A Visualization Technique for Dynamic Probabilistic Risk Assessement

Joseph O'Leary, Arush Das, Lia Anderson, Yunfei Zhao

PSAM 18

21 July 2026

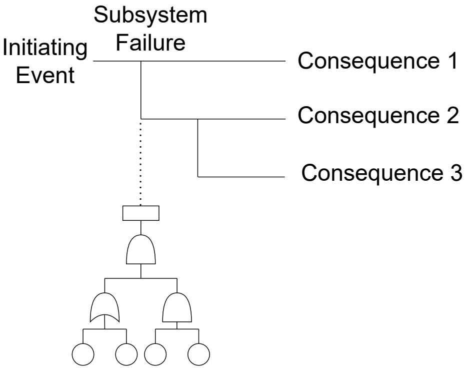
UNIVERSITY OF MARYLAND

Risk and Decision Analysis Laboratory

Probabilistic Risk Assessment

Probabilistic Risk Assessment (PRA)

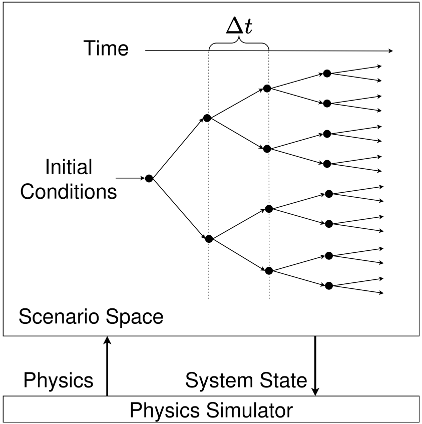
- Expert-driven
- Peer reviewed
- Manual scenario generation
- Event trees and fault trees



Example PRA Event and Fault Tree

Dynamic Probabilistic Risk Assessment

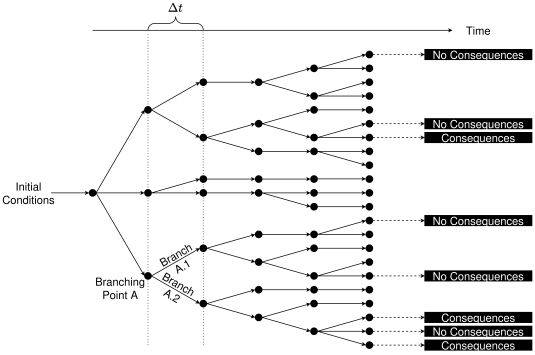
- Dynamic PRA methods: Couple system physics with stochastic system models[1]
- Typically system physics are evaluated with simulations
- Dynamic PRA methods address some limitations in conventional PRA
  - Physics dependencies
  - Event timing/ordering
  - Human reliability



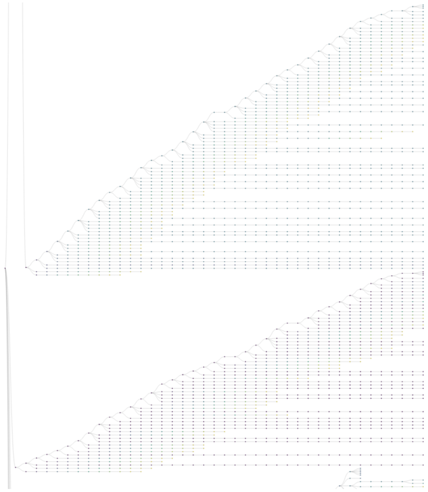
Example Dynamic PRA System

[1] *Siu n.d.*

Motivation



Manually Generated Dynamic PRA Event Tree



Zoomed Out View of Automatically Generated Dynamic PRA Event Tree

Objectives

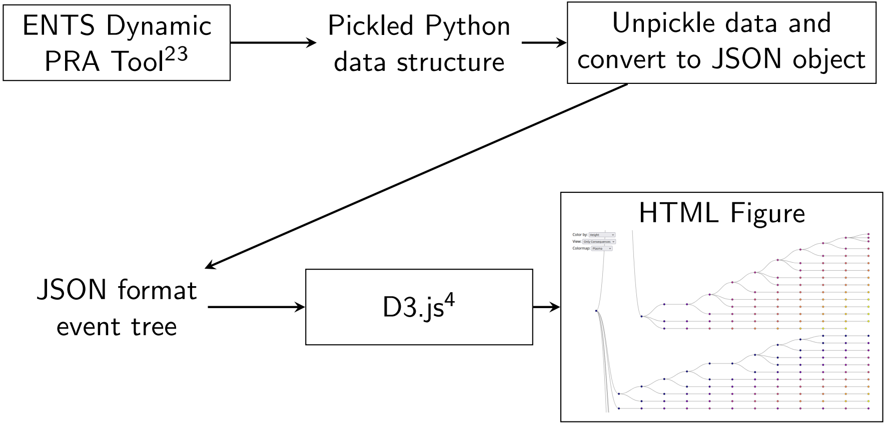
Dynamic PRA generates a huge amount of data

- Large number of generated scenarios
- System dynamics simulation results

This work develops a visualization technique

1. Zoom and pan navigation
2. Interactive expansion of subtrees
3. Color gradient for variables of interest
4. Selectively shows numerical data

Data Pipeline

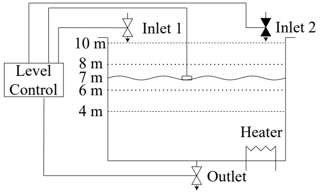


[2] *O'Leary and Zhao 2026; O'Leary et al. 2026.*

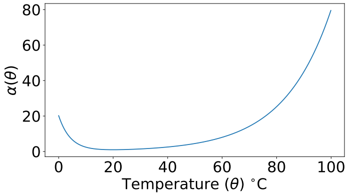
[3] *Either uses the ENTS method or Monte Carlo simulation*

[4] *D3.js 2025.*

Example Case Study



Case Study System[5]



Temperature Dependence of Failure Rates

Control System Function

Fluid Level (m)	**Inlet 1**	**Inlet 2**	**Outlet**
$6 \leq h \leq 8$	Open	Closed	Open
$h \leq 6$	Open	Open	Closed
$h \geq 8$	Closed	Closed	Open

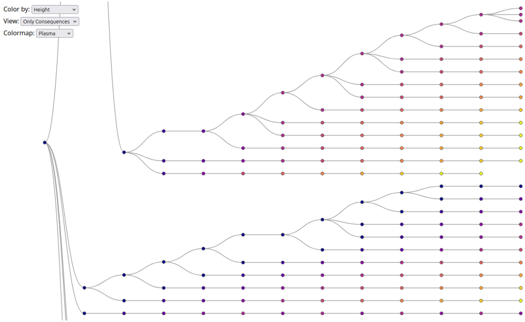
Nominal Failure Rates

Valve	**Failure Mode**	**Nominal Occurrence Rate (min^{-1})**
Inlet 1	Stuck open	2.6×10^{-5}
	Stuck closed	2.6×10^{-5}
Inlet 2	Stuck open	3.8×10^{-5}
	Stuck closed	3.8×10^{-5}
Outlet	Stuck open	4.8×10^{-5}
	Stuck closed	4.8×10^{-5}

[5] *Marseguerra and Zio 1996*

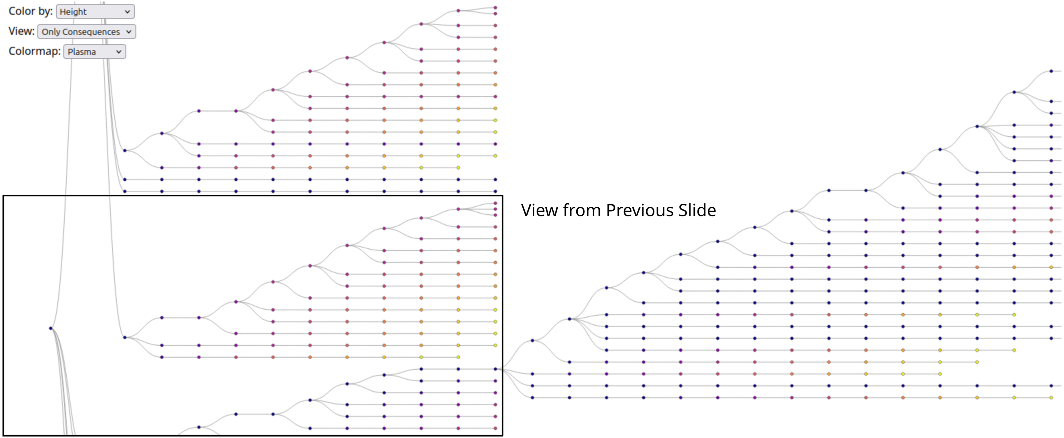
Result: Navigation and Color Gradient

- Can zoom and pan around areas of the full event tree
- All scenarios shown eventually result in consequences
- Colors indicate fluid height difference from nominal



Zoomed in View of Automatically Generated Dynamic PRA Event Tree

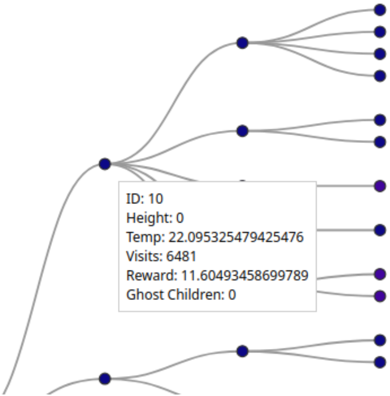
Result: Expansion



View of Expanding from Selected Branch Point

Result: Numerical Data and Node Hover

- Numerical data from physics simulations preserved
- Enables more in-depth analysis of system state at each node
- When combined with the navigation features and expansion feature, enables analyst to explore scenarios in detail



Branch Point Information Displayed on Mouse Hover

Conclusions and Future Work

Developed visualization tool

- Navigate with pan and zoom
- Interactively expand/collapse subtrees
- Uses color to show variables of interest
- Preserves numerical results

Future development of the tool to

- Accept inputs from other dynamic PRA tools
- Expand demonstration case study to full nuclear power plant
- Integrate with risk-informed decision making strategies to support nuclear industry

Acknowledgments

This material is based upon work supported by the Department of Energy Office of Nuclear Energy's Nuclear Energy University Program under Award Number DE-NE0009505.

Arush Das's contributions are supported through the University of Maryland Clark School of Engineering Nebula Research Data Fellowship. Their support is gratefully acknowledged.

Thank You for Your Attention

Questions?
joleary1@umd.edu
yzhao111@umd.edu