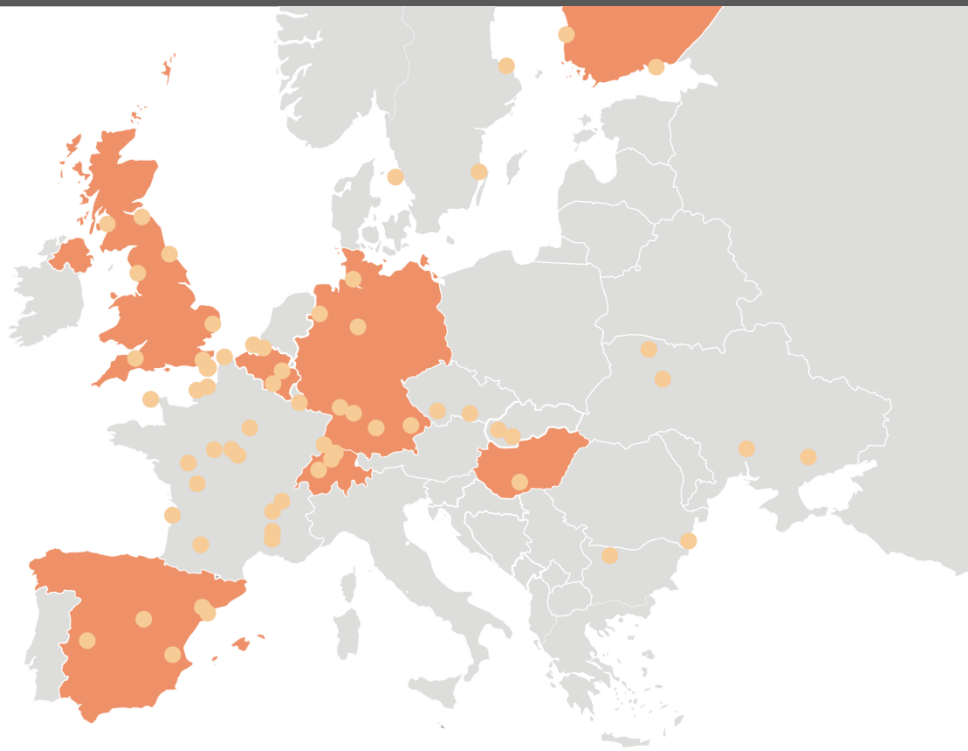
NOMAD

Nondestructive Evaluation (NDE) System for the Inspection of Operation-Induced Material Degradation in Nuclear Power Plants

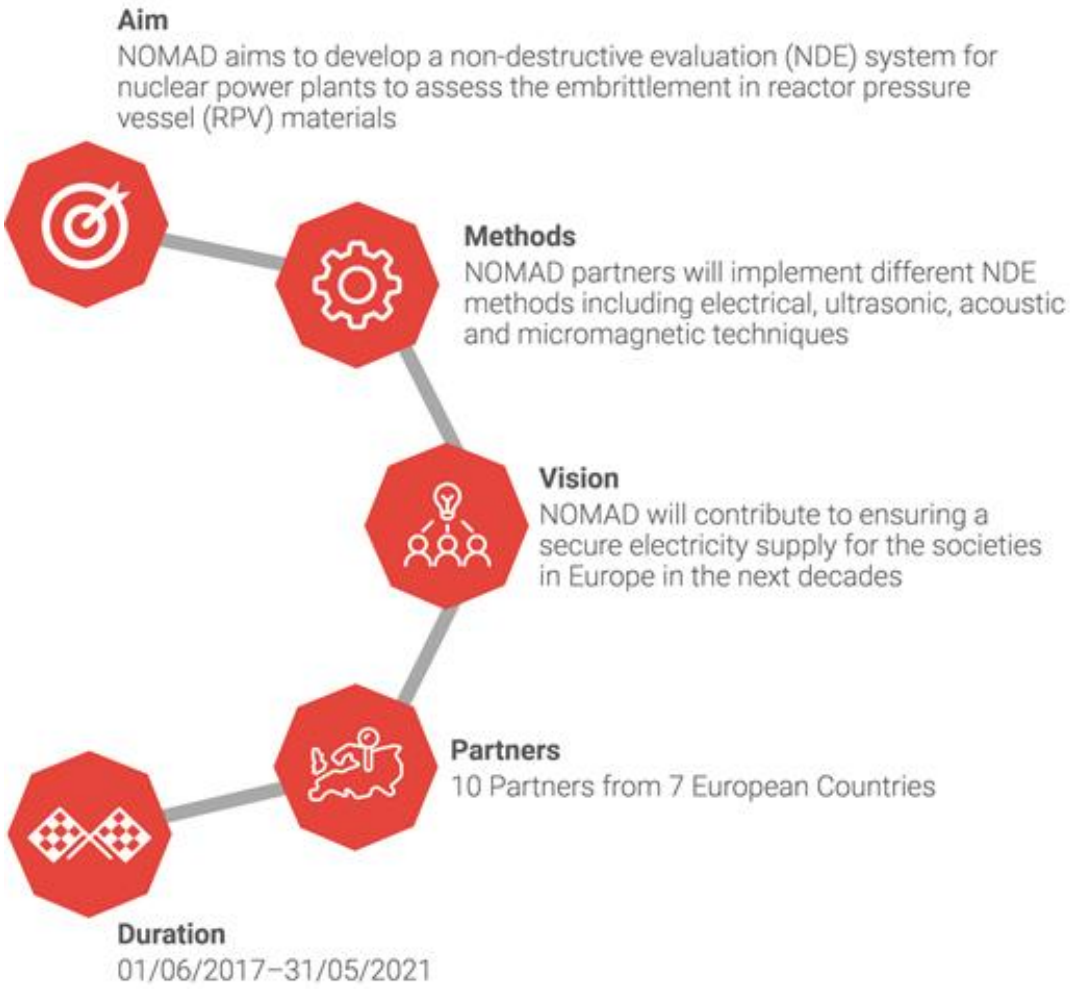


NOMAD – Summary of the 1st Project Year

www.nomad-horizon2020.eu

This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 755330.

The project at a glance



Overview

(1) Goal / Idea / Vision

(2) Work plan

(3) Project progress

(4) Consortium

(1) Goal / Idea / Vision

Overall goal

- Demonstrate a (multi-method) NDE approach that can quantify neutron-induced material degradation (in terms of DBTT etc.) by measuring through cladding under field conditions

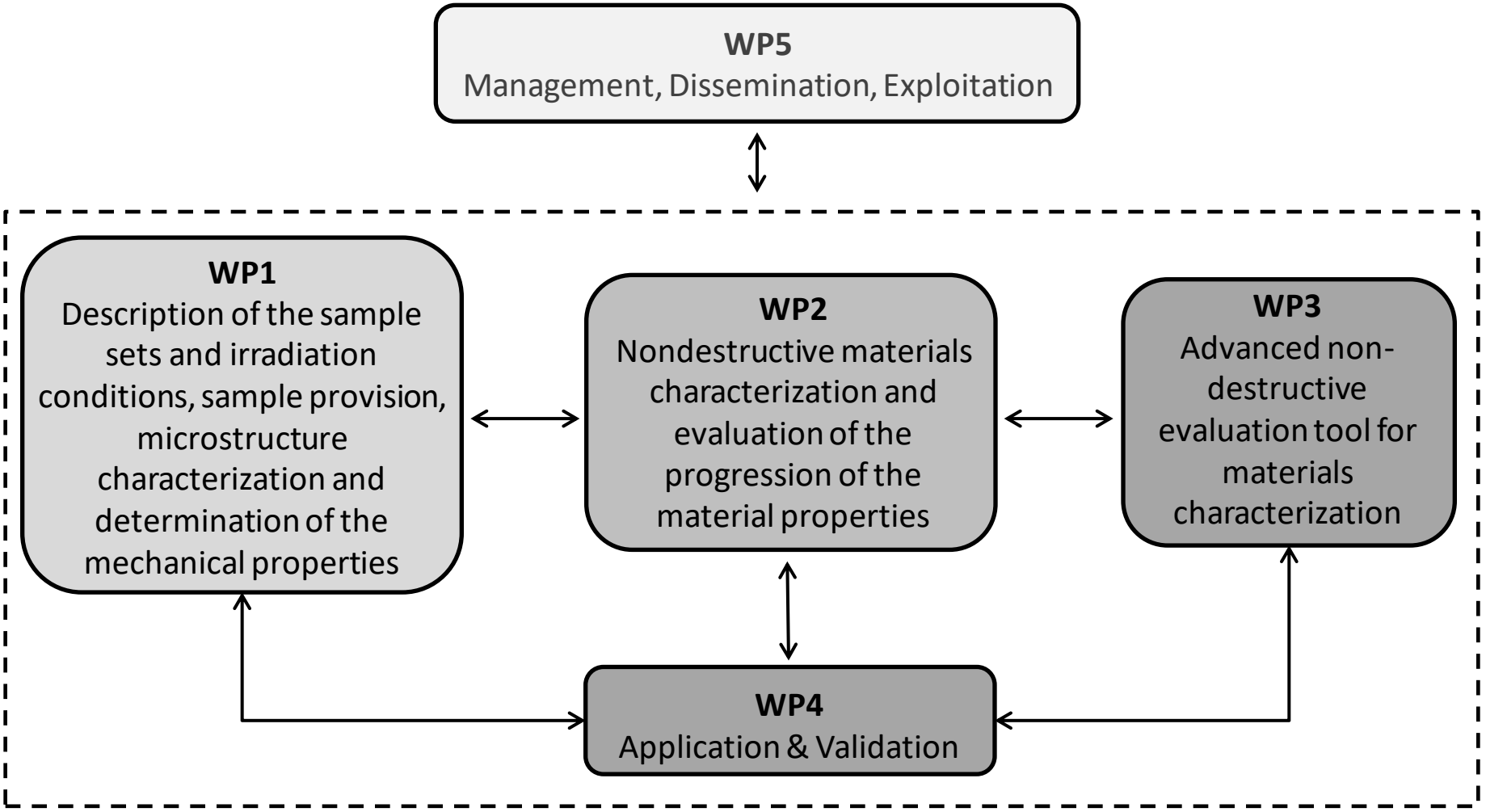
Idea

- Identify a common, material-independent trend in NDE data of multiple methods as a function of degradation
- Use the difference between degraded and non-degraded conditions of cladded material as degradation quantifier

Vision

- Use the fact that part of the RPV is not degraded since radiation is low to recalibrate (zero-offset) the NDE hybrid approach

(2) Work plan


WP5
Management, Dissemination, Exploitation
WP1
Description of the sample sets and irradiation conditions, sample provision, microstructure characterization and determination of the mechanical properties
WP2
Nondestructive materials characterization and evaluation of the progression of the material properties
WP3
Advanced non-destructive evaluation tool for materials characterization
WP4
Application & Validation

(3) Project progress – WP1

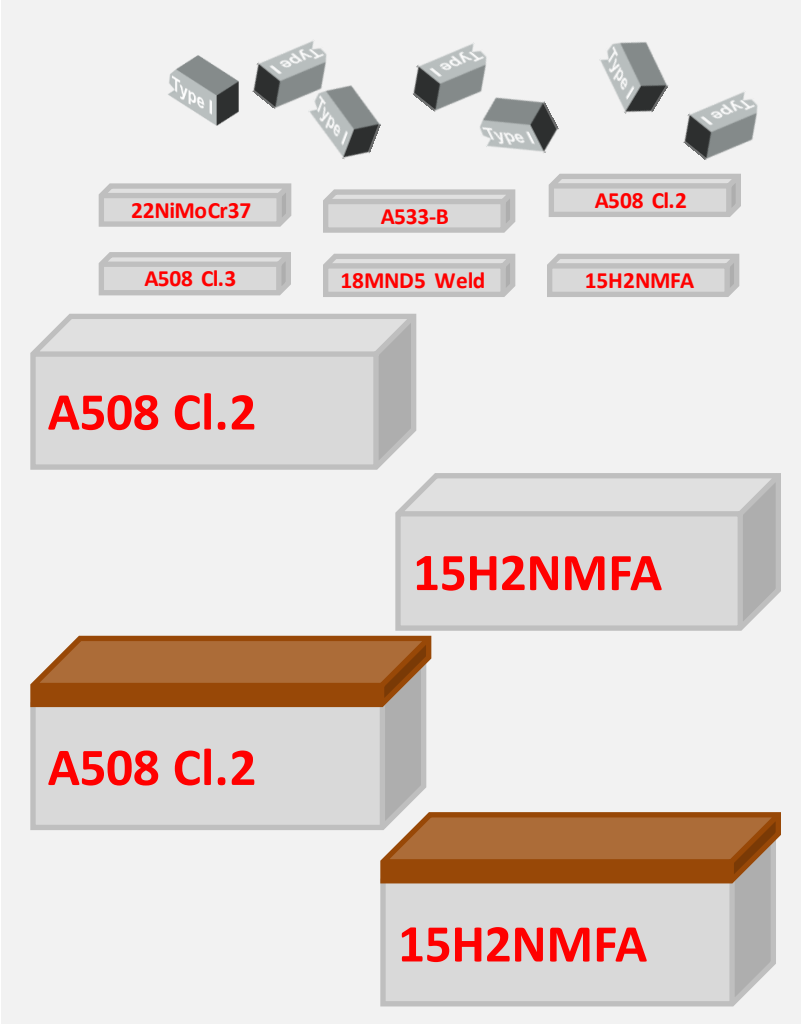
Provision and reference characterization of materials

WP1: Description and delivery of the sample sets (including cladded material) and irradiation conditions, sample provision, microstructure characterization and determination of the mechanical properties

- Sample set definition, degradation degree, irradiation preparation, microstructure features and mechanical properties
- Results of the reference materials and preparation irradiated materials
- Results of the cladded and laboratory materials

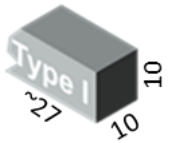
(3) Project progress – WP1

- Different relevant RPV materials
- Weld and base materials
- Western and eastern RPV design materials
- Different samples geometries
- Similar realistic operation conditions



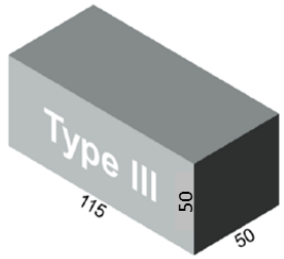
(3) Project progress – WP1

Type 1:
half Charpy



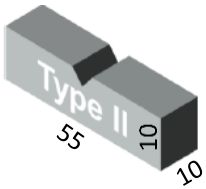
Goal:
assess NDE on half Charpy samples

Type 3:
Non-cladded blocks



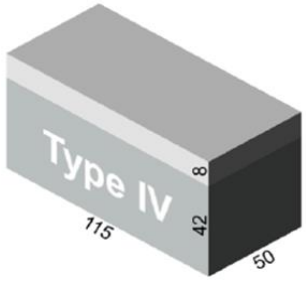
Goals:
validate sensors, verify NDE trend on type 3 vs type 2 (Charpy samples)

Type 2:
Charpy



Goals:
identify common NDE trend,
sensor optimization,
RRT

Type 4:
Cladded blocks



Goals:
proof feasibility of NDE through the cladding,
confirm NDE trend of type 4 vs type 2

(3) Project progress – WP1

Conditions

Neutron irradiation
- high neutron flux
- four fluences
- low temperature

Thermal treatment – „step cooling procedure“
- temperature
- time

Destructive tests

Microstructure characterization
- Metallographic analysis (optical microscopy)

Mechanical tests
- yield and ultimate tensile strength
- Mechanical hardness
- Charpy impact properties

(3) Project progress – WP2

NDE methods development and evaluation

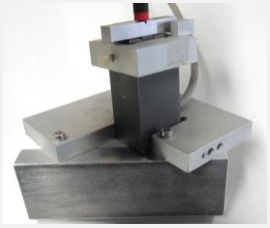
WP2: Nondestructive materials characterization (MC) and evaluation of the progression of the material properties

- NDE results on Charpy samples
- Individual non-destructive evaluation of embrittlement on cladded samples
- Effective individual NDE methods for the characterization of neutron irradiation-induced embrittlement of cladded material

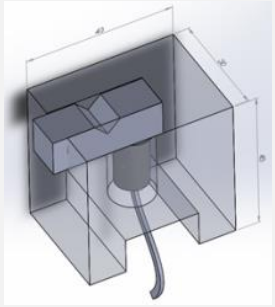
(3) Project progress – WP2

Design / construction of NDE setups

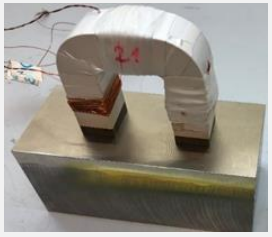
Charpys | **Blocks**



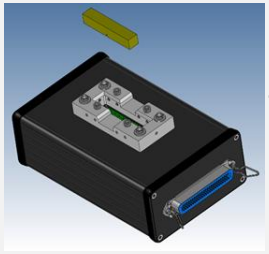
3MA



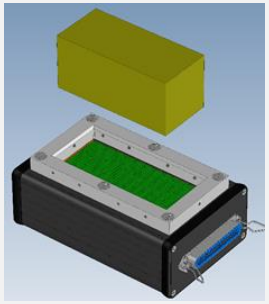
MAT



Piezo-US

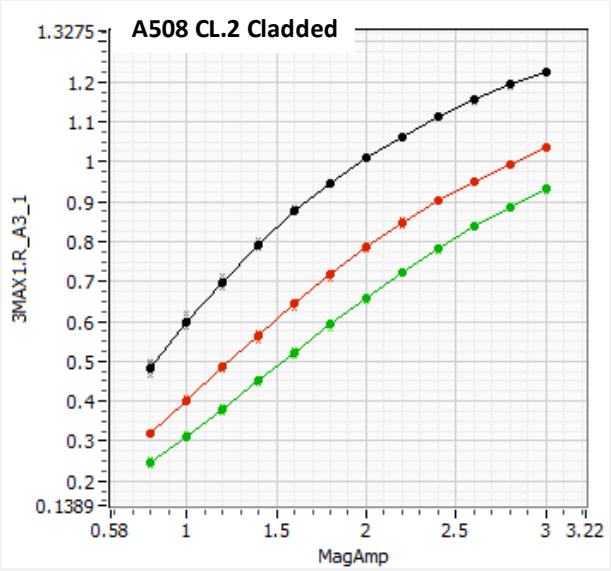


DCRPD



Settings optimization

- Coupling conditions
- Probes geometries
- Samples holders
- Measuring parameters



(3) Project progress – WP2

Preliminary tests of NDE setups and characterization of the RPV steels samples in as-received/thermally treated condition

Charpy samples

Homogeneity and influence of the thermal treatment

- Electrical resistivity (DCRPD)
- Time of flight (Piezo-US)
- Micromagnetic parameters (3MA)
- Magnetic permeability (MAT)
- Seebeck coefficient (TEPMM)
- Magnetic Barkhausen noise (MIRBE)

Blocks

Homogeneity, influence of the surface conditions and thermal treatment

- Magnetic permeability (MAT)
- Micromagnetic parameters (3MA)
- Seebeck coefficient (TEPMM)
- Magnetic Barkhausen noise
- Time of flight (EMAT)

(3) Project progress – WP2

- **Preliminary tests of NDE setups under simulated operational condition (Hot cell)**
- **Characterization of the RPV steels Charpy samples in as-received and neutron-irradiation condition by means of non-destructive evaluation methods**

(3) Project progress – WP3

NDE tool development

WP3: Advanced nondestructive evaluation tool for demonstration of materials characterization

- Method classification and database
- Comparison and selection of measurement techniques
- Demonstration of the tool for advanced non-destructive materials characterization

(3) Project progress – WP4

Application & Validation

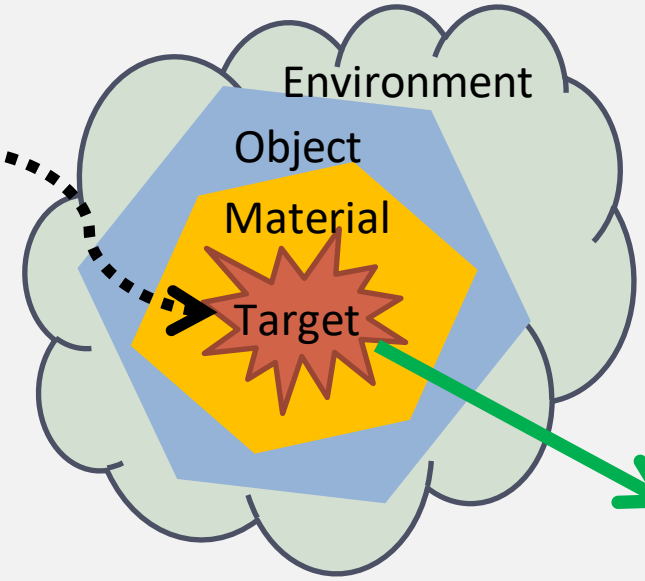
WP4: Validation = proof of meeting the requirements regarding accuracy and performance; Application = demonstration and optimization of the developed NDE tool (WP3) under realistic conditions

- Identification of essential parameters and test conditions
- Parametric study
- Demonstration and field recommendation

(3) Project progress – WP4

Identification of essential parameters and test conditions

NDE Systems
- Physical principles
- Methods
- Techniques
- Procedures
- Parameter selection



NDE Output Information
3MA (IZFP): 21 EM quantities
MAT (MTA): magnetic permeability
MIRBE (CU): several EM quantities
DCRPD (VTT): electrical resistivity
TEPMM (PSI): Seebeck coefficient
US/EMAT (IZFP): time of flight, amplitude

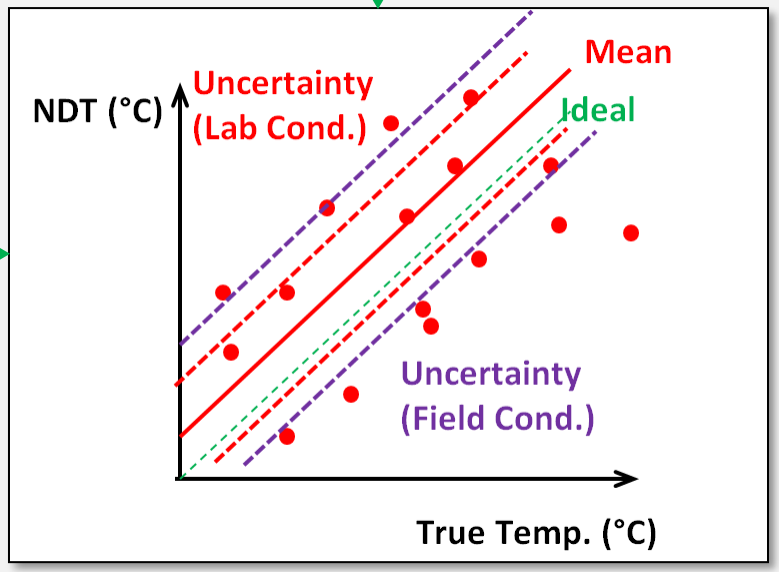
(3) Project progress – WP4

Target: Neutron irradiation-induced embrittlement as ductil-to-brittle transition temperature

NDE Output Information

Final Performance Estimation:
Statistical Analysis of Experiments
+
Compensation for Conditions not Covered

Tool
Empirical Algorithm



(3) Project progress – WP5

WP5: Management, Dissemination, Exploitation

- Implementation of management structures

  (Project Management Platform - ProjectAngel) ✓
- Scientific monitoring and outreach to the public

  (Plan for the dissemination and exploitation of project results) ✓
- External project communication and networking

  (External project website – www.nomad-horizon2020.eu) ✓
- IP Management and exploitation strategy

  (Exploitation workshop)
- Valorization of research outcomes

(4) NOMAD Consortium