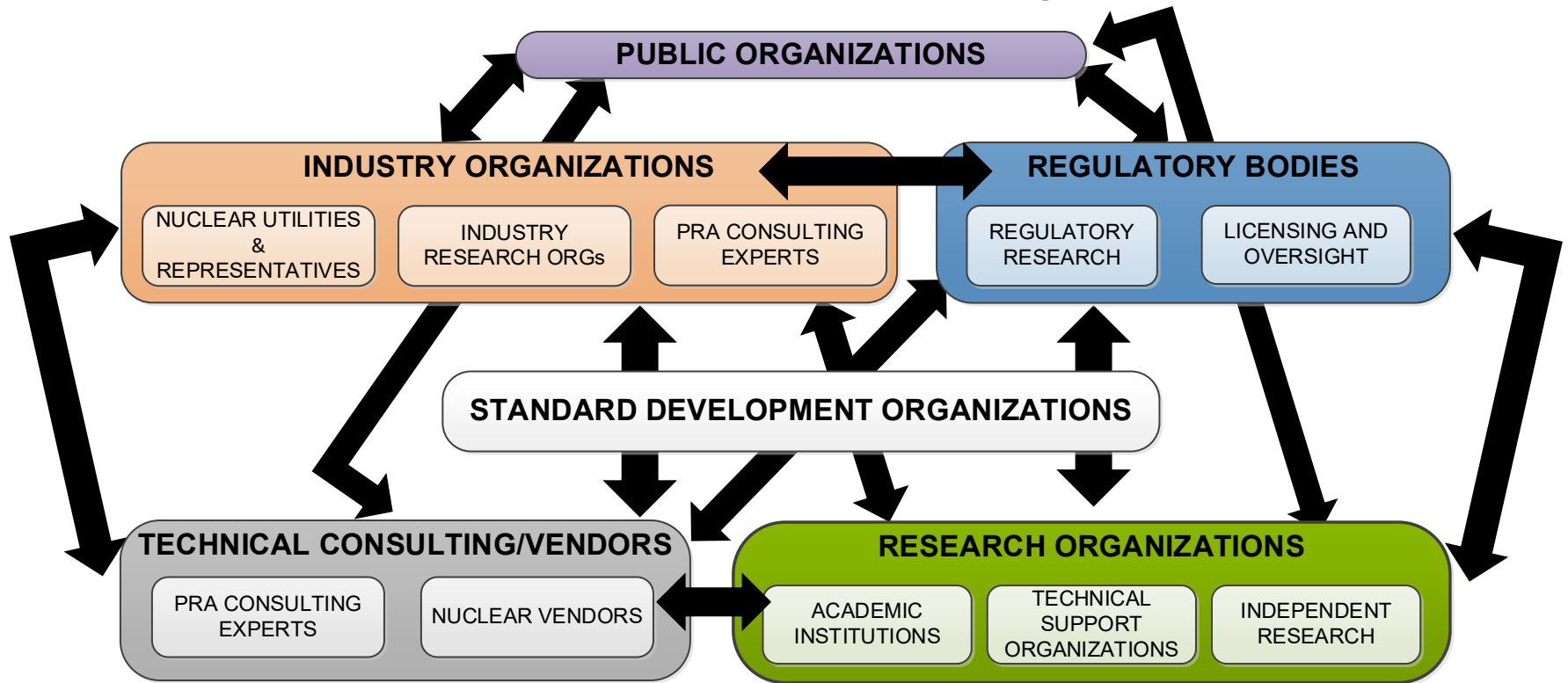
Adapted from US NRC Figure in [Risk-Informed Activities Technical Guidance Program | NRC.gov](https://www.nrc.gov)

Elements that provide confidence in RIDM are essential:

- A living, continuously evolving set of standards and guidance on specific PRA technical adequacy elements
- Robust guidance on the implementation aspects of RIDM
- Venues for multiple stakeholders to participate in the development of RIDM guidance, standards, processes

**LESSON LEARNED = Building/Supporting/Nurturing RIDM is a continuous task**

# Practical RIDM Aspects for Mid-Managers – Confidence



**Coordination Among Organization is Critical**

# RIDM Implementation Takes Time and Effort

*“What is a phased, gradual approach to RIDM implementation?”*

- An example: US NRC’s Action Plan on a Phased Approach (early 2000s)

*“The phased approach defines the needed PRA quality for current or anticipated applications and the process for achieving this quality, while allowing risk-informed decisions to be made using currently available methods until all the necessary guidance documents 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

- Industry movement towards improved and more complete PRAs
- Increased efficiencies in the regulator’s review of risk-informed applications
- Clarification of regulatory expectations (whether in rulemaking, licensing, oversight...)
- Continued near-term progress in enhancing safety through the use of available risk-informed methods while striving for increased effectiveness and efficiency in the longer term

**LESSON LEARNED = Full PRA Technical Completeness is not an Impediment to RIDM**

# Benefits of Risk-Informed Applications

## *The Journey IS the Destination – Not Just “What is the Number?”*

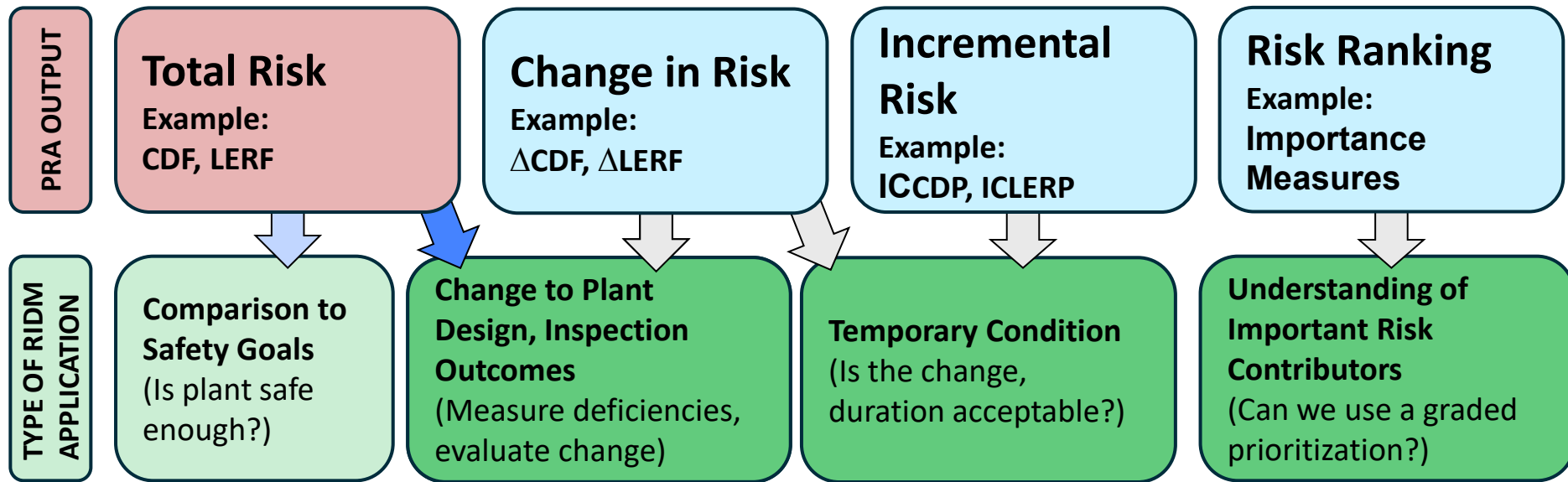
- RIDM identifies weaknesses, vulnerabilities in plant design, operations not always captured in deterministic evaluations
  - More extensive set of scenarios, consideration of likelihood
- RIDM highlights areas where plant design is extremely robust
  - Realistic capabilities (design basis and beyond design bases)
  - Identifies areas for potential improvement (including emergent issues)
- RIDM can provide options when new information or a performance degradation arises (e.g., new hazard info)
  - Prevent unnecessary use of resources if not risk significant
  - Promote discussion and focus on changes with the most benefit



**LESSON LEARNED = Effective RIDM is Intrinsicly Connected to Safety Improvements**

# Communicating the Value is Critical

- RIDM provides benefits beyond cases where the baseline risk of the nuclear power plant is acceptable (or not)



**LESSON LEARNED = RIDM thrives when multiple stakeholders see value**

# Integration is Another Path to Identify Cost vs. Value



As RIDM expanded organically, there is a synergy arising from various uses

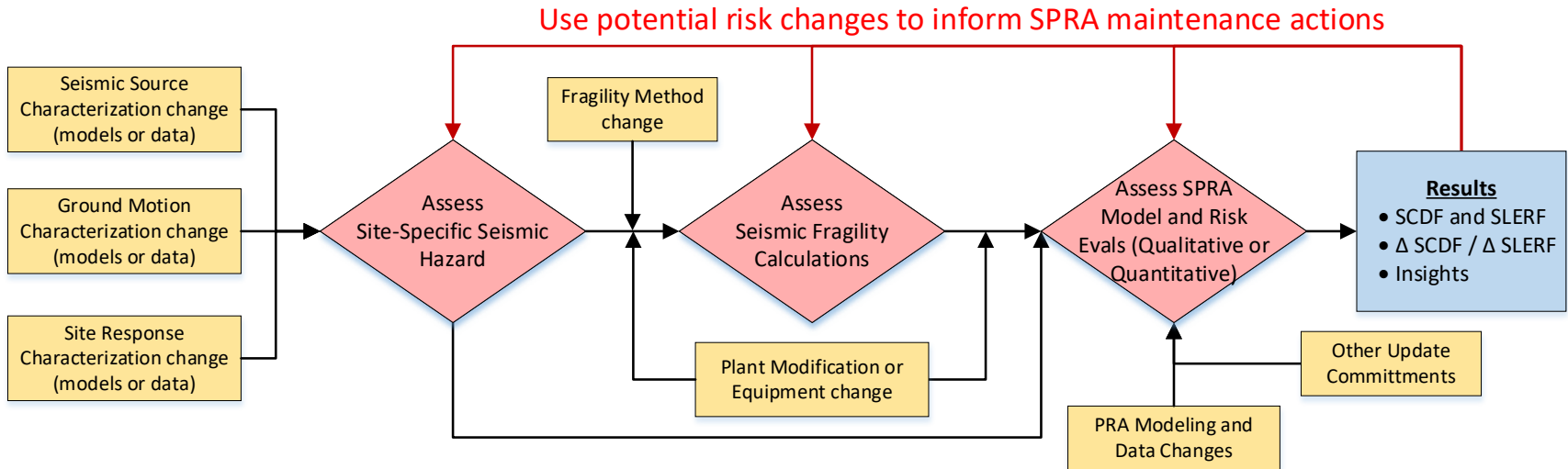
- The inputs/outputs of RIDM applications becoming intertwined
  - **Positive:** as the RIDM expertise builds up, extent of usage opens up
  - **Challenge:** resources are limited
- Additional safety benefit: holistic understanding of RIDM implications
- Further integration is required for:
  - More efficient implementation
  - Optimization of RIDM resources

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

**For Each Implementation, the Question is: Is the cost worth it?**

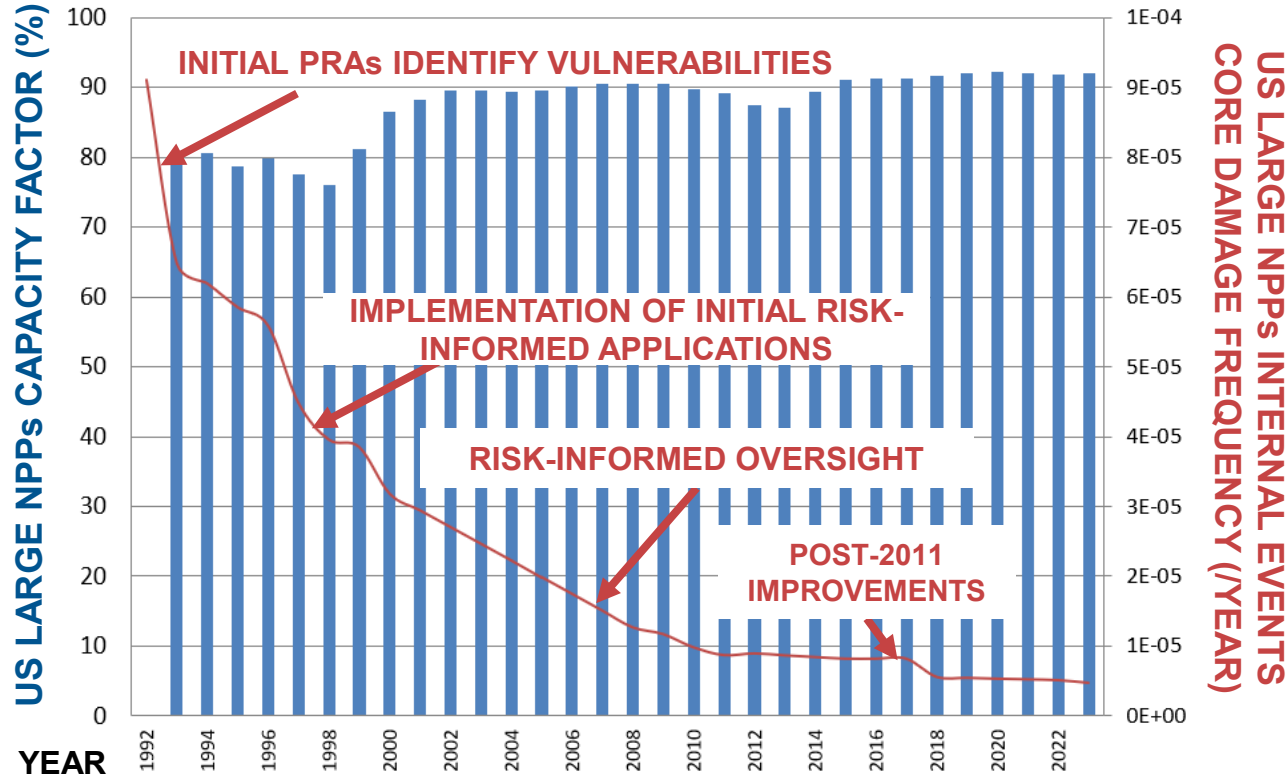
# Some Forward-Looking Directions for RIDM - Complexity

- PRA methods, tools, software, results are becoming **more refined** (complexity ↑)
- Since RIDM relies on PRA inputs (and others), this has a **real impact**
- Multiple efforts to **address complexity** are underway, **more needed**



**LESSON LEARNED = Growth Requires Managing Complexity**

# Benefits of Risk-Informed Applications



- RIDM is about **MUCH MORE** than **saving money and resources** OR always increasing requirements
- We need to do **better** at **communicating** this
- Focusing on items of more significant **safety** impacts, benefits multiple stakeholders (including the **public**)
- Safety benefits are **gained** as the RIDM infrastructure and experience grows

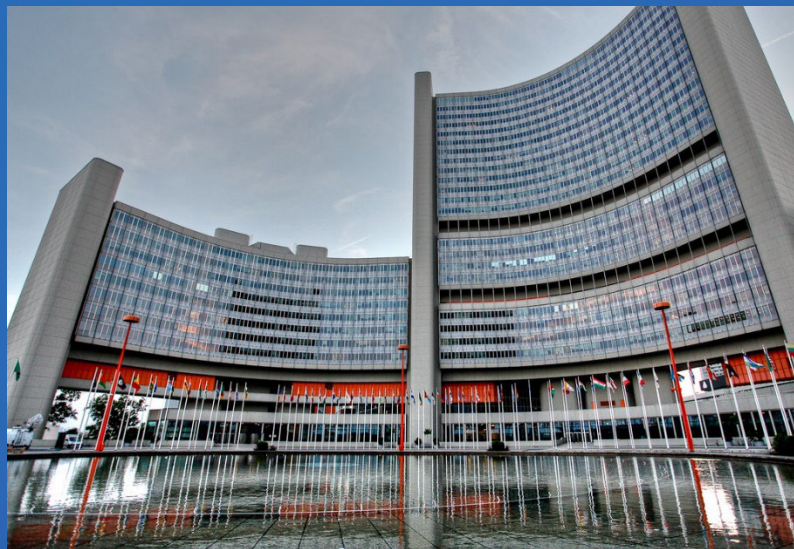
**LESSON LEARNED = Effective RIDM is Intrinsicly Connected to Safety Improvements**



IAEA

*60 Years*

*Atoms for Peace and Development*



*Thank you!*

