# Fatigue management for long-term operation (FATIMA)

## Interim seminar 19.3.2021

# Topic of FATIMA project

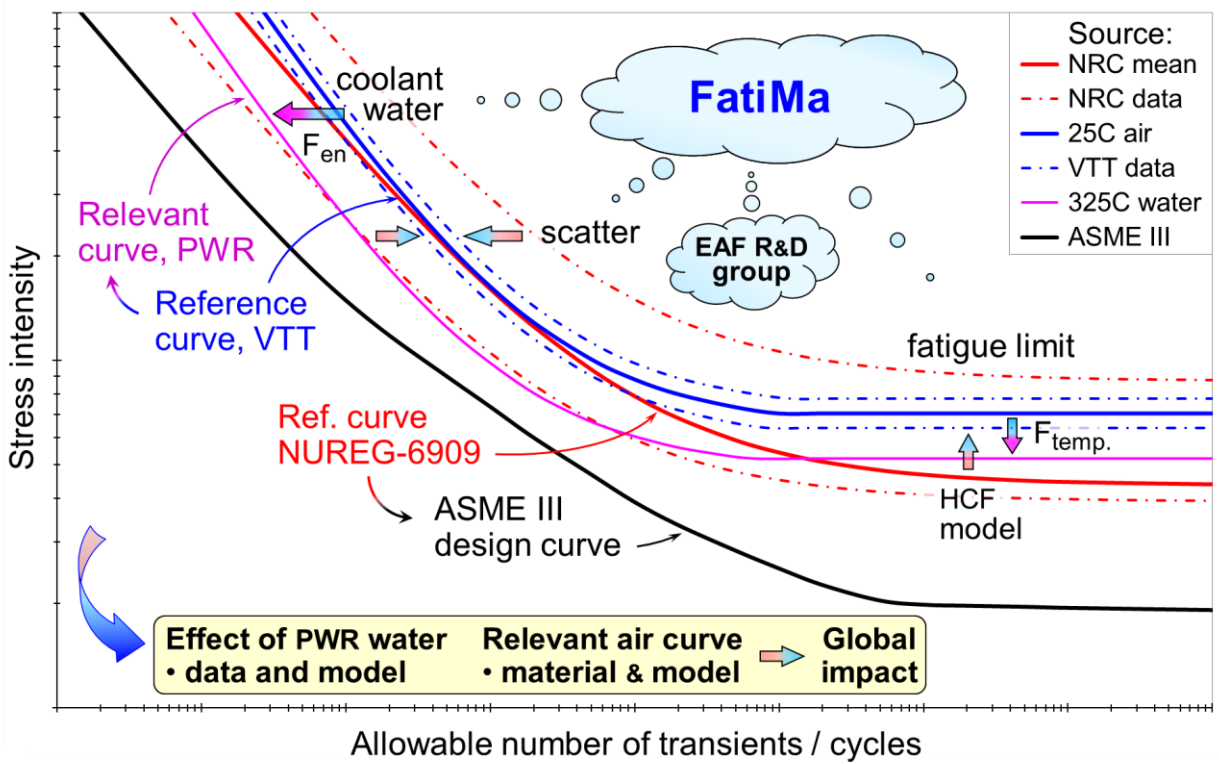
"(Environmentally-assisted) fatigue* management of austenitic stainless steels in NPP primary circuit for long-term operation"

**Progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point and that may culminate in cracks or complete fracture after a sufficient number of fluctuations (ASTM E1823)*

# Project motivation

- Accumulation of (calculated) fatigue usage as a potentially limiting factor for power plant use
  - Realism needed in fatigue management
    → reduce cumulative usage and maintain/improve safety
  - Avoid bias in risk-informed in-service inspection and plant life management
    → focus in critical points and optimize radiation exposure
- Introduction of scientific-based methods into codes and standards
  - Recognition and impact through international collaboration
  - Understand and improve state-of-the-art, not only follow

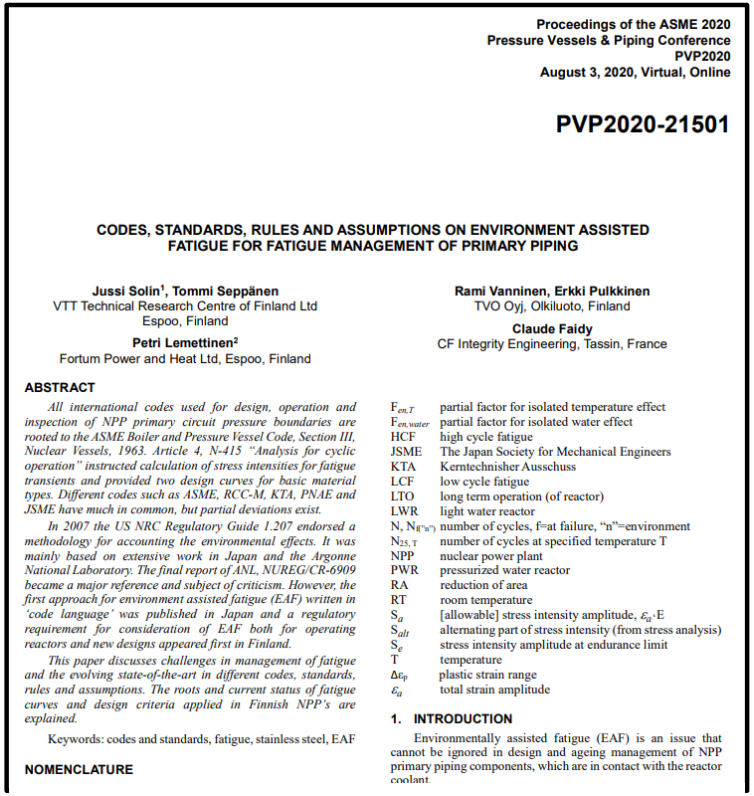
# Project structure



# Achievements in 2020

# WP1 – State-of-the-art & internat. collaboration

- Focus area of the first project year and baseline for other WPs in 2021–22
- State of the art of EAF rules reviewed in ASME PVP2020 conference paper
  - Sequel submitted to ASME PVP2021
  - Task has been completed
- EPRI EAF Collaboration Group
  - ‘Team Finland’ membership accepted
  - Two webinars in 2020, to continue in 2021
- Other participation e.g. ASME Code Week meetings etc.



Proceedings of the ASME 2020
Pressure Vessels & Piping Conference
PVP2020
August 3, 2020, Virtual, Online

PVP2020-21501

**CODES, STANDARDS, RULES AND ASSUMPTIONS ON ENVIRONMENT ASSISTED FATIGUE FOR FATIGUE MANAGEMENT OF PRIMARY PIPING**

**Jussi Solin[1], Tommi Seppänen**
VTT Technical Research Centre of Finland Ltd
Espoo, Finland

**Petri Lemettinen[2]**
Fortum Power and Heat Ltd, Espoo, Finland

**Rami Vanninen, Erkki Pulkkinen**
TVO Oyj, Olkiluoto, Finland

**Claude Faidy**
CF Integrity Engineering, Tassin, France

**ABSTRACT**

*All international codes used for design, operation and inspection of NPP primary circuit pressure boundaries are rooted to the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Vessels, 1963. Article 4, N-415 "Analysis for cyclic operation" instructed calculation of stress intensities for fatigue transients and provided two design curves for basic material types. Different codes such as ASME, RCC-M, KTA, PNAE and JSME have much in common, but partial deviations exist.*

*In 2007 the US NRC Regulatory Guide 1.207 endorsed a methodology for accounting the environmental effects. It was mainly based on extensive work in Japan and the Argonne National Laboratory. The final report of ANL, NUREG/CR-6909 became a major reference and subject of criticism. However, the first approach for environment assisted fatigue (EAF) written in 'code language' was published in Japan and a regulatory requirement for consideration of EAF both for operating reactors and new designs appeared first in Finland.*

*This paper discusses challenges in management of fatigue and the evolving state-of-the-art in different codes, standards, rules and assumptions. The roots and current status of fatigue curves and design criteria applied in Finnish NPP's are explained.*

Keywords: codes and standards, fatigue, stainless steel, EAF

**NOMENCLATURE**

| | |
|---|---|
| $F_{en,T}$ | partial factor for isolated temperature effect |
| $F_{en,water}$ | partial factor for isolated water effect |
| HCF | high cycle fatigue |
| JSME | The Japan Society for Mechanical Engineers |
| KTA | Kerntechnischer Ausschuss |
| LCF | low cycle fatigue |
| LTO | long term operation (of reactor) |
| LWR | light water reactor |
| N, $N_{f("n")}$ | number of cycles, f=at failure, "n"=environment |
| $N_{25,\,T}$ | number of cycles at specified temperature T |
| NPP | nuclear power plant |
| PWR | pressurized water reactor |
| RA | reduction of area |
| RT | room temperature |
| $S_a$ | [allowable] stress intensity amplitude, $\varepsilon_a \cdot E$ |
| $S_{alt}$ | alternating part of stress intensity (from stress analysis) |
| $S_e$ | stress intensity amplitude at endurance limit |
| T | temperature |
| $\Delta\varepsilon_p$ | plastic strain range |
| $\varepsilon_a$ | total strain amplitude |

**1. INTRODUCTION**

Environmentally assisted fatigue (EAF) is an issue that cannot be ignored in design and ageing management of NPP primary piping components, which are in contact with the reactor coolant.

# WP2 – Quantitative environmental effects
# WP3 – Fatigue design curves

- Experimental work packages (in reactor coolant and in air)
- Scaling up of activities in 2021, preparatory work started in 2020
- Nuclear grade stainless steel→maximum relevance for Finnish NPPs
- Revitalization of experimental research in simulated PWR water

# Thank you for listening!