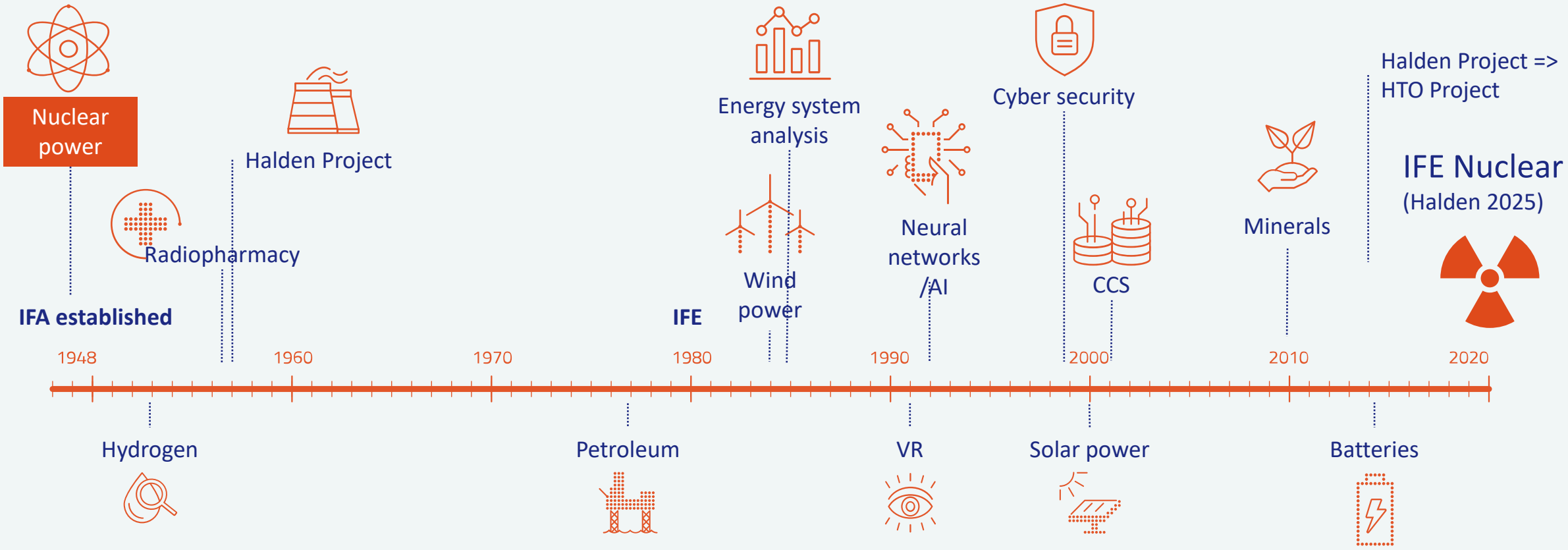
An AI and Digital Twin-Inspired Approach to Modern Radiation Protection

NSFS Conference at Lillehammer 28/8-25

Niels-Kristian Mark (niels.Kristian.mark@ife.no / Senior scientist in the APS dep.)

Thanks for contribution to Bálint Batki, Abdenour Benkrid, Joachim Bratteli, Svein Tore Edvardsen, Istvan Szőke, Omar Zahra

IFE has been at the forefront of advancement for 70 years and plays a key role in the development of Norway as an energy nation



Reactors:

1951: JEEP I — 1967

1959: Halden Reactor — 2018

1961: Nora — 1968

1967: JEEP II — 2019

Norwegian Nuclear Research Centre

Norsk Nukleært Forskningssenter
Norwegian Nuclear Research Centre

NNRC consortium and associates

Academia

UiO
NTNU
Universitetet i Stavanger
Høgskulen på Vestlandet
CHALMERS
Berkeley
iThemba LABS

Research & Application Sector

SYKLOTRON
NORSAR
Norwegian Meteorological Institute
SINTEF
FFI Forsvarets forskningsinstitutt
NILU

Other

Fagskolen i Viken
NND, Halden Municipality, ...

NNRC affiliations

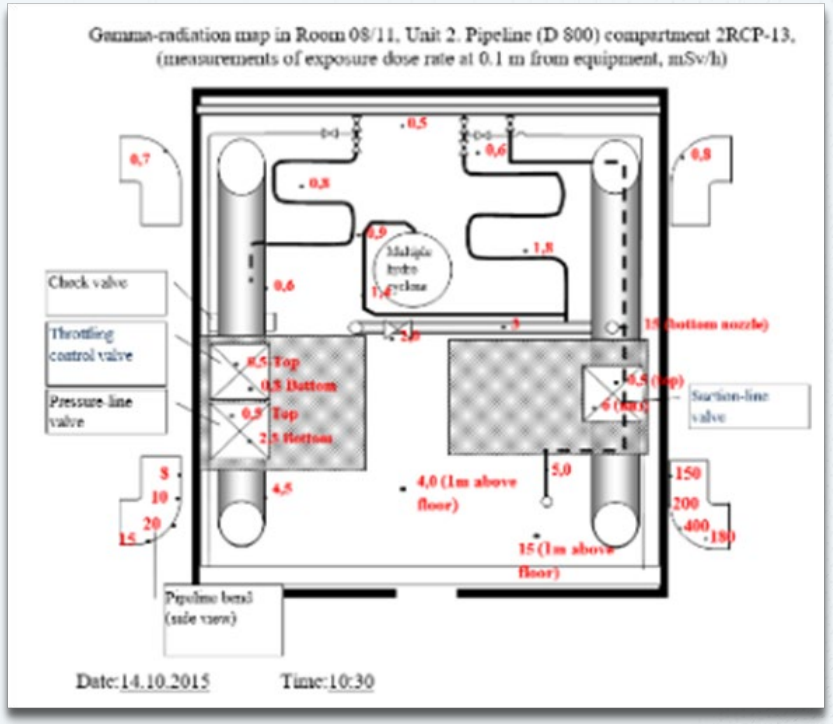
IAEA Collaborating Centre
NCNR
HALDEN PROJECT HTO DECOM
ELINDER
dScience
Digi DECOM'22
INTPART

Other international partners & networks ...

Motivation & Challenges

Modernizing Radiation Protection

- The nuclear industry faces increasing demands for digitalization, enhanced safety, and operational efficiency.
- Current practices often rely on static models, manual measurements, and conservative assumptions.
- The convergence of three key technologies offers a transformative solution :
  - Building Information Modelling (BIM)
  - Robotics
  - Artificial Intelligence (AI)



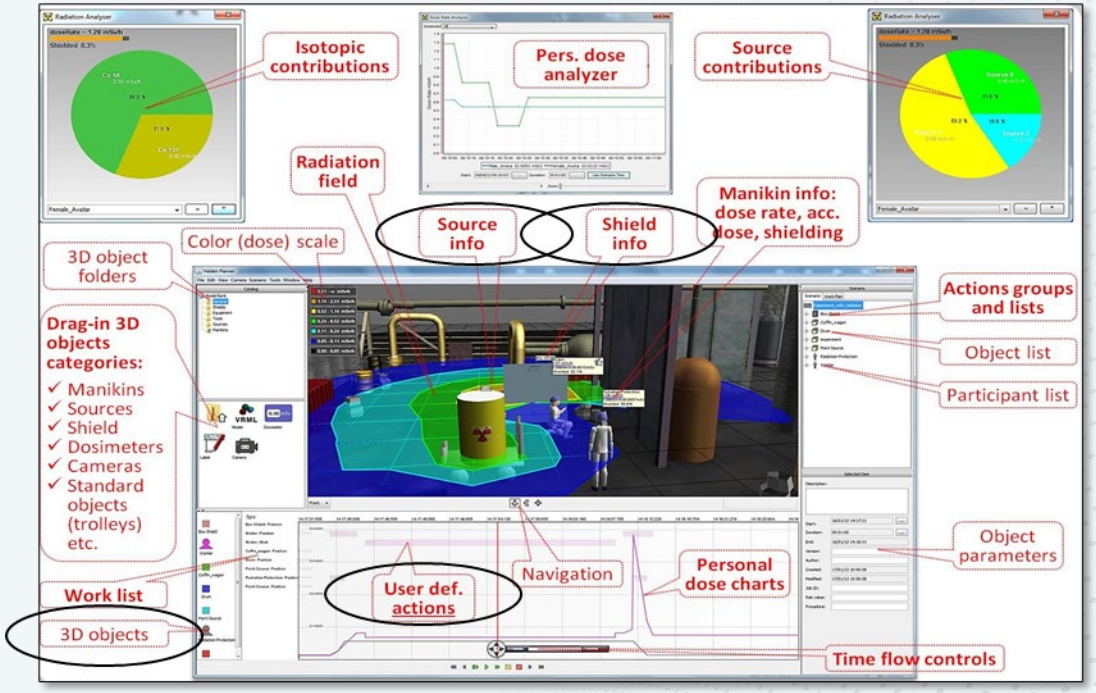
Concept Overview – HADRON

The HADRON Concept

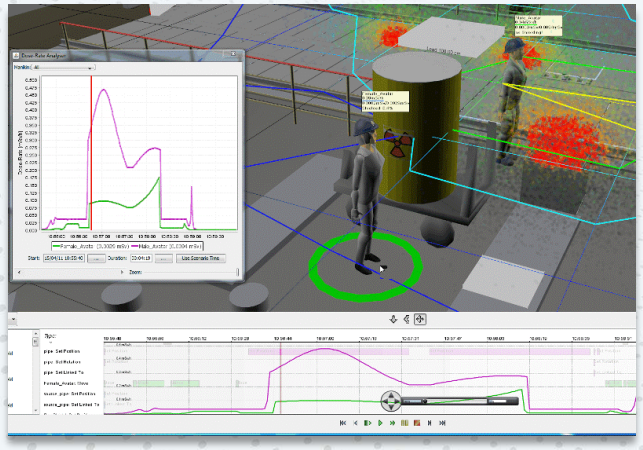
- HADRON - Hazard Aware Digitalization and Robotics in Nuclear.
- An integrated, intelligent ecosystem that creates a seamless "digital thread" between the physical facility and a dynamic digital model.
- To ensure planning and operations are based on the most current and accurate information available, moving from static plans to a living model.

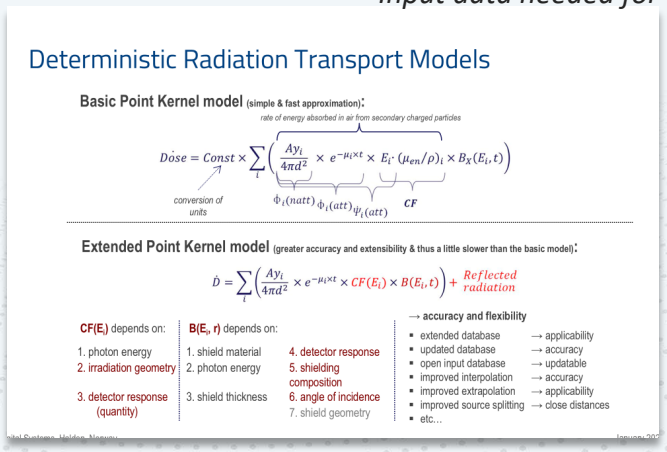
Core Component – VRdose Platform

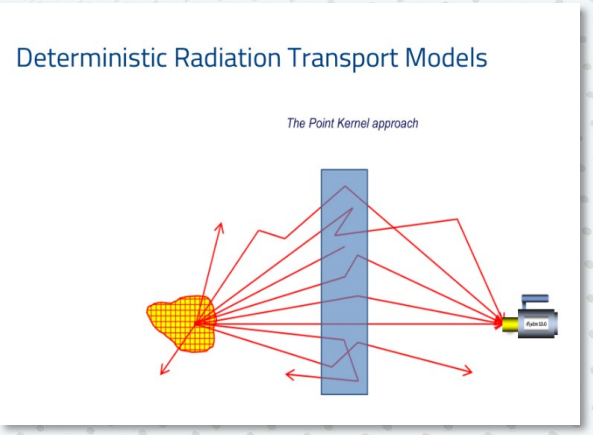
- A real-time 3D simulation and decision-support tool for ALARA planning.
- Key Features:
  - Interactive 3D Visualization: See radiation fields in real-time.
  - Dynamic Scenario Planning: Interactively test work plans, shielding, and source changes.
  - Automated Dose Estimation: Get rapid, quantitative dose calculations to support decisions.
  - Multi-User Collaboration: Plan and train together in an immersive virtual environment.
  - Use of point-kernel method for dose estimation.



Input data needed for using VRdose marked with circles

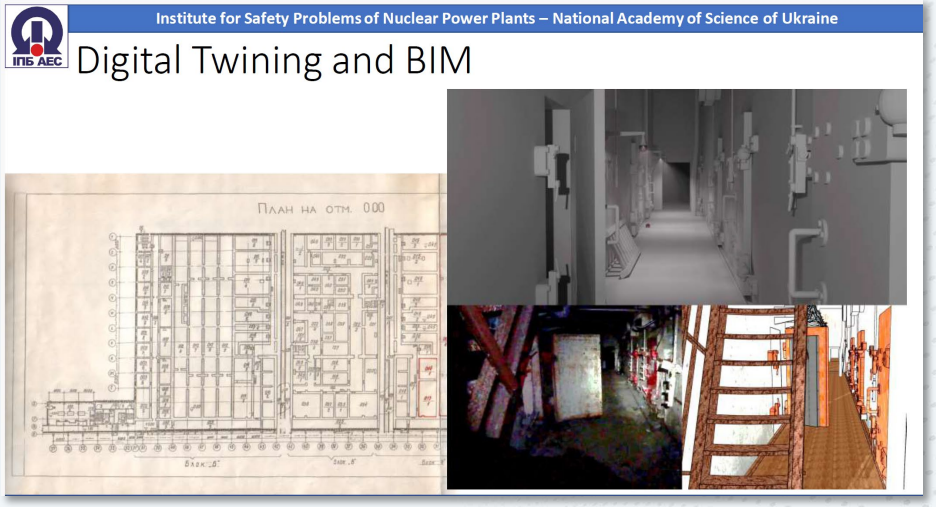


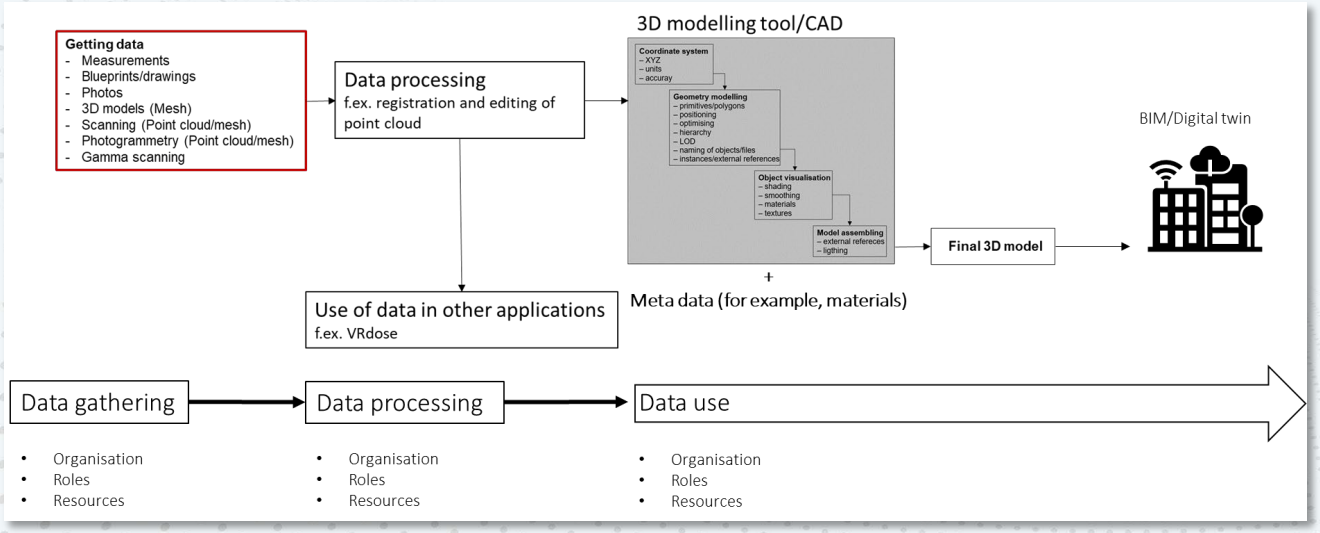


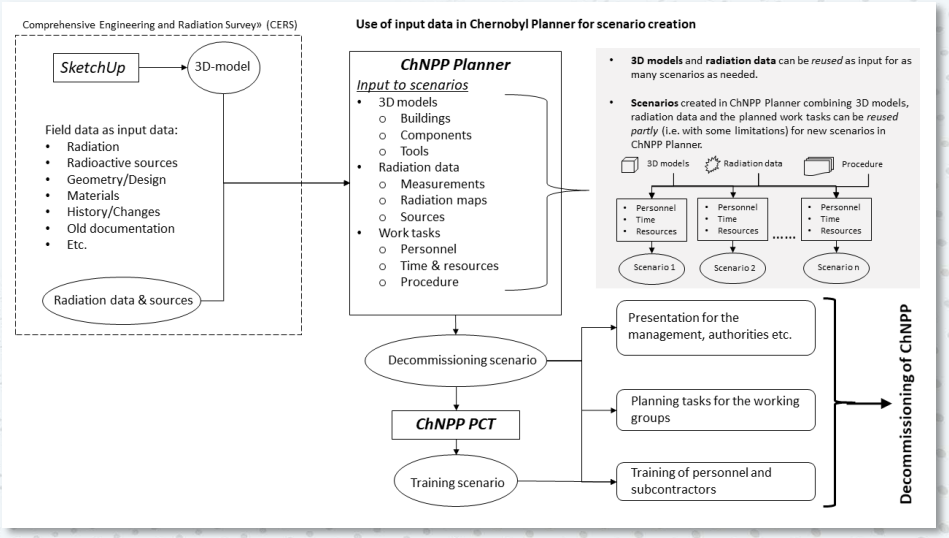


Integration with BIM Systems

- Provides the foundational, context-aware model of the facility.
  It is the "single source of truth" for layouts, materials, and structures.
- VRdose imports standard BIM files (e.g., IFC).
- Ensures simulations are based on the actual physical configuration, including inherent shielding, eliminating errors from outdated drawings.
- Fast updates, improved accuracy, streamlined workflows.

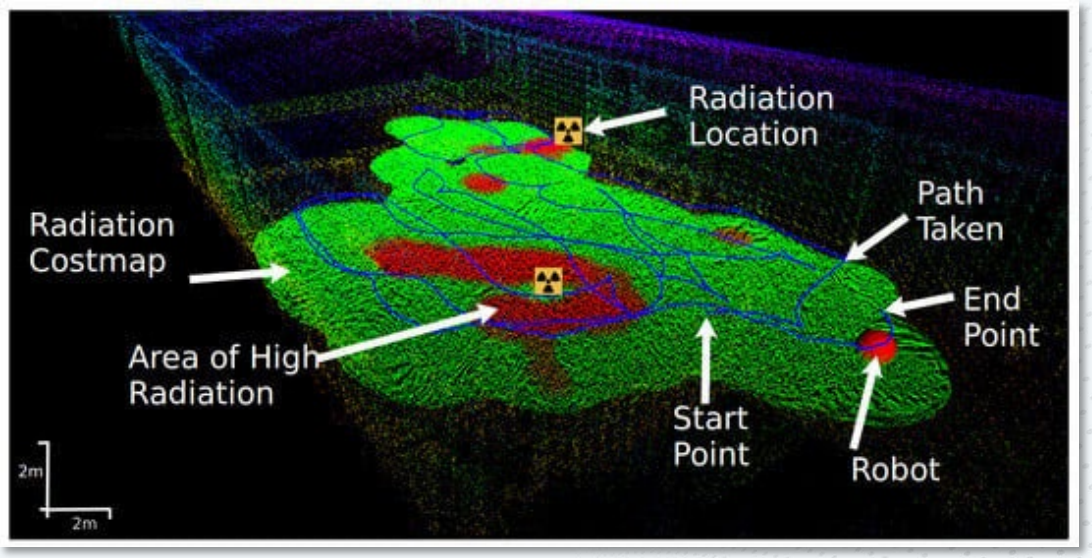


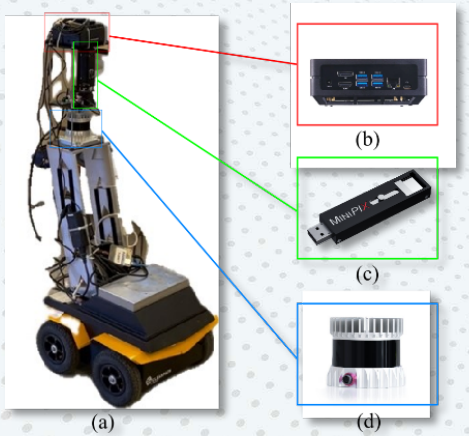


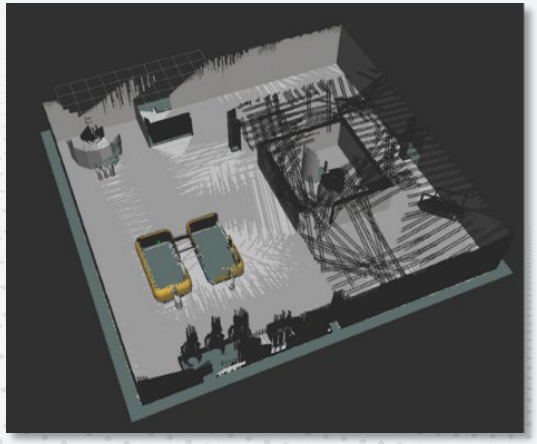


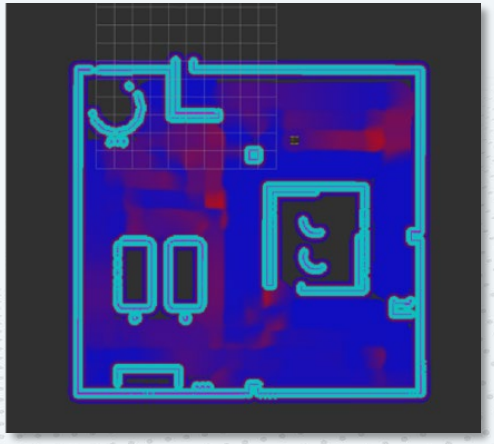
Robotics for Environmental Mapping

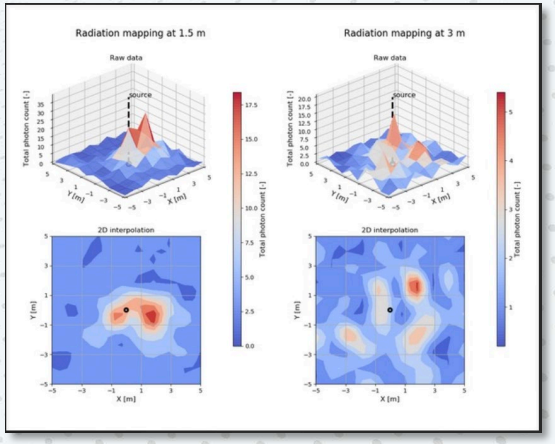
- Role of Robotics: Moves planning from assumption-based to evidence-based.
- Autonomous mobile robots equipped with sensors (Gamma Cameras, LiDAR, Dosimeters) map the real-world radiological environment.
- Accurate, up-to-date spatial and radiometric data imported into VRdose, which is critical for unknown or changing environments like decommissioning sites.





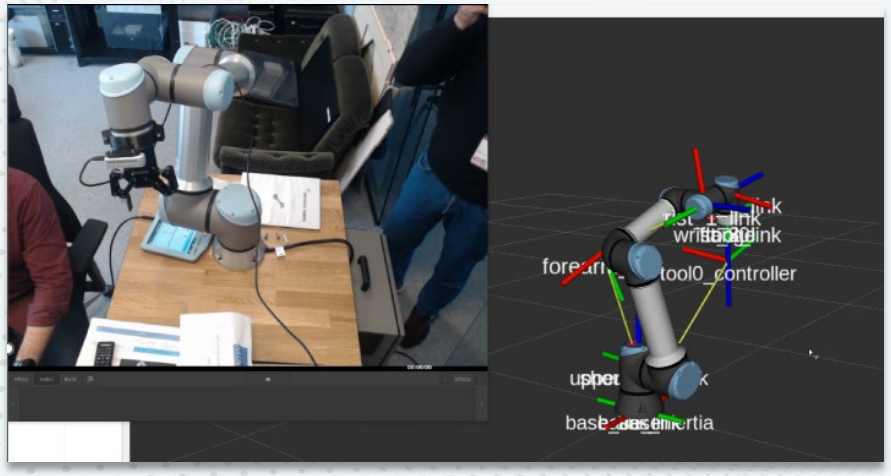


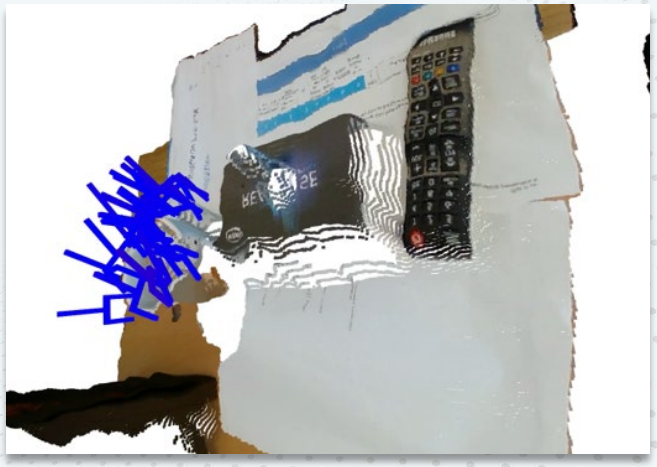




AI Intelligence

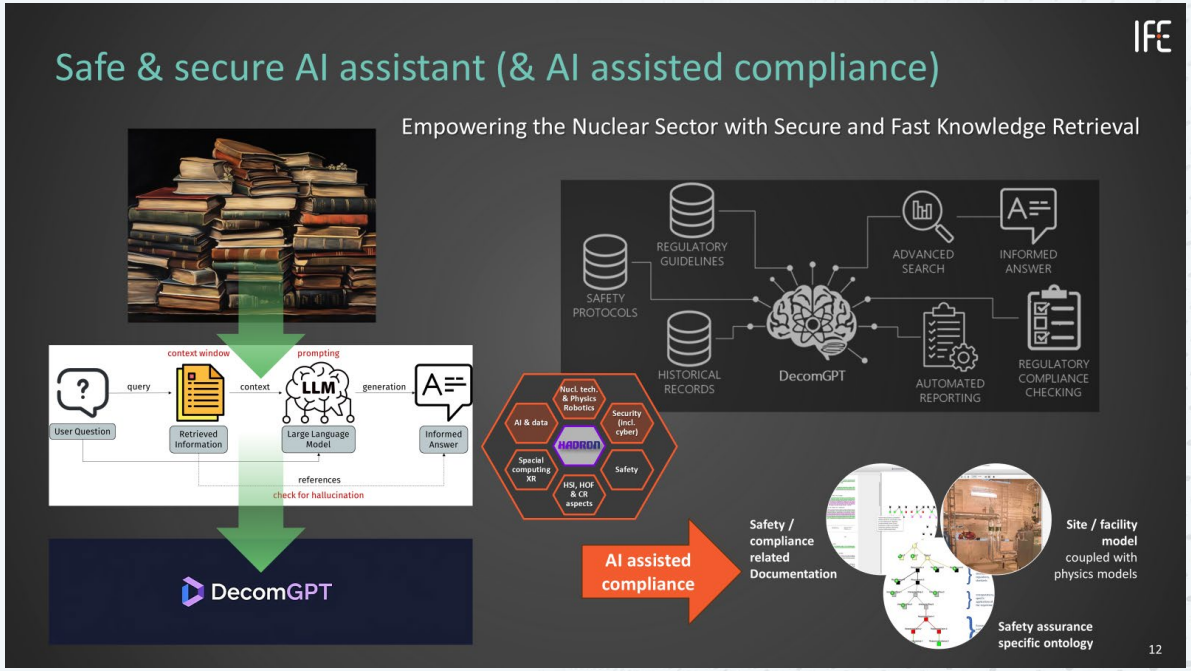
- Role of AI: Augments and automates the radiation protection workflow.
- Robotic Manipulation: Object recognition and graspability





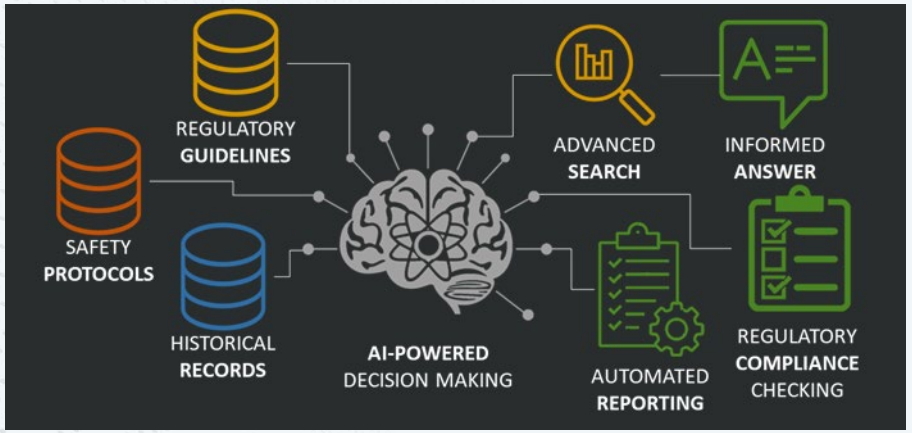
AI Augmentation

- Augments and automates the radiation protection workflow.
- Key Applications:
  - Intelligent Dose Modelling: Faster, more accurate dose calculations.
  - Automated Scenario Generation: AI proposes optimized work plans to minimize dose.
  - Natural Language Interfaces: Simplifies the planning process using plain language commands.
  - Data-Driven Analytics: Identifies trends and predicts future conditions.
- AI tools enhancing VRdose capabilities
- Intelligent dose modelling, automated scenario generation
- Natural language interfaces and data-driven analytics



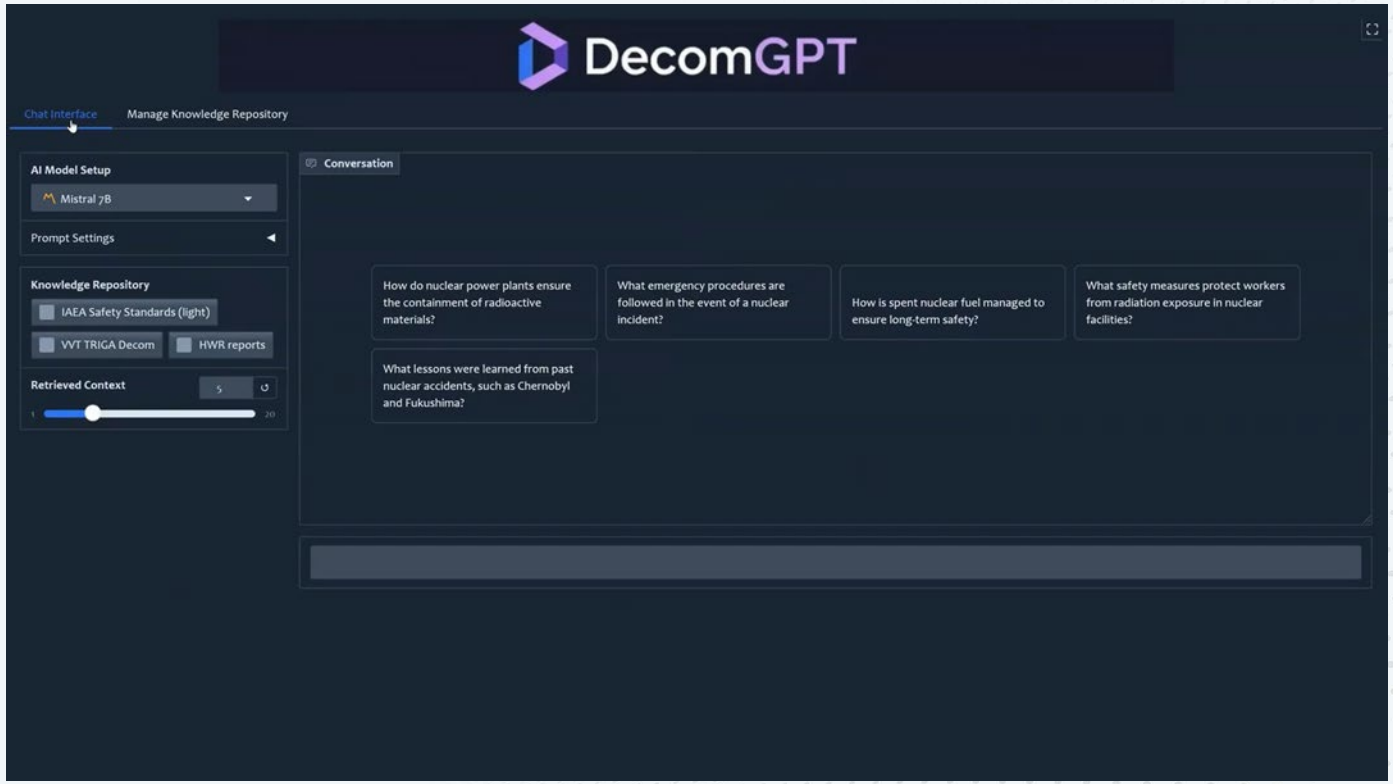
DecomGPT- Secure AI for the Nuclear Sector

Nuclear-Specific Knowledge Base & Use-Cases

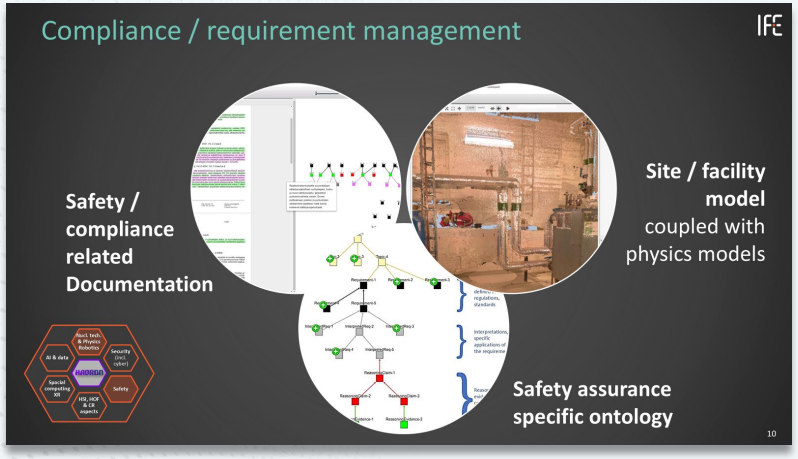


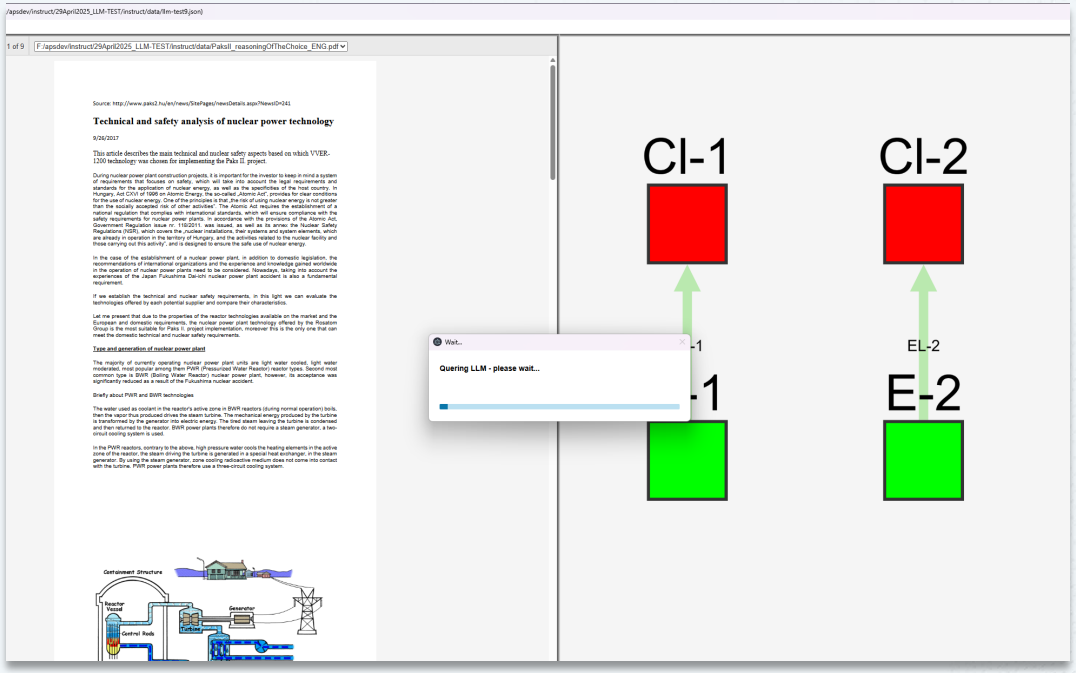
Secure Local Deployment

DecomGPT – Working with IAEA Safety Standards



Instruct – AI checking





Source: http://www.paks2.hu/en/news/SitePages/newsDetails.aspx?NewsID=241

Technical and safety analysis of nuclear power technology

9/26/2017

This article describes the main technical and nuclear safety aspects based on which VVER-1200 technology was chosen for implementing the Paks II. project.

During nuclear power plant construction projects, it is important for the investor to keep in mind a system of requirements that focuses on safety, which will take into account the legal requirements and standards for the application of nuclear energy, as well as the specificities of the host country. In Hungary, Act CXVI of 1996 on Atomic Energy, the so-called „Atomic Act", provides for clear conditions for the use of nuclear energy. One of the principles is that „the risk of using nuclear energy is not greater than the socially accepted risk of other activities". The Atomic Act requires the establishment of a national regulation that complies with international standards, which will ensure compliance with the safety requirements for nuclear power plants. In accordance with the provisions of the Atomic Act, Government Regulation issue nr. 118/2011. was issued, as well as its annex the Nuclear Safety Regulations (NSR), which covers the „nuclear installations, their systems and system elements, which are already in operation in the territory of Hungary, and the activities related to the nuclear facility and those carrying out this activity", and is designed to ensure the safe use of nuclear energy.

In the case of the establishment of a nuclear power plant, in addition to domestic legislation, the recommendations of international organizations and the experience and knowledge gained worldwide in the operation of nuclear power plants need to be considered. Accordingly, taking into account the experiences of the Japan Fukushima Dai-ichi nuclear power plant accident is also a fundamental requirement.

CI-1

CI-2

Based on the provided context, here is an evidence-based response addressing your question about whether there is support for a claim regarding the fulfillment of minimum requirements for a newly constructed nuclear power plant in Hungary (as per the Nuclear Safety Regulation - NSR and National Atomic Act). I'll keep this focused strictly on the given text. ### Claim: Minimum requirements for a newly constructed nuclear power plant will be fulfilled The context does not explicitly confirm that these minimum requirements *will* be fulfilled, as it is primarily descriptive of regulatory standards and their basis in international guidelines. However, there are several pieces of evidence from the text that implicitly support this claim by establishing what must be done to meet the requirements and ensuring they can be met through existing regulations and reactor designs. #### Evidence from the Context: 1. **Clear Definition of Minimum Requirements**: The NSR (Nuclear Safety Regulation) is presented as a key document that sets out explicit minimum safety criteria for new nuclear power plant units, such as the zone melting frequency limit being reduced to 10^{-5}/year and ensuring that significant or early radioactive releases can be practically excluded during accidents. This means that by designating these requirements in regulatory law (the National Atomic Act), there is a defined set of standards against which new plants must be evaluated. 2. **Enforcement Mechanism**: The text emphasizes that for new reactors, licensees must "demonstrate" compliance with specific safety measures, such as the exclusion of radioactive releases and adherence to the tightened zone melting frequency criteria (10^{-5}/year). This requirement implies a process for fulfillment during licensing or operation. 3. **Incorporation of International Standards**: The NSR is based on international regulations like EURATOM 2014/87 directive, which sets minimum requirements globally and has been integrated into Hungarian national laws. By referencing these standards, the context suggests that new plants must align with them to be considered compliant. 4. **Reactor Design Compatibility**: Examples of reactor types available—such as PWR (e.g., AP1000), BWR, EPR, and VVER-1200—demonstrate that designs exist which can meet the NSR criteria based on their capacities (ranging from 1100 to 1700 MW). The text notes that while some types like BWR have seen reduced acceptance due to events like Fukushima, other PWR-based reactors are engineered with these updated minimums in mind. 5. **Contextual Suitability for Domestic System**: Although not directly about fulfillment of requirements, the mention of domestic technical and nuclear safety needs (e.g., fitting reactor sizes into Hungary's electricity system) highlights that the NSR criteria are intended to be relevant for new constructions under consideration. This adds an implicit layer where minimums can be fulfilled if they align with both national regulations and operational realities. ### Limitations: - The evidence is regulatory and normative, not empirical or based on specific instances of plant construction fulfilling these requirements. - There is no data in the text confirming that any particular new nuclear power plant has successfully met all NSR criteria; it focuses instead on what must be done to fulfill them (e.g., demonstration through licensing). In summary, while the context does not explicitly state with certainty that minimum requirements will be fulfilled for future constructions, it provides a strong basis for believing they can be fulfilled by defining them clearly, requiring compliance processes during design and licensing, and ensuring relevant reactor designs are available. If you have additional details about specific regulatory actions or demonstration processes in place (e.g., from the national nuclear authority), this could strengthen the case for fulfillment through adherence to these standards. If your query was meant to ask what these minimum requirements specifically entail based on the context alone, I can provide that summary separately below!

Conclusion & Future Outlook

- The HADRON concept is a viable and powerful solution for modernizing radiation protection.
  - Paradigm Shift: Moves from linear workflows to a cyclical, data-driven process.
  - HADRON + VRdose = Scalable, intelligent infrastructure for nuclear operations
  - Integrates BIM, robotics, and AI for dynamic radiation protection.
- Benefits:
  - Enhanced Safety: Through data-driven, optimized planning.
  - Improved Efficiency: By reducing manual effort and streamlining workflows.
  - Better Collaboration: Fostering shared understanding among all stakeholders.
- Future Focus:
  - Full integration into a digital twin architecture
  - Expanding robotic platform integrations
  - Enhancing AI capabilities

Thank you for your interest

Ife.no