

Severe Accident Management at the Loviisa NPP - Application of Integrated ROAAM and PSA level 2

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Overview

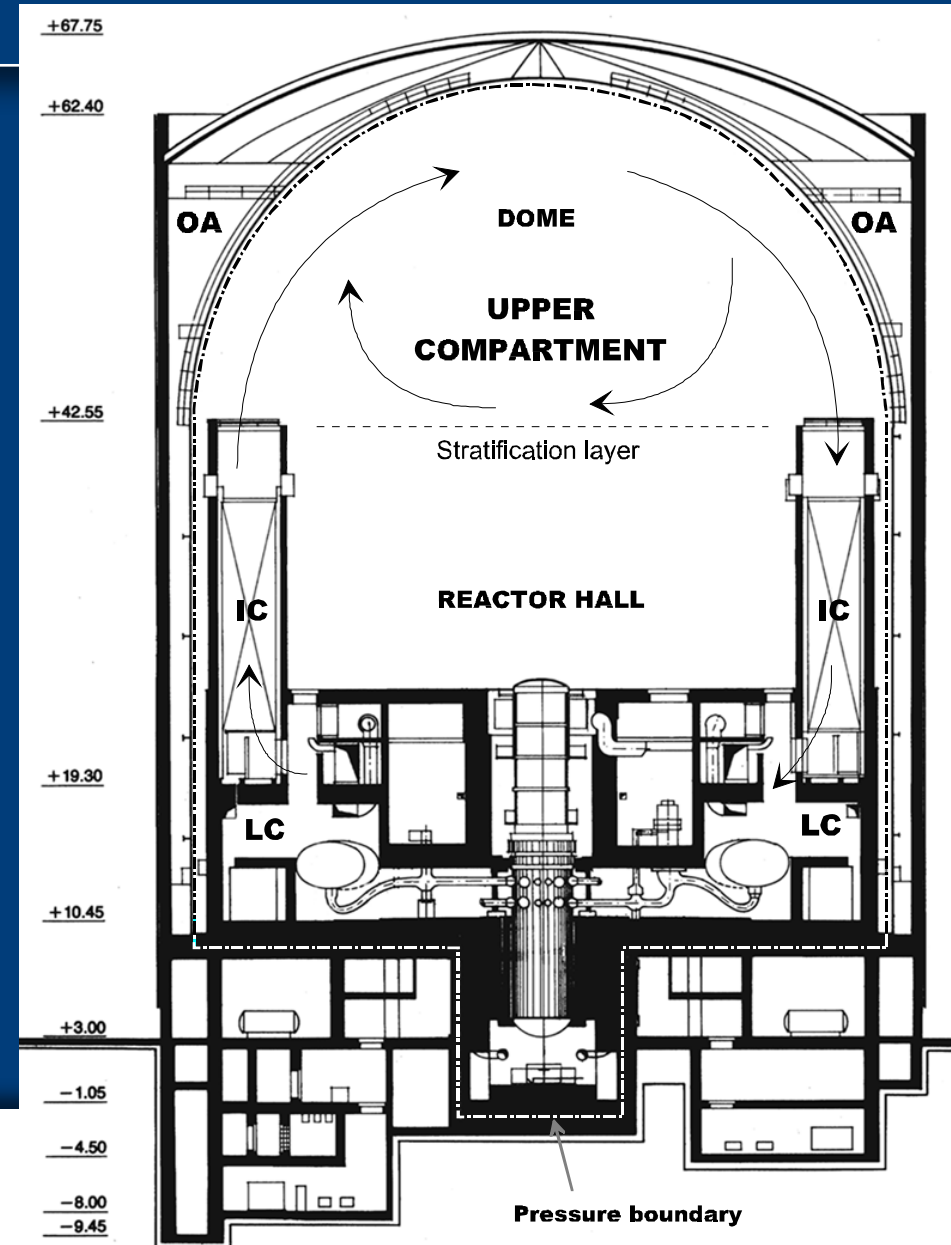
- How Integrated ROAAM has been the key element when constructing well balanced SAM strategy for Loviisa NPP and how the use of Integrated ROAAM analysis has affected level 2 PSA studies
- PSA and ROAAM - advantages in combining two approaches
- ROAAM - credible treatment of phenomenological uncertainties
- Integrated ROAAM - balance between accident prevention and mitigation of containment threatening phenomena
- Going further than ROAAM - Level 2 PSA source term calculations

Contents

- SAM strategy of Loviisa NPP
 - unique features of the plant
 - main aspects of Integrated ROAAM approach
 - phenomenological uncertainties using ROAAM (shortly)
 - overall SAM approach, SAM safety functions
- Level 2 PSA
 - influence of the Integrated ROAAM study
- Summary and conclusions

Loviisa NPP - unique features

- VVER-440 with ice condenser containment
 - steel shell
 - design pressure 1.7 bar (ultimate failure pressure well above 3 bar)
 - low leakage (0.2 %/d)
 - 57 000 m³
 - 835 000 kg ice
- Low decay power level
- Narrow cavity, no penetrations in the RPV lower head



Integrated ROAAM approach - safety goal

"Containment failure at the plant is a physically unreasonable event for any accident sequence that is not remote and speculative"

- at a sufficient level of evidence to the contrary, certain postulated events can be considered "physically unreasonable" (safety goal component focused on physics)
- at a certain high level of reliability, system failure can be considered as "remote and speculative" (equipment/system based component of safety goal)
- Sufficient measures have to be taken at the plant to ensure that high consequence hazards can't happen

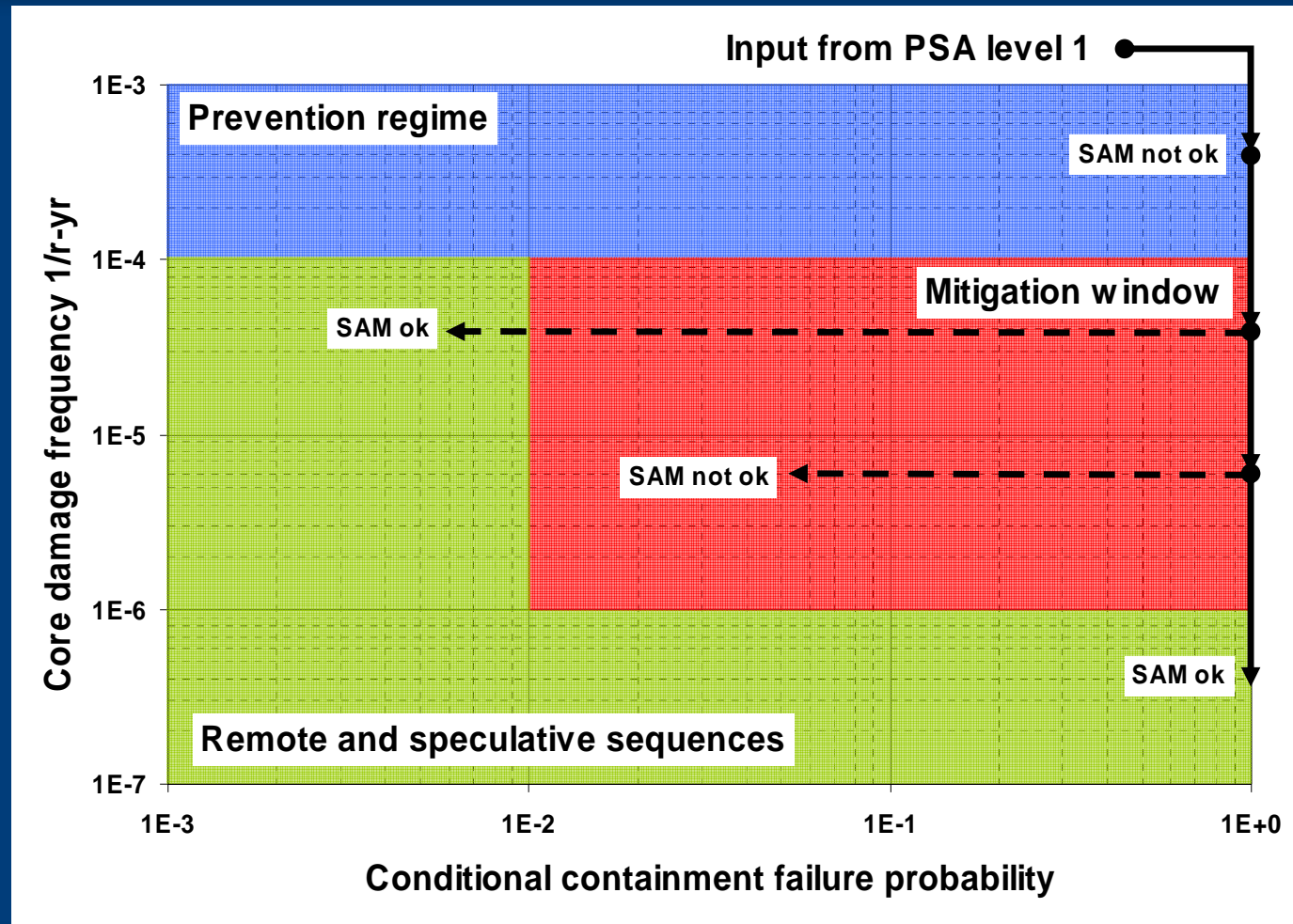
Integrated ROAAM - implementation

- complete system analysis (level 1 PSA)
- "safeguards tree" (an event tree that assesses the availability of safeguards systems)
- use of a screening frequency (determines which accident classes can be considered as "remote and speculative")
- showing that containment failure is "physically unreasonable" or if this is not the case, finding the measures to achieve this goal (ROAAM in issue resolution context)

The idea of Integrated ROAAM

For Loviisa NPP

- screening frequency 10^{-6} 1/r-yr
- design target for failure of each safeguards function $< 10^{-2}$ / demand



Phenomenological uncertainties using ROAAM

- Understanding the phenomena underlying physics (careful studies involving modelling and experimental verification)

The key elements of ROAAM:

- Physically-based decomposition that allows transparency in separating out the essential portions of epistemic uncertainty
- Probabilistic framework (causal relations and intangible parameters)
- Causal relations (key physics) represent well-posed problems. Uncertainty can be reduced to the parameter level (no major modelling uncertainty)
- "Splinter" scenarios in combination with conservative estimates of epistemic uncertainty, so as to obtain convincingly conservative results

ROAAM - studies in Loviisa NPP

IVR:

- Extensive research program (analytical and experimental studies) for demonstrating coolability of corium on the lower head of the reactor pressure vessel
- RPV failure can be considered as "physically unreasonable" situation when requirements (depressurization, lowering of RPV lower head insulation and neutron blocks) are fulfilled

Hydrogen management

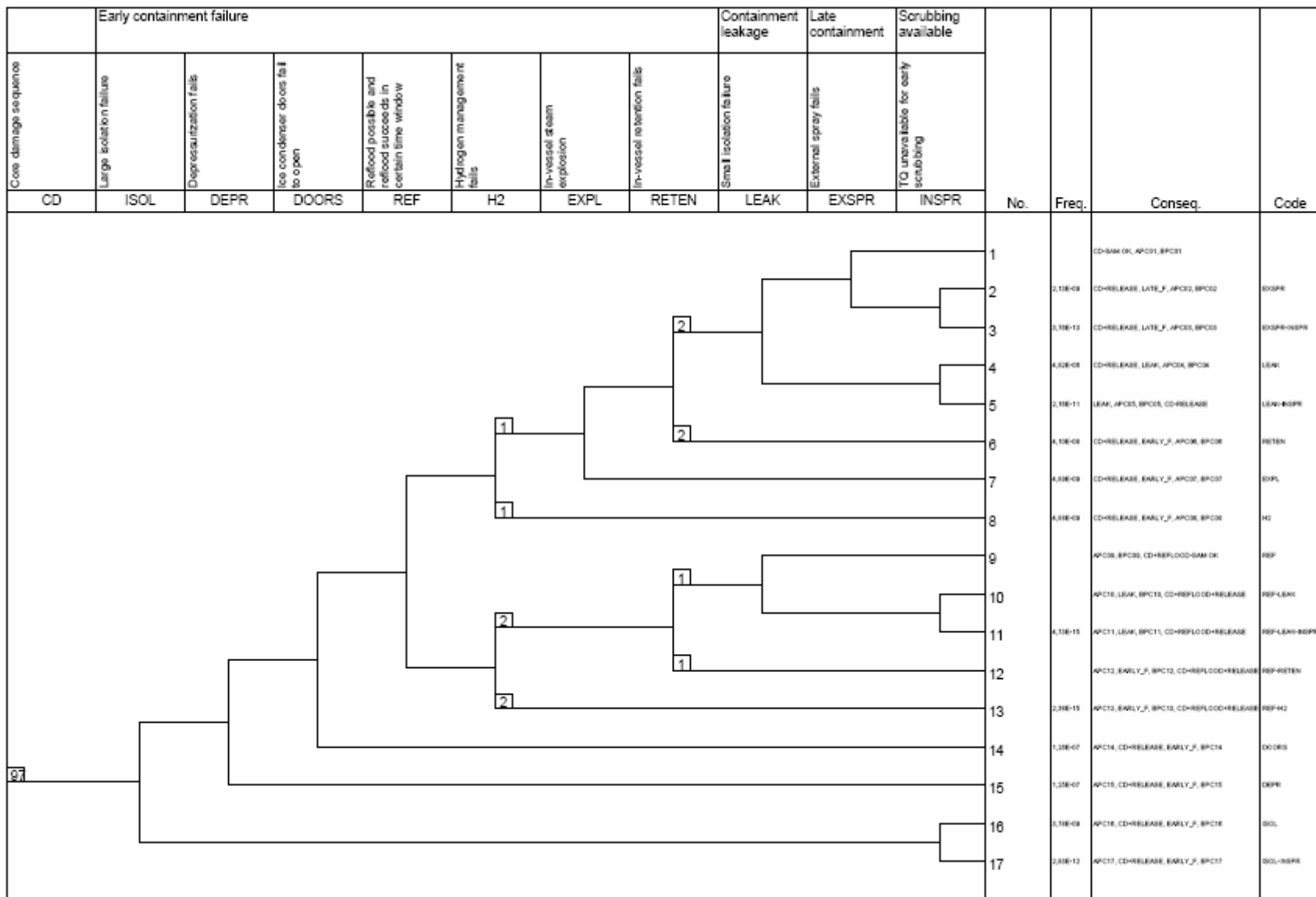
- Significant experimental and analytical efforts
- Current strategy (forcing open ice condenser doors, passive catalytic recombination and deliberate ignition) entailed significant plant modifications
- Containment failure "physically unreasonable" with the new hydrogen management strategy in place

Overall SAM approach in Loviisa NPP

- Prevention of core damage and sequences with imminent threat of large radioactive releases and mitigation of containment threatening phenomena along the lines of Integrated ROAAM
- SAM safety functions
 - successful containment isolation
 - primary system depressurization
 - mitigation of hydrogen combustions (absence of energetic events)
 - cooling of reactor core or core debris
 - mitigation of slow overpressurization
- Hardware and I&C modifications, SAM guidelines, SAM handbook, revision of emergency preparedness organization, versatile training approaches

Level 2 PSA

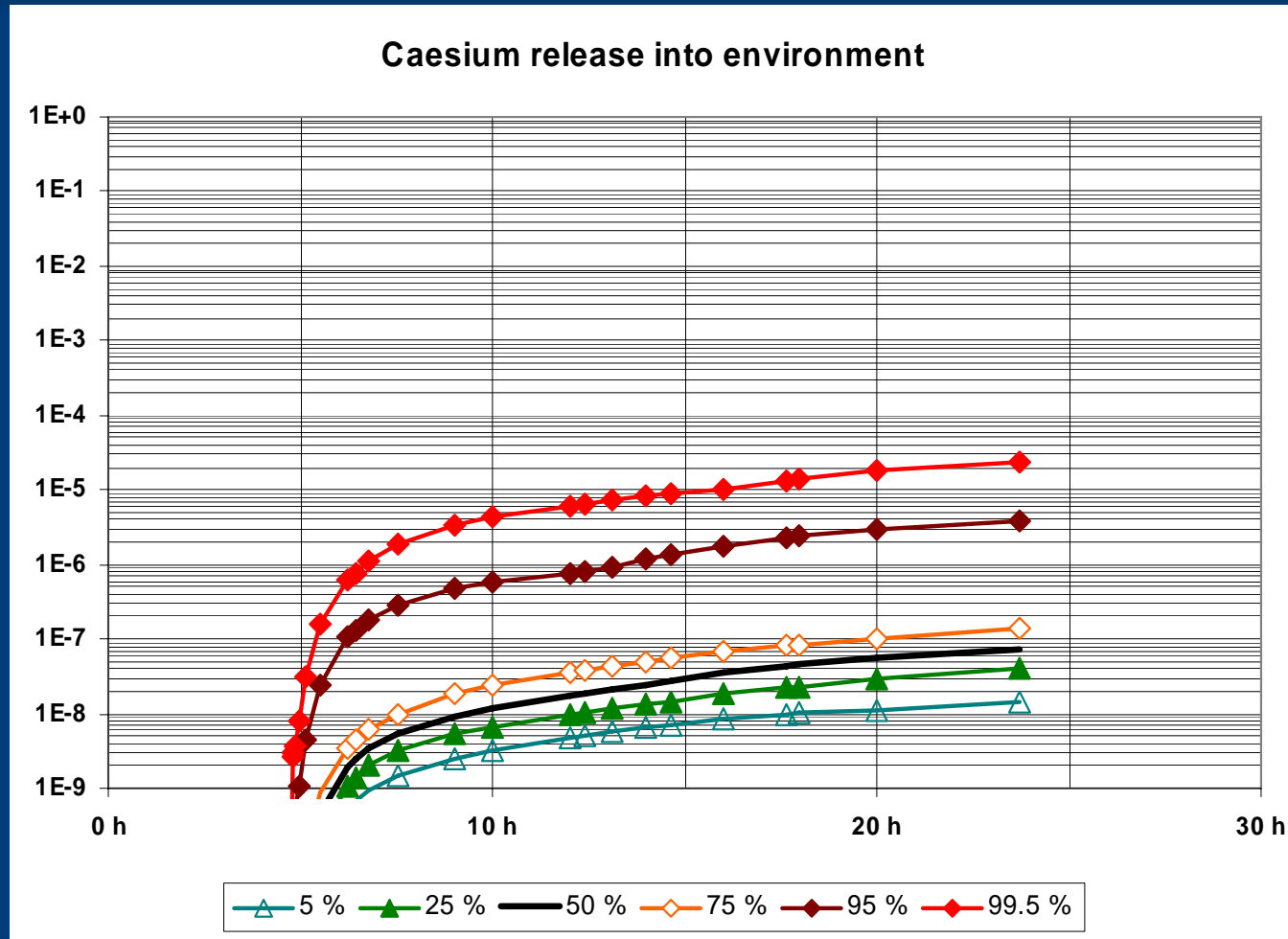
- Status of work
 - at the moment internal hazards for at-power states for unit 1,
 - weather and internal flood hazards (under work, finished by the end of next year)
 - internal hazards extension for normal refuelling shutdown states.
 - Fire risks (after extensive I&C renewal has proceeded far enough)
- Simplification of CET due to ROAAM (number of CET end states reduced)
- The usage of ROAAM in development of the SAM strategy assures that phenomenological uncertainties are covered well during simplification process



Level 2 PSA - source term evaluation

- The key issue in reducing environmental releases is to ensure containment integrity (main goal of the ROAAM approach as well)
- further than ROAAM - issues related to source term evaluation
- Fortum has developed own spreadsheet based tool for source term analyses
 - Loviisa specific
 - issues essential considering SAM strategy
 - source terms for each accident progression category
 - reduced amount of sequence-specific input data
 - wide uncertainty analyses of built-in parameters carried out as Monte Carlo simulations (specific time dependent confidence levels of release fractions for each fission product group)

Example of source term uncertainty result



Level 2 PSA

- Testing the SAM strategy
- containment sequences can be handled well (fraction of sequences with containment failure is small)
- specific problem with containment bypass sequences
 - may (or may not) as such to lead large releases
 - not enough water for cavity flooding
 - cavity failure and significant environmental releases
 - studies of aerosol retention in the bypass route
 - still further actions to either bring down frequency of bypass sequences or modify EOPs to ensure flooded cavity

Summary and conclusion

- Fortum sees significant advantages in combining Integrated ROAAM and PSA when studying severe accidents
 - PSA determines the relevant sequences to be mitigated in the SAM approach and is therefore strongly integrated in the ROAAM work
 - ROAAM increases the credibility and transparency of the level 2 PSA study (significant simplification of CET)
 - With PSA level 2 also source term behaviour is to be analyzed (extremely important when dealing with containment bypass sequences)
- ROAAM has significant advantages in dealing with phenomenological uncertainties, especially in the mitigation regime. PSA is the obvious choice in the preventive regime
- Integrated ROAAM captures the idea behind Finnish safety goal in an ideal way - with Integrated ROAAM a sound balance between preventive and mitigative measures can be found