Engineering and Physical Sciences Research Council

Characterization of micro-structural features in complex parts for use in digital technologies

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CERTEST

Overview

- Background
- The C-spars

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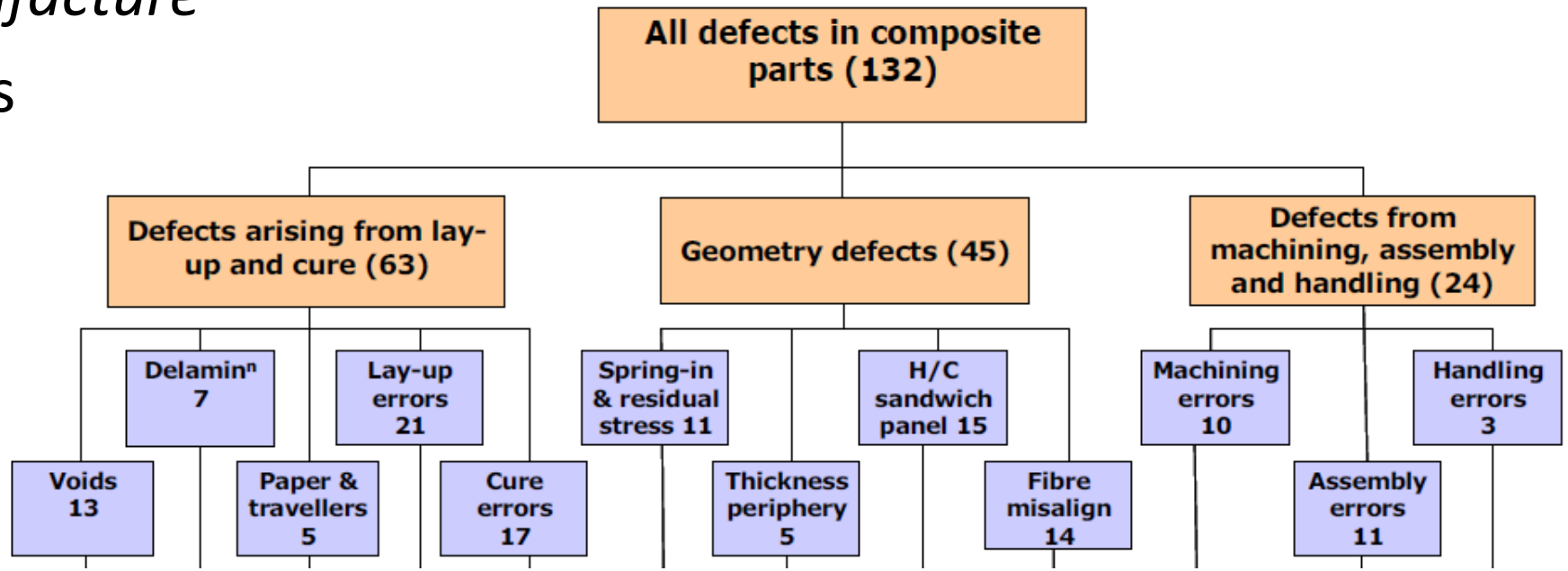
CERTEST

Background: Database Need

- Kevin Potter: *Understanding the origins of defects and variability in composites manufacture*
- 130+ defect types
- 60+ sources



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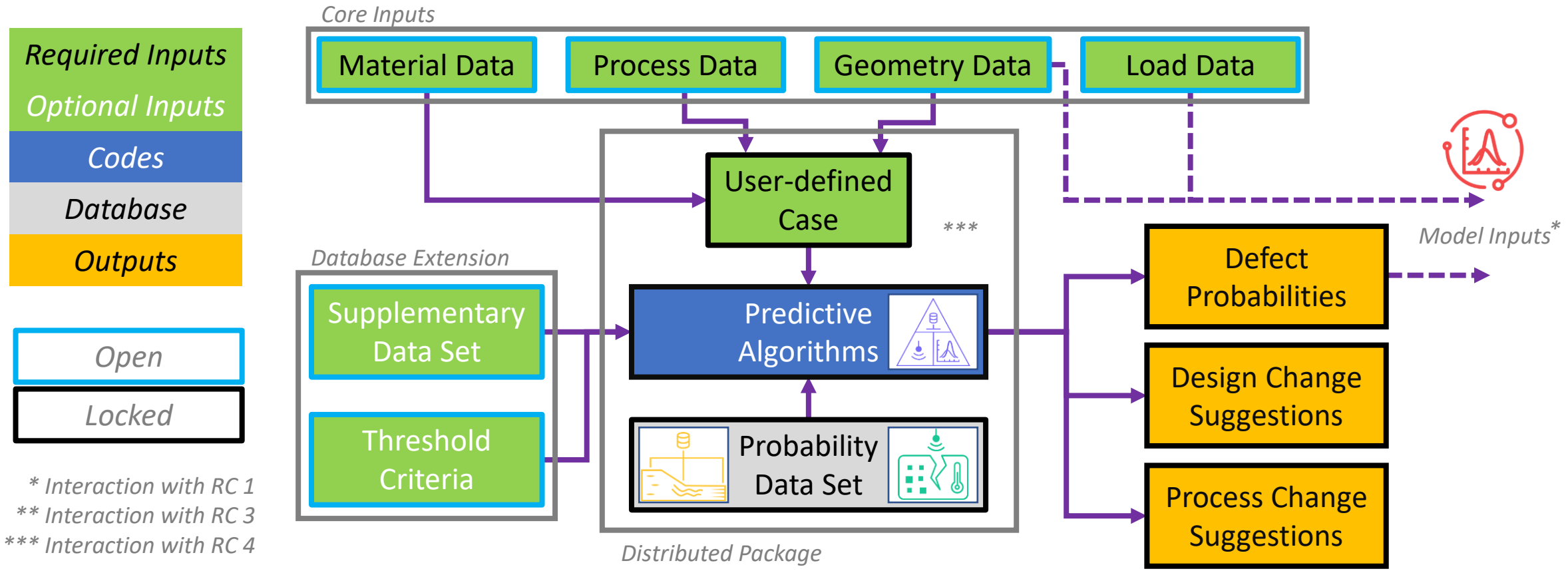
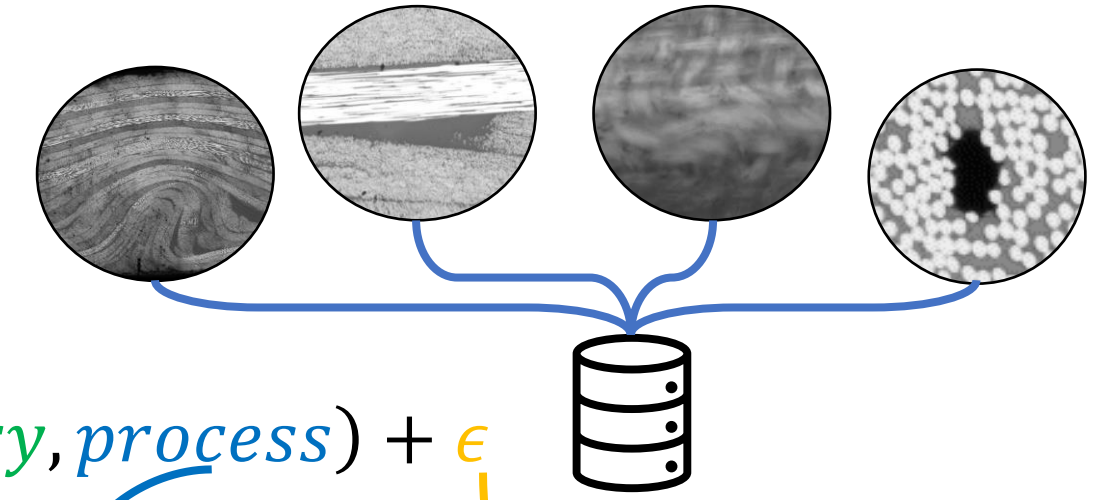
Background: Database Conceptions



Background: Literature Review

- 300+ publications reviewed
- 74 with extractable trends
- 15+ parameters linked to defects



$$DefectState = f(material, geometry, process) + \epsilon$$

Fibre volume fraction
Anisotropy
Fibre architecture
Resin type
Toughening/interleaf

Curvature (single/double)
Thickness change
Convex vs. Concave

Tool material
Caul sheet + material
Out time (shelf life)
Cure temperature + pressure

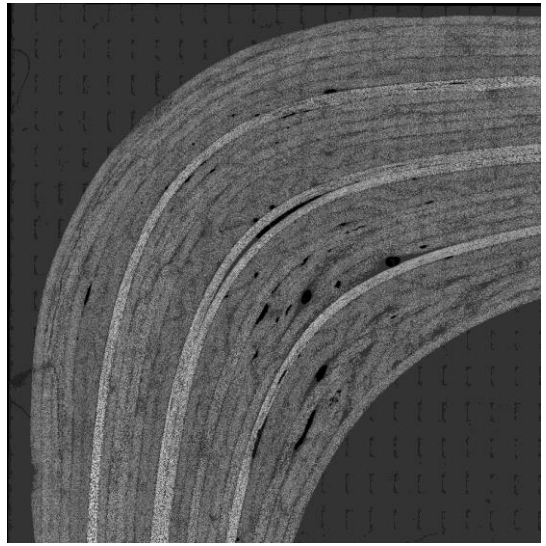
Inherent variability
Uncontrolled variables

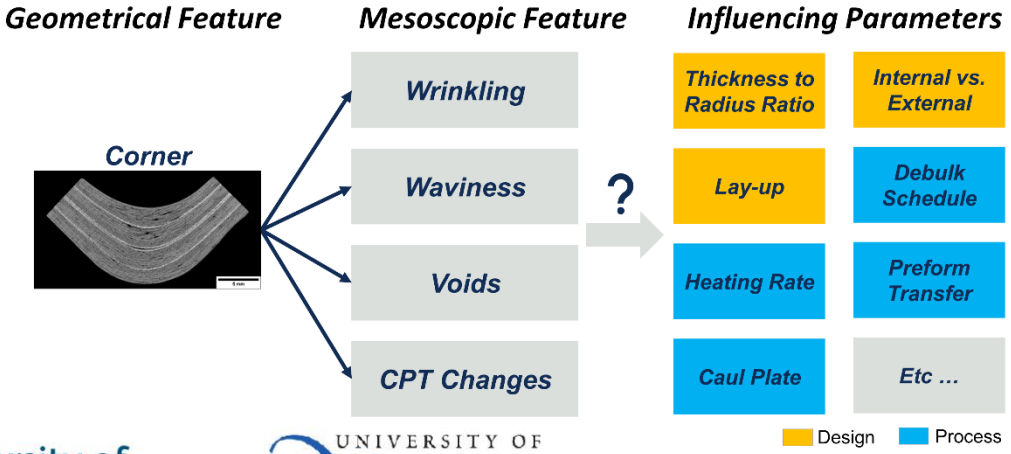
Background: New Taxonomy

- Industry and Literature data is limited:

- New data gathering needed for:
  - Complex defects
  - Evaluate repeated parts
  - Variations in real parts

- Published literature review (P1)



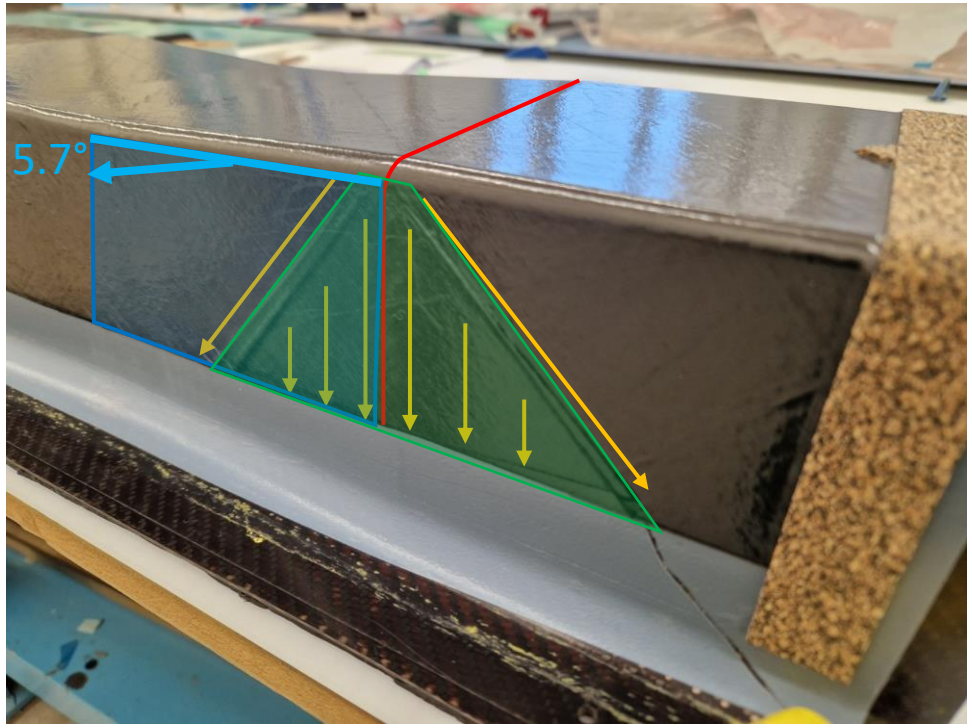


The C-spars: Manufacturing

- 5 spars made:
  - 2 Baseline - Manufacturing Trial
  - 1 Baseline
  - 3 Embedded delamination
- Autoclave cured:
  - In sets of two (single envelope bag)
  - With traveller plates
- Trimmed to final dimensions at NCC

The C-spars: Geometry Driven Features

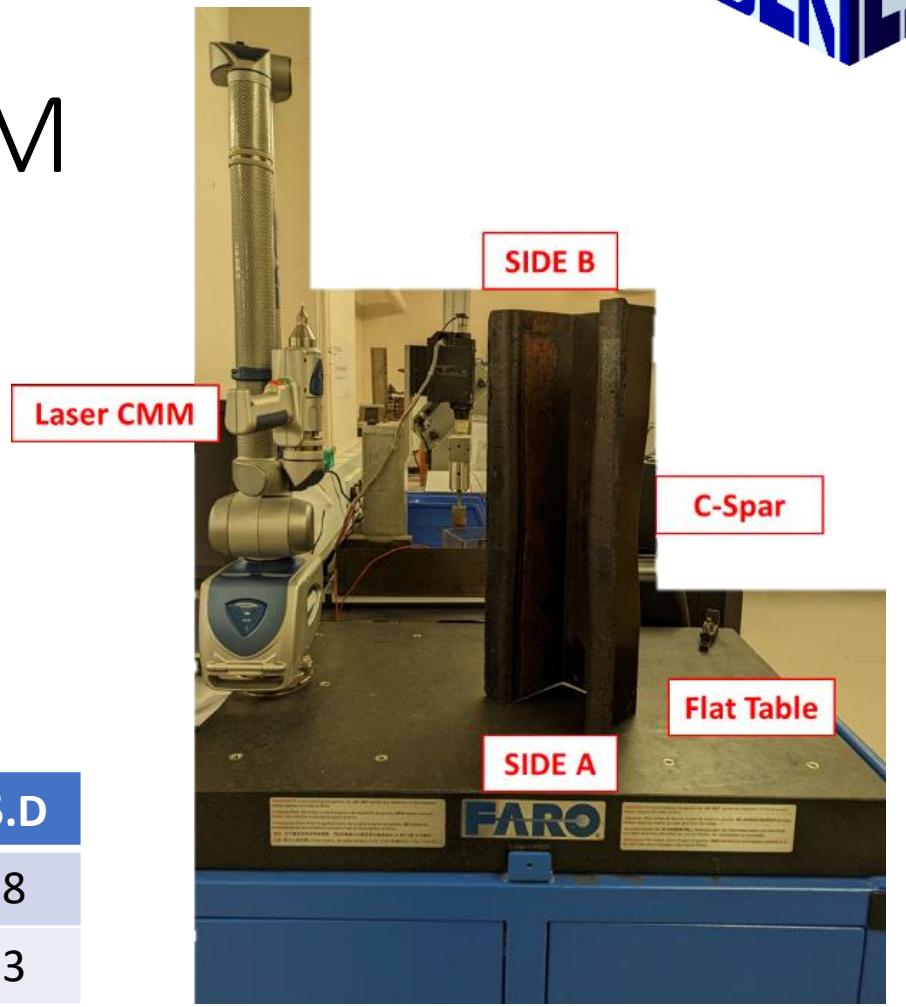
- Web and corners are well formed
- But wrinkles occurred:
  - In +/-45 and 90 plies
  - At start of recess (x4)
  - Contained in triangular area
  - Caused by excess length
- Fibre misalignment occurs in 0 plies in transition



The C-spars: Metrology - CMM

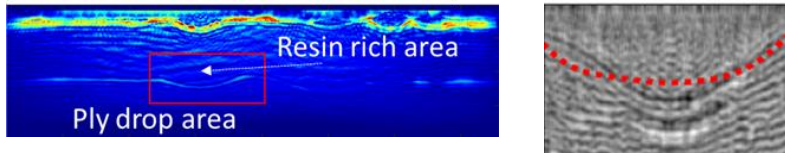
- Using Faro Arm at Bristol
- Scanned:
  - Pre-trimming
  - Internal & External Surface
- Collected basic metrics pre-trimming:

	CS.01.P	CS.02.P	CS.03.D	CS.04.D	CS.05.D
Internal Angle [°]	89.21	89.19	89.47	89.45	89.38
Thickness [mm]	6.082	6.130	6.191	6.111	6.133



The C-spars: NDT - Eddy Current & Ultrasound

- For C-spar full scale inspection:
  - Applied immersion TFM-FMC UT:
    - Resin rich areas, voids, wrinkling
  - Developed 3D Eddy Current system with lift-off compensation:
    - In-plane waviness & wrinkling
  - Developed parametrised strategy
  - Developing registration techniques
- *Data still being evaluated*



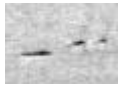
Example outputs from UT scanning

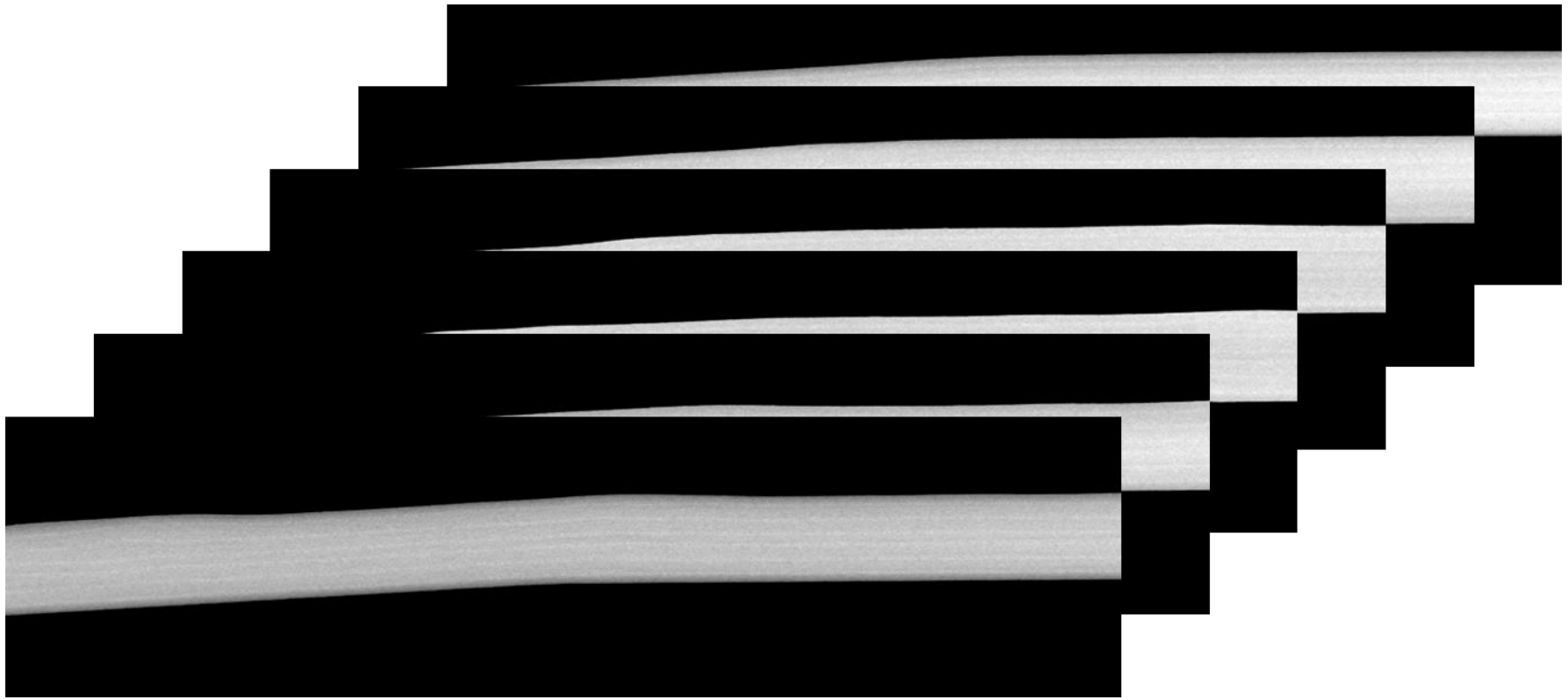
New EC scanning system (left) and sample in-plane orientation reading (right)

The C-spars: NDT - X-CT

- Scanned using D5
- Pre-loading:
  - Local Scan:
    - Focused on wrinkles
    - High resolution ≈40 micron
  - Global Scan:
    - Captures full geometry
    - Medium resolution ≈80 micron
- Post-loading:
  - Local Scan:
    - Focused on damage
    - High resolution ≈40 micron

The C-spars: X-CT Analysis

- Using:
  - 2D Slices
  - From 37µm scans
- Extract:
  - Fibre wrinkling
  - Voids 
  - Inclusion 



The C-spar: Defect Database

- 2 stage process:

2D —— *Compute* ——▶ 3D

ROI	ID
Slice	#
Meso Voids	[Location, Area]
Wrinkling	[Location, Amplitude, Wavelength, Skew Factor, Through-thickness decay rate]

ROI	ID
Meso Voids	[Location, Orientation, Volume, Aspect Ratio]
Wrinkling	[Ply, Start Location, Amplitude, Wavelength, Growth Rates, Running Angle, Running Length, Skew Factor, Through Thickness Decay Rate]

- Accompanied by rich meta data (*material*, *geometry*, *process*)

Summary

- Higher dimensional characterization to decouple defect data into:
  1. Low resolution data for high fidelity simulations
  2. Database with suitable metrics

- Avoid meshing a CT scan of a composite structure … maybe this will be easier in 15 years?

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Thank you for listening

Questions now or e-mail:

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