July 2026

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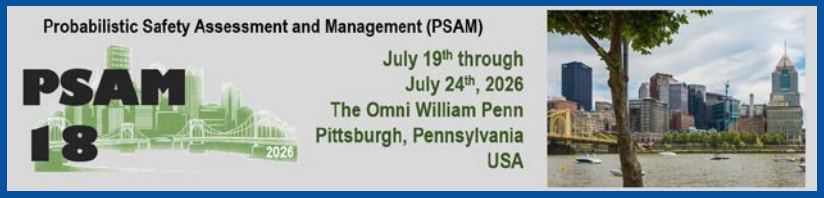
Event Modeling Risk Assessment using Linked Diagrams (EMRALD) Training



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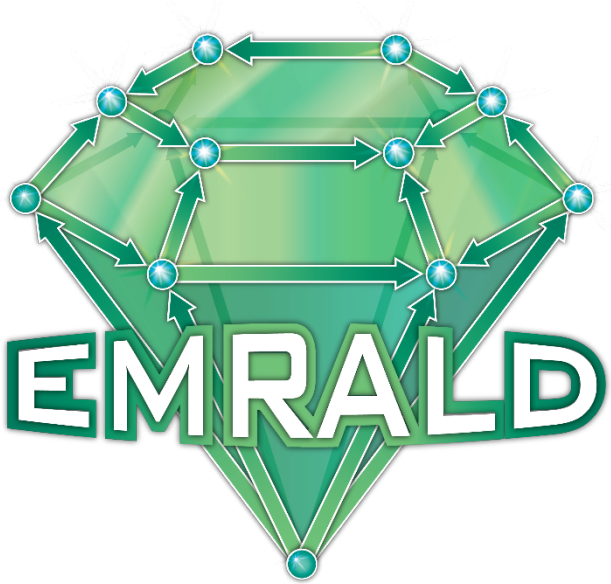
EMRALD Setup



Setup Before Training

Download the Solve Engine and verify you can run.

- Create a new directory in your desired location for EMRALD. Example – c:/temp/EMRALD/
- Download examples from Box.com - https://inlbox.box.com/s/ab40prox22ch41aifmp5st080izk9t9t
- Download the zipped file EMRALD_SolveEngine.zip from emraldapp.inl.gov (see pic above) to that directory.
- Unzip to the created directory
- Run EMRALD_Sim.exe
- If you don’t have it installed already, it may ask you to download .Net

Basic Info

Modeling UI

emraldapp.inl.gov

general information

emrald.inl.gov

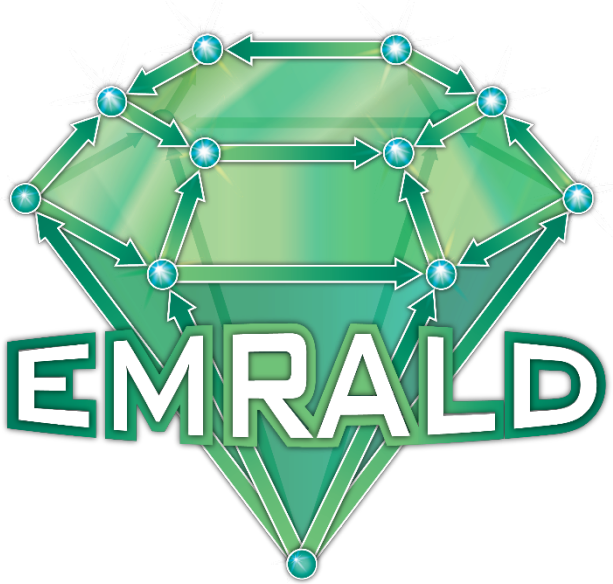
Documentation

emrald-docs.inl.gov

Open Source

github.com/idaholab/EMRALD

EMRALD Dynamic PRA
What, Why and When

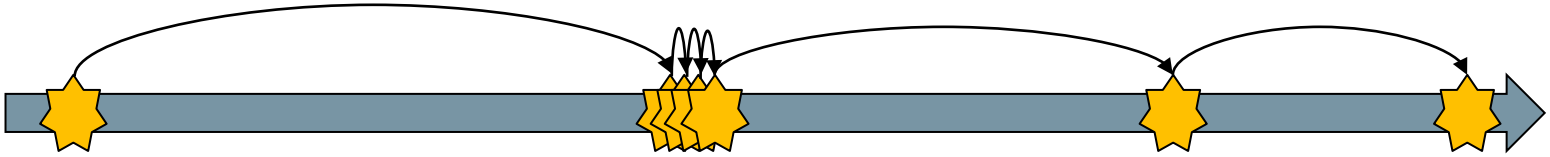


EMRALD

(Event Model Risk Assessment using Linked Diagrams)

Dynamic probabilistic risk assessment (PRA), state modeling based on a three-phased discrete event simulation.

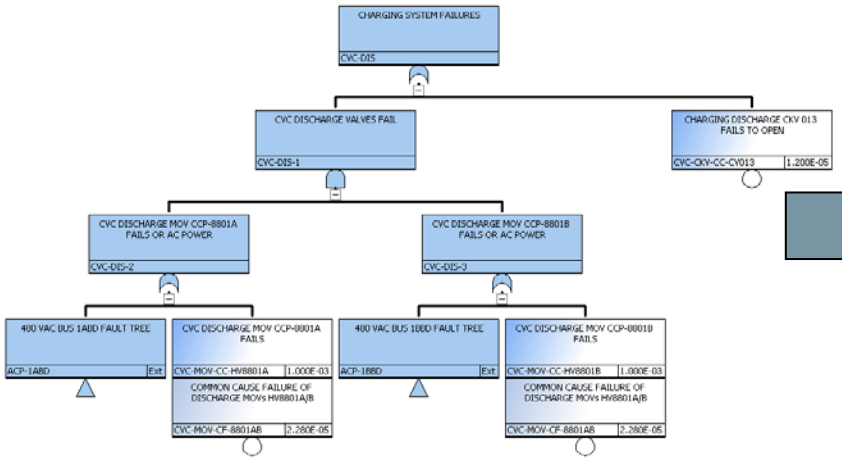
- No time steps
- Jumps to next thing that happens in time.
- Monte Carlo sampling.
- Good for long and/or short time jumps.

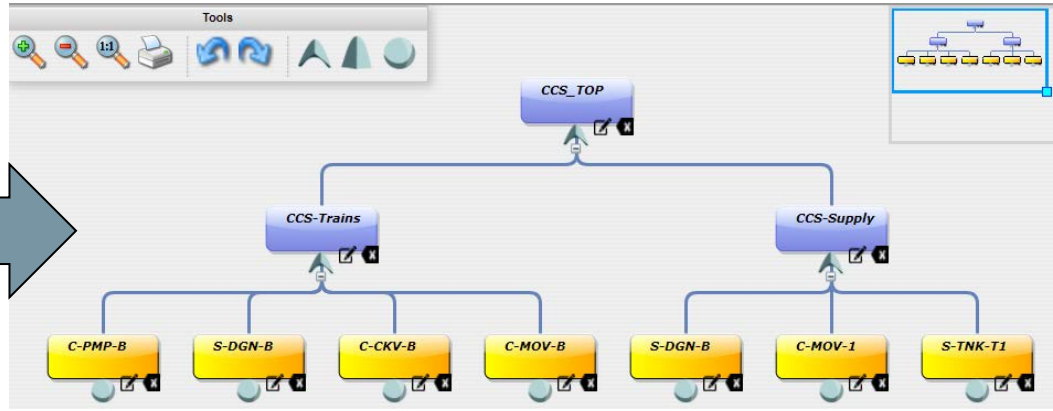


- Condition driven events
- Sampled time driven events

Why EMRALD

1. Combination of dynamic with traditional modeling techniques
2. Industry use focus for UI vs. scientific research



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    <PolynomialOrder>4</PolynomialOrder>
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    <Interpolation quad='ClenshawCurtis' poly='Jacobi'
       weight='2'>x2</Interpolation>
  </ROM>
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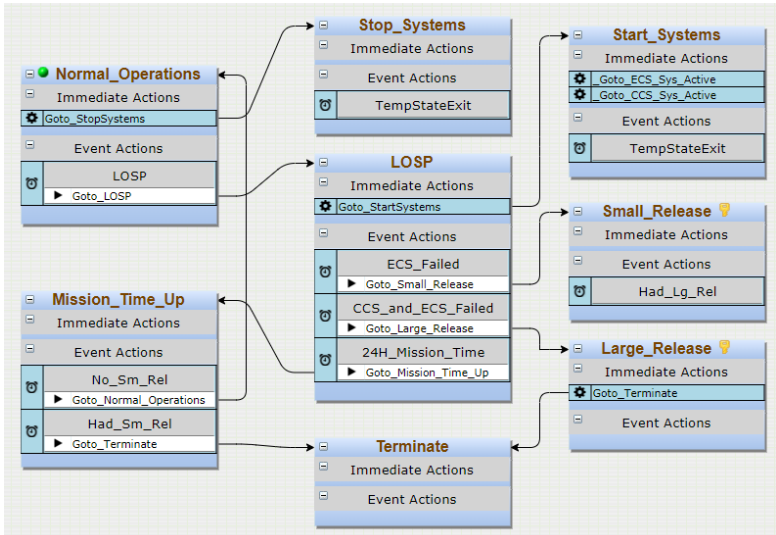
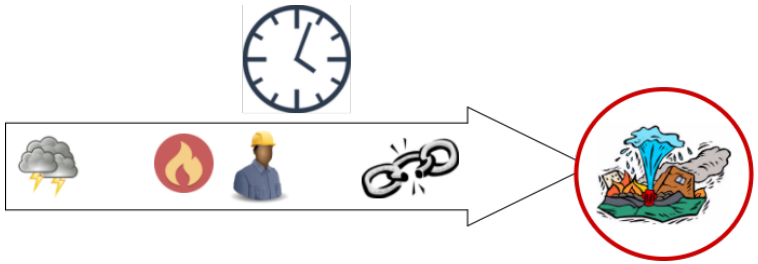
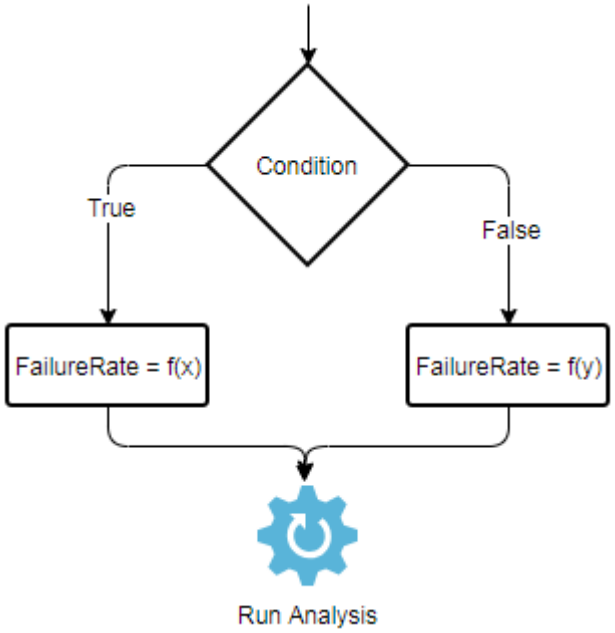
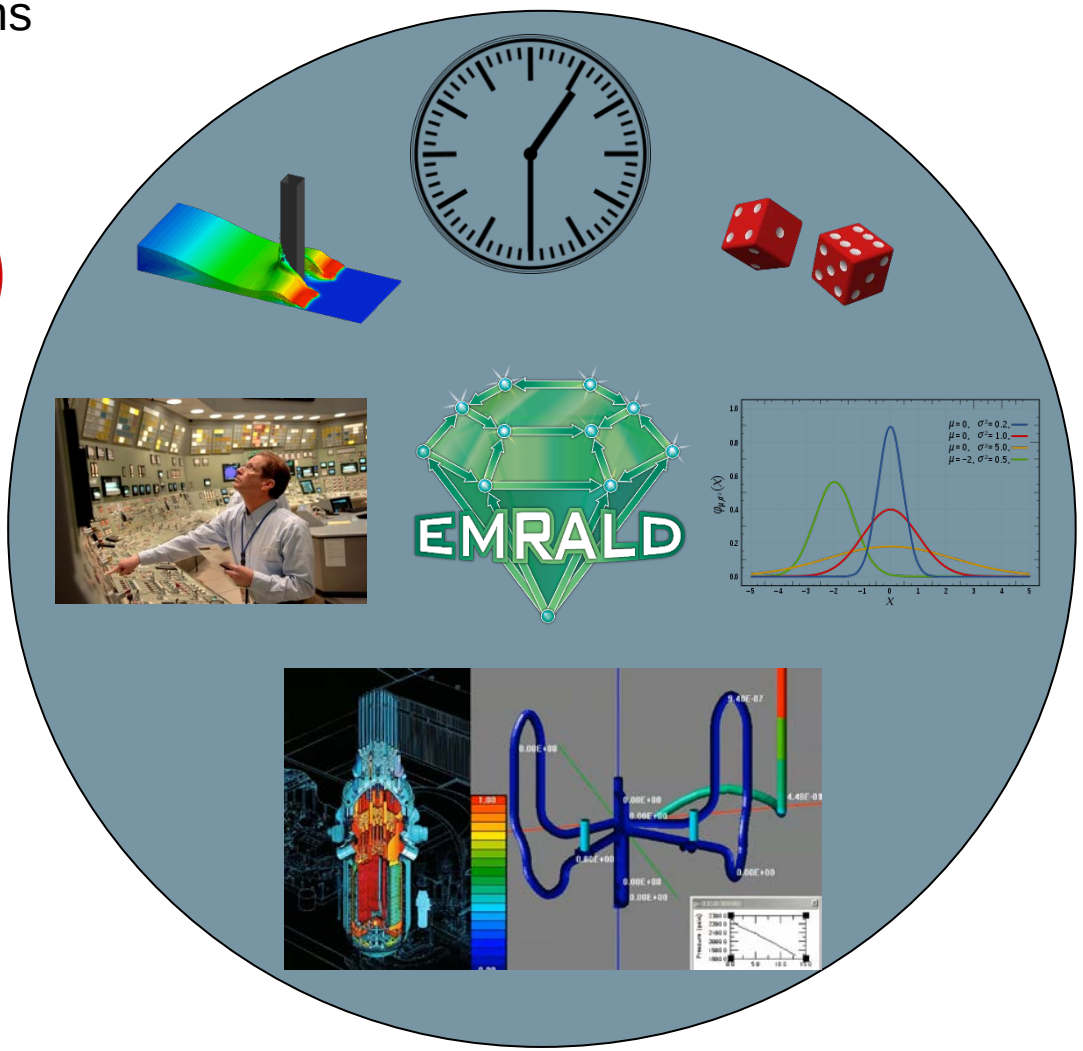


Why EMRALD (cont.)

3. Couple existing physics tools with Dynamic PRA capabilities
4. Avoids the state explosion problem common in Markov Models
5. Analyze time dependent conditions
6. Conditionally adjust failure rates







EMRALD Modeling Use Areas

Yes

- Consecutive Human Actions
- Feedback Systems
- Time dependent conditions or actions
- Add dynamic capabilities to existing deterministic models
- Need failure time or order in results
- Need path analysis of results
- Monty Carlo sampling
- Coupling with other tools/scripts

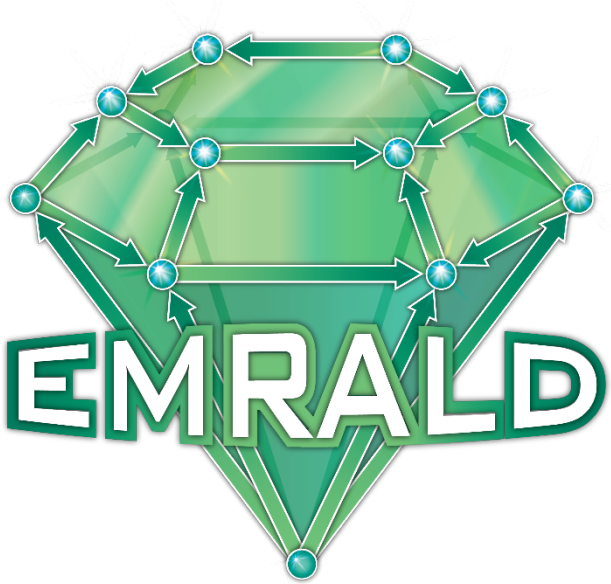
No

- Low probability events or event combinations <1.0e-6
- Replacing Classical PRA
- Machine Learning
- Making surrogate models
- Finding Limit Surfaces

Use Classical PRA

- Very detailed models.
- Low probability events.
- Large sets of failure pathway options.
- Fixed mission time.
- Finding cut sets

EMRALD Modeling UI



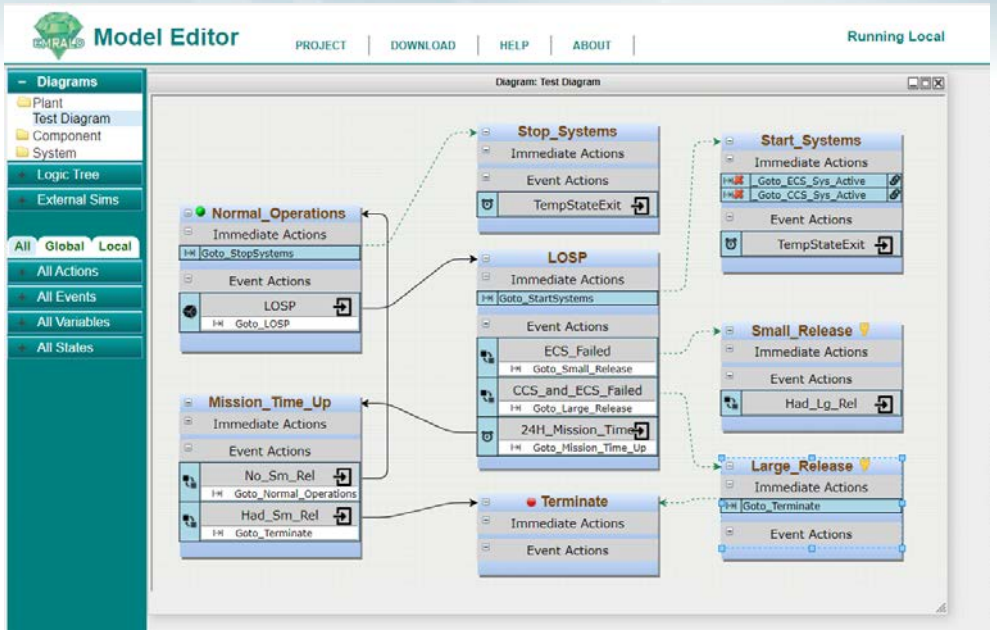
EMRALD 2 Parts

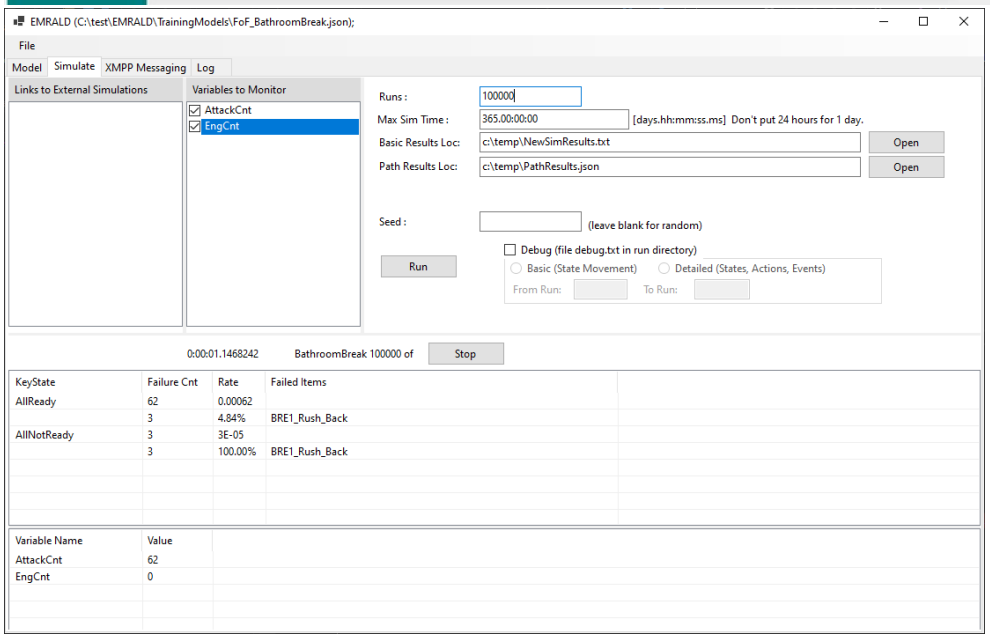
Model Builder

- Web Based
- Chrome Browser
- Offline/Local Exe Option

Solve Engine

- Local Executable or Commercial Server
- Basic UI or Command Line
- Runs Simulation
- Debug Model
- File Results
- Windows / Linux (command line)





EMRALD Modeling

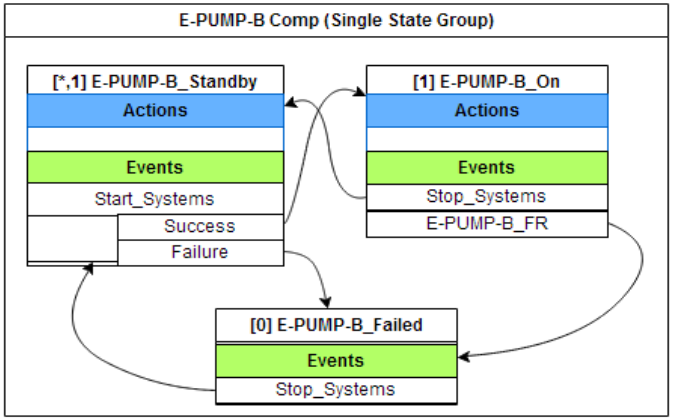
States

- Actions (transition, change variables, run script)
- Events -> Action (sampling, conditions, time, etc.)

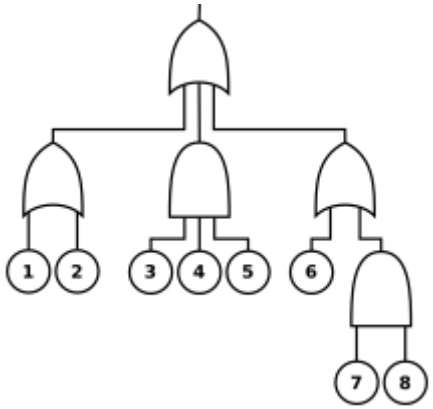
State
Actions
Transition
Change Variable
Run Script
Events
Failure Rate Sampling
Timer
State Change
Logic Tree
Evaluate Variable
External Event

Diagrams

- Components
- Systems
- Plant response



Logic Trees



Variables

External Links

EMRALD Results

Basic

- Key State Probabilities
- Failed Components
- Variable Values

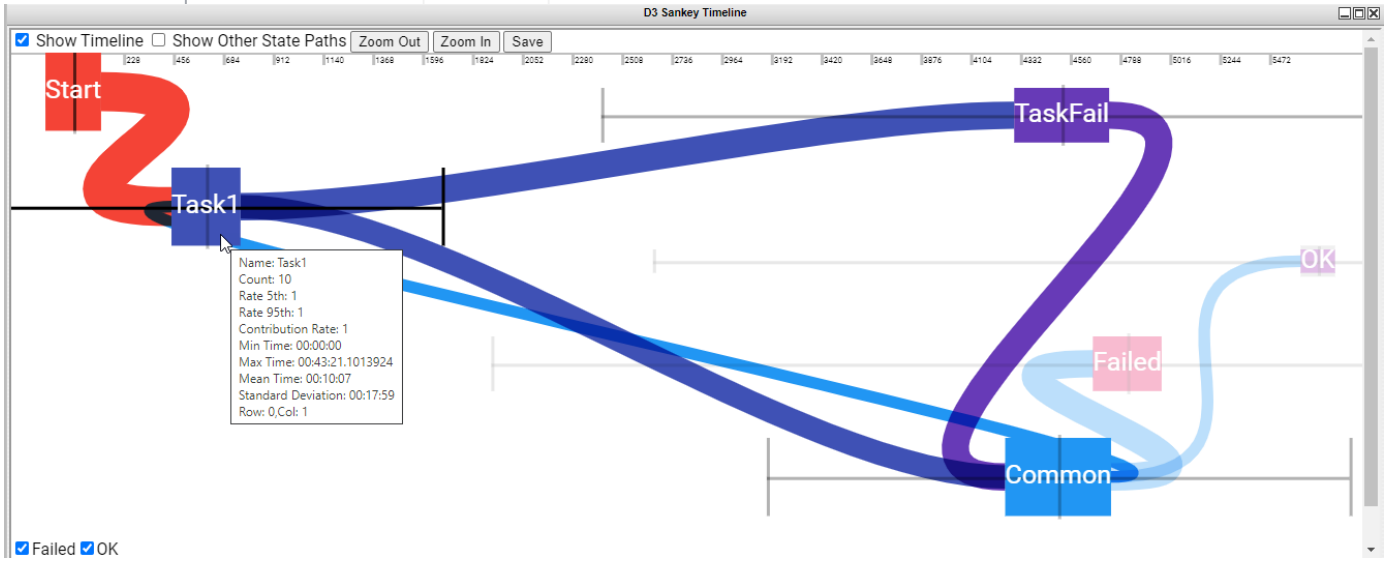
Sankey Timeline

- JSON File
- Key State Paths
- Statistics
- Time Data

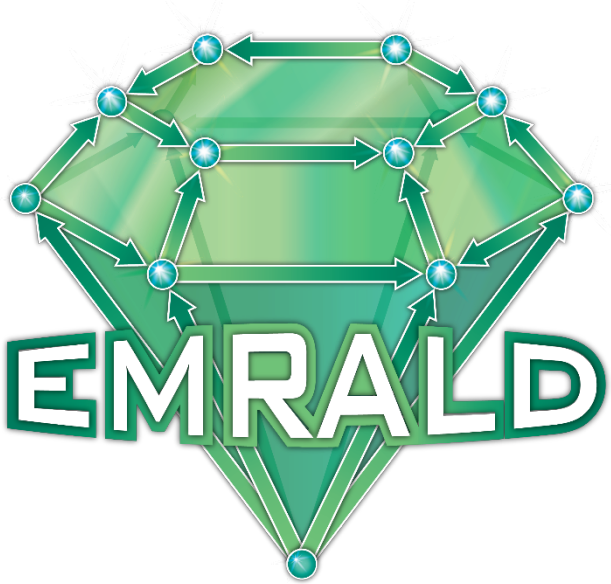
Stop 0:00:02.3733 Untitled_EMRALD_Project 10000 of 10000 runs.

KeyState	Count	Rate	Mean Time or Failed Components
Small_Release	239	0.0239	128.16:18:49 +/- 144.05:27:09
	216	90.38%	S-DGN-A_Failed
	13	5.44%	E-MOV-1_Failed
	1	0.42%	E-PMP-A_Failed, S-DGN-A_Failed
	1	0.42%	C-PMP-A_Failed, S-DGN-A_Failed
	6	2.51%	S-DGN-A_Failed, S-DGN-B_Failed
	1	0.42%	E-CKV-A_Failed, S-DGN-A_Failed
	1	0.42%	E-MOV-1_Failed, S-DGN-A_Failed
Large_Release	6	0.0006	88.10:50:14 +/- 92.09:52:49
	6	100.00%	S-DGN-A_Failed, S-DGN-B_Failed
	158	2633.33...	S-DGN-A_Failed
	12	200.00%	E-MOV-1_Failed
	1	16.67%	E-CKV-A_Failed, S-DGN-A_Failed
	1	16.67%	E-MOV-1_Failed, S-DGN-A_Failed

Variable Name	Value



Interface Overview



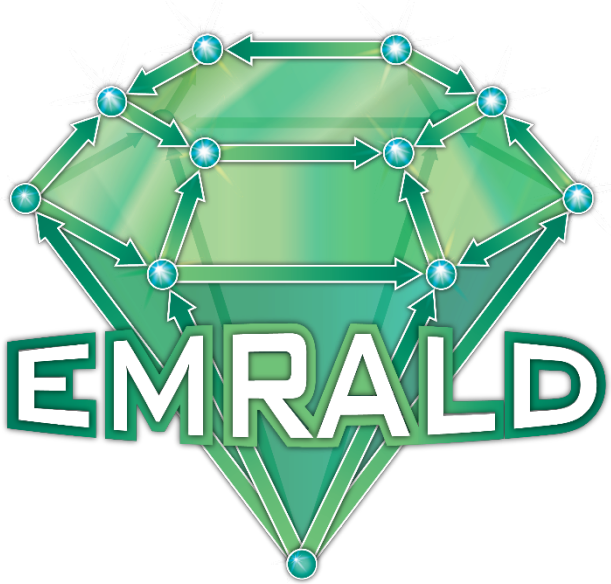
Modeling UI Areas Covered

- Creating a new model
- Screen Areas
  - Key menu items
  - Left Sidebar
  - Speed Options
- Diagrams
  - Groups
  - Single State vs Multi State
- States
  - Types (Start, Standard, Key, Terminal)
  - Immediate Actions
  - Event Actions
  - Arrows (solid, green dashed)
- Events
- Actions

Solver Areas Covered

- Open Model
- Syntax Errors
- UI settings
- Solving
- Basic Results
- JSON/Path Results
- Debug File

Model Building



Example – First Model

- Create a new project.
- Create a diagram.
- Add initial state, good state, bad state.

Example – Retry Repair

[RetryRepair.emrald]

This model evaluates the time a repair person takes to replace an O-ring in a piece of equipment. Must be done in 60 min

1. Start at a random location on site, with request to replace O-Ring,
2. ~5 min to get the O-Ring
3. ~10 min to find the correct one and go to the equipment
4. LogNormal install time 2.5 mean, .7 StdDev
   When installing the following can occur:
   - Repair can be successful. (50%)
   - The O-ring may not be set right and leaks. (40%)
     - Retries the install.
   - The O-ring is damaged or breaks. (10%)
     - Starts over getting a new O-Ring
5. Travel back and restart the system ~10 min

On Your Own

- Initiating event – Large storm happens 0.7 time a year.
- When there is a storm 5% probability it will trip a breaker.
- If breaker is tripped operator does the following:
  - Walk to the panel (5 min with a normal distribution of 2 min)
  - Find and flip the breaker (exactly 2 min)
  - Walk over and reset the system (5 min with normal distribution of 2 min)
- If they complete the task within 15 min the system is fine otherwise it fails.

Hints and Tricks

Naming

- Standards - Transitions, Changing Variables, etc.
- Special Characters - “_” ok, no other special characters including “-”
- Variable Names - CurTime, Start3DTime, ExeExitCode, outputFile, [StateName] & [StateName]_time

Icons

- See Guide

Correct Types

- Correct Diagram Type to start with. Hard to Change
- Action and Event types are not changeable after creation. Create a new one add same references and then remove old one.

Design for Speed

- Model - SlowExample.json
- Model - FastExample.json

Hints and Tricks (Continued)

Test Pieces

- Add additional movement from a transition and set first to 0%
- Develop & Test components

Actions - Process & Ordering

- All Events that meet criteria for a state at the same time are executed.
- Oder of actions matters. (x = 5) then (x = x * 2)
- Multiple “To States” % to A and % to B (Don’t just add another Action)

Scripts

- Model - ScriptTest.json
- https://dotnetfiddle.net/
- dotnetfiddle code - ScriptTest.cs

Global Events & Actions

Don’t save EMRALD exe is open and it failed. Close EMRALD first!

Hints and Tricks (Continued)

Remove Deletes if only one reference

Local Drive References

- External Exe Actions
- Document Link Variables

Buggy Things

- Arrows not showing up – Close/Reopen
- Form Resizing – Move back to the corner and move slower
- Moving States – Click once then click again

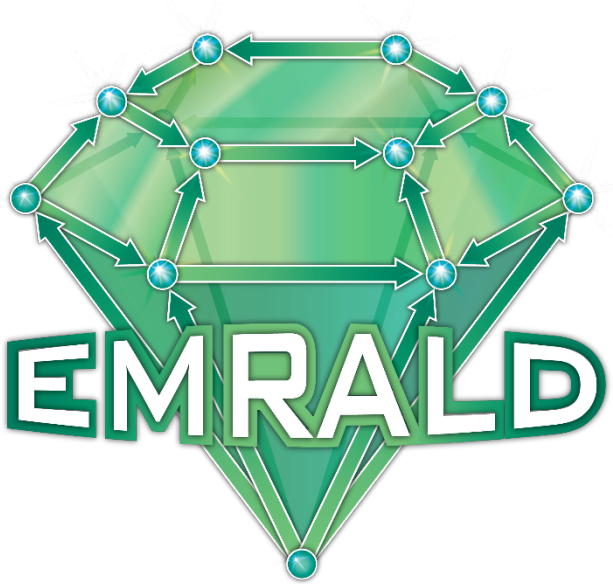
Save Often

- No Undo
- this is BETA

Verify Return Types For Scripts (To minimize compile errors)

- “Var Condition” events return a Boolean
- “Change Var Value” actions must match type in “Variable” field

EMRALD Part II
Advanced Modeling/Features



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Modeling Areas

- New Features
  - Search
  - Variables “Running Parameters”
  - Set variable value – distribution
- Accrual Variable
- Copy Paste Diagrams
- Document Link Variable
- Special Logic Tree evaluation
- Run Application Action
- ~~External Simulations~~

Solving Topics

- Command line JSON options
- Multi Threading
- Sankey Diagram
- Path Results
- ~~External Simulations~~

Example - Redundant Comps with Repair

[TwoRedundantDownTime.emrald]

You have two components needed for a system as long as one is working it is OK. When one fails you can have a crew repairing it, if both fail the system is down until one is fixed. Calculate the total down time for the system.

- Components
  1. Failure Rate 1.0 every 10 days.
  2. If crew available, they can repair.
  3. Repair rate is 1.0 per day.
- One repair crew always on site.
- Mission Time 1 year.

Example – Input File Modification

[TestDocVar.emrald]

A simple example of reading and modifying text in an XML document. This could be used to modify a model or input file before running a simulation or calculation tool or calculation tool or evaluating results.

Uses path relative xml file - .\TestFiles\XML_Example.xml

Example – Common Cause

[CommonCause.emrald & CloseInTimeCommonCause.emrald]

Traditional Common Cause

- Single event causes multiple components to fail.

Close in time Common Cause

- When components fail a % are a common cause issue
- After one fails from common cause the other components to have an event that will occur soon.
- Can allow for identification/repair before others fail.

Example – Self Checking System

[SelfCheckingMaxTime.emrald]

Model of a self checking component and ability to repair.

- You have an automatic tester for component S that checks every hour.
- The tester uses component D.
- If the tester is not failed (component D failed) and S fails then it triggers a repair of S.
- There is a manual test of component D once a day that triggers a repair of D.
- Any repair takes 4 hours.
- System or key failure occurs if component S is down for more than 8 hours.

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