Business from technology

Analysis of Fatigue and Other Cumulative Ageing to Extend Lifetime - FOUND (VTT, Aalto)

LTO Procedure and Application Case Study

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Overview of FOUND – Scope of research

1. Remaining lifetime and LTO of components having defects
2. Susceptibility of BWR RPV internals to degradation mechanisms
3. Fatigue usage of primary circuit
4. Fatigue and crack growth caused by thermal loads
5. Development of RI-ISI methodologies
6. Dynamic loading of NPP piping systems
7. Residual stress relaxation in BWR NPPs

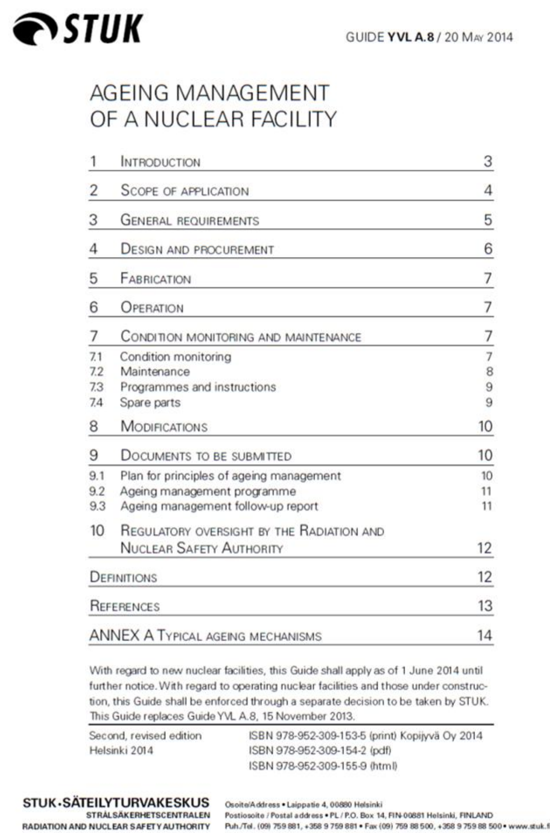
→ Overview of the research performed in other work packages is presented in the Interim Report

Contents of Presentation

- Introduction – Regulatory Framework
- Flow Chart of LTO Procedure
- Verification of Preconditions
- Scoping and Screening
- Assessment and Management of Structures & Components for LTO
- Revalidation of Safety Analyses
- Case Study – OL1/OL2 RPV & Internals

Introduction – Regulatory Framework

- Based on IAEA LTO Guidelines
  - IAEA-TECDOC-1736 (IGALL) - Approaches to Ageing Management for Nuclear Power Plants
  - IAEA Safety Report no. 57 - Safe long term operation of nuclear power plants
  - Etc.
- Review for STUK
  - YVL Guides, e.g. A.8



STUK GUIDE YVL A.8 / 20 May 2014

AGEING MANAGEMENT OF A NUCLEAR FACILITY

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With regard to new nuclear facilities, this Guide shall apply as of 1 June 2014 until further notice. With regard to operating nuclear facilities and those under construction, this Guide shall be enforced through a separate decision to be taken by STUK. This Guide replaces Guide YVL A.8, 15 November 2013.

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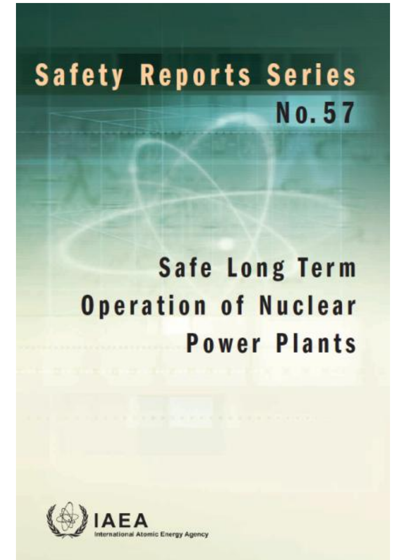
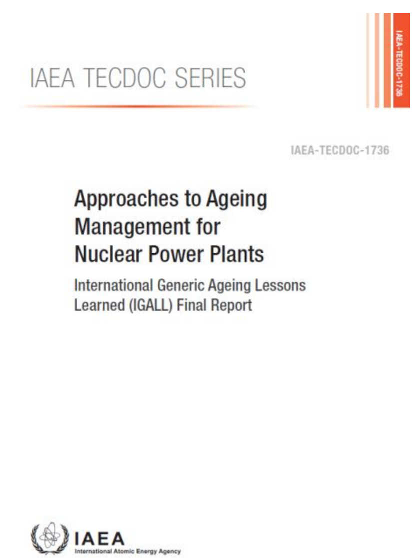
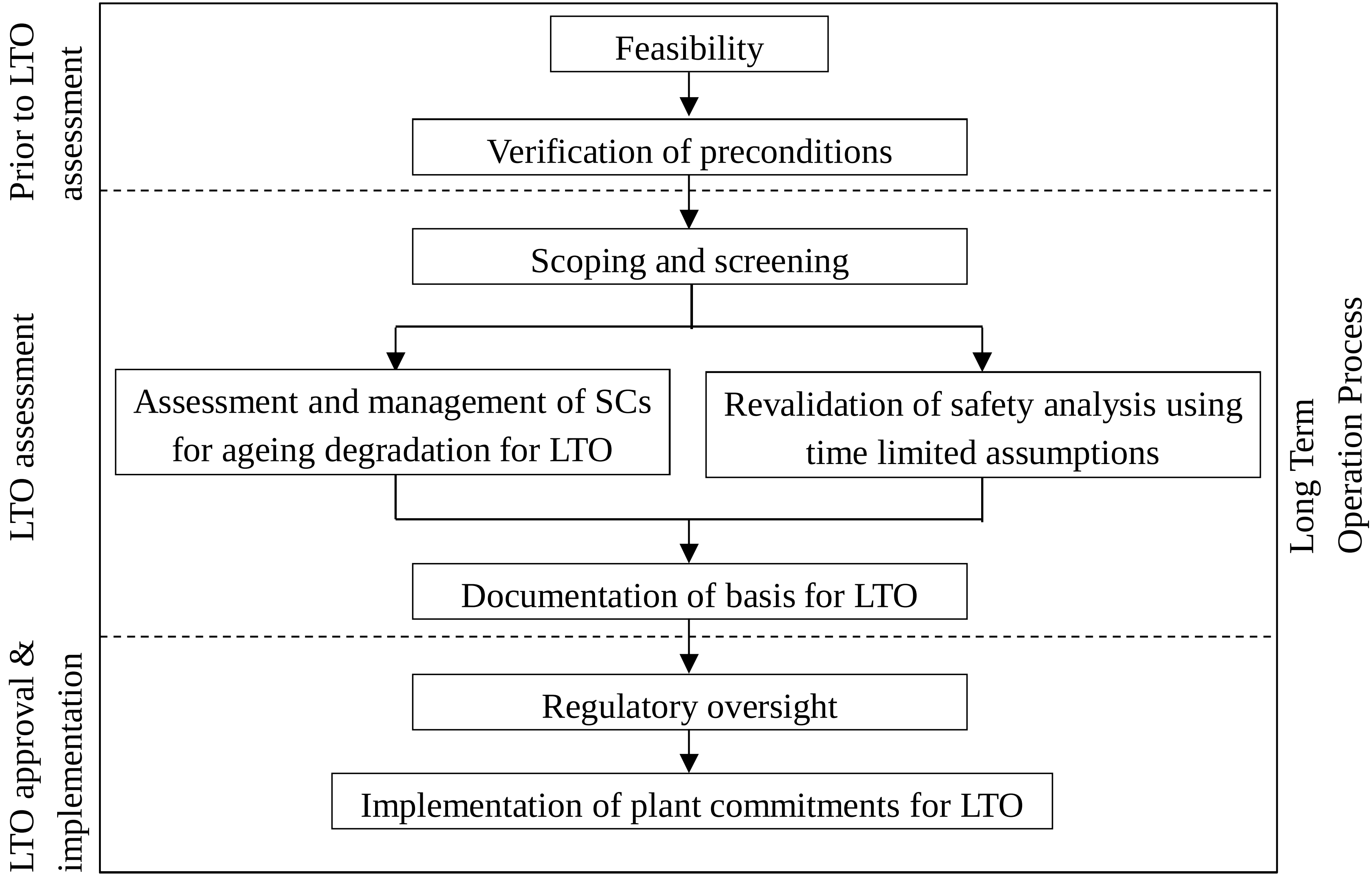




Flow Chart of LTO Procedure acc. to IAEA Safety Report No. 57



Verification of Preconditions - 1

PRECONDITIONS FOR LONG TERM OPERATION (LTO):

- The existing NPP programs and documentation are needed in developing LTO.
- The following NPP programs &documentation are considered for LTO:
  - a) Plant programs,
  - b) A management system that addresses quality assurance and configuration management,
  - c) Original safety analyses involving time limited assumptions,
  - d) Current safety analysis report or other licensing basis documents.

Verification of Preconditions - 2

PLANT PROGRAMS:

- Plant programs are a planned set of activities that are done to achieve the purpose for which the plant was constructed.
- Plant programs listed below are considered preconditions for LTO and are necessary to support the modifications for LTO associated with ageing management:
  a) Maintenance,
  b) Equipment qualification,
  c) In-service inspection (ISI),
  d) Surveillance and monitoring,
  e) Monitoring of chemical regimes.

Scoping and Screening - 1

SCOPE SETTING PROCESS:

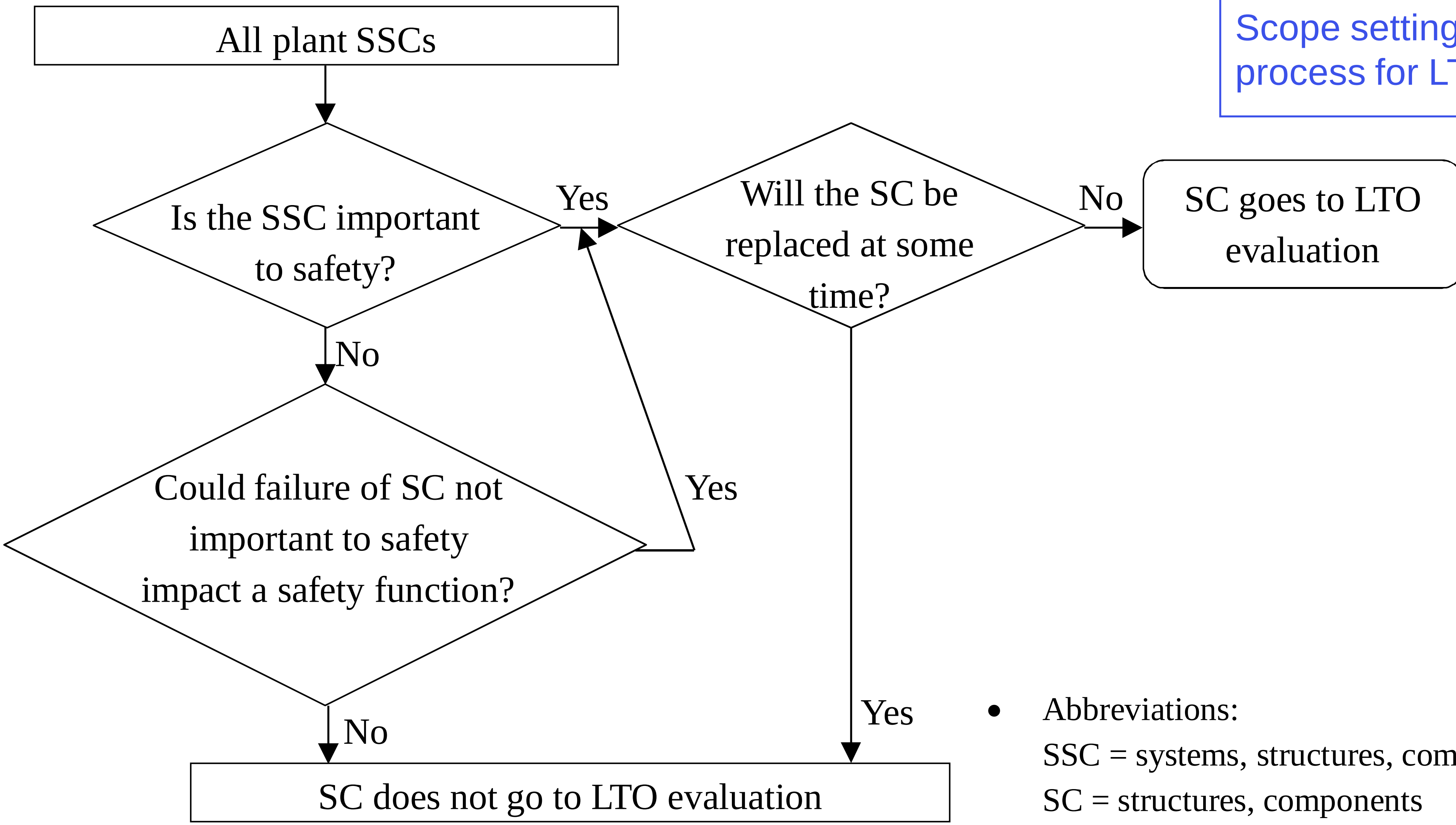
- The scope setting process is carried out at the level of systems & structures & components, whereas the screening process is described at the level of structures & components.
- The systems & structures & components within the scope of LTO are those that are important to safety, e.g. reactor coolant pressure boundary.
- Other systems & structures & components within the scope of LTO are those whose failure may impact upon the safety important components.

SCREENING PROCESS:

- The structures & components are screened to determine:
  - which are subject to revalidation of degradation analyses, and
  - which require evaluation of programs for managing ageing.

Scoping and Screening - 2

Flow chart of Scope setting process for LTO



- Abbreviations:

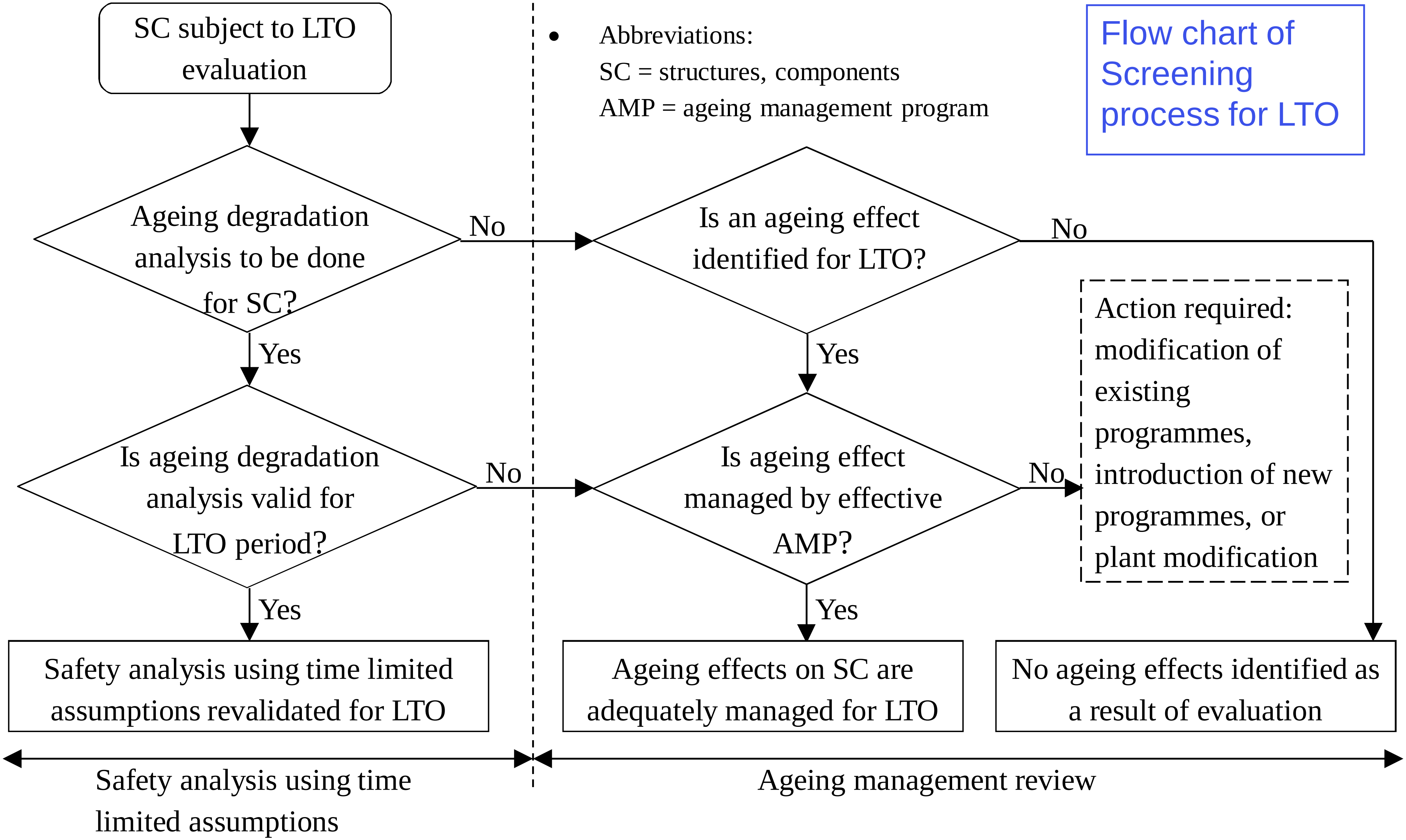
  SSC = systems, structures, components

  SC = structures, components

Scoping and Screening - 3

Flow chart of Screening process for LTO

- Abbreviations:
  SC = structures, components
  AMP = ageing management program



Assessment & Management of Structures/Components for LTO

- Once the scope setting and screening process has been completed, the systems & structures necessary for safe LTO are identified.
- The next step is to assess the conditions of structures & components and justify that their integrity will be managed acc. to current licensing basis for the planned LTO period.
- The ageing management review consists of the following steps:
  a) assessment of the current conditions of the plant,
  b) identification of ageing degradation effects,
  c) review of the existing plant programs and proposed programs for ageing management,
  d) demonstration that ageing degradation effects are being managed,
  e) documentation of the evaluation and demonstration that the effects of ageing for structures & components will be managed for the planned LTO period.

Revalidation of Safety Analyses - 1

According to IAEA Safety Report 57 [1], the safety analyses that are to be revalidated for LTO are those that e.g.:

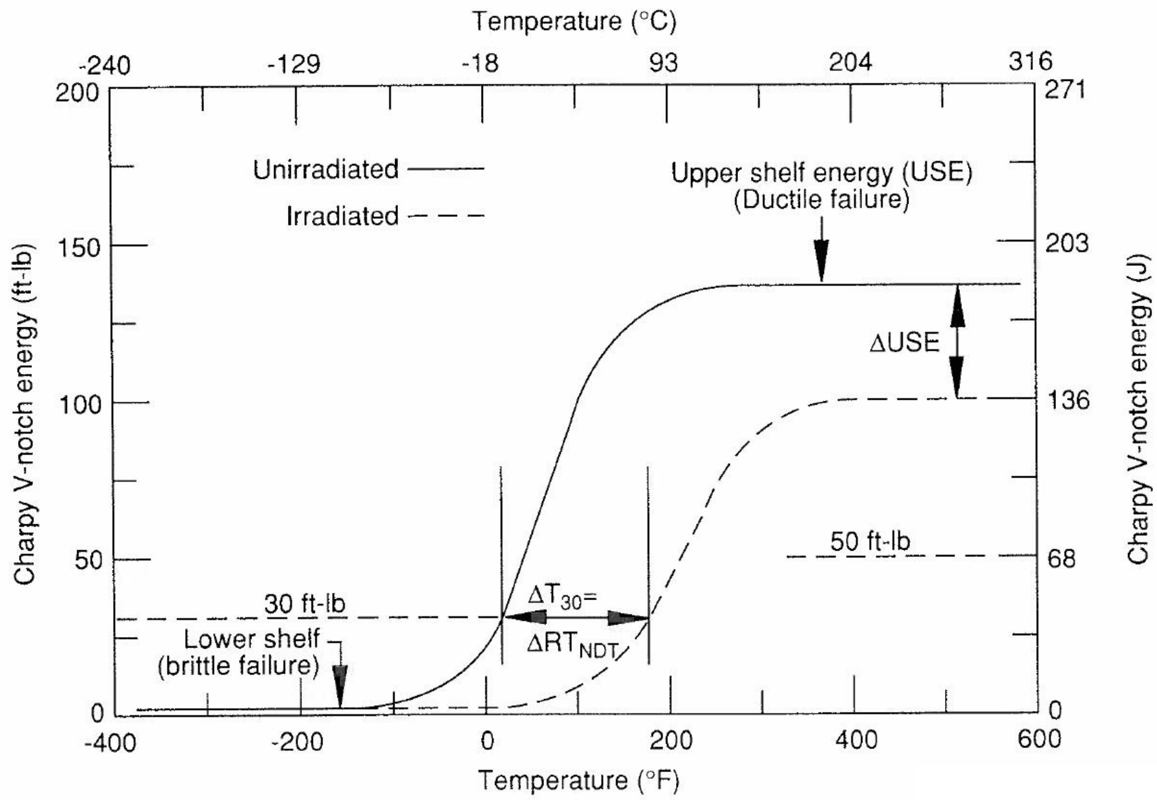
- Involve systems & structures & components within the scope of LTO.
- Consider the effects of ageing degradation.
- Involve degradation extrapolation based on current plant operation.
- Examples for which the safety analysis typically involves time dependency:
  - Irradiation embrittlement of the RPV,
  - Thermal and mechanical fatigue,
  - Thermal ageing,
  - Loss of preload or material.
- The selection of degradation mechanisms and components for safety analysis revalidation is to follow the requirements by STUK, see YVL Guide A.8.

Revalidation of Safety Analyses - 2

Example of time dependent DM - Irradiation embrittlement:

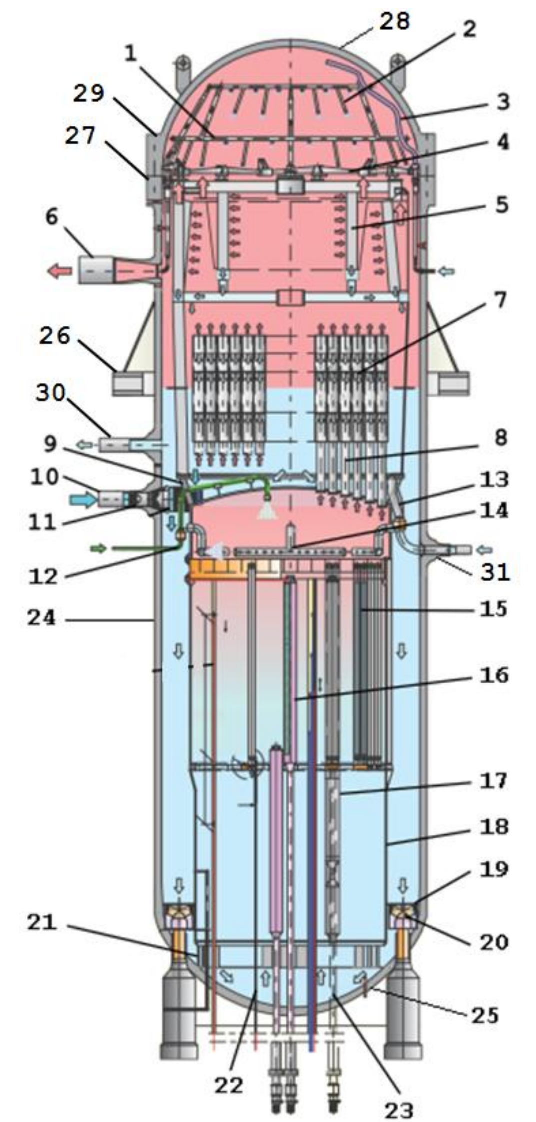
- Depends on the fluence, which is monitored and can also be simulated.
- Decrease of fracture toughness and increase of yield & ultimate strength.

RPV steel



Case Study – OL1/OL2 RPV & Internals - 1

- The degradation mechanisms covered in the TLAAs concerning OL1/OL2 RPV and its internals are:
  - Irradiation embrittlement
  - Thermal embrittlement
  - Fatigue; low-cycle, high-cycle, environmental, flow induced vibration,
  - SCC; IGSCC, IASCC,
  - General corrosion
  - Local corrosion
  - Erosion corrosion, Flow accelerated corrosion,
  - Interaction of degradation mechanisms.
- As can be seen, the scope of covered degradation mechanisms is much larger than that specified in the IAEA Safety Report No. 57 [1]

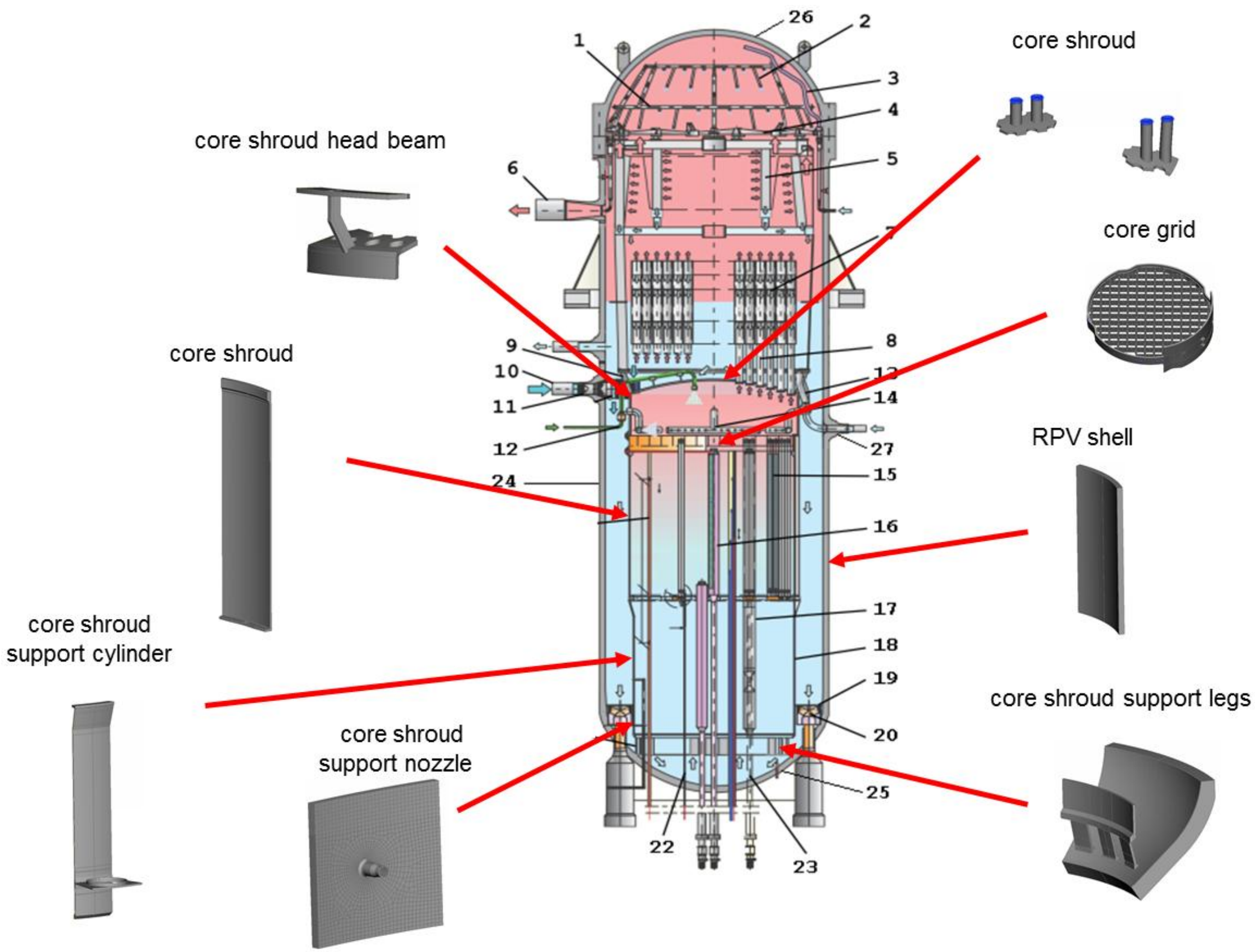


Case Study – OL1/OL2 RPV & Internals - 2

- Of the 31 considered components, those that screened IN are:
  - Steam outlet nozzles,
  - Feedwater nozzles,
  - Control rods,
  - Control rod guide tubes,
  - Core shroud, Core shroud support,
  - Pump deck,
  - Core shroud support legs,
  - Instrumentation guide tubes and nozzles,
  - Control rod guide tubes and nozzles at RPV bottom,
  - Cylindrical RPV shell,
  - Shutdown cooling nozzles,
  - Core spray nozzles.

Case Study – OL1/OL2 RPV & Internals - 3

- FE Models Created for the Analyses:



Case Study – OL1/OL2 RPV & Internals - 4

- TLAA Results and Conclusions:
  - According to the results the operational lifetime of the OL1/OL2 RPV and its internals can be safely continued from 40 to 60 years.
  - According to the conservative TLAA results, the degradation in terms of crack growth is in most cases very or extremely slow.
  - In the few cases with faster crack growth the cracks would be detected in the inspections well before they grow to any critical size.
  - Result example - Feedwater nozzles:
    - The degradation potential is very small.
    - The relatively high structural risk result for this component is governed by the high consequence measure value.
  - Main conclusion: LTO from 40 to 60 years is safe for the OL1/OL2 RPV and its internals!!!

  - => This study will be published as a dissertation within SAFIR2018.

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