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Using Probabilistic Fracture Mechanics in Regulatory Applications

RG_09

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Passive Components

NRC Materials Engineer review typically focuses on the quality of component design, manufacture, and installation followed by periodic inspection. These efforts support maintenance of adequate safety margin.

NRC conducts development of probabilistic fracture mechanics tools to generate failure probabilities for passive reactor components for use in regulatory decision making.

— Paraphrasing NUREG CR 6936

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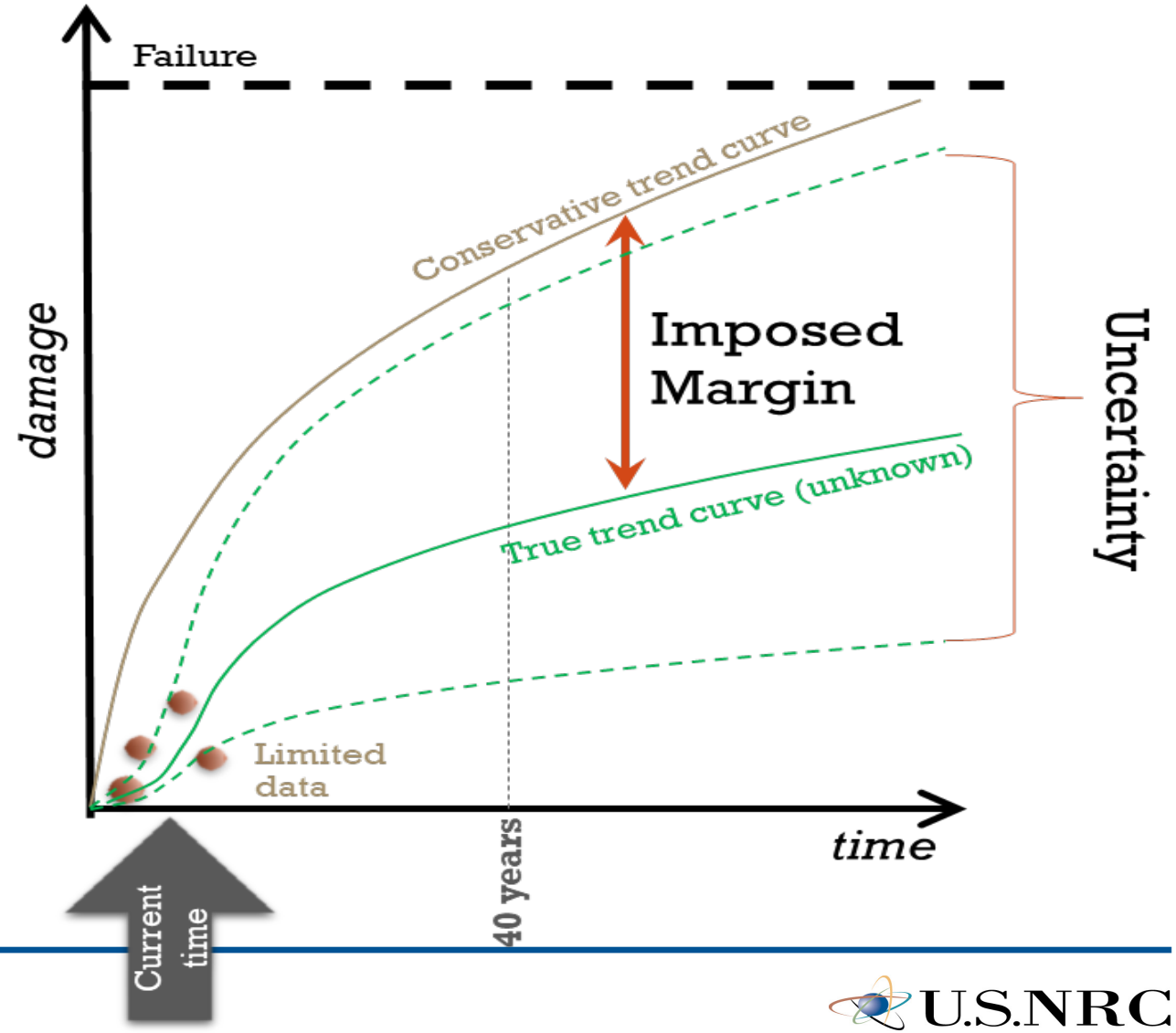
Motivation for Probabilistic Fracture Mechanics

- **Early in Life**
  - Limited data – large uncertainty
  - Every discipline gets its own margin
    - Loading over-estimated
    - Material resistance under-estimated
  - Conservatism does not limit operability
    - Plants are new
    - No plant near failure



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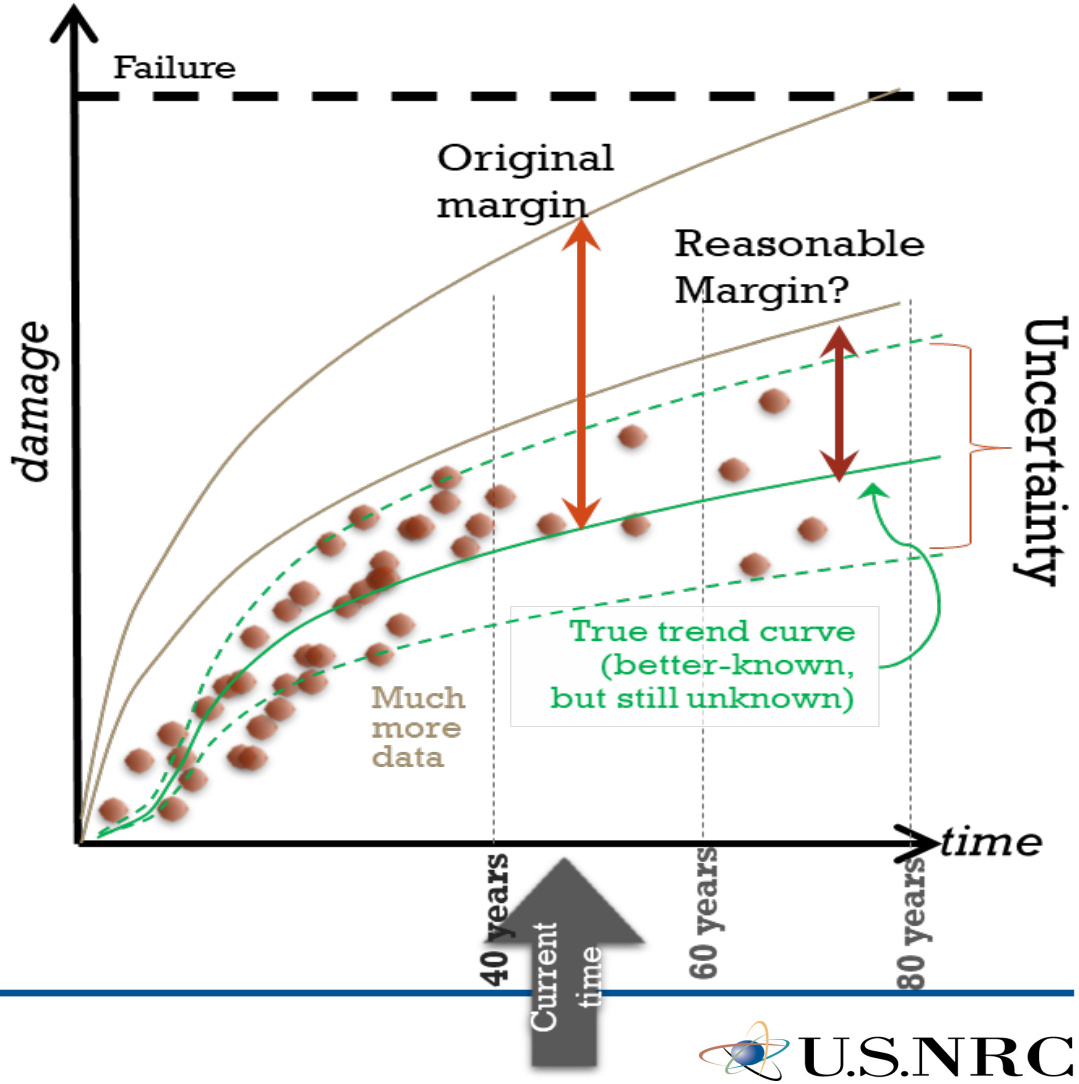
Motivation for Probabilistic Fracture Mechanics

- **Life Extension**
  - More data & knowledge support improved models – less uncertainty
  - Original margin overly burdensome? Do we change the margin with time?
  - Issues
    - Deterministic margins make all inputs conservative
    - Deterministic approaches
      - Not well suited to quantifying actual risk
  - Solution: Probabilistic analyses –
    - Properly account for true uncertainty



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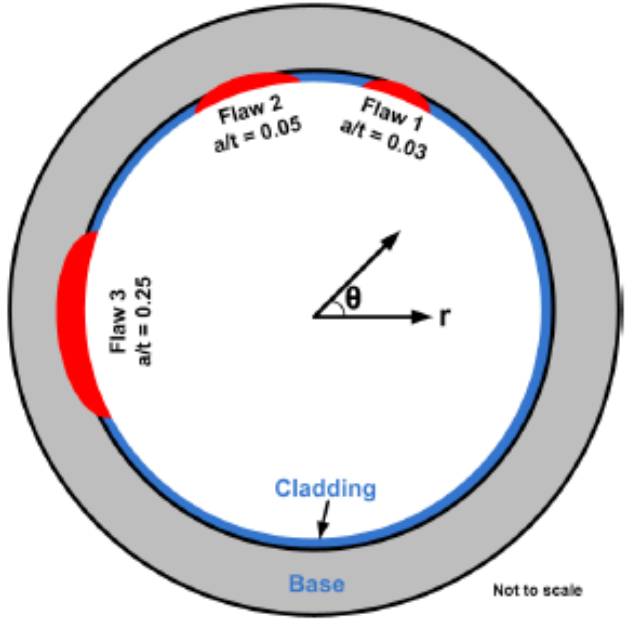
Using PFM to Risk-Inform Materials Topics

Probabilistic Fracture Mechanics (PFM) is an analytical method for modeling degradation likelihood.

"What can go wrong" is an assumption in the analysis.

PFM results can be used as proxies for initiating event frequencies in providing risk-insights. (The "how often" of the Risk Triplet)



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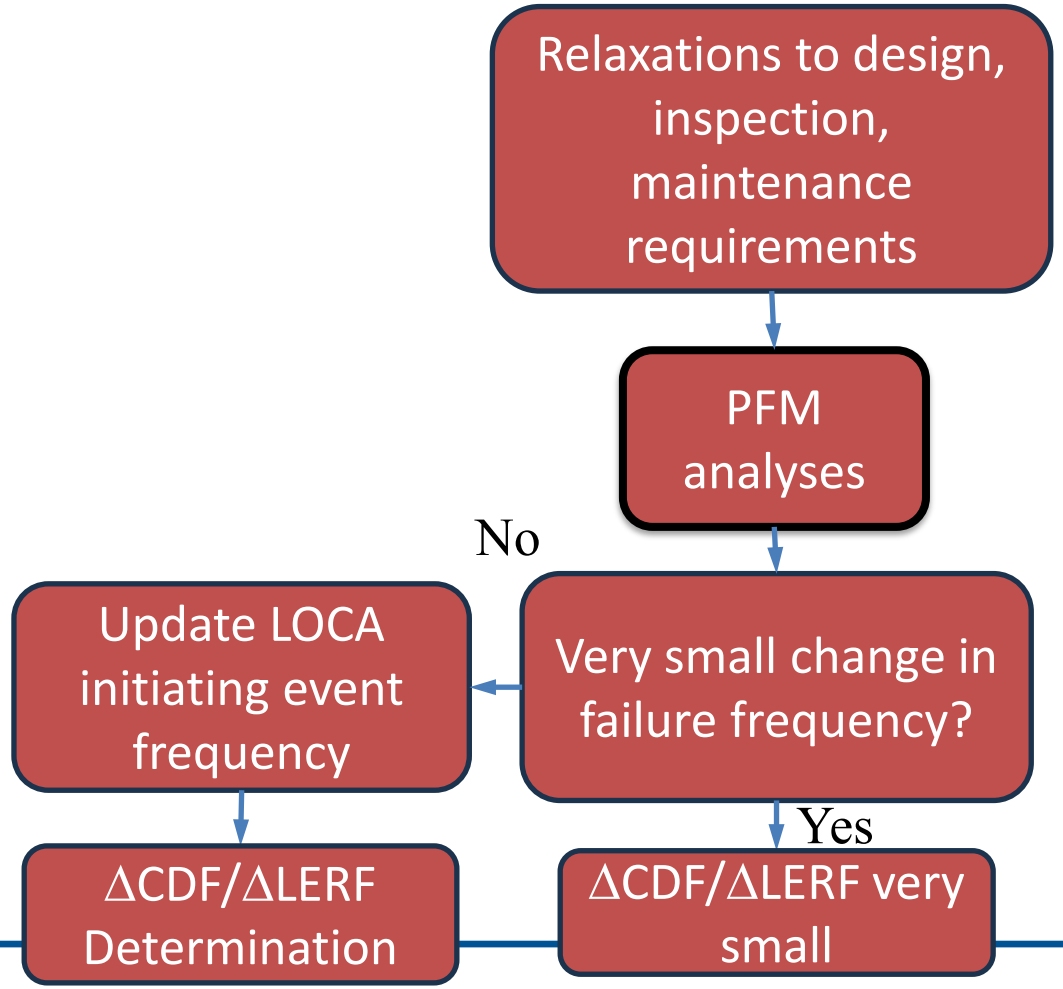
PFM and RIDM

PFM is only one Part of Risk-informed Decision Making



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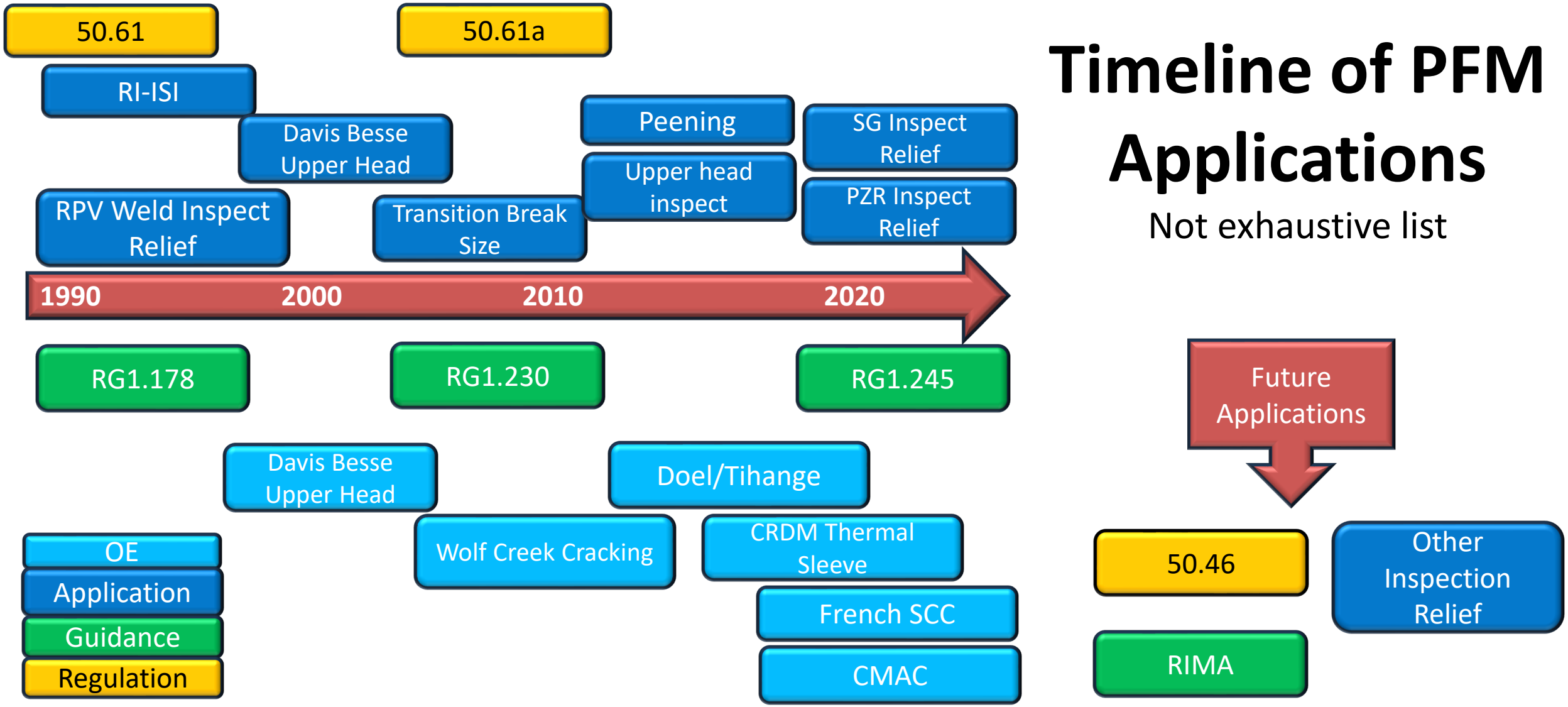
Timeline of PFM Applications

Not exhaustive list



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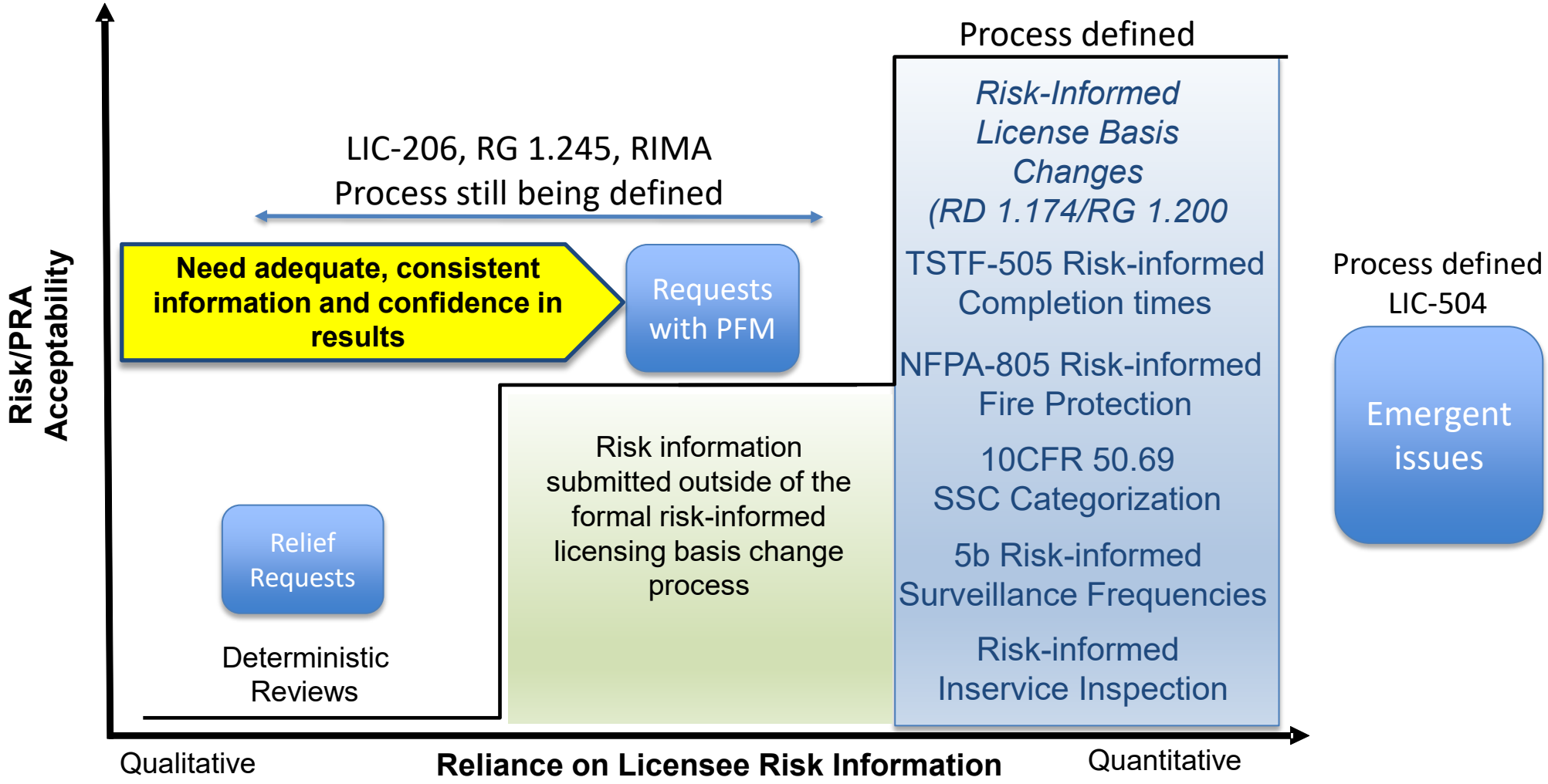
Licensing Reviews and Emergent Issues



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PFM Informs Risk Thinking

The output of PFM is typically an expected time until impact on integrity (through wall cracking frequency, TWCF, LOCA, rupture, etc.) or other measure concerning integrity of a component.

In risk-space, this informs potential initiating events such as LOCAs or loss of availability of trains of equipment.

Typically, PFM results are reported as best-estimates with sensitivity analysis/study results to demonstrate margin and/or management of uncertainties.

Performance Monitoring

Performance monitoring: a foundational aspect of safety bases

Where structural integrity is important, performance monitoring generally takes the form of inspections or testing:

- RPV surveillance programs
- ASME Code ISI
- Etc.

Performance monitoring supports materials-related risk-informed decision making

- Direct evidence of presence of degradation
- Validation of continued adequacy of analyses
- Timely method to detect unexpected degradation

Performance monitoring is not:

- Independent of the significance of a component
- Only one kind of monitoring there are many potential approaches
- Optional

NRC Guidance Efforts

Guidance development for risk-informed applications continues forward

Relevant recent developments:

- LIC-206, Rev. 1
- RG 1.245

Ongoing:

- RIMA

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NRC Guidance Efforts – LIC-206

Improve early integration of review teams when risk-insights would lead to need for integration

Improve use of risk-insights to scope and depth of review

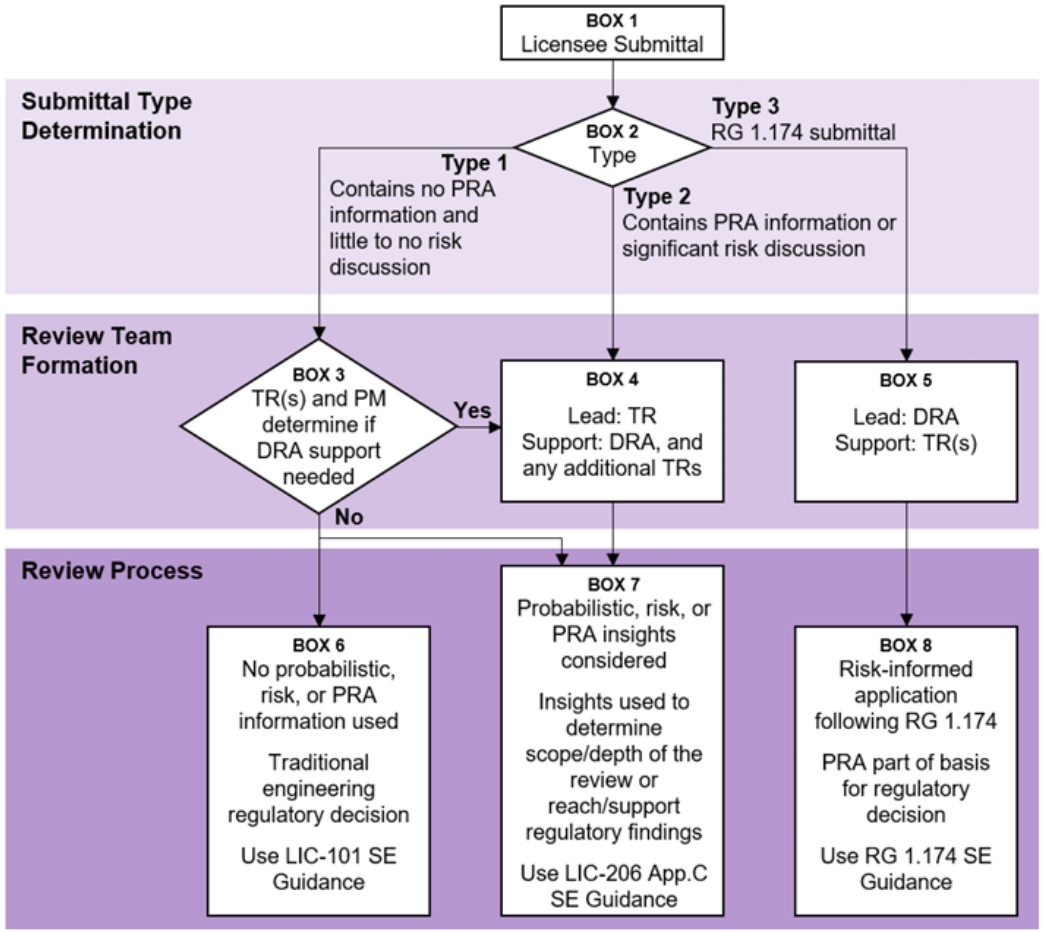

Figure 1: *Integrated Review Team Process Flowchart*

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Regulatory Guide 1.245 - Graded Approach for PFM

PFM is complex

- The depth and breadth of a PFM analysis might vary widely depending on several factors

It makes sense to take a graded approach…

- …for PFM analyses themselves
- …for the level of detail to be presented as part of an evidence package

General Principles

- Higher safety significance
- Higher complexity
- Higher level of novelty

- Topics Covered
  - Software QA and V&V
  - Models
  - Inputs
  - Uncertainty Propagation
  - Convergence
  - Sensitivity Analyses
  - QoI Uncertainty Characterization
  - Sensitivity Studies
- Not Covered
  - Application specific guidance

➢ More analyses, more documentation

➢ Higher burden to create defensible and rigorous evidence

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NRC Guidance Efforts – RG 1.245

RG 1.245 provides substantial actionable guidance regarding the minimum necessary components of acceptable bases for use of PFM in a regulatory application

RG 1.245 is not a holistic guide regarding all aspects of reviews containing PFM element,

> The NRC has an approved methodology for risk-informed decision making for design-basis changes [RG 1.174], and PFM may be used as a tool within that framework. (RG 1.245, Rev. 0)

Risk Informed Materials Assessment

NRC Staff lead project

Goal

Regulatory guidance providing framework for submitting and reviewing materials engineering applications with Risk informed decision-making (RIDM) aspects

Ambitions

Guidance would provide key aspects to include in high-quality submittals as well as the interaction between these key aspects as they may relate to NRC review decisions.

Challenge

Existing NRC RIDM guidance focused on use of PRA
RIDM guidance for passive component integrity not available
Handling of uncertainties lacks guidance

Status

Project officially initiated
NRC staff developing draft guidance language
Public participation in project is ongoing

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Summary

- PFM is a valuable tool that can be used to support a range of regulatory applications
- In most cases, PFM results may provide an insufficient basis for a regulatory decision
- Applicants should consider performance monitoring , safety margins and defense-in-depth to support an augment made using PFM results
- The NRC is currently developing guidance on an acceptable way to meet this need

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