Thermal and White Light Imaging Data Fusion for Complex CFRP Structures

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Engineering and Physical Sciences Research Council

UNIVERSITY OF BATH

Bristol Composites Institute

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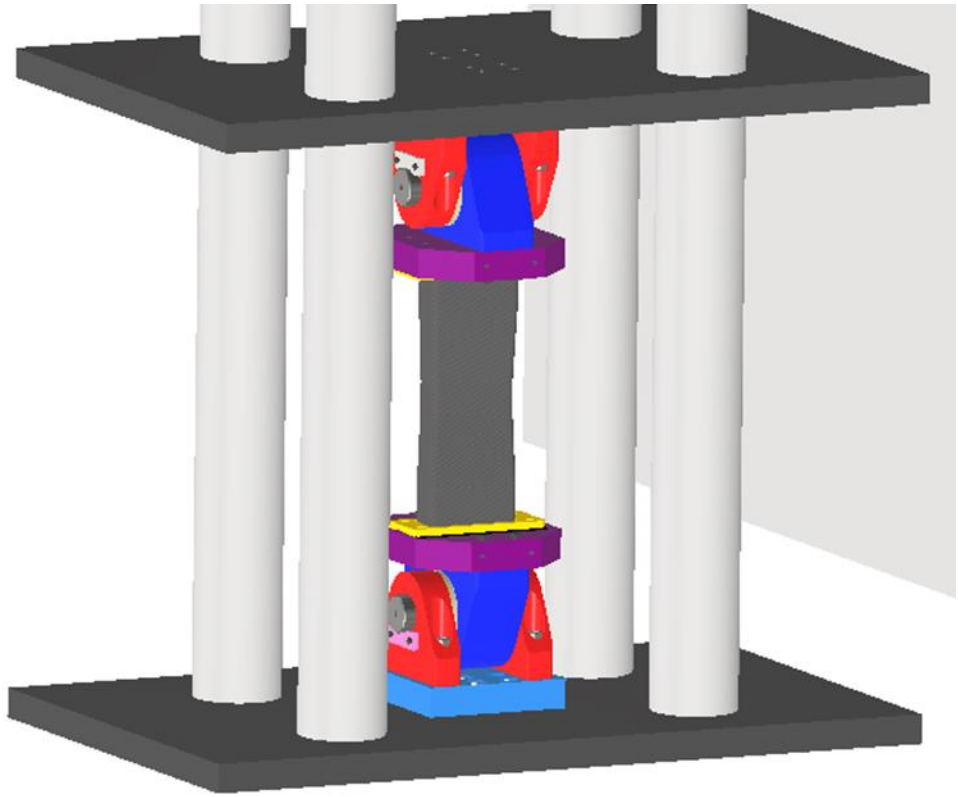
RESHAPING THE TESTING PYRAMID

Content

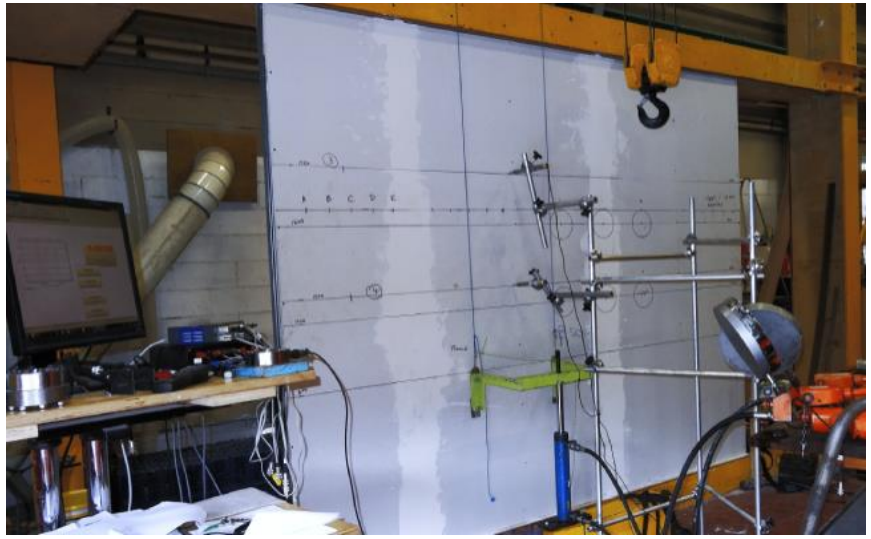
1) Background to CERTEST project
2) Data integration
3) Structural scale
4) Interim results
5) Outlook



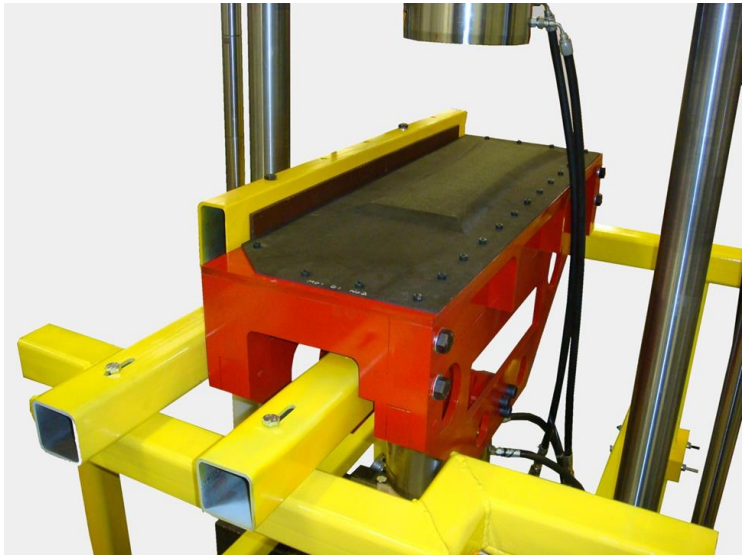
Evolution of structural integrity assessment

1.0 Structural testing and point measurements

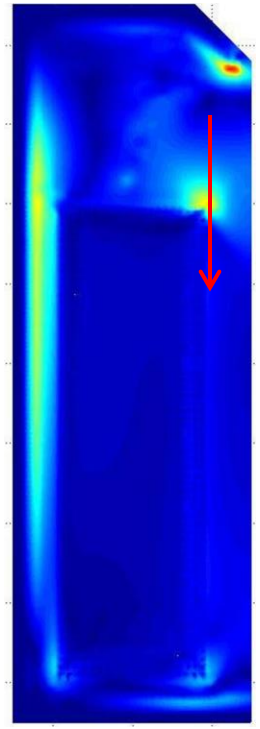
Image Salford Univetsity



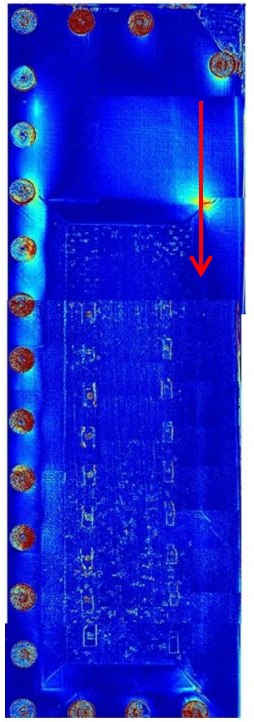
2.0 Validated FEA with full-field imaging



FEA



Thermoelastic stress analysis



Evolution of structural integrity assessment

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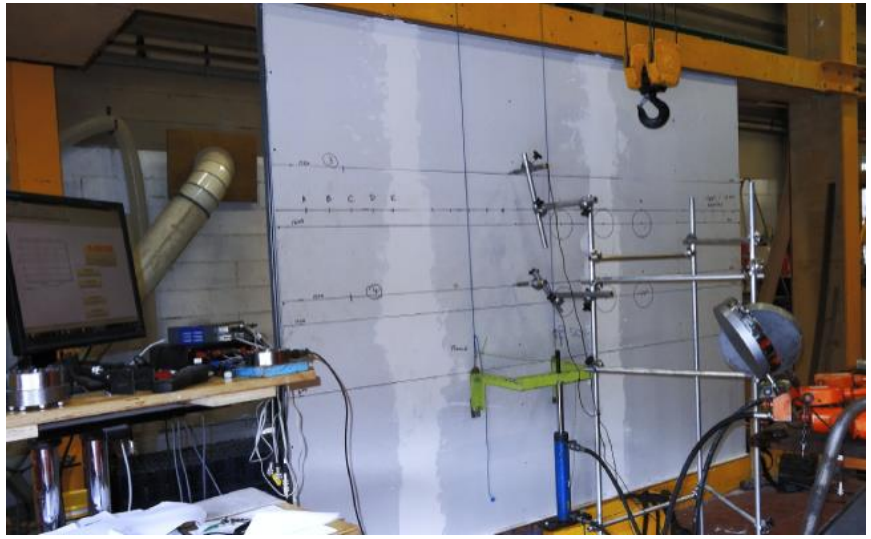

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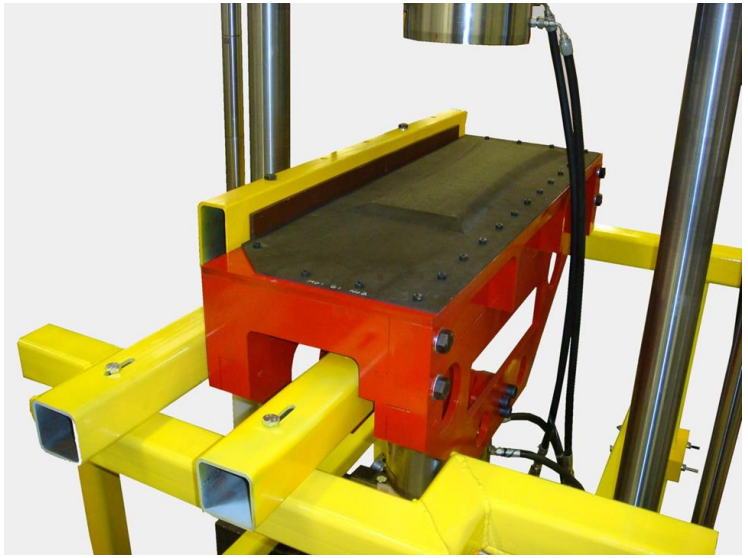

FEA

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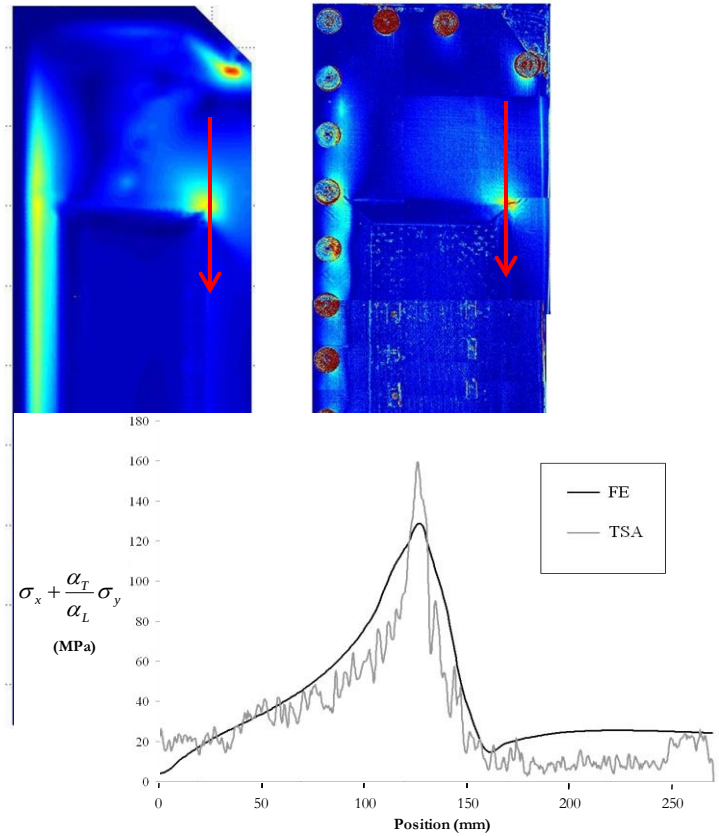
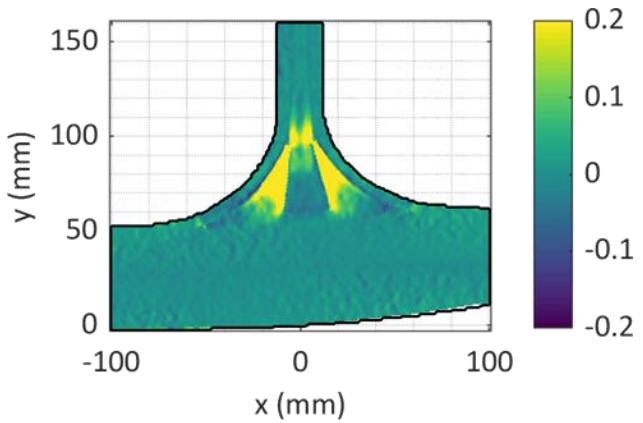


Evolution of structural integrity assessment

3.0 Integrating imaging and models – data fusion



4.0 Virtual testing - uncertainty

$$P(H|E) = \frac{P(H) * P(E|H)}{P(E)}$$

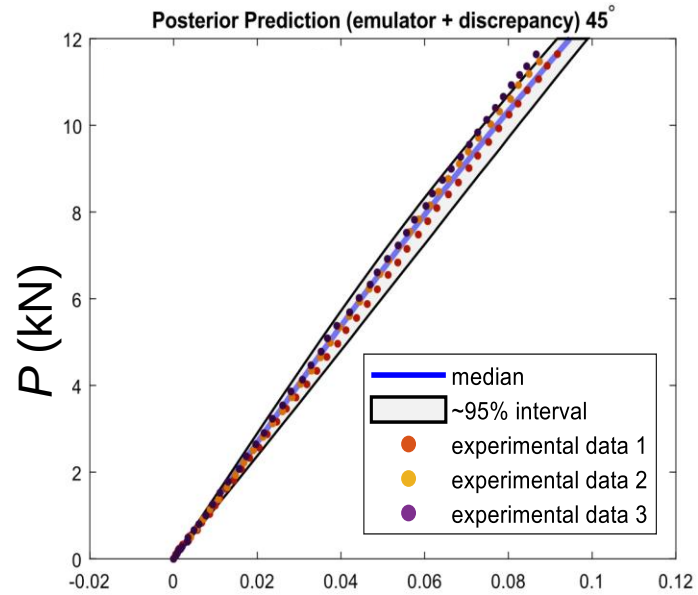
1 Finite element model *'prior'*

\+

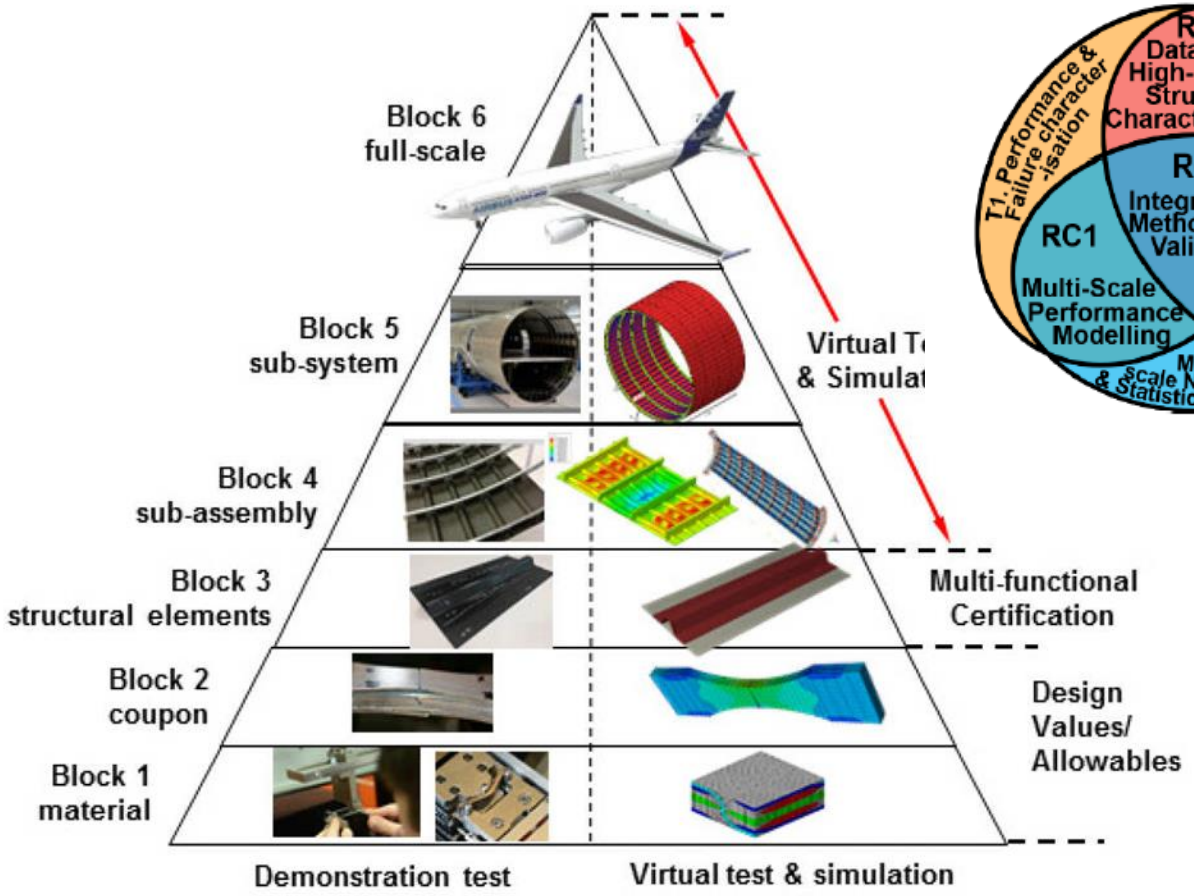
2 Experiment *'new evidence'*

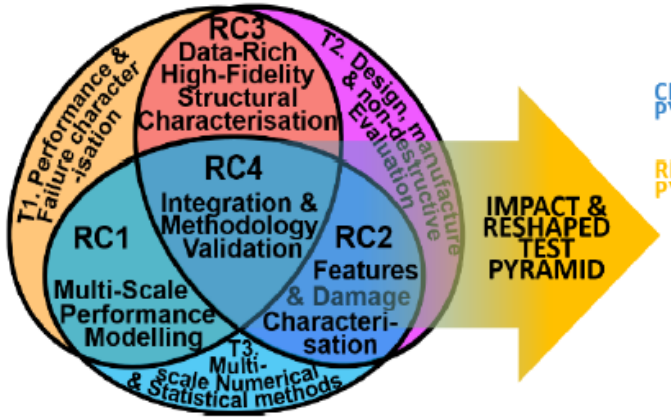
=

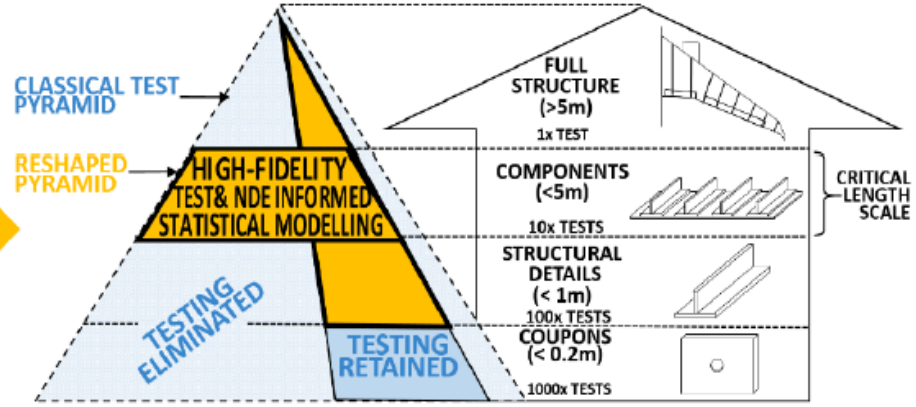
3 Bayesian Prediction *'posterior'*



Motivation – CERTEST Programme Grant

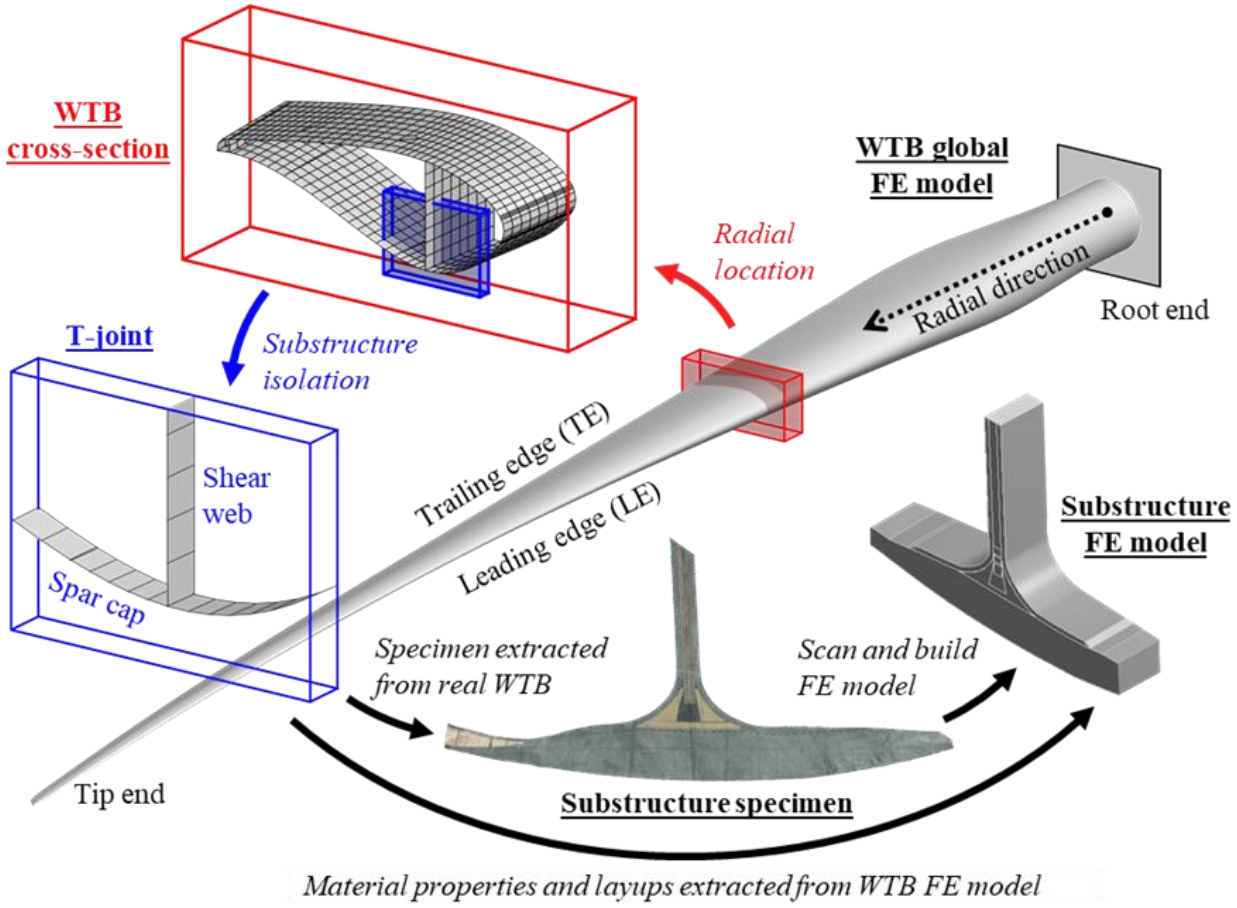


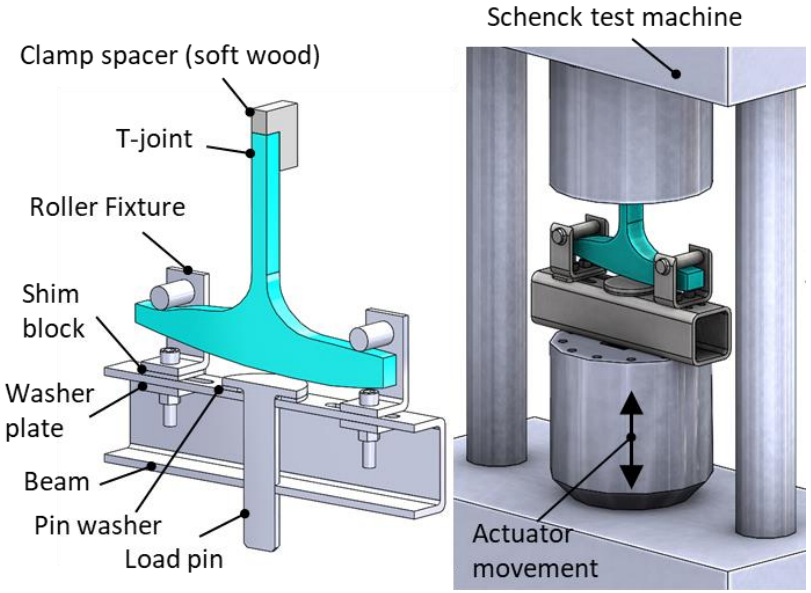




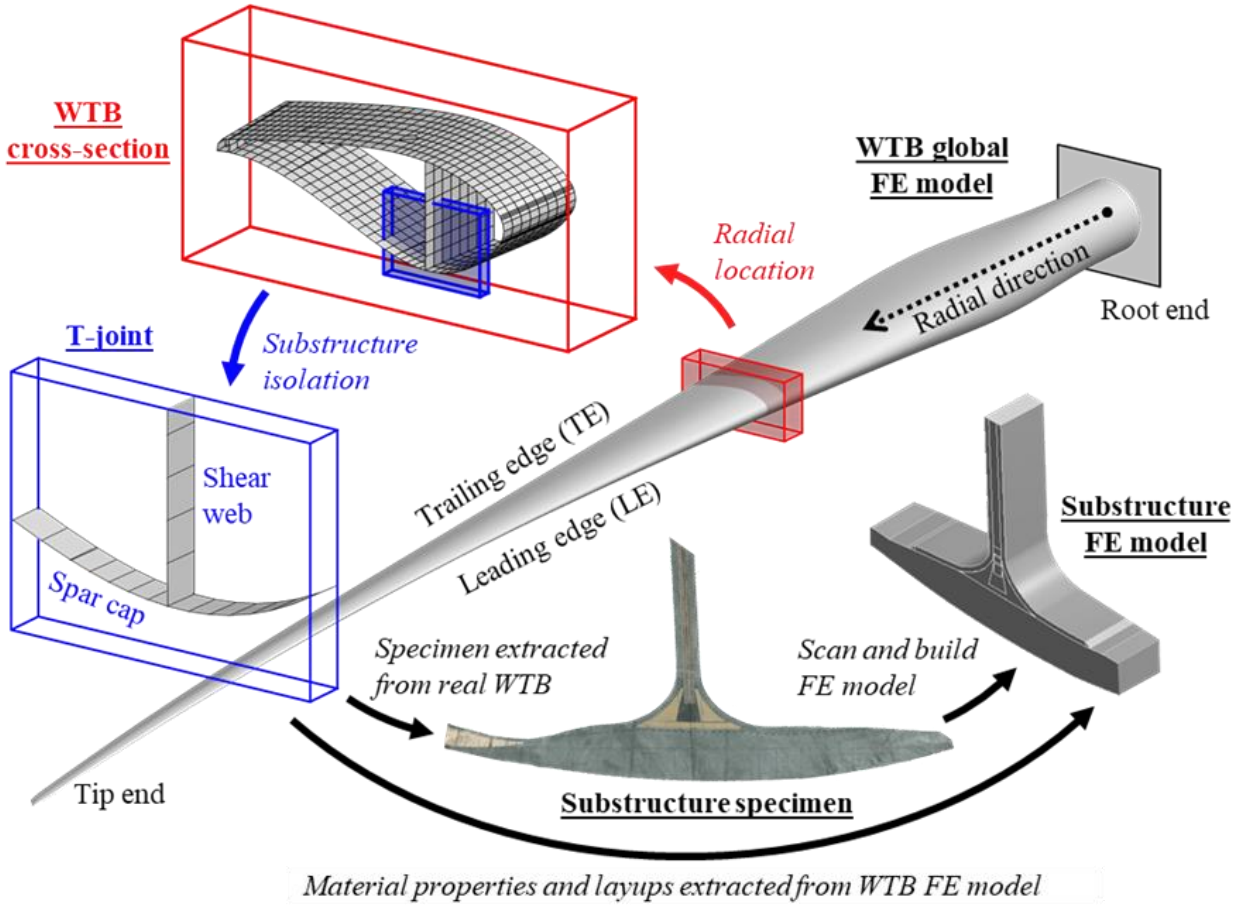
More about this project at 0900 on Wednesday 5th June From Professor Ole Thomsen presentation in Heritage F

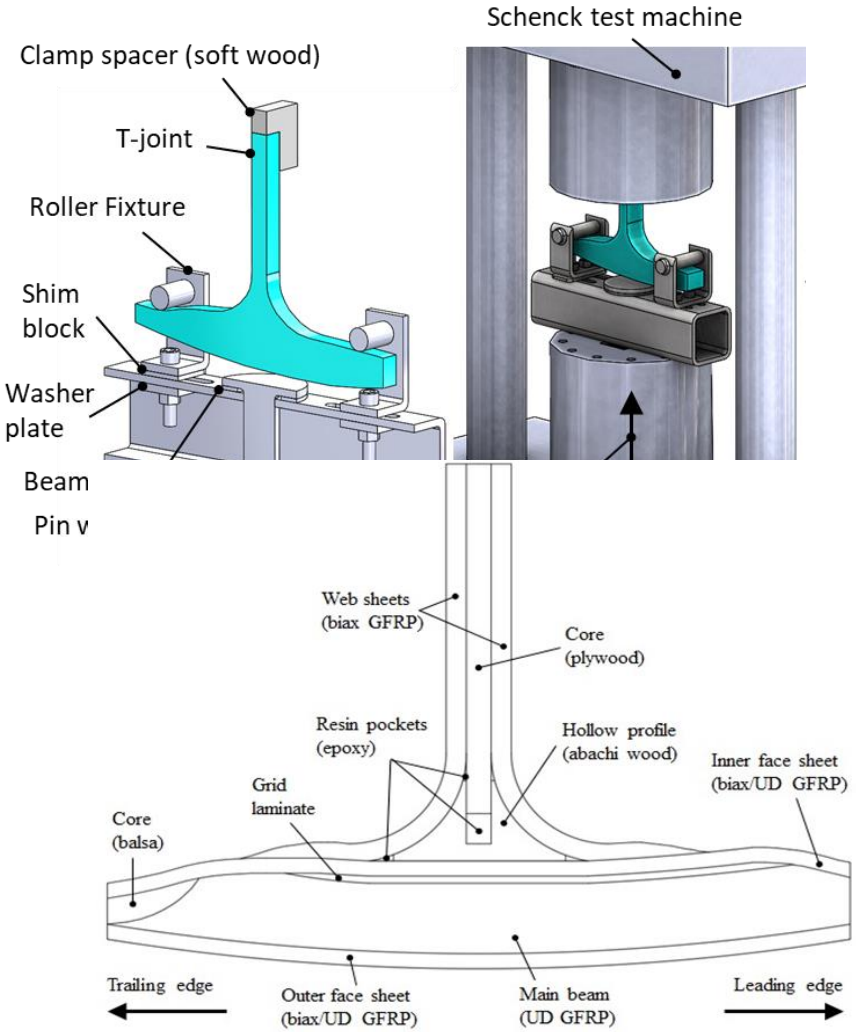
Sub-component testing





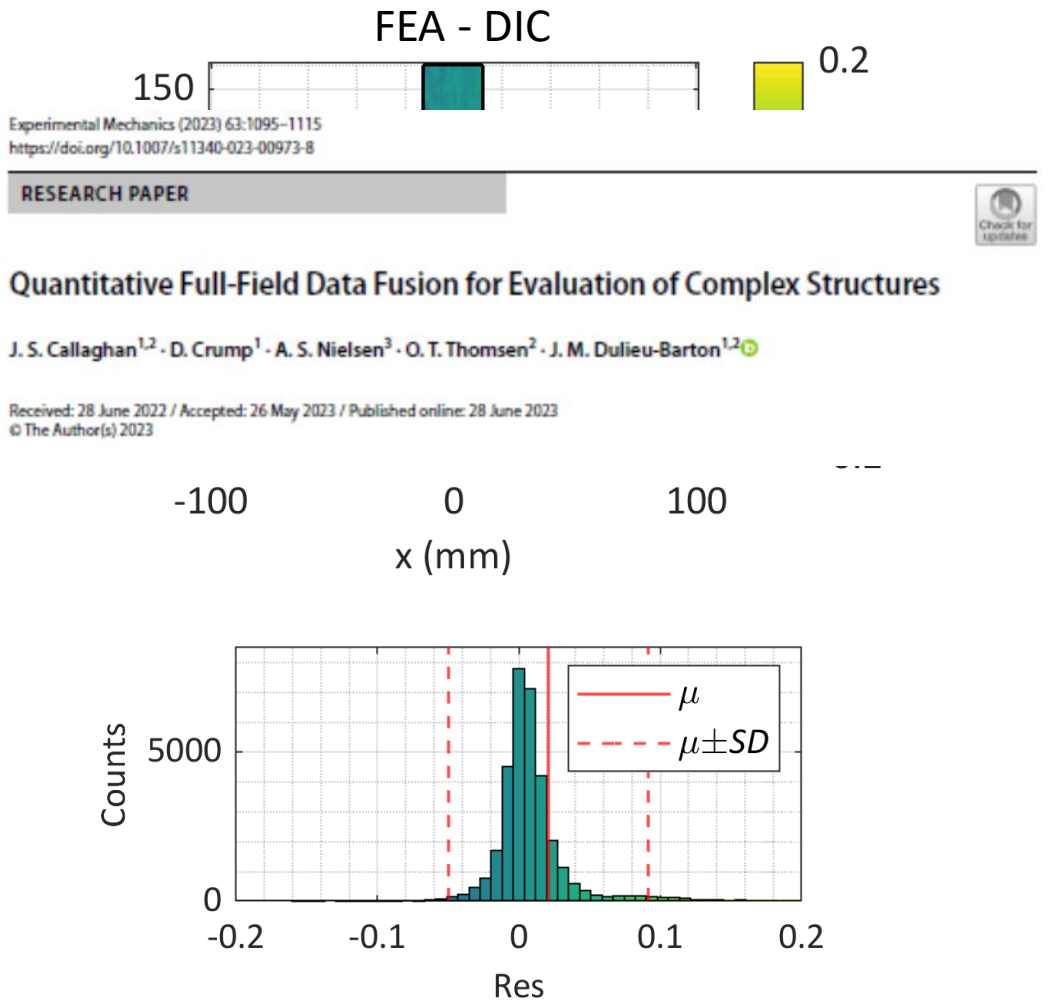
Sub-component testing



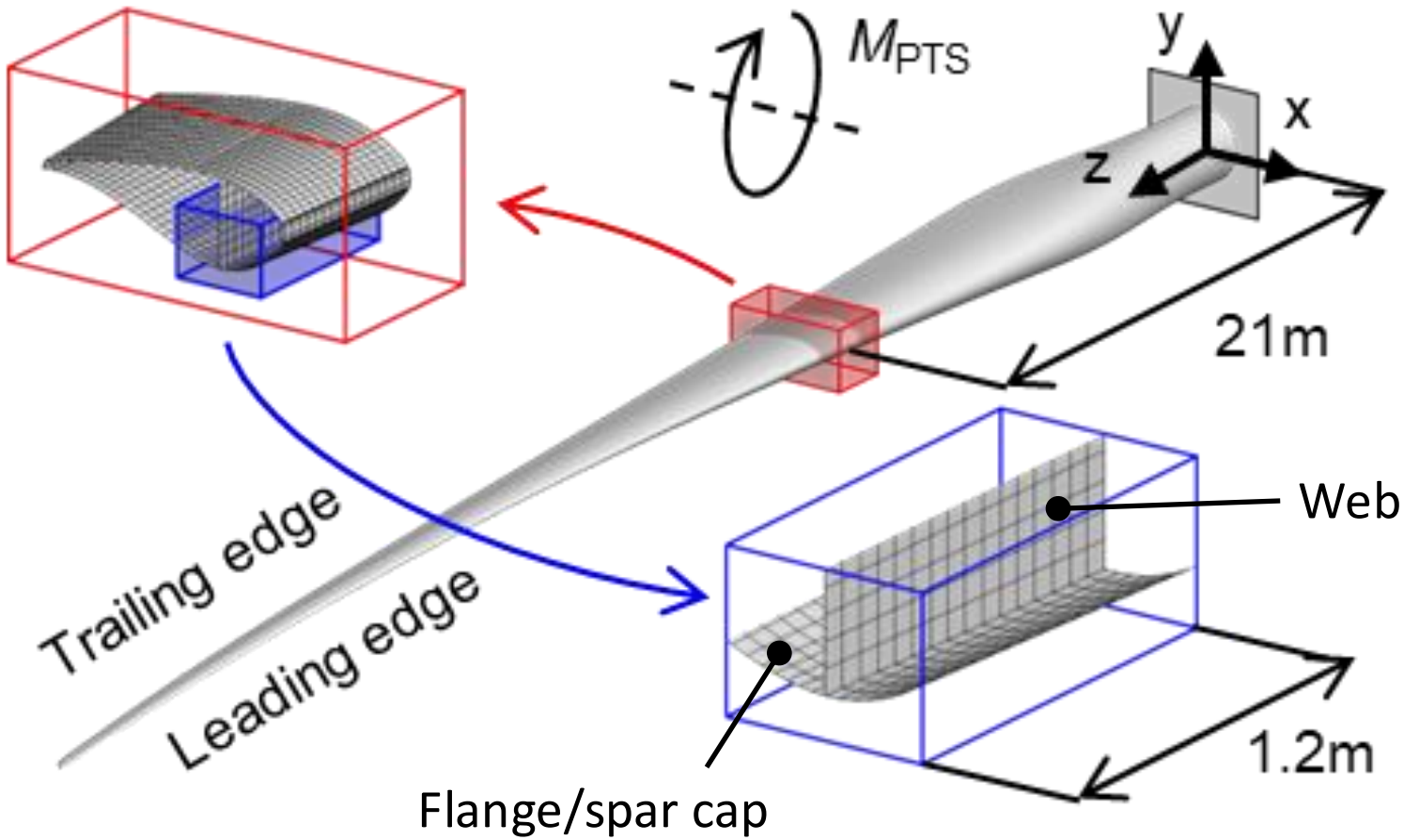


Fusion metrics

Metric type	Metric	Formula	Explanation
Similarity	Residual	$f_1 - f_2$	Difference between fields $Res > 0, f_1 > f_2$ $Res < 0, f_1 < f_2$
	Percentage error	$\left(\frac{\lvert f_2 - f_1 \rvert}{\lvert f_1 \rvert}\right) \cdot 100$	Relative difference between similar fields. The difference between f_1 and f_2 as a percentage amount of f_1
Union	Quotient	$\frac{f_1}{f_2}$	Division of fields



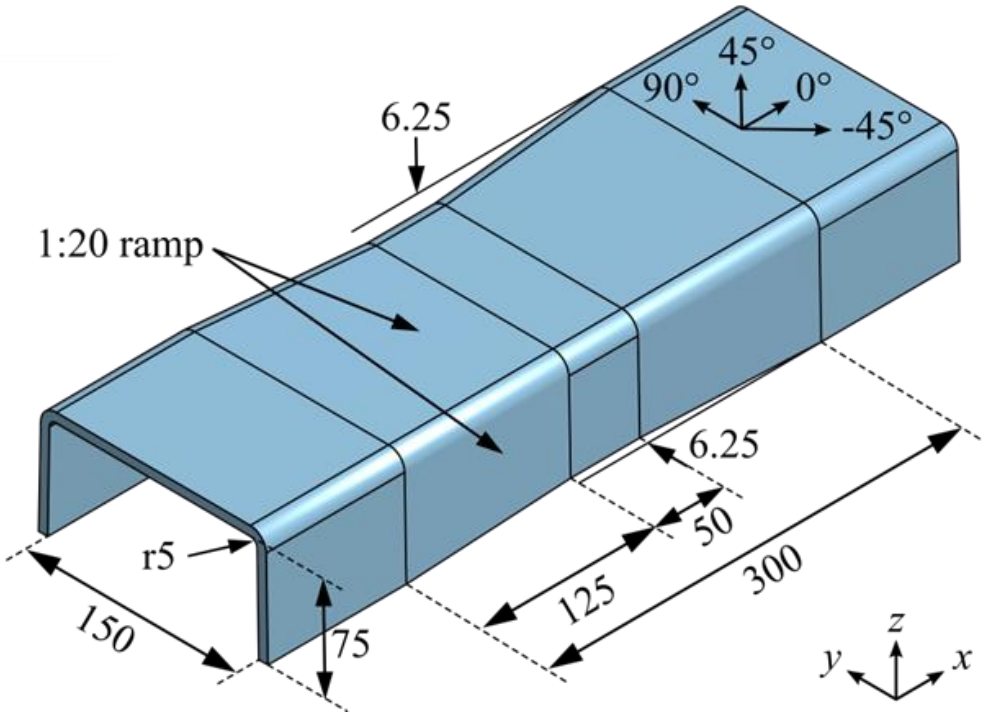
Moving up the scale

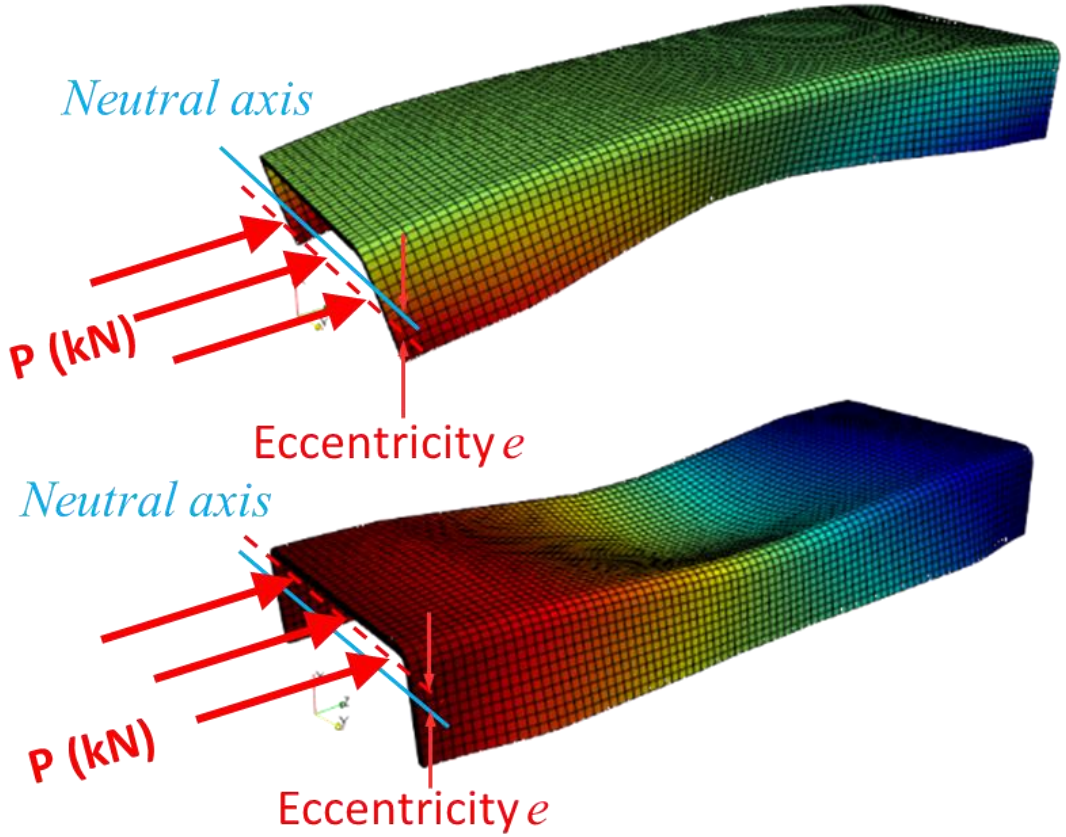


- Spar-cap-to-web **T-joint** subcomponent
- Blade subjected to **pressure to suction side (PTS) bending**

See presentation by Dr Tobias Laux in Hemlock/Oak 4th June 0920

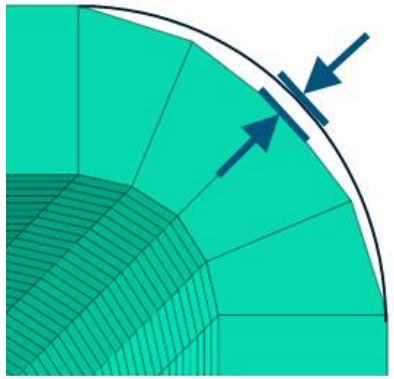
CFRP aircraft structure C-spar

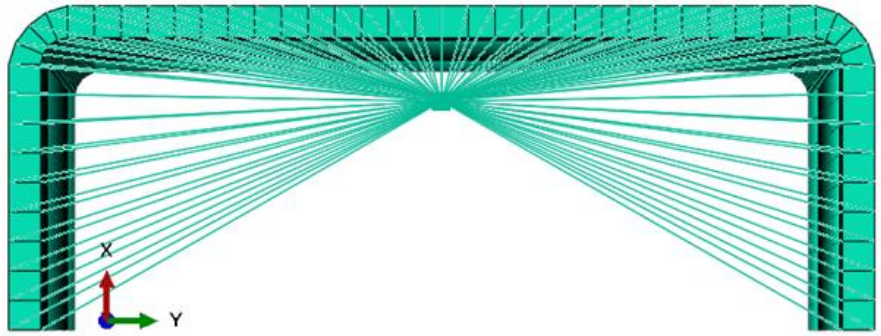




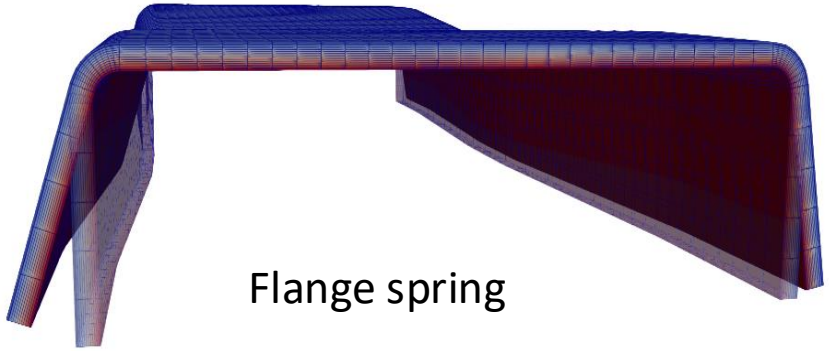
0.25mm plies: $[(45/-45/90/0)_3]_S$

Manufacturing variations





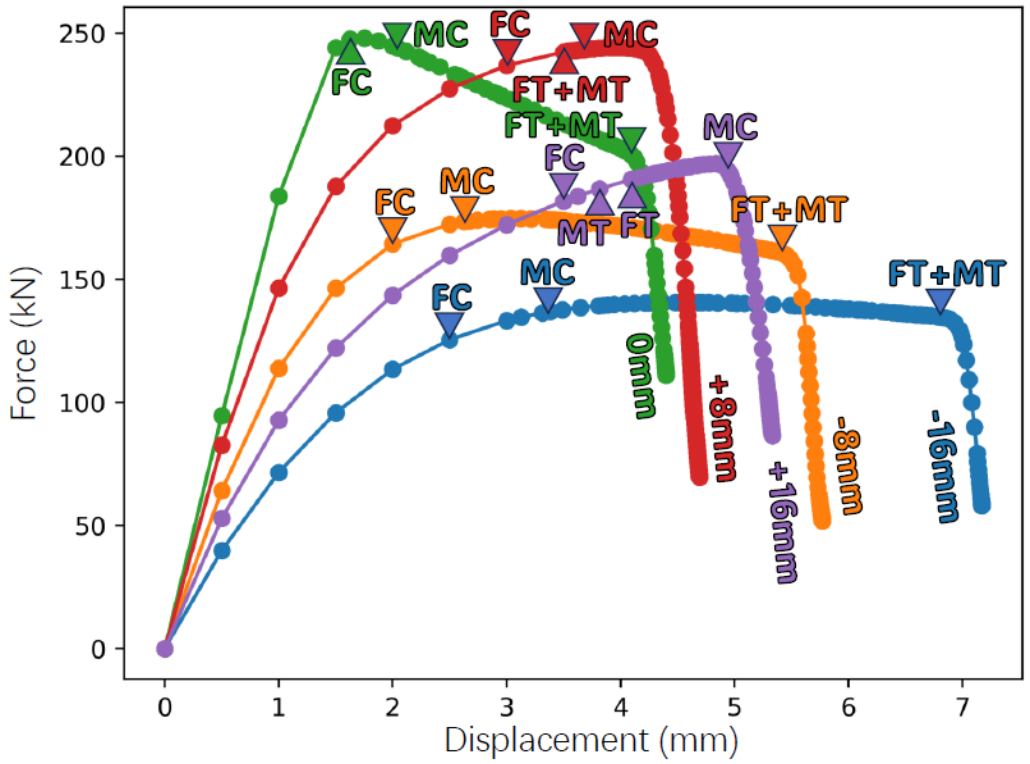
Thickness variation

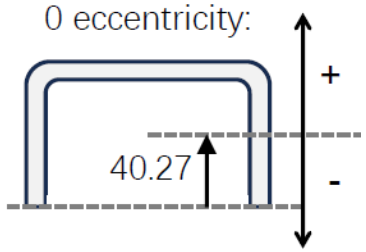


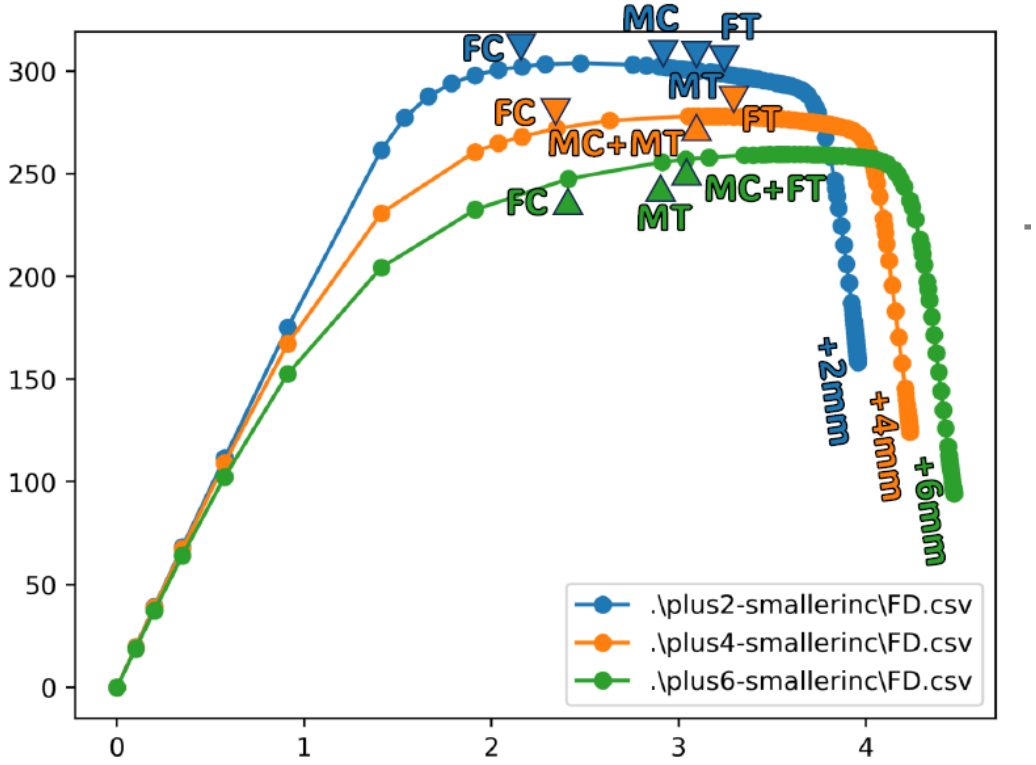
Flange spring

The manufacturing procedure was designed to reduce evolution of typical features such as waviness and wrinkle defects

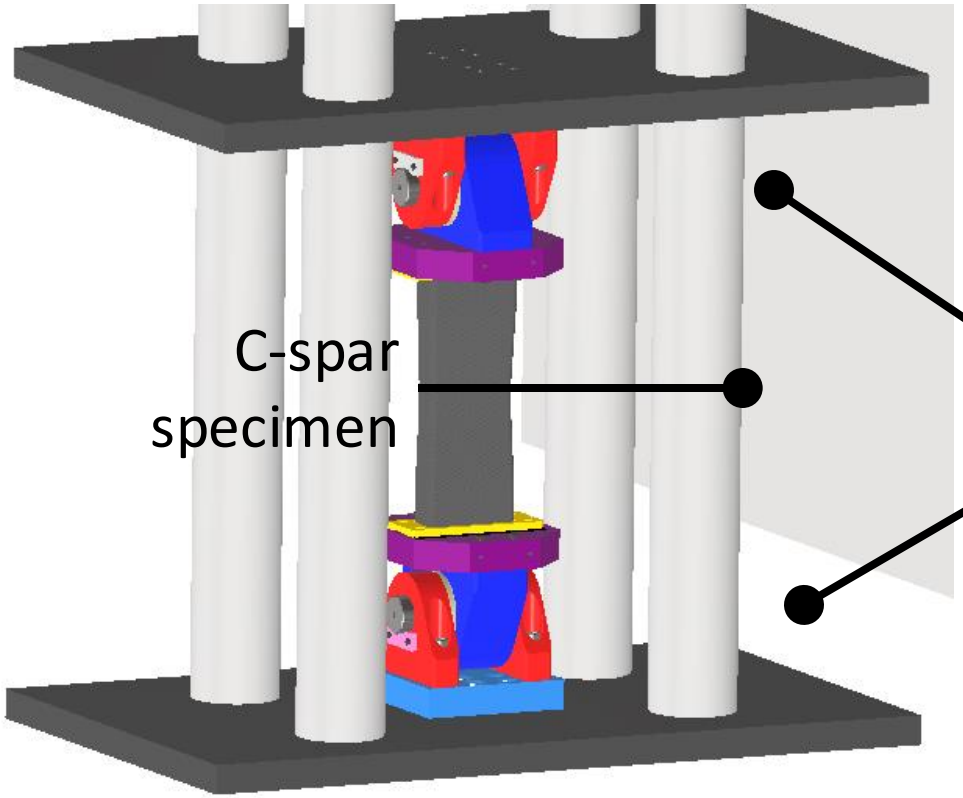
Effect of eccentricity

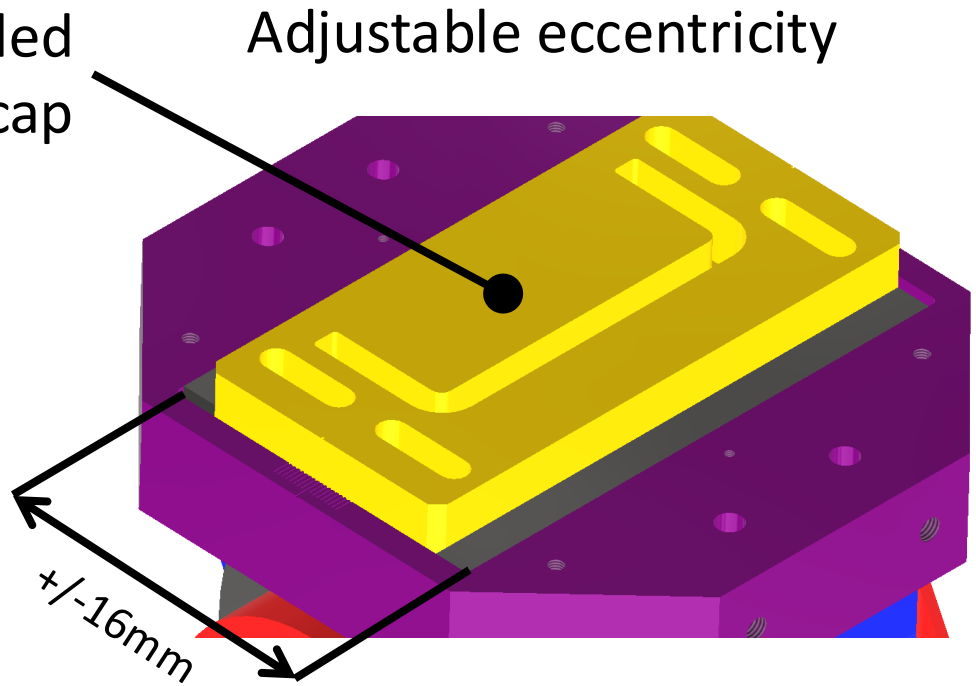






Compression c-spar loading test rig





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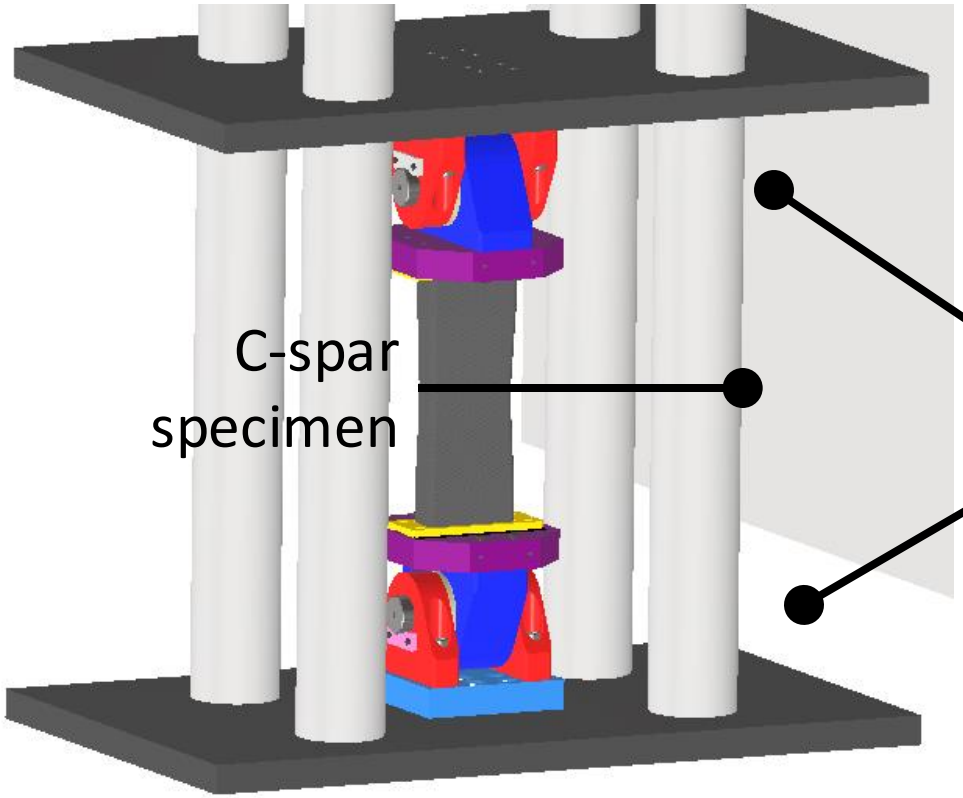
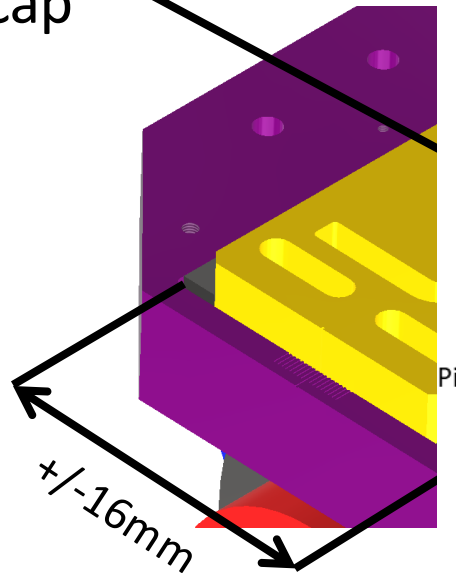
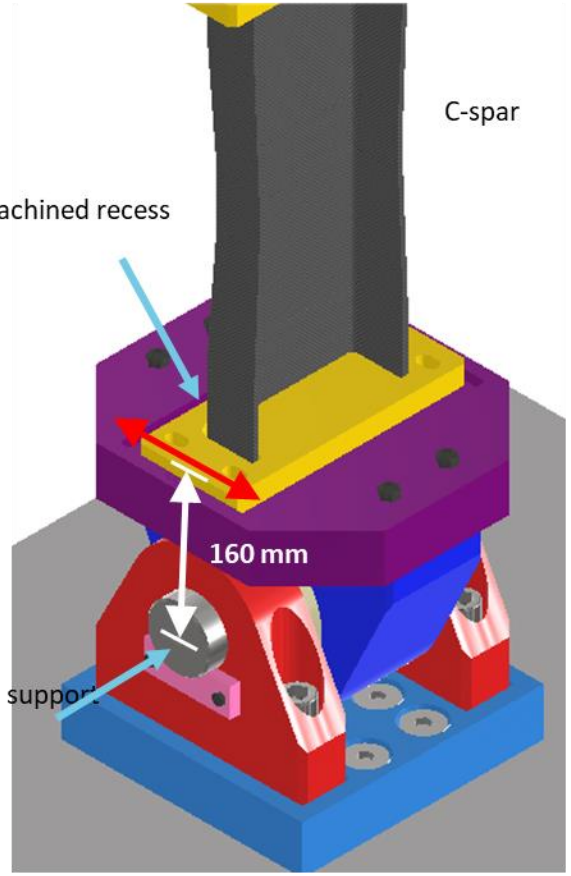
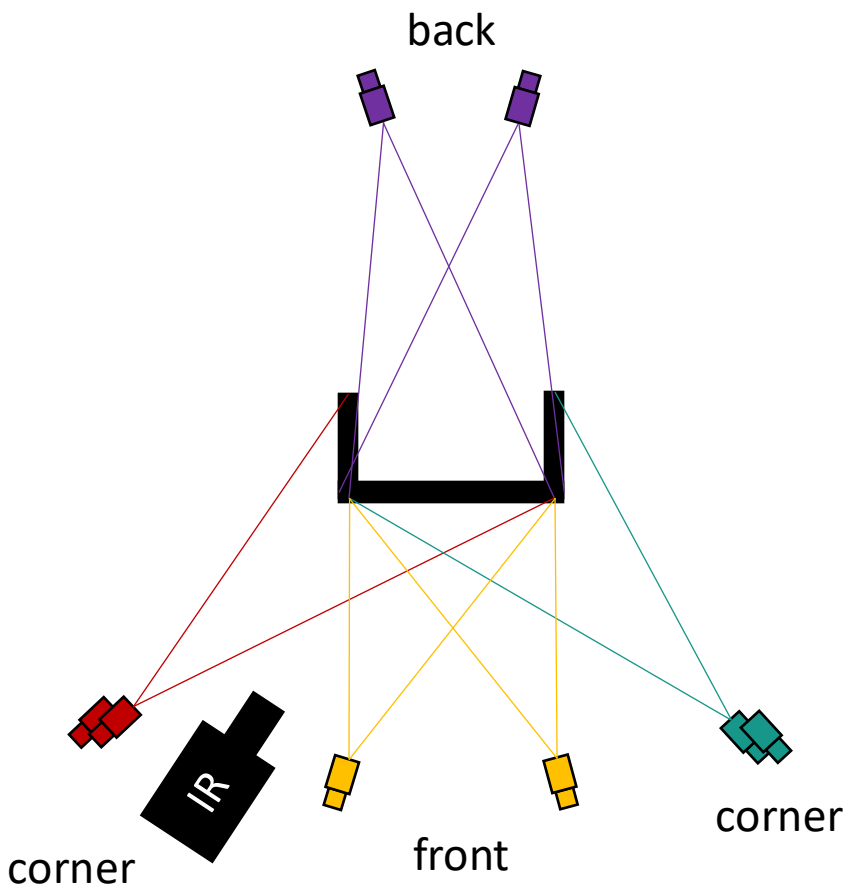
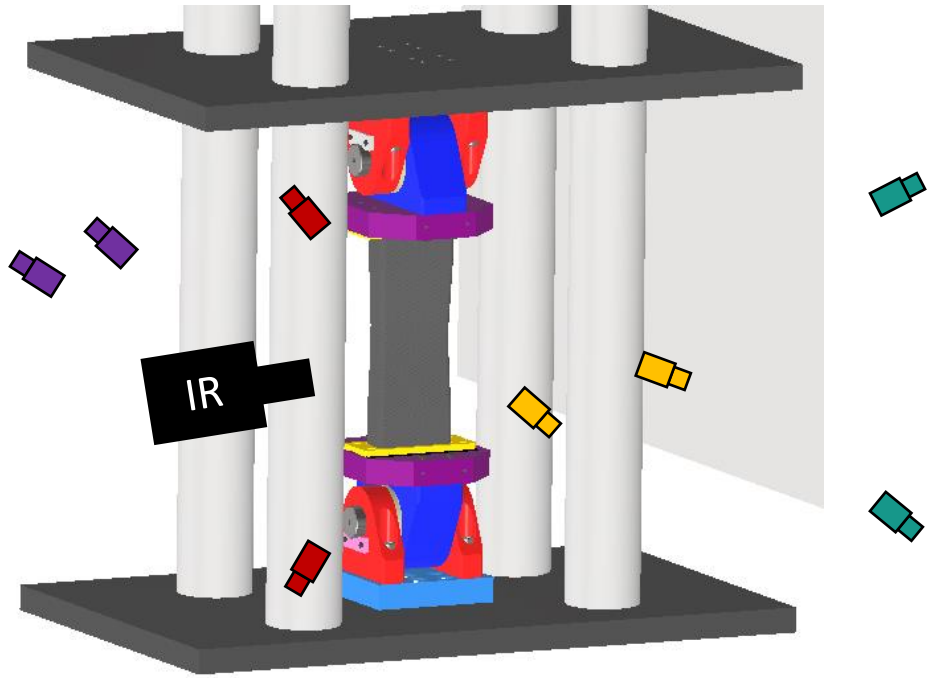






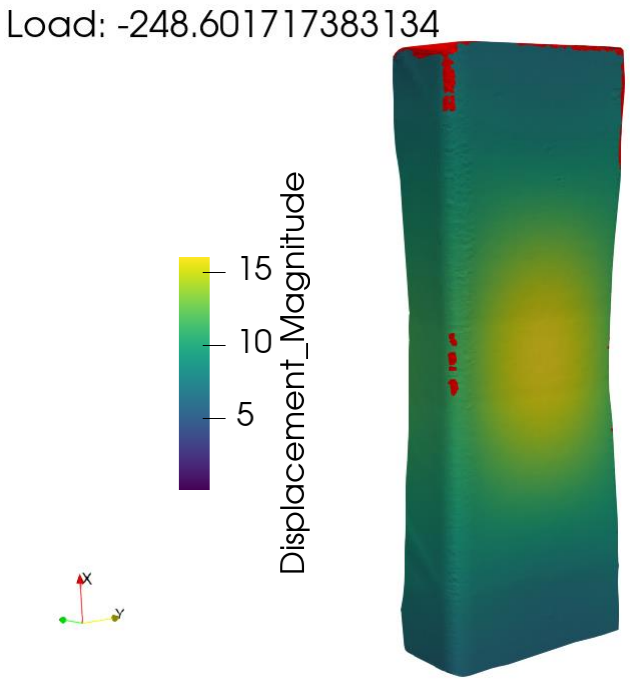
Cameras used in the C-spar test



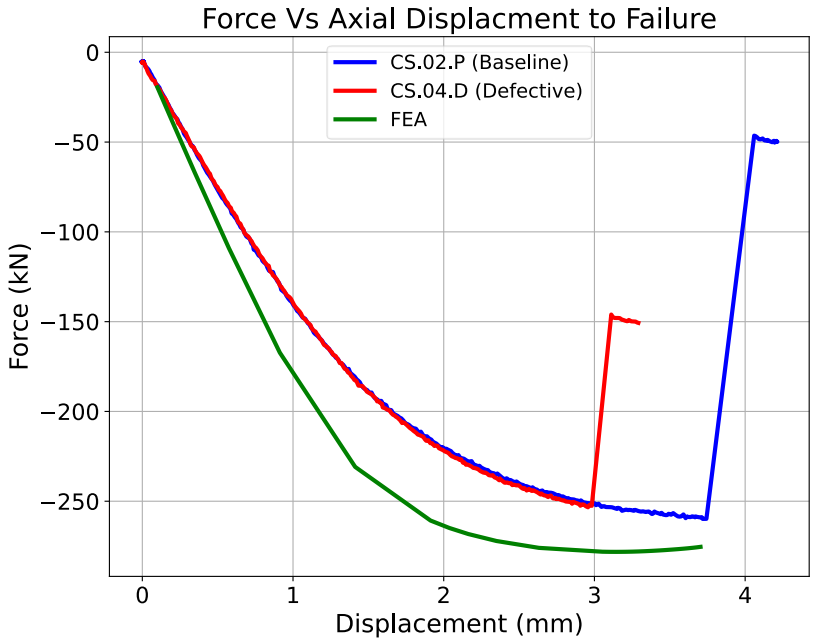


C-spar experimental results

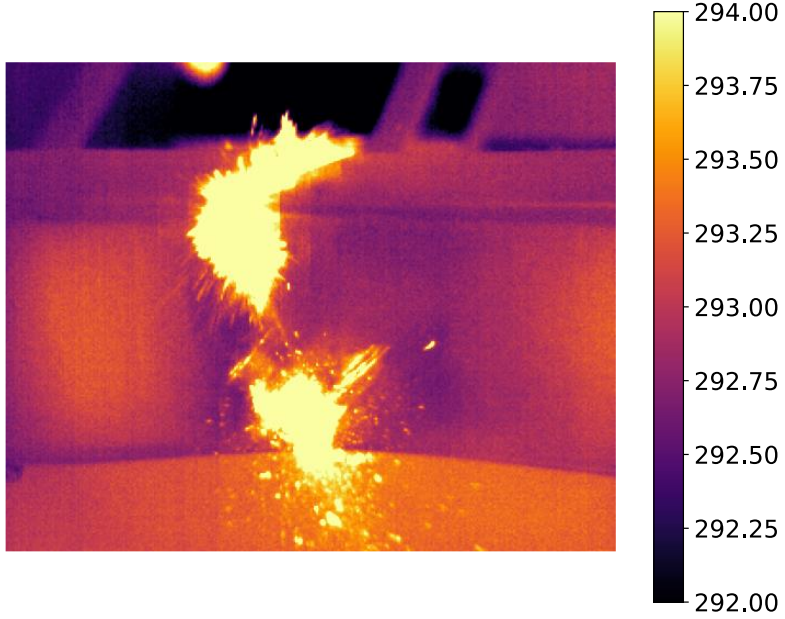
DIC



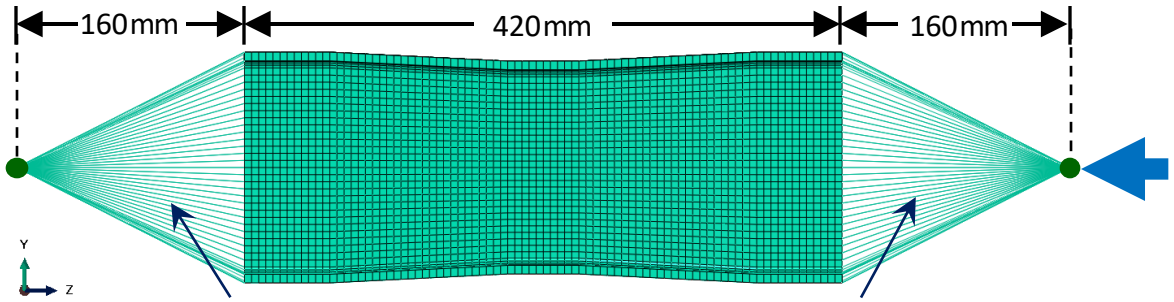
Load displacement curves from DIC



Thermal data

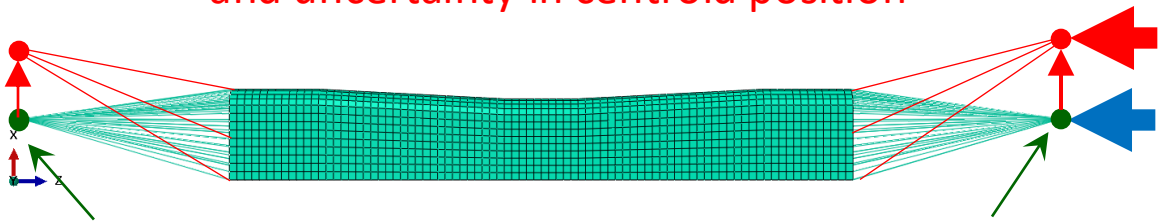


Models, uncertainty and data fusion

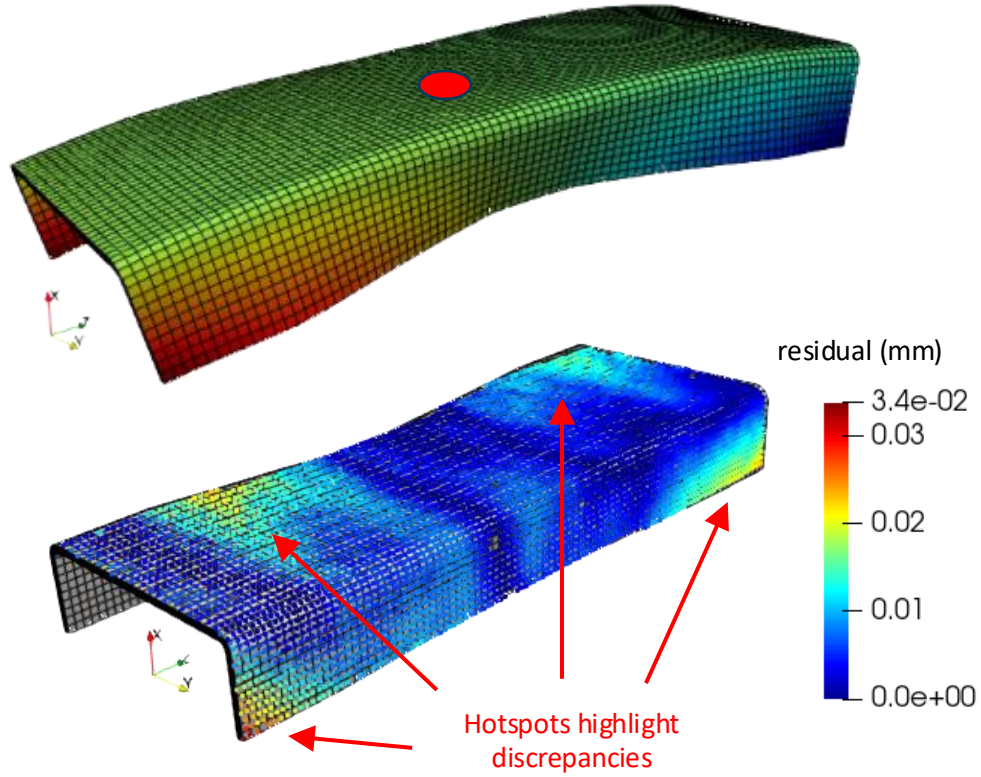


Truss elements with uncertain stiffness (K_{truss}) model rig compliance

Uncertain eccentricity bias models misalignment and uncertainty in centroid position

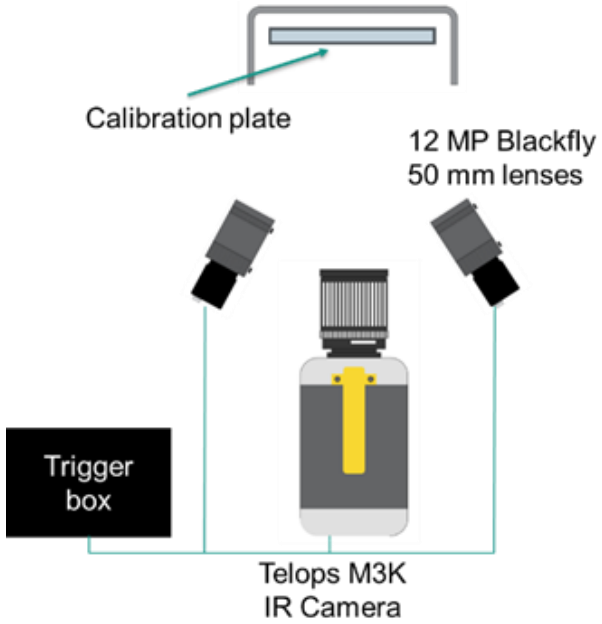


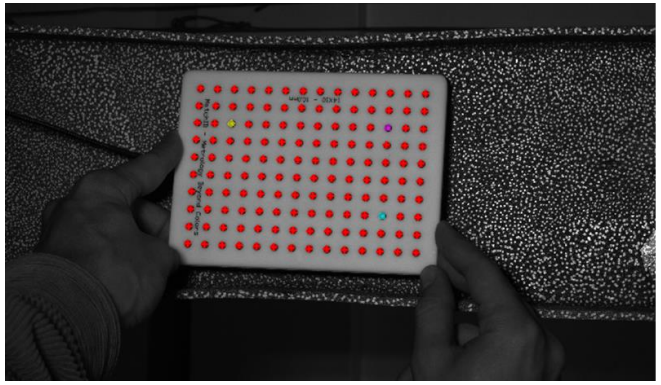
Torsional springs with uncertain stiffness (K_{spring}) model resistance at bearing

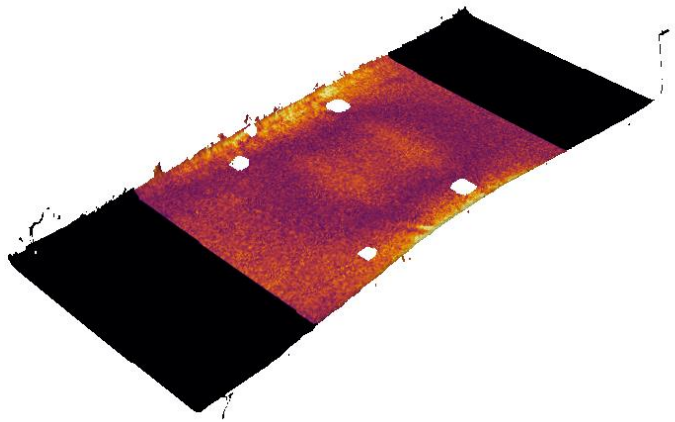


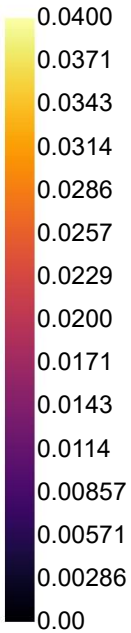
Residuals of DIC compared with average calibrated model

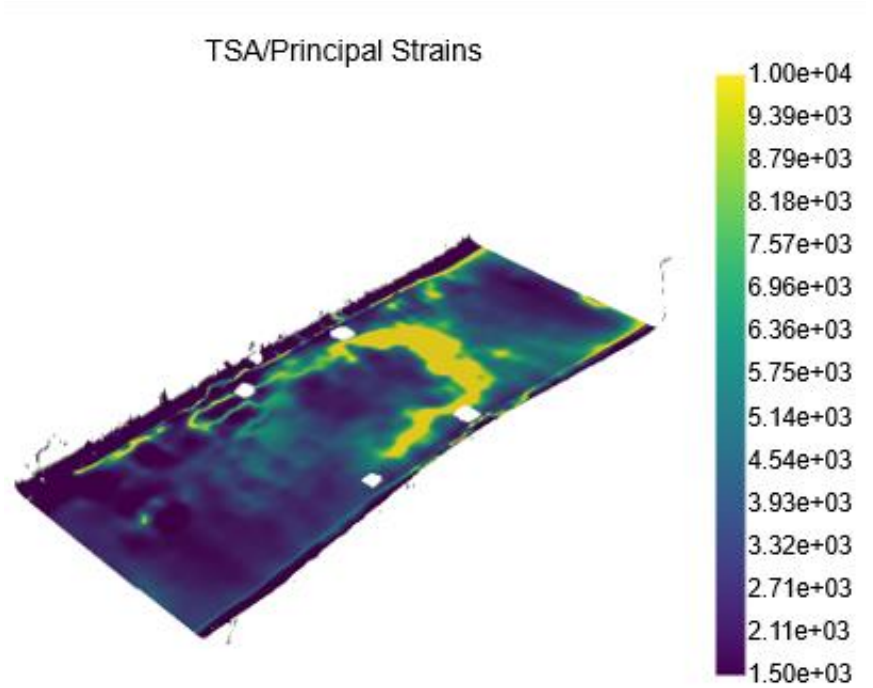
Fusion metric – initial results







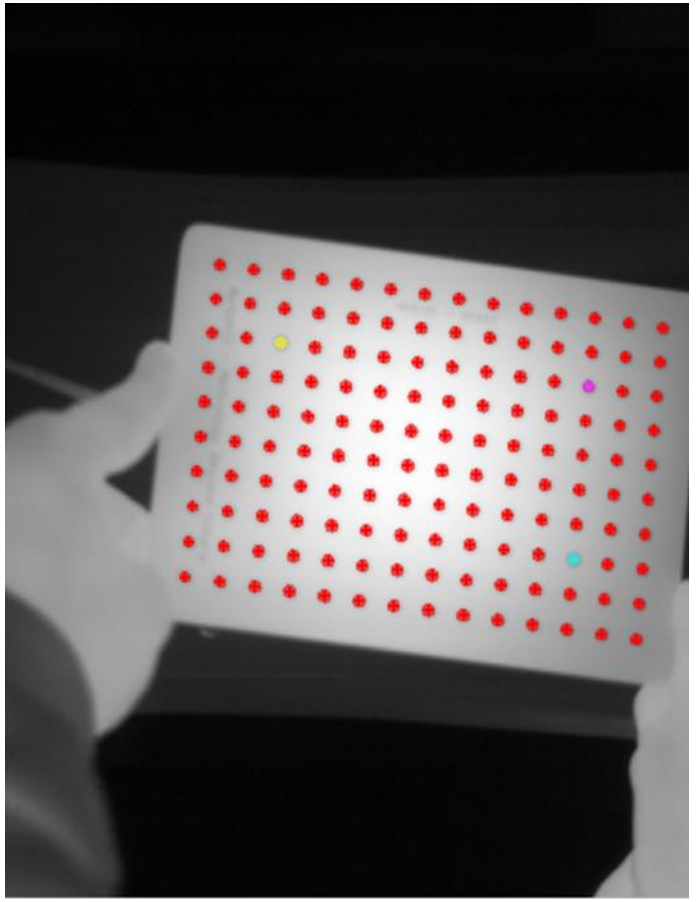




More about c-spar from Dr Riccardo Cappello in Hemlock/Oak 4th June 0940

Conclusions

- Presented a data fusion approach for TSA/DIC/FEA
- Described the construction and manufacturing uncertainties in a realistic CFRP aircraft component
- Described a test that can be used to calibrate FEA models that are later used as basis for a Bayesian uncertainty analysis
- Identified several experimental uncertainties that were incorporated into the model
- Showed preliminary results of data fusion



Engineering and Physical Sciences Research Council

CERTIFICATION FOR DESIGN: RESHAPING THE TESTING PYRAMID

The Alan Turing Institute