Identifying and Prioritizing Sources of Uncertainty in External Hazard Probabilistic Risk Assessment: Project Activities and Progress

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Motivation & Research Needs

Motivation:

- Significant sources of uncertainties in XHPRA are associated with the frequency, severity, and temporal evolution of external hazard events and event impacts on plant response.

Research Needs:

- Evaluate existing XHPRA knowledge and tools and identify their limitations
  - Focus on working across hazard groups
- Develop a technically sound, risk-informed strategy to:
  - Identify and characterize drivers of hazard uncertainty
  - Enable uncertainty reduction activities to be prioritized based on risk significance, risk reduction benefit, and value
- Risk-informed strategy must account for:
  - Impacts of hazard events on SSCs and event progressions
  - Close coupling of the physical aspects of hazard events with plant response and human performance

Project Outcomes

- Develop a **structured process** for identifying, evaluating, categorizing, and assessing the impact of uncertainties on XHPRA modeling elements and **create a common taxonomy** for communicating these uncertainties across hazard groups
- Investigate the spectrum of uncertainties involved in the **physical processes** that underlie external hazards and assess the uncertainties associated with **estimation of hazard frequencies** and **parsing of hazard information** into the XHPRA
- Investigate how uncertainties in the physical hazard characteristics and associated **hazard timing interfaces with plant processes** to prepare for, mitigate, cope, and recover from the external challenge
  - Connect the uncertainties in the **hazard severity/evolution with human response**
- Integrate insights and develop strategies for **prioritization** of uncertainty reduction efforts

Project Outcomes

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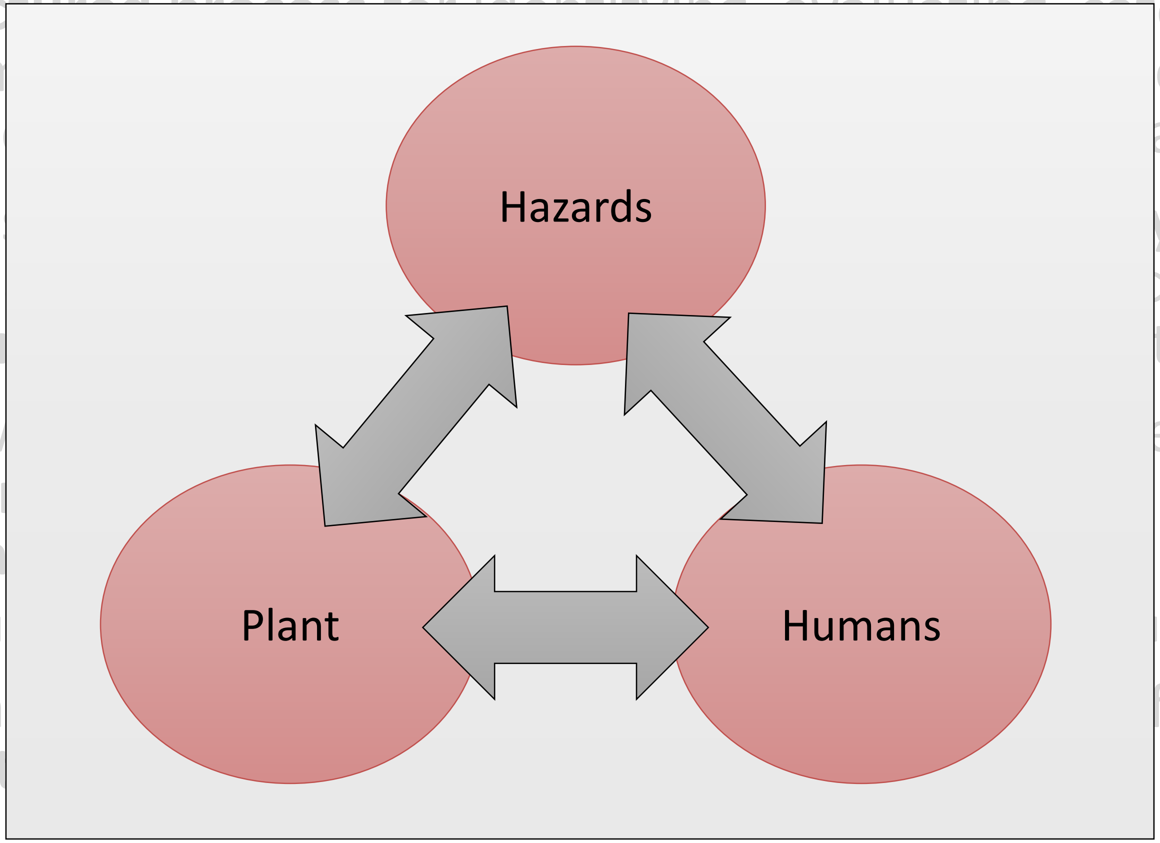

Project Goals and Structure

Project Goals

- Identify significant sources of uncertainty in XHPRA, with particular emphasis on how they relate to the frequency, severity and temporal evolution of hazard events
- Isolate and assess the effects of key sources of uncertainty from the perspective of hazard severity, temporal evolution, physical event impacts, event progression, and interplay between human response and physical event impacts
- Integrate insights related to key sources of uncertainty to develop a risk-informed process for prioritizing measures to reduce uncertainty

Research Execution

Research Thrust 1

- Task 1: Stakeholder Outreach and Development of Uncertainty Taxonomy

Research Thrust 2

- Task 2: Hazard Uncertainty Characterization and Data Analysis
- Task 3: Assessment of Uncertainty in Scenario Development
- Task 4: Characterization of Uncertainty in Human Response Under Physical Effects

Research Thrust 3

- Task 5: Integration & Development of Method for Prioritization of XHPRA Uncertainties

Task 1: Stakeholder Outreach and Development of Uncertainty Taxonomy

Stakeholder Outreach Workshop

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Survey of Existing Uncertainty Taxonomies

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Development of XHPRA (for NPPs) Uncertainty Taxonomy

Task 1: Stakeholder Outreach and Development of Uncertainty Taxonomy

Stakeholder Outreach ~~Workshop~~ Virtual Discussions

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Stakeholder Outreach ~~Workshop~~ Virtual Discussions

Survey of Existing Uncertainty Taxonomies

Development of XHPRA (for NPPs) Uncertainty Taxonomy

- Insights regarding the "most pressing" sources of uncertainty
- The strategies used to address drivers of uncertainty
- Identification of uncertainties w/ potential to change risk metrics
- Sources of "compounding conservatisms" and "blindspots"
- Inconsistencies in practices, conventions, etc. between hazard groups, technical elements, and other aspects of PRAs

Task 1: Stakeholder Outreach and Development of Uncertainty Taxonomy

Stakeholder Outreach ~~Workshop~~

Virtual Discussions

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Survey of Existing Uncertainty Taxonomies

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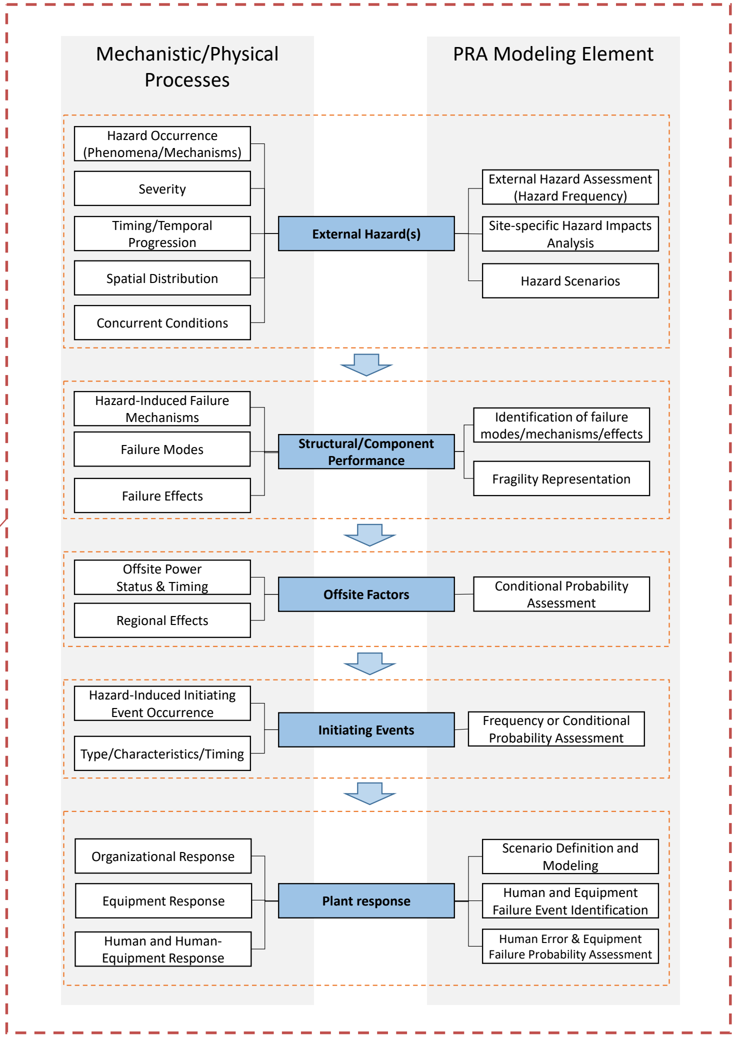
Development of XHPRA (for NPPs) Uncertainty Taxonomy



Additional information in companion paper: MB157

Task 2: Hazard Uncertainty Characterization and Data Analysis

- Focus on external flooding hazards
- Identify key sources of uncertainty related to the probabilistic characterization of:
  - External hazard occurrence
  - Severity (e.g., flood depth, elevation)
  - Timing (e.g., warning time, duration)
- Develop event scenarios for consideration under Tasks 3 and 4
- Understanding the potential "value of information" associated with uncertainty reduction

Image source: https://www.nytimes.com/2011/06/21/us/21flood.html

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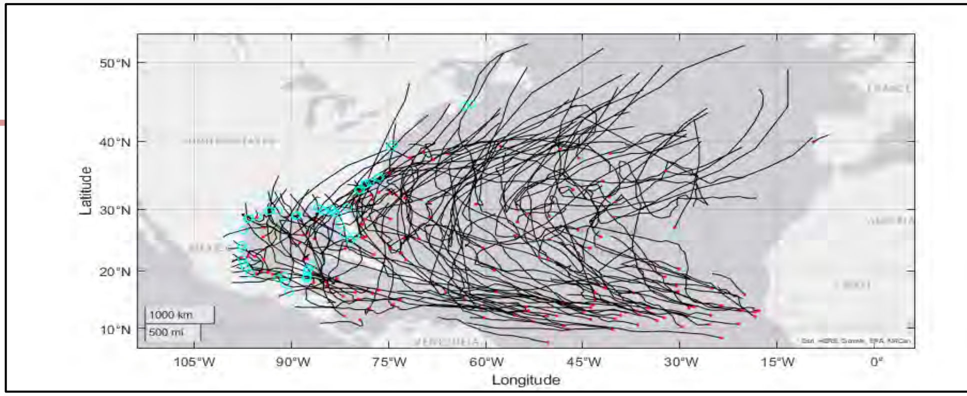
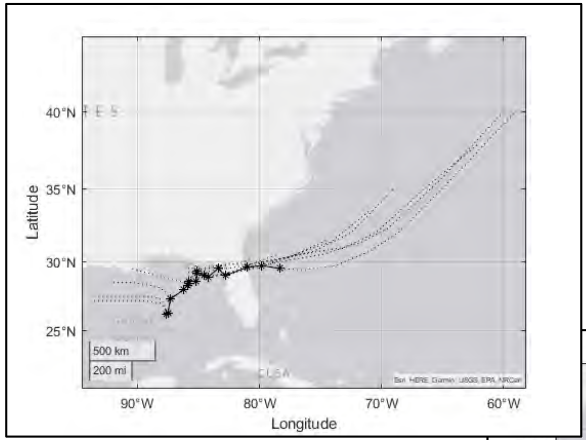
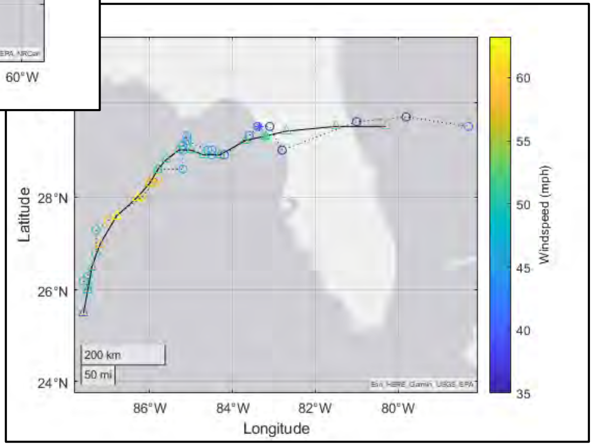
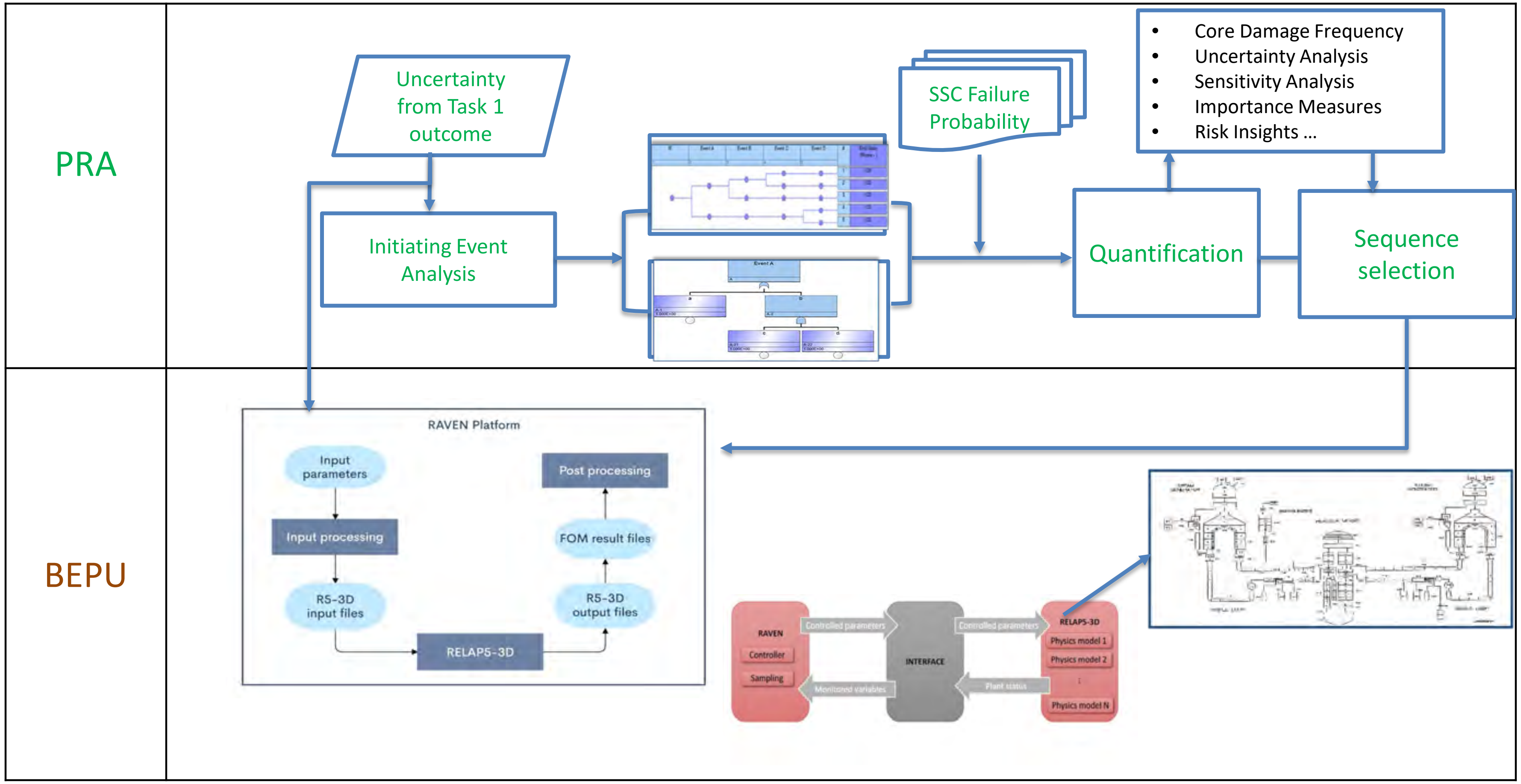






Additional information in companion paper: MB290

Task 3: Assessment of Uncertainty in Scenario Development



Integrated Risk Assessment Framework

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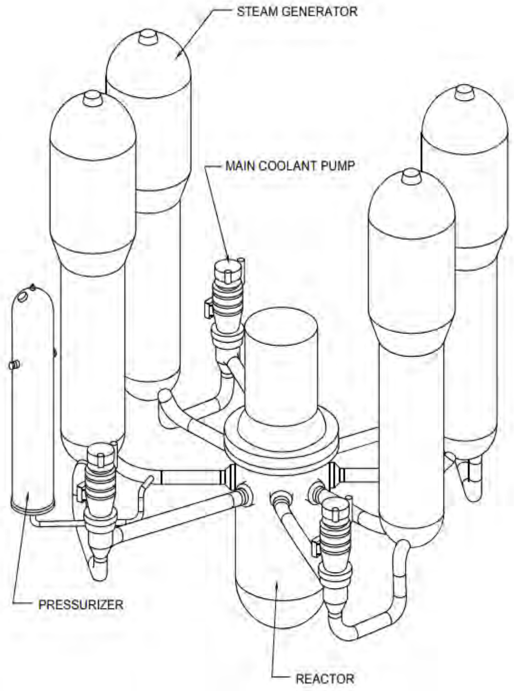
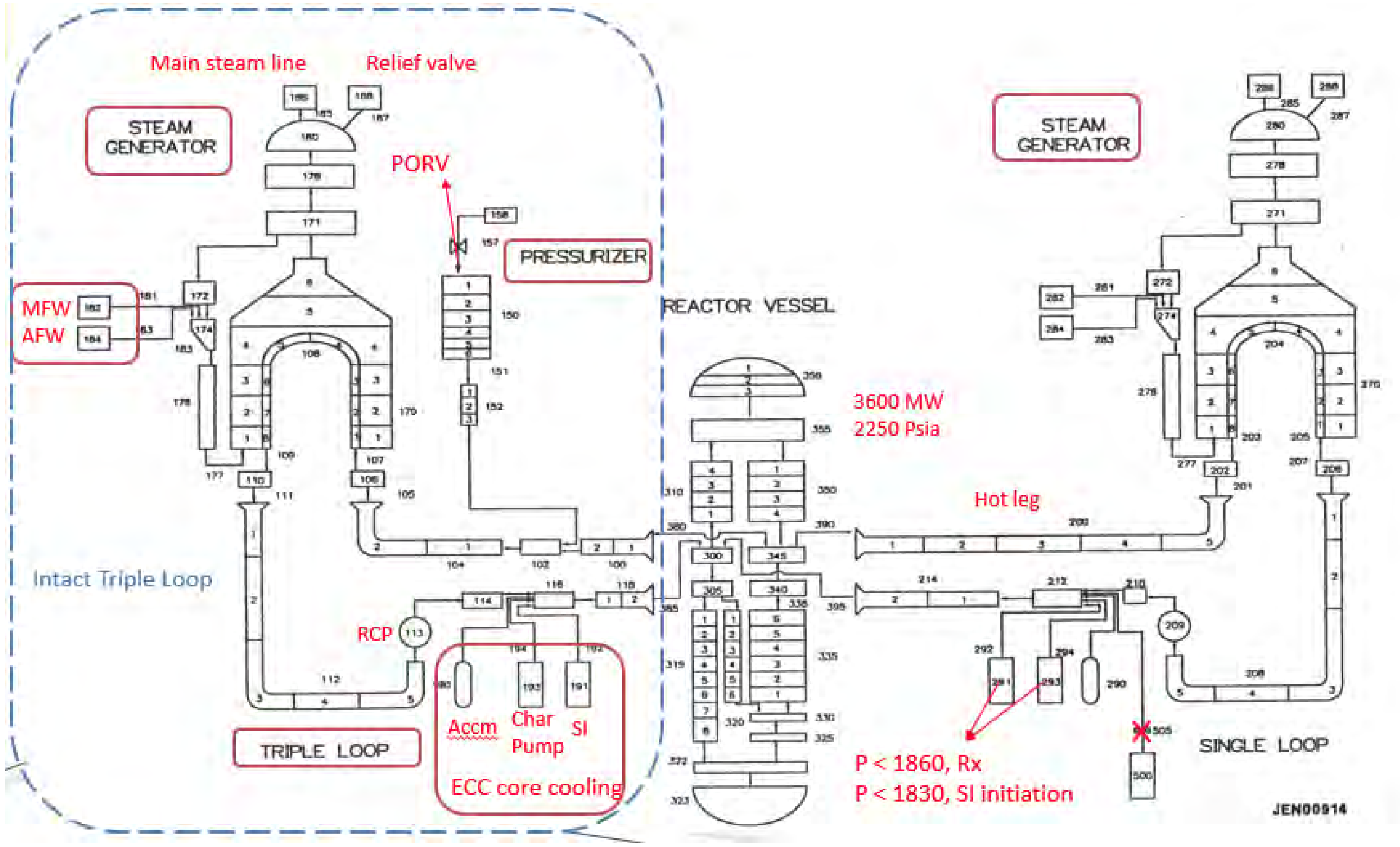
Task 3: Assessment of Uncertainty in Scenario Development

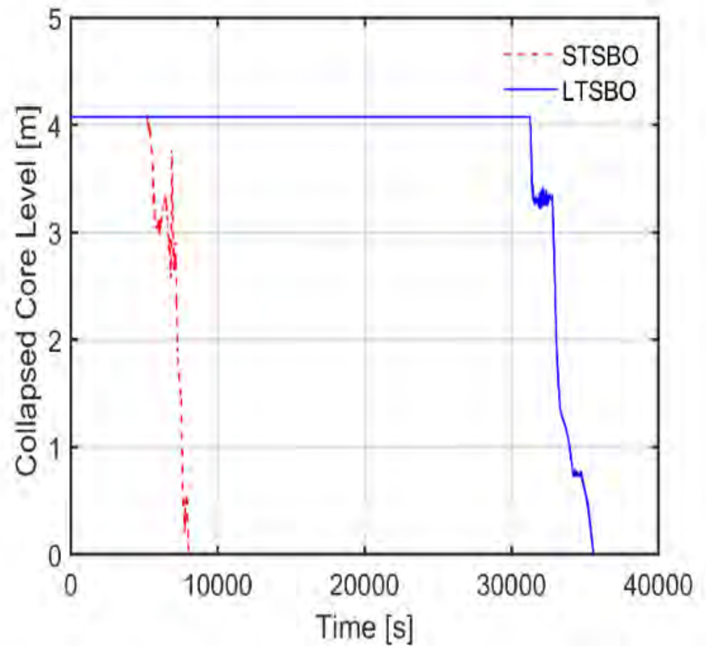




Task 3: Assessment of Uncertainty in Scenario Development

Station Blackout (SBO) Accident Simulation Using RELAP5-3D

- Long term (LT) SBO and Short term (ST) SBO event sequence assumptions were developed
- Thermal-hydraulic simulations for LTSBO and STSBO scenarios for the generic PWR were performed
- The response of various key parameters of interest were analyzed
  - Reactor cooling system (RCS) pressure & temperature, steam generator water level & pressure, core temperature & collapsed level…
- The timing of key event sequences parameters of interest were analyzed
  - the occurrence of steam generator dryout, initiation of core uncovery, and possible core damage, time available for operator to perform mitigation action.



Reactor core level during SBO

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Task 3: Assessment of Uncertainty in Scenario Development

Simulation of Scenarios with Different Event Timing

- Event timing constraints are being incorporated and addressed during loss of offsite power and SBO scenarios that happen in an external flooding event at various points including:
  - Warning time ahead of the event
  - Reactor operation time before shutdown
  - The time at which the external flooding event begins to affect the plant
  - The failure time of the diesel generators and batteries
  - The recovery time of the diesel generators, batteries, and offsite power grid
  - And more ……

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Task 4: Characterization of Uncertainty in Human Response Under Physical Effects

Objective & Approach

T4.1 Identification of human failure events (HFEs)

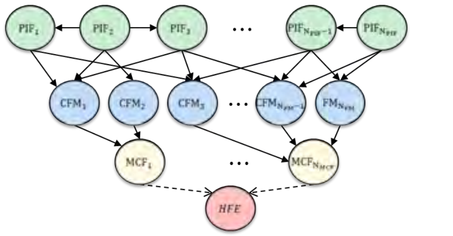
Human and human-machine actions and decisions involved in plant response.

T4.2 Identification of performance influencing factors (PIFs)

Organization-based	Team-based	Person-based	Situation/stressor-based	Machine-based
Training program	Communication	Attention	External environment	HSI
Availability	Availability	To task	Conditioning events	Input
Quality	Quality	To surroundings	Task load	Output
Corrective action program	Direct supervision	Physical & psychological abilities	Time load	System response
Availability	Leadership	Alertness	Other loads	
Quality	Team coordination	Fatigue	Non-task	
Other programs	Team cohesion	Impairment	Passive information	
Availability	Role awareness	Sensory limits	Task complexity	
Quality		Physical attributes	Cognitive	
Safety culture		Other	Execution	
Management activities		Knowledge/experience	Stress	
Staffing		Skills	Perceived situation	
Scheduling		Bias	Severity	
Workplace adequacy		Familiarity with situation	Urgency	
Resources		Morale/motivation/attitude	Perceived decision	
Procedures			Responsibility	
Availability			Impact	
Quality			Personal	
Tools			Plant	
Availability			Society	
Quality				
Necessary information				
Availability				
Quality				

Focus on factors relevant to modeling/quantifying human-machine performance in flooding hazard response.

T4.3 Development of framework for PIF-human failure mechanisms for XHPRA



Encode causal relationships using Bayesian networks (BNs)

Research, education, and industry engagement

Provide a structure to enable inclusion of HRA within the framework for prioritizing hazard uncertainty drivers

Additional information in companion paper: AA176

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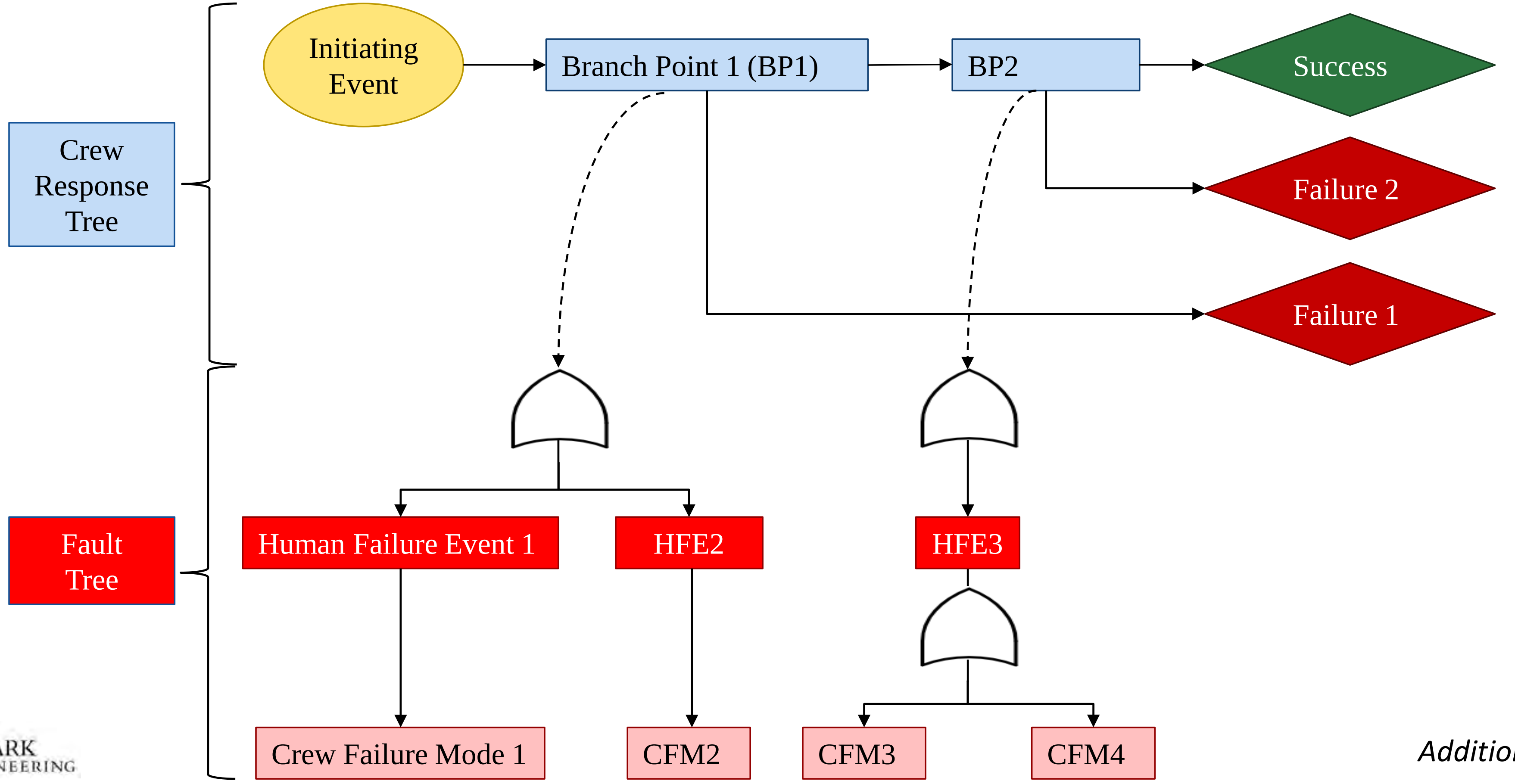
Task 4: Characterization of Uncertainty in Human Response Under Physical Effects

The Phoenix HRA method builds upon this as a layered qualitative analysis



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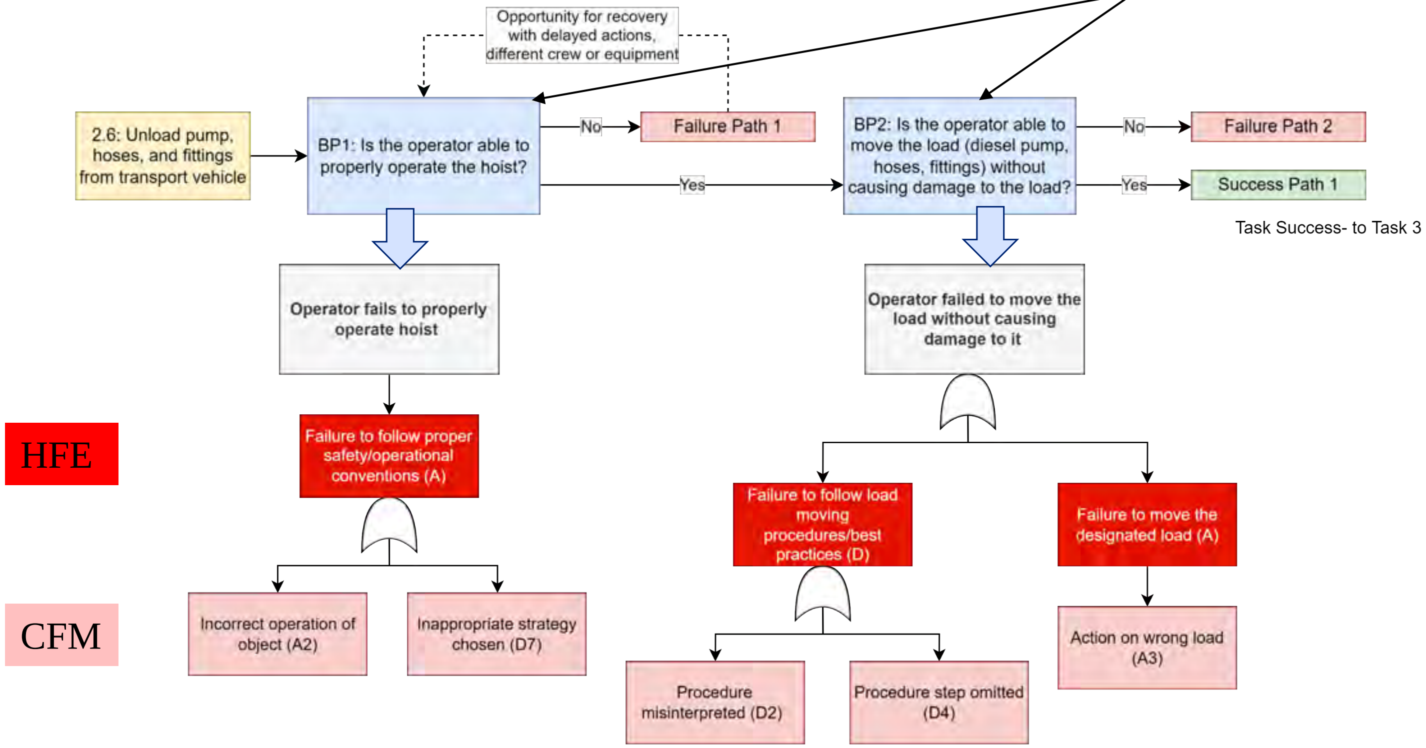
Task 4: Characterization of Uncertainty in Human Response Under Physical Effects

Development of CRTs from Hierarchical Task Decomposition

Subtask 2.6 – Unload Pump, Hoses, and Fittings from Transport Vehicle			
Specific Actions	**Degree of Sheltering**	**Location**	**Comments**
Operate the powered hoist to unload the pump and other equipment from the transport vehicle	Sheltered	Fixed	Involves positioning the hoist over the load, and lifting, moving, and lowering the load using the hoist controls and physical movements.



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Task 4: Characterization of Uncertainty in Human Response Under Physical Effects

Contributions & Next Steps

- Demonstrated applicability of Phoenix method to ex-CR actions
  - Cognitive-based methods (third-generation HRA) are better suited than older methods (first- and second-generation HRA)
- CFMs provided in method are mostly relevant
  - Further refinement needed for Action phase CFMs, but Information and Decision CFMs sufficient to describe scenarios
- Future work:
  - Validation on two more ex-CR tasks and seeking expert feedback
  - Mapping of PIF causal chains to identified CFMs (Task 4.2)
  - Quantification through resultant Bayesian Network (Task 4.3)

This work sets the stage for a systematic treatment of human actions in external environments, allowing for the future development of the causal basis of HRA.

SYRRA

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Questions?

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