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# Thoughts on Sources of Level 2 Probabilistic Risk Assessment (PRA) Model Uncertainty

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# Layout of this presentation

- Introductory remarks
- Generic thoughts on what makes Level 2 PRA unique
- Specific sources of model uncertainty

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# Introductory remarks

- I am not a Level 2 PRA practitioner
  - My views are based on interactions with the real experts – including NRC, industry, consultants, etc.
  - These are my views – they don't necessarily represent organizational views
- Level 2 PRA, like Level 1 PRA and other forms of analysis, is a process
  - If done conscientiously and by an experienced practitioner, valuable insights will be gained regardless of the details
  - It's the regulatory situation (industry peer review, limited NRC staff audits) that necessitates standardization
- Level 1-centric initiatives combined with less-restrictive LERF criteria have stunted domestic Level 2 PRA development
  - This "fact" inherently affects the maturity of our understanding of model uncertainty

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# Introductory remarks (2)

- This presentation focuses on a subset of model uncertainties
  - I've only focused on items that I view to be of high or medium significance; we have enough of those to worry about without cataloguing the low significance items!
  - I've primarily focused on the "PRA side" of the Level 2 versus the deterministic side; recent studies, continued experimentation, and the events in Japan are focusing attention on accident progression and source term characterization aspects
- Electric Power Research Institute (EPRI) TR-1016737 (the EPRI companion document to NUREG-1855) Appendix A also provides a good list of sources of Level 2 PRA model uncertainty
  - Including more focus on accident progression uncertainty than is provided here

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# Introductory remarks (3)

- A related aside on depth versus breadth:
  - What's the goal?
    - Should we be counting all the beans, even if some get squashed in the process? OR
    - Should we be counting the beans carefully, even if some roll off the table while we're counting? OR
    - Something in between?
  - Given the state-of-practice in the various areas, I vote for:
    - Breadth in exploring more pathways for uncertainty in operator action (because almost all actions have positive and negative impacts)
    - Depth in handling phenomenological uncertainty (because I believe that the unknown unknowns now dominate)
    - A mix in handling Structures, Systems, and Components (SSCs) reliability and performance (very design- and scenario-specific but also heavily affected by above uncertainties)

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# What makes Level 2 PRA unique?

Level 1 Internal Events PRA

- Breadth (completeness)
- Individual component contribution to a binary end-state
- Data-driven
- Greater reliance on logic model / Boolean representation
- Plethora of applied HRA models
- Uncertainty correlation focused on relationship of component failure rates

Level 2 PRA

- An inconsistent mix
- Release characteristics, in addition to frequency
- Lack of operating experience
- Greater reliance on phenomenological evaluations
- Human Reliability Analysis (HRA) in research stage
- Uncertainty correlation relates more heavily to dependencies in phenomenological uncertainty

# Specific sources – Level 1/2 PRA interface

Level 1 PRA modeling assumptions made based on Level 1 PRA priorities

- Numerous Level 1 PRA modeling choices can be influenced by the go / no-go nature of Level 1 PRA end-states
  - I'll assume xyz (e.g., bypass this top event) because it doesn't affect whether I go to core damage
- Focus on completeness / SSC reliability in Level 1 PRA drives modeling toward breadth rather than depth
- Consensus rules for how to identify these situations and when to accommodate in the Level 2 PRA versus changing the Level 1 PRA?

High significance

# Specific sources – Level 1/2 PRA interface (2)

Plant damage state (PDS) binning and selection of representative sequences

- Recall: Accident management takes the approach of – we're not sure how we got here, but here's how we'll proceed
- Current Level 2 PRA practices take the approach of hanging on to as much Level 1 PRA completeness as possible, at the expense of scrutability with regards to how Level 2 PRA sequences align with their numerous and diverse Level 1 PRA predecessors
- How do we balance completeness with fidelity in PDS binning (likely an application-specific decision)

High significance

# Specific sources – Containment capacity analysis

Performance of containment penetrations during external hazards

- This affects the results of the containment capacity analysis and its inputs to the accident progression analysis
- Along with the more historical concerns regarding the loss of containment integrity and the point of fission product release (in to an adjoining building versus directly in to the atmosphere), there is the additional issue of the transport of hydrogen and ensuing deflagrations that could affect recovery actions (depending on location)

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# Specific sources – Containment capacity analysis (2)

Performance of containment and penetrations during energetic events given identified and unidentified degradation (e.g., liner thinning)

- Ditto from previous slide

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# Specific sources – Probabilistic logic model

Availability / performance of components under harsh conditions (particularly for supporting Instrumentation & Control (I&C) and electrical distribution)

- This affects both explicit (e.g., equipment availabilities) and implicit (e.g., assumptions about available indication and its effects on operator response) pieces of the Level 2 PRA
- Various approaches can be taken. To my knowledge a consensus does not exist.
- Related to item #14 from Table A-1 in EPRI TR-1016737

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# Specific sources – Probabilistic logic model (2)

Primary piping failure locations under high temperatures (following core damage) given pre-existing conditions (e.g., steam generator tube flaws)

- Affects the probabilistic modeling of various sequence outcomes.
- Lots of attention on this for station blackout-induced consequential steam generator tube rupture; but also of relevance to other situations for all designs
- Related to item #18 from Table A-1 in EPRI TR-1016737

High significance

# Specific sources – Probabilistic logic model (3)

Reliability quantification for SSCs not covered by Licensee Event Reports, EPIX, etc.

- Unlike Level 1 PRA, equipment used in the severe accident management guidelines (SAMGs) often does not have the necessary data to support data-informed failure probability assignment

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# Specific sources – Probabilistic logic model (4)

Seismic fragilities of supporting equipment that is either not relevant to the Level 1 PRA seismic analysis, or is treated in a bounding / screening fashion

- Every component needs all or a subset of the following to perform its mission; realistically characterizing these indirect effects on failure-to-run is very time consuming, but may affect results:
  - indication
  - water source
  - power or instrument air
  - connected piping
  - cooling
  - control
  - I&C protection
  - spatial protection

High significance

# Specific sources – HRA (1)

Treatment of SAMG (and other accident management) actions

- This affects HRA and accident progression analysis portions of the Level 2 PRA
- Most SAMG actions inherently have a positive and negative effect (e.g., containment sprays reduce containment pressure but increases likelihood of a hydrogen deflagration)
- As such, focusing only on “important” post-core damage operator actions is a tough sell if the goal is to be best-estimate
- Current deterministic models are not well-suited for modeling multiple operator actions in terms of ease-of-use
- Focused capability development for the deterministic tools in this area is needed
- Related to item #15 from Table A-1 in EPRI TR-1016737

High significance

# Specific sources – HRA (2)

Nominal human error probabilities (HEPs) and performance shaping factors (PSFs) for operator actions

- This affects HRA aspects of the Level 2 PRA
- While some Level 2 HRA PSF-equivalents are very decision-specific, some scenario-specific aspects exist:
  - Reluctance to make any decision that directly results in a release
  - Communication and decision-making between the control room, technical support center (TSC), and ermergency operations facility (EOF)
  - Parsing of failed versus reliable indication
- A consensus “starting point” for Level 2 HEP development needs to be formulated

High significance

# Specific sources – Accident Progression Analysis

Longer-term recovery actions and termination of sequences based on truncation time

- This affects the accident progression analysis and the presentation of results
- Neglecting long-term recovery actions conservatively biases results toward higher risk from large releases
- Truncating deterministic accident progression simulations at (e.g., 48 hours) non-conservatively biases results toward risk from earlier releases
- A consensus model is needed to address the “everyone walks away until a miracle occurs” tendency

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# Re-cap

- Not an industry practitioner
  - May be unaware of limited-consensus approaches
  - e.g., Owners Group topicals not submitted to NRC
- Have elected to focus on logic model side
- Breadth versus depth is an important issue
- Level 2 is unique, and that is important
- A number of sources of model uncertainty have been identified