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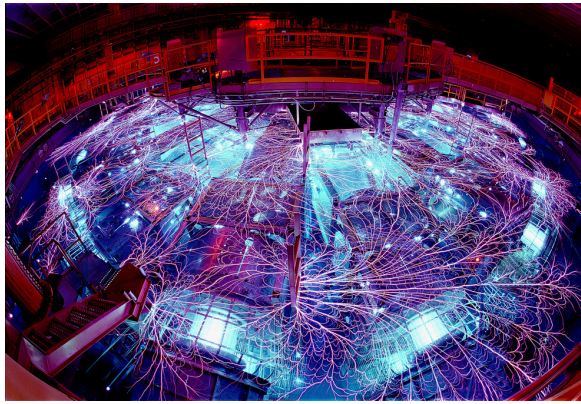

A Dynamic Assessment of an Interfacing System Loss of Coolant Accident

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THE OHIO STATE UNIVERSITY

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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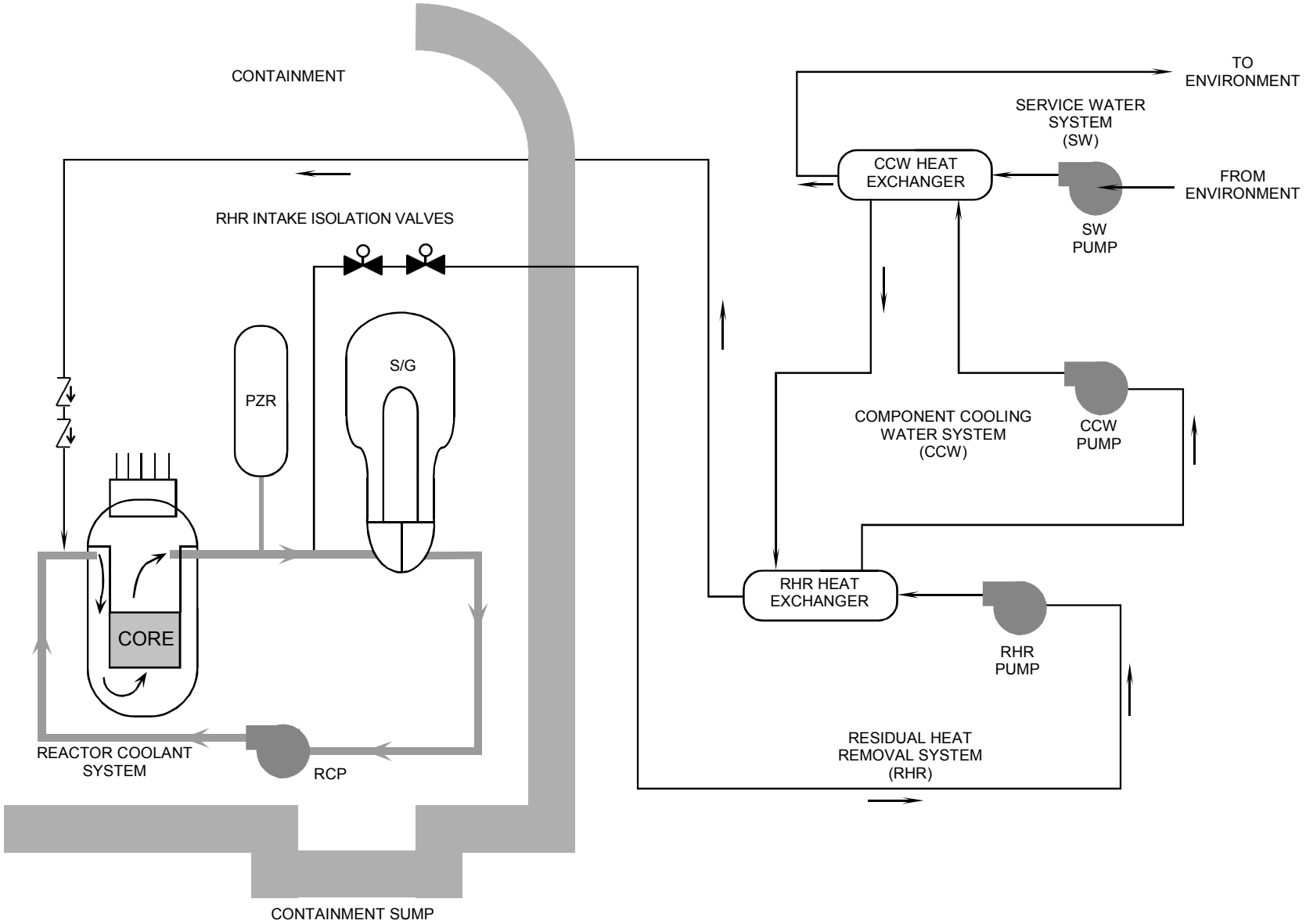
Background

- Interfacing System Loss of Coolant Accident (ISLOCA)
  - Low likelihood, high consequence
    - Often scoped out of PRAs
  - Early release of radionuclides
  - May be induced by controller failure
- Key Results
  - Apply recent DPRA analysis techniques
    - Dynamic importance measures (DYI)
  - Identify input parameters of great impact
  - Identify non-monotonic relationships

Outline

- Physical System Overview
- Accident Characteristics
- Parameters of Interest
- Modeling
- General Results
- Risk Insights & Conclusions

Physical System Overview



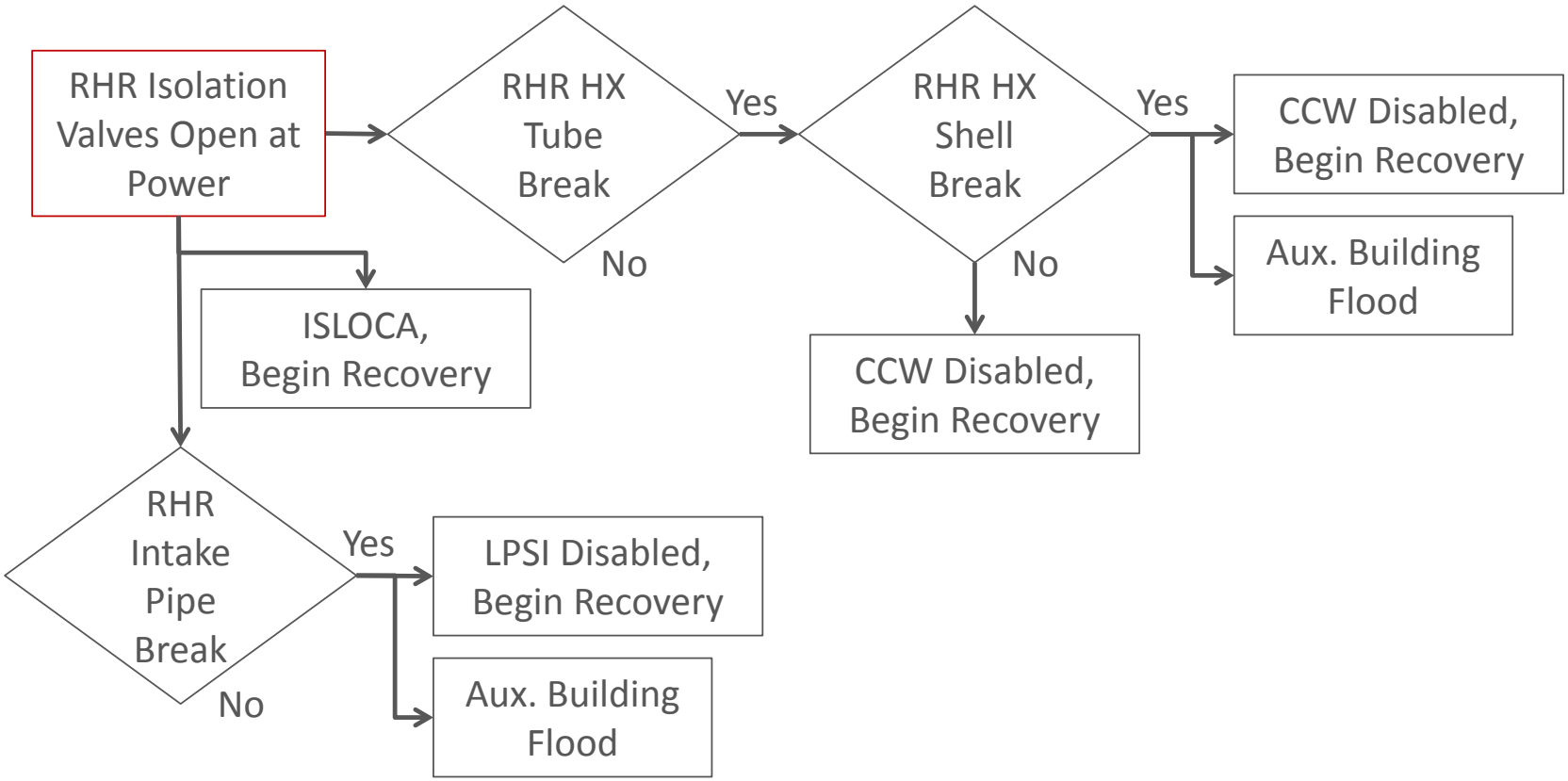
Accident Characteristics (1/3)

- RHR suction path opens during operation
  - Analyses typically consider ISLOCA via discharge check valves
  - RHR suction ISLOCA requires failure of two interlocked MOVs
    - *The multiplicity of barriers that would be required to fail would render the LOCA much less probable than the check valves.* [WASH-1400]
  - Hypothetical controller failure
  - Immediately challenges integrity of RHR components
    - Suction piping
    - Heat exchanger (HX)

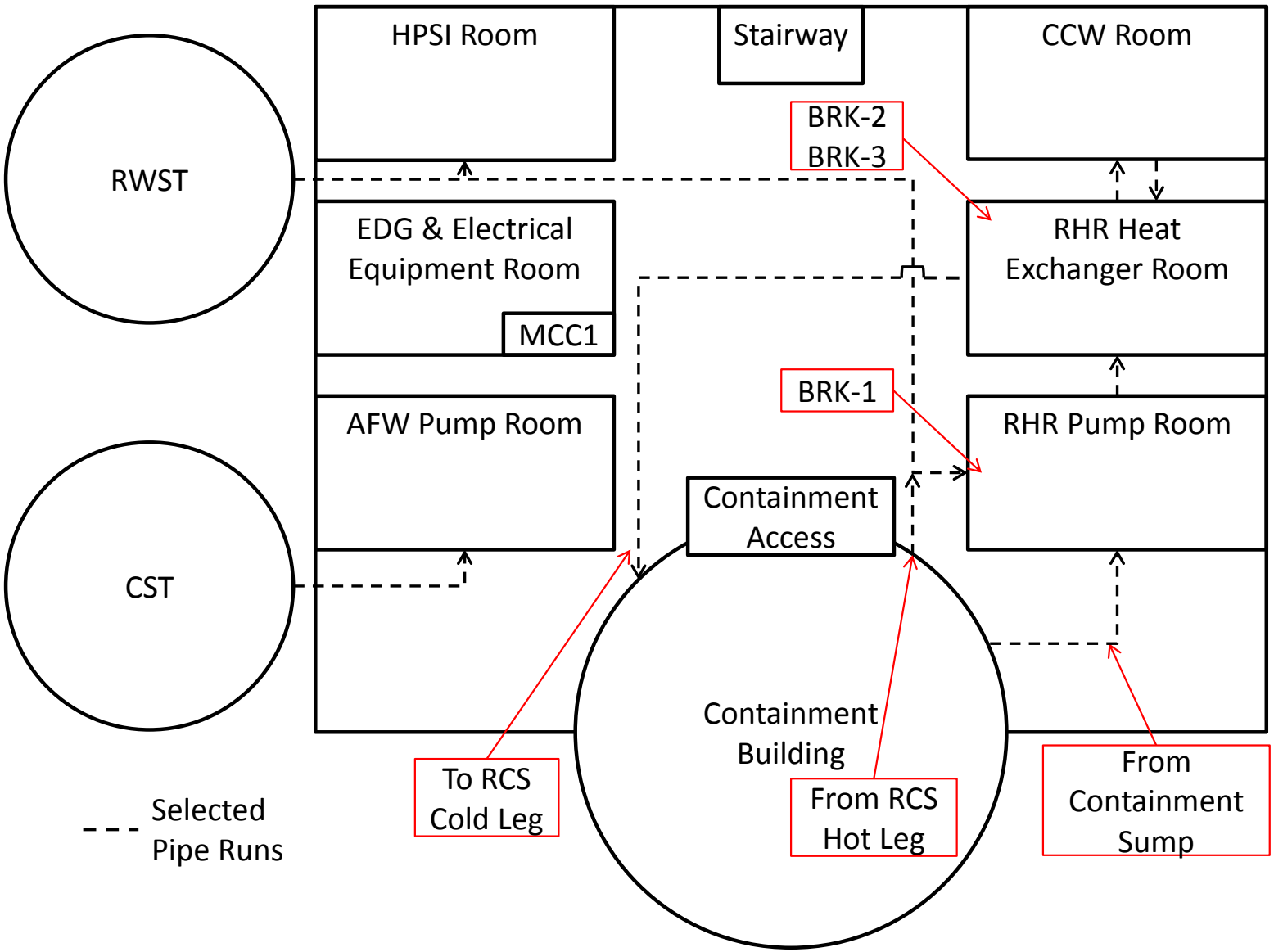
Multiplicity of Barriers

- Davis Besse
  - *Therefore, each time DHI2 was required to be open, a jumper was installed per plant procedure to defeat PSH-RC2B3 thereby allowing the valve to be opened.*
  - *During the subsequent cooldown on 19 January, it was discovered that the jumper for PSH-RC2B3, installed on 23 August 1982, was still in place.* [NUREG/CR-5102]
- Braidwood
  - *Before fully closing an RHR system vent valve in accordance with one surveillance procedure, the staff opened an RHR system isolation valve as specified in the other surveillance procedure. RCS coolant at 360 psig and 180°F exited the vent valve, ruptured a tygon tube line, and sprayed two engineers and the equipment attendant who were in the vicinity of the vent valve.* [Information Notice 91-36]

Accident Characteristics (2/3)



Accident Characteristics (3/3)



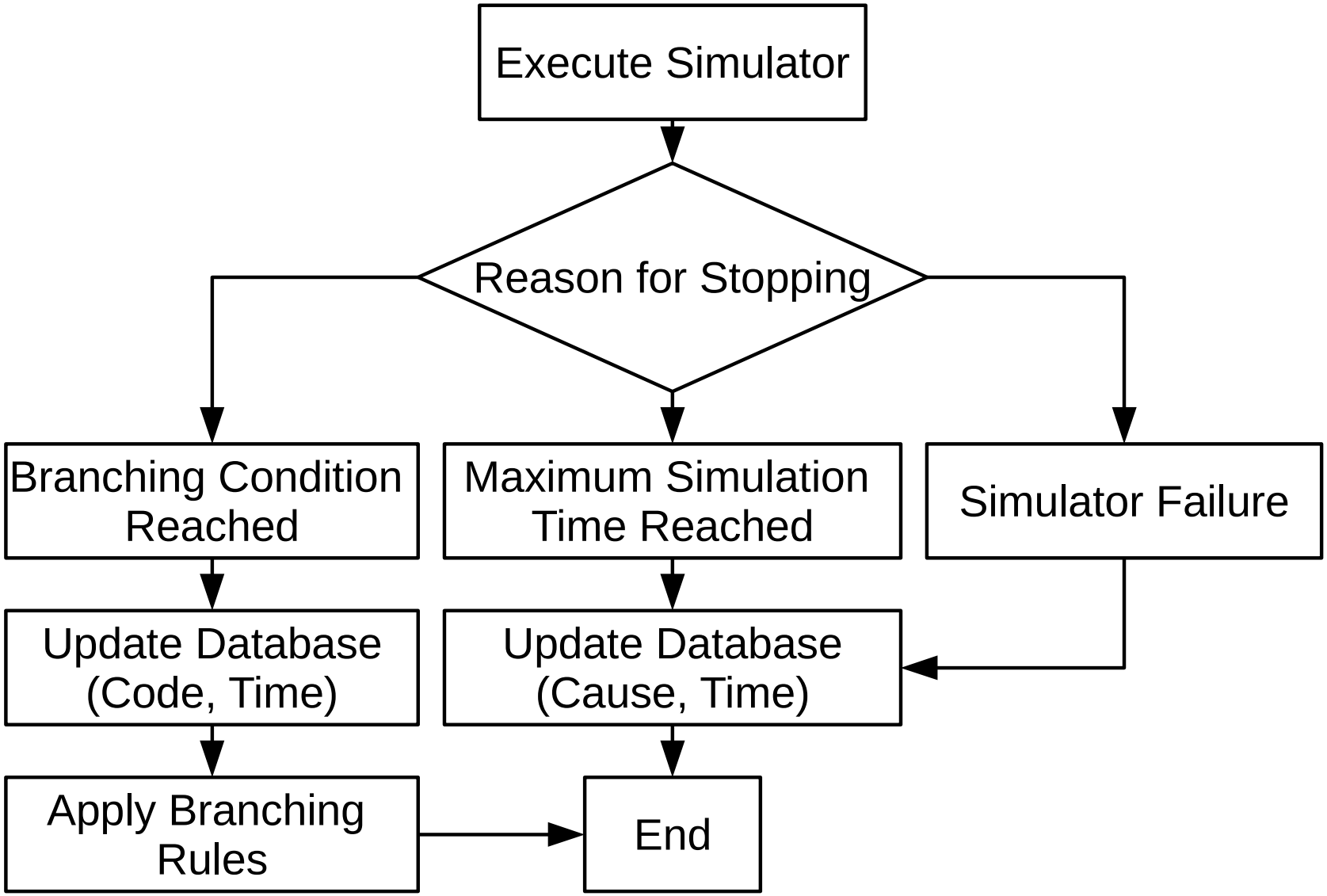
Parameters of Interest

- RHR component pressure capacities
  - Suction pipe
  - HX tube
  - HX shell
- Operator action success and timing
  - Isolate RCS from RHR
  - Isolate RHR HX tube rupture
  - Isolate RHR HX shell rupture
- Auxiliary building door status and capacity
  - RHR pump room
  - RHR HX room

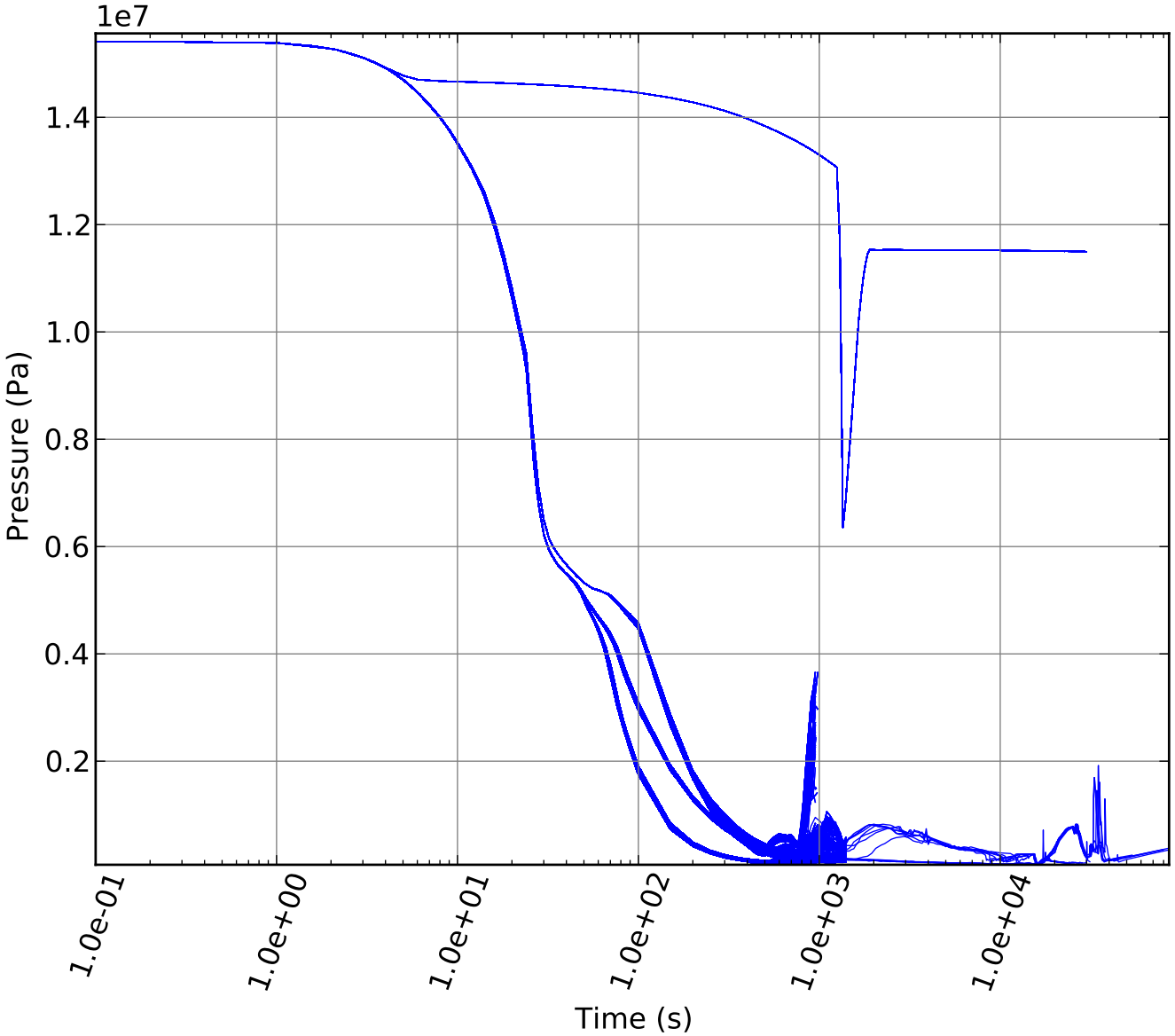
Modeling (1/2)

- ISLOCA well-suited to dynamic event tree (DET) methodology
  - Complex system dependencies, recovery, timing sensitivity
- MELCOR 2.2, USNRC severe accident analysis code
  - Terminate case at 24 hours
- ADAPT, SNL DET driver
  - Define branching rules a priori
  - Launch jobs across Linux computer cluster

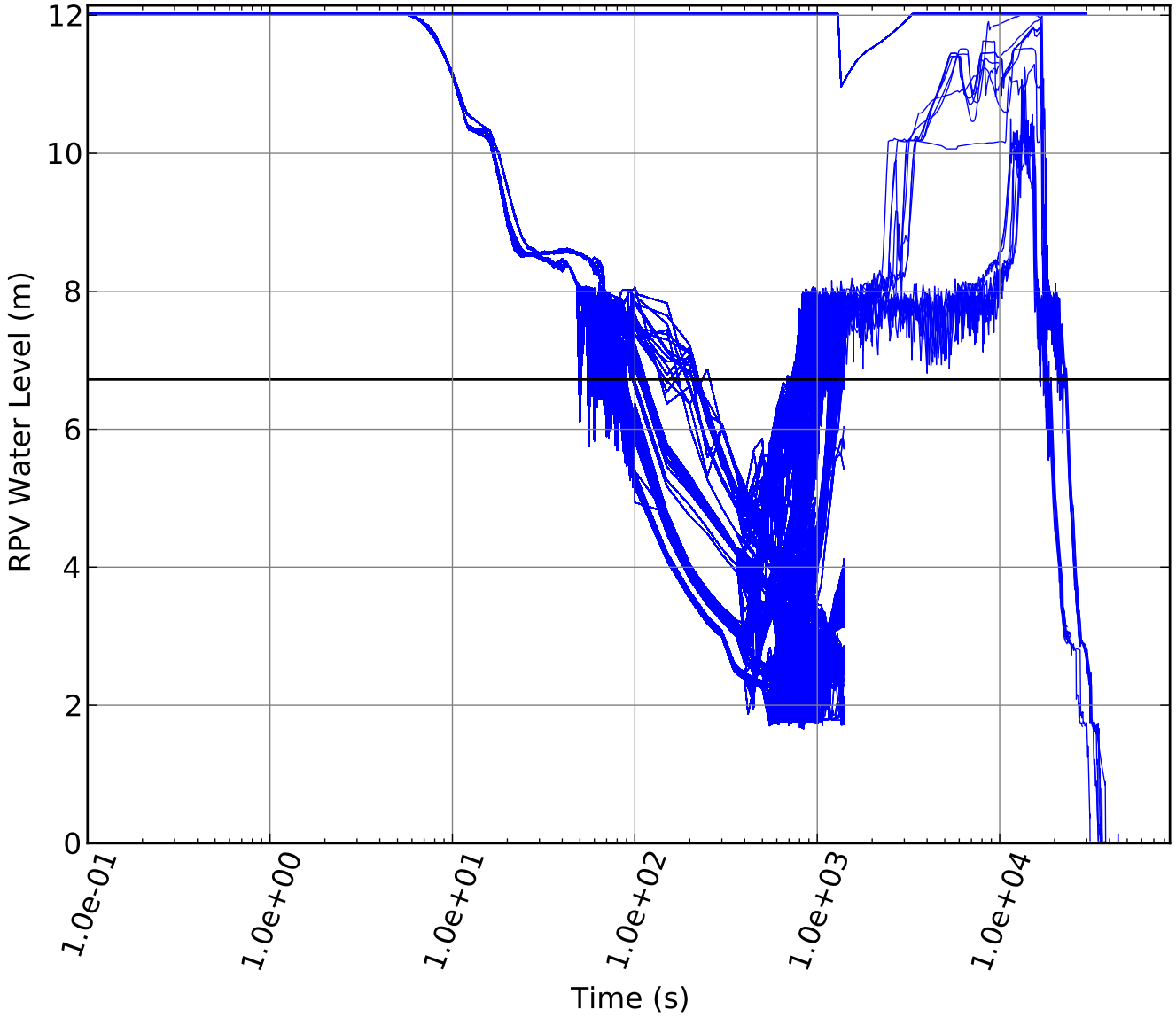
Modeling (2/2)


Execute Simulator
Reason for Stopping
Branching Condition Reached
Maximum Simulation Time Reached
Simulator Failure
Update Database (Code, Time)
Update Database (Cause, Time)
Apply Branching Rules
End

Results (1/8)


1e7
1.4
1.2
1.0
0.8
0.6
0.4
0.2
Pressure (Pa)
1.0e-01
1.0e+00
1.0e+01
1.0e+02
1.0e+03
1.0e+04
Time (s)

Results (2/8)


RPV Water Level (m)
12
10
8
6
4
2
0
1.0e-01
1.0e+00
1.0e+01
1.0e+02
1.0e+03
1.0e+04
Time (s)

Results (3/8)

- Use dynamic importance (DYI) measures to relate input parameters and outputs
- Use peak, final, or all values of output as figure of merit (FOM)
  - Compare weighted average of FOM for sets of sequences

Importance Measure	Description
$DYI1 = \frac{R(x=1)}{R(x=0)}$	Consequence ratio of event occurrence to non-occurrence
$DYI2(i) = \frac{R(x=1_i)}{R(x=0)}$	Consequence ratio of value $x = 1_i$ to non-occurrence
$DYI3(i) = \frac{R(x=1_i)}{R(x=1)}$	Consequence ratio of value $x = 1_i$ to average of occurrence

Results (4/8)

- Example DYI calculation
  - Hydrogen production when RHR suction pipe fails vs no pipe failure
  - $$DYI1 = \frac{R(x{=}1)}{R(x{=}0)} = \frac{\sum_{i=1}^{n_{x=1}} P_i * Cs_i{=}31.7}{\sum_{j=1}^{n_{x=0}} P_j * Cs_j{=}1.69} = 18.8$$

Results (5/8)

- Binary events, effect on H2 production

Event	DYI1
RHR Pipe Break	18.8
RHR HX Tube Break	∞
RHR HX Shell Break	∞
RHR HX Shell Isolation	0.273

Results (6/8)

- Effect of operator action timing on H2 production
  - Versus no action

Branching Condition	Value	DYI2
RHR HX Shell Isolation	393s	$1.9 * 10^{-6}$
	608s	$1.0 * 10^{-4}$
	1050s	$2.6 * 10^{21}$

Results (7/8)

- Effect of door capacities on H2 production
  - Versus being left open
  - Assigned 0.99 probability of being closed
  - Assigned 0.5 probability of either 4ft or 6ft capacity if closed

Branching Condition	Value	DYI2
RHR Pump Room Door Capacity	4 ft	141
	6 ft	$1.07 * 10^{-3}$
RHR HX Room Door Capacity	4 ft	49.9
	6 ft	$5.46 * 10^{-4}$

Results (8/8)

- Effect of physical parameters on H2 production

Branching Condition	Value	DYI3
RHR Pipe Capacity	7.1 MPa	1.18
	11 MPa	$1.37 * 10^{-2}$
RHR HX Tube Capacity	9.7 MPa	62.3
	13 MPa	$1.33 * 10^{-2}$
RHR HX Shell Capacity	7.9 MPa	48.9
	11 MPa	$2.13 * 10^{-2}$
RHR Pump Room Door Capacity	Open	1.90
	4 ft	55.2
	6 ft	$4.21 * 10^{-4}$
RHR HX Room Door Capacity	Open	4.02
	4 ft	47.4
	6 ft	$5.19 * 10^{-4}$

Risk Insights & Conclusions

- Historical analyses screened out recovery actions outside the control room for ISLOCA
  - Analysis of evolving environmental conditions may further inform such decisions
- RHR ISLOCA is a fast-evolving accident
  - 11 minute difference in isolating leak
- Flexible importance measures required for DPRA
  - Non-monotonic relationships of risk measures to input parameters
  - Future work in varying parameter probabilities to determine sensitivity