History of RIDM in the United States, Challenges and Solutions

AESJ Risk Seminar 2025 - Risk Science and Technology Division

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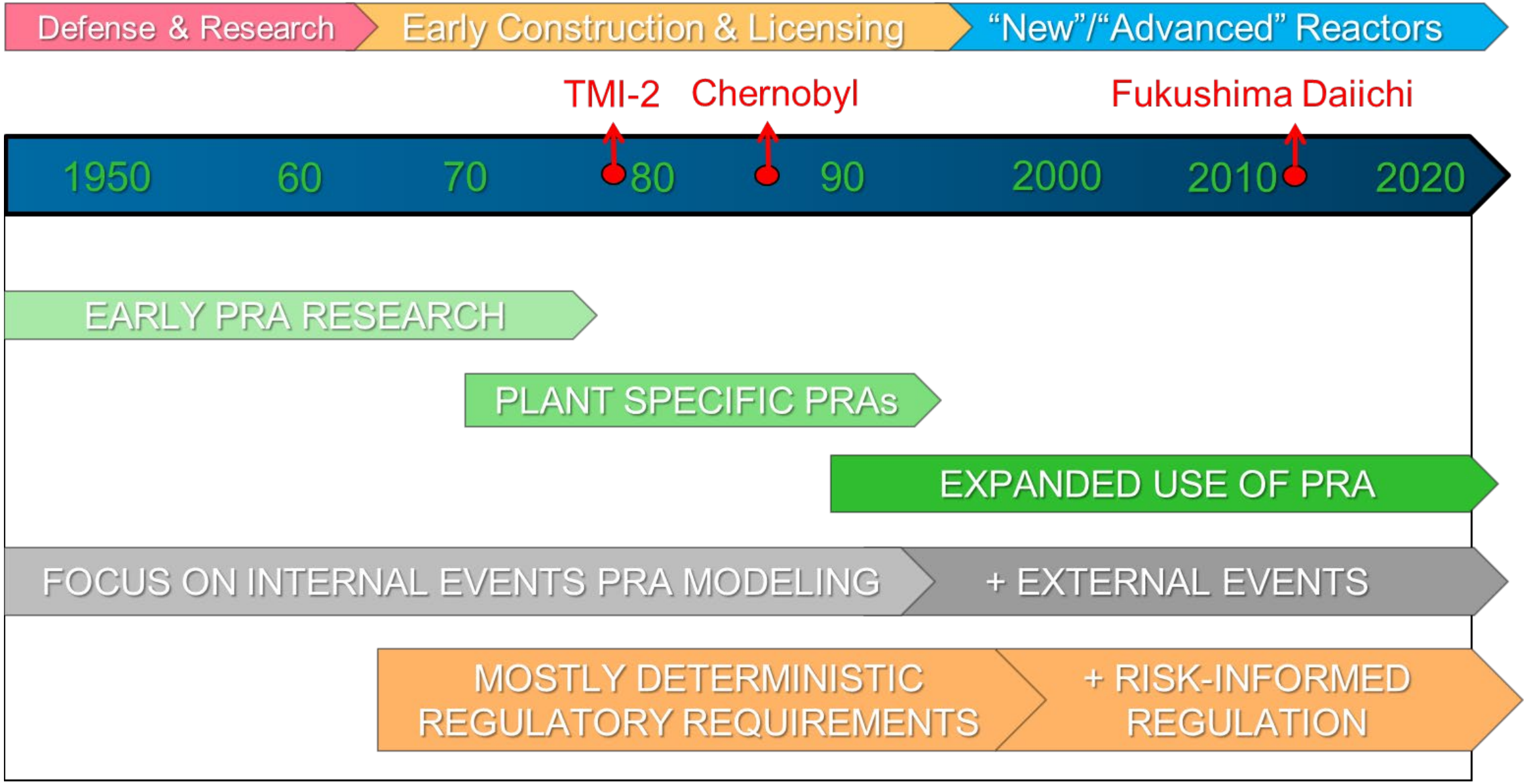
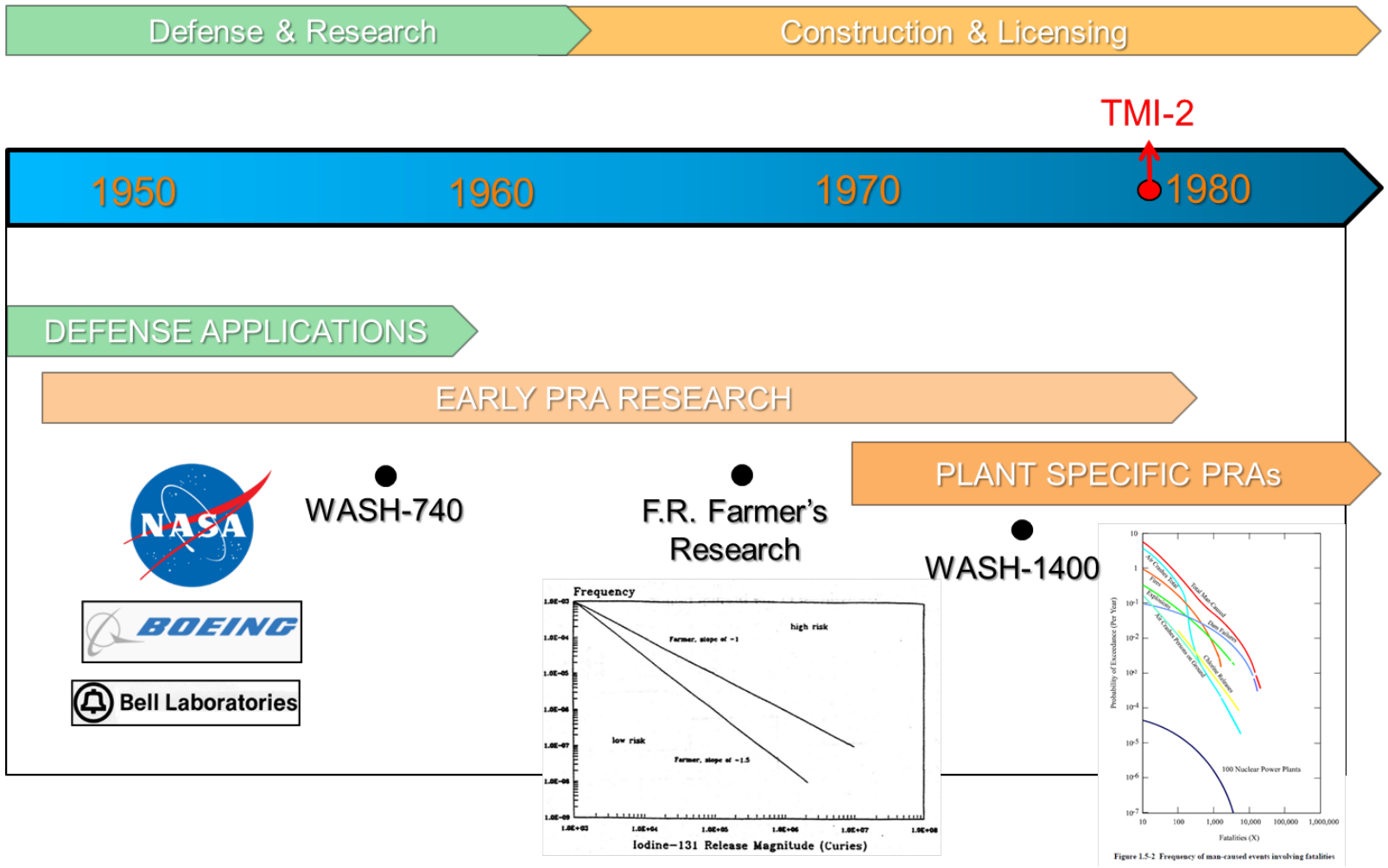
February 18, 2026

General RIDM History - Overview



There were always challenges…

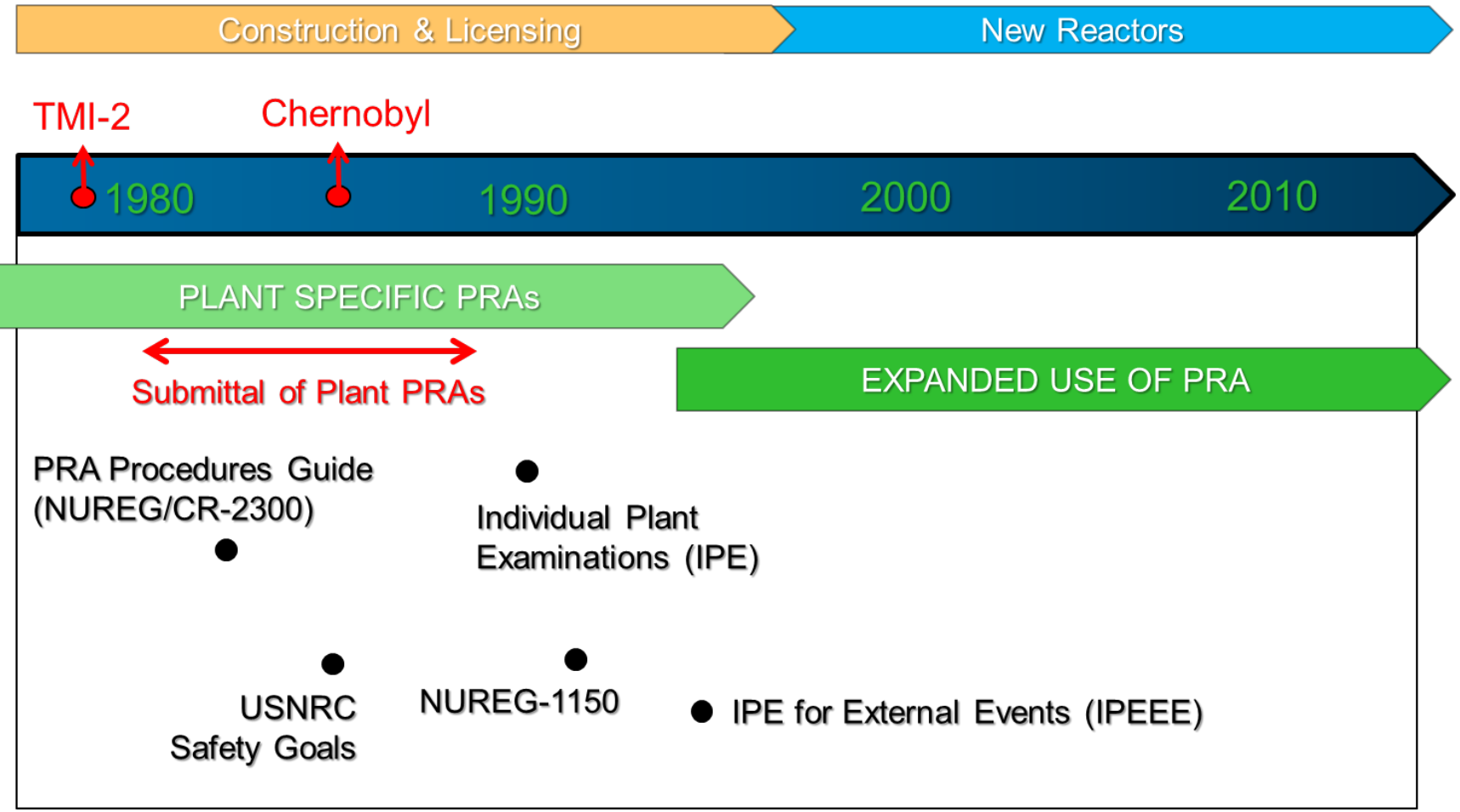


- "WASH-1400" study was **heavily criticized** for:
  - Lack of reliability data
  - Common cause failure model
  - Extensive use of expert judgment
  - Limited treatment of uncertainty
  - Human reliability modeling
  - Approach used for health impact estimation
  - Lack of clear implementable use for the methodology

At the time, idea of a "PRA Policy" was *unthinkable*…

It's not easy to change…RIDM can be a significant change!

But Challenges Can Be Overcome!



- Expansion of the use of risk assessment also had challenges:
  - Evolving but limited consensus on specific aspects of risk model
  - Mostly bounding, screening treatment of external events
  - Varying levels of detail
  - Significant resources for utilities to submit, regulator to review
  - No established industry standard, despite some regulator guidance

Learning from RIDM Implementation Diversity

- Not every country, regulator, site, …, shares the same context
- The key issue is ensuring an appropriate technical basis, sharing of insights, learning from others, continue to evolve

FOR EXAMPLE, CONSIDER =

REGULATORY REGIME 1	REGULATORY REGIME 2
Utility PRA Models NOT shared with Regulator	Goal is to share Utility PRA models with Regulator
Different PRA software, tools, methods used	Single model used, same software/methods
Extensive RIDM Implementation (e.g., 20+ years)	Focus on developing PRA tools, implementing RIDM
Multiple RIDM applications, guidance, methods	Focused implementation of first RIDM applications
PRA modeling NOT required per regulations	PRA required per regulations for operating reactors

LESSON LEARNED = Support for international community strengthens global implementation

And… Where Do We Think We Should Be Going?!?

"RIDM has gone too far – we should go back to a deterministic-based world"

"RIDM is too expensive"

Not a fan of RIDM

"RIDM has not gone as far as I think it should have"

"Why isn't industry using the latest tools/methods?"

Strong RIDM Advocate

"RIDM has come far, with a long way to go"

"RIDM can still expand, if done gradually, efficiently"

Realistic RIDM Mindset

RIDM Takes Time + Effort (But works if done correctly!)

- Implementation of RIDM today can leverage significant expertise from others (as long as it is done in a graded, evolving manner)
- PRA technical adequacy is a continuous journey – NOT A FINAL DESTINATION
- Risk modeling needs to be continuously exercised (not a “one and done”-type effort)
- Completeness is an issue to address, not an impediment to move forward

RIDM Takes Time + Effort (But works if done correctly!)

"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."

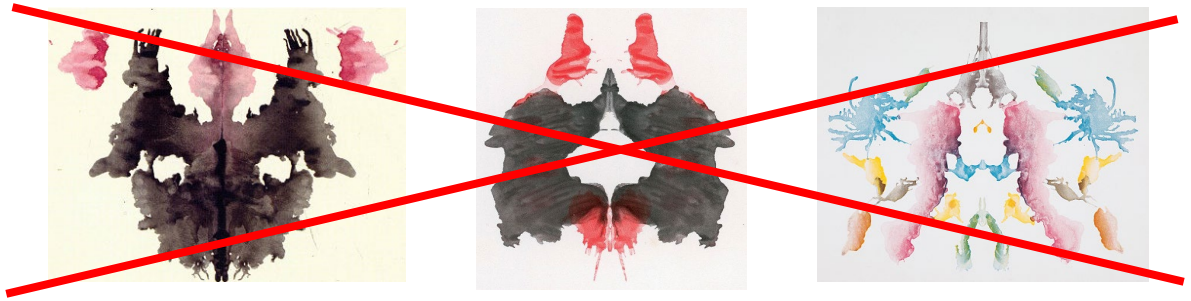
PHASE 1: An "Application-Specific" Phase of PRA Quality	PHASE 2: An "Application Type" Phase of PRA Quality	PHASE 3: An All-Applications Phase of PRA Quality

  - 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

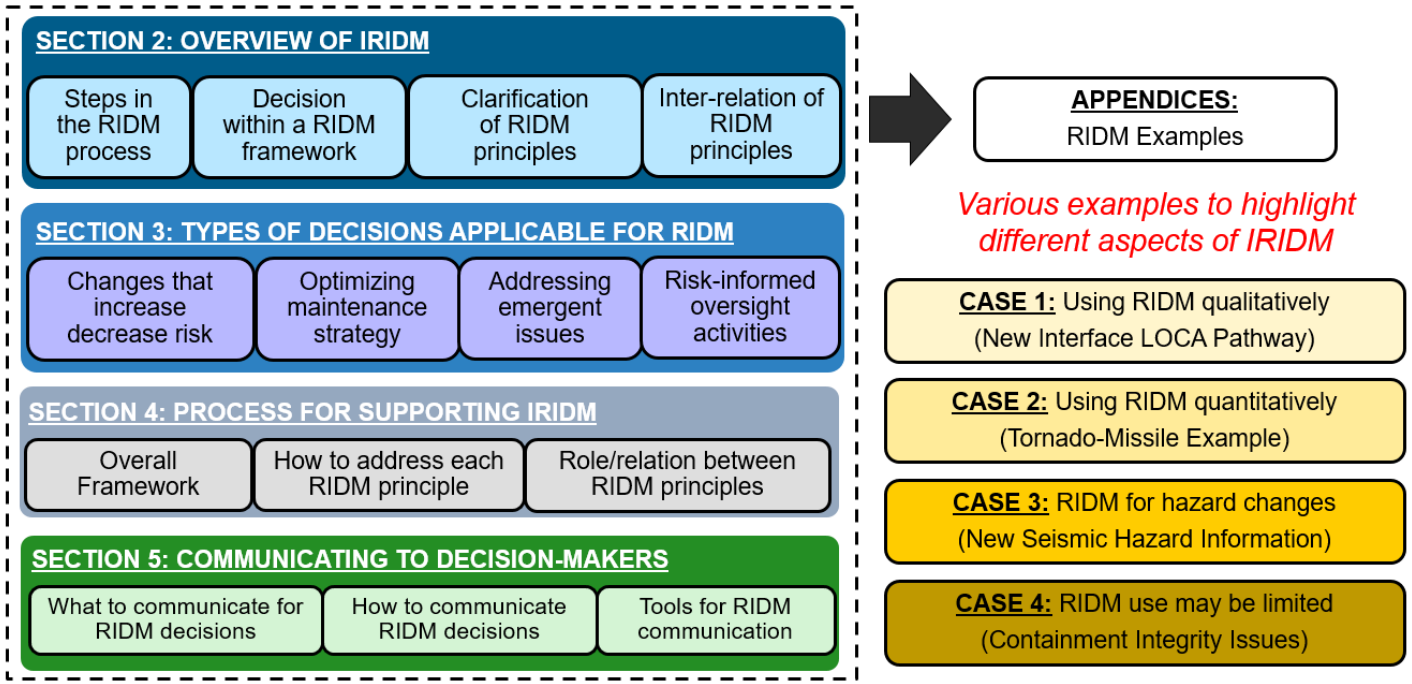
LESSON LEARNED = Full PRA Technical Completeness is not an Impediment to RIDM

RIDM Process is As Important as PRA Technical Aspects

- 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
  - Maybe it shouldn't
  - Maybe adapt existing tools
  - Approach may look different for different issues
- But it should be consistently applied AND the basis and outcome should be clear



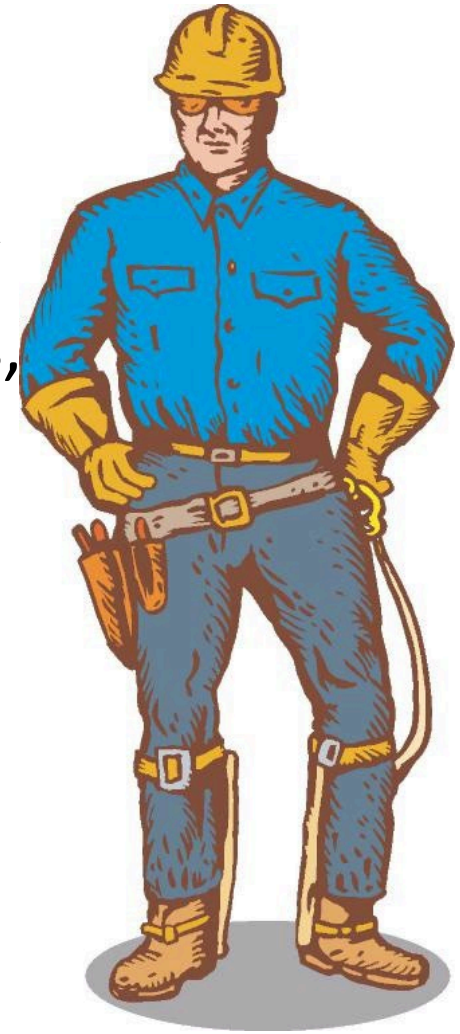
RIDM should not look like a "Rorschach test"



EPRI 3002014783, "A Framework for Using Risk Insights in Integrated Risk-Informed Decision-Making" (2019)

The Maintenance Rule: Early Success of Risk-Informing

Once PRA, RIDM research provided the road for risk methods, tools to be considered, early momentum was gained by:



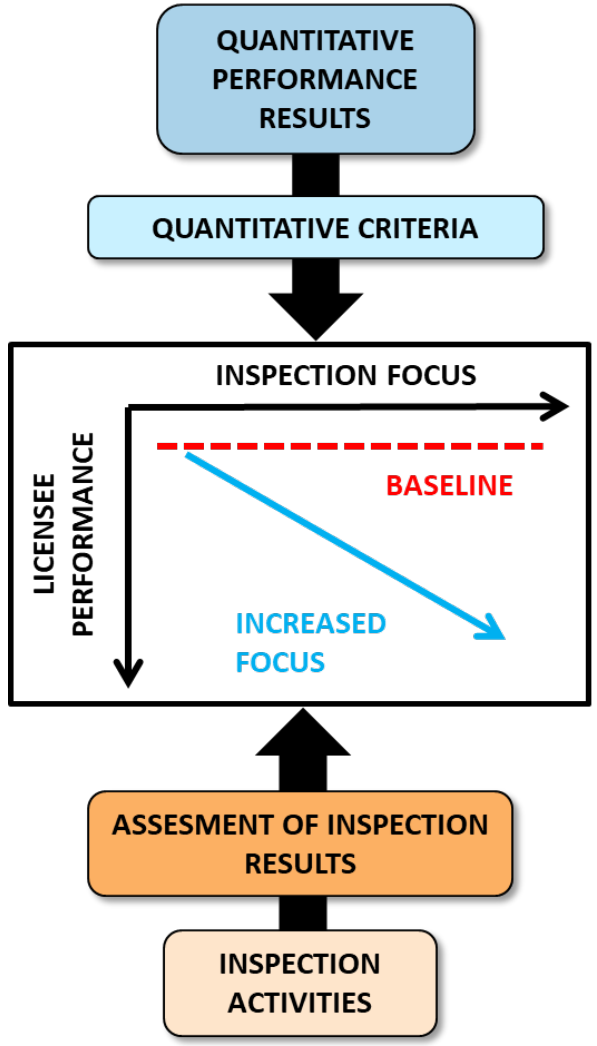
- Push by industry to derive more value for available technology
  - monitor the performance or condition of structures, systems, components against licensee-established goals
  - assess and manage the increase in risk that may result from the proposed maintenance activities
- Recognition by regulator that using risk methods provided (1) safety benefit, (2) better use for resources
- Foundation for risk-informing regulation in other areas

LESSON LEARNED = There has to be momentum/motivation(s) for RIDM

Risk-Informed Oversight Activities – More Progress

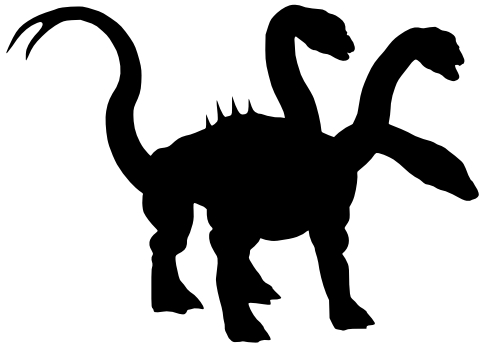
In several countries, a more risk-informed approach to oversight was implemented. In US:

- Transitioned late 1990s/early 2000s (substituted previous process considered less predictable, more subjective)
- Result of extensive discussions with stakeholders
  - Internal and external feedback during the pilot program
  - A first-year implementation period, continuous feedback
  - Continued adaptation and evolution
  - Addressing complexity of using risk tools, timeliness of the overall decision making, and the calibration of quantitative performance metrics



LESSON LEARNED = RIDM is a Process (Not Just About PRA Quantification)

Let's Also Talk About Uncertainty for a Moment



What do we mean when we say…

- "Conservatism"? "Margins"?
- "Uncertainty"? "Defense-in-Depth"?
- "Realism"? "Best Estimate"?, "Reasonable"?, "Bias"?…

More importantly, in what context are we saying it?

- "What is the level of conservatism in your analysis?"
- "Do we have appropriate/sufficient safety margin?"
- "How were the uncertainties addressed in the model?"
- "Was there an impact to the level of defense-in-depth?"

LESSON LEARNED = Need To Move On From Treating Uncertainty As a "Problem"

But Not Just Communicate, Communicate BETTER!

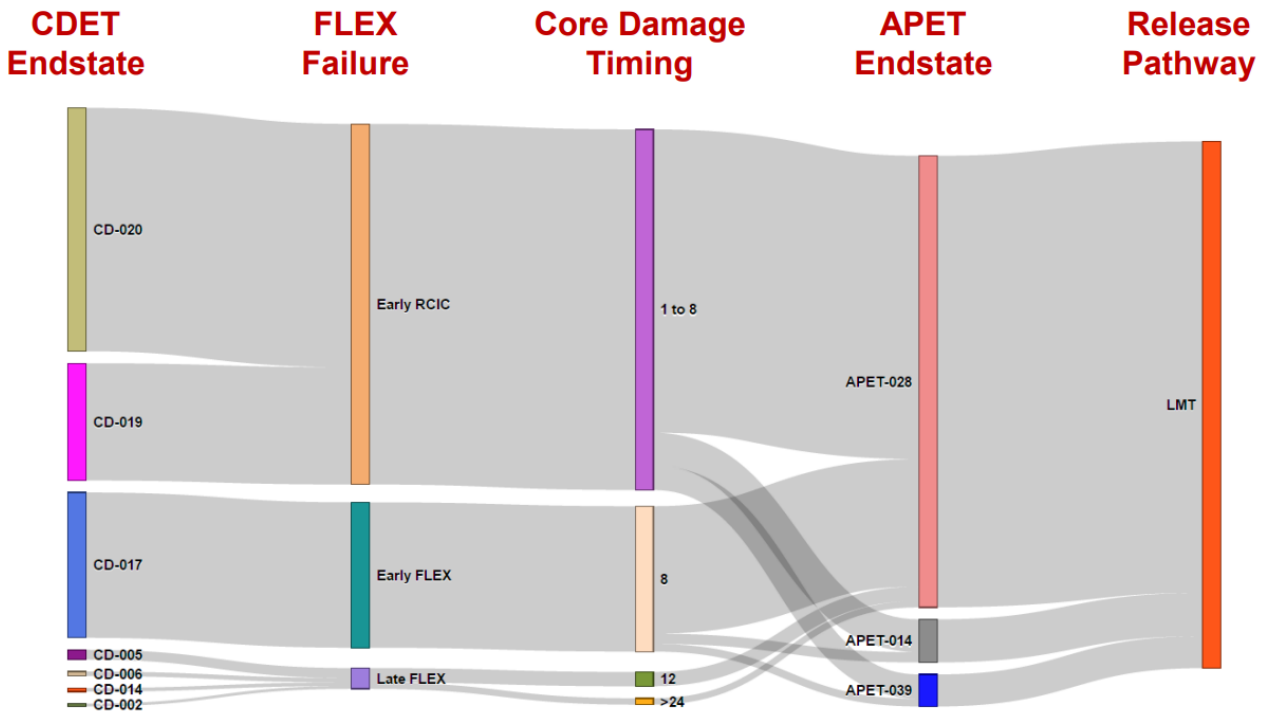
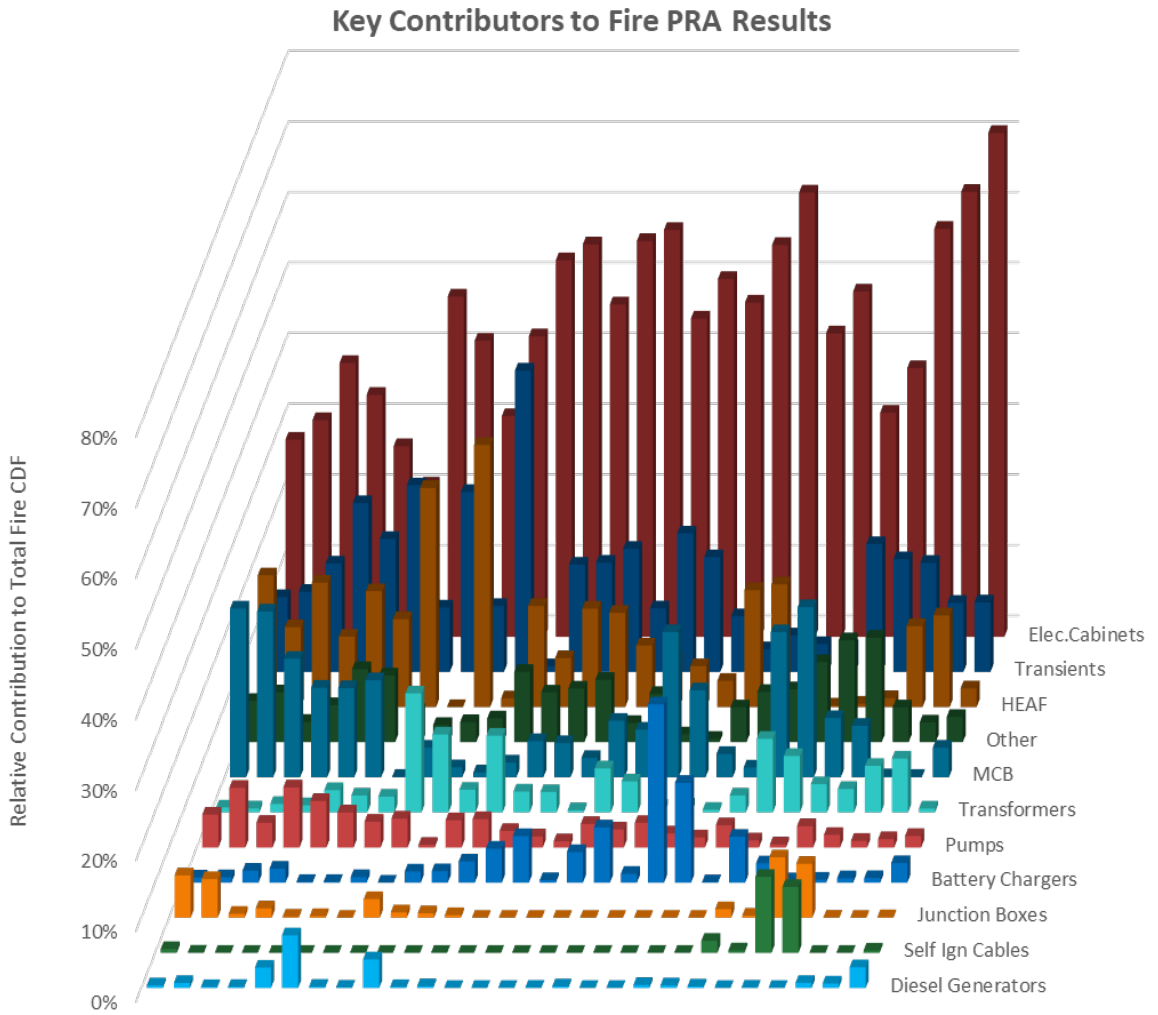


Figure 3-2
Sankey Diagram – Results Visualization for Base Case



LESSON LEARNED = We need to be able to communicate on RIDM/PRA

Workforce Development is an Immediate Critical Need

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

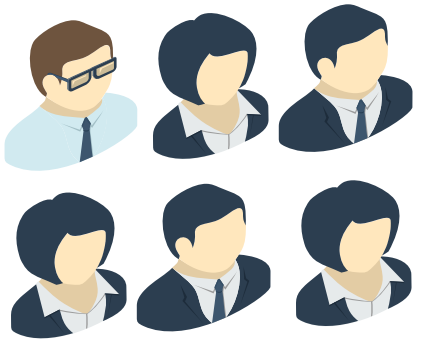
SEISMIC

LEVEL 2/3

HRA

CCF

INTERNAL EVENTS



+

INT. FIRE +

INTERNAL FLOOD +

SEISMIC HAZARD +

CIVIL/ FRAGILITY +

SEVERE ACCIDENT +

ACCIDENT RELEASE +

HRA +

CCF +

APPLICATIONS EXPERT

PRA REGULATIONS

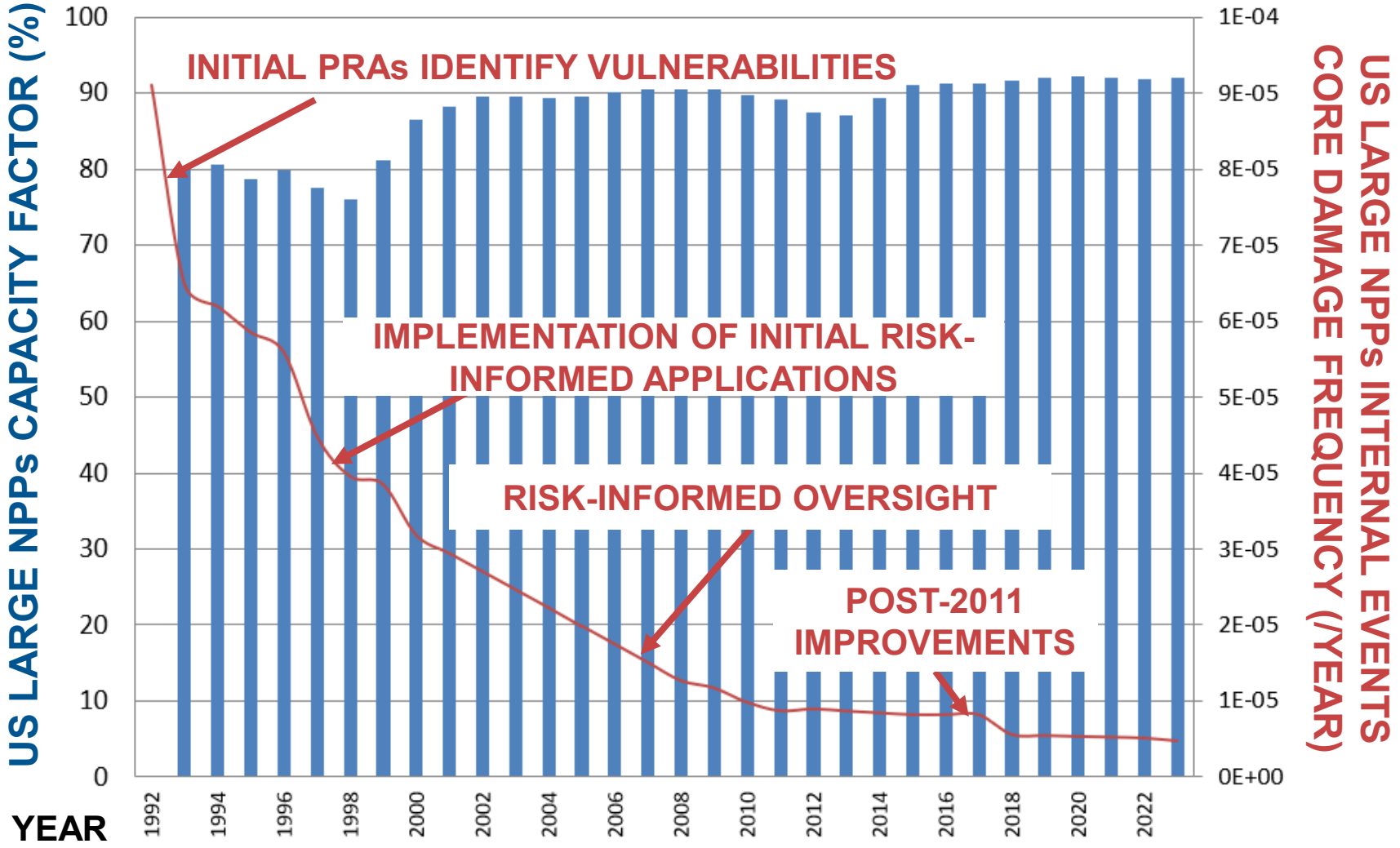
SOFTWARE EXPERT

STANDARDS EXPERT

…

INCREASED SPECIALIZATION/INTEGRATION

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 Intrinsically Connected to Safety Improvements

Some Forward-Looking Directions for RIDM - Synergy

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

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

As RIDM Evolves, New Challenges and Opportunities Arise


QUESTIONS?

PRE-SUBMITTED QUESTIONS AND ANSWERS

QUESTION 1: Completeness of PRA for Risk-Significant Items

For those hazards where PRA is not developed

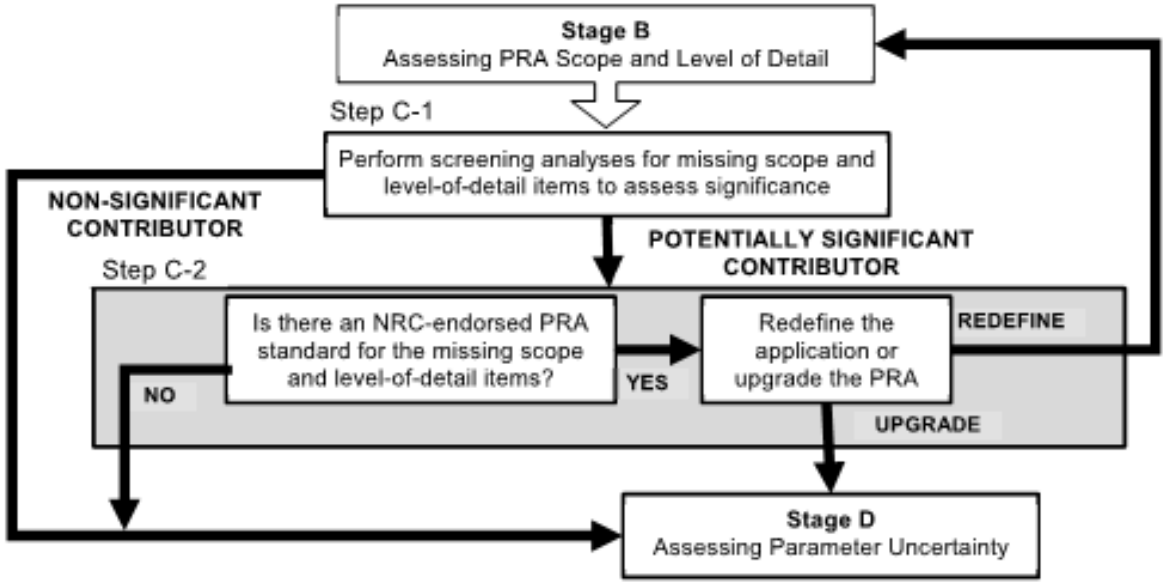
+

which are considered to have significant contribution to the baseline risk (CDF/CFF)

→

Can licensing changes be made without relying on the plant-specific PRA for missing hazard?

?

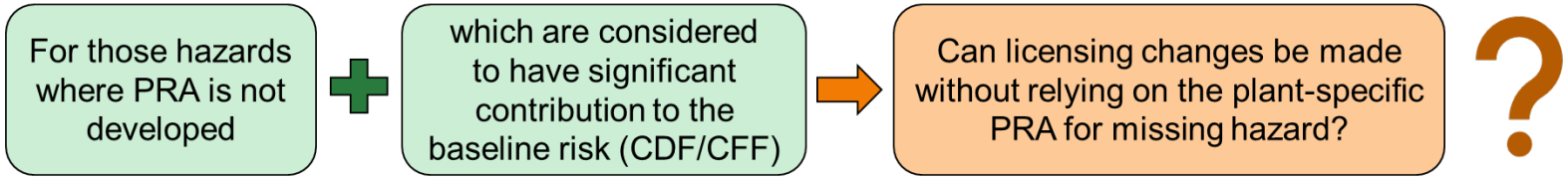


Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking, Final Report (NUREG-1855, Revision 1) | Nuclear Regulatory Commission

- FOR EXAMPLE:
  - Internal Fire PRA not included
  - Internal Flood PRA not include

ANY GUIDANCE DOCUMENTS OTHER THAN EPRI 1026511 OR ACTUAL EXAMPLES FROM LICENSING AMENDMENT REQUESTS?

QUESTION 1: Insights*

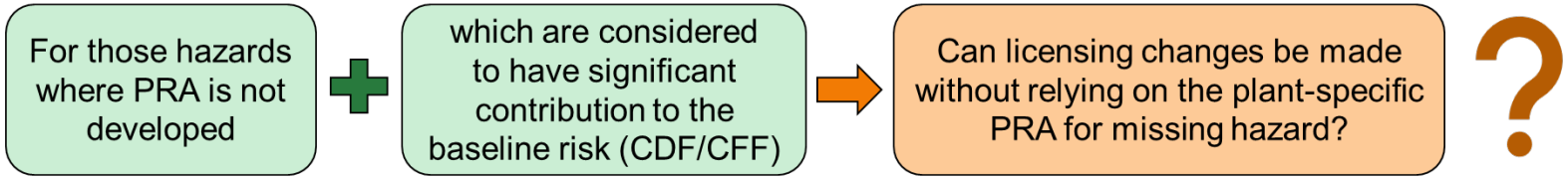


<u>A quick note:</u> NUREG provides important guidance in treating uncertainty and can be used to support reviews; however, regulatory guidance is contained elsewhere (RG1.174).

- The answer to this question depends on a key assumptions:
  - What is the specific licensing change?
  - Is the PRA model (as a whole) *"of sufficient scope and level of detail to support the risk-informed decision under consideration"?*
  - And what is the overall contribution of the missing or incomplete aspects that could impact the decision-making with respect to the <u>specific</u> licensing change, for example:
    - Are the missing quantified hazards significant to the licensing change?
    - Could they be bounded or otherwise estimated to sufficiently address possible impact
  - As stated in NUREG-1855, it is possible to use:
    - *"bounding quantitative analysis*
    - *"conservative, but not bounding analysis"*
    - *"realistic, but limited quantitative analysis"*

**Caveat: Insights based on EPRI guidance and experience, only US NRC can clarify regulatory positions or indicate approval for specific applications*

QUESTION 1: Insights*



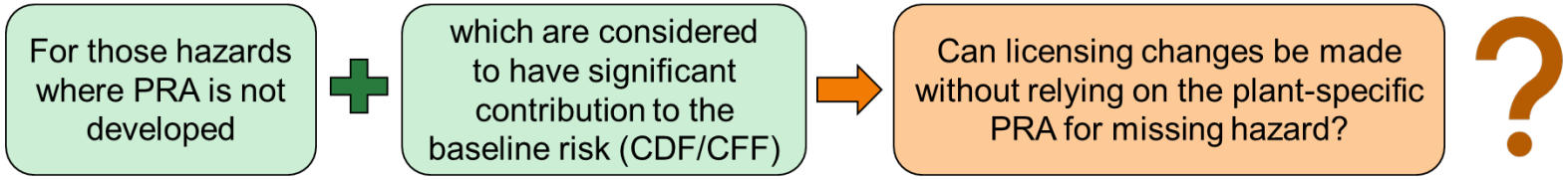
- Furthermore, NUREG-1855 also states: *"examples of bounding analyses that affect the PRA level of detail, are assuming that **all fires or floods in a specific area** (maximum frequency) **fails all equipment in that location (maximum consequences)** combined with taking no credit for mitigation systems"* (underline added)

- Note that this can be **extremely conservative** and, again, it **may or may not be practical**, depending on whether the licensing change in consideration is susceptible to fire and internal flood impacts
  - As mentioned in NUREG-1855, guidance on internal fire includes conservative approaches, such as those contained in NUREG/CR-6850, EPRI 1011989:
    - *"(U)sing conservative fire modeling analyses to identify fire sources that can potentially cause damage to important equipment"*
    - *"This analysis allows for eliminating fire sources that cannot cause damage, thus reducing the compartment fire frequency that is used in the quantitative screening process."*

- It should be noted in practice that if the licensing basis change is significant (i.e., impact multiple equipment, mitigation, hazards, etc), then performing a bounding quantitative analysis could become as costly as doing the PRA itself, i.e., **a balance that must be considered**

**Caveat: Insights based on EPRI guidance and experience, only US NRC can clarify regulatory positions or indicate approval for specific applications*

QUESTION 1: Insights*



- As stated in RG.1.174: *"The NRC does not intend that the search for alternatives should be exhaustive or arbitrary. For the decisions that involve only assessing the change in metrics, the number of model uncertainty issues to be addressed should be smaller than for the case of the base values, when only a portion of the model is affected"*
  - This is a critical statement that answers the question: are all model uncertainty issues (or all hazards, or all PRA Levels, or all modes) always required? NO, with the caveats that NRC provides:
    - *"When the PRA is not full scope, it is necessary for the licensee to address the significance of the out-of-scope items"*
    - "This is related to the margin between the as-calculated values and the acceptance guidelines":
      - *"When the contributions from the modeled contributors are close to the guidelines, the argument that the contribution from the missing items is not significant should be convincing and, in some cases, may warrant additional PRA analyses."*
      - *"When the margin is significant, a qualitative argument may be sufficient. The contribution of the out-of-scope portions of the model to the change in metric may be addressed by bounding analyses, detailed analyses, or by a demonstration that the change has no impact on the unmodeled contributors to risk."*

**Caveat: Insights based on EPRI guidance and experience, only US NRC can clarify regulatory positions or indicate approval for specific applications*

QUESTION 2: Specific Methods for Plant Modifications/Refinements

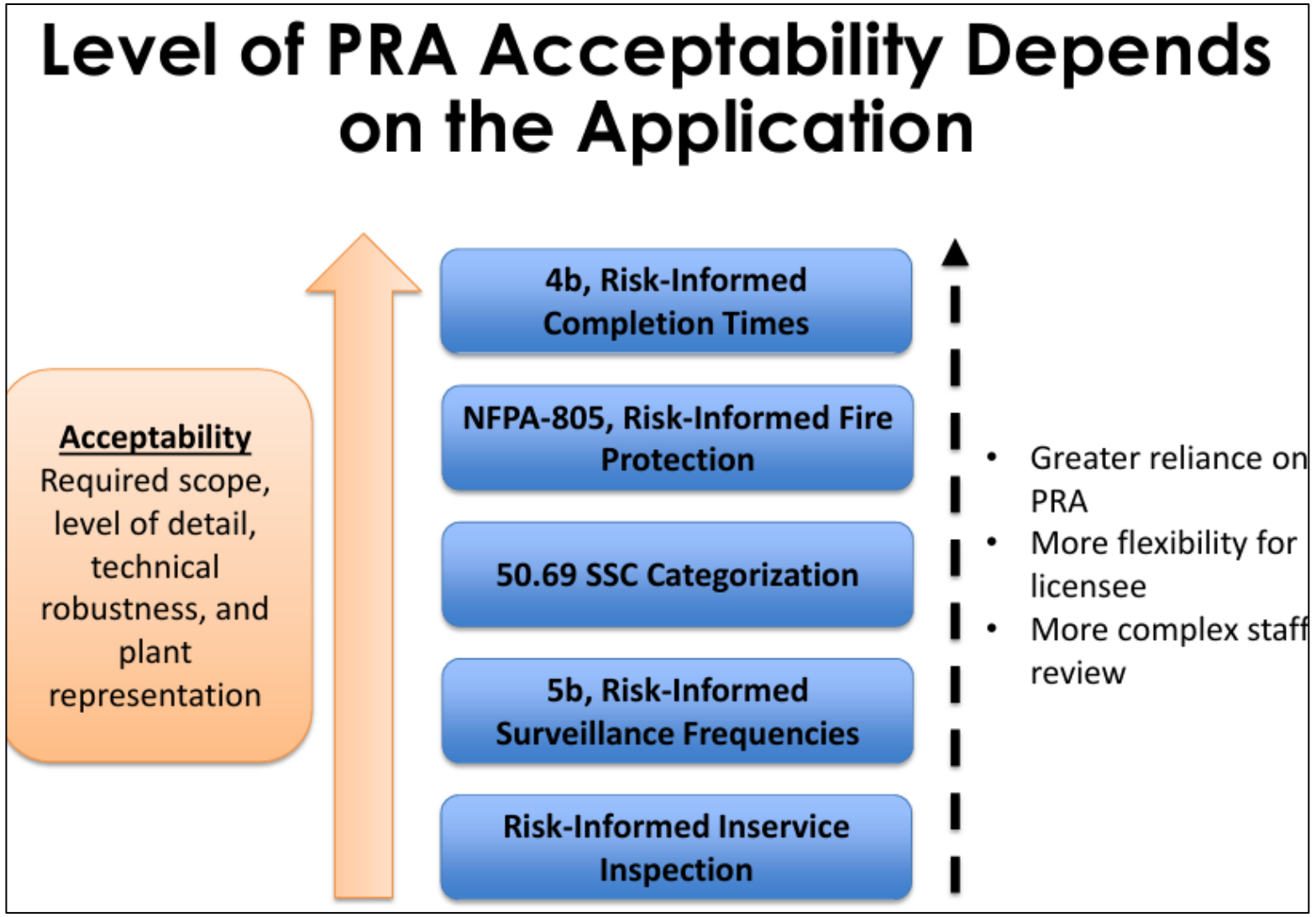
LET'S LOOK AT AN EXAMPLE FOR QUESTIONS 1 AND 2 ON SCOPE COMPLETENESS

In the US, an issue related to the potential for a loss-of-accident cooling (LOCA) to dislodge equipment and material (such as thermal insulation) that could cause clogging to containment sumps and strainers. Therefore, the initiating event was postulated to cause impact to mitigating capabilities if it occurred. ***NOTE = This is just an example for discussion, not an extensive review of the issue or all scope details (see *)***

- The solution to this issue, in the US (which impacted multiple classes of designs, plants), was to:
  - Use a risk-informed approach that relied upon the RG1.174 framework
  - Use a PRA model to consider additional structures, systems, and components (e.g., sump strainers) and events (e.g., core blockage scenarios)
  - Rely on a screening approach was used to focus analysis on a discreet set of breaks that were significant risk contributors
  - Use sensitivity studies and uncertainty evaluations to ensure confidence in the results
- Given the scope of the application-specific details (hazards, sequences, SSCs, input models):
  - The PRA model scope was identified to be: LOCAs of a given set of breaks and potential seismic events that could impact the LOCA likelihood
  - What could be excluded from the scope:
    - Full internal flooding PRA was not in scope, since LOCAs are the limiting condition/sequences
    - Full internal fire PRA, since fire scenarios are typically not expected to cause major breaks

*GSI-191: The Impact of Debris Induced Loss of ECCS Recirculation on PWR Core Damage Frequency (NUREG/CR-6771) | Nuclear Regulatory Commission

QUESTION 3: Rationale for different application specific-PRA scope



Material from NEI Lessons-Learned Workshop, January 30 - 31, 2019 *
*https://www.nrc.gov/docs/ML1906/ML19064B049.pdf

IMPACT OF THE CHANGES

- MAJOR/MINOR
  - E.g., impacts multiple functions

EXPECTATION OF THE PRA USE

- INTENSIVE/LIMITED/FOCUSED
  - E.g., PRA results play major role

REGULATORY FOOTPRINT

- REGULATOR-CONTROLLED
- LICENSEE-CONTROLLED

AVAILABILITY OF GUIDANCE

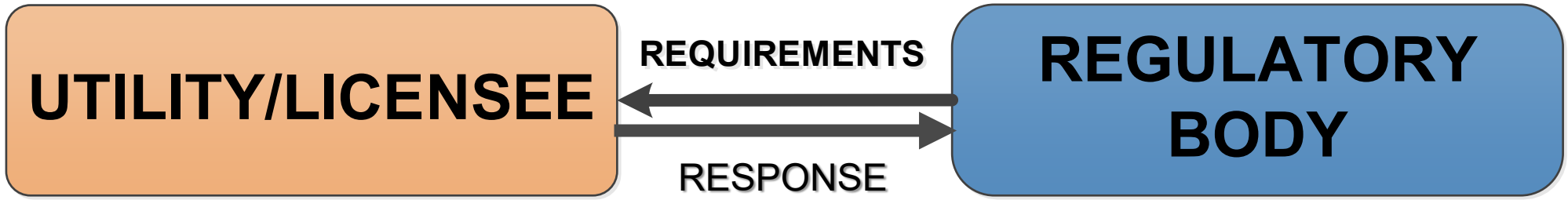
- EXTENSIVE/LIMITED
  - E.g., does a standard apply?

EXPERIENCE WITH APPLICATION

- PILOT vs. ROUTINE vs. STATE-OF-ART

QUESTION 4: Discussions Between Stakeholders

In the U.S., when establishing methods to make risk-informed decisions on plant-specific changes to the licensing basis, what roles were played by the regulator, utilities/operators, and research institutions? Additionally, if there were any key factors that contributed to successful discussions between the regulator and industry, please describe them. Conversely, if there were factors that caused discussions to be prolonged or delayed, please also share insights on those.

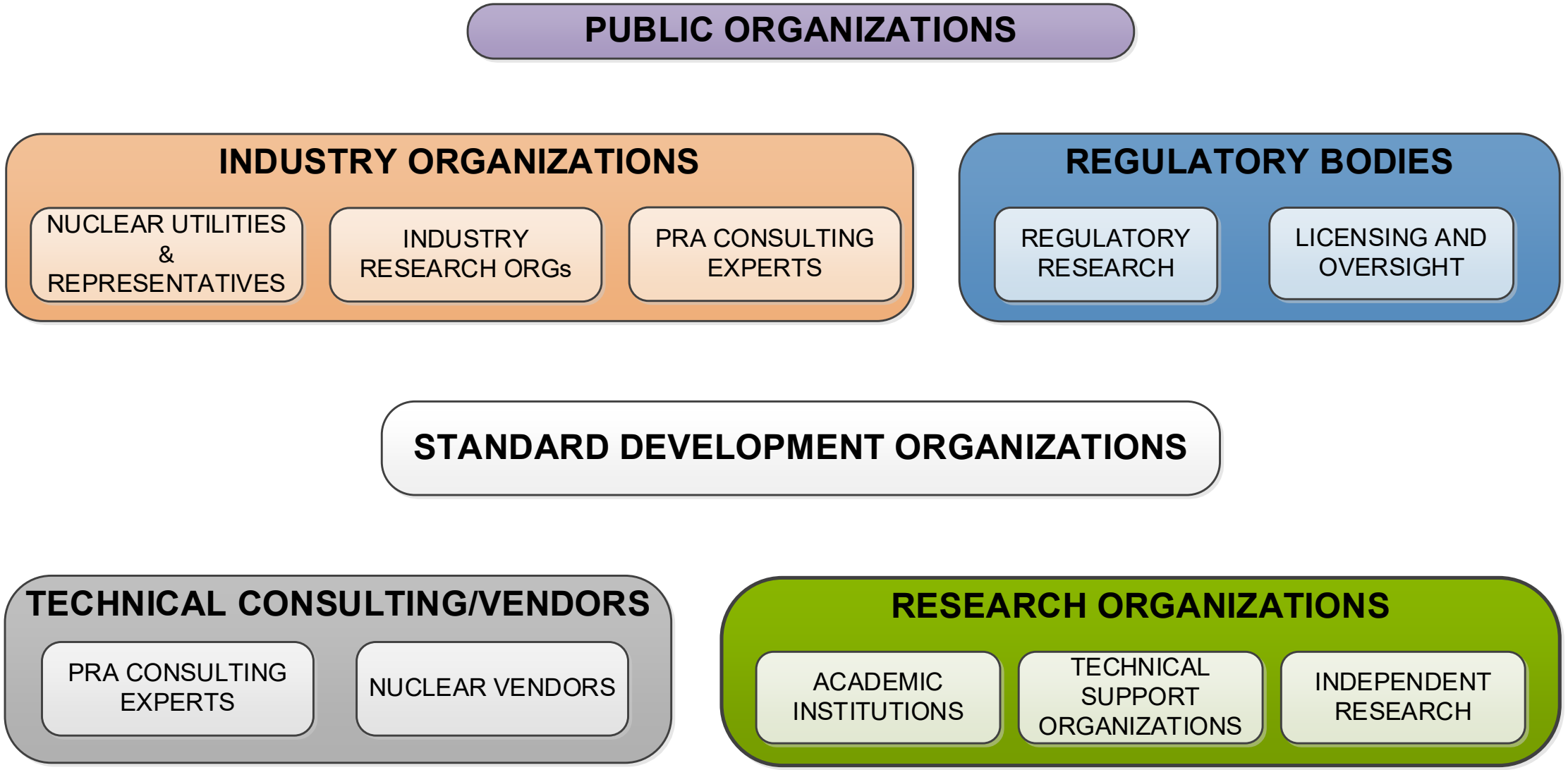


- The expectations on developing a framework for RIDM, and specific processes such as risk-informed licensing bases changes are often focused on the licensed utility and the regulator, but it takes a large body of work, run time, and a much broader community to achieve different aspects

  IMPORTANT NOTE = It does not all have to happen quickly; it is an evolving effort!

- Let's explore some of those organizations, roles, processes (at a high level) next

QUESTION 4: Discussions Between Stakeholders



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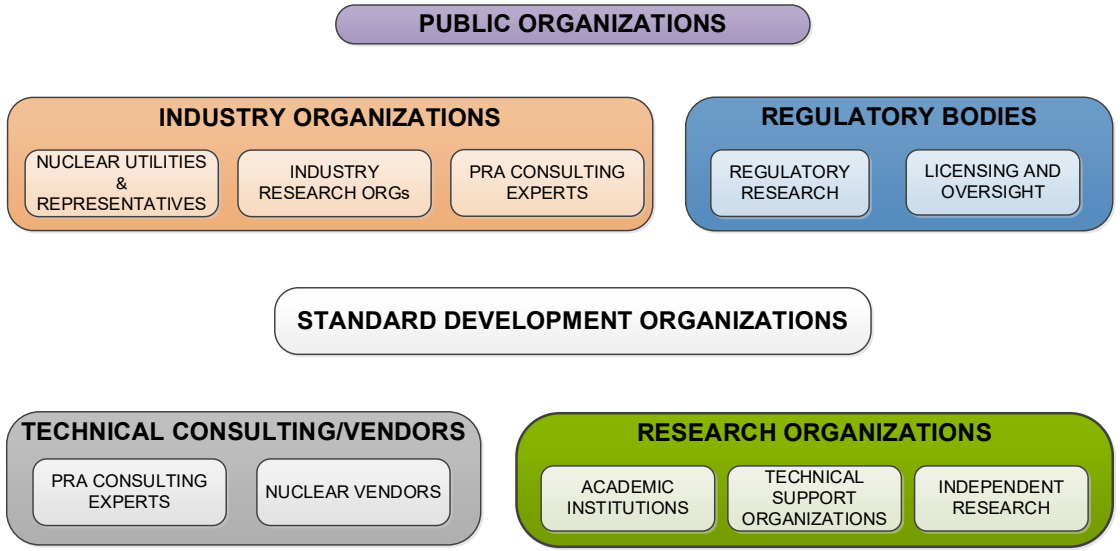
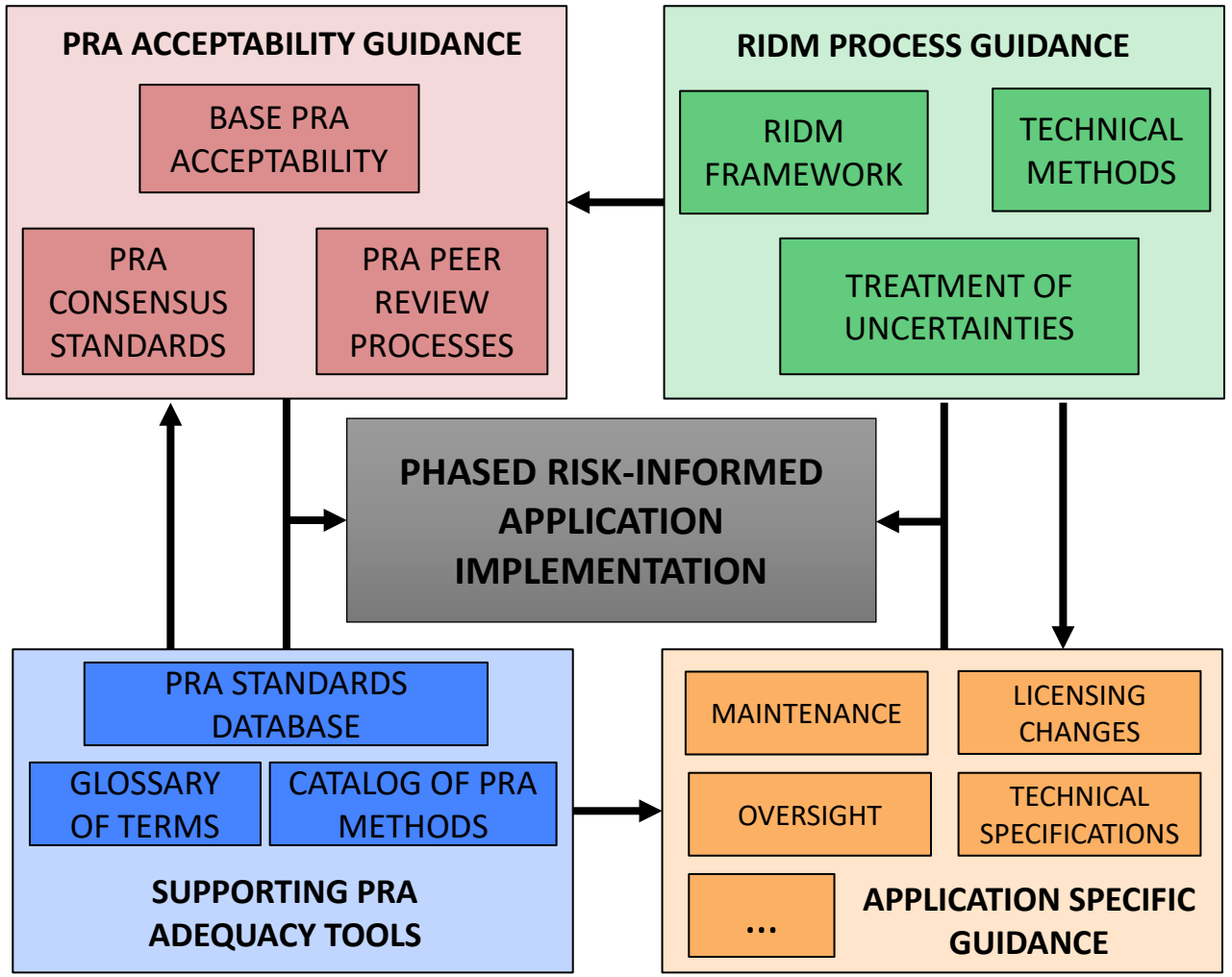


FACTORS THAT SUPPORT RIDM

- Transparent Communication
- Openness from Regulator (clear policy)
- Clear understanding of benefits/costs
- Nurtured technical organizations/research
- Shared experience among practitioners
- Efficient guidance and transparency
- Continuous learning from challenges



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

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