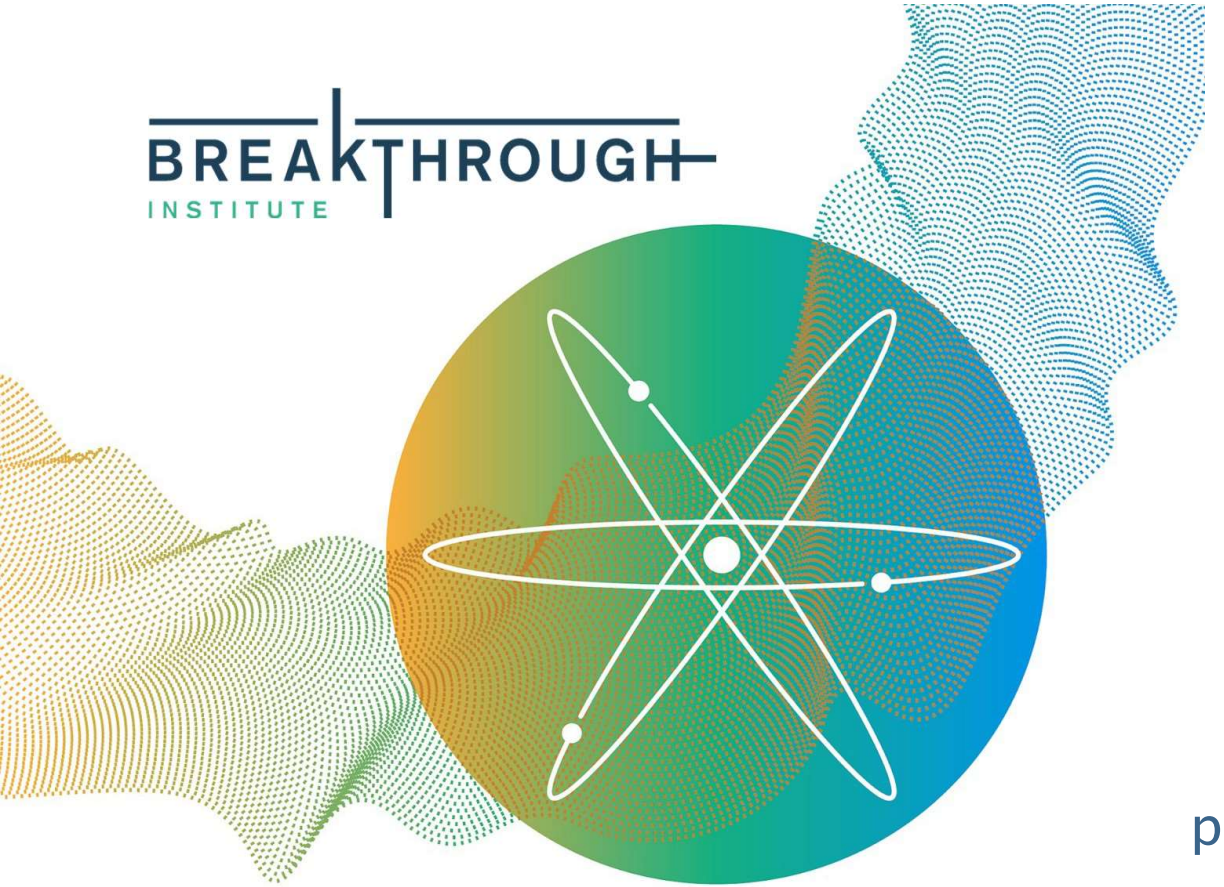

Designing Emergency Preparedness for Robust, Risk-Informed Decisions

Creating an integrated, performance-based framework.

Dr. Adam Stein
Director of Nuclear Energy Innovation
The Breakthrough Institute
March 10, 2026

Emergency Preparedness as Decision Architecture

- Emergency Preparedness (EP) is the decision interface between plant performance and public protection.
  - EP should explicitly define objectives, design structured trade-offs across multiple criteria and test robust metrics under uncertainty
- Why this matters now:
  - Advanced reactors have different risk and siting profiles.
  - Align with the updated Mission to consider benefits to society
  - PRM-50-123: "....to ensure that protective actions …will likely **do more good than harm** considering the health hazards of both radiation exposure and protective actions. "

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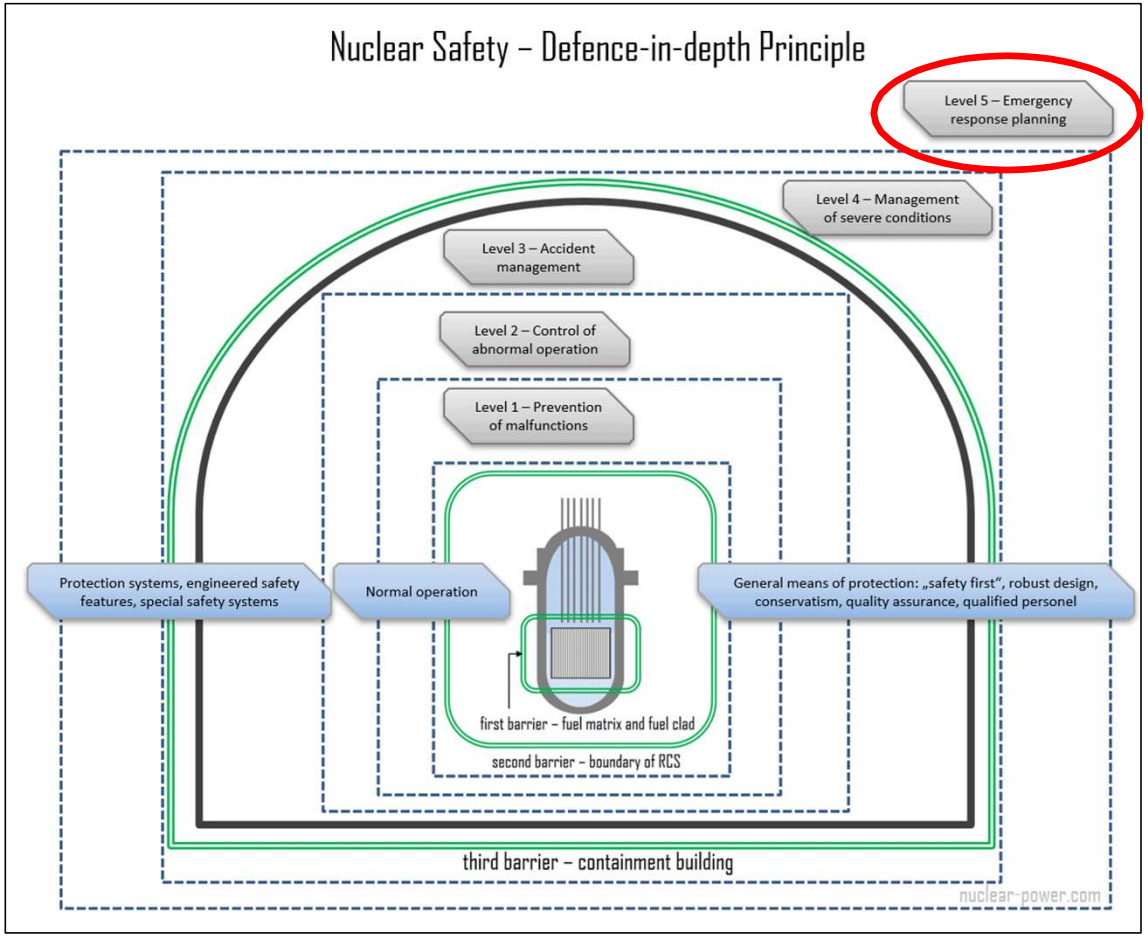
Regulatory Backdrop

- **EP has been on the leading edge of modernization, but constrained to fit in existing frameworks**
- 10 CFR 50.160 : Emergency Preparedness for Small Modular Reactors and Other New Technologies
  - A new alternative performance-based EP framework
  - A scalable EPZ approach
- Proposed Part 53 framework
  - start to move to an integrated approach
  - **still treats EP as a separate objective**

The Legacy Pattern: EP as Add-On



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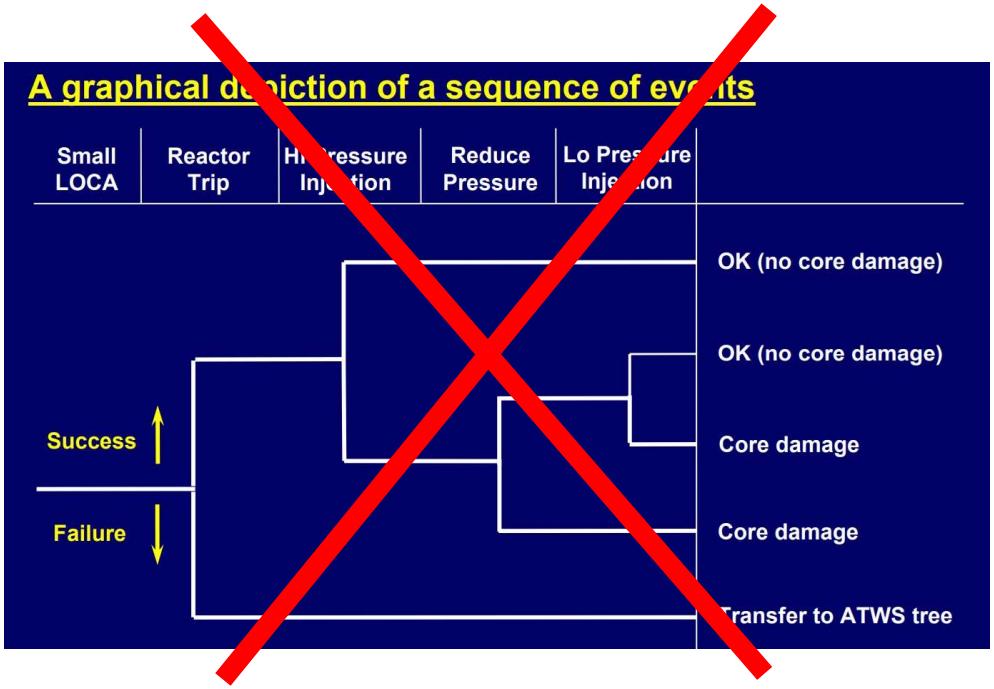
Deterministic Framework

- Deterministic assumptions **limit the information** entered into a model.
- Hard line guidance + short decision windows = uninformed response
- Inputs mismatch with assumption →no prescribed path forward.
  - The solution set is artificially constrained.
- Unlike fault tree analysis, people do not respond with discrete outcomes with clear probabilities.
- Need **robust decisions** after exploring the range of uncertainty.



EP is NOT a PRA Fault Tree. It is a Decision Science and people problem.

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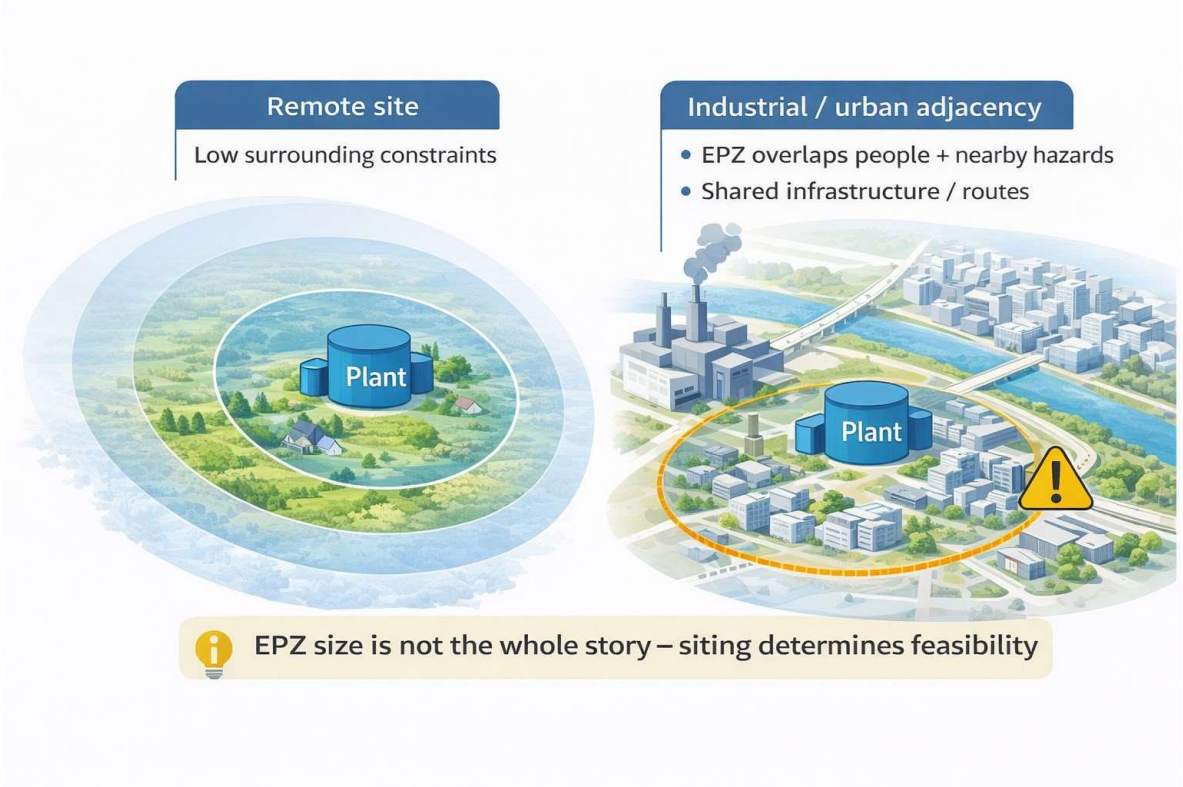
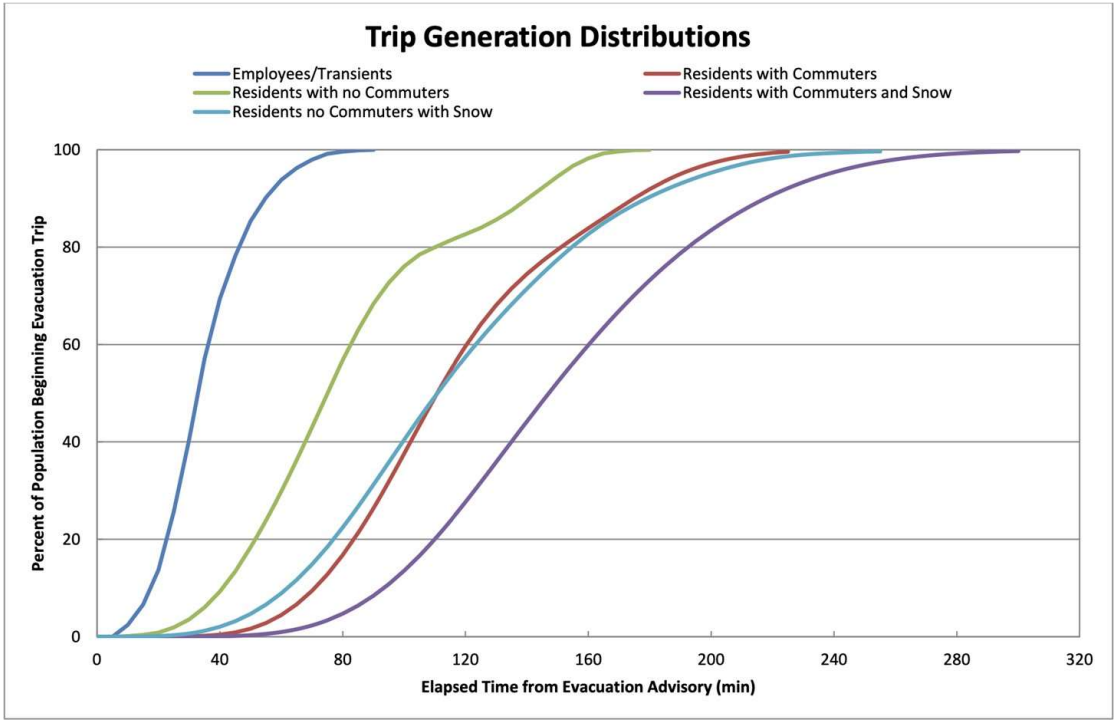
Siting Reshapes the Emergency

- New plants may be located differently than past experience
- EP must be integrated at siting stage
- Nearby industrial hazards constrain emergency response.
  - Protective actions may conflict (evacuation vs shelter-in-place).
  - Shared infrastructure alters assumptions (staffing, evacuation, communications, etc)



Public Response Is Not a Single Number

- Different subpopulations mobilize differently
- Context shifts behavior (day or night, weather, work/home, special events)
- Decision frameworks must represent distributions with robustness checks



Source: KLD Engineering, P.C., *Clinton Power Station, Development of Evacuation Time Estimates*, Final Report (Rev. 0), KLD TR–1248 (July 18, 2022).

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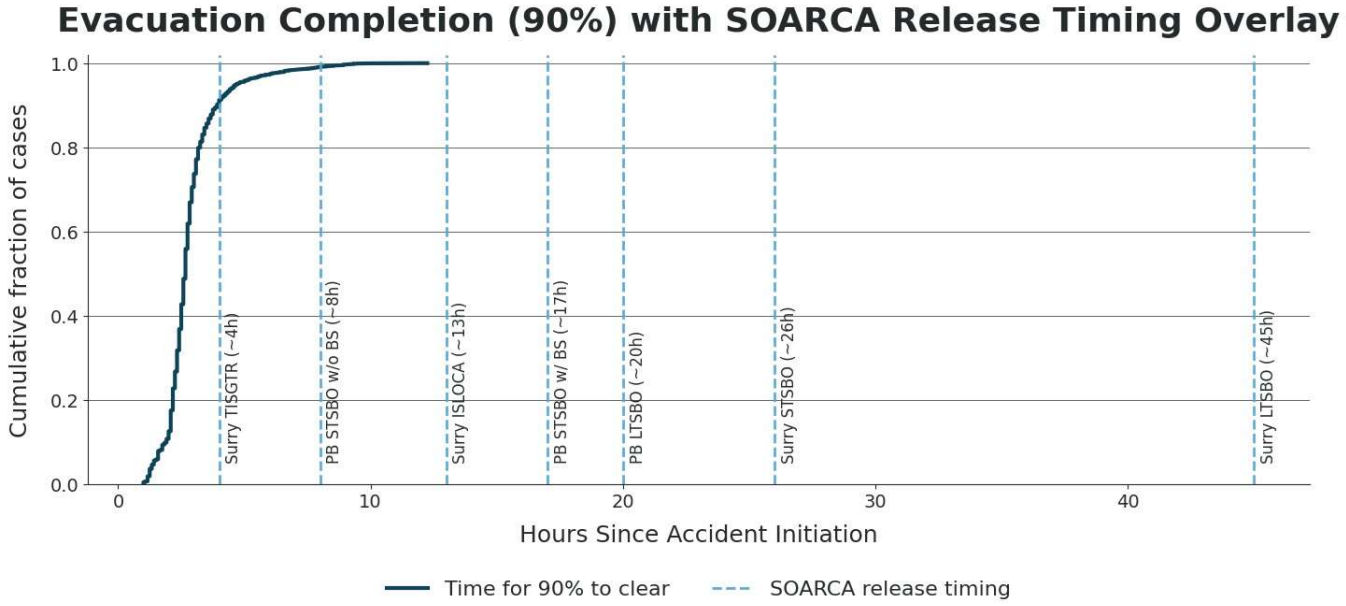
Response vs. Release Timing

- Large variation in evacuation times across existing plants (90% ETE)
- Large variation in potential accident release timing (examples from SOARCA)
- Plan must perform across joint uncertainty



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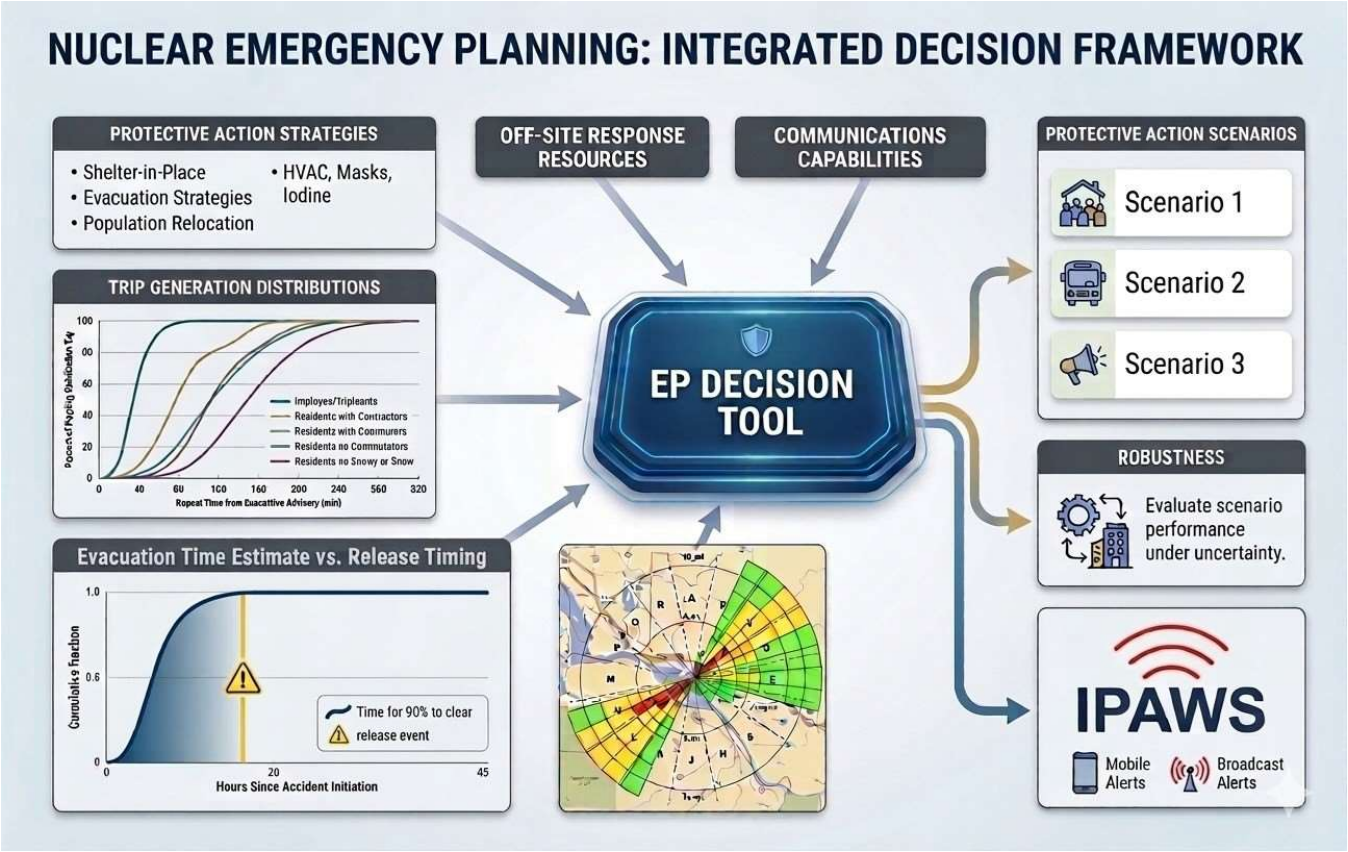
Why “do more” is not a Solution to Uncertainty

- In drills, officials often expand protective actions beyond recommendations when key inputs are uncertain
- Without a comprehensive framework, when uncertainty is felt but not structured, it gets translated into 'do more'.
- Protective actions can introduce measurable risk
  - Traffic fatalities/injuries during evacuation
  - Secondary health impacts for medically fragile population
- A 'more good than harm' framework requires explicit accounting of protective action impacts

Why We Haven't Solved This and The EP Tool We Actually Need



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Improving EP function and outcomes

Legacy: EP as a bolt-on last layer

- EP treated as the **last Defense-in-depth layer** after design & siting
- Optimized for **single-objective proxies** (distance / dose / timelines)
- Metrics become anchors (**"the number"** becomes the decision)
- Implemented via point-case **deterministic planning** (fixed inputs, threshold rules)
- Creates fragmented, non-coherent strategy that **fails in the tails**

Future: Performance-based EP as integrated decision architecture

- Focus on **outcomes**. (performance objectives)
- Built to be **technology-inclusive** to
- Weigh **multiple legitimate objectives** (protection, feasibility, speed, consequences)
- **Risk-informed** across spectrum of events. Models informs judgment, does not substitute for it
- **Robust planning** evaluates performance across plausible scenarios (joint uncertainty), including **extreme outliers**
- Outcome: **better protective actions**, not "better-looking numbers"

Emergency preparedness requires the latter.

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Main Takeaways

- Treat emergency preparedness as an integrated performance objective, embedded in design, siting and operations.
- Define decision criteria before an accident occurs.
- Evaluate strategies across joint uncertainty so protective actions are robust.
- Incorporate protective action risk explicitly.
- EP should be resilient, built for extreme outliers.
- Operationalize performance-based, risk-informed EP through integrated decision architecture.