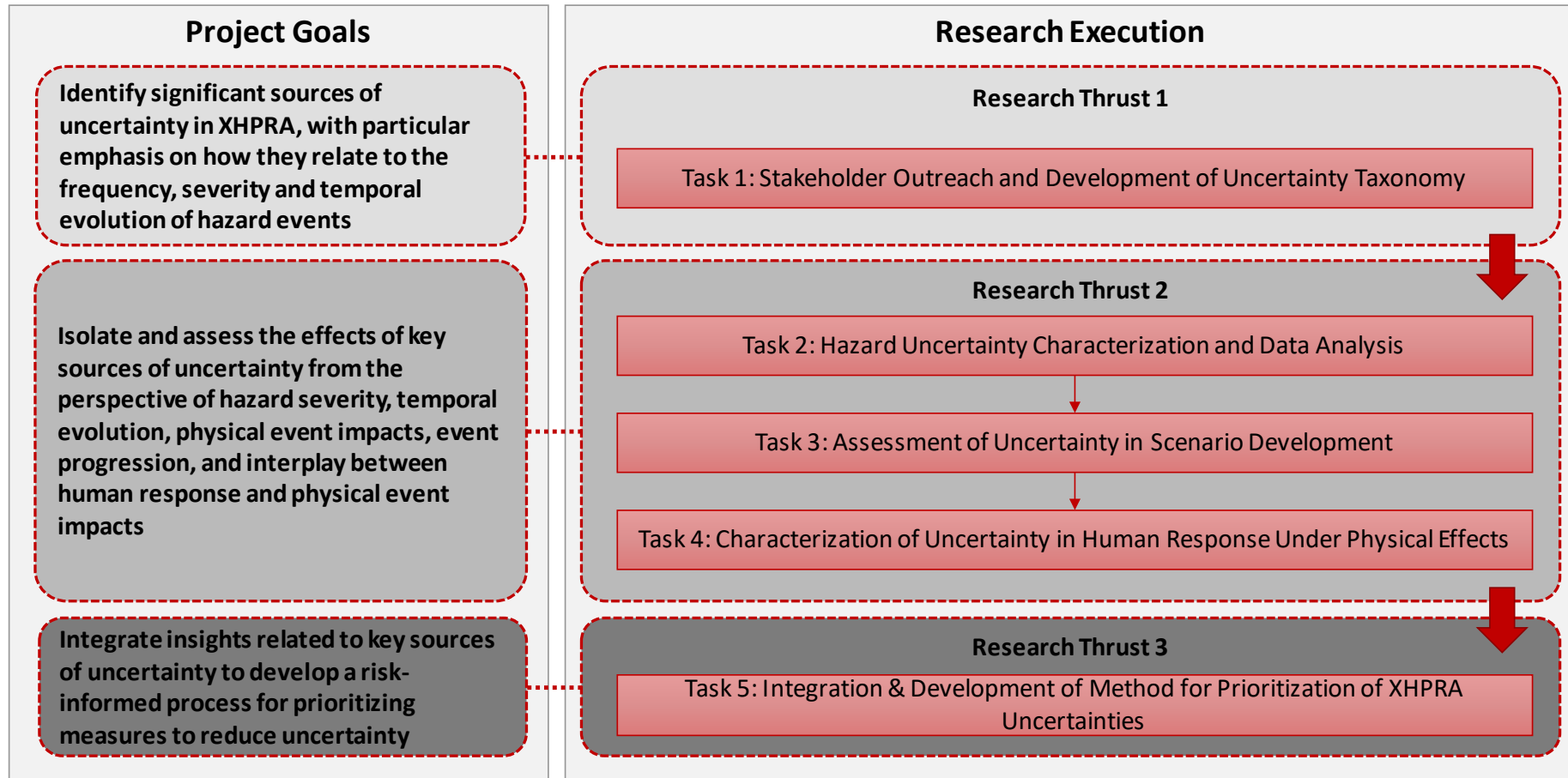# Uncertainty in External Hazard Probabilistic Risk Assessment (PRA): A Structured Taxonomy
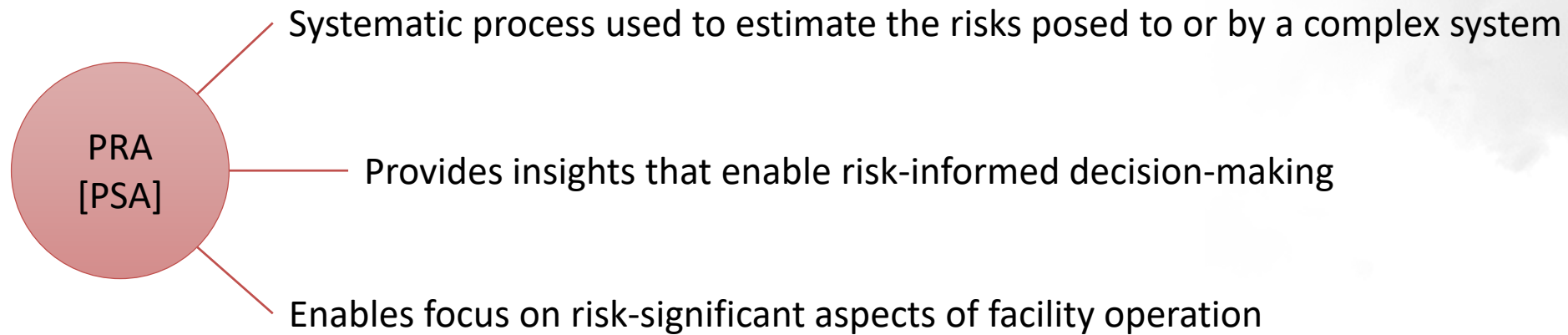
Michelle Bensi (UMD) ● Somayeh Mohammadi (UMD) ● Nilanjana Ghosh (UMD) Tao Liu (VCU) ● Camille Levine (UMD) ● Ahmad Al-Douri (UMD) ● Ray Schneider (WEC) ● Zeyun Wu (VCU) ● Katrina Groth (UMD) ● Zhegang Ma (INL)

PSAM 2022
Honoulu, Hawaii

Identifying and Prioritizing Sources of Uncertainty in External Hazard Probabilistic Risk Assessment

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

Context and Motivation

PRA [PSA]

- Systematic process used to estimate the risks posed to or by a complex system
- Provides insights that enable risk-informed decision-making
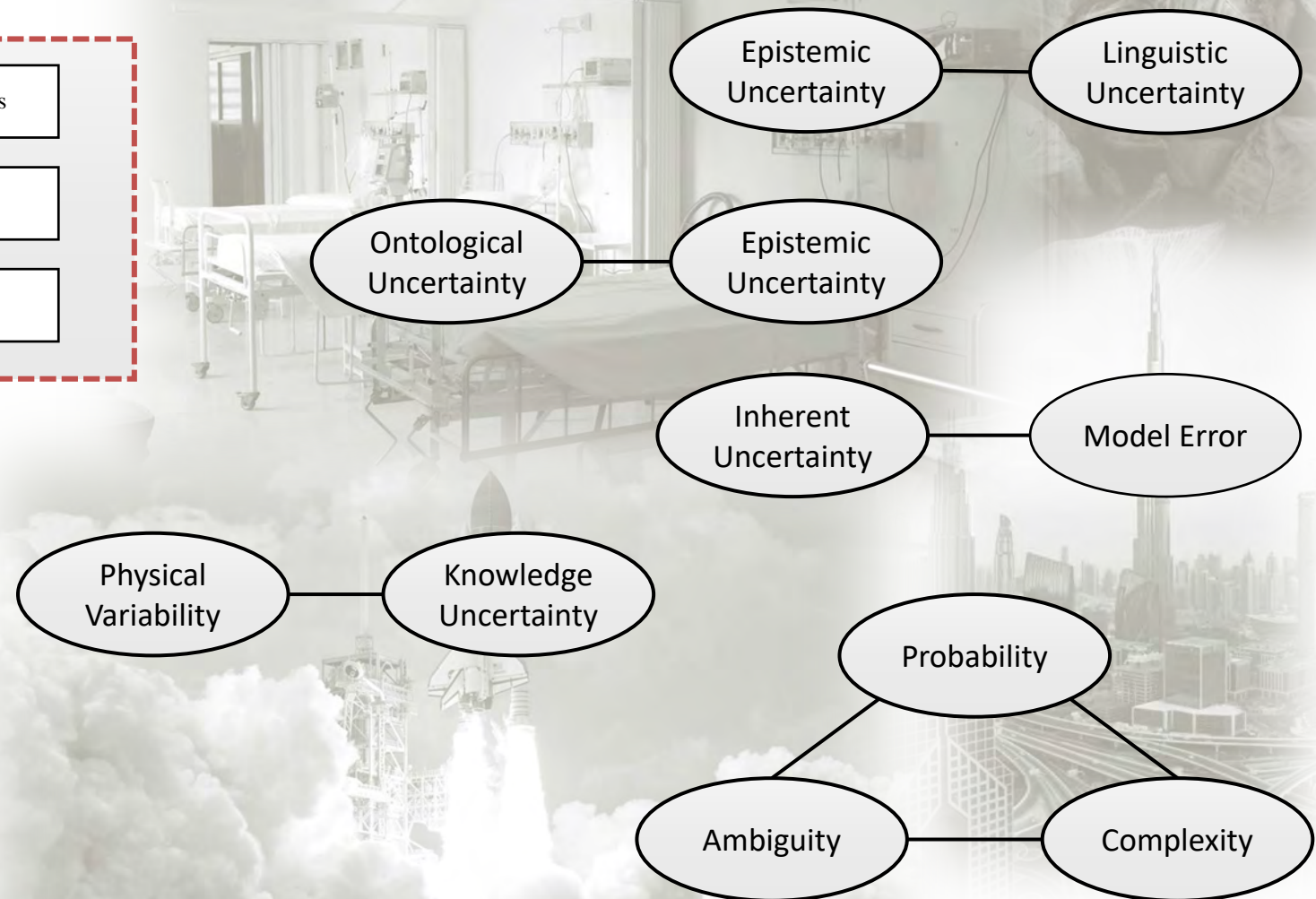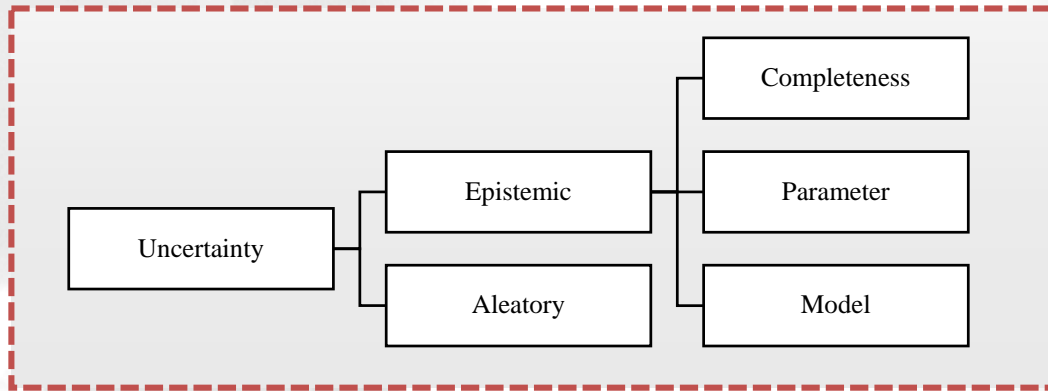- Enables focus on risk-significant aspects of facility operation

Uncertainty exists in all aspects of the operations of complex systems

Understanding and categorizing the sources contributing to that uncertainty enables the characterization, quantification, and (potential) reduction of uncertainty

Taxonomies of Uncertainty
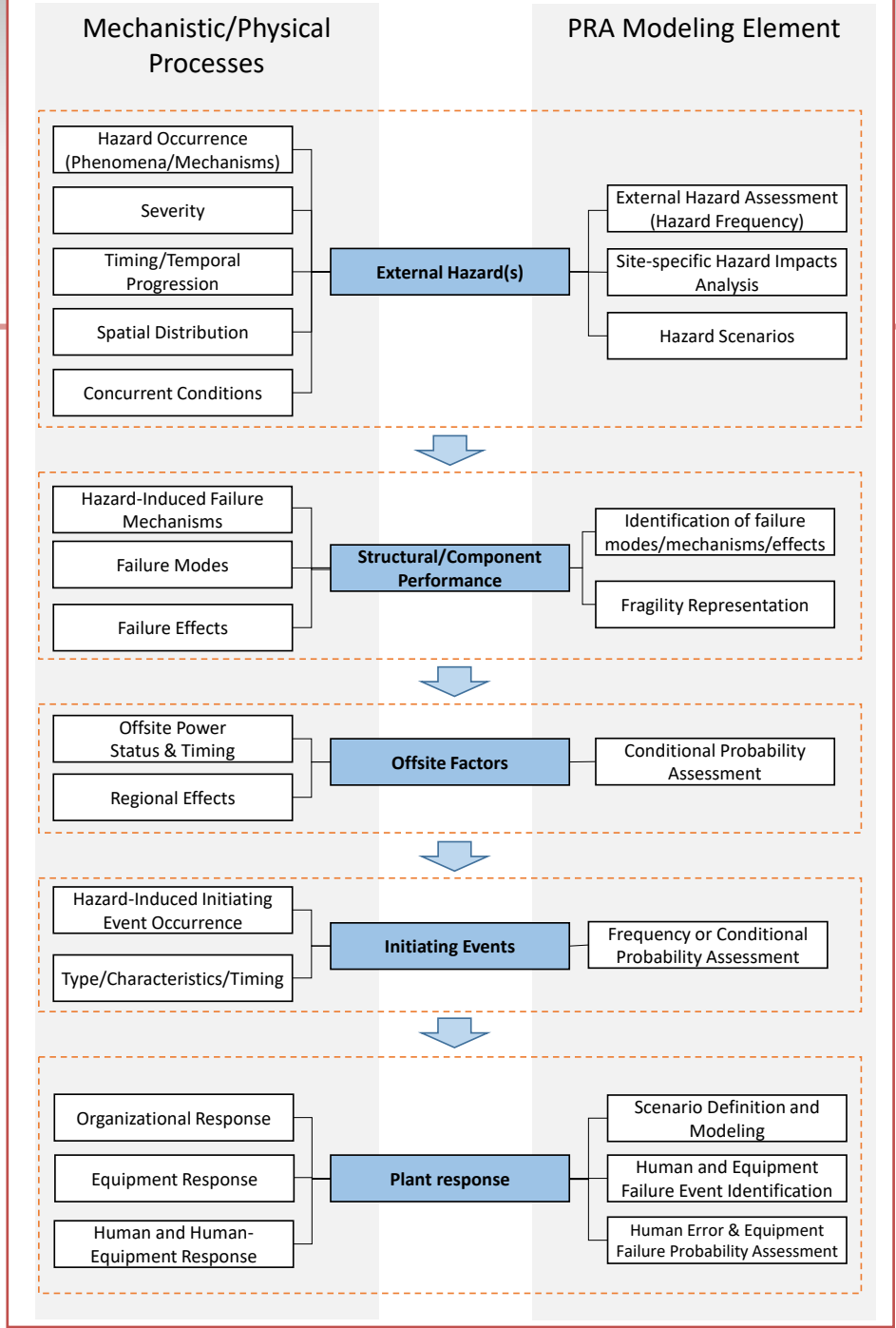
External Hazard PRA (XHPRA)

Hazard Analysis → Fragility Analysis → Plant Response (Systems) Analysis

Mechanistic/Physical Processes	PRA Modeling Element

External Hazard(s)

Mechanistic/Physical Processes:
- Hazard Occurrence (Phenomena/Mechanisms)
- Severity
- Timing/Temporal Progression
- Spatial Distribution
- Concurrent Conditions

PRA Modeling Element:
- External Hazard Assessment (Hazard Frequency)
- Site-specific Hazard Impacts Analysis
- Hazard Scenarios

Structural/Component Performance

Mechanistic/Physical Processes:
- Hazard-Induced Failure Mechanisms
- Failure Modes
- Failure Effects

PRA Modeling Element:
- Identification of failure modes/mechanisms/effects
- Fragility Representation

Offsite Factors

Mechanistic/Physical Processes:
- Offsite Power Status & Timing
- Regional Effects

PRA Modeling Element:
- Conditional Probability Assessment

Initiating Events

Mechanistic/Physical Processes:
- Hazard-Induced Initiating Event Occurrence
- Type/Characteristics/Timing

PRA Modeling Element:
- Frequency or Conditional Probability Assessment

Plant response

Mechanistic/Physical Processes:
- Organizational Response
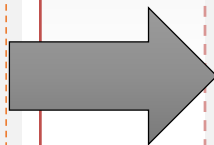- Equipment Response
- Human and Human-Equipment Response

PRA Modeling Element:
- Scenario Definition and Modeling
- Human and Equipment Failure Event Identification
- Human Error & Equipment Failure Probability Assessment

Mechanistic/Physical Processes

Hazard Occurrence (Phenomena/Mechanisms)
Severity
Timing/Temporal Progression
Spatial Distribution
Concurrent Conditions
→ **External Hazard(s)**

Hazard-Induced Failure Mechanisms
Failure Modes
Failure Effects
→ **Structural/Component Performance**

Offsite Power Status & Timing
Regional Effects
→ **Offsite Factors**

Hazard-Induced Initiating Event Occurrence
Type/Characteristics/Timing
→ **Initiating Events**

Organizational Response
Equipment Response
Human and Human-Equipment Response
→ **Plant response**

PRA Modeling Element

External Hazard Assessment (Hazard Frequency)
Site-specific Hazard Impacts Analysis
Hazard Scenarios

Identification of failure modes/mechanisms/effects
Fragility Representation

Conditional Probability Assessment

Frequency or Conditional Probability Assessment

Scenario Definition and Modeling
Human and Equipment Failure Event Identification
Human Error & Equipment Failure Probability Assessment

Hazard Occurrence (Phenomena/Mechanisms)
Severity
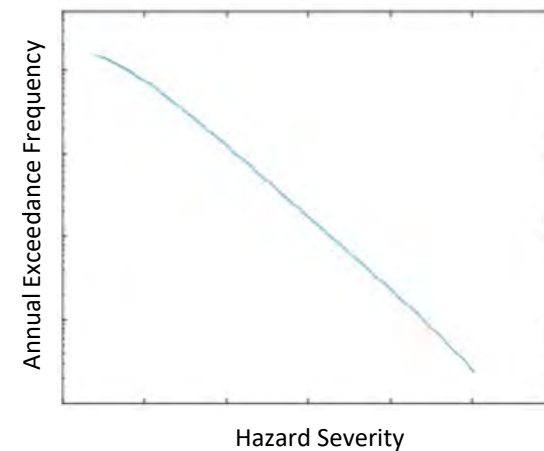Timing/Temporal Progression
Spatial Distribution
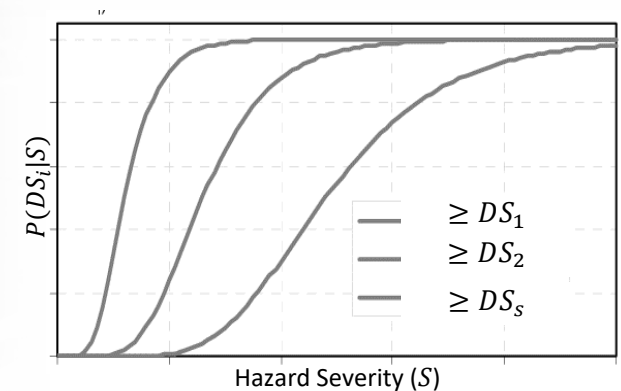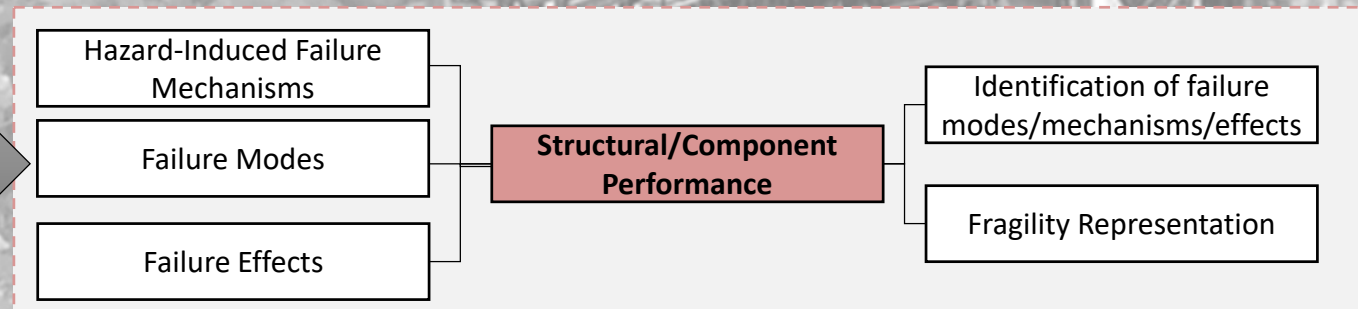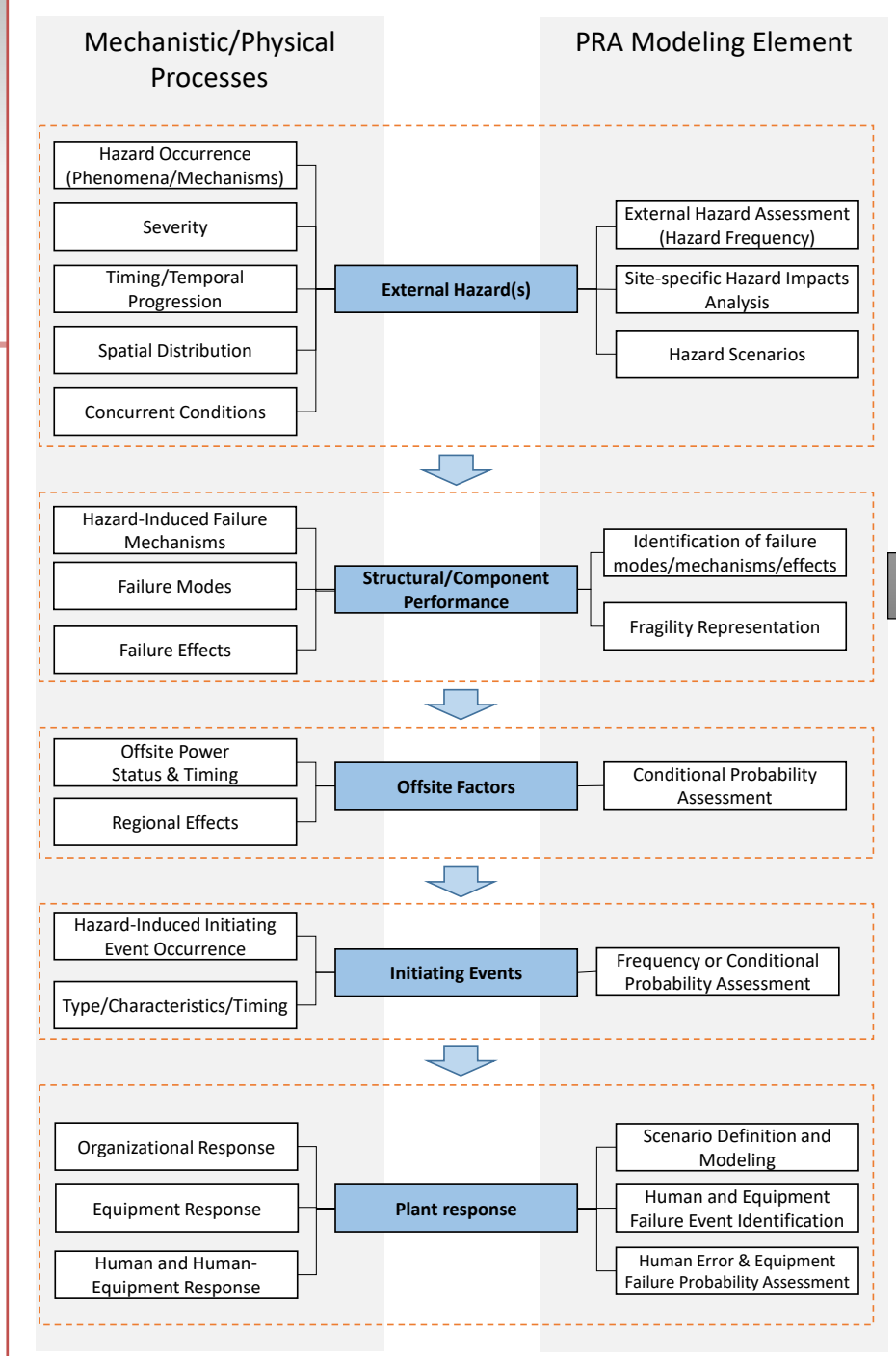Concurrent Conditions
→ **External Hazard(s)** →
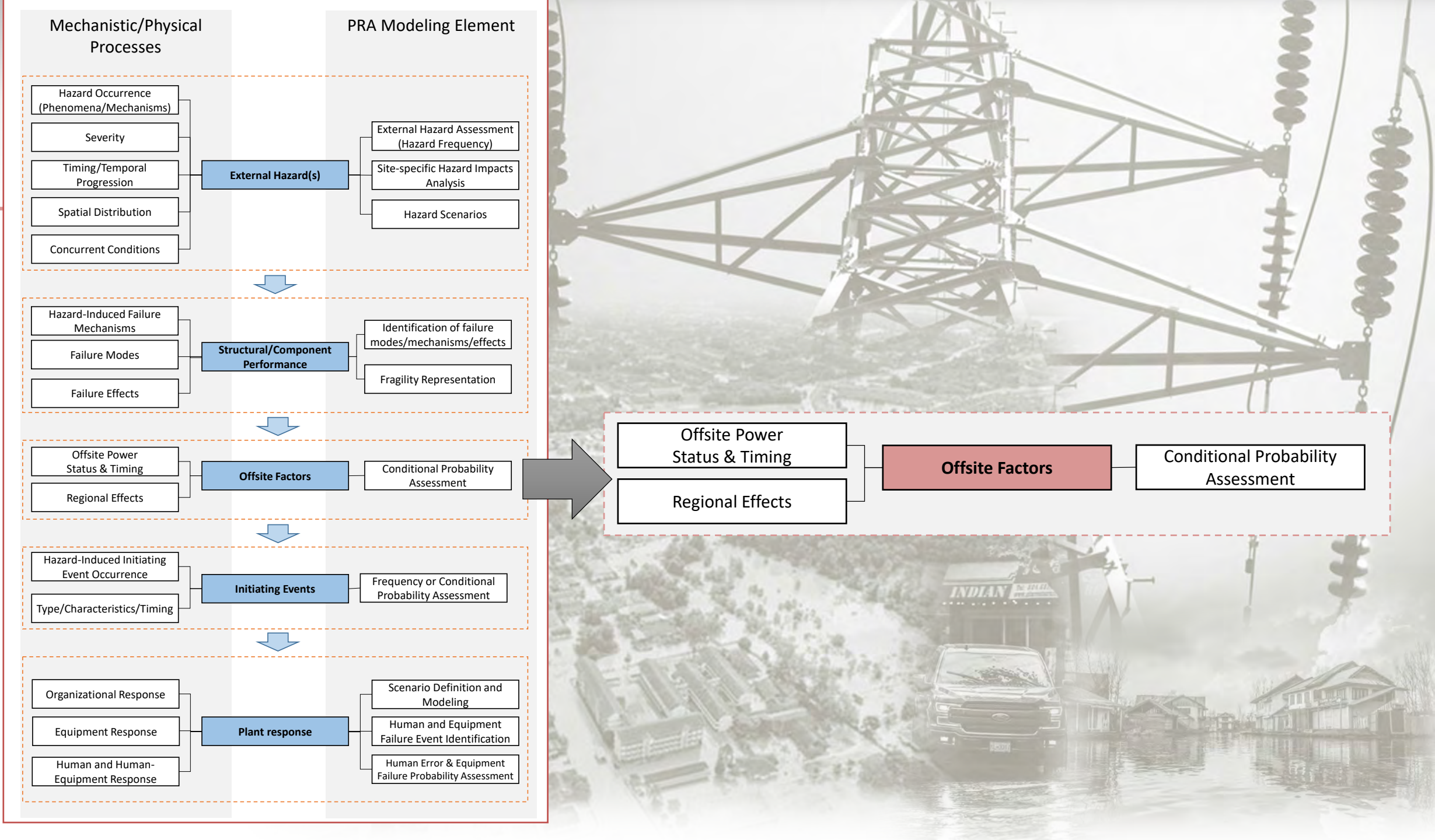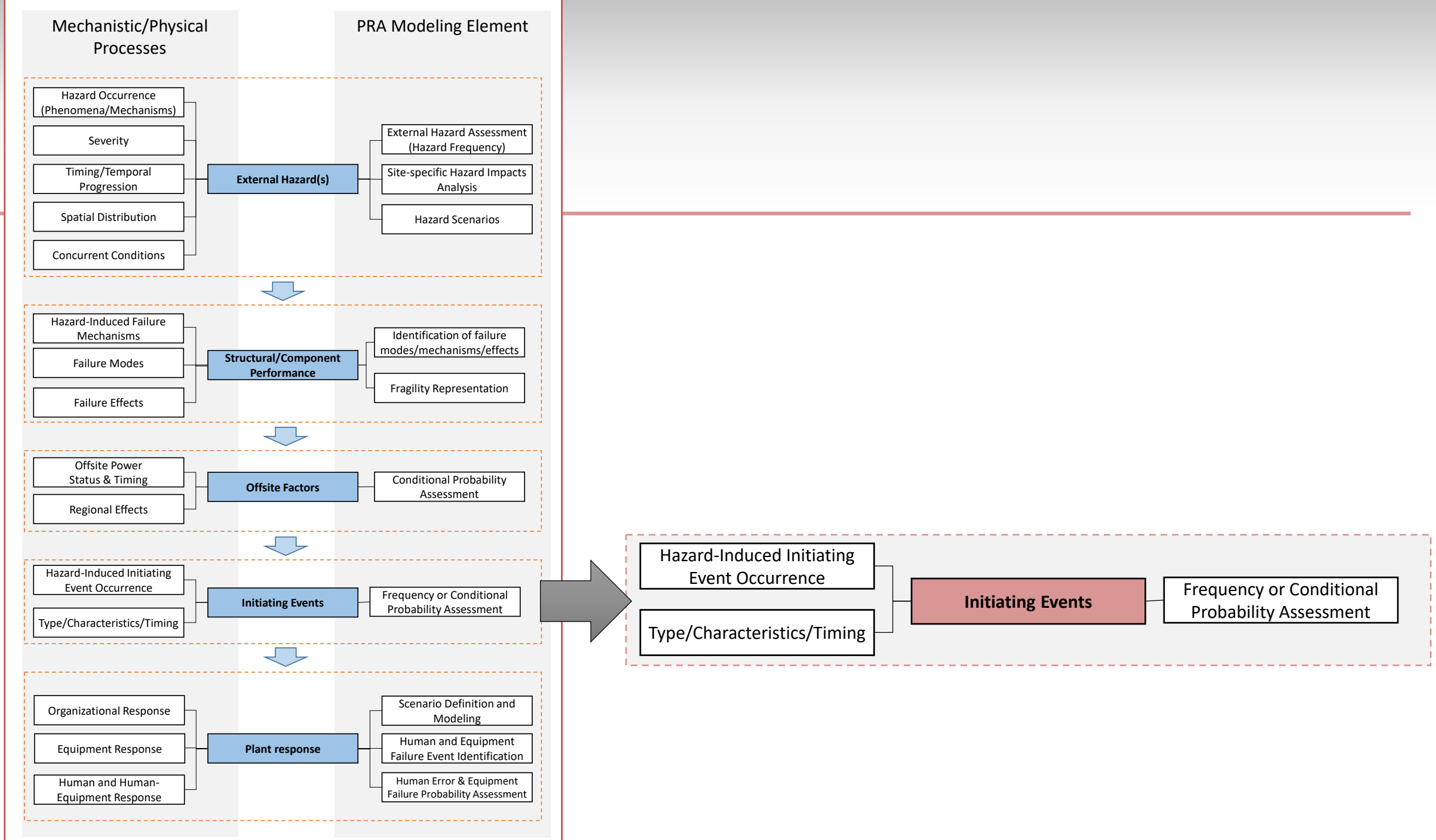External Hazard Assessment (Hazard Frequency)
Site-specific Hazard Impacts Analysis
Hazard Scenarios

Annual Exceedance Frequency

Hazard Severity

Mechanistic/Physical Processes

- Hazard Occurrence (Phenomena/Mechanisms)
- Severity
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- Spatial Distribution
- Concurrent Conditions

External Hazard(s)

- Hazard-Induced Failure Mechanisms
- Failure Modes
- Failure Effects

Structural/Component Performance

- Offsite Power Status & Timing
- Regional Effects

Offsite Factors

- Hazard-Induced Initiating Event Occurrence
- Type/Characteristics/Timing

Initiating Events

- Organizational Response
- Equipment Response
- Human and Human-Equipment Response

Plant response

PRA Modeling Element

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Structural/Component Performance

- Identification of failure modes/mechanisms/effects
- Fragility Representation

$P(DS_i|S)$

$\geq DS_1$
$\geq DS_2$
$\geq DS_s$

Hazard Severity (S)

Mechanistic/Physical Processes | **PRA Modeling Element**

- Hazard Occurrence (Phenomena/Mechanisms)
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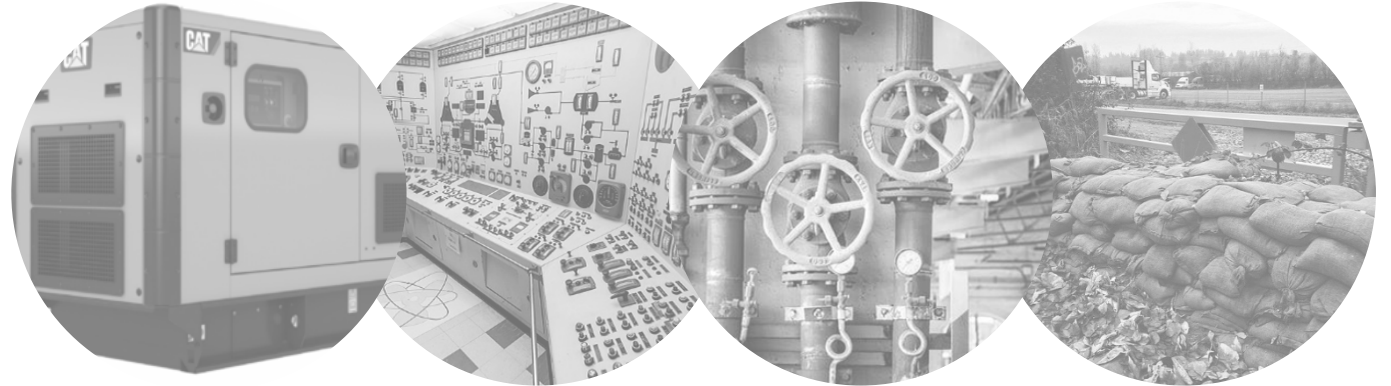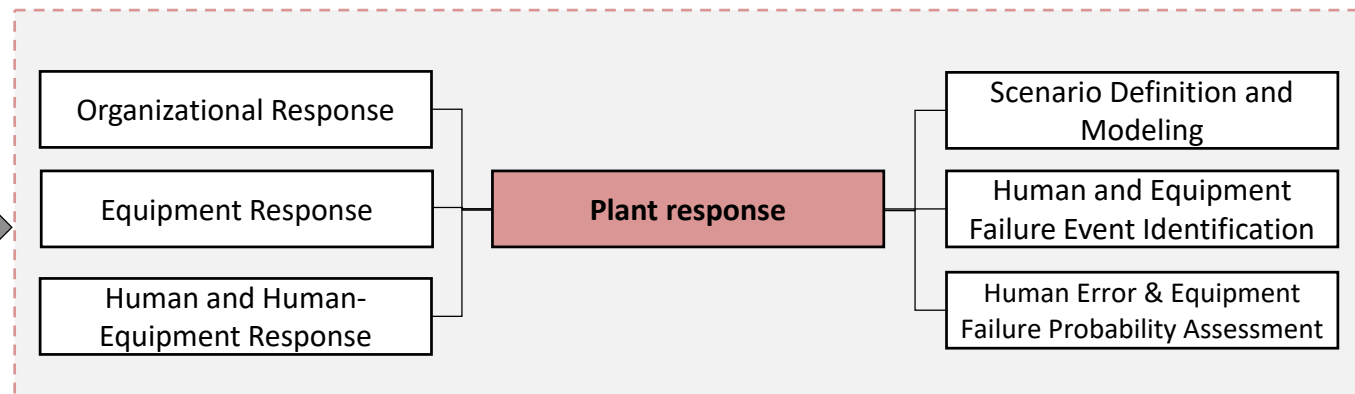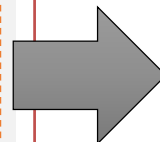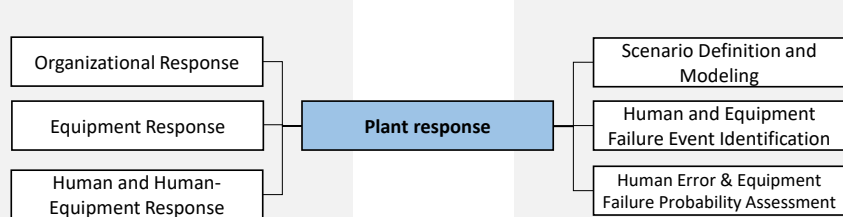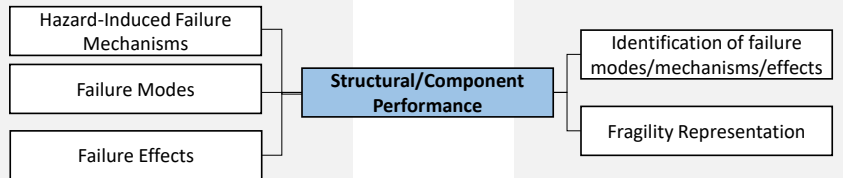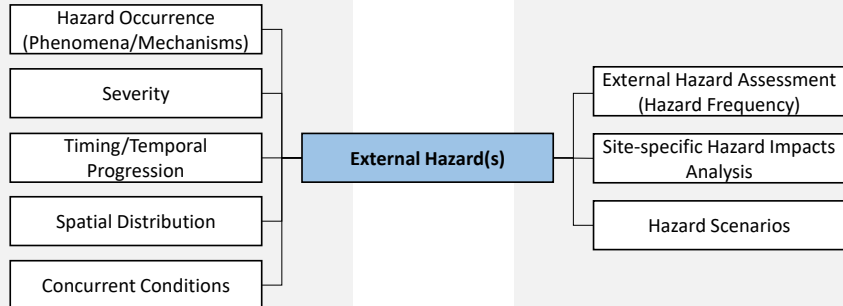
Assessment of Taxonomy
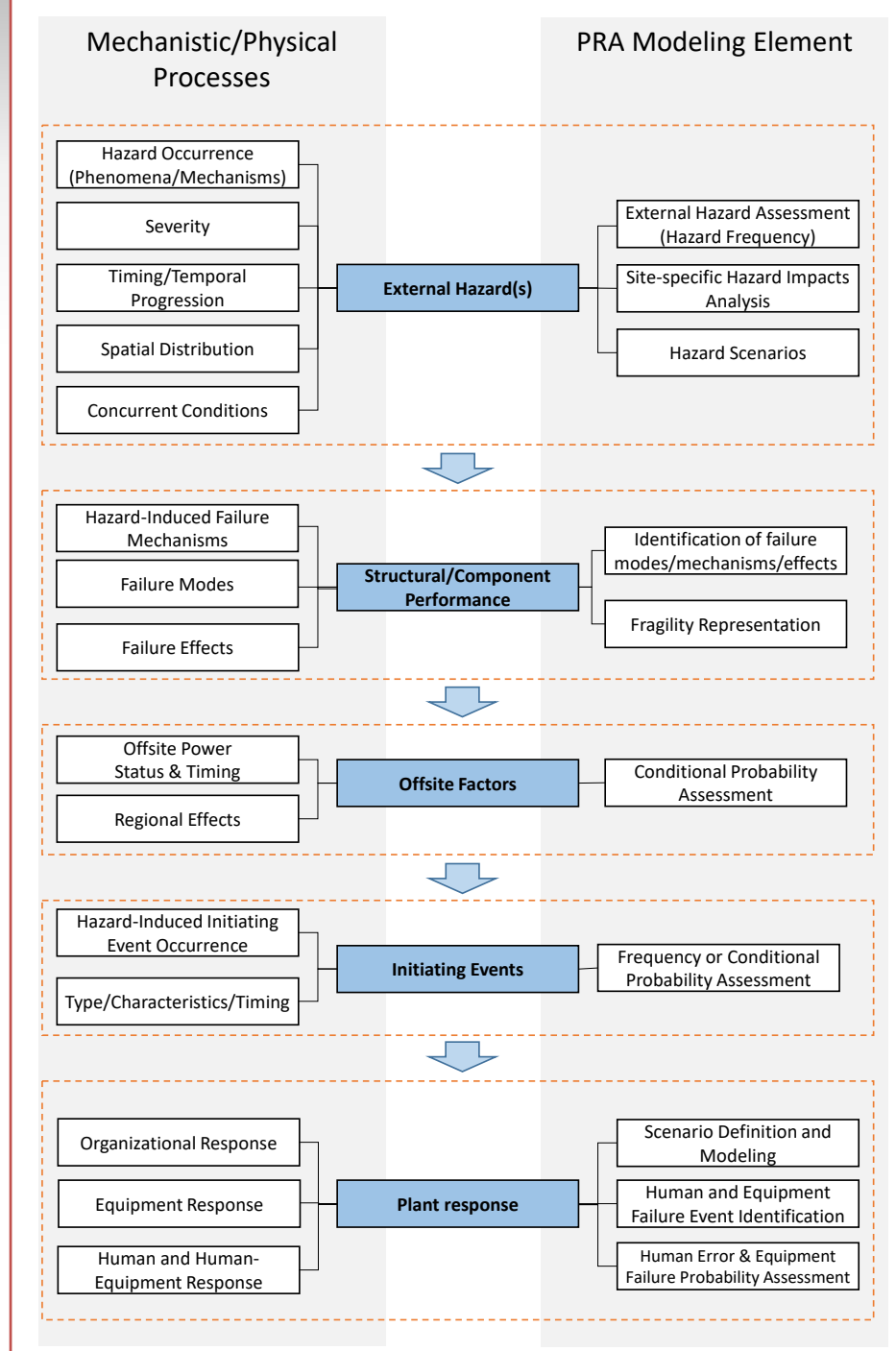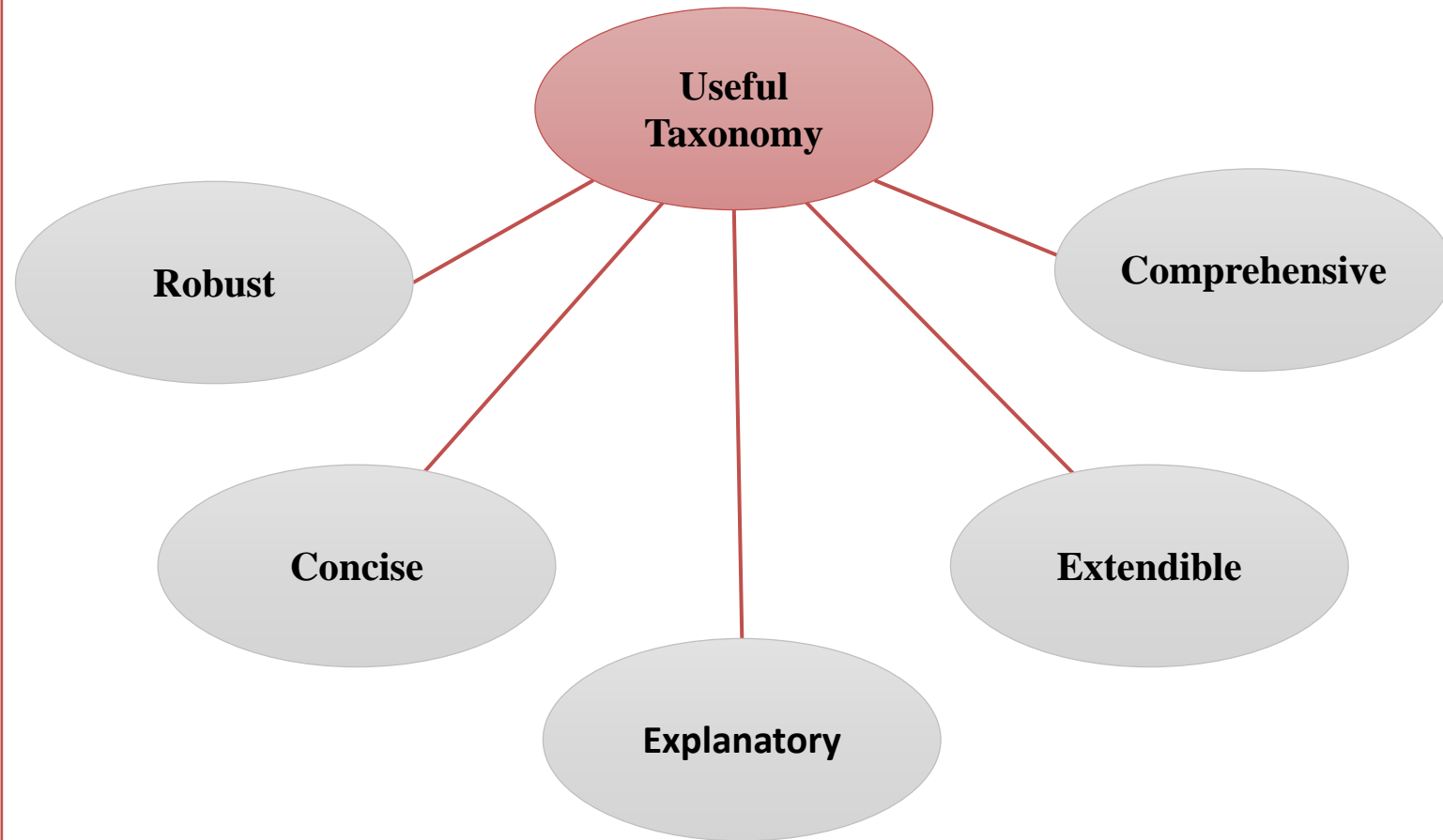
Leveraging work of Nickerson, et al (2013) and Reilly, et al (2021)

Contributors:

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Questions?