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Advanced Reactor Safeguards Scenario Timeline Exploration

May 2022

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Changing the World's Energy Future

Idaho National Laboratory

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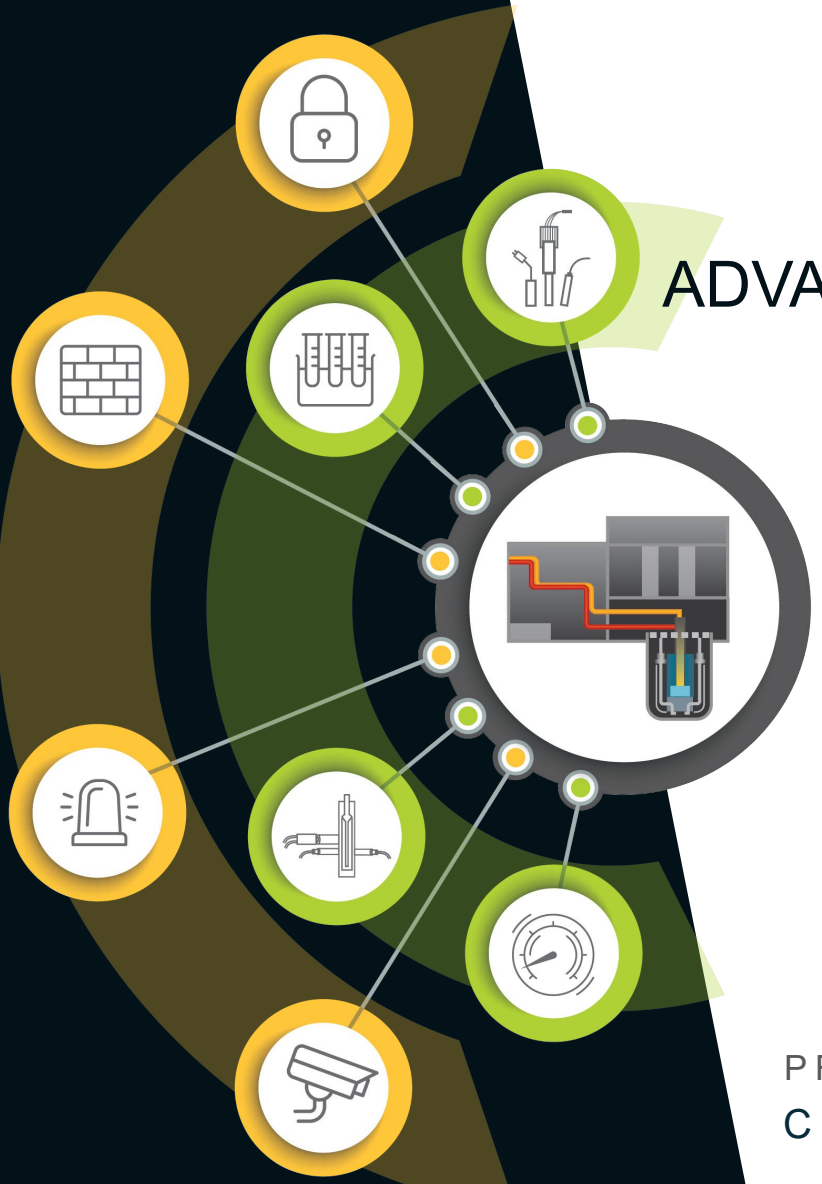

ADVANCED REACTOR SAFEGUARDS

Scenario Exploration and Timeline Analysis for Microreactors

PRESENTED BY
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May 2022

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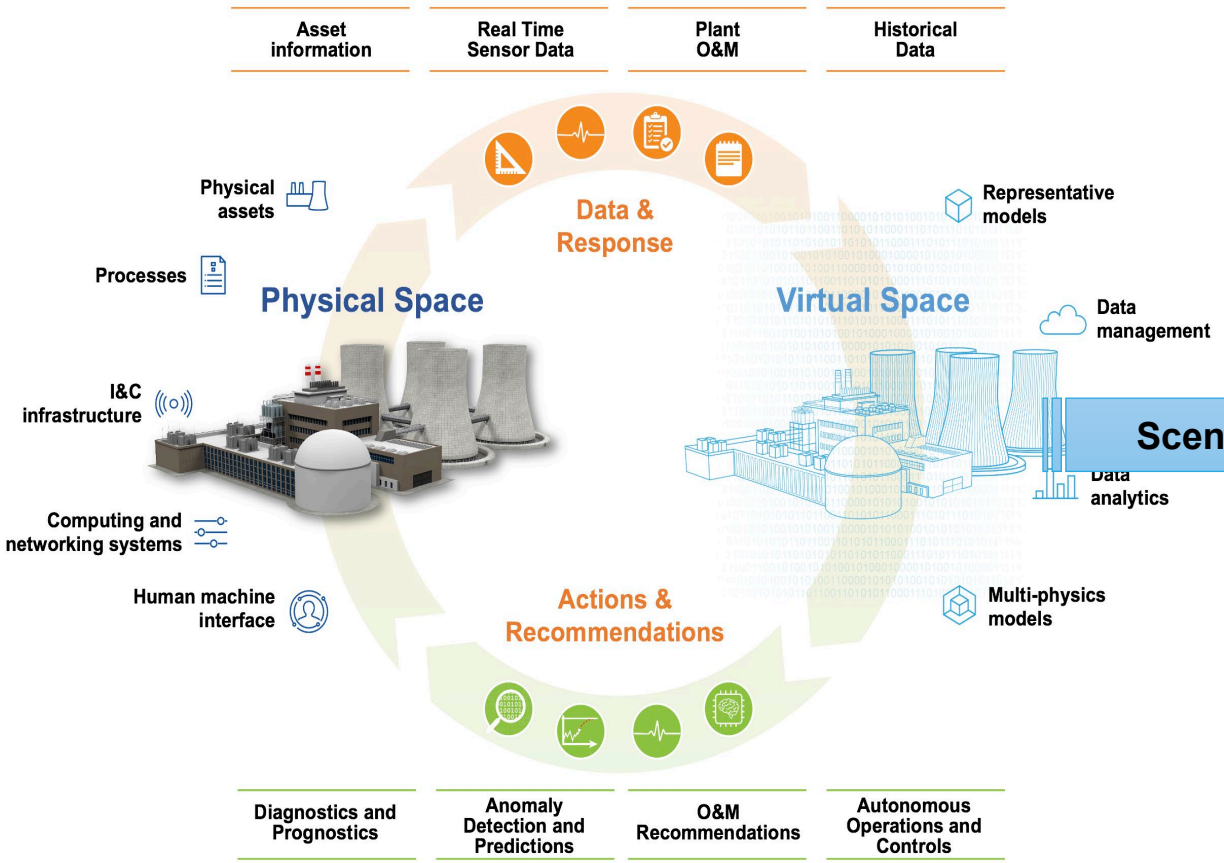
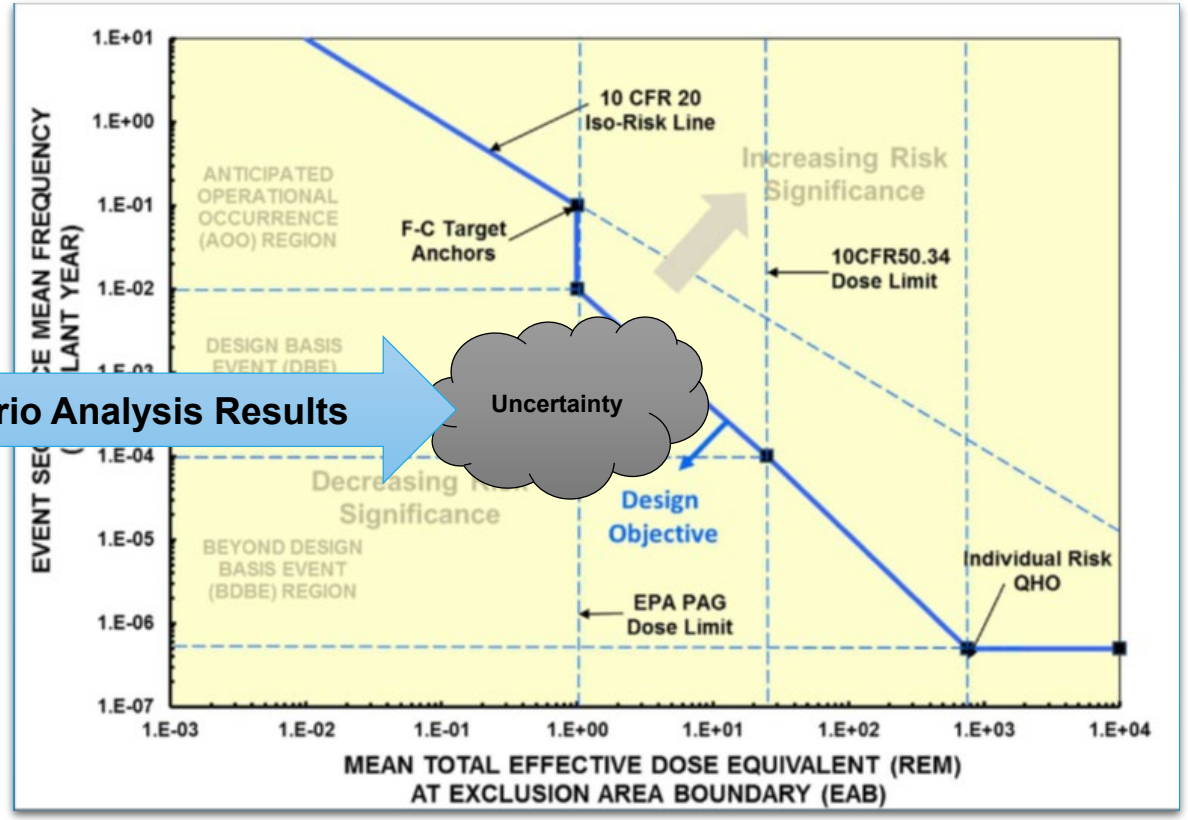
Motivation on Scenario and Uncertainty Research and Development

- Advanced reactors will be able to use risk insights for many design aspects
  - Example risk-informed approach is found in the Nuclear Regulatory Commission's SECY-19-0117
  - Probability is widespread through the guidance via a safety case
  - Probabilistic concepts are built into metrics, such as the frequency-consequence curve
- We need bounding scenarios for screening and scoping purposes
- We need realistic scenarios for input into the licensing basis safety-case
  - These scenarios must include timing and physics
- We need to manage inherent uncertainty
- We need to automate the safety-case creation as much as possible

Advanced Reactor Design Attributes have Links to Frequency-Consequence Metrics



(derived from NEI 18-04)



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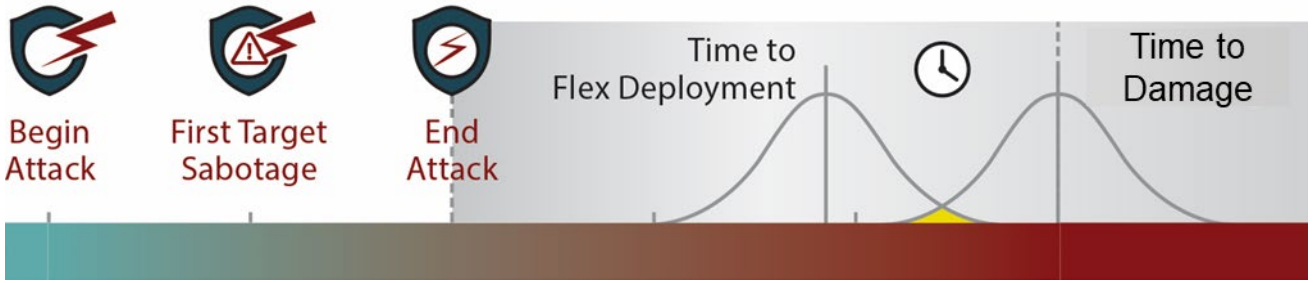
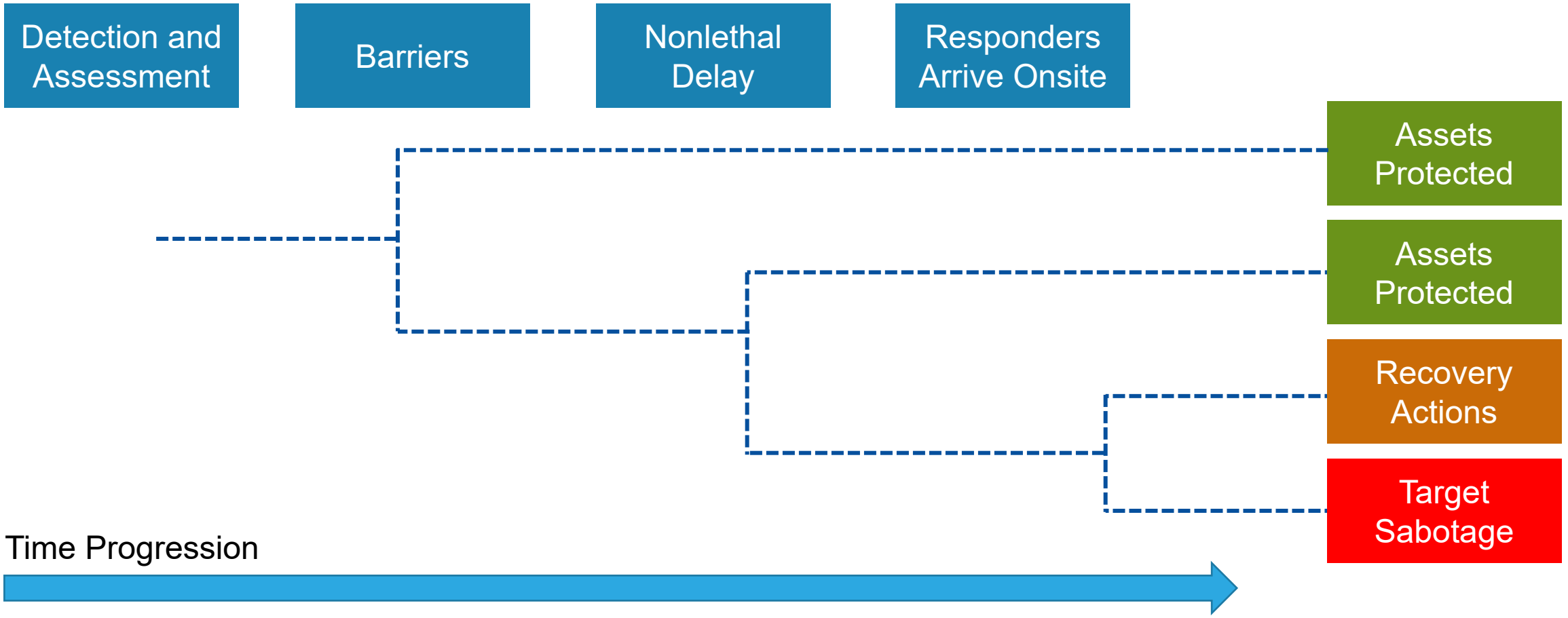
Attributes of the Demonstration Infrastructure

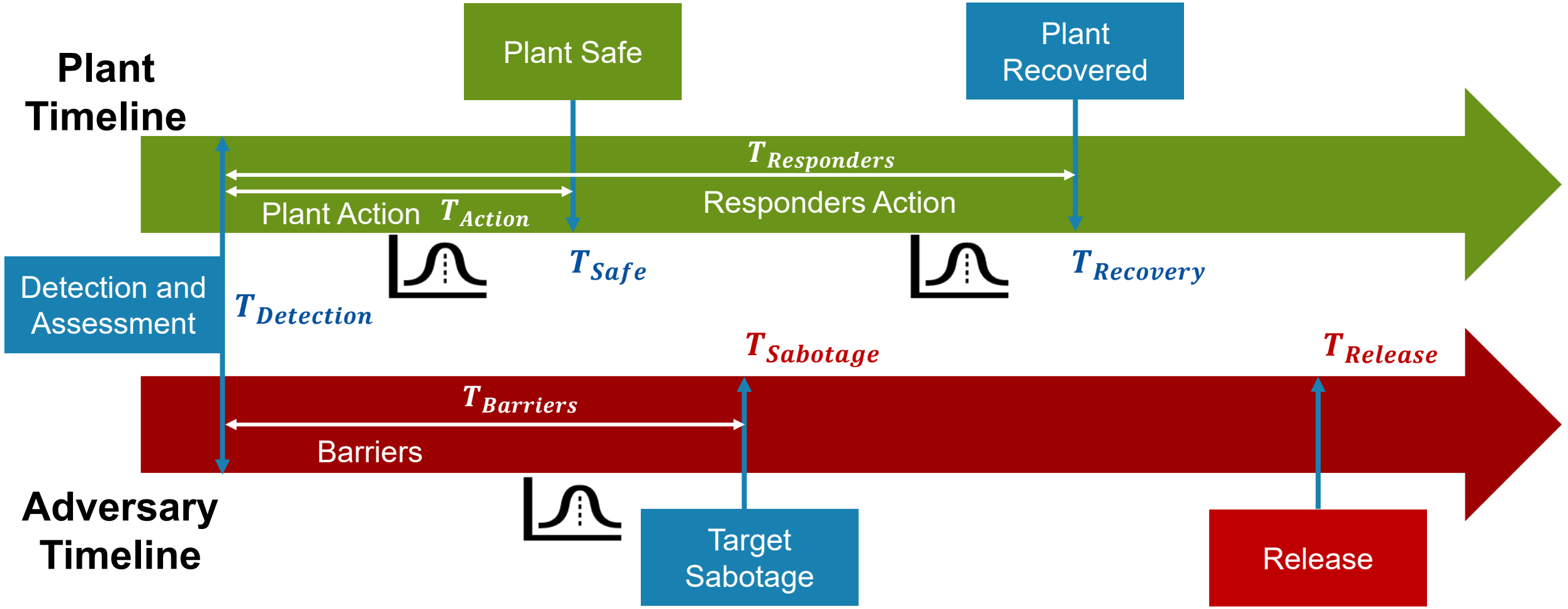
- Simulation to develop a risk-informed safety case
  - A highly transparent, traceable, scrutable framework
  - Used to inform all stakeholders (developers, regulators, operators)
- Leverage established technologies (e.g., EMRALD) for simulations
  - Risk scenario-based analyses & treatment of associated uncertainties
    - Uncertainties are captured by automating the “state space”
    - The state space represents variations in scenarios and outcomes
- Manage complex workflows to facilitate successful design evolution
  - Inform security design evolution from early design to operations
  - Also support creation of the technical basis



Modeling and Analysis in EMRALD (notional)

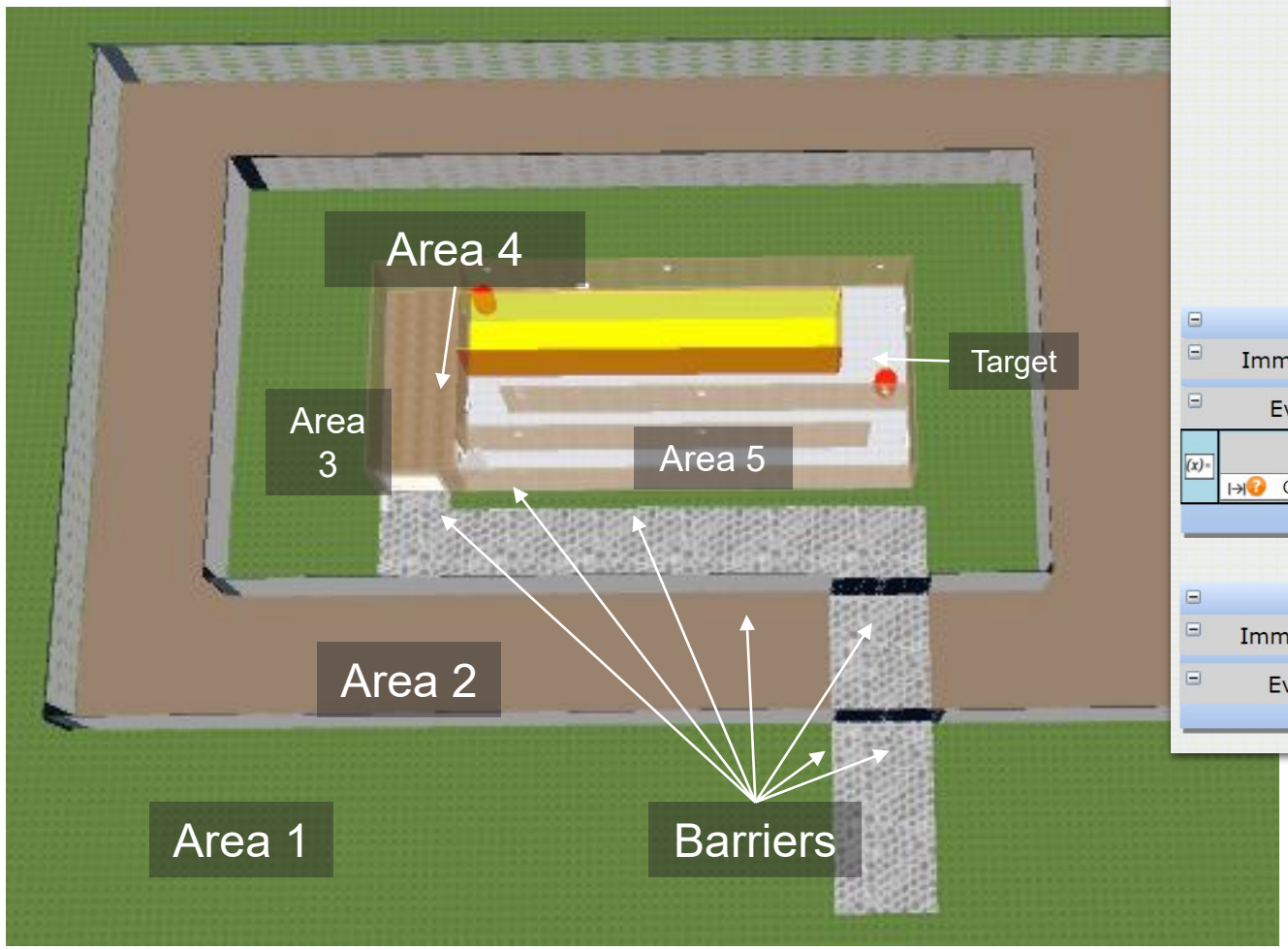


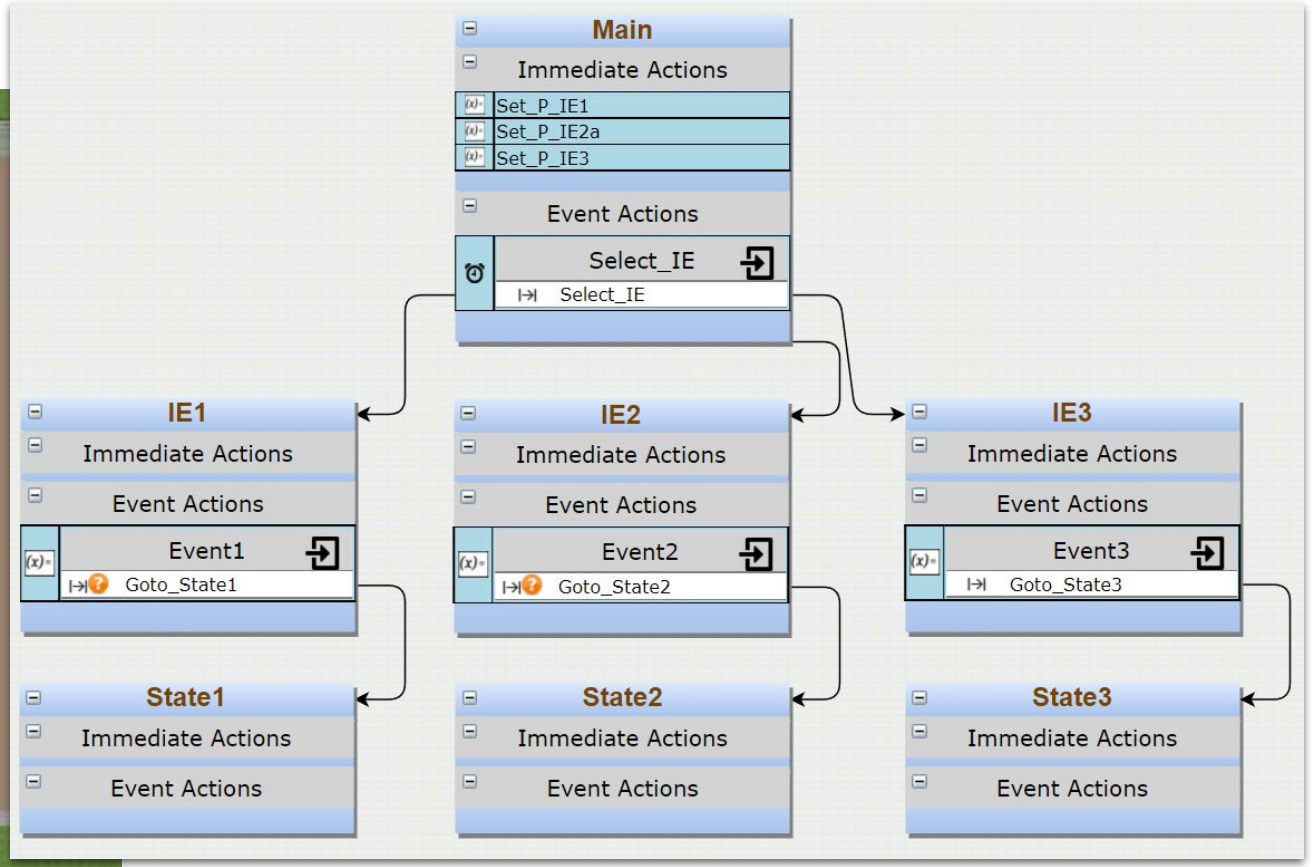
Timeline Analysis in EMRALD



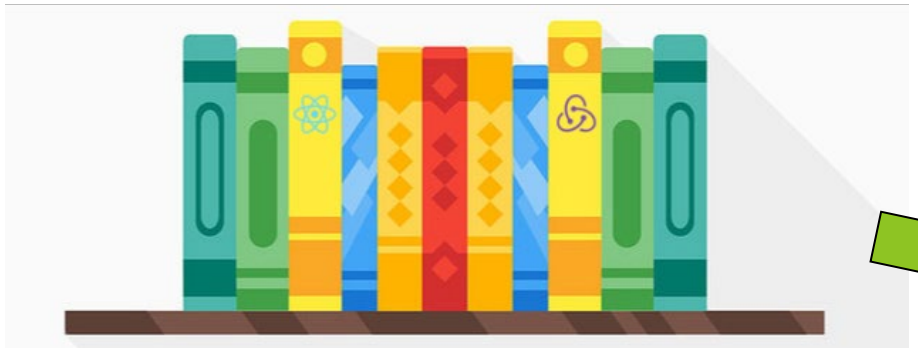
Example: Adversary Sequence Modeling in EMRALD

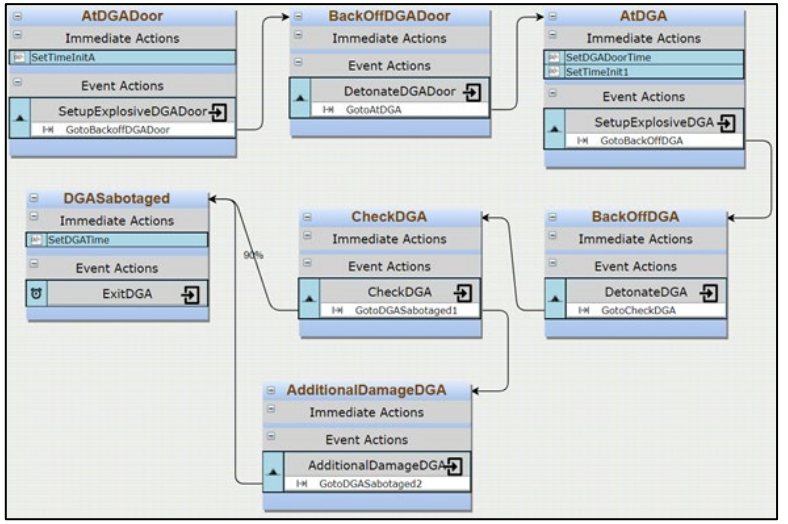
This is a hypothetical facility for demonstration purposes only.





Library of Barriers and Other Model Pieces



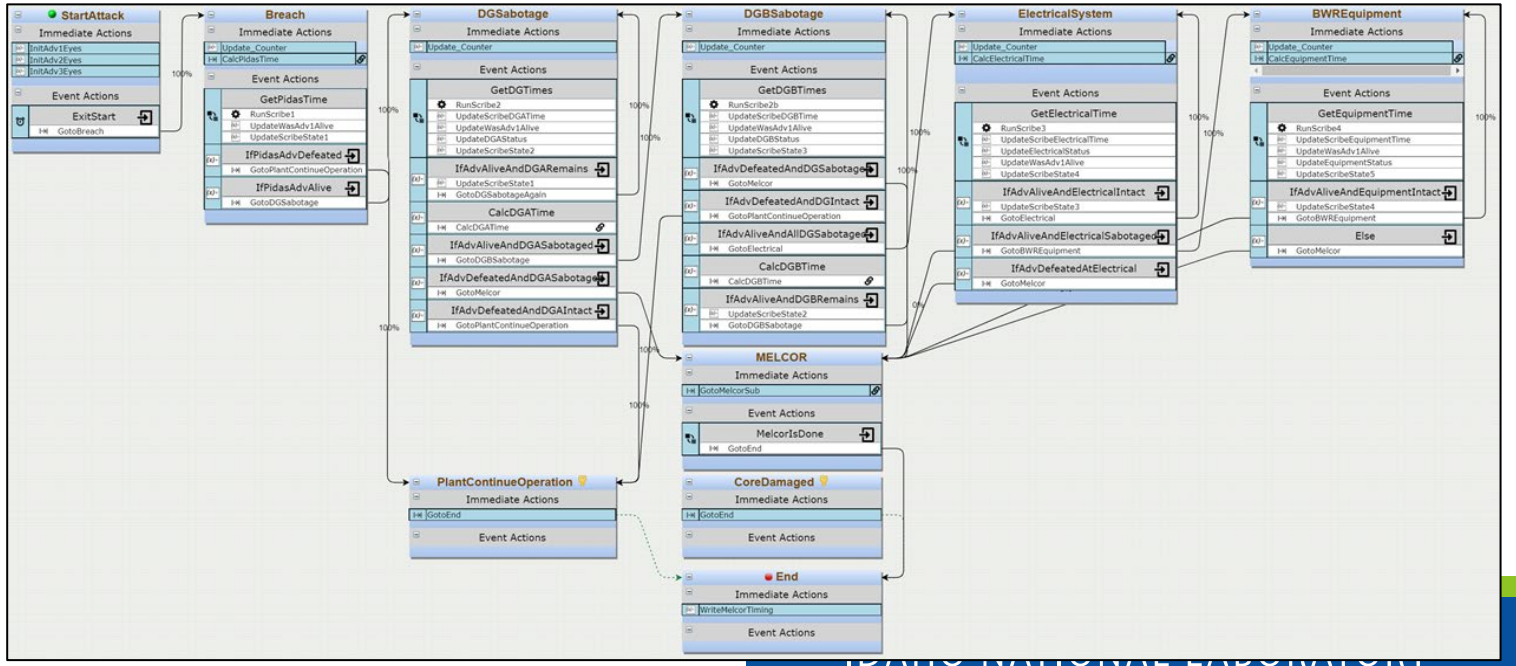


Barriers

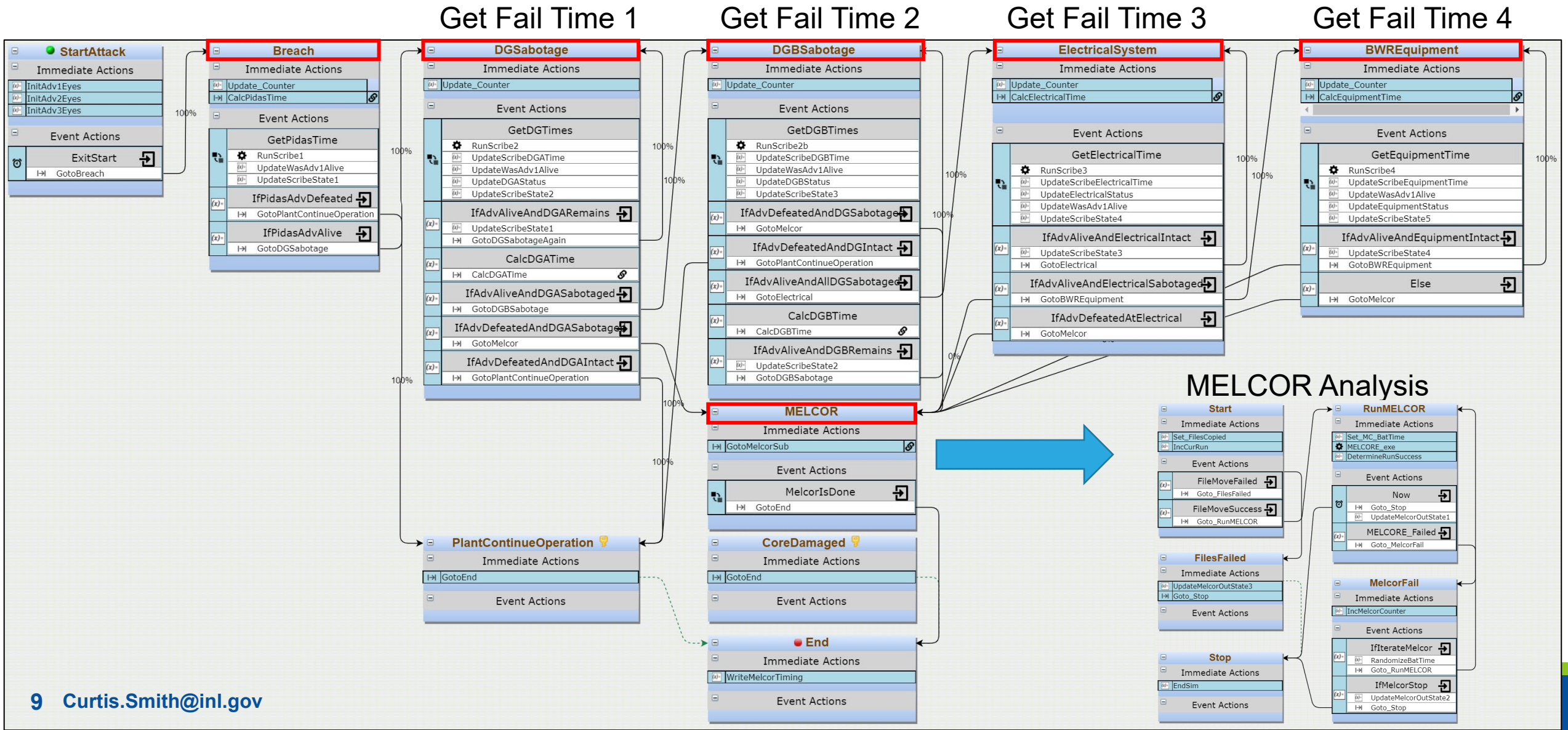
- Fences
- Sticky Foam
- Concrete Walls
- Security Doors
- Etc.

Properties

- Delay Time
- Equipment Requirements
- Detection Probability
- Etc.



Consequence Analysis



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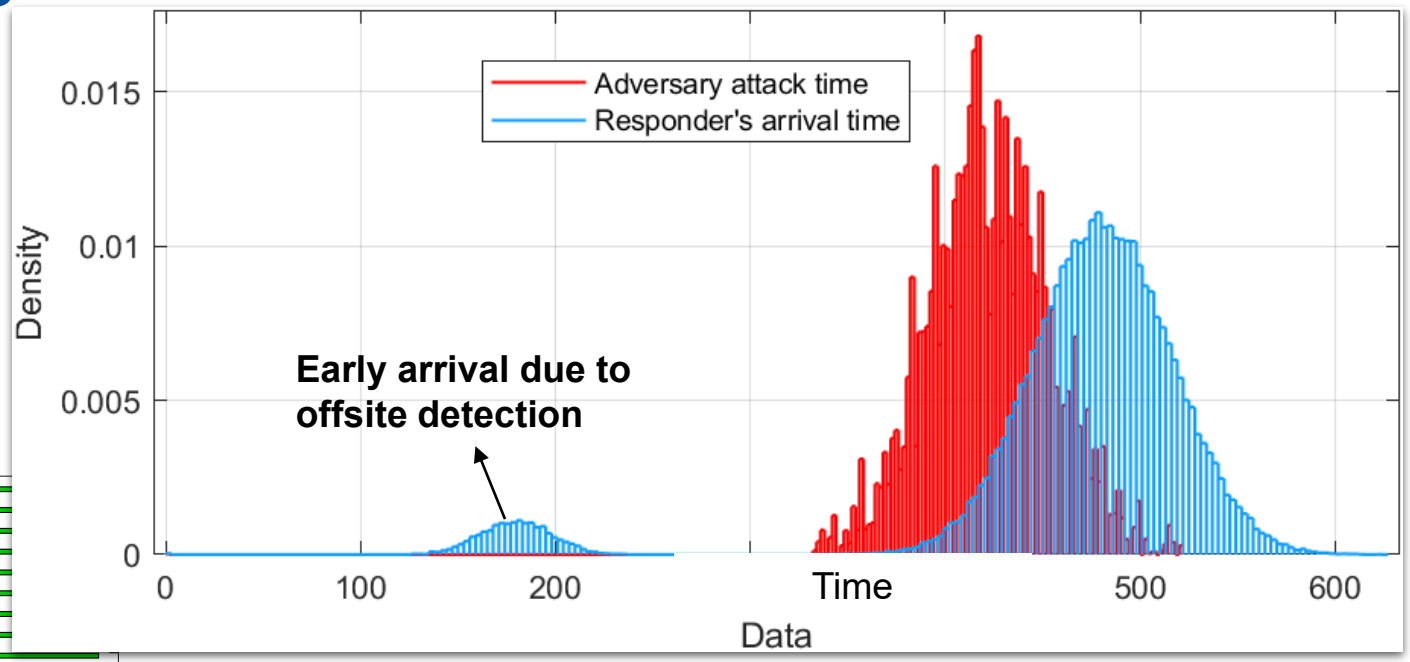
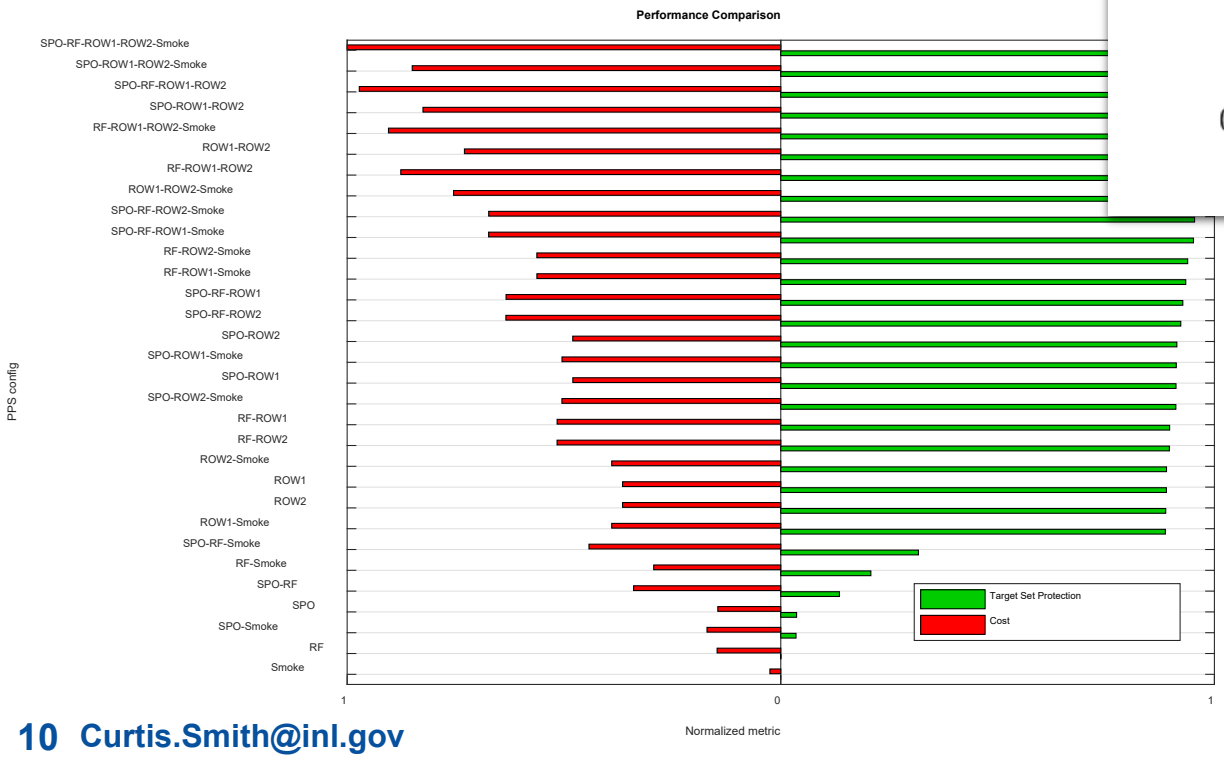
Sample Results & Insights





Summary: EMRALD Capabilities for Adv. Reactors

Different Attack Scenarios
- Different paths
- Adversary capabilities
  - Strategies
  - Equipment
  - Variations

Sample Space
- Timings
- Probabilities
- Outcomes

Portfolio of Hazards/Targets
- List of targets: target super-set
- Combination of targets
- Initiating events as starting point
- Ability to integrate with other hazard types

Different Plant Layout
- Target set
- Topology
  - Geographical entities
  - Impact on timings
  - Plant structures
- Security posture
  - Protective strategies
  - Barriers
  - Responses
  - Law enforcement
  - Recalling off-duty personnel
- Important physics of the advanced reactor

Consequences from EMRALD
- Based on what has failed during a scenario
- To achieve insights that give frequency / consequence curve
- Level 2-3 analysis in EMRALD
  - Capture impact on timings
  - Integration with thermal hydraulics codes: MELCOR / MAAP / RELAP5

Results & Insights
- Quantitative and qualitative results
- Sensitivities
- Visualization

https://github.com/inl-labtrack/EMRALD

And Thanks to the INL Team

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