Focus areas for a Level 2 PSA that supports a site NPP risk analysis

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Presentation outline

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- Why inter-related effects are important for site PSA
- Examples of inter-related effects:
  - Response of structures
  - Accident phenomena
  - Survival of equipment and instrumentation
  - Human actions to intervene
- Conclusions

Introduction

- US NRC is developing an integrated site probabilistic safety assessment (PSA) for two operating reactors and spent fuel storage at the Vogtle site
- The PSA is considering:
  - Reactors and spent fuel storage
  - All modes of operation
  - All hazards (excluding terrorism and sabotage)
  - Off-site consequences from radiological releases
- Though overall scope is beyond ‘state-of-practice’, individual modeling tools are generally ‘state-of-practice’
  - *The accompanying paper provides discussion of the tools being used, which are not covered here*

Note on presentation tone

- This presentation deliberately dwells on areas where the state-of-knowledge and the set of existing analytical tools are relatively weak
  - *The goal is to motivate dialogue and future work in these areas, not to question the collective research to date*
- Risk stems from beyond-design basis events, specifically because they go beyond the plant's design
  - *The possibility of these combinations of failures and challenges does not mean that their occurrence is probable*
- Complete knowledge is not necessary to make sound regulatory decisions
  - *The achievable goal is to limit the risks, not preclude them*
  - *PSA can assess the impact of the uncertainties*

Why inter-related effects are important for site PSA

- When considering integrated site risk, inter-related effects can have positive and negative influences on the course of a given action
- The potential for such effects have been known since the start of using PSA in the nuclear power industry, but are rarely quantified
- Such effects have been observed in actual events (e.g., 2011 Fukushima accident, 2013 Arkansas Nuclear One heavy load drop event)
  - Positive: Leaking from over-pressurized primary containment vessel steam inerts spent fuel pool bay (though fuel in SFP was not uncovered at Fukushima)
  - Negative: Hydrogen explosion at one unit damages equipment and delays recovery actions at an adjacent unit
- All of the items covered on the following slides have high modeling uncertainty

Examples of inter-related effects - Response of structures

- Containment failure location:
  - For the subject plant, possible failure points exist that connect the containment:
    - Directly to the environment
    - Directly to an adjoining equipment building
    - Indirectly to both of these
  - Failure to the environment provides a more immediate path for radiological releases, whereas failure to surrounding structures can affect instrumentation/equipment (survivability) and prevent human actions (habitability) but with potential to mitigate releases
- Seismically-induced spent fuel pool structure failure:
  - For some designs, one or more sides of the pool are “earth-backed” while others adjoin locations housing instrumentation/equipment
  - Exact failure point can affect rate of draining, internal flooding damage to nearly reactor equipment, and access to areas important for mitigation

Examples of inter-related effects – Accident phenomena

- Combustible gas transport and combustion:
  - Hydrogen and carbon monoxide generated during fuel damage in one radiological source can transport to other parts of the plant (as seen at Fukushima)
  - Monitoring is typically hydrogen-specific and in-containment
  - Beyond obvious importance of transport mechanisms, role of steam inerting makes the response of otherwise collateral systems potentially important (fire suppression, room coolers, ventilation)
- Uncertainties in accident phenomena timing (e.g., vessel breach, containment failure) impact the assessment of human actions
  - Post-core damage accident management drills/exercises must rely on predictions that are inherently more uncertain than pre-core damage simulations
  - Realistic modeling of accident management in PSAs must be anchored to these uncertain timelines in order to construct meaningful accident scenarios

Examples of inter-related effects – Survival of equipment and instrumentation

- Establishing the realistic response of equipment and instrumentation to beyond-design basis conditions (e.g., radiation, extended high temperatures) can be difficult and very component-specific
- Earlier in this presentation, transport and combustion of combustible gases was discussed…
  - Combustion events have the potential to cause secondary fires leading to cable damage, which can affect plant response in yet other areas
  - Combustion events can also cause direct pressure or temperature effects
- This can result in a reactor accident damaging equipment important to a spent fuel pool, or visa versa

Examples of inter-related effects – Human actions to intervene

- Human reliability modeling builds off of the deterministic characterization of the plant response, knowledge of factors that drive human performance, and an understanding of the training, guidance, and experience the operators possess
- Accident management infrastructure is typically on a per-site basis (one technical support center, one operations support center, one emergency operations facility, etc.)
  - Thus, the same set of resources is avaiable (at least initially) whether there is one radiological source being challenged, or several
- An accident involving one radiological source can prevent access to plant locations that affect the response to another radiological source
  - For example, boiling of the spent fuel pool (high-temperature high-humidity environment) can inhibit deployment of portable equipment if the deployment path goes through that area of the plant

Conclusions

- US NRC is pursuing an integrated site PRA for a multi-unit operating power plant
  - To model the site response, inter-related effects may be important
- There are many aspects that require additional investigation
  - This does not mean that existing regulatory requirements are deficient
- Comparing notes on approaches and results is important
  - US NRC site PRA project
  - European Union ASAMPSA_E project
  - IAEA and OECD/NEA post-Fukushima initiatives
  - Etc.