Research programme into decommissioning and applications by IFE

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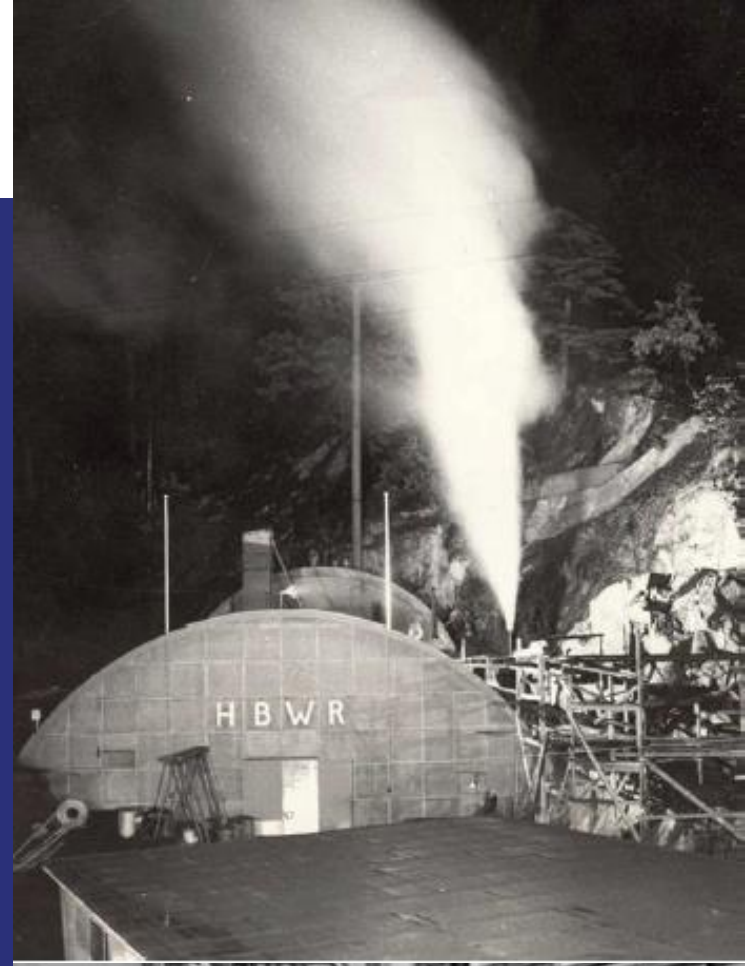
Interregional Workshop on Optimization of Technology Selection for Decommissioning of Large and Small Nuclear Installations

2019 Sep 9-13 Miami

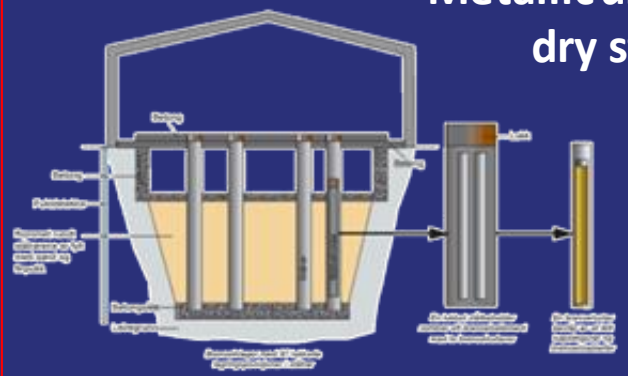
60 years history of nuclear research

- 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



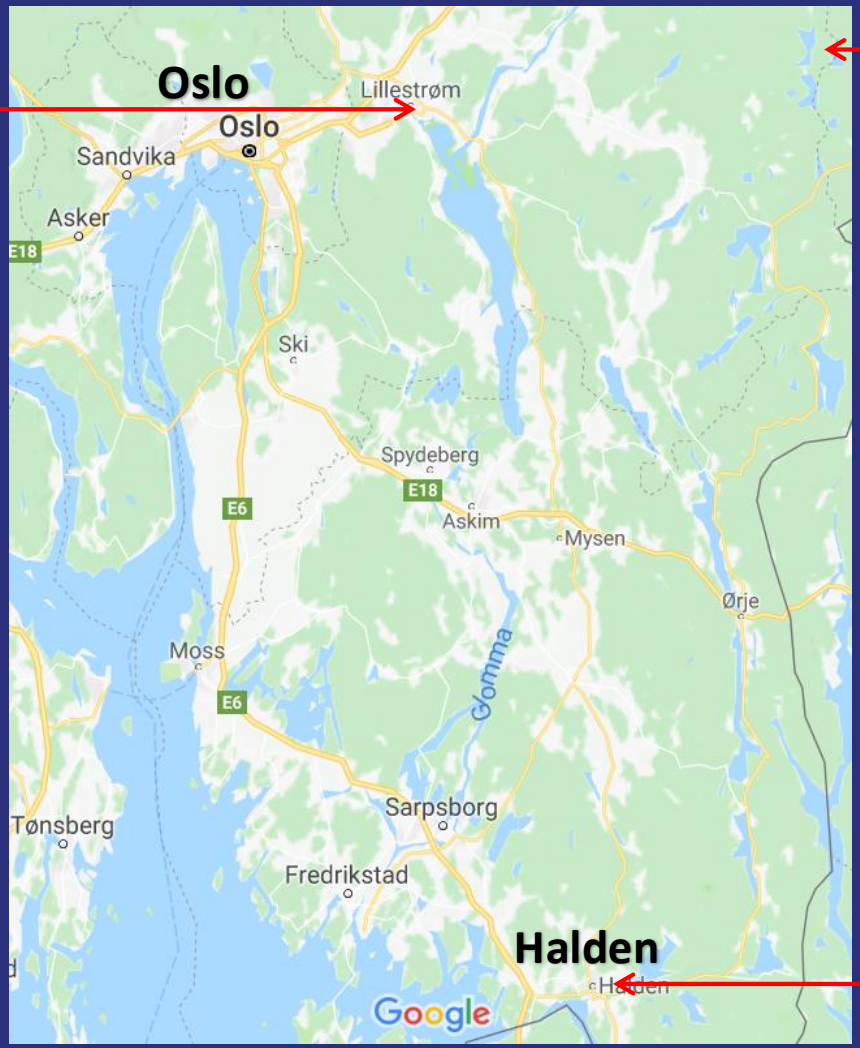
Official opening Oct 10, 1959

Decommissioning sites at IFE



Metallic uranium SF dry storage for

Uranium pilot plant



A key asset to international nuclear R&D

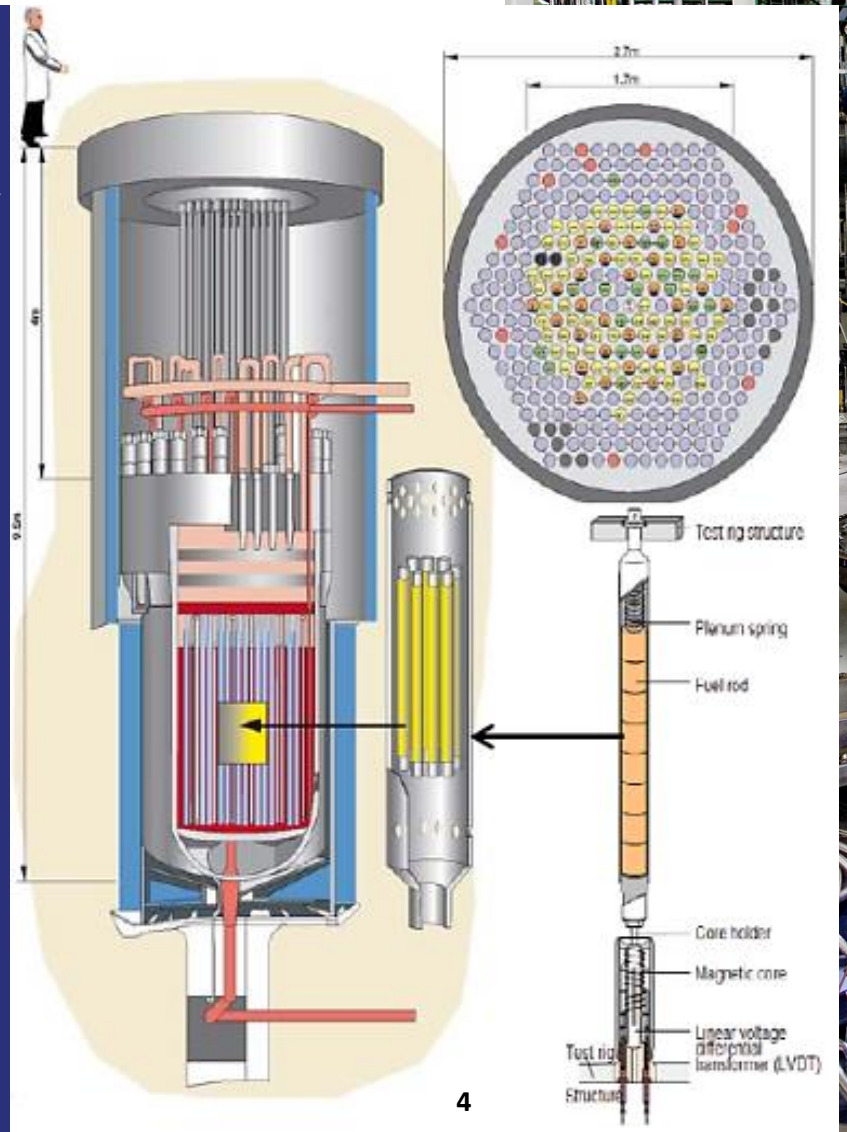
HBWR Research program

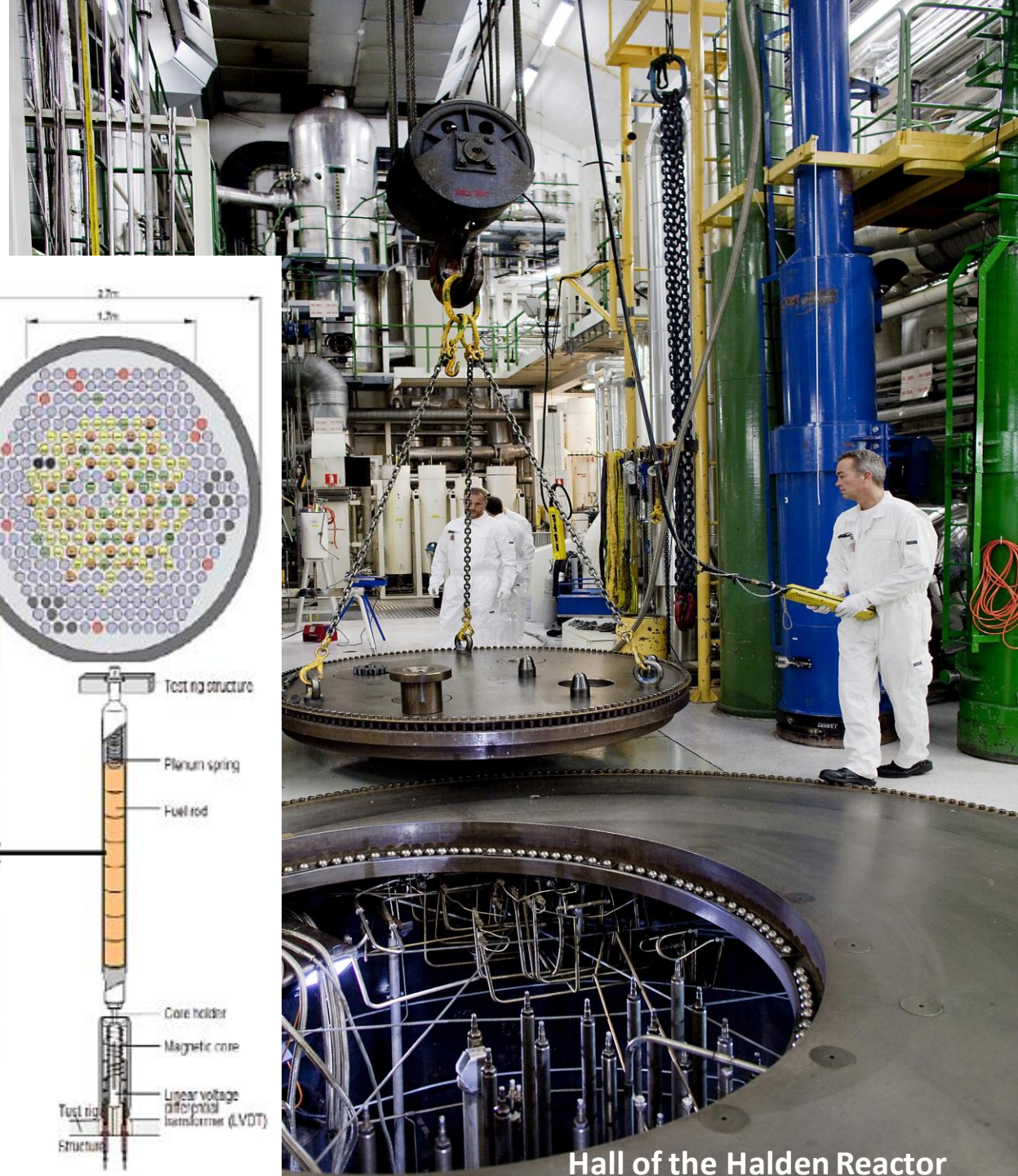
Key-factor: Making In-pile fuel measurements

- 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

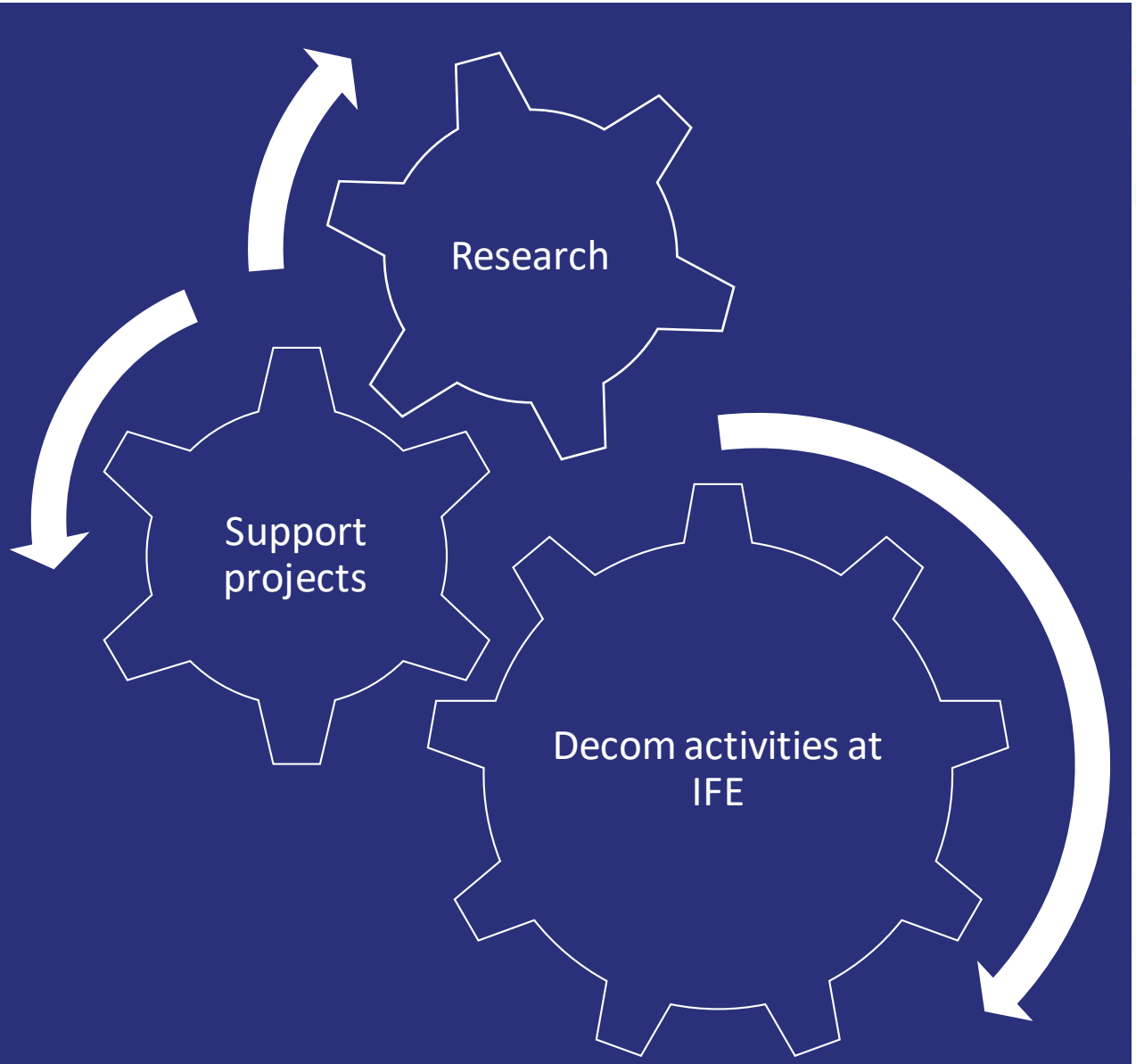
Thermal power:	20 MW
Operating temp.:	235 °C
Operating press.:	31 bar
Moderator:	Heavy water
Heavy water vol.:	14 m^3
Type of fuel:	UO_2
Power control:	30 Control rods





Hall of the Halden Reactor

Tragedy vs. opportunities



world nuclear news

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

Halden Reactor to be decommissioned

28 June 2018

Share

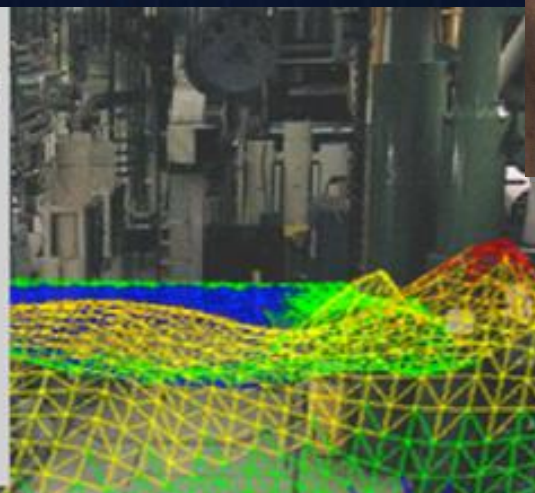
The board of directors of Norway's Institute for Energy Technology (IFE) has decided to close the Halden Reactor permanently and to start its decommissioning. The board will not apply to extend its operating licence, which expires in 2020, and the reactor, which is currently shut down due to a safety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

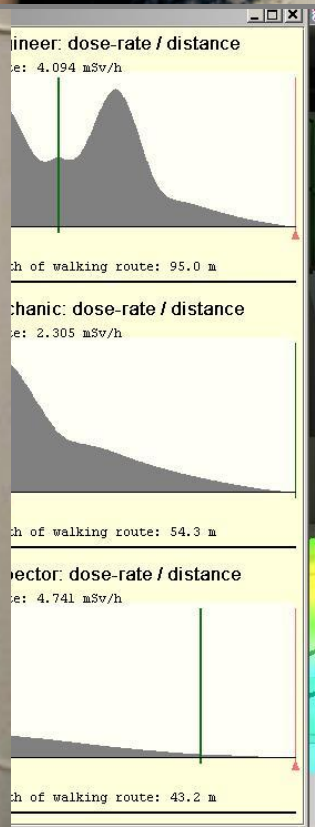
The Halden reactor (Image: IFE)

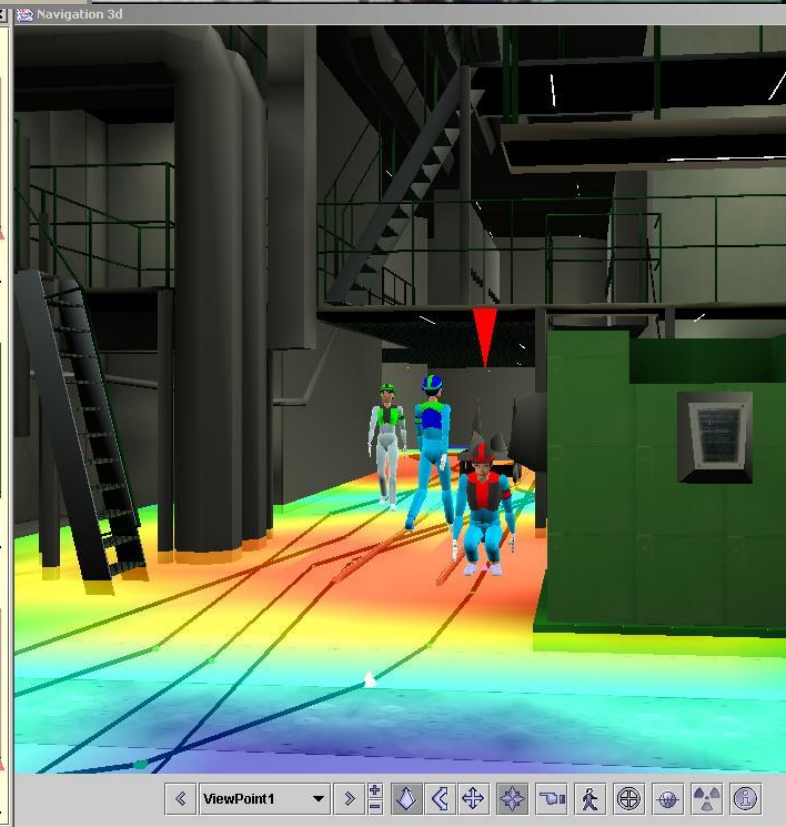
Official opening Oct 10, 1959

Digital support concepts in nuclear environments

(since 1996 till today)







Focus on systemic (MTO) approach

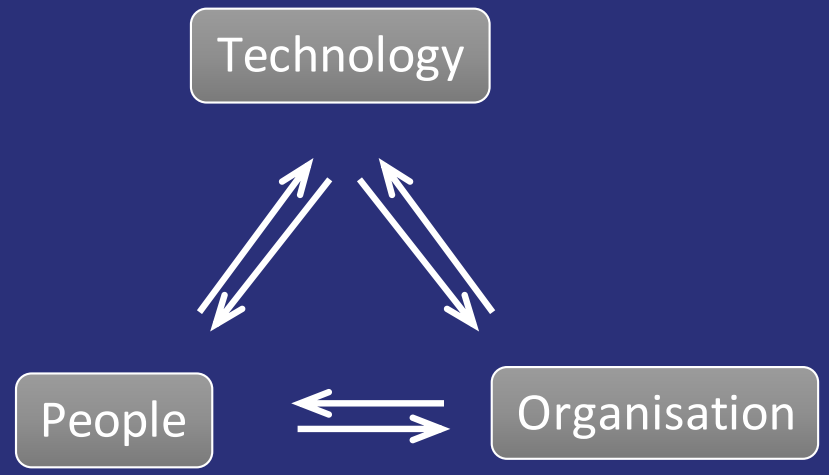
Radiological modelling

- 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



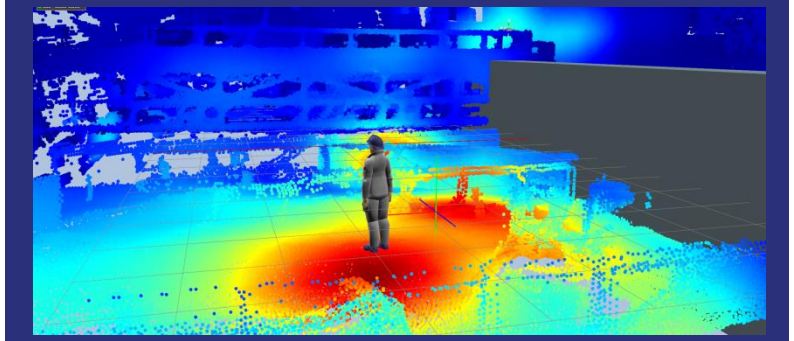
Human and organisational factors

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

Strategic research programmes (SIS)

- DecomSIS: Competence building at IFE within nuclear decom.
- HaLeDi: Acquisition of data for digital support

Digital experience (digital twin)



OECD Halden Rector Project HRP

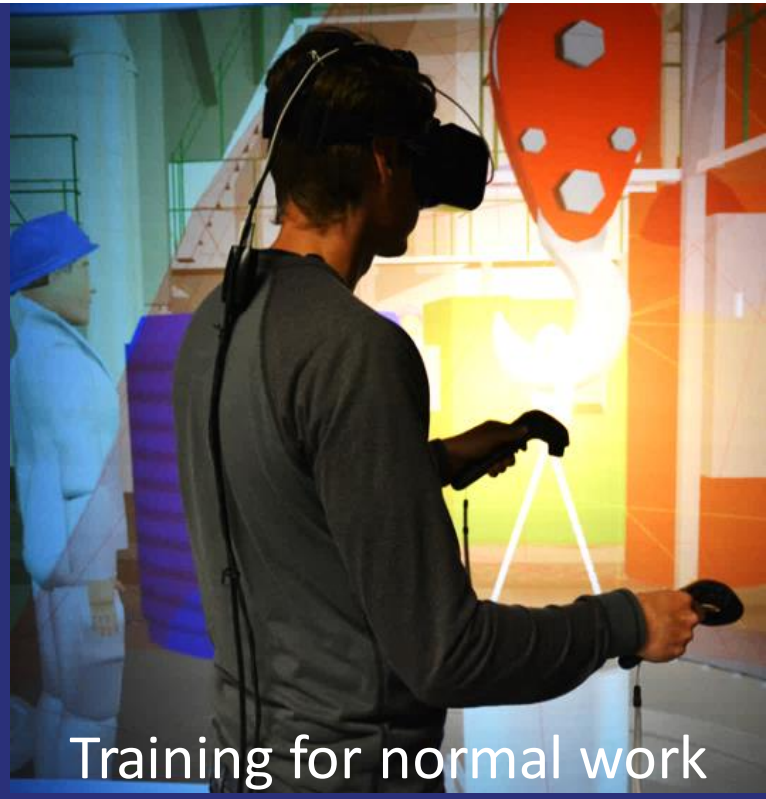
One of the World's longest collaboration program within the nuclear

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

OECD HRP Decom research 2021-22

Spatial Computing and Augmented Reality for Hazard Mapping and Visualisation

Automated Assessment of Field Worker Performance using VR and AR-based Simulator Training

Digitally-Enhanced Safety Assurance

Enabling Robotic and Remote Operations

Overview Displays for Decommissioning of Nuclear Reactors

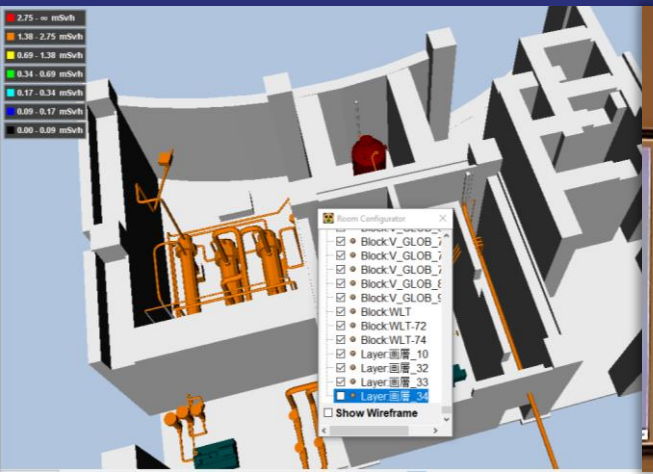
Decom support projects by IFE

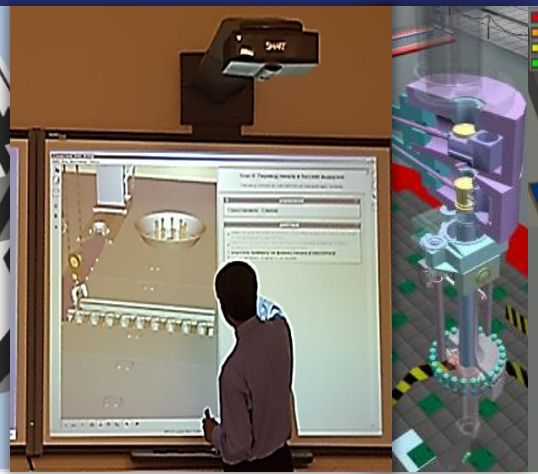
Fugen NPP (JAEA)
(1995 -)

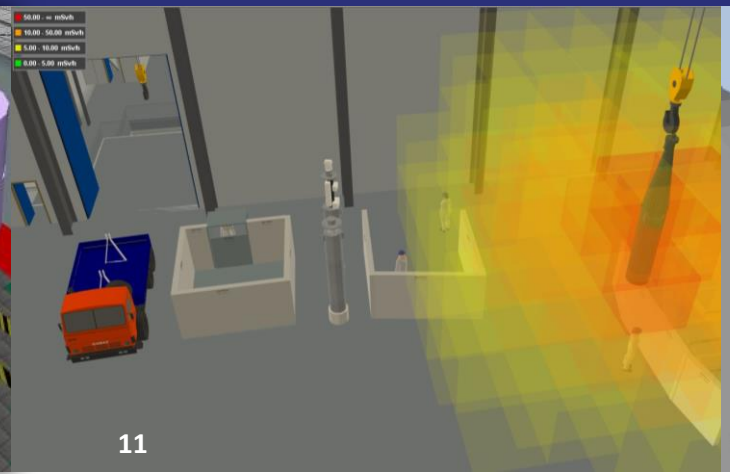
Leningrad NPP
(1999-)

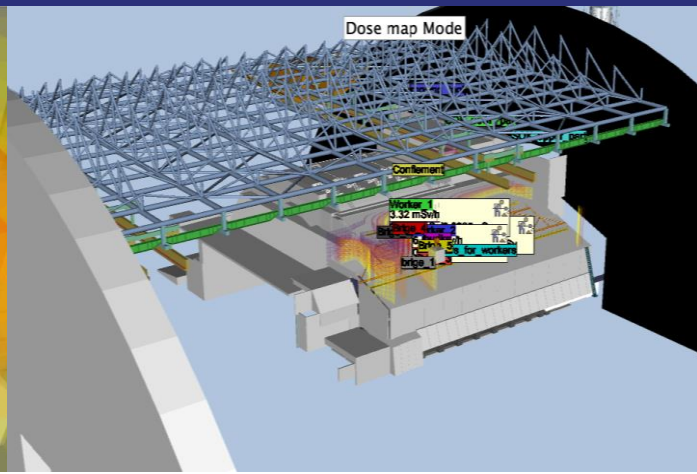
Andreeva bay, NW Russia
(2011-)

Chernobyl NPP
(2008 -)

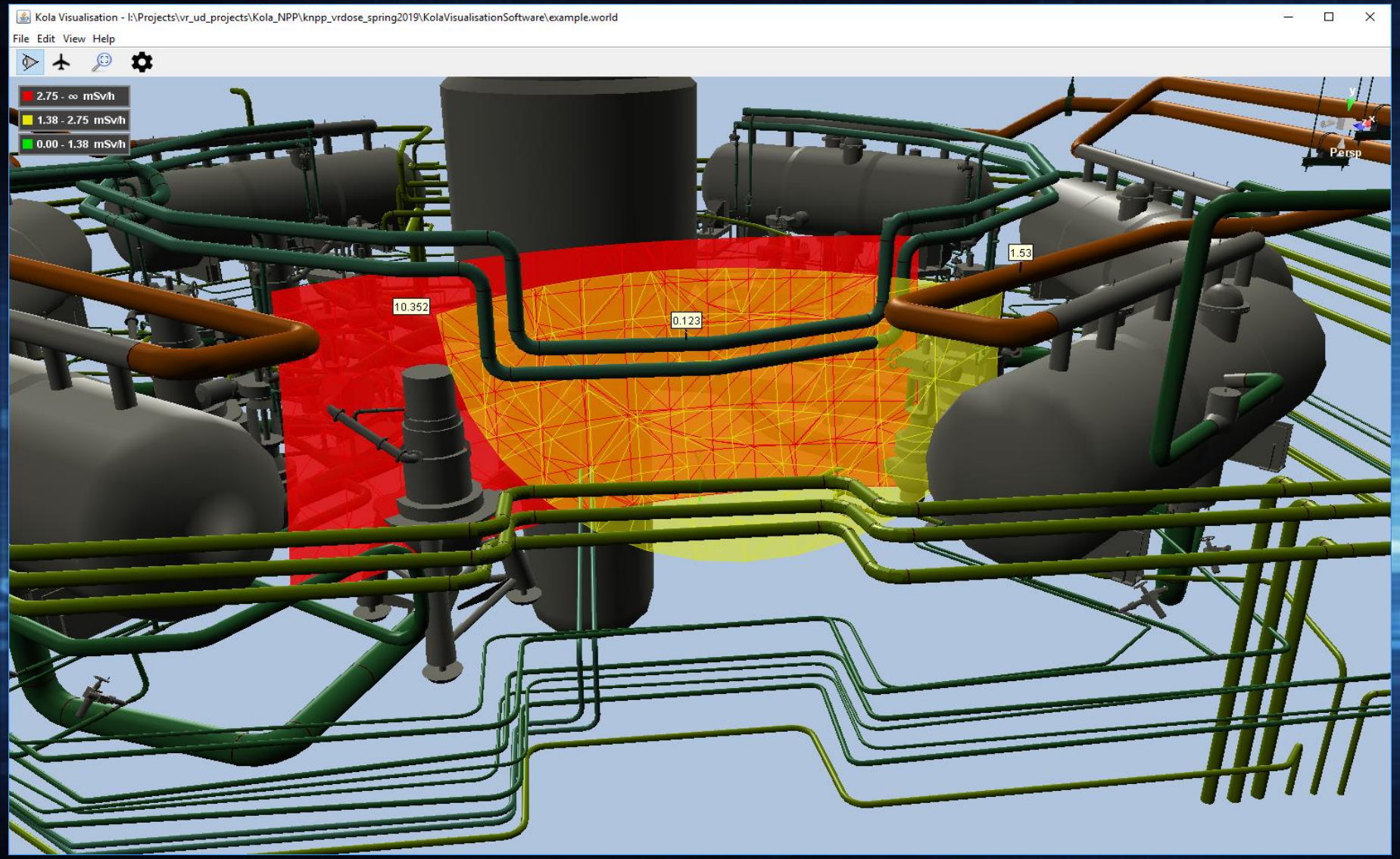






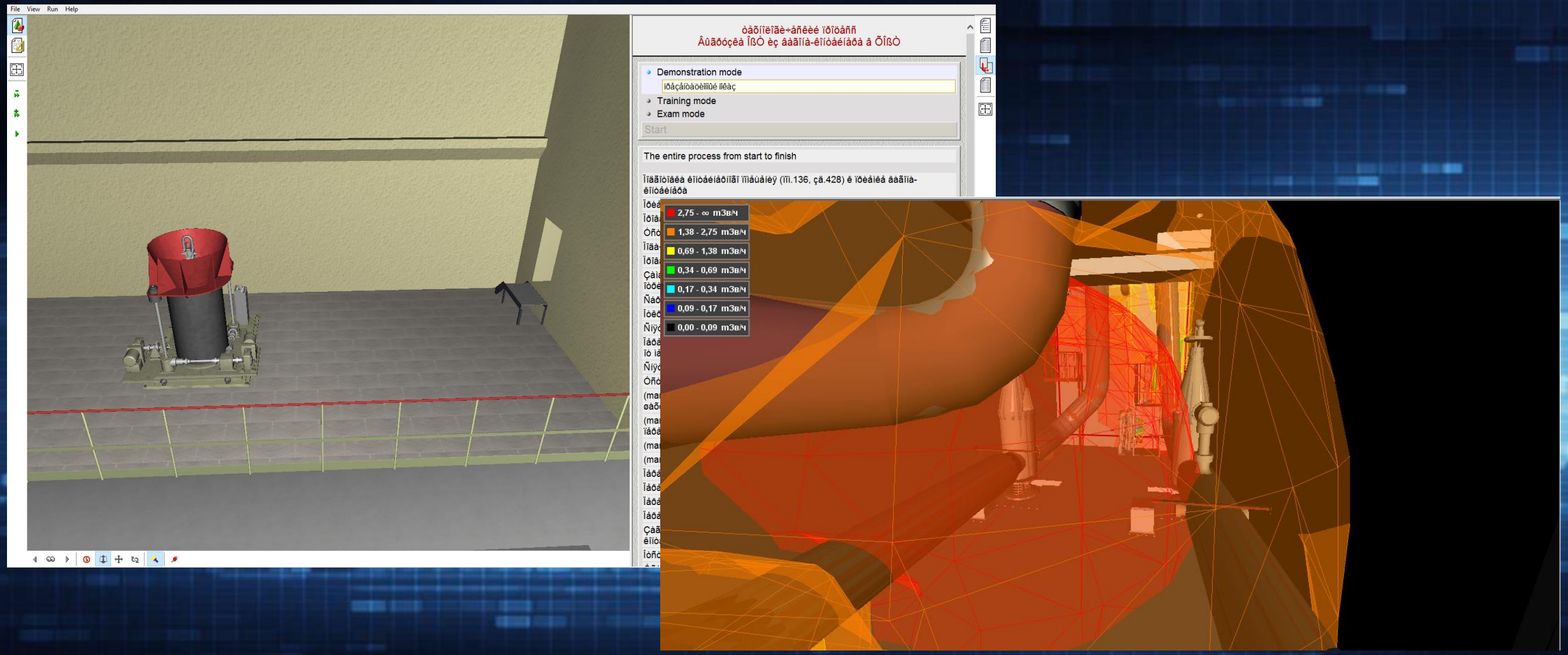


Demo with Kola NPP (KNPP)



3D rad. mapping based on dose-rate measurements for worker dose reduction

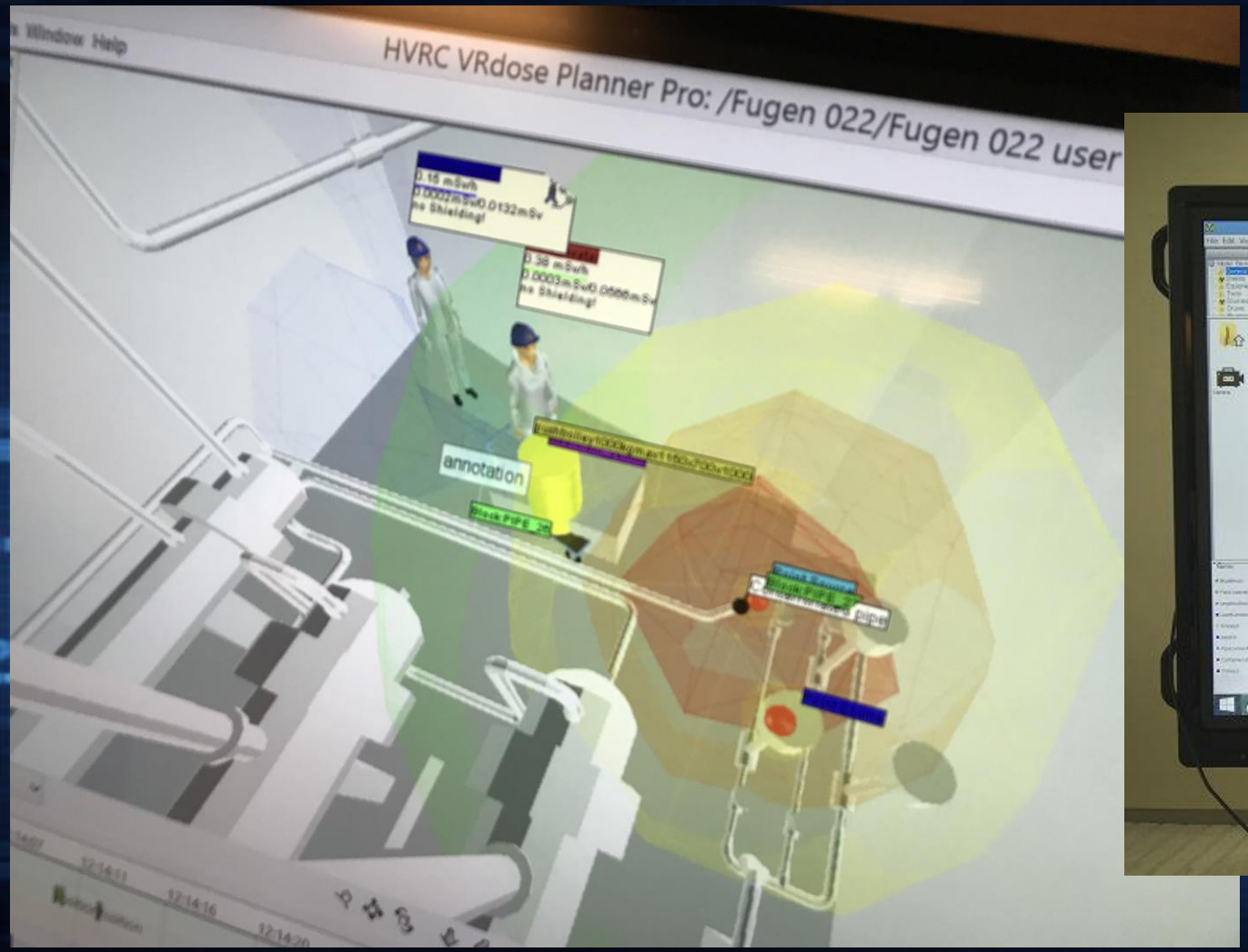
Demo with Leningrad NPP (LNPP)

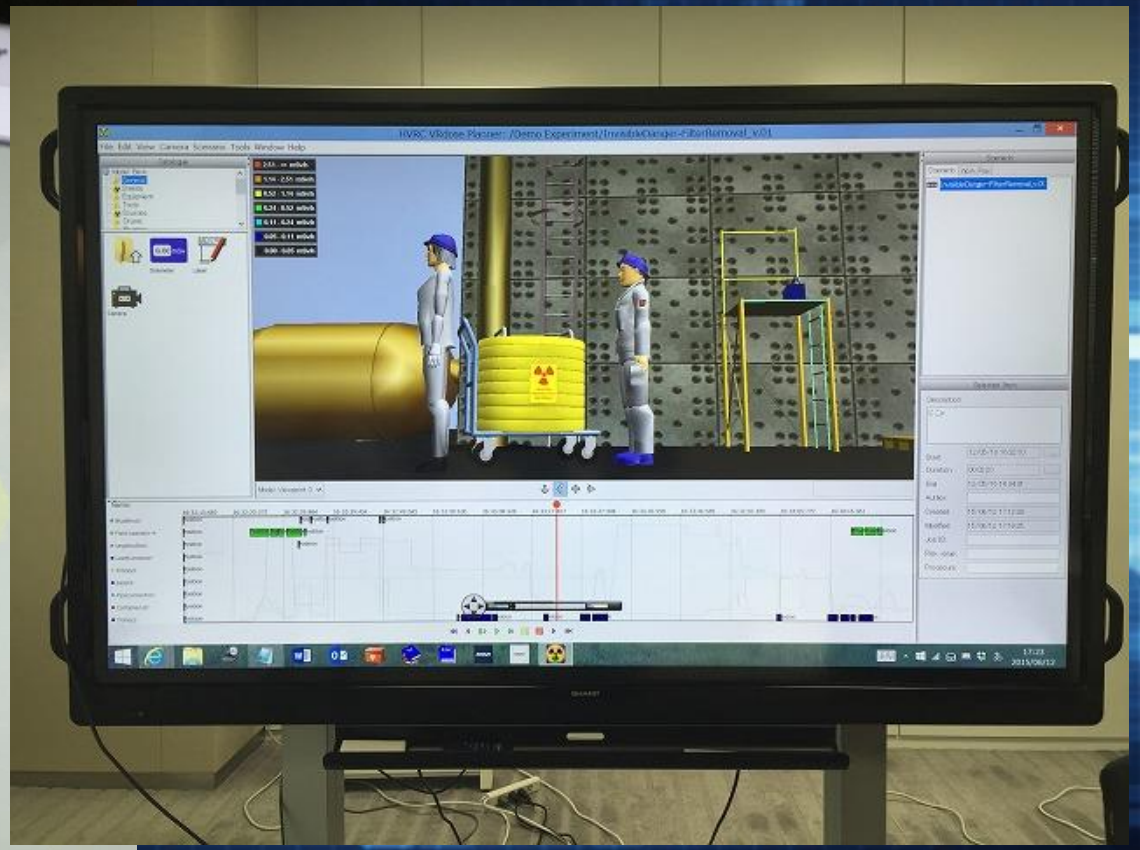


Spent fuel management planning and training

LNPP planner - dose assessments, shielding and work planning

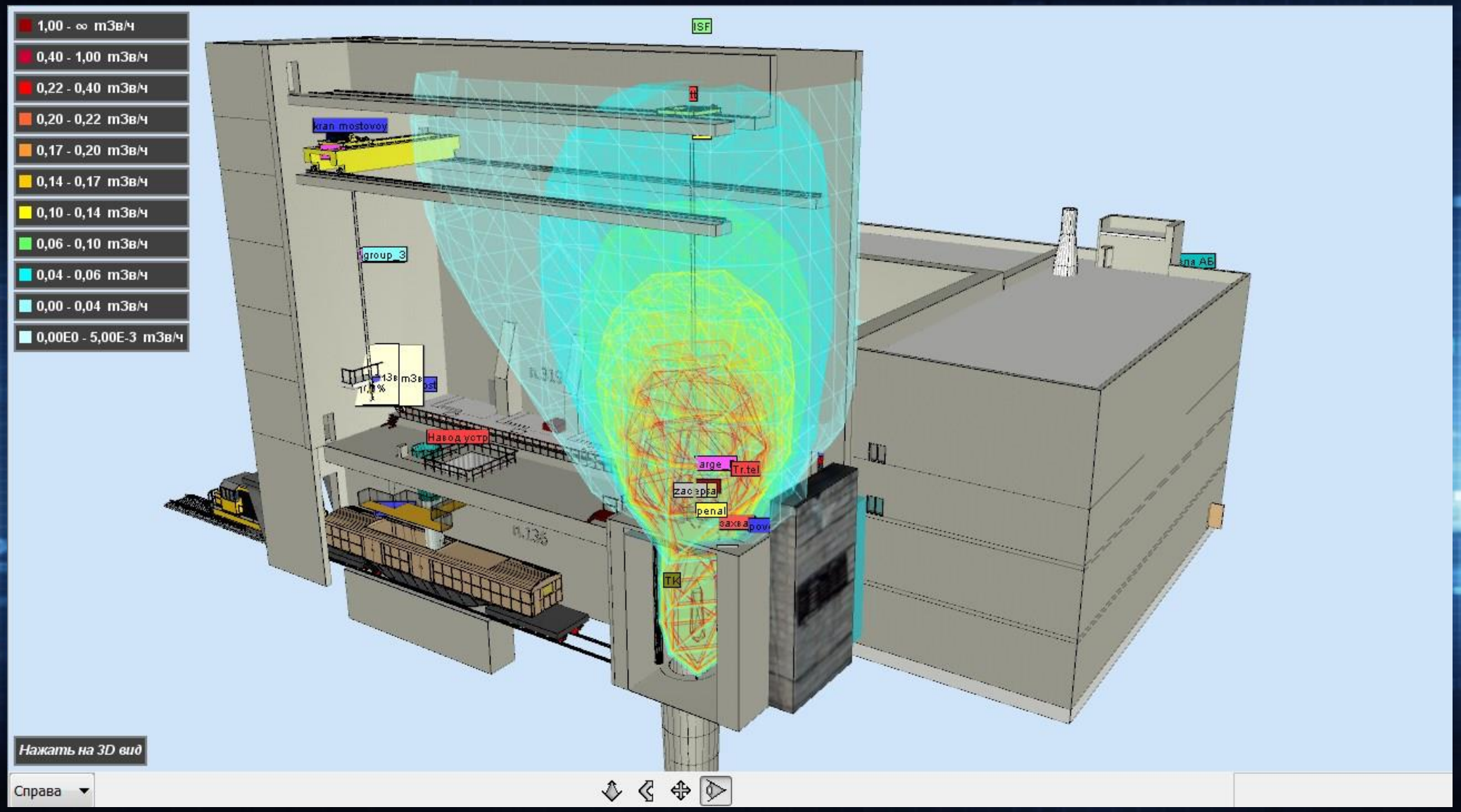
Demo with Fugen NPP (Japan)





3D digital knowledge (info) management system for decom

Demo with Chernobyl NPP (ChNPP)

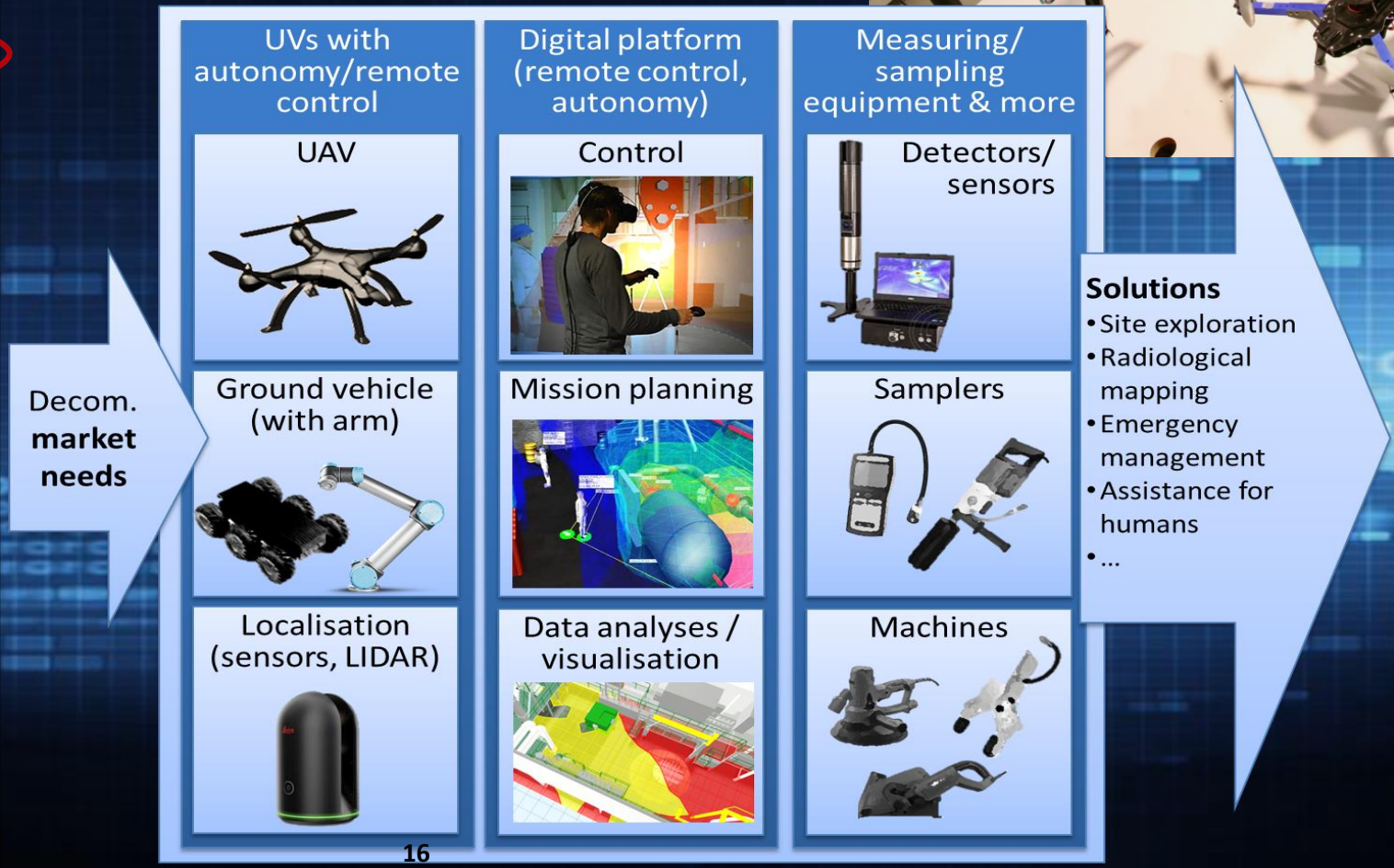


Radiation safety planning for spent fuel management (transportation)

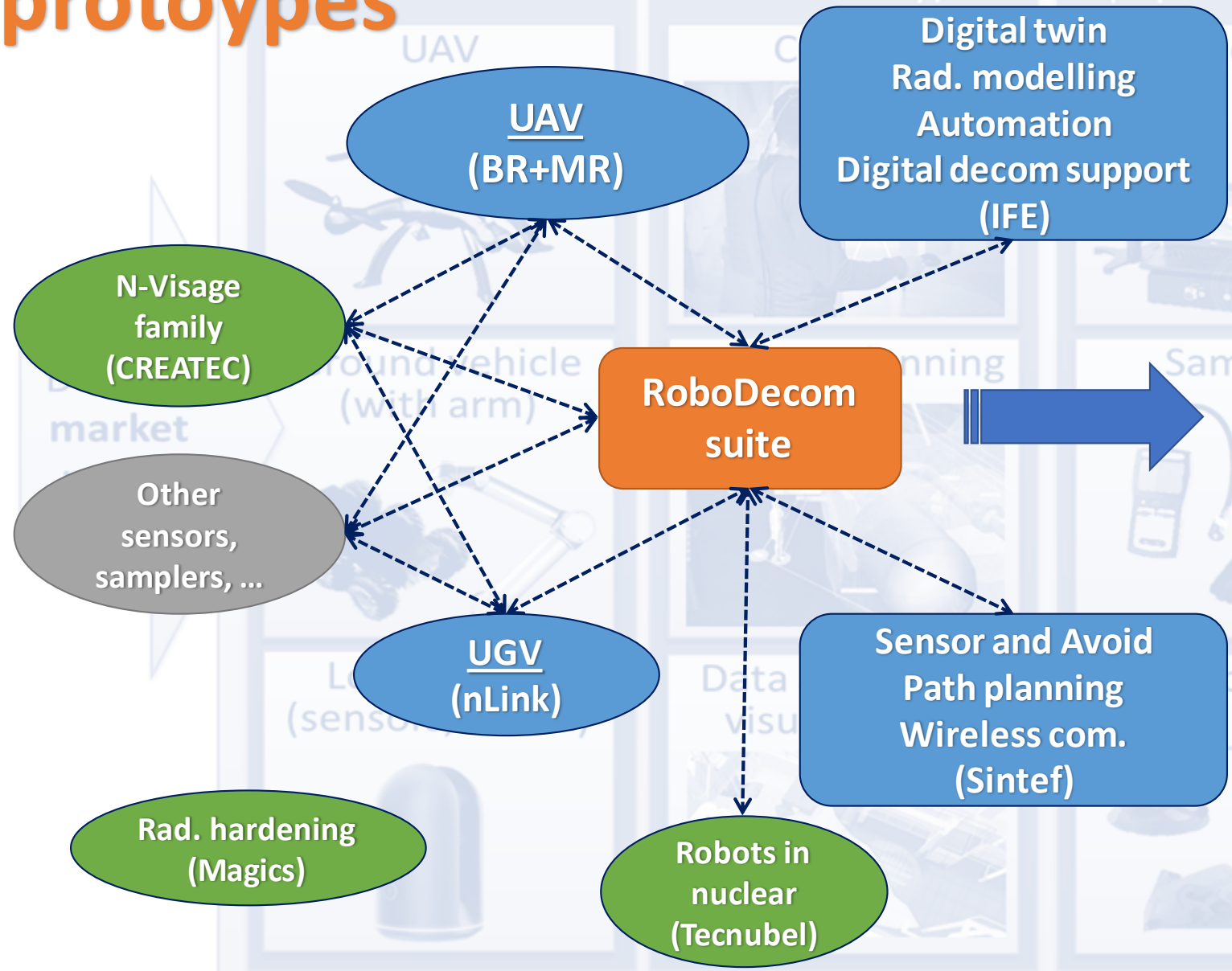
RoboDecom – Digitalisation for Robotics in decom.

IFE · nLink · Bergen Robotics · Maritime Robotics · SINTEF · CREATEC · TECNUBEL (Your project needs our care) · MAGICS®

- 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



RoboDecom protoypes



Remote, semi- or autonomous capabilities for:

360 photography supporting:

- site monitoring
- briefing – situation awareness
- design/config. info checking
- training

3D scanning & radiological mapping for supporting

- design/config. info
  - reconstruction
  - validation - ‘as is’
  - update
- digital capabilities supporting
  - safety planning
  - safety monitoring
  - safety training
  - in-the field safety info

Sampling? – rad. characterisation

Emergency management

RoboDecom prototypes

MARITIME ROBOTICS

SINTEF

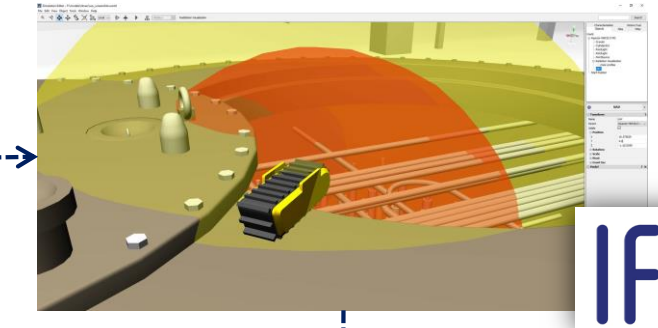
Sensor and Avoid
Path planning
Wireless com.

BERGEN ROBOTICS

CREATEC

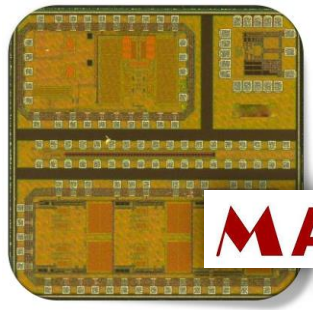
RoboDecom
SW suite

IFE



IFE

Digital assessments, Field tests



MAGICS®

nLink

LiveDecom suite

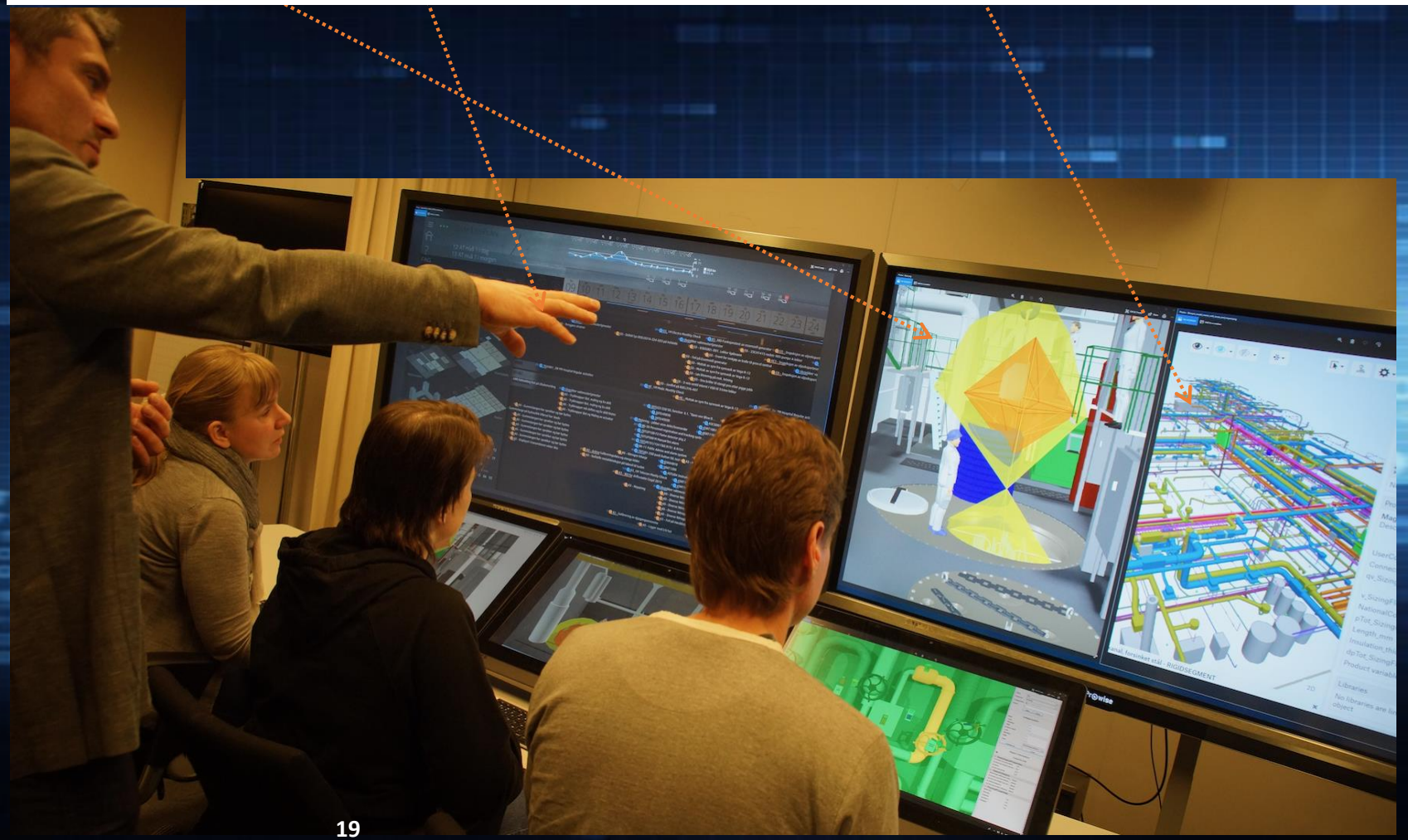
LiveDecom: Prototyping integration of digital capabilities

Demonstrate **integration** of digitalized capabilities for

- project planning,
- configuration management,
- rad. characterisation,
- job planning,
- training,
- costing, and
- reporting for decom

through integration of tech. like

- BIM/PIM,
- advanced project planning interface,
- 3D job and hazard simulation,
- 3D gamma mapping,
- ISCD costing,
- …



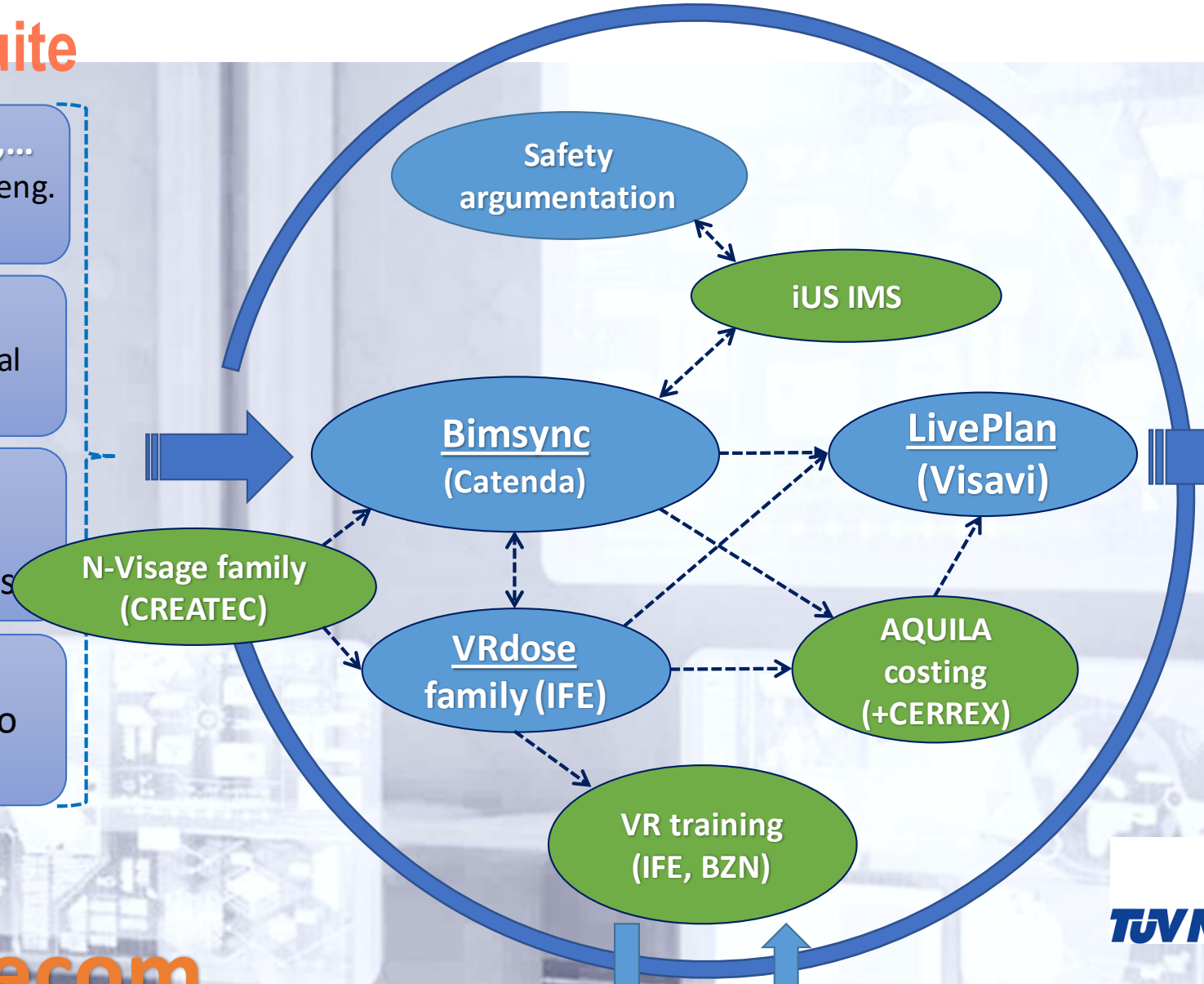
LiveDecom suite

EDMS, SCANNERS,…
point cloud (3D scan), eng. drawings, photos

INVENTORIES
physical & radiological characteristics

INSTRUMENTS
measurements, samples, calculations

WORK PLANS
strategies, scenario descriptions, …



Strategy 1

Strategy 2

Strategy 3
Waste
Exposure
Costs
Risks
Time
Uncertainty
Resources
Skills
Equipment
…

TÜV NORD

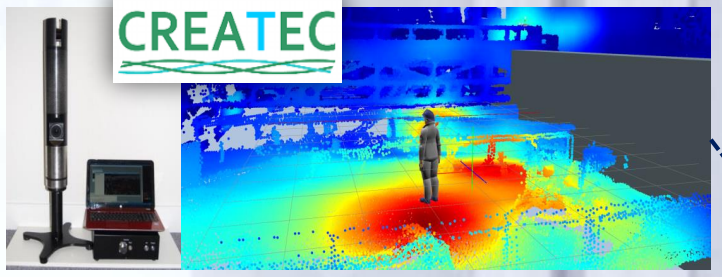
Other software interfacing with LiveDecom
EDMS, MRO, EPR, Safety evaluation, … systems

LiveDecom suite

20

LiveDecom suite

CREATEC



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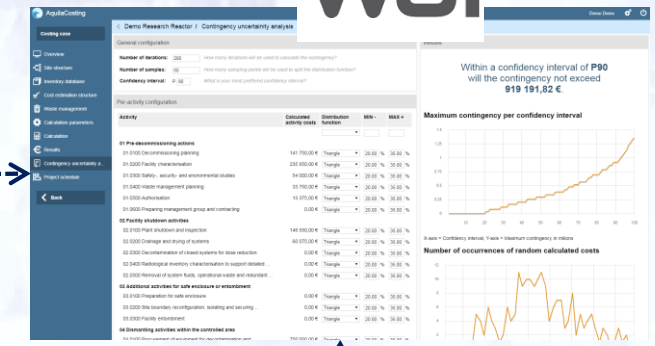
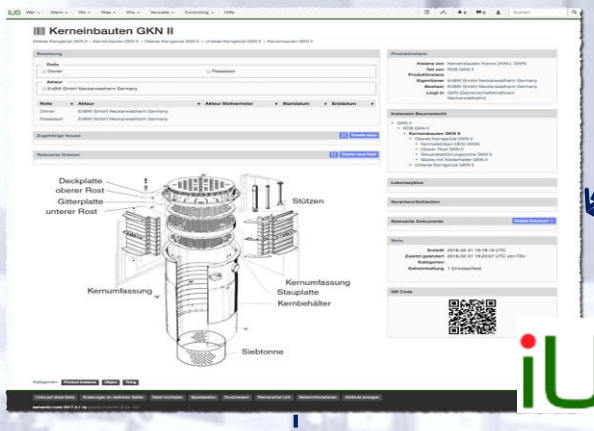
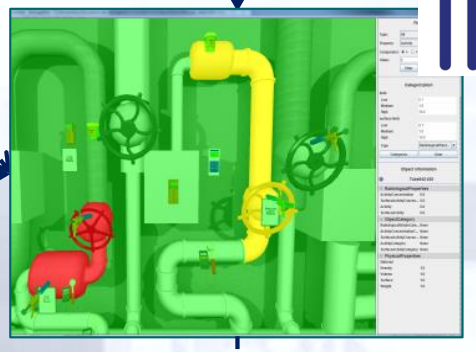




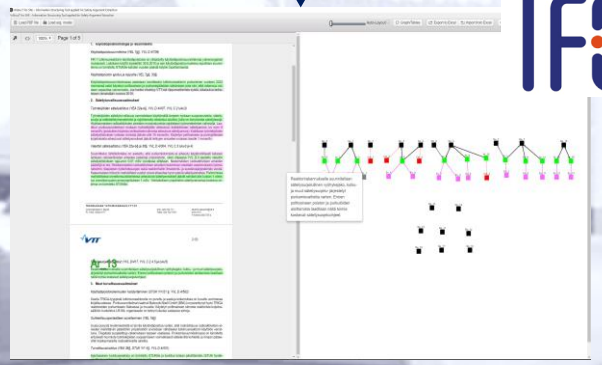
TÜV NORD

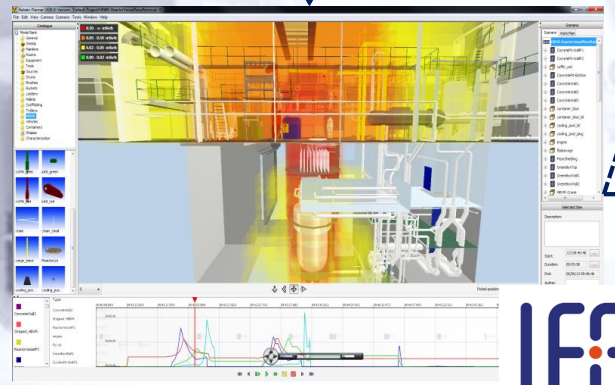
iUS

IFE



VISAVI TECHNOLOGY





bay®

Holistic digital support & Modular robotics systems Questions

1. What are the needs from the industry these techs could satisfy?
2. How would these techs satisfy these needs?
3. What are the current barriers for adoption?
4. How cold we overcome these barriers? What facilitators are there?
5. Who should develop/provide these techs?
6. What tech development is required for field applicability?
7. What risks could be introduced by these techs?
8. Are there any regulatory issues?
9. How to demonstrate safety of such techs?

Integration with CREATEC's technology

Simulation Editor - F:\demos\fukushima_gamma_camera\Project\decom_workshop_2019.world

File Edit View Object Tools Window Help

250.00 - ∞ mSv/h
125.00 - 250.00 mSv/h
0.00 - 125.00 mSv/h

Name: Crawler
DoseRate: 97.62 mSv/h
Accumulated_Dose: 0.8492mSv/6.0384mSv
Shielding: Shielded 41.0%

Persp

Objects Files

World
Box
BoxShield01
BoxShield02
Camera
HUD
Legend
PointCloudSource
Radiation Visualisation
Sample Model

Dose Graph

Animation BoxAnimation Dosimeter All

Dose-Rate mSv/h

1,200 1,100 1,000 900 800 700 600 500 400 300 200 100 0

01:00:09 01:00:19 01:00:29 01:00:39 01:00:49 01:00:59

Dosimeter (6.1097 mSv)

BoxAnimation

BoxShield
BoxShield01
BoxShield02
Camera
FieldOperator1
HUD
Radiation Visualisation

Image Anchor X 1.0
Image Anchor Y 0.0
Image Label

Label

Name Label
Text al time calculation of shields
Icon
Icon Text Gap 4
Opaque
Border Code
Font
Horisontal Align... Leading
Vertical Alignment Center
Horisontal Text... Trailing
Vertical Text P... Center
Automatic Resize

Inbox - Tom-Rob... 1 Reminder(s) capture For 18th How can I deter... Command Prompt crdoc [C:\Users\t... untitled [C:\Users... My first three.js a... OBS 0.16.2 (wind... Simulation Editor... NOB 10:53

Simulation of robot in Fukushima based on input from CREATEC's sensor tech

Integration with Bay Zoltán Nonprofit Ltd's VR platform

Rad. simulation results imported into BZN's VR system

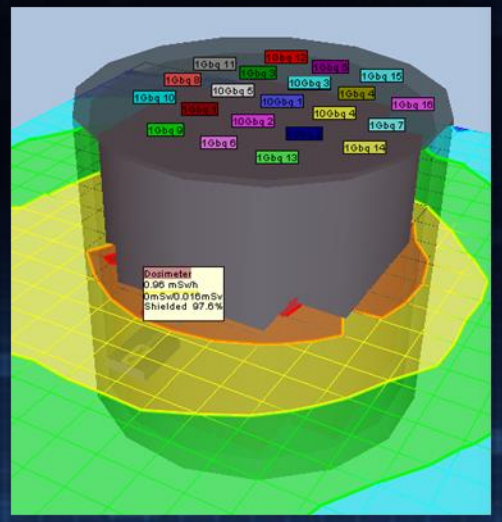
VR training - IFE

VR crane control training with hand tracking and visualisation

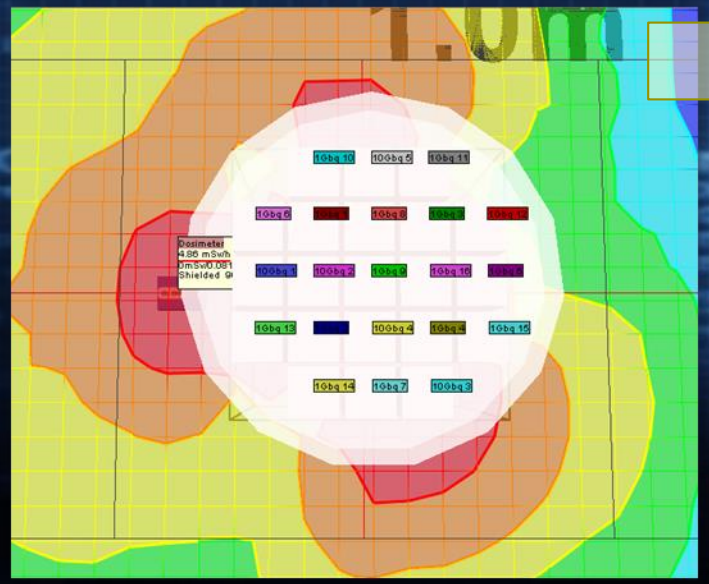
WM Process support demonstration with iUS

Konrad-Container

Waste Packaging support demonstration

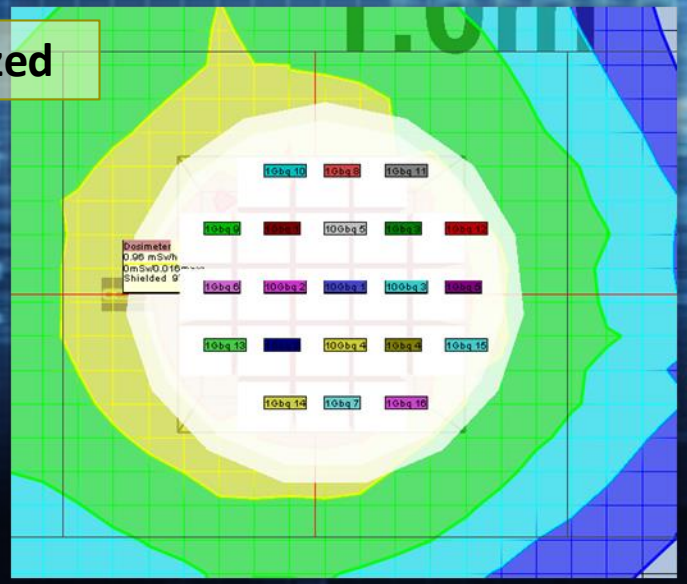


- MOSAIC type shielded container
- 21 slab-like waste pieces
- 5 pieces 10GBq Co-60
- the rest 1GBq Co-60



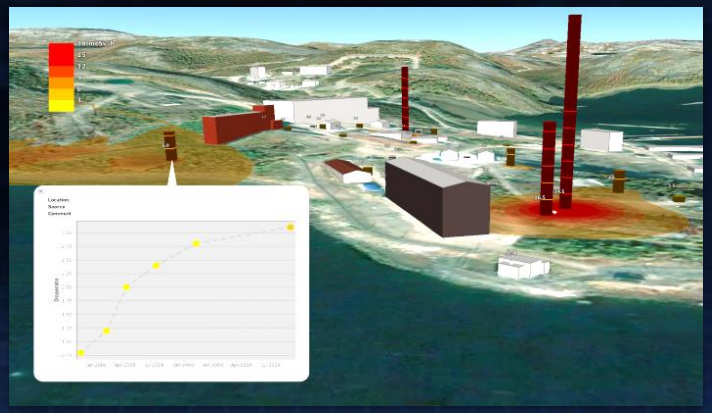
Random

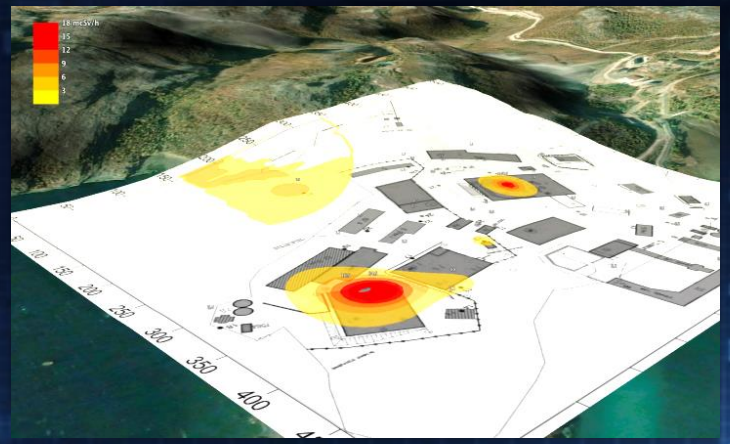
Optimized

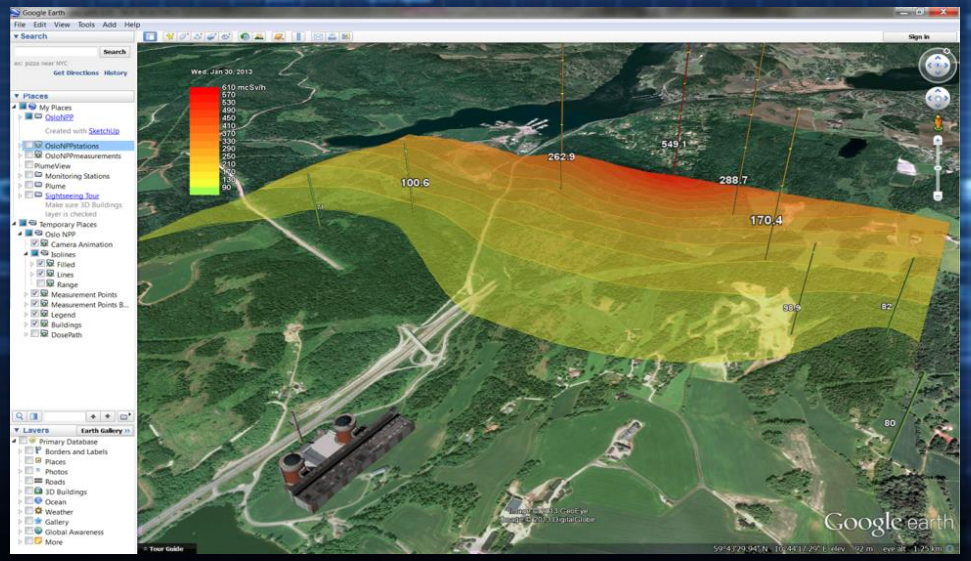


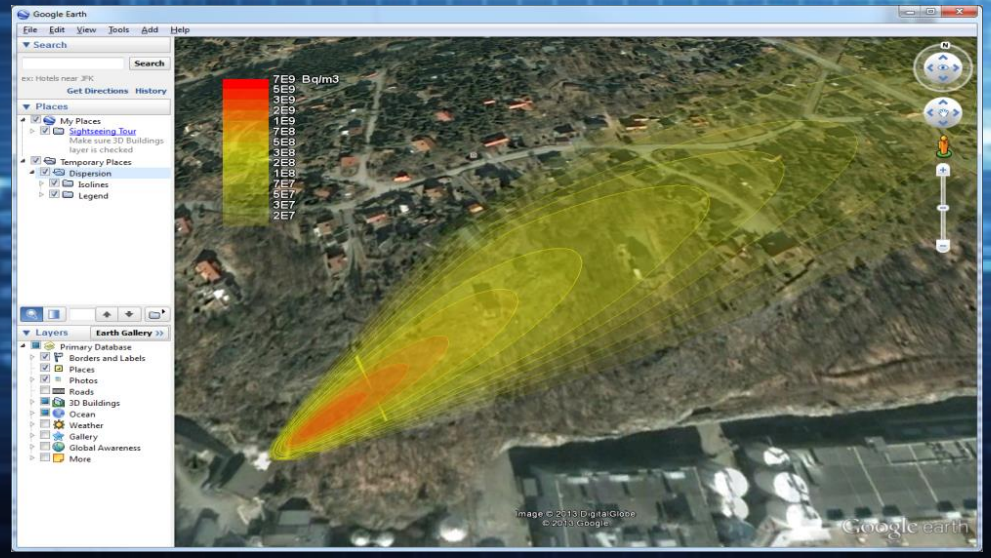
Exploiting shielding effect of heavy waste

Environmental modelling

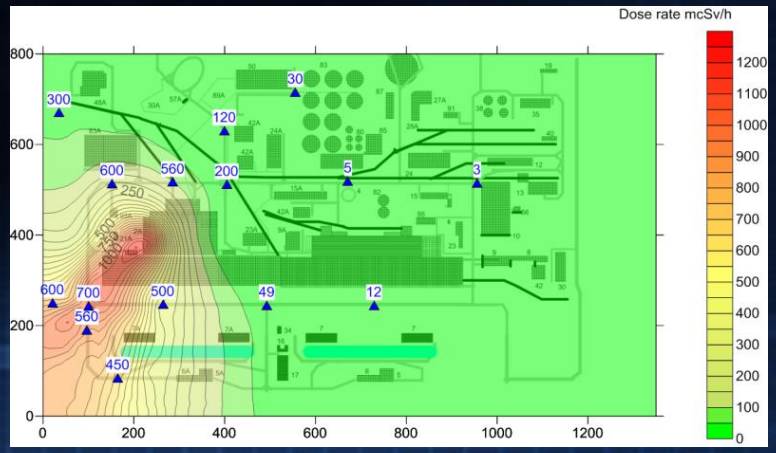


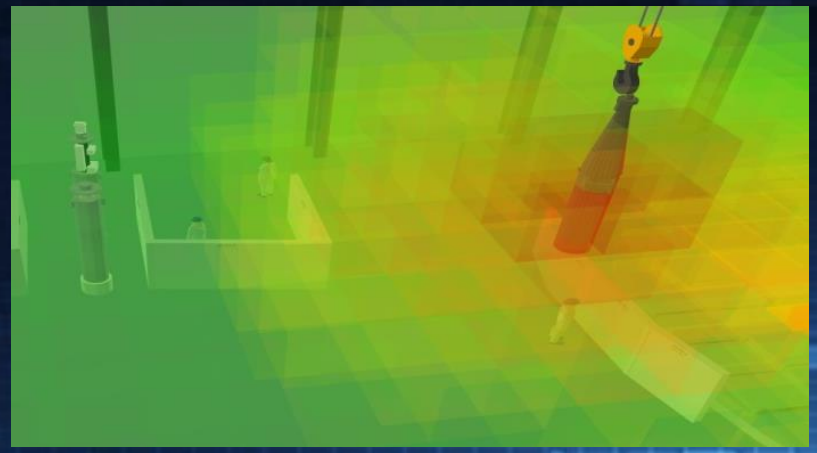






Geostatistical analyses





3D geostatistical spatial analyses of discrete data

- Sampling/measurements optimization
- Identification of hot spots and low certainty areas
- Generation of smooth maps
- …

IFE is now an International Collaborating Centre of the IAEA

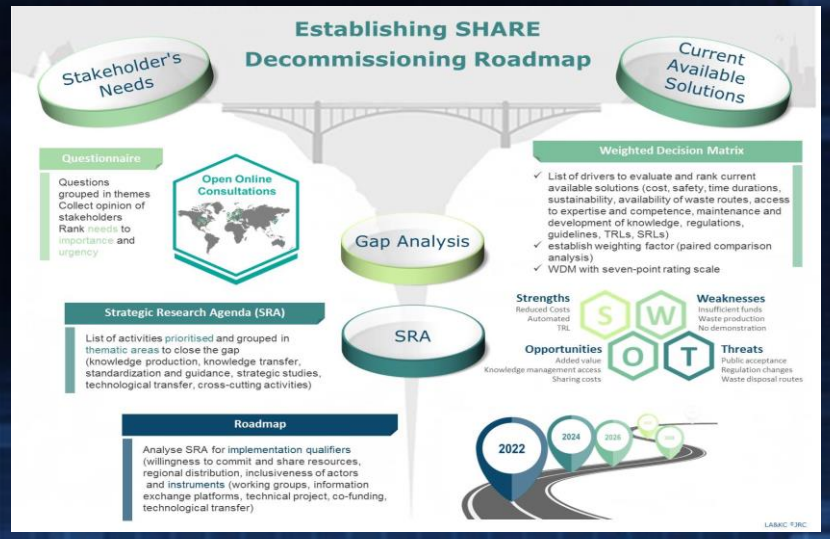
for the digitalisation of knowledge management for nuclear decommissioning

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.

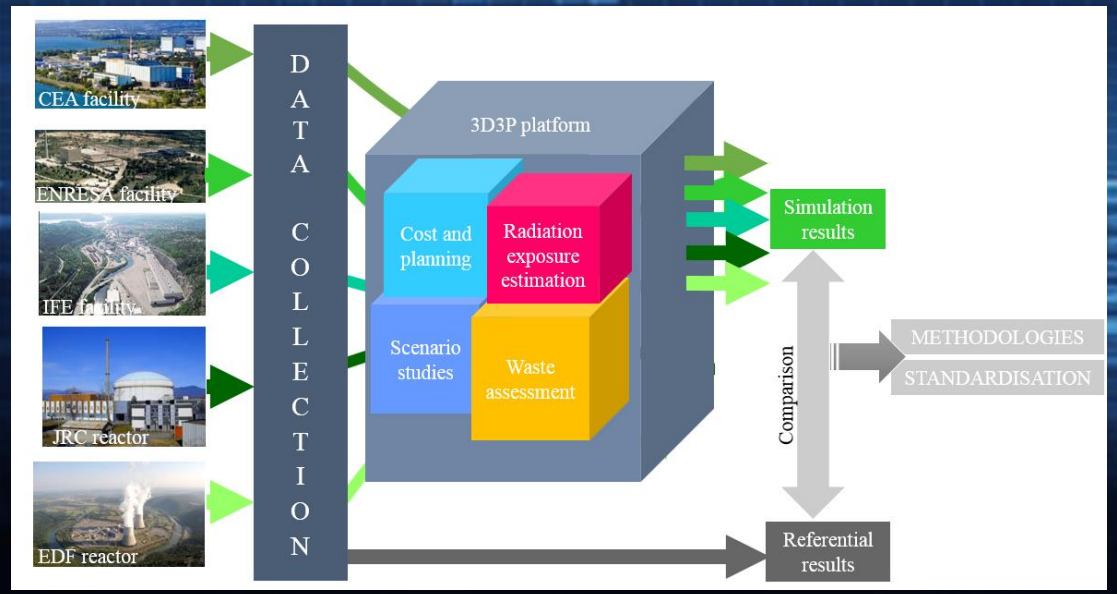
(Left to right) President of the Institute for Energy Technology Nils Morten Huseby signs the Practical Arrangement with IAEA Deputy Director General and Head of the Department of Nuclear Energy Mikhail Chudakov. (Photo: IAEA)

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

EU projects/proposals



SHARE – Roadmap for decommissioning innovation

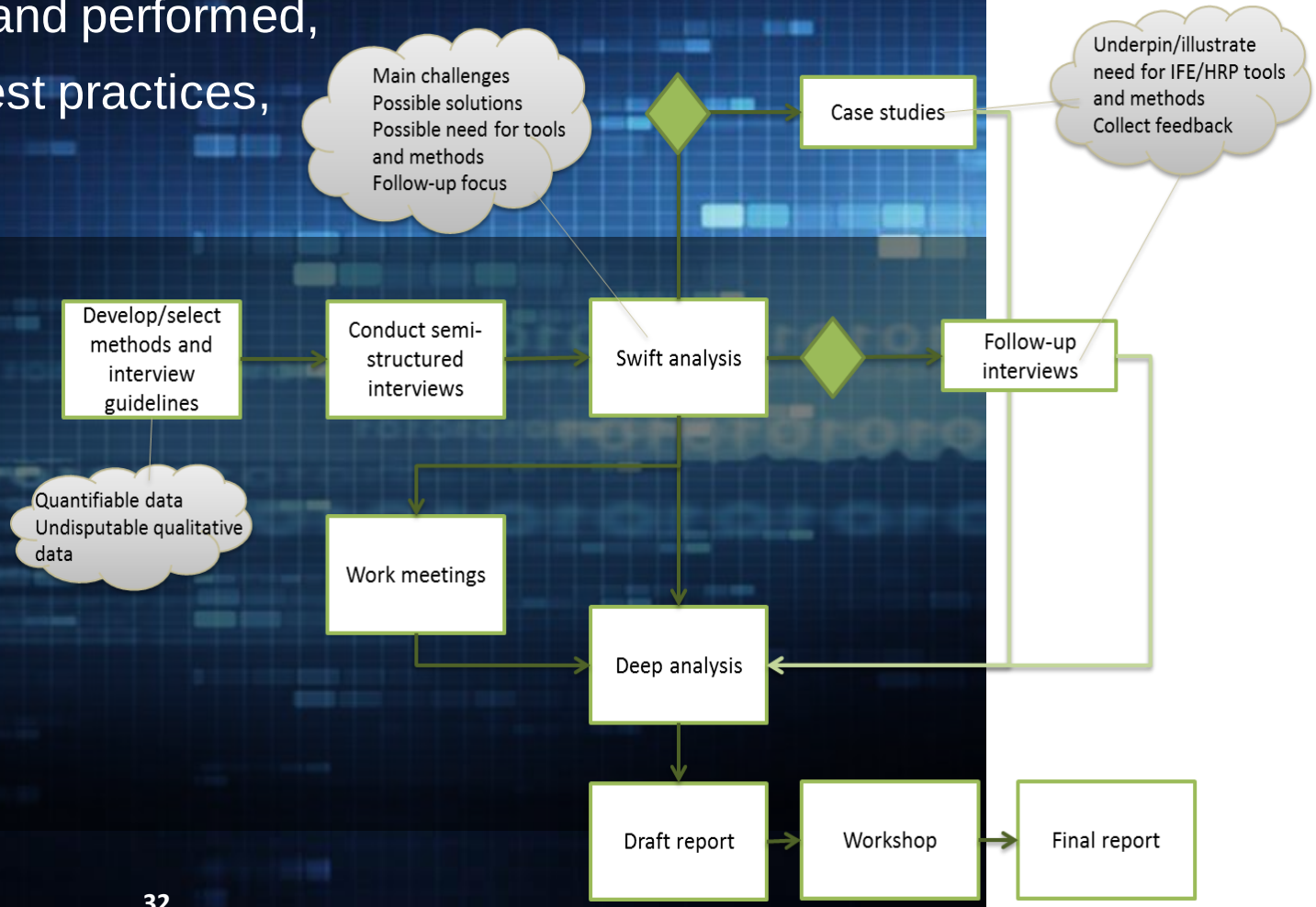


PLEIADES – Integration of digital capabilities and field demonstrations

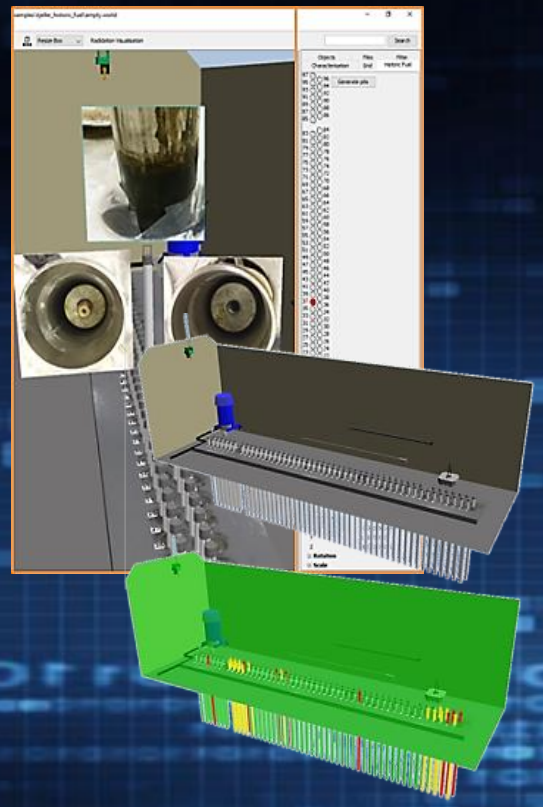
NKS NorDec

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

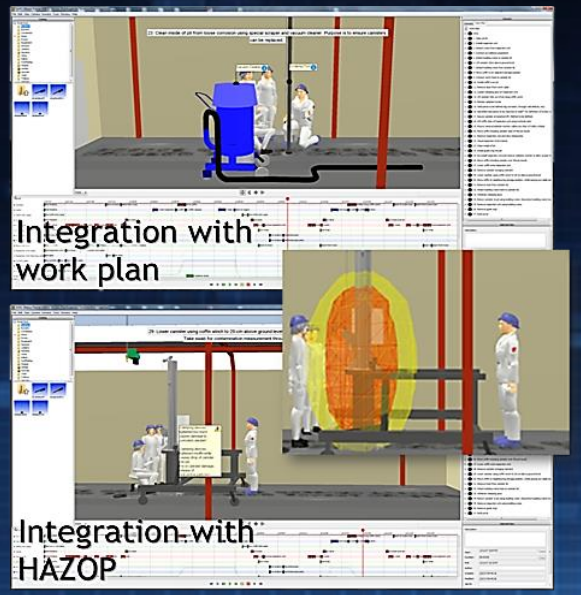
- IFE: Institute for Energy Technology, Norway
- SSM: Swedish Rad. Safety Authority
- NRPA: Norwegian Rad. Prot. Authority
- STUK: Finnish Rad. and Nucl. Safety Authority
- SIS: Danish Health Authority, Denmark
- VTT: Technical Research Centre of Finland Ltd
- Fortum, Finland
- Vattenfall, Sweden
- ÅF,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



Case study – underground waste storage



1. Info management (BIM)

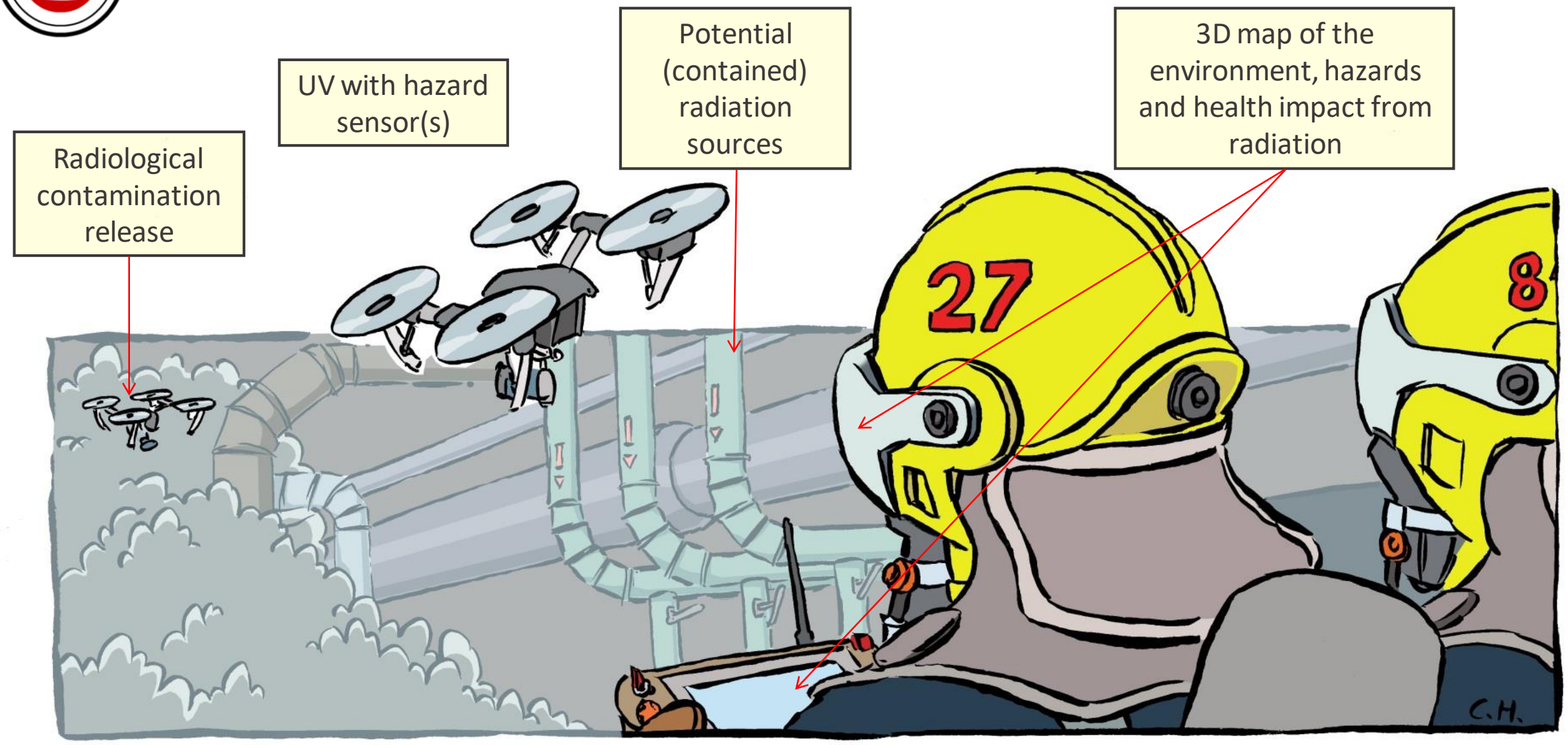


2. Work planning (3D simulations)

3. Interactive virtual presence (VR)

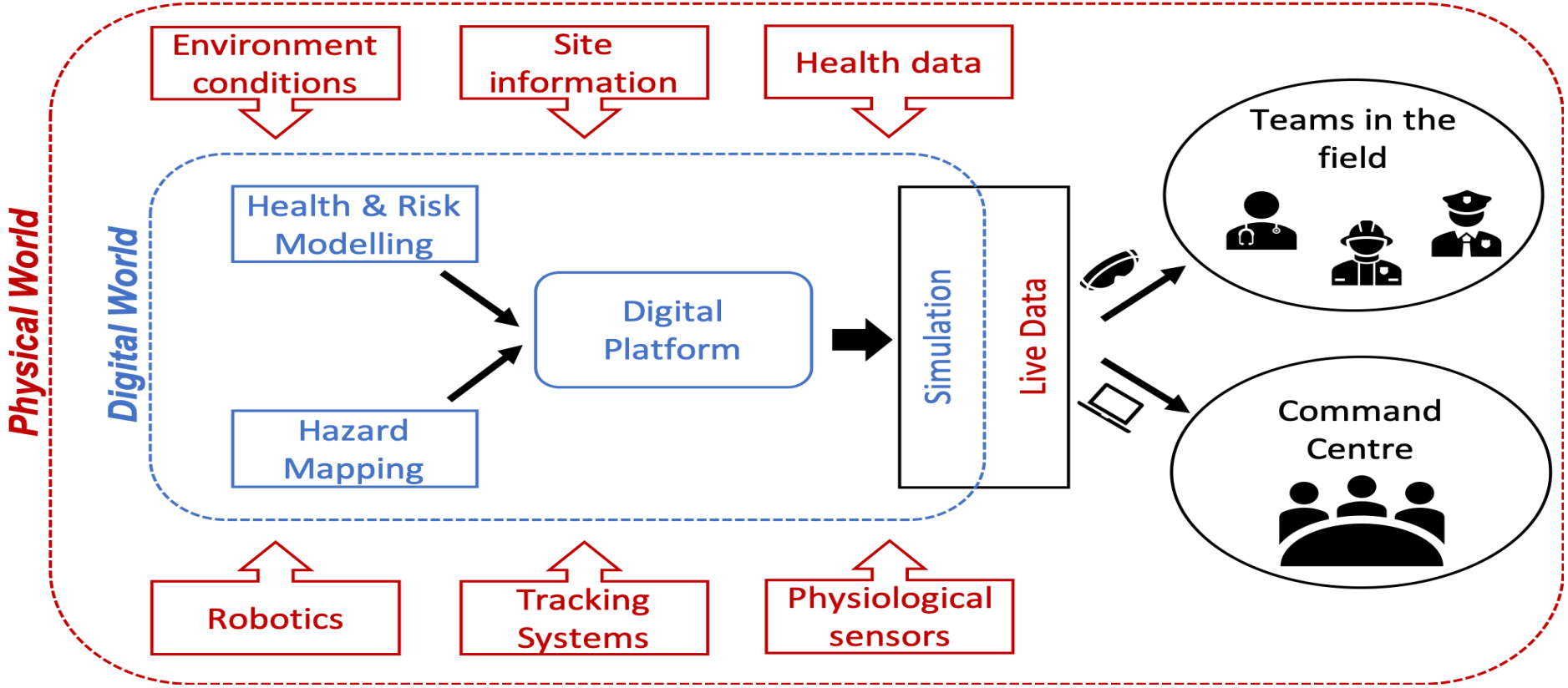
4. In the field info support (AR)

SMARTES – H2020 proposal



SMARTES - emergency management

To create an innovative cyber-physical system supporting first responders in complex emergency scenarios

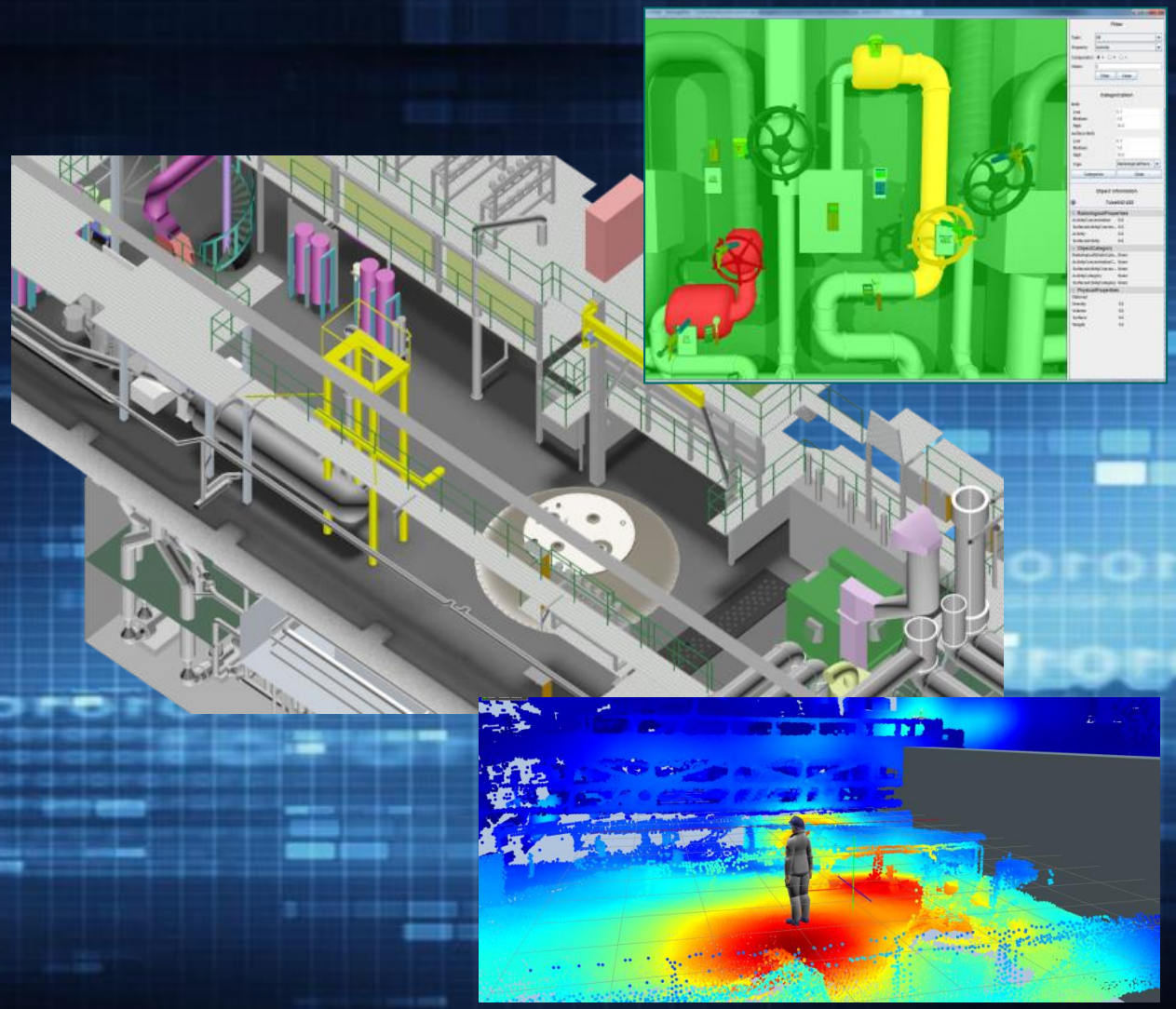


Design info base for decom planning

Support for NND

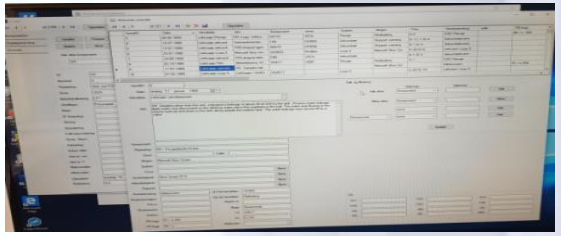
Aim: Develop a full scope as built design info base

- 3D laser scanning of accessible areas
- Definition of model details needed for planning
- Melling inaccessible areas (drawings, …)
- CAD modeling of relevant prats
  - Model structure (SSC), component ID



Integrated decom support system for NND

HR* Component Database



- HR Historical Database
- HR View
- Videos in HR hall
- …

Videos in the HR hall

- Spent Fuel safeguards database
- Other relevant data (production reports)

Drawings

Photos
Documents

BIMS

Autodesk Inventor, Plant 3D

Autodesk Vault

Autodesk Fusion??

?

BIMS

Solid Works

PDM/BIM?

Other systems/ databases

RadPIM?

VRdose

SCALE, MCNP

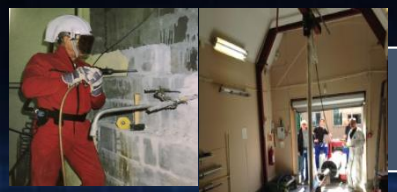
SimEditor

Costing, Scheduling, Documenting

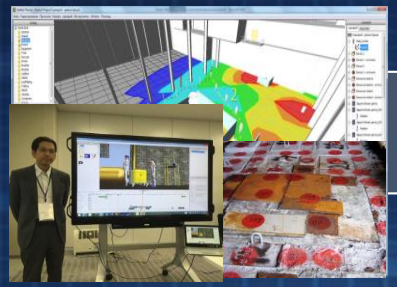
Have, can buy, piloted, to develop

*HR Halden Reactor

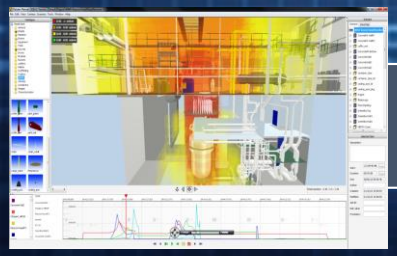
Decommissioning information center



Decom work at IFE (HR, URA, Stavbrønn,…)



Decom support projects in Russia, Ukraine, Japan, …



Industrial innovation & research projects

Case studies (field demonstrations) with partners

- Strategic planning support
- Support for interactions with advisors and the regulator
- Competence building (incl. education)
- Training and briefing support
- Public information
- Knowledge preservation

Information center