16th EMUG

SÚRO TSO

Capabilities of the Czech TSO

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- Brno, Czech Republic

- April 7th – 11th, 2025

Introduction

Main activities at SURO

- Commercial activities
- Research activities and
- **Technical Support to the national regulator body**

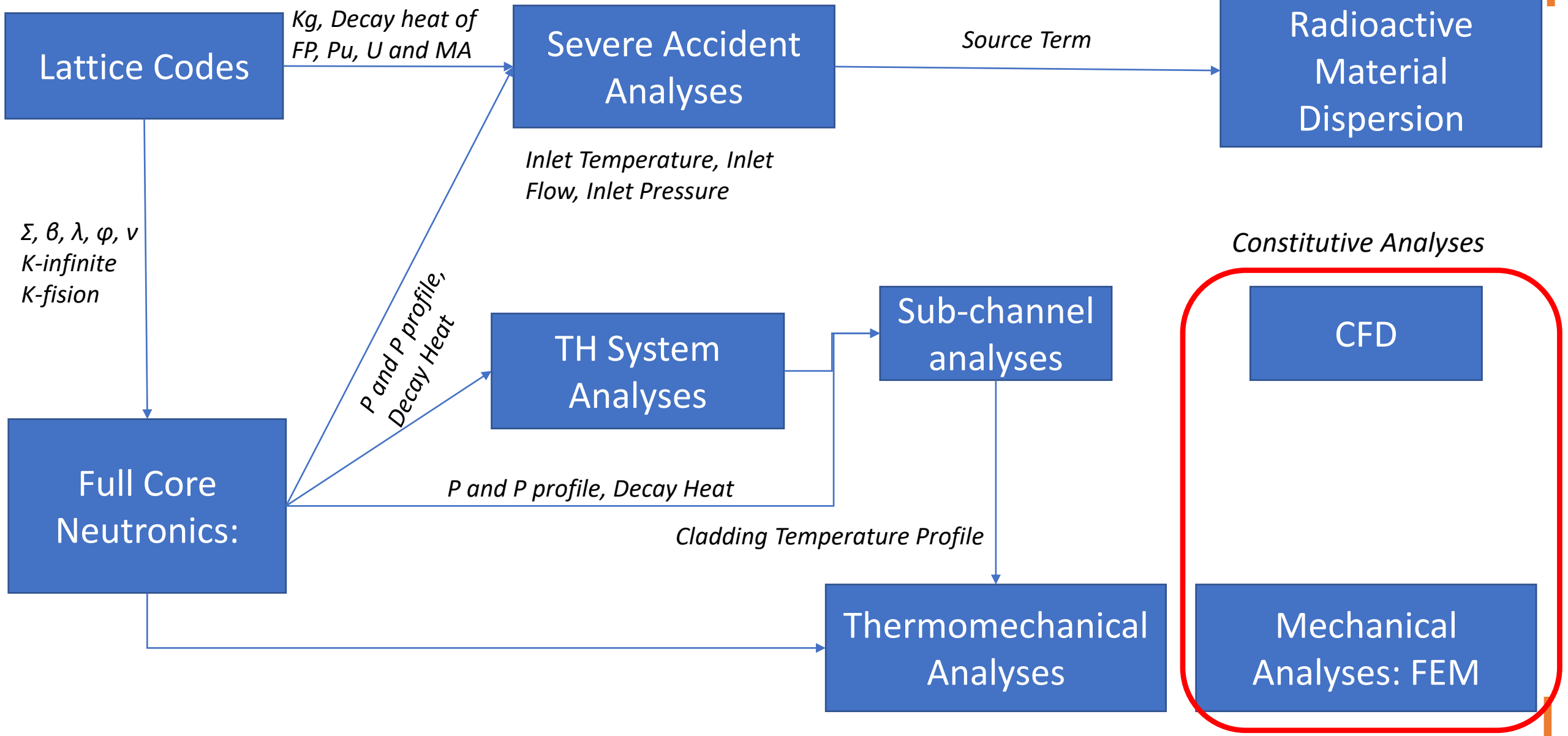
- The goal of the independent analyses is to provide analyses to SUJB that independently evaluate the state of the Czech NPPs.

- The analyses must be independent of the utility, utilize different models and users and may use different codes.

Safety Analyses

Safety Review

CEZ Data – From State Office for Nuclear Safety **(SUJB)**



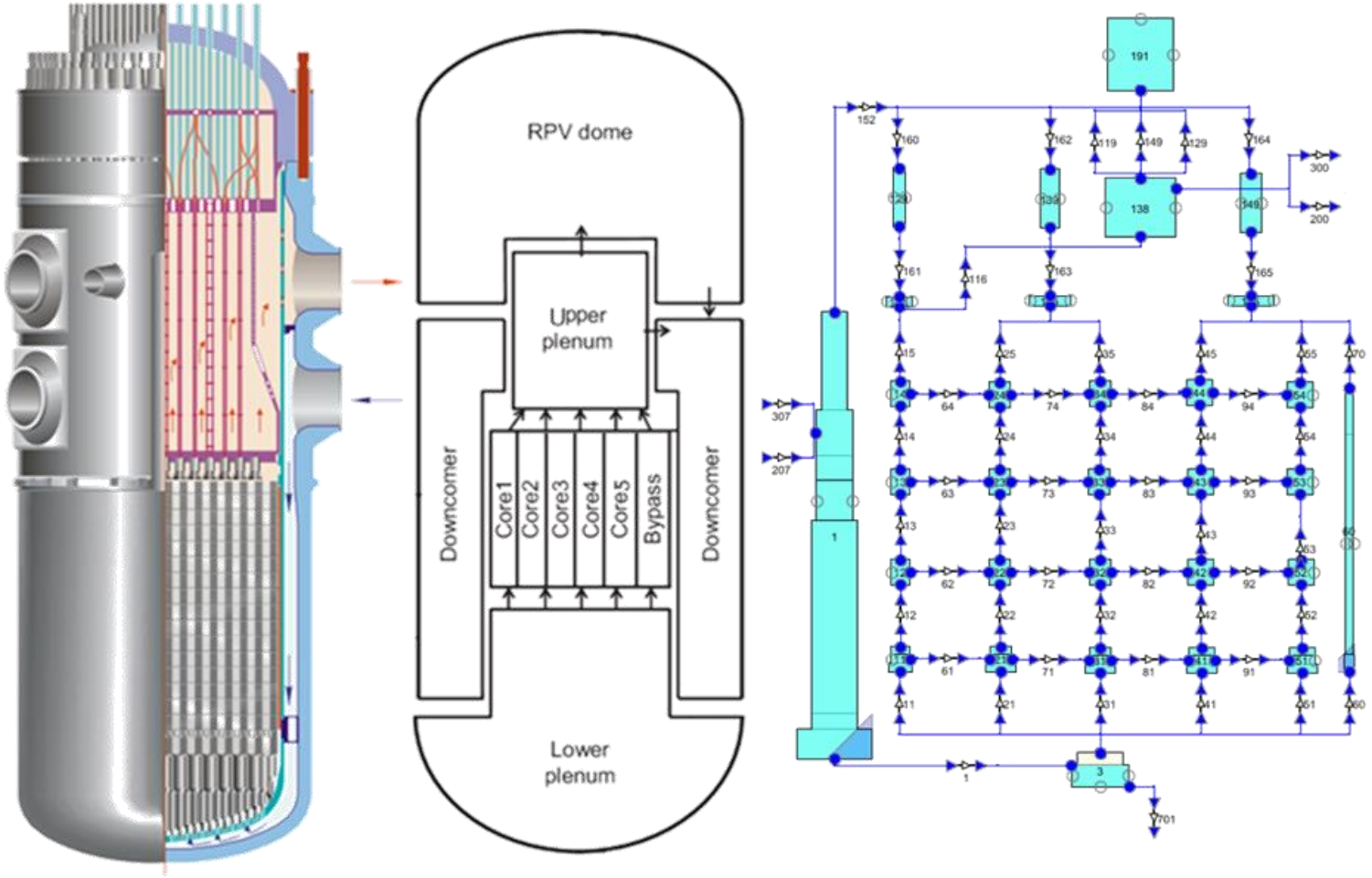
Code Portfolio

- Neutronic Lattice codes: MCNP 6, SERPENT v2, SCALE 6.3, HELIOS
- Neutronic Nodal codes: ANDREA, PARCS
- System Codes: TRACE 5, ATHLET, APROS, RELAP 5
- Subchannel codes: SCF, COBRA-TF
- Fuel Thermomechanical analyses: TRANSURANUS
- Severe Accident analyses: MELCOR 1.8.6, MELCOR 2.2, ASTEC, ATHLET-CD, APROS, COCOSYS, GOTHIC
- Mechanical Analyses: ANSYS
- Computational Fluid Dynamic: ANSYS FLUENT
- Radioactive Material Dispersion: JRODOS (in another department), MACCS, MelMAACS

Examples of model updates

- **VVER-1000 MELCOR model (Temelín)**
  - PARs
  - Filtered Containment Venting System (FCVS)
  - Concrete composition updated
  - Assessment of mixed core
  - Radioprotection

VVER 1000



RPV scheme, diagram and MELCOR model nodalization.

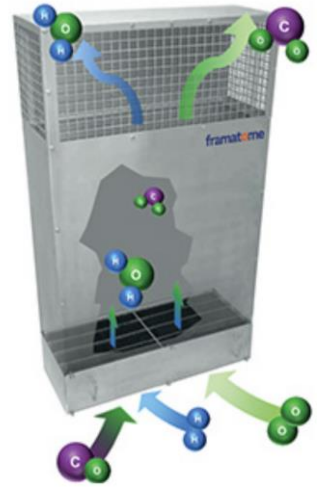
PARs. TEMELIN VVER-1000

- 109 PARs equivalent to NIS-PAR Type 22

The MELCOR ESF package have been used to model the passive autocatalytic hydrogen recombiners behavior.*

Information needed to model the PARs

- PAR location
- Flow correlation.
- Efficiency



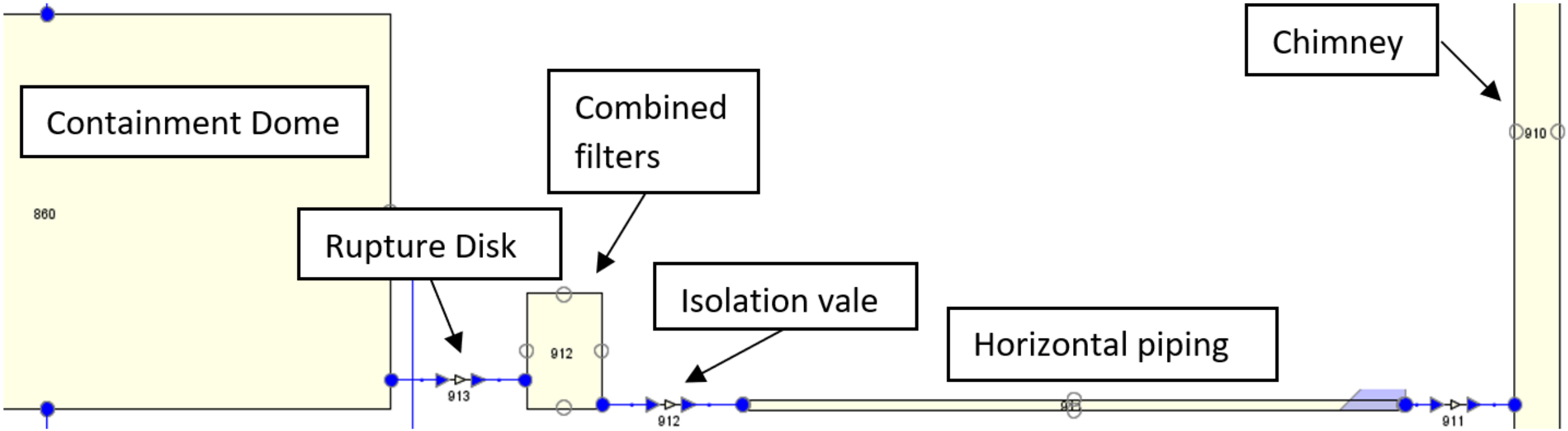
*Current work involves creating a model with dedicated containment code (GOTHIC)

Filtered Containment Venting System - FCVS

- A system connecting the containment building with the chimney, consist of a set of combined filters a rupture disc and two insolation valves.

- Filters are defined in RN package defining the decontamination factors for Aerosols, fission products gas and fission products I_2 as well as its saturation values.

Filtered Containment Venting System (FCVS)



Concrete composition updated

- Despite the MELCOR code have predefined some generic concrete types, the ETE concrete composition was defined according to information collected from the NPP.

Concrete components.

- AL_2O_3
- CaO
- Fe_2O_3
- K_2O
- SiO_2
- MgO
- Na_2O
- CO_2
- TiO_2
- H_2O inside the concrete

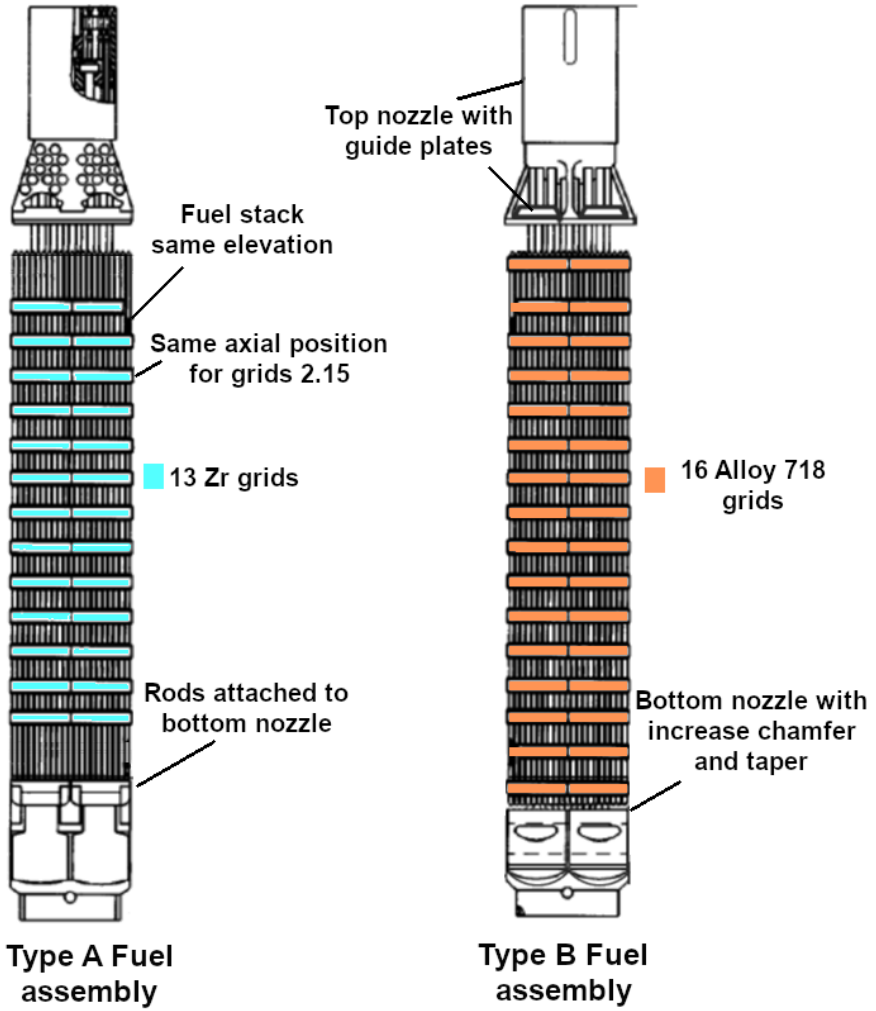
- This will help to have a better estimation of RN and hydrogen production in the case of a MCCI event.

Mixed fuel core

- MOTIVATION
- Since the start of the Ukraine-Russia conflict, the western countries with VVER technology have to look to different fuel vendors in order to ensure the fuel supply for their reactors.

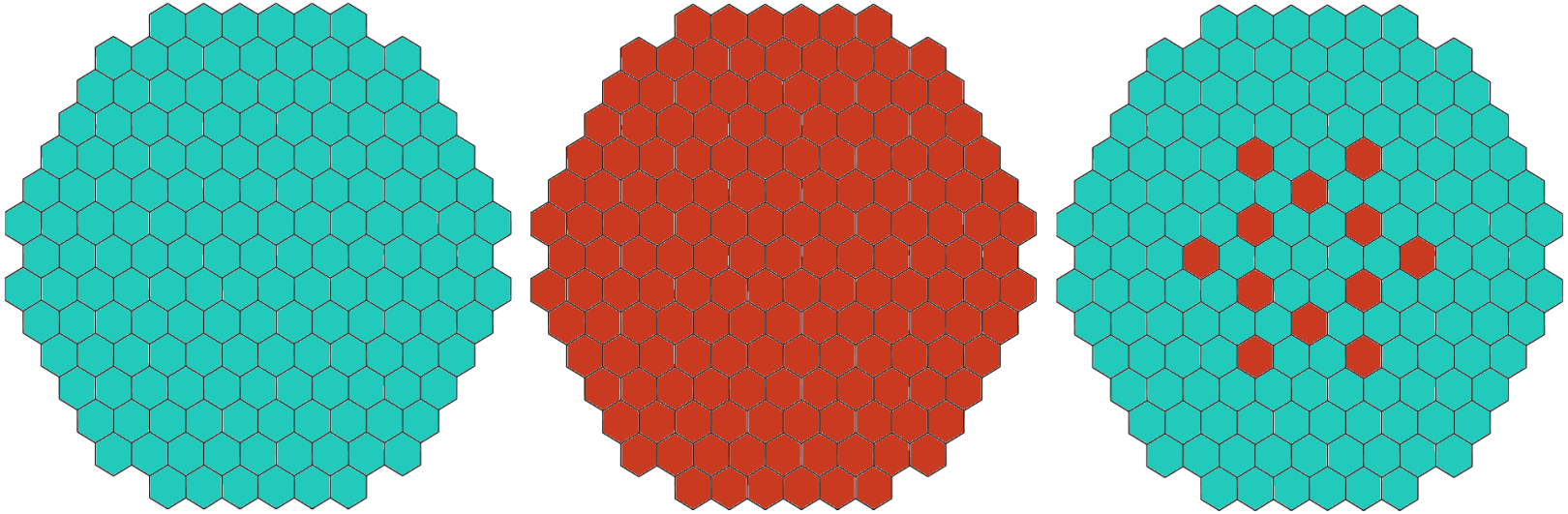
Fuel type A: 13 grids made of Zr-1 %Nb

Fuel type B: 16 grids made of Alloy 718 (aka Inconel)



https://doi.org/10.1016/j.nucengdes.2023.112858

Core layouts for three different MELCOR models



Model A. Type A Fuel

Model B. Type B Fuel

Model C. Mixed Core

There were developed three models which main difference is the core mass composition:

- The Model A is a core with all the fuel assemblies Type A.
- The model B is a core with all the fuel assemblies Type B and
- The model C is a mixed core with 151 FA Type A and 12 FA Type B

Státní ústav radiační ochrany, v. v. i.

National Radiation Protection Institute

LT-SBO Simulation.

VVER 1000 Temelín.

Radioprotection

- Consequences of a hypothetical accident in Zaporizhzhia NPP (ZNPP)
  - Damage of power lines/surroundings

- ZNPP: six Russian-designed VVER-1000 reactors
  - The same technology as in Temelín NPP, Czech Republic

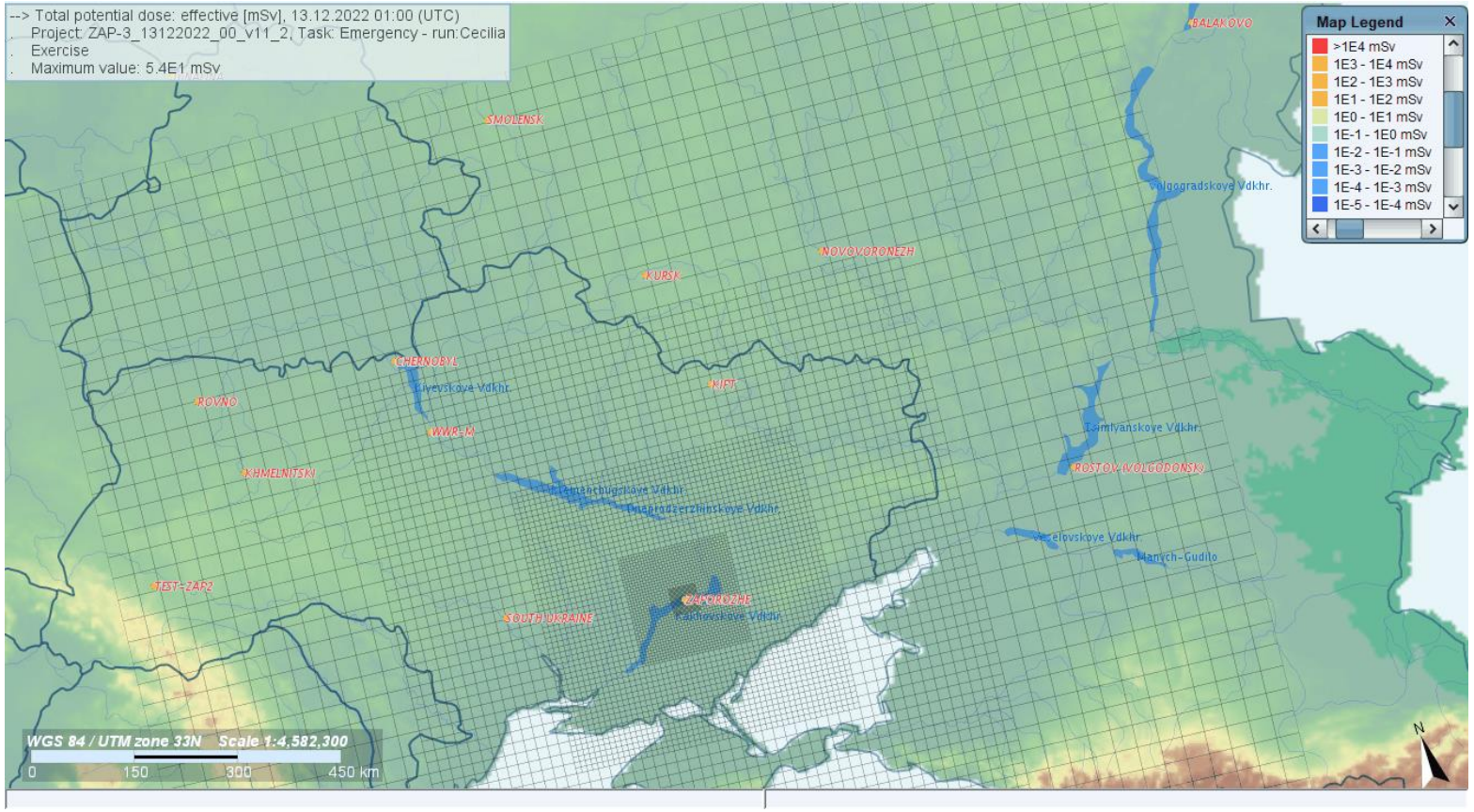
JRODOS scenarios

- 2 + 1 scenarios for 1 unit of ZNPP:
  - Damaged containment (the worst-case) – during operation
  - Undamaged containment (realistic case) – during operation
  - Damaged containment – after shutdown

- Basic set-up:
  - Calculation radius: up to 800 km from ZNPP (can be extended)
  - Release duration: 7 days (to meet legislation criteria)
  - Prognosis duration: 7 days
  - NOMADS meteorological data

JRODOS results for VVER-1000/320 in Zaporizhzhya, after shutdown. Scenario: LT-SBO with depressurization (7 days)

13–20 December 2022 (within daily evaluations)



Damaged containment

Protective measures (CZ criteria)

Sheltering: 10 mSv, 48 h (up to 55 km)
Evacuation: 100 mSv, 7 d (up to 20 km)
Iodine prophylaxis: 100 mSv (up to 20 km)

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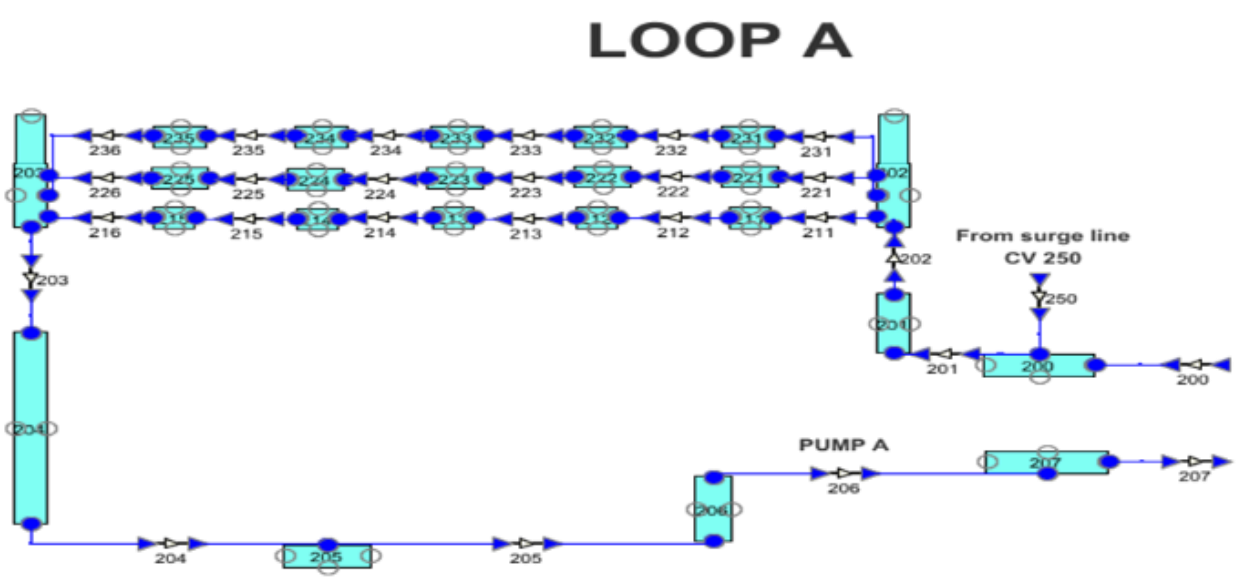
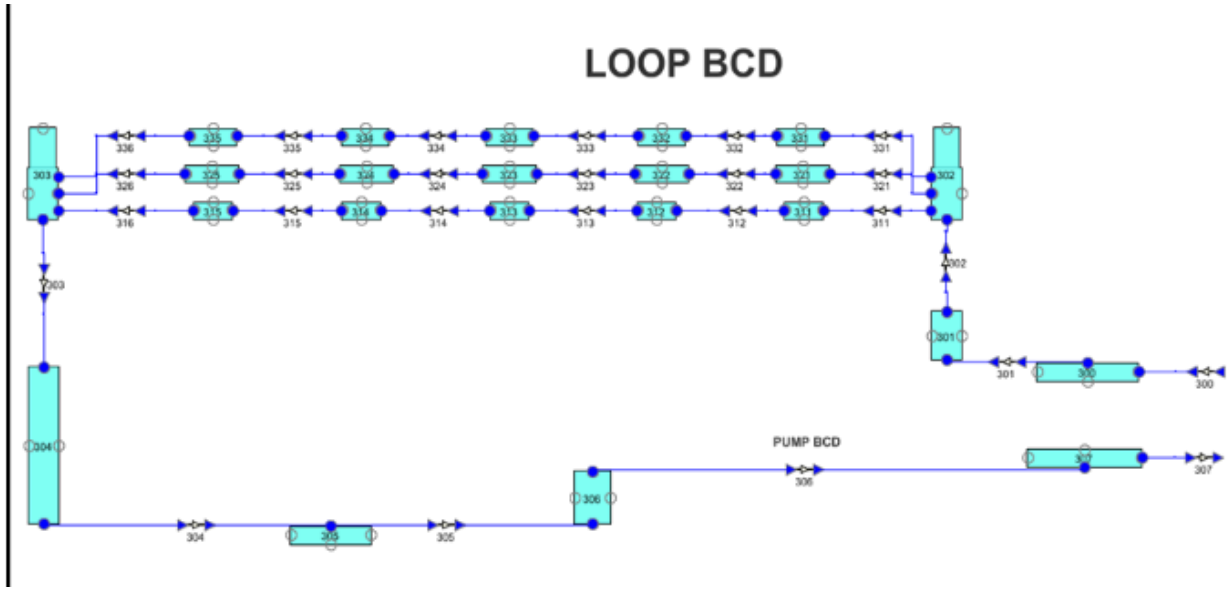
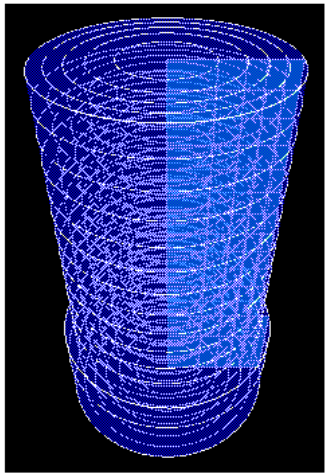
Loops nodalizations

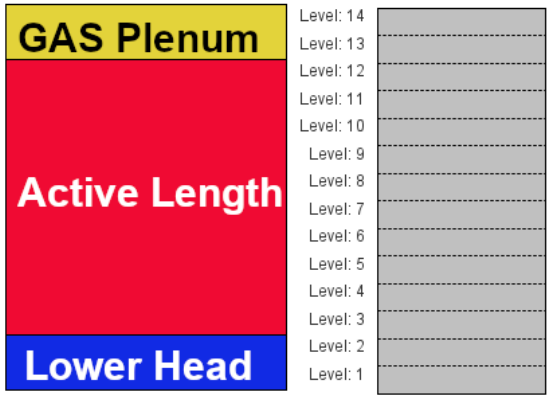


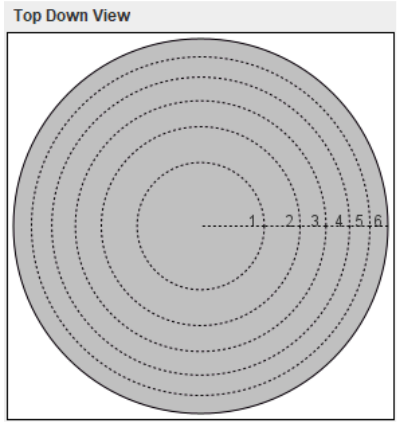


- MELCOR nodalization is arranged in 2 loops to reduce the amount of thermal hydraulic elements and thermal structures; a large number of these elements reduces the stability of the calculation and increases the calculation time.

Core



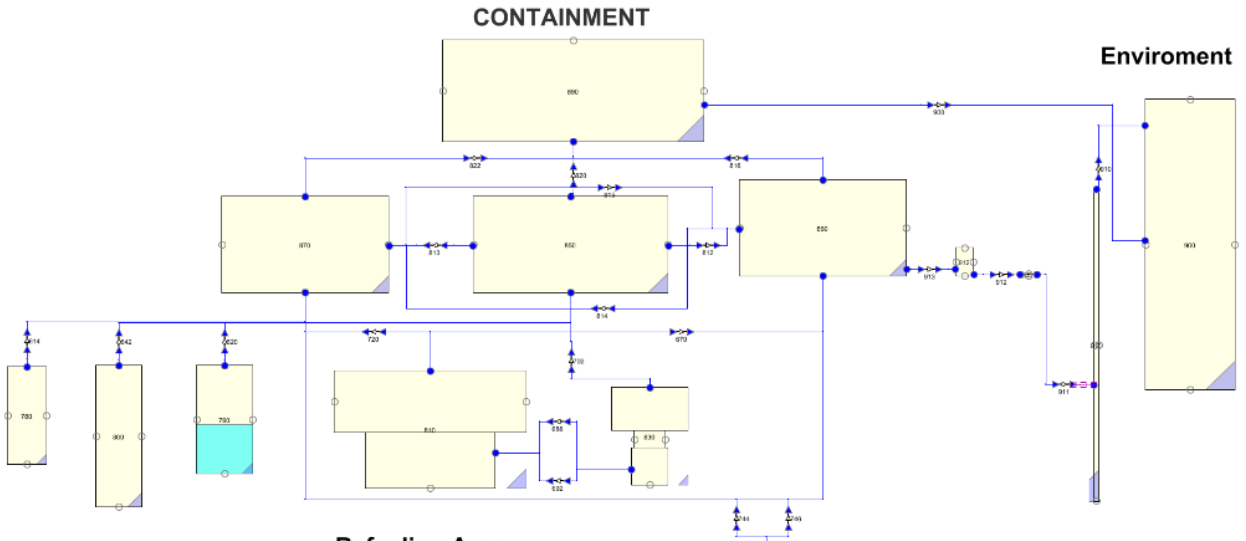


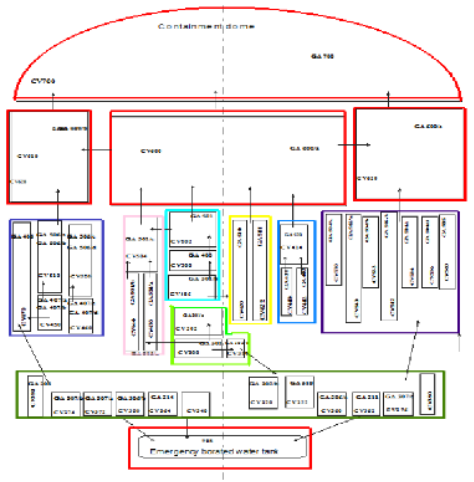


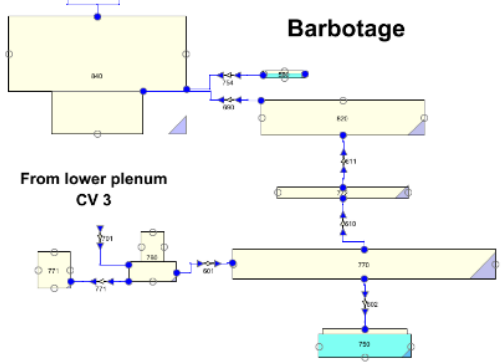
Active Core | Bypass

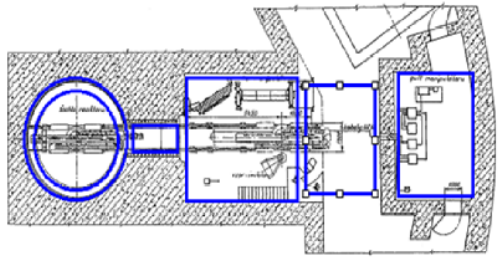
Axial Levels	Ring: 1	Ring: 2	Ring: 3	Ring: 4	Ring: 5	Ring: 6
Level: 14	114	214	314	414	514	614
Level: 13	113	213	313	413	513	613
Level: 12	112	212	312	412	512	612
Level: 11	111	211	311	411	511	611
Level: 10	110	210	310	410	510	610
Level: 9	109	209	309	409	509	609
Level: 8	108	208	308	408	508	608
Level: 7	107	207	307	407	507	607
Level: 6	106	206	306	406	506	606
Level: 5	105	205	305	405	505	605
Level: 4	104	204	304	404	504	604
Level: 3	103	203	303	403	503	603
Level: 2	102	202	302	402	502	602
Level: 1	101	201	301	401	501	601

Containment nodalization



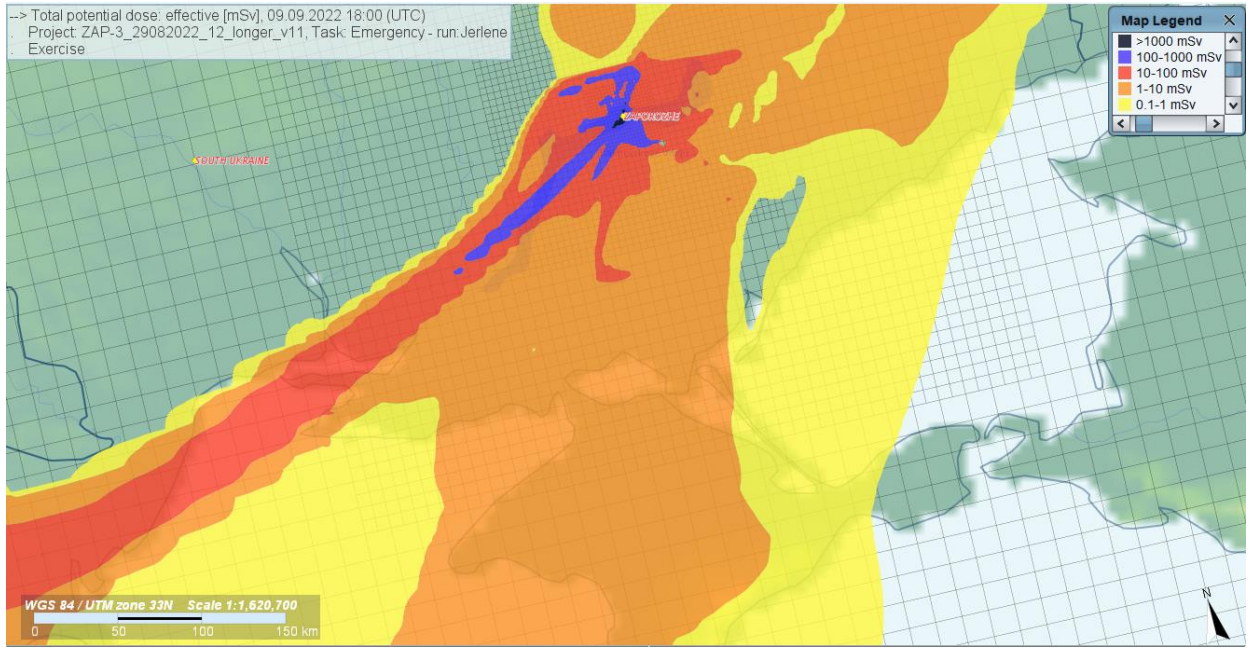




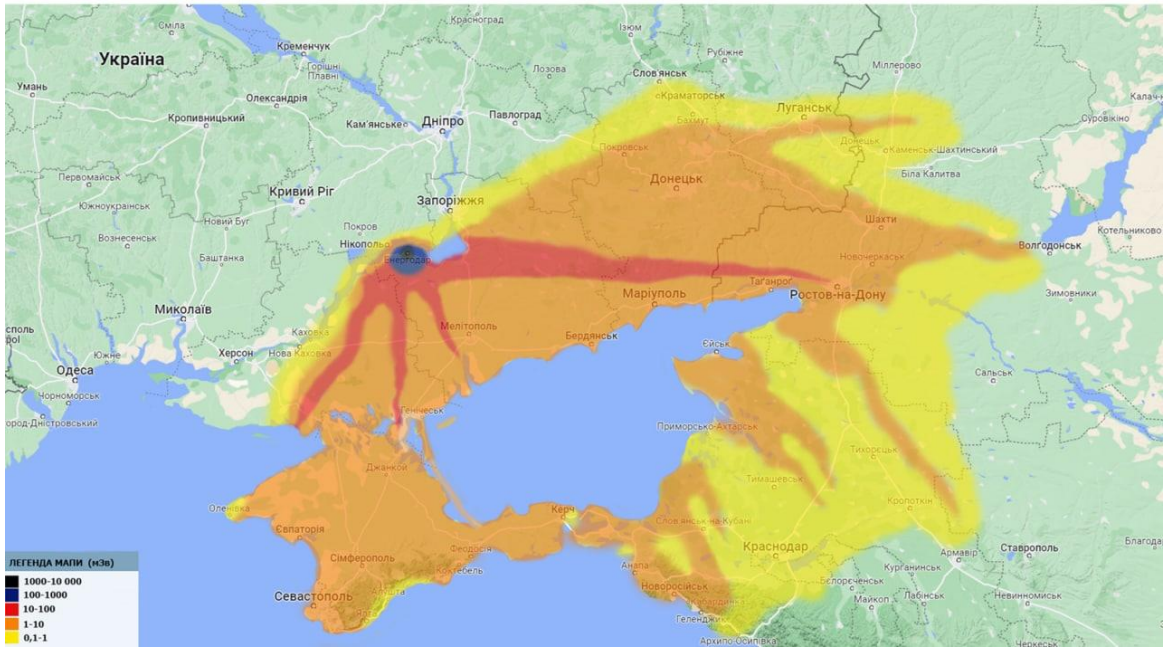


Preliminary* benchmark with UA – 29/08/2022

Total potential dose (cloud+deposition+inhalation) after 11 days



Сумарна доза від усіх джерел, потенційна за 14 днів



SURO 29/08/2022, damaged containment, normal operation

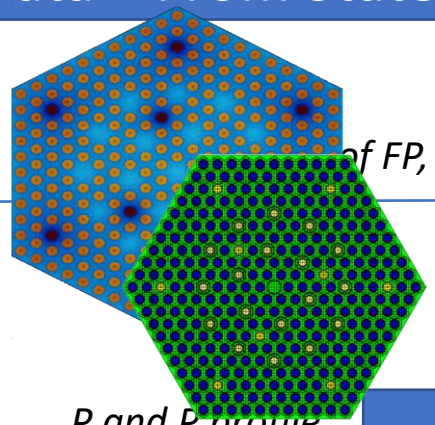
[Energoatom 29/08/2022]

*Detailed data were not known (e.g. start of the release, used set of meteodata,…).

CEZ Data – From State Office for Nuclear Safety **(SUJB)**

SÚROTSO

Lattice Codes:
SCALE
HELIOS



of FP, Pu, U and MA

Severe Accident Analyses: MELCOR

Source Term

Release of radioactive material: JRODOS

Σ, β, λ, φ, ν
K-infinite
K-fision

P and P profile,
Decay Heat

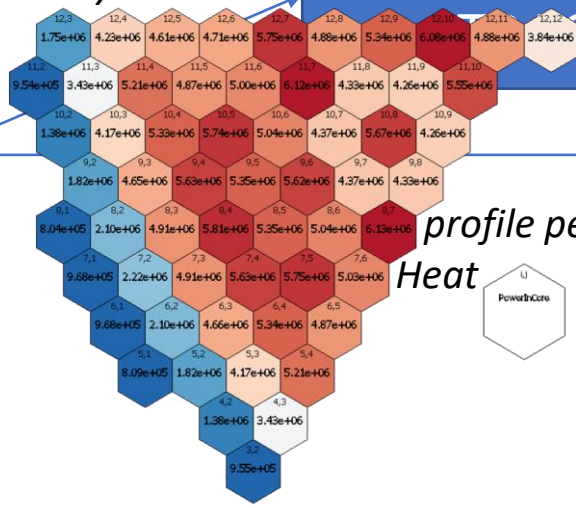
TH Analyses:
[illegible]CE

Inlet Temperature,
Inlet Flow,
Inlet Pressure

Reacto[illegible]

Constitutive Analyses

Full Core Neutronics:
ANDREA
PARCS



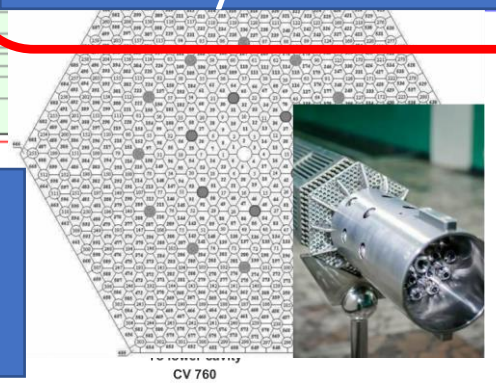
profile per assembly,
Heat

Sub-channel:
SCF

CFD

Mechanical Analyses: FEM

Cladding Temperature Profile



P and P profile,
Decay Heat based on the selected methodology

Thermomechanical Analyses:
TRANSURANUS

Methodology

- Source term assessments
  - Released activities into the atmosphere
  - Based on Temelin NPP, with necessary corrections
  - Long-term station blackout with depressurization
  - Simulations in SCALE and MELCOR codes
- Atmospheric dispersion
  - Simulations in JRODOS tool

- **Continuous work since the end of February, 2022**

Protective measures (CZ criteria)

- **Sheltering**: averted effective dose of 10 mSv during 48 h
- **Evacuation**: averted effective dose of 100 mSv during 7 days
- **Iodine prophylaxis**: averted thyroid dose of 100 mSv

- All prognoses **strongly** depend on weather conditions

Damaged containment, current scenario

- After shutdown – decay corrected (the first approximation)
- **Caused by direct shelling with military weapons**
- Leakage rate: originally 10 % per day, now roughly 14 %
- Release height: 66.25 m
- Source term, roughly: Cs: 75 %, I: 2 %, noble gases (NG): 7 %

Sum (Bq)	Cs (Bq)	I (Bq)	NG (Bq)
3.82E+17	2.84E+17	4.96E+15	2.49E+16