
sindri
PROSPERITY PARTNERSHIP
EDF
University of BRISTOL
MANCHESTER 1824
The University of Manchester
UKRI
Science and Technology Facilities Council
Imperial College London

Nuclear Academic Meeting

7 September 2021

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(on behalf of PI, Prof David Knowles)

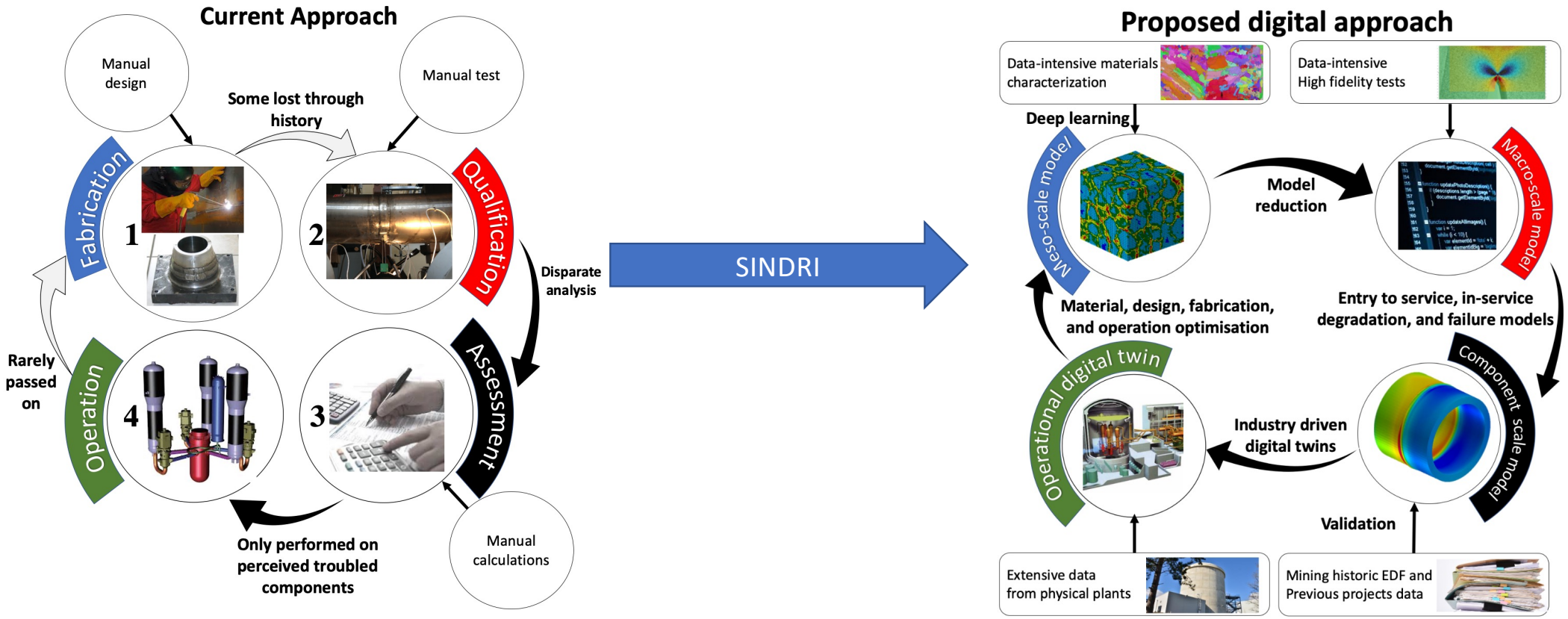
Vision

To develop the digital technology required for a step-change in the design, fabrication, and in-service assessment of nuclear power plant components, helping to drive down the cost of future low-carbon energy generation.

How

- Create a **coherent digital framework**, populated by **modular** multi-physics, multi-scale models of structural materials
- This will replace time consuming and extensive physical testing associated with traditional approaches; **enhance speed and efficiency**

How


Current Approach
Manual design
Manual test
Some lost through history
Fabrication
Qualification
Assessment
Operation
1
2
3
4
Disparate analysis
Rarely passed on
Only performed on perceived troubled components
Manual calculations
SINDRI
Proposed digital approach
Data-intensive materials characterization
Data-intensive High fidelity tests
Deep learning
Meso-scale model
Model reduction
Macro-scale model
Material, design, fabrication, and operation optimisation
Entry to service, in-service degradation, and failure models
Operational digital twin
Component scale model
Industry driven digital twins
Validation
Extensive data from physical plants
Mining historic EDF and Previous projects data

Key facts and numbers

- Total project: ~£8M
- EPSRC Contribution (@100% FEC): £3M
- EDF Contribution: £2.4M
- Duration: 5 years
- 16 years PDRA
- Currently 18 PhD students associated with it
- We are very much keen to expand the project (discussion with RR is ongoing)

Who

sindri

High Temperature Centre Est 2006

University of BRISTOL

Imperial College London

eDF

MANCHESTER 1824
The University of Manchester

JACOBS

NATIONAL NUCLEAR LABORATORY

Modelling and Simulation Centre Est 2010

UKRI Science and Technology Facilities Council

UKRI Engineering and Physical Sciences Research Council

UK Atomic Energy Authority

HENRY ROYCE INSTITUTE

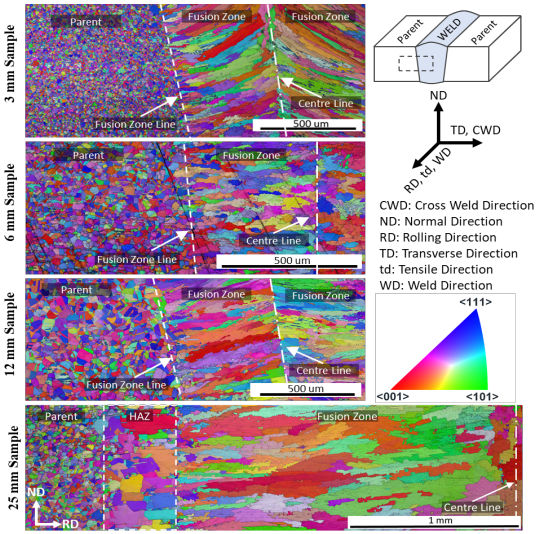
The Alan Turing Institute

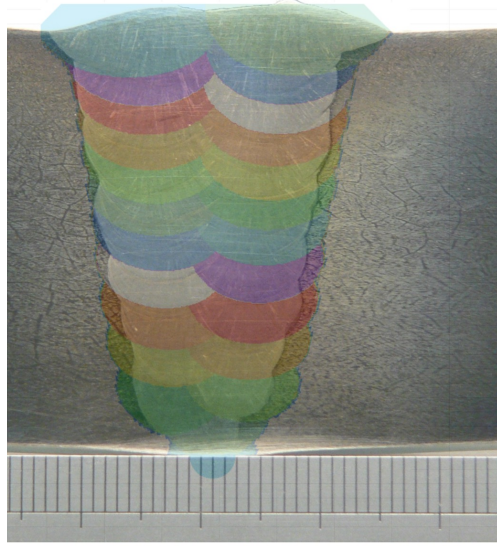
ROLLS ROYCE

NUCLEAR AMRC

WP1: Entry into service

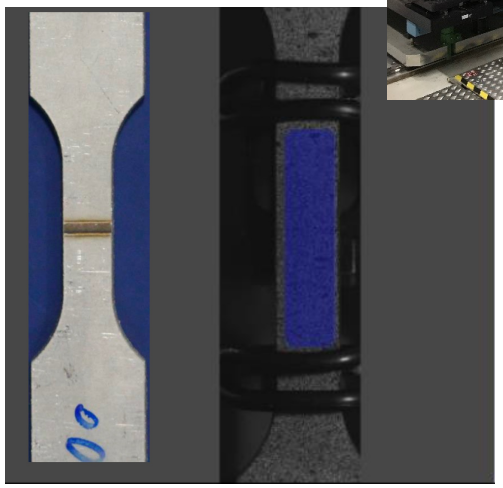
- Initial focus: Simulation and characterisation of welding
  - Will consider current and future welding/manufacturing technologies
  - Predict the as-manufactured microstructure
  - Predict the initial residual stress
  - Materials of interest are stainless steel and low allow steels (focus on balance of plant – no irradiation)





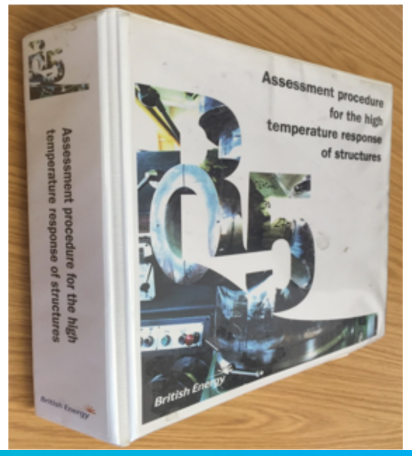
WP2: In-service degradation

- Built on an accurate deformation modelling platform to synergise with other large scale projects such as H2020 ENTENTE
- Damage mechanisms to be prioritised as the UK nuclear landscape evolves
- Models to be validated against high fidelity experiments to capitalise on UK investment (e.g. Royce)



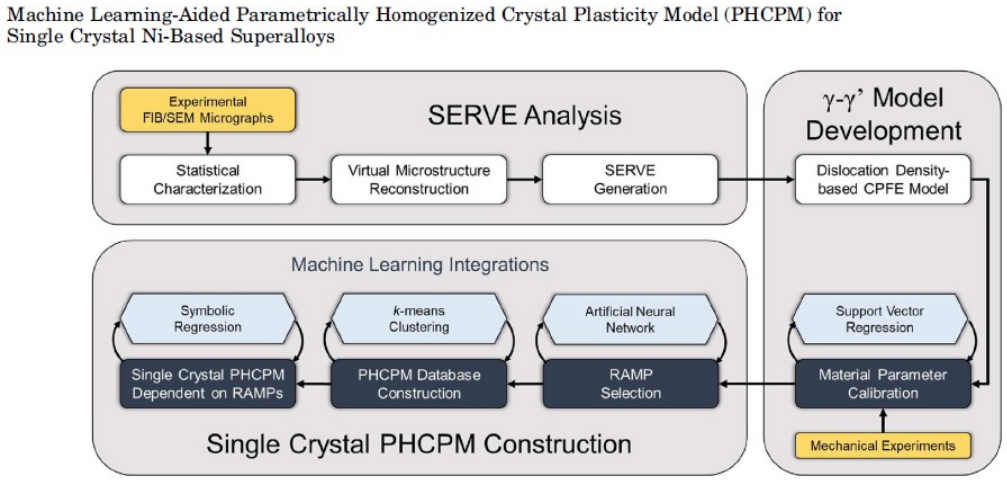
WP3: Implementation

- Implementation of the models in the multi-physics platform Salome_Meca, which makes use of the Code_Aster solver and several data analytics modules therein.
- The validated models developed in WP1 and WP2 update the advice in R5 and R6 to reduce uncertainties in the assessments
- Potentially expand R5 and R6 to go beyond the current generation of plants (e.g. probabilistic integrity assessment)

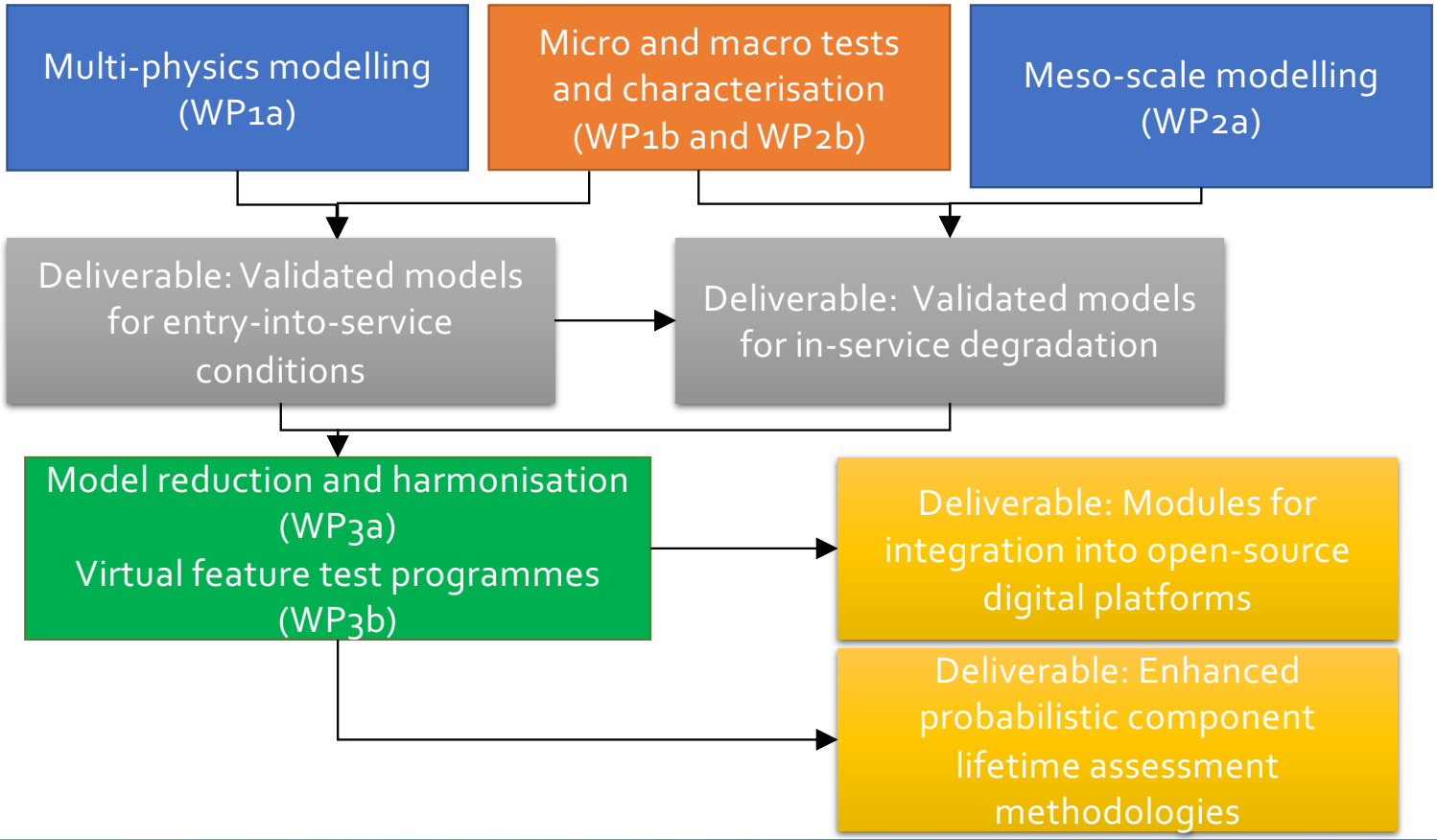


Cross-cutting AI work

- Two main streams:
  - Produce reduced order surrogate models
  - Develop machine learning software to analyse characterisation data
  - This is a hotly pursued current topic
  - Large scale programmes in other countries (e.g. NIST's Materials Genome Initiative) will be used.
  - Keen to engage with the whole community



How it all fits together



Stage 1: Proof of concept (month 0 - 6)

- Devise the framework, information flow and development platform through an example
- Focus on what we can do well individually and integrate
- *Material:*
  - stainless steel 316L
- *Mechanism:*
  - plastic deformation
- *Macroscale model:*
  - electron beam weld residual stress simulation
- *Mesoscale model:*
  - crystal plasticity finite element model
- Investigation of surrogate modelling

Stage 2: Development (month 6 - 24)

- Development of new knowledge within the framework and integration with EDF software/assessment methodology
- *Material:*
  - Low alloy steel
- *Mechanism:*
  - Deformation and damage
- *Challenges:*
  - Macromechanical weld modelling
  - Micromechanical characterisation and experiment
  - Micromechanical modelling
  - Surrogate modelling!

Stage-gate review (May 2023)

- What material?
  - austenitic, ferritic-martensitics, low alloy steel
- What damage mechanism?
  - fatigue, fracture, creep, corrosion
- Which reactor condition?
  - AGR, PWR
- Confirmation of the resources based on the decisions above

Thank you