05. JUNI 2024

ÅPENT

Kjernekraft, risiko og pålitelighet

Bjørn Axel Gran
Konstituert Vise President

Dagens agenda

01 Repetisjon fra sist ESRA års seminar

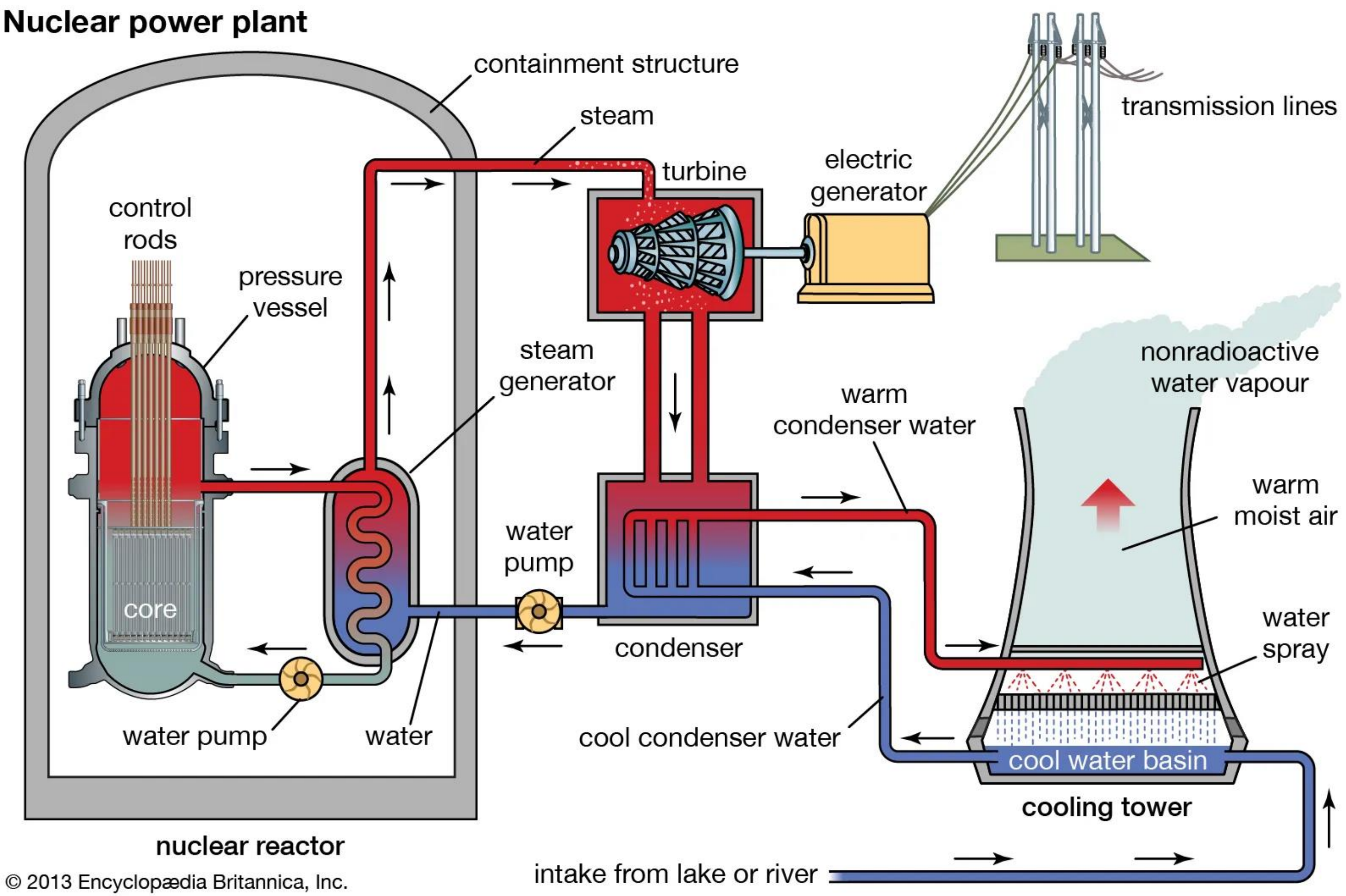
02 Utfordringer

03 Utfordringer med SMR

04

05

Slik fungerer et kjernekraftverk



ESRA Norge
Norsk forening for risiko- og pålitelighetsanalyse

En forening tilknyttet Tekna

ESREL 2023 – Seminar / Webinar, 1. Juni 2023 kl. 10:00 – 14:30

kl. 10:00-10:10 **Velkommen,** Bjørn Axel Gran, Styreleder ESRA Norge
kl. 10:10-10:40 **Introduction to nuclear power and Small Modular Reactors,** Rob McDonald, IFE
kl. 10:40-11:10 **Rules and guidelines,** Fredrik Espegren, DSA
kl. 11:10-11:30 **Pause**
kl. 11:30-12:00 **Probabilistic Safety Assessment – hva er det – og hvordan vurdere sikkerheten til et anlegg?,** Anders Olsson, VysusGroup Sweden
kl. 12:00-12:30 **Risikoanalyser på den skarpe enden,** Terje Tverberg, IFE
kl. 12:30-13:00 **Lunsj**
kl. 13:00-13:30 **Human Reliability Analysis – hva er det – og er mennesket en kritisk barriere?,** Andreas Bye, IFE
kl. 13:30-14:00 **Control Room – hvordan sikre at operatøren har god oversikt over anleggets sikkerhet,** Lars Hurlen, IFE
kl. 14:00-14:30 **Avfallshåndtering – krav og muligheter,** Håvard Kristiansen, Norsk Kjernekraft AS

Webinaret ble tatt opp.

Hvordan sikrer vi trygg og pålitelig kjernekraft? - YouTube

En forening tilknyttet Tekna

Kort repetisjon

Which safety functions?

- Reactor shutdown
- Pressure relief
- Core cooling
- Residual heat removal
- Containment integrity

Internal hazards

- Pipe breaks
- Turbine trip
- Load drops

External hazards

- Fire, flooding, earthquake, airplane crach
- Digital I&C common causes
- Cyber events
- Nearby industry

Kort repetisjon (ii)

Shall apply both:

- Deterministic – a safety margin between load and strength
- Probabilistic – probability of failure low enough

Basic concepts of PSA/PRA

- Event Trees
- Fault Trees
- FMEA
- Bow Tie
- Operator studies

Factors of uncertainty

- Scenarios not accounted for in design basis
- Variability in operation
- External factors
- Aging
- Human factors

Accidents

- Three Mile Island
- Chernobyl accident
- Fukushima

Kort repetisjon (iii)

Use of:

- Risk informed regulations
- During design
- Safety in operation
- Periodic safety reviews

Benefits

- Reduce outage durations
- Increase plant reliability (life-time)
- Reduce amount of inspection
- Reduce exposure to radiation

Challenges

From ongoing projects

- Many dependencies in complex plants
- Realism
- Completeness
- Accident progression (rare events)
- Data (including Human Reliability)
- up-to-date Models

As said by HTO Halden

- Human Performance (control room crews, digital control rooms, teamwork)
- Digital I&C – Safety assurance (methods for ensuring safety and reliability of digital I&C)
- Control Room Design & Evaluation (Control room validation, design of overview displays)
- Human-Automation Collaboration (SMRs, multi-unit operation, higher levels of automation)
- Digital Systems for Operations and Maintenance (Condition monitoring, outage)
- Sustainable Decommissioning (VR, AR, Robotics)
- Cyber Security for Main Control Rooms (Handling of cyber threats and attacks)

Focus on Diversity since 1977

A LIST OF RELEVANT HALDEN REPORTS

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- Halden Work Report HWR-xx.
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HIR-95. 1978:
G. Dahll and J. Lahti: "Investigation of Methods for Production and Verification of Safety Related Computer Programmes".

HWR-97, May 1983.
S. Yoshimura: "Test Strategy for Back-to-back Testing."

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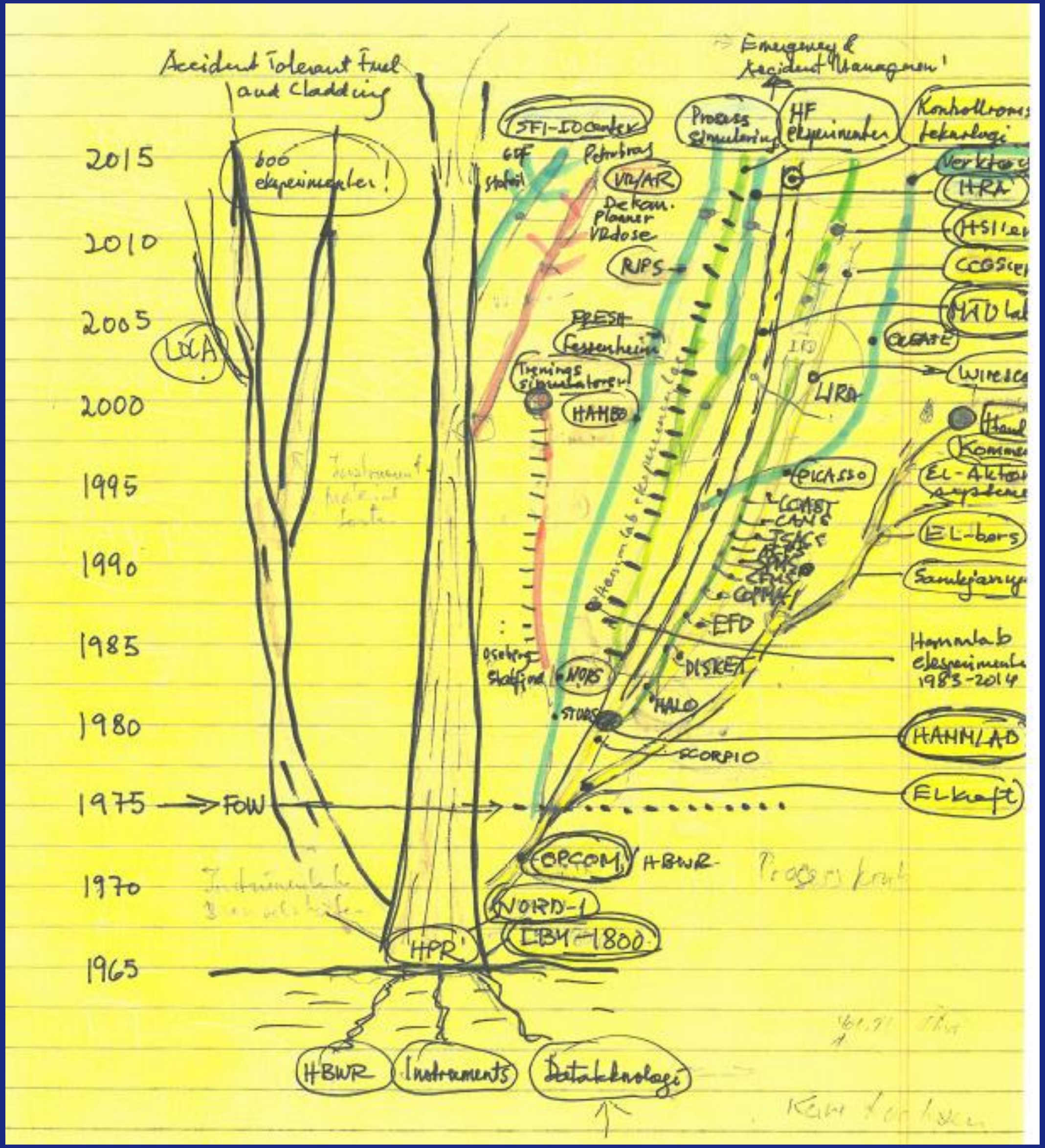
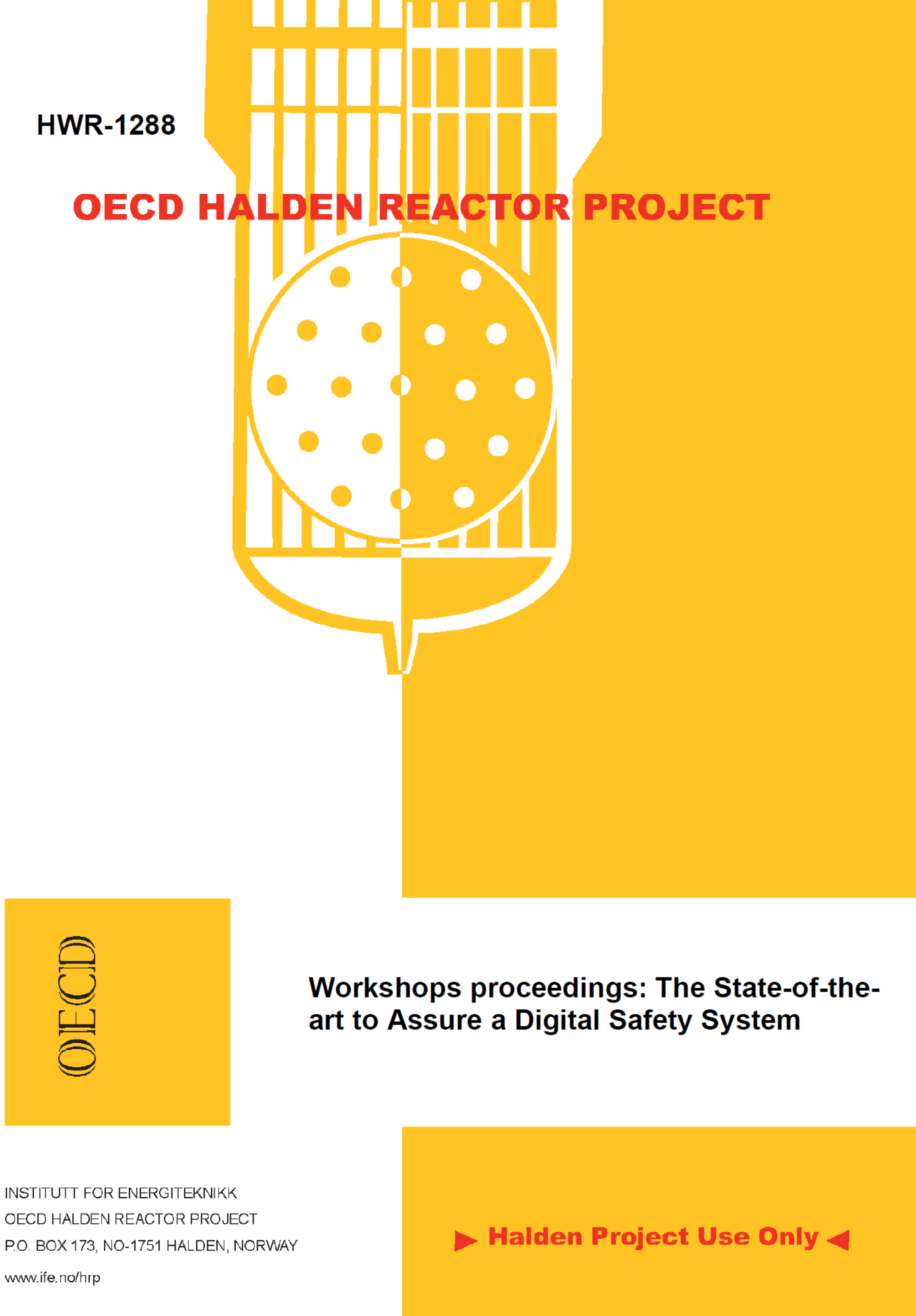


The view of a former Programme Manager

HALDEN PROJECT HTO

Highlights from the 2020 workshop series

By Coralie Esnoul, Bjørn Axel Gran, John Eidar Simensen, Silje Arendt Olsen, Sizarta Sarshar, Peter Karpati, Xueli Gao


HWR-1288

OECD HALDEN REACTOR PROJECT

OECD

Workshops proceedings: The State-of-the-art to Assure a Digital Safety System

INSTITUTT FOR ENERGITEKNIKK
OECD HALDEN REACTOR PROJECT
P.O. BOX 173, NO-1751 HALDEN, NORWAY
www.ife.no/hrp

▶ Halden Project Use Only ◀

Scope for the overarching assertion

- A safety function is implemented with digital technology.
- Focus: A safety function of the highest criticality – reactor protection.
- Only this safety function is allocated to the system to which this position statement applies.
- Existing (functional and human) diversity and layers of defence in depth (outside the instrumentation & control safety system) are not changed.

The application logic, types and numbers of inputs and outputs are comparable to current NPPs, see Table 4 of HWR-1288 for examples of characteristics of critical nuclear safety functions.

Input Source	Input parameter	Trip Set point	Response Time (ms) (not incl. sensor response)	Output action
Reactor	Power	High	≤ 186	Trip (Scram) Reactor
Reactor Coolant System Reactor	Flow Rate; Power	Adjustable	≤ 186 (flux) ≤ 769 (flow)	Trip (Scram) Reactor
Reactor Coolant Pump Reactor	Pumps On/Off; Power	Low (Power)	≤ 186 (flux) ≤ 131 (power)	Trip (Scram) Reactor
Reactor Coolant System	Pressure	High	≤ 175	Trip (Scram) Reactor
Reactor Coolant System	Pressure	Low	≤ 175	Trip (Scram) Reactor
Reactor Coolant System	Pressure	Adjustable Low Set Point	≤ 175	Trip (Scram) Reactor
Reactor Coolant System	Temperature	High	≤ 425	Trip (Scram) Reactor
Reactor Building	Pressure	High	≤ 150	Trip (Scram) Reactor
Main Feedwater Pump Reactor	Oil Pressure; Power	Low (Power)	No existing requirements	Trip (Scram) Reactor
Main Turbine Reactor	Turbine On/Off Line; Power	Low (Power)	No existing requirements	Trip (Scram) Reactor
Reactor Coolant System	Pressure	Low	≤ 175	Inject High Pressure (HP) coolant
Reactor Coolant System	Pressure	Low Low	≤ 175	Inject Low Pressure (LP) coolant
Reactor Building	Pressure	High	≤ 150	Inject HP coolant Inject LP coolant Cool Reactor Building Isolate Reactor Building
Reactor Building	Pressure	High High	≤ 150	Reactor Building Spray

Table 4 of HWR-1288

Overarching assertion

It is technically feasible within the state-of-the-art to provide reasonable assurance that a digitally implemented safety function will be performed as intended.

Such reasonable assurance will not require diverse design means of performing the same safety function or one with an equivalent effect.

Support for the overarching assertion covered for:

1. General
2. Hazard identification
3. Requirements specification
4. Architectural specification and verification
5. Unit verification
6. Integration and organization of all the evidence to enable independent assurability

Elicitation – Hazard identification – Limitations/Gaps

4.1 Completeness of a hazard analysis cannot be guaranteed.

4.2 Operating experience and historical data are considered in hazard analysis.

4.3 No published authoritatively accepted specifications of the competence required to perform hazard analysis.

4.4 No certification or similar evaluation agents or processes to examine whether the hazard analysis have the requisite competence.

4.5 No accredited curricula or training resources through which practitioners can acquire the requisite competence.

4.6 Limited independent research-grade evaluation to confirm the assertion.

4.7 Lack of scientific basis to relate operating experience to a future application.

Focus on Diversity since 1977

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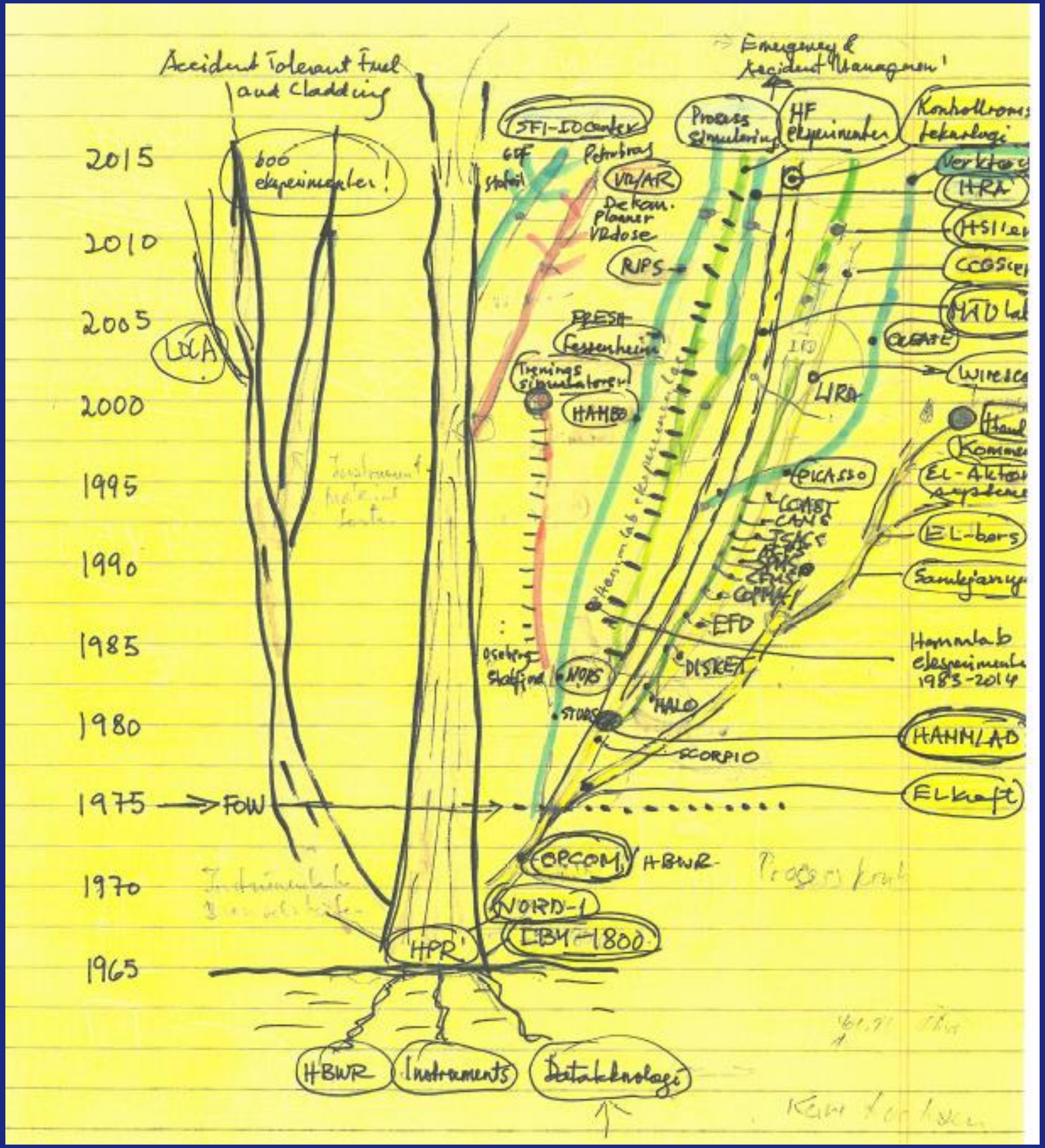


The view of a former Programme Manager

Challenges (ii)

Elaborated based upon the 1st assembly in the European Alliance on SMRs

- Industrial applications: demonstrate and communicate safety
- Technology: many designs in progress – need of test facilities and demonstrators
- Supply chain: geopolitical, cyber, efficiency, resilience
- Skills: a strong, skilled and resilient workforce
- Public engagement: trust and confidence, scientific justifiable vs. subjective perception
- Safety and Safegaurds: internal and external hazards in combination with other renewables, safety and cybersecurity, safe state definition,
- Fuel cycle and waste management: safety, safeguards and environmental issues with new fuel cycles
- Financing: funding for research on safety is also depending upon joint private projects

SMR research questions (courtesy IFE team: Rob McDonald, Claire Blackett, Maren Eitrheim, Stine Strand)

Multi-user/multi-unit issues

- Unit confusion
- Variability and differences between units (similar or different)
- “Carry over” effects between units
- Multi unit disturbances (Situation Awareness and workload issues)
- Staffing

Remote operation issues

- Aspects of Latency
- Degrees of automated operation
- HMI presentation “local vs. remote”
- Psychological detachment, local vs remote
- Operators' familiarization and competence with differences between units

SMR simulator and services

One of a kind: Our facility offers independence, facilitating objective research crucial for advancing the field.

- Platform for research, evaluation, and training
- HSMR capabilities:
  - **Flexible Simulation:** Simulate 1 to 12 integrated pressurized water reactors (iPWR), with each unit operating independently but sharing a common electric system and ultimate heat sink.
  - **Advanced Features:** Advanced automation and state-based deviation detection and alarming for operational efficiency.
  - **Customizable HSI Deployment:** Empower operators with customizable Human System Interfaces (HSIs) across multiple screens, enabling operators to monitor and control all or specific subsets of units, whether locally or remotely over web

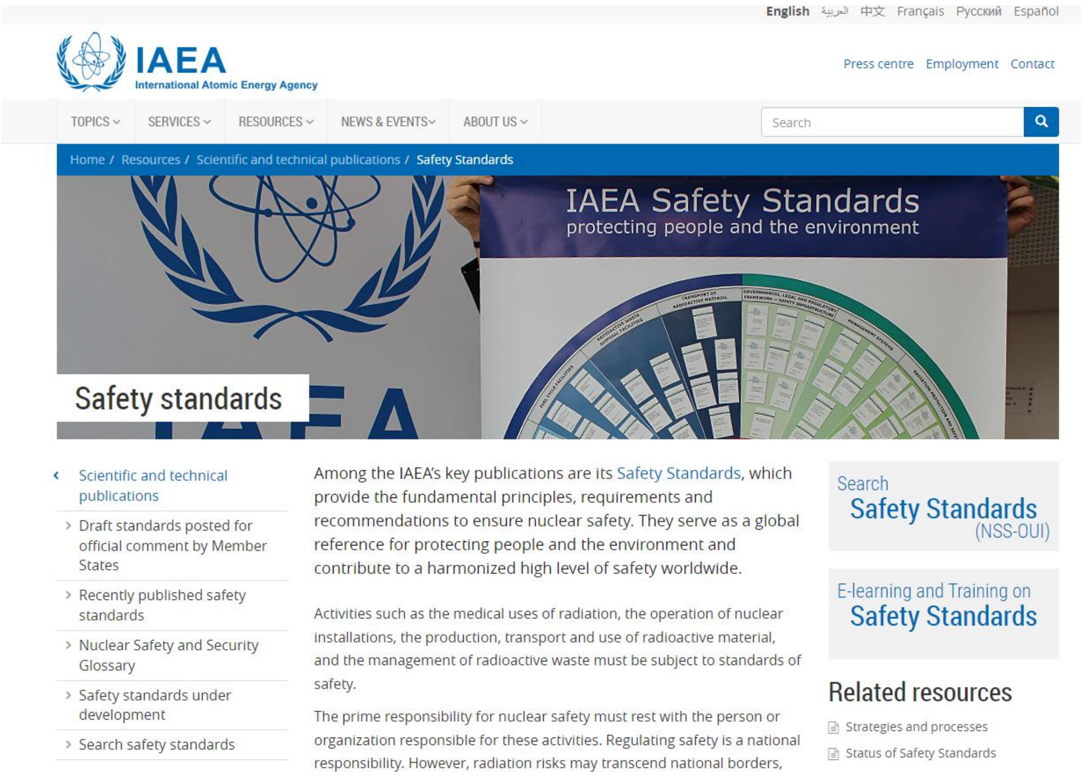
We offer a comprehensive suite of services aimed at enhancing the safety and efficiency of Small Modular Reactor (SMR) operation.

- Human Factors Studies
- Scenario Development
- Testing of Operational Concepts
- Control Room Systems Design
- Control Room Design and evaluation
- Support tool for Operator Training (STEAMS)
- Integrated System Validation (ISV)
- Performance Measurements
- Situational Awareness Assessments
- Cognitive Workload Assessment

Photo: HAMMLAB, IFE Halden. Credit: Stein Johnsen, Contentvideo

Challenges (iii)

IAEA - Safety standards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IAEA International Atomic Energy Agency

Press centre Employment Contact

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Safety standards

- Scientific and technical publications
- Draft standards posted for official comment by Member States
- Recently published safety standards
- Nuclear Safety and Security Glossary
- Safety standards under development
- Search safety standards

Among the IAEA's key publications are its Safety Standards, which provide the fundamental principles, requirements and recommendations to ensure nuclear safety. They serve as a global reference for protecting people and the environment and contribute to a harmonized high level of safety worldwide.

Activities such as the medical uses of radiation, the operation of nuclear installations, the production, transport and use of radioactive material, and the management of radioactive waste must be subject to standards of safety.

The prime responsibility for nuclear safety must rest with the person or organization responsible for these activities. Regulating safety is a national responsibility. However, radiation risks may transcend national borders,

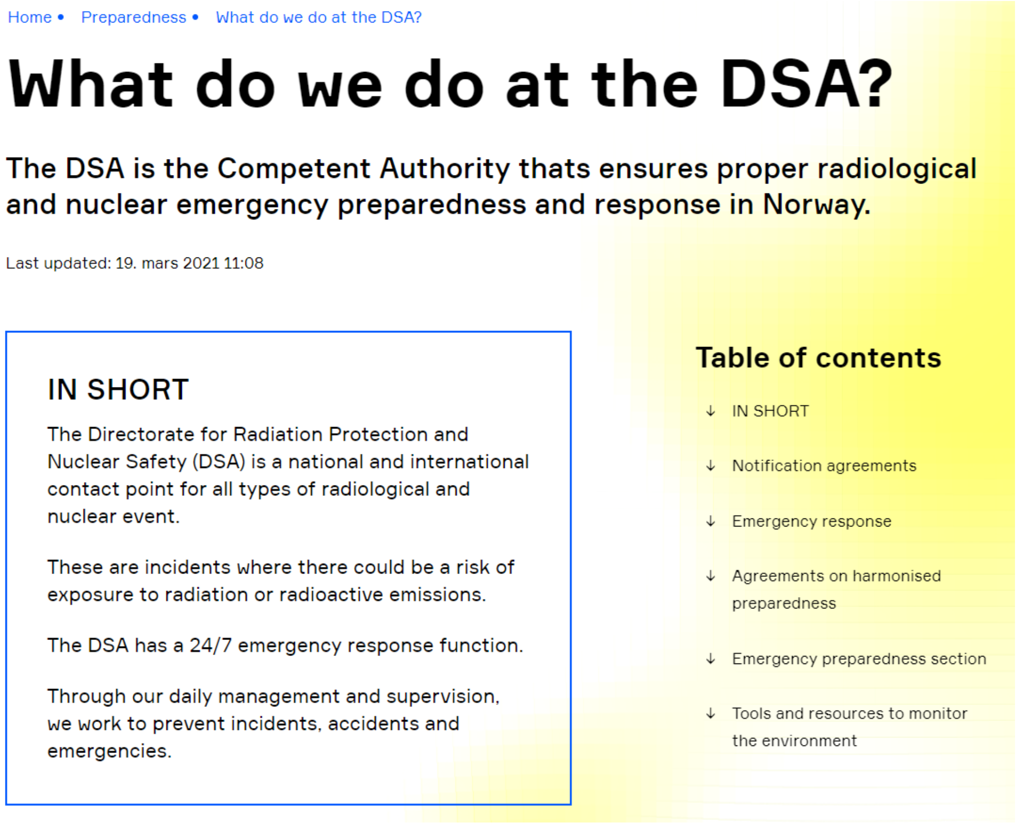
Search Safety Standards (NSS-OUI)

E-learning and Training on Safety Standards

Related resources

- Strategies and processes
- Status of Safety Standards

What do we do at the DSA? - DSA


Home • Preparedness • What do we do at the DSA?

What do we do at the DSA?

The DSA is the Competent Authority thats ensures proper radiological and nuclear emergency preparedness and response in Norway.

Last updated: 19. mars 2021 11:08

IN SHORT

The Directorate for Radiation Protection and Nuclear Safety (DSA) is a national and international contact point for all types of radiological and nuclear event.

These are incidents where there could be a risk of exposure to radiation or radioactive emissions.

The DSA has a 24/7 emergency response function.

Through our daily management and supervision, we work to prevent incidents, accidents and emergencies.

Table of contents

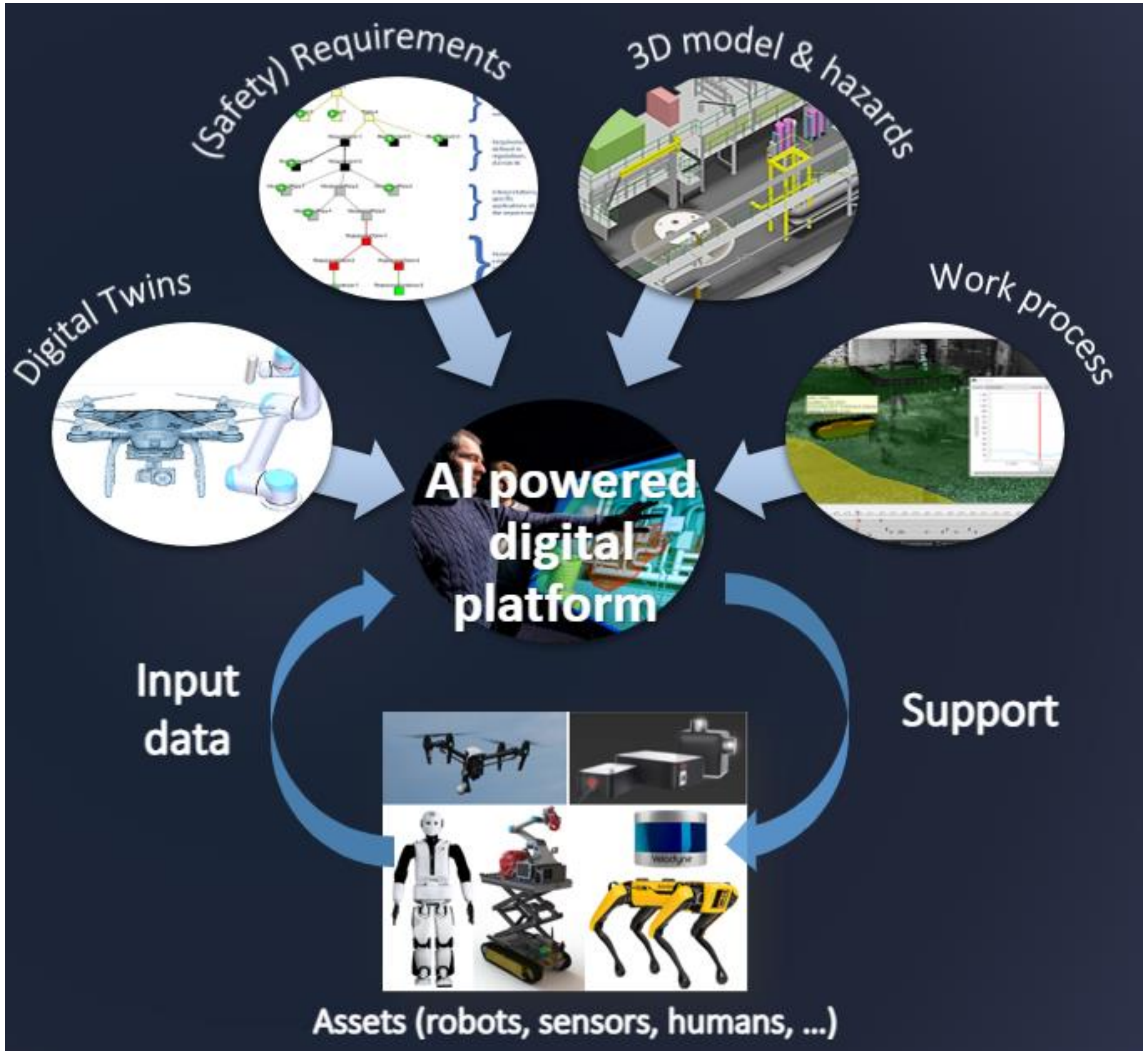
- IN SHORT
- Notification agreements
- Emergency response
- Agreements on harmonised preparedness
- Emergency preparedness section
- Tools and resources to monitor the environment

Risk Assessment vs. Safety Case?

A risk assessment yields a list of control measures, emphasizing the process of risk reduction.

A safety case provides a positive argument and evidence, justifying the safety choices made throughout the system or project.

- HADRON (**H**azard **A**ware **D**igitalisation & **RO**botics in **N**uclear & other domains) describe an approach to more efficient safety processes



Ved IFE bygger vi bro mellom forskning, utdanning og industriell virksomhet

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