Regulatory point of view on additive manufacturing for nuclear facilities

(Originally presented in Additive manufacturing in nuclear energy applications – Energiforsk webinar 23.9.2020)

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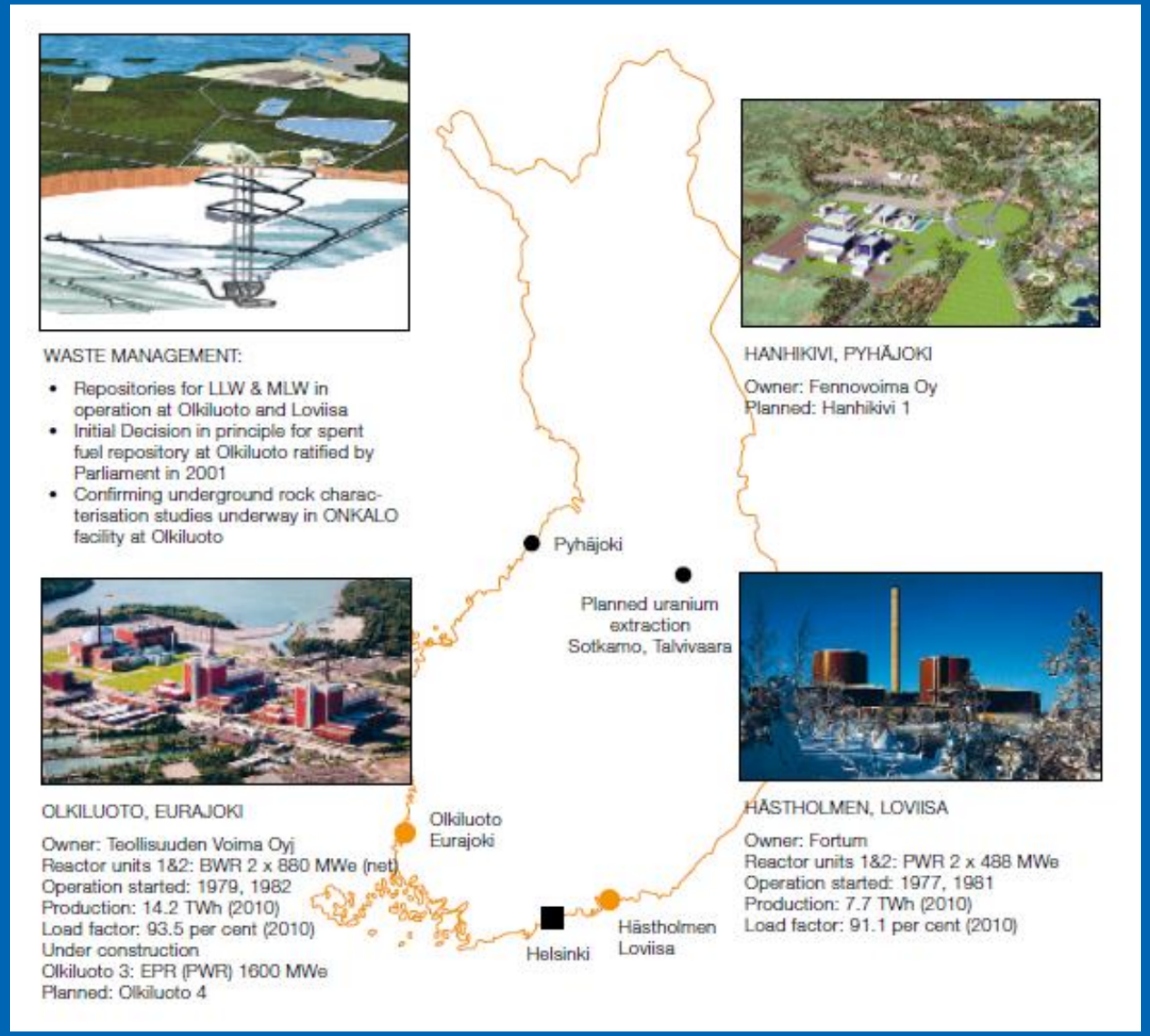
Content

- The Finnish Nuclear Facilities in brief
- Legal framework and guidelines from regulator
- Regulator oversight of additive manufacture
- Discussion of conventional standards in relation to additive manufacture

Finnish Nuclear Facilities in Brief

- Operating NPPs
  - Loviisa LO1/LO2
  - Olkiluoto OL1/OL2
- NPP under construction
  - Olkiluoto OL3
- NPP in construction licensing phase
  - Hanhikivi FH1
- LLW & MLW repositories
- Spent fuel disposal facility under construction
- Research reactor FiR in decommissioning
- Uranium extraction, Terrafame, Talvivaara



stuk
SÄTEILYTURVAKESKUS
STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

Finnish nuclear legislation and safety requirements

Nuclear Energy Act

- "nuclear energy utilisation shall be safe"; "licensee is responsible for safety", other principal safety req's (including security and on-site emergency preparedness)

Nuclear Energy Decree

- administrative details for licensing and regulatory oversight
- radiological acceptance criteria

STUK Regulations

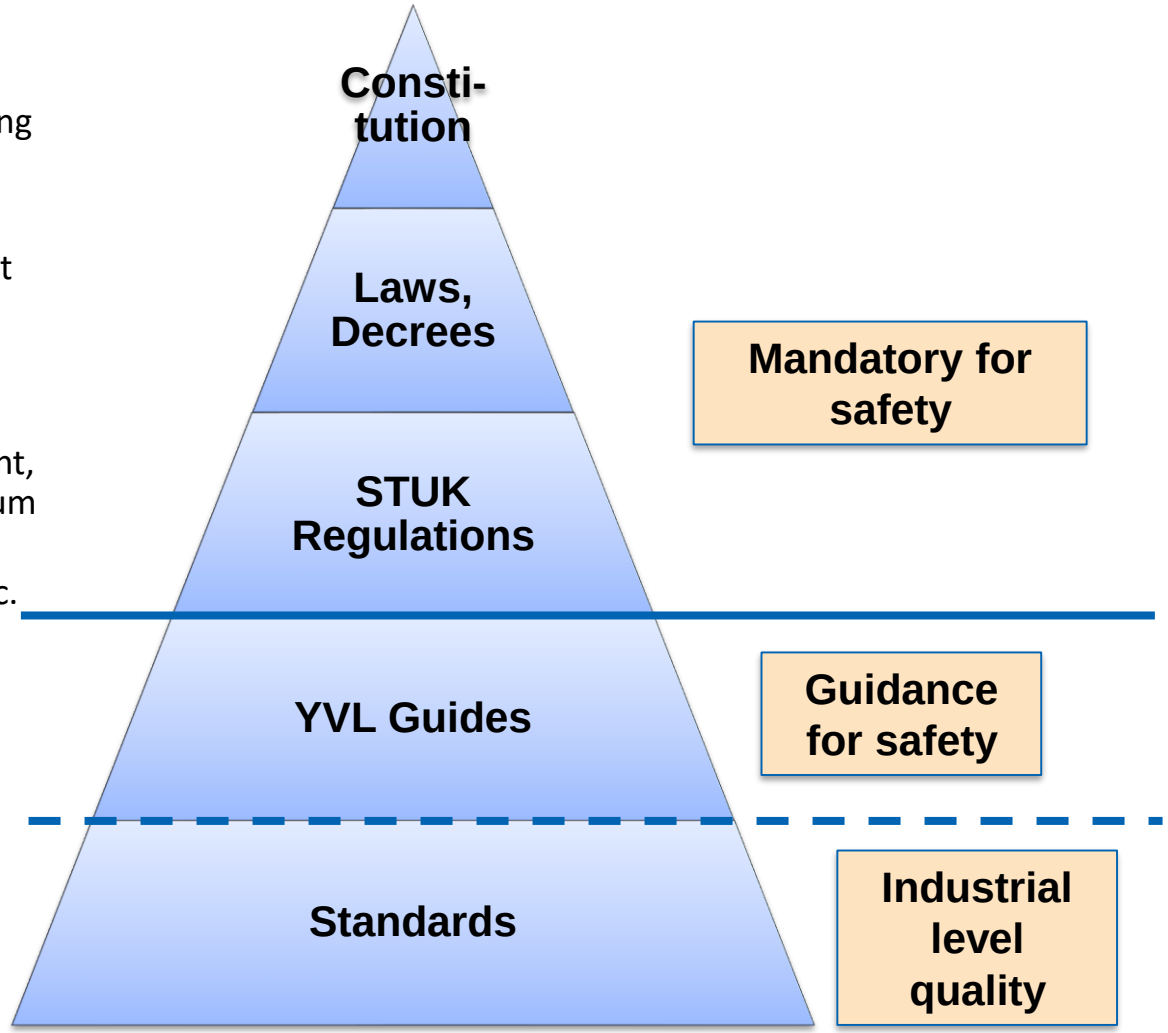
- mandatory requirements for Nuclear safety, Emergency preparedness, Nuclear security, Nuclear waste management, Safety of Mining and Milling Practices for Producing Uranium and Thorium
- general principles, fundamental technical requirements etc.

YVL Guides

- status as Reg. Guides in USA
- detailed technical requirements, acceptable practices, guidance for licensee-STUK interaction, STUK's oversight

Standards

- Detailed guidance to fulfil and follow contractual issues in industry



Evolution of the Finnish YVL Guides from 1975

NPP design principles

- General design principles of a nuclear power plant, 1976
  - 55 criteria
  - Based on 10CFR50, Appendix A (US.NRC regulations)
- YVL 1.0 Safety criteria for design of nuclear power plants, 1982 (revised 1996)
- YVL 2.0 Systems design for nuclear power plants, 2002
- **YVL B.1 Safety design of a nuclear power plant, 2013 (revised 2019)**

Today YVL Guides (47) in (5) groups

- Group A: Safety management of a nuclear facility (12)
- Group B: Plant and system design (8)
- Group C: Radiation safety of a nuclear facility and environment (7)
- Group D: Nuclear materials and waste (7)
- Group E: Structures and equipment of a nuclear facility (13, 12 published, 1 pending)

https://www.stuk.fi/web/en/regulations/stuk-s-regulatory-guides/regulatory-guides-on-nuclear-safety-yvl-

Background

- Additive manufacturing (AM) is a new promising solution to fabricate complexly shaped components from great variety of industrial materials.

- AM has been already used in manufacturing for e.g. aviation industries showing that acceptable quality and safety can be reached for demanding applications with optimised processes and parameters.

- AM has been applied also in nuclear sector including e.g. nuclear fuel components, pump impellers, nozzle debris filters and other complexly shaped parts. It is applicable also for composite structure optimisation through multi-material fabrication.

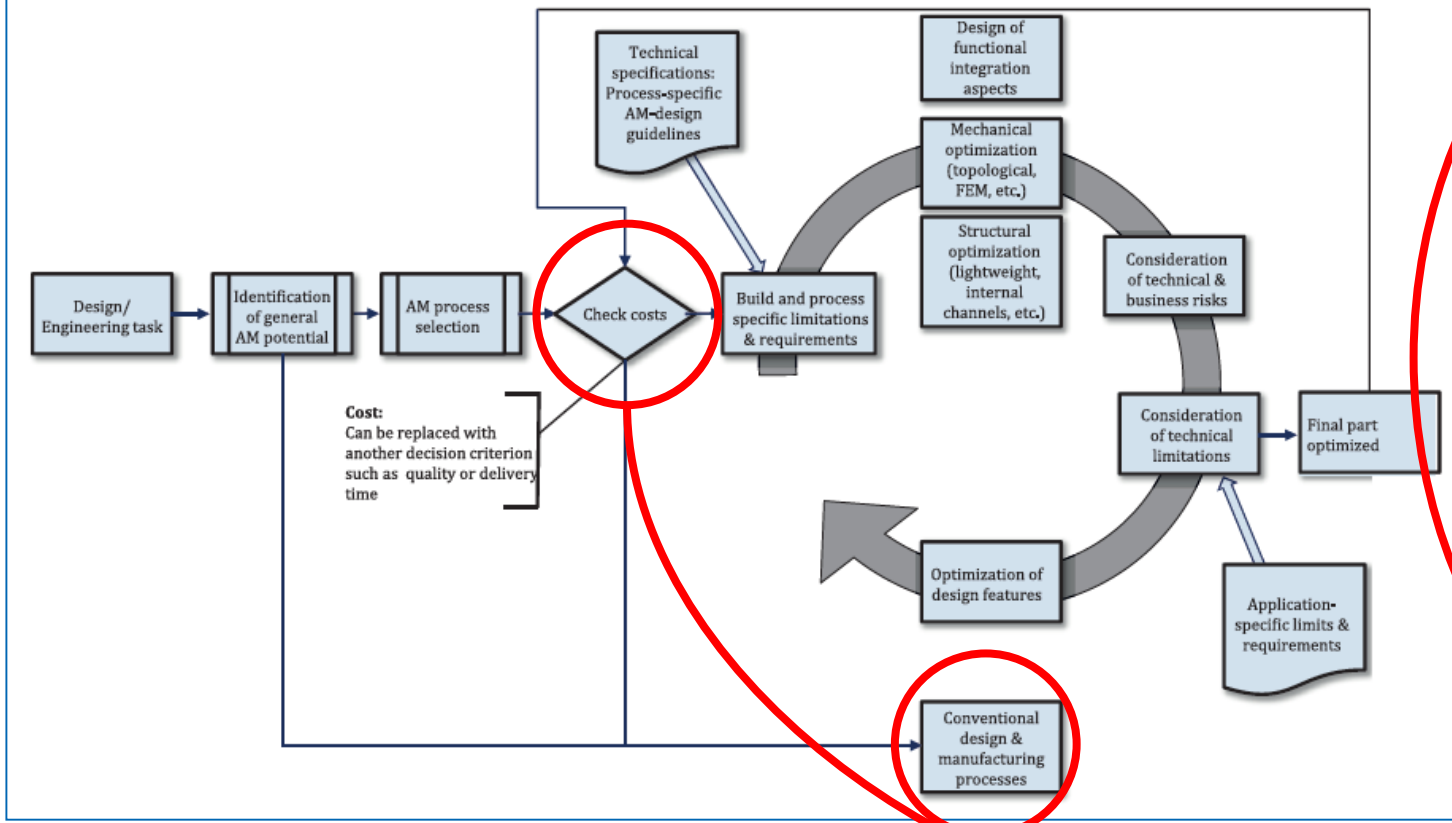
- One important benefit of the AM is the possibility to produce additional spare/replacement parts which are already obsolete (not any more available).

Regulator oversight of additive manufacture (AM) (1/3)

- Oversee the reliability of AM processing and quality of parts
  - Compare AM to conventional manufacture
    - Detailed standards concatenate design, materials, manufacture, inspection and testing as well as quality management and qualification protocols for personnel
    - Lack of standards shall be compensated by R&D and testing
  - The structural performance of AM parts, including required inspections
    - Mock-ups in-line with safety classification
  - The service performance and aging degradation of AM parts
    - In-line with Aging Management plan starting from design through the whole life cycle of the nuclear facility

Regulator oversight of additive manufacture (AM) (2/3)

SFS-EN ISO/ASTM 52910:2019, overall strategy for AM



Issues in YVL Guides

- Safety classification
- Design documentation
- Description of organisation
- Supervision of manufacture
- Quality control
- Commissioning
- Control during plant operation

Regulator oversight of additive manufacture (AM) (3/3)

- Follow the development of codes and standards for AM
  - Analogy between traditional standards and AM standards
  - Benchmarking between traditional and AM processes
  - Basic thinking for AM manufacture (SFS-EN ISO/ASTM 52910:2019) vs. safety requirements
- Follow research and international development of AM
  - Finnish safety research program SAFIR combine AM-technology, quality and safety thinking
  - International R&D, including co-op. with e.g. aviation industry etc.
- Gradual implementation of AM to Nuclear facilities
  - Starting from lower level safety classified systems and components
  - References from nuclear facilities abroad are appreciated

Conventional standards vs. AM 1/2

Commonly used for NPPs	Questions to AM standards
• Detailed standards for **design**: – **PED, ASME** for reactor, primary and main circulation systems and containment – **ASCE** for earthquake resistance to nuclear facilities – **KTA** liner structures of radioactive fuel pools – **PED, EN-ISO, Finnish Building Code (RakMK)** conventional steel and concrete structures – **RCC** codes are under development for common European usage • Advanced coordination between nuclear design codes and EN-ISO standards	• **Design**: – How AM is introduced in detailed design standards? • Selection criteria between AM and conventional manufacture – How design criteria are set and ensured? • Analysis / testing methodology • Design margins / robustness

Conventional standards vs. AM 2/2

Commonly used for NPPs according to design requirements	Questions to AM standards
• Materials: – **KTA, ASTM, EN-ISO** for concrete, steel, welds – **ASTM, EN-ISO** for coatings against radiation • Manufacture / Execution: – **PED, ASME** – **KTA, RCC-M, EN-ISO, RakMK** • Inspection and testing: – **ASME, ASTM, KTA, EN-ISO** • Quality management: – **EN-ISO 9001:2015** • **ISO 19443-2018** for supply chain management • **IAEA 50-C-Q** nuclear safety related quality management	• Materials: – Standards not as specific as conventional standards? • Manufacture – Not as specific as conventional standards? – How manufacture is related to design and material standards? • Inspection and testing – How inspections and testing is related to materials and manufacture? • Quality management – Are there any AM standards?

Consideration needs

- Additional/continuous development work is still needed to ensure the quality of AM components for nuclear applications:
  - Qualification requirements stipulated for nuclear and radiation safety
  - Further development of applicable standardisation
  - Certification and qualification requirements for AM manufacturers
  - Qualification of the AM processes applied
  - Approval of the AM filler materials
  - Qualification of testing technology and personnel (NDT/DT)
  - Paying attention to Safety Culture as well as QA/QC

- These actions shall be supported with applicable R&D work
- Class EYT would be a reasonable starting point
- In higher safety classes (3→2→1) the Graded Approach principle shall be followed
- Pressure boundary components would need special attention (Pressure equipment legislation & PED)