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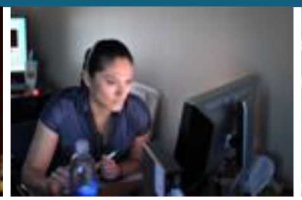
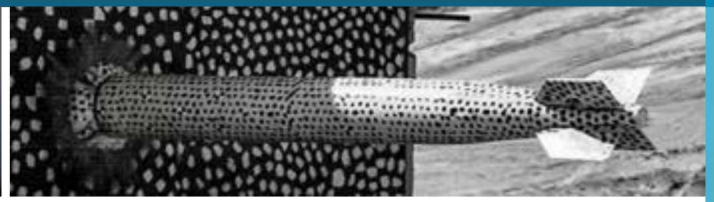
Sandia National Laboratories

SAND2019-14140C

Dynamic PRA at SNL





Zachary Jankovsky

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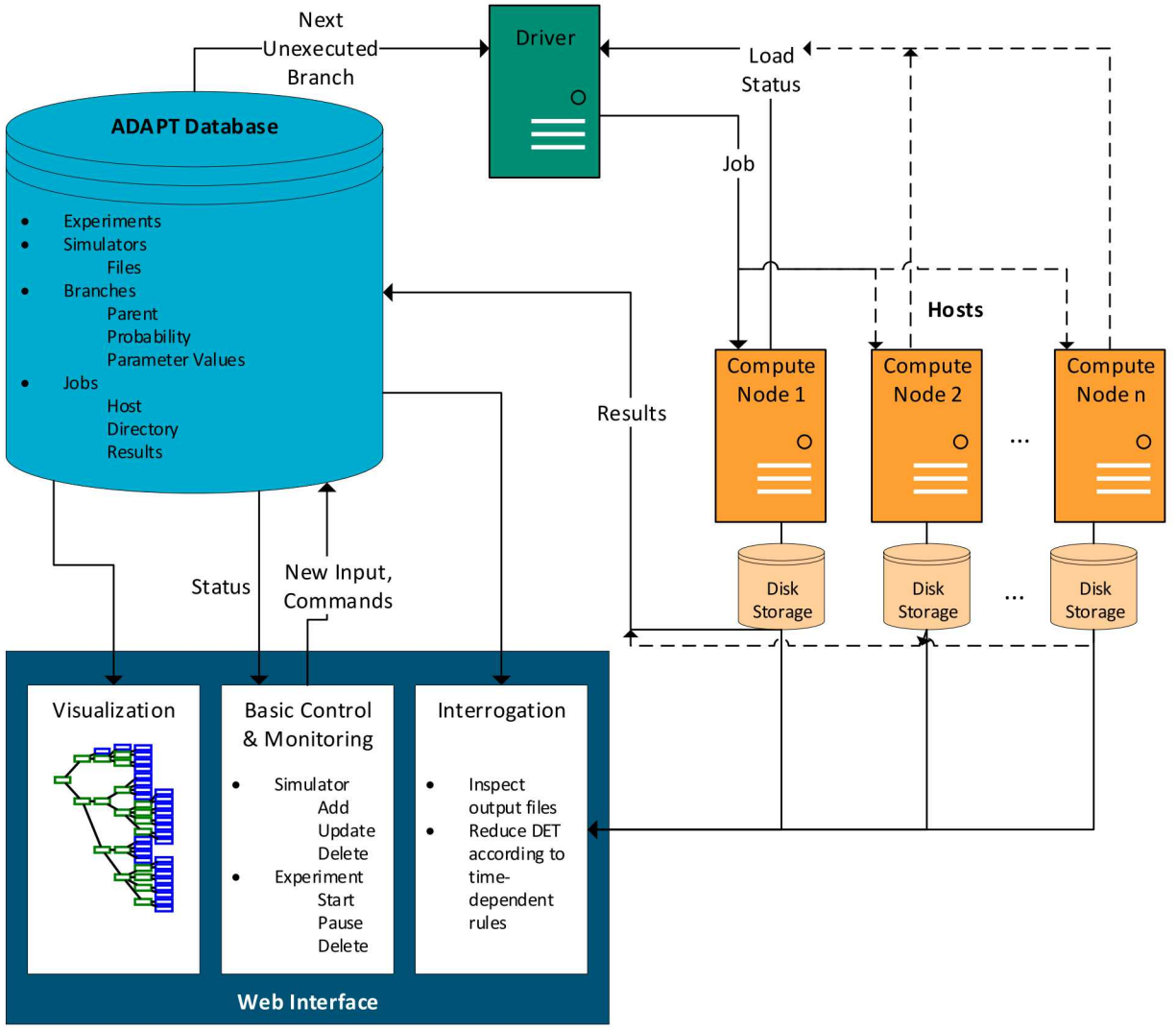
ADAPT – SNL's Dynamic Event Tree Driver

Independent jobs sent to compute nodes
- Identify number of jobs a single node can accommodate

Historically used with small Linux clusters
- Finalizing support for Slurm HPCs
- Reducing OS dependence to support Windows

Simulator- and domain-agnostic
- Interactions performed via files rather than shared memory
  - Traceability
  - Portability over diverse hosts and operating systems

Output assembly and analysis tools
- History-based plotting
- Calculation of simple figures of merit



Current SNL DPRA Approach

A dynamic PRA examination of a problem should:

Add minimal modeling complexity

- Leverage existing simulation codes
  - E.g., MELCOR, SAS4A, RADTRAD
  - Rely on pedigree of known industry codes
- Leverage existing simulation inputs
  - Perturb inputs of interest in a known, exercised model

Add minimal complexity of code

- About 10,000 lines of Python in ADAPT
  - User is responsible for about 200 lines to define simulator interactions
  - For comparison, 600,000+ Fortran lines in MELCOR
- Keep the physics in the physics codes
  - Generalized statistical calculations on outputs are ok

History of SNL DPRA Projects (1/2)

AIM *(SAND2012-9346)*

- ADS-IDAC coupled with MELCOR
- Operator emergency management actions in a PWR station blackout
  - SG feed and bleed and SG water supply realignment
- Physical parameters
  - RCP seal leakage rate and battery depletion time

108 end states

iPWR *(SAND2013-2514)*

- ADAPT and MELCOR
- SRV reliability
  - First, sampled epistemic contribution to number of cycles to failure
  - Next, aleatory sampling at each demand to determine FTO or FTC
- Decay heat distribution
- Other valve reliability

576 end states

History of SNL DPRA Projects (2/2)

SFR *(SAND2015-8872, SAND2017-4764)*

- ADAPT and SAS4A
- Accident type and severity
  - TOP, LOF, and LOHR
- Status of passive mitigation systems
  - Includes sampling of inherent reactivity coefficients
- Outputs fed into Bayesian Network to diagnose transient and corrective action from symptoms
  - Only instrumented parameters available to model, i.e., what an operator would have available

7,188 end states

RHR ISLOCA *(SAND2017-10307)*

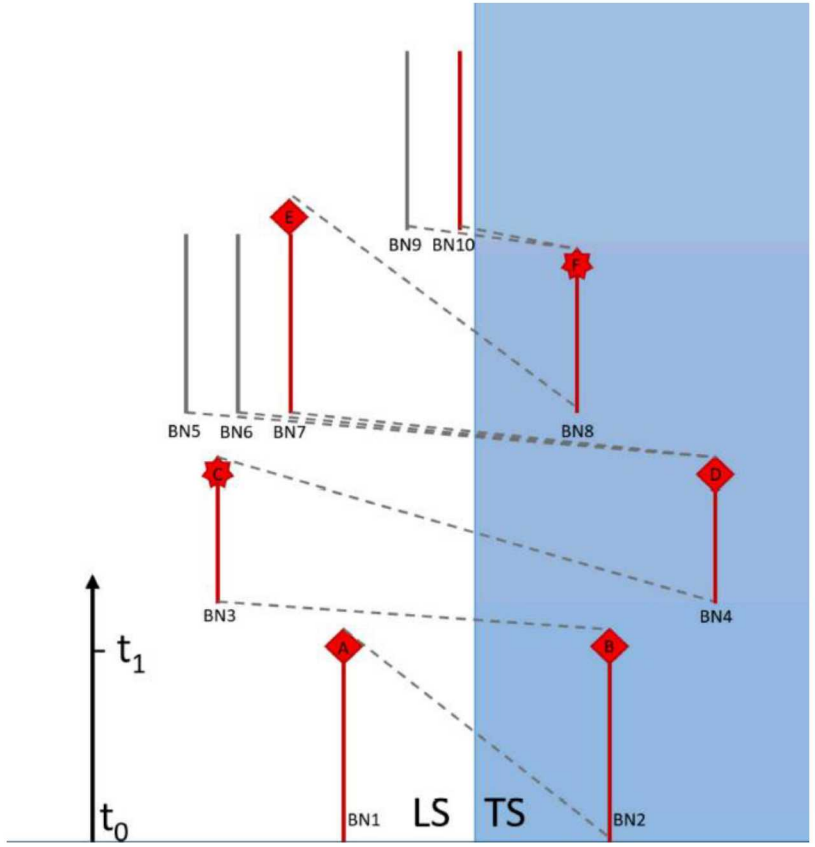
- ADAPT with MELCOR and RADTRAD
- RHR system component capacities
- Timing and success of operator actions in auxiliary building
  - MELCOR source term and mitigating action timing passed to RADTRAD whenever operator action outside control room is queried
  - Operator acceptable dose sampled and compared with expected dose from RADTRAD
    - Action fails if acceptable dose exceeded

1M+ end states

Current SNL DPRA Work

Physical Security *(SAND2019-12014)*

- ADAPT with MELCOR and Scribe3D (force-on-force tabletop software)
- Coupling of physical security and effects on plant safety
- Rapid transfer of control between simulators to step through same simulation time



Regulatory Applications

OKLO DG-1353 Pilot *(ML19038A473)* used DPRA

- Dynamic event tree analysis under ADAPT
- NRC response (ML19079A387) sought more information about DPRA
  - Learning curve for staff and reviewers may be steep
  - **Does the method used fit into the non-LWR PRA standard?**
  - **What risk importance information is available?**

17	PRA Acceptability	Can a DPRA meet the Non-LWR PRA Standard "ASME/ANS RA-S-1.4"? The time dependent PRA modeling may not fit the stationary sequence approach envisioned in the PRA Standard, which was written as a product of the IE frequencies and BE probabilities. If Oklo DPRA cannot meet the Non-LWR PRA Standard, how would Oklo justify its PRA acceptability in support of the DC application?
18	Other Uses of PRA	DPRA, does not provide the traditional risk important measures, would there be sufficient risk information to support other PRA applications during DC and COL stages, i.e., physical security (vital equipment, target sets), Tech Spec, environmental review (costs and benefits of SAMDAs), etc.

Non-LWR PRA Standard

Trial use non-LWR PRA standard *(ANS RA-S-1.4-2013)*

- Supporting requirements (SRs) are meant to say what to do, not how to do it
- Traditional methods (fault tree/event tree) were assumed in developing SRs
  - "USE the event trees and fault trees…"
- Alternative methods may be used if results are equivalent or superior to usual methods and meet high level requirements and SRs
- New edition will retain this philosophy

DPRA guidance document prospectus in development

- Proposing that JCNRM issue guidance to practitioners and peer reviewers as to expected elements and methodologies for dynamic applications using the ASME/ANS PRA standards
- Not necessarily tied to the non-LWR standard
- For now, practitioners need to convince reviewers on their own
  - Appropriateness of tools (e.g., systems codes)
  - Selection and handling of uncertain parameters
  - Key metrics such as CDF and LERF
    - Non-LWR standard has mostly excised these terms in favor of key event sequence families and release categories
  - Willingness to bear first-of-kind costs?

Measures of Importance

Traditional importance measures can be calculated from dynamic event trees

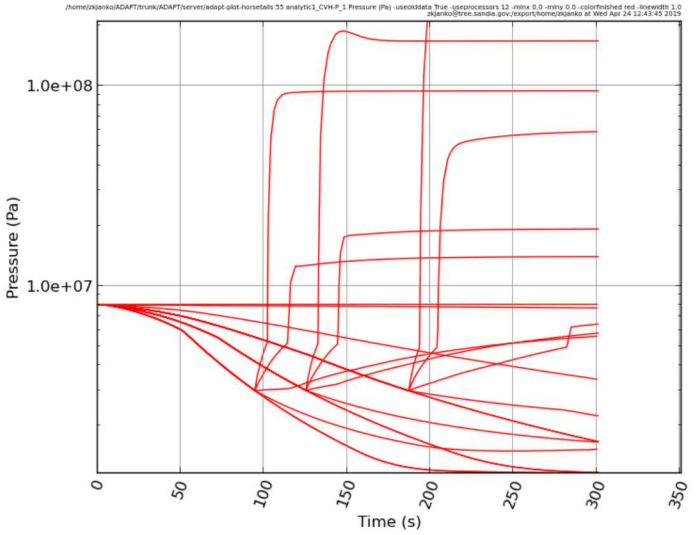
- For well-behaved branching conditions and success/failure metrics

Generally, a more flexible uncertainty/sensitivity mindset may be required to gather insights

- Effect of a continuous uncertain physical parameter on a continuous output measure
  - E.g., how does peak fuel temperature vary with sampled passive heat removal capacity?

Measures of Importance

Example for water addition to depressurization case

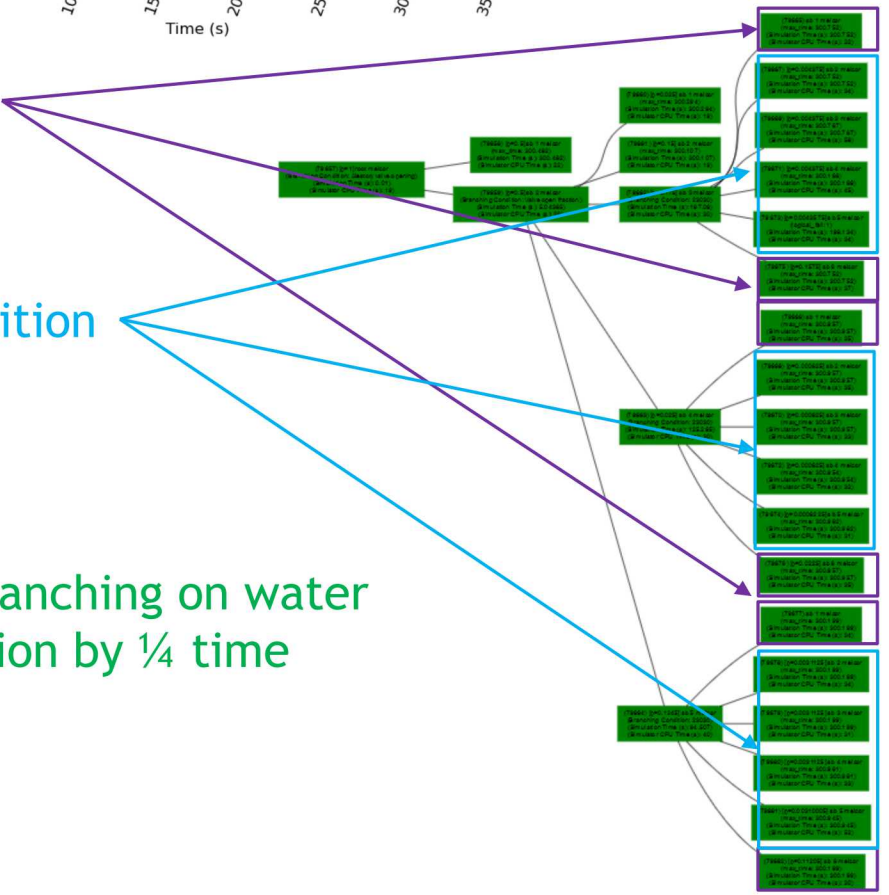


Type	Ratio Pres.(occurrence)/ Pres.(non-occurrence)
Peak Value	6.8
Lowest Value	1.9
Last Value	36.3
¼ Time Step	1.0
½ Time Step	6.0
¾ Time Step	12.6

Zero addition

Non-zero addition

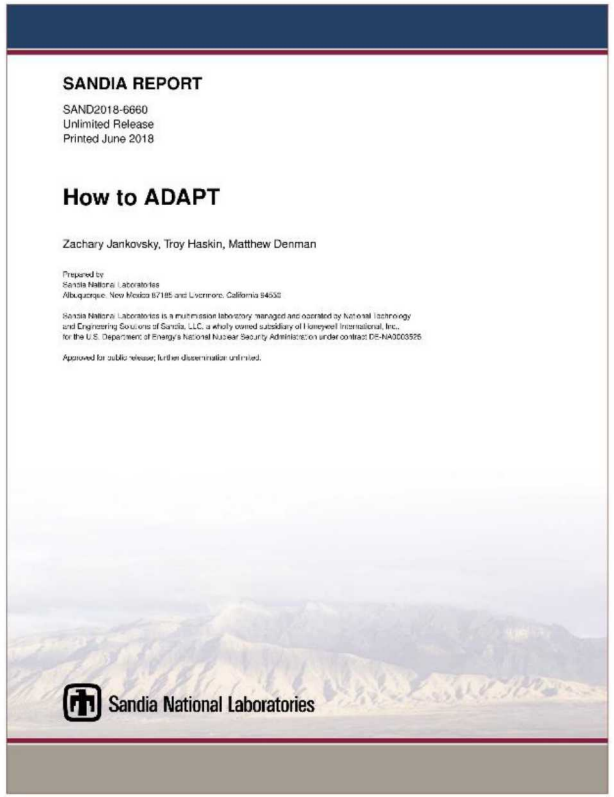
No branching on water addition by ¼ time

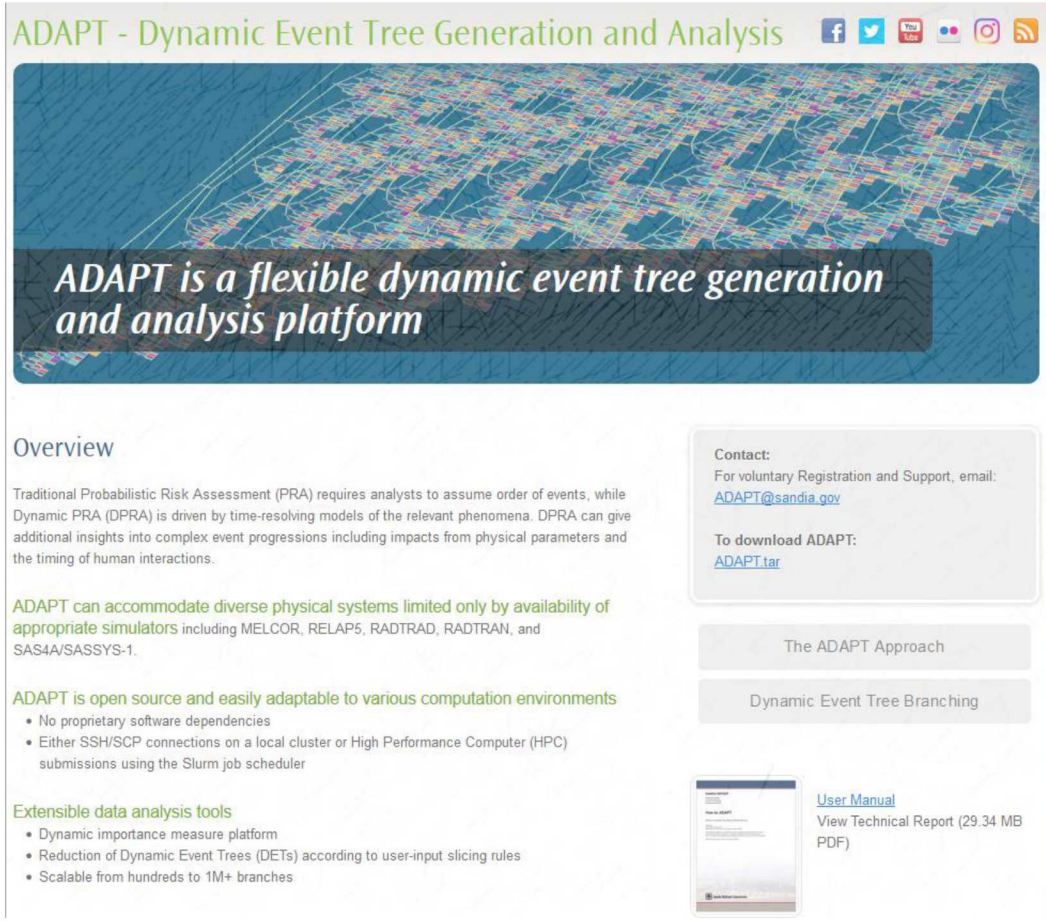


Getting ADAPT

http://www.sandia.gov/adapt/

Current manual: SAND2018-6660





Thanks

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