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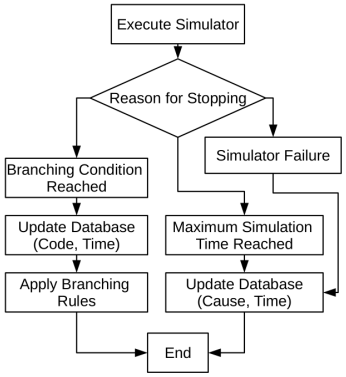
Recent Developments in the ADAPT Discrete Dynamic Event Tree Framework



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Outline

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- Background
- Code Improvements
- Expansion
- Significance

(Dynamic) Probabilistic Risk Assessment

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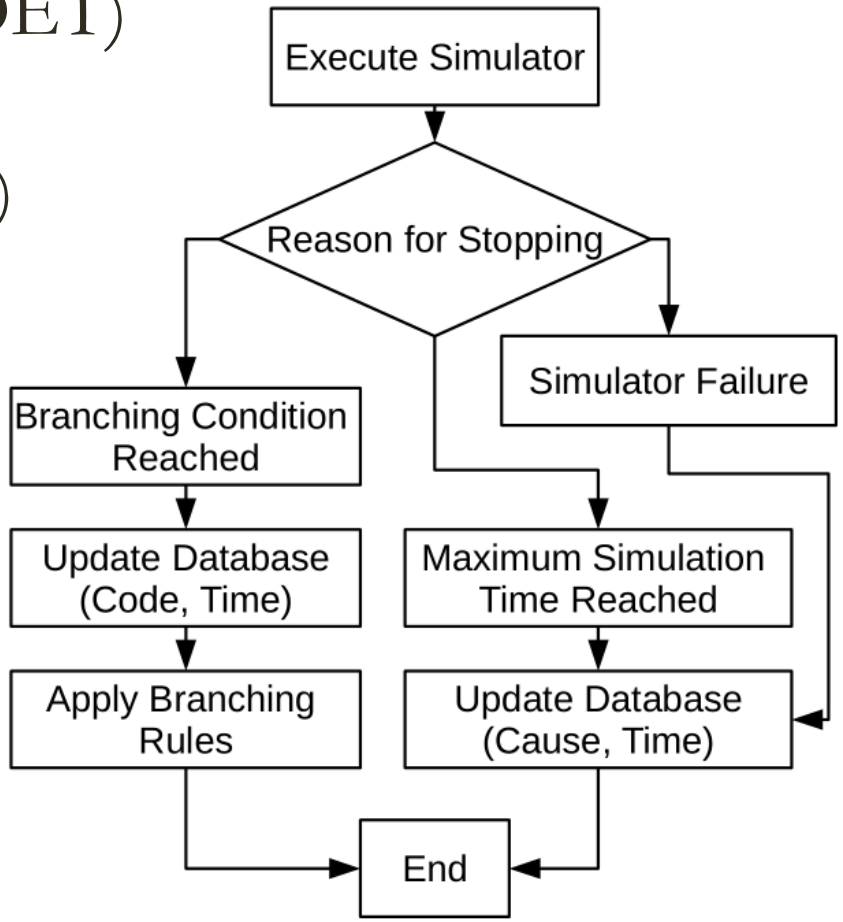
- **Traditional safety margins (conservatism)**
  - Assign system capacity at low end of distribution and load from high end, then add a safety factor
  - Usually effective, often not efficient ($)
- **Probabilistic risk assessment (PRA)**
  - Assigns best-estimate capacity and load
  - Construct fault trees for combinations (AND/OR) of basic events (with probability) that lead to system failure
  - Use failure probabilities to inform event trees for accident initiators (e.g. loss of offsite power)
- **Dynamic PRA (DPRA)**
  - Mechanistic assembly of event trees

ADAPT Background

- **A**nalysis of **D**ynamic **A**ccident **P**rogression **T**rees
  - Sandia LDRD circa 2006
  - OSU Nuclear Engineering & Biomedical Informatics
- Discrete dynamic event tree (DDET) driver and database code
- Simulator results (e.g. MELCOR) drive progression of DDET
- Efficient uncertainty analysis
- Branching rules set in input:

```
T1    0.76 1.00 1.31 1.93 1.e20
T1p   25    50    75    95    96
INIT V30903 0.52
310   1 V30903 T1
310   2 V30903 0.0
```



ADAPT Database Structure

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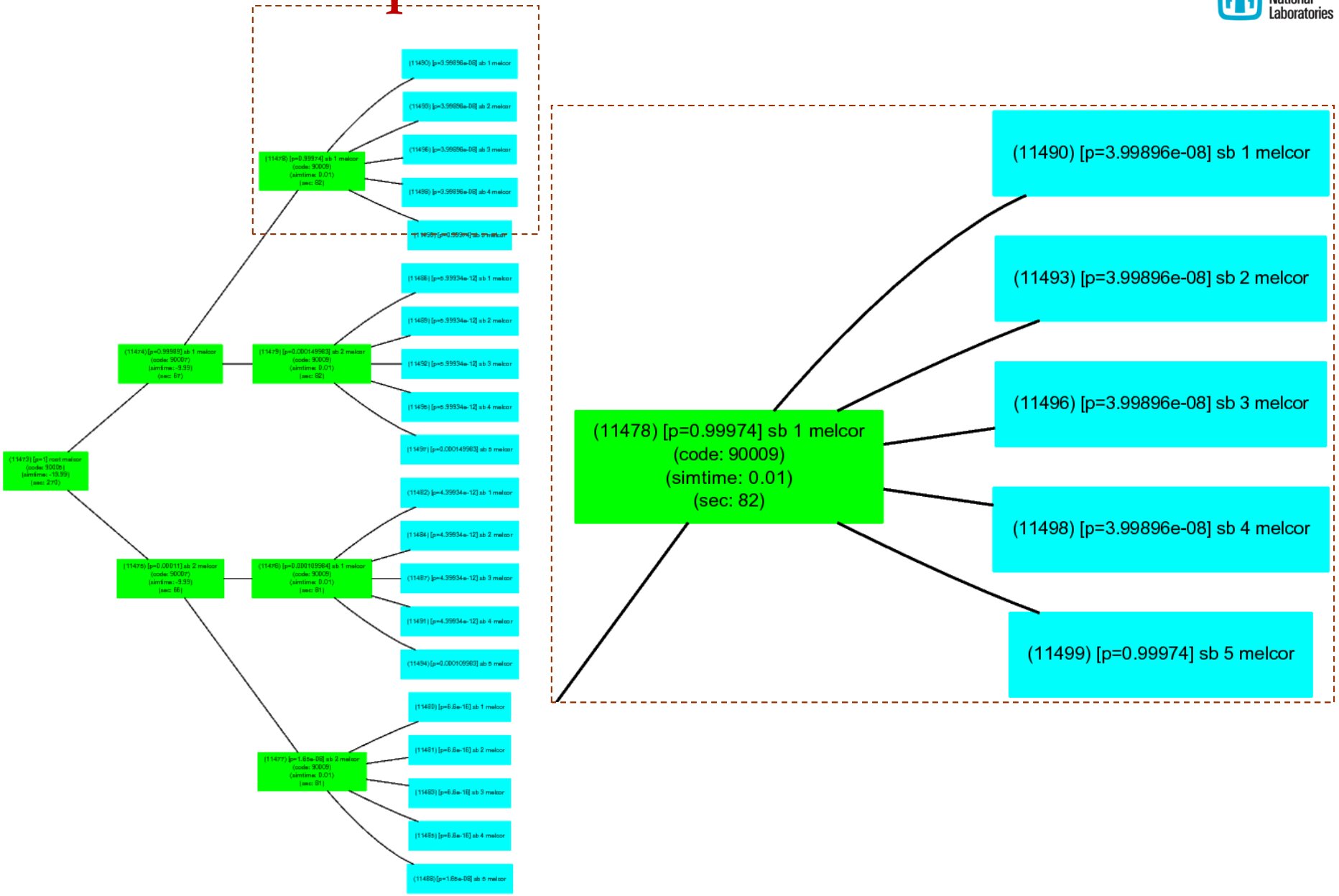
- db_zkj_tree
  - Tables
    - branches
    - branch_input_blobs
    - branch_input_refs
    - branch_scripts
    - control_messages
    - dynamic_importance_measures
    - experiment_environment_variables
    - experiments
    - job_checkpoints_taken
    - job_output_blobs
    - job_output_info
    - job_output_ls
    - jobs
    - pending_directories_to_remove
    - simulators
    - simulators_installer_prereqs
    - simulators_prereqs

```
1 • SELECT * FROM db_zkj_tree.branches WHERE experimentid=23;
```

#	id	experimentid	parentid	branchdescription	jobscript	submittime	probability
1	11…	23	NULL	root	BLOB	2016-08-04 09:22:51	1
2	11…	23	11473	sb 1	BLOB	2016-08-04 09:27:22	0.99989
3	11…	23	11473	sb 2	BLOB	2016-08-04 09:27:23	0.00011
4	11…	23	11475	sb 1	BLOB	2016-08-04 09:28:30	0.0001099835
5	11…	23	11475	sb 2	BLOB	2016-08-04 09:28:30	1.65e-08
6	11…	23	11474	sb 1	BLOB	2016-08-04 09:28:30	0.9997400165
7	11…	23	11474	sb 2	BLOB	2016-08-04 09:28:30	0.0001499835
8	11…	23	11477	sb 1	BLOB	2016-08-04 09:29:51	6.6e-16
9	11…	23	11477	sb 2	BLOB	2016-08-04 09:29:51	6.6e-16
10	11…	23	11476	sb 1	BLOB	2016-08-04 09:29:52	4.39934e-12

Sample ADAPT Visualization



Code Improvements*

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- Development dormant from ~2011 to late 2015
- Added to version control system
  - Multiple incompatible versions at SNL, OSU
  - ~120 committed, tested changes
- Python upgraded to version 3
  - Still compatible with version 2 on SNL servers
- Database operations modularized
  - Permits swapping from MySQL
- Branching behavior made explicit
  - Interpretation of tables
  - Calculation of outer and inner branch probabilities

*Featuring John Reynolds

Expansion (1/2)

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- DDET may now be driven by multiple arbitrary simulators
  - Expand problem scope (e.g. combined MELCOR & MACCS analysis)
  - Split problem space (e.g. primary system & auxiliary building)
  - Treat initiating events dynamically (previously static)
- Slice DDET according to condition-at-time rules
  - DDETs may be unwieldy (100,000+ branches)
  - e.g. return cases with primary pressure below 8MPa at any time before 1hr and hydrogen production only after 10hr
  - Re-calculate probabilities conditional on meeting set of rules

Expansion (2/2)

- Dynamic importance measures (IMs)
  - Traditional IMs insufficient for DDETs
    - Inherently binary, success or failure
  - Gauge impact of (varying degrees of) occurrence vs non-occurrence of event on chosen consequence
  - Ratio of consequence for each sampled value vs:

Non-occurrence

Branching Condition	Value	DIM2
RHR ISLOCA	9000s	$1.25 * 10^{-4}$
	9900s	0.956
	10800s	0.815
	11700s	13.2

Average of occurrence

Branching Condition	Value	DIM3
RHR ISLOCA	9000s	$3.34 * 10^{-5}$
	9900s	0.255
	10800s	0.217
	11700s	3.53

Significance

- Risk-informed decision-making
  - 1986: **Risk** of cancer fatality to population near a nuclear plant should not exceed 0.1% of all cancer fatalities
  - 1995: Use PRA to reduce unnecessary **conservatism**
- DPRA reduces subjectivity in event trees
  - Branching occurs when (and only when) conditions are appropriate
- (Relevant) Goals of NRC for advances in PRA[1]:
  - *Reduces reliance on unnecessary modeling simplifications and surrogates*
  - *Allows for consideration of alternative risk metrics*
  - *Makes process and results more scrutable*

1: Don Helton, Scoping Study on Advancing Modeling Techniques for Level 2/3 PRA

Related Publications

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- **2016 ANS Winter Meeting** (accepted):
  - Extension of the ADAPT Framework for Multiple Simulators
  - Dynamic Importance Measures in the ADAPT Framework
  - Conditional Tree Reduction in the ADAPT Framework
- **PSAM13** (accepted):
  - Application of Dynamic Probabilistic Risk Assessment to a Seismically-Induced Internal Flood Event
- In **draft**:
  - Discrete Dynamic Event Tree Analysis with the SAS4A Safety Analysis Code
  - ISLOCA Analysis using Multiple Simulators in the ADAPT Discrete Dynamic Event Tree Framework

Personal: Zac Jankovsky

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- MS: Clustering Analysis of Nuclear Proliferation Resistance Measures, 2014
- PhD (tentative): Dynamic Assessment of a Cyber-Induced Nuclear Power Plant Accident
- SNL:
  - Modified SAS4A to run dynamically & linked with ADAPT
  - Modified ADS-IDAC-RELAP to IDAC-MELCOR in anticipation of ADAPT-IDAC-MELCOR
  - Resurrecting lost SFR reliability database CREDO from reactor reports & run logs
  - ADAPT modernization & new features