RASTEP – A versatile tool for decision support in nuclear emergency situations

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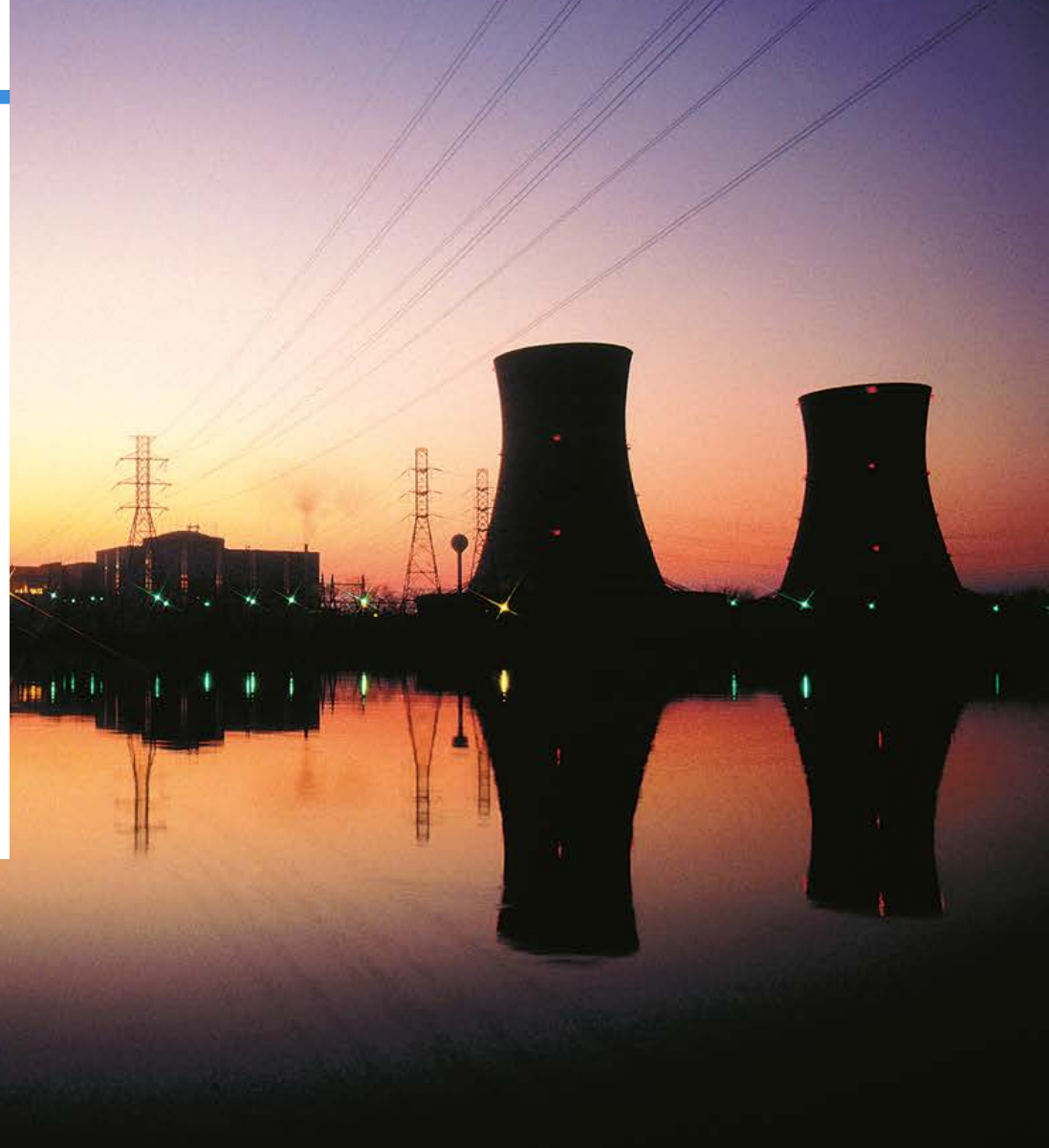


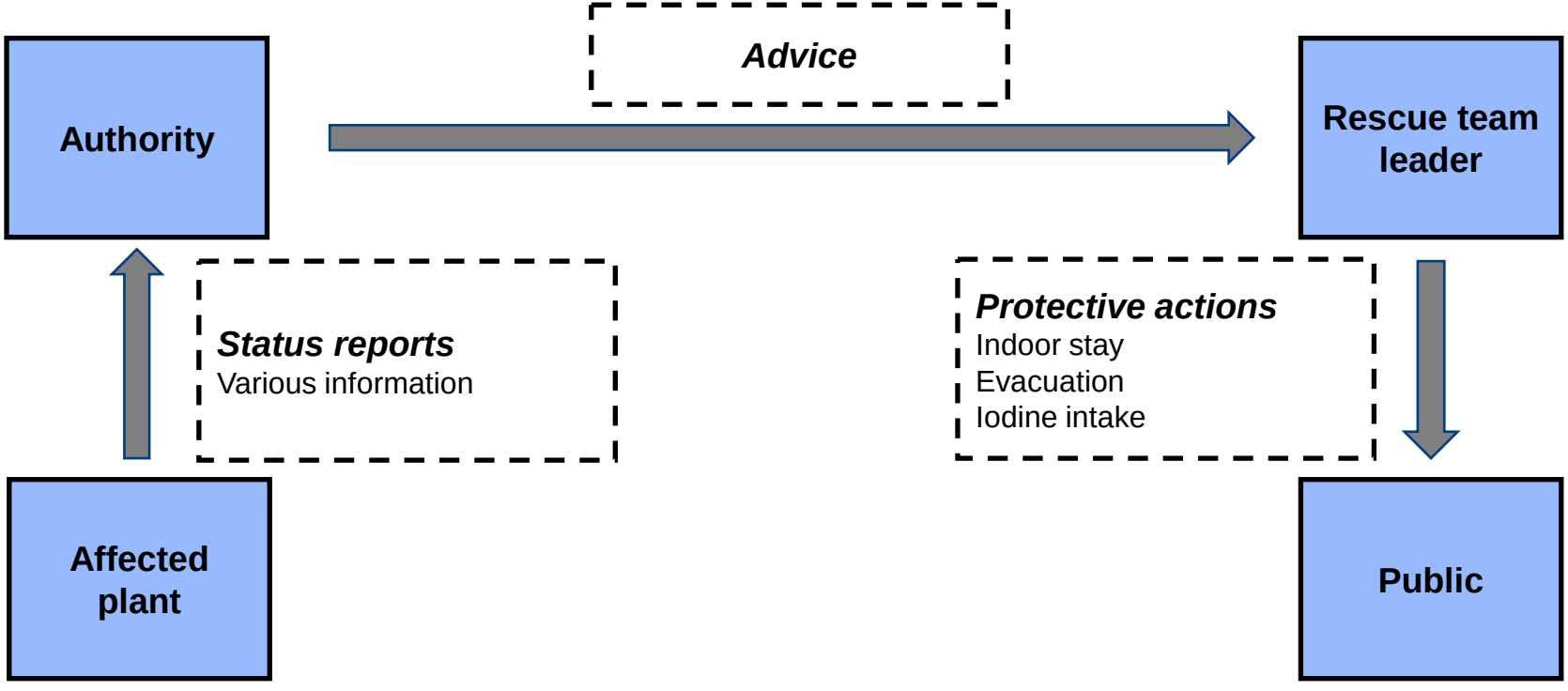
Context

Emergency Preparedness and Response

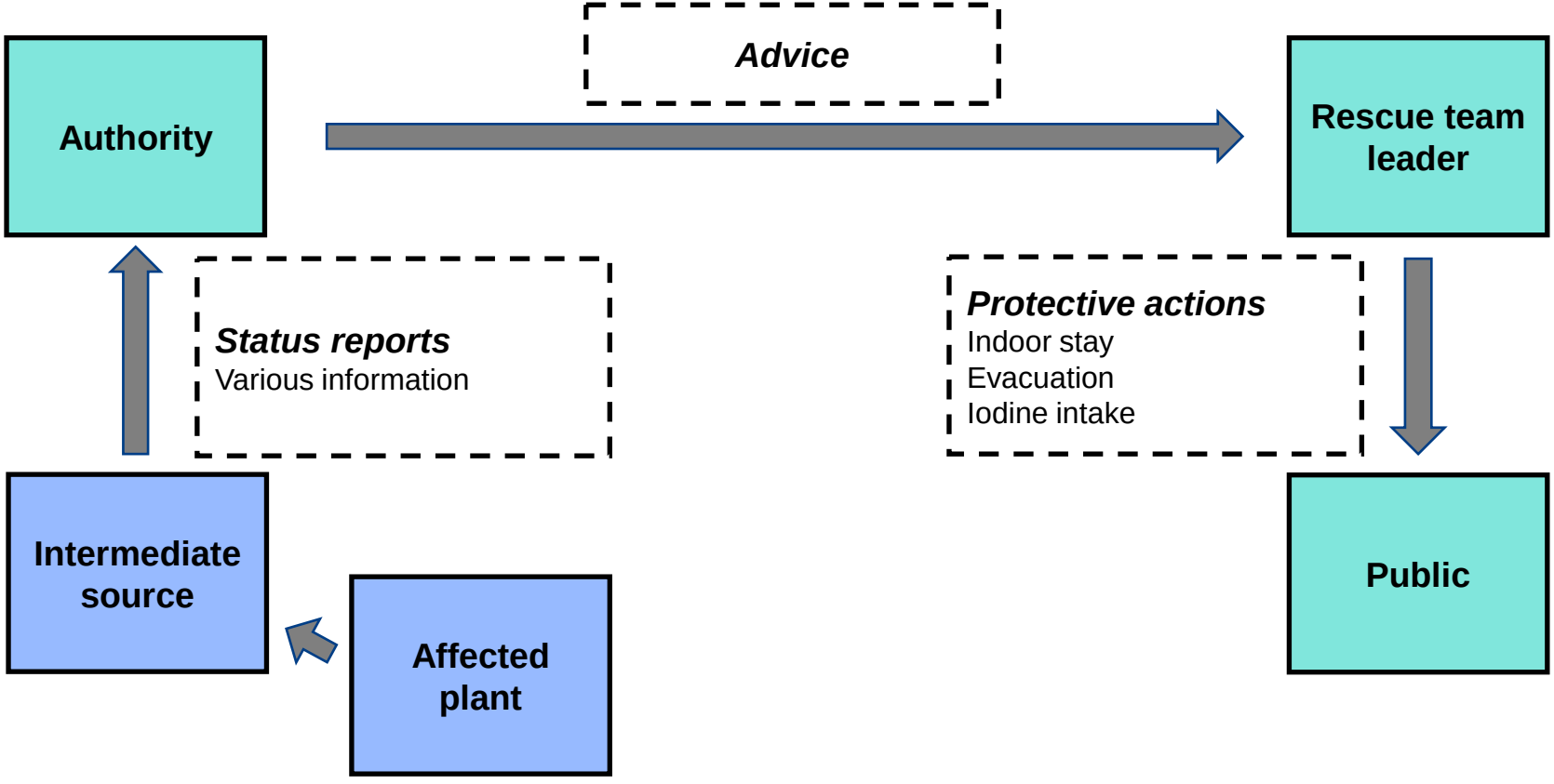
- To make appropriate decisions on emergency response, there is a need to make predictions of the potential consequences of an ongoing event.

- Two basic approaches
  - **Deterministic** Use simulation of the ongoing situation to calculate radioactive releases (*the source term*).
  - **Probabilistic** Perform source term simulation of a number of representative scenarios beforehand. Use probability data to select the most likely one for the ongoing situation.

Domestic context



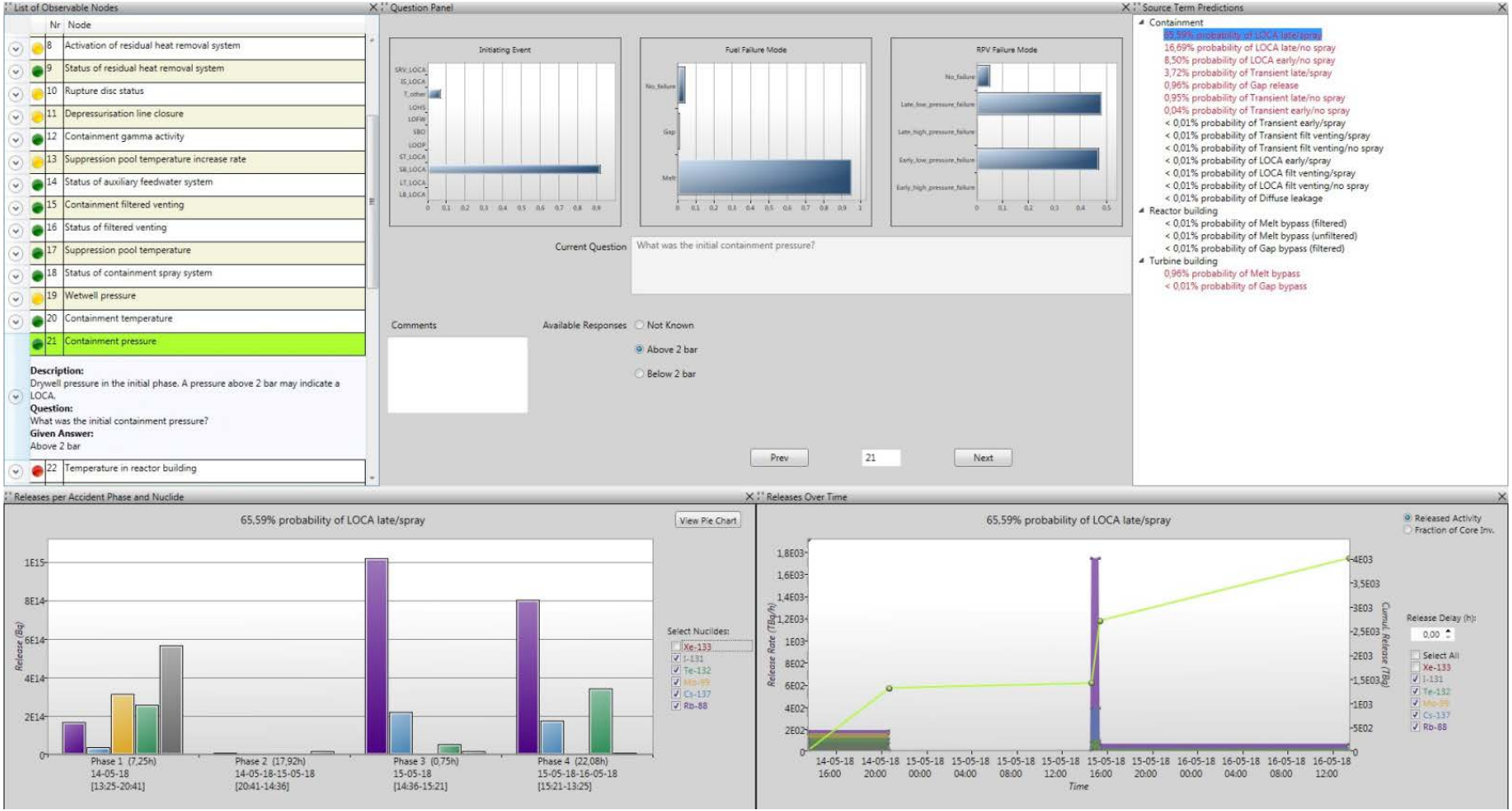
International context



RASTEP – RApid Source TErm Prediction

- The development of RASTEP started in 2009 in cooperation between SSM and LR.
- Provides emergency preparedness organisations with the possibility to estimate a source term independently in stressed situations with lack of information.
- Source term estimate**s** are given with associated likelihood**s**
- A simple interface asks the user questions on observations of the ongoing event.

Graphical user interface



FASTNET (Fast Nuclear Emergency Tools)

European commission funded project

- Aiming to develop and harmonize nuclear emergency response across the European Union.
- Participating organisations are authorities or technical support organisations from EU as well as from Norway, Canada and Russia.
- RASTEP and PERSAN were initially chosen as representatives for the two complementary approaches (Probabilistic & Deterministic).
- Five work packages
  - WP1 - Development of deterministic calculations database
  - WP2 - Adaptation of RASTEP and PERSAN models
  - WP3 - Adaptation of RASTEP and PERSAN methodology
  - WP4 - Exercises
  - WP5 - Dissemination

RASTEP basics

RASTEP – RApid Source TErm Prediction

- Deterministic source term calculation in real time is difficult, especially in a stressed situation with lack of information.
- An alternative to the real-time deterministic approach is to use a set of pre-calculated source terms and make selections in this set.
- RASTEP makes such a selection based on probabilistic data and any available information from the plant. The relations between these entities are represented in a probabilistic model called a Bayesian Belief Network (BBN).
- Expert judgements will always play an important role. One advantage of the BBN approach is that expert judgements can be built into the model beforehand.

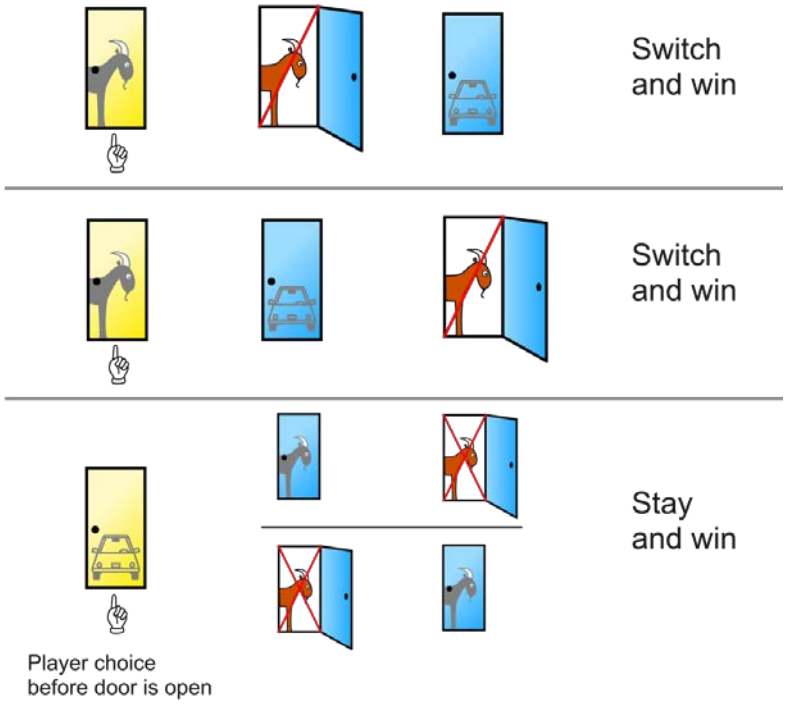
Bayesian Belief Networks (BBN)

Using Bayes theorem, prior belief in an event (hypothesis) can be updated given additional evidence (observation, finding):

$$P(State|Observation) = \frac{P(Observation|State) \cdot P(State)}{P(Observation)}$$

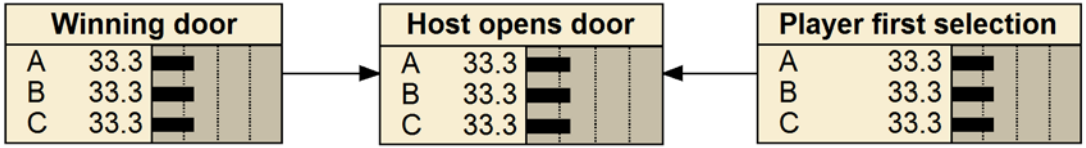
Bayesian Belief Networks (BBN)

Monty Hall problem



Bayesian Belief Networks (BBN)

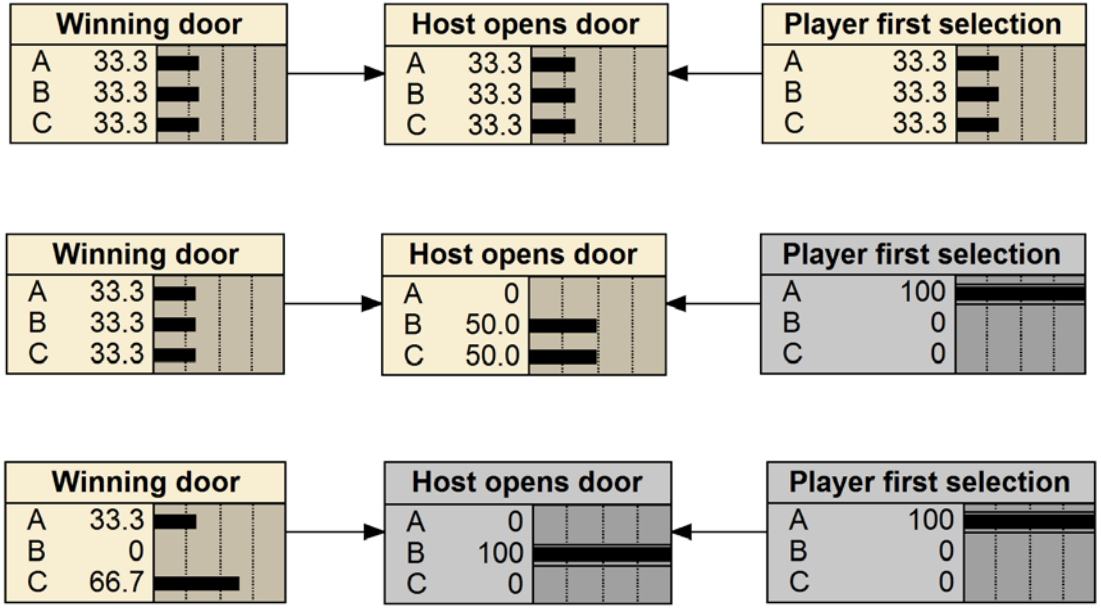
Monty Hall problem



Player first selection	Winning door	A	B	C
A	A	0.000	50.000	50.000
A	B	0.000	0.000	100.00
A	C	0.000	100.00	0.000
B	A	0.000	0.000	100.00
B	B	50.000	0.000	50.000
B	C	100.00	0.000	0.000
C	A	0.000	100.00	0.000
C	B	100.00	0.000	0.000
C	C	50.000	50.000	0.000

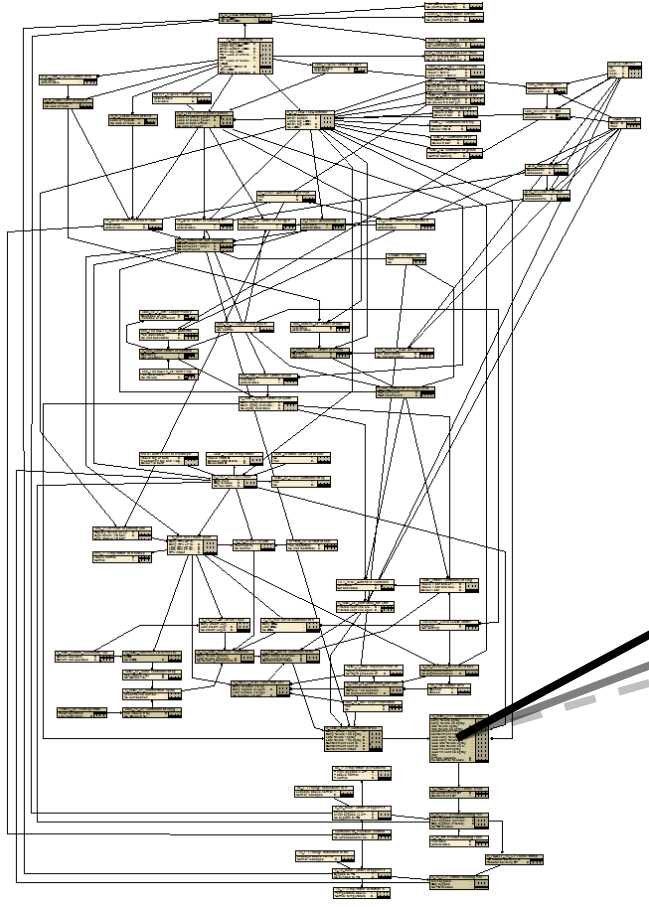
Bayesian Belief Networks (BBN)

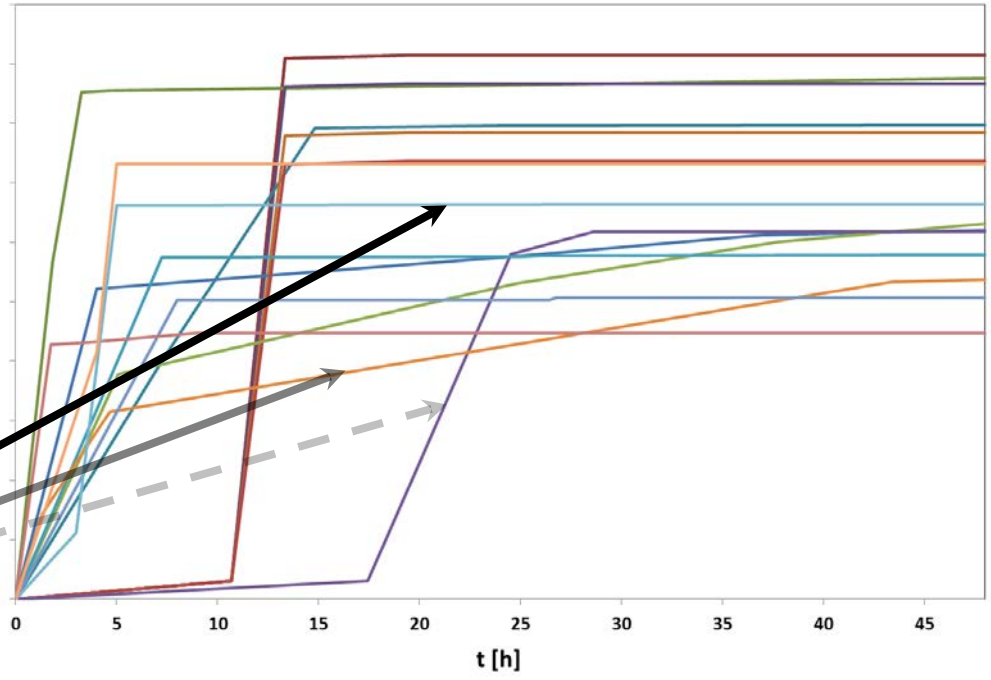
Monty Hall problem



Player first selection	Winning door	A	B	C
A	A	0.000	50.000	50.000
A	B	0.000	0.000	100.00
A	C	0.000	100.00	0.000
B	A	0.000	0.000	100.00
B	B	50.000	0.000	50.000
B	C	100.00	0.000	0.000
C	A	0.000	100.00	0.000
C	B	100.00	0.000	0.000
C	C	50.000	50.000	0.000

BBN and source terms





RASTEP model library

Type	Plant
PWR	Ringhals 3 & (4) for SSM Generic PWR for FASTNET
BWR	Oskarshamn 1 for SSM Oskarshamn 2 for SSM Oskarshamn 3 for SSM Forsmark (1) & 2 for SSM Forsmark 3 for SSM Generic BWR for FASTNET
CANDU	Generic single-unit CANDU6 for FASTNET
VVER	Generic VVER 440-213 for FASTNET
Spent fuel storages	Halden reactor facility for NRPA Generic SFP for FASTNET

User results

Preliminary RASTEP results from FASTNET WP4 exercise 1

18 organisations with varying experience on nuclear power plants and RASTEP

- **Generic PWR model - LOCA with failing ECCS and CSS**
  Responses received:15
  Representative scenario: 50-60 % of responses
  Correct scenario: 33 % of responses
- **Generic BWR model - LOCA with failing ECCS and CSS**
  Responses received: 14
  Representative scenario: 100 % of responses
  Correct scenario: 85 % of responses
- **Generic CANDU6 model - Station blackout**
  Responses received:15
  Representative scenario: 70-100 % of responses
  Correct scenario: 60 % of responses
- **Generic VVER440-213 model - Station blackout**
  Responses received:12
  Representative scenario: 75 % of responses
  Correct scenario: 75 % of responses

Some food for thought

If we have a core melt, what then?

- Typical conditional probabilities of scenarios for various nuclear power plants (large variations however!)
  - Diffuse leakage 70 %
  - Filtered venting, no containment spray 15 %
  - Filtered venting, containment spray 4 %
  - Large (early) releases 1 %
  - Other scenarios 10 %

Concluding remarks

RASTEP is a decision support tool for nuclear emergency situations

- RASTEP uses best available knowledge and observations of an event, and estimates associated representative source terms and likelihoods.
- RASTEP models are flexible and can be modified by the user.
- RASTEP also supports what-if-analyses and emergency response exercises

Future

Continuous development

Examples

- Adaptation of result export to IAEA IRIX format
- Automated transfer of plant parameters into RASTEP (pilot study ongoing with SSM)

- Improved formulation of questions to minimize uncertainty due to misinterpretation
- Improved visualization of uncertainty in prediction and underlying source term data
- Fine-tuning of source term calculation directly in RASTEP

https://www.lr.org/rastep

Thank you

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