INL/MIS-21-64886-Revision-0

Presentation: Scenario Timeline Exploration

November 2021

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Changing the World's Energy Future

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ADVANCED REACTOR SAFEGUARDS

Scenario Timeline Exploration

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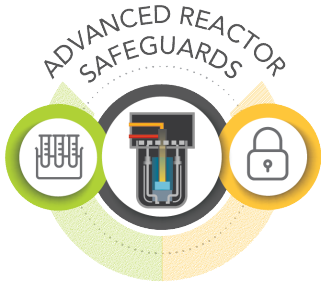
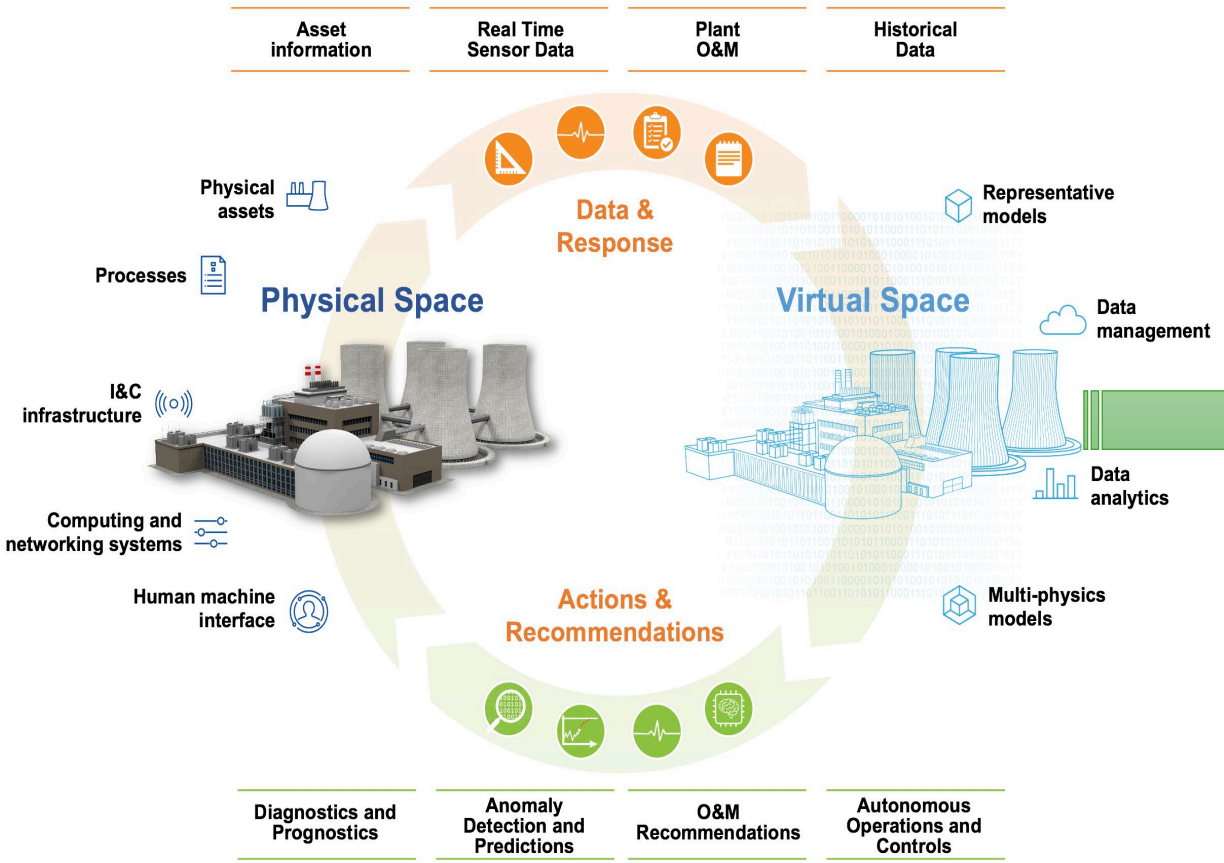
Motivation on Scenario and Uncertainty R&D

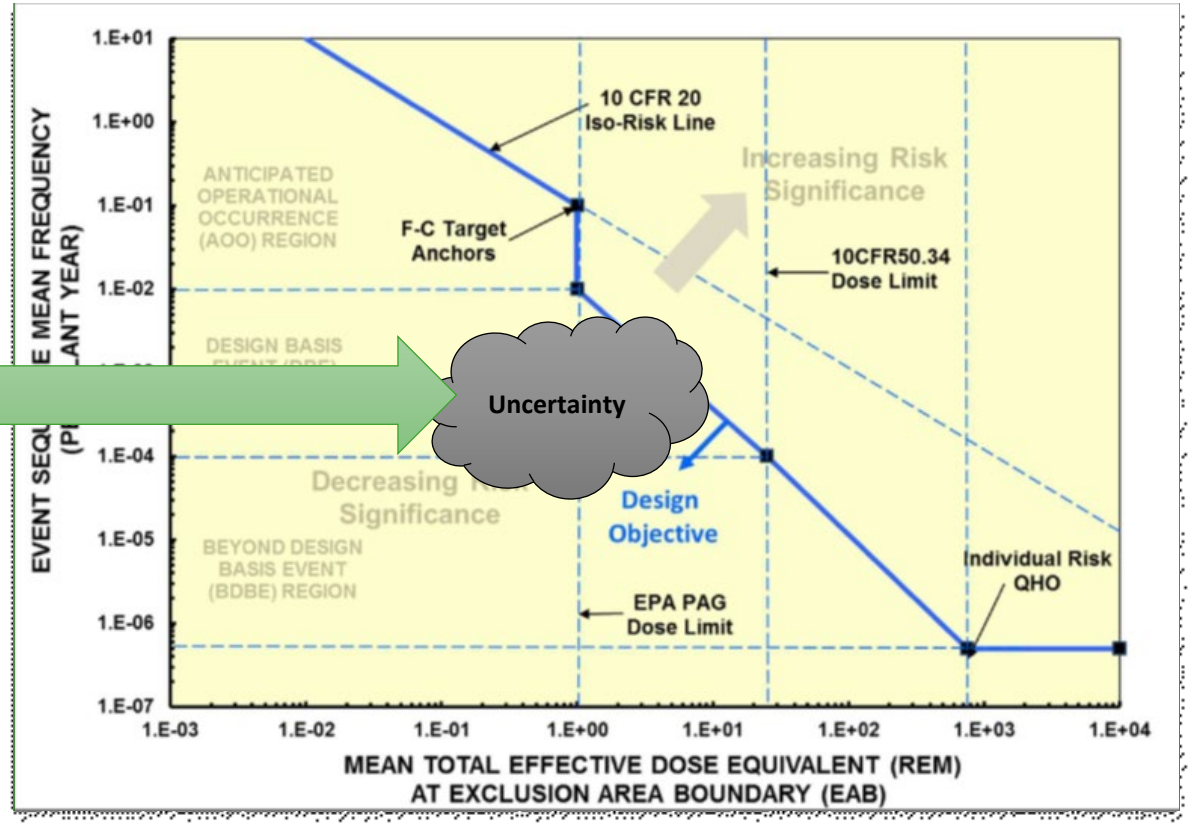


- Advanced reactors will be able to use risk insights for many design aspects
  - Example risk-informed approach is found in NRC's SECY-19-0117
  - Probability is widespread through the guidance via a safety case
  - Probabilistic concepts are built into metrics, such as the frequency-consequence curve
- We need bounding scenarios for screening and scoping purposes
- We need realistic scenarios for input into the licensing basis safety-case
- 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



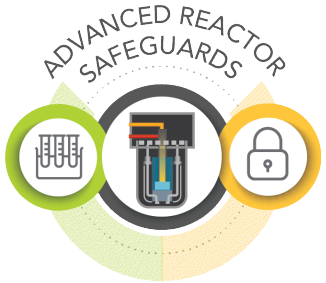
(derived from NEI 18-04)



Our R&D Focus

- The goal of this task is to demonstrate a method to automate scenario exploration for a representative advanced reactor facility
  - This demonstration will provide an acceptable analysis approach and a varied set of scenarios and timelines for different reactor classes
- For the R&D demonstration, we are focusing on simulation
  - Automating risk scenarios gives a more comprehensive view of possible outcomes and associated uncertainty
    - This uncertainty includes potential variations in physical phenomena and stochastic variability in processes and parameters
- The outcome will be a vetted and automated approach to explore design changes for security applications in advanced reactors

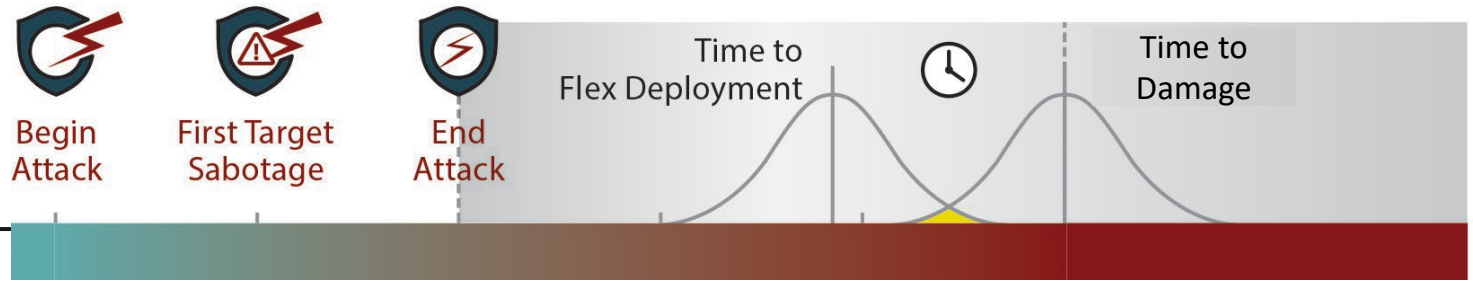
R&D Elements for Investigating Uncertainty



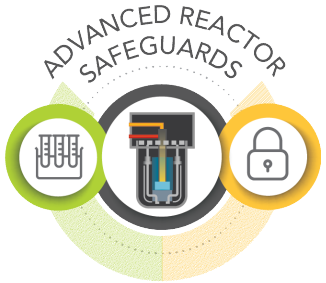
1. Creation of representative scenarios that advanced reactor designs might face related to security challenges.
2. Population of scenarios with hypothetical data and relevant physics such that real reactor-specific information can be introduced in an efficient fashion for other end users.
3. Quantification of scenario details, including timelines, and associated uncertainty on analysis simulation through automated methods.
4. Data mining of the quantification results to provide design information to focus on vulnerabilities or potential design tradeoff considerations.

Attributes of the Demonstration Infrastructure

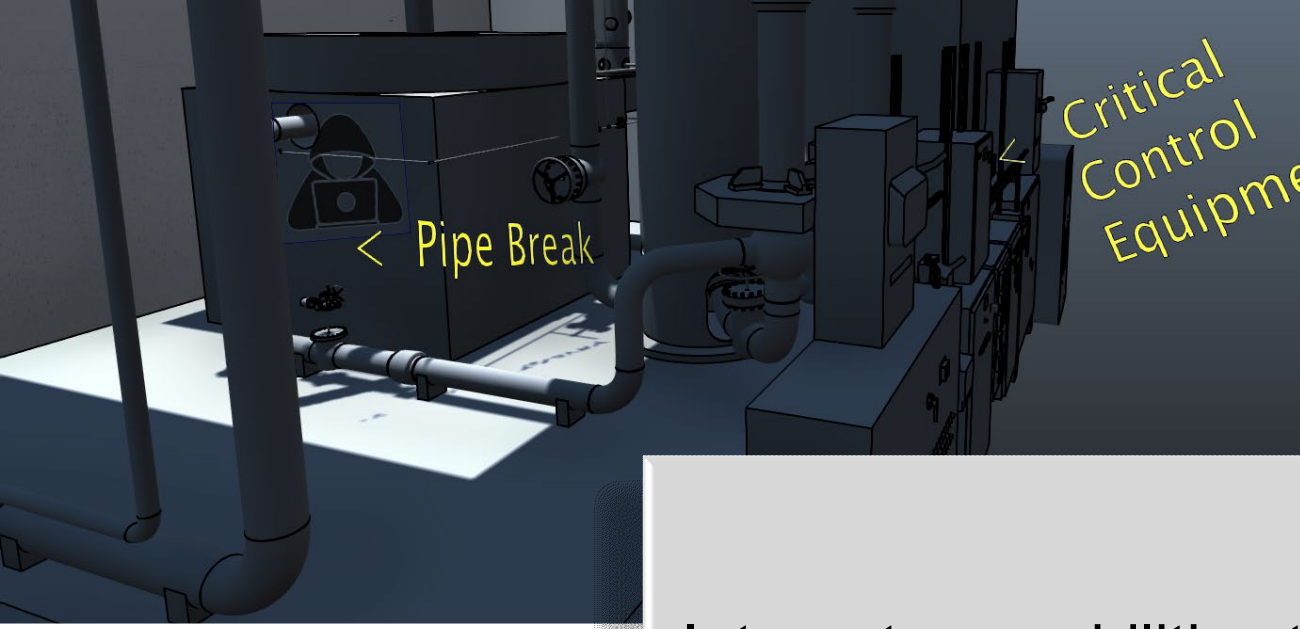
- Probabilistic digital twin to realize a risk-informed safety case
  - A highly transparent, traceable, scrutable framework
  - Used to inform all stakeholders (developers, regulators, operators)
- Leverage established technologies (e.g., RAVEN, EMRALD) for simulations
  - Risk scenario-based analyses & 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 evolution of design
  - Inform security design evolution from early design to operations → also support creation of the technical basis

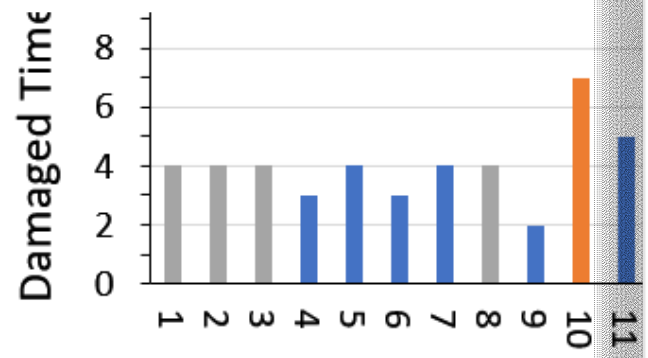


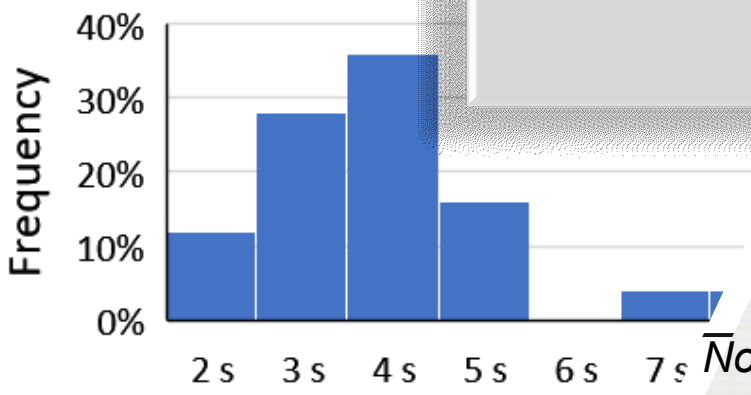
Graded Approach to Scenario Representation

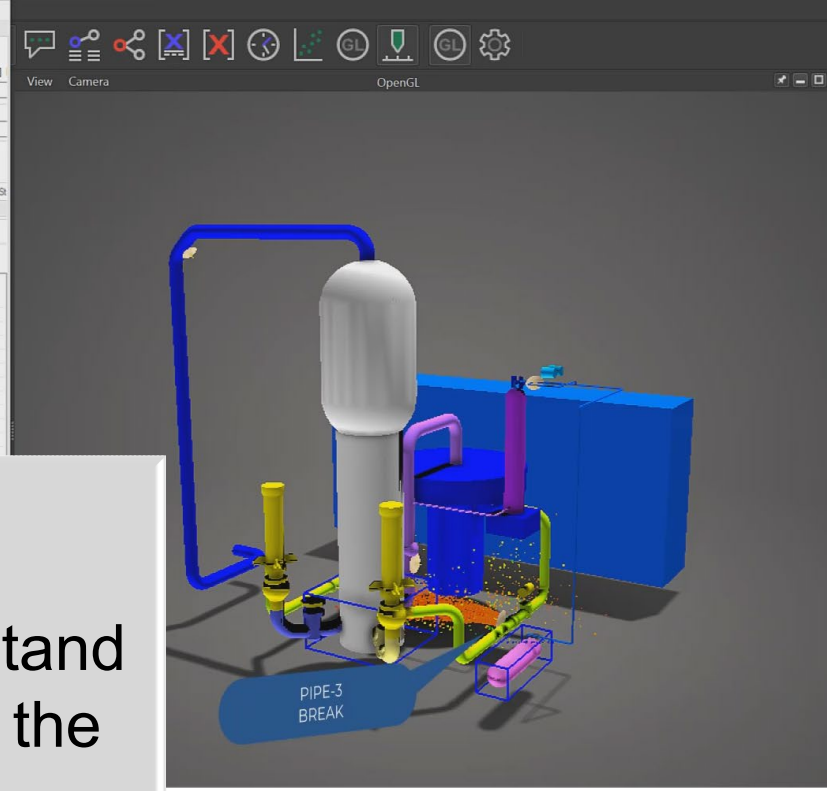


- Advanced reactors that are “simple” (compared to traditional reactors) should have corresponding simple
  - Hazards
  - Scenarios
  - Consequences
  - Risks
- Less-simple reactors will have a corresponding increase in the safety case technical basis
- One integrated approach can address different analysis needs



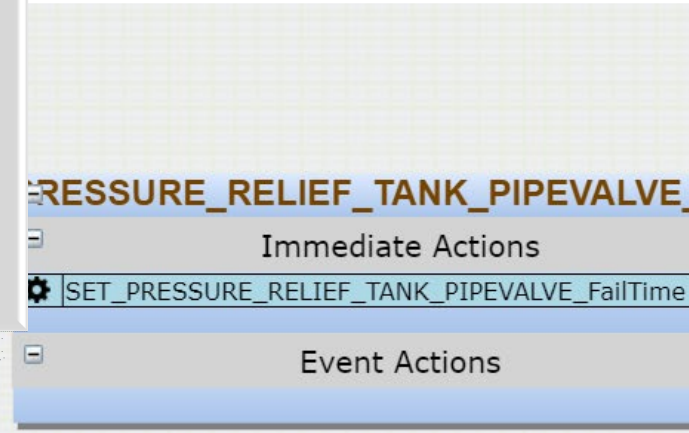






Integrate capabilities to better understand uncertainties on potential impacts to the safety case

Visualization and Data Mining!

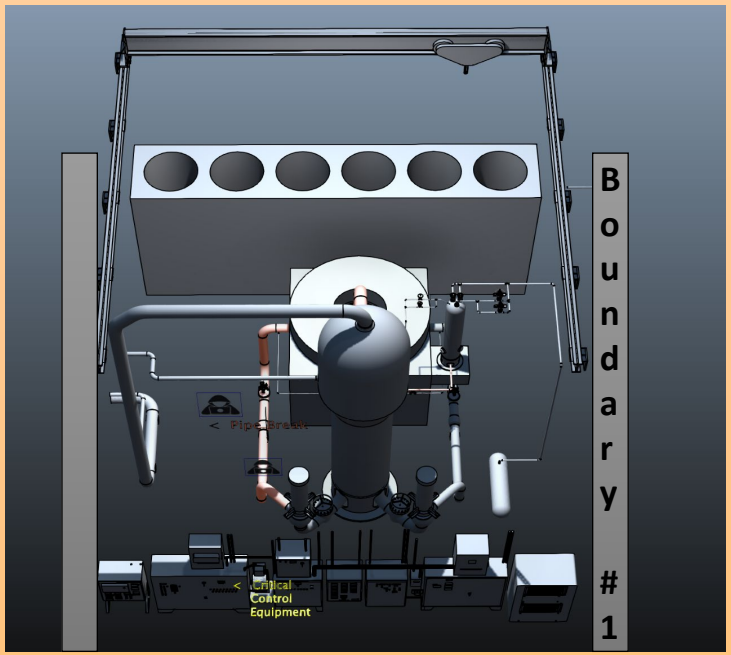


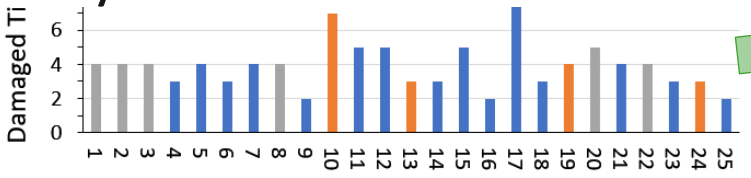
Note these examples are for a fictional hypothetical facility created for this discussion.

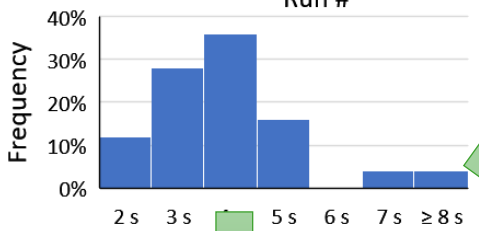
Analysis Allows for Extraction of Insights

- Current framework & model allows for security scenarios, provides time through boundaries and impacts on components using simulation
  - These times provide links to thermal-hydraulics and recoverability

Boundary #2







Characterization of uncertainties in scenario outcomes

Automation to explore uncertainty in state space

Quantification of frequency and consequence drivers

Insights into importance metrics

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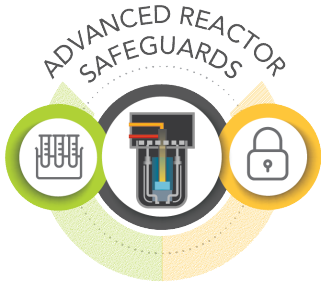
Summary



- Risk-informed approaches support advanced reactor design and licensing
  - However, uncertainties exist in novel technologies
- Uncertainty is a challenge, and lack of understanding can lead to conservatism
  - Must manage design uncertainty in operation, security, and safeguards
- Approaching the uncertainty for advanced reactors in two ways
  - Using simulation (e.g., Dynamic PRA) to characterize uncertainties
  - Automate, via a professional workflow approach, scenario analyses and technical basis
- These approaches are packaged using the digital twin concept
  - Used to provide a risk-informed safety case based upon different potential scenarios, including bounding analysis

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Thank you!