On advanced information technology as an aid in the management of legacy fuel at IFE

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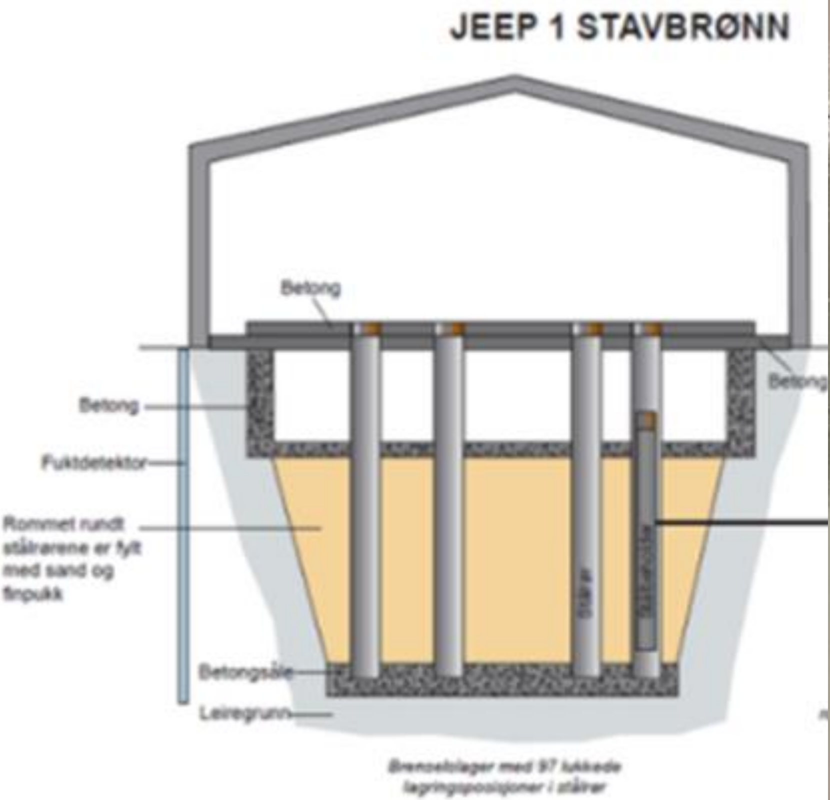
Norwegian Research Reactors (RR) and spent nuclear fuel (SNF)

- 1948 Norway started to construct and built a RR – JEEP I.
- IFE (formerly IFA) operates RRs since 1951 until presently at Kjeller (near Oslo) and in Halden.

  - **JEEP I** at Kjeller (1951 to 1967) - now **decommisioned**
  - **NORA** at Kjeller (1961 to 1968)– now **decommissioned**
  - **HBWR**, 25 MW, in Halden (1959–) in **operation**
  - **JEEP II**, 2 MW, at Kjeller (1966-) – in **operation**

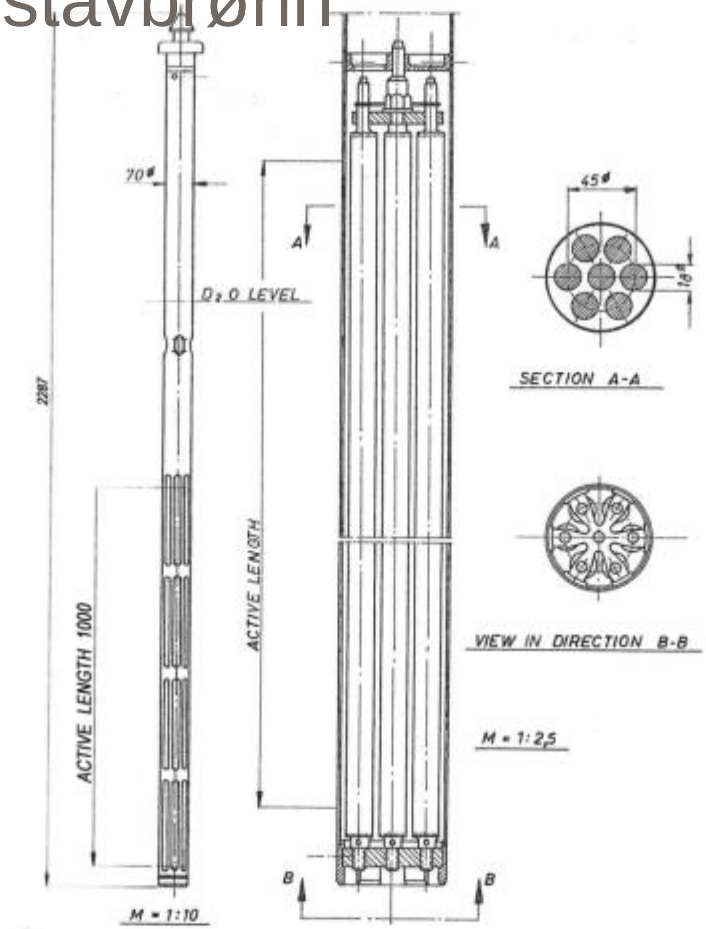
- Since more than 60 years IFE has experience in managing and storing of SNF from the RRs.
- IFE manages **three dry storage facilities for SNF,**
  - 2 at Kjeller and 1 at Halden.

The dry storage site "JEEP I stavbrønn" is for legacy fuel



- SNF from Norwegian RRs is currently stored on the reactor sites by the reactor operator (IFE).
- "JEEP I stavbrønn" is an underground, vertical dry storage for JEEP I SNF.
- "JEEP I stavbrønn" is in use since the mid 60s.
- Organisational and financial arrangements for long-term SNF management have not been defined.

Typical fuel inventory in JEEP I stavbrønn



JEEP I 1. loading in 1951:
Al-clad metallic uranium fuel elements. (Most canisters)

JEEP I 2. loading: Al-clad 1.7% enriched, ceramic UO_2 fuel element. (Few canisters)

Hazards with Al-clad metallic uranium SNF

- Metallic uranium is soluble in water and poisonous.

- Defected SNF of metallic uranium contains hydrides (UH_3).
- UH_3 is pyrophoric (self-ignition) in air.

- Al-clad metallic uranium (both Al and U) corrodes in humidity and releases hydrogen.
- Hydrogen and oxygen can cause an explosion.

- Irradiation induced defects in graphite end plug in SNF can start a fire (Wigener effect).

Management of ageing storage site “stavbrønn"

- «JEEP I stavbrønn», storage site for legacy Al clad metallic U fuel, was a “static” storage for many years and storage pits were sealed by IAEA.

Ageing management programme for “JEEP I stavbrønn” control isues (safety): environment, storage site and pits, canisters and SNF elements.

- Prior to start-up of the ageing fuel management program the seals were removed.
- Examined were : concrete top (cracks), storage pits (humidity, corrosion), movability of SNF canisters in the pits and one SNF element on defects and corrosion by PIE after more than 50 years of underground dry storage.

- **Signs of ageing** of the storage site and the SNF elements **led to increased risk assessments** and followed by a **need for a systematic examination and updating** of the fuel inventoryand safety.

Fuel ageing management (1)

- Maintenance / restorations / implementations to improve the functionality of the >50 year old storage in terms of

  - Storage site environment – Systematic monitoring (air, groundwater, etc)
  - Improvements to storage site concrete structure, steel lining of storage pits (97).
  - Improvements to storage site infrastructure (equipment for: handling, transport, shielding, gamma monitoring, air heating, drying, filtered ventilation, fire fighting, alarms, communication, radiation protection monitors and measuring and experimental units: visual inspection, leakage control of SNF canisters, gas analyses, gamma monitoring, ….

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Fuel ageing management (2)

Working steps in ageing fuel management Phases 0 to 4

Phase 0: SNF canisters in storage pits – check canister movability

Phase 1: Check SNF canister lid tightness and envrionment in fuel canister (humidity, hydrogen, water, pH, etc).

Phase 2: Check SNF canister gas tightness (with special gas tight lid).

Phase 3: Full length gamma monitoring and visual inspection of SNF canisters & pit inspection,& pit drying & pit cleaning for corrosion products (rust) – **a first trial is in process to simulate fase 3 by VR**

Phase 4: Full length gamma monitoring and visual inspection of SNF element

All working steps with SNF are based on QA and include

- written work-instructions/routines based on
- HAZOP, Risk assessment
- Earlier SNF element documentation
- Data from earlier examinations

Fuel ageing management (3) Application of advanced information technology

A first attempt to do VR simulation is in progress for Phase 3 tasks of fuel ageing management of «JEEP I stavbrønn».

VR simulations are done in advance to the experimental/ technical work .

Benefits of the VR simulations are:

* Visualisation of the prosess steps and hazards
* Easy accessable data for comparison in a visual data base
* Training of personell
* Efficiency, demo ……

Data used for process simulation and JEEP I stavbrønn database were gathered from

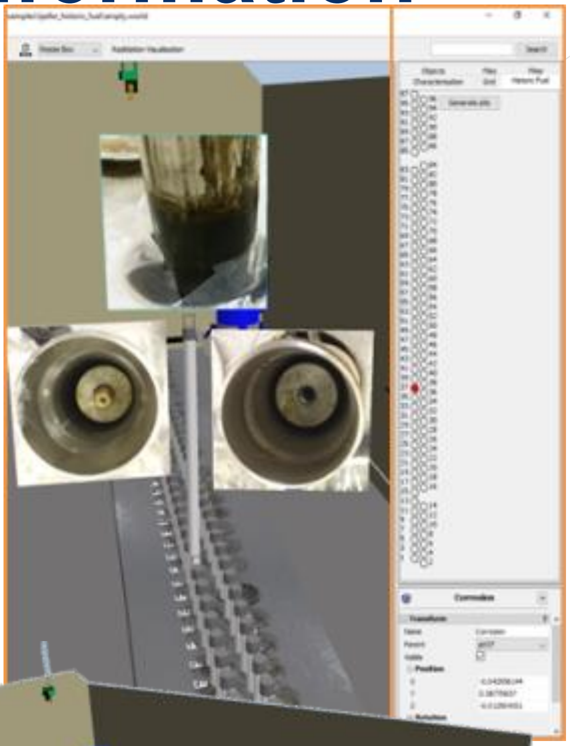
- Technical drawings,
- Measuremente on site
- written HAZOP, work steps in instructions
- data from earlier examinations, etc were collected in formate exel files and jpg-photos

Application of advanced information technology - RadPIM

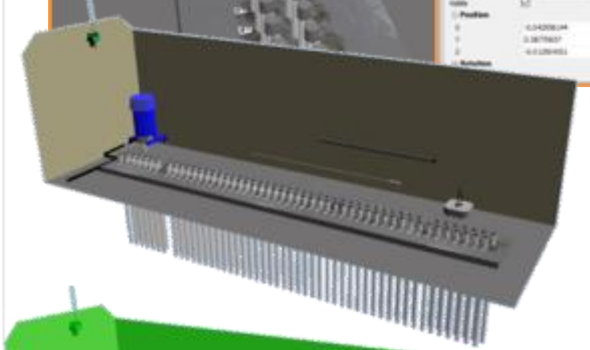
RadPIM shows stavbrønn with navigation and

*showing labels with data on canister content

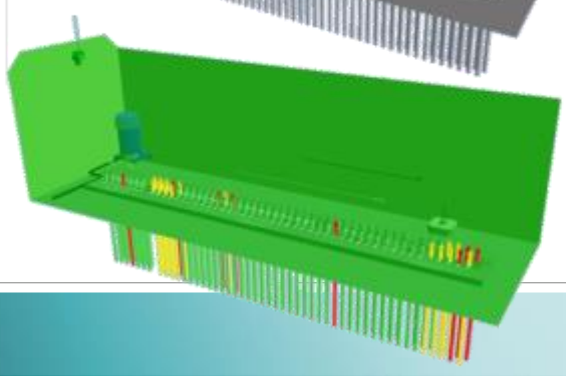
*show detailed object info (incl. attached documents and photos) on click



- Filter info (e.g. color/highlight objects) based on criteria (e.g. wells with warnings/pending actions)



- Move objects around (attached data follows) e.g. fuel canisters, insert notes (annotations)



Application of advanced information technology – VR (VIVE), VRdose, SimEditor or VR

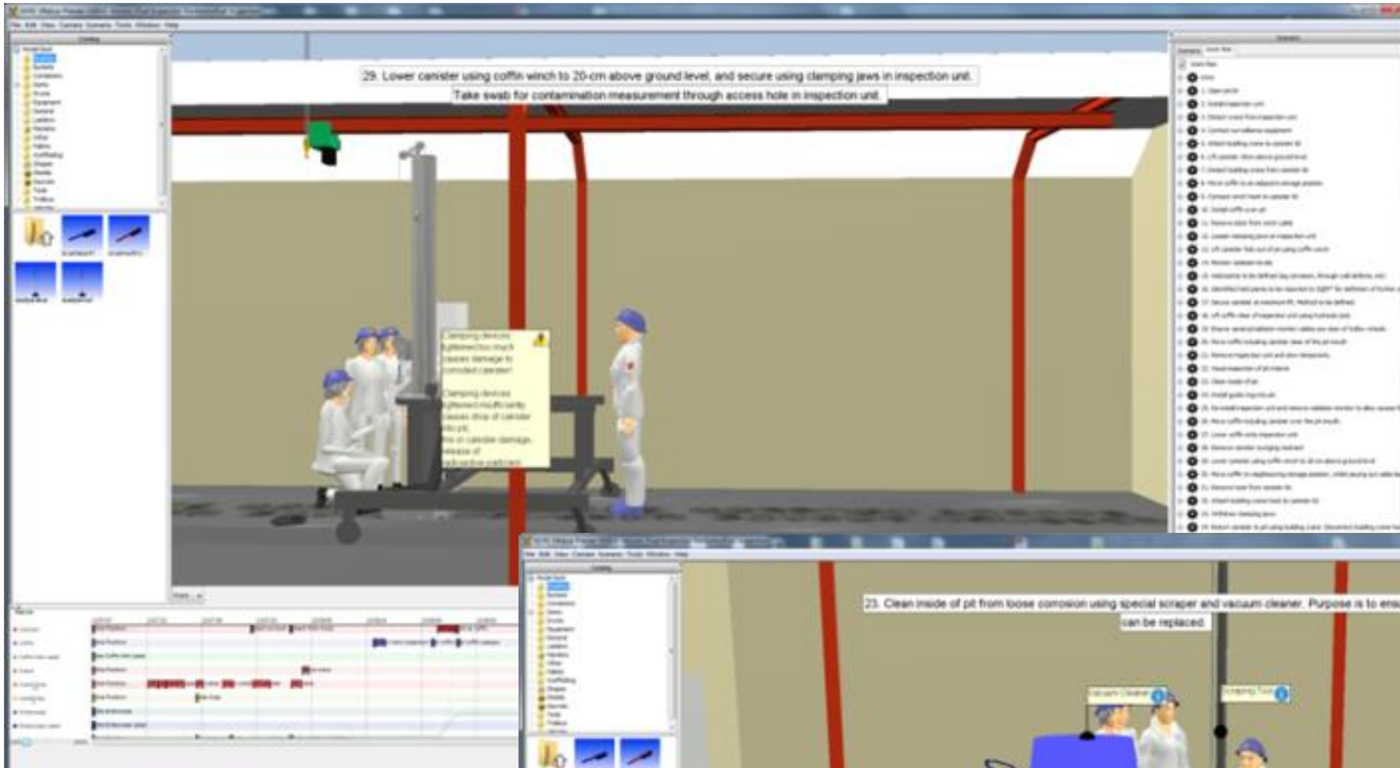
Virtual reality (VR) VIVE:

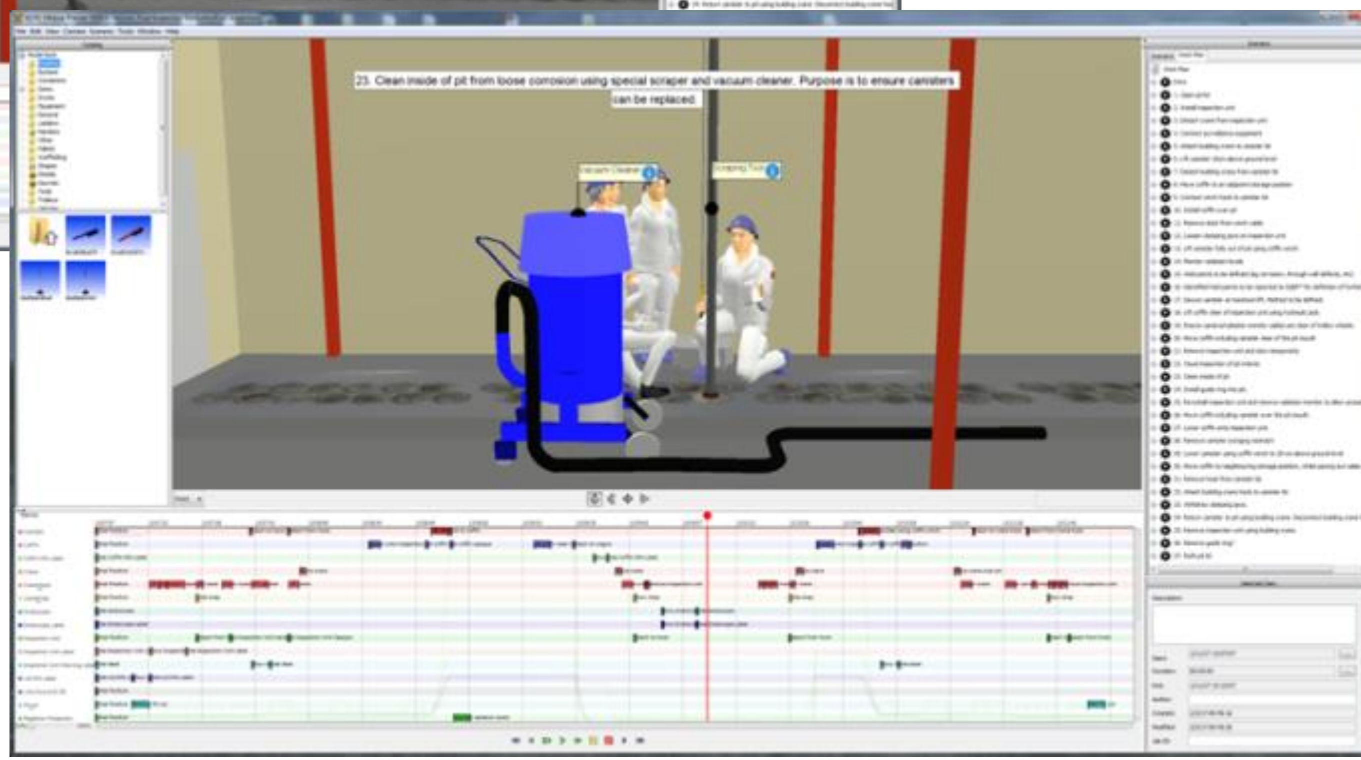
- Show stavbrønn with navigation (teleport) for multiple users
- interaction with objects (grab, move, rotate) with
- possibility for marking locations…

User with VR headset

Training simulator

VR (dose)

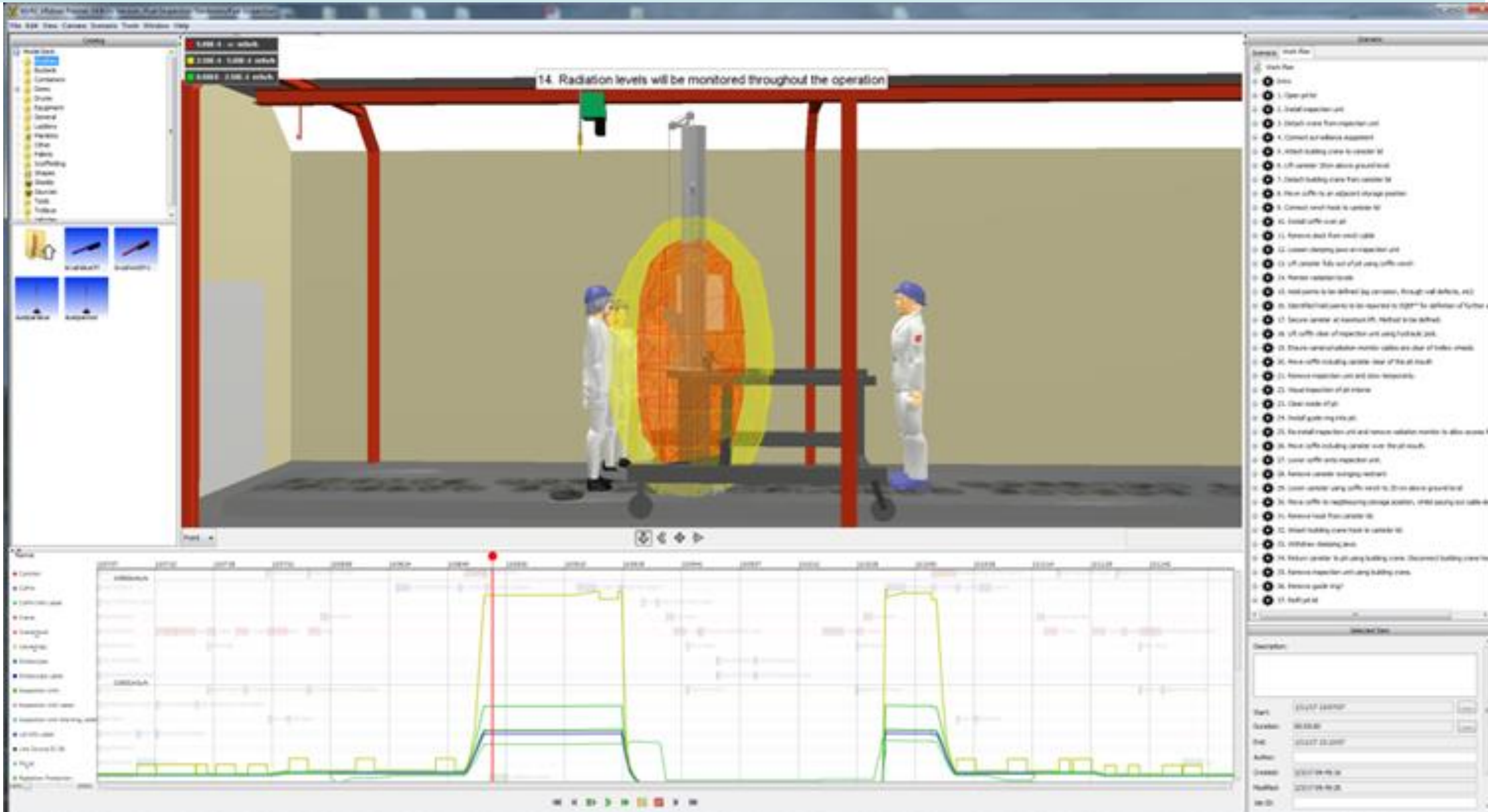


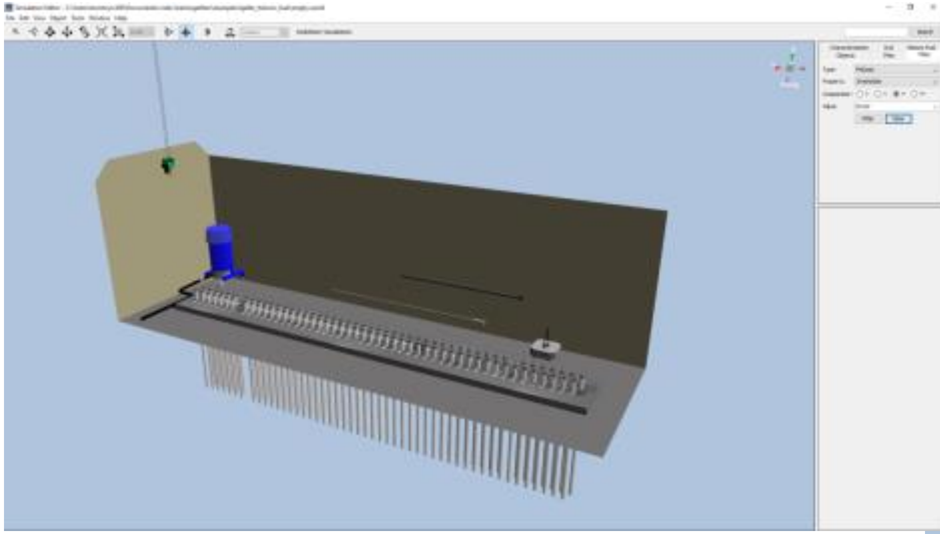


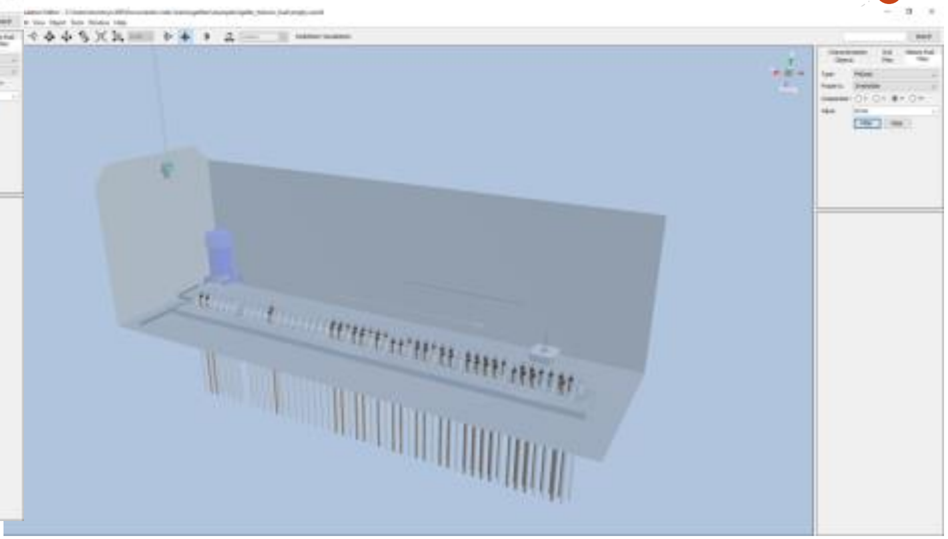
Allows a play-back of the scenarios in Phase 3 operations

incl. pop-up labels with instructions

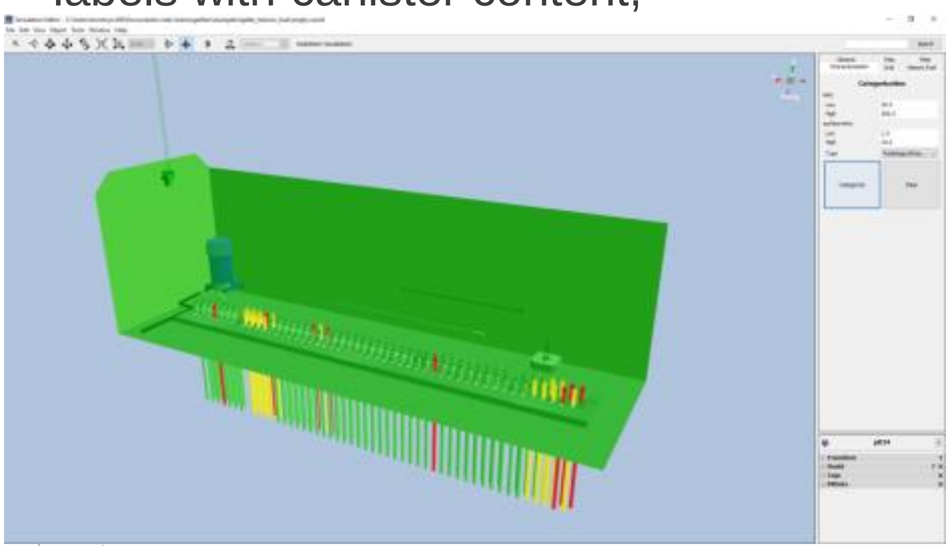
VR (dose): play back the scenario for Phase 3 operations with pop-up labels indicating assosicated risks

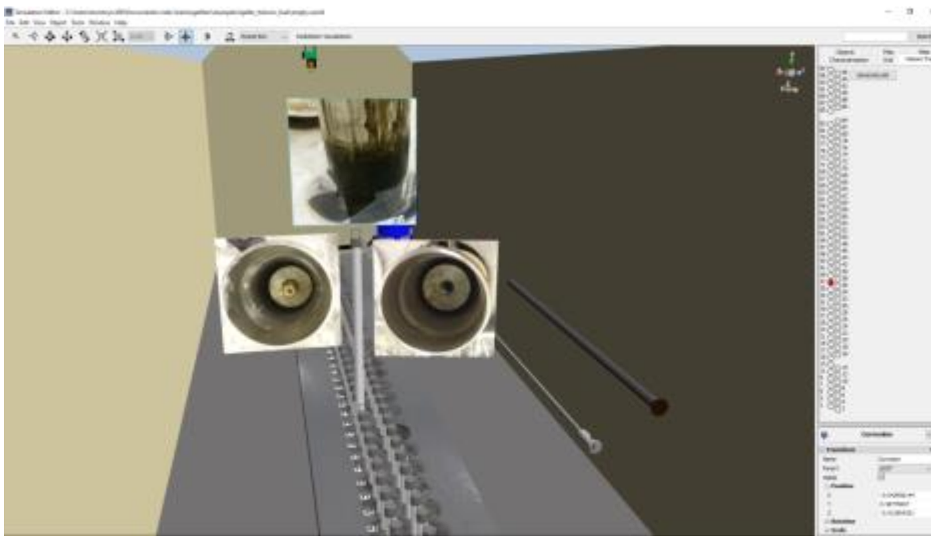






HoloLens: Show invisible parts (below flor parts) with possibility for activating labels with canister content,





VR demos to «Ageing fuel management - phase 3» - Welcome to demo session!

Thank you for your attention!