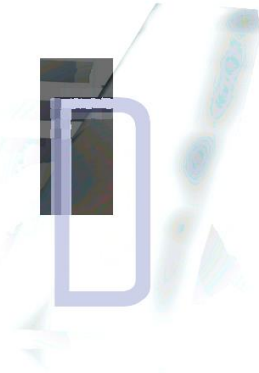
# Digital Design strategies using hybrid models to Certify & Manufacture Composite structures

**Project presentation**

David DUMAS (david.dumas@cenaero.be)







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# Rationale


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Introduction of new materials or structural concepts require

- TESTING
- fundamental understanding at the lower size scale to feed methodologies at the macroscopic scale
- Research entities play a crucial role in the later stages of design and testing
  - Production Method
  - Impact Damage and Tolerance


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Links scales through machine learning & hybrid testing

*[2020 – P. Beaumont, University of Cambridge]*





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# The DIDEAROT Project

*Current active Advisory Board*

- 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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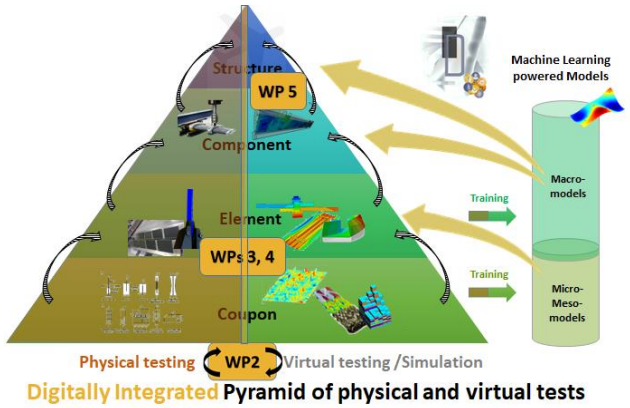
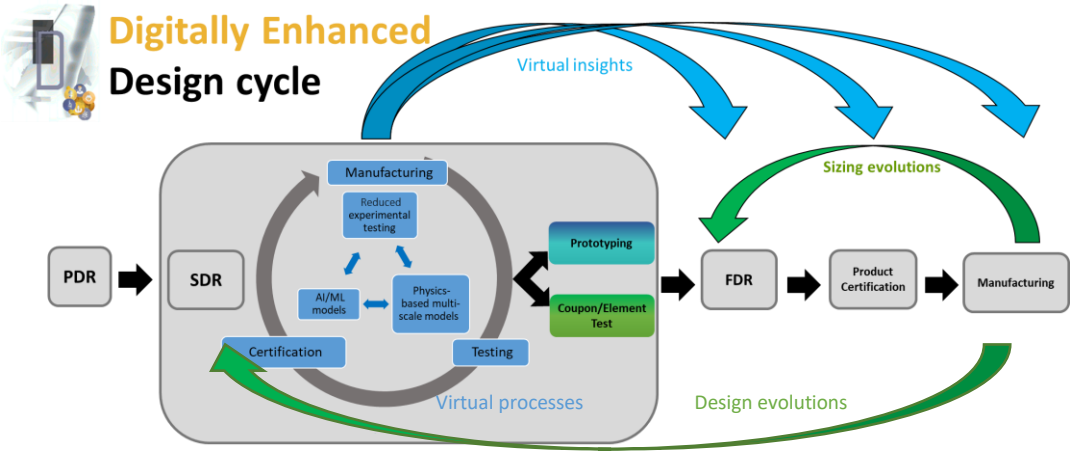
# Technical scope & objectives

- Improve the quality & speed of evaluation of complex multi-scale & multi-physics simulation
  - High performance computing environments & optimized codes
  - Adapted models over scales to solve the right problem at the right level




- Build hybrid approaches (machine learning) for response predictions feeding higher levels in the test pyramid

- High end objective
  - Allow simulation to cover manufacturing & vulnerability at the design phase to enable earlier appropriate decisions to limit costly design iterations





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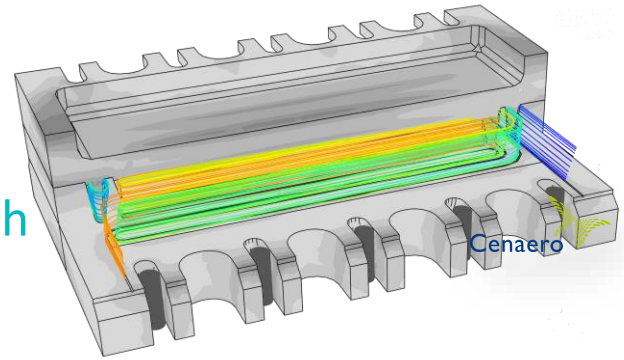
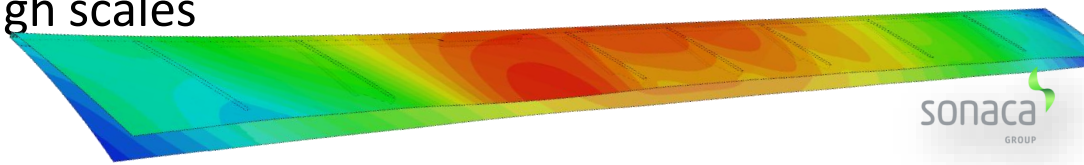
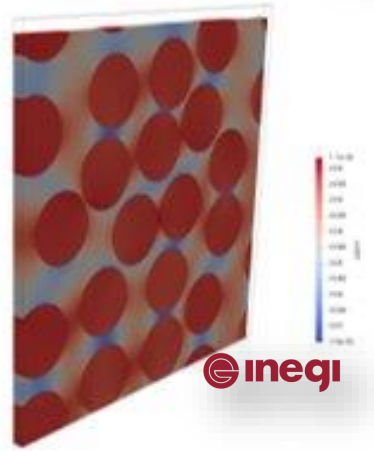
# Drawing out the blueprint

- 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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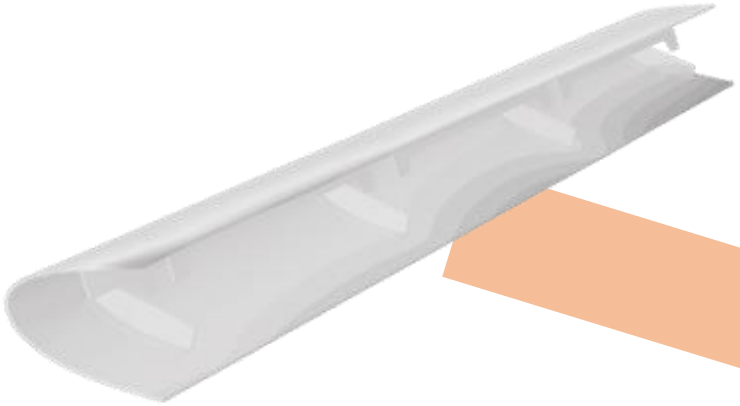
# Why perform predictions through machine learning – the case for process simulations



- Large multi-part integrated structure
  - Design iterations too costly (test process parameters, layups, geometries)





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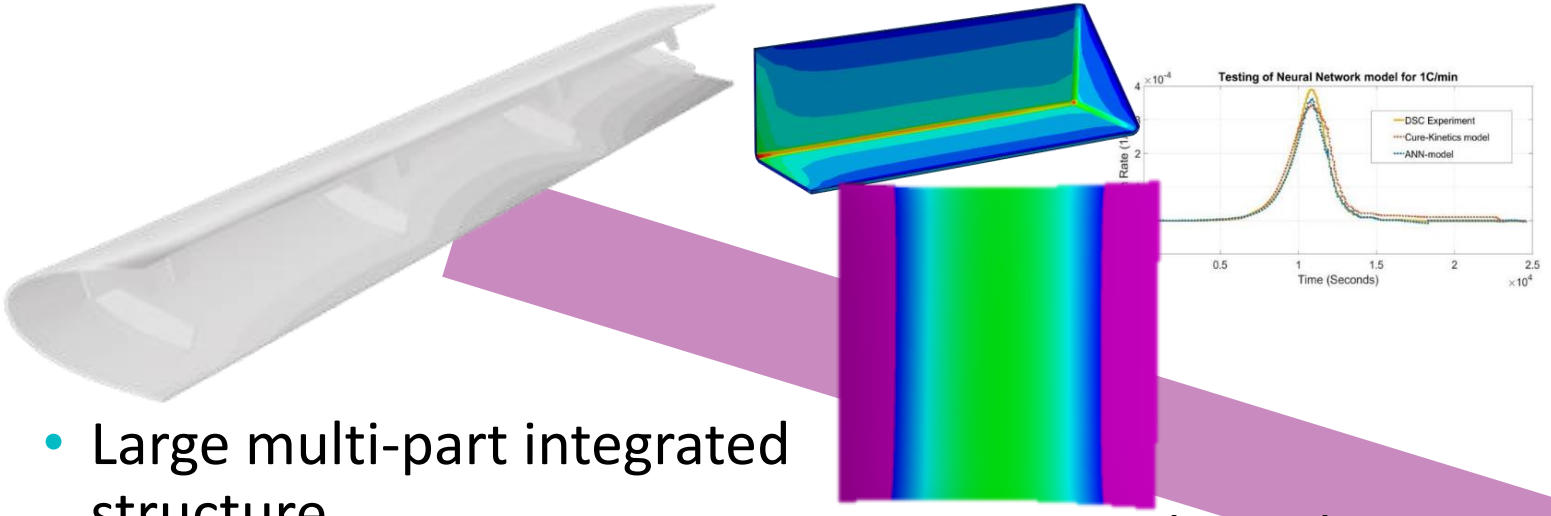
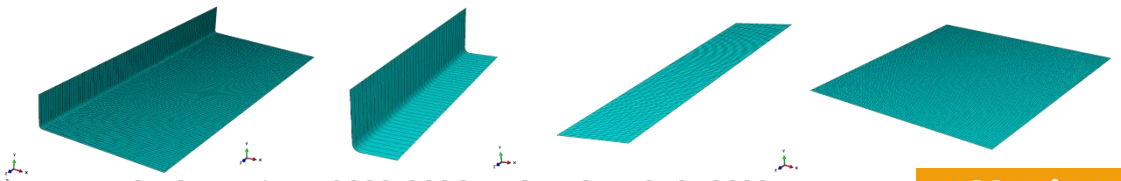



- Large multi-part integrated structure
  - Design iterations too costly (test process parameters, layups, geometries)
- Fast & High-quality predictions on features
  - Build larger design space & train surrogates for different configurations



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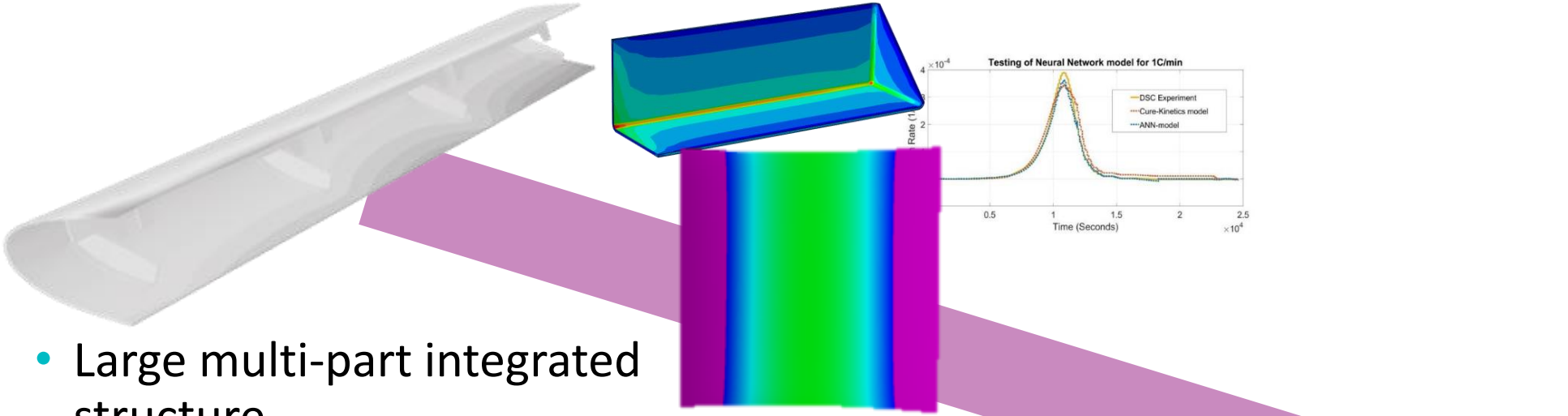


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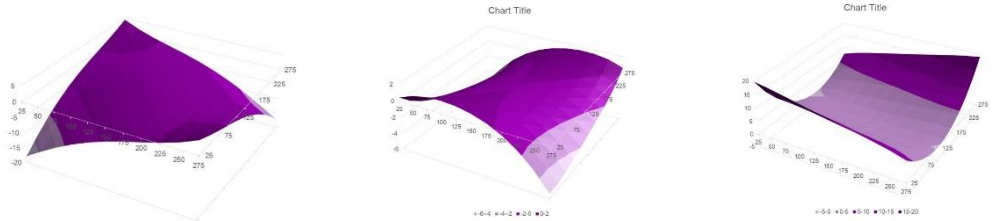

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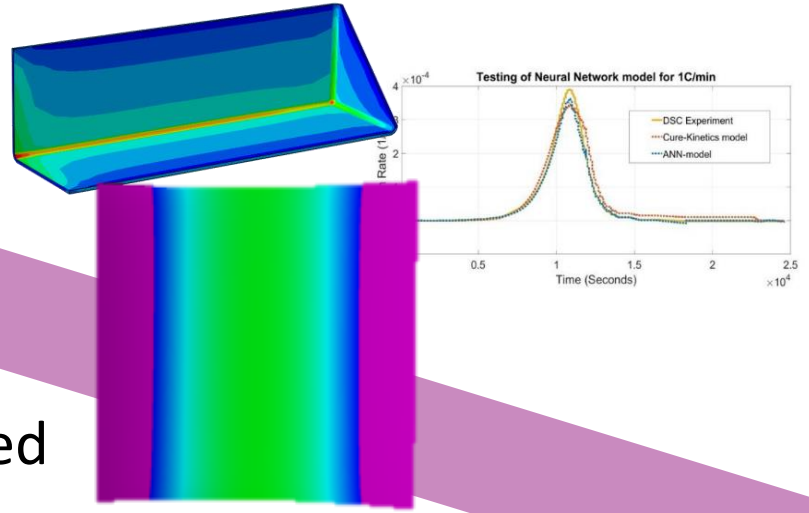


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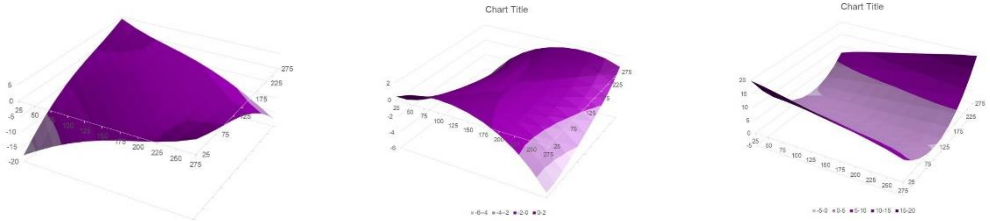
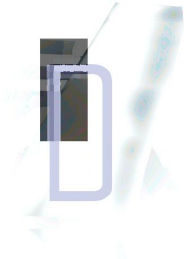



- Build large scale predictions
  - Break down large parts into features
  - Test training of assembly of surrogates from large scale simulations
  - Find processing trends, UQ & build robust configurations







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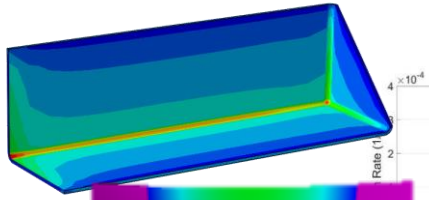
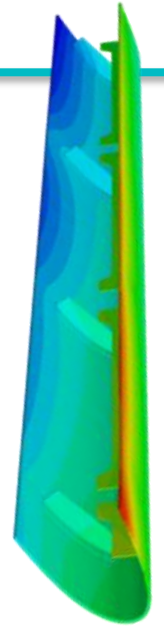
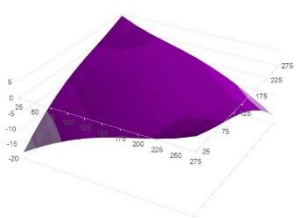
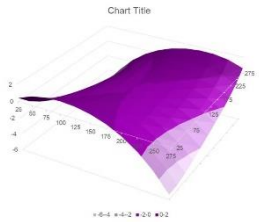


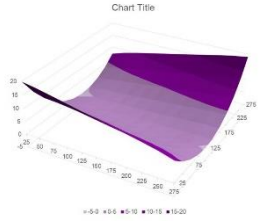


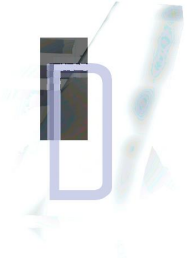



- Large multi-part integrated structure
  - Design iterations too costly (test process parameters, layups, geometries)
- Fast & High-quality predictions on features
  - Build larger design space & train surrogates for different configurations
- High-fidelity large-scale predictions
  - Validate processing route on 1-2 configurations through high fidelity simulation
- Build large scale predictions
  - Break down large parts into features
  - Test training of assembly of surrogates from large scale simulations
  - Find processing trends, UQ & build robust configurations









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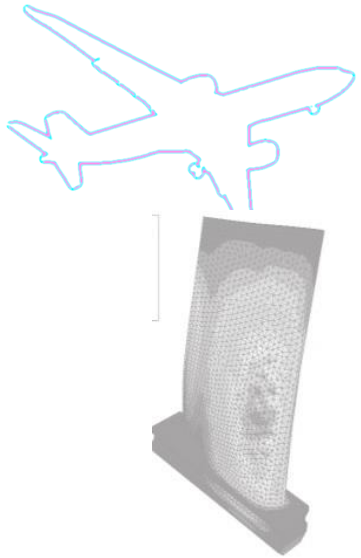
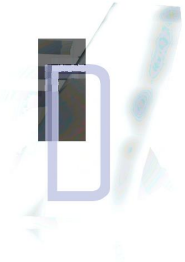


# Why perform predictions through machine learning – the case for process simulations

- Composite behaviour to damage on large parts
  - Difficulty to have a converged & robust prediction of the failure analysis







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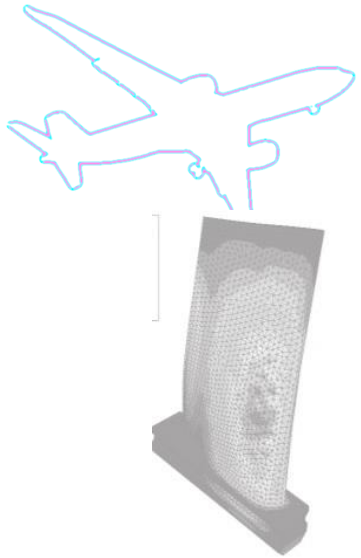
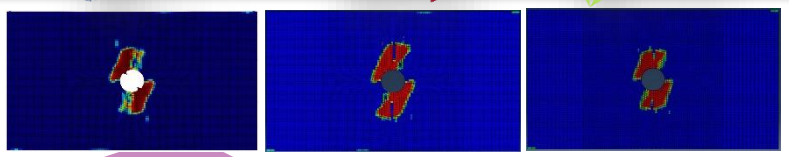
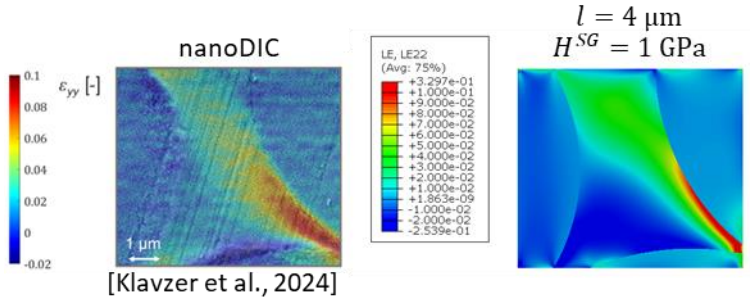




- Damage models applicable to many load cases




[Klavzer et al., 2024]

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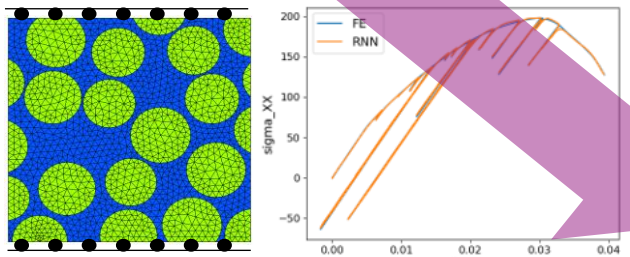
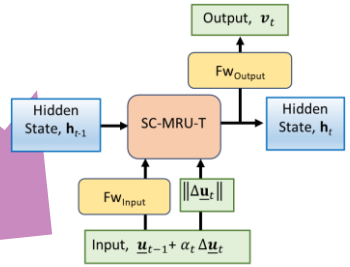
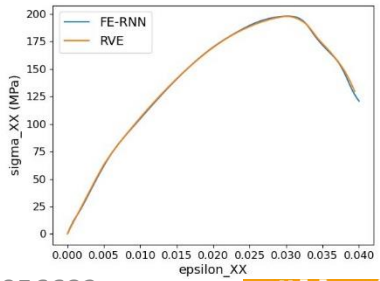
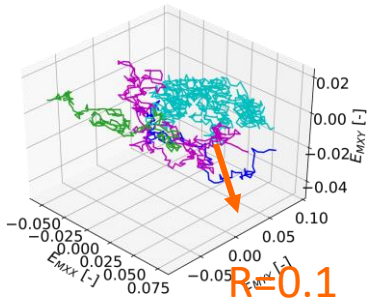
- 3D elasto-plastic RNN with damage to predict evolution on random load paths







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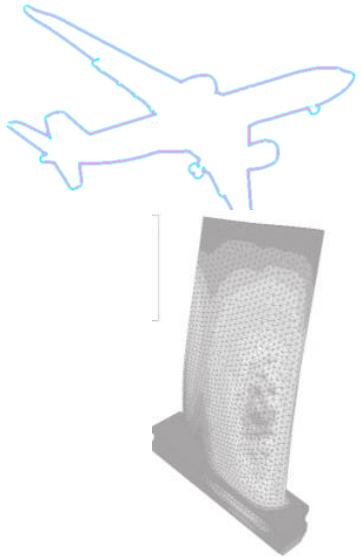

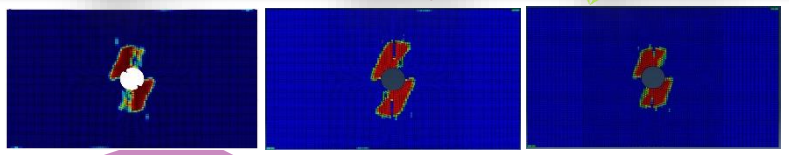

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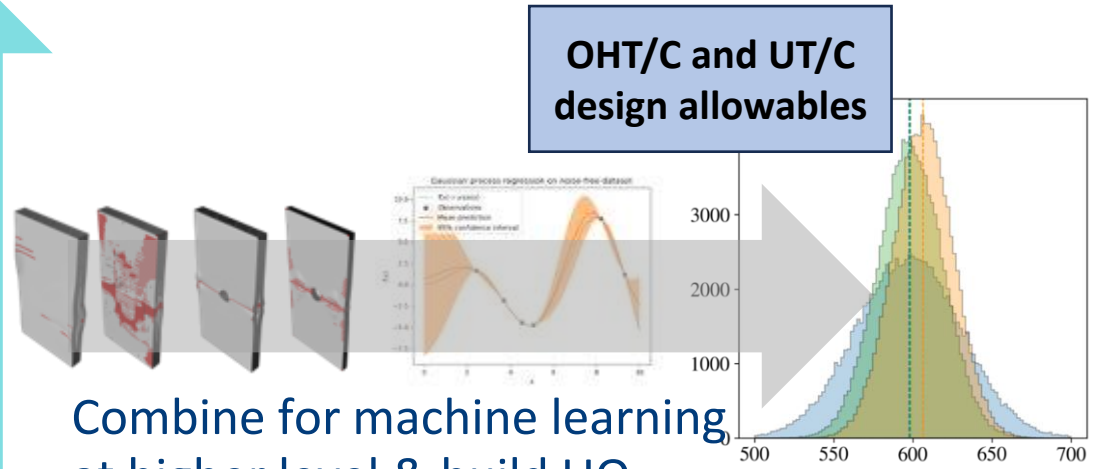
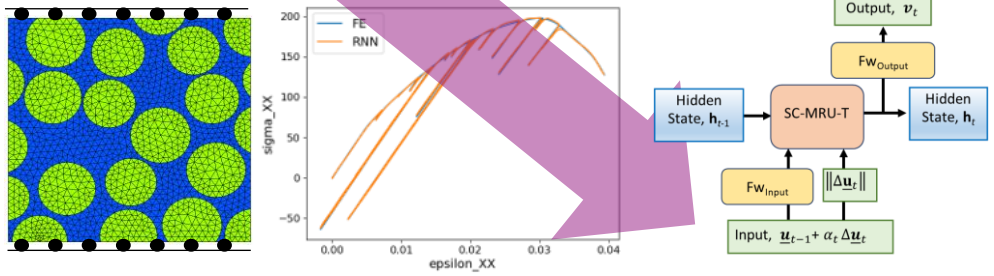
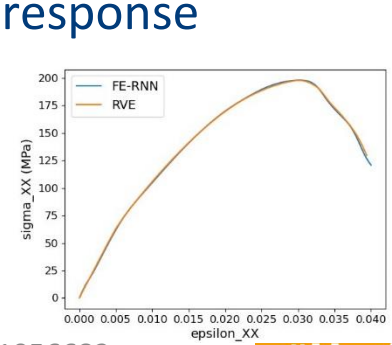
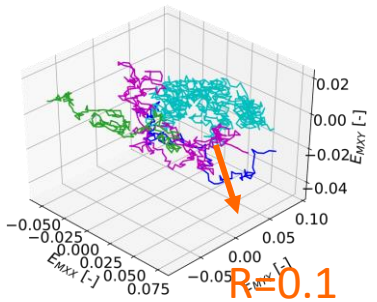
**OHT/C and UT/C design allowables**




- Combine for machine learning at higher level & build UQ response



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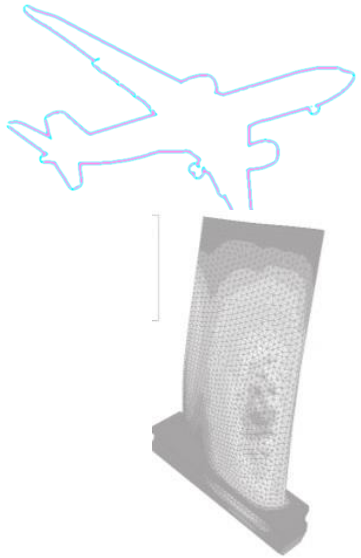

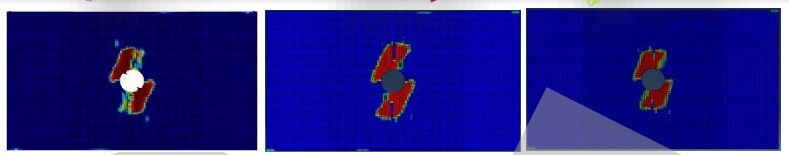

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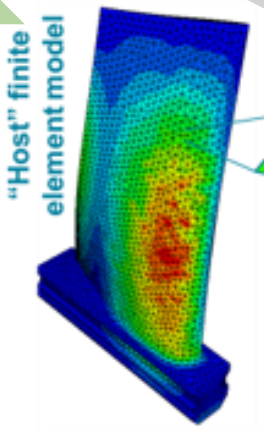


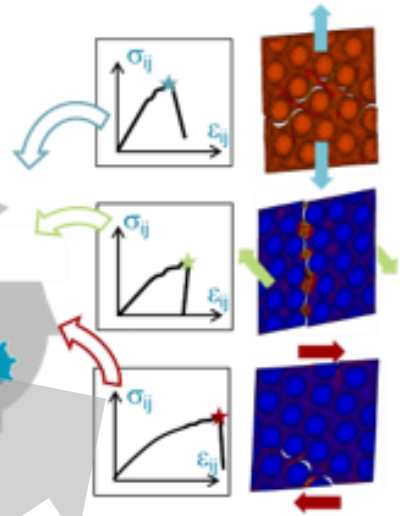


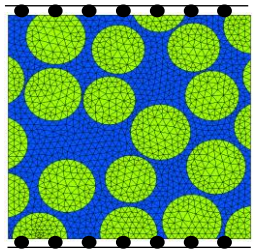

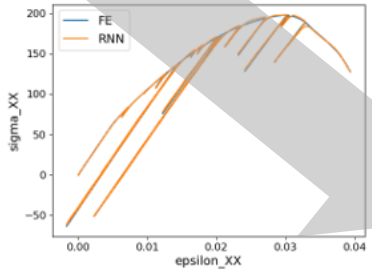


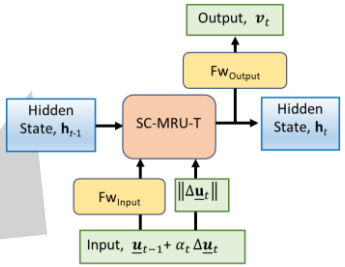


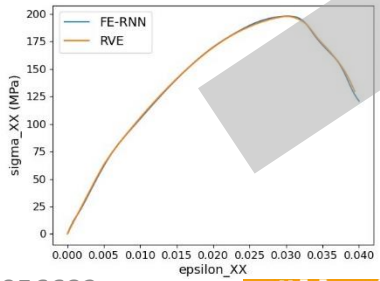


- Predict full part response fed through ML models





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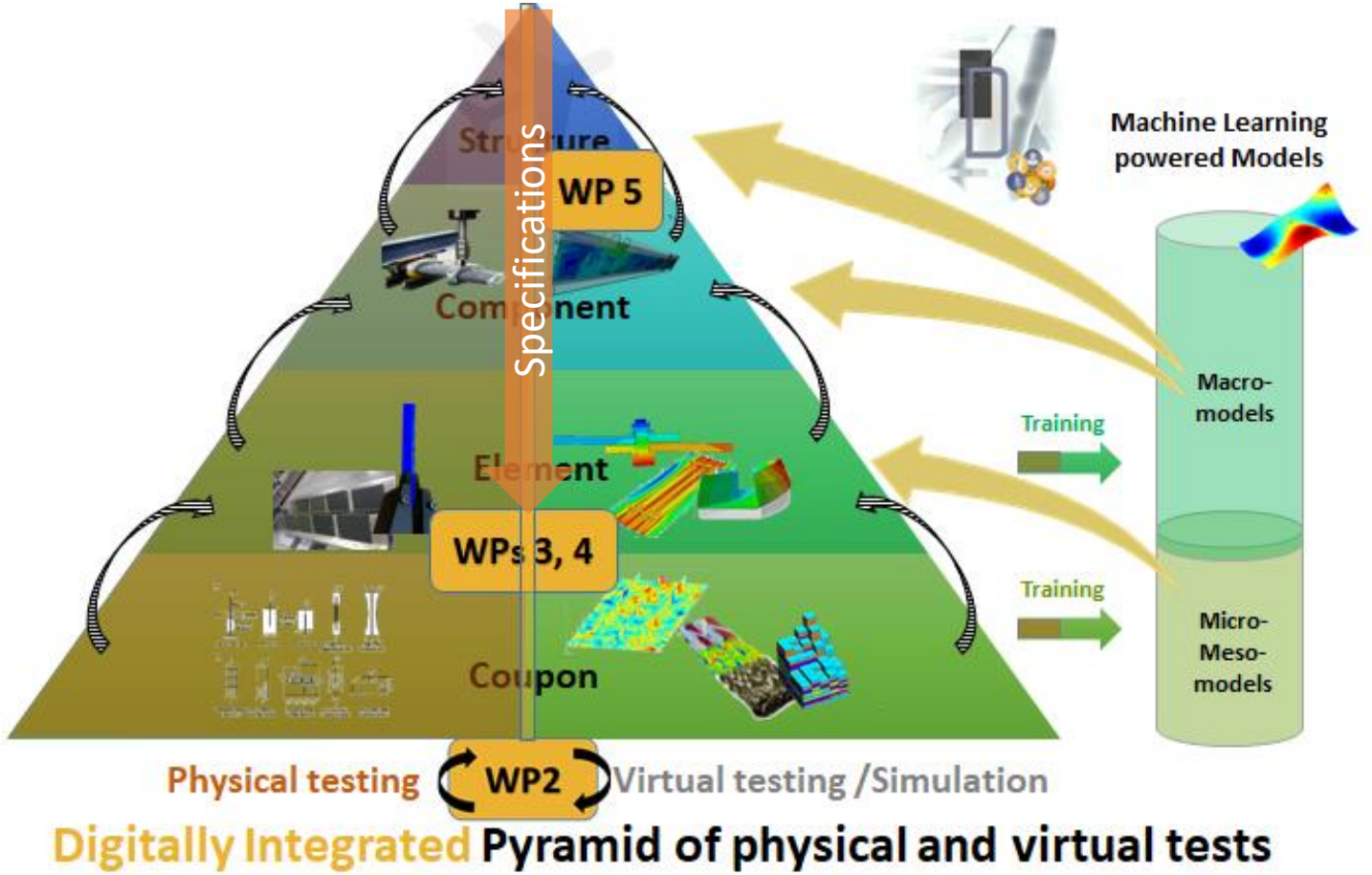
# Simulation enhanced validation over scales

- Approach in building a hybrid testing pyramid



# Path to exploitation for integration & certification

- Perform assesment of the numerical approaches
  - Performance benchmarks & Performance Optimisation of codes
  - Verification of the portability of the numerical approaches in other architectures
- Optimization of algorithm & computational efficiency of codes for HPC
- Account for uncertainty for the implementation of robust simulation



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# Upcoming activities

- DIDEAROT project will be carried out until end of 2026
- Regular bi-monthly internal technical progress meetings for partners
- Advisory board meetings at annual intervals
  - M36 (2025)
  - M48 (2026)
- Workshop initiatives near end of project
  - One with more focus on Academics & HPC
  - One focused on applications & tranfer industry
  - Link to network of projects in the same call & Clean aviation
- Feedback and interactions with Advisory board based on specific requests
- Build exploitation plan with industrial partners (demonstrators & software)



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# Thank you for your attention

linkedin.com/company/didearot-horizon-Europe

www.didearot-project.eu

https://gitlab.uliege.be/didearot

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*Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neitherthe European Union nor the granting authority can be held responsible for them.*

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