Nuclear decommissioning: end of lifecycle - cradle of new technology

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Key Figures

Annual turnover:
> 100 Mill €

Annual scientific publications with referee:
120

1948: IFA

1980: IFE

No. of employees:
650

Nationalities: 37

Researchers: 218

PhDs: 105

14000
Visitors a year

National Centers for Environment-friendly Energy Research 2

Advanced Laboratories:
24

International projects:
> 120

IFE, three organisations in one

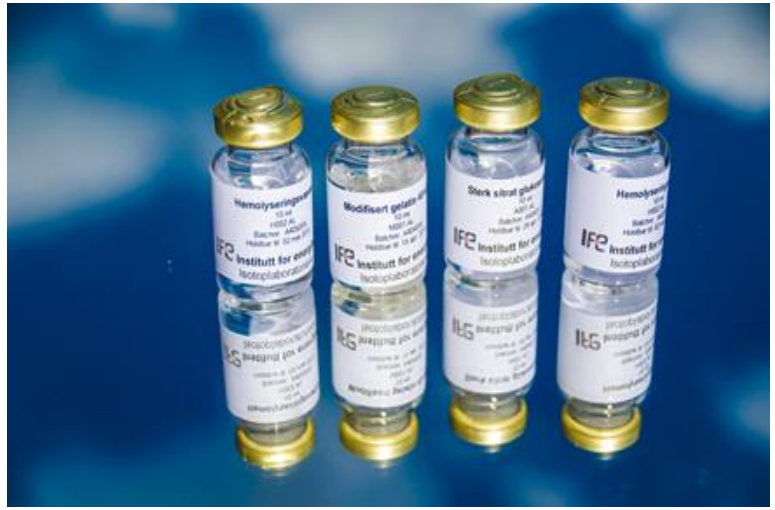
Research & Development

- Material and Prosess Technology
- Flow Technology and Environmental Analysis
- Digital Systems

Nuclear Technology

- Two research reactors
- Research within physics, materials, nuclides for medicines, nuclear safety, denuclearization, nuclear waste and decommissioning

Radio-pharmacy



- Development of radiopharmaceuticals
- Production of Xofigo for Bayer
- Production of other radiopharmaceuticals
- Pharmacy and distribution of radiopharmaceuticals

60 years history of nuclear research

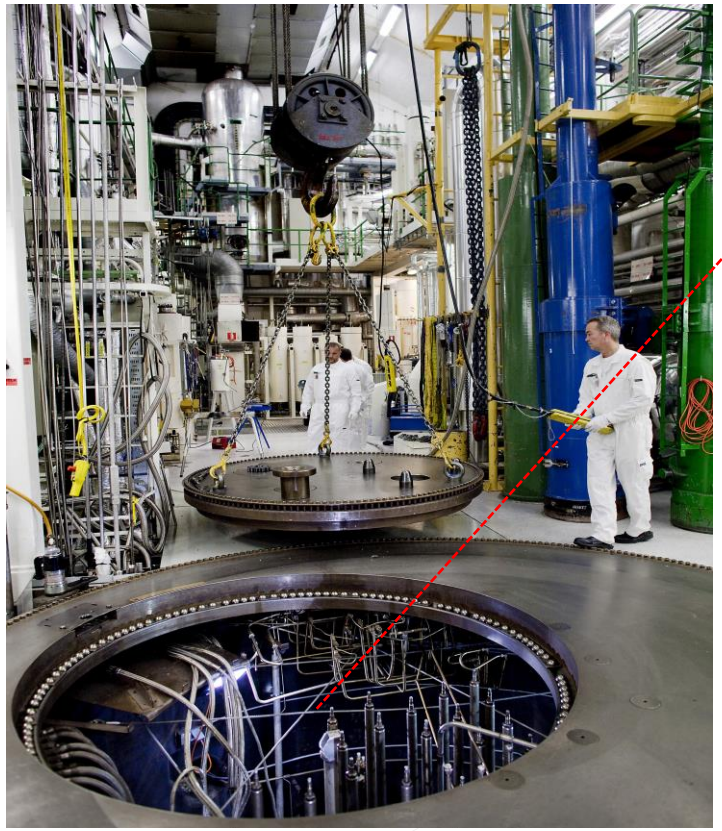
- 1939 Nuclear fission demonstrated
- 1942 First nuclear reactor in the world started at Stagg football stadium, Chicago USA

HBWR

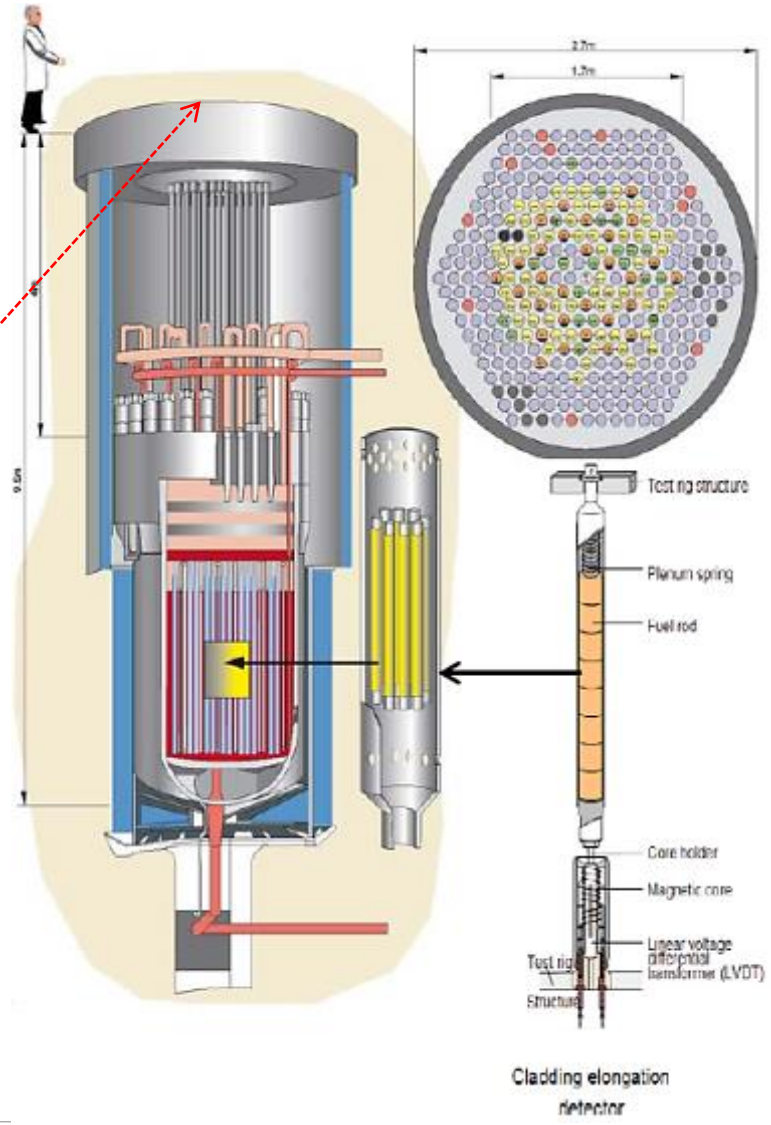
- 1948 IFA (Institutt for Atomenergi) started
- 1951 Jeep 1 reactor at Kjeller started. One of the first experimental heavy water research reactors in the world
- 1954 Halden Boiling Water Reactor (HBWR) decision made to build the reactor in Halden
- 1958 OECD Halden Reactor Project established
- 1959 HBWR critical June 29th
- 2018 HBWR permanent shutdown June 27th

Official opening 10. Oct 1959

A key asset to international nuclear R&D



Hall of the Halden Reactor



HBWR Research program

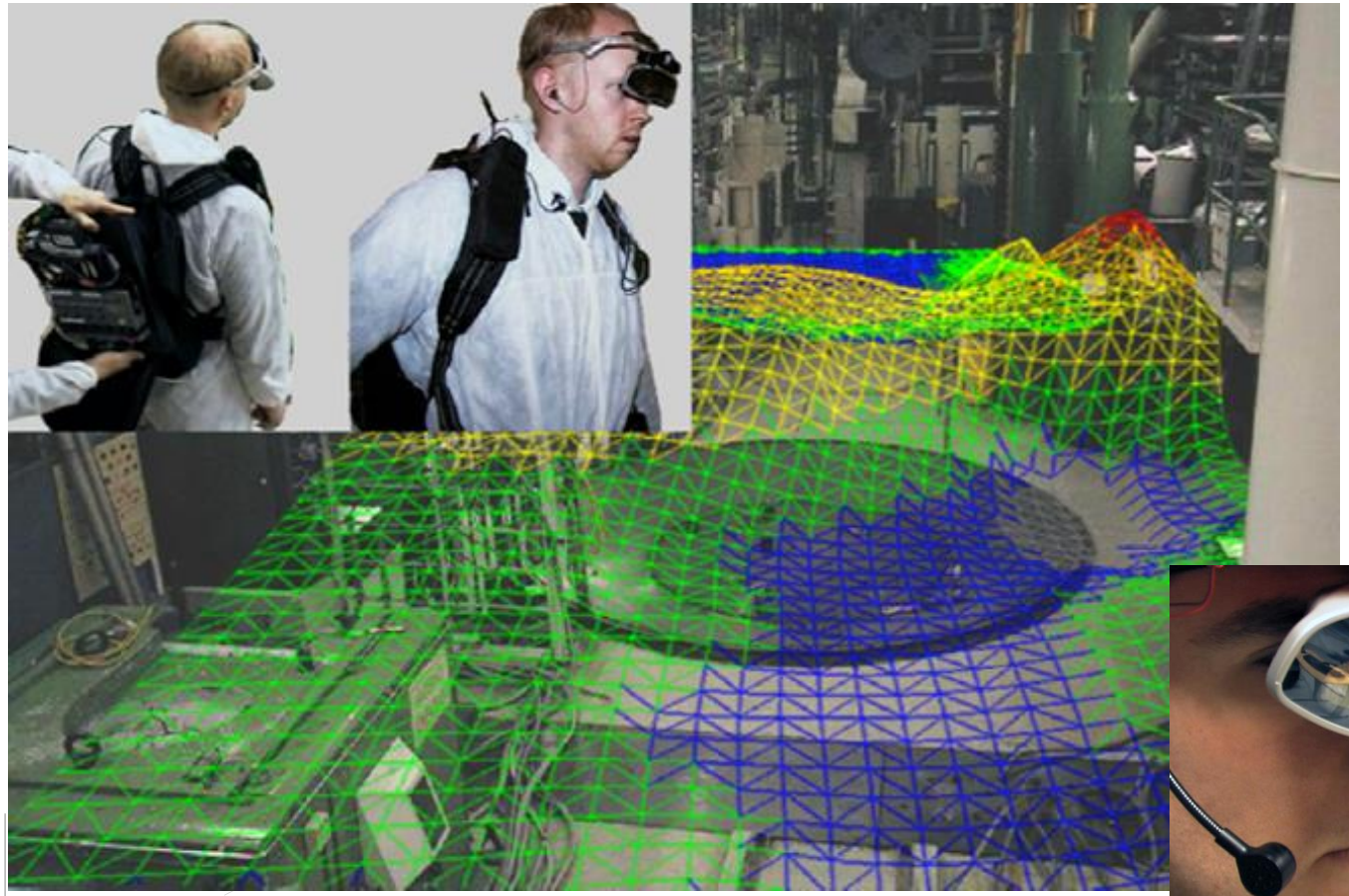
Key-factor: Making In-pile fuel measurements

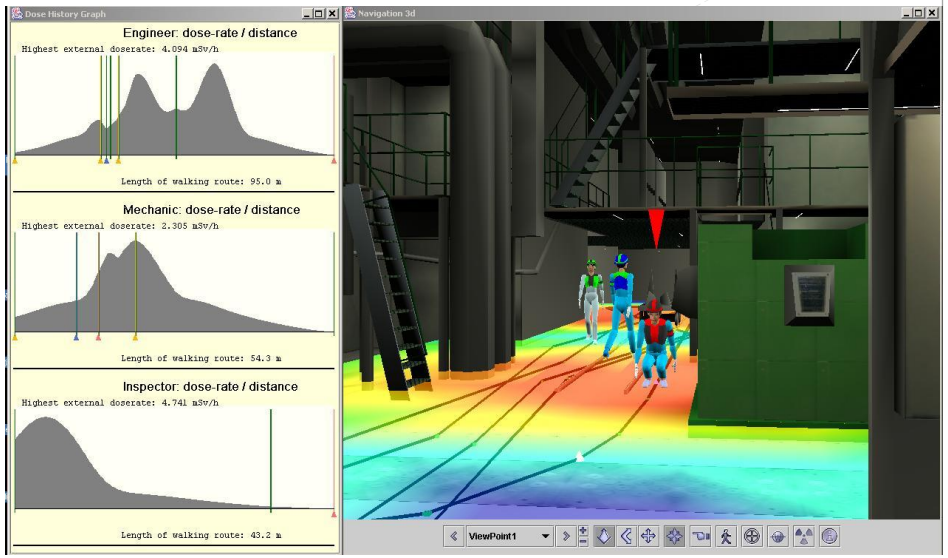
- Fuel performance
- Cladding performance
- Safety Criteria (fuel behavior under LOCA conditions)
- Material test (IASCC)
- Loop systems for simulating BWR/ PWR/ CANDU conditions

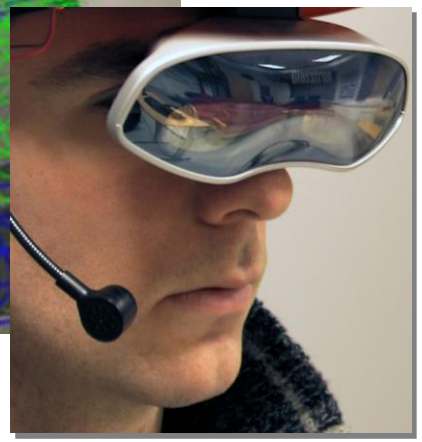
HBWR Technical Data

- Thermal power: 20 MW
- Operating temp.: 235 ^{o}C
- Operating press.: 31 bar
- Moderator: Heavy water
- Heavy water vol.: 14 m^3
- Type of fuel: UO_2
- Power control: 30 Control rods

20+ years history of research into digital support





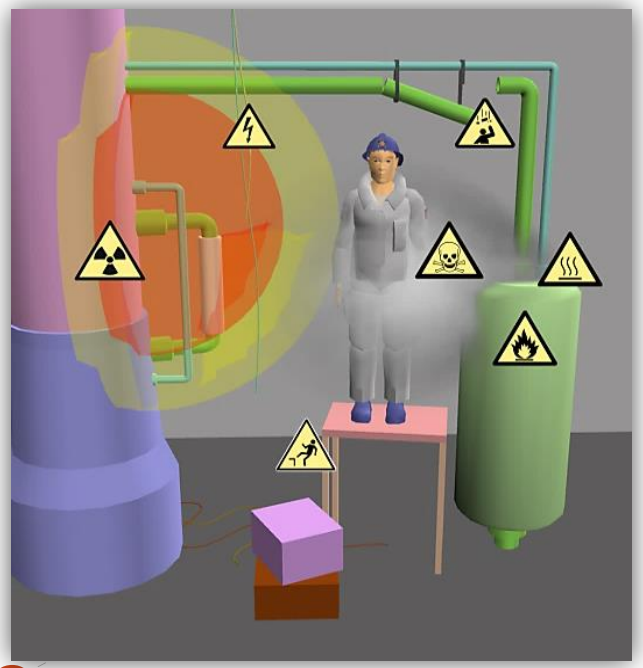


The OECD Halden Reactor Project (HRP)

>100 nuclear organizations from 20 countries

utilities, vendors, licensing authorities and R&D centres:

CEA, CIEMAT, CNPRI, CRIEPI, FRAMATOM, DTU, EDF, E.ON, ENSI, EPRI, EU JRC, FANR, GE/GNF, GRS, IRSN, JAEA, KAERI, Kazatomprom, MEE, Mitsubishi, MTA EK, NNL, NRA, NRG, PSI, SCK/CEN, SNERDI, SSM, TVEL, UJV, US DOE, US NRC, VUJE, Westinghouse …



Safety management for decommissioning

Training for normal work and emergencies in decom.

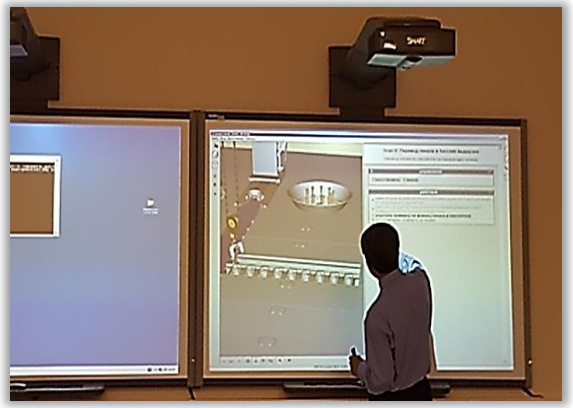
20+ years history in digital support for decommissioning

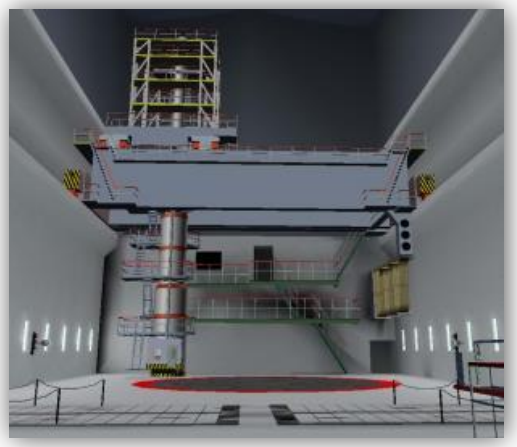
Fugen NPP (JAEA)
(1995 -)

Leningrad NPP
(1999-)

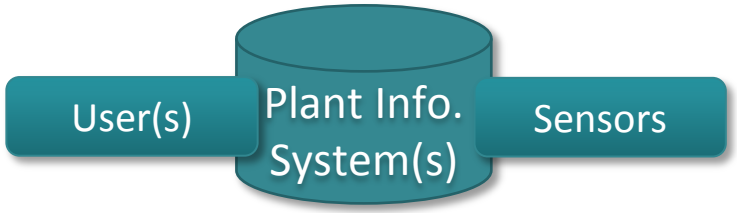
Andreeva bay, NW Russia (2011-)

Chernobyl NPP
(2008 -)



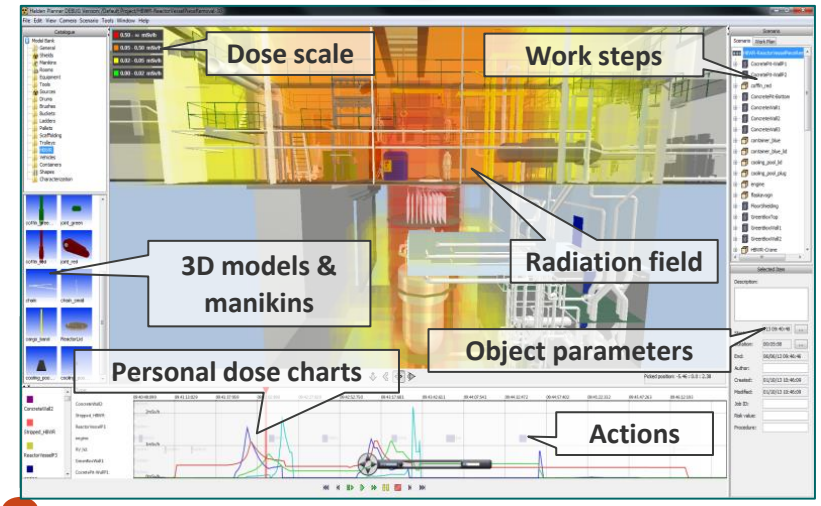


Industrial support systems and services



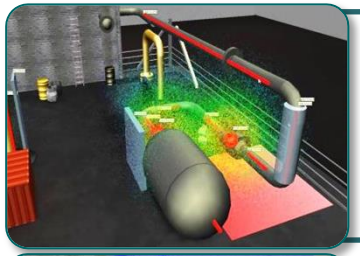
Plant information
- 3D models,
- Radiological data,
- Structure/component properties, …

Work plan

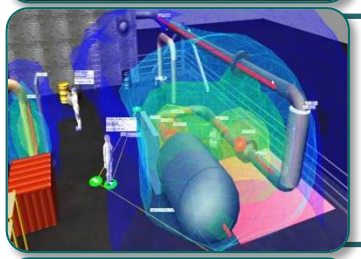


The **VRdose™** tool family

- Optimal work procedure
- Worker dose/risks
- Comparison of alternatives
- Documentation
- Demonstrations
- Training material



Visualize
- The environment (digital model),
- Radiation emission/exposure, and
- Work scenarios (3D technology)



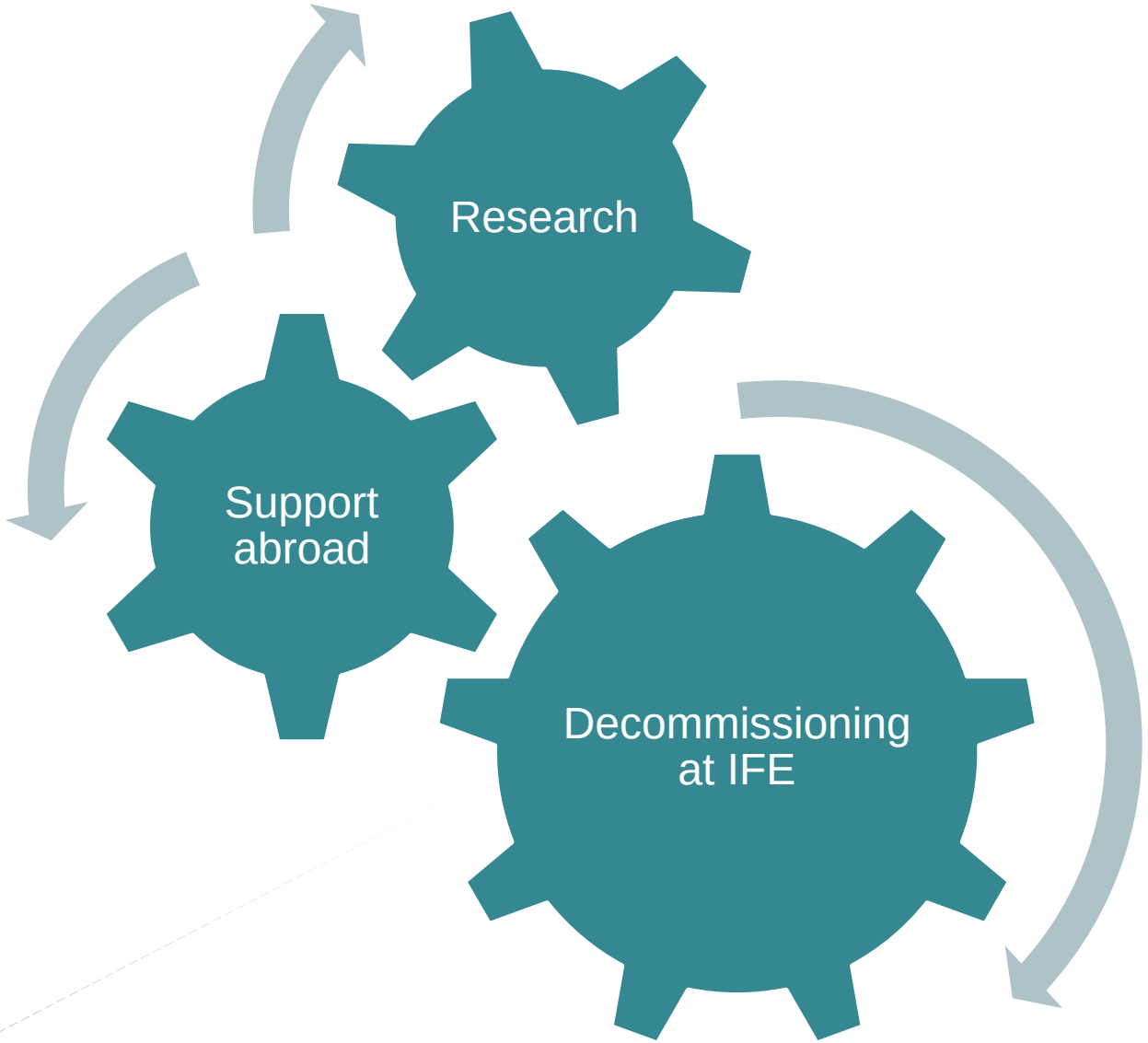
Optimize
- Modify (with interactive real-time 3D visualisation)
- Compare alternative scenarios

Demonstrate & document
- Playback with interactive navigation and visualisation
- Output printer-friendly reports

Train/support
- Desktop and immersive material
- Classroom type and interactive
- Augmented Reality in-situ support

Customization, application, data import, ….

Now histories meet



world nuclear news

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Halden Reactor to be decommissioned

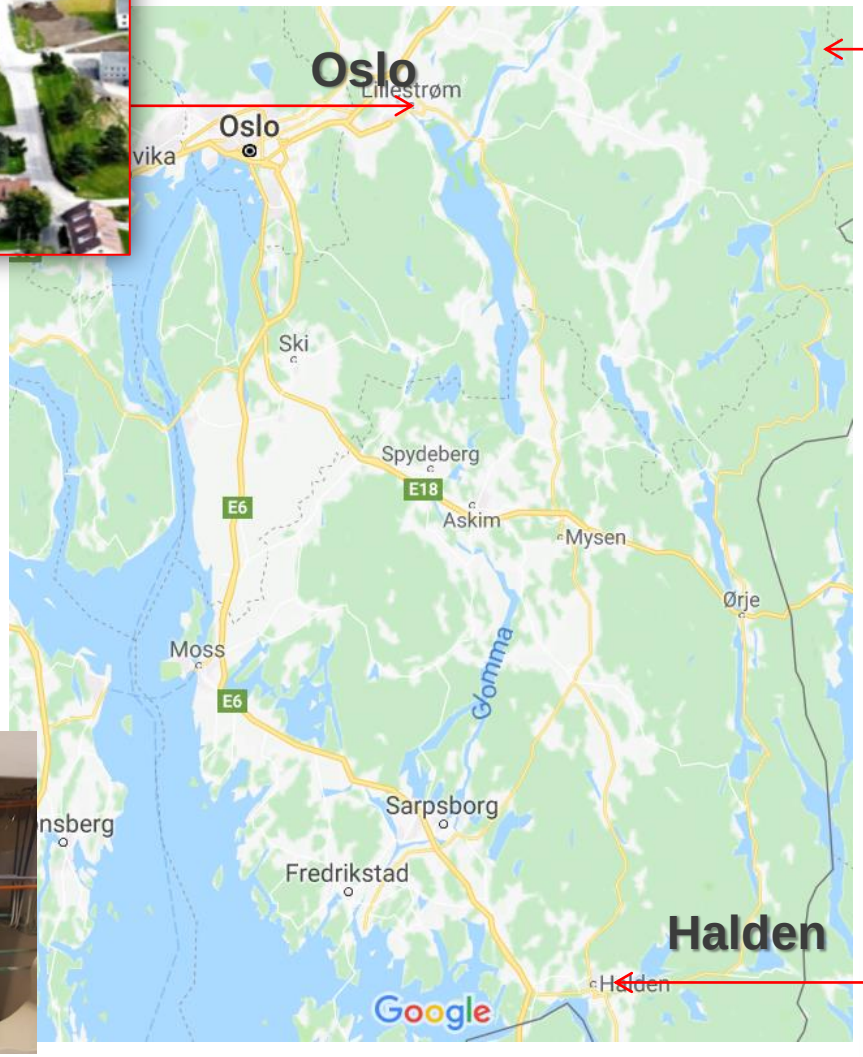
28 June 2018

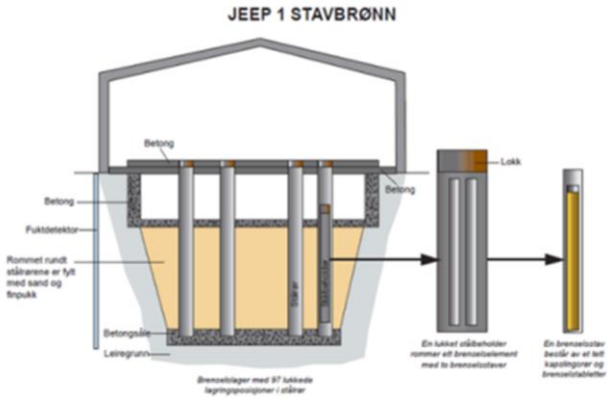
Share

The board of directors of Norway's Institute for Energy Technology (IFE) has decided to close the Halden Reactor permanently and to start its decommissioning. The board will not apply to extend its operating licence, which expires in 2020, and the reactor, which is currently shut down due to a safety valve failure, will not be restarted.

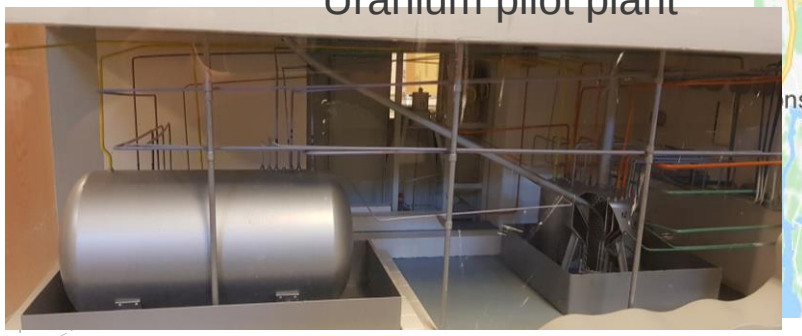
The Halden reactor (Image: IFE)

Decommissioning sites at IFE





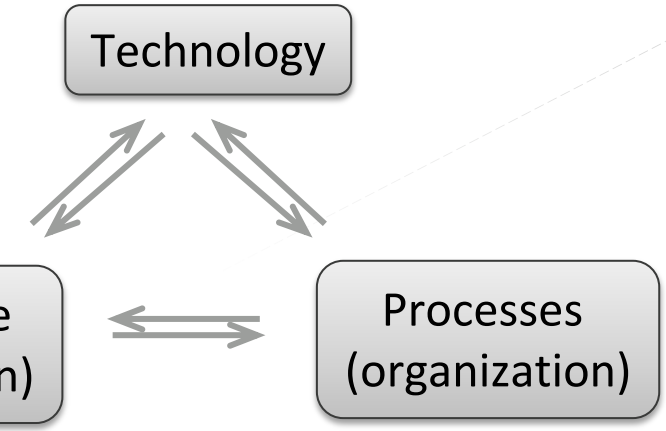
Uranium pilot plant



Focus on systemic (MTO) approach

Radiological modelling

- Real time radiation transport
- Geostatistical analyses
- Monte Carlo radiation transport
- Source deconvolution
- Internal dosimetry



- Sematic web technology
- Robotics
- 3D gamma mapping

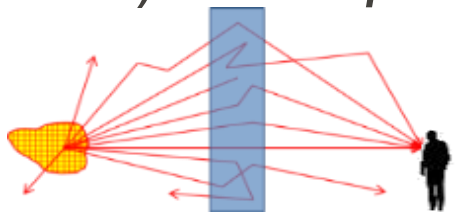
- 3D modelling
- Virtual and Augmented reality
- Advanced user interfaces
- Mobile and wearable devices

Human and organisational factors

- Gap analyses (key capabilities, maturity)
- Capability development - road map for minimising H&O issues
  - Staffing – optimisation / Trening / Change management

Radiological (risk) modelling

Real-time (Point Kernel) rad. transport

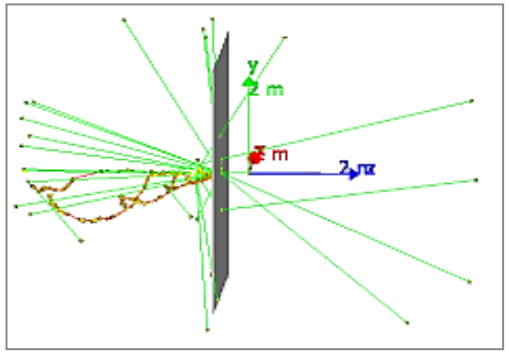


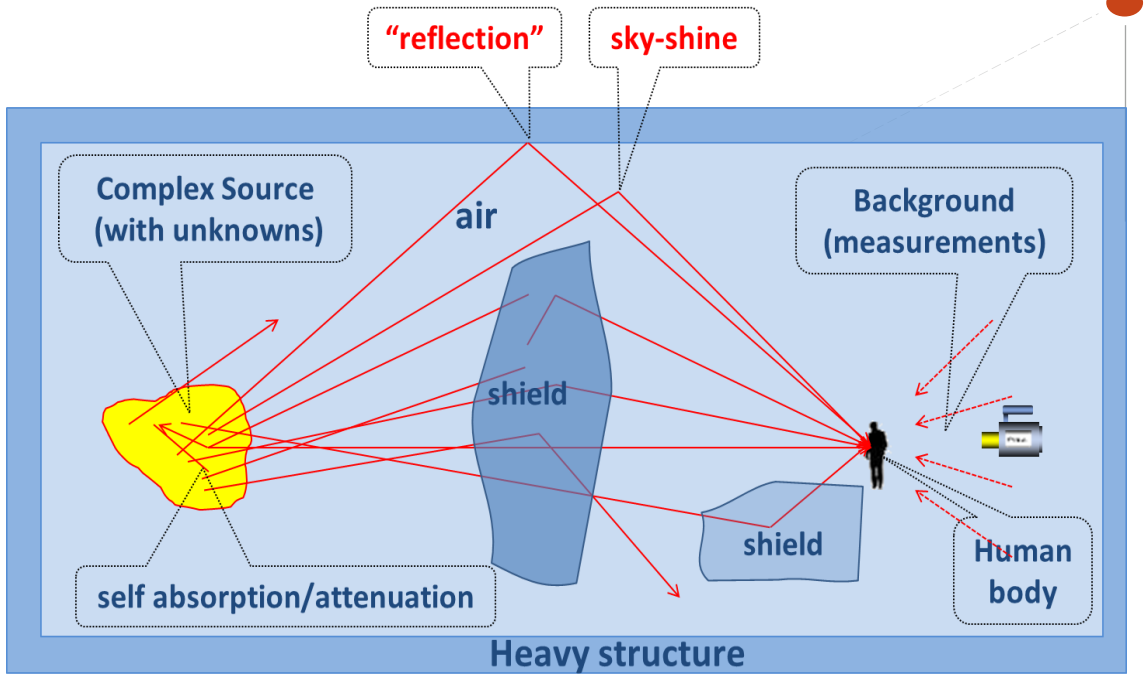
rate of energy absorbed in air from secondary charged particles

$$Dose = Const \times \sum_i \left(\frac{Ay_i}{4\pi d^2} \times e^{-\mu_i x t} \times E_i \cdot (\mu_{en}/\rho)_i \times B_X(E_i, t) \right)$$

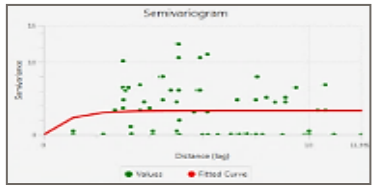
conversion of units — $\Phi_i(natt)$ $\Phi_i(att)$ $\psi_i(att)$ — CF

MC rad. transport (MCNP, GEANT4)





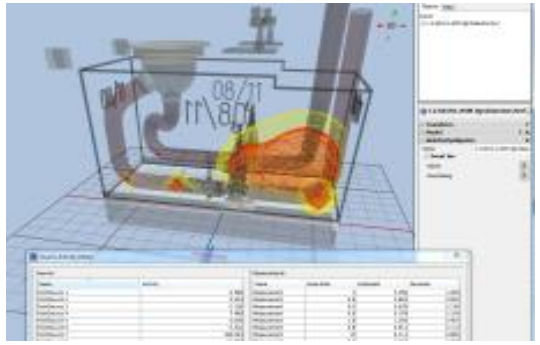
Interpolation - Geostatistics



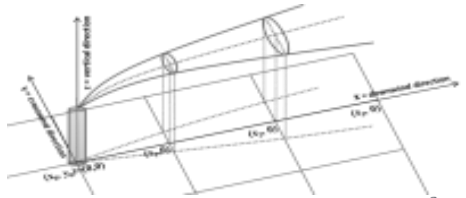
$$Z^*(\mathbf{u}) = m(\mathbf{u}) + \sum_{\alpha=1}^{n(\mathbf{u})} \lambda_\alpha(\mathbf{u})[Z(\mathbf{u}_\alpha) - m(\mathbf{u})]$$

$$= \sum_{\alpha=1}^{n(\mathbf{u})} \lambda_\alpha(\mathbf{u}) Z(\mathbf{u}_\alpha) + \left[1 - \sum_{\alpha=1}^{n(\mathbf{u})} \lambda_\alpha(\mathbf{u})\right] m(\mathbf{u})$$

Source deconvolution



Atm. dispersion

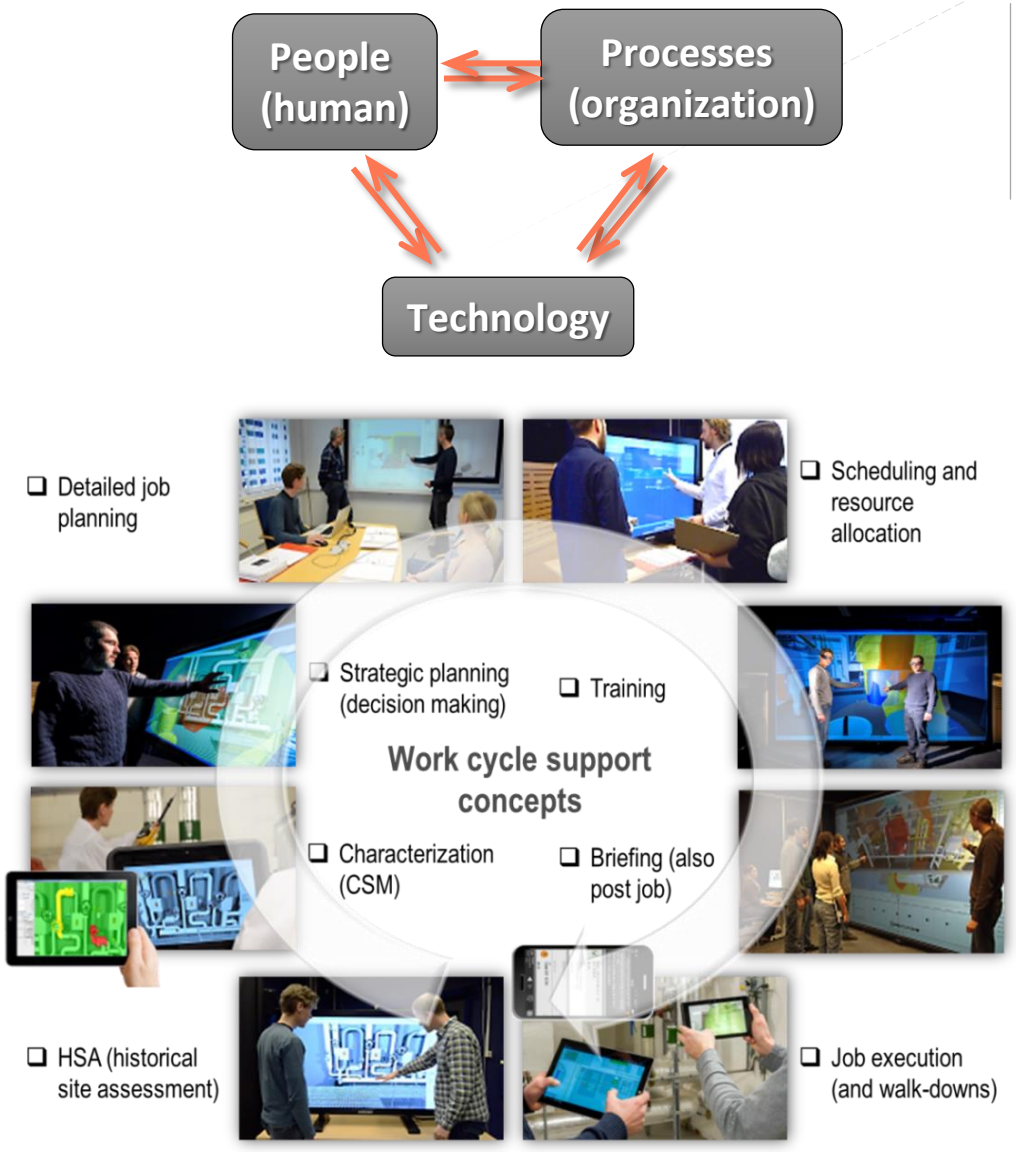


$$C(x,y,z) = \frac{Q(x)}{2\pi \cdot \sigma_y(x) \cdot \sigma_z(x) \cdot \mathrm{u}_{10}} exp\left[\frac{-y^2}{2\sigma_y(x)^2}\right] F(x,z)$$

$$C(x,y,z) = \frac{Q(x)}{\sqrt{2\pi} \cdot \sigma_y(x) \cdot A \cdot \mathrm{u}_{10}} exp\left[\frac{-y^2}{2\sigma_y(x)^2}\right]$$

Holistic (digital) support

- Plant information management (PIM)
- Rad. characterization
- Informed decision making
- Job planning (optimization: risk/hazards - costs)
- Regulatory interaction
- Team collaboration & coordination
- Training & Briefing
- Knowledge Management (KM)
- Emergency preparedness
- Robotic & autonomous systems



IAEA PRESS RELEASE (2018)

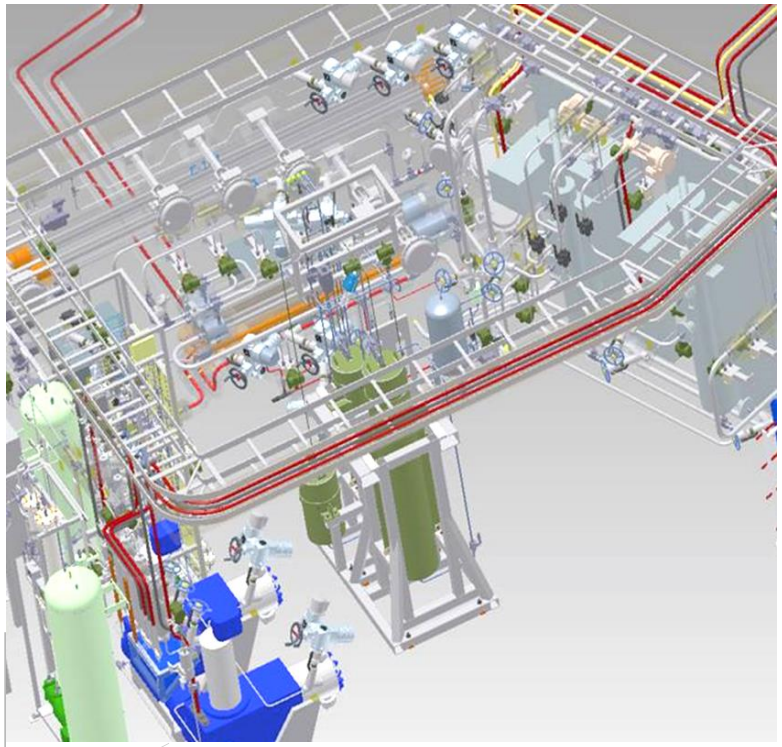
General Conference Day 2 Highlights
IAEA and Norway

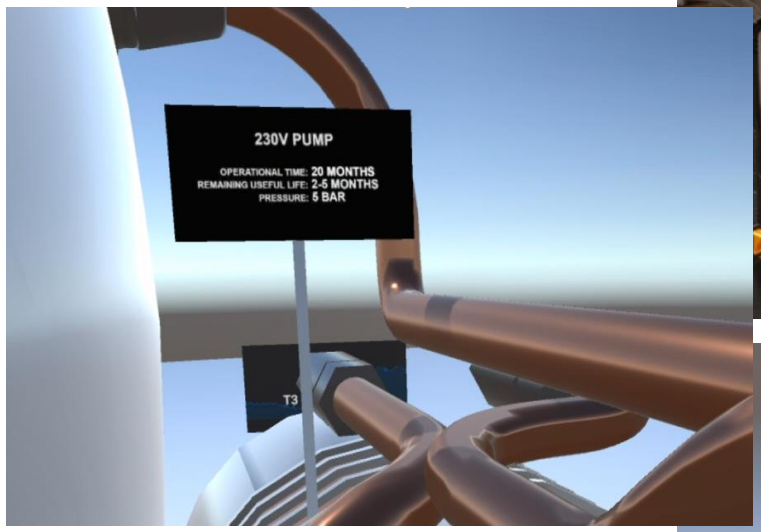
The IAEA and Norway's Institute for Energy Technology will work together on the use of digital technologies in decommissioning and nuclear knowledge management under an agreement signed by the two parties on the side-lines of the 62nd General Conference.

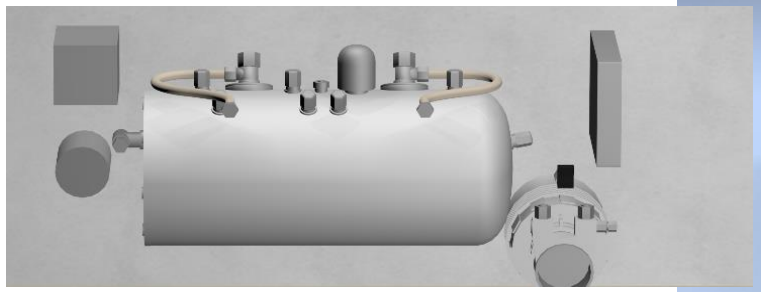
(Left to right) President of the Institute for Energy Technology Nils Morten Huseby signs the Practical Arrangement with IAEA Deputy Director General and Head of the Department of Nuclear Energy Mikhail Chudakov. (Photo: IAEA)

www.iaea.org/newscenter/news/general-conference-day-2-highlights-18-september-2018

Digital twins

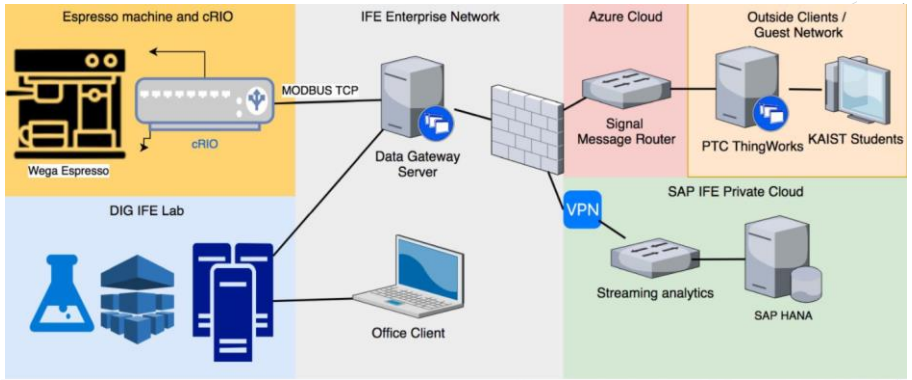


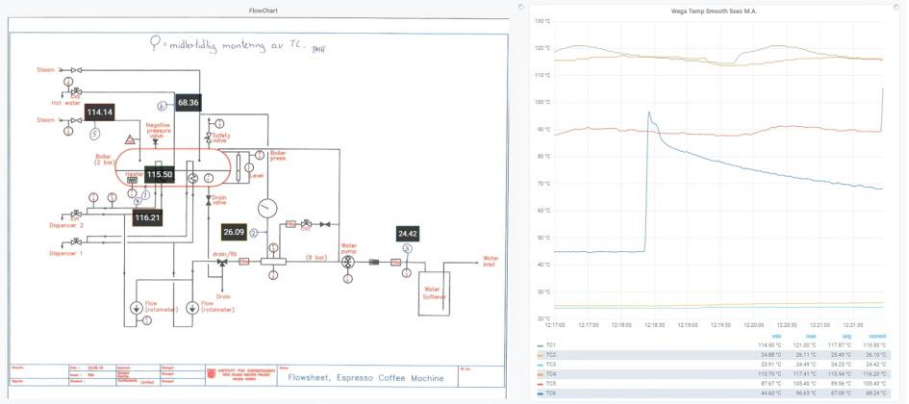




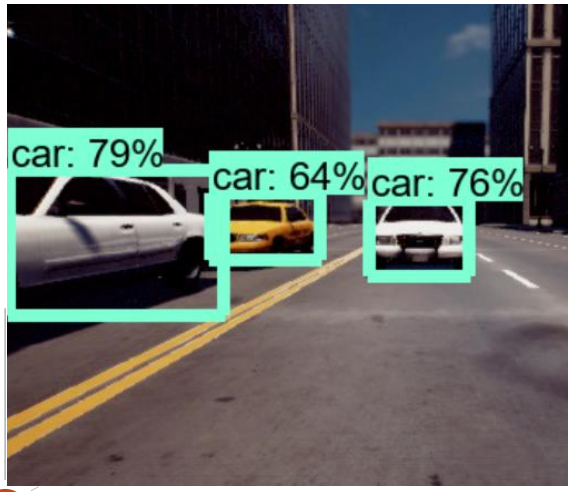
Machine learning - AI

Visual inspection of the quality of produced radiopharmaceuticals

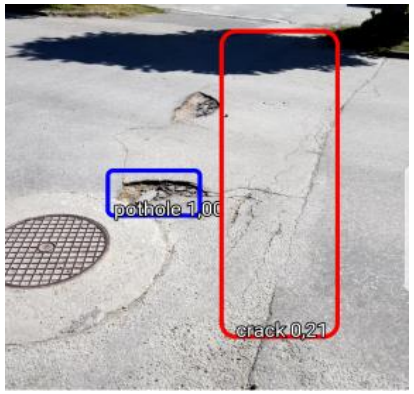




Virtual

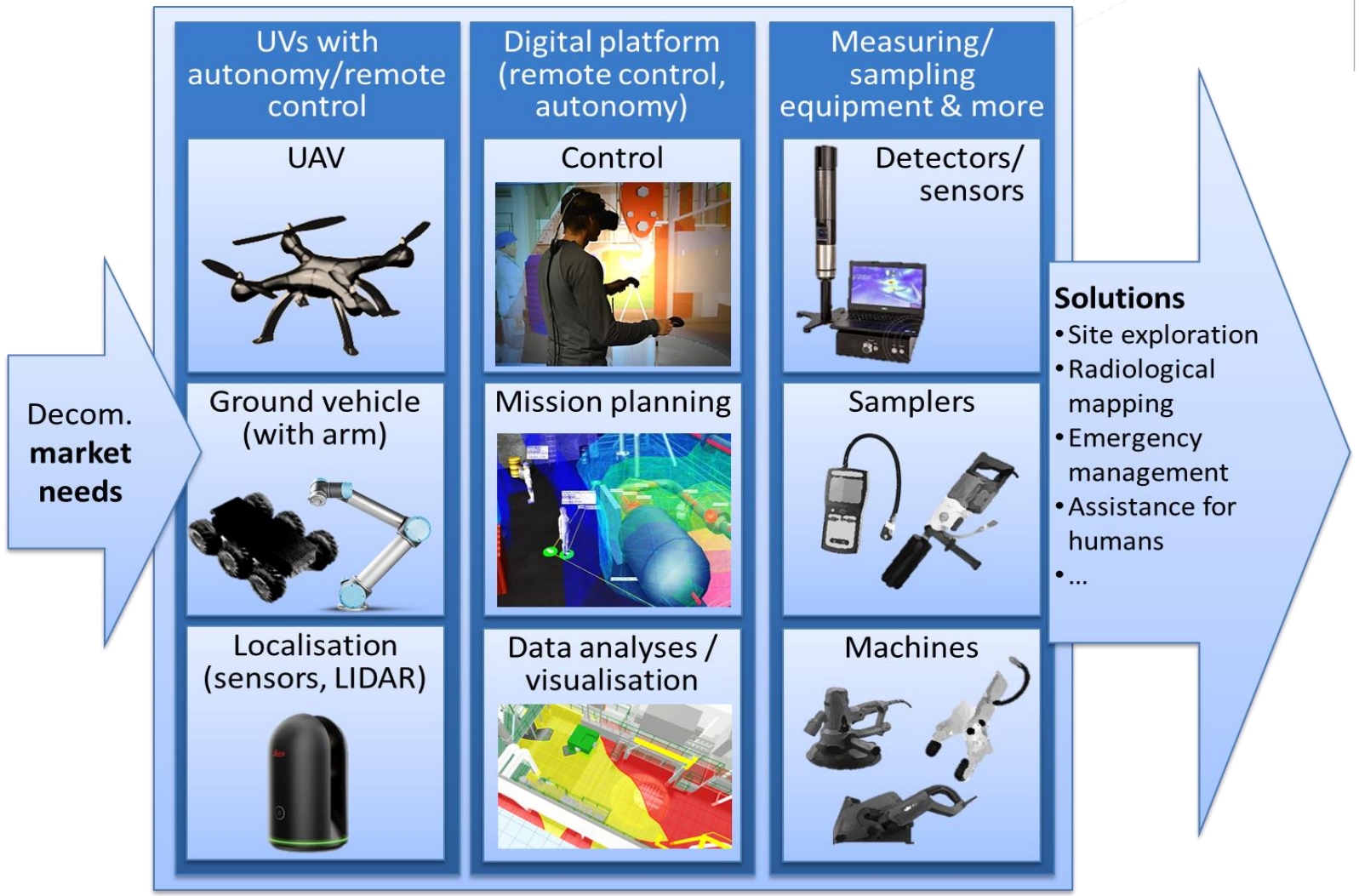


Real

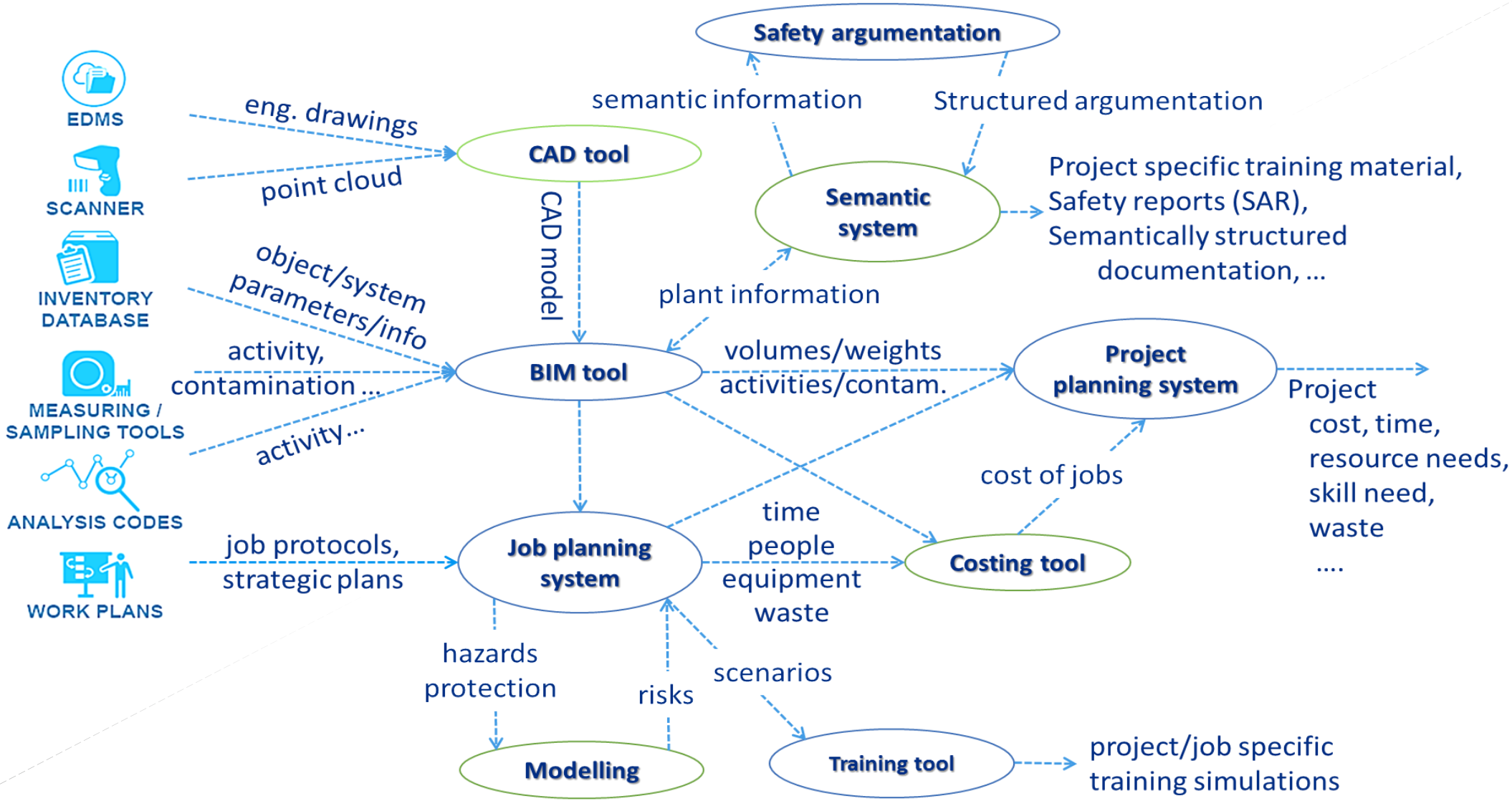


Initiative: Digitalization + sensors + robotics

- Integrate standard / emerging equipment in a modular design
- Integrate digital, sensor and robotic tech
- Enable high autonomy
- Prove safety/security
- Validate in the field and prove efficiency
- Full scope support: design, training, control, …
- Guidance for application to specific needs

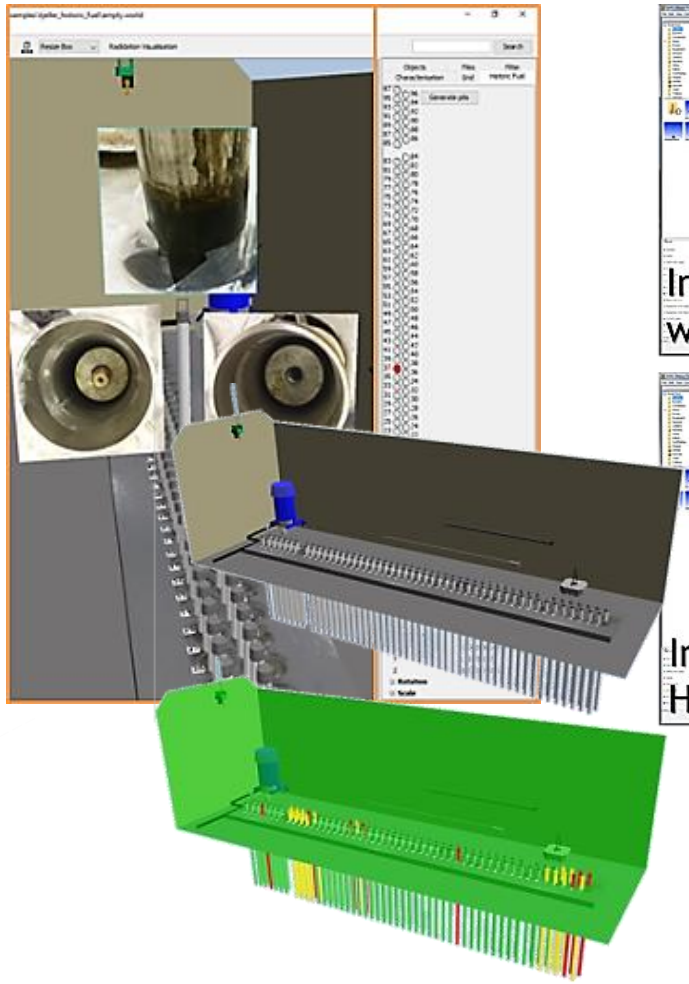


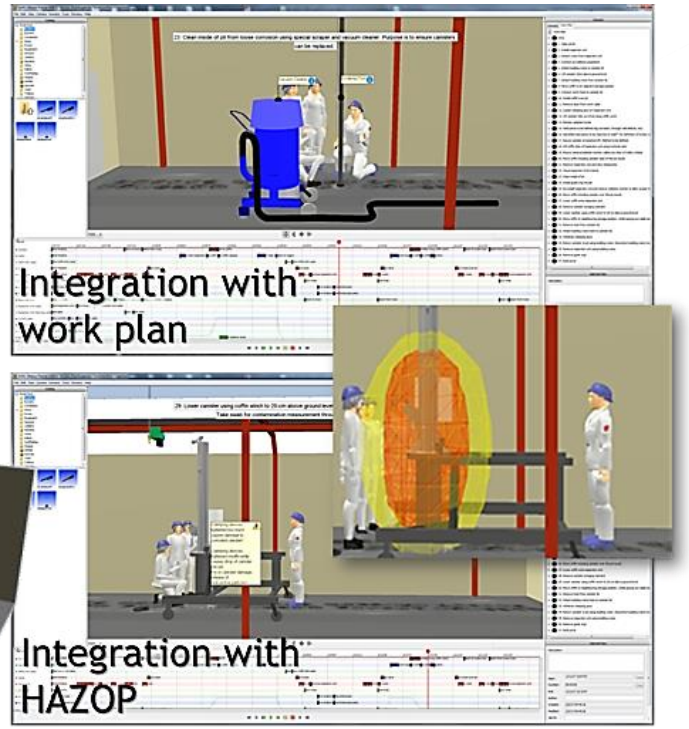
Initiative: Holistic digital support



Piloting comprehensive digital support

1. Building info system (BIM)
A 3D interactive information system, based on integration of 3D CAD data with characterization and other information (e.g. activities) for supporting decisions (planning meetings)



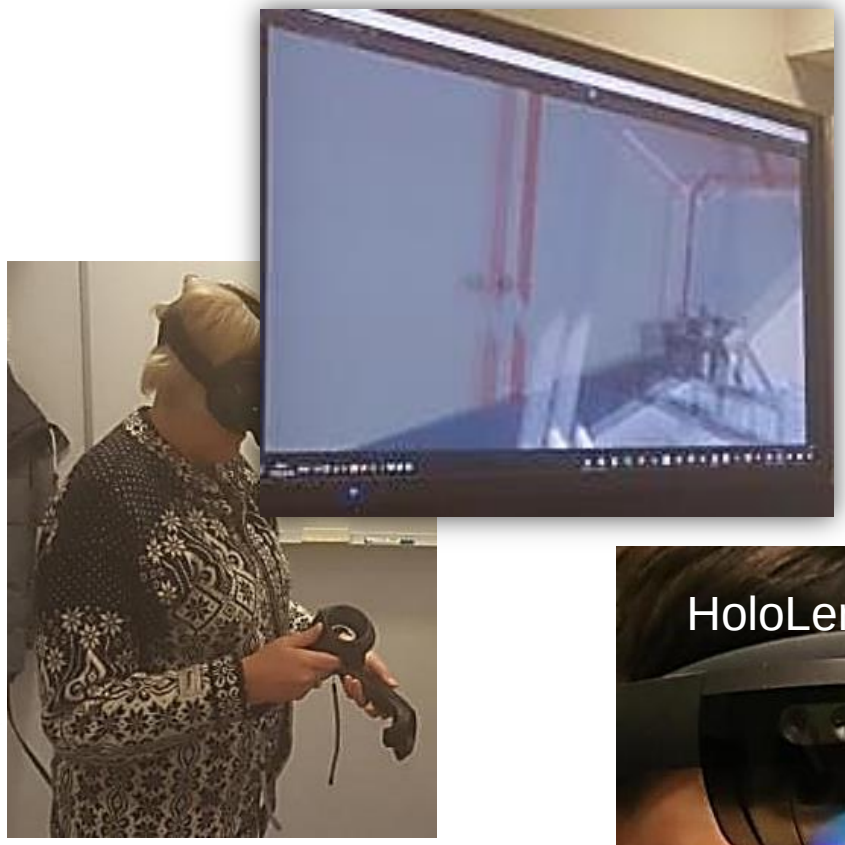


2. HAZOP and work planning
3D interactive simulation of operations (with real-time radiation risk visualization) for finalization of HAZOP results and step-by-step work plan

Piloting comprehensive digital supprot (cont'd)

3. Immersive presence
Virtual Reality based support:

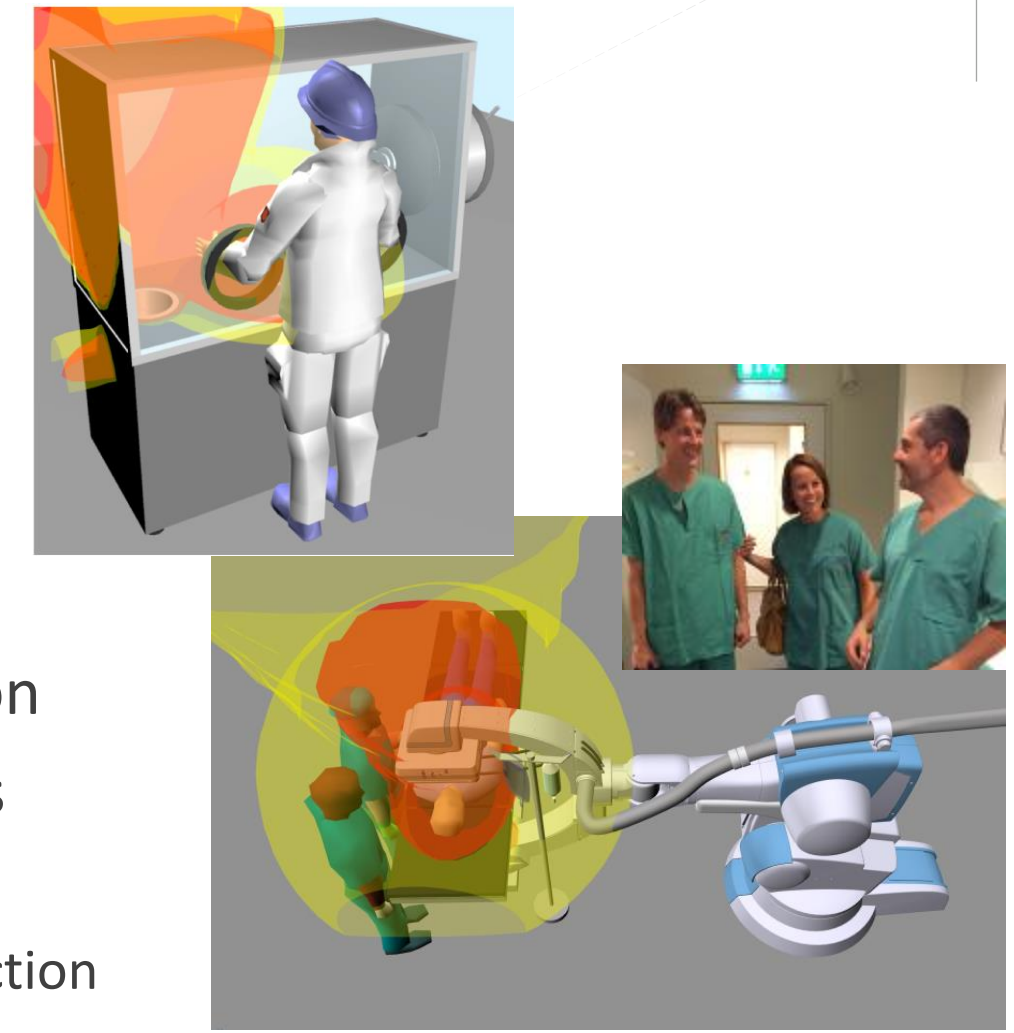
- Visualization of information and radiation
- Interaction with objects (sketching scenarios)
- Visualization of work process



4. In the field information
Augmented Reality based interactive in-situ visualization could support inspections and field workers

Business case – digitalization, robotics in decom

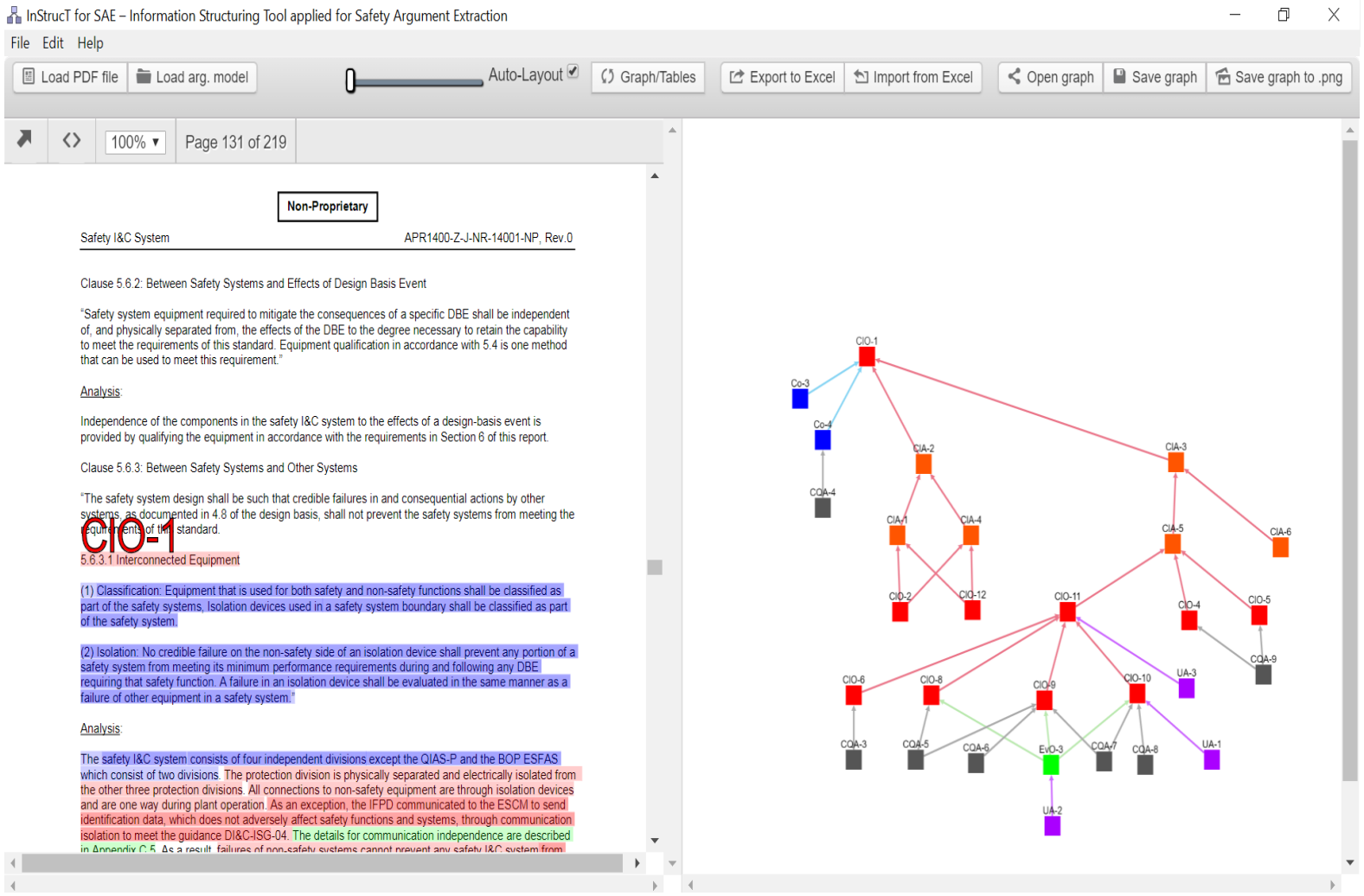
1. Special situations
    1. Accident sites – e.g. Fukushima, Chernobyl
    2. Unique work – e.g. graphite reactors
2. Holistic application
    1. Application for multiple types of tasks
    2. Use across the whole stakeholder team
    3. Start early, use through the whole process
3. Don’t underestimate the impact on motivation
4. Leverage knowledge across projects/domains
    1. Big organisations, National strategy
    2. Other domains – e.g. radiopharmaceutical production



Demos – Monday and Tuesday

Structured safety argumentation

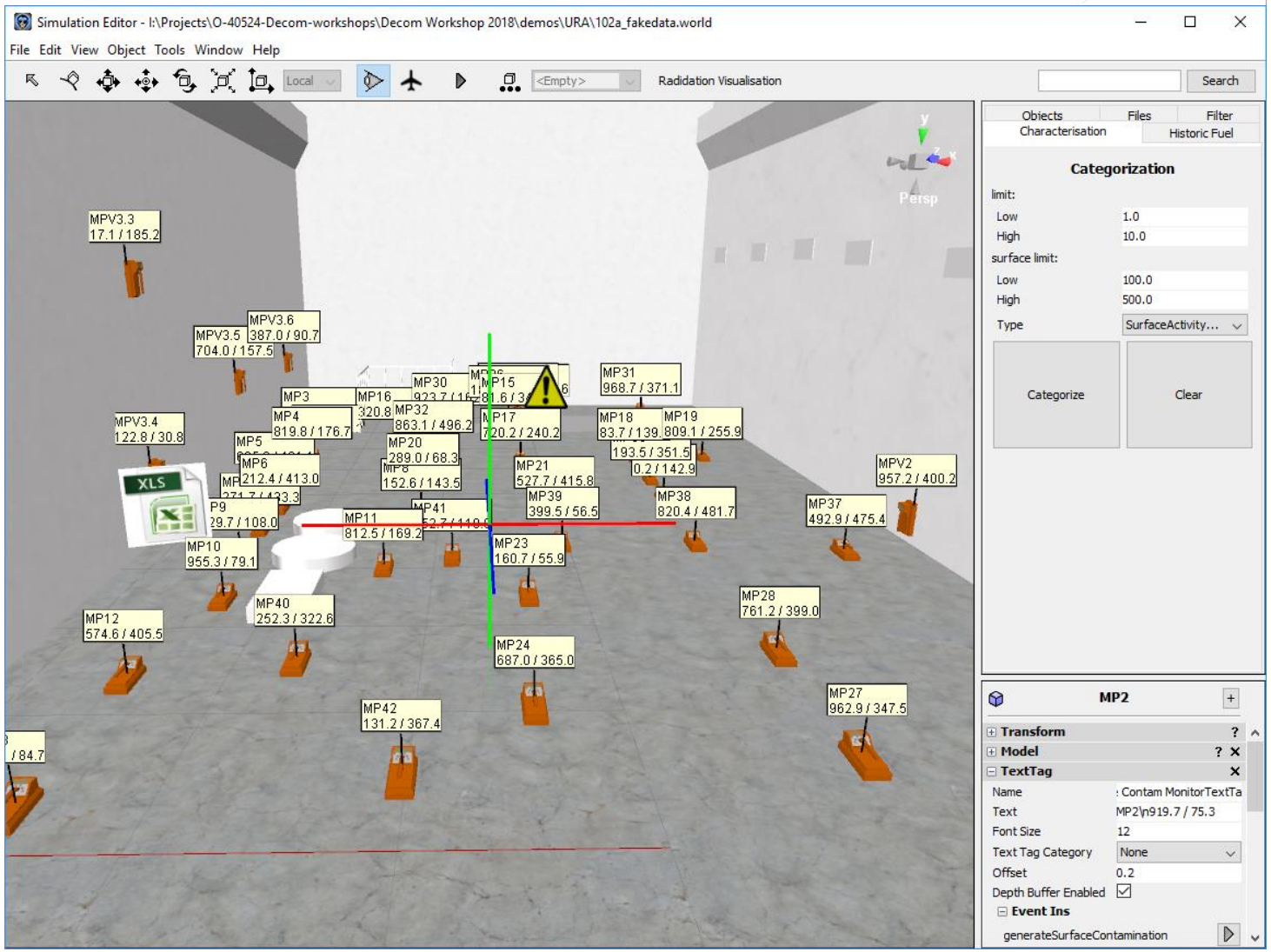
- Analyse reports from a safety/regulatory compliance perspective
- Update reports efficiently in case of deviation
- Create argumentation as a “back-bone” for new reports
- Support communication before development of full report



Demos – Monday and Tuesday

Radiological characterisation - digital support

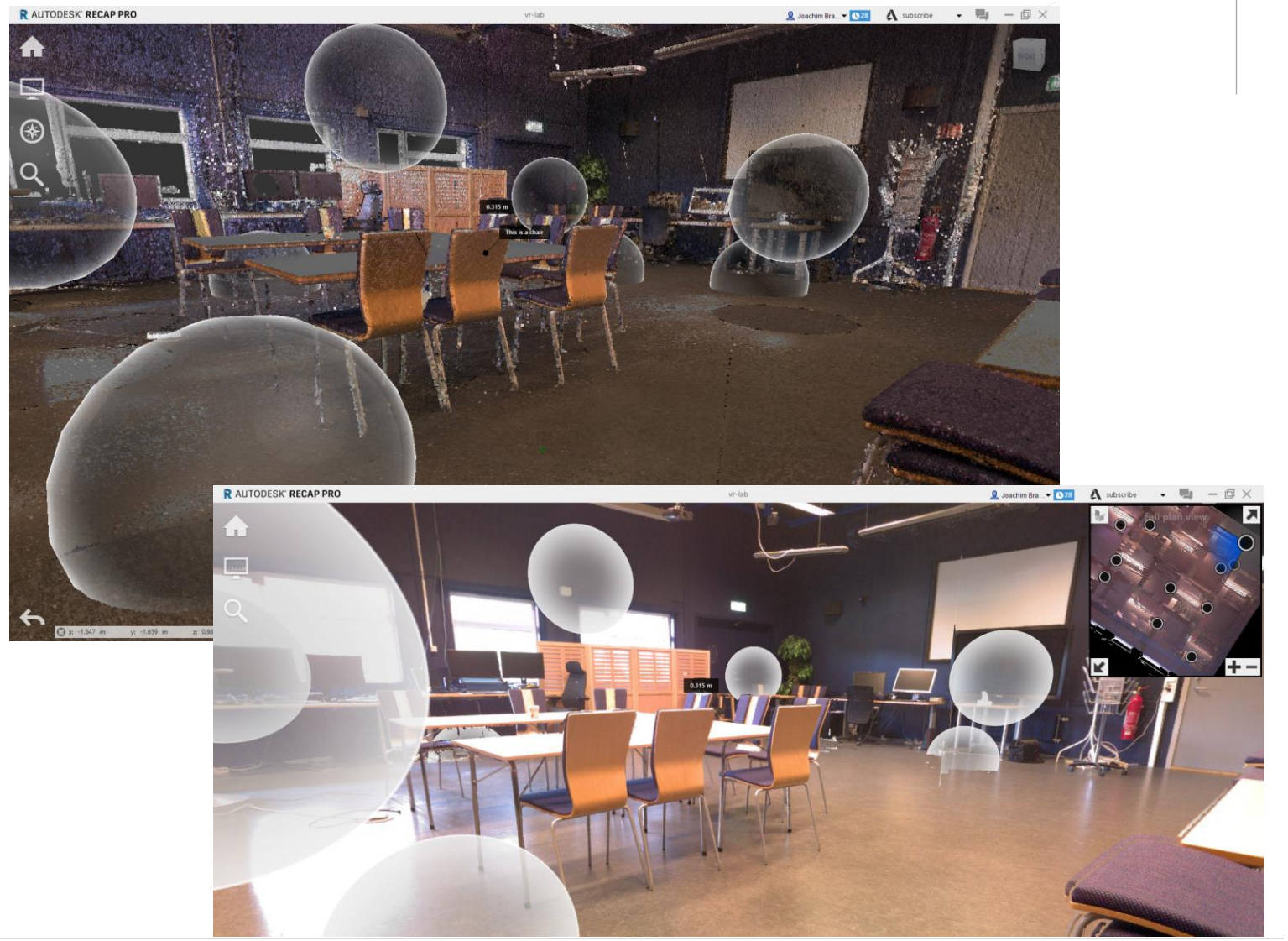
- Historical site assessment – combination of docs, interviews, …
- Visualisation and analysis for strategic decisions
- Documentation and traceability
- In-situ information – AR tech
- Compatible with holistic digitalisation



Demos – Monday and Tuesday

Laser/3D scanning/imaging

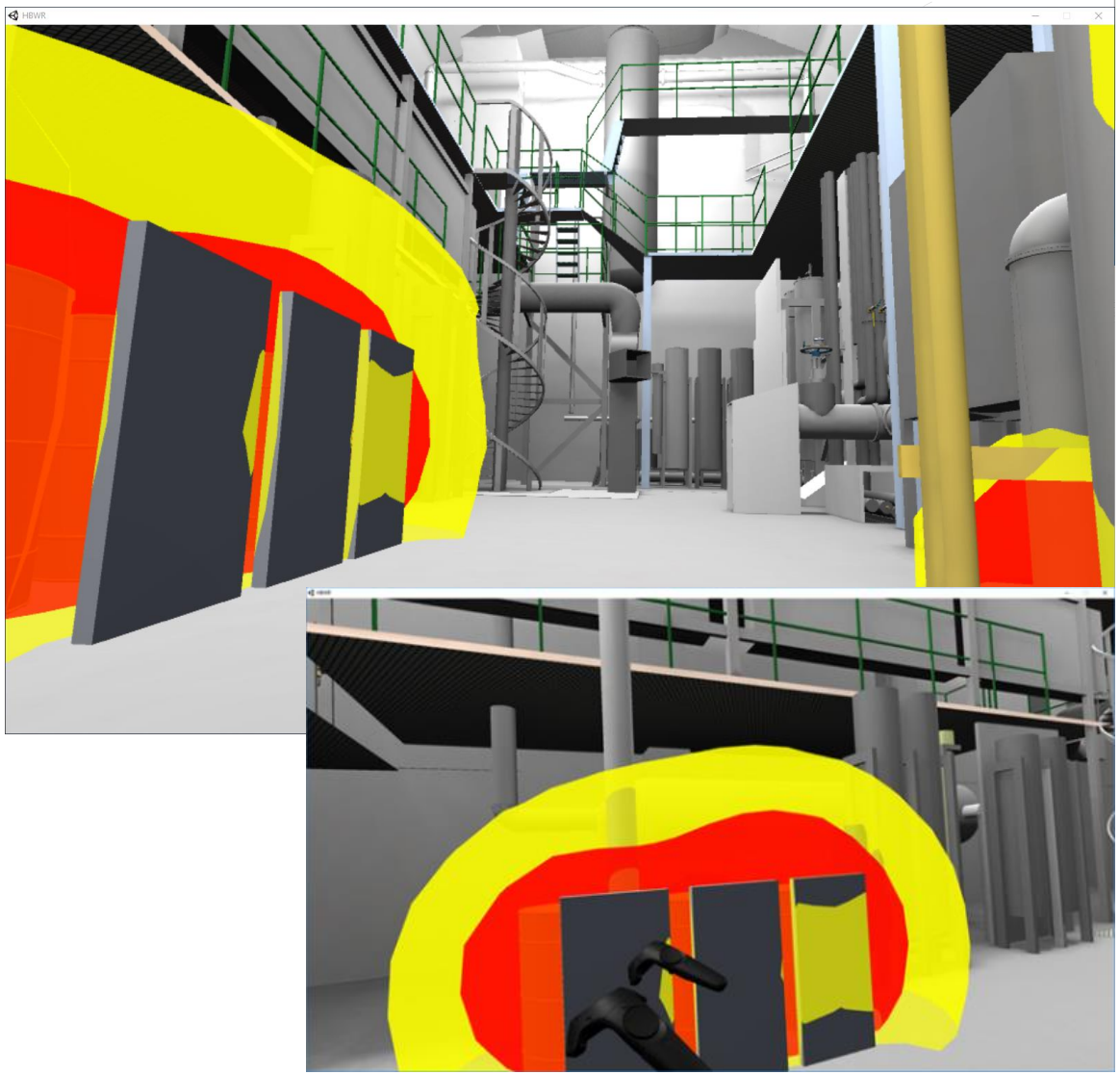
- Virtual tours for familiarisation
- Regular updating of 3D CAD models and engineering drawings (design info verification)
- Strategic planning – verification of feasibility, e.g. space req.
- Enabling other digital support concepts e.g. PIM



Demos – Monday and Tuesday

VR based interactive presence

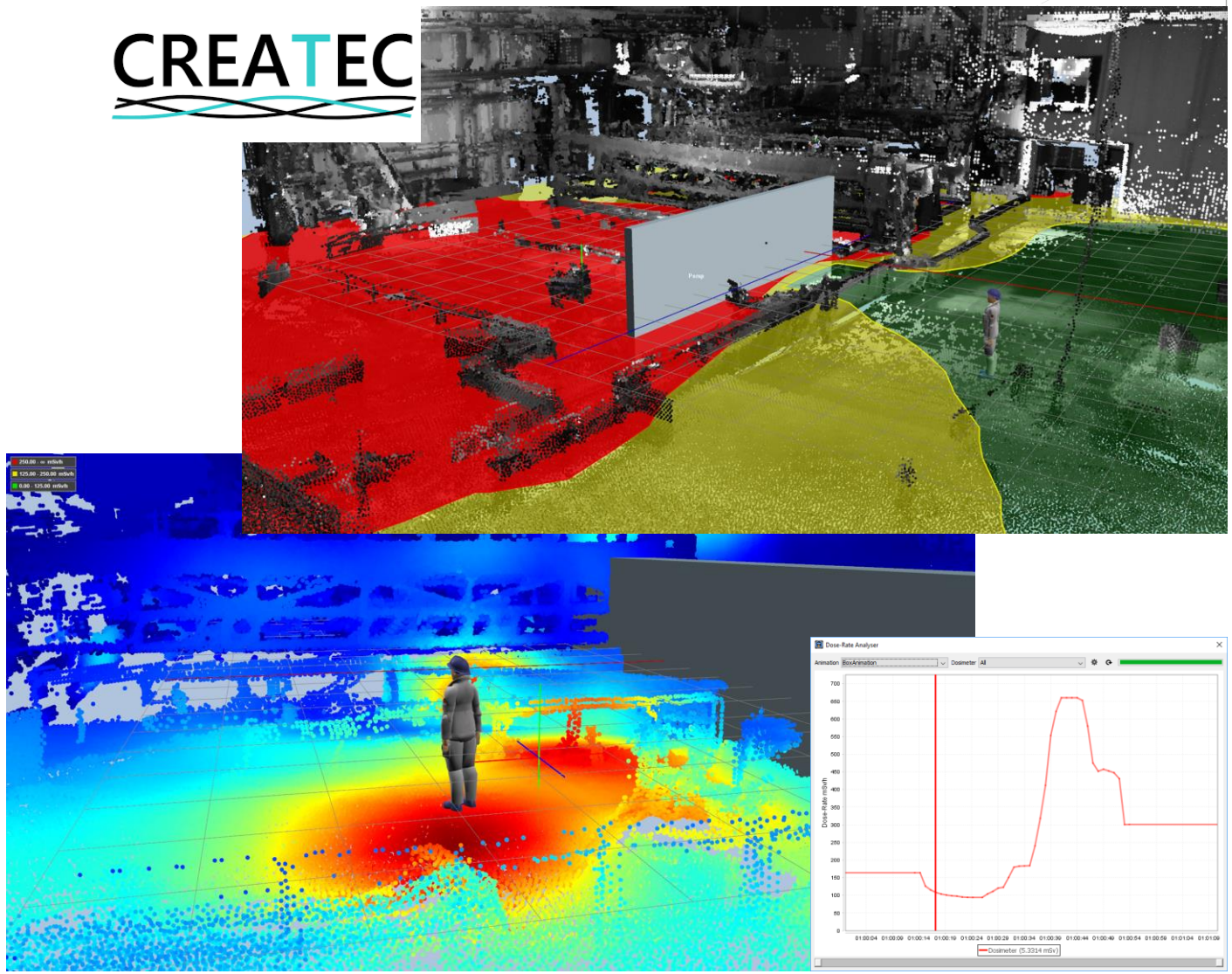
- Virtual work planning – e.g. shielding design
- Access plan information in VR e.g. see systems
- Training for normal work and emergency situations
- Collaborative planning – telepresence from multiple physical locations
- Briefing – immersive display of work plans and risks



Demos – Monday and Tuesday

3D gamma mapping based work planning – Fukushima demo

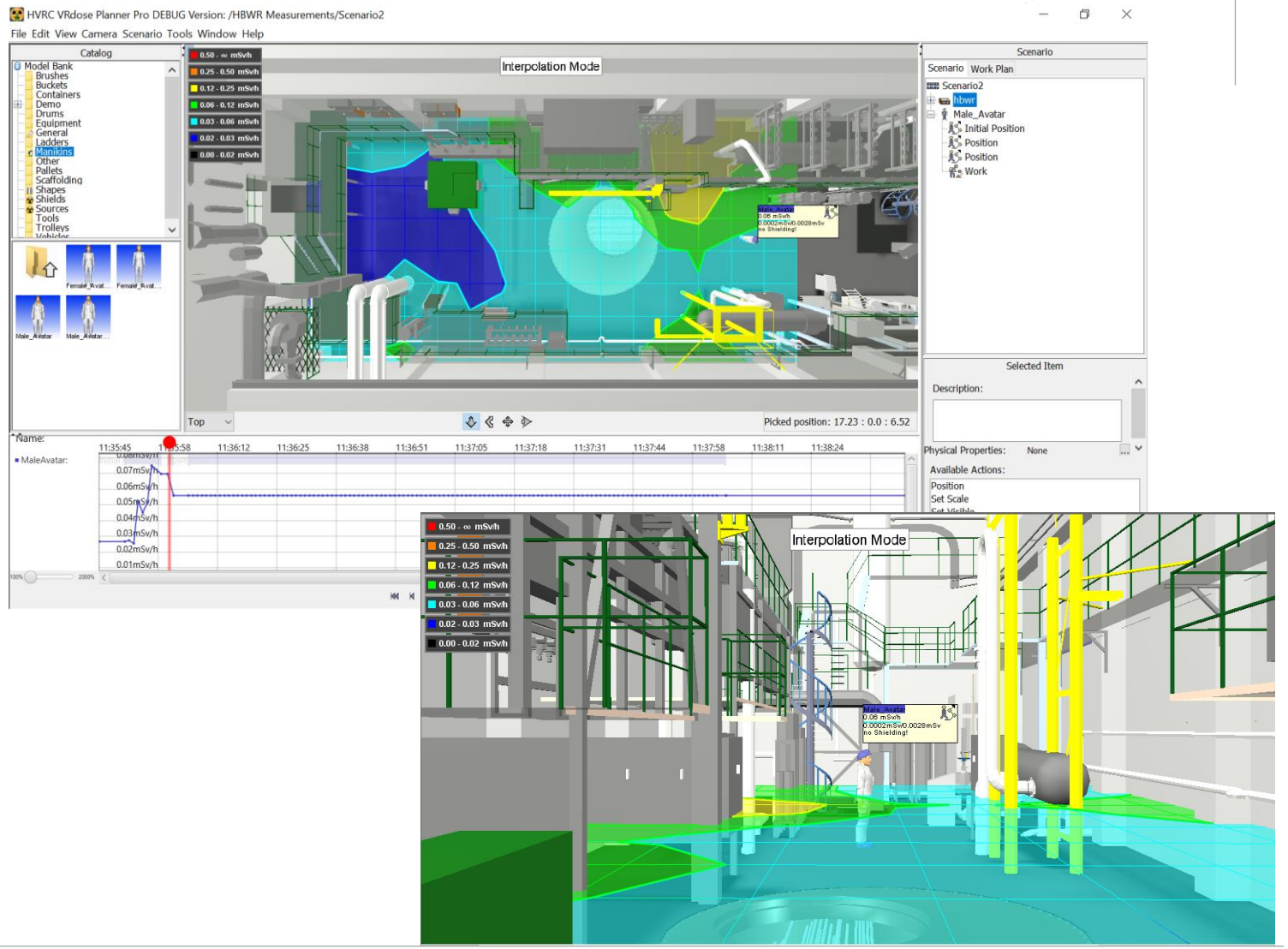
- 3D gamma scanning based source mapping
- Interacting 3D gamma mapping with decom support systems
- Work planning based on actual radiological mapping
- Shielding design based on radiation transport and work simulation tech



Demos – Monday and Tuesday

VRdose and geostatistical analyses – Halden Reactor demo

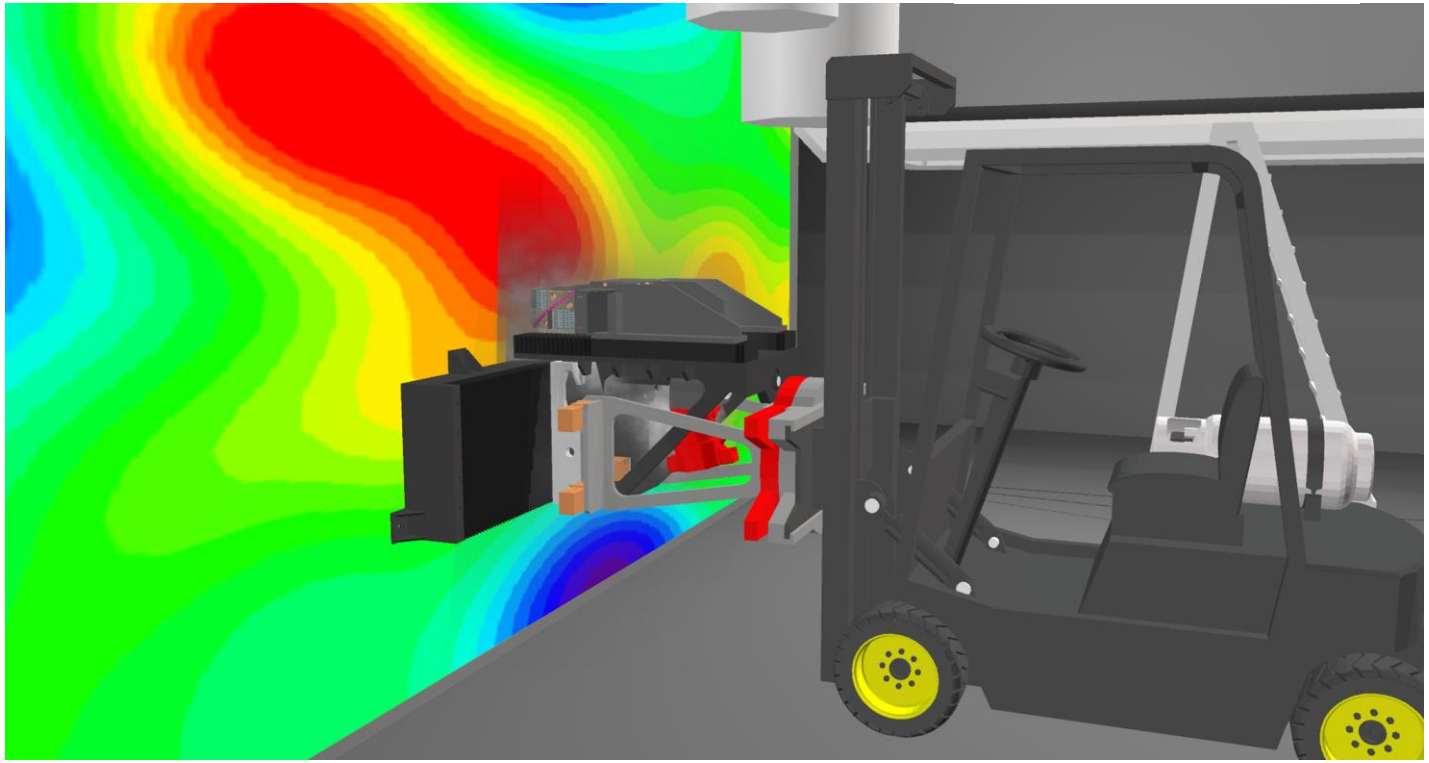
- Geostatistical analyses (KRIGING) based dose mapping from measurements
- Dose planning based on dose maps
- Combination of dose map and radiation transport
- Planning/Optimisation of sampling/measurements



Demos – Monday and Tuesday

Digital support for robotics bases procedures – concrete grinding process

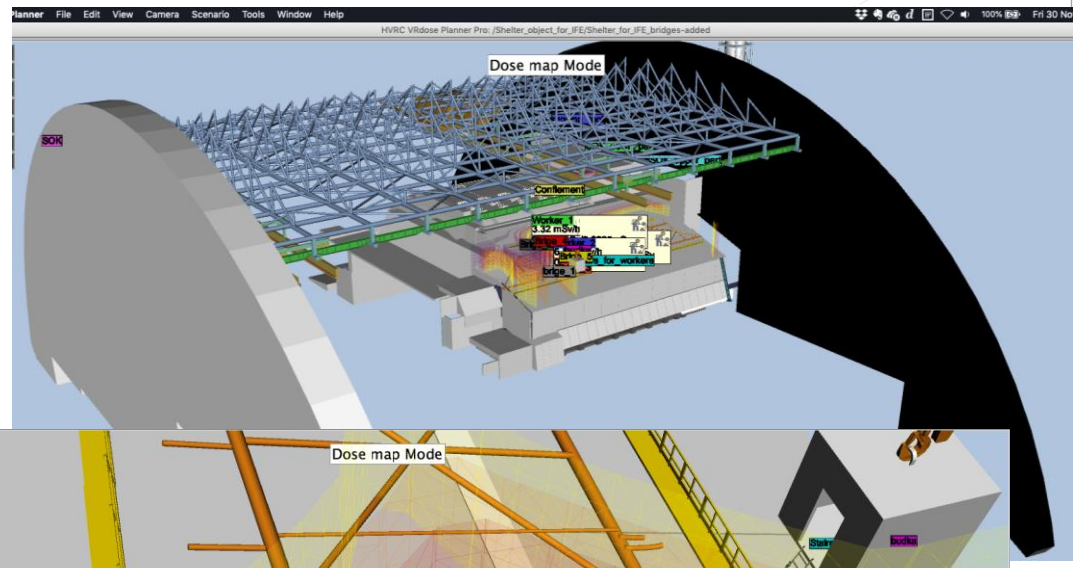
- Visualisation of the environment strategy planning
- Geostatistics for surface and subsurface contamination mapping
- BIM based process planning
- Grinder programming based on contamination map
- BIM based process control

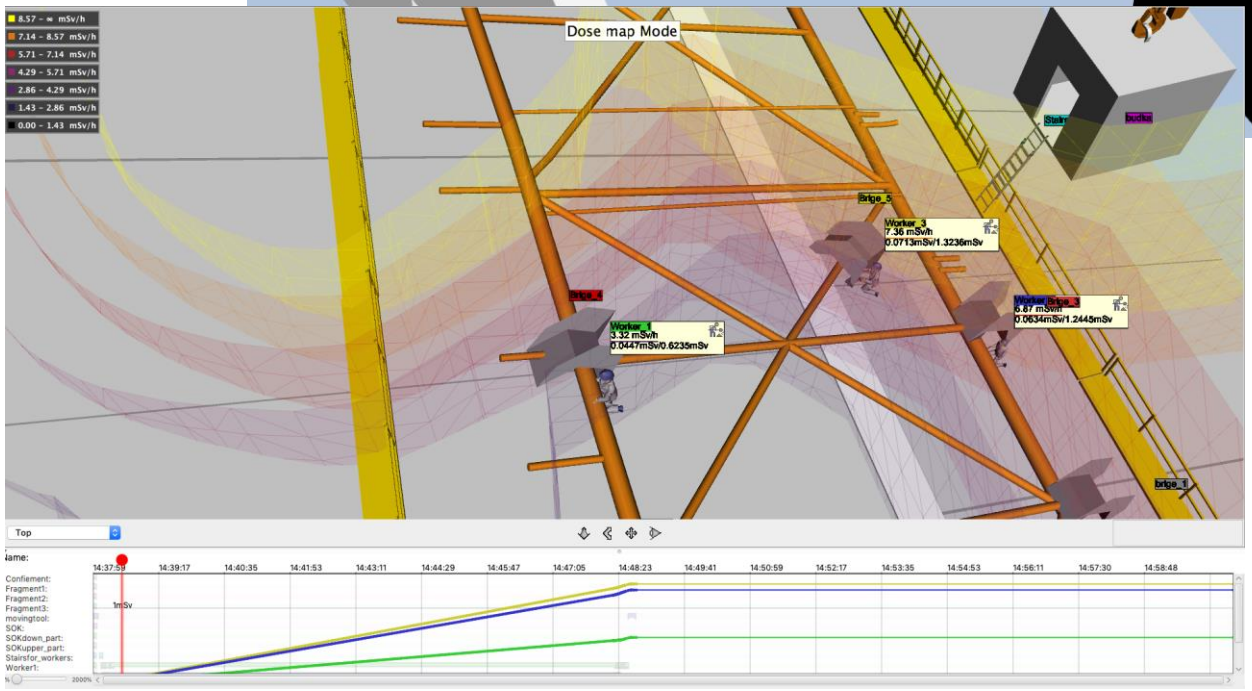


Demos – Monday and Tuesday

3D simulation based work/dose planning – Chernobyl demo

- 3D simulation based planning of work procedures
- Dose estimation with real-time radiation transport
- Training and briefing of field workers
- Demonstration, regularity process and documentation
- Preserving experience
- Public information





Workshops and training courses in 2019

Focus on knowledge management and training/education

- Immersive and interactive presence
- Serious gaming
- Mixed reality – AR based in-situ info
- Trainee performance measures
- Story telling
- Simulation based knowledge exchange

Invitation

Digitalisation for nuclear decommissioning (2019)
Workshop on
Advanced methods for knowledge management, training and education for nuclear decommissioning

Tentative date/venue :
2019 June 18-20
Halden, Norway


Photo: Joachim Bratteli /IFE

Based on feedback from the participants of our first event under the umbrella of **digitalisation for nuclear decommissioning** (www.ife.no/hrpdecom2017), we are organising this third event for 2019 www.ife.no/digidecom2019. (see also: www.ife.no/digidecom2018).

A growing shortage of skilled nuclear decommissioning specialists is foreseen in the upcoming decades, due to the rapidly increasing demand and low supply (resulting from social and political trends). The workshop will bring together a multidisciplinary group representing the professional community working on implementation and oversight of decommissioning for discussing opportunities and lessons learned from innovative digital methods for knowledge management, training and education in nuclear decommissioning.

The workshop aims at taking advantage of technologies like **storytelling, serious games, 3D simulation, digital twin, and virtual/augmented reality** allowing the participants to:

- **Demonstrate** technology, tools and methods
  Software and tech support will be provided by IFE
  Best demos will be rewarded!
- **Share** interesting technical solutions
  Input will be provided for IFE beforehand
  Technical demos will be prepared in groups
  Selected demos will be rewarded!
- **Experience**
  - Become immersed in 3D interactive virtual decommissioning sites: explore site, control equipment e.g. robotic/remote equipment, …
  - Be engaged in entertaining stories from our experience through serious gaming
  - Participate in virtual/augmented tour of our facilities

Rewards may include a gift pack, 2 year license for the VRdose® tool (www.ife.no/vrdose_overview), *exemption from registration fee…*

Organising committee: digidecom@ife.no

International advisors: G Kwong (OECD NEA), PJ O'Sullivan (IAEA), V Michal (IAEA), A Ganesan (IAEA), O Glöckler (IAEA), V Ljubenov (IAEA), R Reid (EPRI), J. de Grosbois (indep. consultant)

Chairman: I Szőke, Institute for Energy Technology, Norway

Digitalisation for Decommissioning **S?**

This course focuses on digitalisation of the nuclear decommissioning process from early planning (during operation) un… the final site release, with special focus on inte… igital concepts enabling holistic mana… of p… t and safety.
Te… inclu… 3D modelling and simulation, s… tic i… nati… technology, physics modelling, dig… twins, …rocess …mulation and visualisation, imm… presence a… …nced user interfaces.
Applica… area… de: information management (BIM/PIM), si… elling, strategy and work planning, safety as… nt and demonstration, emergency preparedness… ning and briefing … workers, robotics, as well as team co… ation and … ng.
Trainees will so… examp… in interactive group sessions using digital te… y.
The course will also t… vanta… telling, serious games, and mixed reality for … highly engaging deep learning experien… sed … real-l… project experience.

Expected audience: All professio… olved in … or overseeing decommissioning, a… well as … onal… starting a career in decommissioning
Education level: EQF Level 6 or 7

Learning outcomes from the course:

- ✓ Overview of the international landscape for research … pl… n of digital technologies for nuclear decommissioning
- ✓ International overview of available technologi… well a… eds a… ends for future development and application
- ✓ Understanding of the regulatory aspects of digitiz… for de…commis…
- ✓ Overview of digital technologies applied in the Oil&… ndustry
- ✓ Lessons learned from application of digitalization for d…comm… g and … te management in Norway
- ✓ International experience from application of digitalization … decon… f hazardous legacy nuclear sites (including Chernobyl NPP)
- ✓ Skills in application of digital technology for different aspects of d… missionin…
- ✓ Learnings from experiencing examples and solving problems thro… immersive (gaming) experiences based on international real-life projects

Institute for Energy Technology

Price:
200 EUR

Norway

Next courses:
2019 November

Language: English