Digital technology aided innovation for planning and cross-cutting issues in nuclear decommissioning

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IFE, three institute in one

Research and Development

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

Nuclear Technology

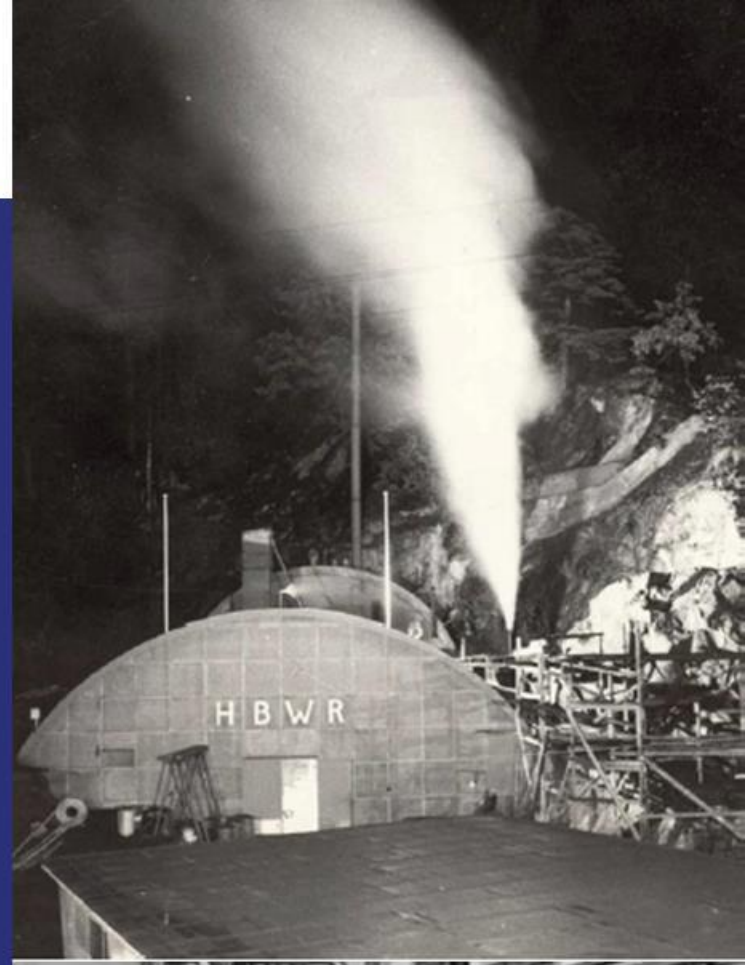
- Two research reactors
- Research within physics, materials, nuclides for medicines, nuclear safety, denuclearization, nuclear waste and decommissioning

Radiopharmaceuticals

- 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
- 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 Oct 10, 1959

A key asset to international nuclear R&D

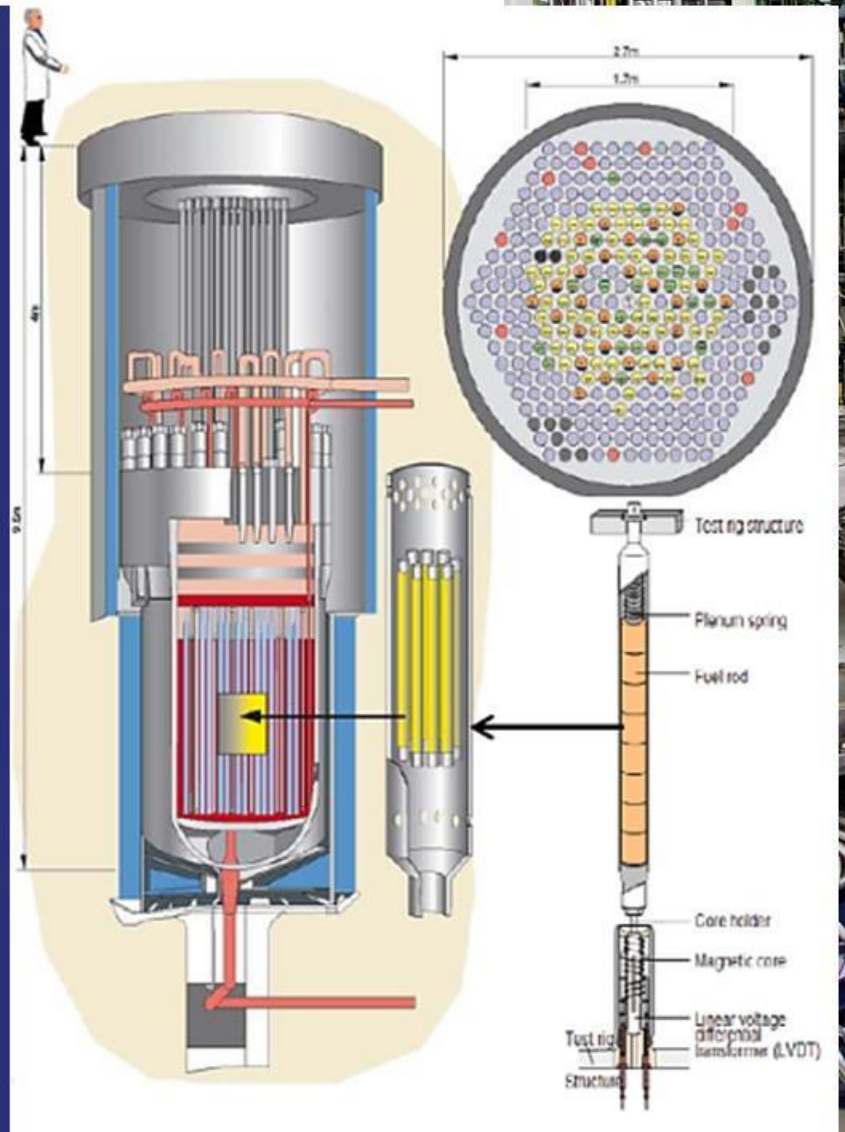
HBWR Research program

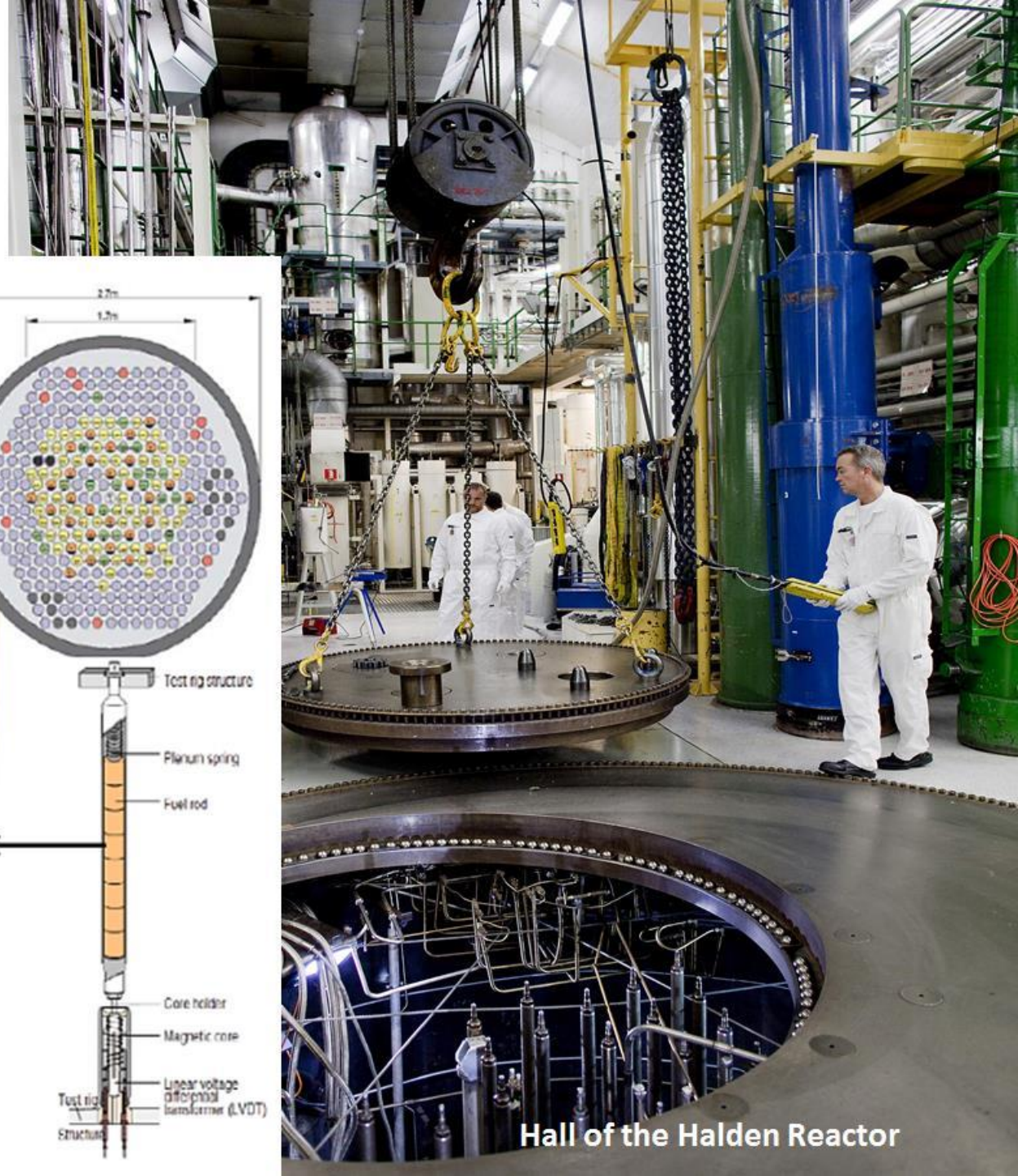
Key-factor: Making In-pile fuel measurements

- 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 °C
Operating press.:	31 bar
Moderator:	Heavy water
Heavy water vol.:	14 m^3
Type of fuel:	UO_2
Power control:	30 Control rods

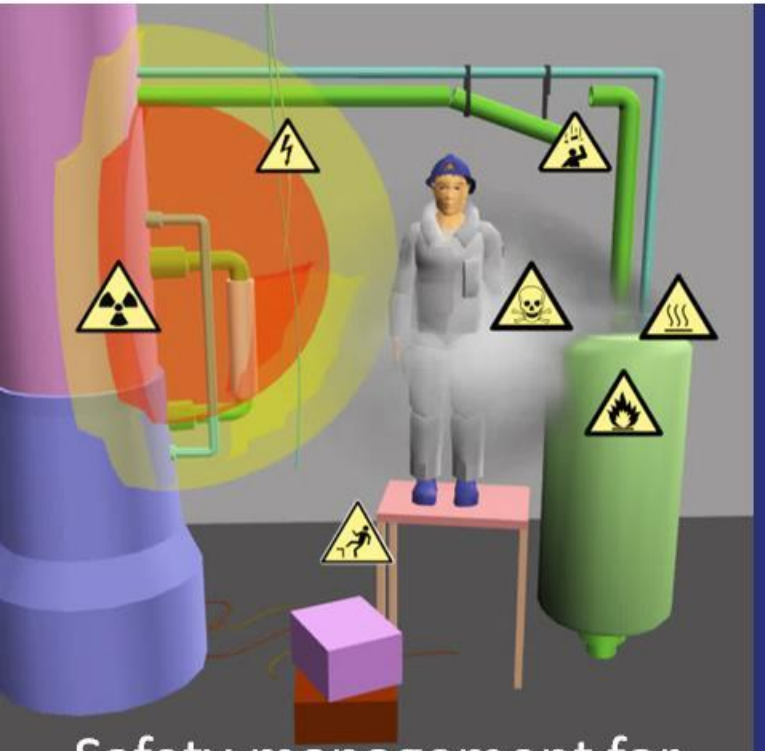




Hall of the Halden Reactor

OECD Halden Rector Project HRP

One of the World's longest collaboration program within the nuclear

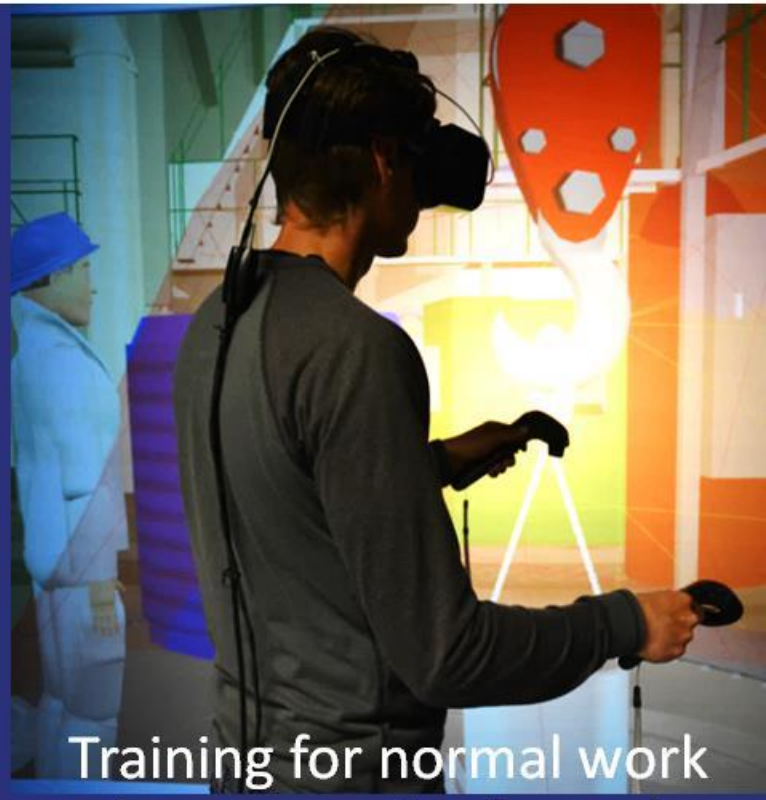


Safety management for nuclear decommissioning

<u>>100 organization</u>
<u>19 countries</u>

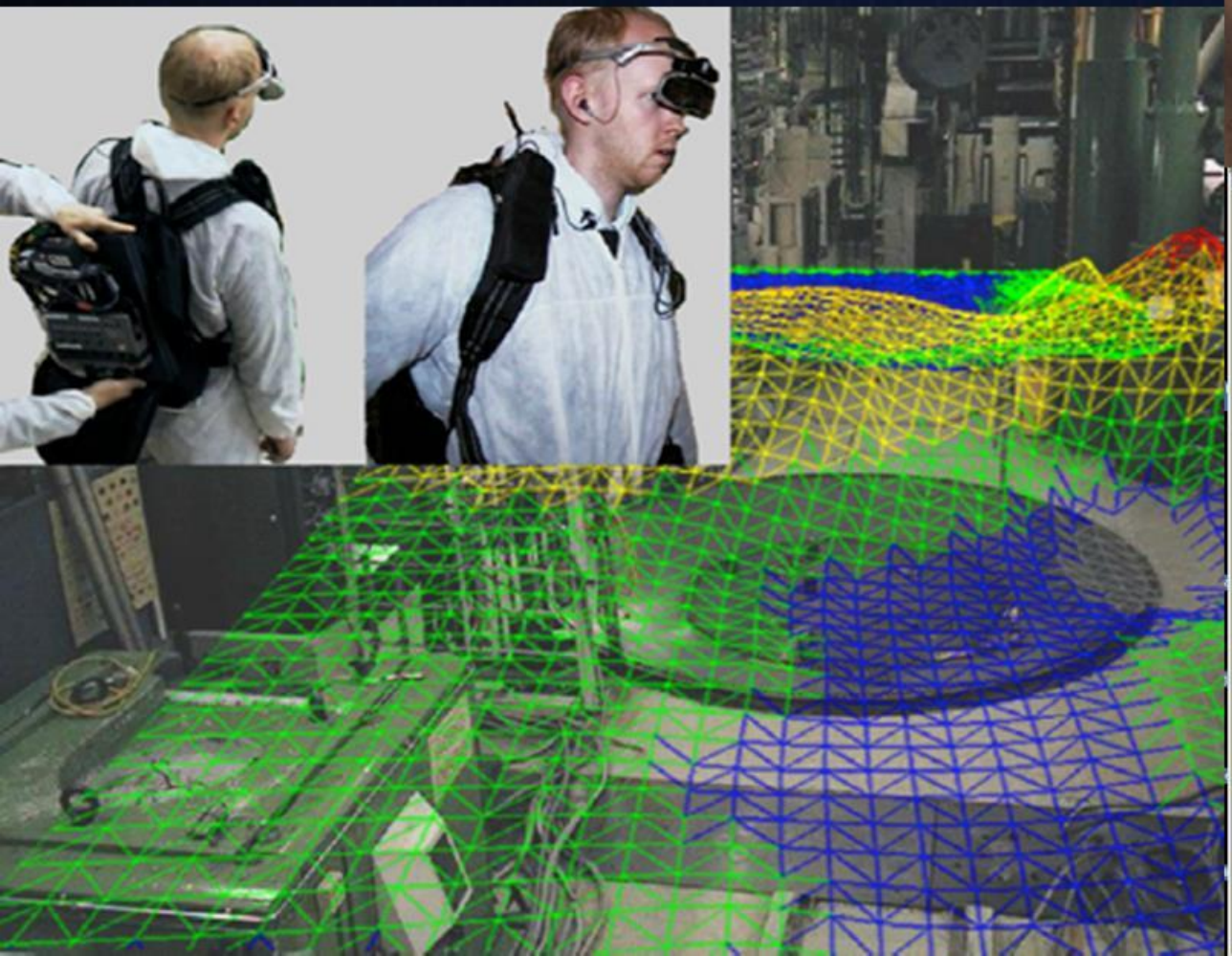
utilities, suppliers, authorities and R&D centers:

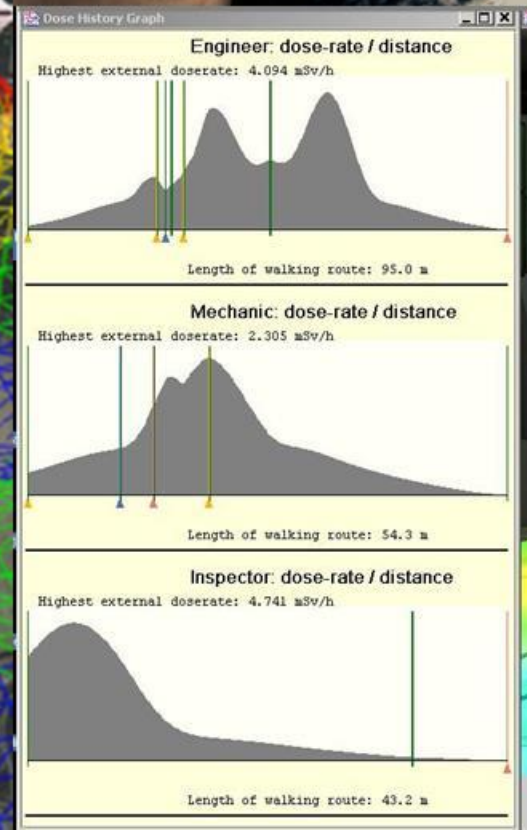
CEA, CIEMAT, CNPRI, CRIEPI, FRAMATOM, DTU, EDF, E.ON, ENSI, EPRI, EU JRC, FANR, GE/GNF, GRS, IRSN, JAEA, KAERI, Kazatomprom, MEE, Mitsubishi, **<u>MTA EK</u>**, NNL, NRA, NRG, PSI, SCK/CEN, SNERDI, SSM, TVEL, UJV, US DOE, US NRC, VUJE, Westinghouse …

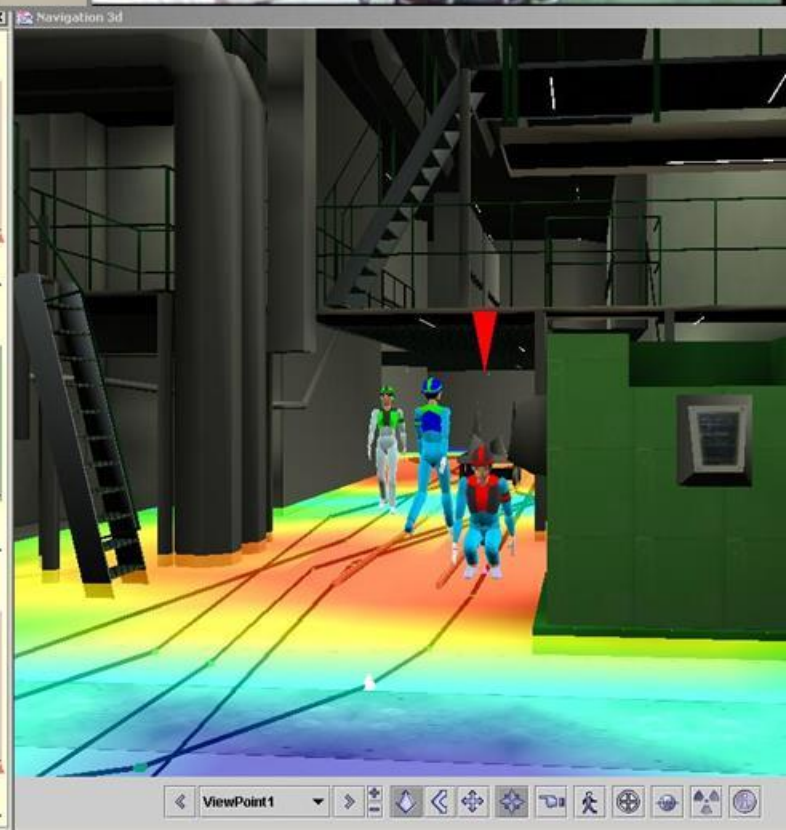


Training for normal work and emergencies in nuclear decommissioning

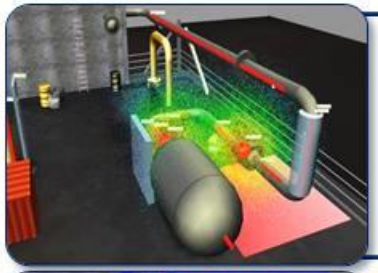
20+ years background in digital support concepts in nuclear environments





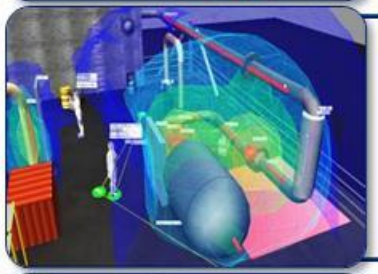


The IFE VRdose™ software family



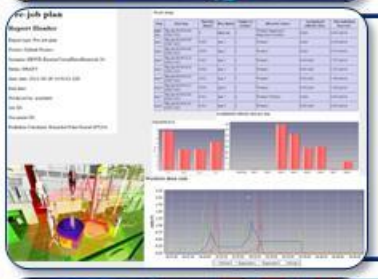
Visualize

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



Optimize

- Modify (interactive, real-time)
- Compare alternative scenarios



Demonstrate & document

- Playback with interactive navigation and visualisation
- Output printer-friendly reports

Training/field support

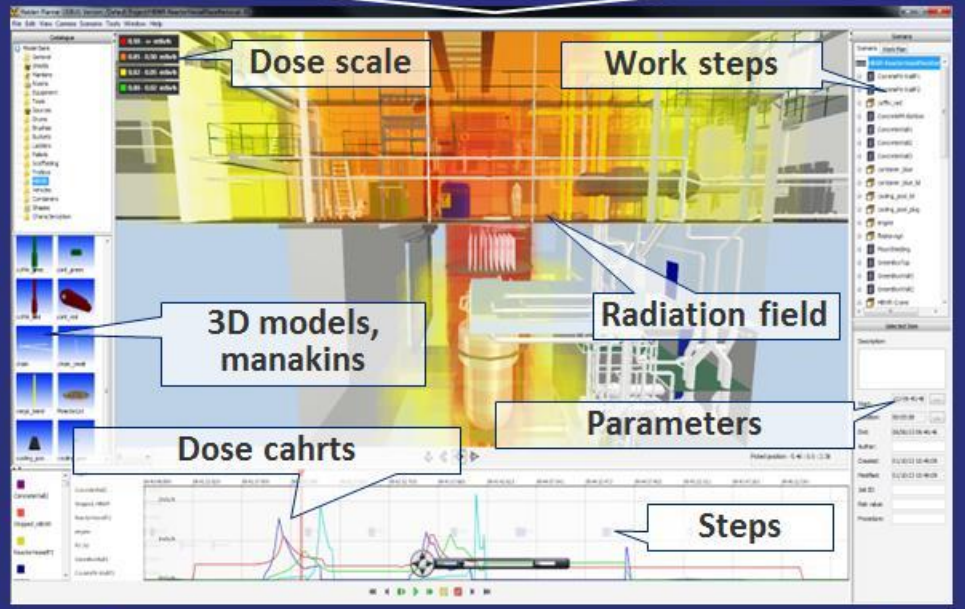
- Mobile and interactive material
- Augmented / mixed reality

User(s)

Info. systems

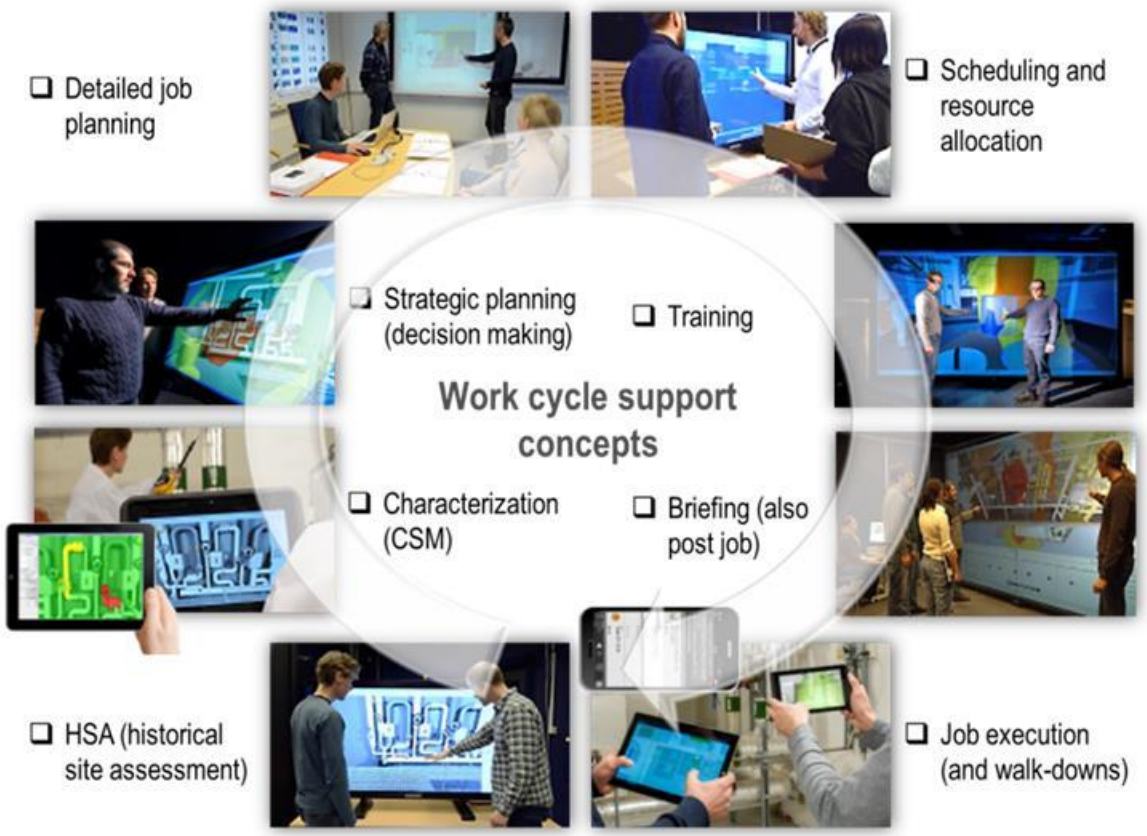
Sensors

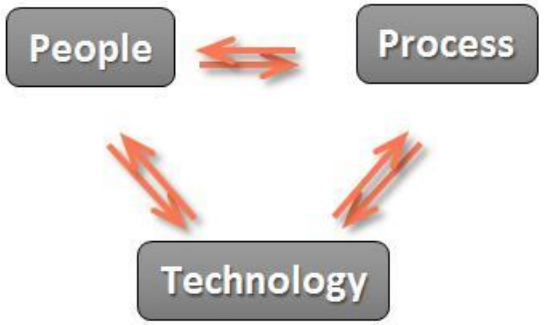
Plant information:
3D models, radiological data, other parameters, work plan



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

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

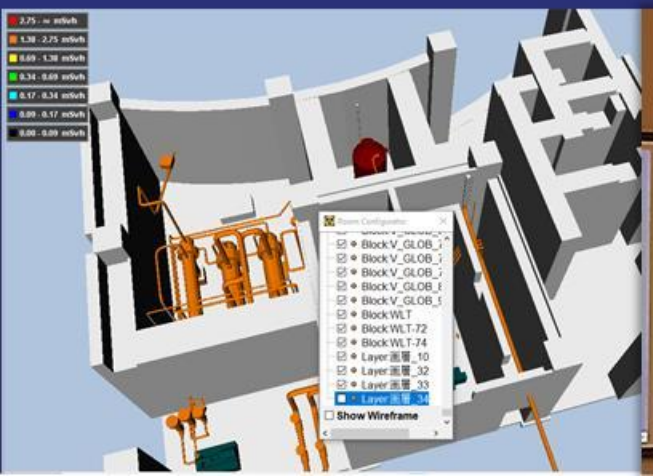
20+ years background in practical application of digital support systems

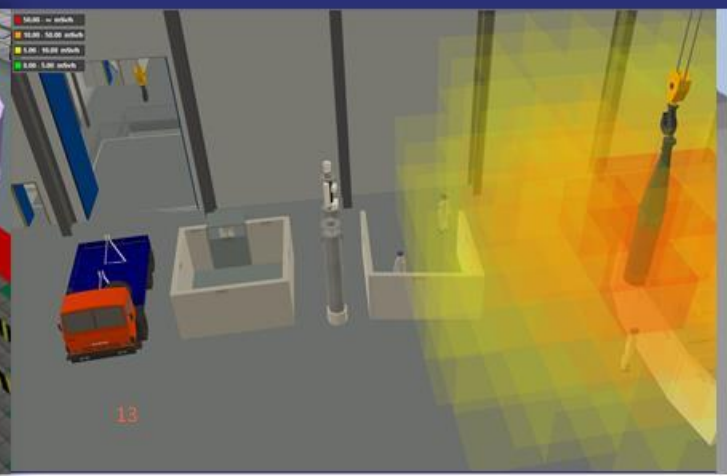
Fugen NPP (JAEA)
(1995 -)

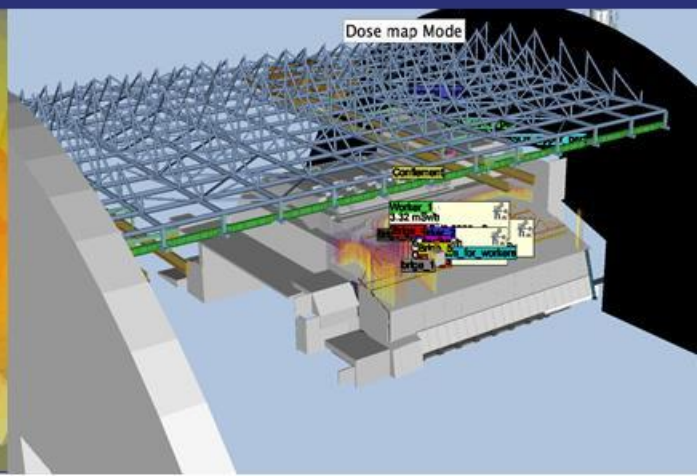
Leningrad NPP
(1999-)

Andreeva bay, NW Russia
(2011-)

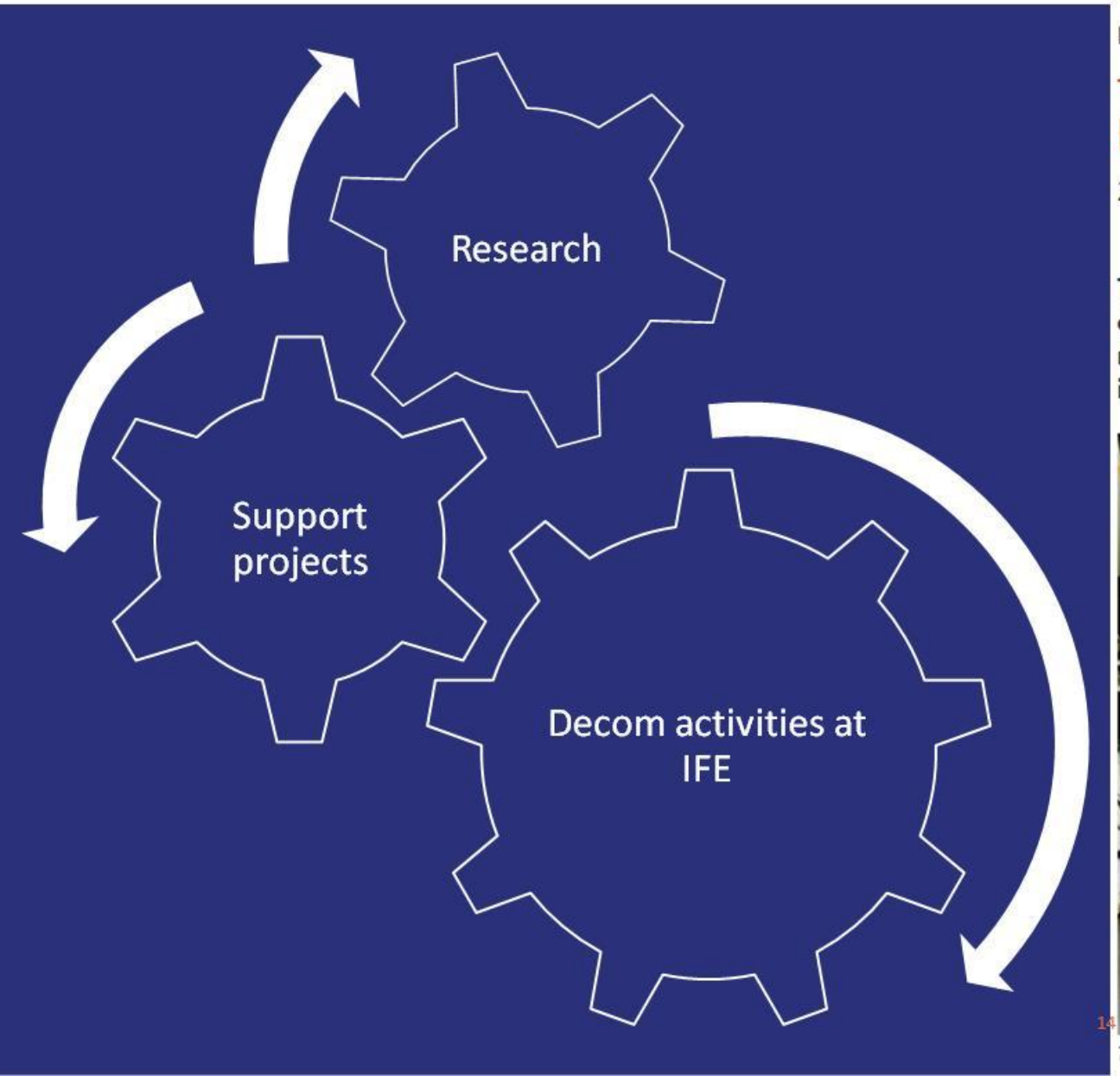
Chernobyl NPP
(2008 -)







Tragedy vs. opportunities



wnn world nuclear news

Energy & Environment | New Nuclear | Regulation & Safety | Nuclear Policies | Corporate | Uranium &

Halden Reactor to be decommissioned

28 June 2018

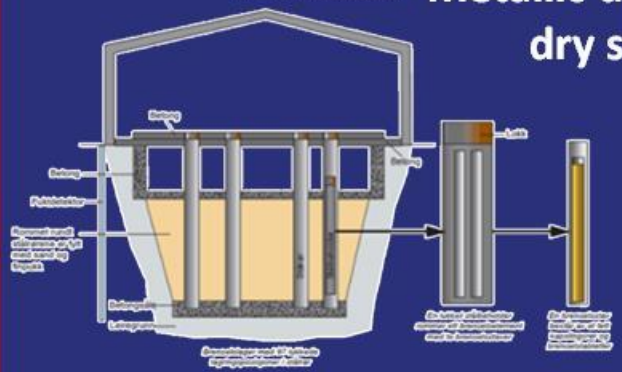
Share

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.

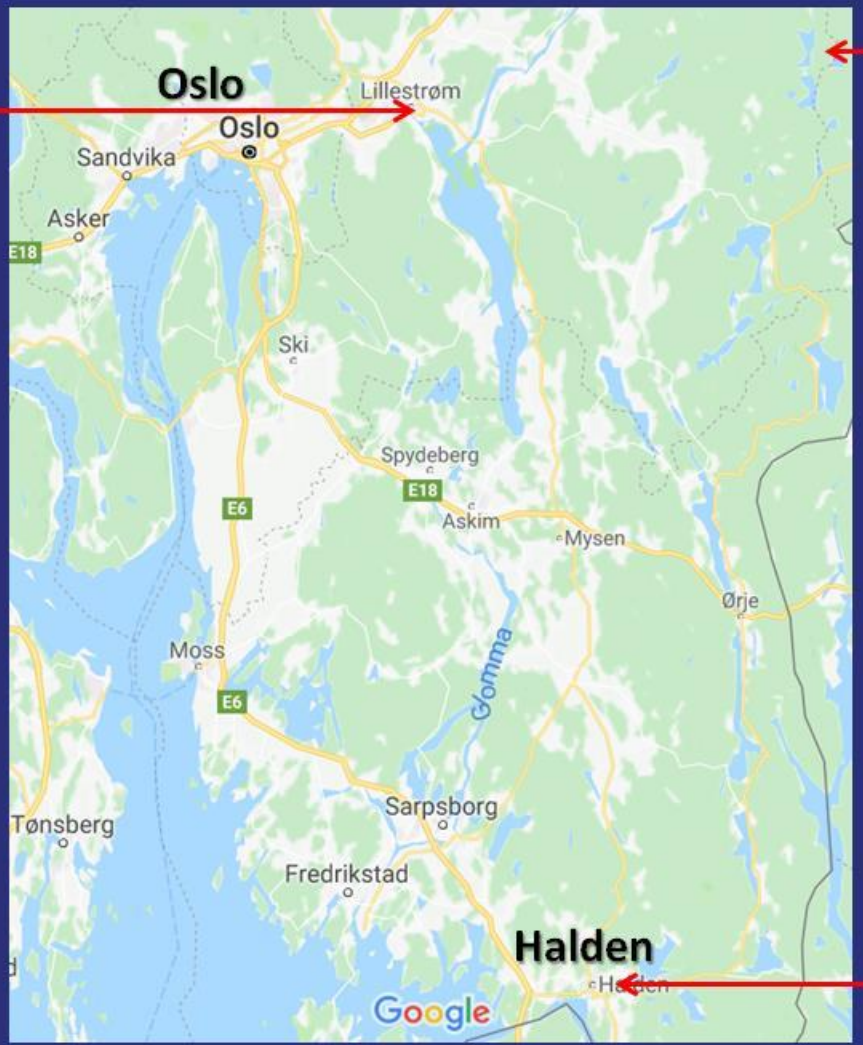
The Halden reactor (Image: IFE)

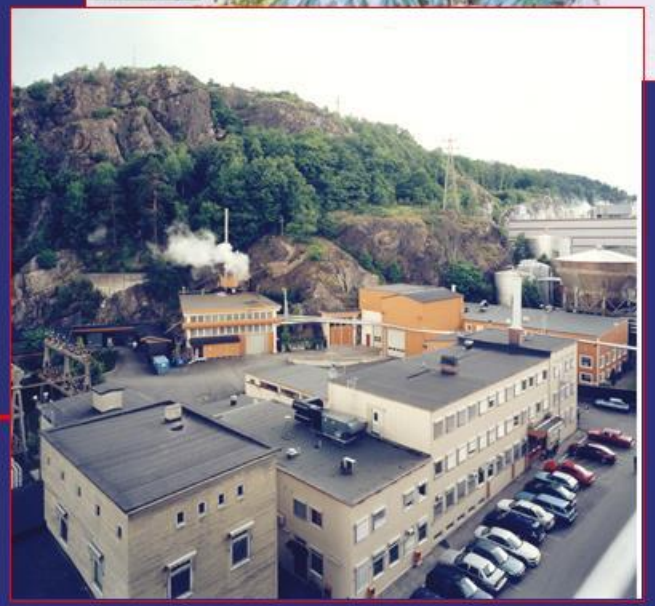
Decommissioning sites at IFE

JEEP 1 STAVBRØNN **Metallic uranium SF dry storage for**



Uranium pilot plant





Focus on systemic (MTO) approach

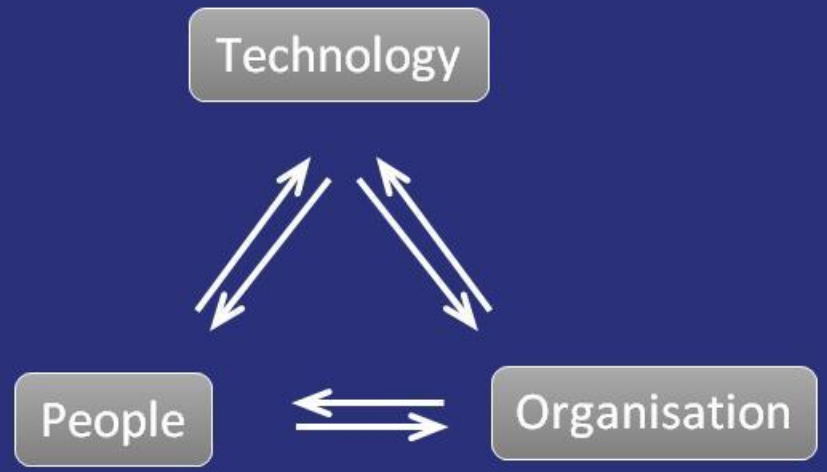
Radiological modelling

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

- Sematic web technology
- Robotics
- 3D gamma mapping

IT

- 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 / Training / Change management

IAEA PRESS RELEASE (2018)

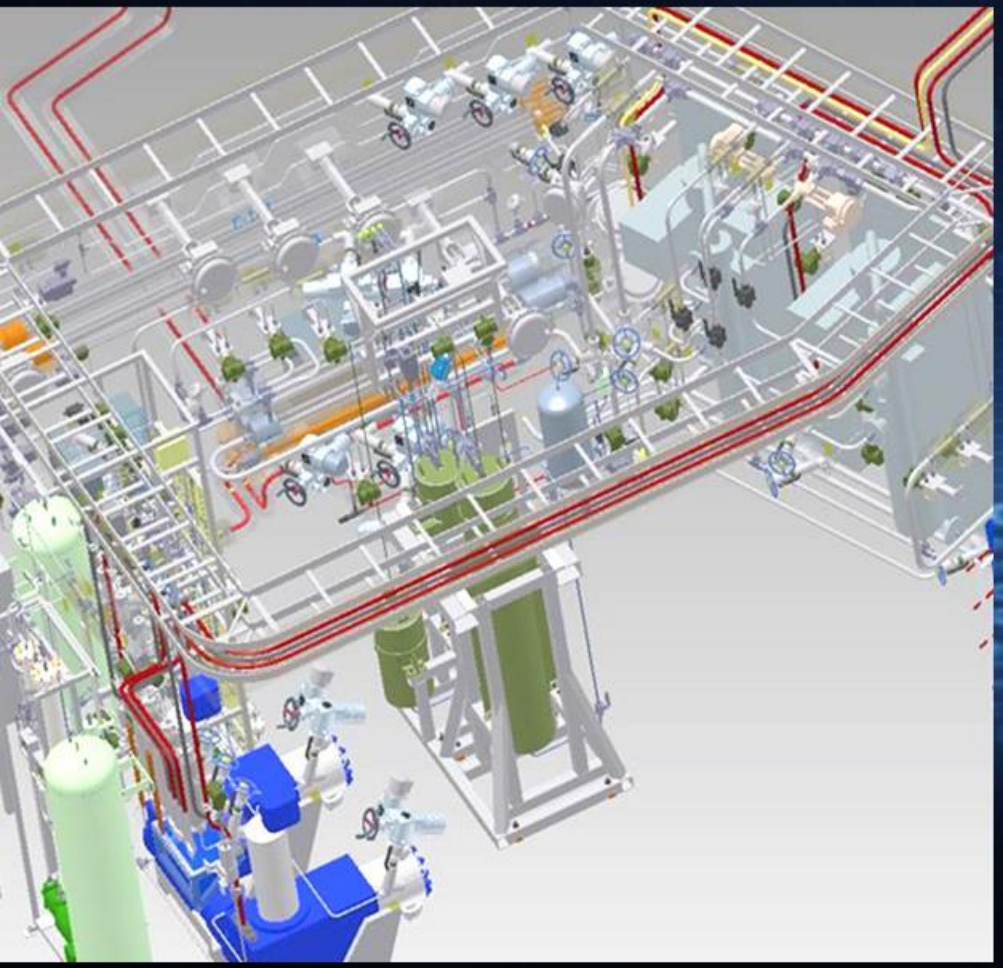
General Conference Day 2 Highlights
IAEA and Norway

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)

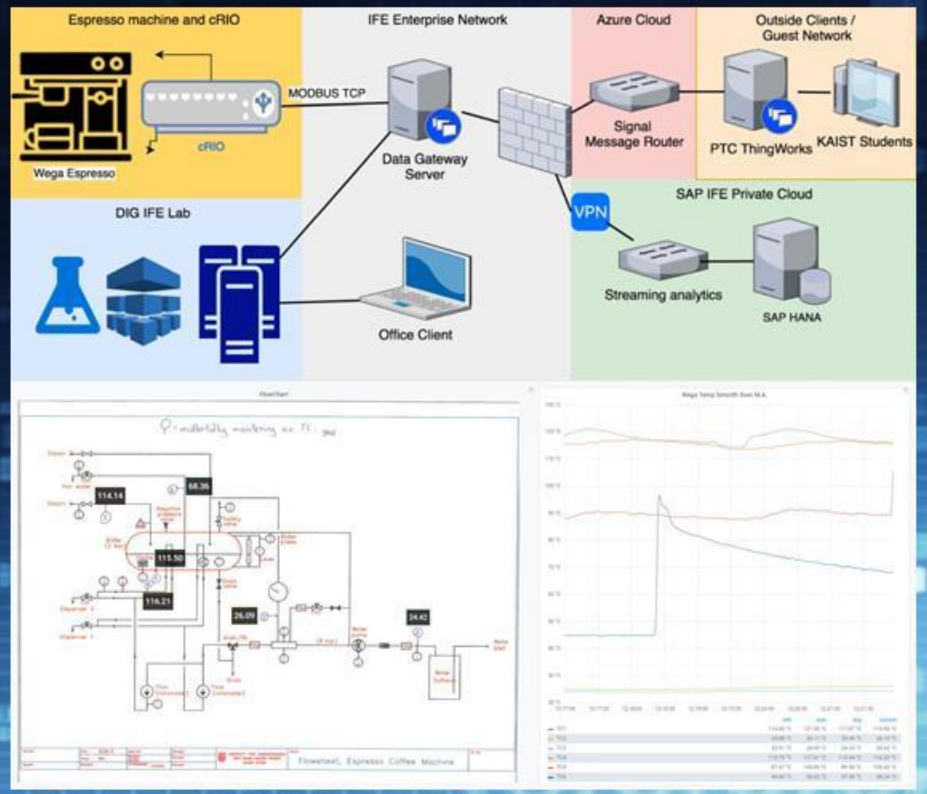
www.iaea.org/newscenter/news/general-conference-day-2-highlights-18-september-2018

Digital twins

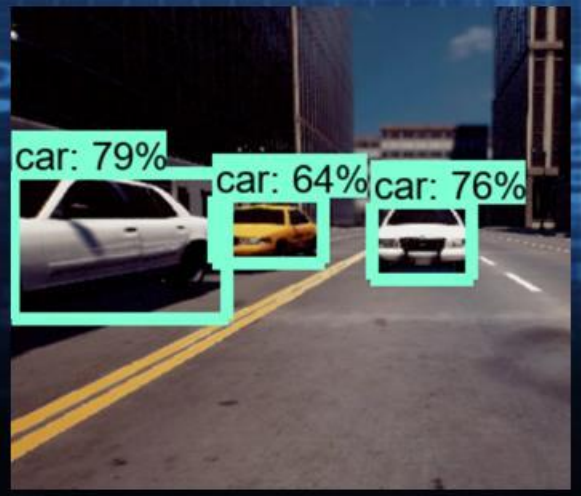


Machine learning and AI

Visual quality inspection for radiopharmaceuticals



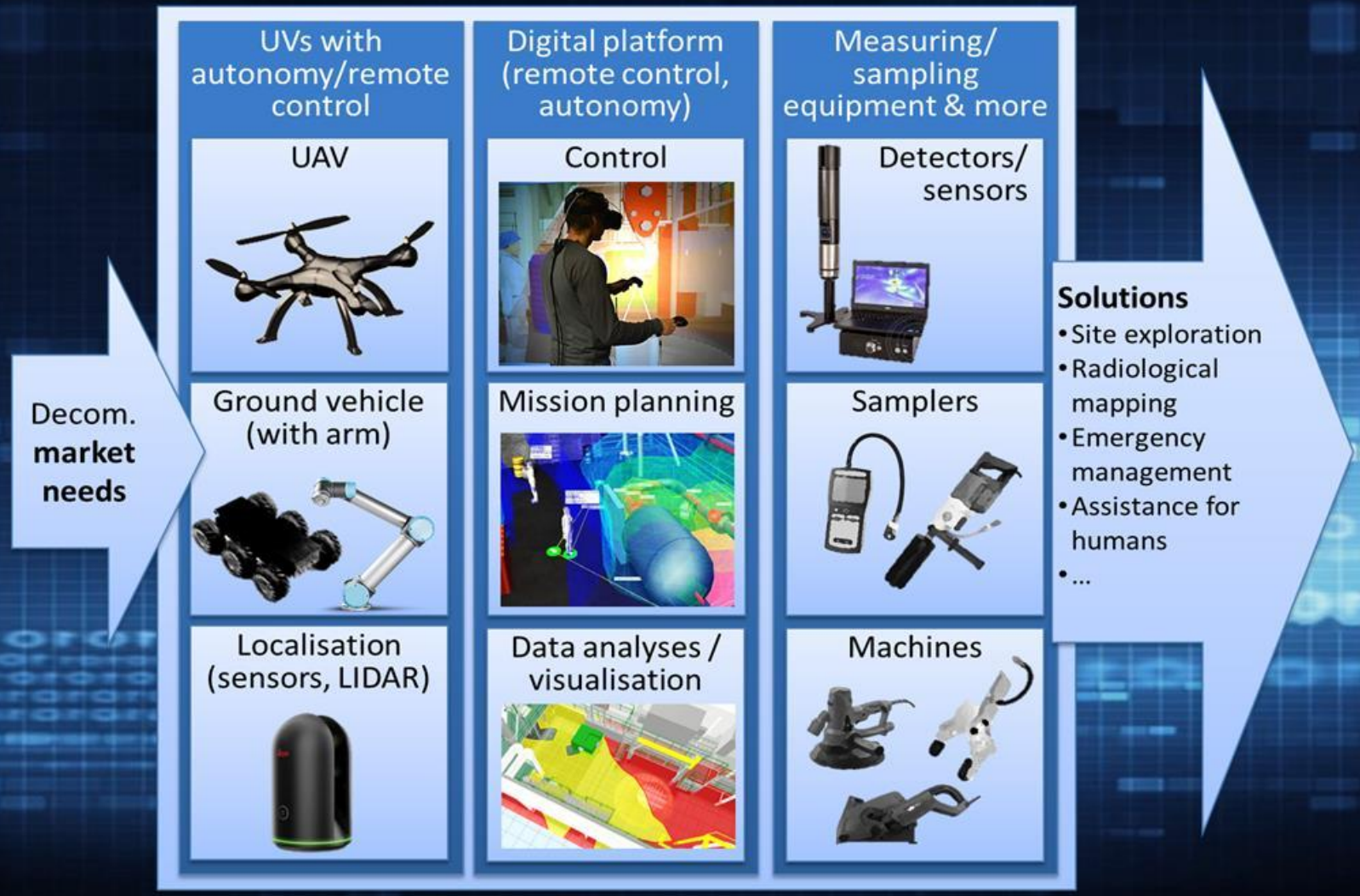
Virtual



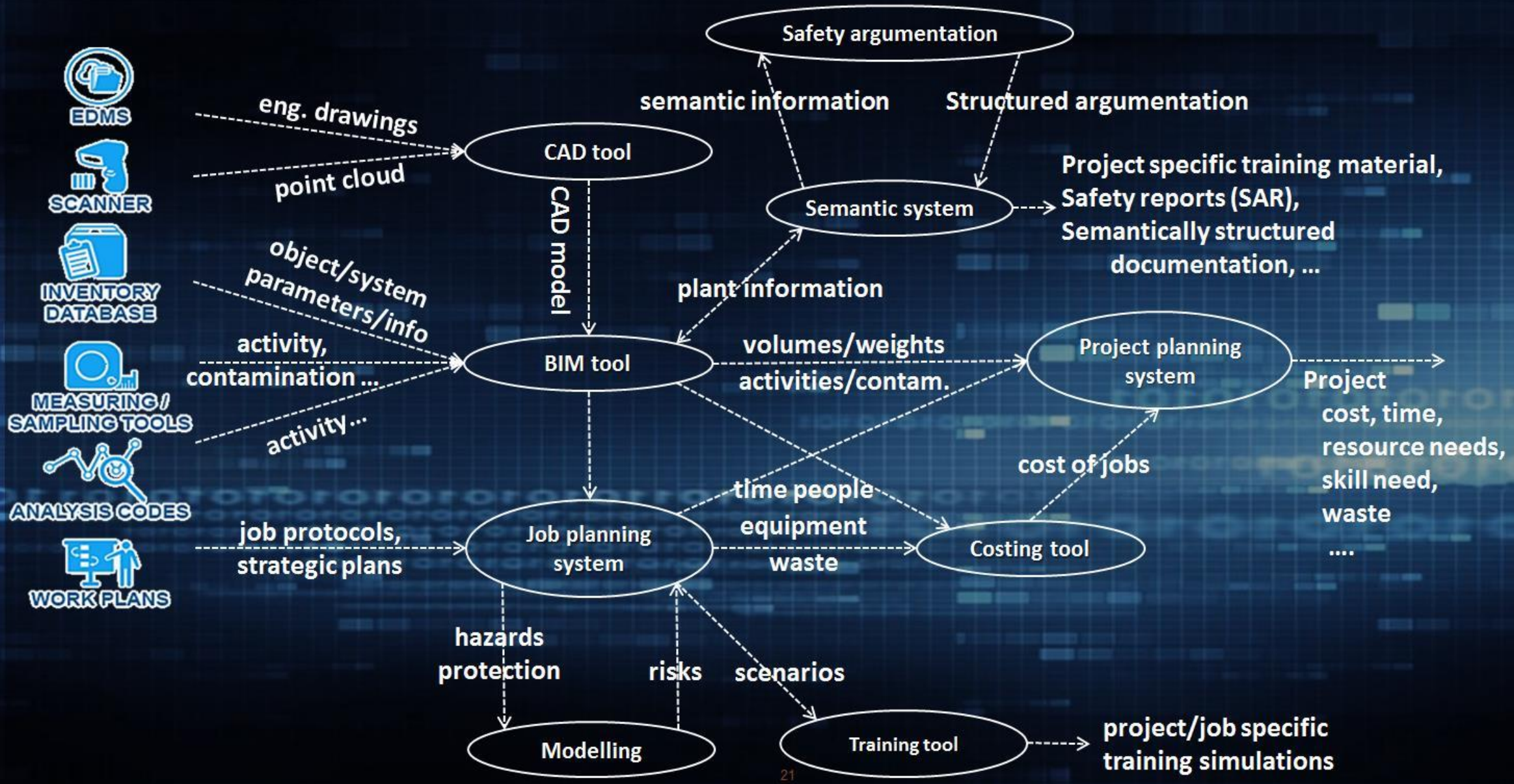
Real

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

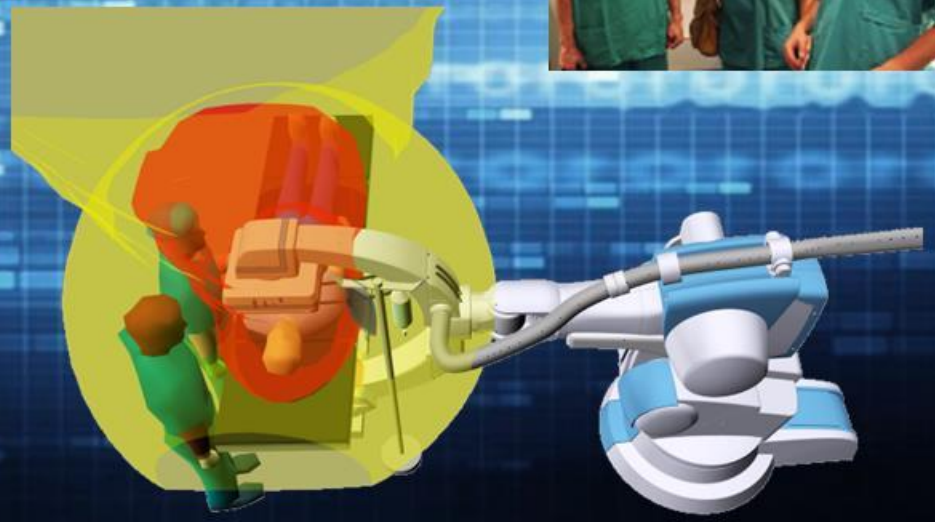


Holistic digital support



Business case – digitalization, robotics in decom

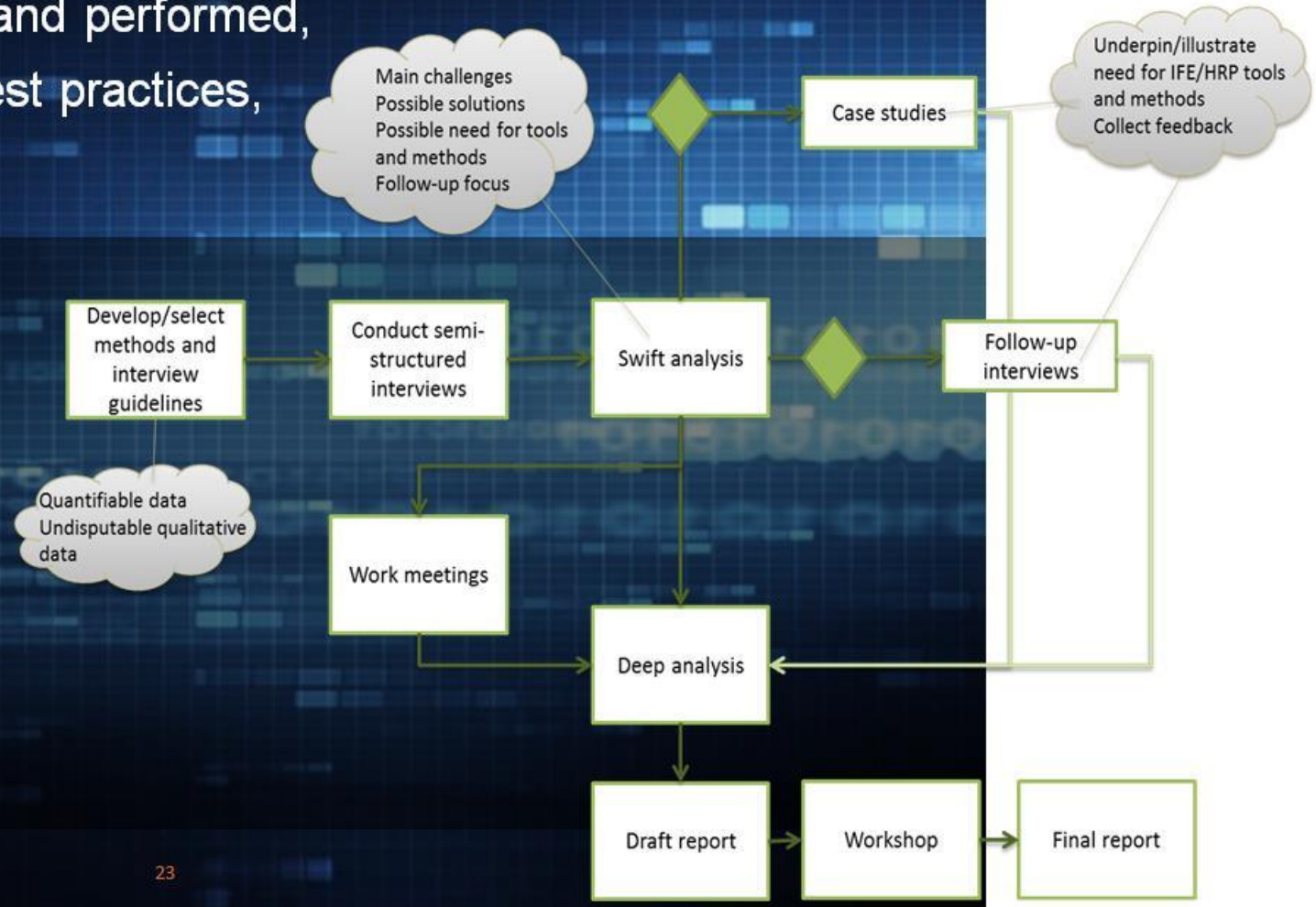
1. Special situations
    1. Accident sites – e.g. Fukushima, Chernobyl
    2. Unique work – e.g. graphite reactors
2. Holistic application
    1. Application for multiple types of tasks
    2. Use across the whole stakeholder team
    3. Start early, use through the whole process
3. Don’t underestimate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



NKS NorDec

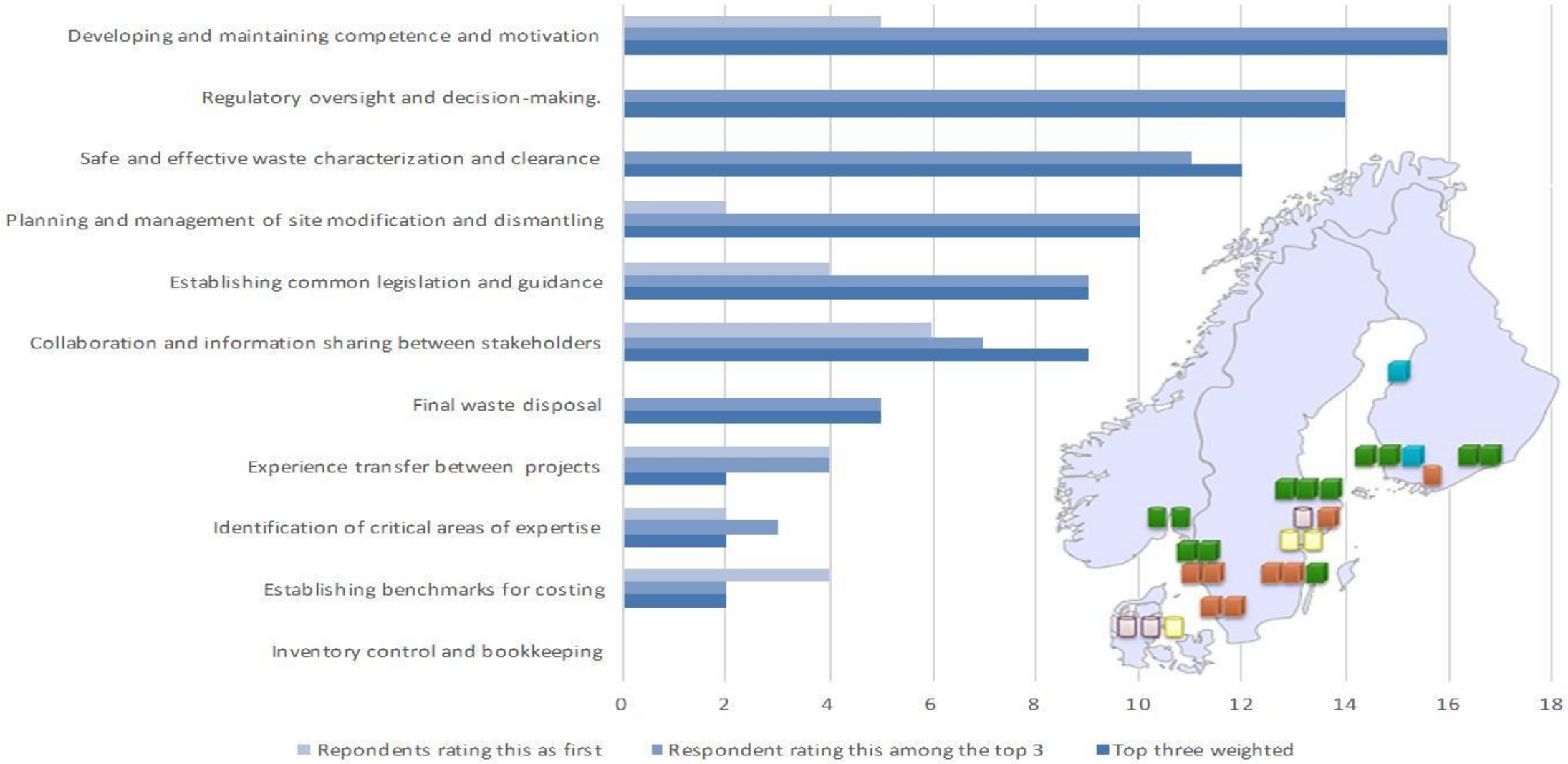
- **NorDec: Challenges and opportunities for improving Nordic nuclear decommissioning**
  - How is decom regulated, planned and performed,
  - Identify main challenges, collect best practices,
  - Foster collaboration

- IFE: Institute for Energy Technology, Norway
- SSM: Swedish Rad. Safety Authority
- NRPA: Norwegian Rad. Prot. Authority
- STUK: Finnish Rad. and Nucl. Safety Authority
- SIS: Danish Health Authority, Denmark
- VTT: Technical Research Centre of Finland Ltd
- Fortum, Finland
- Vattenfall, Sweden
- ÅF, Sweden



NKS NorDec

Key Challenges for Decommissioning in the Nordic Countries



NKS NorDec

nks
Nordic nuclear safety research

Organization and planning

- Challenges
  - Lack of decom. experience in Nordic countries
  - The scale of the decom. projects
  - Logistics planning
  - Lack of national final waste repository (delay plans and increase costs)
  - Decom. of different units at different times
- Good practices
  - Planning for decom. should start early

Regulation and guidance

- Challenges
  - Lack of regulatory experience (decom. will be a learning experience for the regulator too)
  - Lack of regulatory guidelines (application/interpretation of regulation)
  - Need for clear and effective reporting and decision making processes (safety demonstration)
  - Regulatory framework may be especially challenging for legacy sites
- Good practices
  - Some decom. experience exists for research reactors
  - Recommendation on reference levels from ICRP

Interaction between regulator and operator

- Challenges
  - Interpretation of regulation in practice - Need for more flexible approach?
  - Need to understand each other's roles
    - Calibrate expectations, optimise communication
    - What are contractors' role in this interaction?
  - Need for more efficient process to handle "small" issues quickly
- Good practices
  - Important to build and maintain a relationship based on trust
  - Active, open information exchange between regulator and operator
  - Local representative from regulator
  - Graded approach (especially for legacy projects)

Development and maintenance of competence and motivation

- Challenges
  - Do existing staff have the right competence and motivation?
  - How to maintain tech. and scientific competence at the regulator?
  - Lack of nuclear education on a national level
  - Contractors may lack nuclear experience
- Good practices
  - Recognise as an essential part of safety and efficiency
  - Utilise competence across the Nordic countries
  - Close interaction (and workforce mobility) between regulator and operator

Safe and effective waste characterisation and clearance

- Challenges
  - Compared to operation, decom. produces larger amounts, and new kinds of waste
  - More effective waste characterization methods are needed
  - Reuse (free release) can reduce costs, but challenging
- Good practices
  - Start planning for waste management early (early characterisation)
    - Waste acceptance criteria for future depositories?

Decommissioning strategy

- Preference for immediate decom.
  - Economical and more efficient
  - Low competence and knowledge loss
  - Low chance for change in regulation
  - Don't have to do modifications later

  BUT not always possible/optimal!
- Exceptions:
  - Olkiluoto 3 will operate until 2090, all three units will be decommissioned at same time
  - Barsebäck: political decision to use deferred decom.

DigiDecom2018 (3-7 Dec. 2018)

More than
80 participants
from
25 organizations
from
16 countries

www.ife.no/digidecom2018

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

IFE NEA IAEA EPRI

Digitalisation for nuclear decommissioning (2019)

Workshop on

Advanced methods for knowledge management, training and education for nuclear decommissioning

Invitation

Tentative date/venue :

2019 June 18-20

Halden, Norway

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) up to the final site release, with special focus on integrated digital concepts enabling holistic management of project and safety.

Technologies include: 3D modelling and simulation, semantic information technology, physics modelling, digital twins, process simulation and visualisation, immersive pres… d advanced user interfaces.

Applicatio… s …de: information management (BIM/P… …odel…g, strategy and work planning, safety …sessm… and demonstration, emergency prepared… , training …efing of workers, robotics, as well as tea… …oordi… and monitoring.

Trainees will … example task… in interactive group sessions using … l technolog…

The course will a… …ke a… …ge of storytelling, serious games, and mixed rea… provi… highly engaging deep learning expe… …ce ba… real-life project experience.

Norway

Next courses:
2019 November

Language: English

Expected audience: All professio… …d in pl…nning or overseeing decommissioning… as pro… …als starting a career in decommissio… …g

Education level: EQF Level 6 or 7

Learning outcomes from the course:

- ✓ Overview of the international landscape … …lication of digital technologies for nuclear decommissioning
- ✓ International overview of available technol… …as w… …s needs and trends for future development and application
- ✓ Understanding of the regulatory aspects of digi… …tion for… …ioning
- ✓ Overview of digital technologies applied in the Oil&Ga… …ry
- ✓ Lessons learned from application of digitalization fo… …om… …and waste management in Norway
- ✓ International experience from application of digitalizatio… …decommissio… …of hazardous legacy nuclear sites (including Chernobyl NPP)
- ✓ Skills in application of digital technology for different aspects of de… …ing
- ✓ Learnings from experiencing examples and solving problems t… …gh immersive (gaming) experiences based on international real-life projects

IFE Institute for Energy Technology

Price:
2000 EUR

www.ife.no/digidecom2019