LTO and Maintaining the Design Integrity of the Loviisa Power Plant

Harri Tuomisto, Fortum, Finland

World Nuclear Association, 2nd Regional Workshop on Technical and Regulatory Issues Facing Nuclear Power Plants – Leveraging Global Experience

25-26 October 2016, Moscow, Russia

Fortum

Contents

- Fortum
- Loviisa NPP
- Plant performance
- Plant modifications
- Long-Term Operation (LTO)
- Design Authority

Fortum worldwide in power and heat business

Nordic countries

- Power generation capacity 8,484 MW (+ Fortum Värme* 639 MW)
- Heat production capacity 1,974 MW (+ Fortum Värme* 3,891 MW)
- Electricity sales customers 1.3 million

Baltic countries

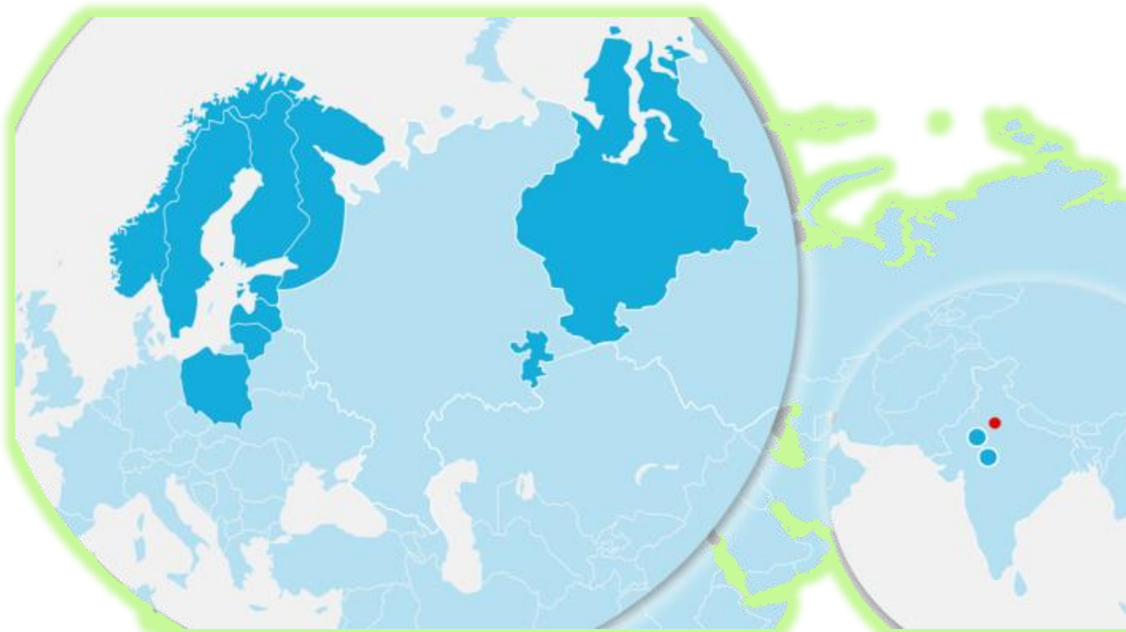
- Power generation capacity 93 MW
- Heat production capacity 812 MW

Poland

- Power generation capacity 197 MW
- Heat production capacity 1,129 MW

Russia

- Power generation capacity 4,903 MW
- Heat production capacity 12,696 MW



India

Power generation capacity 15 MW

Expert services globally

Figures: 2015

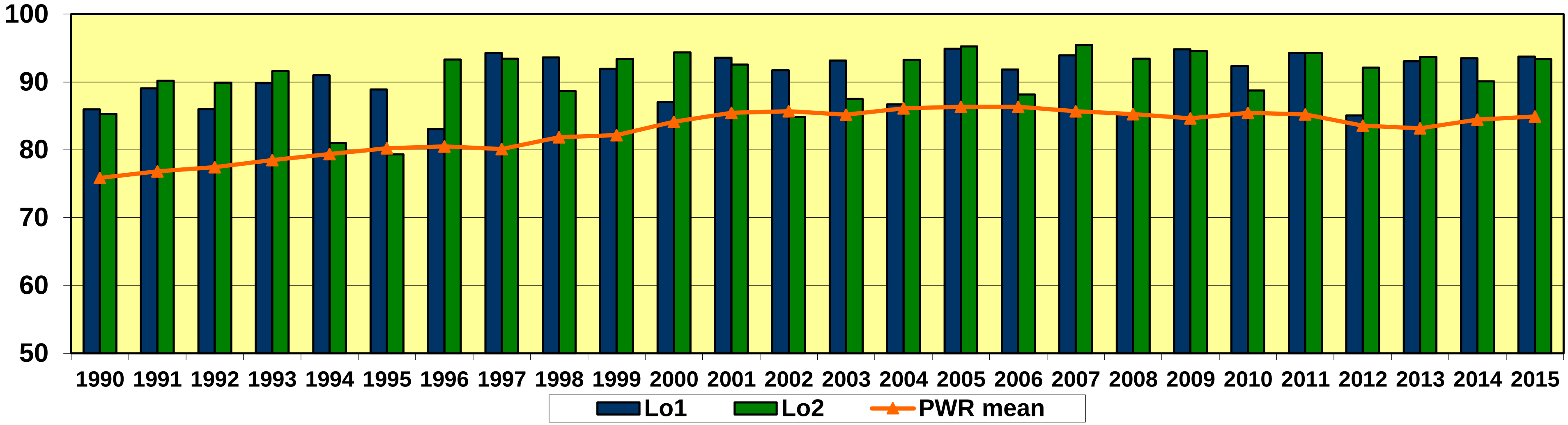
*Joint venture AB Fortum Värme samägt med Stockholms Stad

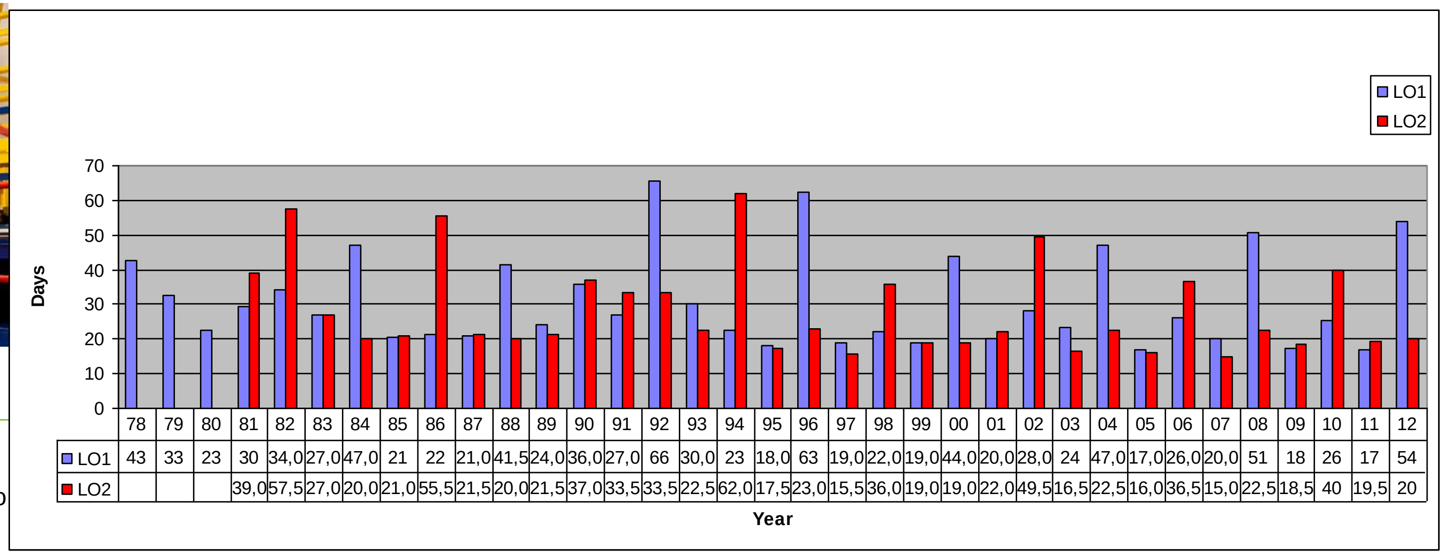
Loviisa Power Plant

- Two VVER-440 units, 1004 MW (2 x 502 MW).
- Loviisa 1 started operation in 1977 and Loviisa 2 in 1980.
- Current operating licenses are valid until 2027 and 2030, respectively.
- Safety and performance reliability indicators have been good throughout the operational history.
- The annual load factors exceeded 90%.
- In 2015 Loviisa produced 8.47 TWh of electricity.
- Load factor describing the power plant's availability was 93%.

Fortum

History of load factors and outage durations at Loviisa NPP





	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
LO1	43	33	23	30	34,0	27,0	47,0	21	22	21,0	41,5	24,0	36,0	27,0	66	30,0	23
LO2				39,0	57,5	27,0	20,0	21,0	55,5	21,5	20,0	21,5	37,0	33,5	33,5	22,5	62,0

	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12
LO1	18,0	63	19,0	22,0	19,0	44,0	20,0	28,0	24	47,0	17,0	26,0	20,0	51	18	26	17	54
LO2	17,5	23,0	15,5	36,0	19,0	19,0	22,0	49,5	16,5	22,5	16,0	36,5	15,0	22,5	18,5	40	19,5	20

Life span of the Loviisa power plant

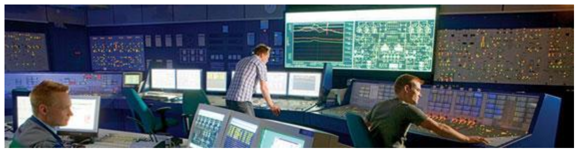
1969-1981 Planning, construction and commissioning phase

- Main contracts signed and construction permit in 1970
- Construction started 1971, commissioning in 1977 and 1980

1981-2004 Period of major safety modifications and upgrades

- TMI-modifications, reactor pressure vessel upgrades, emergency feedwater, primary-to-secondary leakage management etc.
- Modernization and power upgrading 1997
- Severe Accident Management implementations

2004-2030… Plant life management phase



- I&C renewal 2004-201x
- Current operating licenses up to 2027 and 2030 (50 yrs.)

Fortum

Plant modifications at Loviisa NPP after commissioning

- Improving protection against **internal and external hazards** (1980-2003)
- **SAM Programme** including hardware modifications (1986-2004)
- **Modernization and power upgrading** with 9% (1996-1997)
- Plant life management: **I&C renovation** (ongoing)
- **Fukushima modifications** (2011-)
  - Ultimate heat sink with air cooling (independent of sea water)
  - Assessing the protection of excessively high sea level
  - Battery and diesel fuel capacity will be increased
  - Guidelines for long-lasting accident situations that affect both plants

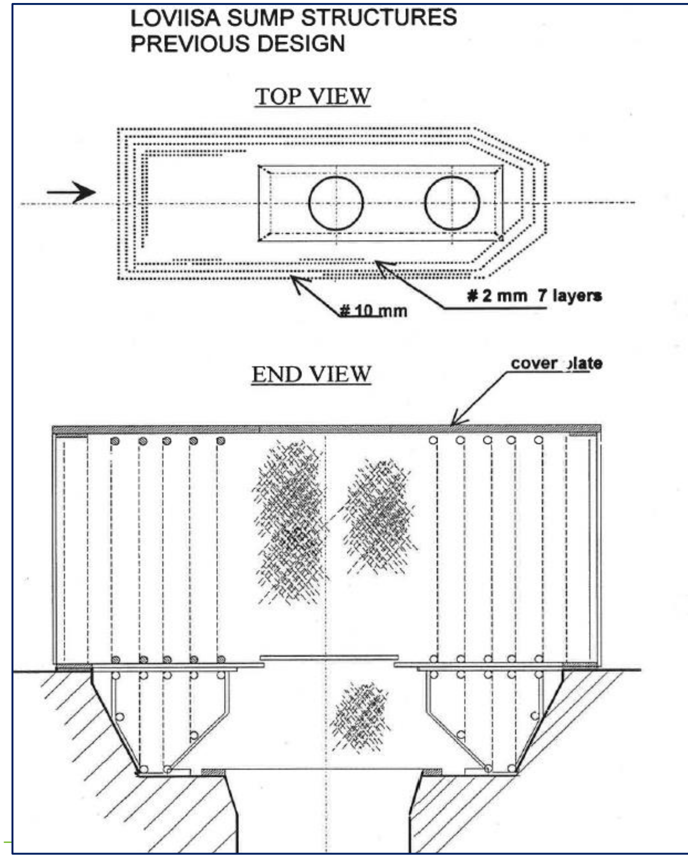
- **Radioactive waste management**
  - Interim storage for spent nuclear fuel
  - Deep repository for low and intermediate level waste
  - Liquid waste solidification plant

Protection against Internal and External Hazards (1980 - 2003)

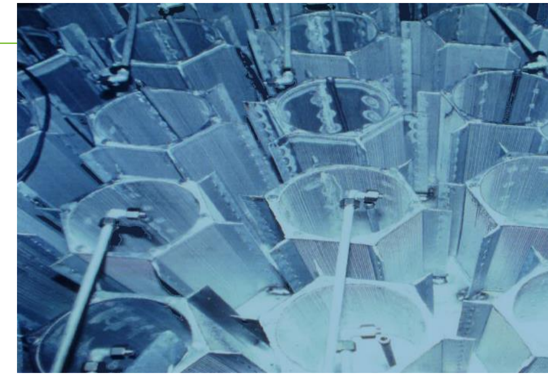
- **modifications after Three Mile Island**: hydrogen monitoring and igniters, improved PORV, solution to the "loop seal" issue
- measures against **pressurized thermal shock (PTS)** of the reactor pressure vessel: introduction of dummies to the core periphery, heating up the ECCS water, modifying the ECCS capacity, additional I&C, and finally thermal annealing of the pressure vessel of unit 1
- new **autonomous emergency feedwater** system, particularly to manage turbine hall fires
- new containment **sump strainer** designs to prevent sump clogging by insulating materials
- management of primary-to-secondary leakage accident (**PRISE**): PZR spray, safety valve upgrades, increased tank capacity for feeding SGs
- management of **inhomogeneous boron dilution**
- protection against **frazil ice** in cooling channels

Evolution of sump strainers

Initial design 1978: sumps protected by screening nets



Modification after Barsebäck event (early 90's):



Modified protection against fuel assembly blockages (early 2010's)

Top level SA critical safety functions at Loviisa

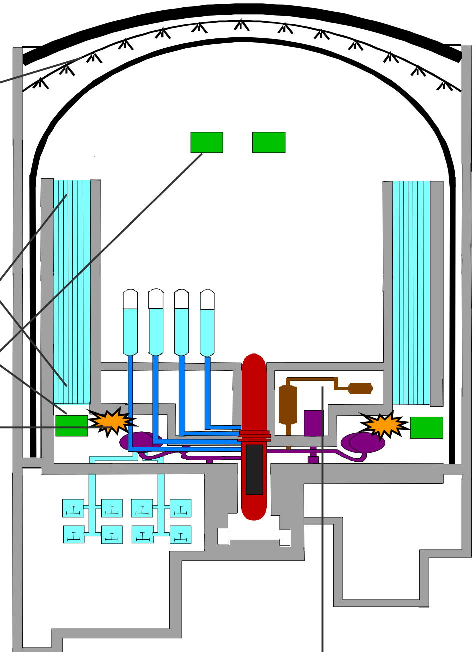
SAM safety function	Measures
Ensuring containment isolation	Dedicated I&C
Primary system depressurization	Dedicated relief valves
Absence of energetic events: hydrogen combustion	Hydrogen management strategy - Mixing of the containment atmosphere (forced opening of the ice condenser doors) - PARs (upper and lower compartment) - Igniters (lower compartment)
In-vessel melt retention by external cooling	IVR strategy by cavity flooding
Long-term containment heat removal (overpressure protection)	External containment spray

Implementation of SAM at Loviisa 1990-2004

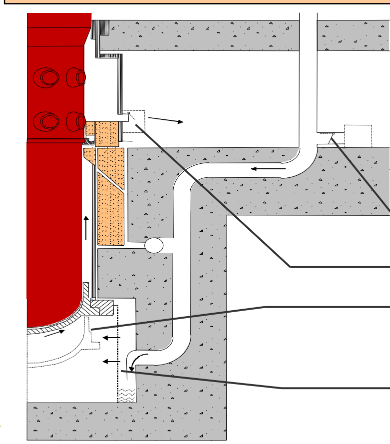
Long-term containment cooling with external spray of the dome

Hydrogen mitigation
- **Forcing the ice condenser doors open**
- **Catalytic recombiners**
- **Igniters (glow-plugs)**

Depressurization of the RCS



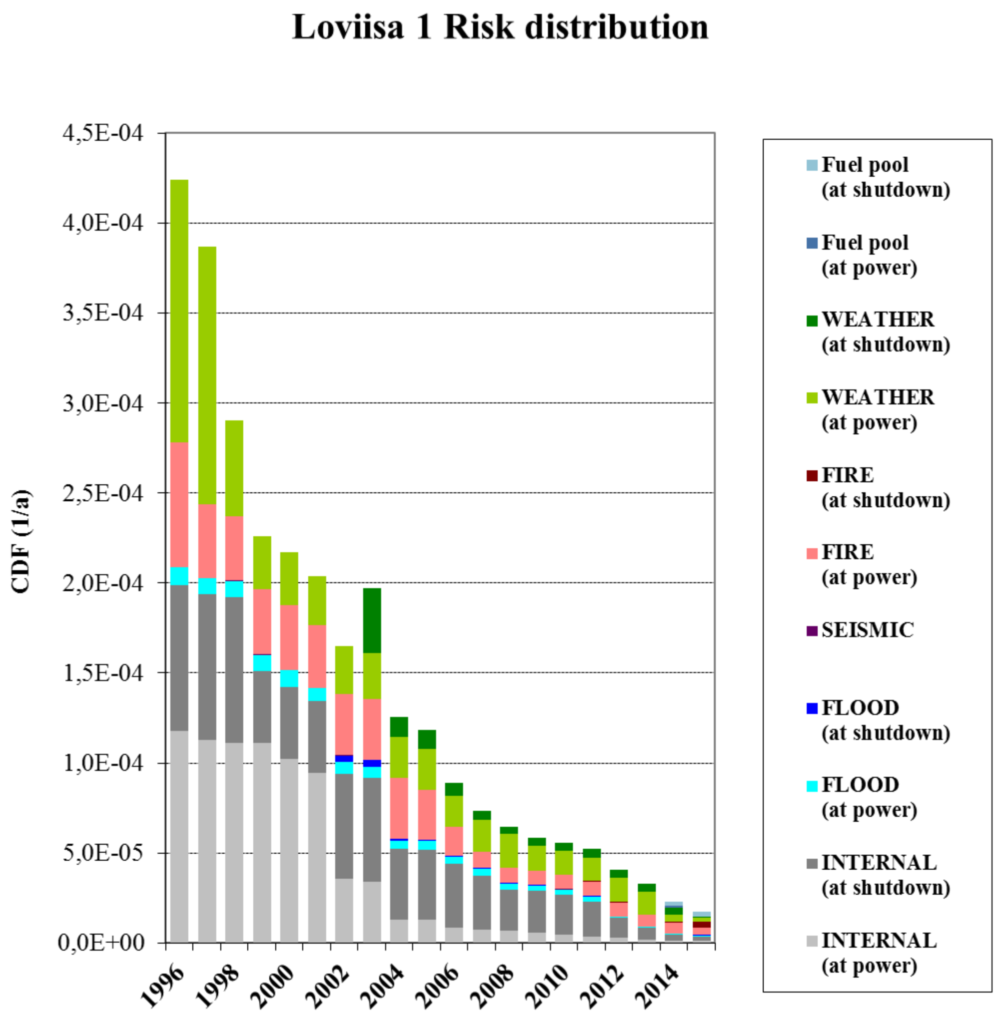
Containment isolation
- Manual backup
- Local control centres
- Monitoring of the isolation success
- Monitoring of the leakages

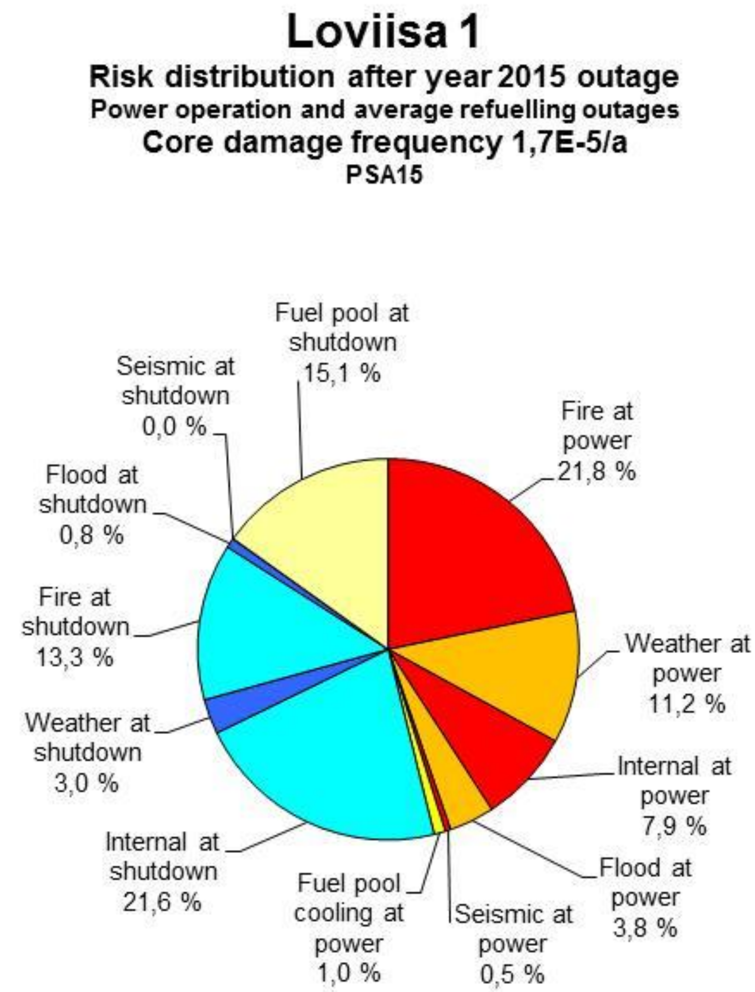


In-vessel retention of corium
- Inlet valves
- Outlet valves
- Lowering of the bottom part of thermal insulation/neutron shield
- Screening of impurities

Fortum

Nuclear safety: Evolution of the Core Damage Frequency (CDF)





Continuous development of safety, reliability and production of the Loviisa power plant

Modernisation of turbines and reheaters

Implementation during 2014–2017. Increases the plant's electricity production capacity by a total of 29 MW.

Automation modernisation

The modernisation of safety related automation systems will be implemented during 2016–2019.

Ultimate heat sink independent of seawater

Air-cooled system secures the removal decay heat in situations where the normal seawater cooling isn't available, e.g. due to oil spill accident

Fortum

Maintaining the design integrity throughout the operational lifetime

- INSAG recommendations
- IAEA requirements
- WANO principles

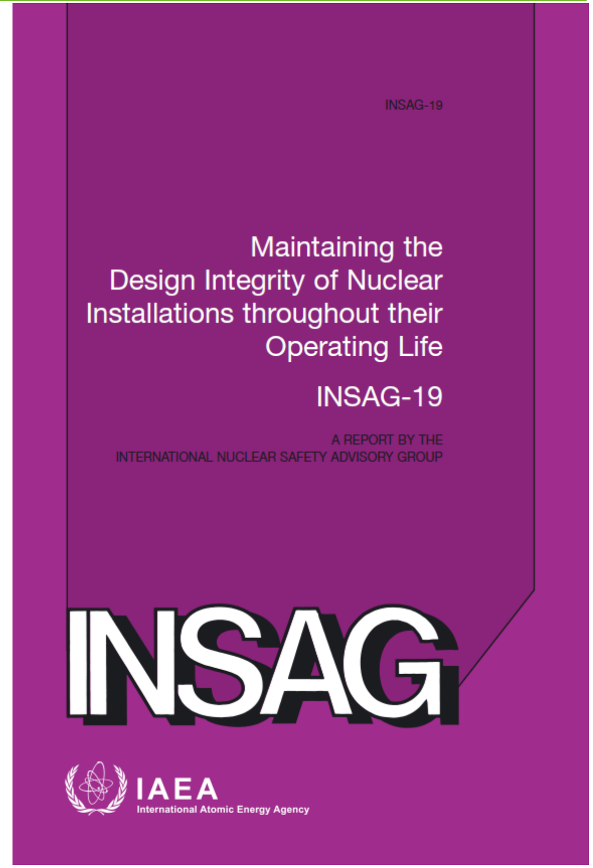
- Compliance with the Finnish regulatory requirements

- Establishment of the Design Authority

Recommendations by INSAG-19

- **Design Authority:** The entity that has the overall responsibility for the design process, approval of design changes, and for ensuring that the requisite knowledge is maintained

- Design Authority responsibilities include:
  - *Ensuring the Design Basis meets safety and performance requirements.*
  - *Maintaining knowledge of design and Design Basis.*
  - *Approving design changes.*
  - *Establishing, controlling and maintaining design and Design Basis change processes.*
  - *Maintaining up-to-date records and configuration information.*



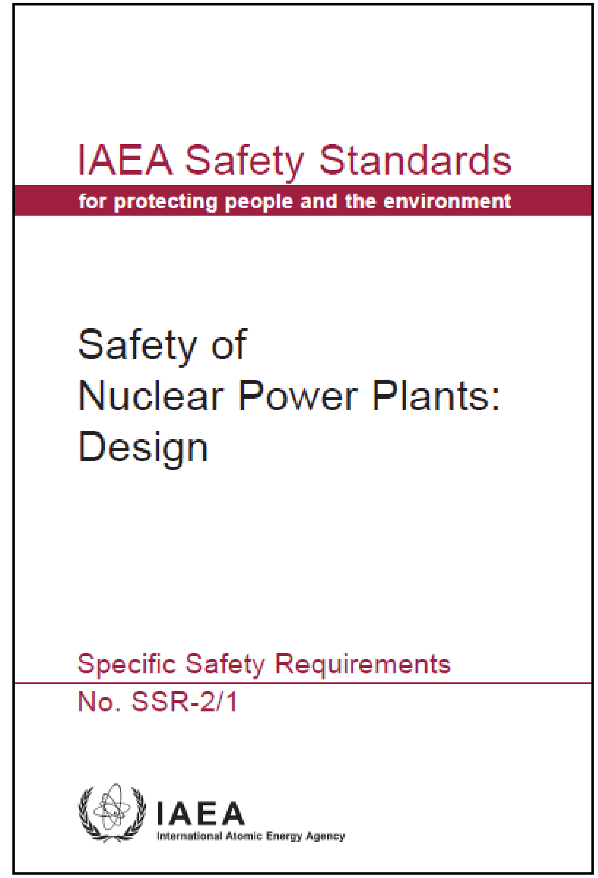
- The responsibilities, authorities, and accountabilities must be clearly documented for each role in the design change process. However, overall responsibility for the integrity of the design of the plant cannot be delegated.

Fortum

IAEA: Specific Safety Requirements, SSR-2/1

<u>Requirement 3: Safety of the plant design throughout the lifetime of the plant</u>

- **The operating organization shall establish a formal system for ensuring the continuing safety of the plant design throughout the lifetime of the nuclear power plant.**
- 3.5. The formal system for ensuring the continuing safety of the plant design shall include **a formally designated entity responsible for the safety of the plant design** within the operating organization's management system. Tasks that are assigned to external organizations (referred to as responsible designers) for the design of specific parts of the plant shall be taken into account in the arrangements.



Development of Design Authority for Loviisa NPP

- The requirements in the Finnish regulatory system (STUK Guide YVL B.1 “Safety Design of a Nuclear Power Plant), as well as WANO principles concerning the Design Authority are in line with the INSAG recommendations and IAEA safety requirements.
- Fortum as a licensee decided to establish the entity that is formally responsible for the Design Authority function in 2015.
- In the Loviisa Management System, the Design Authority function has been included as a sub-process of the change management process.
- Currently, the Design Authority is in the pilot phase at Loviisa NPP

Design Authority model

Pilot phase ongoing

Design Authority model for Loviisa 1 & 2

Licensee	**Administration level** • Ensuring prerequisites and decision making process 1. *Start-up permit (classification according to safety and extent)* 2. *Design permit* 3. *Implementation permit*	DESIGN AUTHORITY
Customer	**Expert level** • Design and Implementation • Reviews, inspections and approvals for Documents • Configuration Control and Management: ➢ *identification, change control, status accounting, audit* ➢ *document updating process* ➢ *closing permit for modification*	CENTRAL ENGINEERING
Customer	**Owner level** • Ownership of Modifications and Projects	
Supplier	**Implementation level** • Engineering work by responsible design organization • Installation work by responsible installation organization • Commissioning work by responsible commissioning organization	

Ensuring Design Integrity and Safety

Design Authority model for Loviisa 1 & 2

DA BOARD

NP/NE Senior Advisers Group

DA BOARD – NP/NE Senior Advisers Group	Decisions and steering
Responsible System Engineers	Approvals
Experts of Nuclear Production & Engineering	Inspections & reviews
Configuration Control Board: CCT process, CCT electricity, CCT automation, CCB ELSA	Reviews and audits
Projects / Line Organisations / Suppliers	Implementation

Concluding remarks

- Fortum has a good experience of operating the Loviisa VVER-440 units since 1977
- After the plant modernization programme in the mid 1990's, the units have operated with an upgraded power 1500 MW_{th} and 500 MW_e (+9%)
- The units have undergone continuous plant improvements to manage
  - Internal hazards
  - External hazards
  - Severe accidents
  - Fukushima induced actions
- Current operation licenses are valid until 2027 and 2030
- In order to ensure maintaining the design integrity of the Loviisa plant, the formal entity and process of Design Authority has been established, and it is currently in the pilot phase

Fortum