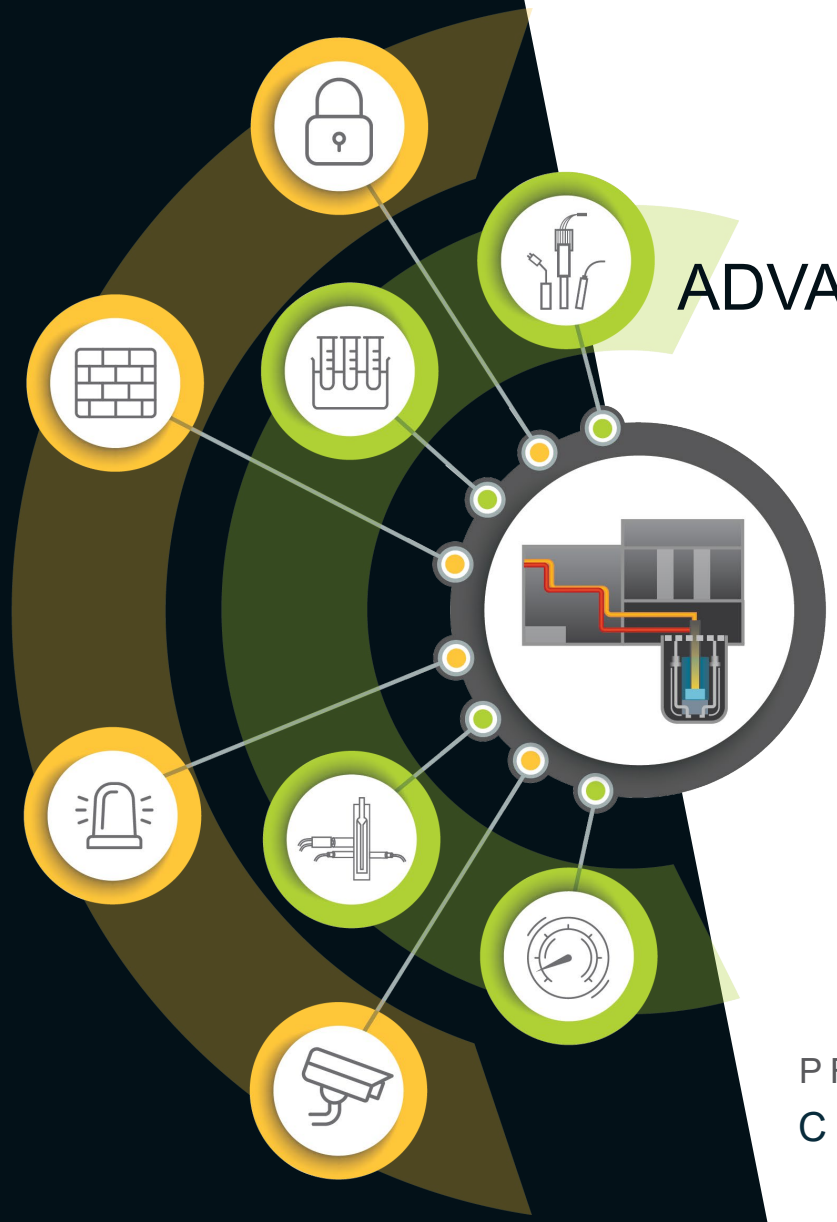


ADVANCED REACTOR SAFEGUARDS

Scenario Exploration and Timeline Analysis for Microreactors

PRESENTED BY
Curtis Smith, Director, Nuclear Safety and Regulatory Research

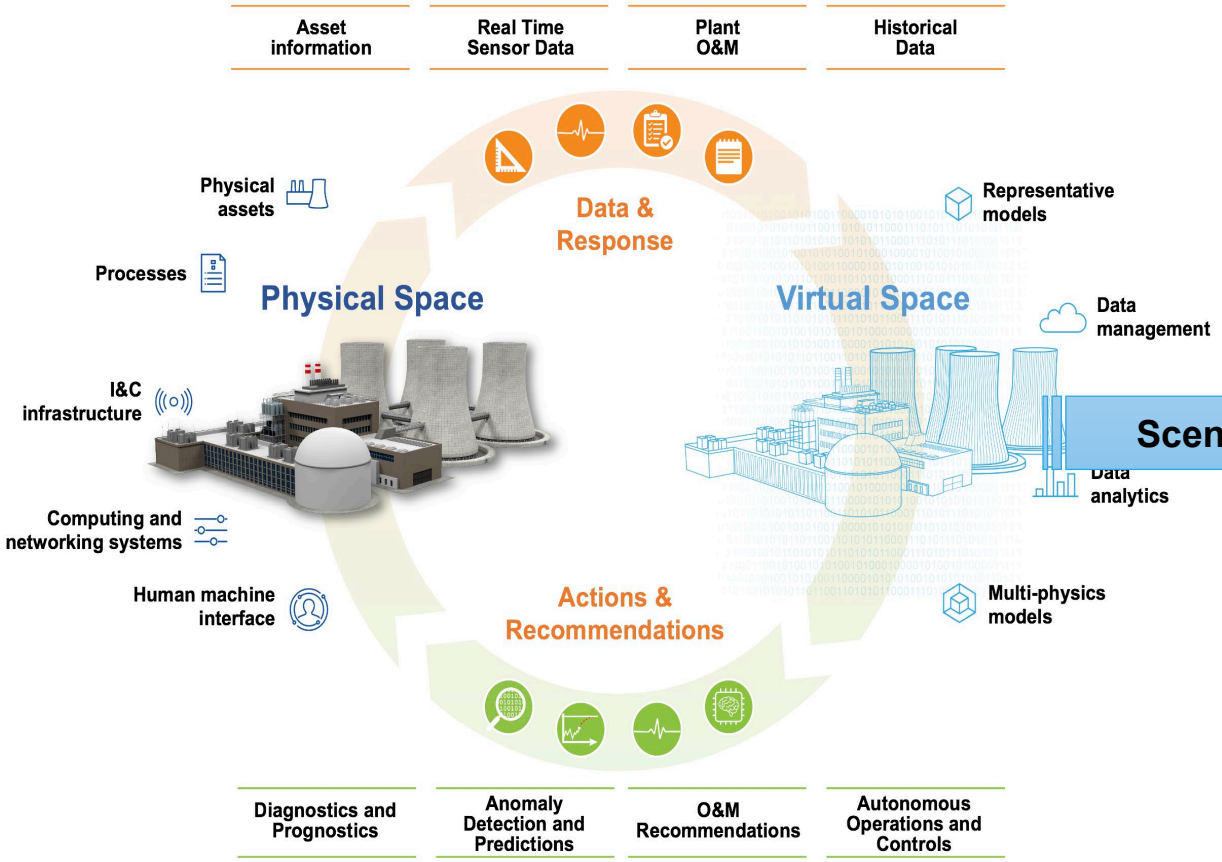
May 2022

Idaho National Laboratory
U.S. DEPARTMENT OF ENERGY

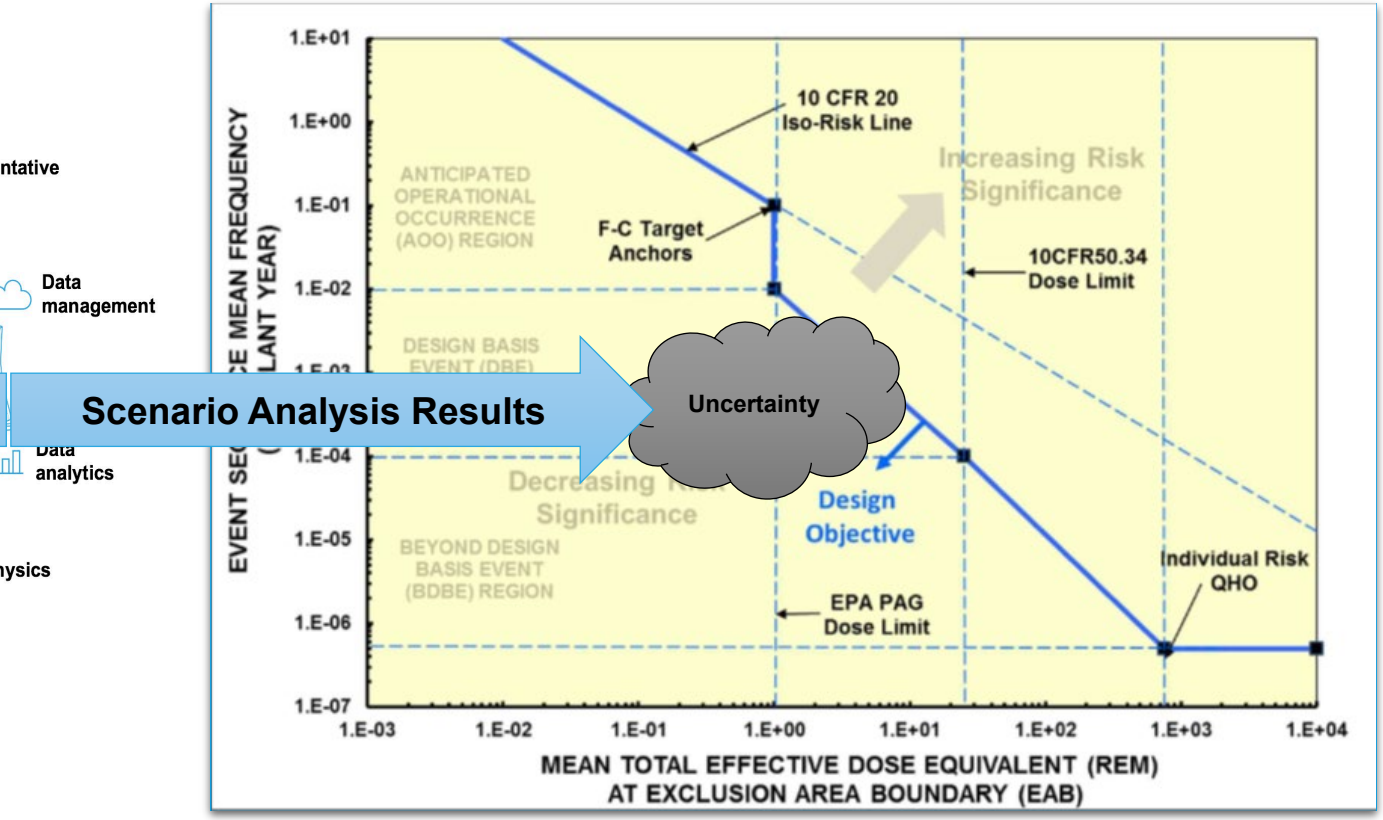
Motivation on Scenario and Uncertainty Research and Development

- 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



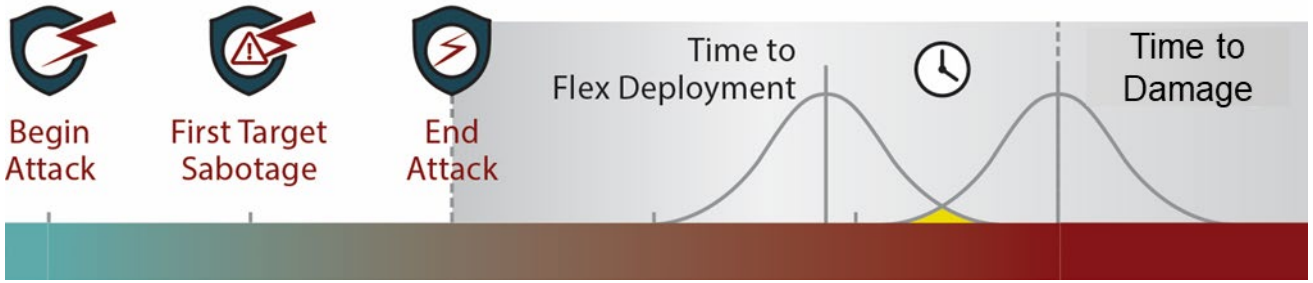
(derived from NEI 18-04)



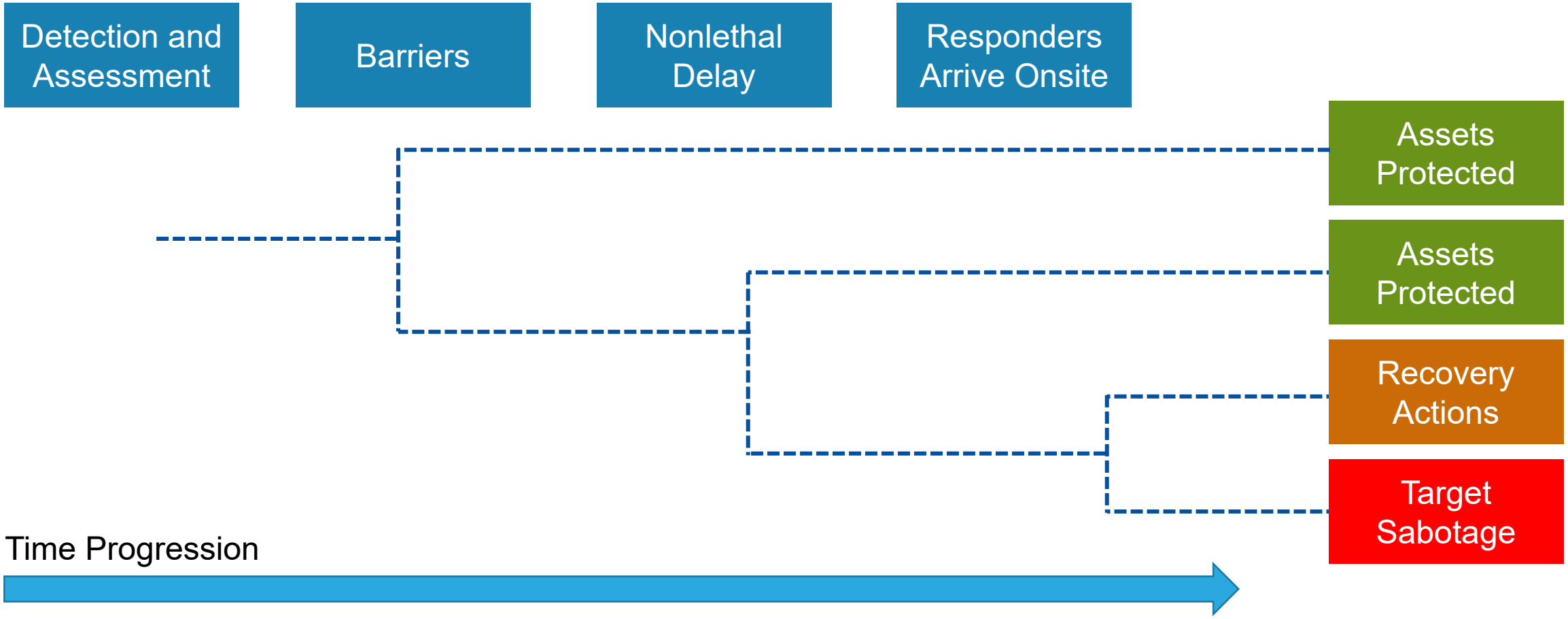
Curtis.Smith@inl.gov

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

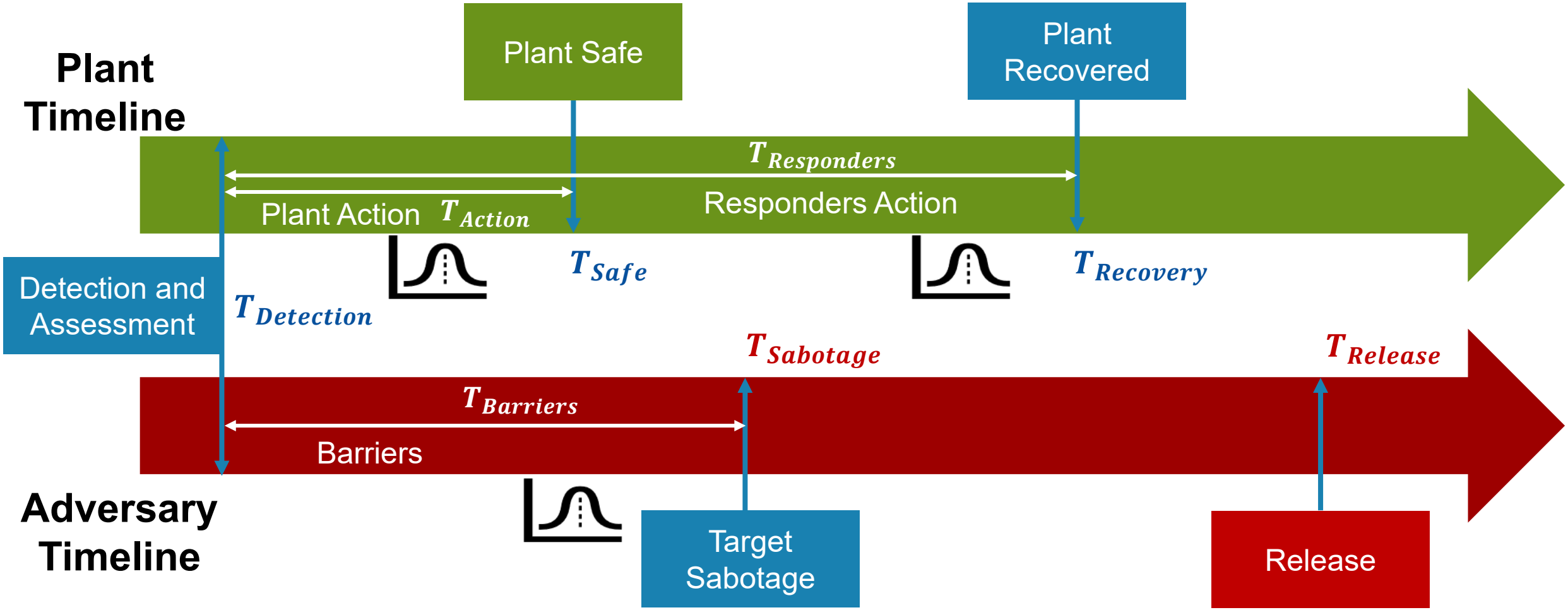


Modeling and Analysis in EMRALD (notional)



 Curtis.Smith@inl.gov

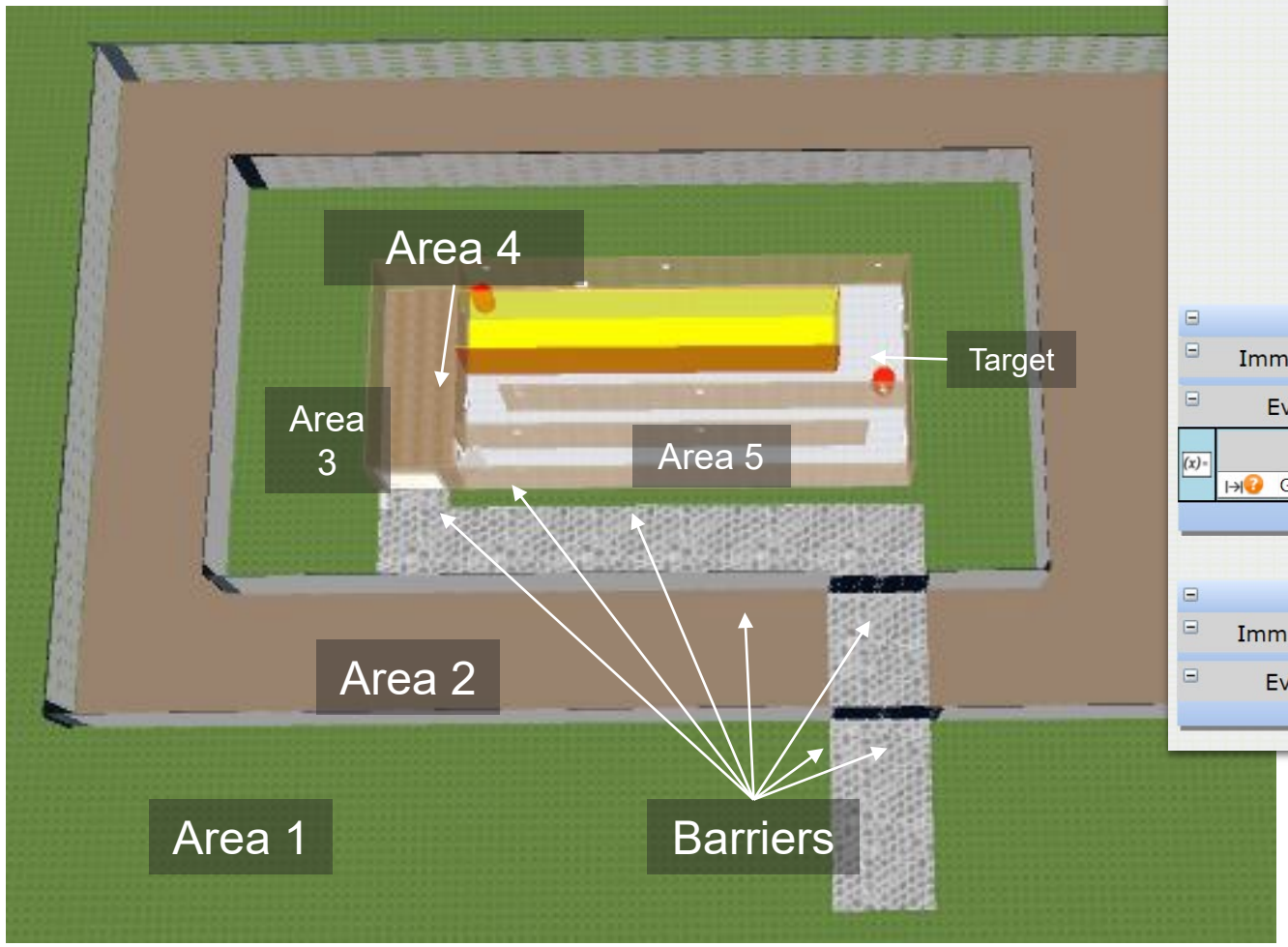
Timeline Analysis in EMRALD

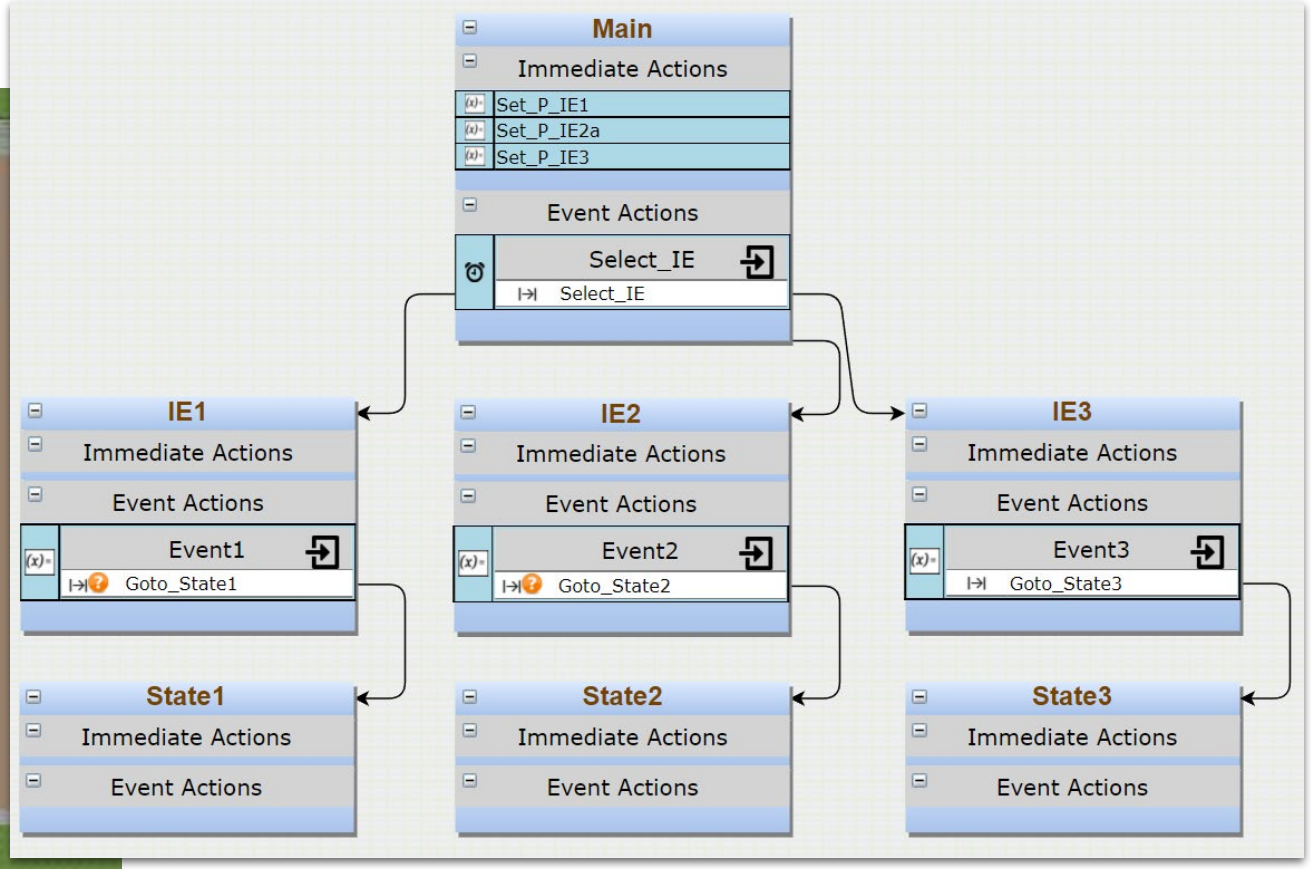


 Curtis.Smith@inl.gov

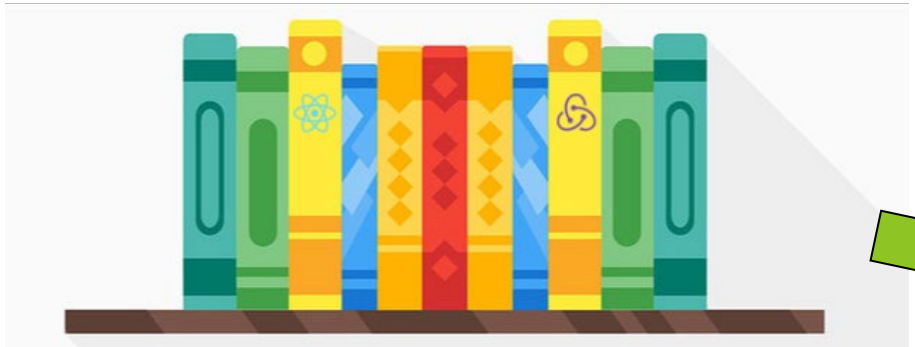
Example: Adversary Sequence Modeling in EMRALD

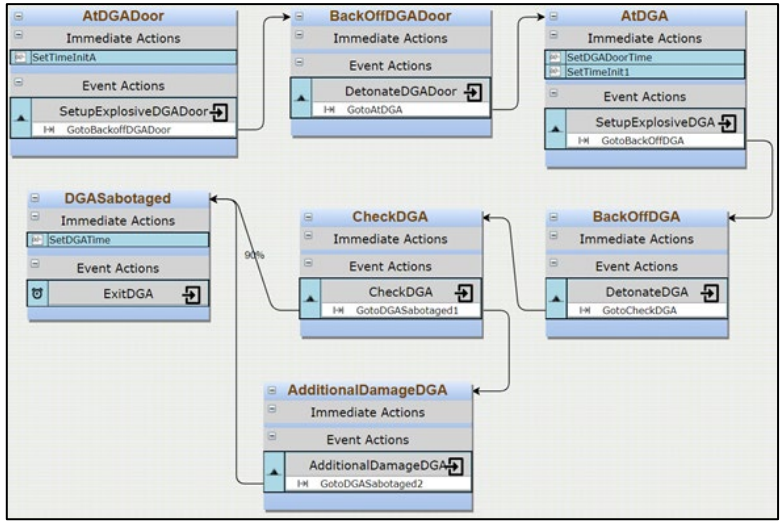
This is a hypothetical facility for demonstration purposes only.





Library of Barriers and Other Model Pieces



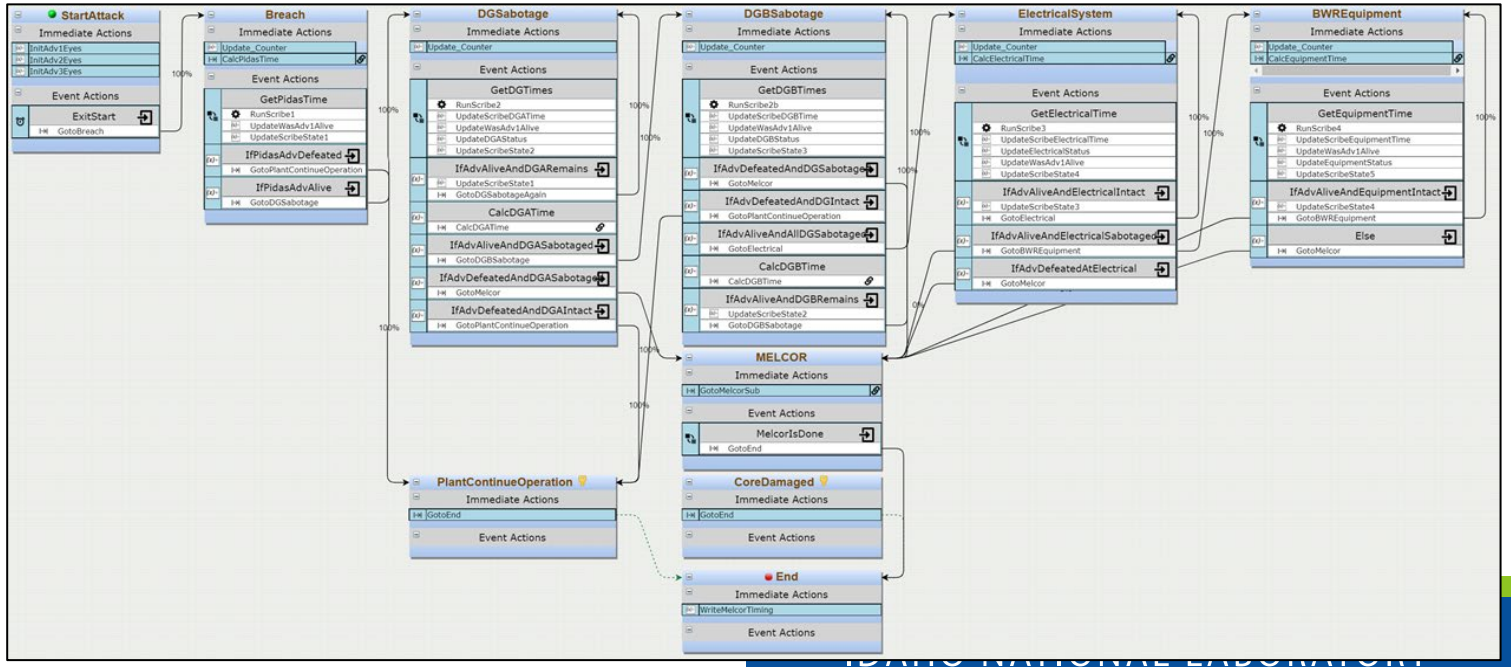


Barriers

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

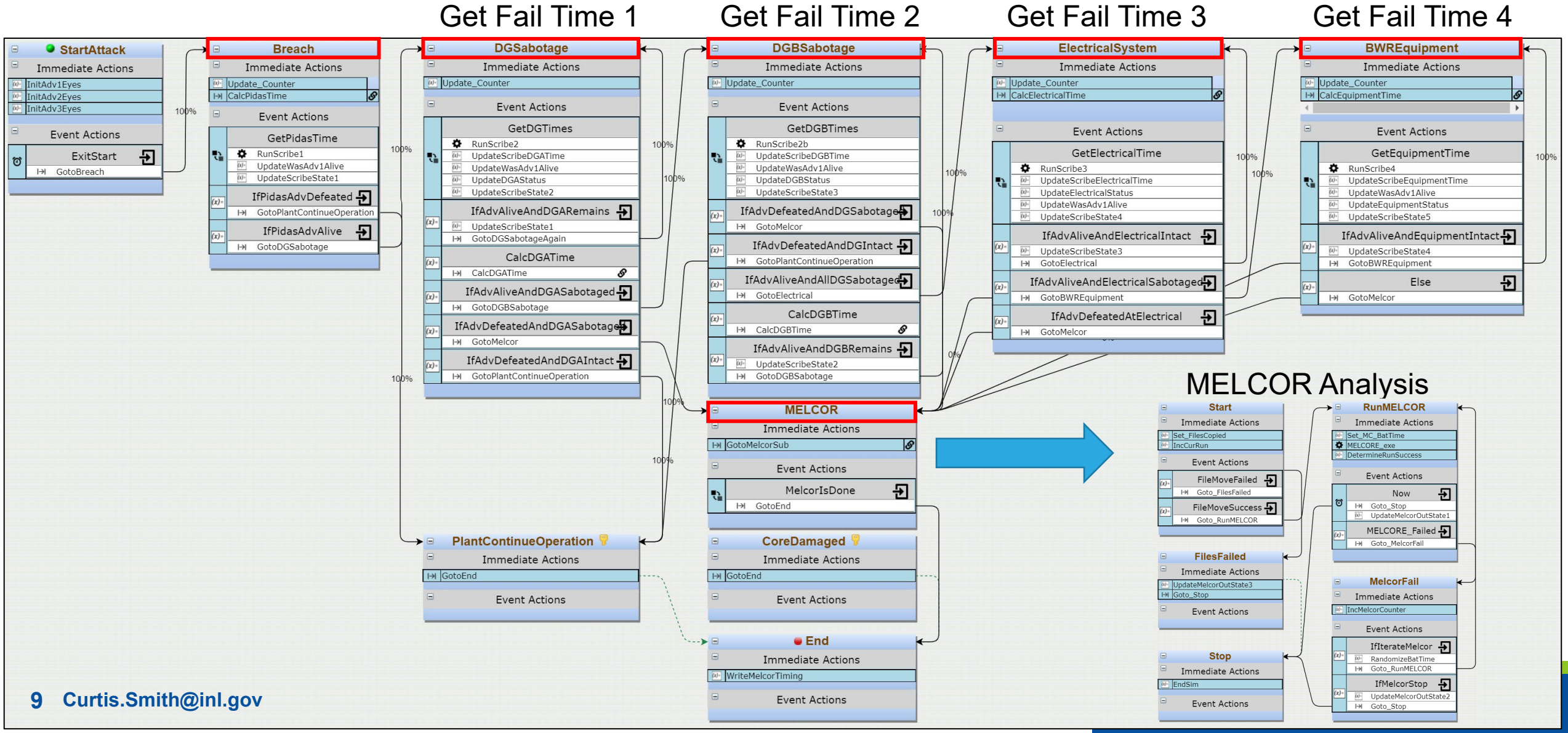
Properties

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



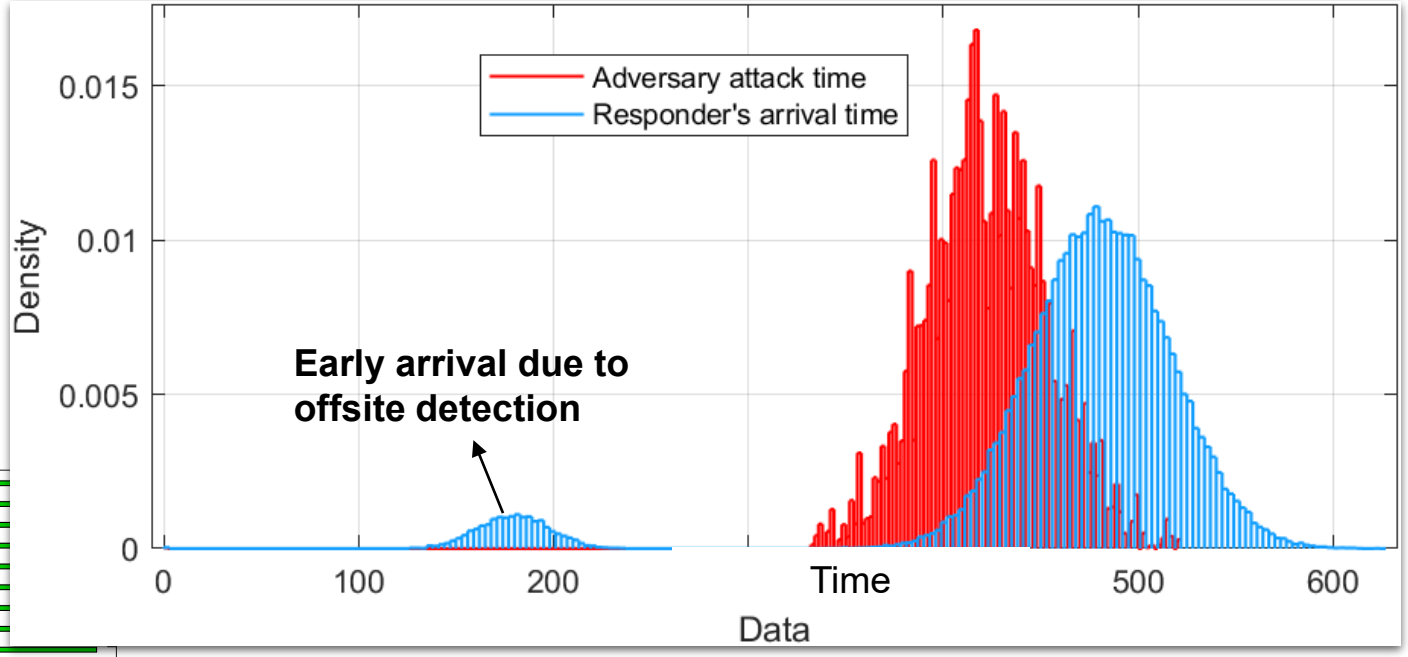
 Curtis.Smith@inl.gov

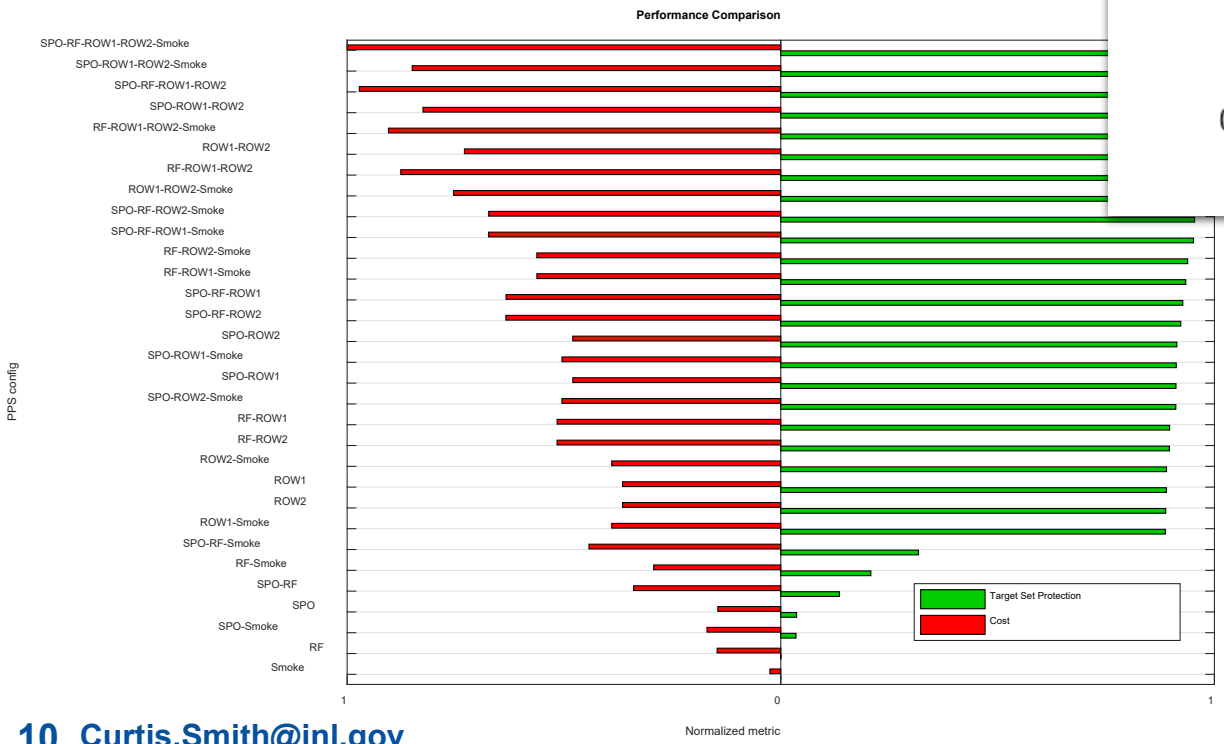
Consequence Analysis



 Curtis.Smith@inl.gov

Sample Results & Insights





 Curtis.Smith@inl.gov

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

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

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

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

And Thanks to the INL Team

Robby Christian
Chris Chwasz
Shawn St. Germain
Steven Prescott
Vaibhav Yadav