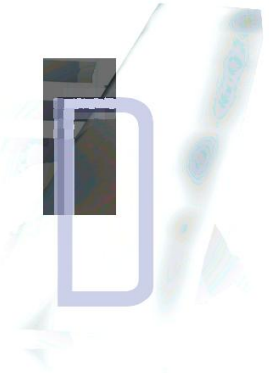
Design strategies using hybrid models for manufacturing and vulnerability of composite structures

CM3 Transport 2023 ECCOMAS Thematic conference

David DUMAS (David.dumas@cenaero.be)



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The DIDEAROT Project

LIÈGE université
Cenaero
Barcelona Supercomputing Center
Centro Nacional de Supercomputación
HEXAGON
inegi
tecnalia
sonaca GROUP
AERnnova

DIDEAROT

- Horizon Europe project
  - September 2022 – August 2026
  - CINEA agency support
- TRL 2-4 levels
  - Possible outcomes at TRL6 for direct Clean Aviation exploitation

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The framework for building the project

HORIZON-CL5-2021-D5-01-06

- The challenges addressed in the call
  - Next generation digital aircraft transformation in design, manufacturing, integration and maintenance
  - real digital transformation with a holistic and circular* approach for the aviation ecosystem
  - Accelerate processes as well as allow flawless entry into service of new aircrafts and systems

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Project Partners

- Expertise & expectations
  - Design challenges in long fibre reinforced polymer composites in aerospace
  - Complex multi-scale effects
    - Manufacturing
    - Non-linear behavior
  - HPC deployment & efficiency of algorithms
  - Integration in industrial design framework

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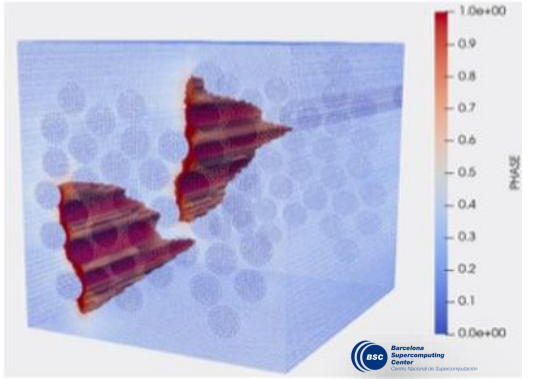
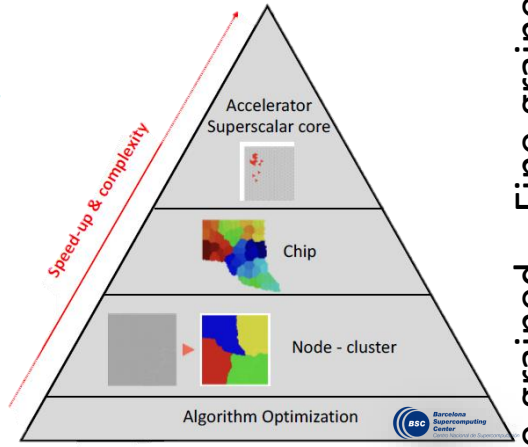
Drawing out the blueprint

- Challenges of industrial design through simulation
  - Handle design changes, new materials or extreme loading conditions that need to be addressed for certification
  - Hybrid physical & data driven approaches to build efficient DoE requiring less testing
  - Exploit high fidelity local models capable of predicting complex phenomenon
  - Use physical models in the real-time process & monitoring applications
  - Exploit many-core processors (CPU) & stream processors (GPU) in structural & manufacturing problems





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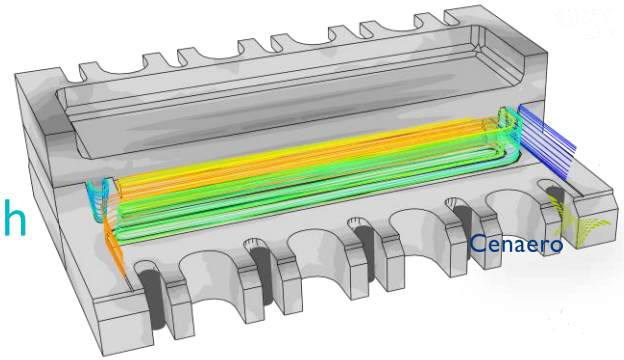
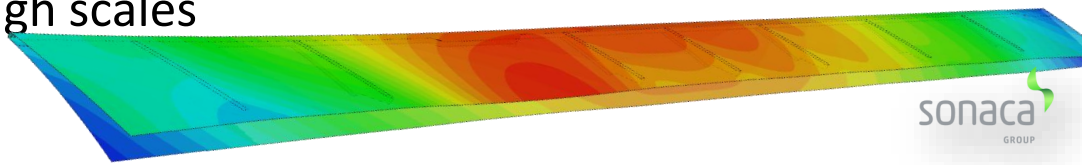
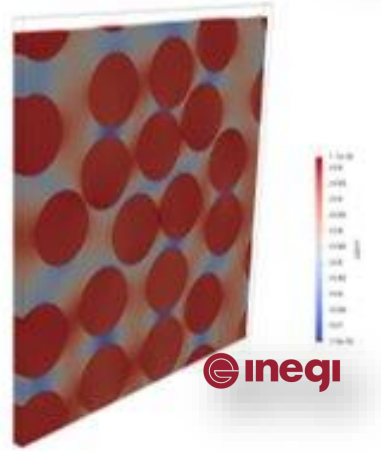
Drawing out the blueprint

- Challenges of physics through simulation
  - Process simulation
    - Handle coupled fluid-thermal-structural problems through HPC with enhanced performance
    - Account for complex interaction mechanisms (possibly enrich simulations with experimental results) up to high scales





  - Vulnerability simulation
    - Streamline model parameter identification through hybrid methods to bridge the gap between scales
    - Efficiently extend multi-scale methods to non-linear response
    - Taking account variability in prediction of response at different scales



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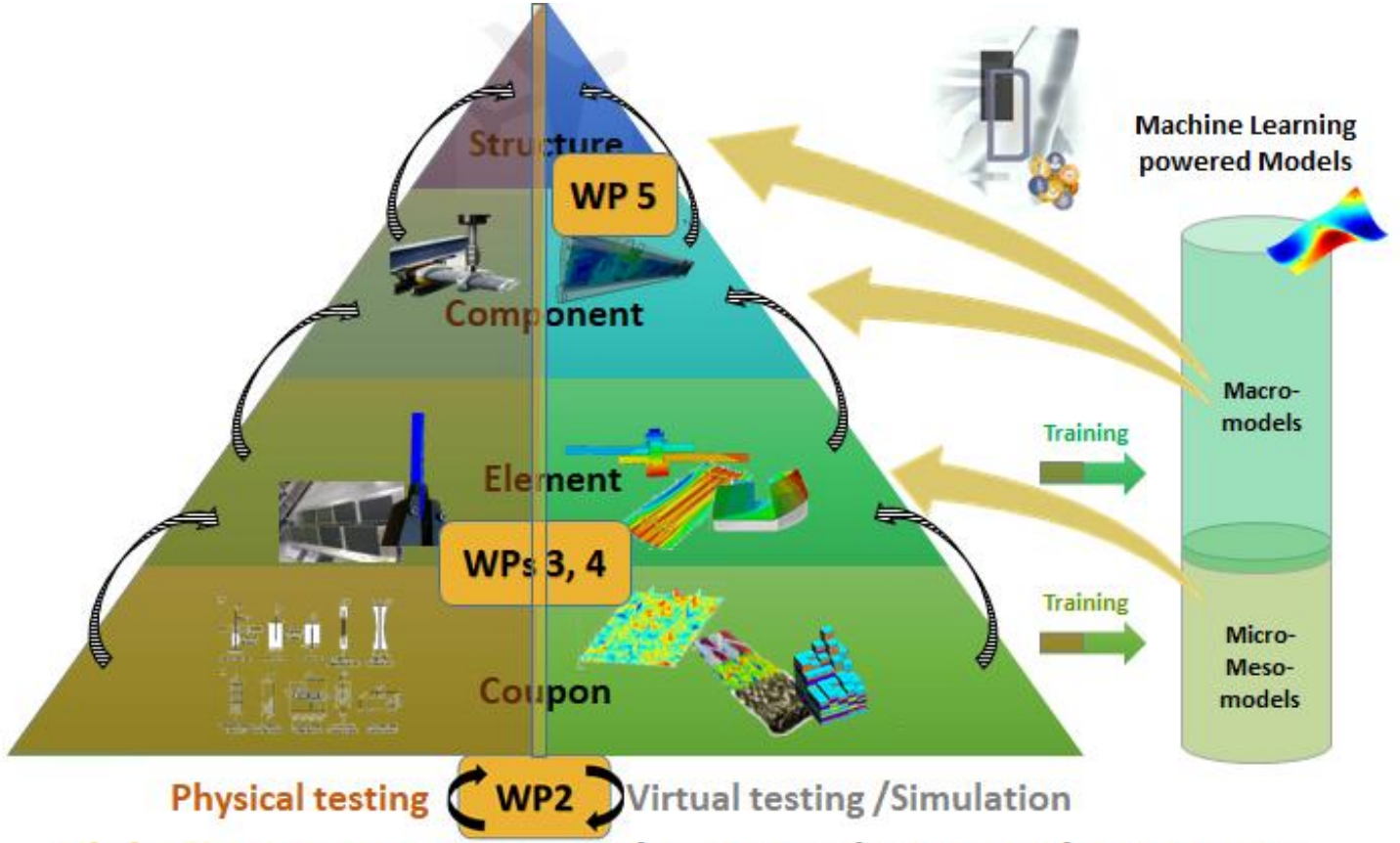
Simulation enhanced validation over scales

- Approach in building a hybrid testing pyramid



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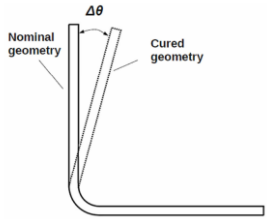
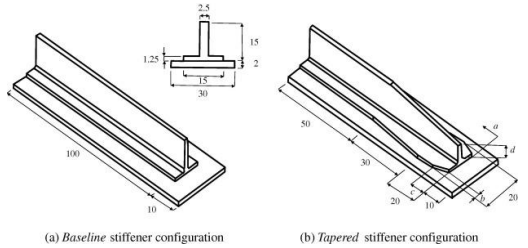
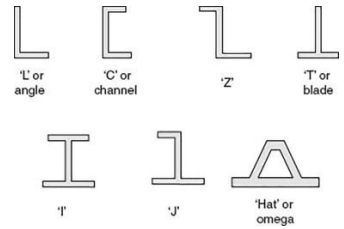
Combining material-process & geometric effects in process simulation

- Efficient transition of process simulation over scales
  - Take advantage of data on existing experimental campaigns
  - Be representative of a final aerostructure through PoC building blocks
    - Layup configurations (monolithic – sandwich – multi-material)
    - Stiffener configurations & Curvature configurations (single – double – discrete - …)

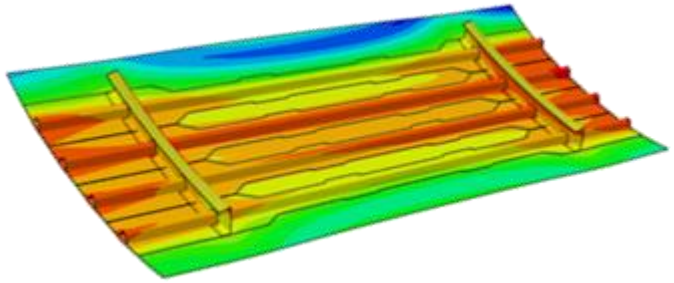


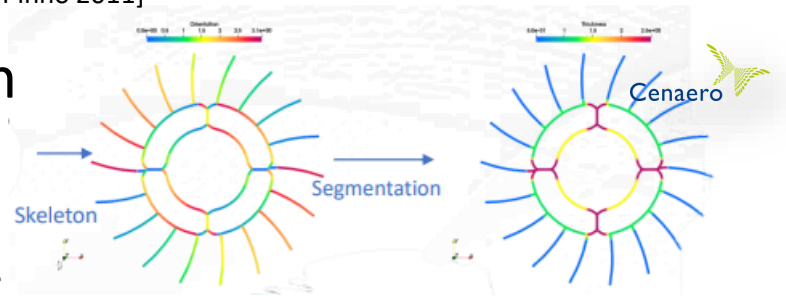




[Psarras,Pinho 2011]

- Build prediction on application through segmentation





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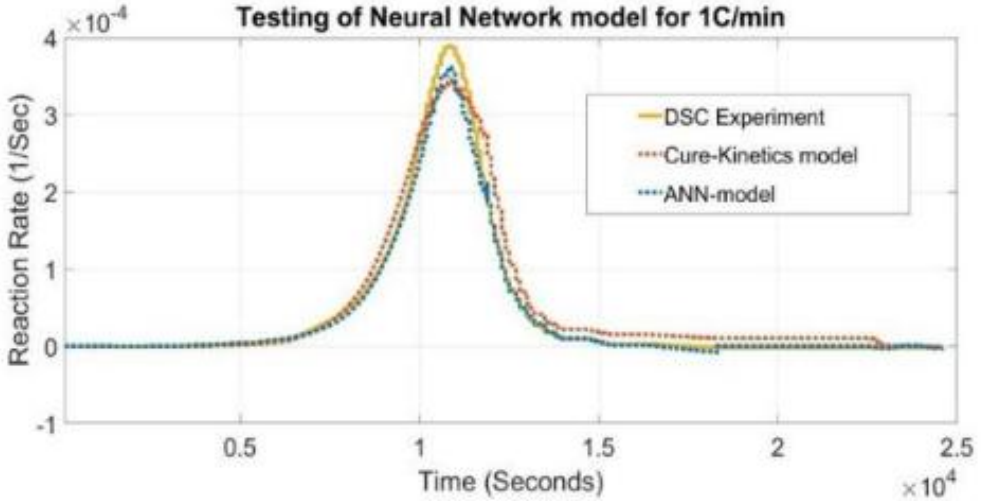
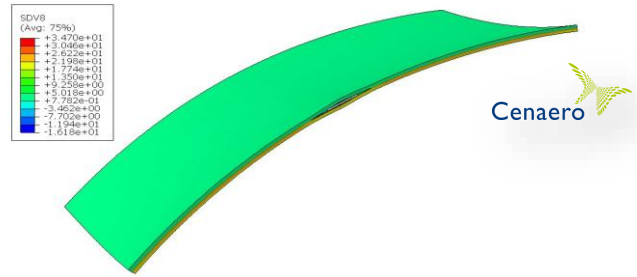
Hybrid models applied to process simulation

- At meso-scale
  - Evolution of cure response different rates
  - Change in volume fraction of fibers
  - Enhanced with DCS and coupon tests
- At macro-scale (feature)



- At macro-scale (structure)



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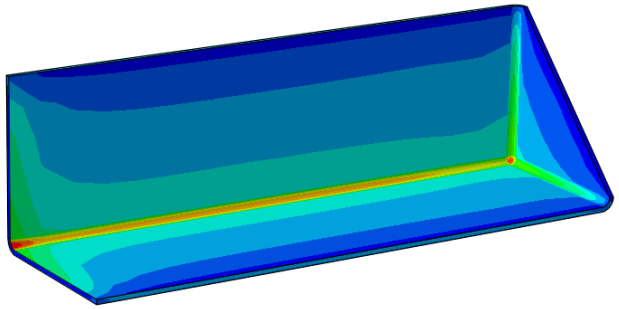
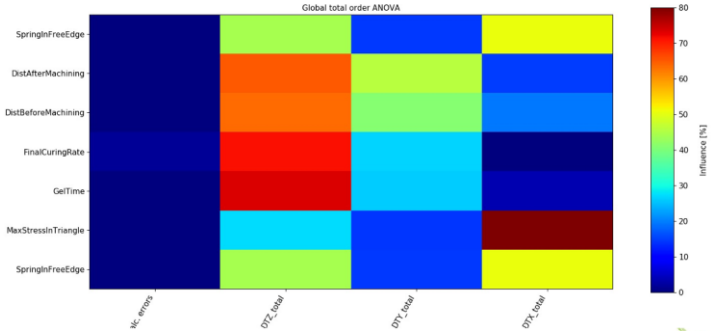
Machine learning applied to process simulation

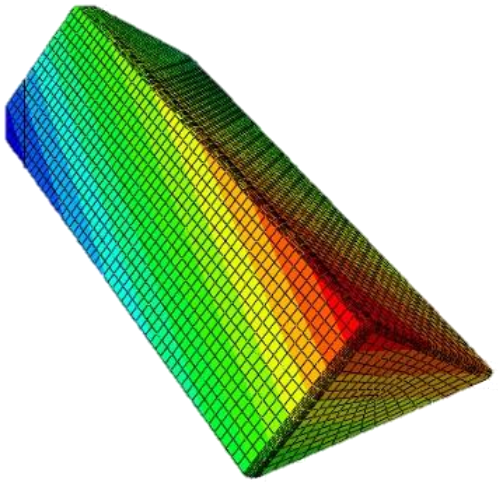
- At meso-scale

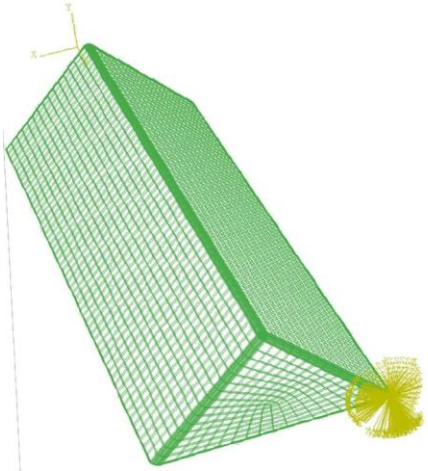




- At macro-scale (feature)
  - Layup effects & geometrical
  - Detailed process effects
  - Enhanced with spring in measurements & distortions

- At macro-scale (structure)





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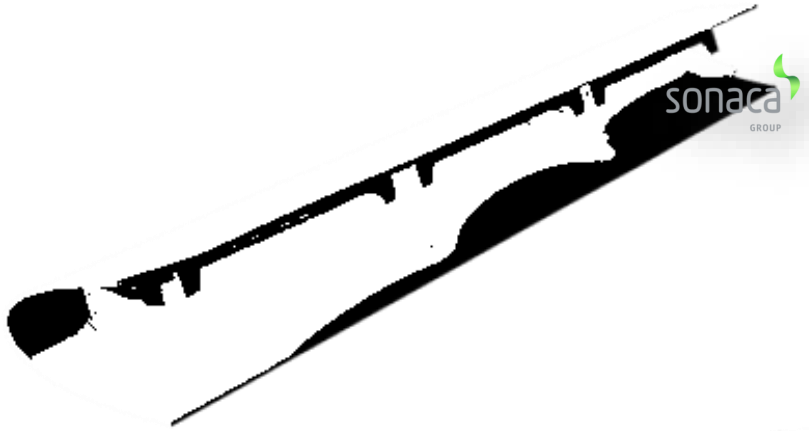
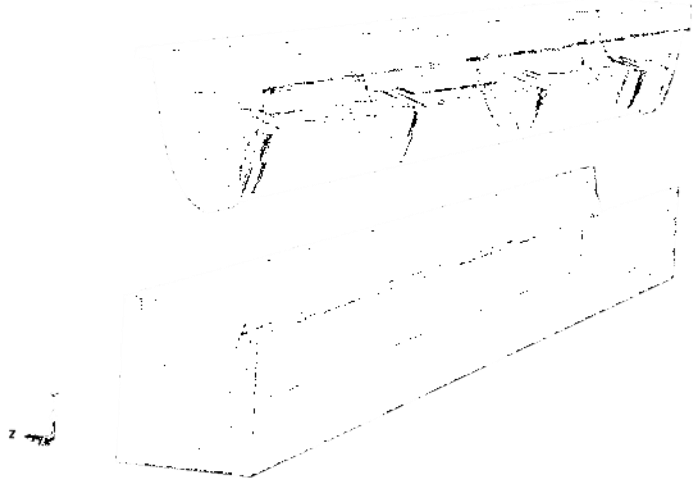
Machine learning applied to process simulation

- At meso-scale
- At macro-scale (feature)
- At macro-scale (structure)
  - Curing temperature distribution models
  - Full distortion predictions first on simplified feature based model that can be validated on full FEM





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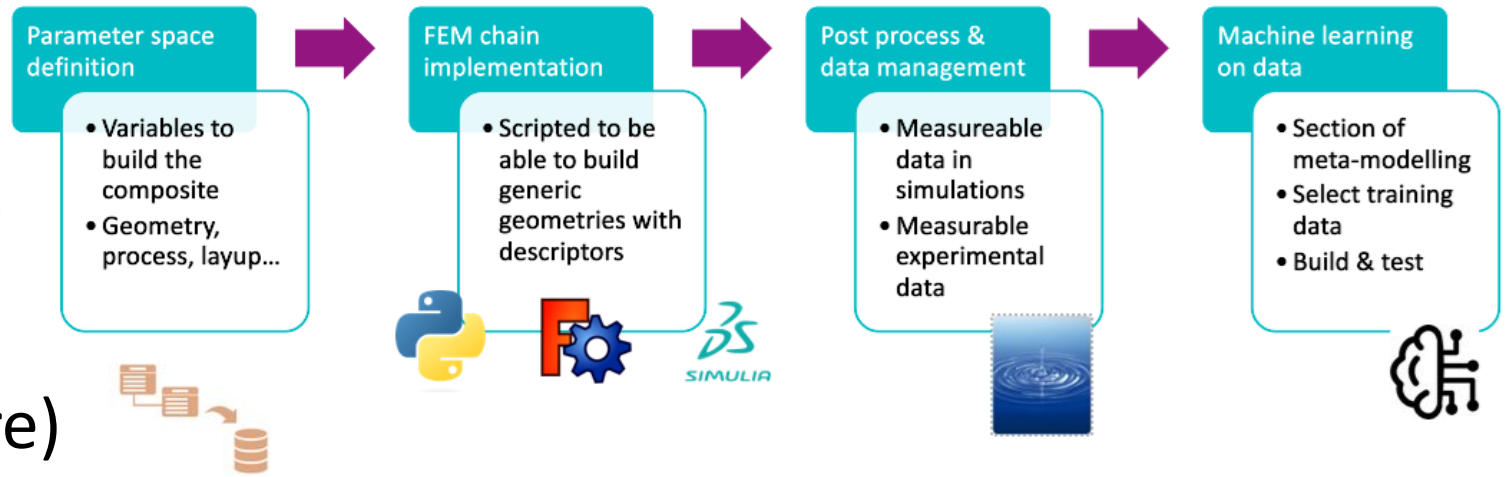
Machine learning applied to process simulation

- At meso-scale
- At macro-scale (feature)
- At macro-scale (structure)



- Ongoing critical steps
  - -> Gathering of experimental data for different parts
  - -> Generate simulation data at feature levels
  - -> Select & Test machine learning approaches for validation

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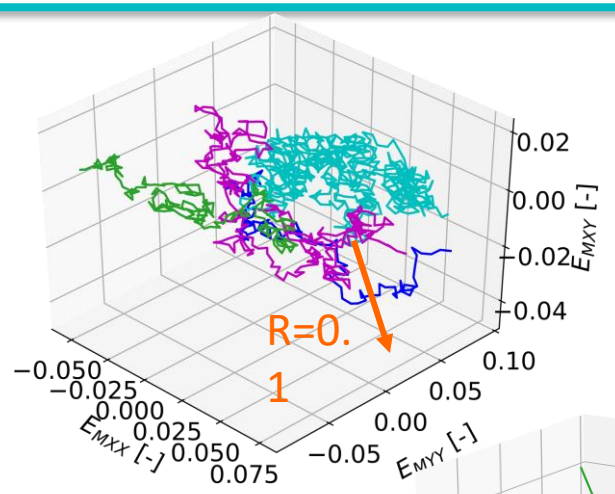
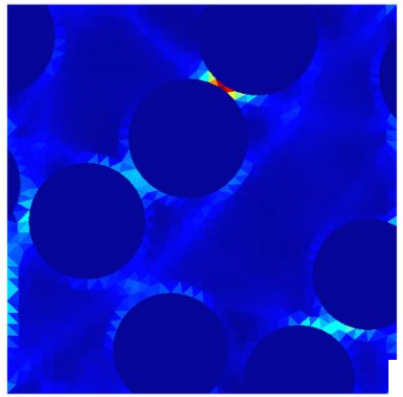
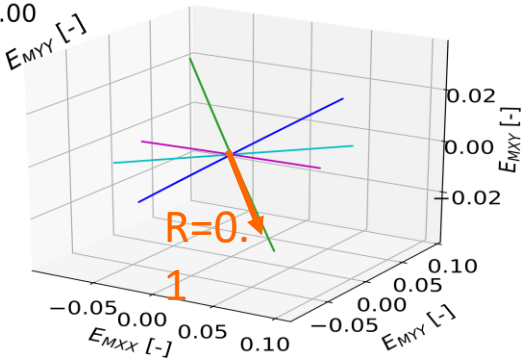
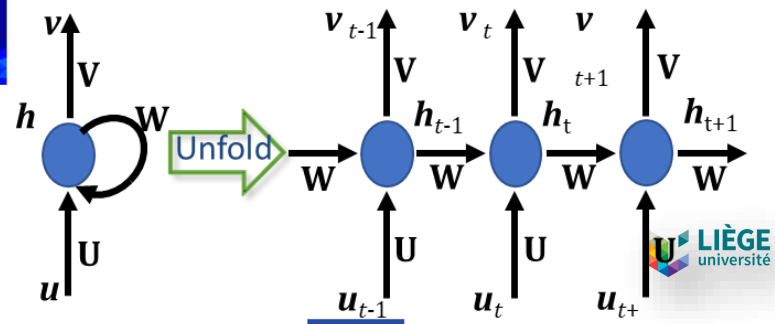
Machine learning applied to vulnerability

- At micro-scale
  - Data generation of 3D Elasto-plastic composite RVE with damage mechanism
  - Also done at interfaces for Gc
  - Training done on a Recurrent Neural Network
- At meso-scale
- At macro-scale









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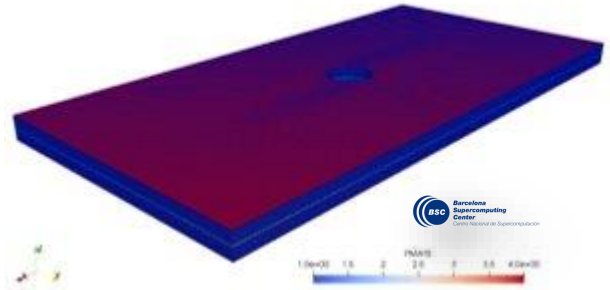
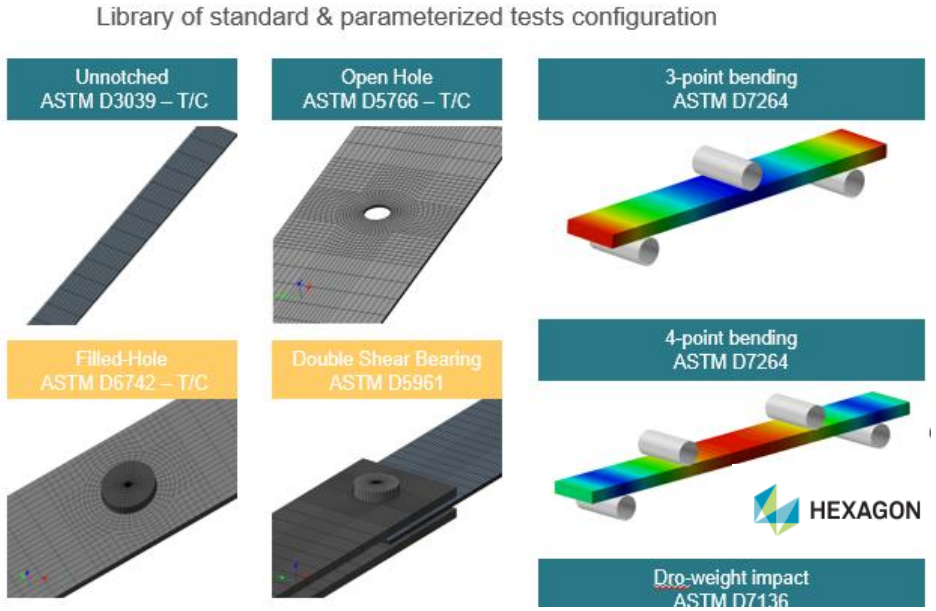
Machine learning applied to vulnerability

- At micro-scale

- At meso-scale
  - Build simulation models at the coupon level
  - Speed up using RNN material models
  - Possible training on prediction of allowables for macro-scale simulations

- At macro-scale





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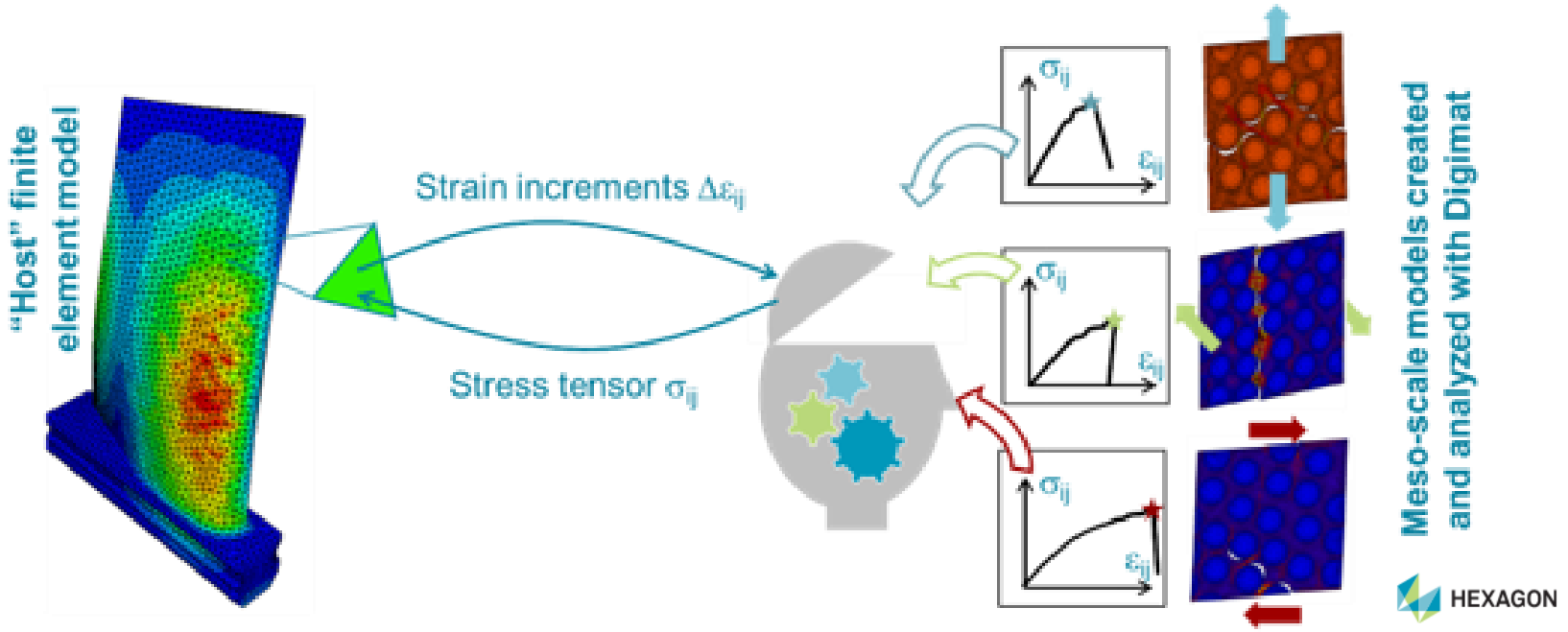
Machine learning applied to vulnerability

- At micro-scale
- At meso-scale
- At macro-scale



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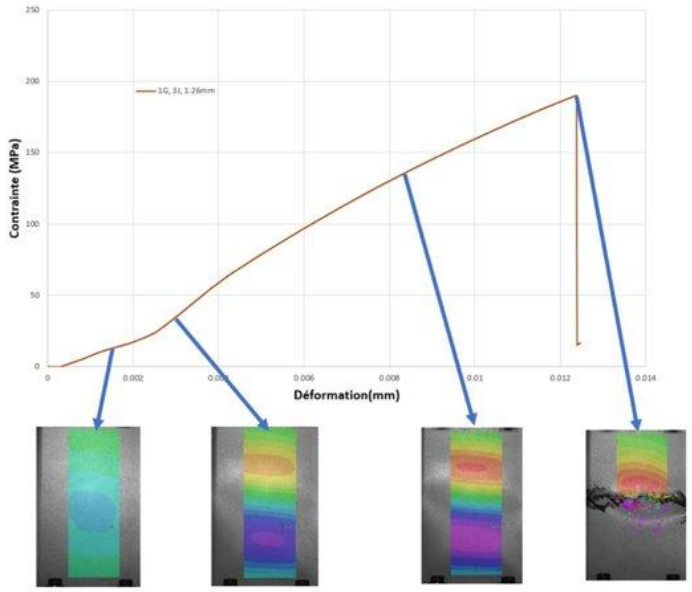
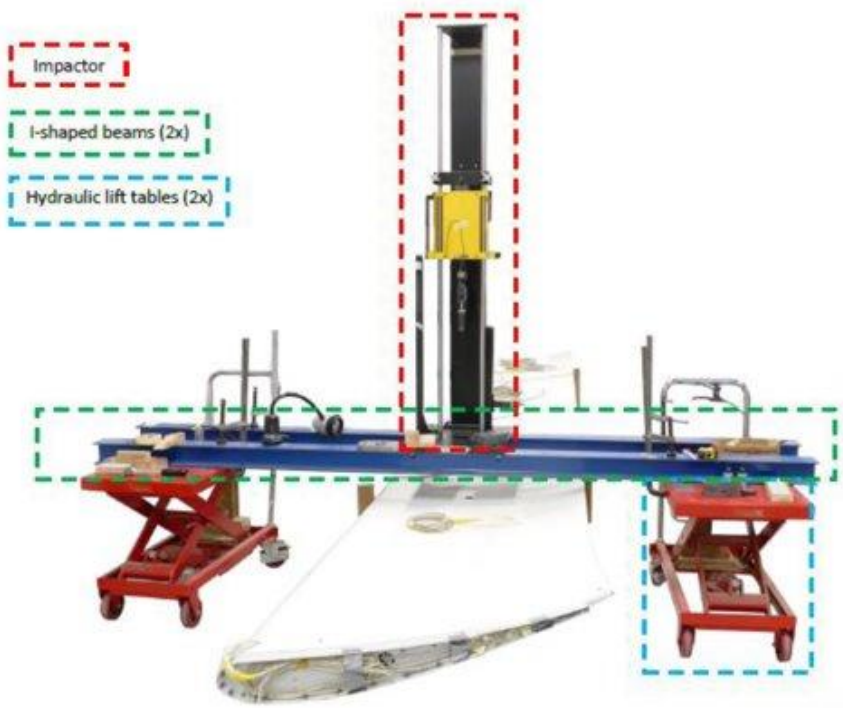
Testing through vulnerability

- Tests performed at different levels





- Tackle bottleneck of computational time building response under uncertainty using trained hybrid models

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Clustering initiative

- Exploit results from multiple projects and build new initiatives
- Covering HE-2021-CL5-D5-01-06 projects
  - **CAELESTIS**: **Hyperconnected** simulation ecosystem supporting probabilistic design and predictive manufacturing of next generation aircraft structures (coordinator: AIMEN)
  - **DIDEAROT**: Digital Design strategies to certify and mAnufacture **Robust cOmposite** sTructures (coordinator: CENAERO)
  - **NEXTAIR**: **multi-disciplinary** digital - enablers for NEXT-generation AIRcraft design and operations (coordinator: ONERA)
  - **GENEX**: New end-to-end digital framework for optimized manufacturing and **maintenance** of next generation aircraft composite structures (coordinator: ITA Innova)
  - **INFINITE**: Aerospace **Composites** digitally sensorised from manufacturing to **end-of-life** (coordinator: IDEKO, more especifically my colleagues Peio/Arkaitz, in CC)

> 50 different partners involved in the call

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Conclusions

- DIDEAROT project will be carried out until end of 2026
- As project is in early stages of progress
  - Many open technical & strategical questions
  - need of convergence on gathering and sharing of data
  - Building blocks being built and interactions growing between partners
- News on activities
  - Internet site: www.didearot-project.eu
  - Looking forward to new more technical conference presentations & papers…

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