



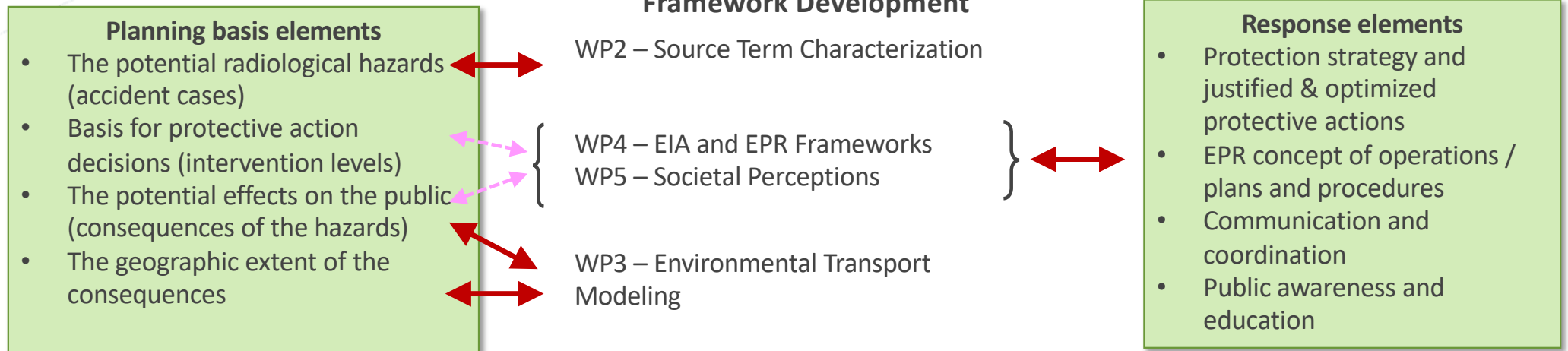
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CNL accident cases for iPWR, SBWR, HTGR GIROSCOPE WP2

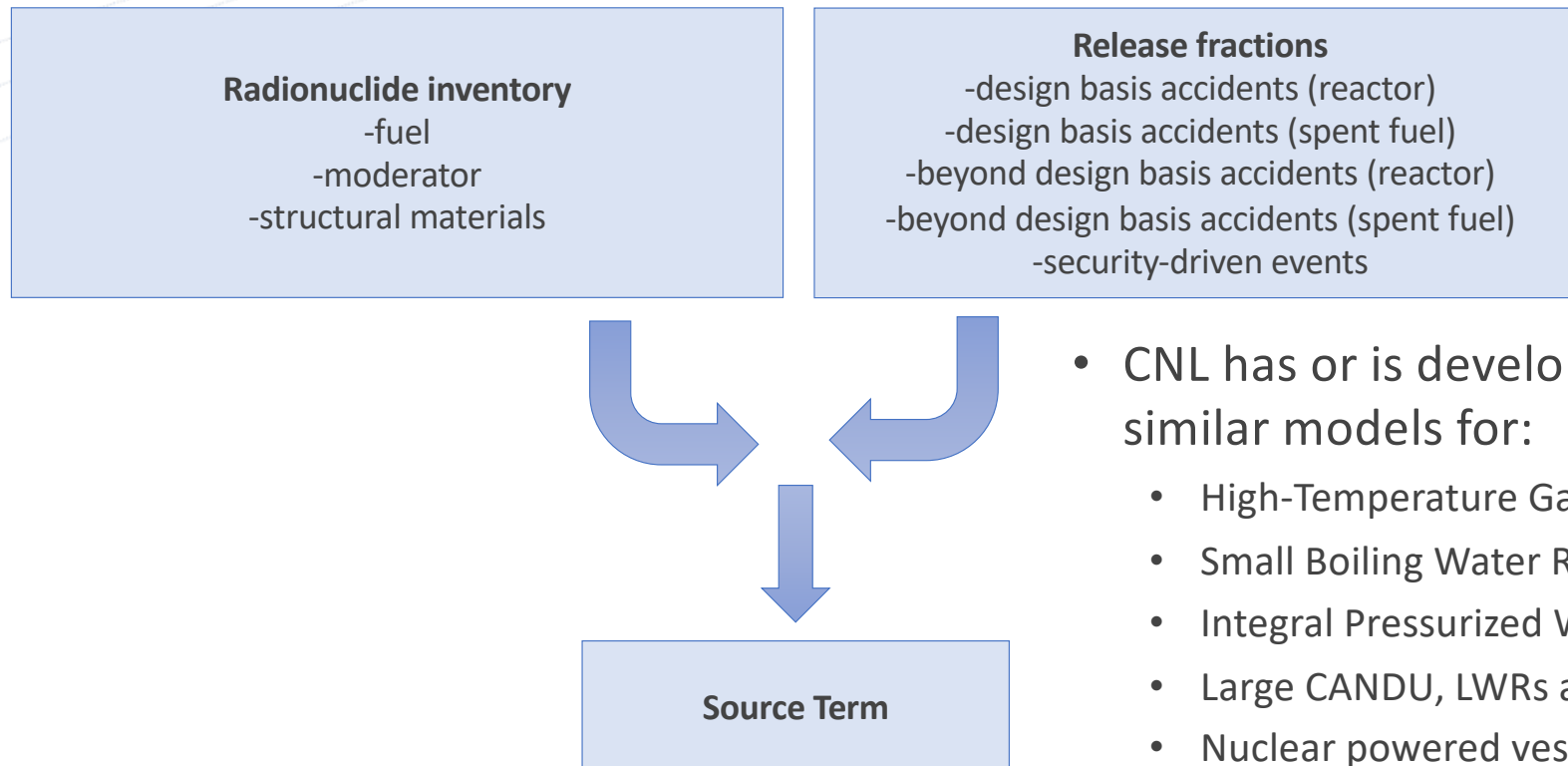
Garik Patterson, **Luke Lebel**

2026 APRIL 29

Mapping of GIROSCOPE to NNR EPR Framework Development



Planning Basis Element #1: Potential Radiological Hazards



- CNL has or is developing MELCOR or similar models for:

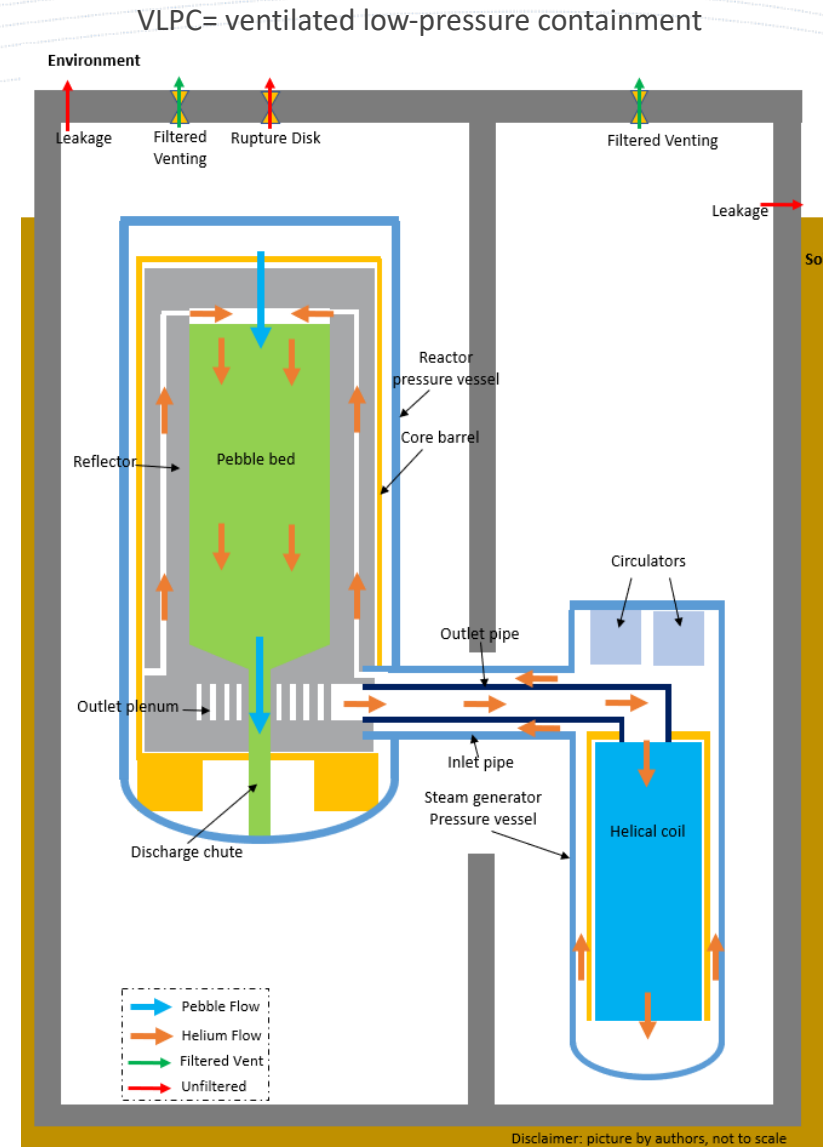
- High-Temperature Gas Reactor
- Small Boiling Water Reactor
- Integral Pressurized Water Reactor
- Large CANDU, LWRs and spent fuel
- Nuclear powered vessels

} **GIROSCOPE**

HTGR MELCOR Model

- Representative generic HTGR SMR
- Incorporated models for:
 - Reactor pressure vessel and heat transport system
 - Temperature-dependent TRISO fuel failure
 - Reactor cavity cooling system (RCCS)
 - Containment ventilation (Negative pressure ventilation system).
- Radionuclide inventory for fuel and graphite moderator
- Investigated “depressurized loss of forced circulation” accidents (D-LOFC) causing severe air ingress.

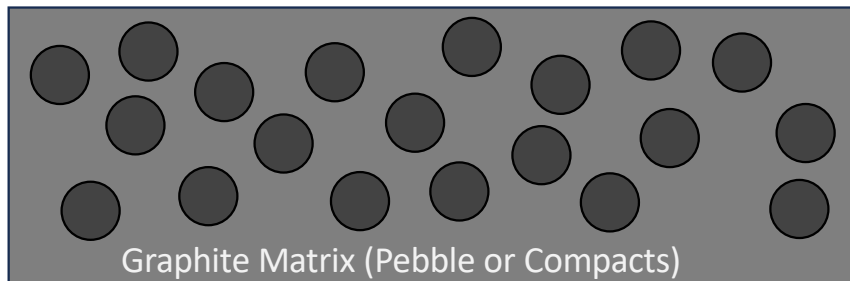
Reference publications: [1] Zhou et al. “Simulation of DLOFC Accident in a Generic Pebble Bed High-Temperature Gas-Cooled Reactor using MELCOR,” G4SR-4, Ottawa, 2024.[2] Lebel et al. “Beyond EPZs: nuclear emergency management frameworks when using site boundary emergency planning zones, with a case study on high temperature gas reactors,” Annals of Nuclear Energy, 226, p.111808. 2026.



Radionuclide Releases from TRISO Fuel & Graphite in HTGRs

- Possible accidents with reactor or spent fuel involves either:
 - High temperature diffusion releases of fission products from fuel
 - Oxidation of activation products in graphite

2



- Activation products from contaminants in graphite (^{14}C , tritium, ^{60}Co , etc.)
- Graphite oxidation during air ingress scenarios volatilizes species

1

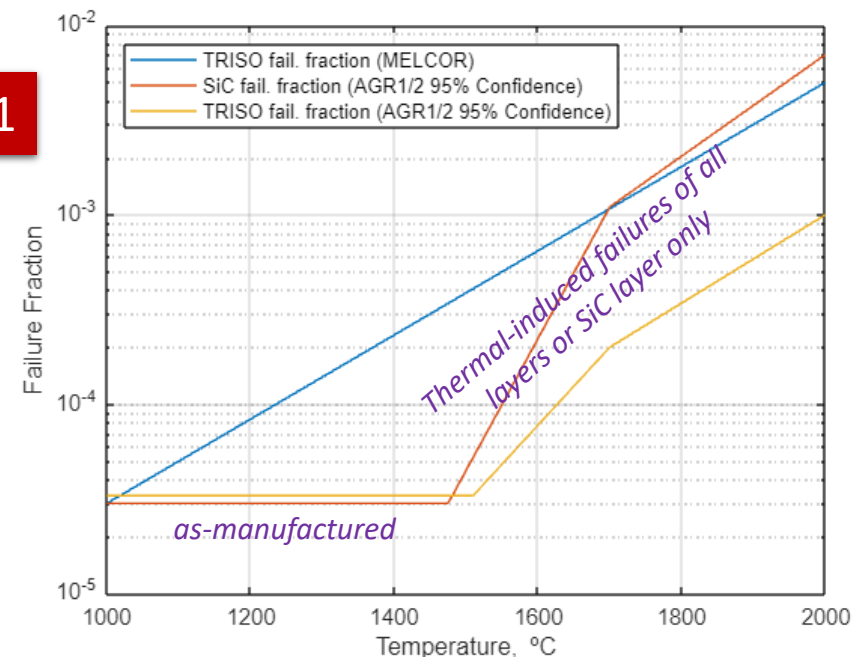
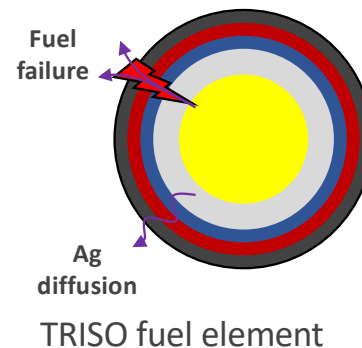


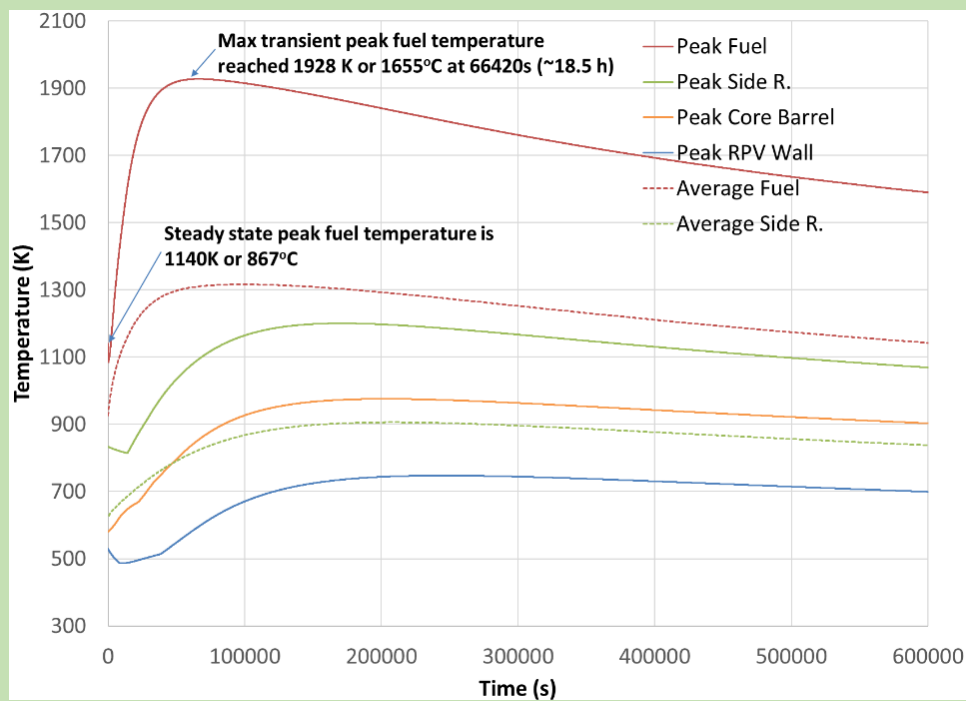
Figure: TRISO fuel failure fractions with temperature



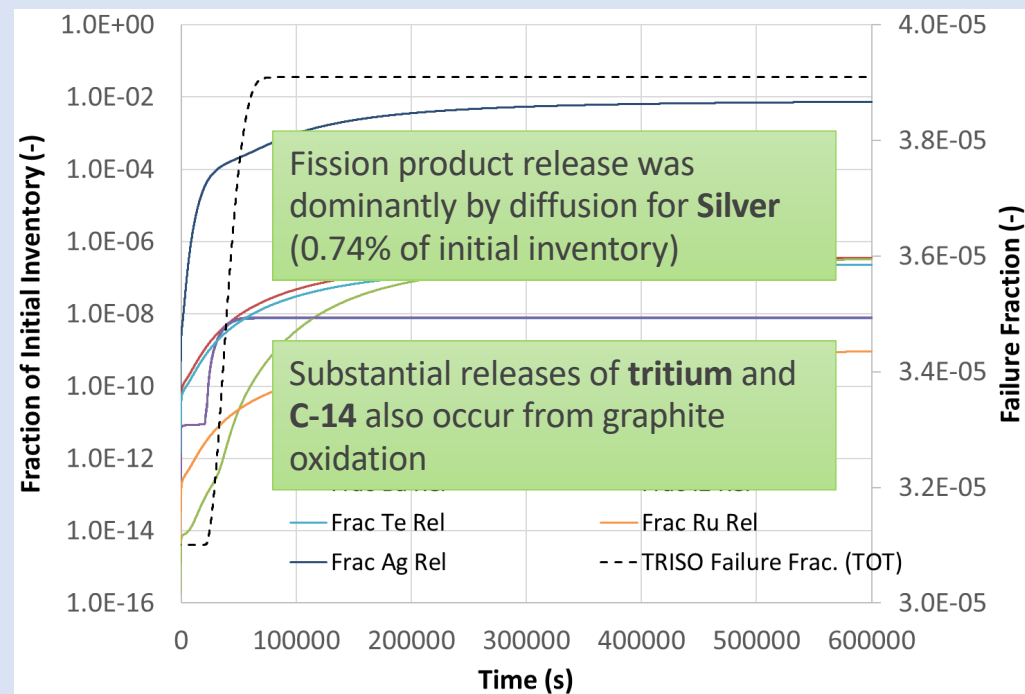
- Fission product inventory in fuel
- Intact outer layers effectively block diffusion of most nuclides (except Ag)
- Other nuclides need failed layers to escape

D-LOFC Results

Component/Structure peak and average temperature



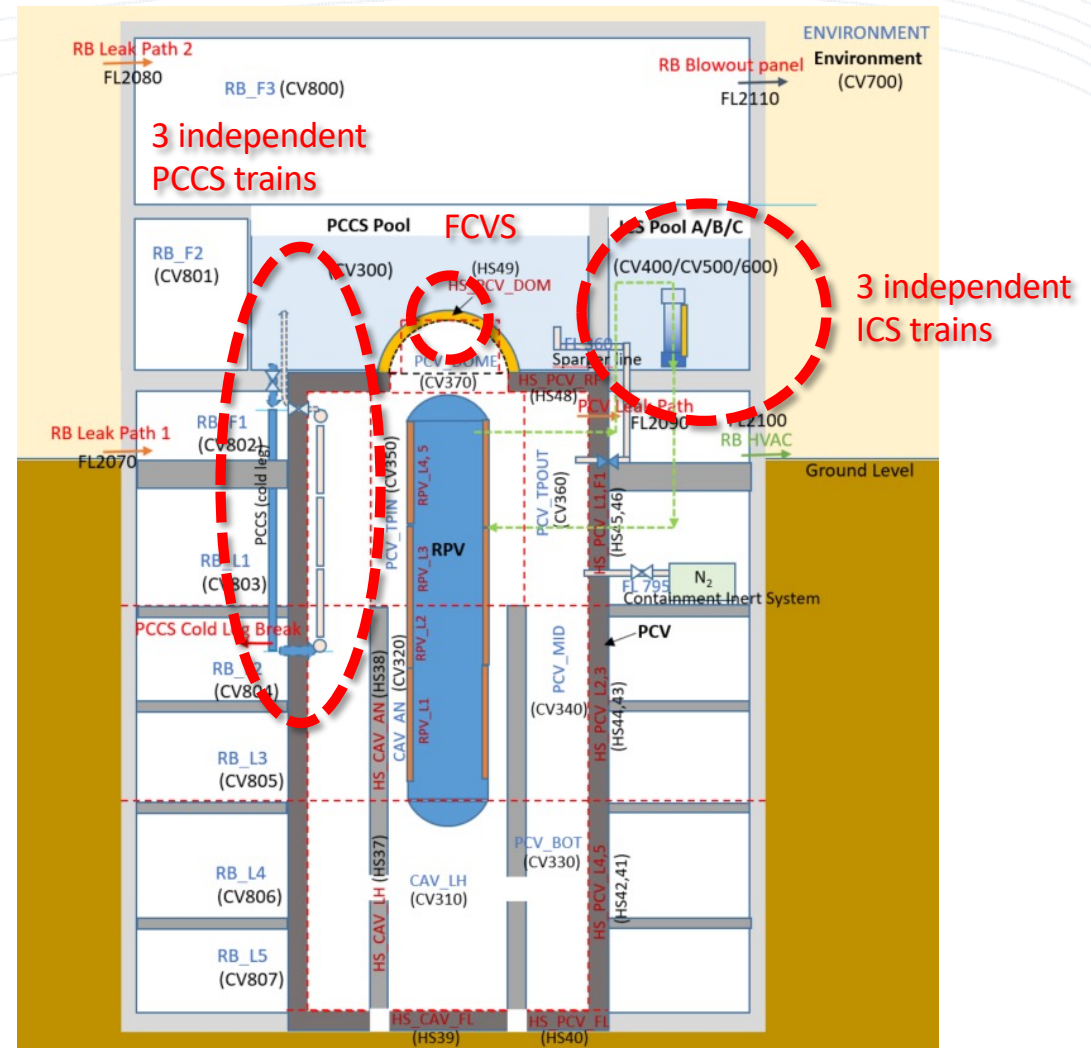
TRISO failure fraction and FP release fractions



Small BWR MELCOR Model

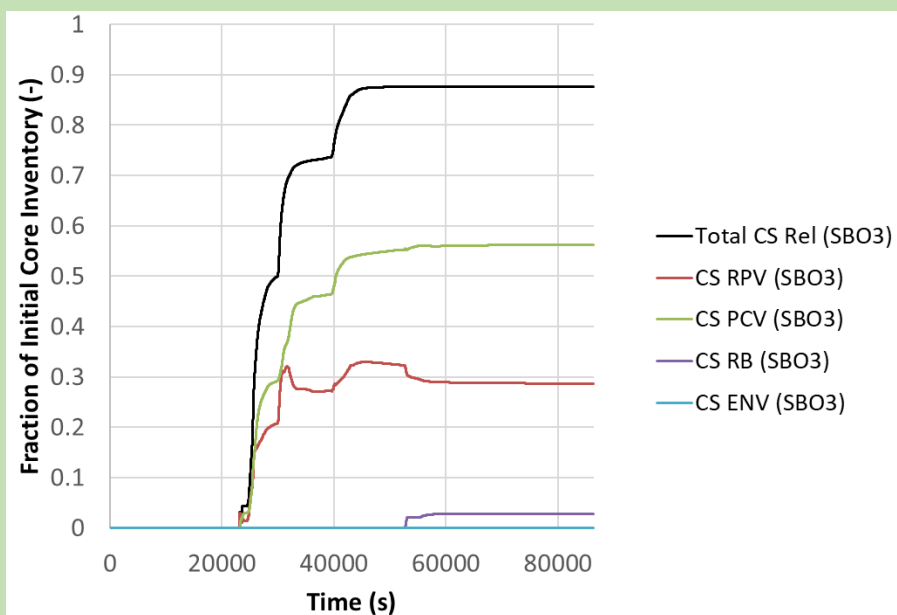
- Representative generic BWR SMR
- Incorporated models for:
 - Natural circulation flows within RPV
 - Isolation Condenser System (ICS)
 - Passive Containment Cooling System (PCCS)
 - Filtered venting into PCCS pool
- Scaled BWR radionuclide inventory
- Investigated degradation of passive safety systems with:
 - Station blackout (SBO) with impaired or total loss of ICS trains and/or partial loss of PCCS
 - Small-break LOCA (SBLOCA) with water inventory loss and nitrogen ingress into the RPV, reducing ICS efficiency

Reference publications: [3] Zhou, "Severe Accident Analysis of a Generic Small Boiling Water Reactor," NUTHOS-14, Vancouver, 2024.



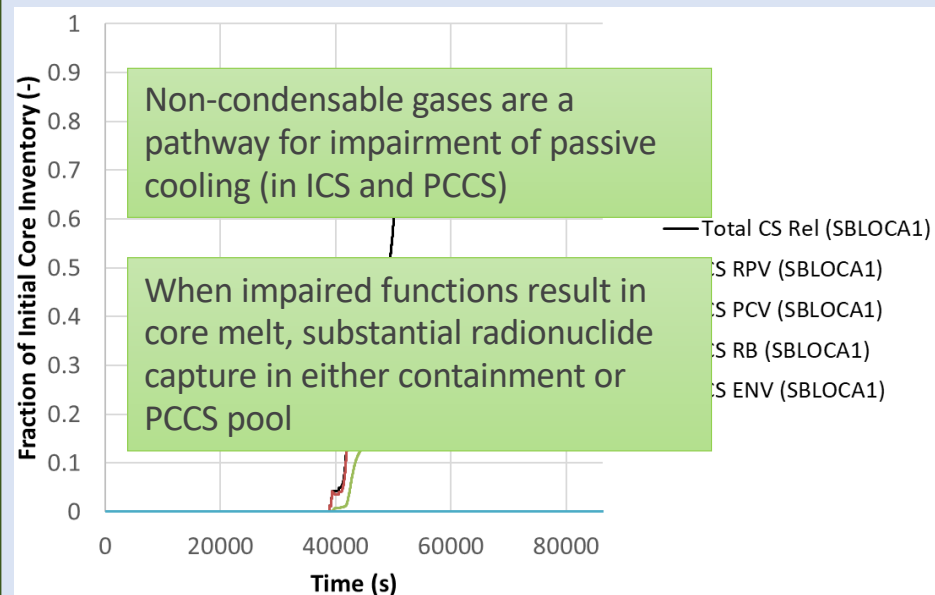
Small BWR Source Term Analysis Cases

Case 1: SBO + ICS impairment



Cesium release and distribution

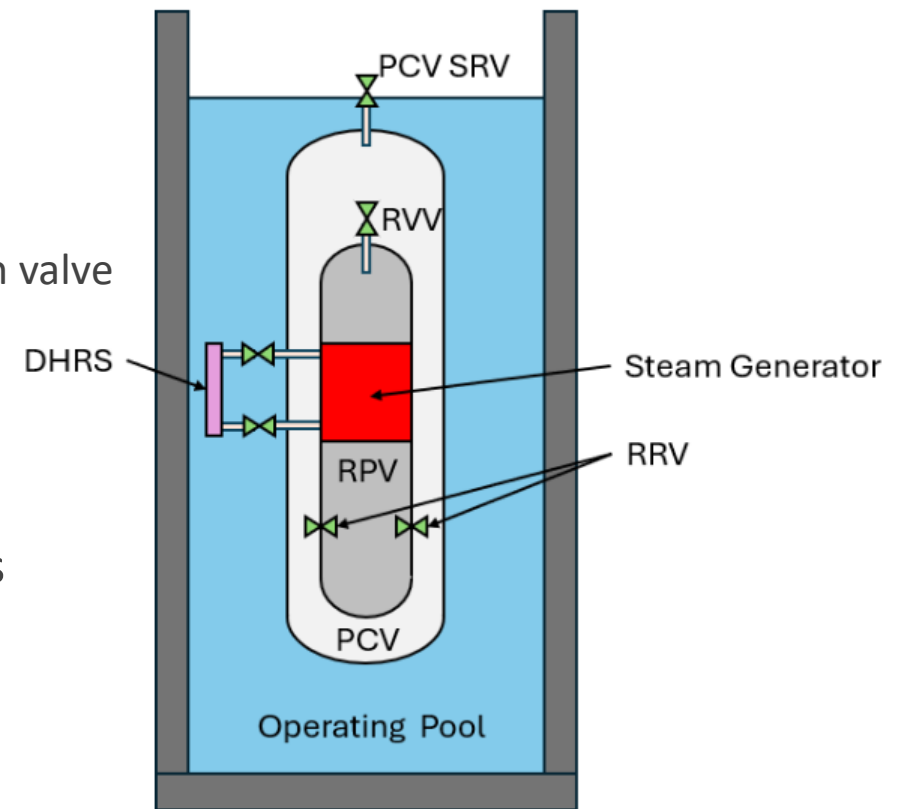
Case 2: Small-Break LOCA



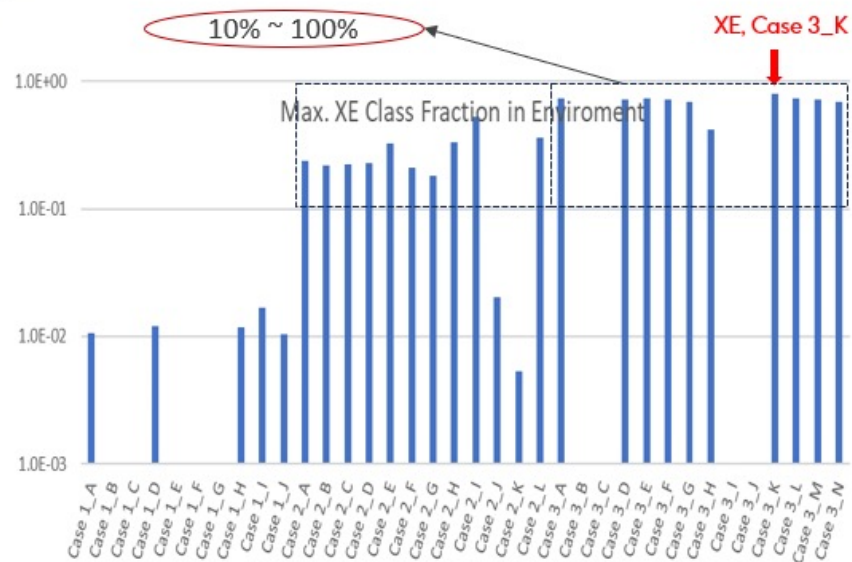
Cesium release and distribution

iPWR MELCOR Model

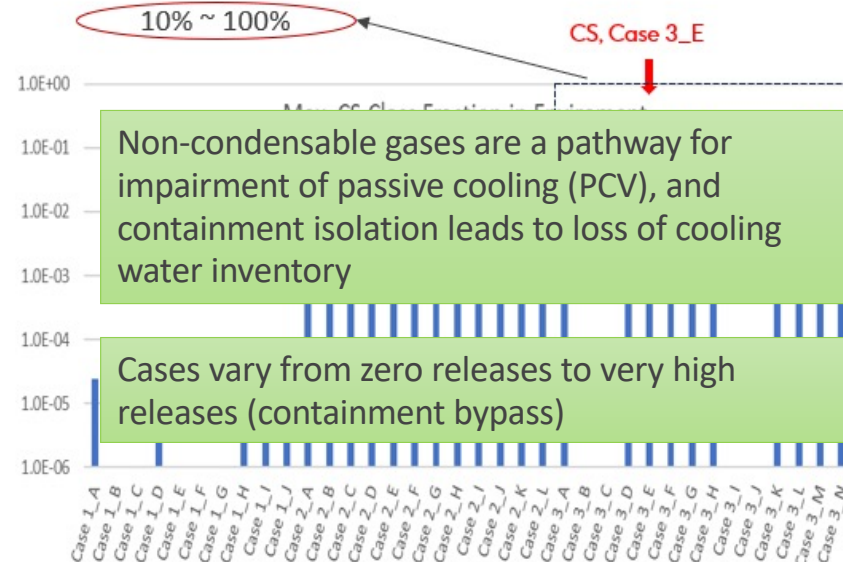
- Representative generic iPWR SMR
- Incorporated models for:
 - Natural circulation flows within RPV
 - Strong condensation within submerged high pressure containment vessel (PCV)
 - Passive emergency core cooling via reactor recirculation valve (RRV) condensate return
 - Decay heat rejection system (DHRS)
 - Operating pool (OP)
- Scaled PWR radionuclide inventory
- Investigated degradation of passive safety systems through comprehensive sensitivity during an SBO:
 - Set with loss of steam generator and DHRS
 - Set with loss of water in operating pool
 - Set with loss of containment isolation



iPWR Source Term Analysis Case Example



Xenon releases for all cases



Cesium releases for all cases