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

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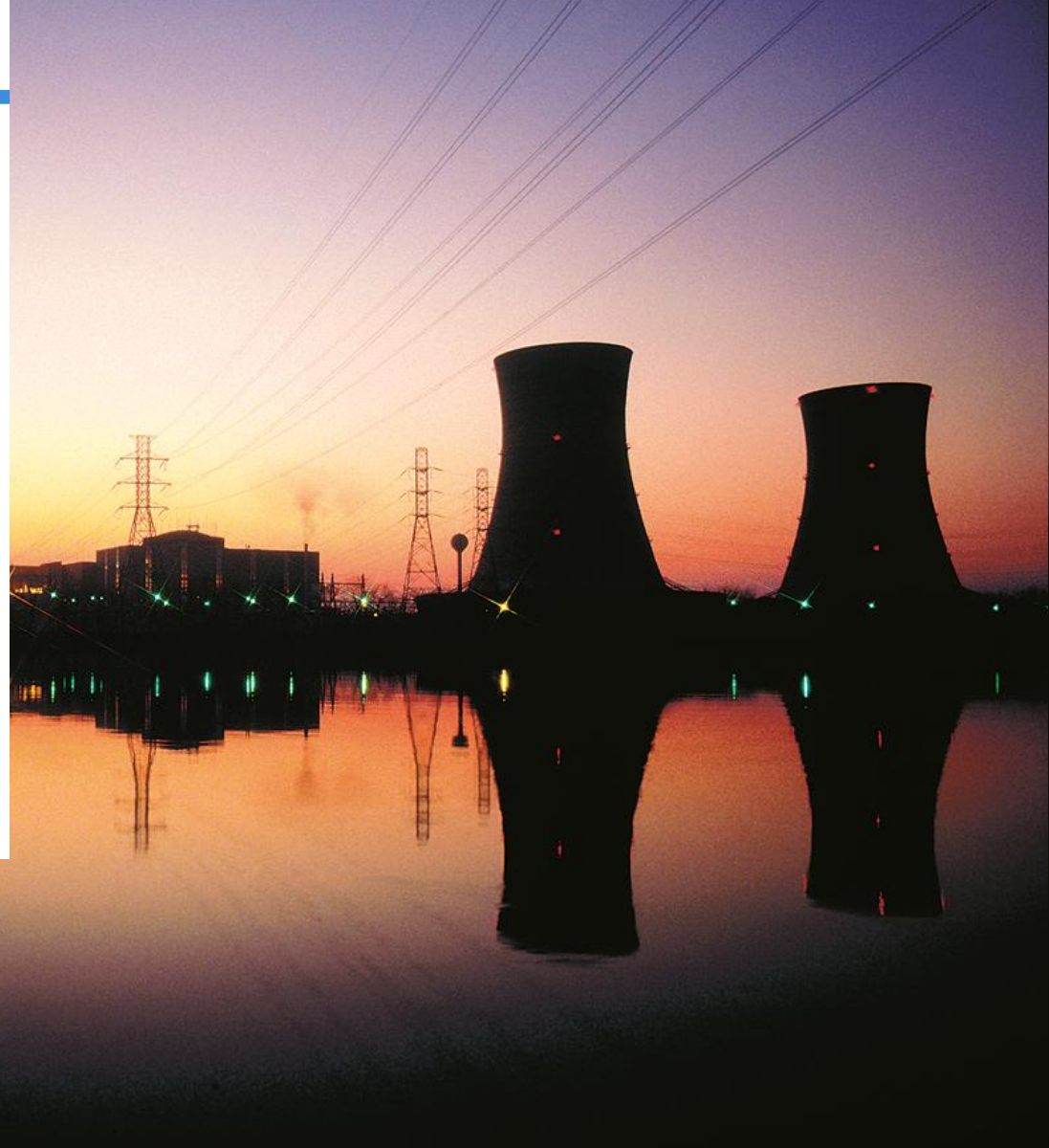
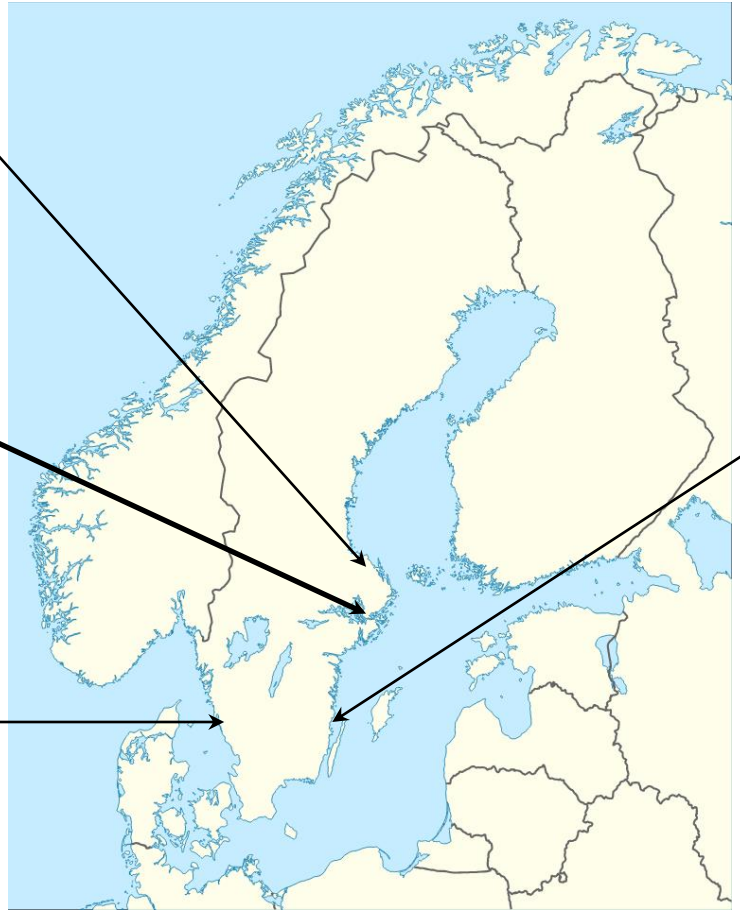


RASTEP – Context and SSM application



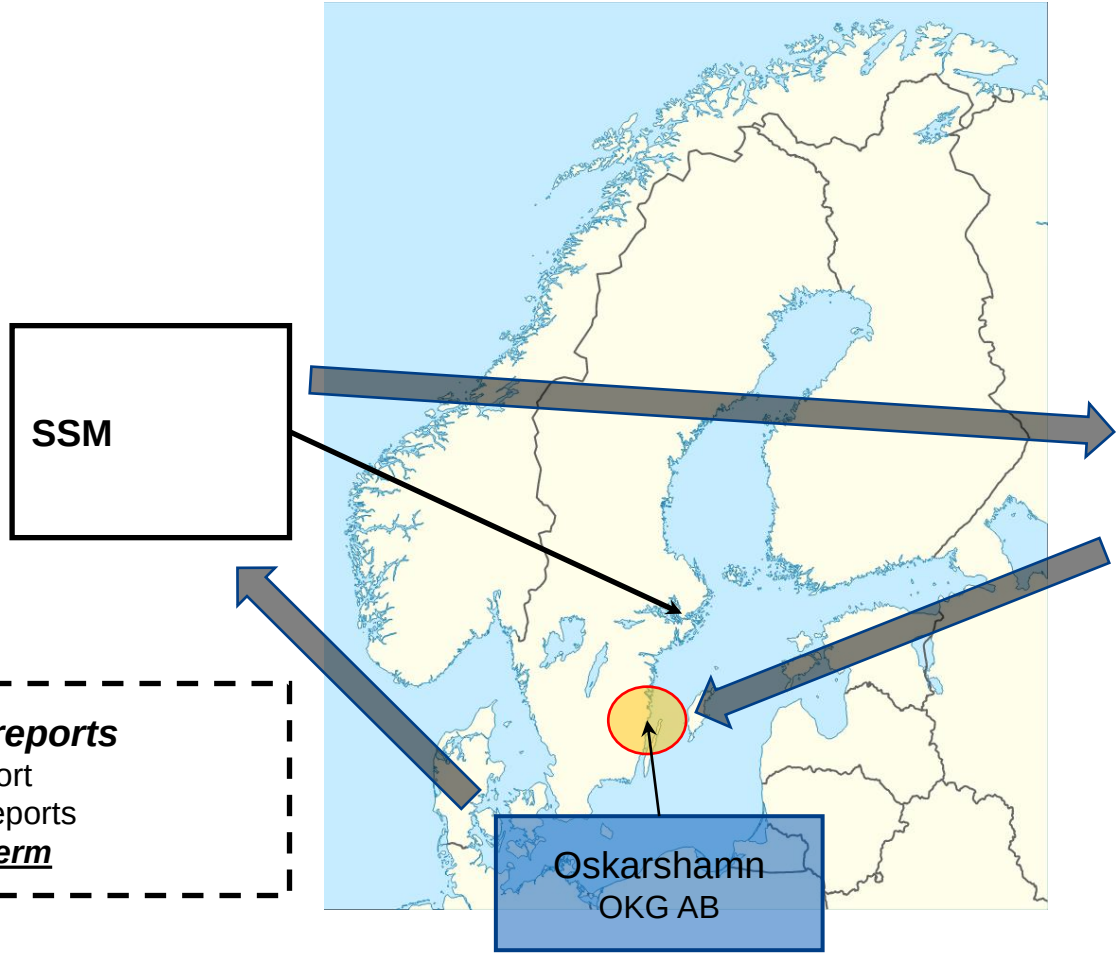
Forsmark
3 BWR

Swedish Radiation Safety Authority SSM

Ringhals
3 PWR
1 BWR

Oskarshamn
1 BWR (3900 MW_{Th})

RASTEP – Context and SSM application



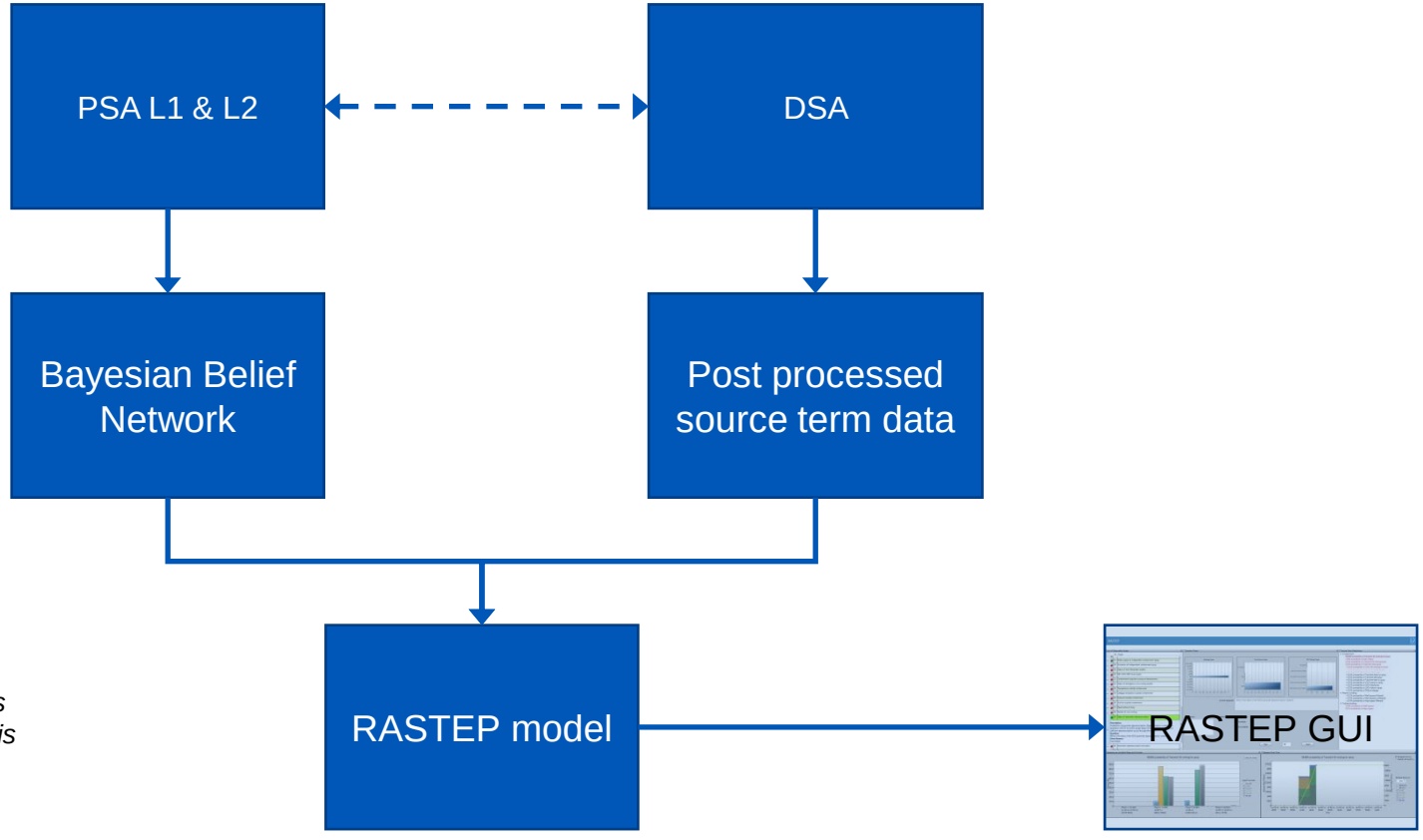
Source: www.msb.se

RASTEP – Context and SSM application

RASTEP – RApid Source TErm Prediction

- The development of RASTEP started in 2009 in cooperation between SSM and LR.
- Provides emergency preparedness organisations with an independent view of the accident progression and possible off-site consequences.
- **Model starting point:**
  - Initiating event
- **Model end point / results:**
  - Source term rankings with associated likelihoods
- Export functionality to interface with off-site consequence analysis tools, e.g. ARGOS and possibility to export data using the IRIX format.
- Simple user interface.

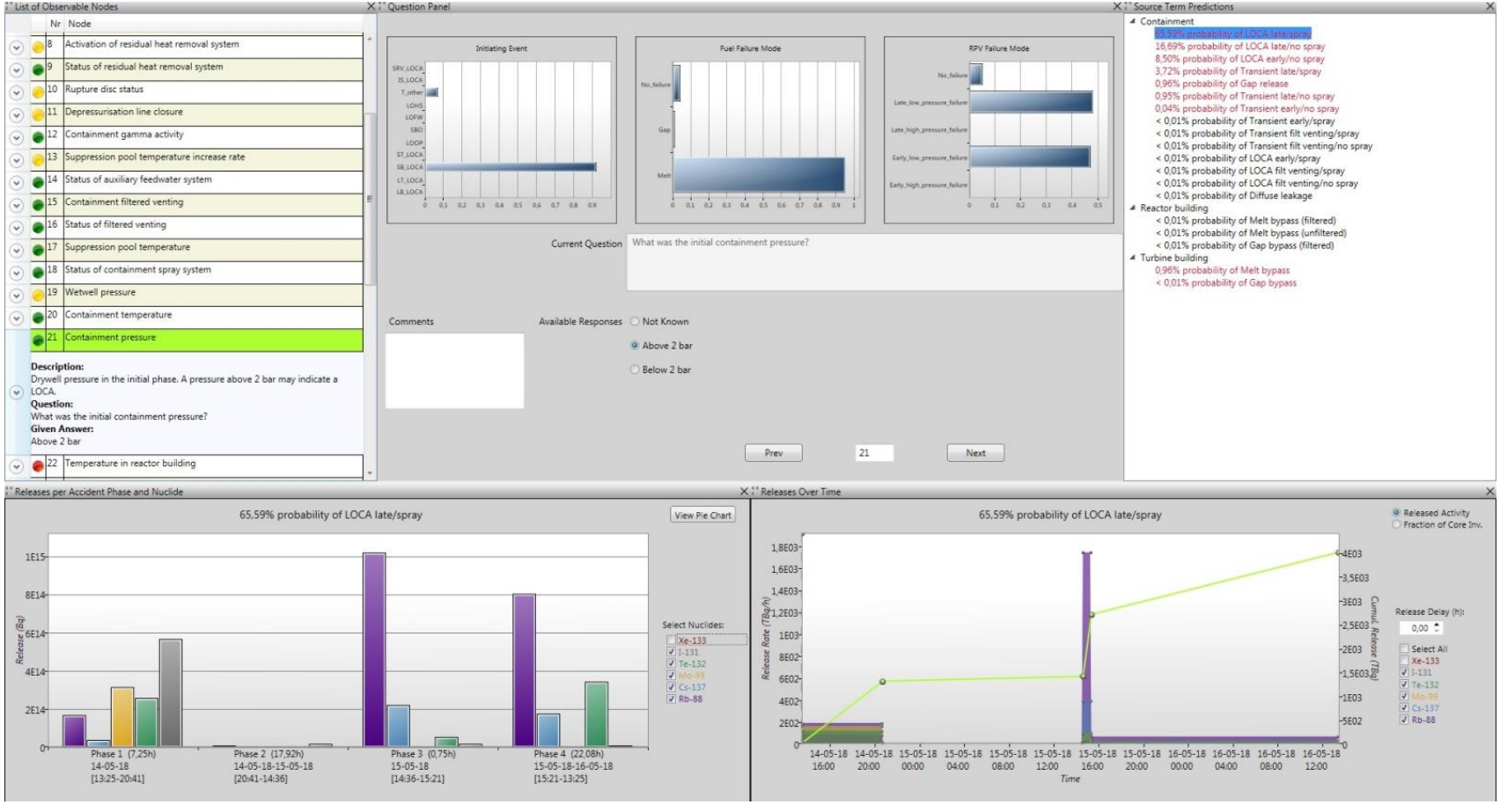
RASTEP overview



Abbreviations

PSA	*Probabilistic Safety Analysis*
DSA	*Deterministic Safety Analysis*
GUI	*Graphical User Interface*

Graphical user interface



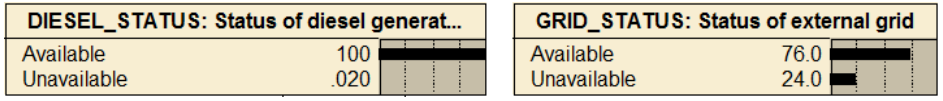
Bayesian Belief Networks (BBN)

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

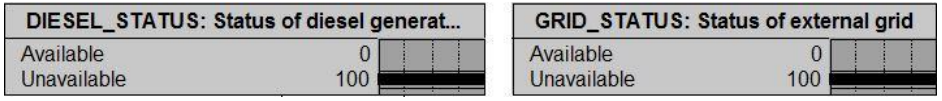
$$P(State|Observation) = \frac{P(Observation|State) \cdot P(State)}{P(Observation)}$$

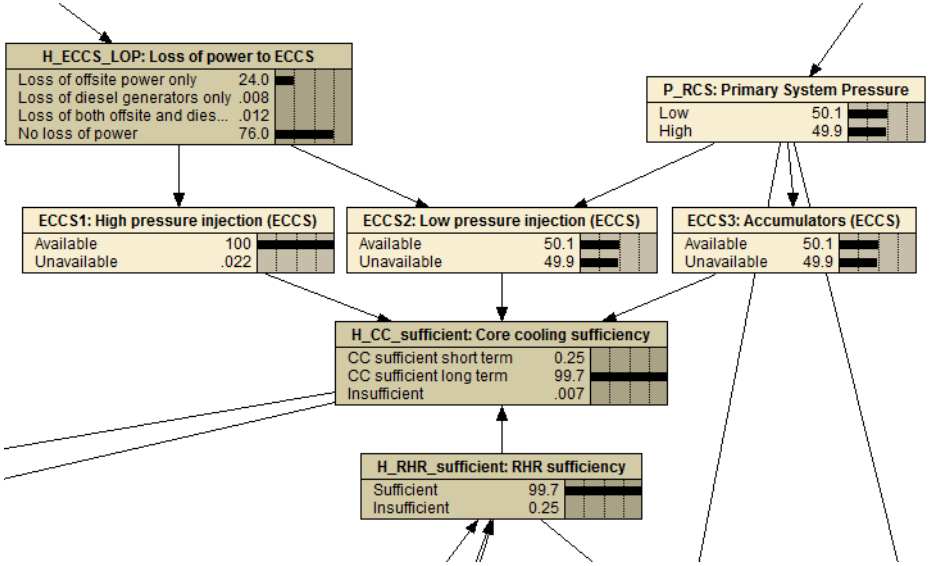
Example: BBN for emergency core cooling for PWR plant

Starting point (no observations made)

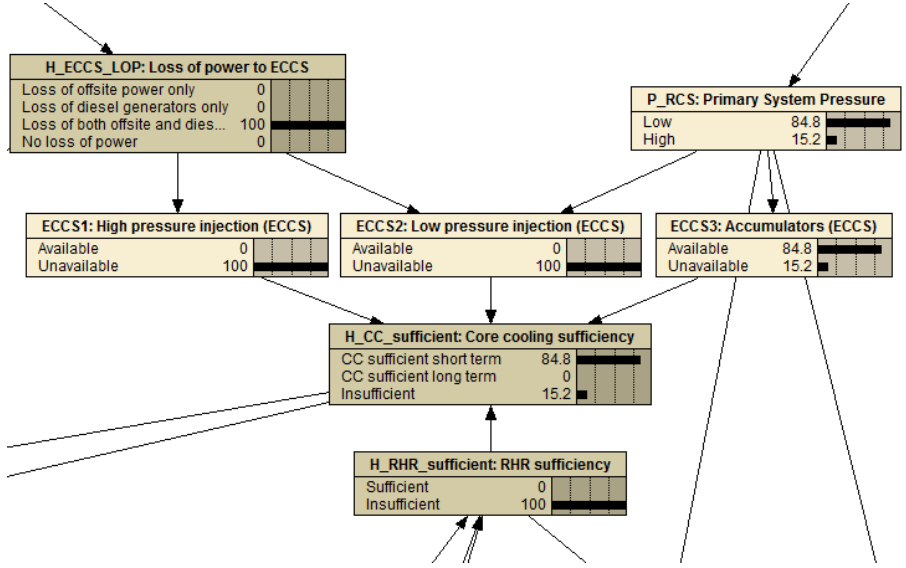


Updated beliefs due to observations





Leads to update of belief in all nodes



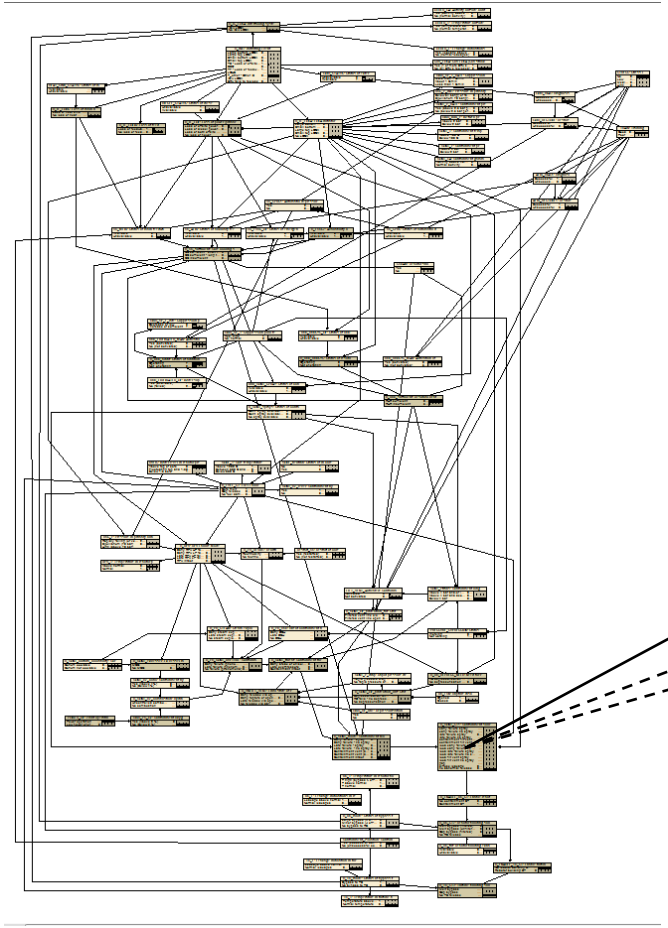
Source terms

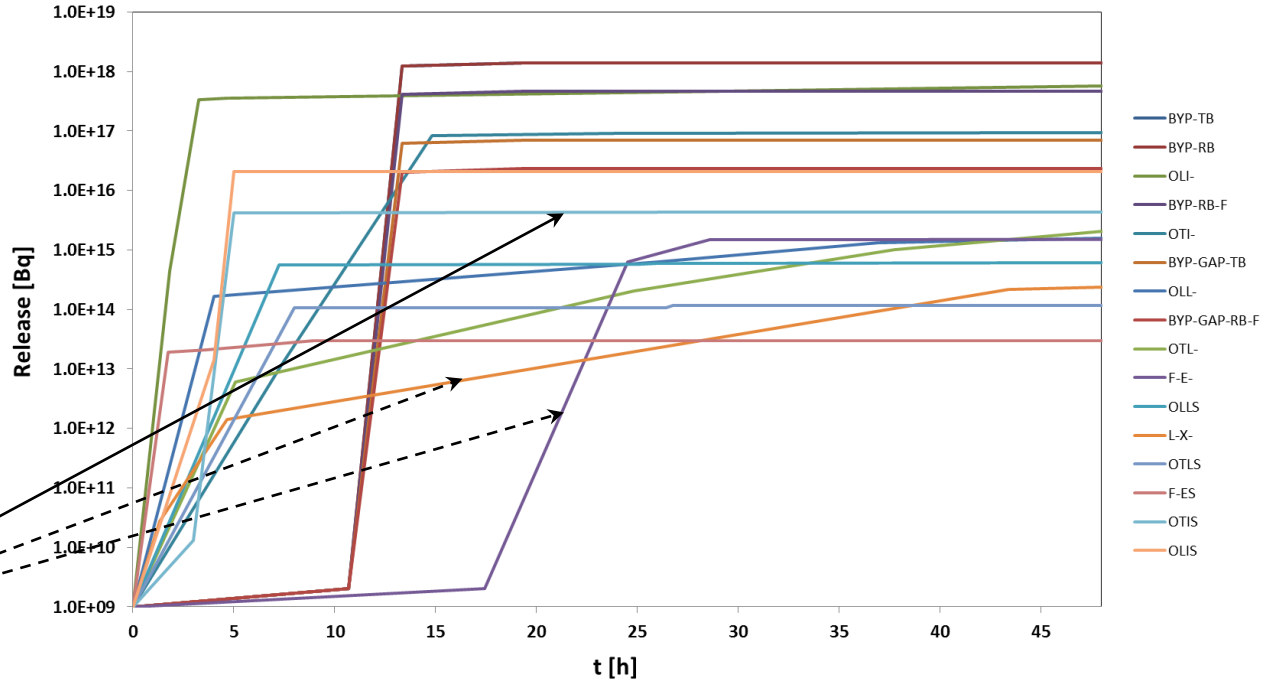
- Source terms for RASTEP models are pre-calculated and can thus come from any appropriate software (MAAP / MELCOR / ASTEC etc.)

- The main requirement is that the simulations used for the source term set have a logical connection to the BBN.

- Source terms can be post-processed for customization to customer requirements, including
  - Nuclide selection
  - Source term phasing
  - Simple models for decay and growth during accident sequence

BBN and source terms - the combination





Modeling

Overview of procedure for creating a RASTEP model

- Gather data
  - Probabilistic data, mostly on function level
  - Source terms
- Create BBN with relevant level of detail in initiating events, barriers, safety functions and end states.
- Couple observable BBN nodes with questions and link them to the RASTEP GUI.
- Couple BBN end states with source term set.
- BBNs are built in Netica and source terms are gathered in Excel files. RASTEP will therefore never be a black box.
- The level of detail in both BBN and source term set is flexible.

Modelling - models developed by LR

Type	Plant
PWR	Ringhals 3 & (4) Generic PWR
BWR	Oskarshamn 1 Oskarshamn 2 Oskarshamn 3 Forsmark (1) & 2 Forsmark 3 Generic BWR
CANDU	Generic single-unit CANDU6
VVER	Generic VVER 440-213
SFP	SFP for Halden reactor (Ongoing) Generic SFP (Ongoing)

Concluding remarks

Tool for prognosis and source term estimation

- RASTEP provides the most likely end state based on observations and best available knowledge during a nuclear accident and estimates an associated representative source term.

- RASTEP models are flexible and can be modified by the user.

- RASTEP also supports:
  - What-if-analyses in conjunction with severe accident sequences
  - Emergency response exercises

Future

Continuous development

Examples

- Automated transfer of plant parameters into RASTEP (SSM project, pilot study ongoing)
- Fine-tuning of source term directly in RASTEP

- Possibility to display uncertainty bounds in underlying source term data
- General development of user friendliness
- Data sensitivity analysis
- Improved visualization of underlying BBN
- Built-in source term calculation engine

https://www.lr.org/rastep

Thank you

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