

## **Crack assessment in irradiated EUROFER steel**

EEG21-04 A methodology for cracks tolerance  
assessment in irradiation embrittled EUROFER  
Reduced Activation Ferritic Martensitic (RAFM)  
Steel

04/05/2022    Andris Freimanis

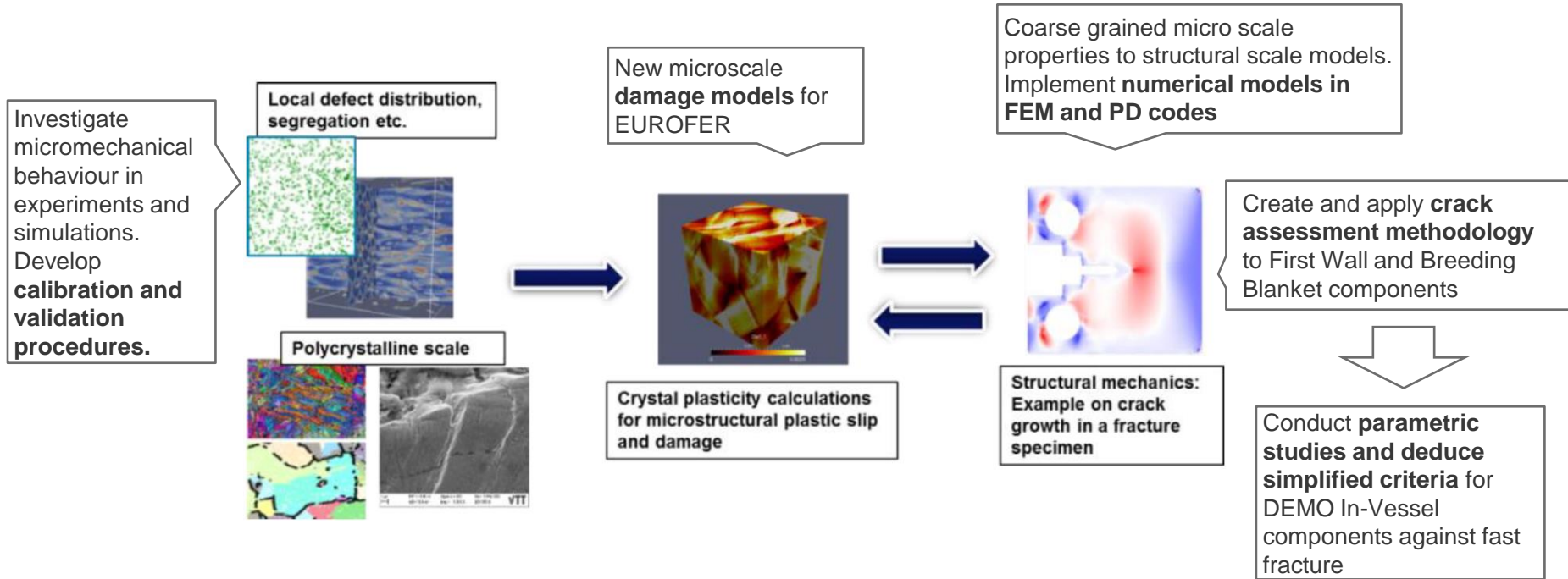
# Outline

- Problem
- Goal and concept
- Multiscale
- Multiframework
- Work programme

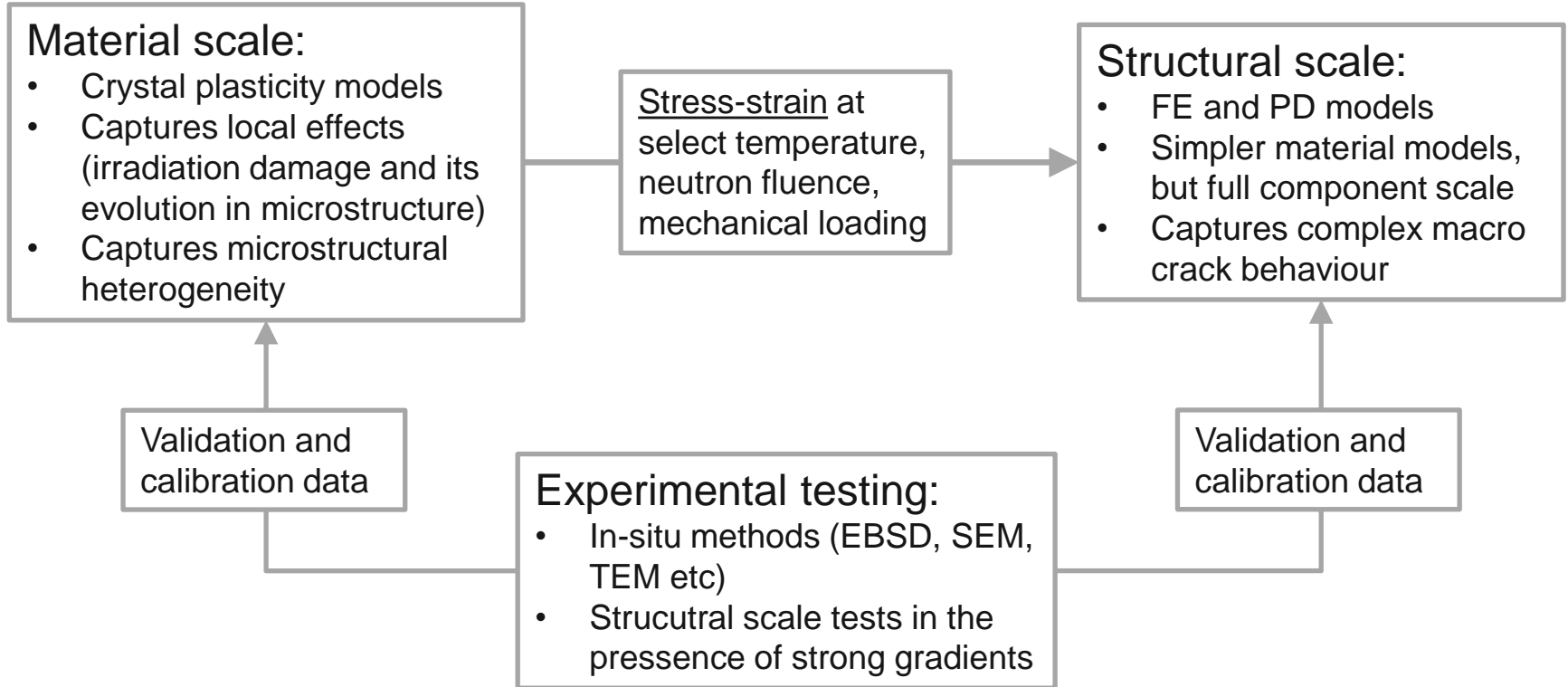
# Problem and solution

- EUROfusion problem → The development and validation of **new tools and methodologies for assessing and predicting crack behaviour are urgently required** to review current engineering DEMO IVC designs against safe operation.
- Solution → use multiscale (micro and structural) and multiframework (FEM and PD) fracture mechanical approach to develop **modelling tools, crack assessment methodology, and design rules** for DEMO In-Vessel components
  - **Links the assessment of effects of irradiation, local gradients** etc. at the material scale to structural response and complex crack behaviour
  - Physics-based predictive **abilities exceed present day methods** and enable EUROfusion to reliably review structural designs and their safe operation

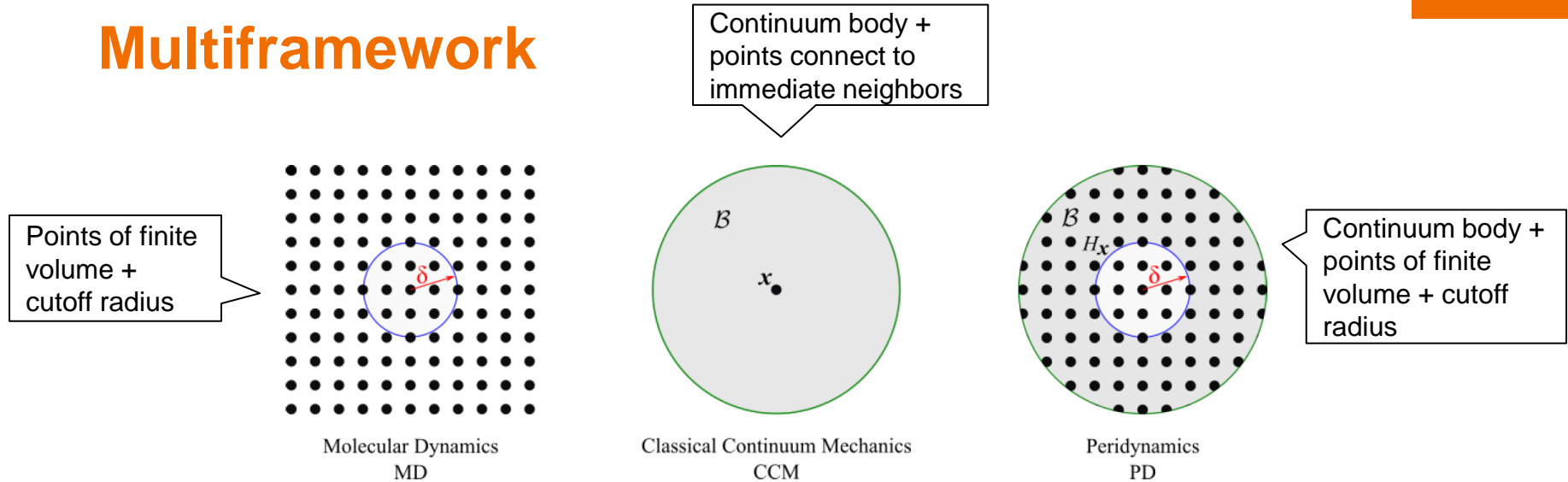
# Concept



# Multiscale



# Multiframework



- Continuum mechanics (CCM) – uses **differential equations**, which are **undefined** when the displacement field is discontinuous
- Peridynamics (PD) – uses **integral equations**, which are **defined** when discontinuities (e.g. cracks) are present – no special treatment for crack initiation and propagation necessary
  - Novel mechanics theory better suited for cracks, voids, steep gradients, large deformations etc.
- We will use FEM (CCM) as the main framework with PD in select areas where steep gradients, cracks, large deformations etc. arise → **solve situations that are impossible today**

# Peridynamics

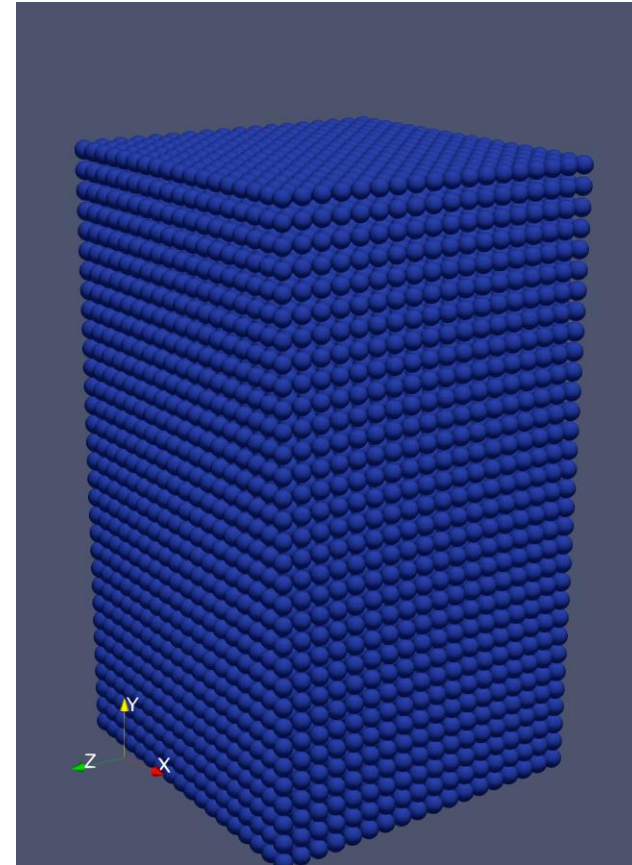
- Classical continuum mechanics
  - Stress – a function of strain – **differential equations** undefined when the displacement field is discontinuous
- Peridynamics
  - Force density – a function of deformation – **integral equations are defined** when discontinuities are present
  - Especially suited for complex crack behaviour (self-contact, branching, merging etc.)
  - Correspondence models – a way to include CCM materials in PD → **double development not required**

Density and acceleration

$$\rho_i \ddot{\mathbf{u}}_i(t) = \int_{H_i} (\mathbf{T}_{ij} - \mathbf{T}_{ji}) dV_j + \mathbf{b}_i(t)$$

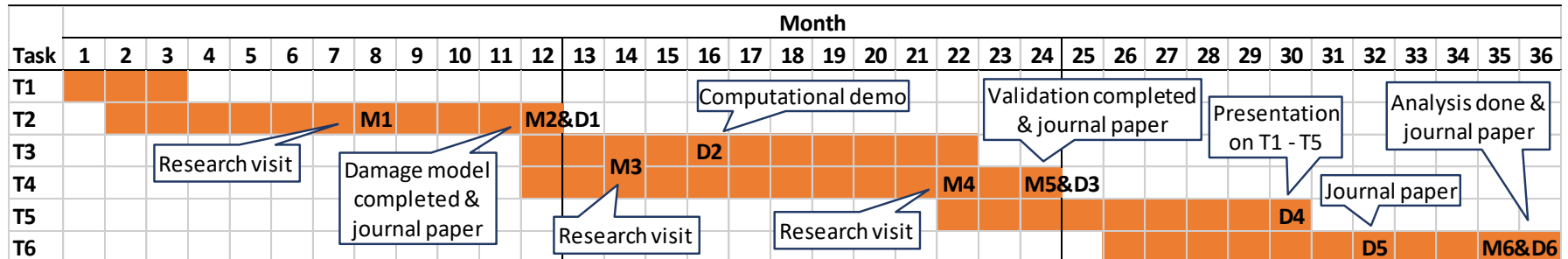
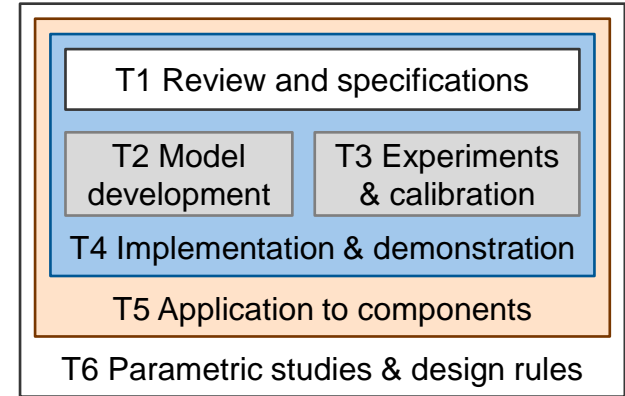
External forces

Internal forces



# Work programme

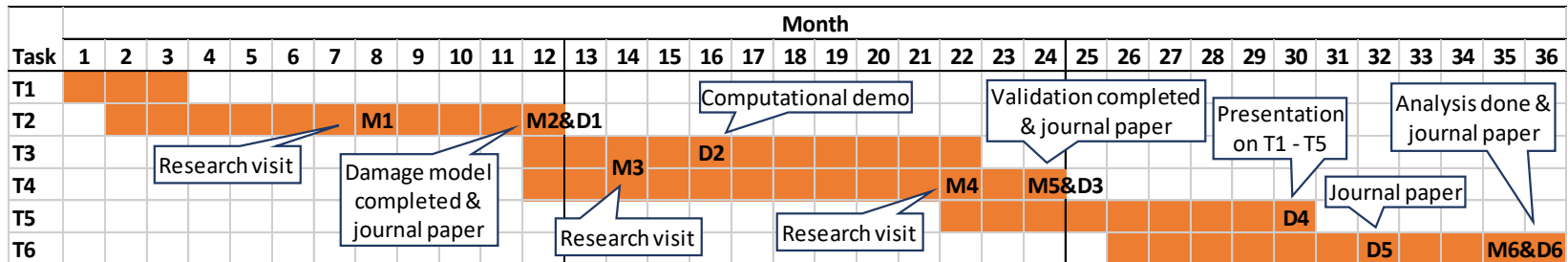
- T1 - Review and specifications
  - Outcome → learn about radiation material science, define environment, use-cases, relevant mechanisms etc.
- T2 - Model development
  - Outcome → FEM (PD) multiphysics damage model
- T3 - Experiments, calibration & validation
  - Outcome → data sets and procedures for model calibration and validation





# Work programme

- T4 - Implementation & demonstration
  - Outcome → computational models implemented in FEM codes e.g. Abaqus, Ansys etc.
- T5 - Application to components
  - Outcome → crack assessment methodology demonstrated on First Wall and Breeding Blanket
- T6 - Parametric studies and design rules
  - Outcome → parameter studies and simplified design rules to assess DEMO IVC structural safety and integrity
- 3+ research visits – 4 journal papers – 6 conferences



# bey<sup>0</sup>nd

## the obvious

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