

PRAMEA – Probabilistic risk assessment method development and applications

Presentation at the SAFIR2018 research programme final seminar, Hanasaari 21.3.2019



Aalto University

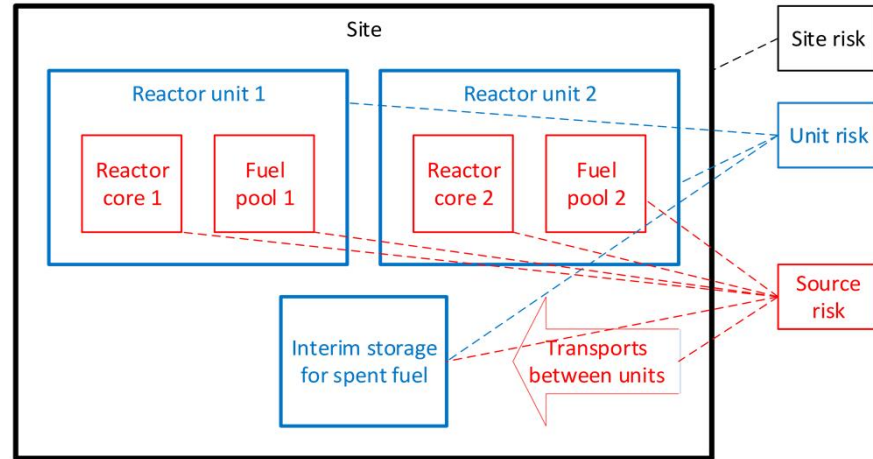


HRA and advanced control rooms

- § Accepted review manuscript about the effect of digitalization of NPP control rooms, in RESS (Reliability Engineering and System Safety)
 - Digital systems provide operator with more information but also with secondary tasks, compared with analogue systems
 - With digital UI, operator is not self-evidently aware of activities of other operators
 - Digital systems are more often updated, causing pressure to plant design and training
- § User study among Finnish hybrid main control room operators about possible human errors in an emergency; comparison of errors
 - Operator interviews related to PRISE procedures in a hybrid control room (analogue for controlling, digital for monitoring the system) about possible errors
 - In practice, less possible errors in digital UI (user interface)
 - In principle, in most cases the same error could take place in both types of UIs
- § The cause behind digitally originating/analogue originating error may be different → may affect error probability BUT the mere digitality/analogueity does not dictate the amount or level of human errors

Site risk analysis

- Current PRAs are unit-specific
 - Inter-unit dependencies taken into account in a limited manner
- Operational experience world-wide shows that multi-unit disturbances are not uncommon
- No international consensus yet with regard to
 - Applicable risk criteria for a site
 - Method



Site PRA developments and findings: NKS project SITRON, report NKS-419

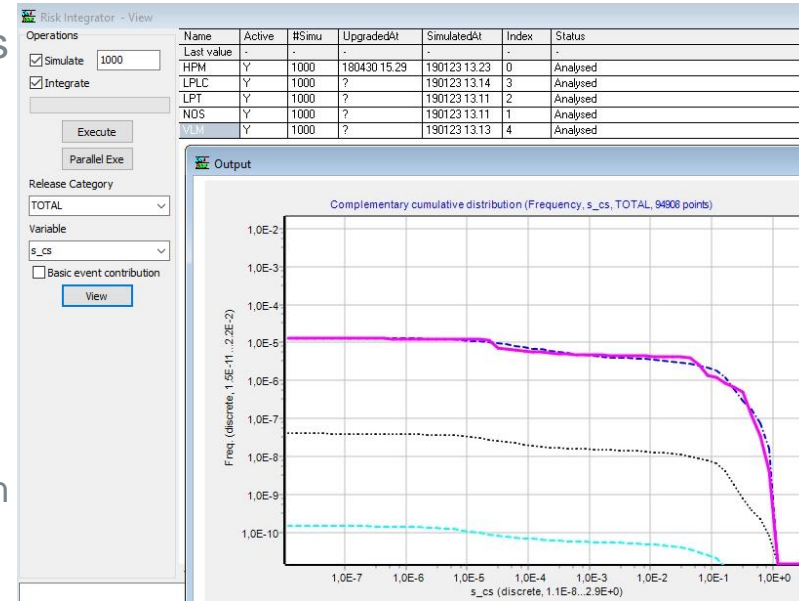
- Site risk analysis has two purposes
 - Complement single-unit PSAs
 - Provide multi-unit risk metrics
- Safety goals are still connected to units, not at site level



- SITRON method provides a practical and cost-effective way of performing a site risk analysis based on unit-specific PRAs
- Multi-unit initiating events can be limited to external hazards
 - Loss-of-offsite power, Loss-of-ultimate heat sink

FinPSA level 2

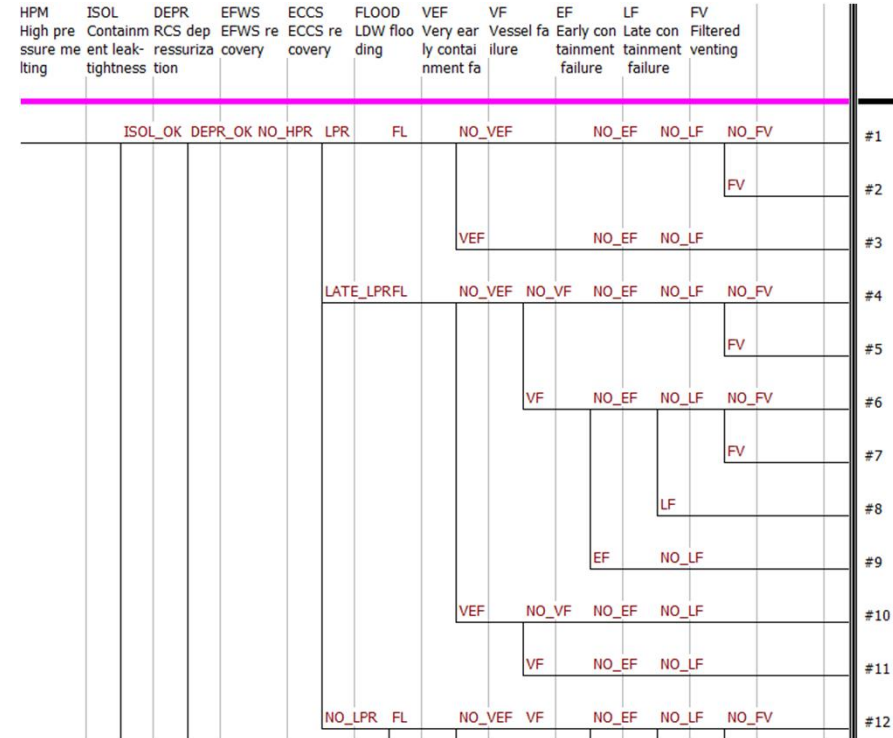
- § Tool based on dynamic containment event trees (CETs) developed further
- § Risk integrator combines results of different CETs and calculates total results
- § Tight integration of PRA levels 1 and 2 implemented
 - Contributions of basic events and initiating events in level 2 results
 - Level 1 results can be utilised in level 2 modelling



Level 2 PRA modelling

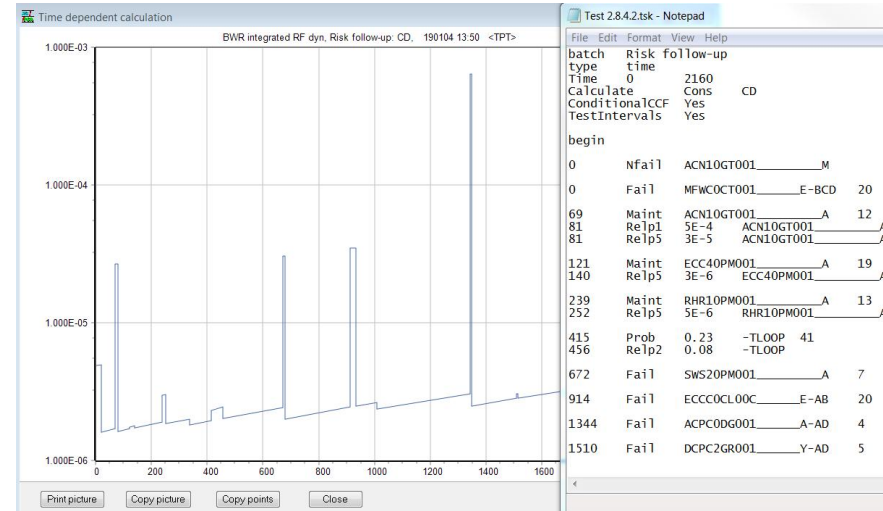
- § A simplified BWR plant PRA model has been developed
 - Five containment event trees
 - Levels 1 and 2 tightly integrated
 - Model can be utilised in further research, demonstrations, trainings and FinPSA testing

- § Uncertainty analysis
 - Problems and good practises identified and demonstrated
 - In dynamic modelling, proper handling of epistemic and aleatoric uncertainties is important



Time-dependent analysis in FinPSA

- § Can be used for maintenance planning, risk follow-up and analysis of seasonal variations
- § Time-dependent task file
 - User specifies events to a time line
 - e.g. maintenance activities, tests, parameter changes, configuration changes
 - FinPSA calculates time-dependent risk curve, using existing PRA results



Level 3 PRA

Improvements to an analysis method

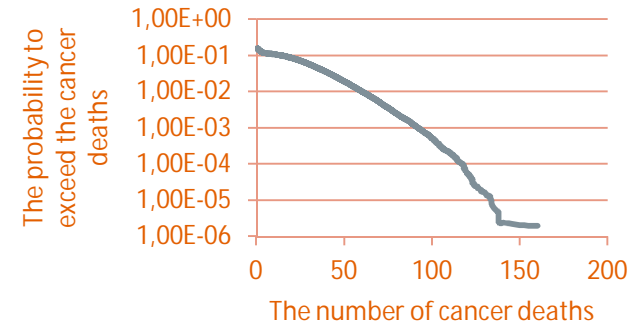
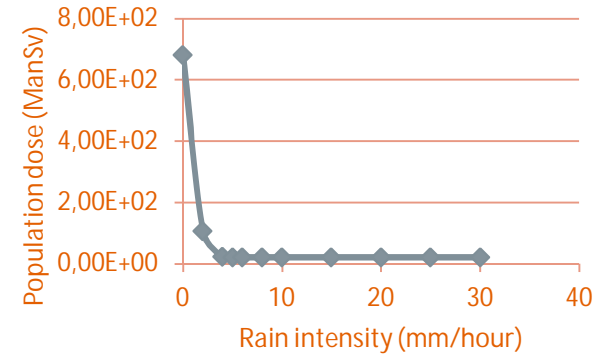
- Developed earlier by VTT
- Systematic analysis of scenarios with event trees
- Improvements: no discretization of continuous factors (e.g. wind speed) needed, source term uncertainty taken into account

Nordic guidance document on level 3 PRA

- Uses, benefits, regulations, analysis steps etc.

Seasonal and contextual factors in level 3

- Groundwork for systematic incorporation in analyses



Portfolio optimization in PRAMEA

§ Pipe inspections (c.f. RI-ISI)

- **Problem:** Which pipes should be inspected based on incomplete information about failure probabilities and failure impacts?
- Large-scale optimization of inspections of the sewerage network in Espoo



§ Defence-in-depth

- **Problem:** Which combinations of safety measures are cost-efficient in a system with event dependencies and multi-state failures?
- Optimization of safety measures for the airlock system of a CANDU Nuclear Power Plant

