

# FIND

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Future Instrumentation and coNtrol based on innovative methods and Disruptive technologies for higher safety level

17/04/2025 - FIND - SNETP webinar



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# Increasing safety thanks to online monitoring system

- ❑ **Innovations make it possible to monitor safety system continuously**
  - A key added-value for an ageing reactor fleet
- ❑ **Early detection / anticipation of damages due to corrosion, fatigue, aggressions...**
  - Prevention of abnormal situations (1<sup>st</sup> level of defence in depth)
  - Robust with respect to non-linear, aleatory or even unanticipated phenomena
  - Control difficult to access zones
  - Anticipation of maintenance to restore safety margins more rapidly
- ❑ **Instrumentation supporting incident and accident management**
- ❑ **High acceptability**
  - Deployment with limited impact on existing systems (time, complexity, modifications)
  - Reduction in dosimetry
  - Positive impact on operational performance



# Consortium organisation

- ❑ NRT 01-01: Safety of existing reactors (long term operation) + crosscutting with new builds
- ❑ 5.8 M€ including 5 M€ Euratom subsidy
  - Significant experimental budget: 900 k€ for equipment and facilities
- ❑ Partners:
  - ASNR (coordinator), CEA, Framatome, SSTC NRS, VTT, IPP, EDF, KTU, Vuez, Tractebel, LGI (management)
  - Possibility to join the end-user group of the project or to participate without funding
- ❑ Contact:
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### WP1: Coordination

### WP2: Specifications

- Early detection / anticipation of damages in normal operation
- Improved management of incidents/accidents
- Roadmap for future developments

### WP3: Innovative technology development

- Defect detection with SHM
- Advanced simulation with real plant data: the Digital Twin
- Accidental instrumentation

### WP4: Testing in experimental and industrial conditions

- Performance assessment in controlled conditions
- Robustness tests (irradiation, humidity, temperature, vibration)
- Tests in industrial conditions

### WP5: Evaluating the acceptability of technologies

- Human, social and organisational impacts of the new technologies
- Qualification of the technology
- Recommendations for the adoption of the technology

### WP6: Communication, dissemination, preparation of exploitation

# Selected use-cases

## ❑ Selection criteria during the project preparation

- Added value for safety
- Generalisation to other systems
- Feasibility

## ❑ Use-cases for normal operating conditions

- Partially buried raw service water pipes
- Fatigue cracks on the pressurizer surge line
- Stress corrosion cracking (SCC) on the safety injection line
- Flow-accelerated corrosion on the high-pressure turbine extraction line

## ❑ Use-cases for accidental conditions

- Breach localisation during a loss-of-coolant accident (LOCA)
- Hardened water level measurement in the sumps
- Fission product measurement during severe accident



# Direct detection of defects with ultrasonic methods

## ❑ Ultrasonic methods

- Low-intrusive delocalised measurement
- Advanced signal treatment

## ❑ Passive guided-waves for flow-accelerated corrosion (CEA)

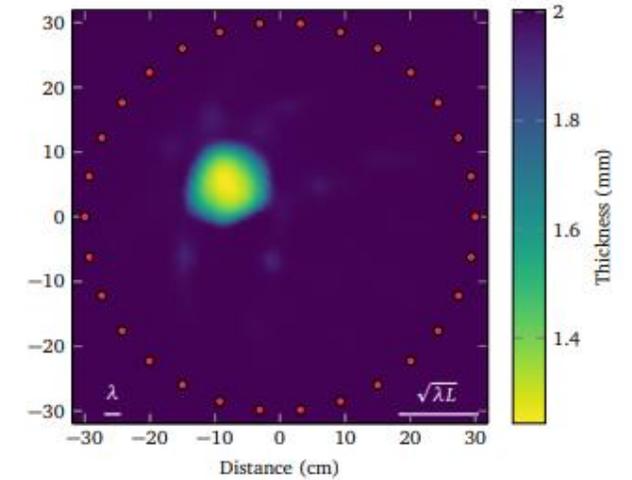
- Fibre Bragg Grating sensors on optical fibres
- Robust and insensitive to noise

## ❑ Active GW for crevice corrosion (KTU)

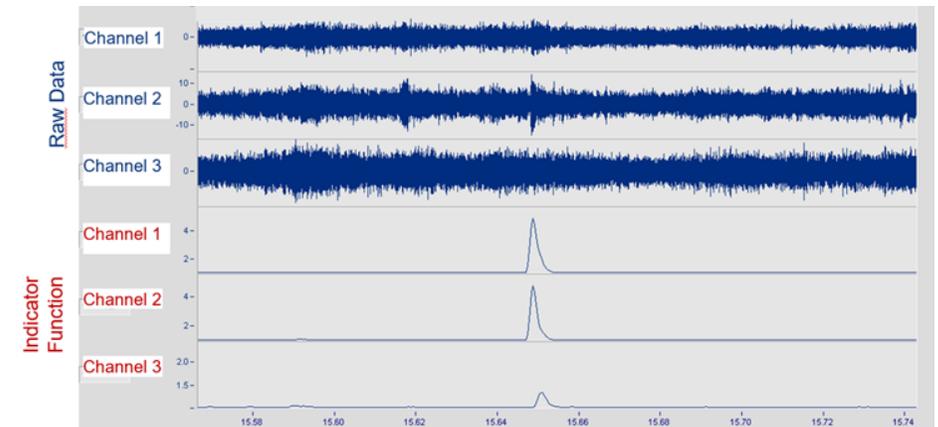
- Piezoelectric transducers

## ❑ Acoustic monitoring

- Acoustic Emission for SCC (Framatome)
- Acoustic monitoring of leakages on concealed pipes (SSTC-NRS)



Thickness map reconstruction thanks to guided waves



Acoustic events detection in noisy environment

# Continuous monitoring of stresses affecting pipes

## □ Digital twin:

- Combining real plant data from sensors and fast running high-fidelity simulations
- To reconstruct the complete stress field in the component

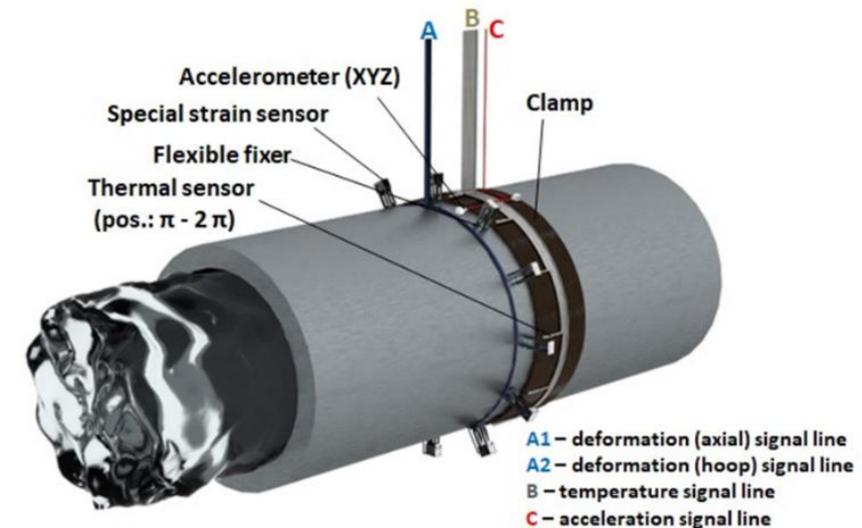
## □ Monitoring of soil movements affecting concealed pipes (IPP)

- Strain gauges
- Embedded acquisition system

## □ Monitoring fatigue on the pressurizer surge line

- Thermal sensors
- Accelerometers for vibration
- Process data (CADIS software)
- IPP & Framatome

Conceptual view of the Digital Twin for high-energy pipes



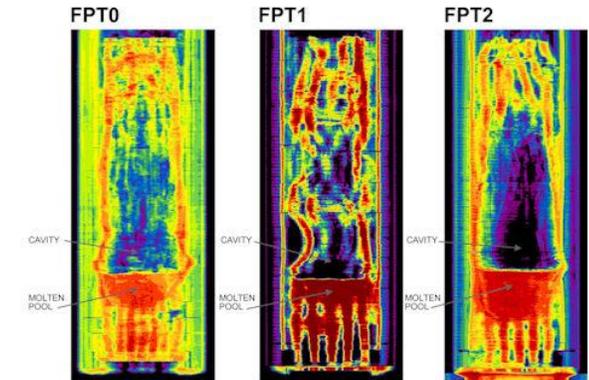
# Monitoring technologies: accident conditions

## ☐ Humidity and water level sensors

- Hardened humidity sensor + heated thermocouples
- Localisation of a breach during a LOCA
- Water level in the sumps in severe accident

## ☐ Fission product detection in the reactor building

- Support decisions about accident mitigation actions and emergency response
- Impedance measurement on Metallic Organic Frameworks trapping specific species (Iodine, Xenon)



Radiographie of PHEBUS test samples after irradiation

# Experimental tests

## ❑ Main experimental loops:

- VIKTORIA loop for concealed pipes and leakage detection
- Thermal stratification loop at IPP
- Corrosion loop at VTT (primary circuit conditions)

## ❑ Robustness tests in the IRMA irradiator

VIKTORIA facility (Vuez)



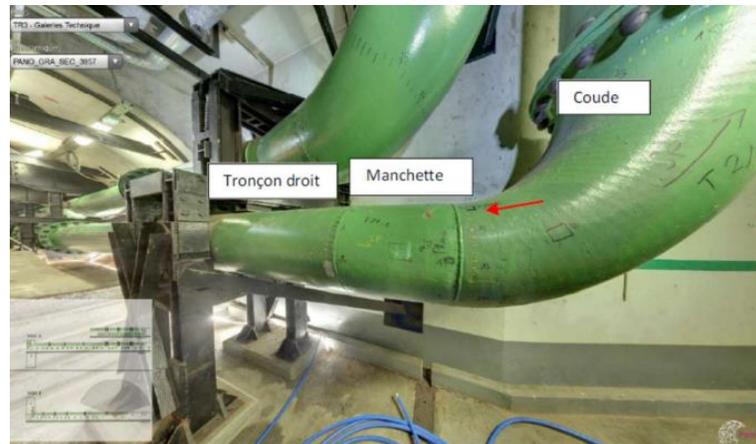
IRMA irradiator (IRSN)

# Industrial tests

- ❑ Turbine extraction line of the Tihange NPP subject to flow accelerated corrosion
- ❑ Raw service water pipes of Gravelines and other tertiary circuit components in Tricastin
- ❑ Representative pipes in conventional industries:
  - urban water supply
  - oil & gas industry



Turbine extraction line



Raw service water pipes



Oil & gas transport pipe

# Expected outcomes of the project

- ❑ Several proofs-of-concepts adapted to nuclear environment
- ❑ Recommendations to put technologies to the market
- ❑ A roadmap for future developments:
  - Extending the approach to new systems and technologies
  - Robotised controls
  - Quantum sensors
  - Infrared thermography, 2D-laser scanning...
- ❑ **Objective: Generalise the strategy to many other relevant cases**
  - Support safety in the context of long-term operation



# Thank you!



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