Nordic nuclear safety research

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Challenges and opportunities for improving Nordic nuclear decommissioning

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February 2019

Abstract

The overall goal of the NorDec project has been to explore challenges related to how decommissioning regulation is applied, and how projects are planned and performed in the Nordic countries, as well as collect best practices and share experiences between the Nordic stakeholders and the international community of experts. The contributions for this project came from a wide range of international stakeholders, including regulators, operators and contractors, and via the use of questionnaires, interviews, workshop presentations (including questions and answers during and/or after the presentations), and break-out group discussions.
This second phase of the project mainly focused on organization of a large scale workshop with the project participants and international experts to discuss the outcomes of the first (2017) phase of this project as well as challenges, innovation opportunities and experience in general related to nuclear decommissioning. The workshop has been co-organized with the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NAE) and the Electric Power Research Institute (EPRI). In addition, the workshop has also been supported by the Norwegian Research Council.
This report combines all the outcome material from the workshop. Additional material and information is available at www.ife.no/digidecom2018

Key words

Decommissioning, research needs, digitisation, Nordic cooperation

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Challenges and opportunities for improving Nordic nuclear decommissioning

Final Report from the NKS-R NorDec II activity

(Contract: AFT/NKS-R(18)123/6)

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1. Introduction

Approaching large-scale nuclear decommissioning projects in the Nordic countries make it important for both regulators and operators to build new capabilities for handling up-coming challenges. Sweden and Finland both have a mixed legacy of nuclear sites, including commercial plants and research reactors in different stages of operation or decommissioning, whereas in Denmark, some decommissioning projects have been completed for research reactors and others are well on the way to completion. In Norway no large scale decommissioning activities have yet been started. However, with the unexpected sudden shot-down of the Halden Reactor, combined with needs for decommissioning of on-site spent fuel and other historical nuclear facilities, collaboration with other Nordic countries in this field has become highly important. In addition IFE (the leader of this project) has been carrying out research towards innovation of knowledge and information management in decommissioning for many years in a strongly international setting and also collaborating with the International Atomic Energy Agency and the Nuclear Energy Agency. Application of the results of this research has the potential for improving decommissioning in Nordic countries, provided that the connection between this research and actual Nordic challenges and good practices is understood. Hence, the overall aim of the NorDec project has been to explore challenges related to how decommissioning regulation is applied, and how projects are planned and performed in the Nordic countries, as well as collect best practices and share experiences between the Nordic stakeholders. The contributions for this project came from a wide range of stakeholders, including regulators, operators and contractors. The Norwegian Radiation Protection Authority (NRPA), Swedish Radiation Safety Authority (SSM), Danish Health Authority (SIS), Finnish Radiation and Nuclear Safety Authority (STUK), the energy companies Fortum and Vattenfall, the consulting company ÅF in Sweden, VTT Technical Research Center of Finland, and Institute for Energy Technology (IFE) in Norway have participated in the project. The project collected information from experts based on their experience from completed and on-going decommissioning-related activities in Sweden, Finland, Denmark and Norway. Evaluation of this information aimed at identifying areas where stronger Nordic collaboration would facilitate improvements in processes, methods and tools. The project has fostered collaboration among Nordic stakeholders through providing a new arena for discussing challenges and best practices.

This second phase of the project mainly focused on organization of a large scale workshop with the project participants and international experts to discuss the outcomes of the first (2017) phase of this project as well as challenges, innovation opportunities and experience, in general, related to nuclear decommissioning. The workshop has been co-organized with the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NAE) and the Electric Power Research Institute (EPRI). In addition, the workshop has also been supported by the Norwegian Research Council.
This report combines all the outcome material from the workshop. Additional material and information is available at www.ife.no/digidecom2018

Invitation

Nordic nuclear safety research

OECD-HRP/NKS workshop on Challenges and opportunities for improving nuclear decommissioning in HRP member and Nordic countries

December 6-7, 2018

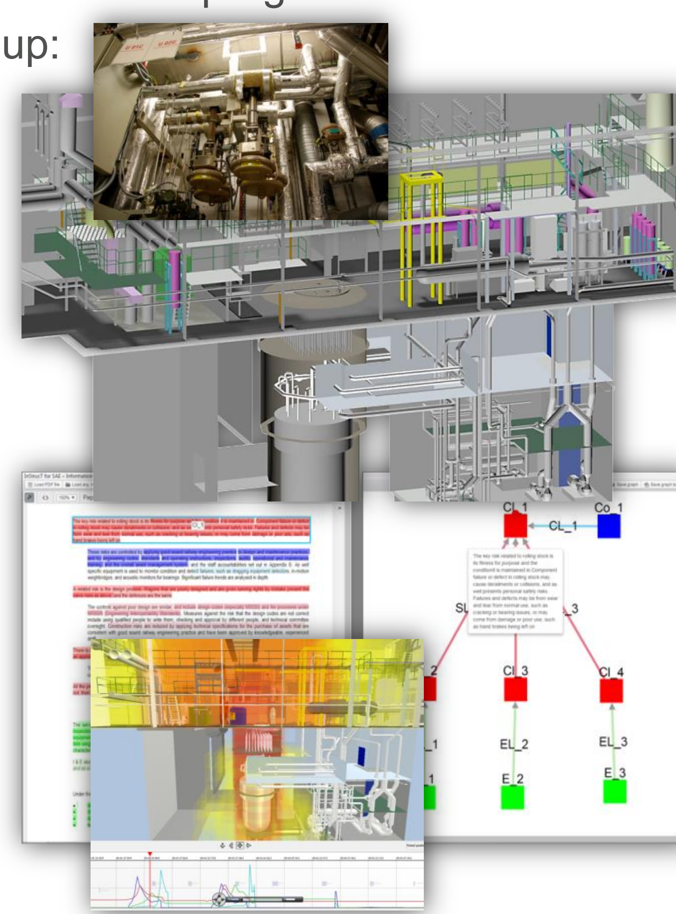
Hotel Scandic

Lillehammer, Norway

This workshop is organised within the OECD **H**alden **R**eactor **P**roject (www.ife.no/en/ife/halden/hrp/the-halden-reactor-project) and the Nordic Nuclear Safety Research Forum (www.nks.org/en/nksr/current_activities/nordec.htm). The workshop aims at bringing together a multidisciplinary group representing the professional community working on implementation and oversight of decommissioning for discussing opportunities and challenges for improving nuclear decommissioning in HRP member and Nordic countries. Special focus will be on bringing stakeholder organisations closer together through digitally enhanced innovative concepts. This workshop will also host the first meeting of a nuclear decommissioning advisory group to be launched by the OECD-HRP programme.

Examples for specific subjects to be addressed by the group:

- Collaborative development of guidance for practical application of regulation.
- Application of advanced information systems for demonstrating regulatory compliance.
- Joint development of case studies with digital support concepts.
- Establishing and testing digital experience based training methods.
- Joint development of e-Learning material for nuclear decommissioning.
- Interfacing big contractors with the regulators through digital safety demonstration methods.
- Collaborative testing of new decommissioning technologies using digital twins.



3-5 December: Within our series on “Digitalisation for nuclear decommissioning” an international workshop on **Application of advanced plant information systems for nuclear decommissioning and life-cycle management** will be held (www.ife.no/digidecom2018) at the same venue, providing the opportunity for interested participants to attend both events. (see also: www.ife.no/digidecom2019)

Organising committee: **digidecom@ife.no**

Chairman: I Szőke, Institute for Energy Technology, Norway

Institute for Energy Technology · IAEA International Atomic Energy Agency · HRP · nks Nordic nuclear safety research · EPRI · Forskningsrådet · NEA Nuclear Energy Agency

Workshop on
" International Workshop on Application of Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management "

3 – 5 December 2018
Hotel Scandic Lillehammer, Norway

PROGRAMME

Sunday, 2 December 2018
Registration: 18:00 – 19:00

Monday, 3 December 2018
Registration: 8:15 – 9:00

Welcome and Opening Speeches	
8:30	**Welcome and Introduction to IFE** Nils Morten Huseby, CEO IFE
9:00	**Welcome by Digital Systems Research Director** Tomas Nordlander, IFE
9:30	**Introduction to the Workshop and Practicalities** Réka Szőke, IFE
9:40	**Coffee break**

Workshop Introductory Presentations Chairs: Gerard LAURENT, Tomas NORDLANDER	
10:00	**Session opening**
10:10	**International Workshop on Application of Advanced Plant Information for Nuclear Decommissioning and Life Cycle Management** Patrick Joseph O'Sullivan, IAEA
10:40	**Nuclear decommissioning: end of lifecycle - cradle of new technology** István Szőke, IFE
11:10	**Digital Technologies Supporting Lifecycle Nuclear Knowledge Management of NPPs**

	Ashok Ganesan, IAEA
11:40	**Session closing**
11:45	**Lunch**

Session 1: Decommissioning planning Session Chairs: Patrick Joseph O'SULLIVAN, Jean-Michel CHABEUF	
13:00	**Session opening**
13:10	**D&D: Innovation for strategy and early scheduling** Caroline Watripont (CGI) and Gerard Laurent (In Solutions), France
13:30	**The integration of 3D engineering simulation and virtual technology to the planning of TRR decommission** Tzu-Chin Kuo, Institute of Nuclear Energy Research, Republic of China
13:50	**Modelling of the process of dismantling of the metal farm of the "Shelter" object with the calculation of radiation doses of personnel at all stages of the work execution** Sergiy Paskevych, ISP NPP NAS, Ukraine
14:10	**Integrated management systems for OPEX and early decommissioning planning within Orano History-Lessons learned-Prospects** Jean-Michel Chabeuf, Orano, France
14:30	**Coffee break**
14:55	**Development of decommissioning information management system for nuclear power plants combined with demolition method simulation** Sheng-Chang Cheng, Institute of Nuclear Energy Research, Republic of China
15:15	**Evaluation of VR software** Yasuyoshi Taruta, Japan Atomic Energy Agency, Japan
15:35	**Virtual reality to Prepare Decom Operations** Adeline Auzou, Orano, France
15:55	**Preliminary Design of Heavy Water Research Reactor Decommissioning Engineering Technology Supporting System** Zhang Yu, China Institute of Atomic Energy, China
	Chernobyl NPP Decommissioning Visualization Centre Alexander Novikov, Chernobyl NPP, Ukraine

16:15	**Session closing**

16:30 – 18:30 Demo session with coffee

Advanced information technology developed at IFE for supporting decommissioning

19:00	**Welcome party: "gløgg i hyttene". Wear warm clothes!**
20:00	**Buffé dinner**

Tuesday, 4 December 2018	
9:00	Presentation by Richard REID, EPRI
Session 2: Risk, safety and knowledge management Session Chairs: Céline PORET, Richard REID	
9:30	**Session opening**
9:40	**Safety issues of Decommissioning projects from an organizational perspective** Céline Poret, IRSN, France
10:00	**ELINDER - European Learning Initiatives for Nuclear Decommissioning and Environmental Remediation** Diederik Van Regenmortel, Pierre Kockerols, European Commission Joint Research Centre
10:20	**Structured argumentation applied to decommissioning licensing – case study with ongoing decommissioning licensing of the FiR 1 research reactor** Markus Airilia, VTT Technical Research Centre of Finland Ltd, Finland
10:40	**Risk assessment of nuclear waste package planning demonstrated on activated core internals of a German BWR** Maarten Becker, Institut für Umwelttechnologien und Strahlenschutz GmbH, Germany
11:00	**Coffee break**
11:20	**Decommissioning as a Step Forward for Risk Governance** Jérémy Eydieux, Grenoble INP, France
11:40	**The Perception of Traditional Training Techniques and Employment of Alternative Advanced Solutions for Sustainable Capacity Building** Eric K. Howell, ÅF, Sweden
12:00	**PPDI®: Integrated project management approach to nuclear decommissioning, from detailed planning to project risk management** Silvia Mucchi, Mario Lazzeri, Società Gestione Impianti Nucleari, Italy
12:20	**Conceptual design on the safety management of radioactive waste using by cutting-edge technologies** Hee Seoung Park, Korea Atomic Energy Research Institute, Korea
12:40	**Lunch**

14:00	**Group discussion**
15:30	**Session closing**

16:00– 18:30 Demo session with coffee and small bites

19:30	**Aperitif**
20:00	**Banquet dinner**

Wednesday, 5 December 2018	
Session 3: Characterisation, waste and logistics management Session Chairs: Alan SHIPPEN, Markus AIRILIA	
8:30	**Session opening**
8:40	**N-Visage Fusion – 3D Plant characterisation and analysis software to plan worker dose up-take and decommissioning activities** Alan Shippen, Create Technologies Limited, England and Wales
9:00	**Use of NPP Information Modelling for radiological characterization, waste estimation and planning removal of components** Francisco Ballester, Marina Llama y Jesús de Paz and Nieves Martín, Enresa, Spain
9:20	**Research on Structure of Online Monitoring and Diagnosis System of Nuclear Power Plant** Guo Guangyue, Shanghai Nuclear Engineering Research & Design Institute, China
9:40	**Digital Decommissioning Logistics Concept** Hans Frohlund, ÅF, Sweden
10:00	**Innovative tools to improve physical and radiological characterization of nuclear zones** Camille Theroine, Orano, France
10:20	**ReGuard: a digital track and trace waste management system for nuclear decommissioning** Niels Beuker, Nuclear Research & Consultancy Group, The Netherlands
10:40	**Coffee break**
11:00	**Defined removal of highly reinforced concrete structures** Sebastian Friedrich, Karlsruhe Institute of Technology, Germany
11:20	**Group discussion**
12:40	**Session closing**
12:45	**Lunch**

Workshop closing	
14:00	**Meeting summary and closure of the workshop (all chairs)**
15:30	**Meeting adjourned**

OECD-HRP/NKS workshop on
Challenges and opportunities for improving nuclear decommissioning in HRP member and Nordic countries

6 – 7 December 2018
Hotel Scandic Lillehammer, Norway

PROGRAMME

<table>
<tr><th colspan="3">Thursday, 6 December 2018</th></tr>
<tr><td>09:00</td><td>Meeting starts</td><td rowspan="6">1. Decom activities at IFE – short summary of status and plans (Grete Rindahl)
2. Decommissioning information management at IFE (Jan Erik Farbrot, IFE)
3. Information management for spent fuel at IFE (William Beere, IFE)
4. Digital technology enabled new concepts supporting planning and cross-cutting issues in nuclear decommissioning (István Szőke, IFE)
5. Licensing Finland’s first reactor for decommissioning (Airila Markus, VTT)
6. Review of the license application for decommissioning at VTT (Mia Ylä-Mella, STUK)
7. Safety demonstration and structured argumentation (Péter Kárpáti, IFE)
8. Enabling and ensuring safety of autonomy in nuclear decommissioning – application of machine learning (Jens-Patrick Langstrand and Péter Kárpáti, IFE)
9. Updating the decommissioning plan of the Loviisa NPP (Matti Kaisanlahti, Fortum).
10. Security and cyber security considerations for advanced information tech based concepts for decommissioning (André Hauge, IFE)</td></tr>
<tr><td>10:30</td><td>Coffee</td></tr>
<tr><td>12:45</td><td>Lunch</td></tr>
<tr><td>15:30</td><td>Coffee</td></tr>
<tr><td>16:30</td><td>End of day</td></tr>
<tr><td>19:00</td><td>Dinner</td></tr>
</table>

Friday, 7 December 2018		
9:00	Meeting starts	1. The RiskBIM concept (André Hauge, IFE) 2. Automatic and semi-automatic verification of layouts against requirements (Michael N. Louka) 3. Integrating information on Legal Requirements in Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management (Bjørn Olai Bye, IFE/Negota) 4. Decommissioning activities in Norway (Naeem UI Syed, NRPA - DSA) 5. Competence mapping and workforce planning for decommissioning at IFE (Grete Rindahl) 6. Modelling in the context of management of VLLW to reach sustainable clearance decisions (Del Risco Norrlid Lilian, ÅF consult)
10:30	Coffee	
11:30	Lunch (end of day)	

First name	Last name	Company name	Country
Auzou	Adeline	Orano	France
Markus	Airila	VTT Technical Research Centre of Finland	Finland
Gunhild	Andreassen	IFE	Norway
Francisco	Ballester	UNIVERSITY OF CANTABRIA	Spain
Maarten	Becker	iUS Institut für Umwelttechnologien und Strahlenschutz GmbH	Germany
William	Beere	IFE	Norway
Niels	Beuker	Nuclear Research & Consultancy Group	Netherlands
Daowei	Bi	Shanghai Nuclear Engineering Research & Design Institute Co.,Ltd.	China
Joachim	Bratteli	IFE	Norway
Tom Robert	Bryntesen	IFE	Norway
Bjørn Olai	Bye	IFE	Norway
PORET	Céline	Institut de Radioprotection et de Sûreté Nucléaire	France
jean-michel	chabeuf	Orano	France
Sheng-Chang	Cheng	Institute of Nuclear Energy Research	Taiwan
Jesús	de Paz	INGECID	Spain
Svein Tore	Edvardsen	IFE	Norway
Jeremy	Eydieux	Grenoble INP	France
Jan Erik	Farbrot	IFE	Norway
Vladimir	Fiser	UJV Rez, a.s.	Czech Republic
Martin Smedstad	Foss	IFE	Norway
Sebastian	Friedrich	Karlsruhe Institute of Technology	Germany
Hans	Frohlund	ÅF Infrastructure AB	Sweden
Hilde	Gillebo	IFE	Norway
Guangyue	Guo	Shanghai Nuclear Engineering Research & Design Institute Co.,Ltd.	China
Åse Marit	Hansen	IFE	Norway
Jørn-Harald	Hansen	IFE	Norway
Kjell Tore	Hansen	IFE	Norway
Christian	Hartmann	IFE	Norway
André	Hauge	IFE	Norway
Ann-Helen	Haugen	IFE	Norway
Christian	Helsengreen	IFE	Norway
Scott	Holcombe	IFE	Norway
Eric	Howell	ÅF Industry	Sweden
Nils-Morten	Huseby	IFE	Norway
Alexandru	Josef	Israel Atomic Energy Commission	Israel
Peter	Karpati	IFE	Norway
Peter	Keyser	Negota Project AS	Norway
Tzu-Chin	Kuo	Institute of Nuclear Energy Research	Taiwan
Jens-Patrick	Langstrand	IFE	Norway
Knut Bjørnar	Larsen	IFE	Norway
Gérard	Laurent	Integrated Nuclear Solution	France

Rosie	Lester	Create Technologies Limited	United Kingdom
Per	Lidar	Studsvik	Sweden
Marina	Llama	INGECID	Spain
Michael	Louka	IFE	Norway
Kaisanlahti	Matti	Fortum	Finland
David	Mendes	Mirion	Belgium
Ylä-Mella	Mia	STUK	Finland
Pål	Mikkelsen	Norsk nukleær dekommisjonering	Norway
Lise	Moen	IFE	Norway
Silvia	Mucchi	SOGIN	Italy
Guido	Mulier	Tecnubel	Belgium
Tomas	Nordlander	IFE	Norway
Oleksandr	Novikov	State Specialized Enterprise "Chornobyl Nuclear Power Plant"	Ukraine
Svein	Nøvik	IFE	Norway
Miko	Oikkonen	Fortum	Finland
Patrick	O'Sullivan	International Atomic Energy Agency	Austria
Hee Seoung	Park	Korea Atomic Energy Research Institute	Korea
Sergii	Paskevych	Institute for Safety Problem of Nuclear Power Plant NAS Ukraine	Ukraine
Jan	Porsmyr	IFE	Norway
Rick	Reid	Electric Power Research Institute	United States
Sathiya Kumar	Renganayagal u	IFE	Norway
Grete	Rindahl	IFE	Norway
Tapani	Ryynänen	VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD	Finland
Alan	Shippen	Create Technologies Limited	United Kingdom
Even	Solbakken	IFE	Norway
Steinar	Solstad	IFE	Norway
Réka	Szőke	IFE	Norway
István	Szőke	IFE	Norway
Yasuyoshi	Taruta	Japan atomic energy agency	Japan
Camille	Theroine	ORANO DS	France
Henning	Vahr	IFE	Norway
Diederik	Van Regenmortel	European Commission	Italy
Dimitri	Vinnikov	Leningrad NPP	Russian Federation
Artem	Vladimirov	Leningrad NPP	Russian Federation
Roman	Vnukov	State Specialized Enterprise "Chornobyl Nuclear Power Plant"	Ukraine
Caroline	Watripont	CGI BUSINESS CONSULTING	France
Jan	Wethe	IFE	Norway
Yu	Zhang	China Institute of Atomic Energy	China
Matilda	Åberg Lindell	IFE	Norway

Workshop on
" International Workshop on Application of Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management "

3 – 5 December 2018
Hotel Scandic Lillehammer, Norway

Group Discussion Summary

Moderator: Patrick Joseph O'SULLIVAN, IAEA

The group shared **experience with the creation of 3D models intended for use in developing plant information models (PIMs) of facilities to be decommissioned**. This experience suggested there is broad acceptance of the advantages of developing 3D models to aid decommissioning planning, for facilities ranging from nuclear power plants, fuel cycle facilities and research reactors. In the case of nuclear power plants there was evidence of increasing acceptance of the benefits of using a complete PIM to support the detailed planning of decommissioning of the entire facility. For nuclear fuel cycle facilities current experience suggests the models are used more selectively, e.g. to assist planning the dismantling of specific plant items, including for training of personnel who will implement the dismantling of the items in question.

Two approaches to model development were being followed: (1) establishing the model from existing 2D drawings, photographs and other documentation already in existence, followed by use of laser scanning to provide confirmation of the accuracy of the model; and (2) establishing the model directly by laser scanning.

The first option has been used successfully to create the basis for a PIM for a nuclear power plant recently shutdown in Spain. The approach offered important advantages in cases where accurate drawings were available:

- Supplementary information about the plant being modelled (e.g. the system of which a specific component formed part and the material of which it was comprised) could be directly associated with individual objects, e.g. through linkage with a separate database containing such information;
- Detail not visible to the laser beam are directly included in the model, e.g. the thickness of piping covered by insulation or buried in concrete.
- Laser scanning provided a means of subsequently validating the completeness and accuracy of the model.
- The total resource requirement to establish the model (e.g. 15000 hours for a typical PWR) was in line with resources needed to compile information into a form needed to support decommissioning by traditional means.

The second approach (i.e. beginning with a point cloud developed by laser scanning) has been used in modelling selected areas of larger facilities and also for modelling of smaller facilities. In this case, the completeness of the model may be checked against other available information, including drawings. If the model is intended to form the basis for a PIM, additional information (from drawings etc.) will in any case need to be associated with the modelled objects. Newly available scanning tools enabled both the plant configuration and the radiological situation to be quickly modelled; feedback from the early use of such equipment was very positive and it is likely that their use will become commonplace.

It was noted that the use of 3D models, coupled with the use of virtual reality, to support training of personnel was gaining increasing acceptance. The creation of such virtual environments for training was still used only in selected situations (e.g. high dose environments) due to its cost. These included situations with the potential for significant exposure of workers, in which case technologies using virtual reality (e.g. to show the location of radioactivity) were also beginning to be used to provide increased safety of workers.

Workshop on
" International Workshop on Application of Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management "

3 – 5 December 2018
Hotel Scandic Lillehammer, Norway

Group Discussion Summary

Moderator: Richard Reid, EPRI

Topic 1: Sharing Experiences in the Development of Digital Tools

The initial focus of the group was a discussion of software products. There was a consensus opinion that off-the-shelf software should be used to the extent practicable, as opposed to development of new software modules. Further, it was noted there should be a preference on the use of open-source software when available. The group generally agreed that the necessary modules already existed, and that the required effort was mainly in identifying and integrating the different modules to develop digital tools tailored to decommissioning applications.

A follow-on discussion centered around development of a generic roadmap for integrating software modules. The discussion included considerations for funding such generic development, and for distributing the resultant guidance. The concept of starting a decommissioning software user's group came out of this discussion. The group then discussed who might organize such a group, with the IAEA, EPRI, NEA and the European Commission offered as potential leads. EPRI indicated they would be consider publication of general guidance for use of software tools during decommissioning, but didn't commit to organizing a user's group. The group agreed a user's group would be a good idea, and the idea should be discussed in future meetings.

The final sub-topic discussed was whether it was too late to start an initiative to develop guidance for use of software tools, including integration of commercially available modules, given that efforts were already underway within a number of organizations to develop their own approaches. The consensus was that it was not only not too late, but that there would be good value in capturing what has been done and encouraging standardization across the industry in the digital tools area.

Topic 2: Use of Internal versus External Resources for Decommissioning Planning and Execution

This topic was discussed only briefly due to time constraints. The consensus was that it was preferable to use primarily internal resources, but that use of some external resources with practical decommissioning experience would typically be necessary. A key area for development is on guidance for transitioning staff from plant operations to decommissioning tasks. This includes not only training in the conduct of new tasks, but changing from an operational to decommissioning safety culture and mindset.

Workshop on
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3 – 5 December 2018
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Group Discussion Summary

Moderator: Jean-Michel Chabeuf, Orano

The question we initially addressed in our group was:
“Can digital twins and VR change and simplify the relations with the regulators, and if yes, how?

The first analogy we made referred to the shipbuilding industry where customers are invited to be involved from the design of the virtual twin, so that they can make their comments, modifications at an early stage.

Along this line, the group said that sharing a virtual twin with the customer (the decommissioning fund owner is seen as the client) would definitely be beneficial, for instance, for establishing waste inventories and waste costs, and enabling a shared planning process.

There was a consensus on the fact that such tools can only be beneficial in the relation between customer and contractor.

The situation is different with the regulator in the sense that he is not a customer, but rather an authorization provider and controller.

We first evaluated to which extent virtual scenarios made on digital twins could reduce and simplify the paperwork required for approval of decommissioning activities.

This immediately raised the question that the regulator may not be in capacity to judge the relevance/quality of the digital tools used to establish the scenario, in which case they could not commit to provide a validation.

A first solution could be that the regulator might call upon an independent entity that would be in charge to validate the tools/method used on behalf of the regulator.

In fact this is what happens in France and UK to some extent where regulators use independent expert groups to validate certain technical aspects of safety cases. This could thus be a solution.

Another alternative would be to provide a certification process for the tools and methods used.

This may also lead to a degree of standardization that would later simplify the regulator’s challenge.

In order to provide this validation/certification process, it was suggested that one way could be to develop an international “virtual Model for decommissioning”, against which tools would be benchmarked/tested.

This virtual model would be a nuclear facility made available for actors to test their approaches/tools on, and have them approved.

Remark made after the working session: Software certification exists in other industries. How applicable is it to decommissioning, is a question to investigate.

Workshop on
" International Workshop on Application of Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management "

3 – 5 December 2018
Hotel Scandic Lillehammer, Norway

Group Discussion Summary

Moderator: István Szőke, IFE

Staffing for decommissioning:

In-house personnel is important for supporting the decommissioning activities. The optimal mix of in-house and contracted personnel depends on the capabilities for decommissioning existing in-house. It is important to efficiently transfer knowledge from in-house staff to involved contractors.

Business case for application of digitalization:

In an ideal case, full scope digitalization is desired for the whole process. However, investing in full scope digitalization from the start may be difficult, for instance due to inadequate data indicating a clear positive business case. Hence, it is more feasible to start with smaller pilot projects that are easy (quick and cheap) to implement and entail low risks.

Based on the positive outcomes of such pilot projects value for money can be demonstrated for larger scope implementation. Pilot projects can also reveal the optimal level of effort (investment) for digitalization for a specific task. For instance efforts into detained 3D CAD modelling and laser scanning (mainly for higher risk jobs and more contaminated areas) versus rougher scanning and modeling (for the whole facility and site) can be streamlined to achieve best value for money.

Requirements for digitalized material should be integrated into the tendering procedure. This will allow development of better and safer contracts.

Digitization is also foreseen to enable better re-use of material resulting from decommissioning, and make better tactical decisions about sentencing material and components.

Motivating decommissioning teams for adopting innovative digitally enhanced solutions:

Digitalization should be adopted by the whole organization involved in the decommissioning process.

Generational shift will enhance natural adoption of higher digitalization.

Application of digitalization has to be integrated into international training initiatives/programs for facilitating efficient adoption.

For people responsible for financial aspects (management), profit margin has to be demonstrated for facilitating adoption of higher level of digitalization.

Proving efficiency (and cost-efficiency) of digitalization in decommissioning:

Success stories from earlier (e.g. pilot) applications should be demonstrated.

Allow end-users (e.g. field workers) experiment with the new concepts to realize benefits first-hand and provide feedback on usability and efficiency. Enable end-users to maintain (e.g. update) the new systems themselves. Ensure an iterative implementation of the new systems in close collaboration with the end-users, to ensure good alignment of the new solutions with actual needs of the users.

Demonstrate the benefits of the new concepts to the management level through showing the results of the pilot projects with the end-users.

Optima level of detail for modelling decommissioning sites/facilities:

Learn from the construction industry.

Detail of the model(s) should be proportional with the risks entailed by component/environment when manipulating/working within (e.g. higher level of contamination requires higher details).

Use of the 3D model should be defined beforehand and the details (resolution) should be determined based on the requirements for the intended use. For instance high resolution photos, by default, contain high detail of the captured area, and may be a suitable alternative to 3D CAD models for some purposes.

At least a rough model of the whole facility/site should be prepared with details being added to it as/when needed.

Use of historical knowledge from the operation/design phase:

Knowledge on operational history of the facility/site is very important for informing the decommissioning process. Hence, considerable efforts should be dedicated for reviewing historical records and find information relevant for decommissioning.

Employees should be interviewed in time (before they retire or leave the organization for other reasons) in order to capture relevant information, for instance unrecorded information (e.g. contamination) affecting risks of planned decommissioning jobs.

Both historical record review and interviews can help reconstructing information that is hard or impossible to new surveys and measurements. A combination of historical information review and performing new surveys is the optimal strategy.

Good practices and bottlenecks in digitalization for decommissioning:

A flexible approach defining investment into acquiring input data (e.g. 3D modelling) for the new digitally enhanced concepts should be adopted. More investment into details should be dedicated as needed by the tasks at hand.

In order to avoid investing into modeling that will later become outdated and not used, it is important to ensure that digital input (e.g. 3D models) will be regularly maintained. Enable the end-users to own and maintain the data throughout the process. This way the data can be updated on a regular basis through using the data in tasks that would be done anyway (with or without a using a digitalized process).

Acknowledgements
The authors wish to thank the all the project participants, who contributed with valuable insights and efforts in steering the project towards a good result. They participants came from the following organisations:

The Norwegian Radiation Protection Authority (NRPA)
The Swedish Radiation Safety Authority (SSM)
The Danish Health Authority (SIS)
The Finnish Radiation and Nuclear Safety Authority (STUK)
The energy company Fortum in Finland
The energy company Vattenfall in Sweden
The consulting company ÅF in Sweden
VTT Technical Research Center of Finland

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Bibliographic Data Sheet	**NKS-417**
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Author(s)	István Szőke, Réka Szőke, Grete Rindahl, Joachim Bratteli
Affiliation(s)	IFE
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Date	February 2019
Project	NKS-R / NorDec II
No. of pages	26 + Appendix
No. of tables	0
No. of illustrations	1 + figures in the Appendix
No. of references	0
Abstract max. 2000 characters	The overall goal of the NorDec project has been to explore challenges related to how decommissioning regulation is applied, and how projects are planned and performed in the Nordic countries, as well as collect best practices and share experiences between the Nordic stakeholders and the international community of experts. The contributions for this project came from a wide range of international stakeholders, including regulators, operators and contractors, and via the use of questionnaires, interviews, workshop presentations (including questions and answers during and/or after the presentations), and break-out group discussions. This second phase of the project mainly focused on organization of a large scale workshop with the project participants and international experts to discuss the outcomes of the first (2017) phase of this project as well as challenges, innovation opportunities and experience in general related to nuclear decommissioning. The workshop has been co-organized with the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NAE) and the Electric Power Research Institute (EPRI). In addition, the workshop has also been supported by the Norwegian Research Council. This report combines all the outcome material from the workshop. Additional material and information is available at www.ife.no/digidecom2018
Key words	Decommissioning, research needs, digitisation, Nordic cooperation

Appendix – Presentations from the NKS/HRP workshop (6-7 Dec.)

Presentations from the main workshop (3-5 Dec.) can be downloaded from:
www.ife.no/digidecom2018

OECD-HRP/NKS workshop on
Challenges and opportunities for improving nuclear decommissioning in HRP member and Nordic countries

6 – 7 December 2018

Hotel Scandic Lillehammer, Norway

PRESENTATIONS

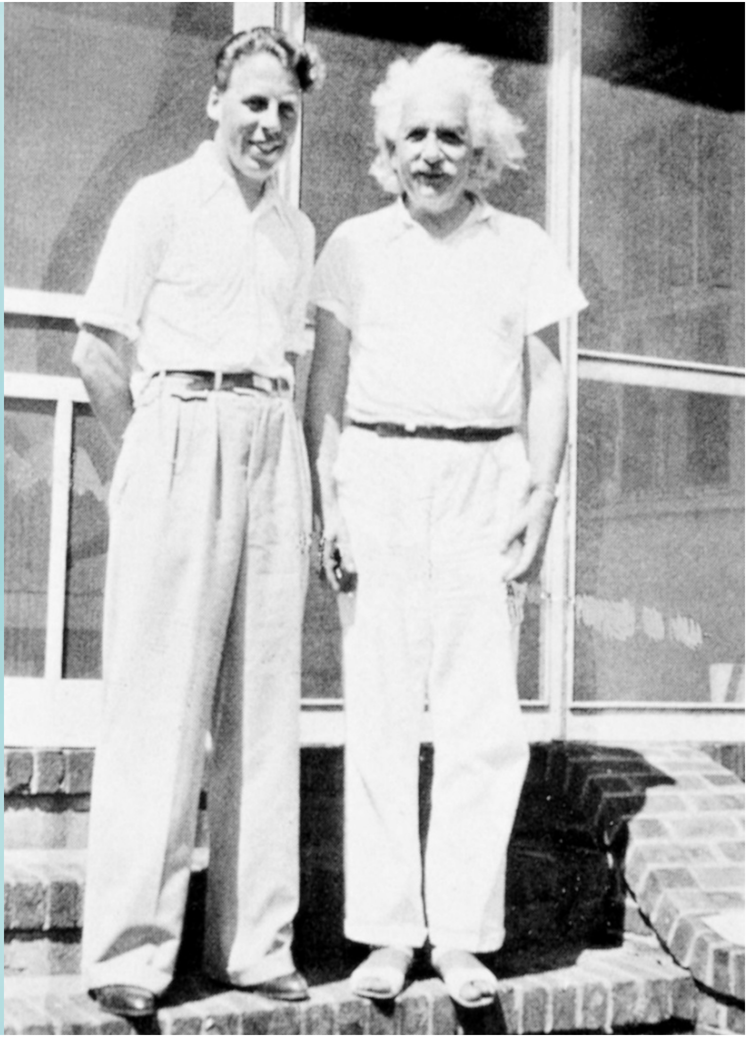
Thursday & Friday, 6-7 December 2018

1. Decom activities at IFE – short summary of status and plans (Grete Rindahl)
2. Decommissioning information management at IFE (Jan Erik Farbrot, IFE)
3. Information management for spent fuel at IFE (William Beere, IFE)
4. Digital technology enabled new concepts supporting planning and cross-cutting issues in nuclear decommissioning (István Szőke, IFE)
5. Licensing Finland's first reactor for decommissioning (Airila Markus, VTT)
6. Review of the license application for decommissioning at VTT (Mia Ylä-Mella, STUK)
7. Safety demonstration and structured argumentation (Péter Kárpáti, IFE)
8. Enabling and ensuring safety of autonomy in nuclear decommissioning – application of machine learning (Jens-Patrick Langstrand and Péter Kárpáti, IFE)
9. Updating the decommissioning plan of the Loviisa NPP (Matti Kaisanlahti, Fortum).
10. Security and cyber security considerations for advanced information tech based concepts for decommissioning (André Hauge, IFE)
11. The RiskBIM concept (André Hauge, IFE)
12. Automatic and semi-automatic verification of layouts against requirements (Michael N. Louka)
13. Integrating information on Legal Requirements in Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management (Bjørn Olai Bye, IFE/Negota)
14. Decommissioning activities in Norway (Naeem Ul Syed, NRPA → DSA)
15. Competence mapping and workforce planning for decommissioning at IFE (Grete Rindahl)
16. Modelling in the context of management of VLLW to reach sustainable clearance decisions (Del Risco Norrlid Lilian, ÅF consult)

Decommissioning programme at IFE

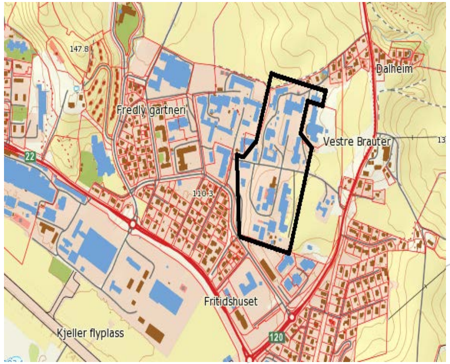
Åse Marit Hansen
Sector Nuclear Waste Management and Decommissioning

Presented by Grete Rindahl
Sector Digital Systems



KJELLER

HALDEN



Planning and implementation of decommissioning activities

Strategic Several years ahead of time	Overall and long-term planning and decision Adds guidelines for tactical and operational plans and activities Starting with end state for the waste and planning backwards in time
Tactic Quarterly and yearly	Collaboration between strategic and operational part of the organization to develop tactical plan, including measures to ensure competence, comprehensive processes and good interfaces to externals
Operational Months, weeks and days	SAR. Detailed and technical planning, staffing, execution and documentation of work packages / subprojects Responsibility for nuclear safety, HSE and security is in line with all internal and external guidelines

Planning tool between sector ATOM and NFS. Other sectors at IFE (DS, IED, STAN, ...) participate and support when needed at all levels

Transition from Operation to decommissioning of Nuclear Installations

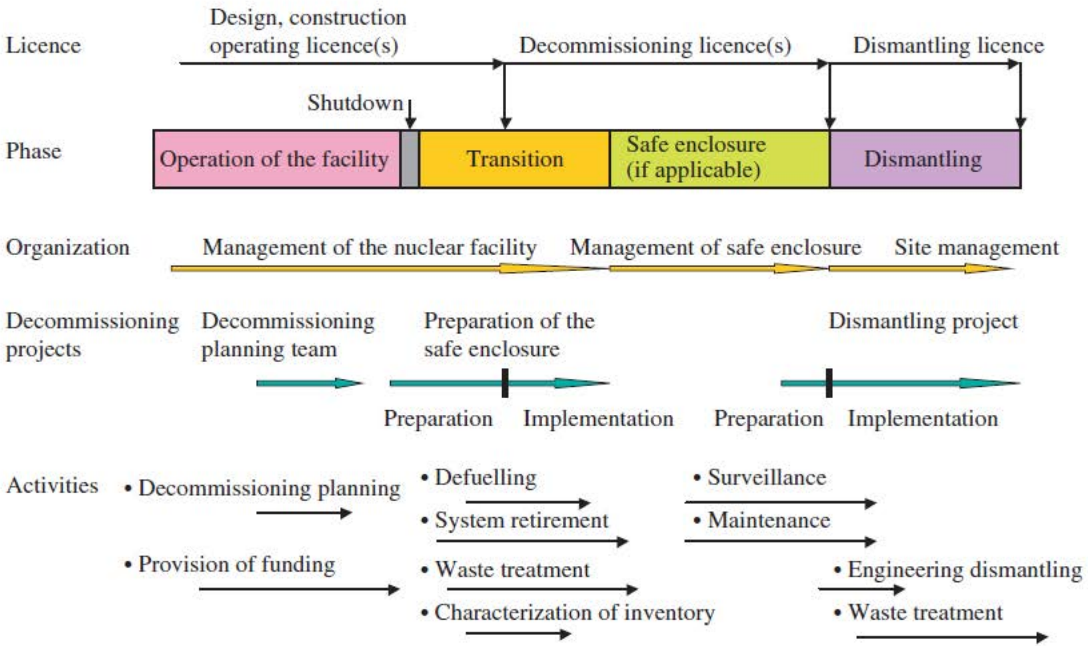


FIG. 1. Decommissioning related activities during the life cycle of an NPP.

Reference:
IAEA Technical reports series no.420
«Transition from Operation to decommissioning of Nuclear Installations»
2004

Ongoing decommissioning activities – Kjeller

- **Pilot projects Decommissioning URA**
  - Gamma scanner – Dissolver cell
  - Robotics – Dissolver cell
  - Information management system

- **Decommissioning of URA (expected to be completed in 2022)**
  - Room 102A ongoing

- **JEEP I and NORA, Kjeller**
  - Estimation of waste volumes that will go to KLDRA
  - JEEP I and NORA were both decommissioned under previous regulations
  - Must be re-entered, decommissioned to "out of regulatory control"

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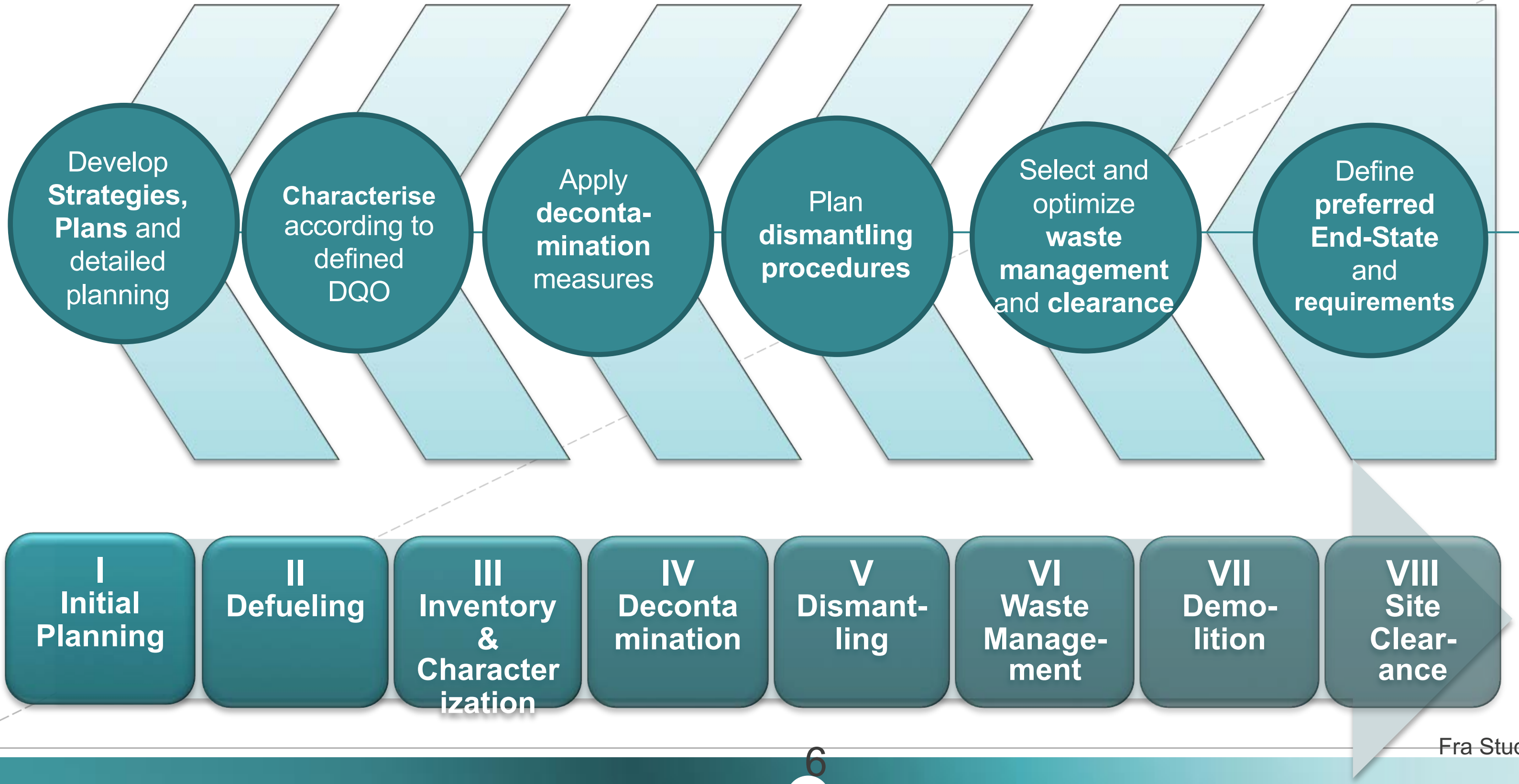
Decommissioning activities, Halden and Kjeller

- Competence mapping
- Retrieving historical data from the HBWR (log books)
- 3D scanning of the reactor hall - Building 3D model of HBWR
- Engage in Norwegian regulations and guidelines from the IAEA
- Setup of Schedule and WBS in accordance with ISDC / IAEA
- Cost estimation of decommissioning activities - use of the CERREX
- Start-up characterisation of components HBWR
- Harmonisation of decommission plans – Ongoing and Final
- Prepare a Nuclear Dictionary, Norwegian – English

Decommissioning planning – reverse from execution



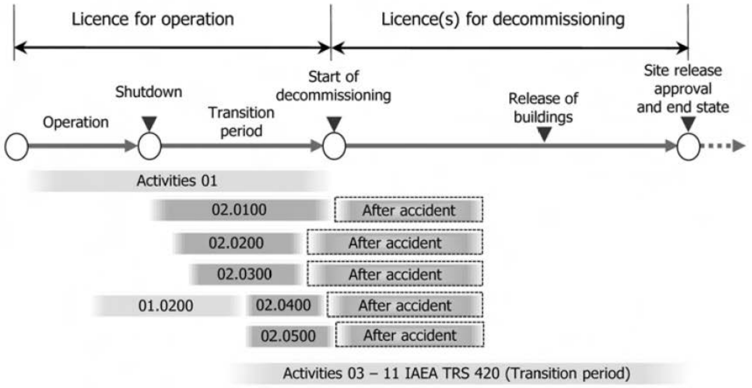
Fra Studsvik Nuclear AB

International Structure for Decommissioning Costing (ISDC) of Nuclear Installations, NEA No. 7088

Cost structure hierarchy

01 – Pre-decommissioning actions.
02 – Facility shutdown activities.
03 – Additional activities for safe enclosure and entombment.
04 – Dismantling activities within the controlled area.
05 – Waste processing, storage and disposal.
06 – Site infrastructure and operation.
07 – Conventional dismantling, demolition and site restoration.
08 – Project management, engineering and support.
09 – Research and development.
10 – Fuel and nuclear material.
11 – Miscellaneous expenditures.

Typical schedule for decommissioning activities of Principal Activity 02



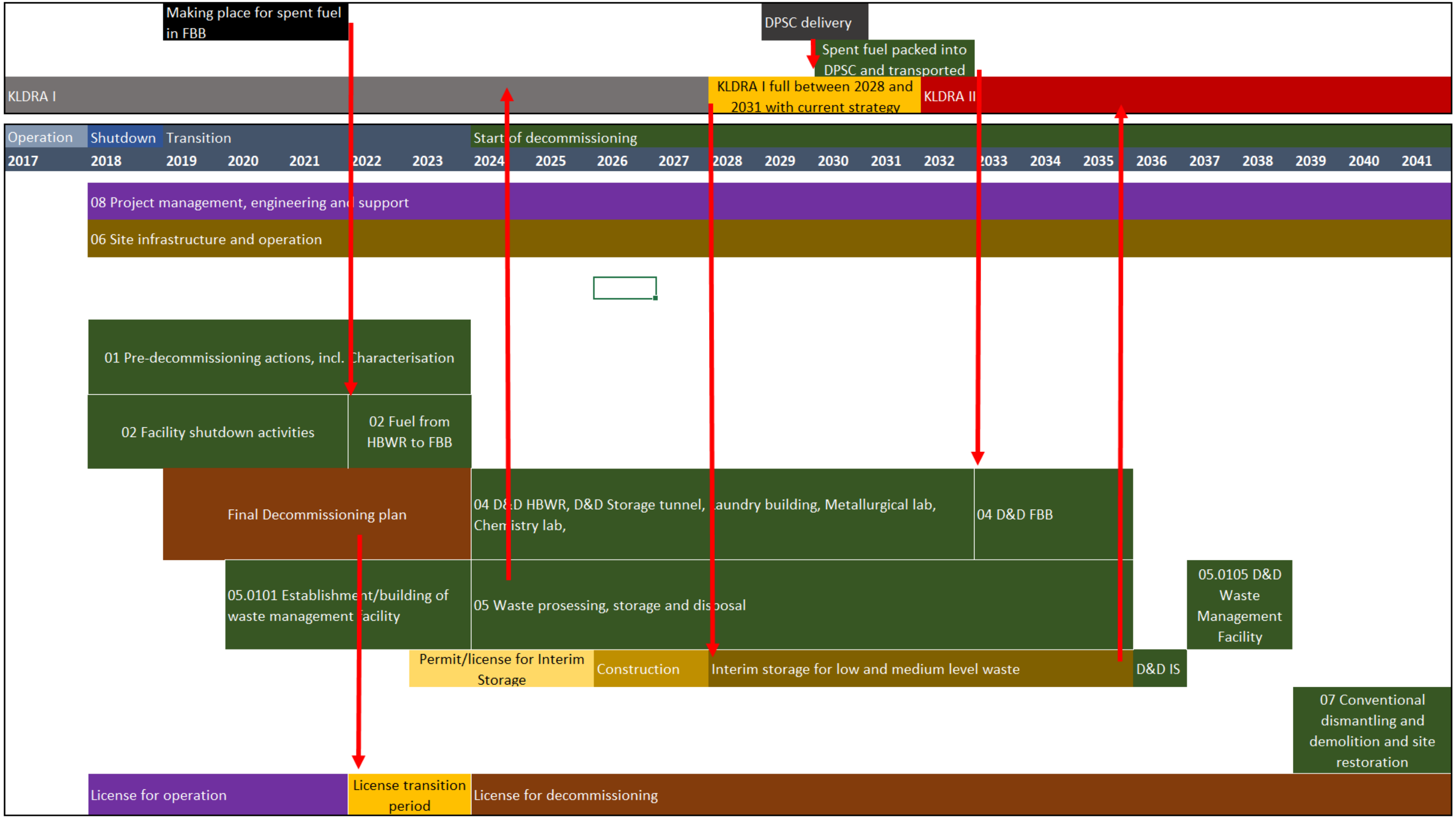
Note: The last row represents the time frame of the transition phase activities.

Overordnede faser i prosjektet

1	Overgangsfase og pre-dekom
2	Dekontaminering og demontering
3	Frigivning av regulert område

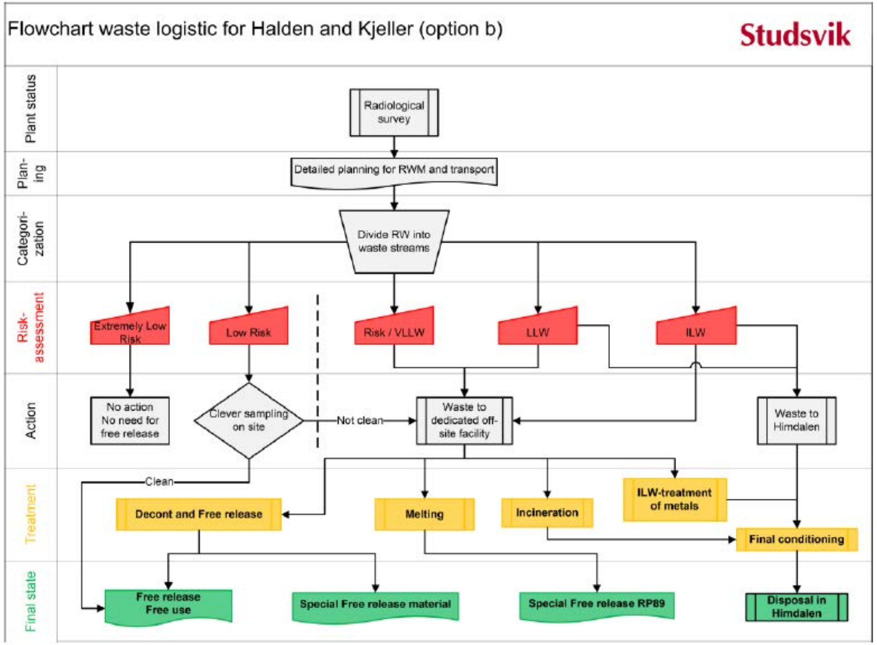
HBWR DEKOMMISJONERING

Overordnet fase			i prosjektet		NND / ATOM		NFS	HUKI		
No.			ISDC Nr.	Aktiviteter	Strategisk	Taktisk	Operasjonel	ovedansvarl	Utførende	Konsultert
		3	07.0601	Routine maintenance						
		3	07.0602	Surveillance and monitoring						
1	2	3	08	**Project management, engineering and support**	S	T				
1			08.0100	**Mobilisation and preparatory work**						
1			08.0100-1	Få opp en beskrivelse av roller – og nødvendig kompetanse		T		ATOM	NFS, ATOM	
1			08.0101	Mobilisation of personnel						
1			08.0101-1	Utpeke: Prosjektleder, overgangsfasen		T		NFS	NFS	ATOM
1			08.0101-2	Ansette: Planlegger og kostnadsestimerer			O	NFS	NFS	ATOM
1			08.0101-3	Eget prosjektkontor i Halden ASAP (samlokalisering)		T		NFS	NFS	ATOM
1			08.0102	Establishment of general supporting infrastructure for ...						
1			08.0102-1	Etablering av generell støtteinfrastruktur for dekommisjoneringsprosjektet			O	NFS	NFS	ATOM, ADM "-& "
1			08.0102-2	Utarbeide føringer for design av anlegget ved dekommisjonering (inkl. intern avfallsflyt og buffer)		T	O	ATOM	ATOM	NFS
1			08.0102-3	Kartlegge behov for verksteder/Labber/ nye fasiliteter		T	O	NFS	NFS	ATOM, "-& "
1			08.0102-4	Kartlegge behov for spesielt utstyr (Hot celle)	S	T	O	ATOM	ATOM	NFS, "-& "
1			08.0102-5	Kartlegge behov for annet utstyr (kraner, sager etc)		T	O	NFS	NFS	ATOM, "-& "
1			08.0102-6	Utarbeide overordnet design av anlegget ved dekommisjonering (inkl. intern avfallsflyt og buffer), logistikkflyt og areal				NFS	NFS	ATOM
1			08.0102-7	Etablering av database arkitektur		T		ATOM	NFS, ATOM	DS, "-& "
1	2	3	08.0200	**Project management**						



Making place for spent fuel in FBB
DPSC delivery
Spent fuel packed into DPSC and transported
KLDRA I
KLDRA I full between 2028 and 2031 with current strategy
KLDRA II
Operation
Shutdown
Transition
Start of decommissioning
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
08 Project management, engineering and support
06 Site infrastructure and operation
01 Pre-decommissioning actions, incl. Characterisation
02 Facility shutdown activities
02 Fuel from HBWR to FBB
Final Decommissioning plan
04 D&D HBWR, D&D Storage tunnel, Laundry building, Metallurgical lab, Chemistry lab,
04 D&D FBB
05.0101 Establishment/building of waste management facility
05 Waste prosessing, storage and disposal
05.0105 D&D Waste Management Facility
Permit/license for Interim Storage
Construction
Interim storage for low and medium level waste
D&D IS
07 Conventional dismantling and demolition and site restoration
License for operation
License transition period
License for decommissioning

Ongoing discussion – waste management strategy



Utdrag fra et av bakgrunnsdokumentene til KVU rapporten "Study on future decommissioning of nuclear facilities in Norway – Task 3 Waste management - :**4.9.7 Melting of metals for recycling or volume reduction. Background.**

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Possible measures on how to reduce waste volumes to Himdalen / KLDRA

- Characterisation of the plants to be decommissioned
- Consider on-site waste treatment

versus

- Export of radioactive waste for off-site recycling
  - Combustion
  - Melting
  - Chemical decontamination

- Acquisition of equipment at each plant that enables better characterisation and sorting of today's waste
- National strategy for the management of radioactive waste
- Establishment of reception for "non-deposit" radioactive waste

Decommissioning strategy - preparation for decommissioning

- Templates and recommendations (IAEA) in the work
- Established a core team (NFS-ATOM-DS)
- Involve other sectors in IFE
- Use of external consultants to learn and to establish a solid foundation
- Financing - IFE is working actively with NND and NFD

Keep competence – hire specialists	Relocation of the fuel out of the reactor
Characterisation	Scheduling and cost estimation
Information management - database	immediate decommissioning

Environmental mapping and end state

Original state

Background values

No restrictions on use of the areas

Environmental mapping at Kjeller in progress

Free release

Restricted / Unrestricted

Outside regulatory control

Thank you for your attention

Decommissioning information management at IFE

Jan Erik Farbrot
farbrot@ife.no

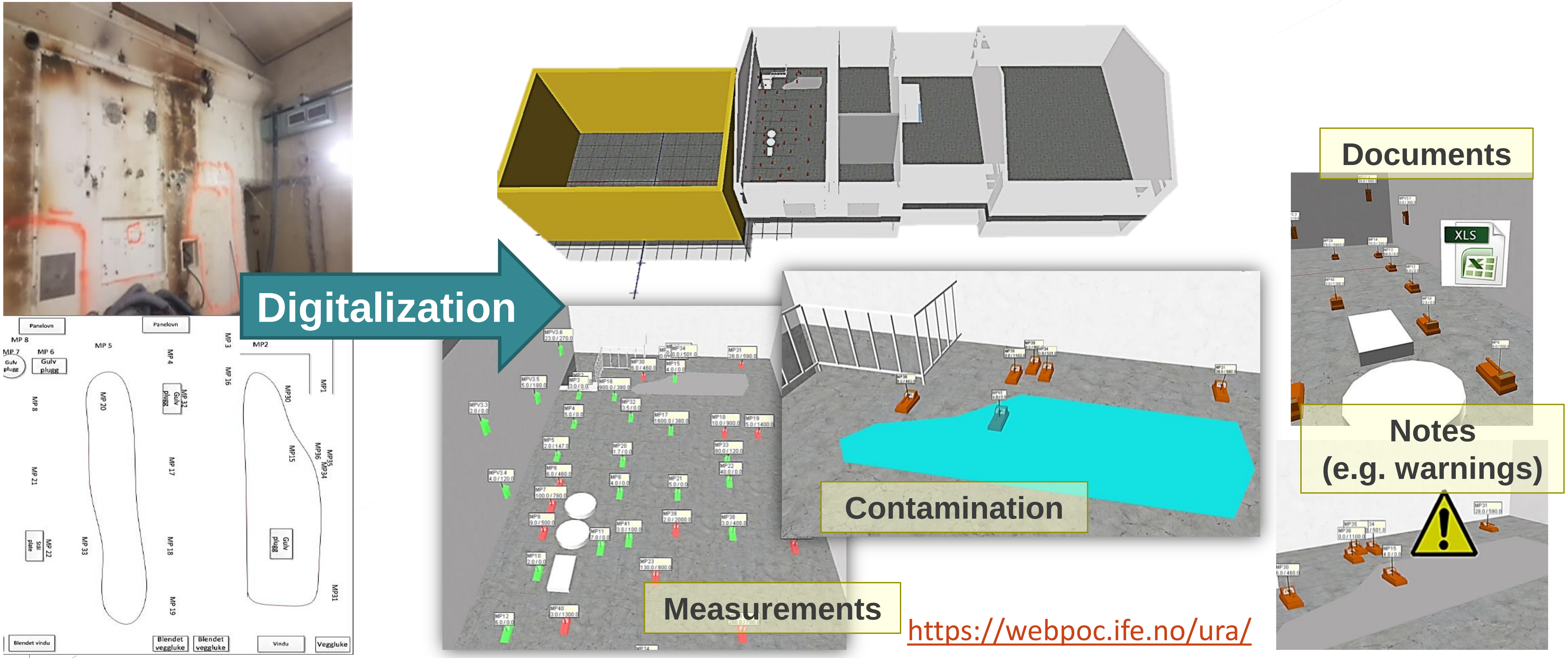
Information management

Have the correct information available when needed, adapted to the task at hand

Present situation and international experience → Identify and prepare decom cases → Case sessions on future situation → Measures and follow up, including implementation plan

Common front-end information solution

Example: Uranium Reprocessing Facility



https://webpoc.ife.no/ura/

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A3 process

Present situation

- What is the problem/issue – the new mission?
- What is the consequence of the problem?
- How is it done by others with similar missions?
- What is new, and what will be continued?
- Why is it important to address this?

Wanted situation

- Which goals do we want to achieve?
- How do we measure this?
- What does the ideal situation look like?
- Which criteria should be fulfilled for the problem to be solved?

Analysis of the present situation

- Which underlying things are causing the problems?
- What are the key challenges – and why?
- What needs to be improved?

Measures and follow-up

- Which possible solutions are available?
- Which measures will lead us to the goal? Prioritisation
- Who should do what, and when?
- How to secure follow up?

A3 process

Present situation

- What is the problem/issue – the new mission?
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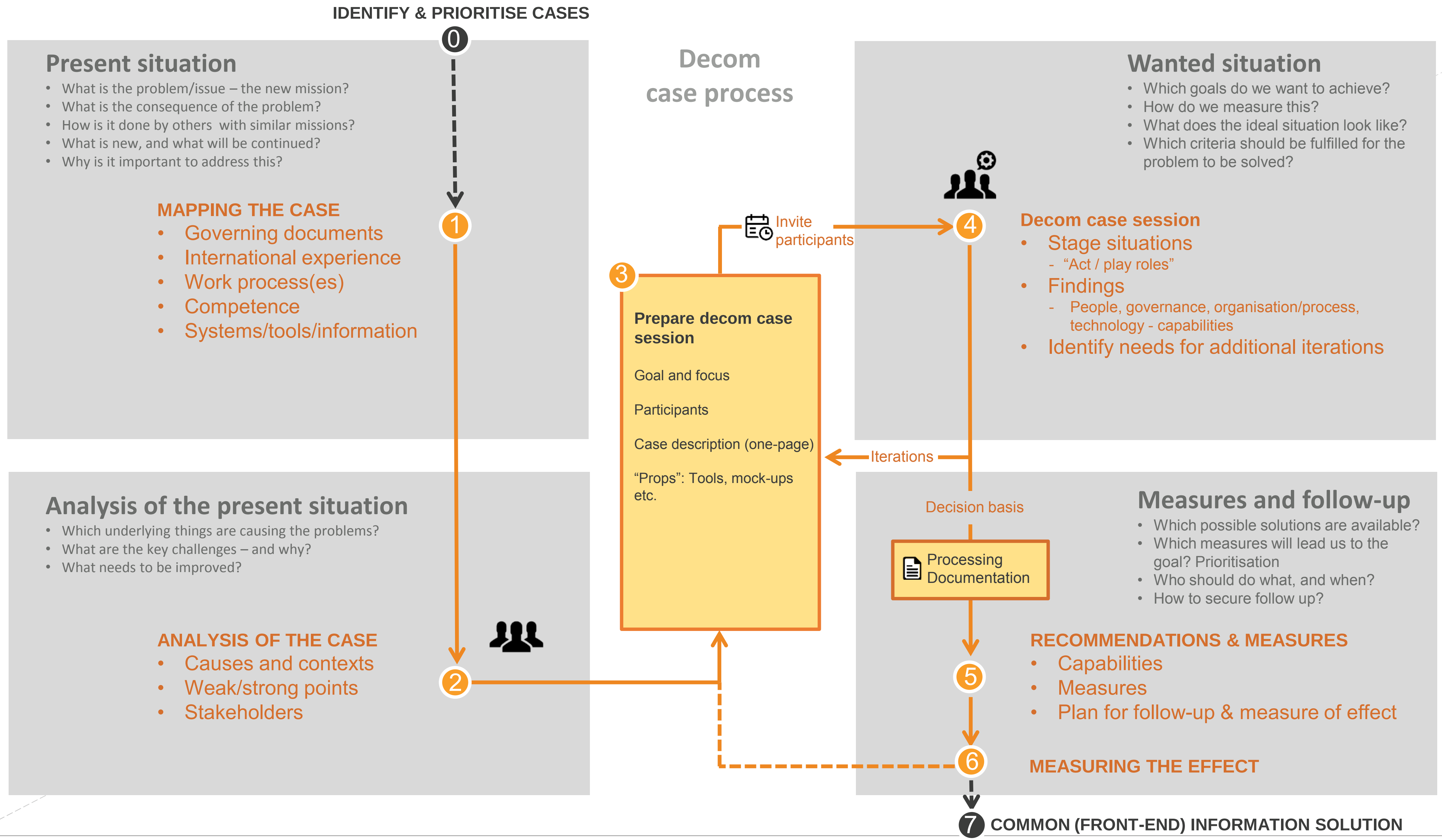
IDENTIFY & PRIORITISE CASES
0
Decom
case process
Present situation
• What is the problem/issue – the new mission?
• What is the consequence of the problem?
• How is it done by others with similar missions?
• What is new, and what will be continued?
• Why is it important to address this?
MAPPING THE CASE
1
• Governing documents
• International experience
• Work process(es)
• Competence
• Systems/tools/information
Analysis of the present situation
• Which underlying things are causing the problems?
• What are the key challenges – and why?
• What needs to be improved?
ANALYSIS OF THE CASE
2
• Causes and contexts
• Weak/strong points
• Stakeholders
3
Prepare decom case session
Goal and focus
Participants
Case description (one-page)
"Props": Tools, mock-ups etc.
Invite participants
Iterations
Wanted situation
• Which goals do we want to achieve?
• How do we measure this?
• What does the ideal situation look like?
• Which criteria should be fulfilled for the problem to be solved?
4
Decom case session
• Stage situations
- "Act / play roles"
• Findings
- People, governance, organisation/process, technology - capabilities
• Identify needs for additional iterations
Decision basis
Processing Documentation
Measures and follow-up
• Which possible solutions are available?
• Which measures will lead us to the goal? Prioritisation
• Who should do what, and when?
• How to secure follow up?
RECOMMENDATIONS & MEASURES
5
• Capabilities
• Measures
• Plan for follow-up & measure of effect
6
MEASURING THE EFFECT
7
COMMON (FRONT-END) INFORMATION SOLUTION

Potential outcome?

- Before and during decommissioning, the system will provide a clear overview and support in planning. Furthermore, being kept updated, anybody can view the planned activities, current status, etc., improving safety and efficiency.
- A 3D-based system may give a very clear, strong overview of current status etc., which in turn may help ensure nothing is missed or forgotten (“Why is that wall blank, are there no measurements?”)

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Research for a better future

Spent Fuel DataBase

William Beere
Rossella Bisio
Geir Pettersen
Aleksander Toppe
Finn Brodal

Spent Fuel Database

- Why?
  - Need to organize data
  - Qualified data required by
    - NRPA
    - Cask producer
    - Re-processor
    - Fuel treatment
- Requirements expected to change.
- Need to accommodate varied types of fuel information.

Scope of problem

- Data
  - About 1500 test fuel rods (almost as many different types)
    - Special data
      - Instrumentation
      - Fuel additives
      - Cladding treatment
  - About 6200 driver/booster fuel rods (much fewer types).
  - Plus more fuel elements at Kjeller
- Relevant information
  - Fuel isotopics
  - Structural components
  - Power history?
  - Fission gas release?
  - Cladding integrity?

Where to get the data from?

- Existing data
  - Safeguards database, Halden
  - Safeguards reports, Kjeller
  - TFDB ..
  - Data-sheets

Users

- Current – needs definable
  - Safeguards
    - Fissile material accounts
    - IAEA inspections
  - Criticality
    - Limits on placement of fissile material
  - Transport coordinator

- Future – plan for ability to accommodate needs
  - Characteristics
  - Spent fuel management
    - Loading schemes for stores
    - Planning storage casks

Main principals

Repeatability

Portability

Authority/verifiability

Traceable

Uniqueness

Extendible

Security

Accountable

Longevity

Accessible

Objectivity/validity

Integrity

Scope-of-coverage, comprehensiveness

Composition and organization

It’s all about the Data and Users not the Database

- Quality depends on use of data
  - Quality - Resolution of data, e.g. burnup or power history, fissile content or detailed isotopics
  - Use – safety case – will fuel survive a drop during transport?
    - Need to know cladding properties after irradiation.
    - No credit for cladding integrity after drop – more expensive transport container and shipments required.
- Time required depends on quality
  - Cost of collation of data vs. cost of storage/transport/disposal solution
    - Note: Choice of storage/transport/disposal solution not yet known

Challenges

- Need to say what is where
  - Restricted information
  - Increased security
- Need to plan what can go where
  - Plans should be recorded and shareable.
    - Evaluations could form basis for ordering casks or planning shipments
  - Need to know starting point for logistics
    - Handling cost of planned end point needs to be considered
  - Tools and assessment needs for such planning not currently known
    - Flexible solution to allow future development.

Solution (so far)

- Documents
- Data objects – physical objects
- Data packages (managed)
  - Safeguards
  - Isotopic inventory
  - PIM/BIM
- Reference to underlying documentation
- Users (managed)
- Roles (access control, managed)
- Tasks (story line, user defined)
- Connections – on given task

Why?

- A description of location and condition of fissile material at IFE is a MAJOR deliverable and will be required by all future decommissioning activities related to spent fuel.
  - Design authority
  - Expert knowledge management

What?

- Document based database
- Supporting independent data packages liked to role and task

Keep it simple

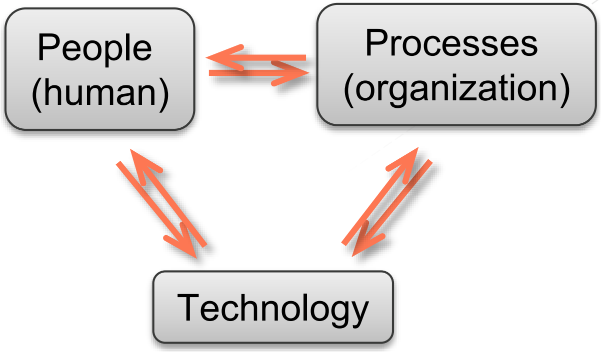
Institute for Energy Technology

Digital technology enabled new concepts supporting planning and cross-cutting issues in nuclear decommissioning

Presentation by István Szőke
Istvan.Szoke@ife.no

Digitally enhanced support concepts

- 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
- Automation

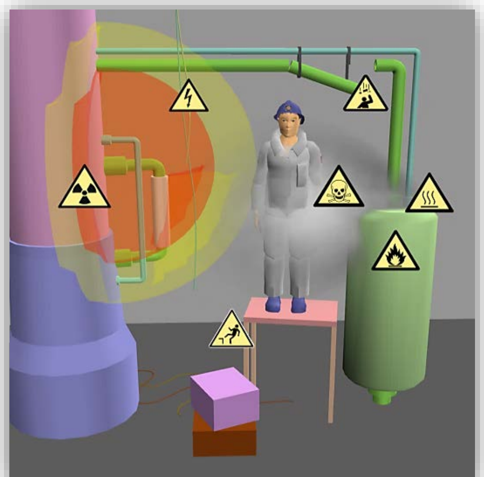


The OECD Halden Reactor Project (HRP)

<u>>100 nuclear organizations from 20 countries</u>

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

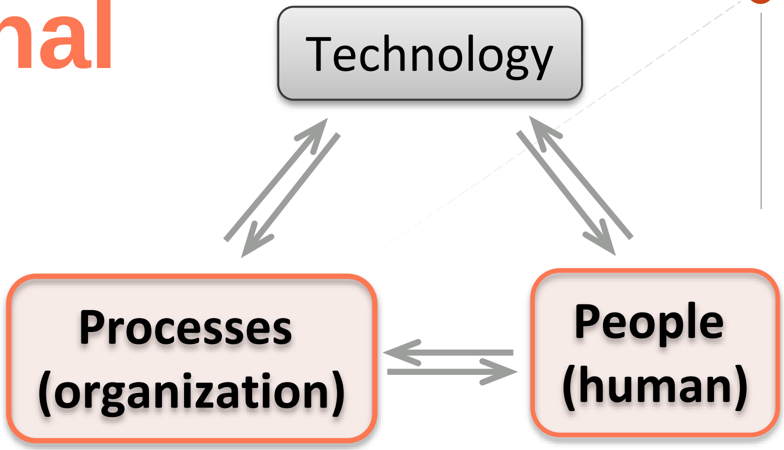
CEA, CIEMAT, CNPRI, CRIEPI, FRAMATOM, DTU, EDF, E.ON, ENSI, EPRI, EU JRC, FANR, GE/GNF, GRS, IRSN, JAEA, KAERI, Kazatomprom, MEE, Mitsubishi, MTA EK, NNL, NRA, NRG, PSI, SCK/CEN, SNERDI, SSM, TVEL, UJV, US DOE, US NRC, VUJE, Westinghouse …



Safety management for decommissioning

Training for normal work and emergencies in decom.

Human & Organizational factors



- Gap analyses
  - Identification of required key capabilities
  - Evaluation of organisational maturity
- Capability development - road map for minimising H&O issues
  - Staffing – optimisation: knowledge and skill requirements vs. availability and costs
  - Training of staff: skill needs and preparedness
  - Change (transition) management:
    - timely planning and allocation of roles and responsibilities
    - clear communication, motivation and career planning

Organisational issues

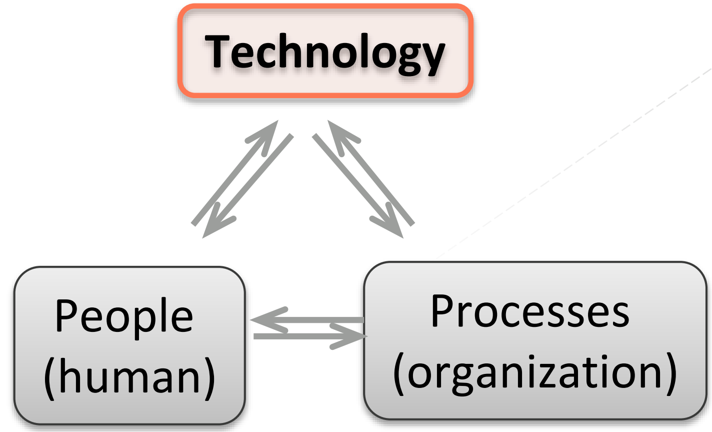
Planning for decom

- When to **start** planning (When is early enough)?
- When/what to **communicate** with the staff?
- What is the **optimal detail** of planning in the different stages?
- What is the best **organisational structure** (departments, locations, people)
- How to ensure a smooth **regulatory acceptance** process?
- What is the best **team composition** (in-house, contractors)?
- What **expertise** is required and when (workforce planning)?
- What kind og **training** is required?
- How to measure/monitor organisational **KPIs** (safety culture)?
- Which influence the different **characteristics** have on project performance?
- How to **preserve** experience (who is responsible)?

Organisational issues

- Is there a **general recipe** for all this or it's different in each case (project), company, country,…?
- How to **draw conclusions** (answers) from on-going/completed projects? – Is benchmarking reliable?
- Are there relevant lessons learned from **other industries** (e.g. oil&gas)? – severe accidents vs. accidents in nuclear decom.
- <u>What **research** could contribute to answering these questions?</u>
- Is it possible to develop **guidance** or **coaching** is the answer (both utility and regulator)?
- Research for future: robotics (automation), HMI, process control, ???

Technology



Radiological modelling

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

IT

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

- Sematic web technology Starting!
- Robotics: digitalization, sensors, control Starting!
- Rad. mapping with gamma cameras Starting!

Scenario (safety) analyses

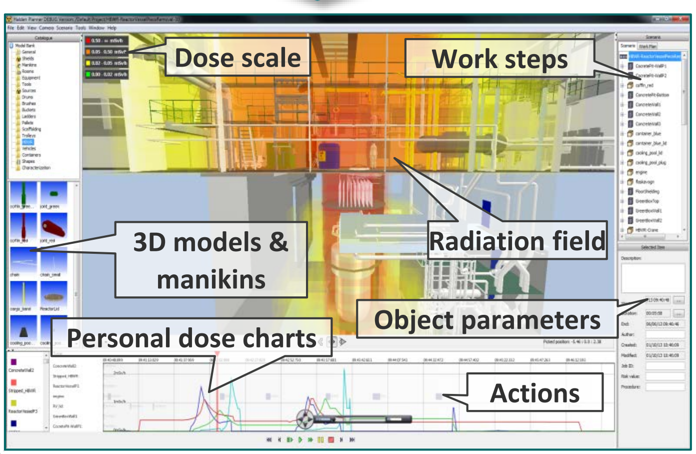
User(s)

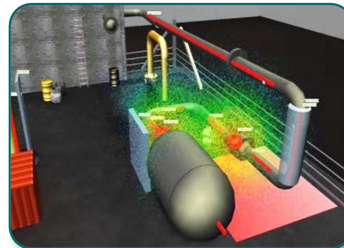
Plant Info. System(s)

Sensors

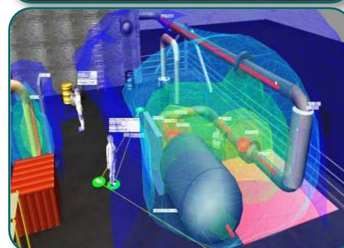
Plant information
- 3D models,
- Radiological data,
- Structure/component properties, …

Work plan

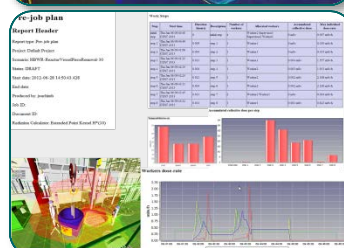




Visualize
- The environment (digital model),
- Radiation emission/exposure, and
- Work scenarios (3D technology)



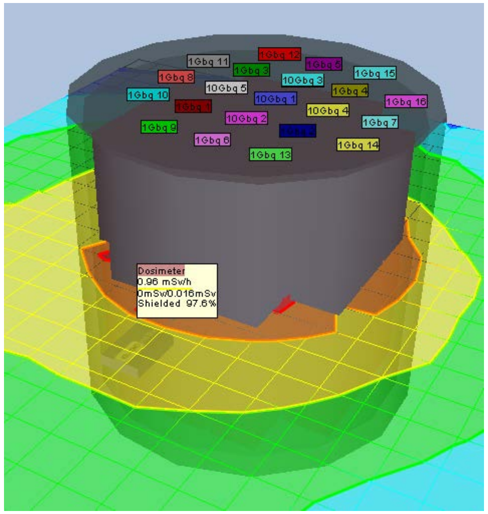
Optimize
- Modify (with interactive real-time 3D visualisation)
- Compare alternative scenarios



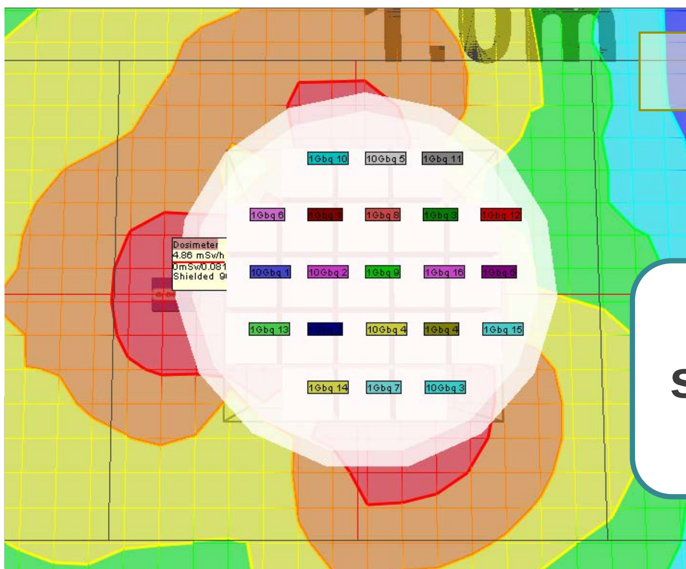
Demonstrate & document
- Playback with interactive navigation and visualisation
- Output printer-friendly reports

- Optimal work procedure
- Worker dose/risks
- Comparison of alternatives
- Documents
- Demonstrations (interactive simulations, videos, …)

Shielding & Waste packaging studies

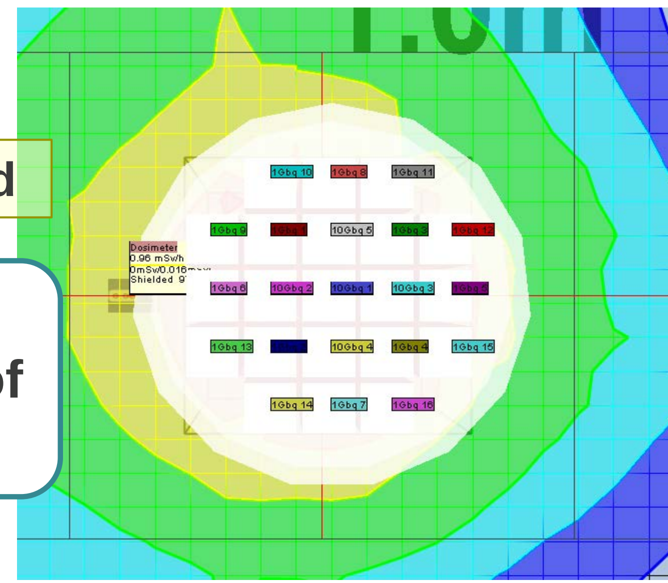


- MOSAIC type shielded container
- 21 slab-like waste pieces
- 5 pieces 10GBq Co-60
- the rest 1GBq Co-60



Random

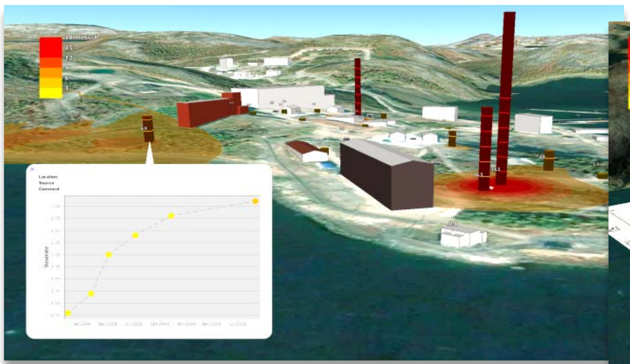
Optimized

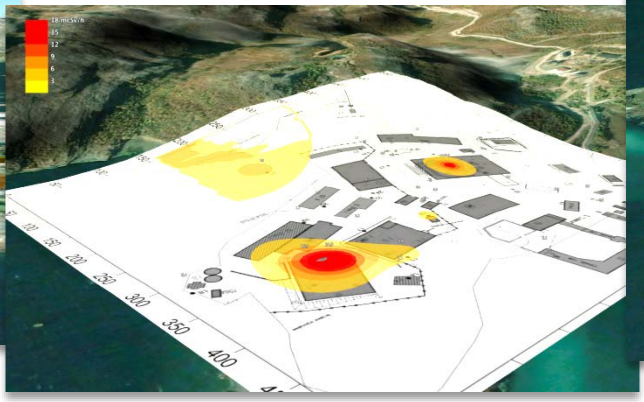


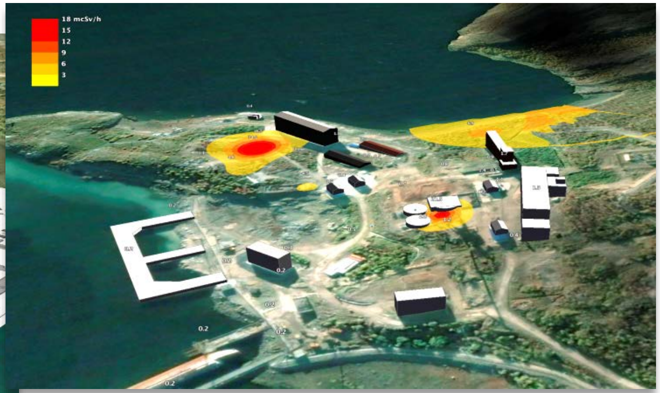
Exploiting shielding effect of heavy waste

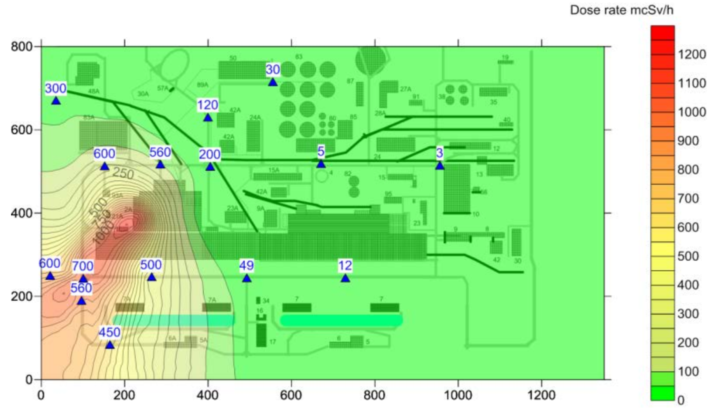
IFE

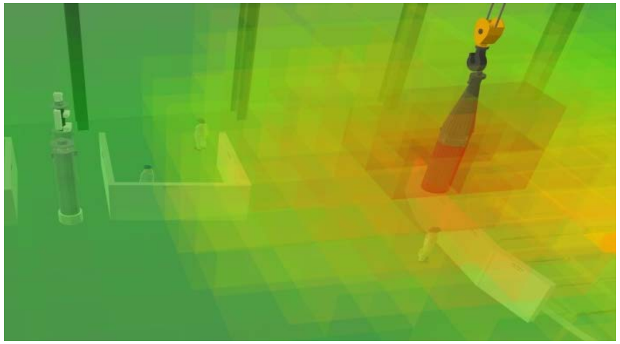
Environmental modelling & Geostatistics



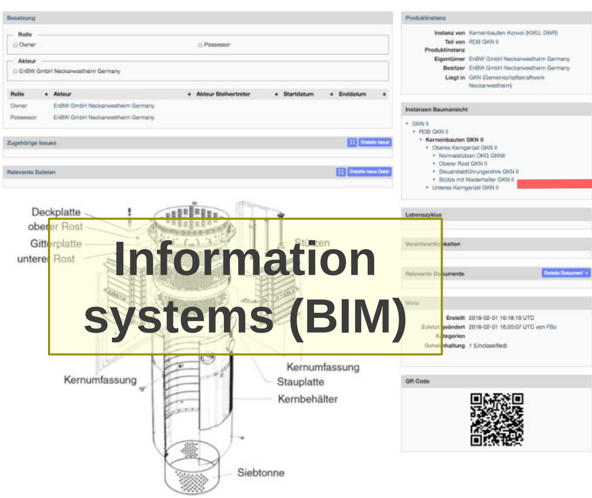








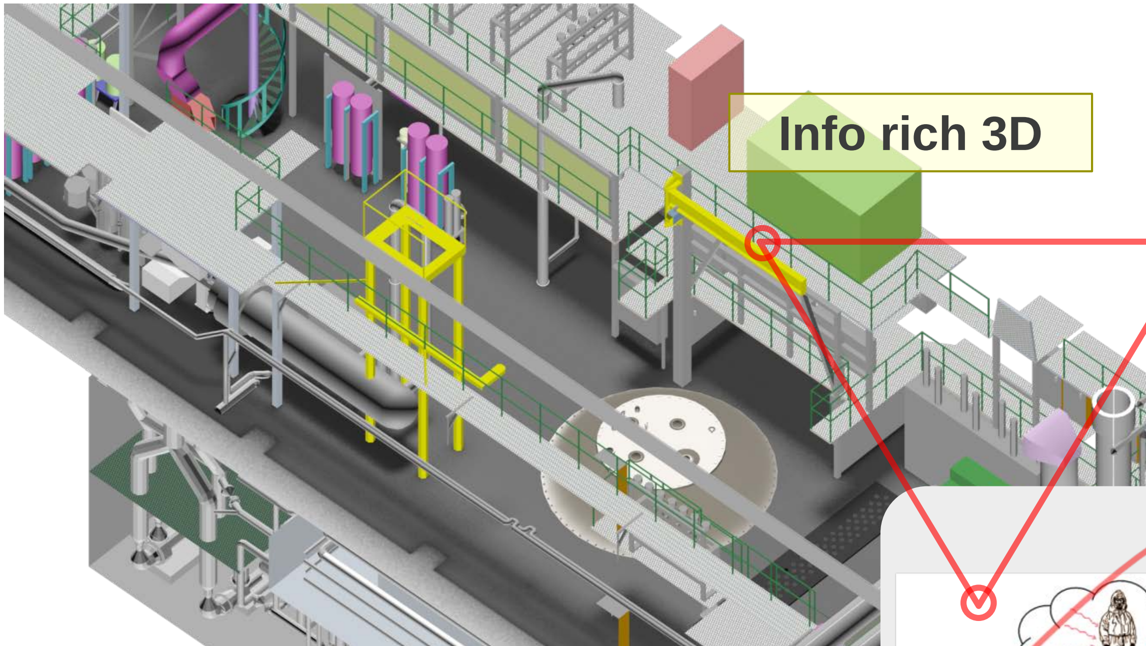
Integration with BIM systems and sensors

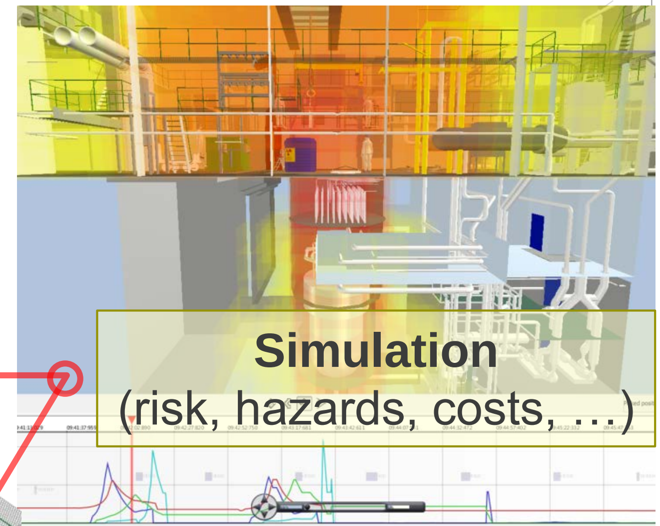


Digital experience (digital twin)

How to acquire and update input?

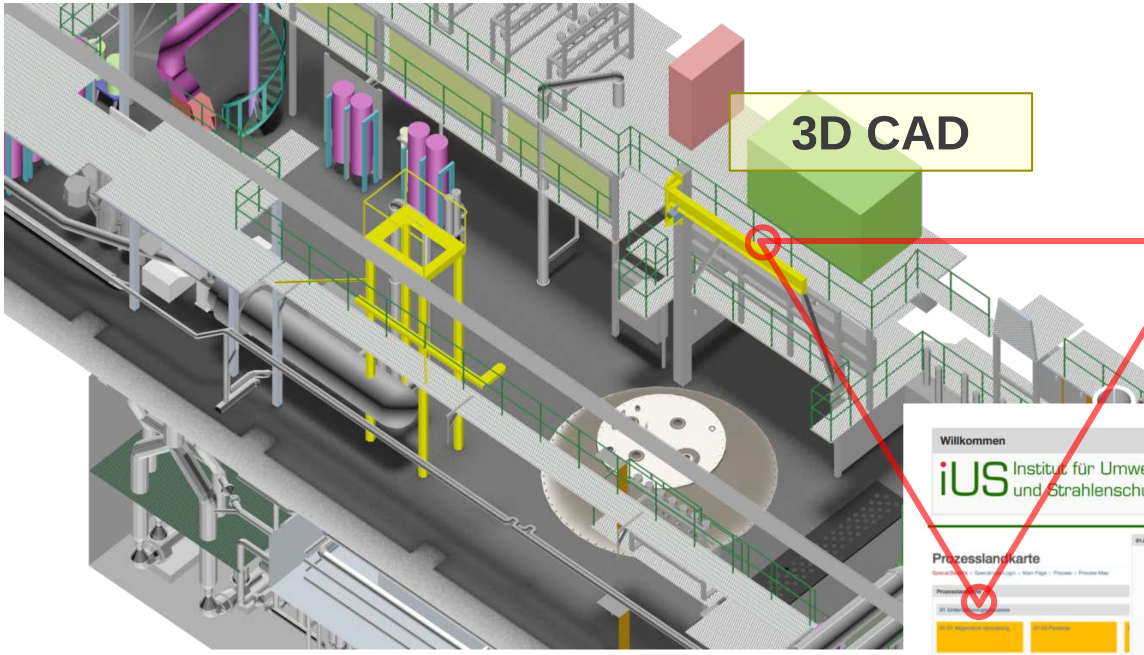
Project management

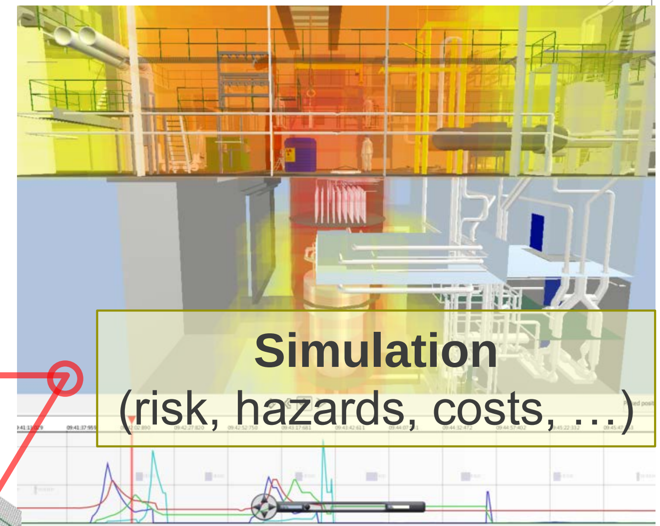


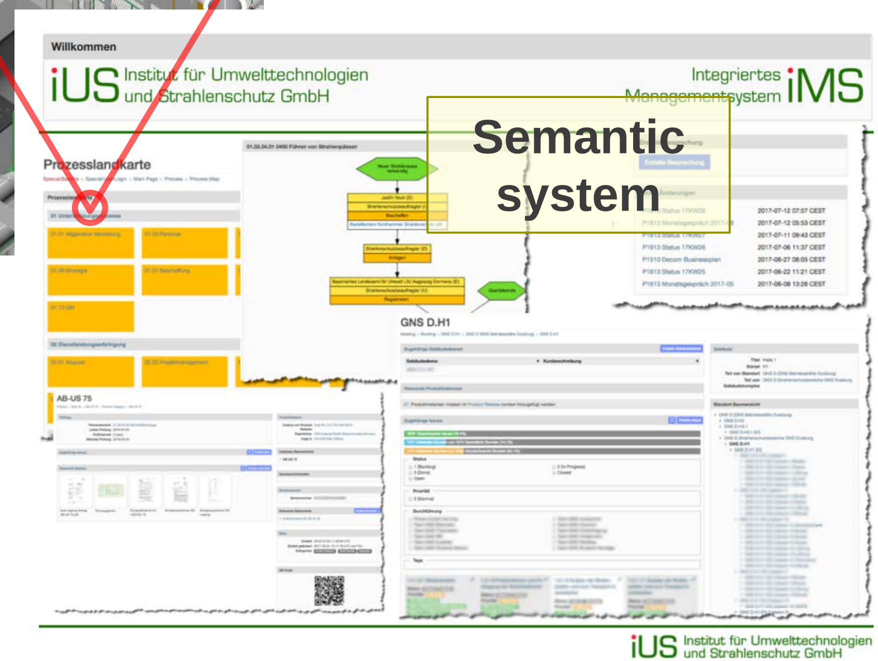


Accessibility (semantic)
Visualization (3D CAD)
Applicability (simulation)
of information

Safety management

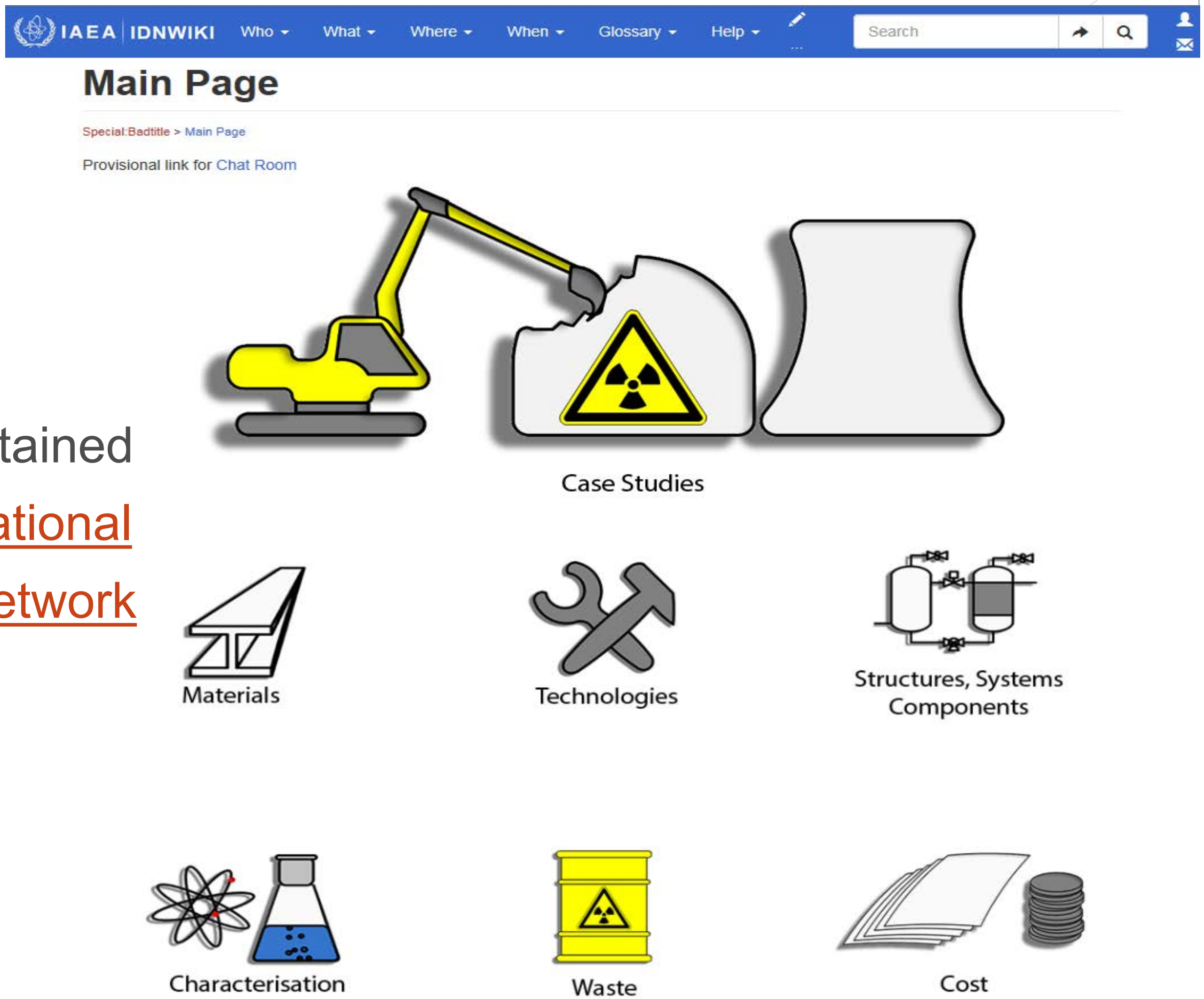






Accessibility (semantic)
Visualization (3D CAD)
Applicability (simulation)
of information

IDN Wiki

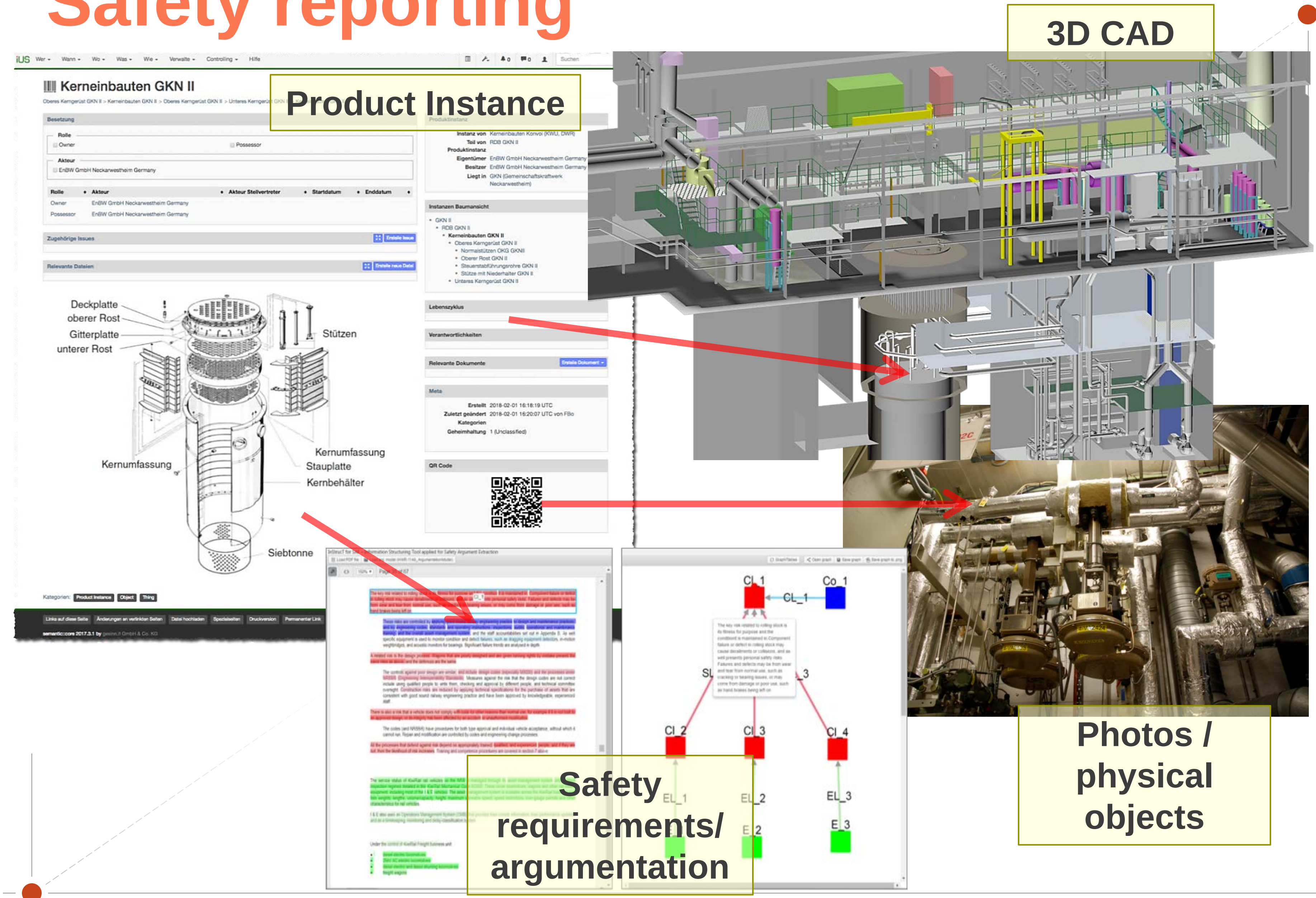


The IDN Wiki is based on MediaWiki software (works like Wikipedia) and maintained by the IAEA's International Decommissioning Network (IDN) on the IAEA CONNECT platform.

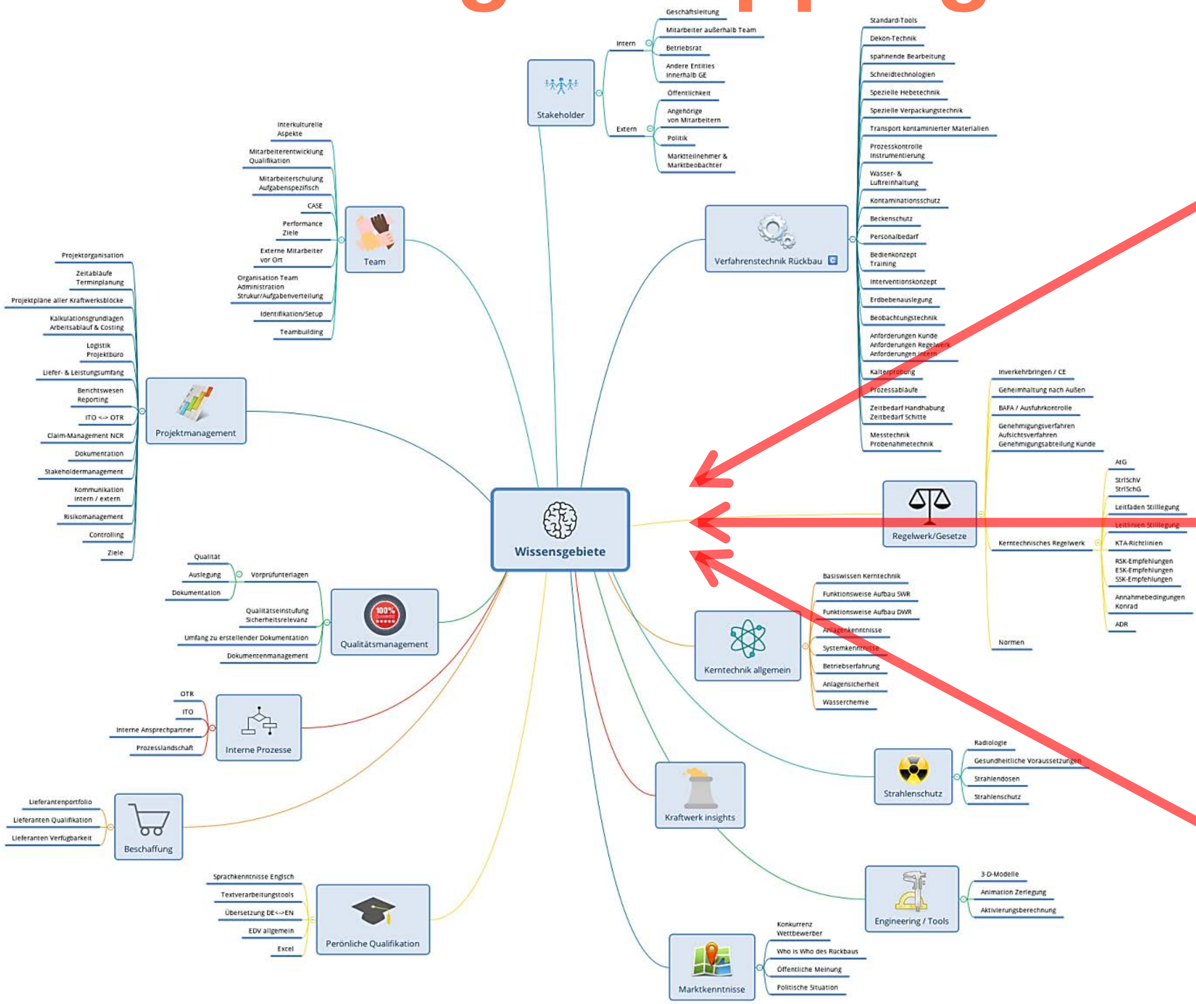
Designed by

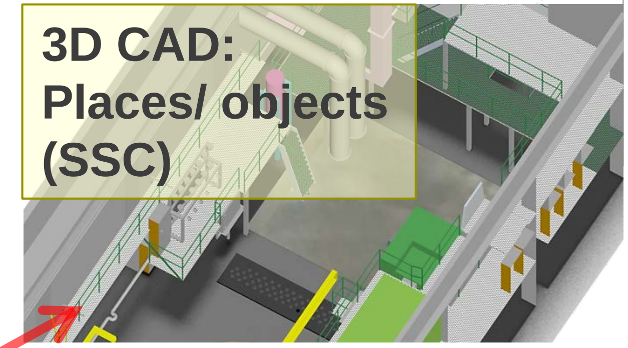
https://nucleus.iaea.org/sites/connect/IDNpublic/Pages/IDN-Wiki-Introduction.aspx

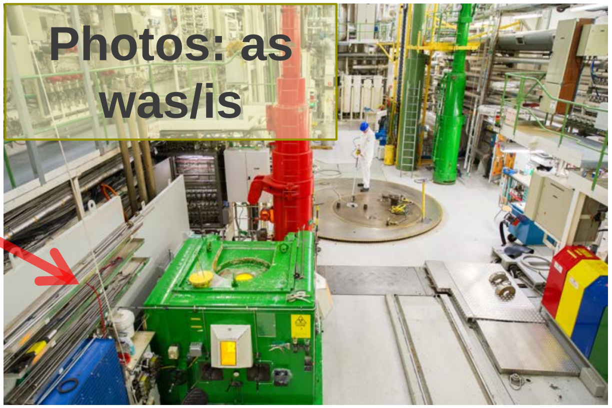
Safety reporting



Workforce planning /knowledge mapping

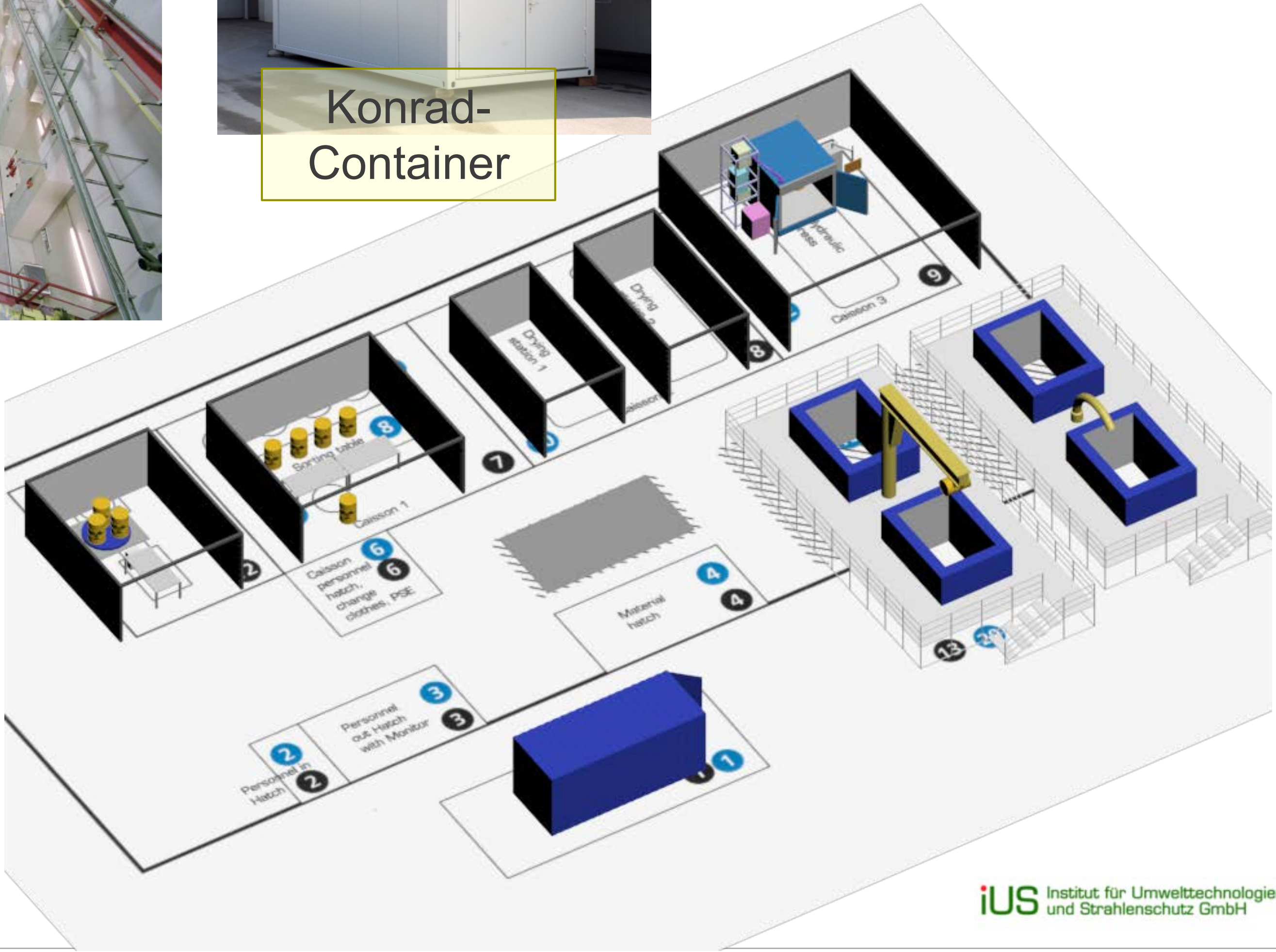






Process planning / control

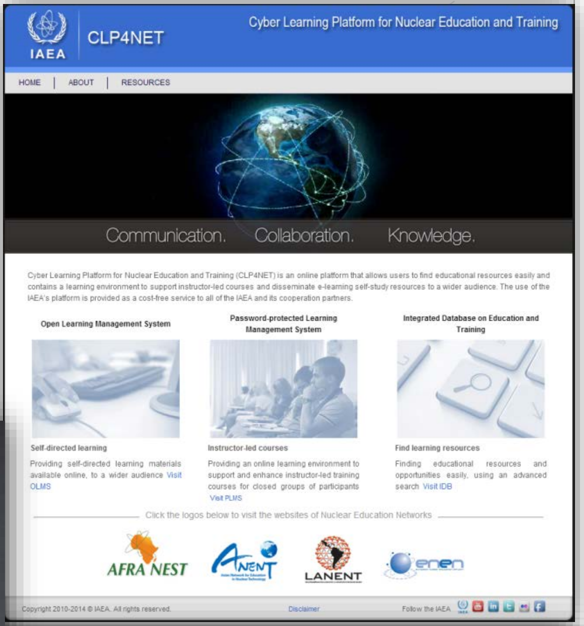
Konrad-Container

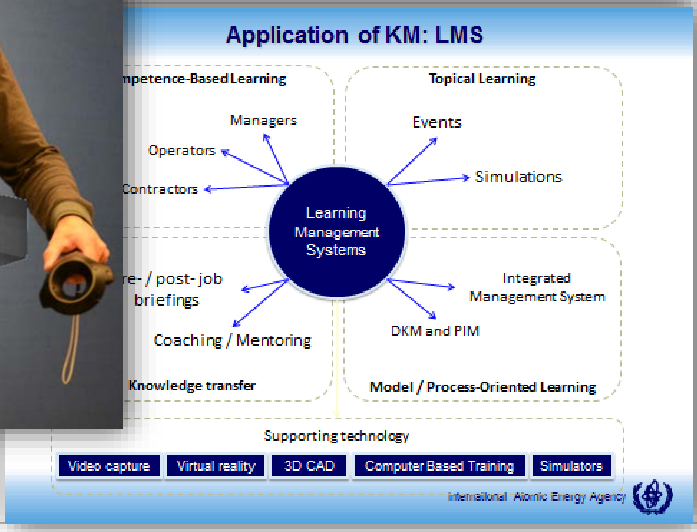


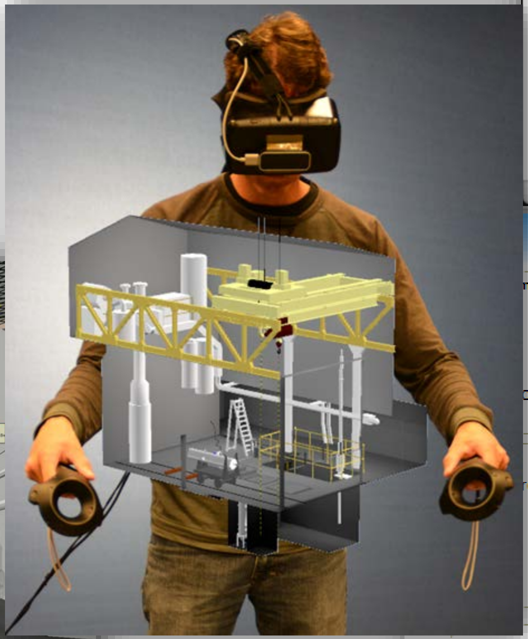
Training & Education

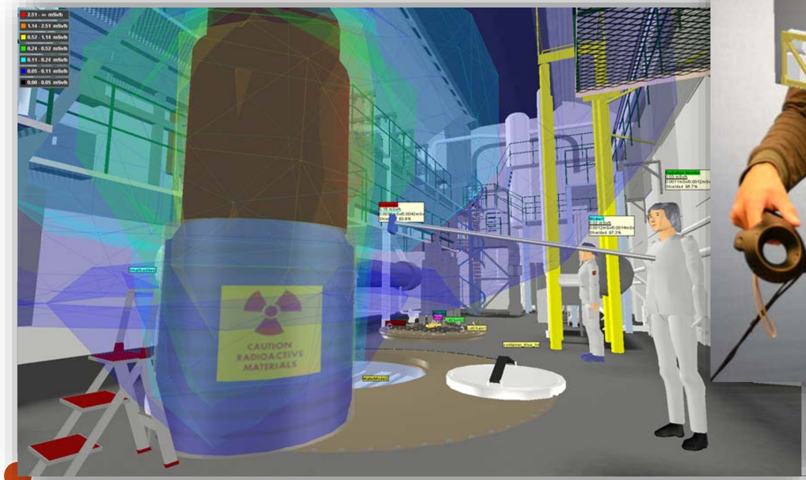
- Online platforms / E-learning
- Organizational learning management
- Mixed Reality
  - site/job specific training
  - emergency training
  - refresher training
  - deep training

CLP4NET

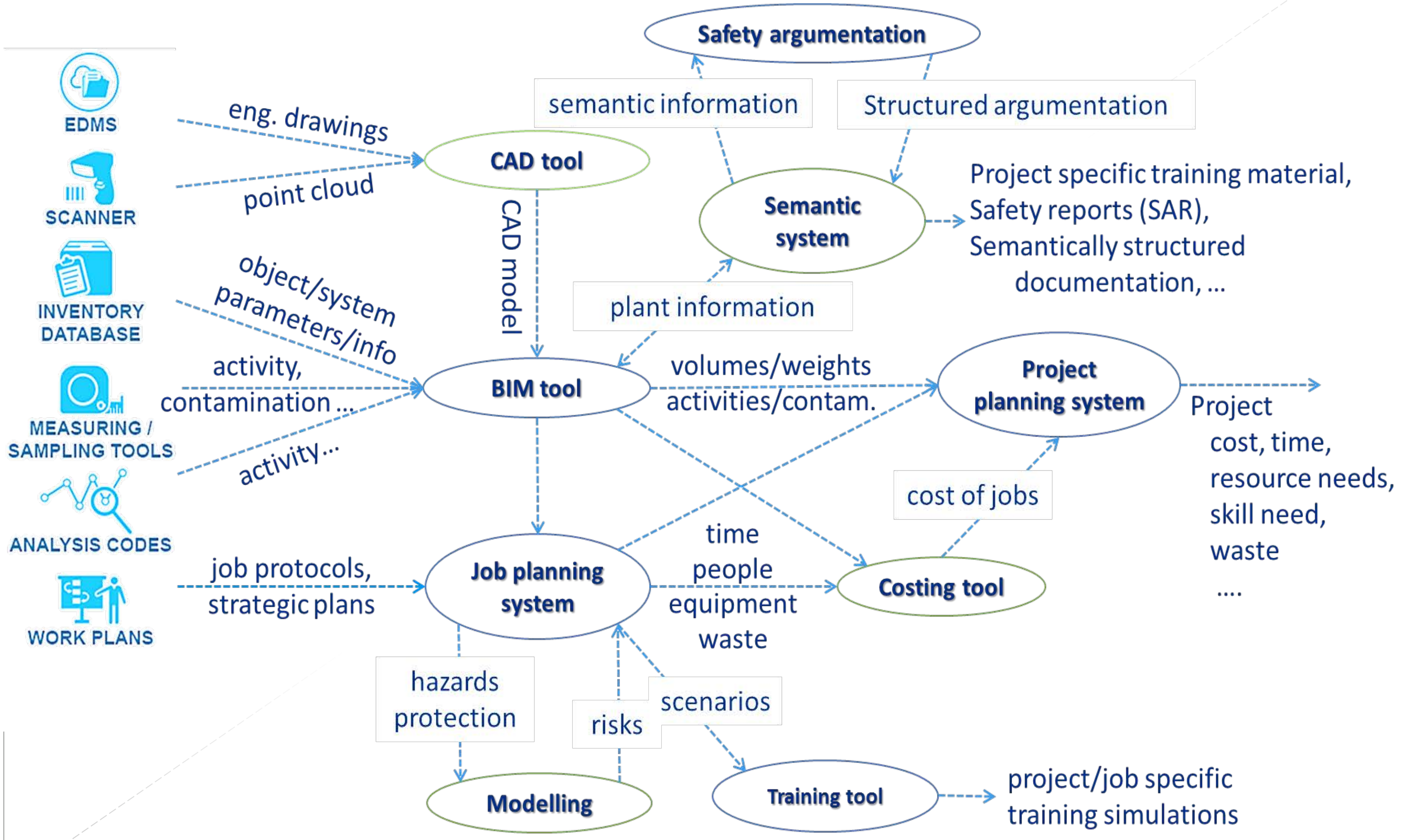






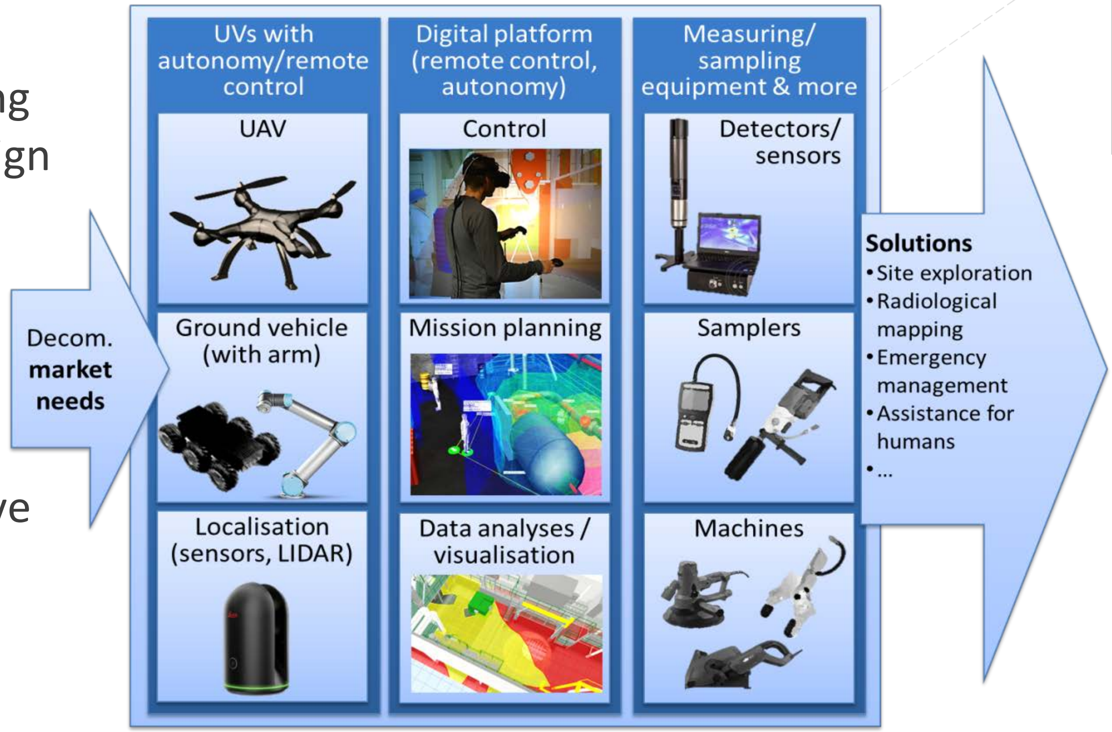


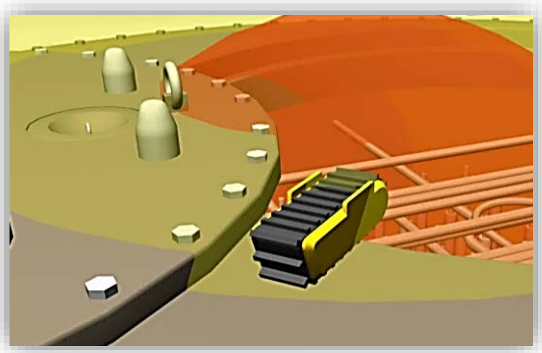
Information management

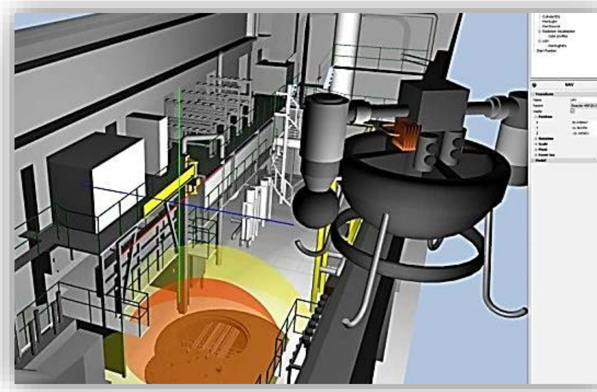


Robotics

- 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



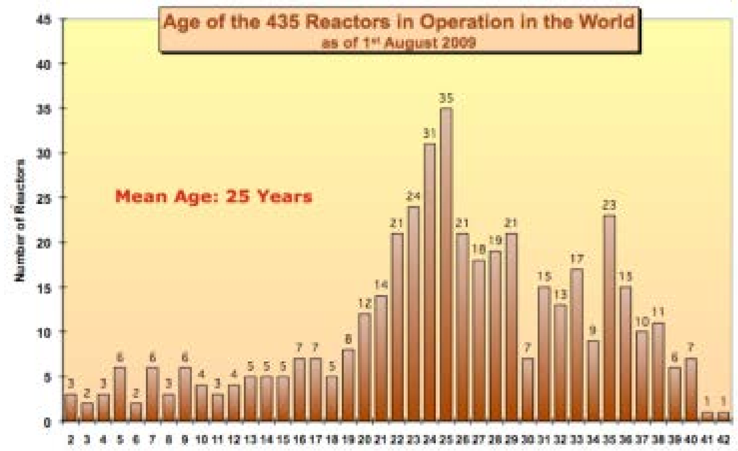




Why is research needed?

Aging plants, political decisions, commercial issues =>

Nuclear decom. will be a major activity Worldwide



Source: IAEA-PRIS, MSC, 2009

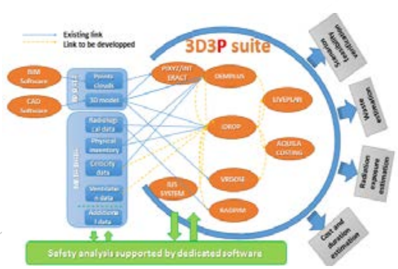
Decommissioning process has to be modernized

- Sporadic decom. R&D — outdated methods
- Assorted teams — communication/data exchange issues (regulators, licensees, contractors, …)
- Mixture of hazards and risks, new types of jobs
- Robotics not ready/expensive
- Low probability of accidents BUT not negligible — preparedness

Collaboration with the IAEA

- Important member of the **International Decommissioning Network** (IDN) of the IAEA
- Participated in IAEA coordinated **technical meetings and publications**
- Organized **events** jointly with the IAEA
- Important participant in **IAEA supported international project consortia**:

SHARE: Development of a roadmap for decommissioning research aiming at safety improvement, environmental impact minimisation and cost reduction



3D3P: 3D Digitally enhanced Decommissioning Planning

IAEA collaborative project activities *(under development)*

Activity
1. Strategic **planning** techniques (site and project level). Application for holistic safety and efficiency management, and comparison of various strategies
2. **Knowledge and workforce management** (with information/knowledge centric plant info, PIM, concepts)
3. **Training** of field workers (normal and emergency) with interactive and immersive digitally enhanced methods.
4. **Safety demonstration** and documentation with structured safety argumentation models and 3D modelling
5. **International competence** building relating for use of digital technologies in decom (secondee programme, the eLearning material).
6. **Workshops** (DigiDecom), **training courses** (ELINDER?), **school** (KM for decom)

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 cou… on digitalisation of the nuclear dec…ng p…ss from early planning (during o…n) … the … site release, with special focus on …egrat… digit… concepts enabling holistic mana…ent o… …ject and …afety.
Techn…s include… …modelling and simulation, semanti… inform… …chnology, physics modelling, digital twi… …ess simulation and visualisation, immersive … …ce and advanced user interfaces.
Application …s include: information management (BIM/PIM), sit… …odelling, stra… …nd work planning, safety assessm… and … …tration, emergency preparedness, training … …ng of w… …ers, robotics, as well as team coordi… …and mo…
Trainees will solve exampl… …teractive group sessions using digital te…
The course will also take …vanta… …story… …, serious games, and mixed reality for pr… …n… …y engaging deep learning experience b… …eal-life …roject experience.

Norway

Next courses:

2018 Spring

Language: English

Expected audience: All professiona… …ed in plann… or overseeing decommissioning, as … as professiona… starting a career in decommissioning
Education level: EQF Level 6 or 7

Learning outcomes from the course:

- ✓ Overview of the international landscape …ar… …d ap… …ion of digital technologies for nuclear decommissioning
- ✓ International overview of available technolo… as we… …needs and trends for future development and application
- ✓ Understanding of the regulatory aspects of digi… …ion for … …ning
- ✓ Overview of digital technologies applied in the Oil&G…
- ✓ Lessons learned from application of digitalization t… …omi… …oning … waste management in Norway
- ✓ International experience from application of digitalization f… … …oning of hazardous legacy nuclear sites (including Chernobyl NPP)
- ✓ Skills in application of digital technology for different asp… …of decommis…
- ✓ Learnings from experiencing examples and solving problem… through immersive (gaming) experiences based on international real-life projects

Price:
Will be defined in due time

Institute for Energy Technology

HRP and Nordic surveys

Nordic nuclear safety research

Interviews with decommissioners


Ringhals NPP (Sweden)


Barsebäck NPP (Sweden)

AREVA Germany


EC JRC (Italy)


SSM (Sweden)

VTT (Finalnd)


CEA (& NUVIA) (France)


NNL & Sellafield (UK)


EDF (Lyon, France)


IRSN (France)

Interviews - findings

- **National/international infrastructure** (e.g. final disposal) and regulatory framework not keeping up with needs / not flexible enough.
- **Contracting** and **regulatory acceptance** process is slow – communicating and evaluating offers/reports.
- Redundancy and inadequate founding in **R&D** into decom.
- Good opportunities for remote and **robotic technologies**, BUT manual work will continue to be used.
- Innovative methods based on systemic **MTO thinking** is rarely applied – e.g. smart logistics / resource allocation

Interviews - findings

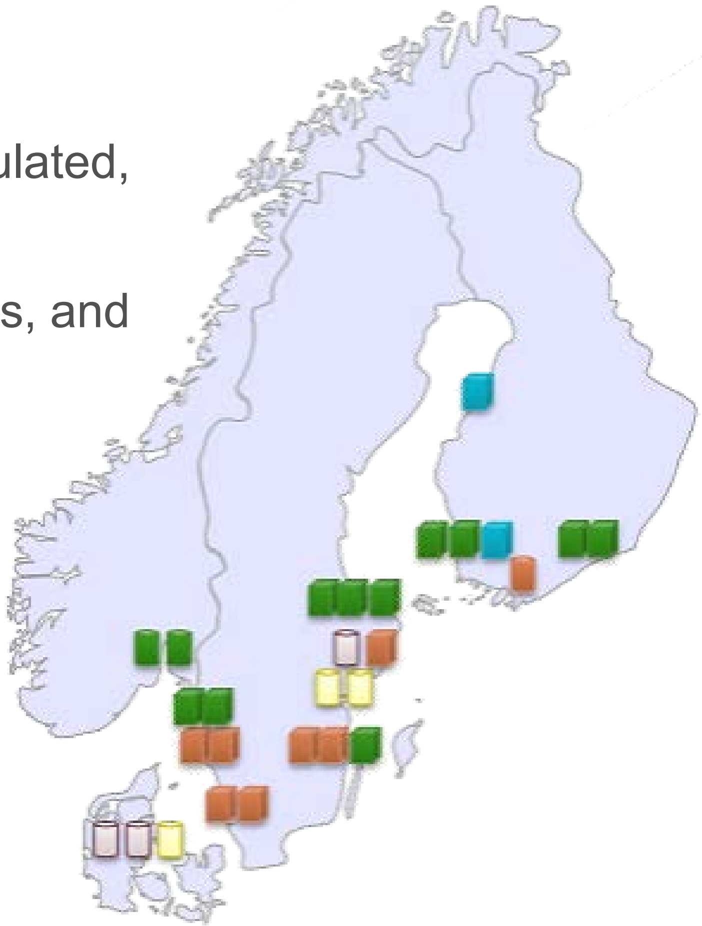
- As opposed to cutting, robotic and similar modern technologies, advanced info techniques are rarely used –> **Knowledge Management** is a general problem
  - Safety and cost (feasibility) assessment and comparison
  - Risk monitoring – team briefing and coordination
  - Training: decentralised, costly **/** inefficient out-dated methods
  - Data management (big data, data mining, data filtration and representation)

Nordic survey

nks
Nordic nuclear safety research

Challenges and opportunities for improving Nordic nuclear decommissioning

- Nordic study on how decommissioning is regulated, planned and performed,
- Identify main challenges, collect best practices, and
- Foster collaboration by fostering sharing of experiences between the Nordic participants.

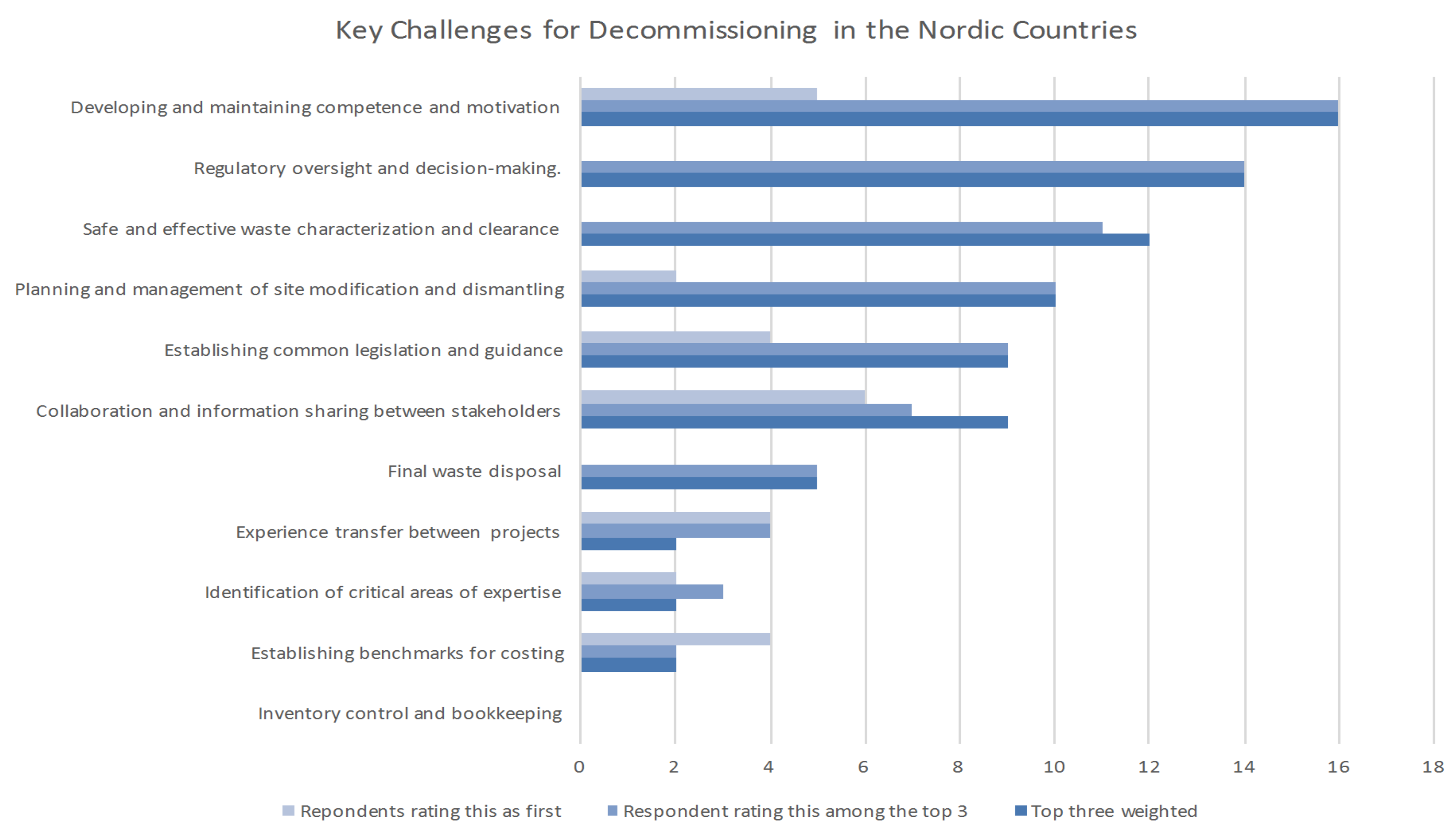


Activities:

- 1. Decommissioning of Nordic legacy sites
- 2. Large scale decommissioning in a Nordic setting
- 3. Nordic collaboration arena

IFE

Key challenges



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

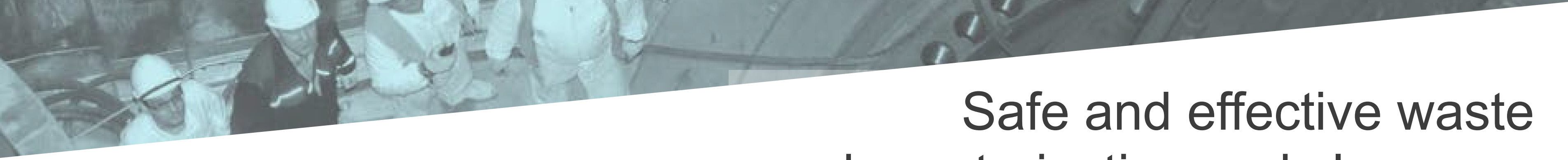
- Challenges
  - Lack of regulatory experience (decom. will be a learning experience for the regulator too)
  - Lack of regulatory guidelines (application/interpretation of regulation)
  - Need for clear and effective reporting and decision making processes (safety demonstration)
  - Regulatory framework 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.

Nordic and international collaboration

- There is a desire to collaborate across Nordic countries
- NKS meetings support informal discussions
- All can gain from sharing experiences
- Transferring lessons from international experience may be limited
  - Differences in legislation, clearance levels, waste management
  - Lessons from guidance level transfer easier than legislative level (Easiest to transfer technical lessons. Strategic issues are more difficult).

FiR 1 TRIGA Reactor
Decommissioning Licensing

Markus Airila
VTT Technical Research Centre of Finland

NORDEC Final Workshop
Lillehammer 6.12.2018

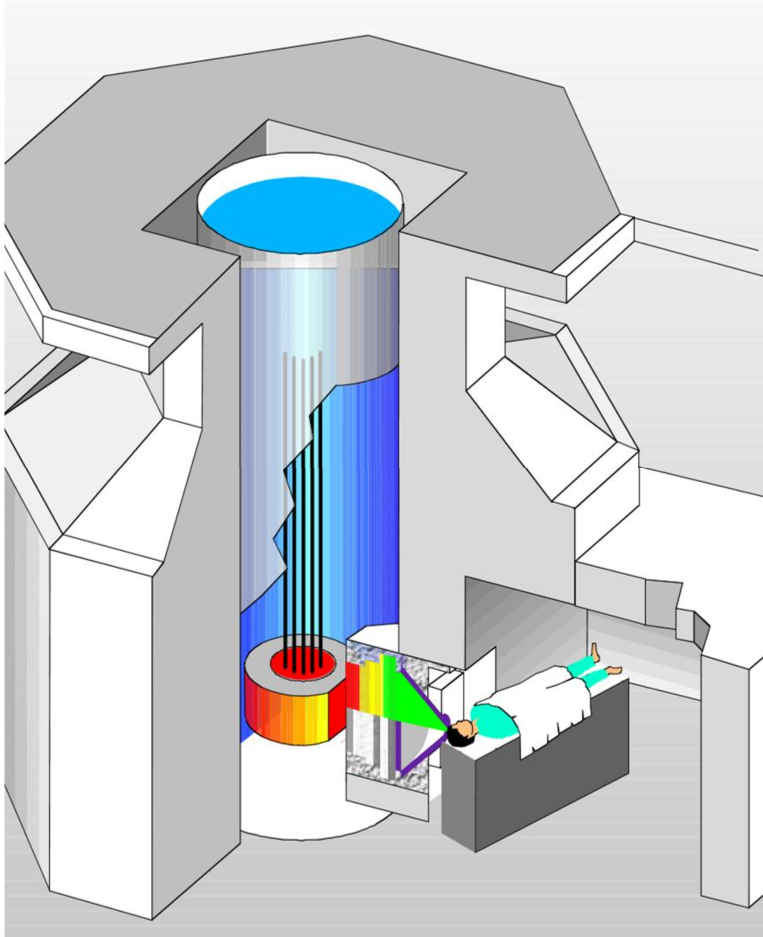
FiR 1 in the Finnish nuclear energy program

30 May 1960: TRIGA order was signed by Frederic de Hoffman (General Atomics) and Minister Pauli Lehtosalo

31 August 1962: FiR 1 inauguration
President of the Republic Urho Kekkonen and Director of General Atomics Dr. Frederic de Hoffman with high level state and industry representatives

History of FiR 1 in brief
TRIGA Mark II, 250 kW

- Neutron beam research, activation analysis
- Isotope production (^{82}Br, ^{24}Na, ^{140}La etc.), irradiation testing
- Facility for Boron Neutron Capture Therapy
  - BNCT treatments (> 200 patients) in 1997–2012
  - Special materials to be managed in decommissioning
- Operating license until 2023, shutdown 2015
- New “operating license” for decom 2019
- Inventory estimates (excluding fuel):
  - Mass 75 tons, volume 40 m^3 (mainly concrete
  - Activity 3.3 TBq (BNCT moderator and steel > 1 TBq)

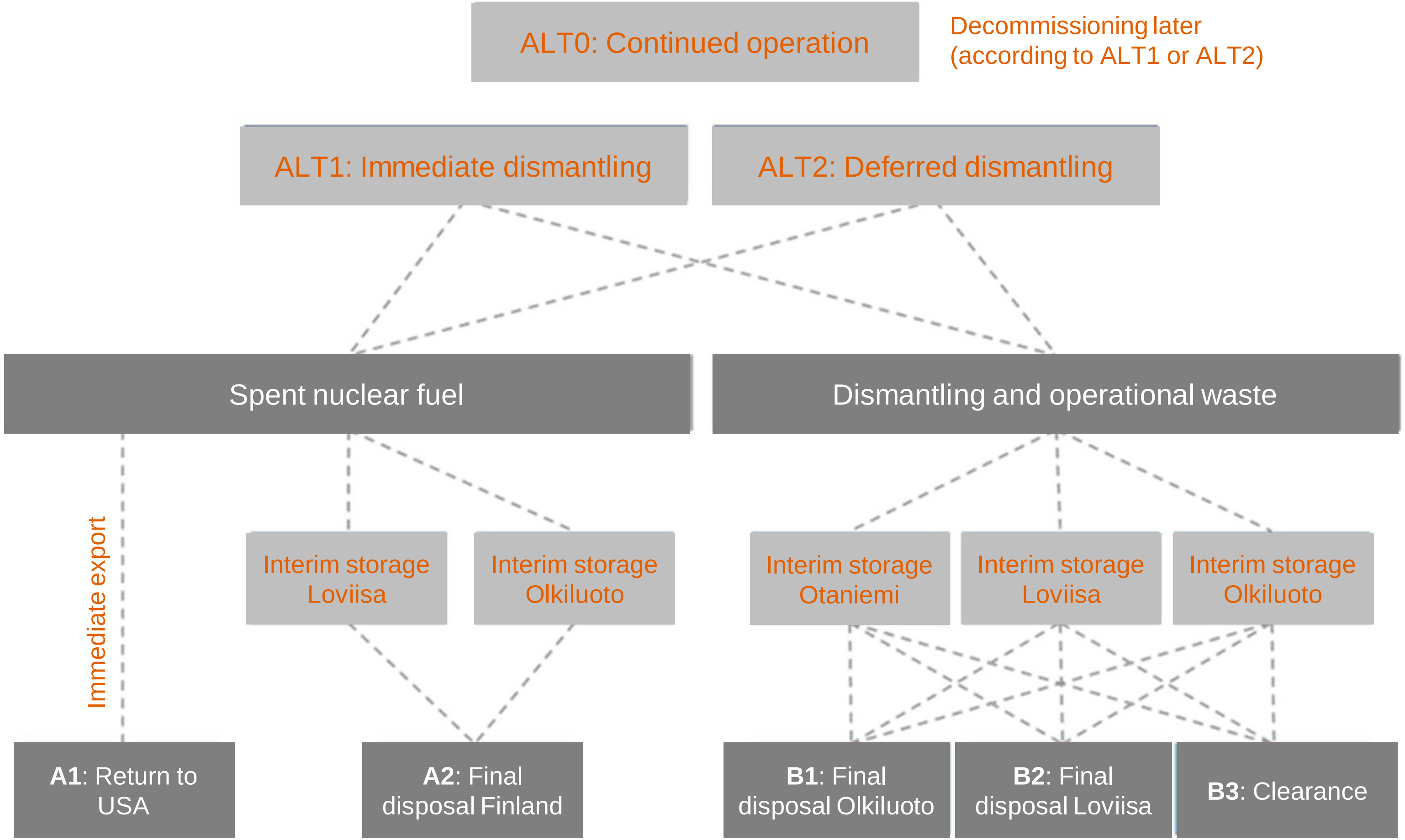


Status of decommissioning

2012	VTT’s decision to shut down FiR 1
2013–15	EIA for decommissioning
2015	End of operations
2016	Dismantling planning
2017	License application for decommissioning Public hearing → 31.3.2018 STUK’s safety assessment → 31.3.2019
2021–24	Dismantling begins, subject to SNF solution

Options for nuclear waste management

FiR 1 Environmental Impact Assessment 2013–15

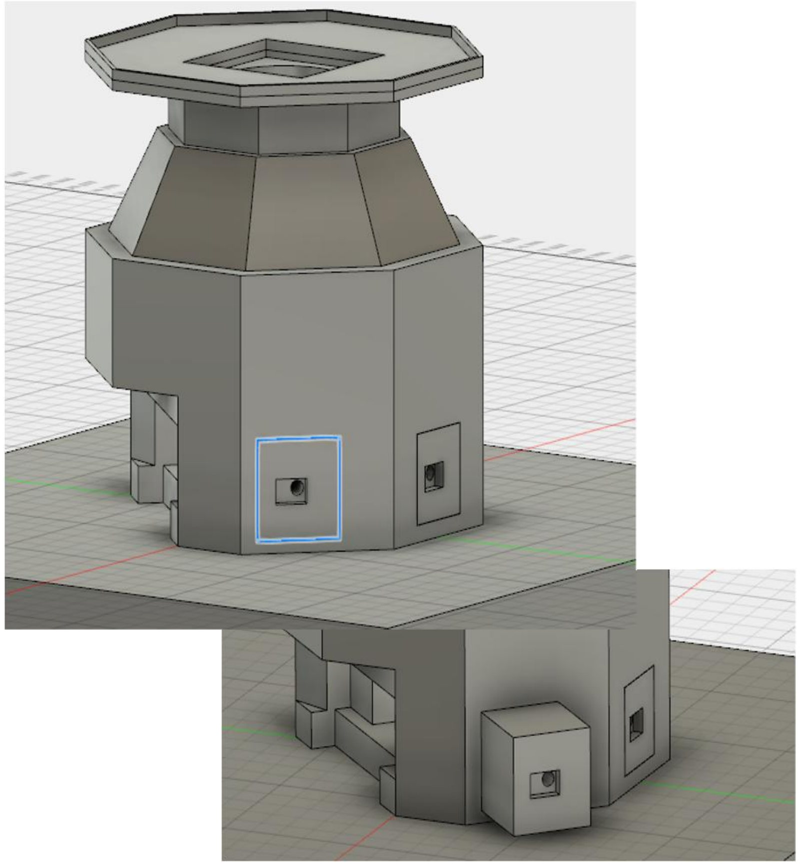


Dismantling planning 2016–17
Example: cutting of the biological concrete shield

Competitive tender for planning
- Relatively high interest, good tenders
- Selected contractor: Babcock Noell GmbH & Fortum

Work completed by BNG and reviewed by VTT
- Practically in schedule (+ 1 month)
- One small additional work order
- Domestic regulation, packaging plan and safety classification scheme by Fortum

The plan forms the basis for…
- Technical part of the licensing documentation
- Also supports costing calculations



Babcock Noell GmbH

Licensing for decommissioning

Division of duties between ministries

According to the Finnish Radiation Act

Ministry of Economic Affairs and the Employment

Ministry of Social Affairs and Health

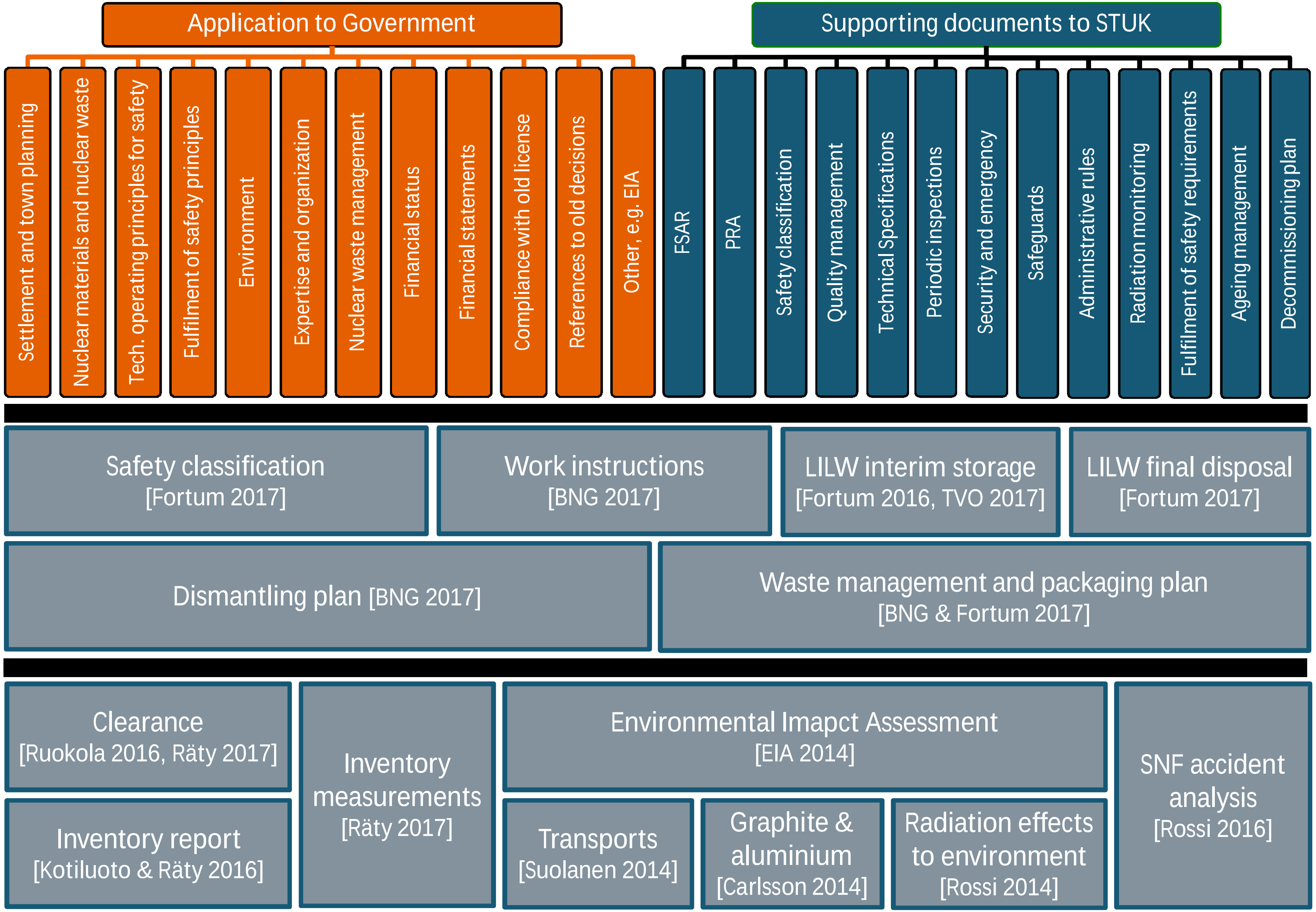
Nuclear Energy Act

Radiation Act

Radiation and Nuclear Safety Authority STUK

Licensees (NPP's, VTT)

Users of radiation (incl. VTT)



Application to Government
Settlement and town planning
Nuclear materials and nuclear waste
Tech. operating principles for safety
Fulfilment of safety principles
Environment
Expertise and organization
Nuclear waste management
Financial status
Financial statements
Compliance with old license
References to old decisions
Other, e.g. EIA
Supporting documents to STUK
FSAR
PRA
Safety classification
Quality management
Technical Specifications
Periodic inspections
Security and emergency
Safeguards
Administrative rules
Radiation monitoring
Fulfilment of safety requirements
Ageing management
Decommissioning plan
Safety classification [Fortum 2017]
Work instructions [BNG 2017]
LILW interim storage [Fortum 2016, TVO 2017]
LILW final disposal [Fortum 2017]
Dismantling plan [BNG 2017]
Waste management and packaging plan [BNG & Fortum 2017]
Clearance [Ruokola 2016, Räty 2017]
Inventory measurements [Räty 2017]
Environmental Imapct Assessment [EIA 2014]
SNF accident analysis [Rossi 2016]
Inventory report [Kotiluoto & Räty 2016]
Transports [Suolanen 2014]
Graphite & aluminium [Carlsson 2014]
Radiation effects to environment [Rossi 2014]

Steps during review of application

- Submission of application (Ministry / Government)
- Submission of technical documentation
  - Several batches
- Public hearing + invited statements (7 months)
- VTT supplements the application + additional hearing
  - Status of waste management plans (contracts)
  - Schedule update
  - Any other updates
- STUK prepares safety assessment
  - Statement by Advisory Committee on Nuclear Safety
  - Statement by the Ministry of the Interior
- Hearing of the applicant before final decision

Total time almost 2 years (insufficient information originally)

Työ- ja elinkeinoministeriö
Arbets- och näringsministeriet

Ilmoitus

Teknologian tutkimuskeskus VTT Oy:n tutkimusreaktorin käytöstäpoistoa koskevan lupahakemuksen vireilläolosta

Työ- ja elinkeinoministeriö ilmoittaa hallintolain 41 §:n nojalla, että Teknologian tutkimuskeskus VTT Oy (jäljempänä VTT) on jättänyt 20.6.2017 valtioneuvostolle hakemuksen (TEM/1311/08.05.01/2017), jolla se hakee ydinenergialain (990/1987) 20 §:ssä tarkoitettua lupaa:

1. poistaa FiR 1 -tutkimusreaktori käytöstä siten, että laitosalueella jäljellä olevien radioaktiivisten aineiden määrä on ydinenergialain nojalla asetettujen vaatimusten mukainen;
2. pitää hallussa, käsitellä ja varastoida reaktorin käytettyä ydinpolttoainetta sekä muita käytön ja purkamisen yhteydessä syntyneitä ydinjätteitä;
3. pitää hallussa, käyttää, käsitellä ja varastoida VTT:n hallinnoimalla materiaalitasealueella jo olevia muita ydinmateriaaleja, jota Säteilyturvakeskus, Euratom ja IAEA valvovat.

VTT pyytää samalla reaktorin nykyisen, vuoden 2023 loppuun voimassa olevan käyttöluvan raukeamista.

Jäljennös lupahakemuksesta on nähtävissä virka-aikana 29.8.2017–31.3.2018 seuraavissa paikoissa:

- Espoon kaupungin kirjaamo, Siltakatu 11 (Kauppakeskus Entresse, 3. kerros), Espoo
- Kauniaisten kaupungintalo, Kauniaistentie 10,

Delivery of VTT’s license application

License application delivered to the ministry on 20 June 2017.From left: Jorma Aurela and Linda Kumpula (MEAE); Satu Helynen and Markus Airila (VTT).

Project manager Markus Airila delivering the first set of documents for STUK’s review on 30 June 2017.

Antti Räty delivering the last set of documents for STUK’s review on 29 March 2018.

Primary option for SNF is repatriation to US

Idaho National Laboratory

FiR 1 fuel is US origin and is covered by the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program of US DOE.

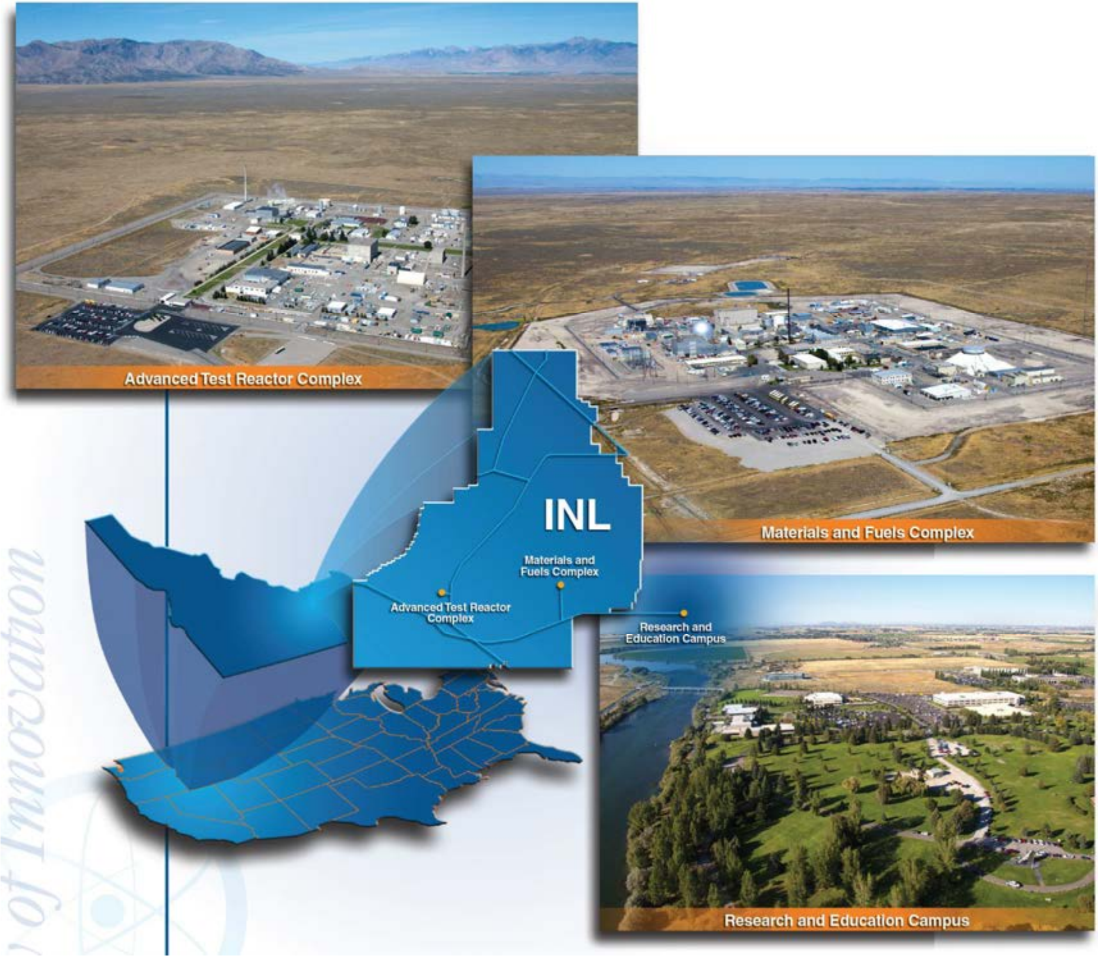
Several shipments from other TRIGA type reactors in the past

SNF export (repatriation) is allowed by the Finnish Nuclear Energy Act as an exception only for the research reactor

The return program is currently halted – delayed processing of historical waste

VTT negotiates on extension beyond May 2019

DOE is executing an Environmental Assessment for the extension



VTT and Fortum have signed a letter of int decommissioning of a research reactor an laboratory

03/12/2018

VTT and Fortum have signed a letter of intent on cooperation in the decommissioning of the FII research reactor and the nuclear power plant structural materials research laboratory. In additic cooperation over dismantling and waste handling, the companies investigate possibilities for ir storage and final disposal of the decommissioning waste at the Loviisa nuclear power plant sit

The cooperation will make Fortum's long experience in nuclear power plant operation and nuclear was management available to VTT.

VTT applied to the Government in 2017 for permission to decommission the reactor. The spent nuclea must be removed from the facility before the reactor is dismantled. VTT primarily intends to repatriate t fuel to its country of origin, the United States. The secondary alternative is deep geological disposal in Olkiluoto, Eurajoki, after interim storage. The actual demolition phase will begin in 2021 at the earliest. Preparations have been made for the decommissioning of the laboratory, which will begin in 2019

Fortum and VTT signed a letter of intent on the decommissioning of a research reactor and laboratory

Share this:

Fortum and VTT have signed a letter of intent on cooperation in the decommissioning of the FIR 1 research reactor and the nuclear power plant structural materials research laboratory.

The cooperation will make Fortum's long experience in nuclear power plant operation and nuclear waste management available to VTT. In addition to cooperation over dismantling and waste handling, the companies investigate possibilities for interim storage and final disposal of the decommissioning waste at the Loviisa nuclear power plant site.

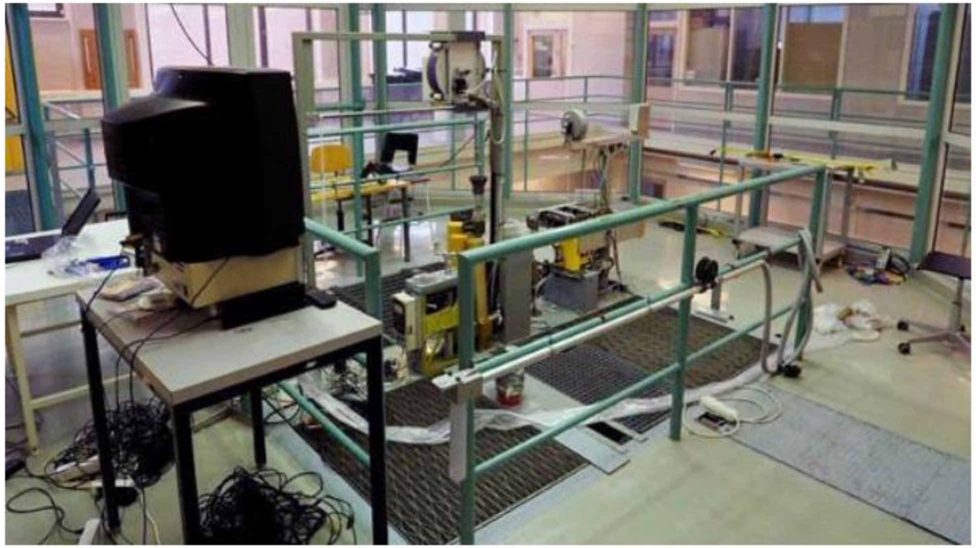
More information:

Fortum to assist in decommissioning research reactor

04 December 2018

Share

Finnish utility Fortum has signed a letter of intent to cooperate with VTT Technical Research Centre of Finland in the decommissioning of the Finnish Reactor 1 (FiR 1) research reactor and the nuclear power plant structural materials research laboratory.



The Finland Reactor 1 (Image: Stuk)

The FiR 1 water-cooled, pool-type TRIGA Mark II research reactor at Otaniemi, Espoo, was commissioned by the Helsinki University of Technology in 1962. The reactor was originally built for research and education and later also for isotope production and radiotherapy. Operational responsibility for the reactor was transferred to VTT in

Website	NIC2019 Introduction	Register	Contact Us

Dear Madam/Sir,

Finnish utility Fortum has signed a letter of intent to cooperate with VTT Technical Research Centre of Finland in the decommissioning of the Finnish Reactor 1 (FiR 1) research reactor and the nuclear power plant structural materials research laboratory.

The FiR 1 research reactor, which has served as a key nuclear energy and educational research facility for 50 years, was shut down permanently on 30 June 2015.

FIR 1 timeline
2015: The reactor is run for the last time on 30 June 2015.
2019: The spent nuclear fuel is transported to the US or interim storage.
2021: The reactor is dismantled, and the resulting waste placed in interim storage.
2022: The empty reactor building is decontaminated and released.
2030's: The waste is transported from the interim storage facility to a final repository.

Fortunately, Fortum has confirmed to attend **5th Central & Eastern Europe Nuclear Industry (New Build/Life Extension/Decommissioning/WM) Congress 2019, January 28-29, Prague, Czech Republic**.

If you wanna know the decommissioning program in Finland, their progress in dismantling and waste

Summary and outlook

First nuclear facility to be decommissioned in Finland

License application for decommissioning June 2017

- STUK's statement expected Q1/2019 → followed by new license by the Government

Uncertainties remain in waste management

- Relatively small activity and amount of waste
- Spent fuel: primary option US return, delayed
- Dismantling waste management with Finnish NPP operators

See also

VTT's info pages on the decommissioning project

http://www.vttresearch.com/services/low-carbon-energy/nuclear-energy/decommissioning-of-finlands-first-nuclear-reactor

Decommissioning license application (Website of the Ministry)

http://tem.fi/en/vtt-technical-research-centre-of-finland-ltd-s-licence-application-for-decommissioning

Decommissioning status and challenges in Finland

Mia Ylä-Mella

6.12.2018

Content

- Legislative framework – updated Nuclear Energy Act and Decree in force from 1.1.2018
- Decommissioning license
- Main decommissioning related challenges in Finland
- Preliminary conclusions from the safety review of the license application of VTT

Nuclear Energy Act 7 g § sets the basic safety principles for the decommissioning of a nuclear facility

- Decommissioning of the nuclear facility shall be taken into account in the design of the nuclear facility and also during operation
- Decommissioning plan is required in connection with construction and operation license applications and shall be updated every 6 years, if not otherwise required in license conditions. The final decommissioning plan is required for the decommissioning license application.
- Decommissioning of a nuclear facility shall be performed in accordance with the safety requirements and with a decommissioning plan approved by the Radiation and Nuclear Safety Authority (STUK)
- Dismantling the nuclear facility and other measures taken for the decommissioning of the facility may not be postponed without due cause
- Funding is secured for waste management including decommissioning

Decommissioning License is added into the Nuclear Energy Act 20 a §

- When the operation of a nuclear facility is ended, the licensee shall apply for the Decommissioning License. The license application shall be submitted to the authorities in time to ensure that the they are able to review the application while the Operating License is still in force

- The Decommissioning License application shall contain two parts: 1) Decommissioning License Application to the Goverment (33 a § and 34 a §) and 2) Documentation to STUK for approval (36 a §)

- The Ministry of Employment and Economy asks for a statement from STUK about the decommissioning license application

The documentation provided to STUK for approval
(Nuclear energy degree 33 a §)

1) the final decommissioning plan;

2) risk assessment for the decommissioning;

3) the final safety analysis report;

4) a classification document, which shows the classification of structures, systems and components important to the safety of the nuclear facility, on the basis of their significance with respect to safety;

5) a quality management programme ;

6) the Technical Specifications;

7) a summary programme for periodic inspections for the structures, systems and components important for safety during decommissioning;

8) plans for the security and emergency arrangements;

9) a description on how to arrange the safeguards that are necessary to prevent the proliferation of □ nuclear □ weapons;

10) administrative rules for the nuclear facility;

11) a programme for radiation monitoring in the environment of the nuclear facility;

12) a description of how safety requirements are met; and

13) a programme for the management of ageing.

14) In addition to documents 1-13 any other document required by regulatory authority

Decommissioning plan

- Nuclear facility shall have a decommissioning plan, which should be detailed enough and respond to the design and current state of the nuclear facility. At the minimun the decommissioning plan shall contain:

  1) Selected decommissioning strategy and justification for it
  2) Planned decommissioning phases and the project time schedule
  3) General description of the decommissioning and nuclear waste management methods;
  4) Cost estimation for the decommisioning and nuclear waste management
  5) Planned end-state

- The Ministry of Employment and Economy shall ensure that the plan is technically possible, follows the safety principles and cost estimates are reliable. STUK is asked to give statement about the decommissioning plan.

The Decommissioning License may be granded according 20 a §, if

1. The nuclear facility and its decommissioning plan meet the safety requirements laid down in Nuclear Energy Act and appropriate account has been taken of the safety of workers and the population, and environmental protection;
2. The methods available for the decommissioning and to the nuclear waste management are sufficient and appropriate;
3. The applicant has sufficient expertise available and, in particular, the competence of the staff and the organisation of the nuclear facility are appropriate for the decommissioning;
4. The applicant is considered to have the financial and other prerequisites to engage in operations safely and in accordance with Finland's international contractual obligations; and
5. The planned decommissioning activities fulfils the general safety principles laid down in Nuclear Energy Act.

The end of the decommissioning

- Nuclear facility is decommissioned, when the Licencee has proven to STUK that the buildings and environment are clear from radioactive materials.

- When the decommissioning of a nuclear facility has been brought to completion and all waste has been removed from the site, the licensee shall submit to STUK for approval an application for the clearance of the site and any buildings therein.

- When STUK has noted that the building and environment are clear, Licensee can apply for an order on the expiry of his waste management obligation with the Ministry of Employment and the Economy

Challenges in the decommissioning in Finland

- Updated Nuclear energy act and decree contains basic requirements for the decommissioning planning, but the detailed requirements are not yet updated (e.g. it is not very clearly defined in the safety guides, what should be presented in the decommissioning plan and what in FSAR, more clear requirements are probably needed to define what activities related to decommissioning can be done under operating license and for what activities the decommissioning license is required)

- Detailed tehcnical requirements concerning decommissioning are missing from the guidance (not very clear yet, if these are even needed)

- No experience on regulatory oversight of the decommissioning project

Licensing for decommissioning of research reactor FiR 1

- Environmental Impact Assessment (EIA) was conducted in 2014 –2015
- Operation license application for decommissioning was send to state council at the end of June 2017
- The first batch of the licensing documentation required by STUK was delivered at the end of June 2017. The last licensing document, plans for the security arrangements during decommissioning, was delivered to STUK at September 2018
- VTT aims to update its operation license application still with
  - updated time schedule of the decommissioning project
  - list of nuclear materials remaining in VTT's operation application
  - updated information on nuclear waste management plans for spent nuclear fuel and nuclear waste

- STUK's safety review and statement to the Ministry of Economic Affairs and Employment is planned to be ready in March 2019

Final decommissioning plan of FiR 1

- The Final Decommissioning plan for FiR 1 reactor was sent to STUK for approval at the end of June 2017

- Main decommissiong principles:
  - Final decommissioning plan: 2017 (approved as part of operating lisence application)
  - Strategy: immediate dismantling
  - End state: brown field
  - Spent fuel management: 1) the first option is to return the fuel back to USA by spring 2019. 2) the second option is interim store the spent fuel in Finland and return it back to USA later. 3) the third option is final disposal in Finland
  - Nuclear waste management: storage and final disposal in Loviisa NPP site (estimated amount for disposal is about 100 m^3 packed waste), contract negotiations are on-going

Requirements raised up during the licensing documentation handdling

- VTT has to provide detailed description of the spent fuel transfer arrangements for approval to STUK separately and apply license for the transportation according nuclear energy act and degree and YVL D.2

- VTT has to provide the FSAR of decommissioning phase for STUK for approval at latest six months before the decommissioning phase starts
  – currently there is only preliminary draft available for the decommissioning phase
  – STUK had several detailed comments and requests for more detailed descriptions of the dismantling activities, radiation safety arrangements, nuclear waste management plans and working area arrangements

Preliminary conclusions from the safety review of STUK

- VTT fullfills all the safety requirements in permanent shutdown state.

- For the decommissioning phase the plans must still be updated in the following areas:
  – Radiation safety protection arrangements and instructions
  – Spent fuel management has to be resolved until the dismantling of the research reactor can be started. If spent fuel cannot be sent back to USA in reasonable timeframe, VTT shall have licensed interim storage for spent fuel until the dismantling of the research reactor can be started
  – VTT has to develop and describe in more detailed radioactive waste handdling methods (including also arrangements for free-release) for all different waste streams
  – Low and intermediate level wastes shall have licensed interim storage until the dismantling of the research reactor can be started
  – VTT has to ensure that it will have competent resources available for the decommisioning phase especially if the decommissioning phase is delayd with several years.

Preliminary conclusions from the safety review of STUK

- VTT has to ensure that it has competences and instructions in place for the suppliers selection and management until decommissioning phase starts

Safety demonstration and structured argumentation

IFE Digital Systems

Peter Karpati

Svein Tore Edvardsen

André A. Hauge

Bjørn Axel Gran

Silje Olsen

Fabien Sechi

Vikash Katta

VTT

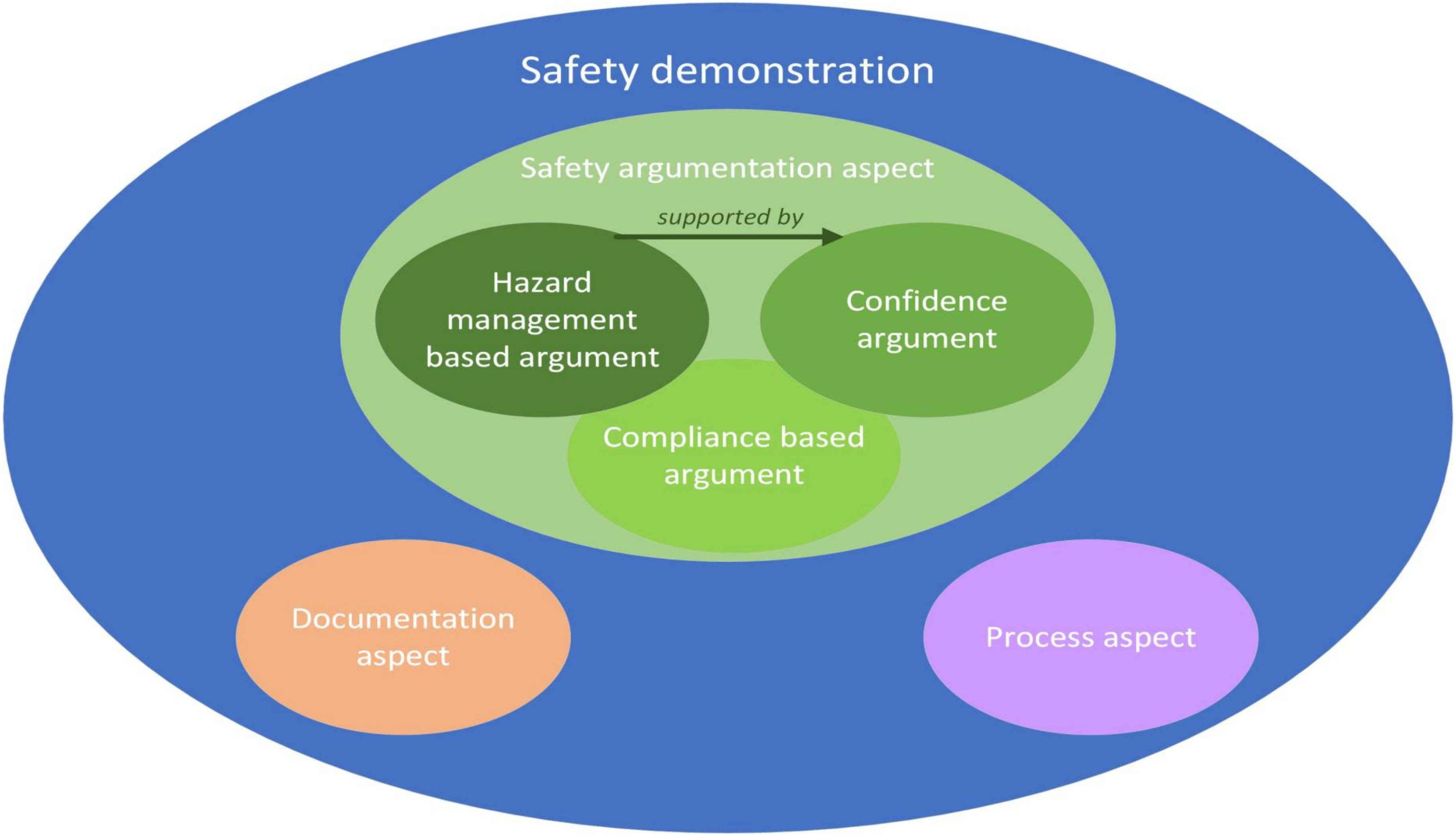
Markus Airila

6.12.2018, Lillehammer

Outline

1. Concepts of safety demonstration and structured argumentation
2. Tool support for information structuring: InStrucT
3. Application for decommissioning

Safety demonstration: *documents*, *tasks*, and ***argumentation*** intended to demonstrate that the safety of a system and/or related activities are sufficiently taken care of.



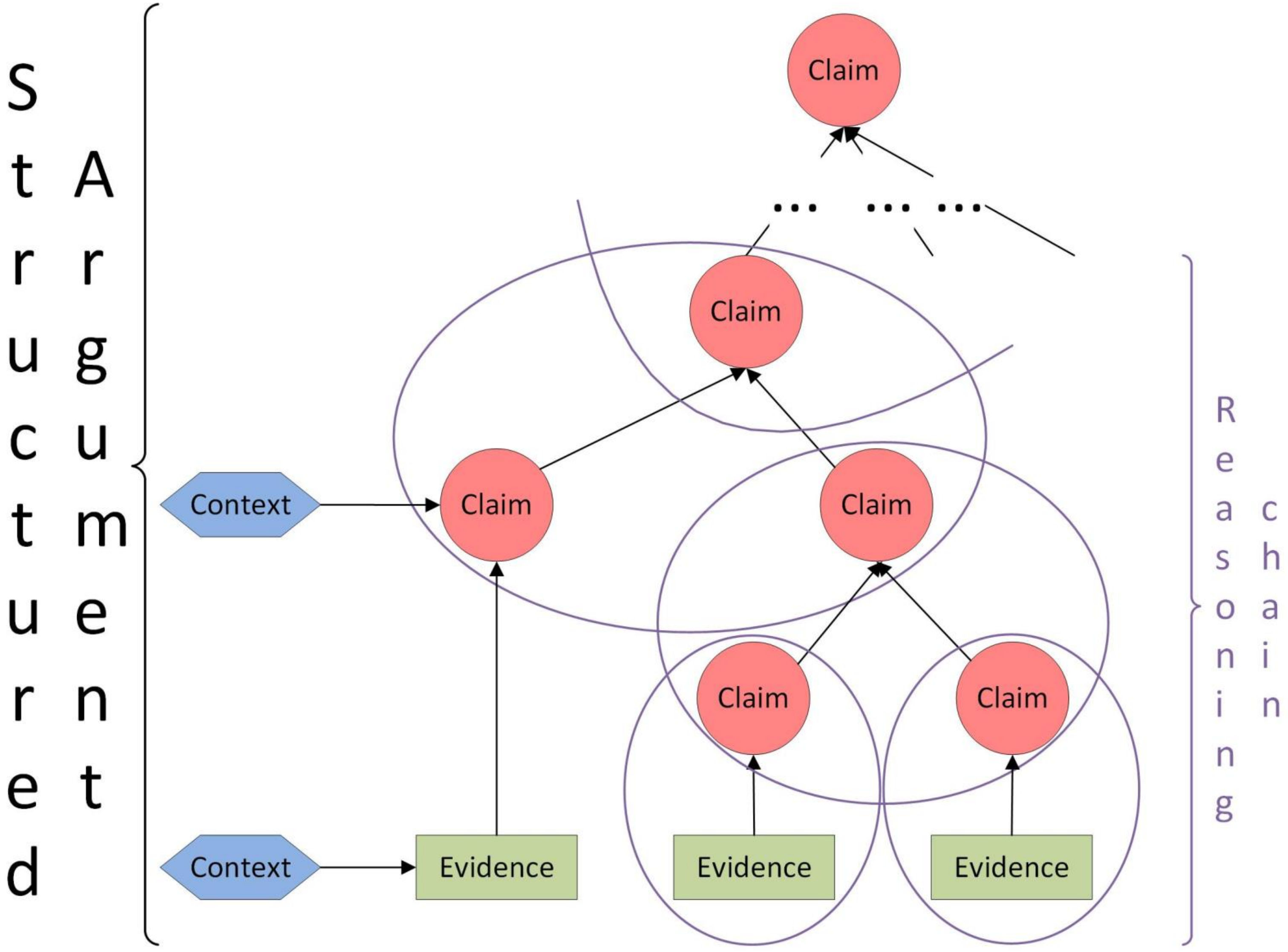
Structured safety arguments

Safety demonstration is usually presented as a set of linear, natural language documents in pdf.

Structured safety arguments can be used to present the relevant information and its logical structure explicitly.

- Better assessable
- Supports communication between parties
- Improves safety
- Reduces regulatory uncertainty
- Saves costs

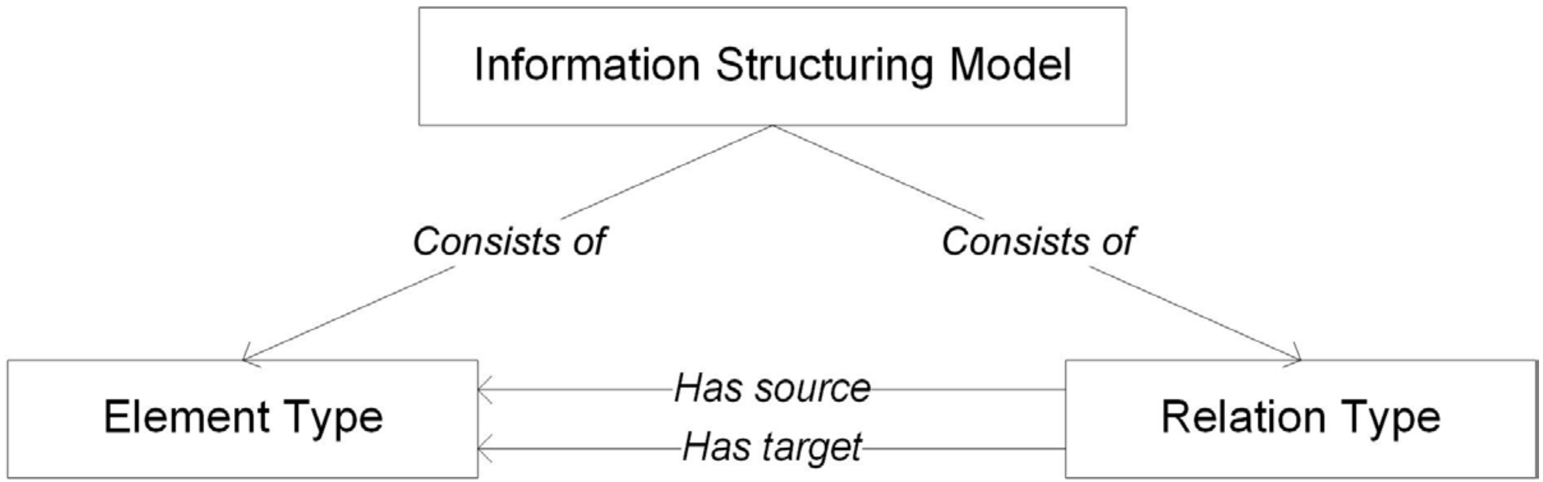
Basic model of structured argument



2. Tool support for information structuring: InStrucT

- Information structuring – usual generic case
  - *Input*: mixed information, linearly presented (e.g. in pdf)
  - *Process*: extracting the important pieces, categorizing and organizing them according to a goal
  - *Output*: categorized and interrelated information pieces
- Motivation
  - Helps pinpointing unclear parts and missing information
  - Helps avoiding/reducing misunderstandings
  - Helps communication and discussion
  - Reduces related risks and thus costs

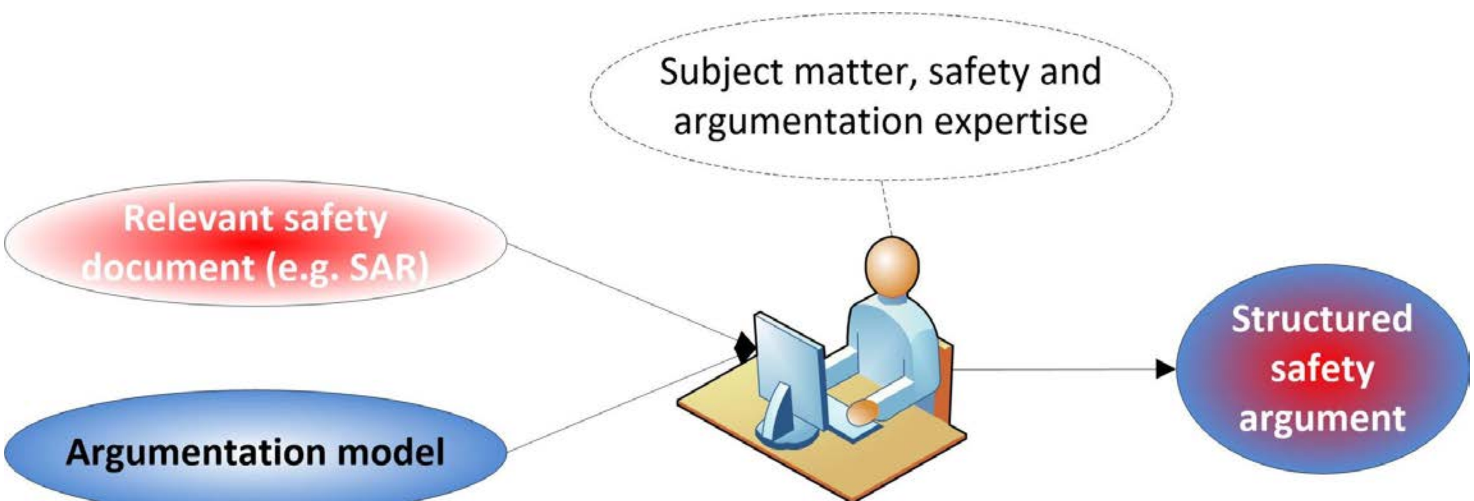
Information structuring model



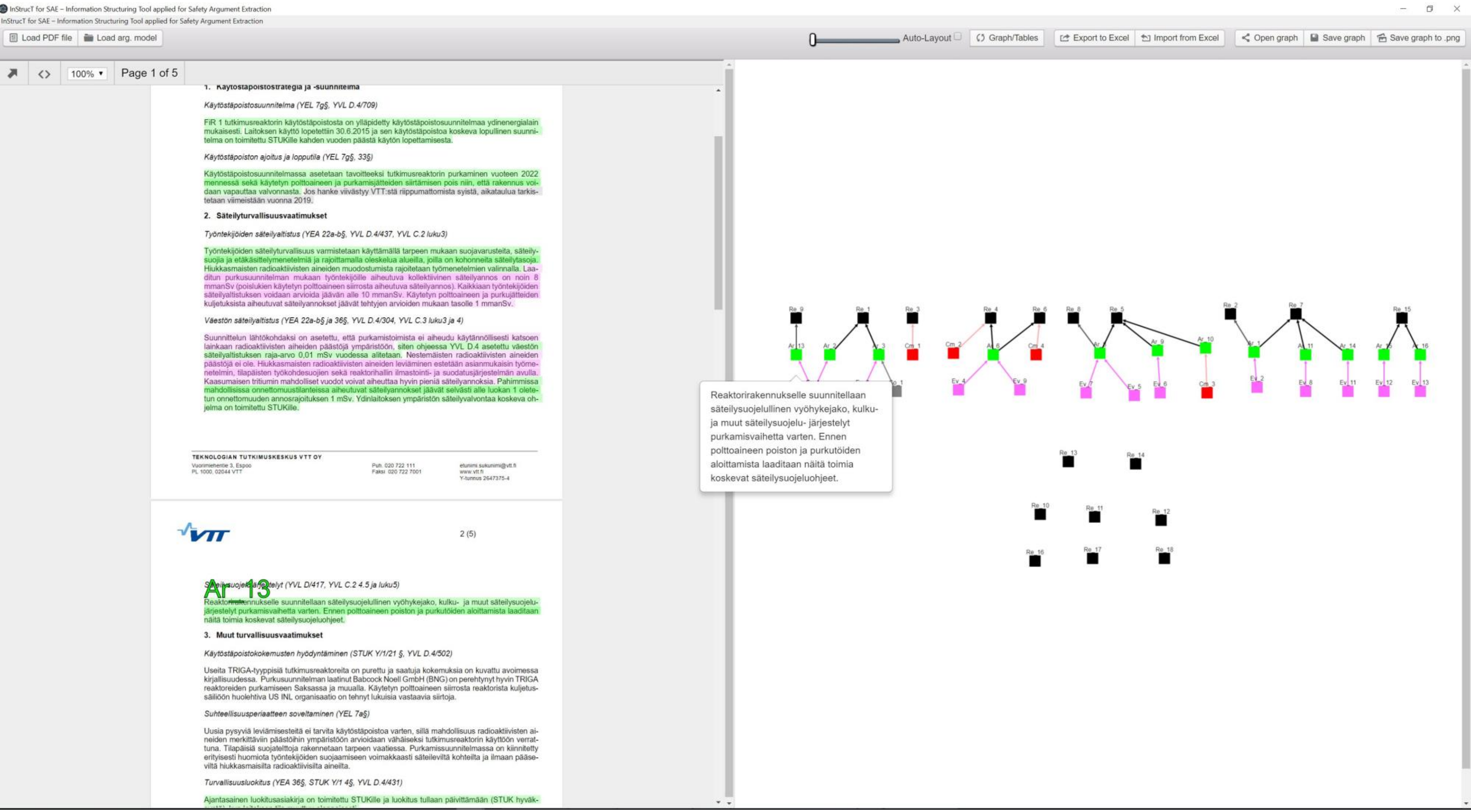
- *Element Type*: categories to group and tag the same kind of information pieces
- *Relation Type*: links between categories representing the nature of their relations

InStrucT: Information Structuring Tool

- Prototype
- Used in 2 case studies to create safety arguments (reasoning structures)
- Functionality
  - Organising and structuring information according to *pre-defined categories and relations* between them



InStrucT in use (decom. case)



Main functionalities of InStrucT

- *Reading* one *pdf* document and an information structuring model description
- *Tagging* continuous text parts in pdf-s
- Presenting the structured information graphically as a *directed graph,* or as a *table*
- Creating *freely definable nodes and rel*ations
- Saving and loading extracted information structure as a *graph* (*keeping links* to the pdf)
- Saving and loading extracted information structure as a *table* (*loosing links* to the pdf)

InStrucT Viewer

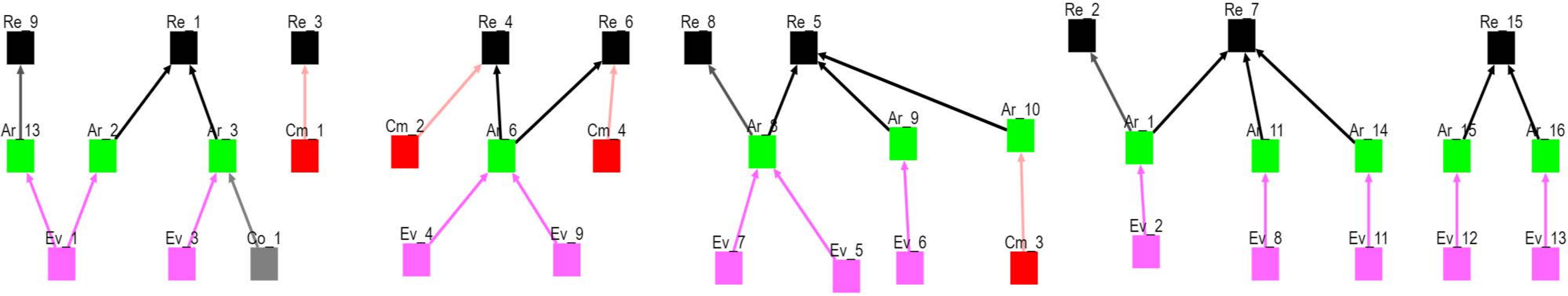
- Goal: to be able to share an information structure with another party for viewing without the need to install InStrucT
- The graph created in InStrucT can be viewed through this online viewer
- The owner of the graph has to share the graph and the related pdf document with the targeted person
- Ready but needs testing yet
- Web address

  http://instruct-viewer.hrp.no/

3. Application for decommissioning

- In cooperation with VTT in Finland
- Case
  - Research reactor FiR 1 in Espoo, Finland
  - The reactor is currently in permanent shutdown state, and VTT's license application for decommissioning is under review by Finnish authorities
- InStrucT was used for
  - Stage 1 – regulatory documents
    - Extracting and analyzing regulatory requirements
  - Stage 2 – applicant documents
    - Analyzing a part of the decommissioning license application
    - Defining the reasoning structure how parts of the license application fulfill the regulatory requirements from Stage 1

Illustration of the case study in 7.1



- Back rectangles: requirements from the regulations
- Purple rectangles: pieces of evidence from the license applications
- Green rectangle: arguments from the license applications, how the evidence show that the requirements are fulfilled
- Red rectangles: comments, remarks from the user
- Grey rectangles: context from the license application

Future sights

- Handling of multiple documents
- Tagging of documents (not just their context)
- Communication support for stakeholders
- Integration/extension into an information management system
  - Interrelated, queryable information
  - Change management
  - Traceability
  - Filtering of information
  - Pre-defined views/perspectives (e.g. safety argument, decommissioning plan, cost estimate, etc.)
  - Multi-media capable (e.g. safety argument integrated in a 3D scenario)

Thank you for your attention!

Questions?

Peter.Karpati@ife.no

Reserve slides

+1. Barriers to assuring of autonomous systems

- Based on the Assuring Autonomy International Programme at University of York
  - https://www.york.ac.uk/assuring-autonomy/
- Scope: assurance of Robotics and Autonomous Systems (RAS)
- Critical Barrier to Assurance and Regulation (C-BAR) is a problem that must be solved for a particular system or domain, in order to avoid one or more of the risks presented next.

Risks (to be avoided by coping with C-BARs)

- a safe system cannot be deployed (losing the benefit of the technology)
- an unsafe system is deployed (lack of clear evidence to assure operation)
- the adoption of safe technology is slow
- there is a lack of progress in adoption in a particular domain
- the level of accidents and incidents leads to a backlash

C-BARs

- Adaptation – of behaviour in operation
- Bounding Behaviour – safe operation within known bounds
- Cross-Domain Usage – known to be effective in one domain, how can it be assessed for adequacy in another environment
- Explanations – of decisions made by a RAS
- Handover – handing (back) control to a human
- Human-Robot Interaction – in sight of potential for physical harm to humans
- Incident and Accident Investigation – information needed to be provided to support incident/accident investigations

C-BARs – cont.

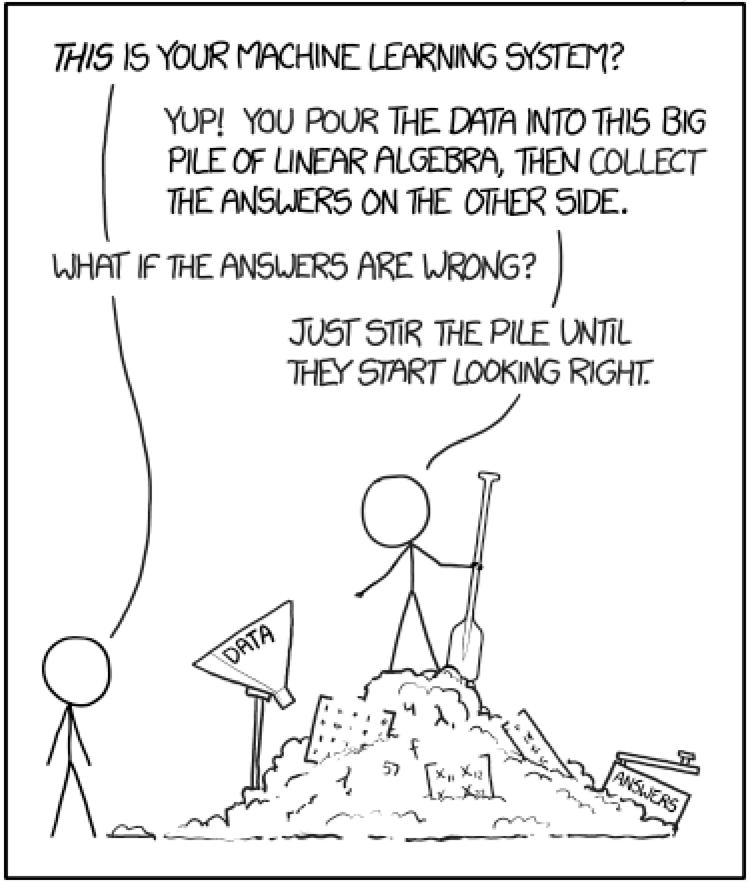
- Monitoring – retain sufficient levels of attention and concentration of operators
- Risk Acceptance – how can risk be estimated, communicated and accepted?
- Role of Simulation – how can it enable assurance and regulation, and when does it provide sufficient evidence to allow controlled use of the RAS?
- Systems of Systems –when given SoSs which are ‘individually safe’ how can safe interaction be assured, in their intended operational environment?
- Training and Testing AI – how can it be shown that the training sets (and test sets) give enough coverage of the environment to provide sufficient evidence (in itself or in combination with other means of V&V) to allow controlled use of the RAS?
- Validation & Verification – effective means of RAS/AI V&V

Application of Machine learning

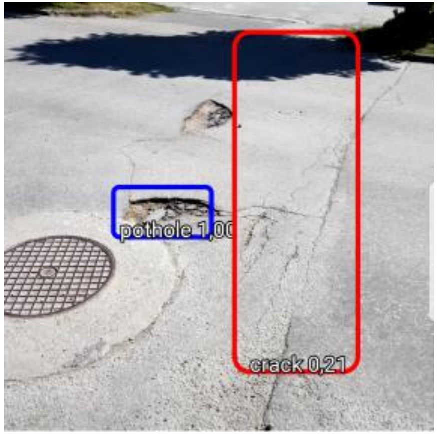
Jens-Patrick Langstrand (DS - AUM)

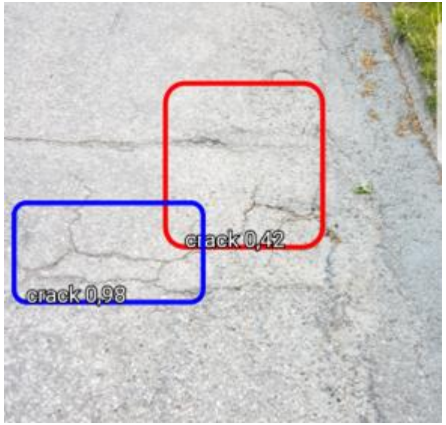
Machine Learning

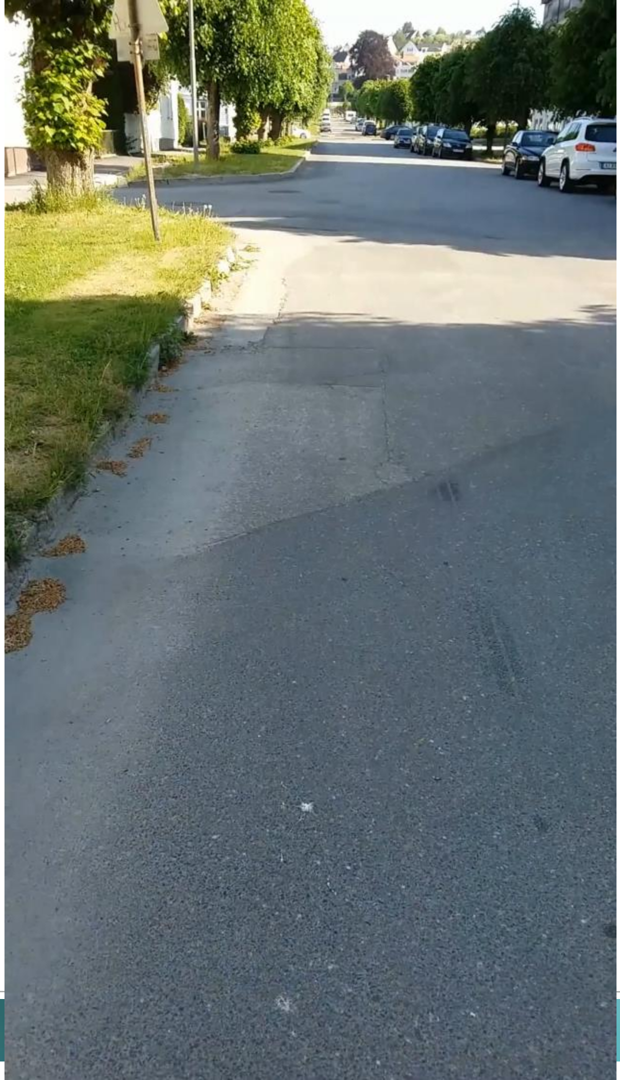
- Uses data to learn without explicit programming
- Tries to estimate a function that maps input to output data
- Use test data to verify that the model can generalize to unseen data
- Output labels, real values or actions depending on the task
  - Classification, Regression, Reinforcement Learning



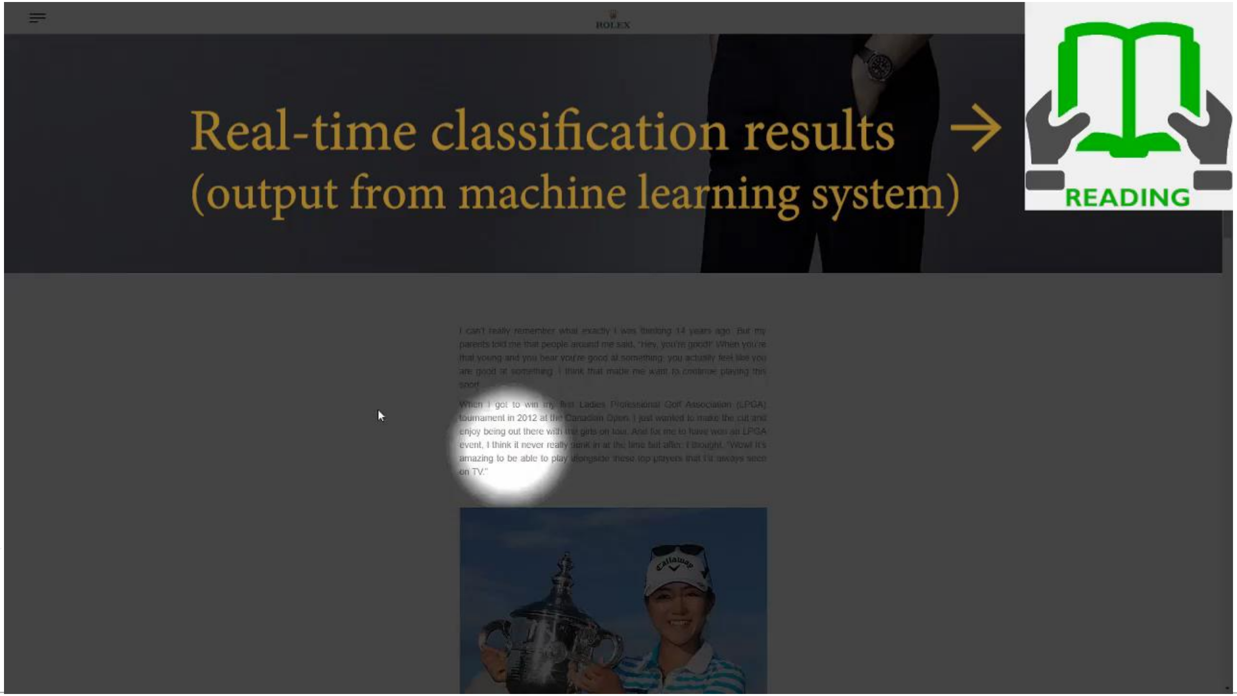
Road Damage Detection Model







ReClass


ROLEX
Real-time classification results →
(output from machine learning system)
READING

Supervised Learning

- Train using a labelled dataset with input and output pairs
  - E.g. Rust detection

Rust

No Rust

- Use the trained model to know if an image contains rust or not
- Great when large amounts of **labelled** data is available

Supervised Learning

- Visual inspection of the quality of produced radiopharmaceuticals

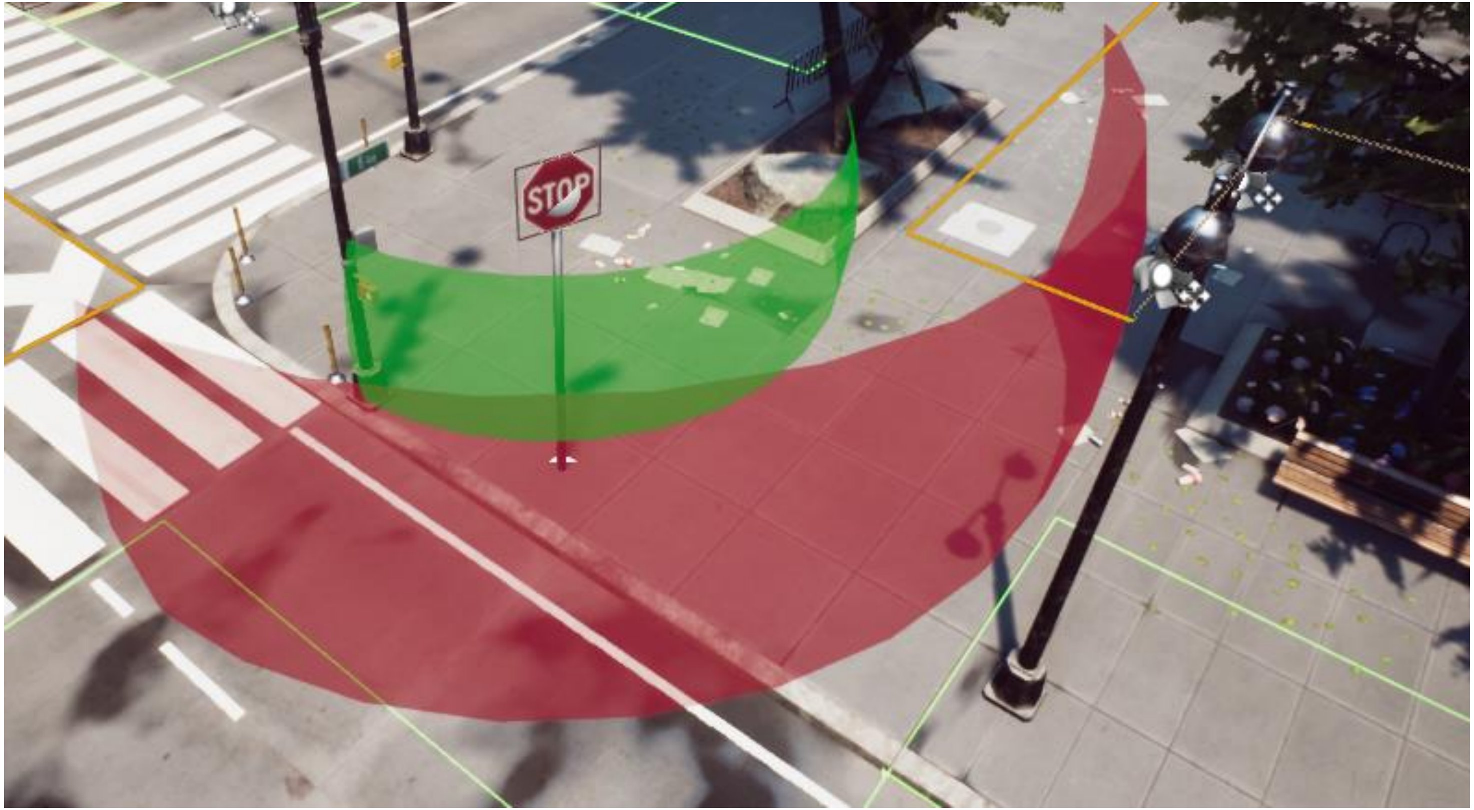
The need for data

- Supervised learning requires a substantial amount of **labelled** data
  - Collected/Generated
  - Labelled
  - Cleaned/Processed

AI Bench: Training AI models in Virtual Reality

Define camera paths to take sample photos

The application automatically labels the training sets



You can vary environmental conditions

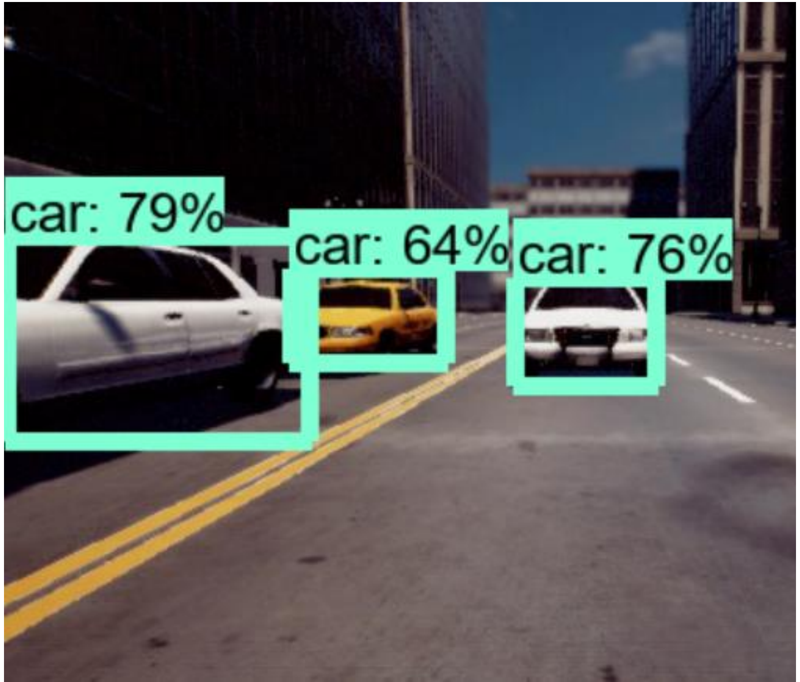
Classification outputs

Virtual

Real

Classification outputs

Virtual



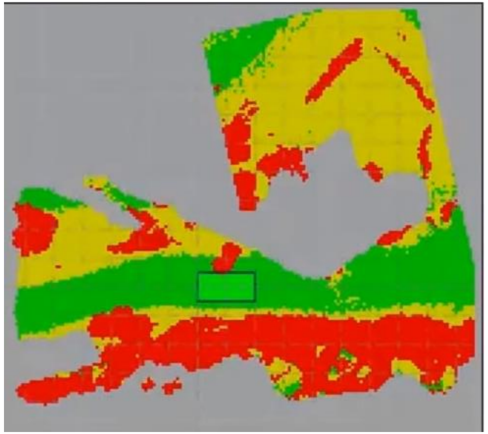
Real

Reinforcement Learning

- Actions, Goal
- Penalty / Reward based learning
- Learn through feedback
- Great if you have a safe environment to explore (driving track, simulated environment).

Reinforcement Learning

- Teach a machine learning system to control a robot and move it in an environment in order to take measurements of radiation levels and map out radiation in the environment.
- Teach the system to avoid areas with high radiation levels by penalizing it for being in those areas.



Questions?

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C-BARs

- Adaptation – of behaviour in operation
- Bounding Behaviour – safe operation within known bounds
- Cross-Domain Usage – known to be effective in one domain, how can it be assessed for adequacy in another environment
- Explanations – of decisions made by a RAS
- Handover – handing (back) control to a human
- Human-Robot Interaction – in sight of potential for physical harm to humans
- Incident and Accident Investigation – information needed to be provided to support incident/accident investigations

C-BARs – cont.

- Monitoring – retain sufficient levels of attention and concentration of operators
- Risk Acceptance – how can risk be estimated, communicated and accepted?
- Role of Simulation – how can it enable assurance and regulation, and when does it provide sufficient evidence to allow controlled use of the RAS?
- Systems of Systems –when given SoSs which are ‘individually safe’ how can safe interaction be assured, in their intended operational environment?
- Training and Testing AI – how can it be shown that the training sets (and test sets) give enough coverage of the environment to provide sufficient evidence (in itself or in combination with other means of V&V) to allow controlled use of the RAS?
- Validation & Verification – effective means of RAS/AI V&V

Updating the Decommissioning Plan of the Loviisa NPP

Matti Kaisanlahti

Chief Engineer, Decommissioning

Join the change

fortum

Bases

- Feedback from previous update
  - Description of decommissioning organization
  - More accurate description of working phases
- Other research
  - Decommissioning strategy comparison
  - Construction of final disposal facility
  - Decommissioning waste characterization
  - Decommissioning cost update

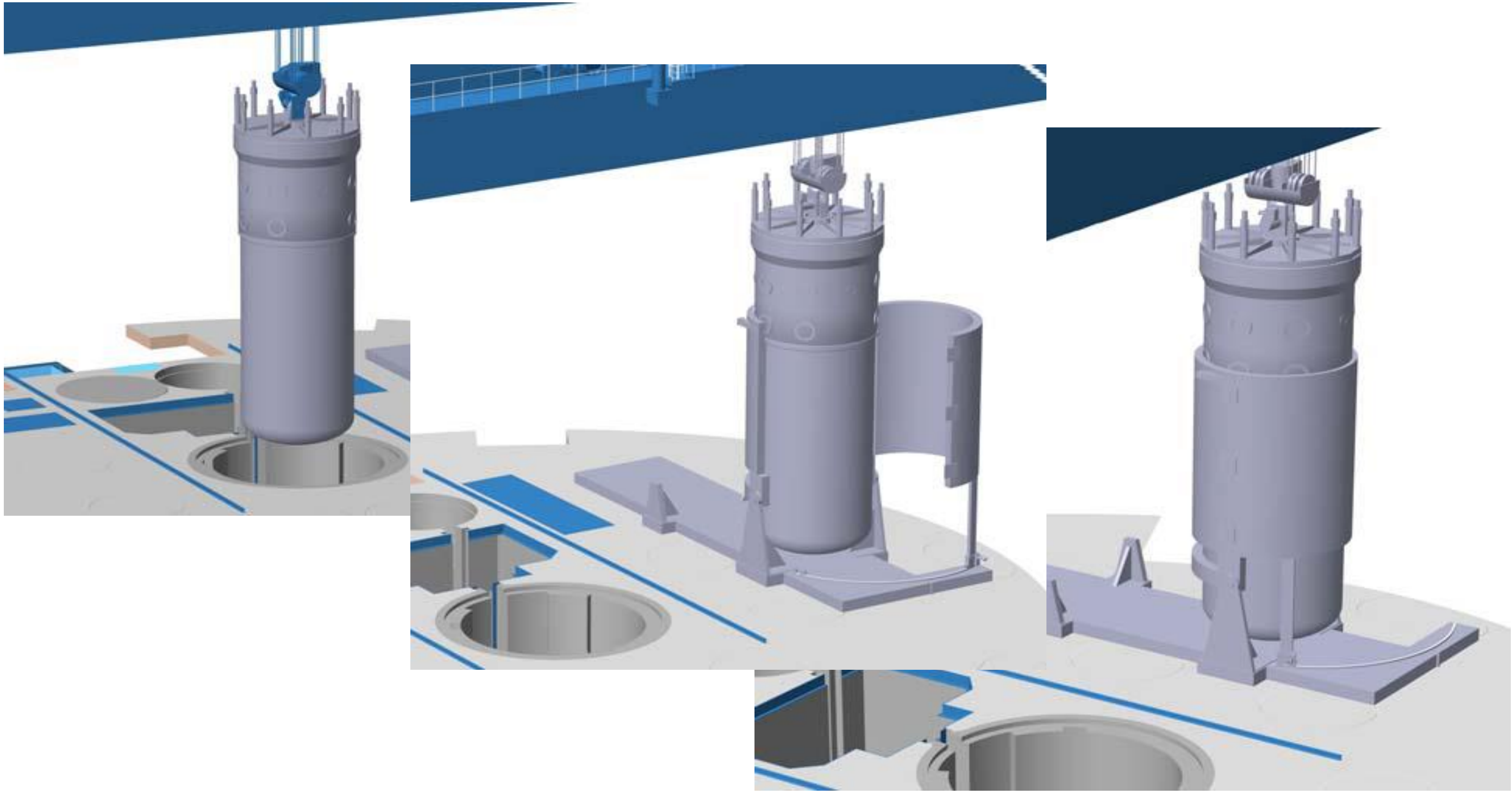
Decommissioning strategy comparison

- Immediate dismantling with fuel casks, immeadiate dismantling with fuel pools and deferred dismantling were compared
- Immediate dismantling with fuel pools was chosen
  - Used fuel is allready stored in fuel pools
  - The operating personnel can be used for decommissioning
  - There is no other activities in the plant site

The characterization of decommissioning waste

- The decommissioning waste differs from operational waste
  - The methods used in operating time has to be updated
  - The waste volume is higher
  - The waste items are bigger
  - New waste packages will be used
- Updating waste characterization plan
  - Measurement plan for waste items
  - Measuring equiment
  - Logistic plan for waste handling

Lifting of the reactor pressure vessel 1/2



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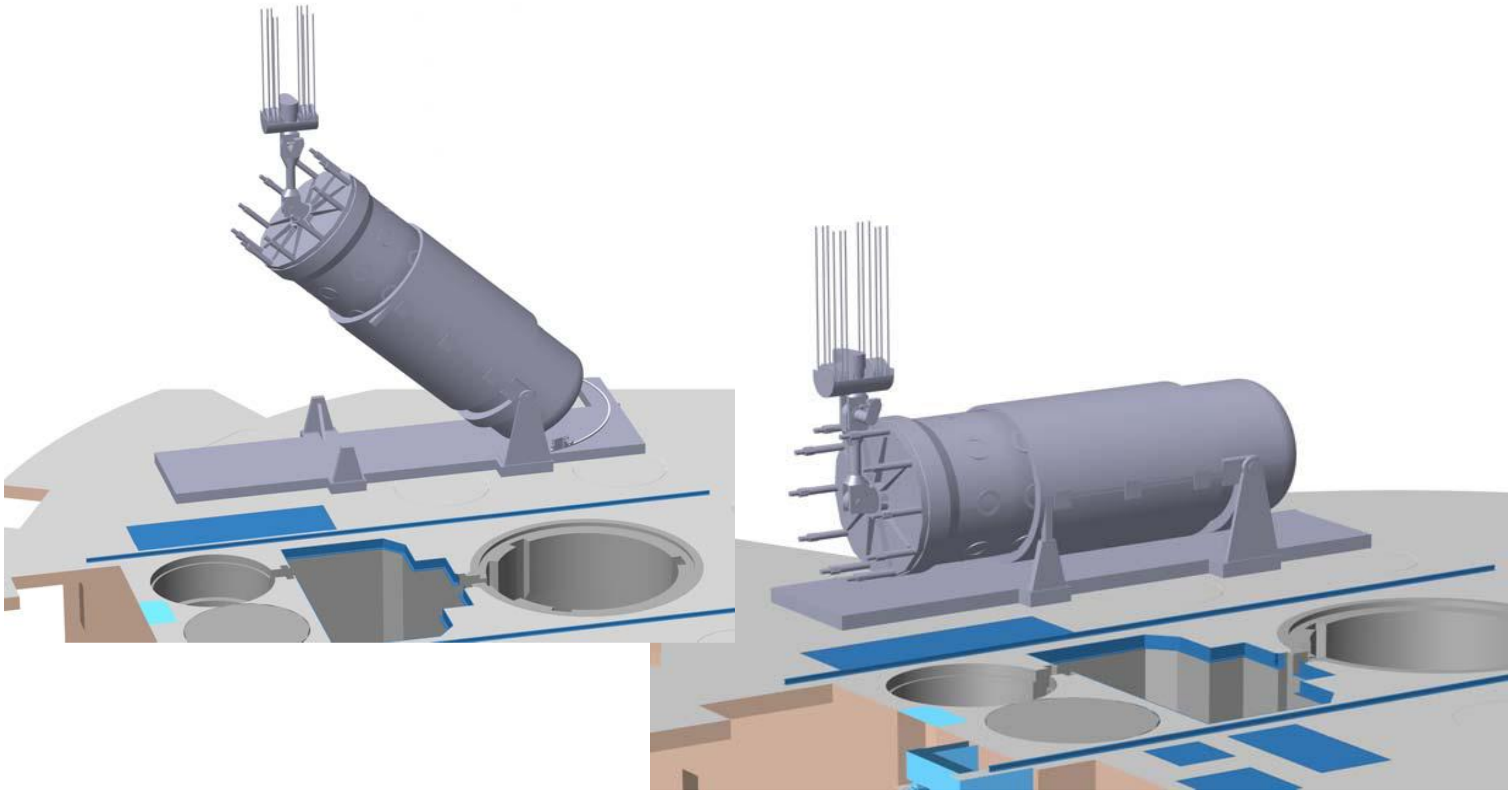
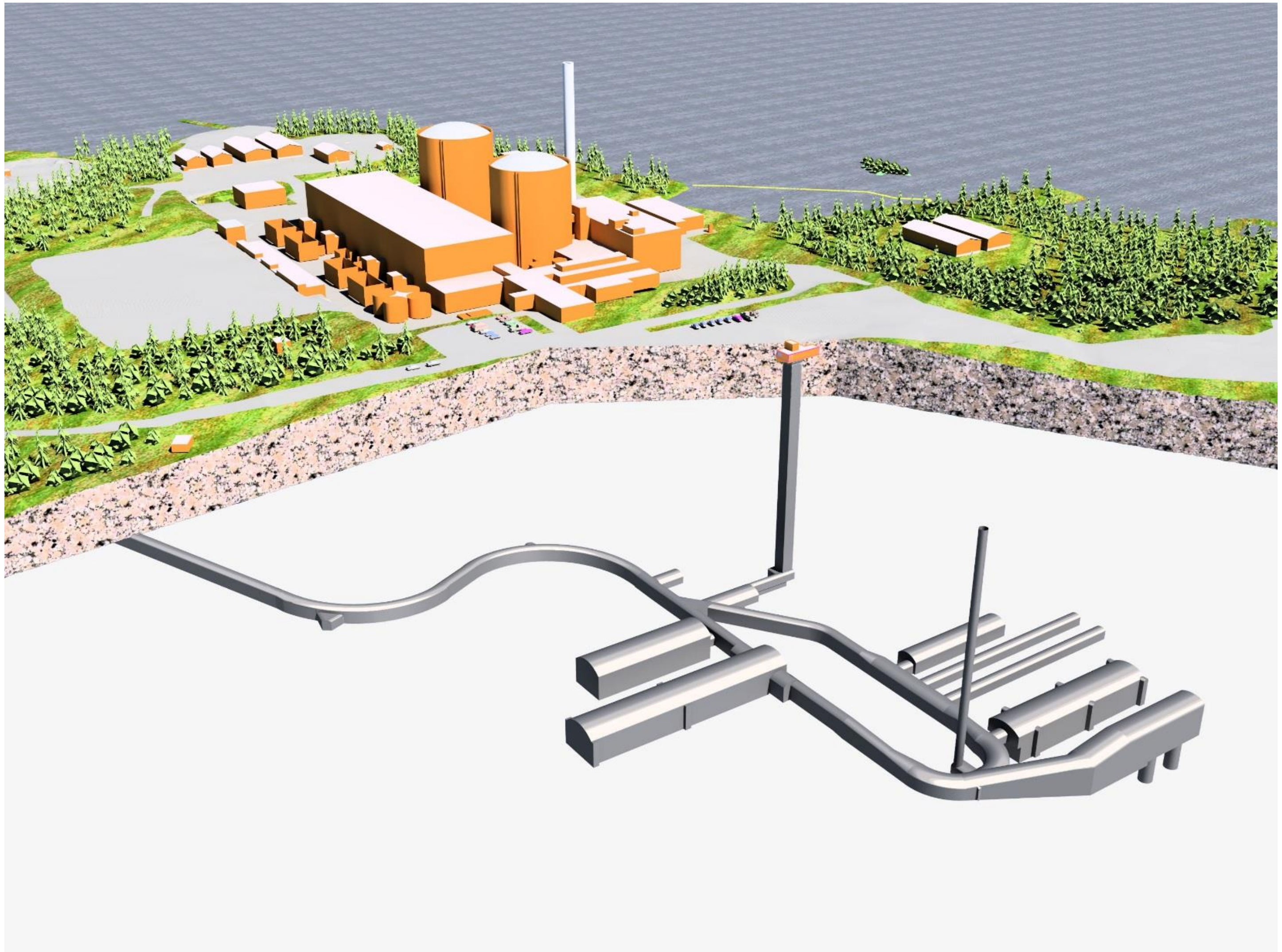
Lifting of the reactor pressure vessel 2/2

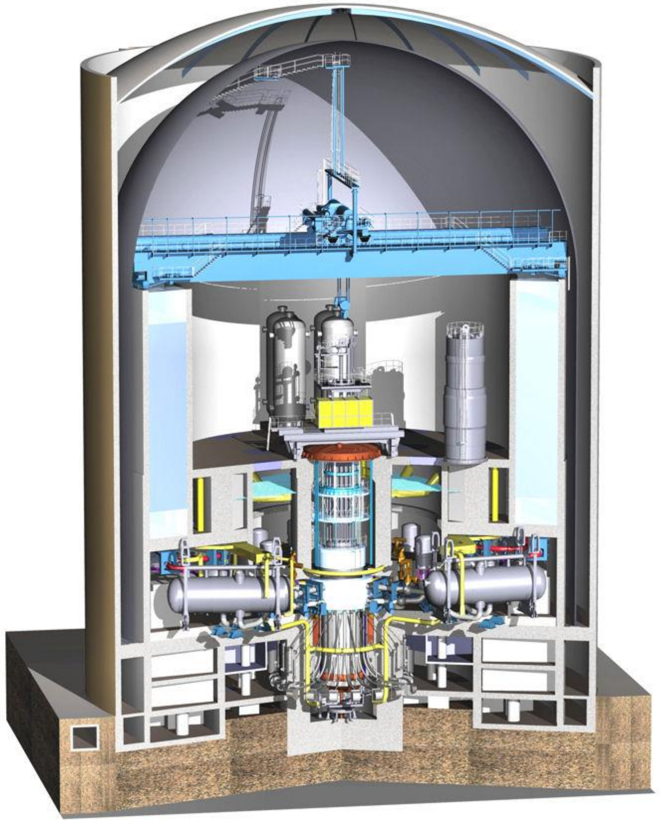


Final disposal



New technologies for decommissioning planning

- Virtual simulations for working phases
  - Developing working methods
  - Lower dose rates
  - Better time schedule planning
- 360 videos from the plant
  - Visiting in the plant is possible everywhere
  - Developing working methods
  - Outages and decommissioning
- Laser-scanning
  - 3D modelling



Cost Estimate

- Decommissioning funding and cost estimate is limited to radioactive structures, systems, and components only.
- Decommissioning cost estimate is based on decommissioning work plan, estimate of workload and budget offers from service providers.
- Real construction and operational costs of LILW repository are used for disposal cost estimates.
- Labour costs are dominating the decommissioning costs, covering almost 80% of the total decommissioning costs, if the subcontracted work is taken into account.
- Own disposal facility on-site

Decommissioning costs of Loviisa 1 and 2 reactors	Costs (M€)
Preparatory works	47
Main equipment, constructions and material	20
Dismantling work	136
Waste treatment and disposal	33
Other costs including Fortum's on-site personnel and insurances	120
Total costs	356
Reservation 10%	36
Total costs with reservation	392

fortum

Thank You

Cyber security

consideration for advanced technology based support systems

OECD-HRP/NKS decommissioning workshop – 6-7 December 2018, Lillehammer

André Alexandersen Hauge
on behalf of Bjørn Axel Gran, Vikash Katta
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IFE Digital Systems
Research for a better future

Why consider risk, safety and security?

- Lack of well defined and tested requirements for the support system
  can lead to unforeseen downtime and inefficient services.
- Lack of safety and risk assessment
  can lead to hazardous incidents working with high energy sources.
- Leak of sensitive data
  will potentially be breach of laws and regulations, and
  will undermine the trust in the services.
- Manipulation of data or denial of service attacks
  will besides having costs, also undermine the trust in the services.

IEC 61508 about cybersecurity

Functional safety of electrical/electronic/ programmable electronic safety-related systems –

Reference to:

- IEC 62443 series
- ISO/IEC/TR 19791

- requirement 7.4.2.3:
  - "If the hazard analysis identifies that malevolent or unauthorised action, constituting a security threat, as being reasonably foreseeable, then a security threats analysis should be carried out"
- requirement 7.5.2.2
  - "if security threats have been identified, then a vulnerability analysis should be undertaken in order to specify security requirements"
- the safety manual
  - "details of any security measures that may have been implemented against listed threats and vulnerabilities."

Security assessment

Step1: **Value**

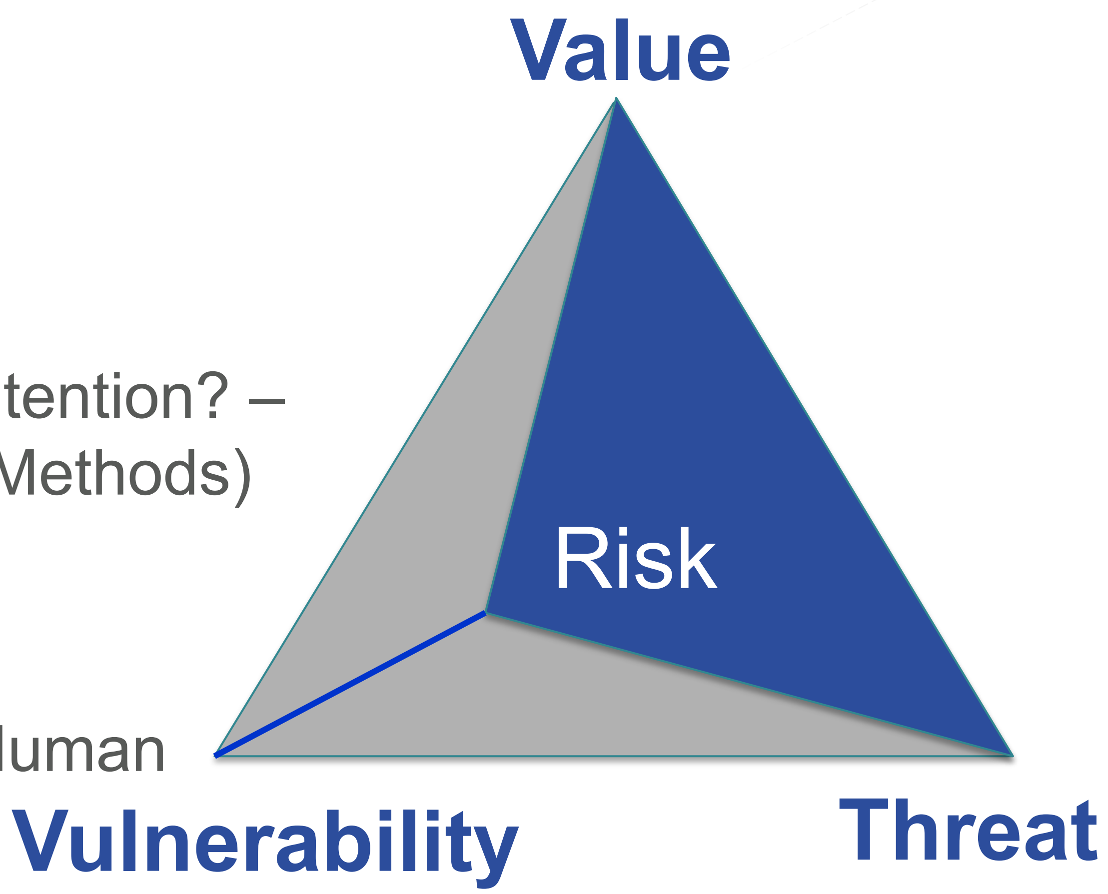
Which values/assets do you have?

Step 2: **Threats**

What are the actors capacity and intention? – (4M: Motivation, Mission, Mindset, Methods)

Step 3: **Vulnerability**

Physical, Logical, Organizational, Human



«See it coming: The Four M's of Digital Espionage»

Ref:

Frode Hommedal

On LinkedIn 21. sep 2014

Former: Senior Advisor Difi

Now: Cyber security specialist, Telenor

- Motivation

  «These «viruses» are security incidents, and the results of deliberate actions from hostile entities»

  «Spying on you gives the threat actor – your adversary – some kind of advantage over you, or someone else through you»

- Mission

  «They are highly trained professionals – cyber special forces so to speak – who have been purposely deployed within the perimeters of your network»

- Mindset

  «How can we subvert this» and «what can we make this do», «how can we break into it» and «how can we hide within it».

- Methods

  «The list of methods employed by the wide range of possible cyber adversaries is way too long for me to even contemplate compiling»

Didn't see this coming: Short on the Maersk story

full text at wired.com «THE UNTOLD STORY OF NOTPETYA, THE MOST DEVASTATING CYBERATTACK IN HISTORY»

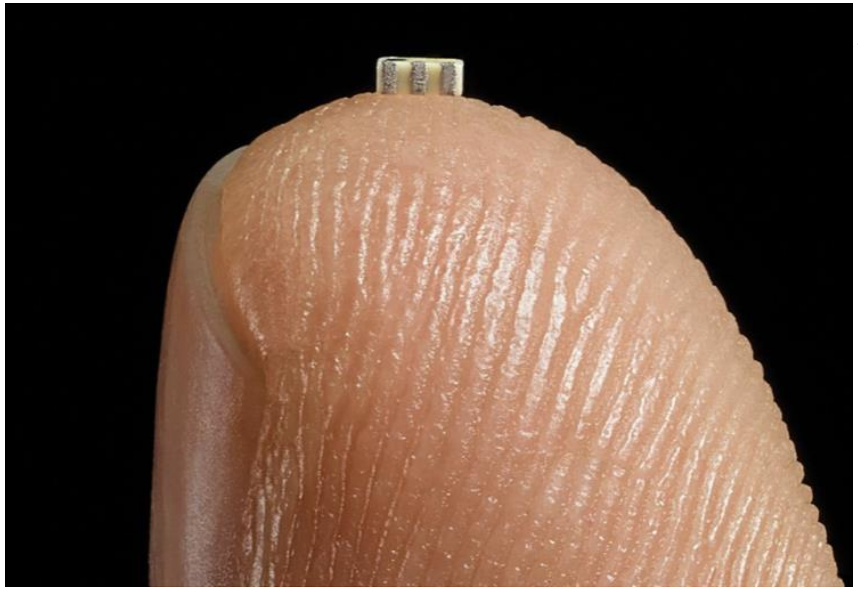
- 27 june 2017, the **NotPetya** virus run through Maersk systems in Copenhangen
- Started with **"repairing file system on C:"** on office machines with a stark warning not to turn off the computer and also **"oops, your important files are encrypted"** and a demand of $300 worth of bitcoin to decrypt them. Then, a wave of screens started turning black at the Maersk headquarters
- **Ground zero was actually Kiev** office in Unkrain, an attack that began, at least, as an assault on one nation by another. Russian cyber agents known as Sandworm used a Windows back door to release a piece of malware called NotPetya to different targets.
- It **irreversibly encrypted computers' master boot records**, the deep-seated part of a machine that tells it where to find its own operating system
- It **crippled multinational companies** including Maersk, pharmaceutical giant Merck, FedEx's European subsidiary TNT Express, French construction company Saint-Gobain, food producer Mondelēz, and manufacturer Reckitt Benckiser. In each case, it inflicted nine-figure costs. It even spread back to Russia, striking the state oil company Rosneft.
- The result was more than **$10 billion in total damages**

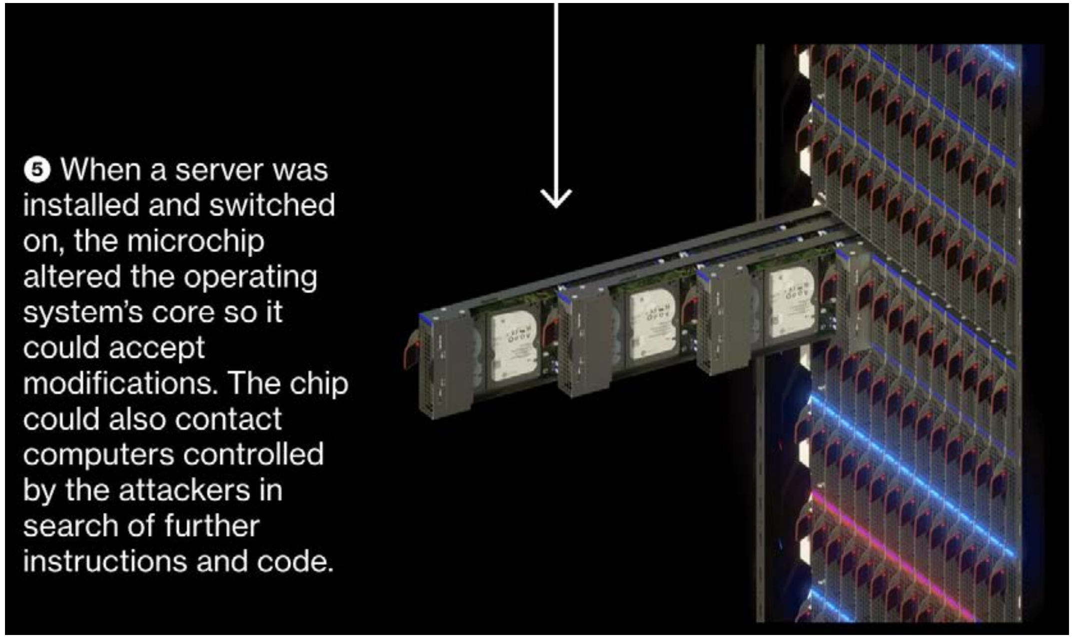
Any assets in decommissioning?

- Examples:
  - Man down – there is a need to not share position & video to outsiders
  - Radioactive materials - there is a need to not share data to outsiders
  - Sensitive data – should not be shared with outsiders
  - Critical data/procedures – signals sent from app. A to app. B shall not be corrupted
  - Critical data/procedures – signals sent from app. A to app. B shall not be delayed
  - ..
  - AND: your advanced technology based support systems

The Big Hack (full text at bloomberg.com)

- Amazon started investigating Elemental in 2015
- Elemental's staff boxed up several servers and sent them to Ontario, Canada, for the third-party security company to test. Servers were assembled for Elemental by Super Micro Computer
- The testers found a tiny microchip
- Elemental's servers could be found in Department of Defense data centers, the CIA's drone operations, and the onboard networks of Navy warships. And Elemental was just one of hundreds of Supermicro customers.
- Investigators found: The chips had been inserted during the manufacturing process (Made in China)





Is cyber a problem?

- The process is not connected.
- And if it is, they can not stop it.
- .. and other system protect the people from harm.


SYSTEM FAILURE

It is a problem!

- *My process is not connected.*
- *And if, they can not stop it.*
- *.. and other system protect the people from harm.*

- They studied the design
- … studied the vulnerabilities
- … used it for a DoS
- … and gained 1M$ on their stocks

The RiskBIM concept

or at least some thoughts for a concept

OECD-HRP/NKS decommissioning workshop – 6-7 December 2018, Lillehammer

André Alexandersen Hauge
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IFE Digital Systems
Research for a better future

Outline

Some bits about the current practice within railway working with RAMS
and future directions,
and relevancy for decom

- The Law
- The Practise
- The Future
- The Decom link

The Law: EN 50126-1 about RAMS within railway

- Requirement 7.4.2.1: Risk Assessment
  - "…structured process for …identifying undesired events…the causes….control measures…in case of explicit risk estimation then identify frequencies…consequences"
- Requirement 7.4.2.2 Hazard Log
  - "A hazard log shall be established as the basis for on-going risk management for safety…."

Reference to:

- EN 50126/8/9 series, CENELEC

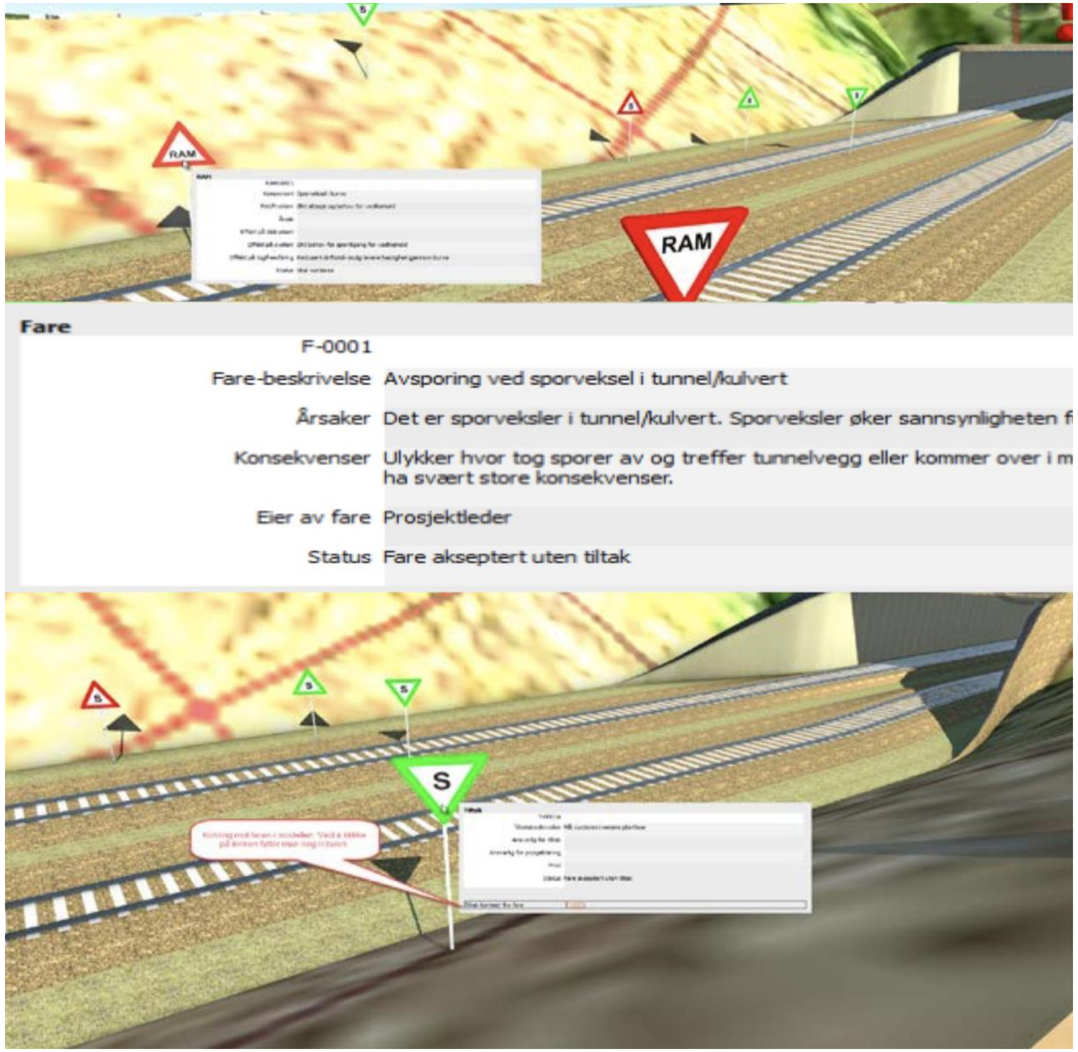
The Practice

Illustrations from Bane NOR in f-b.no 27. Nov 2018

New station and tracks in Fredrikstad

The Practise

- All engineering fields define their solution with BIM (e.g. track, electro, signalling, water, geology,...)
- All engineering models are combined into one and assessed
- RAMS uses the information within the model for system definition and assessments
- Results from RAMS assessments are not (some few exceptions) shown in the model, managed separatly



The Future

Have applied to NFR for funding a project named **RiskBIM**, focusing on developing BIM capabilities supporting RAMS and risk management within transport

Partners: Bane NOR, SVV, COWI, Multiconsult, IFE, NTNU

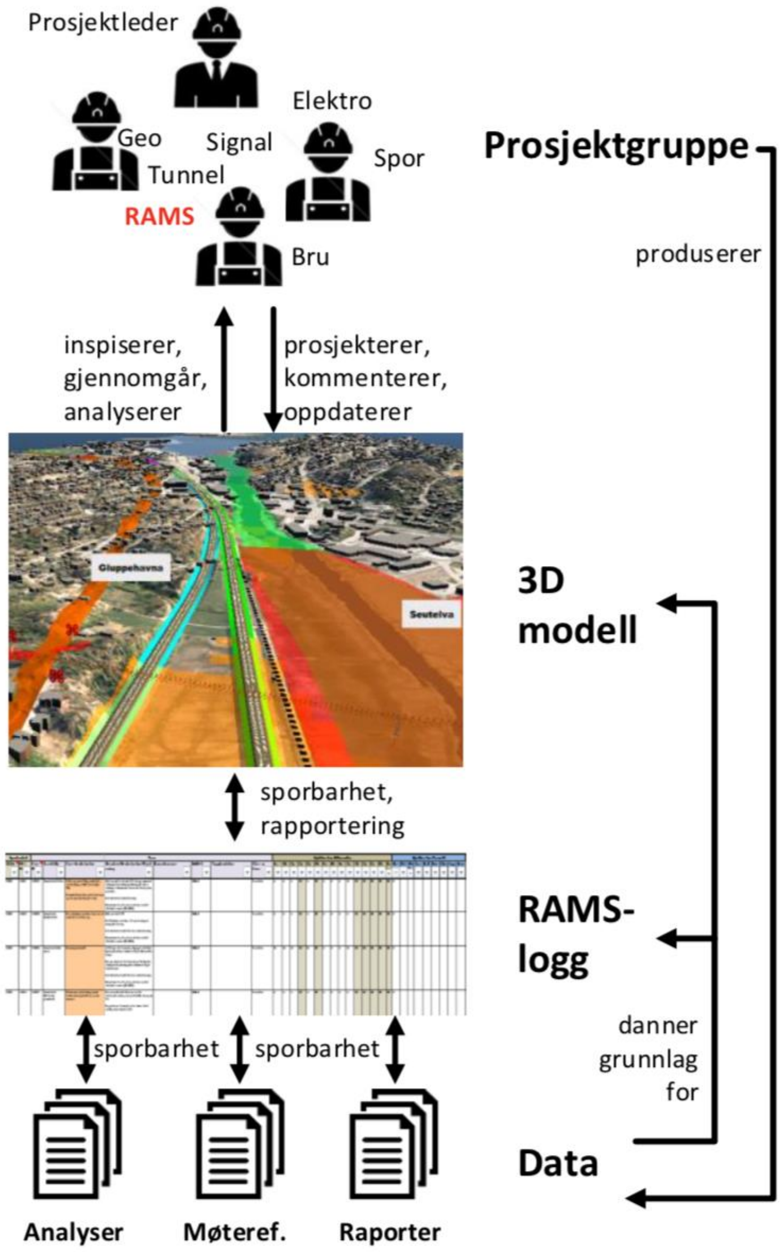
Budget: 15 MNOK, requested funding 7MNOK

Partners clearly express that within road and railway solutions development in Norway the BIM environment is the main platform for expressing and developing their solutions and that proper RAMS, SHA and Risk support is absent.

In Jan/Feb 2019 we know if application receives NFR support

The Future

- RAMS info in BIM models, need better visualisations and new interaction for RAMS in BIM
- BIM integrated with Hazard Log
- Quicker information loops between development and RAMS, more lean process
- Advanced methods in BIM, e.g. supporting automatic/semi-automatic assessments or requirements verification
- New ways of information exchange and cooperation, new methods and work processes



The Future

- Turning from static analysis in the format of documents into digitalised, flexible, dynamic and connected to models
- Semi-automatic and automatic analysis
- Looking at the uses of VR and AR for simulation and training
- New work processes and information sharing
- Holistic risk picture, risk visualisation, risk awareness, decision support

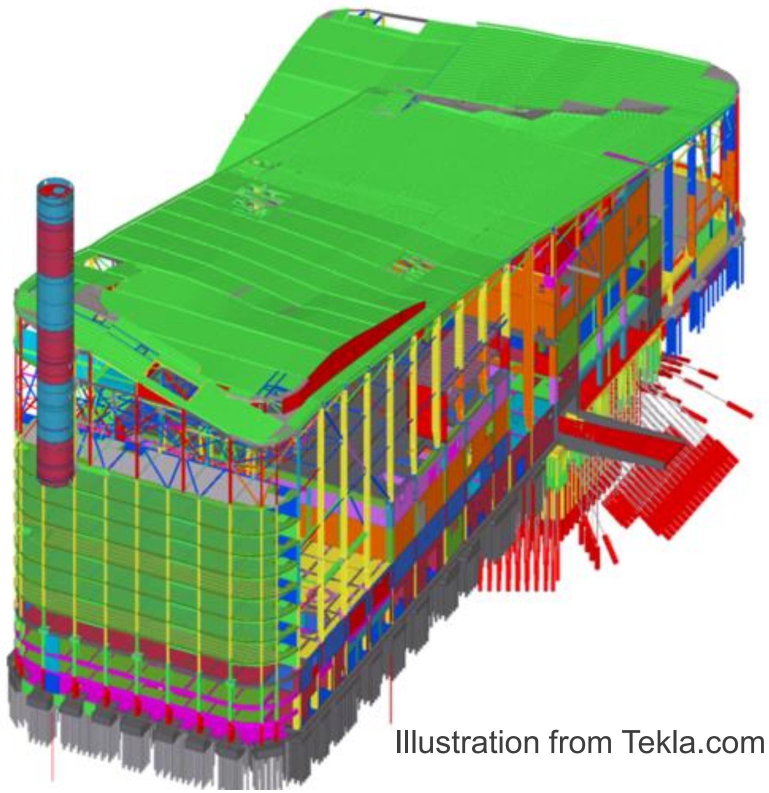


Illustration from Tekla.com

The Decom link

Each step of the process includes risks that must be adressed whether we build something up or something down

RiskBIM addresses road and rail development. It´s other kinds of risks. The general process and the methods used still has many similarities

We all need powerful tool support for risk management and maybee some changes in the work processes

Digital Systems

Automated Compliance Checking for Layouts:

Knowledge-based evaluation of layouts 2009–2011
Validation of Use of Virtual Prototypes for Control Room Verification and Validation 2012–2014

Morten A. Gustavsen
Michael N. Louka

Objectives

- Develop a spatial evaluation method that can be used to define sets of tests to support knowledge-based evaluation of a 3D layout
  - Use-cases include
    - Review of control centre ergonomics
    - Operations and outage planning
    - Decommissioning

Knowledge-based Spatial Layout Evaluation

- Method based on encoded knowledge
  - Properties of things/people in a virtual layout (ontologies)
  - Design rules (required/desirable) to check against
    - Design patterns to aim for and anti-patterns to avoid
- Represent guidelines and/or requirements as rule-based tests (e.g. based on NUREG-0700)
  - Tests can be executed by an analysis tool
  - Tests are reusable/repeatable
- An evaluation or review comprises of a set of reusable tests

Objective: Accuracy

- Rules combined with scene analysis techniques
  - More consistent and accurate results
  - Faster repetition of tests while maintaining accuracy

POINT	DESCRIPTION	YES	NO	NA	REFERENCE TO DOCUMENTATION	COMMENTS/RECOMMENDATIONS	RESP.
1.4.8	Can the operator get in and out of the chair at the workplace freely? *Minimum requirements for operator manoeuvring space are approximately 760 mm laterally ("sideways") and 915 mm from the edge of the desk to any opposing surface ("backwards"). Ref. Figure 4.3, inspired by NUREG0700*					NUREG 0700, rev 2, 12.1.1.3.5 DC: NORSOK S 002, REV 4, Annex C. *The chair should be able to be rotated to allow easy access - at least 180 degrees.*	

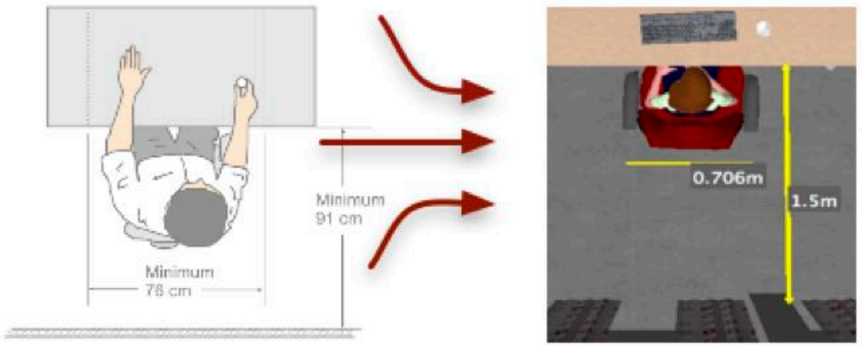


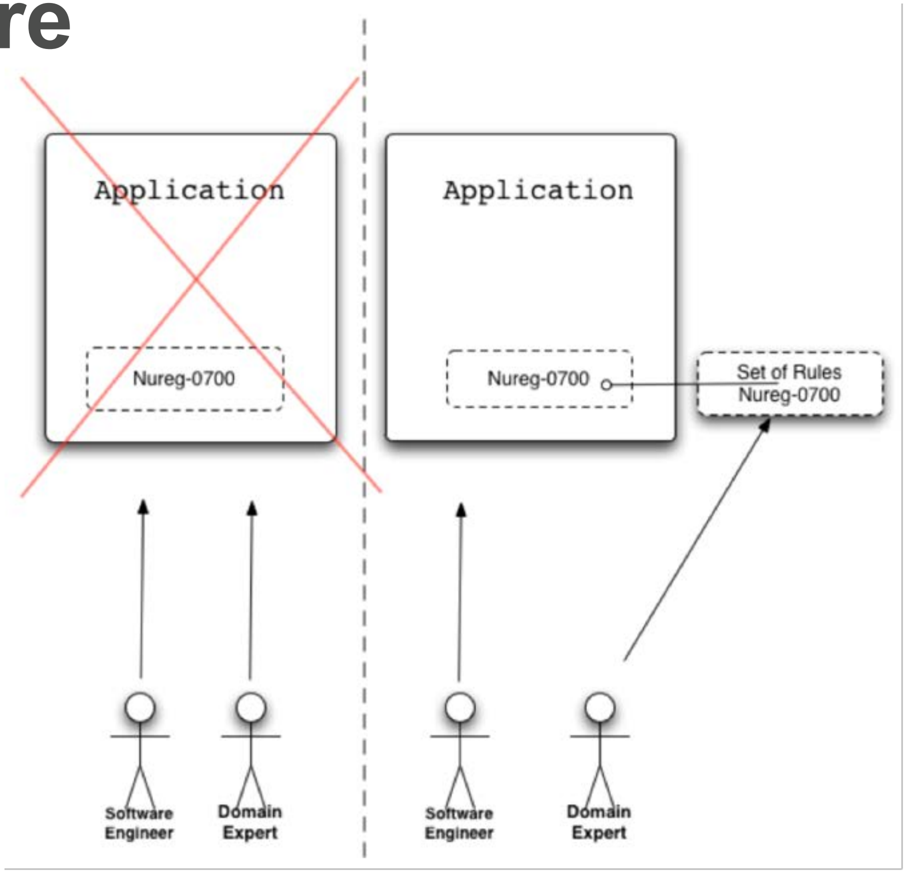
Figure 4.3: Spacing of equipment to accommodate seated users (In cm as suggested in original figure)

Objective: Open Architecture

- Can incorporate knowledge from multiple sources, e.g.
  - Ergonomic guidelines
  - Fire and emergency procedures
  - Input from operator experience interviews
  - Knowledge from earlier design phases & iterations
- Broader scope of information can help designers make good decisions early

Objective: Open Architecture

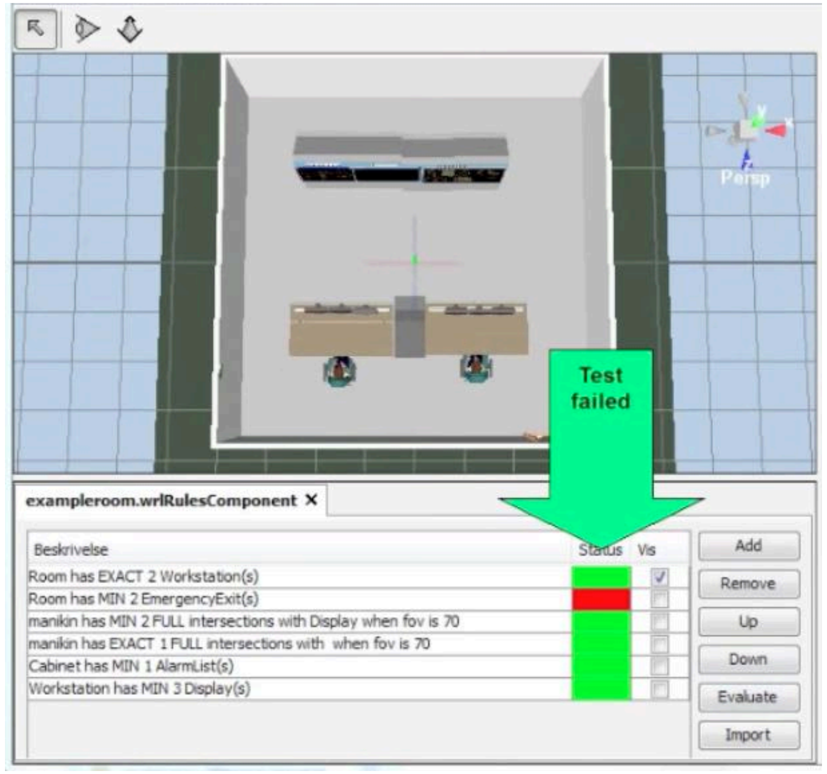
- Specify semantics and rules using open standards if possible
- Underlying knowledge handled separately from application
- Reuse tests without changing application code
  - Define once and reuse across projects
  - Domain experts can adapt tests to different guidelines



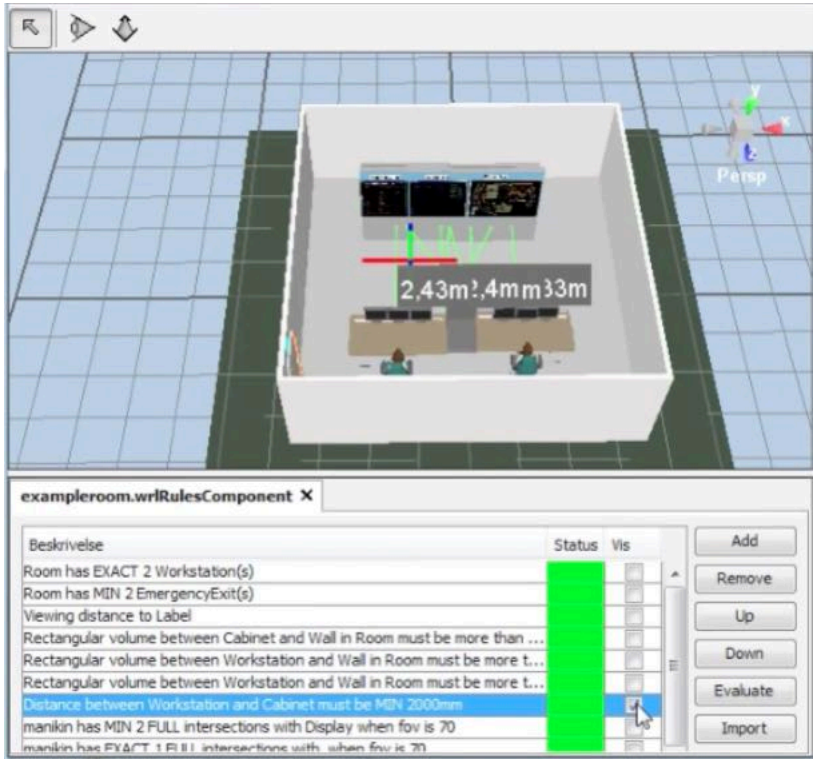
Approach

- Focused initially on W3C Semantic Web
  - Open standards for semantic data and knowledge representation
  - Well-established technologies
- Using RDF and OWL
  - Applications of XML
  - Human and machine readable
  - Inference and knowledge reasoning supported by open rule-engines

Testbed and Proof of Concept 2009-2011



Requirements handling using knowledge-based techniques



Geometry analysis to enable spatially-oriented tests

Ref: Gustavsen & Louka

Examples of guidelines from NUREG-0700 Rev. 2

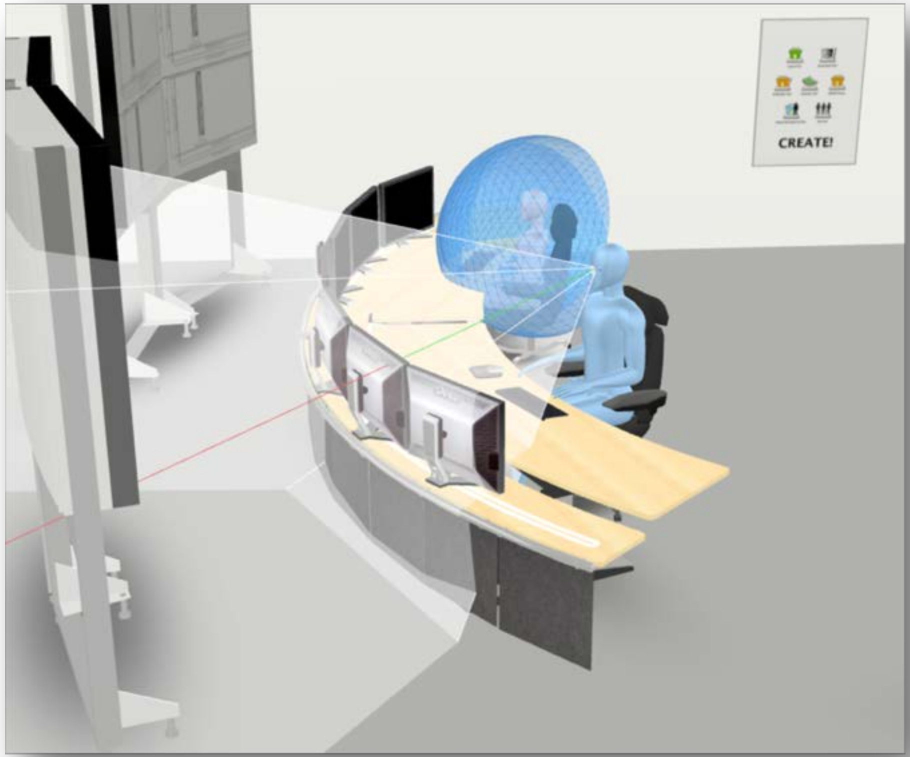
Semi-Automated
Control Room Layout Verification

Control Room V&V

- Does the design contain everything it needs to?
  - Human-system Interface inventory and categorisation
    - Overview of all needed HSI items and their categories
  - Task support
    - Overview of HSI items needed to support specific tasks
- Will it meet user & organizational requirements as an interactive system?
  - Compliance with HFE guidelines
  - Supports task scenarios
  - Checklist of specific requirements
- Collecting evidence that a design is fit for purpose

Evaluating Ergonomics

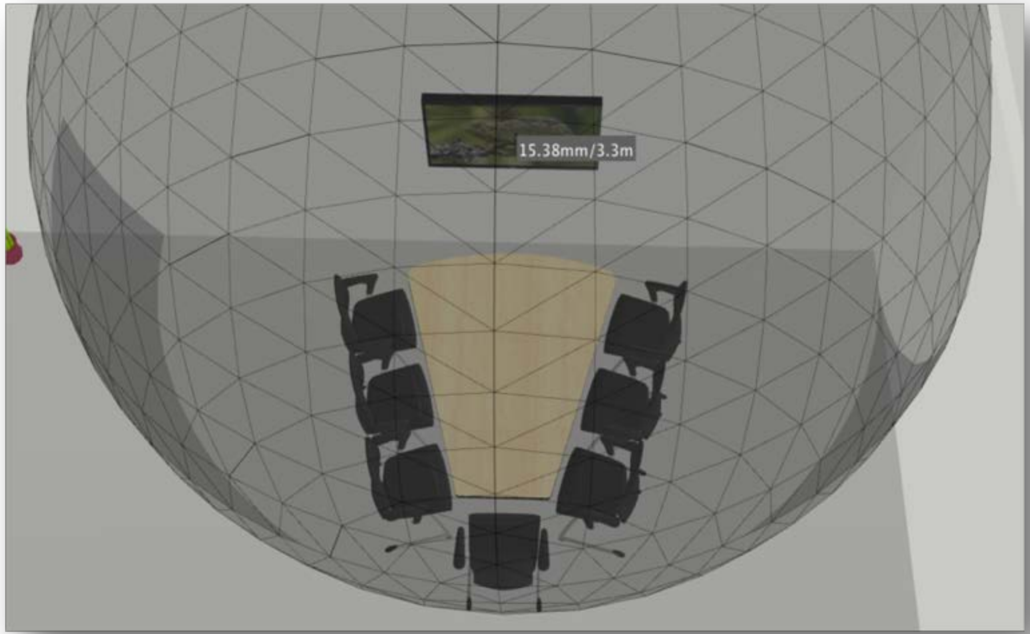
5th & 95th Percentile manikins of target population. Line of sight, view cone, reach, simulated view



Distance, Perpendicular Distance, Angles, Volumes, Dimensions

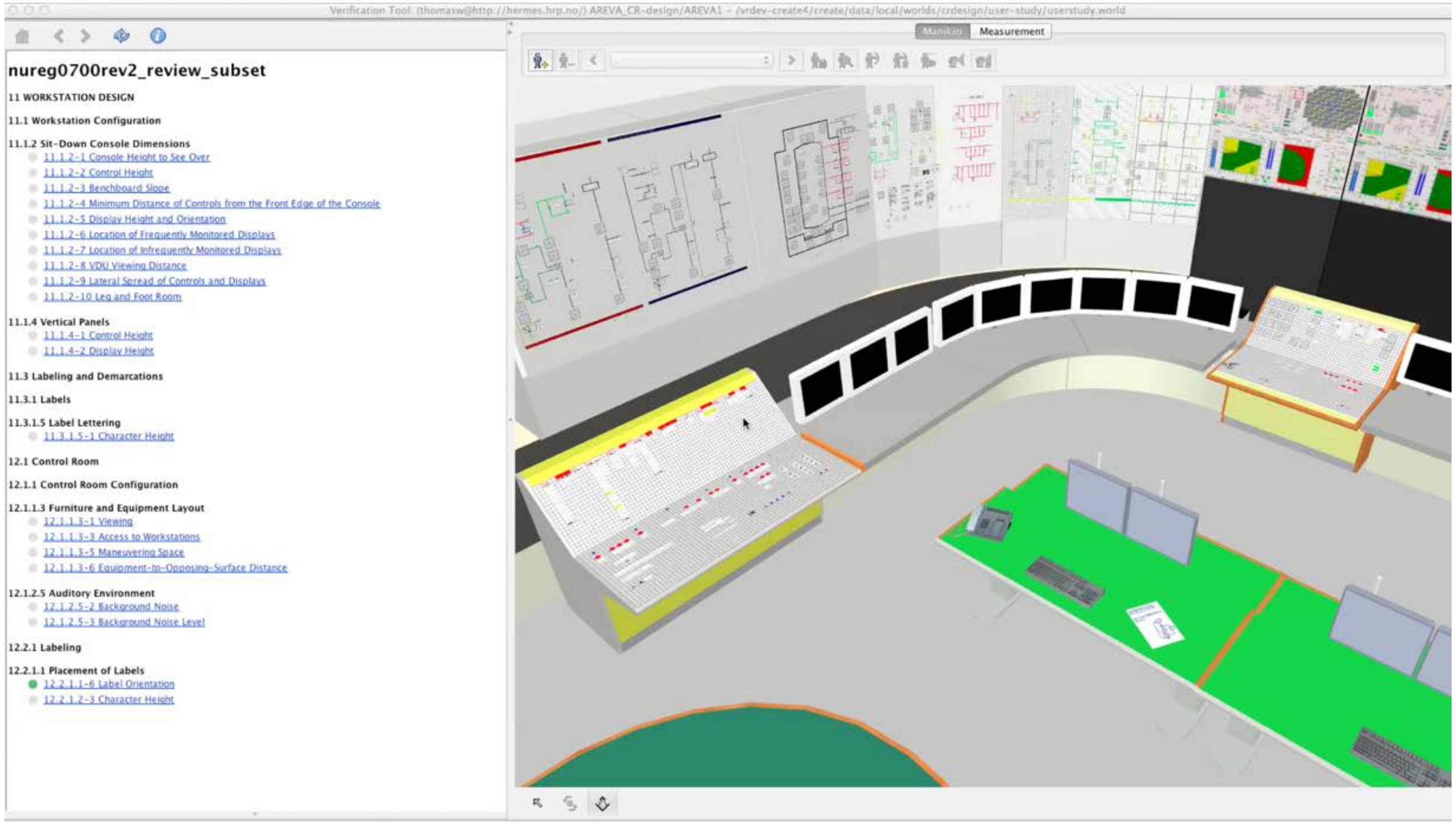
Evaluating Ergonomics

Viewing Angle

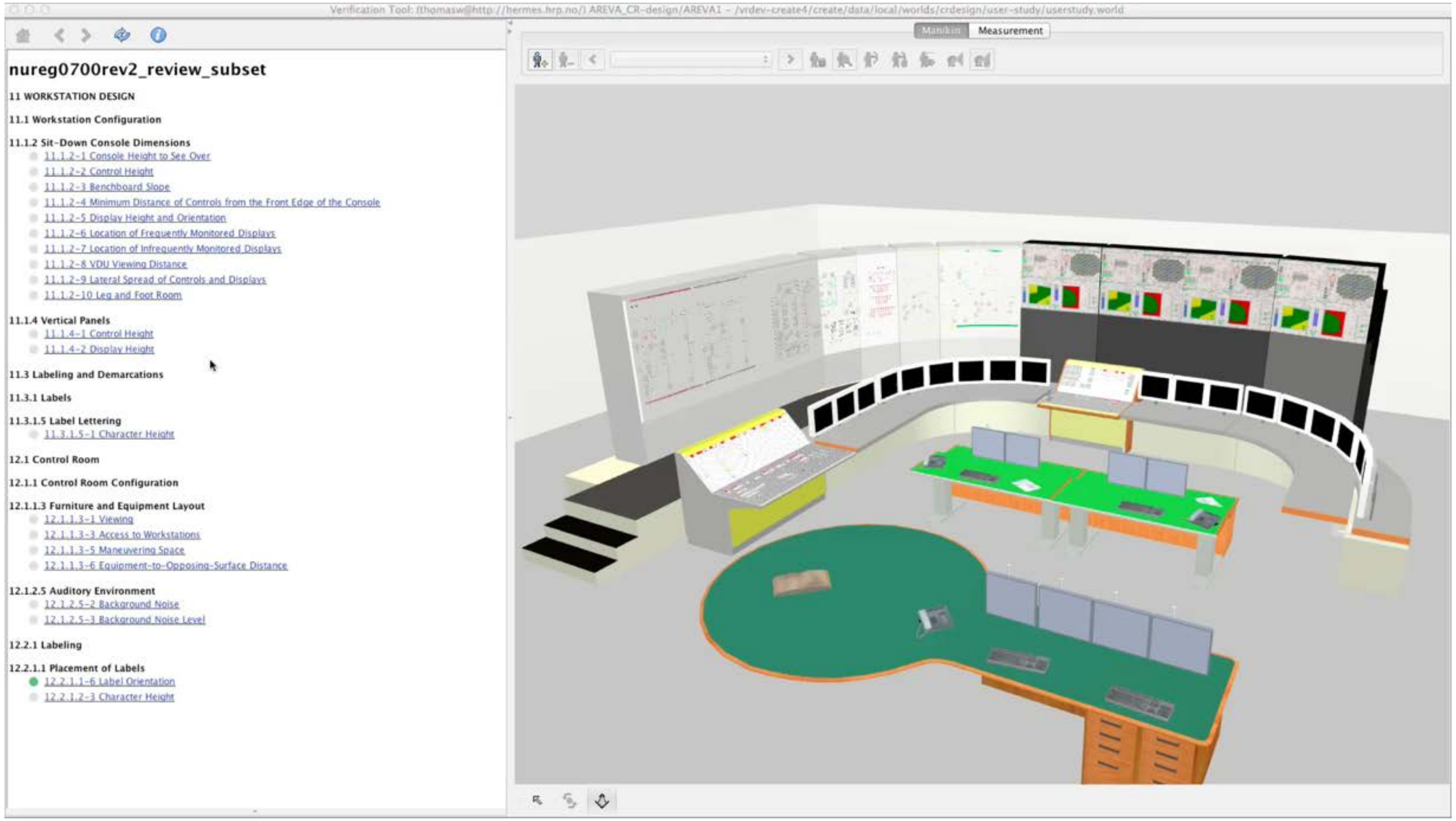


Minimum legible text size

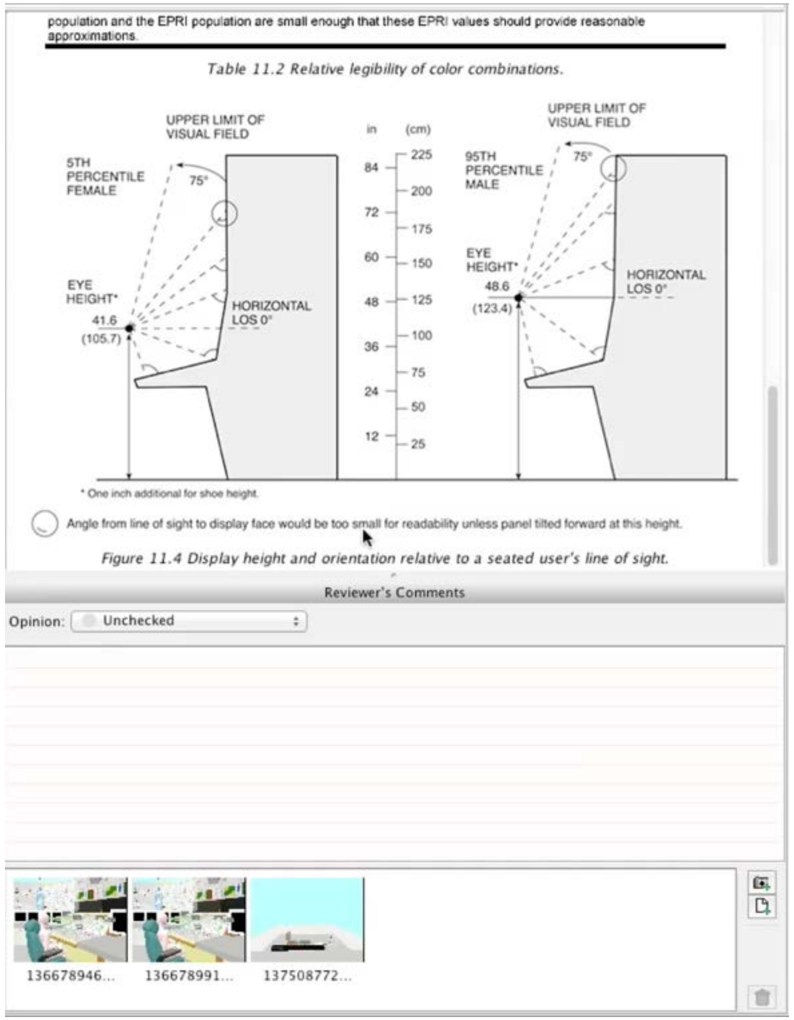
Sit-down Console Control Height



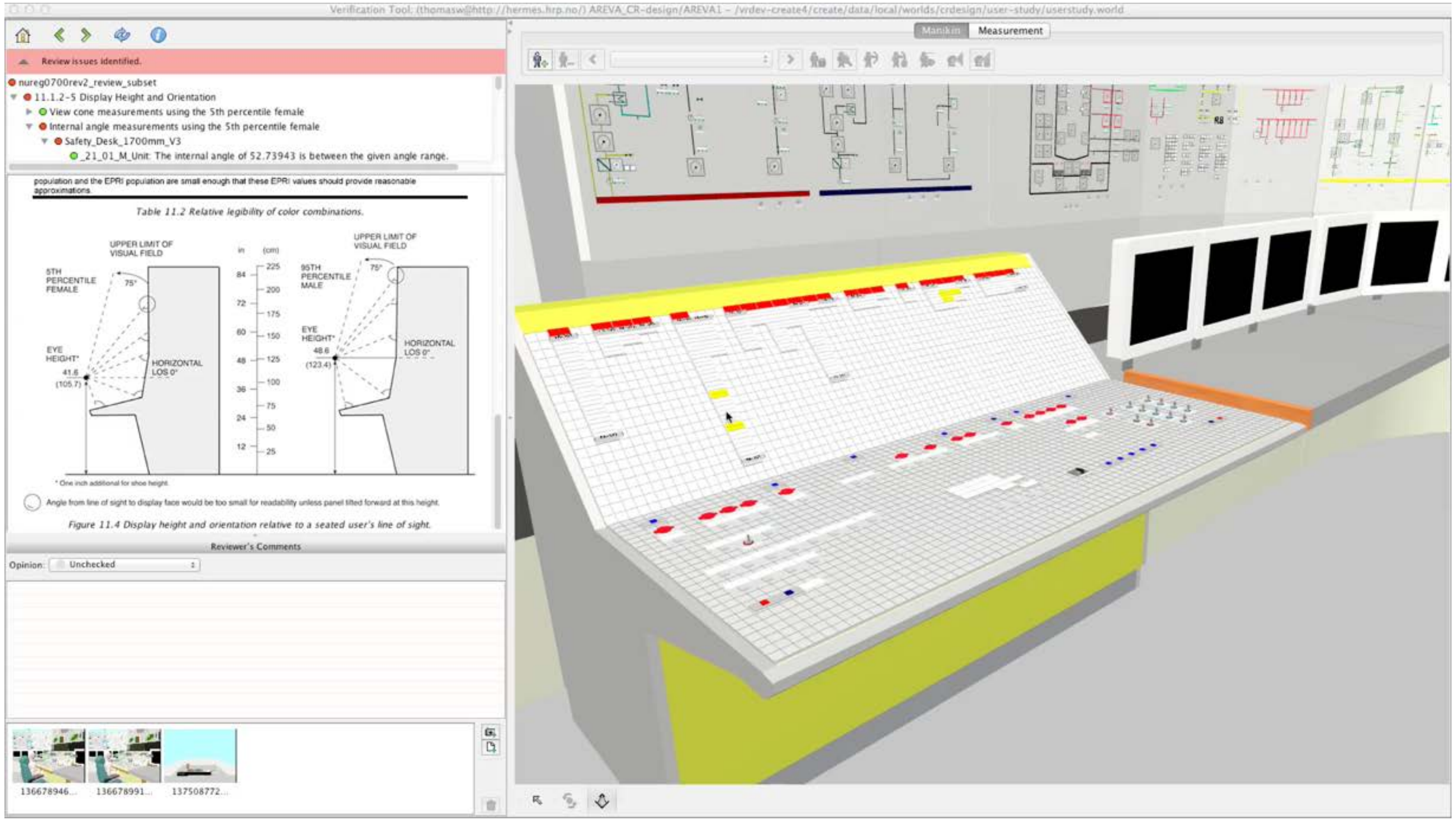
Vertical Panels Control Height



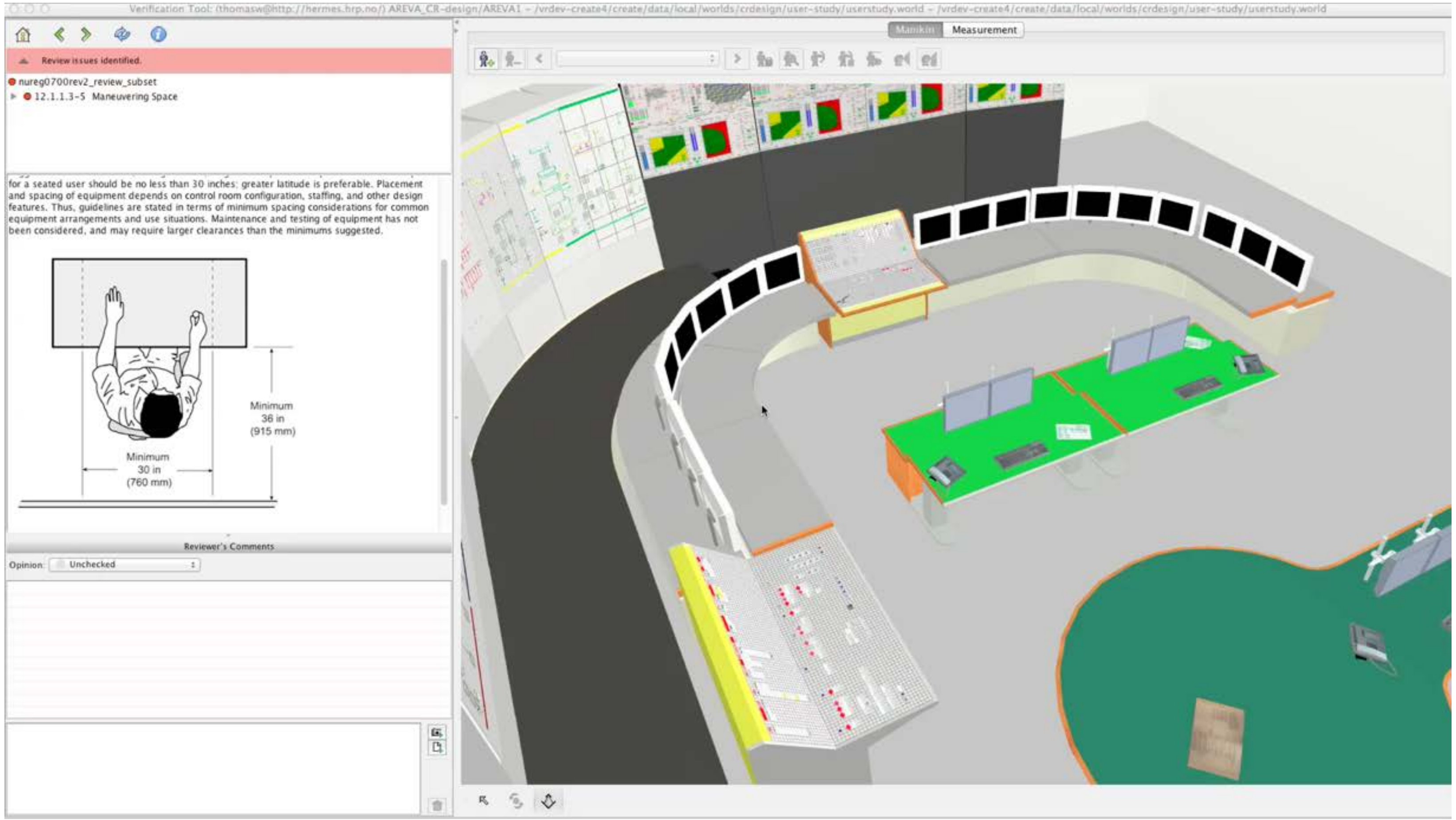
Interior Angles



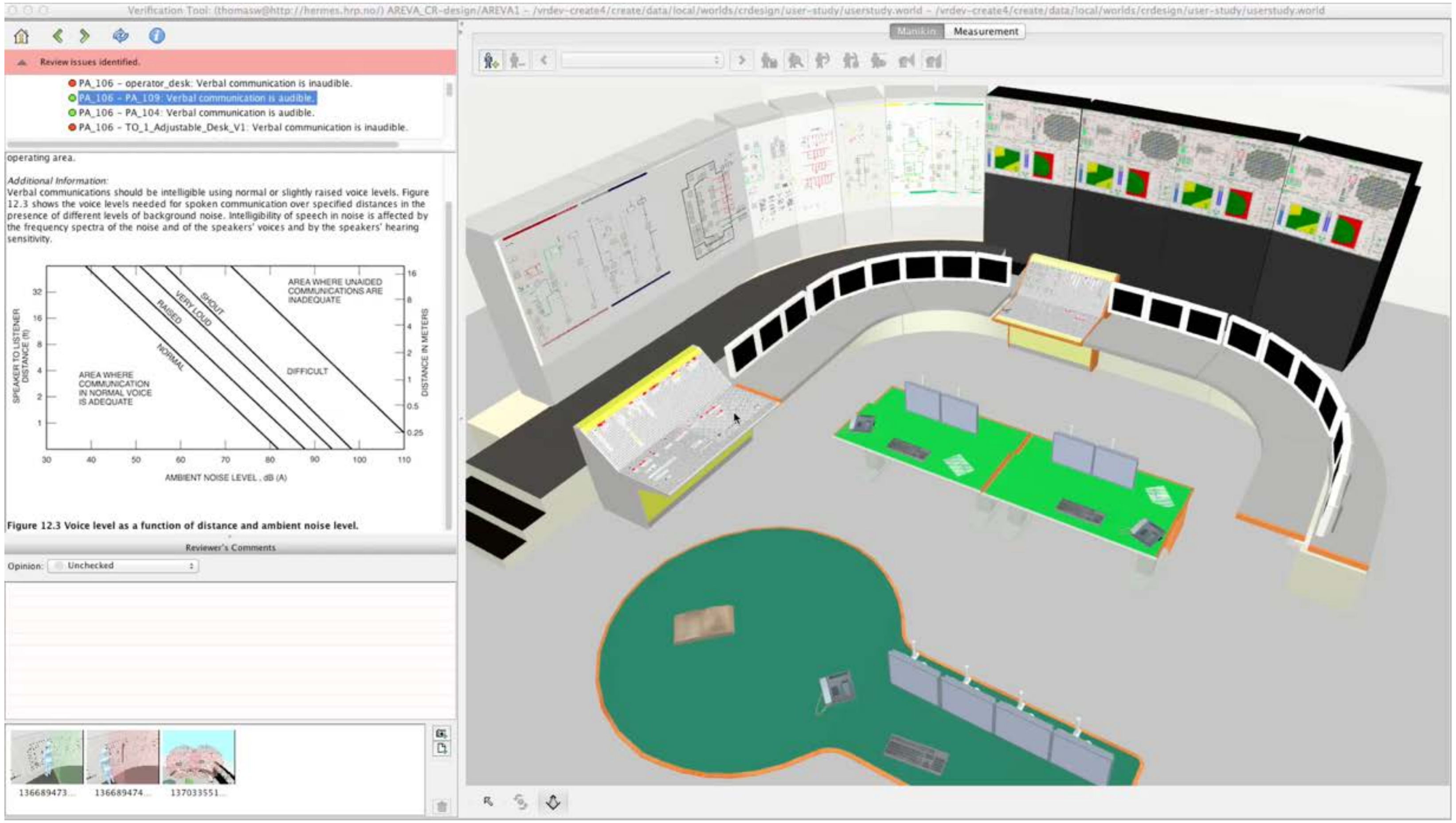
Console Display Height & Orientation



Operator Manoeuvring Space



Auditory Environment



Summary of Results of Validation Study

- Good agreement between subjects for tasks with automated assistance
- Some guidelines were considered difficult to understand
- Automated assistance helpful for most tasks where it was available
  - Time saving potential was frequently highlighted
  - Important to be able to see an explanation of how the software came to its recommendations with as much detail as possible.

Our plans/needs regarding decom

- Define/Standardise to support interchange of data between systems:
  - Discipline profiles for BIM/IFC
  - Ontologies for data objects that support the disciplines
- Will enable these types of analyses and more advanced risk (including radiological risk) analyses to be done using the shared BIM model and integrate with planning/optimisation
  - In addition, for decom we can also leverage the rule-checking in BIM tools intended for construction
    - Mostly focussed on collision checking and rules about objects

NEGOTA

Automating Compliance

Integrating information on Legal Requirements in Advanced Plant Information Systems for Nuclear Decommissioning and Life-cycle Management

NEGOTA

Advanced Plant Information Management Methods

The scope and duration of decommissioning activities demand an integrated management system (IAEA SSG-47 art. 4.1)

- Safety management / compliance
- Project management
  - Work breakdown
  - Scheduling
  - Cost control
- Information sharing (regulators and contractors)
- Training

Integrated systems may provide 3D models based on physical attributes of the environment, and real time adaption and presentation of relevant meta information to calculated changes

Aim of the presentation is to address the opportunities and challenges of including information on contractual and regulatory requirements in adaptive plant information systems

Standard information management

Standard approach

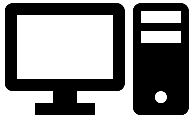
- Analyse legal instruments
- Develop new documents with detailed requirements
  - Operating procedures
  - Safety guidelines
  - Checklists and forms
- Upload documents to information management system
- Instruct workers to comply with procedures described in information management system

The information management system consists of a static collection of extensive documentation

The system does not detect the relevance or significance of any given procedure or requirement

Human error = non-compliance

Input
- Legal instruments
- Operating procedures
- Safety guidelines
- Checklists
- Risk assessments
- Contracts

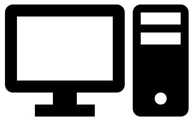


Output
- Legal instruments
- Operating procedures
- Safety guidelines
- Checklists
- Risk assessments
- Contracts

Adaptive plant information system

Operation → Transition period → Decommissioning

Identification
- Facilities
- Tally - Inventory
- Characterization
- Waste routes (WAC)
- Transport
- End-state
- Costs
- Internal resources
- Contractors (T&C)
- Procedures
- Safety standards
- Regulations
- Licenses



Adaptive information system
- Database
- 3D model / BIM
- Education/training modules
- Task simulation
- Safety cases
- Resource management
- Project management
- Document management

Adaptive output
- Work breakdown structure
- Schedule
- Staffing
- Budget
- Deviation alerts

NEGOTA

Legal input - Format

- A key challenge for adding a legal dimension to adaptive information management systems is to reduce legal standards and requirements into functional requirements that may be organised in a database with relevant triggers/tags

- The original format of legal information does not lend itself easily to structured information management
  - Legal writing is more systematic than standard prose
  - However, regulations, licenses and guidelines are still drafted in a relatively holistic manner

DIRECTIVES

COUNCIL DIRECTIVE 2013/59/EURATOM

of 5 December 2013

laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom

THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Atomic Energy Community, and in particular Articles 31 and 32 thereof,

Having regard to the proposal from the European Commission, drawn up after having obtained the opinion of a group of persons appointed by the Scientific and Technical Committee from among scientific experts in the Member States, and after having consulted the European Economic and Social Committee,

Having regard to the opinion of the European Parliament,

Having regard to the opinion of the European Economic and Social Committee,

Whereas:

(1) Point (b) of Article 2 of the Euratom Treaty provides for the establishment of uniform safety standards to protect the health of workers and of the general public. Article 30 of the Euratom Treaty defines "basic standards" for the protection of the health of workers and the general public against the dangers arising from ionising radiations.

(2) In order to perform its task, the Community laid down basic standards for the first time in 1959 by means of Directives of 2 February 1959 laying down the basic standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation [1]. The Directives have been revised several times, most recently by Council Directive 96/29/Euratom [2] which repealed the earlier Directives.

(3) Directive 96/29/Euratom establishes the basic safety standards. The provisions of that Directive apply to normal and emergency situations and have been supplemented by more specific legislation.

(4) Council Directive 97/43/Euratom [3], Council Directive 89/618/Euratom [4], Council Directive 90/641/Euratom [5] and Council Directive 2003/122/Euratom [6] cover different specific aspects complementary to Directive 96/29/Euratom.

(5) As recognised by the Court of Justice of the European Union in its case-law, the tasks imposed on the Community by point (b) of Article 2 of the Euratom Treaty to lay down uniform safety standards to protect the health of workers and the general public does not preclude, unless explicitly stated in the standards, a Member State from providing for more stringent measures of protection. As this Directive provides for minimum rules, Member States should be free to adopt or maintain more stringent measures in the subject-matter covered by this Directive, without prejudice to the free movement of goods and services in the internal market as defined by the case-law of the Court of Justice.

(6) The Group of Experts appointed by the Scientific and Technical Committee has advised that the basic safety

(1) OJ L 11, 20.2.1959, p. 221.
(2) Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation (OJ L 159, 29.6.1996, p. 1).
(3) Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure, and repealing Directive 84/466/Euratom (OJ L 180, 9.7.1997, p. 22).
(4) Council Directive 89/618/Euratom of 27 November 1989 on informing the general public about health protection measures to be applied and steps to be taken in the event of a radiological emergency (OJ L 357, 7.12.1989, p. 31).
(5) Council Directive 90/641/Euratom of 4 December 1990 on the operational protection of outside workers exposed to the risk of ionising radiation during their activities in controlled areas (OJ L 349, 13.12.1990, p. 21).
(6) Council Directive 2003/122/Euratom of 22 December 2003 on the control of high-activity sealed radioactive sources and orphan sources (OJ L 346, 31.12.2003, p. 57).

NEGOTA

Legal input – Where to start? (Q&A)

- The underlying structure of legal information is generally based on logical conditional arguments (if-then)
- However, extensive work is required to reduce official legal texts to precise logical statements
- This raises some fundamental questions:
  - Is such precise logic necessary for the system?
  - What is the preferred and/or required format?
  - Can artificial intelligence assist the process?
  - Is it possible to prioritize legal information based on cost/benefit to the system

Norwegian regulation on radiation protection § 32
"The operator shall ensure that all exposure to radiation is kept as low as practically possible, and that the following dose limits are not exceeded:
(a) Effective dose for occupationally exposed employees shall not exceed 20 mSv per year"

An attempt at logic structure

1. If a task may be achieved by alternative operations then recommend alternative with the lowest risk of radiation exposure to affected workers
2. If the effective radiation dose of operation exceeds 20 mSv then recommend replanning of task
3. If the employee's effective radiation dose the preceding 12 months plus the effective radiation dose of operation exceeds 20 mSv then recommend replanning of task or replacement of employee

NEGOTA

Legal Input – Cost / Benefit

Discretionary assessments
- ALARA
- BAP
- Fit for purpose

Objective standards
- Deadlines
  - Notification to/from contractors
  - Notification/reports to authorities
  - Delivery milestones
- Measurable physical attributes
  - Waste acceptance criteria
  - Permitted radiation levels
  - Required shielding material
- Existence of documentation
  - Status of permit / license
  - Existence of necessary records
  - Status of contracts
  - Existence of change orders

IAEA Safety Standards Series No. SF-1

3.21. The safety measures that are applied to facilities and activities that give rise to radiation risks are considered optimized if they provide the highest level of safety that can reasonably be achieved throughout the lifetime of the facility or activity, without unduly limiting its utilization.

IAEA Specific Safety Guide No. SSG-47

8.17. *Decommissioning actions might involve the deliberate removal of SSCs that fulfilled specific safety functions during operation of the facility (e.g. confinement, shielding, ventilation and cooling). Such actions should be recorded and aligned with the ongoing decommissioning phases, work packages and tasks identified in the final decommissioning plan*

NEGOTA

Legal output

Drafting contracts:

Contractors may in tender submit correctly formatted data directly to interactive models

Key elements of the contracts may be defined by reference to the interactive models, e.g.:

- Scope of work - Tally
- Schedule
- Regulatory requirements

Change management:

- System automatically reports the effects of new information:
    - Inventory, radiation levels or other physical attributes
    - Technical execution
    - Regulatory requirements
    - Overall schedule
    - Costs
    - Receipt of deliverables (reports, milestones)
- New tasks / work package may be identified
- Proposed positive changes (project optimisation) may be used in IPD models
- Change order procedure in affected contracts may be triggered and recorded
- Procedure to obtain regulatory approval and update regulatory requirements may be triggered and recorded.

Change Procedure
(Ticket #7231)

Registered change in «Project Schedule» affects agreed schedule for the following contracts:

(1) IFE:31455 – Structure reinforcement
(2) IFE:31273 – Security
(3) IFE:31244 – Transport

Affected schedules must be updated and cost allocated.

Registered change in «Project Schedule» affects the following regulatory requirements:

(1) SSV:20229 – Final report decom alpha lab

Deviation must be approved by relevant authority and regulatory requirement updated.

Negota in brief

- Advokatfirmaet Negota AS is a Halden based law firm established in 2010, with a branch office in Oslo
- Our clients consist of medium and large Norwegian and international businesses, and are largely based in the energy sectors (oil & gas, hydro, wind and nuclear).
- The firm offers specialised legal advice on commercial contracts, public procurement and regulatory issues (including nuclear law)
- In addition to traditional legal services, a number of our emloyees provide contract managemnent as an «in-house» consultant service to our clients
- We are the only Norwegian firm with a number of our employees being members of the International Nuclear Lawyers Association

NEGOTA

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Advokat/partner

—

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Les mer

09.01.2019

Decommissioning of Norwegian Nuclear Facilities

Naeem Syed

NORDEC seminar, Lillehammer
6 – 7 Dec. 2018

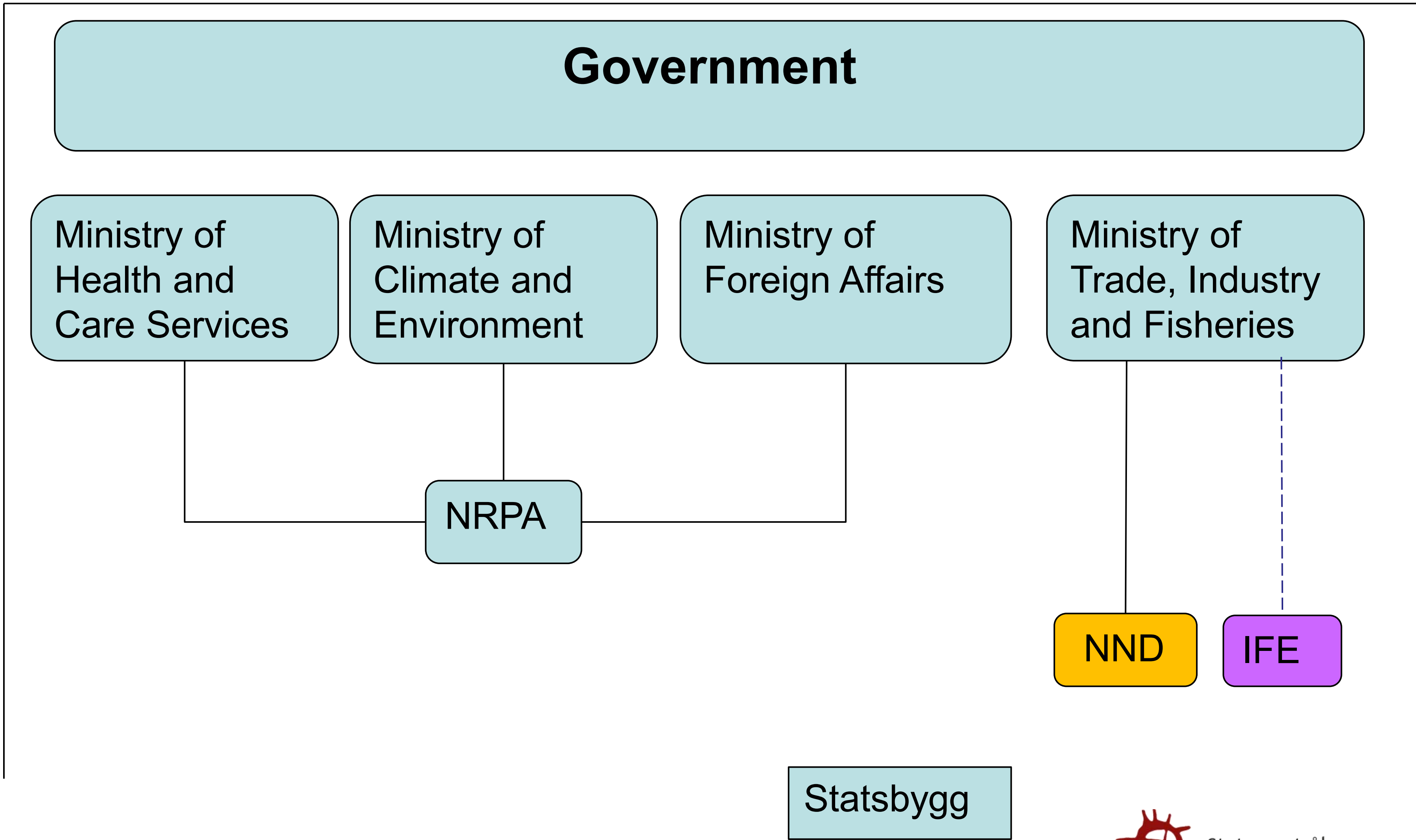
Statens strålevern
Norwegian Radiation Protection Authority

www.nrpa.no

Presentation Outline

- Background
- Legal framework
- Decommissioning of Norwegian nuclear facilities
- Current and future challenges
- Summary

Organizations in Norway



Norwegian Radiation Protection Authority

- 1993 – Norwegian Radiation Protection Authority as independent regulatory body
  - Staff 125 persons

- Responsible for nuclear safety and security; environment; radiation protection; and emergency preparedness & response.

Name change – January 2019

Norwegian Radiation and Nuclear Safety Authority

DSA

In Norwegian: Direktoratet for strålevern og atomsikkerhet

New website address will be ***www.dsa.no***

New mailaddress : ***name.surname@dsa.no*** *(only details after @ will be changed)*

Legal Framework

- **Act No. 28 (12 May 1972) on Nuclear Energy Act**
  - Regulations No. 1809 (2 November 1984) on Physical Protection of Nuclear Material and Nuclear Installations
  - Regulations No. 433 (12 May 2000) on possession of nuclear material and use of equipment

- **Act 13 March 1981 concerning Protection against Pollution and Concerning Waste (Pollution Control Act)**
  - General regulations (1 June 2004) on the waste management, chapter 16 on radioactive waste.
  - Regulations, 1 Nov. 2010 on the application of the Pollution Control Act on Radioactive Pollution and Radioactive Waste

Decommissioning - Legal Framework

- **Nuclear Energy Act**
  - Nuclear energy act § 4 demands a licence to possess and operate a nuclear facility during a decommissioning period
  - As per § 15-2 and 3, the licensee is obliged to perform all necessary measures of decommissioning such that the decommissioned site becomes safe to general public after decommissioning. These measures have to be approved by NRPA
  - For reactor in operation decommissioning plans need to be updated periodically
- **Pollution Control Act**
  - Has a provision about reactor stop and decommissioning demanding licensee to perform necessary actions counteracting the pollution.
  - The authorities can put further conditions on decommissioning measures taken to hinder the pollution. The licensee can be asked for guarantees to cover the future costs in this regard.
  - If reactor stop can generate further pollution problems, it should be shared with NRPA
  - NRPA will impose terms and conditions on decommissioning and dismantlement to counteract the radioactive pollution and safe radioactive waste handling.

Decommissioning - Legal Framework

- **Radiation Protection Law**
  - Sets conditions on the working environment

- **Act on planning and building (Plan og bygningsloven)**
  - While performing the decommissioning of nuclear reactors, environmental impact assessments shall be performed.
  - This should give a complete picture of the alternate solutions and environmental impact assessments of decommissioning.
  - NRPA (HOD and KLD) will be the regulating authorities

- NRPA is working on General Safety Guidlines that also covers decommissioning requirements.

Institute for Energy Technology (IFE)

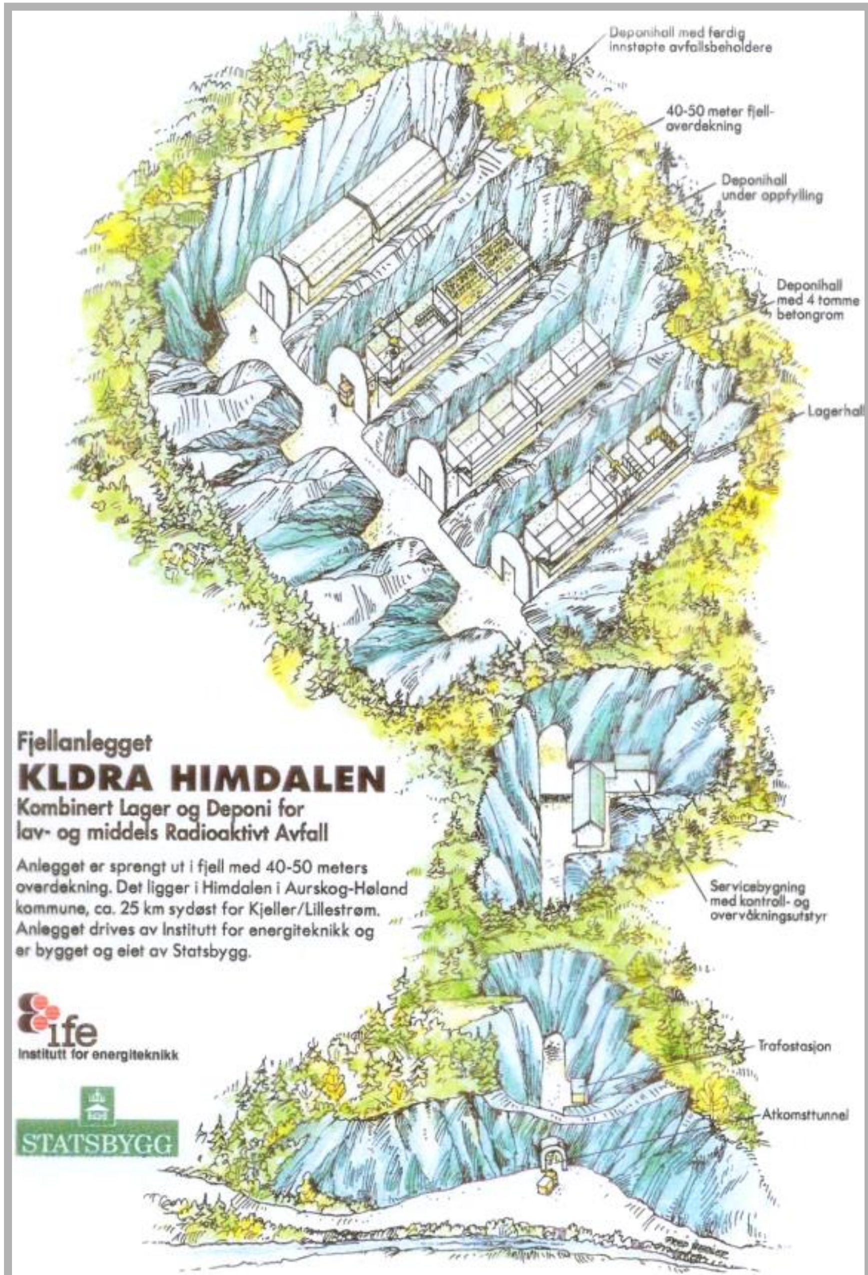
- Independent research foundation
  - Staff ~ 550

- 1959 – HBWR, 25 MW (Halden)
  - Operational licence expires in Dec. 2020
  - Reactor is permanent shut down since June 2018.

- 1966 – JEEP II, 2 MW (Kjeller)
  - Operational licence expires in Dec. 2018
  - NRPA has put forward its recommendations to the HOD for a new license 2019 - 2028

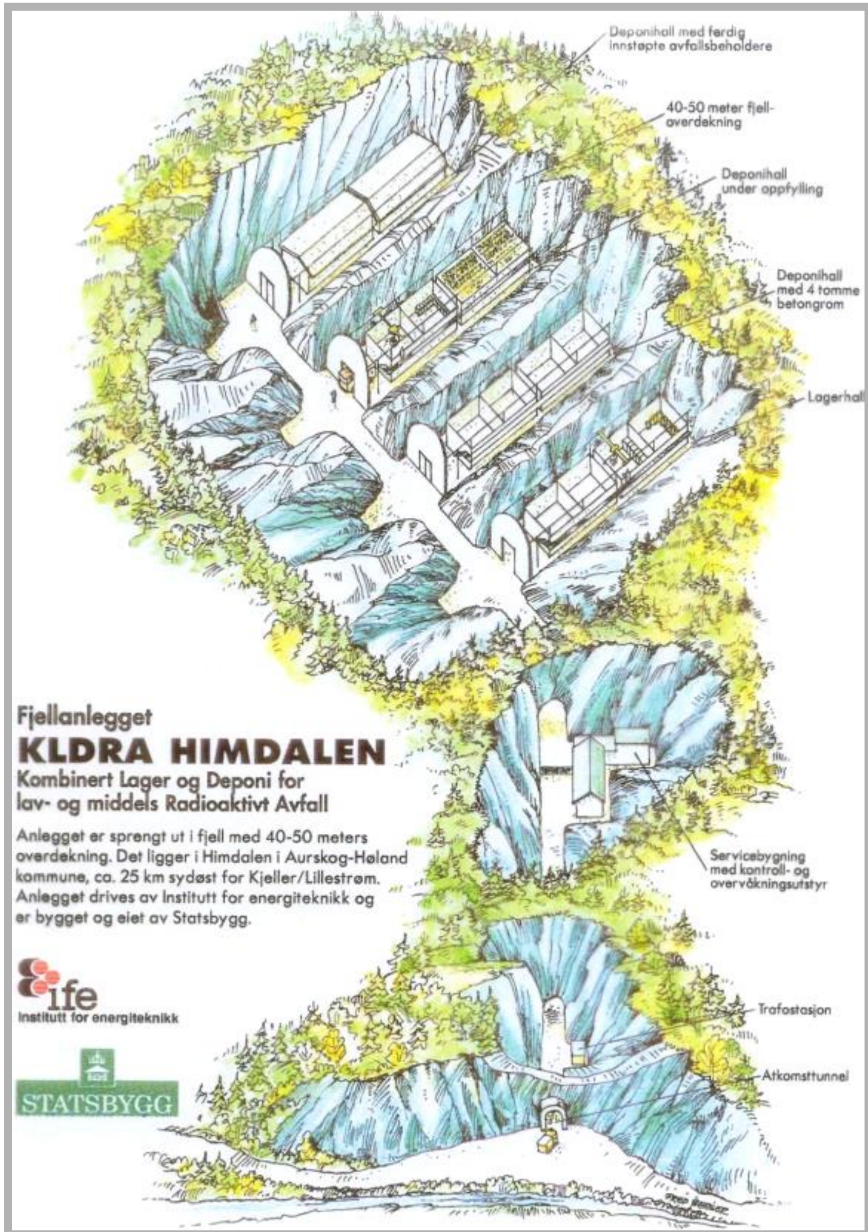
KLDRA - Himdalen

- 1998 – LILW facility at Himdalen
  - Operational licence til 2028
- The facility is built in crystalline bedrock
- Total capacity 2000 m^3 (10,000 210 l drums) – ca 62% is exhausted
- Need new KLDRA or extension of existing facility
- IFE is the operator of the facility as per today
- Future operator will be Norwegian Nuclear Decommissioning (NND)



KLDRA - Himdalen

- Owner - Directorate of Public Construction and Property (Statsbygg)
  - State owned organization: State's central adviser in construction and property matters, builder, property manager and property developer.
- The NFD has given a task to the Statsbygg regarding the initiation of the study on conceptual design, localization analysis and cost estimate for a new repository or expansion of the existing repository for LILW.
- Above task will be followed-up by NND.
- Future owner of the new KLDRA facility (LILW repository).



Governmental Concept Evaluation Studies - Present national strategy

- Development of national strategy based on various governmental studies conducted since 2000:

  – In 2015 two governmental concept studies were presented on :

    - The future decommissioning of nuclear facilities in Norway.
    - Finding solutions for handling spent fuel and radioactive waste.

  – In 2016 the above mentioned studies were quality assured by third party organisations.

National Strategy highlights

- Ensure safe interim storage of SF
- Assess the possibility of repatriation of SF
- Initiate the consideration of reprocessing of SF
- Assess other possible options other than reprocessing
- Establish an independent radioactive waste management organization
- Ensure the application polluter pays principle in relation to SF and radioactive waste.
- Initiate the planning of increased capacity of the LILW repository.
- Assess the possibility for international cooperation on deep geological repository for the SF.
- Assess alternative repository solutions in Norway.

Establishment of Norwegian Nuclear Decommissioning

- Norwegian Nuclear Decommissioning (NND) was established by a Royal decree 12. February 2018.
- The NND is established under The Ministry of Trade, Industry and Fisheries (NFD)
- The NND – organization responsible for radioactive waste management and decommissioning
- Fully operative within 2020 – 2021
- Will be regulated and inspected by NRPA

Main responsibilities of NND

- Planning and performing decommissioning of the Norwegian nuclear facilities.
- Planning and performing the safe handling and management of spent fuel
- Handling of other radioactive waste from the industry
- Taking part in relevant international forums to build competence, cooperation and knowledge sharing

Decommissioning end state and cost estimation

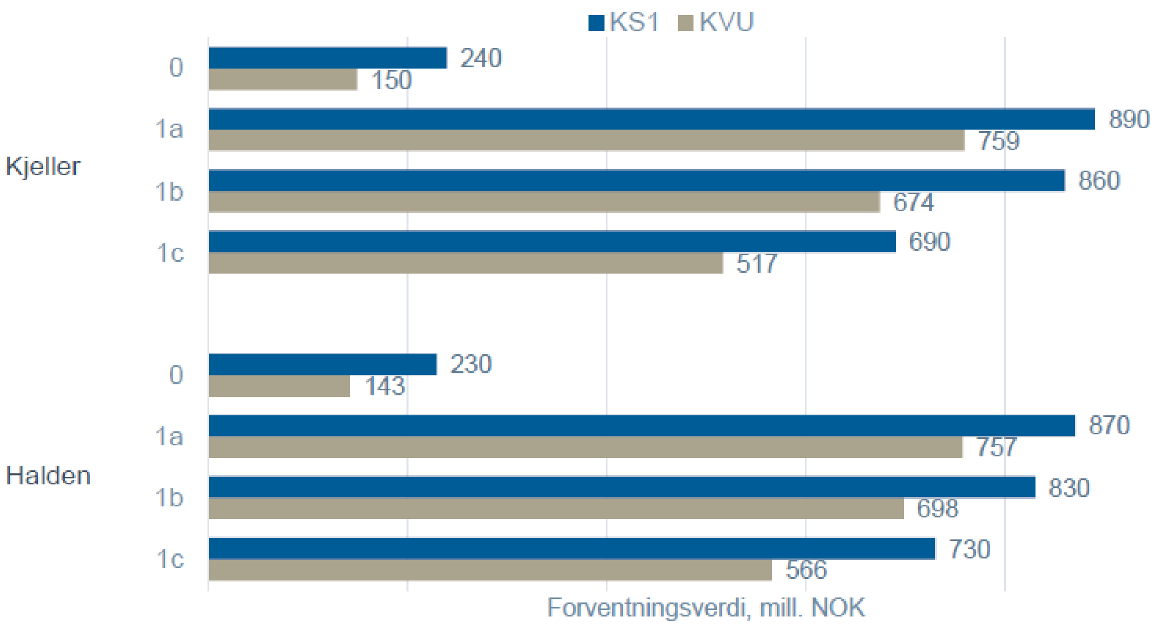
Decom End-state

Controlled area

- 0 = No new use
- 1C = Nuclear industry
- 3 = Entombment

Uncontrolled area

- 1A = Green field
- 1B = Non-nuclear industry



Recommendation:
The immediate dismantling to “Green field”.

Decommissioning Process

- IFE's decommissioning plans – ongoing

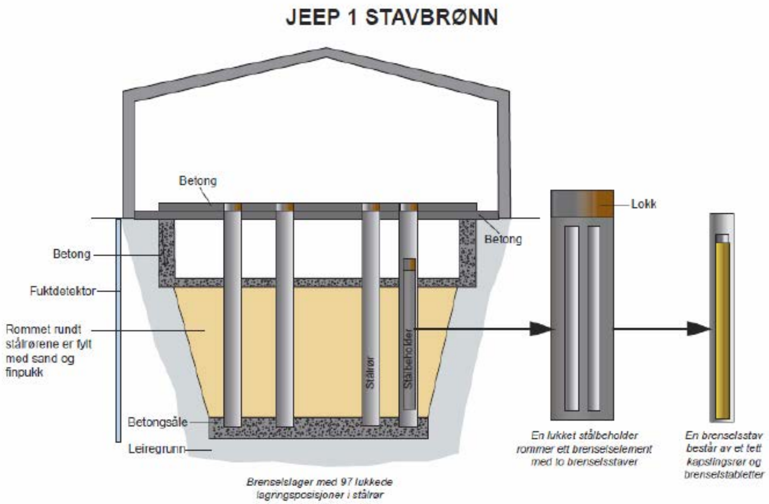
- Financing of decommissioning:
  - The Government will finance the decommissioning cost.
  - IFE was instructed to establish a decommissioning fund for the IFE facilities (300 K€/year).

- Concept study: new KLDRA + no restrictions on use after decommissioning

- IFE will apply for a new license to continue their activities …..

Safety of SF Management

- Total SF > 17 metric tons
  - ~145 kg SF generated each year
- IFE – responsible for spent fuel management.
- NND – Will be responsible for the spent fuel management
- SF currently stored on site – Kjeller and Halden



Progress in a national strategy for the disposal of SNF and RW

- The Ministry of Trade, Industry and Fisheries are following up the concept study, which has formed the present national strategy.

- Concept study/present national strategy identified reprocessing as one of the main options for unstable metallic SF.

- Alternate options are also under consideration.

- Additional studies are underway on the stabilization of the metallic fuel and options of the final disposal of the spent fuel; HLW; and long lived radioactive waste.

- The finale decision on the management of the SF and RW will be formulated on the finalization of this work.

Challenges of Decommissioning

- Transfer of knowledge and other human aspects of decommissioning
- Handling the spent fuel including legacy fuel of JEEP I and first charge of HBWR
- Long term management of SF and RW
- Further development of the national strategy and final decision on the disposal of SF and RW

Summary

- HBWR is in permanent shutdown state since June 2018
- Two conceptual studies, as a part of national strategy on the nuclear decommissioning and the management of SF and rad. waste.
- NND has been established, which is under development.
- As part of national strategy, Statsbygg has initiated a study to increase the capacity of LILW repository.
- The safe and long term management of spent fuel and RW is a challenge for Norway.

Thank you for your attention!

Competence mapping and workforce planning for decommissioning at IFE

Grete Rindahl, Espen Nystad

Competence mapping: Approach

What competence do we need for waste handling and decommissioning?

Dekom -plan

Other's experien ces

Basis for

- Questionnaire
- Interview guide

What competence do we have?

Collect questionnaire data

Perform mini-workshops

Perform interviews

What is needed to fill the gap?

Analyse and find gap

Propose actions

Competence needs for decommissioning

Can reuse competences from operation:

- Radiation protection
- Engineering
- Analysis / characterisation
- Maintenance
- Waste handling
- Chemistry
- Decontamination
- Specialists (workshop, design etc.)
- Knowledge of systems, structures and components

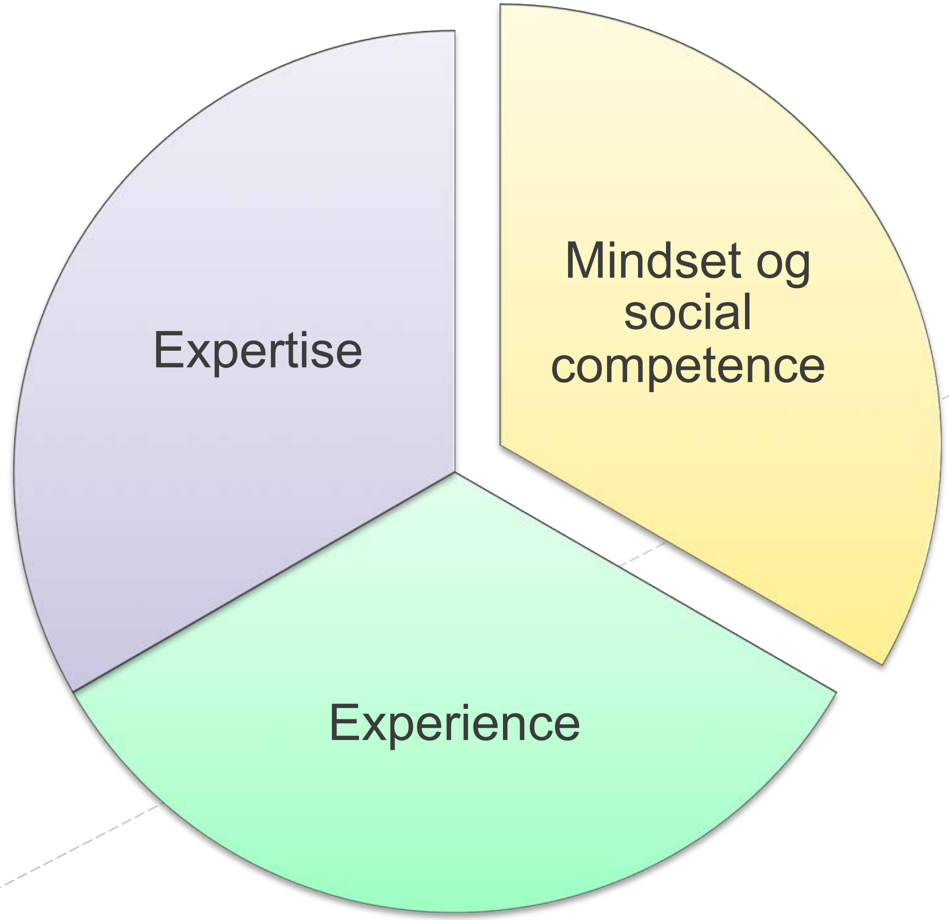
New competences that are needed:

- More advanced characterization
- Dismantling
- Demolition
- Decontamination (additional techniques)
- Waste management (additional techniques and concerns)
- Robotics and remote handling

Change in focus for decommissioning

- Unique, new and non-routine tasks
- Less predictable environment
- Changed radiological and industrial risks
- Project orientation
- Flexible work teams
- Risk assessment
- Waste production / categorisation and minimization

Competence for decommissioning



Expertise = Education and formal skills

Experience = Application of knowledge routines and knacks, trying, failing and learning over time

Mindset og social competence = Motivation, attitudes og skills for learning and collaboration

«Formal» knowledge

- Easiest to measure – on a diploma or possible to test
- Discipline knowledge, like mechanics or health physics
- Other professional knowledge and competencies
  - Documenting planned and executed work tasks
  - Knowledge on relevant rules and procedures
  - Measures, e.g. Safe Job Analysis – how and when to perform, what to contribute

Experience

- Partly hidden competency
  - May count the years in a position, more demanding to identify and quantify actual
  - People tend not to remember all: Their experience becomes inherent
- Focus on this in questionnaires and interviews

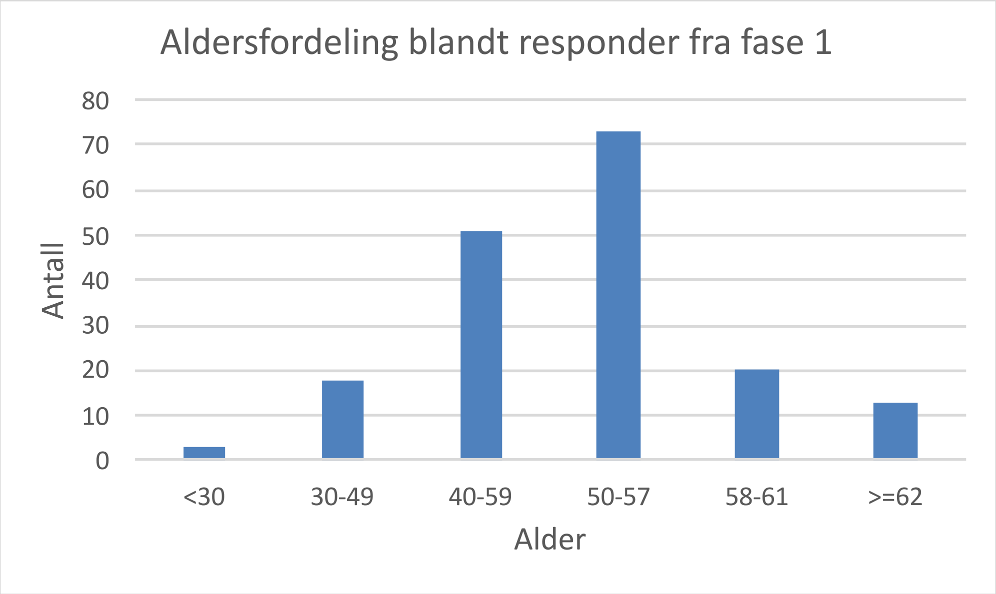
Mindset

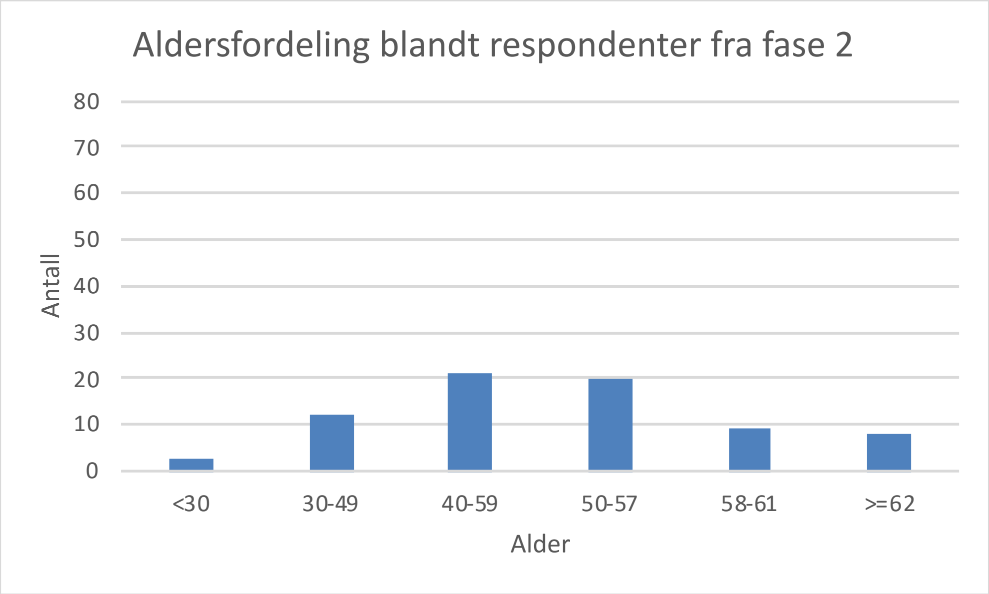
- A hidden aspect of competence that is forever changing
  - Learning and collaboration skills may well be evaluated
  - Motivation and attitudes will depend on the situation
- Concern about factors influencing on motivation and mindset
  - Security
  - Predictability
  - Wellbeing
  - Trust in management and colleagues

Main findings

- High base competence, and subjects report on ability and willingness to learn.
- Some disciplines have to few people with high competence, especially when age is taken into account, and it is urgent to transfer competence and experience.
  - Health physics and radiation protection
  - Characterisation
  - Planning, project management and traceability
  - Waste management
- Within som areas new competence and experience needs to be built. E.g. Advanced decontamination and characterisation methods.
- The exact competence required can not be clarified before decisions are made on questions like waste minimisation, end state etc.
- At the present stage, the main issue is to secure the base competence upon which we can build new required skills.

Age distribution





Sektorer: NFS, HMS (VERN/RP), REAK, ATOM

Sektorer: STAN, ADM (IED), DS

Performing functions

De-fueling	Dismantling	Decontamination	Waste processing and handling	Engineering support
Operators, handling	Operators, electro, mechanic	Operators, rad. protection, engineers	Operators, handling/mechanic	Adm. staff, operators, rad. prot., engineers

Supporting and preparing functions

Engineering / maintenance	Analysis / characterization	Radiation protection	Specialists	Safety support
Engineers, senior skilled workers	Researchers / enfineers/ lab/teknikere	Researches, rad. protection	Workshop,, design, electro ++	Safety staff, researchers, operational staff

Decision-making functions

Line leaders

Capacity and/or competence within these functions must be strengthened immediately to secure redundancy. Competence transfer is urgent in certain areas.

Capacity and/or competence within these functions must be strengthened before decommissioning

Capacity and basic competence within these functions are so far satisfactory. General competence building is needed in the transition to new tasks within decommissioning.

Calibration

- Same main findings, but some adjustments
- Main focus in calibration has been Halden
- In addition to calibration, we have also added data from a larger part of the organisation in the second phase of the project

Performing functions

De-fueling	Dismantling	Decontamination	Waste processing and handling	Engineering support
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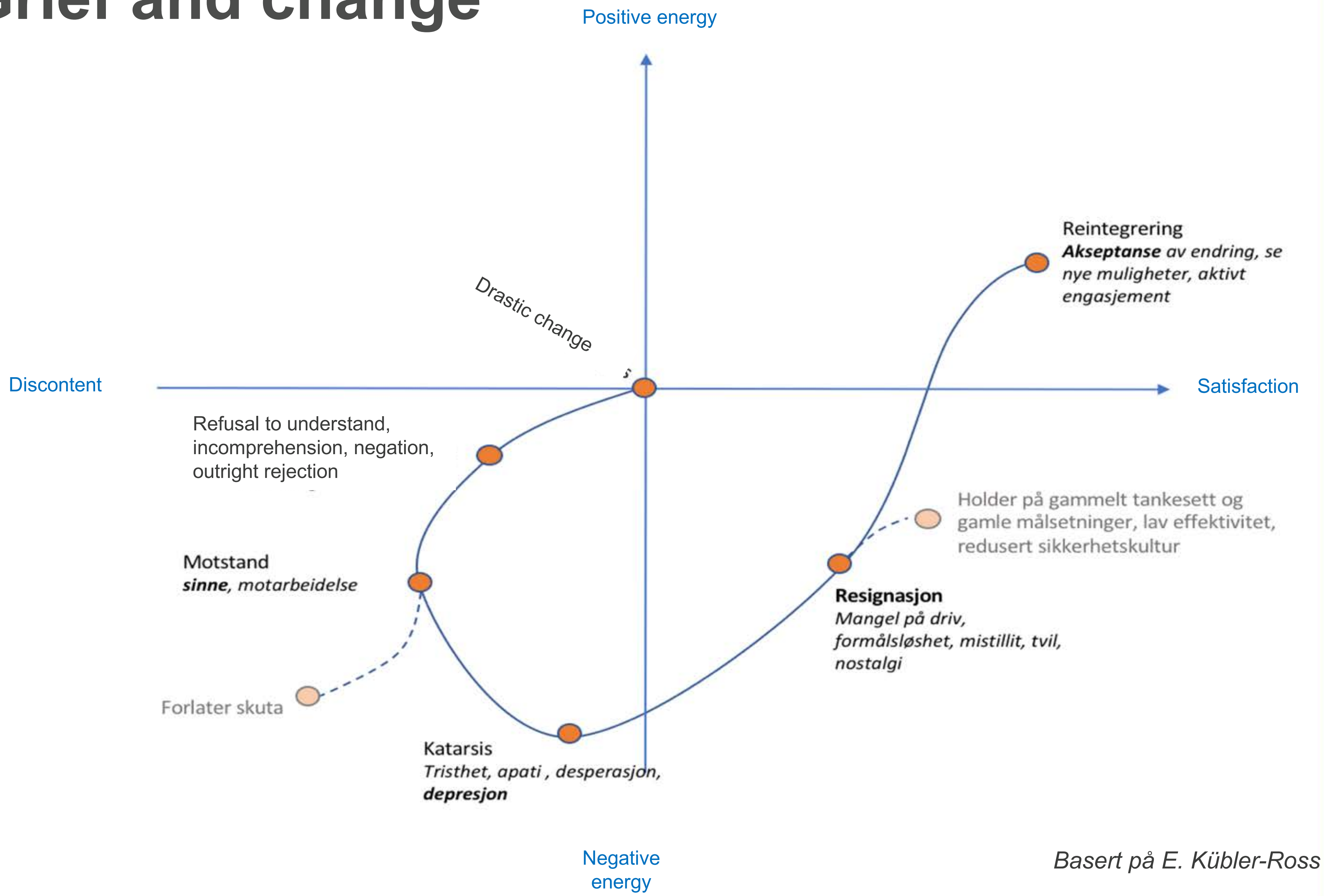
Capacity and basic competence within these functions are so far satisfactory. General competence building is needed in the transition to new tasks within decommissioning.

Safety

- All disciplines put focus on radiation safety and score well on safety focus
- There is however a need for more experience and knowledge of documenting safety
  - «Working safely is my concern, reporting on safety is somebody else´s problem»
  - Traceability
  - Mutual learning
- As for all organisations moving into decommissioning, focus on industrial safety and HSE under changing conditions needs to be increased

Grief and change



Basert på E. Kübler-Ross

One proposed action from competence mapping project: Individual development plans

- Leader and employee together (with expert support where needed) sit down and outline a short plan, typically containing:
  - Work tasks that will be continued
  - New types of work tasks that are expected in future, and a plan for how the employee can prepare for these
  - New challenges and responsibilities that the employee would like to target.
- Such plans will contain many uncertainties, as several preconditions for future work tasks still are not established
  - Waste management and minimisation, levels of decontamination, regulations and guidelines etc.
  - Addressing such uncertainties, and identifying points in time where these will be discussed again will still reduce insecurity and frustration

Next steps

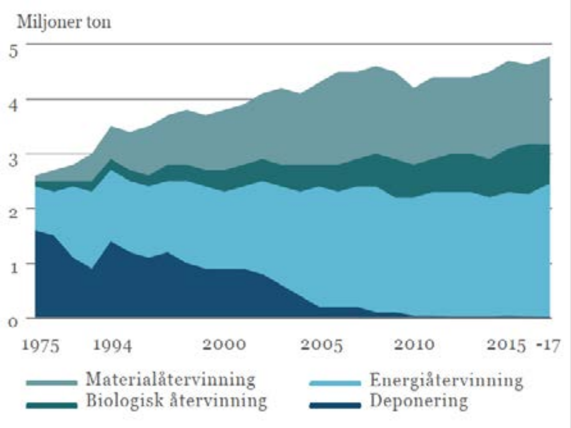
- Building and maintaining competence development plans
  - On the job training
  - Courses
  - Workshops
  - Visits and hands-on experience
- Put in place routines for regular reassessment of competence
- Continue to work on decommissioning leadership and motivational factors
  - Involvement
  - Communication
  - Predictability
  - Job security
- Calibrate data for the rest of the organisation

Management of VLLW

Modelling as the support in sustainable clearance decisions

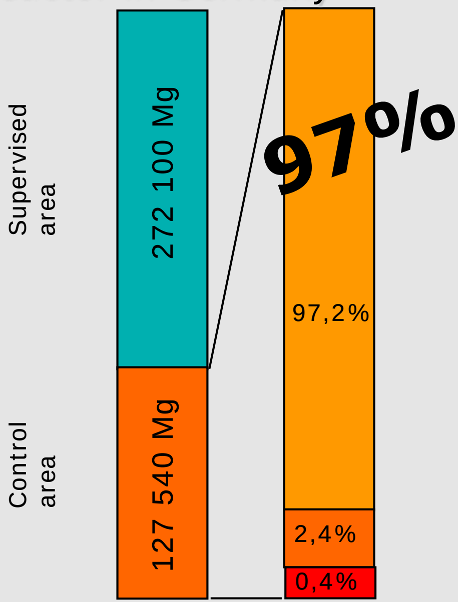
Outlook for wastes in general

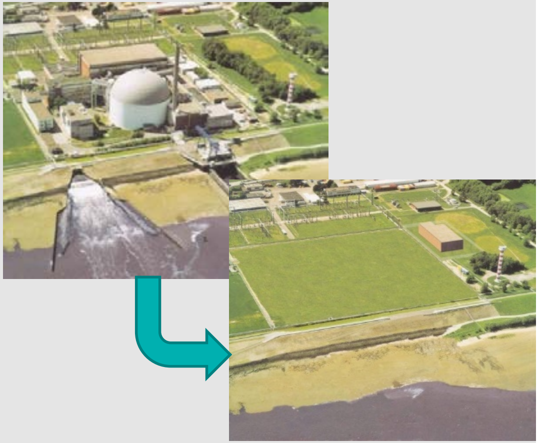
- Reduced waste volumes in society with the vision "There is no waste"
- EU moving towards circular economy concepts and enforcing to target at recycling in new legislations on waste.
- By 2025, at least 55% of waste in the EU will be recycled [NV, AS]
- Decision: Forbidden the disposal of incinerable waste



What is the problem?

Example of masses of waste generated in the D&D of reactor in Germany





Final destinations for VLLW:

- Clearance following SSM FS 2018:3 (unconditioned)
- Recycling (ex. Metal melting), incinerators for energy
- Re-use of construction material and soils
- Disposal in MSW lar

Radioactive was

- Disposal in final
specially engineere

Near surface landfill (MLA)
250 000 tons
Operational costs
25 years: 200M€
Post closure surveillance
30 years: 50M€

VLLW, clearance, decontamination

Some experiences from Germany

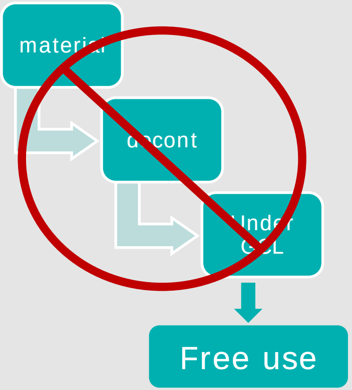
Contaminated areas

Non contaminated areas

Areas with low risk of contamination

Areas with moderate risk of contamination

- Clearable material is dubble as much (or more) than non clearable material
- The final disposal of radioactive waste is coupled to high costs.
- Decontamination to meet clearance levels is an expensive way.
- Clerance levels linked to a specific use for the material (conditional clearance) lead to an alltogether cheaper approach for management of VLLW



Rules for conditioning the clearance?

- Material

Friklassning med särskilda förutsättningar (villkorat till riktad användning)

”En ansökan om friklassning av material som inte kan friklassas enligt 3 §, ska innehålla en analys av olika alternativ till den sökta friklassningen, en beskrivning av de omständigheter som gör att en högre grad av radioaktiv förorening kan accepteras samt beräknade radiologiska konsekvenser”

- Byggnader och mark

”En ansökan om friklassning av byggnadsstruktur eller område ska beskriva hur kvarvarande radioaktiv förorening med hänsyn tagen till ingående osäkerheter förhåller sig till de friklassningsnivåer som gäller enligt dessa föreskrifter eller till friklassningsnivåer som har beslutats av Strålsäkerhetsmyndigheten och i övrigt innehålla de uppgifter som anges i bilaga 7”

SSMFS 2018:3

ÅF tool is IAEAs std method

Clearance tool

Rationale:

Individual effective doses are calculated by evaluating a selected set of scenarios covering all relevant pathways, which lead to the exposure of workers and members of the public from radionuclides in the material to be recycled or disposed of, both on the short-term and the long-term.

- Source term: Waste characterization
- Processer: All treatments to the waste are tracked to characterize the primary and secondary waste
- Scenario: the scenarios (generic or case specific) that cover the range of situations to explore the fate of radionuclides disposed on landfills, possible transfer routes of radionuclides to the atmospheric and aquatic environment, possible exposures to workers and the public arising from the recycling re-use and disposal
- Effective doses are estimated
- Comparison with the limits for general public and workers
- Derivation of the activity concentrations of the radionuclides in the waste linked to the specific destination, that give rise to the accepted dose level => CCL

=> conditioned clearance levels

Key elements of the methodology

- Consistent with the approach used in IAEA Safety Standards Series No. RS-G-1.7:

  Evaluation of a selected set of scenarios covering all relevant pathways leading to an exposure of workers and members of the public (short and long term)

  Determination of activity concentrations such that effective doses

  - for reasonable foreseeable scenarios would not be higher than 10 µSv/a
  - for low probability scenarios not exceed an individual dose of 1 mSv/a

- The derivation CCL takes into consideration:

  The likelihood that a scenario will occur

  The probability of the input parameters used

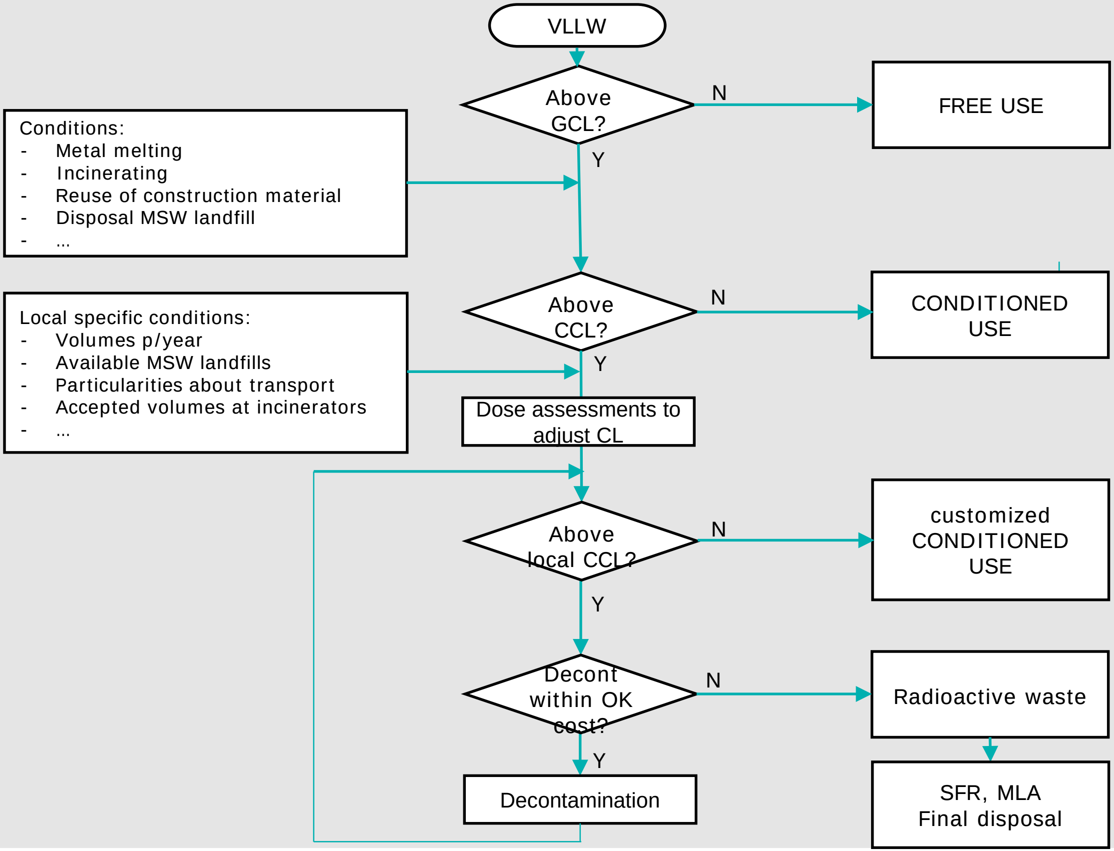
- Deterministic modelling: using realistic and case specific input parameters

- Probabilistic modelling: based on pdf representing the probabilitiy estimates for the different values of the input parameters

Radiological criteria

Group considered	Scenario likely to occur	Scenario unlikely to occur *
Public	Dose less than 10 µSv/a	Dose less than 1 mSv/a
Worker	Dose less than 10 µSv/a	Dose less than 1 mSv/a

Process overview



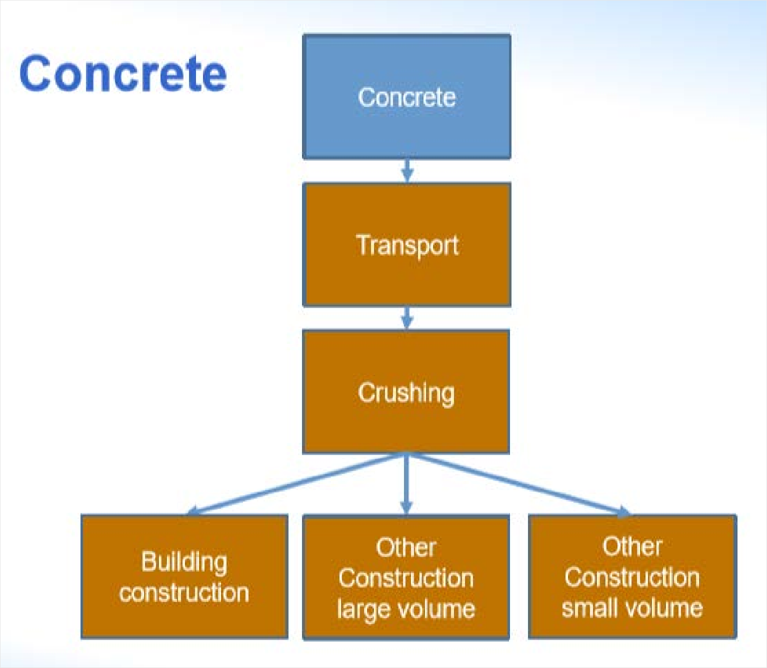
Material types in the waste

- Concrete and other building rubble
- Metals
- Combustible Materials
- Soil
- Secondary materials (e.g. bottom and fly ashes from recycling of metals)
  - Slag and bottom ash from incinerator and smelting furnaces
  - Fly ash from incinerators and dusts from smelting furnaces

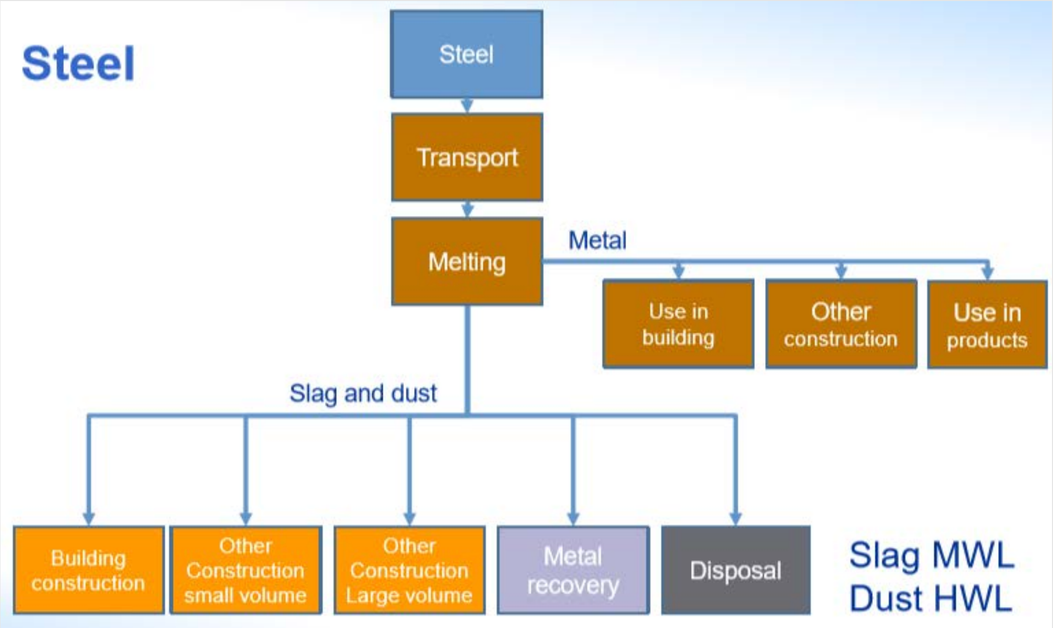
Example of management options

Material type	Management options
Concrete and other building rubble	• Use in building construction after used for making new concrete • Other constructions with small volume and negligible risk of leakage to the water pathways. • Other constructions with large volume and non-negligible risk of leakage to the water pathways. (e.g. as fill material for noise protection walls at streets or for landscaping)
Steel and other metals	• Direct use of metals treated in specialized melting furnaces • Smelting in a foundry and use for new products
Combustible material	• Incineration at a facility for municipal waste • Incineration at a facility for hazardous waste
Soil	• Use in constructions with small volume and negligible risk of leakage to the water pathways. • Use in constructions with large volume and non-negligible risk of leakage to the water pathways. (e.g. as fill material for noise protection walls at streets or for landscaping)

Recycling, re-using



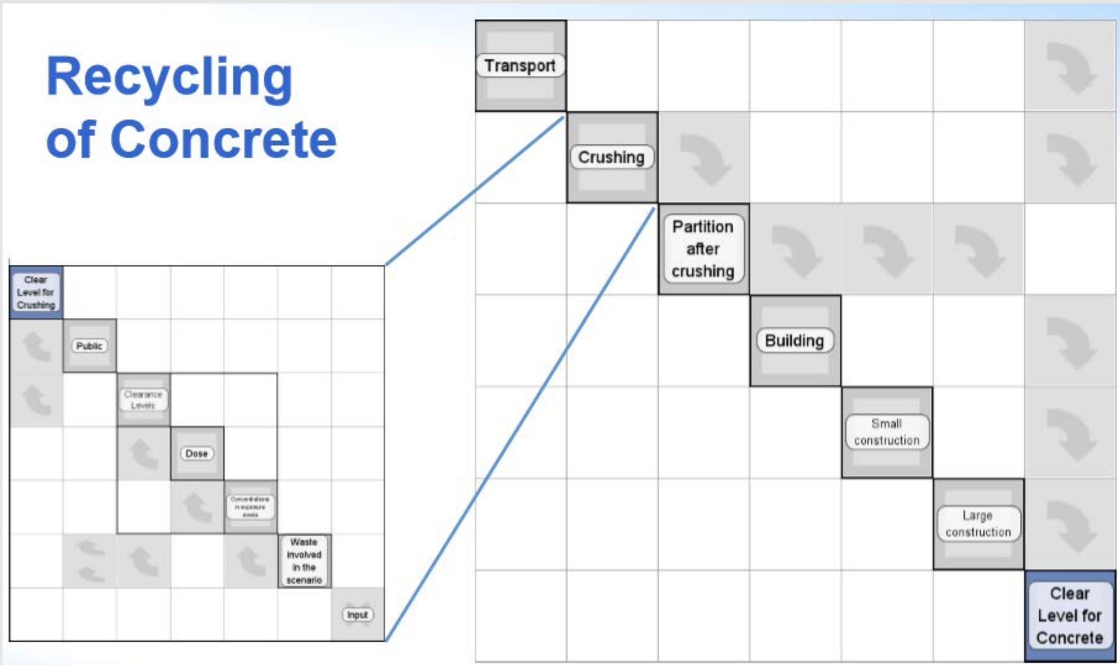
Recycling, re-using



Assumptions for exposure scenarios

Scenarios	Workers	Public
Transport	Transport of material to the recycling facility and unloading: • Exposure of workers from **external irradiation** and **inhalation** of contaminated dust. • Deposition of contaminated dust on uncovered body parts causes **skin exposure**.	Not considered. Less dose than for workers.
Crushing	Concrete is crushed at a special facility: • Exposure of workers from **external irradiation** and **inhalation** of contaminated dust. • Deposition of contaminated dust on uncovered body parts causes **skin exposure**.	Contaminated dust released from crushing facilities may expose nearby residents: • **External irradiation** • **Inhalation** of contaminated dust. • **Ingestion** after deposition on garden crops.
Melting	Metal scrap is handled at a scrap yard and then melted. • Exposure of workers from **external irradiation** and **inhalation** of contaminated dust. • Deposition of contaminated dust on uncovered body parts causes **skin exposure**.	Contaminated dust released from the smelter may expose nearby residents: • **External irradiation** • **Inhalation** of contaminated dust. • **Ingestion** after deposition on garden crops.
Incineration	Combustible waste is incinerated in a waste incinerator facility. • Exposure of workers from **external irradiation** and **inhalation** of contaminated dust. • Deposition of contaminated dust on uncovered body parts causes **skin exposure**.	Contaminated dust released from the incinerator may result is exposure of nearby residents • **External irradiation** • **Inhalation** of contaminated dust. • **Ingestion** after deposition on garden crops.

ECOLEGO - compartmental modelling



Some applications

Derivation of specific CGL (IAEA)

Description: Guidance for application of the CGL. Linkage of the waste types to all generic possible final destinations

Results of project

- Safety report series IAEA std
- Methodology
- Softwares

Post accidental handling of VLLW in Japan - ongoing (Fukushimma prefecture)

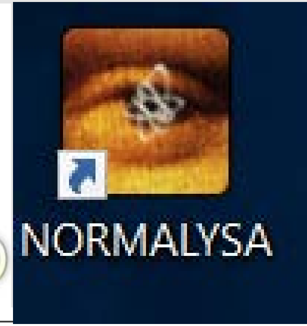
Description: Management of VLLW generated in the aftermath of clean-up operations. Aprox. 1 000 000 m^3 of waste is spread over the territory in 1000 temporary storage facilities

Results of project

- Optimization of the waste storage plans
- Proposal of levels of clearance for disposal in municipal waste landfills

Advantages

- Reduced costs for transport and final disposal of radioactive waste to SFR
- Reduced costs for onsite repository solutions (MLA)
- Decreased decontamination costs
- Possible revenue from the sale of waste
- Proven and implemented IAEA standard method in many countries => facilitates approval process by authorities
- Operators brand strengthened by acting sustainably for society



radionuclide	exemption level			clearance												
				unrestricted clearance of					clearance o							
	activity in Bq	specific activity in Bq/g	HASS activity/ 1/100 A_1 in Bq	surface contamination in Bq/cm²	solid substances and liquids in Bq/g	demolition waste, excavated soil of more than 1 000 t/a in Bq/g	soil areas in Bq/g	buildings for reuse and further use in Bq/cm²	solid substances up to 100 t/a to be disposed of on landfills in Bq/g	solid substances and liquids up to 100 t/a to be disposed of in an incineration facility in Bq/g	solid substances up to 1,000 t/a to be disposed of on landfills in Bq/g	solid stan ar liquid t 1,00 to disp of ir incir tion facility in Bq/g	[illegible] for demolition in Bq/cm²	debris for recycling in Bq/g		
1	2	3	3a	4	5	6	7	8	9a	9b	9c	9d	10	10a	11	
Fe-52	1 E+6	1 E+1	3 E+9	1 E+2	1 E+1	7 E-2		1					2 E+3	1 E+1	8,3	h
Fe-55	1 E+6	1 E+4	4 E+11	1 E+2	2 E+2	2 E+2	6	1 E+3	1 E+4	1 E+4	7 E+3	1 E+4	2 E+4	1 E+4	2,7	a
Fe-59	1 E+6	1 E+1	9 E+9	1	[illegible]	[illegible] E-1	[illegible]	1	[illegible]	[illegible]	[illegible]	4	3 E+1	1 E+1	45,1	d
Fe-60+	1 E+5	1 E+2													1,0 E+5	a
Co-55	1 E+6	1 E+1	5 E+9	1	[illegible]	[illegible]	[illegible]	[illegible]					1 E+3	1 E+1	17,5	h
Co-56	1 E+5	1 E+1		1	[illegible]	[illegible]	[illegible]	1	4	5	1	1	6	0,4	78,8	d
Co-57	1 E+6	1 E+2	1 E+11	1 E+1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5 E+1	1 E+2	2 E+1	271,3	d
Co-58	1 E+6	1 E+1	1 E+10	1	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	5	3 E+1	1	70,8	d
Co-58m	1 E+7	1 E+4	4 E+11	1 E+2	1 E+4	1 E+4		1 E+3					1 E+9	1 E+4	8,9	h
Co-60	1 E+5	1 E+1	4 E+9	1	1 E-1	9 E-2	3 E-2	4 E-1	6	7	2	2	3	0,6	5,3	a
Co-60m	1 E+6	1 E+3		1 E+2	1 E+3	6 E+1		1 E+3					7 E+7	1 E+3	10,5	m

TACK