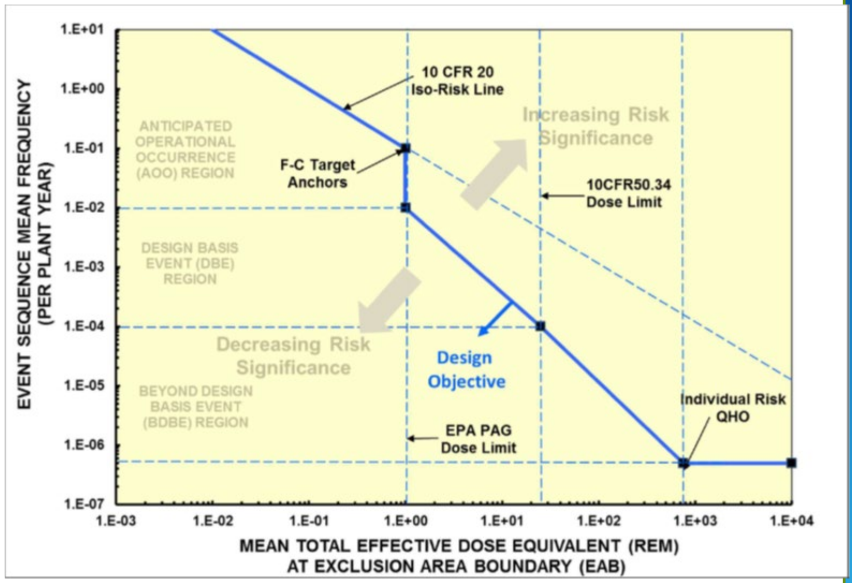

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SAPHIRE

DIAMOND

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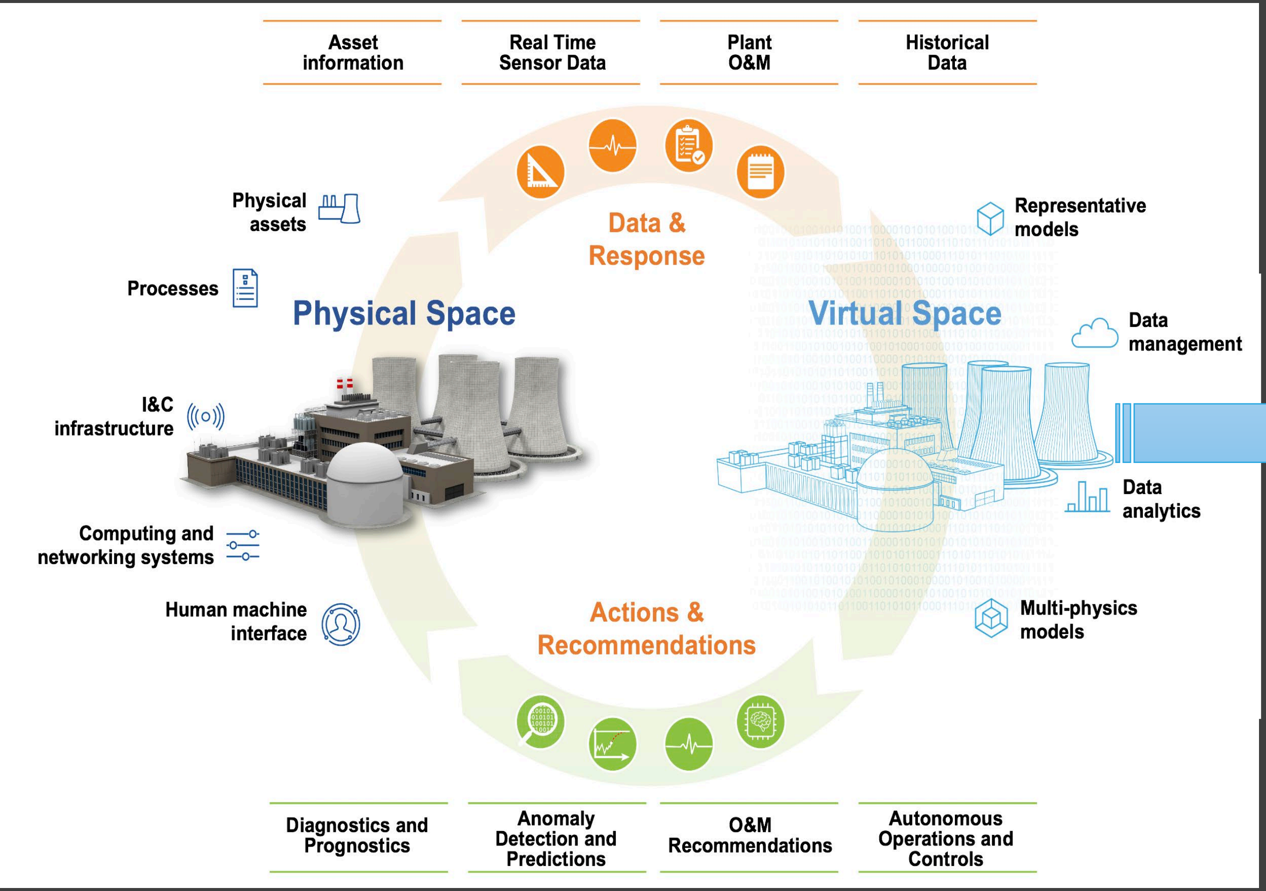
Treatment of Uncertainty in a Risk Informed Licensing Approach

Idaho National Laboratory

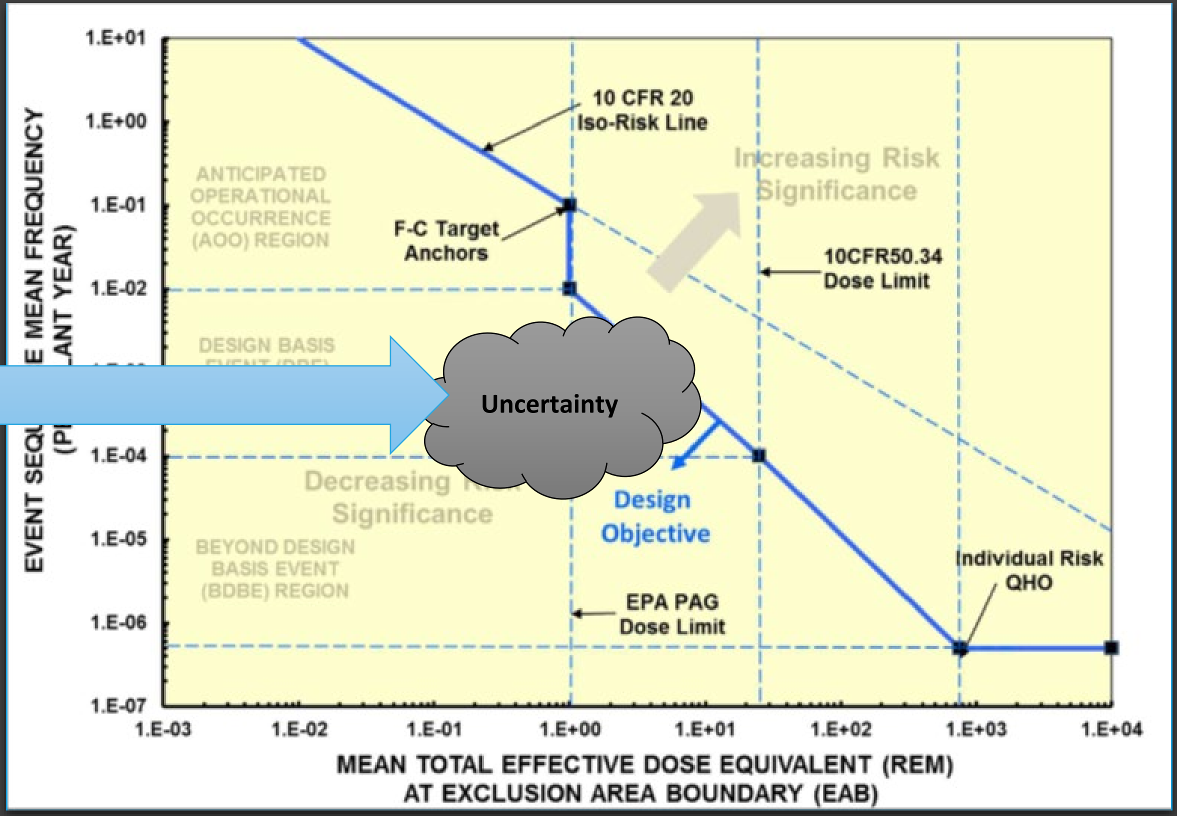
Motivation on Uncertainty R&D

- **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
- **However, we need to manage inherent uncertainty**
  - Designers should be **"considering uncertainty"** but…
    - Approach of how to do this in a real way is not well understood
    - Not many of the existing tools and methods are set up to facilitate a technically-defensible treatment of frequency-consequence uncertainties
- **We are demonstrating "how to" of uncertainty for security aspects**

Advanced Reactor Design Attributes have Links to Frequency-Consequence Metrics



(derived from NEI 18-04)



Our R&D Focus

- **Uncertainty is a challenge to the nuclear industry**
  - We are a risk-adverse industry → uncertainty has typically invited conservatisms in our decisions and reactor designs
  - Conservatisms lead to overly costly design and operations
- **We are approaching the uncertainty R&D in two ways**
  - Capturing best practices
  - Demonstrating approaches via examples and tools
- **For the R&D demonstration, we are focusing on simulation**
  - By automating risk scenarios, we can do a more complete job of capturing uncertainty
    - This uncertainty includes potential variations in physical phenomena and stochastic variability in processes and parameters

R&D Elements for Investigating Uncertainty

1. **Screening based upon frequency- or physics-based methods**
   - Gathering best practices and examples
2. **Characterizing uncertainty on analysis output metrics**
   - Describing what is in security safety case uncertainty
3. **Comprehensive uncertainty treatment going beyond traditional parametric uncertainty**
   - Represent phenomena and associated scenarios
   - How to operationalize these through examples and automation
4. **Communicating security-related uncertainty while still capturing the underlying technical basis**
   - Gathering best practices and examples that support effective communication between designers and regulators

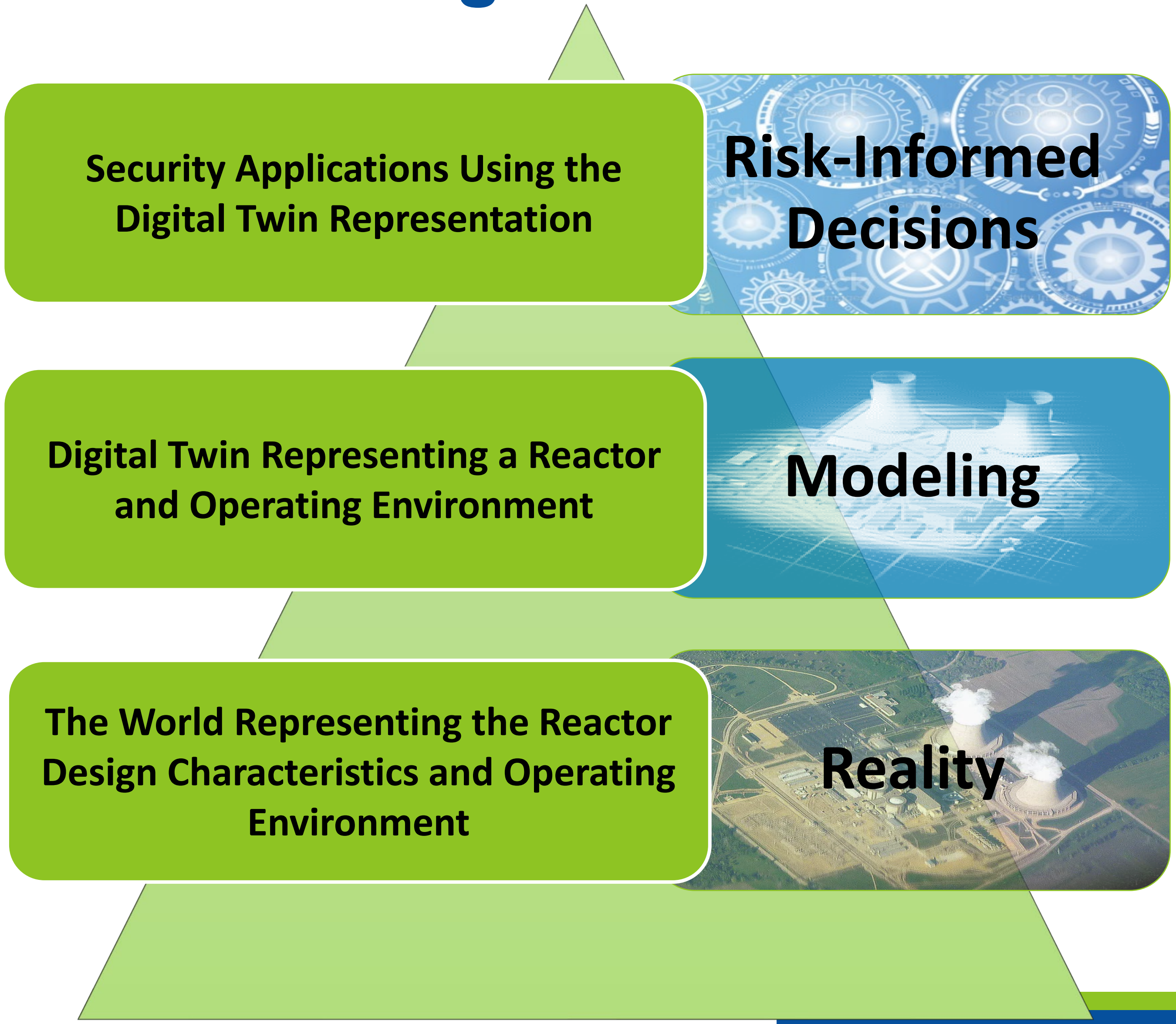
Digital Twin Approach is Being Used

Security and safeguards design and operational questions that are answered via the digital twin.

Models for physical phenomena, models for probabilistic outcomes, models for reactor operation, models for reactor physical properties, etc.

The actual advanced reactor design including how, when, and where it operates.

UNCERTAINTY

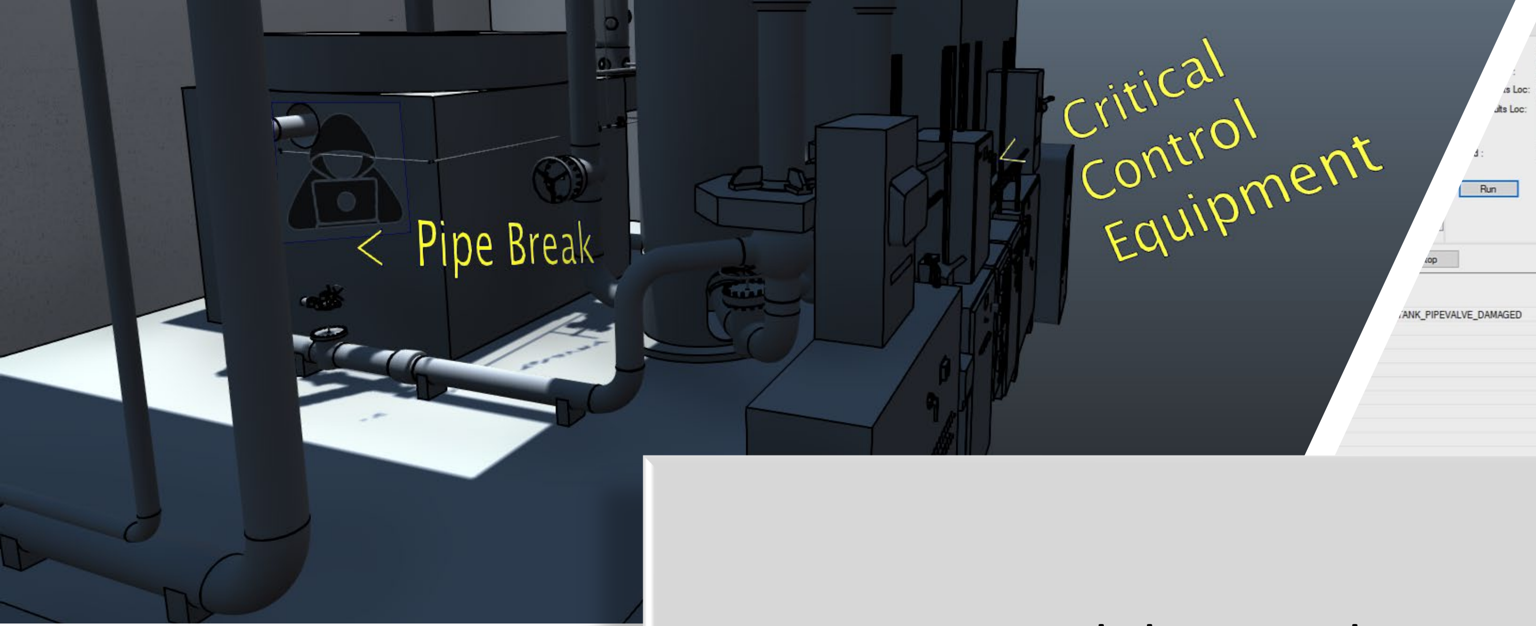


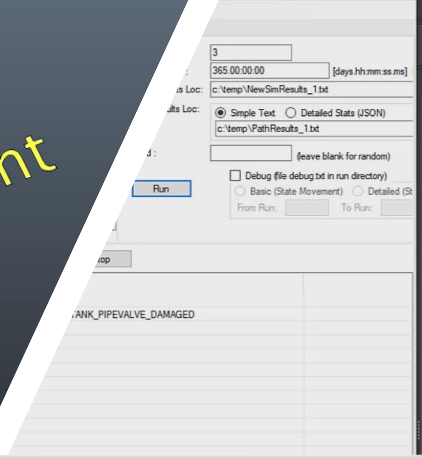
Attributes of the Demonstration Infrastructure

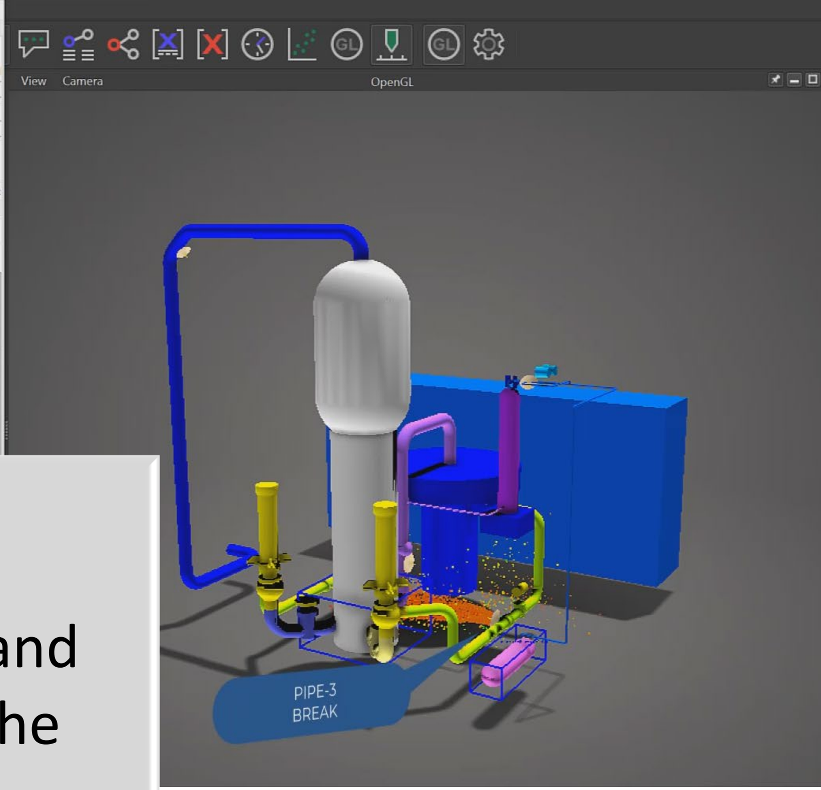
- **Probabilistic digital twin to realize a risk-informed safety case**
  - A highly transparent, traceable, scrutable framework
  - Used to inform all stakeholders (developers, regulators, operators)
- **Leverage established technologies (e.g., RAVEN, EMRALD) for handling simulations**
  - Risk scenario-based 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

Simulation to Capture Uncertainties in Scenarios

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

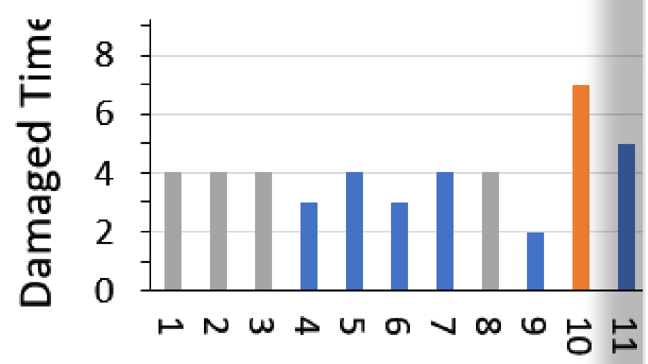


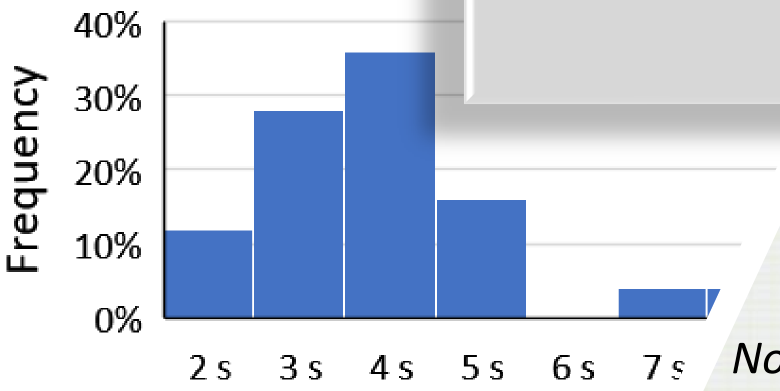


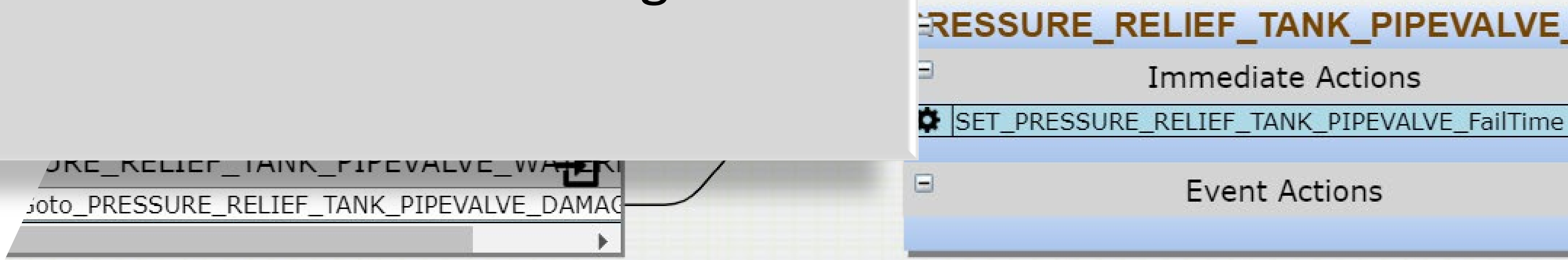


Integrate capabilities to better understand uncertainties on potential impacts to the safety case

Visualization and Data Mining!



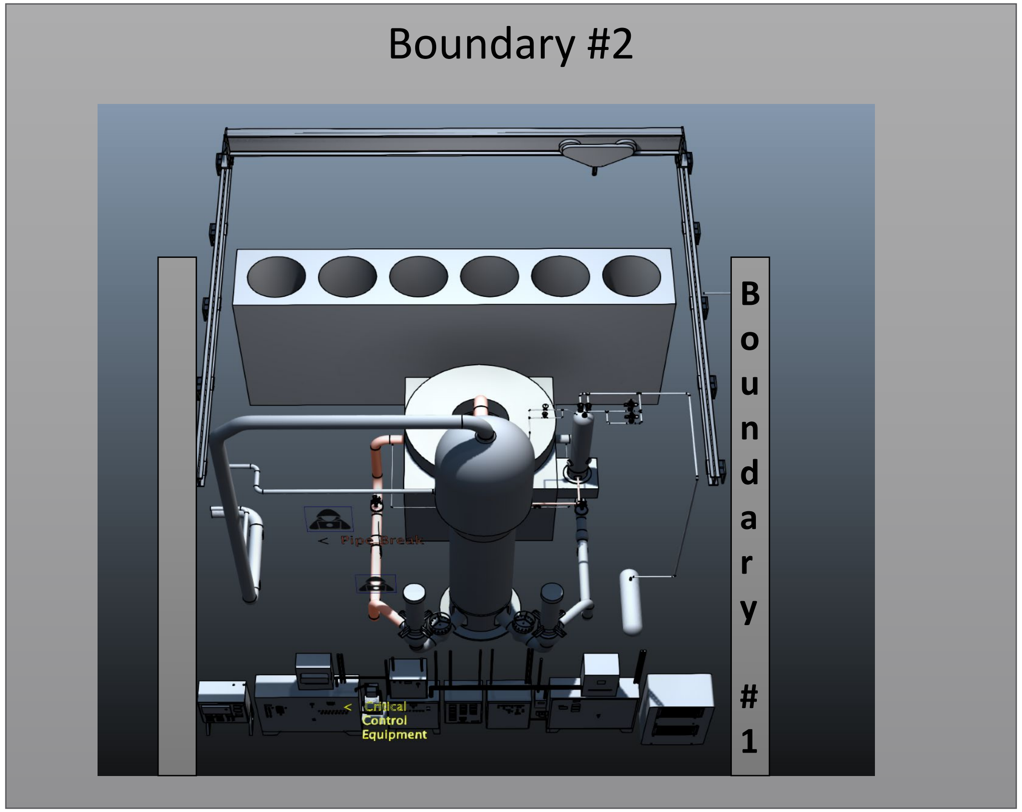


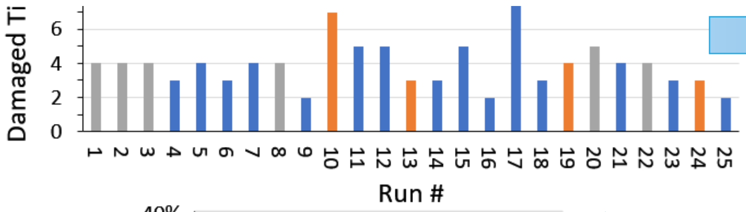


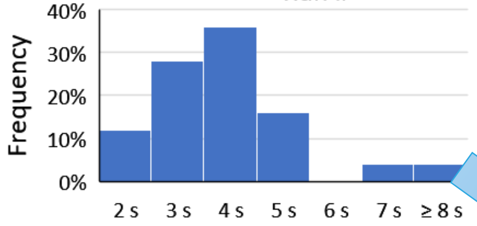
Note these examples are for a fictional hypothetical facility created for this project.

Analysis allow for extraction of insights

- **Current framework & model allows for security scenarios → time to interact through boundaries and impact components using a stochastic model**
  - These times provide links to thermal-hydraulics and recoverability







Characterization of uncertainties in scenario outcomes

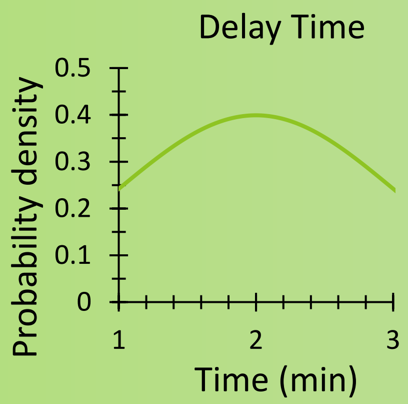
Automation to explore uncertainty in state space

Quantification of frequency and consequence drivers

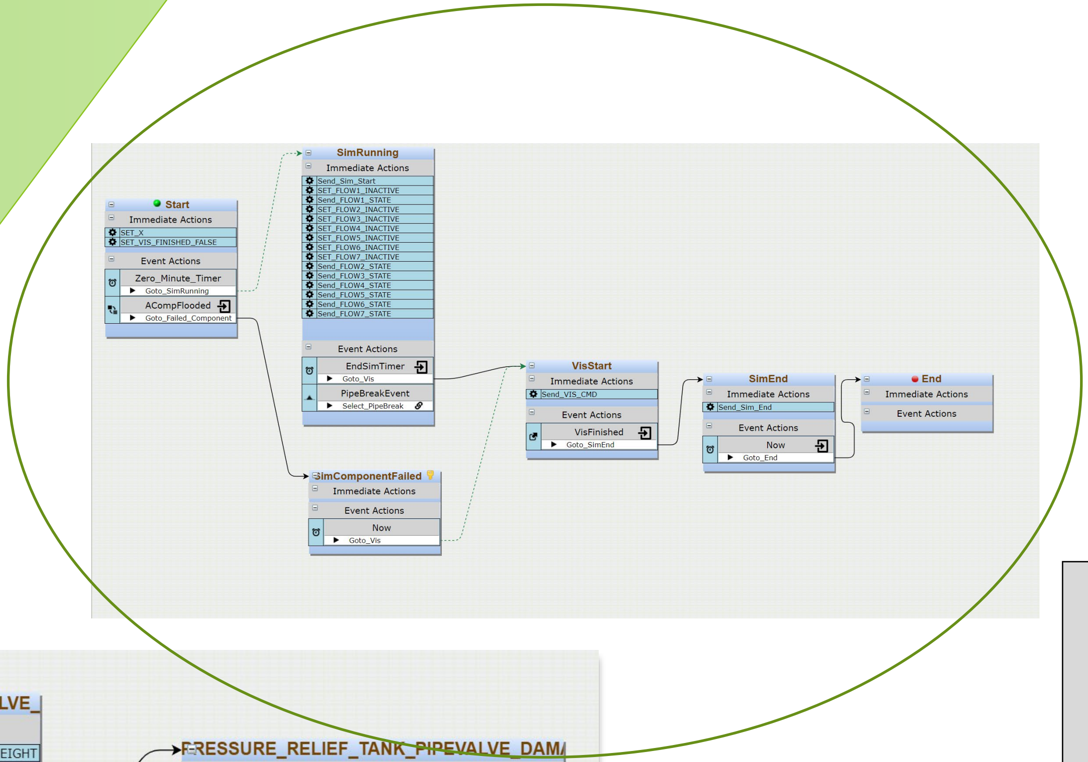
Insights into importance metrics

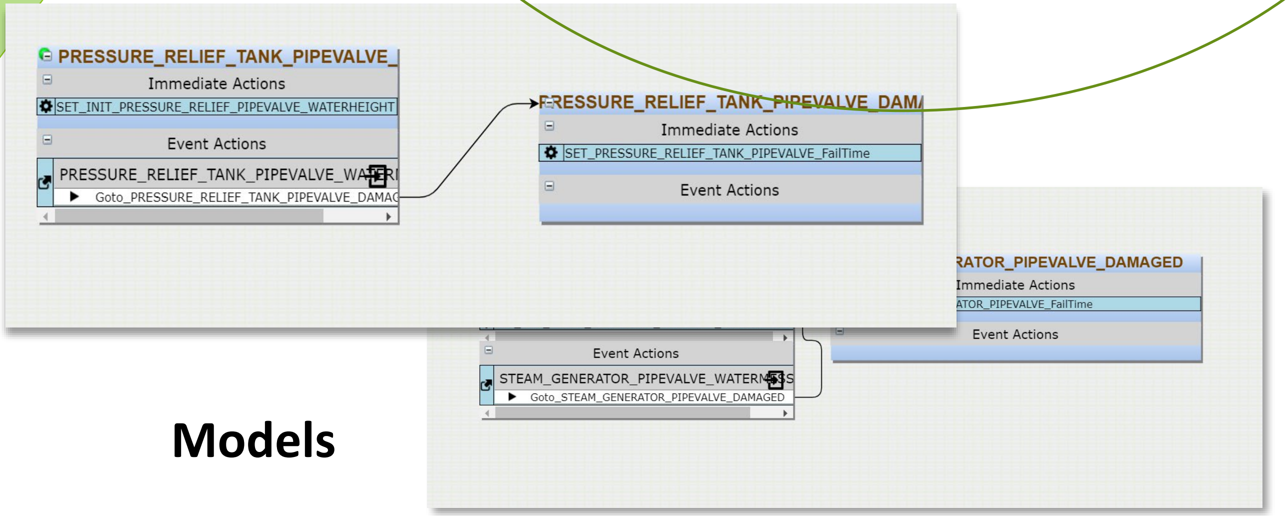
Note these examples are for a fictional hypothetical facility created for this project.

State-based Simulation to Describe Scenarios



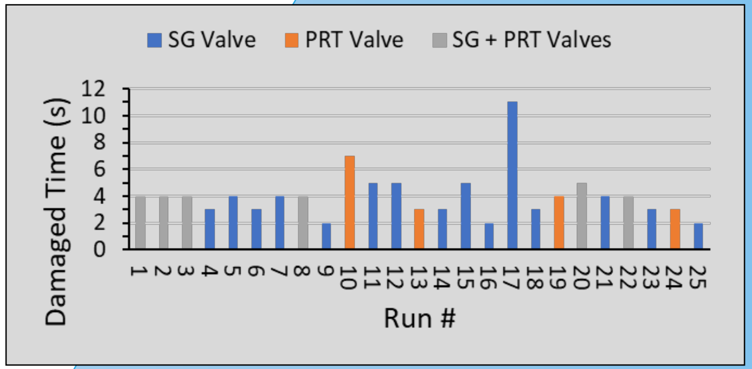
Inputs



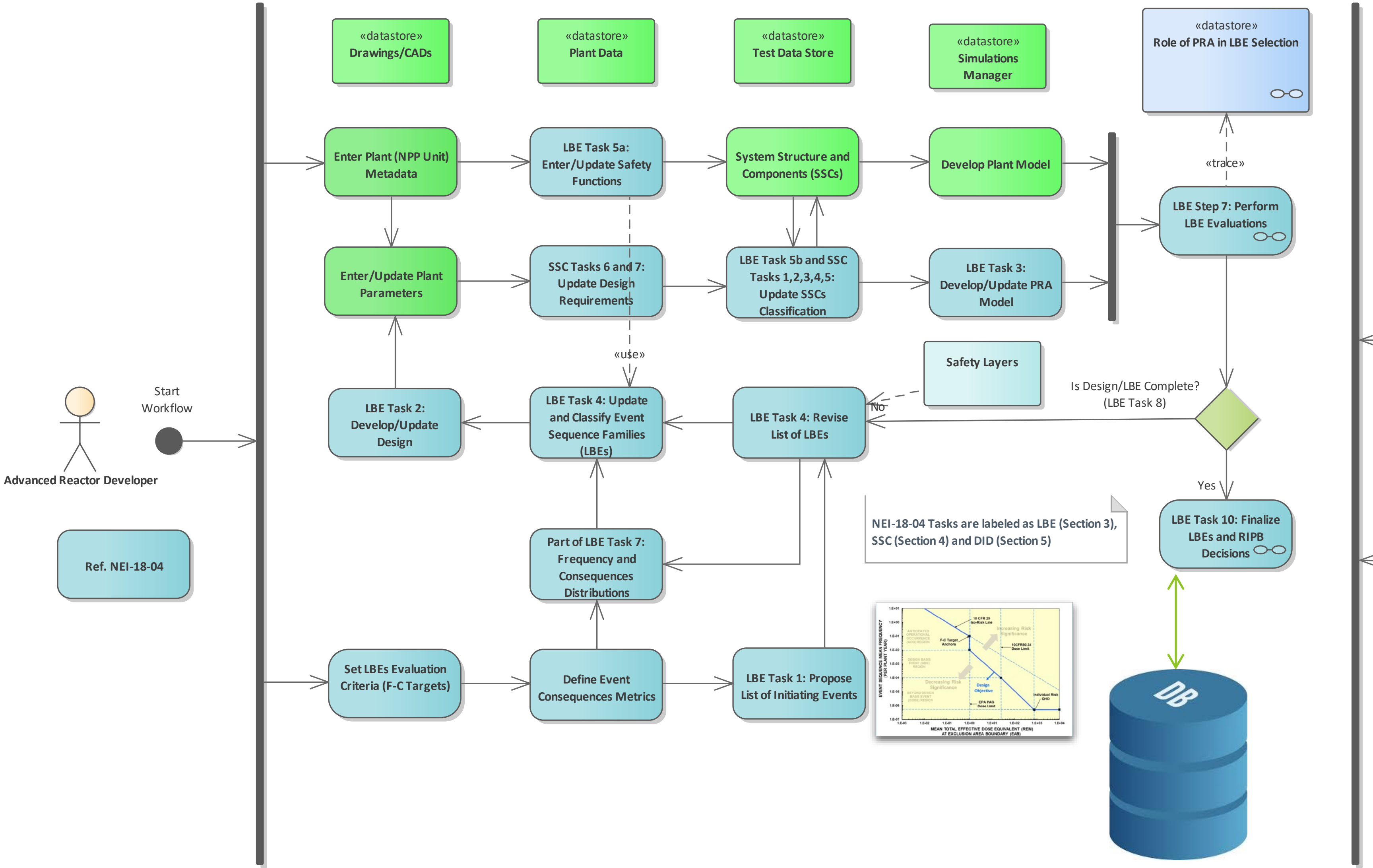


Models

Results



Deployed on Digital Infrastructure



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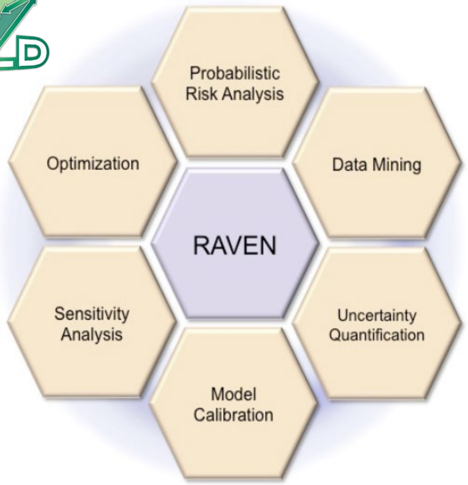

Summary

- **Risk-informed approach support advanced reactor design and licensing**
  - However, uncertainties exist in novel technologies
- **Uncertainty is a challenge, lack of understanding can lead to conservatism**
  - Must manage uncertainty inherent in design and operation and 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, analyses and technical basis
- **These approaches are packaged via the digital twin concept**
  - Used to realize a risk-informed safety case

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Thank you!