Towards an International Standard for PSA Models (Event Trees / Fault Trees)

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Why a Standard?

- Reduce tool dependency
- Cross check calculations
- Develop new calculation engines
- Design new browsers
- Review the existing models
- Document models
- Clarify (unify?) modeling methodologies
- Extend fault trees/events trees formalism
- Call external tools (Level 2)
- ...

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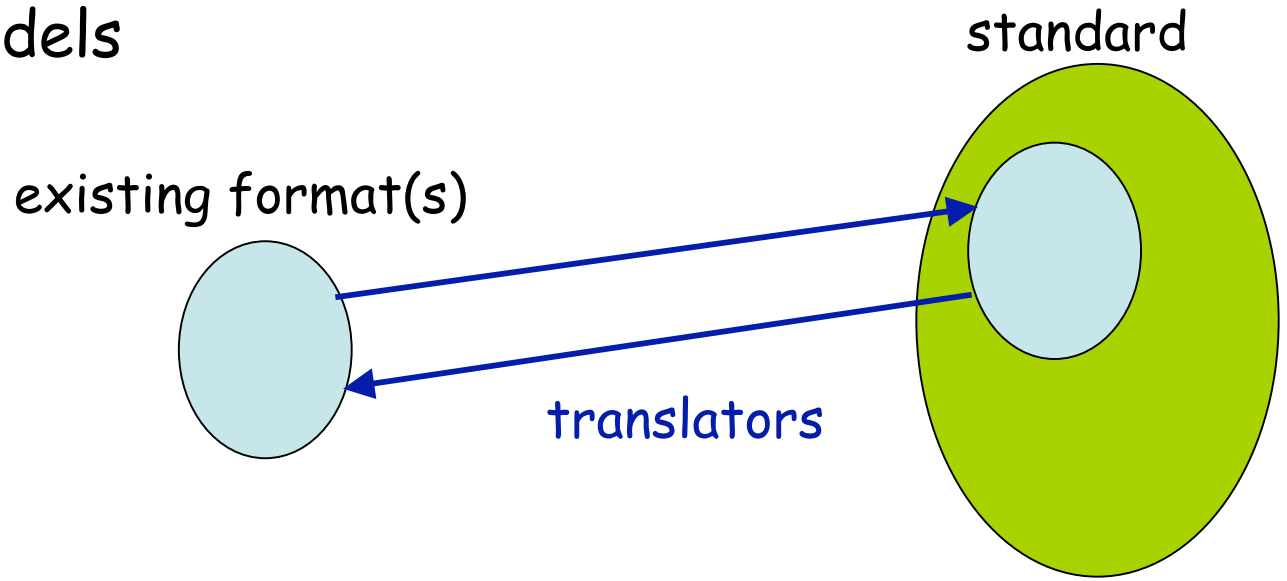
Requirements

- Large enough to make it possible to cast existing models



- Easy to extend … XML format
- Easy to embed into existing tools

5 Layers Architecture

Reports: traces of rewritings and calculations, results, …

Calculations: consequences, recovery rules, delete terms

Sequences: event trees, initiators, end-states

Logical: fault trees, common causes

Stochastic: probability, distributions

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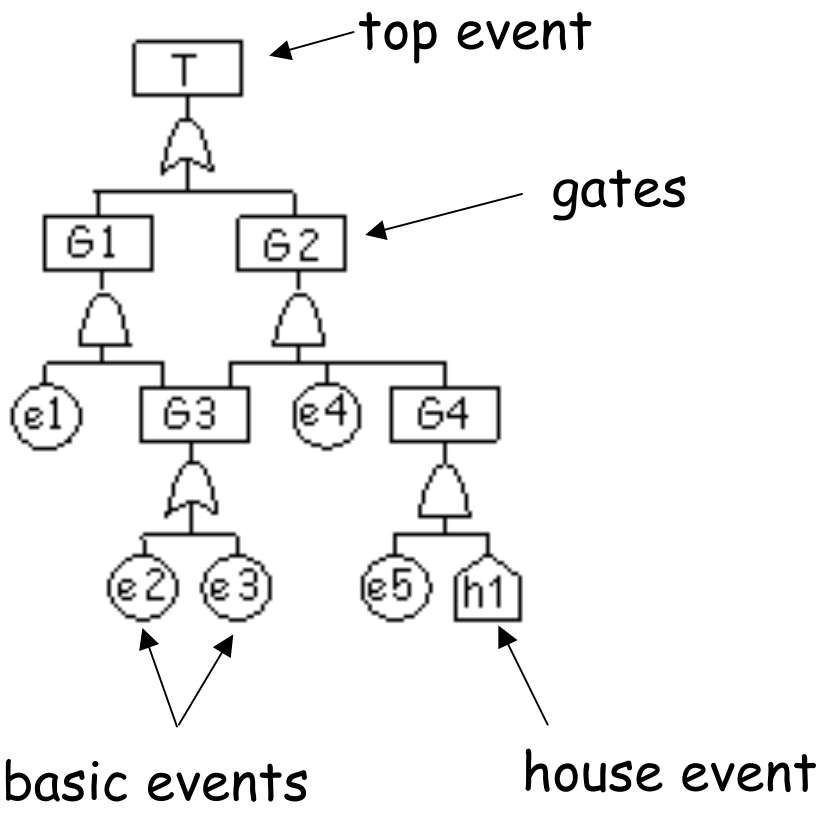
Layer 2 (logical): Fault Trees

Fault Trees




```
<fault-tree top-event="T">
  <gate name="T" >
    <or>
       <gate name="G1" />
       <gate name="G2" />
    </or>
  </gate>
  …
  <gate name="G4" >
    <and>
      <basic-event name="e5" />
      <house-event name="h1" />
    </and>
  </gate>
</fault-tree>
```

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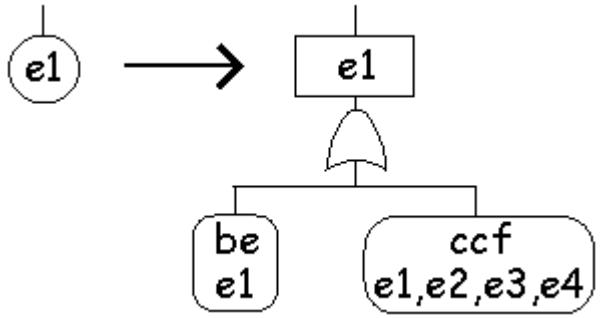
Layer 2 (logical): Common Cause Groups

Group: e1, e2, e3, e4
Model: beta factor
Value: 0.15




```
<common-cause-group model="beta" value="0.15" >
  <basic-event name="e1" />
  <basic-event name="e2" />
  <basic-event name="e3" />
  <basic-event name="e4" />
</common-cause-group>
```

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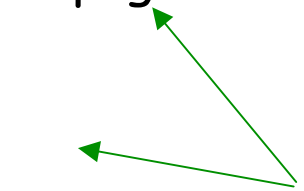
Layer 2 (logical): Tools

Software components, e.g.

- Constant (house events) propagation
  F + 1 ® 1, F + 0 ® F,…
- Expansion of CCF events
- Heuristics to simplify formulae
  E.g. F.G + F.H ® F.(G+H)
- Modularization
- …



back translation to existing formats and calculation engines

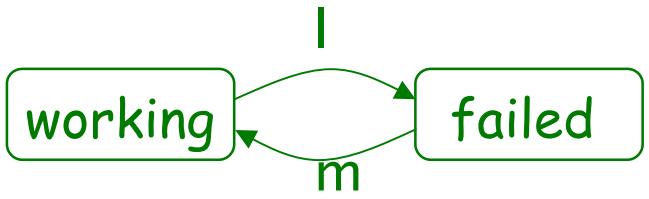
These small pieces of software could be public domain

Layer 1 (stochastic): Basic Events

Probability laws associated with basic events

- Raw numbers
- Negative exponential law
- Weibull law
- …

$$Q(t) = \frac{\lambda}{\lambda + \mu} \times \left(1 - e^{-(\lambda+\mu)t}\right)$$




```
<law basic-event="pump-failure">
  <exponential>
    <parameter name="lambda" />
    <parameter name="mu" />
    <parameter name="t" />
  </exponential>
</law >
…
```

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Layer 1 (stochastic): Parameters

Parameters:

- Constant
- Parameters (variables)
  - time
- Arithmetic operations
  - +, -, *, /, …
- Analytic functions
  - Exponential, Weibull, …
- Distributions
  - Uniform, Normal, Lognormal
  - Histogram
- …

```
<parameter name="lambda">
  <sum>
    <parameter name="lambda1" />
    <parameter name="lambda" />
  </sum>
</parameter >
<parameter name="lambda1">
  <constant value="0.001" />
</parameter >
…
```

sensitivity analyses

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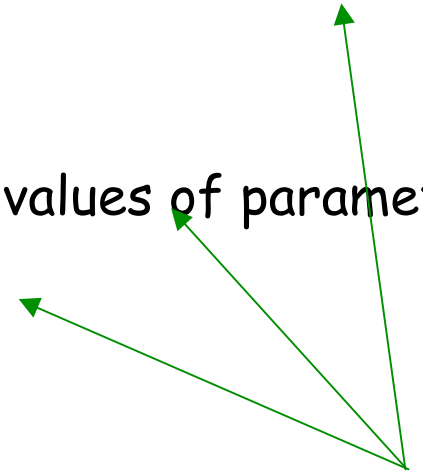
Layer 1 (stochastic): Tools

Software components, e.g.

- Calculation of the value at time t of a probability distribution
- Calculation of mean values of parameters
- Calculation of CDF
- …



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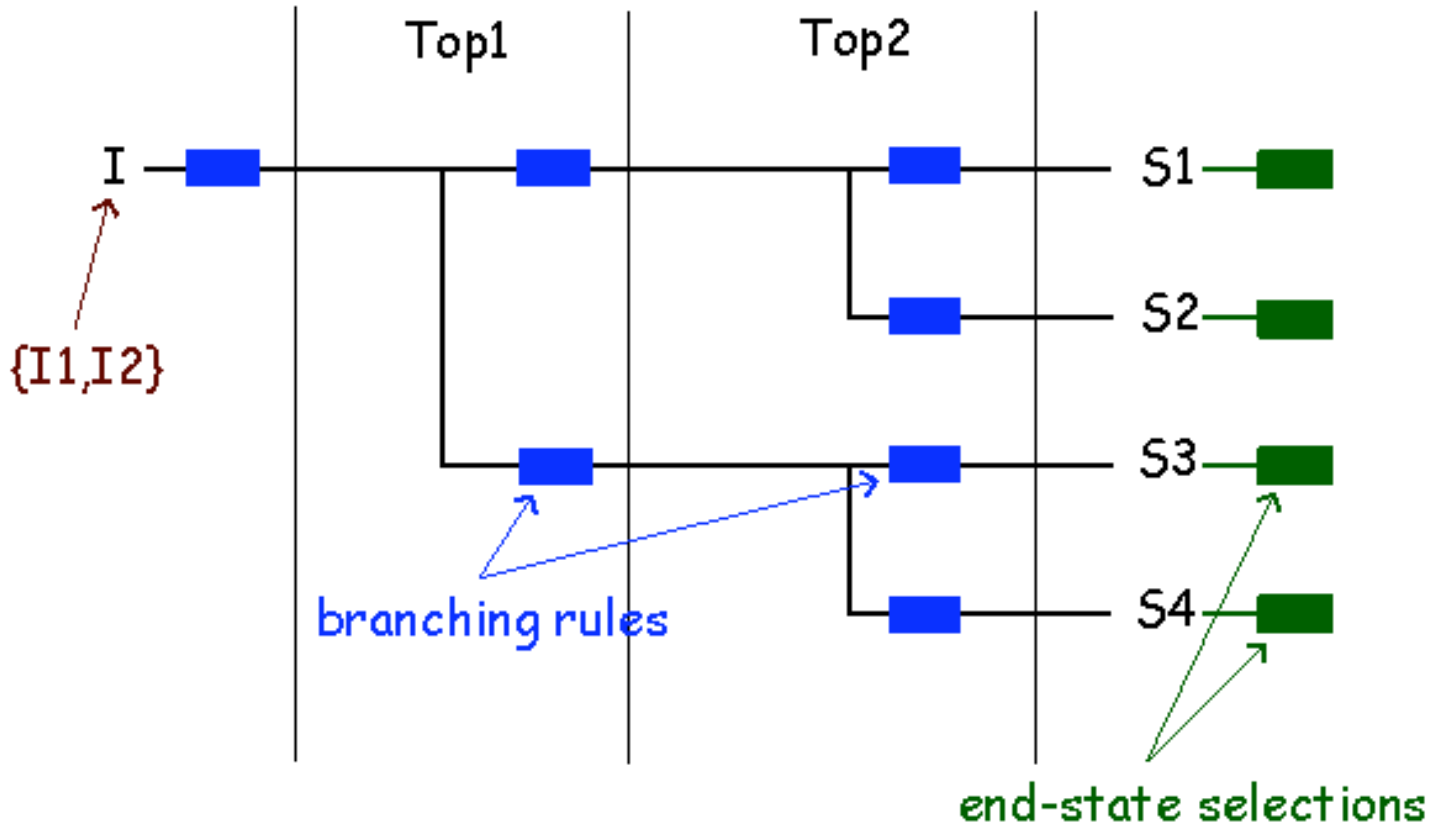
Layer 3 (sequences): Event Trees

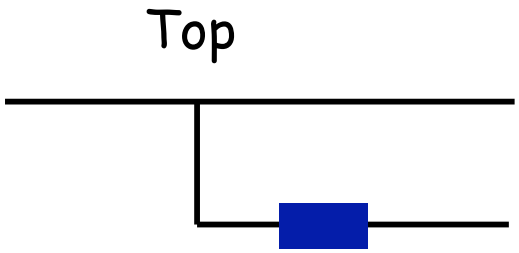


Layer 3 (sequences): Branching rules

Branching rules are (simple) procedures that transform an environment into another environment

Environment → Branching rule → Environment

- Initial event
- Probability
- Boolean formula
- House event values



HE1 = 0
HE2 = 1
HE3 = if (initiatior=I1) then 1 else 0
Formula = Formula and Top
HE1 = 1
…

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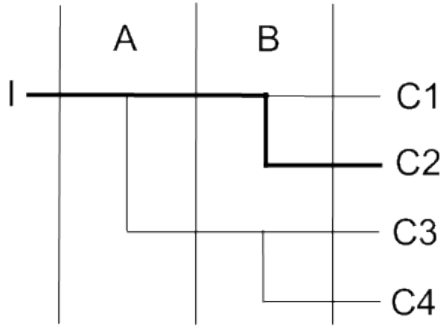
Layer 3 (sequences): Event Trees




```
<event-tree>
  <initiator name="I" />
  <branch top-event="A" type="success" >
     <rule>
       <set house-event="H1" value="1" />
       <append top-event="A" polarity="0" />
     </rule>
    <branch top-event="B" type="success"  >
      <rule>
        <set house-event="H2" value="0" />
      </rule>
     …
  …
  </branch>
</event-tree>
```

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Layer 4: Calculations

- Consequences and groups of consequences
  - defined by means of names of sequences and/or end-states
- Initiator groups
- Recovery rules & delete terms
  - extra-logical instructions to post-process cutsets
- …

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Layer 5 (reports): Minimal Cutsets

trace of the calculation

```
<minimal-cutsets size="10651" >
  <calculation>
    <consequence name="CMELT" />
    <preprocessing modularization="on" />
    <algorithm name="MOCUS" absolute-cutoff="1.0e-11" />
  </calculation>
  <cutset order="6">
    <basic-event name="pump1-failure" />
    <basic-event name="pump2-failure" />
    …
  </cutset>
  <cutset>
  …
  </cutset>
  …
</minimal-cutsets>
```

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Future Work

- Draft of the standard
- Pilot project
  - Prototyping
  - Benchmarking (on various PSA pieces coming from different tools)
- Workshops

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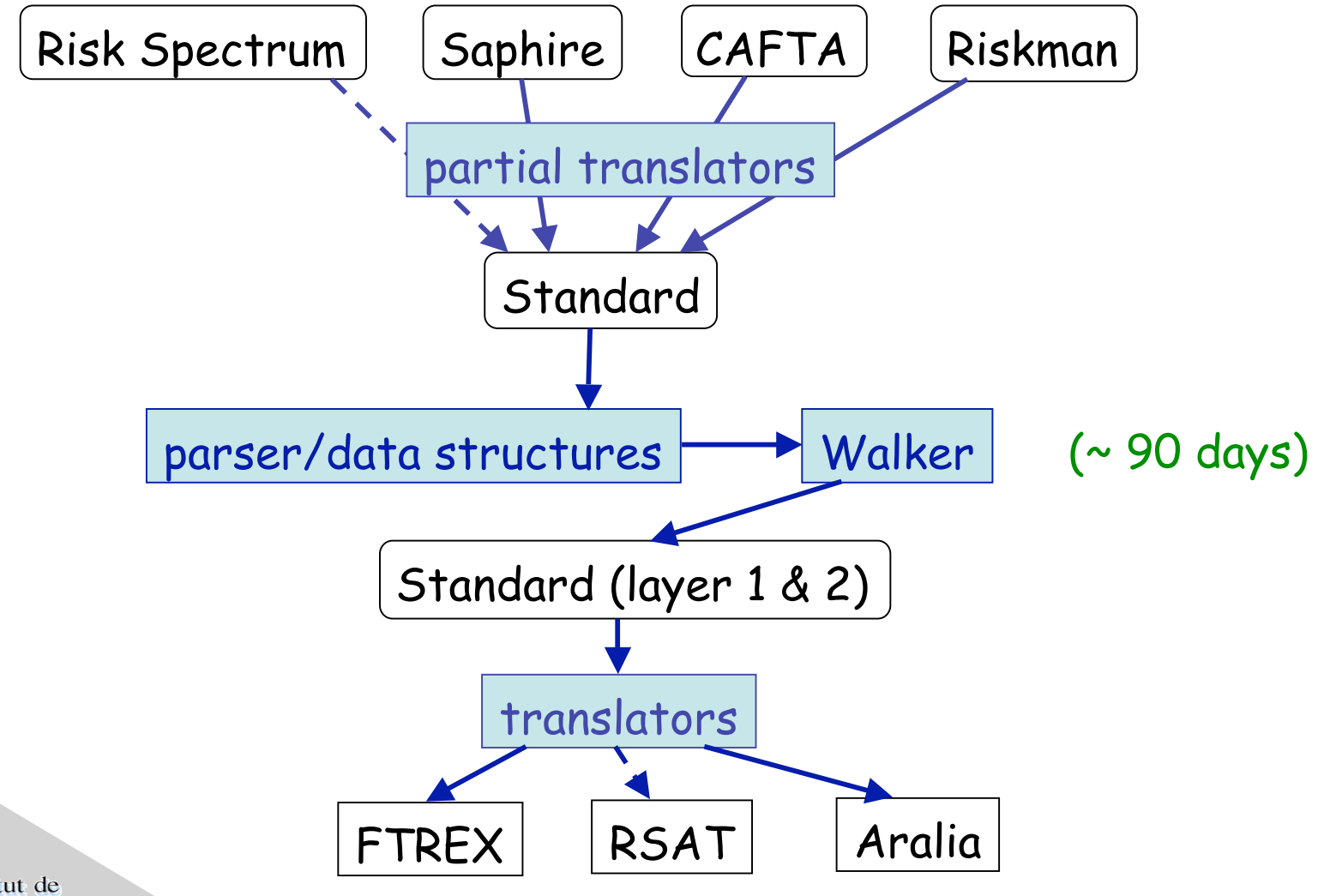
Prototyping



(~ 90 days)

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Benchmarking

- Consider models (2 or 3) coming from the different tools
- Cast them into the standard
- Possibly make some calculations

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PSA Open Standard Working Group

- Redaction of the draft
  - 1 or 2 meetings this year (1 in july?)
- Steering commitee?
- Website?
- Presentation at various conferences (PSAM, PSA, ...) ?
- ASME working group?

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