Quantitative Inspection of Complex Composite Aeronautic Parts Using Advanced X-ray Techniques

Aerodays 2015

London / UK, 21.10.2015

Christoph Heinzl

OBERÖSTERREICH
University of Applied Sciences

Motivation

Rising Demands on Components

- Cost effectiveness
- Function orientation
- High integration
- Light weight

Advanced Composites

- Most promising candidate materials
- Integrate demands for the aircraft of the future

Mission statement: "…to take the next big step in quality control and development of new advanced composite components for the aircraft of the future…"

QUICOM Technology Platform

Hardware | Software | Simulation

- Consists of **3 Pillars**:
- In order to …

Provide highly detailed nondestructive characterization methods based on **X-ray computed tomography**

Implement the **assessment of CRFPs based on XCT data** in aeronautic industry

Generate a **unique understanding** of the real inner structures of composite components in 3D (e.g., by the **assessment of damage tolerances** of CFRP components)

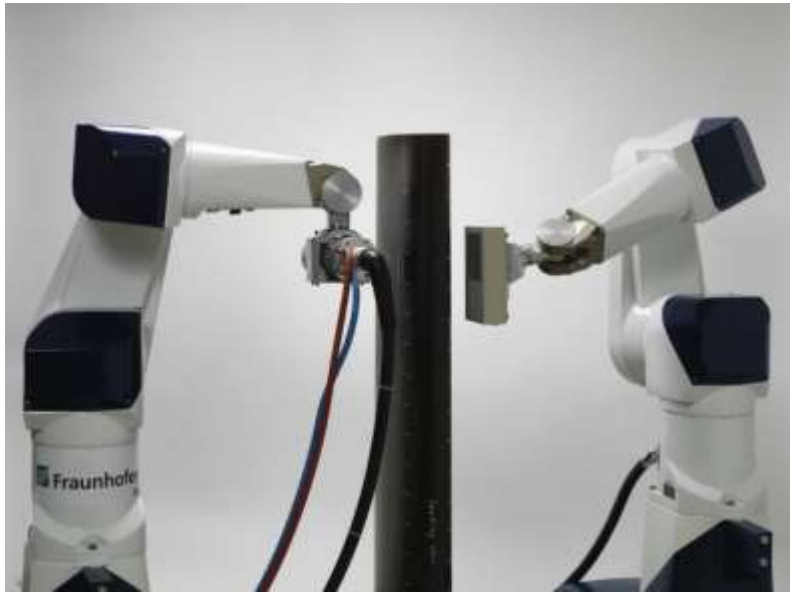
Provide input for the design office or the potential of rework of the produced CFRP parts based

Provide input for optimized design of new composite parts

QUICOM Technology Platform

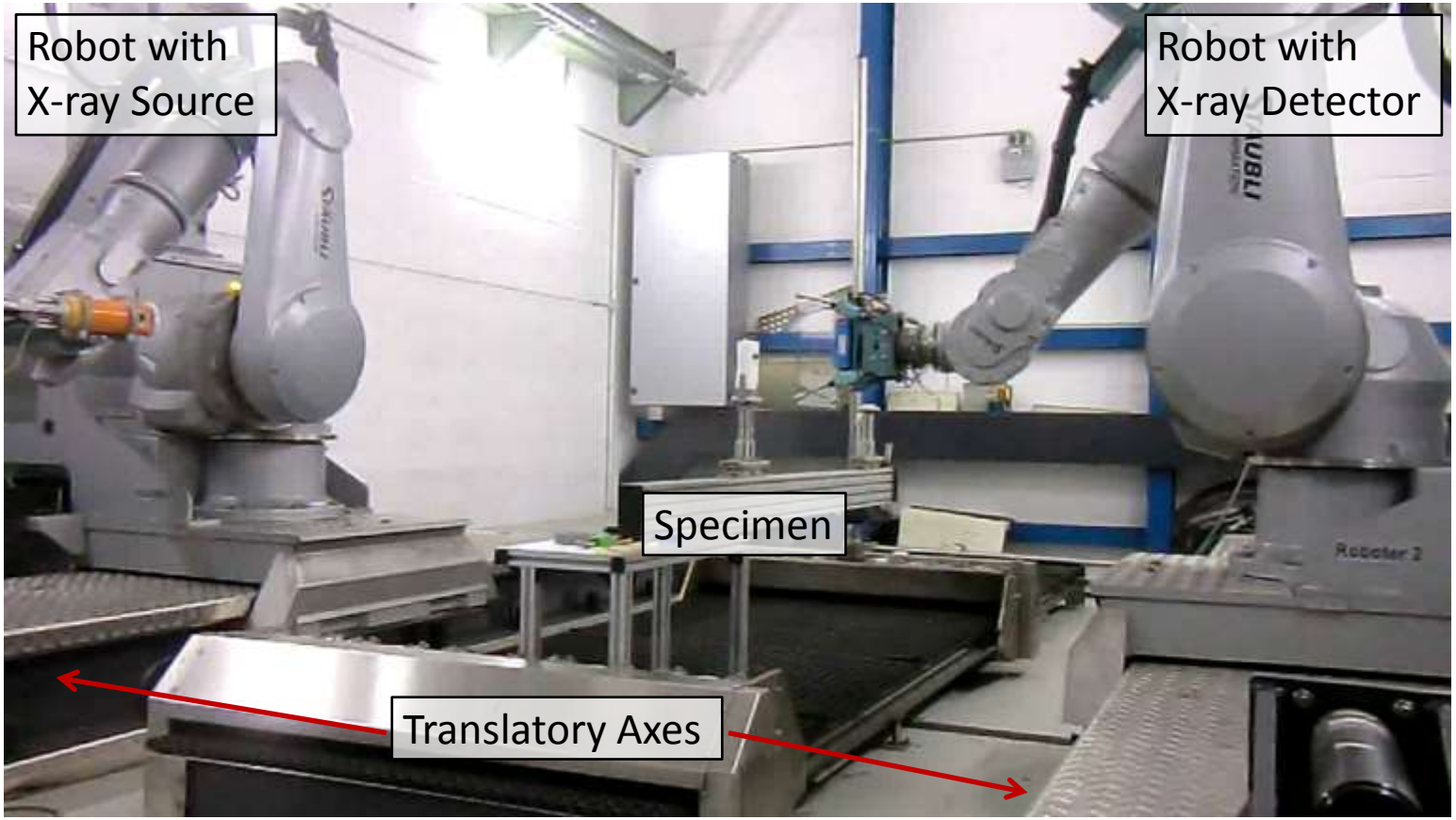
Hardware | Software | Simulation

- **Robot based XCT** for large and complex aeronautic parts at production site
- **Fast process integrated XCT** for fast and reliable inspection of small high volume parts
- **X-ray radioscopy, tomosynthesis and Computed tomography**



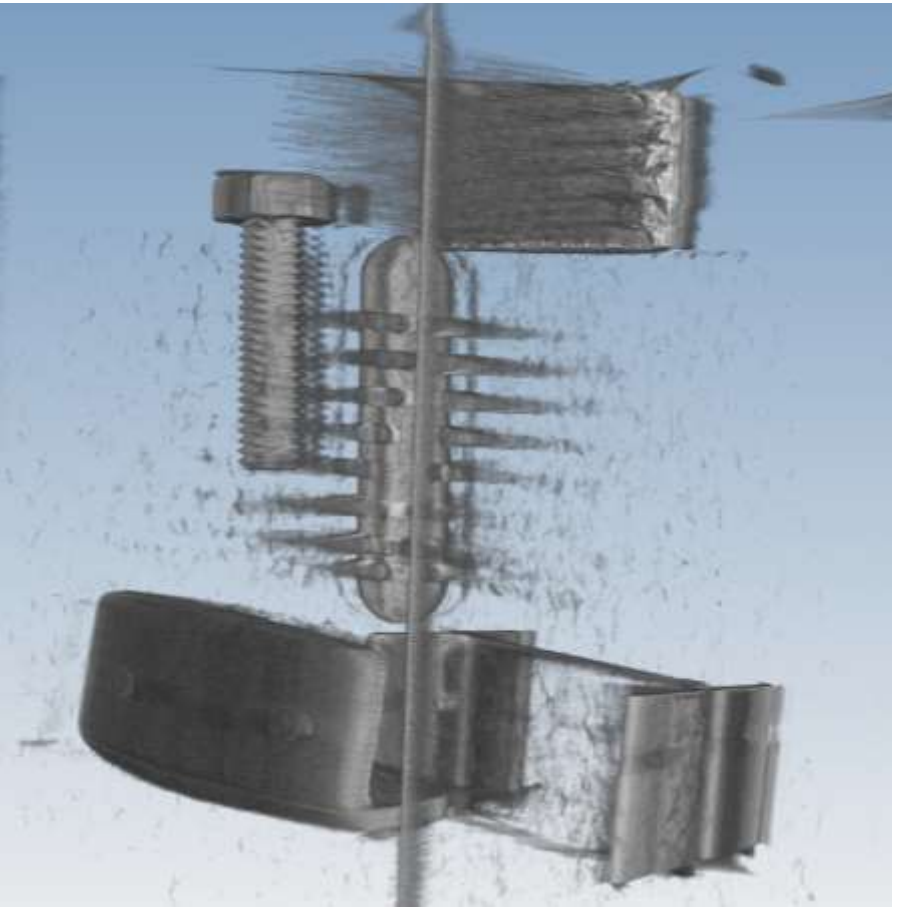
Robot Based CT

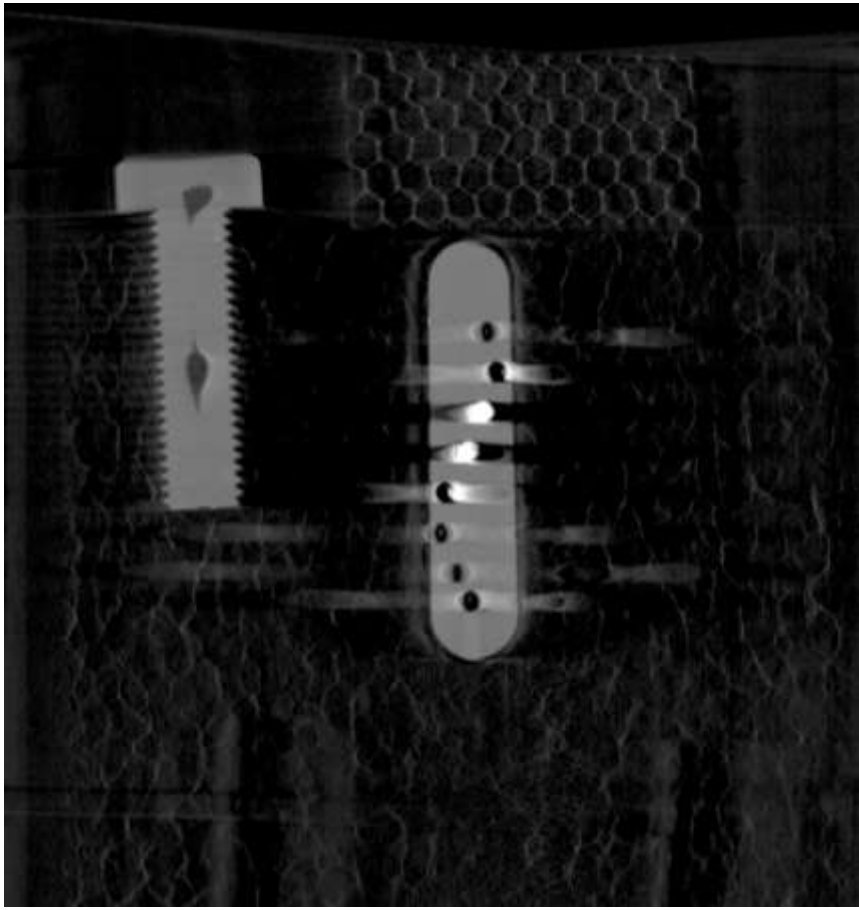
- **Computed Tomography**
  with cooperating industrial robots as manipulators for X-ray source and detector
- **Extreme flexibility** to acquire CT at large or inaccessible objects



Robot Based CT

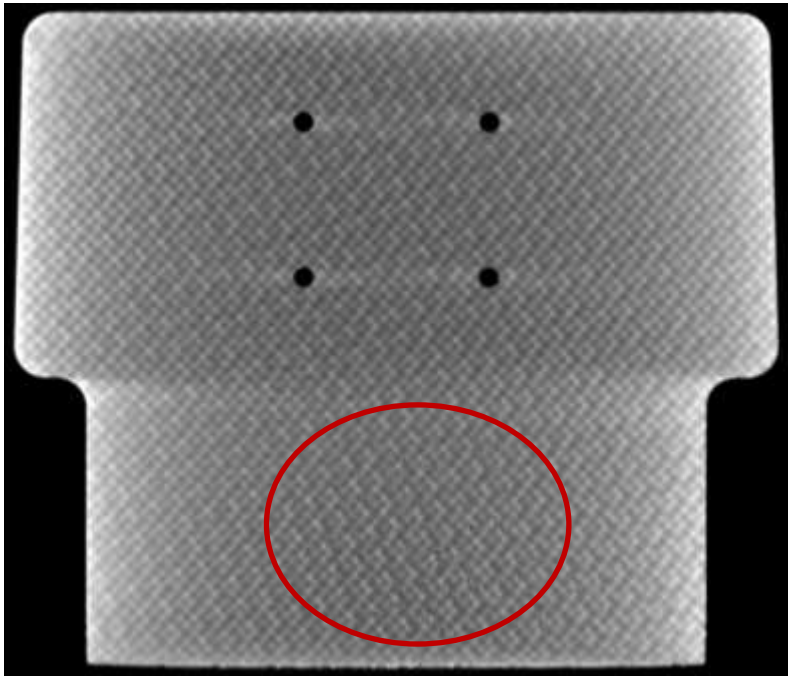
- **Solution for unknown geometry**
  (industrial robots are only precise for approx. 0.5 mm to 1 mm)
- Computed tomography with details **down to few tens of microns**





Fast Process Integrated XCT

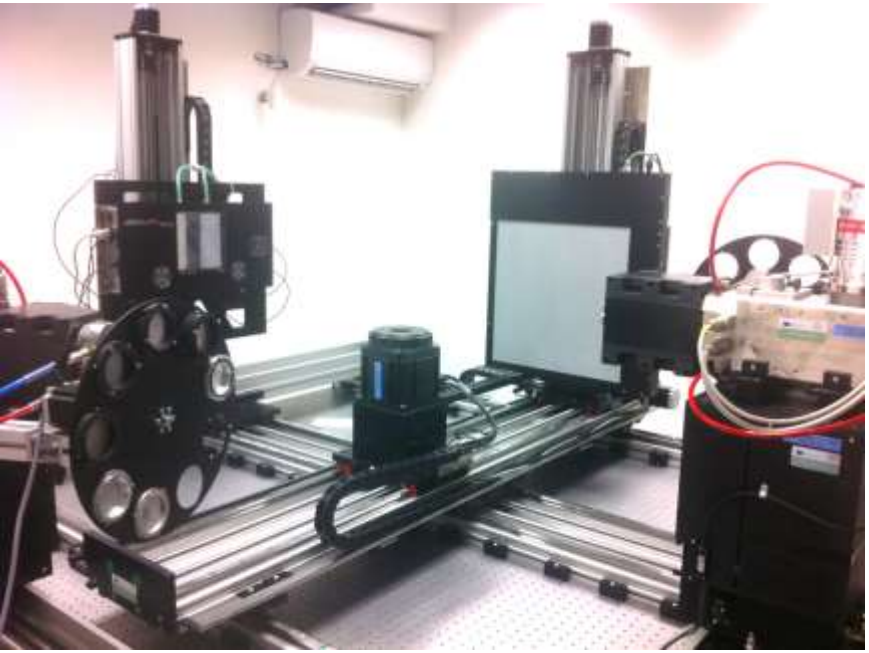
- Process integrated XCT of **thermoplast clips** (typically 100 mm · 150 mm · 200 mm)
- **Multi-Clip scan** with automatic separation of individual clips
- **Automatic dissection** in planes and radii
- **High resolution** to detect porosity and delaminations
- **½ to 5 minutes per clip** for scan and **automatic defect recognition**



Composite metallic parts

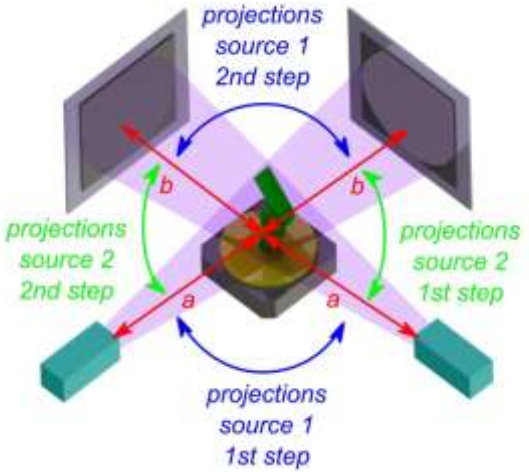
Characterization of **light-weight, fiber reinforced plastic composites combined with metallic parts**.

Composites with **metallic inlays**
Sandwich structures with **metal core**
Metal fasteners



Dual Energy CT (DECT)

Resultant reconstruction obtained combining two CT measurements at two different X-ray spectra.



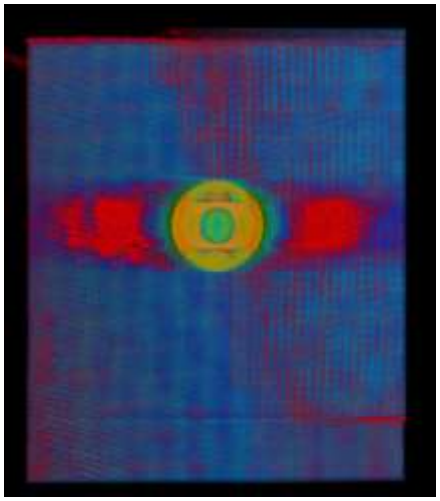
Disbonding of two glued parts

3 basic material components:

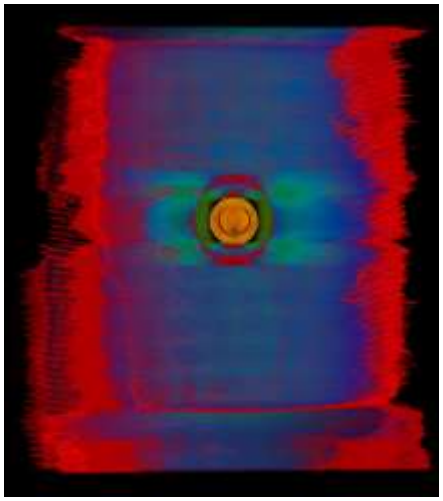
- **CFRP** (two 1.2 mm thick flat parts, each from 6 layers),
- **metal fastener** (steel rivet Avinox II) and
- **Cu grid** (4AE420539).

Artificial disbonding between glued CFRP parts was prepared in the rivet vicinity

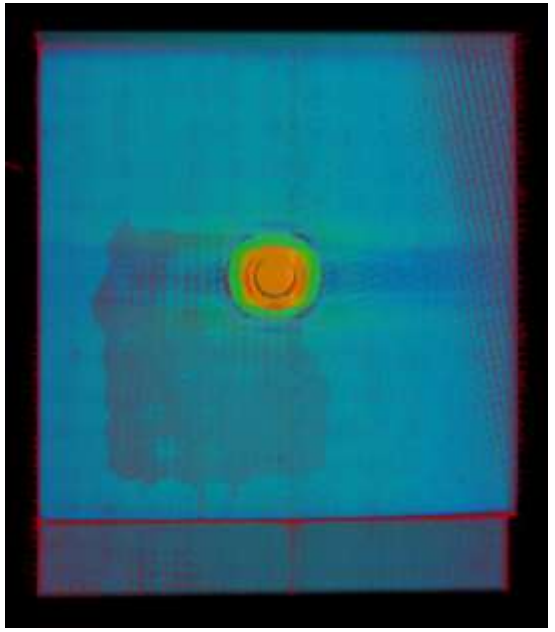
LE @80kV,
1.5 mm Al filter
CT reconstruction



HE @160kV,
0.8 mm Sn filter
CT reconstruction



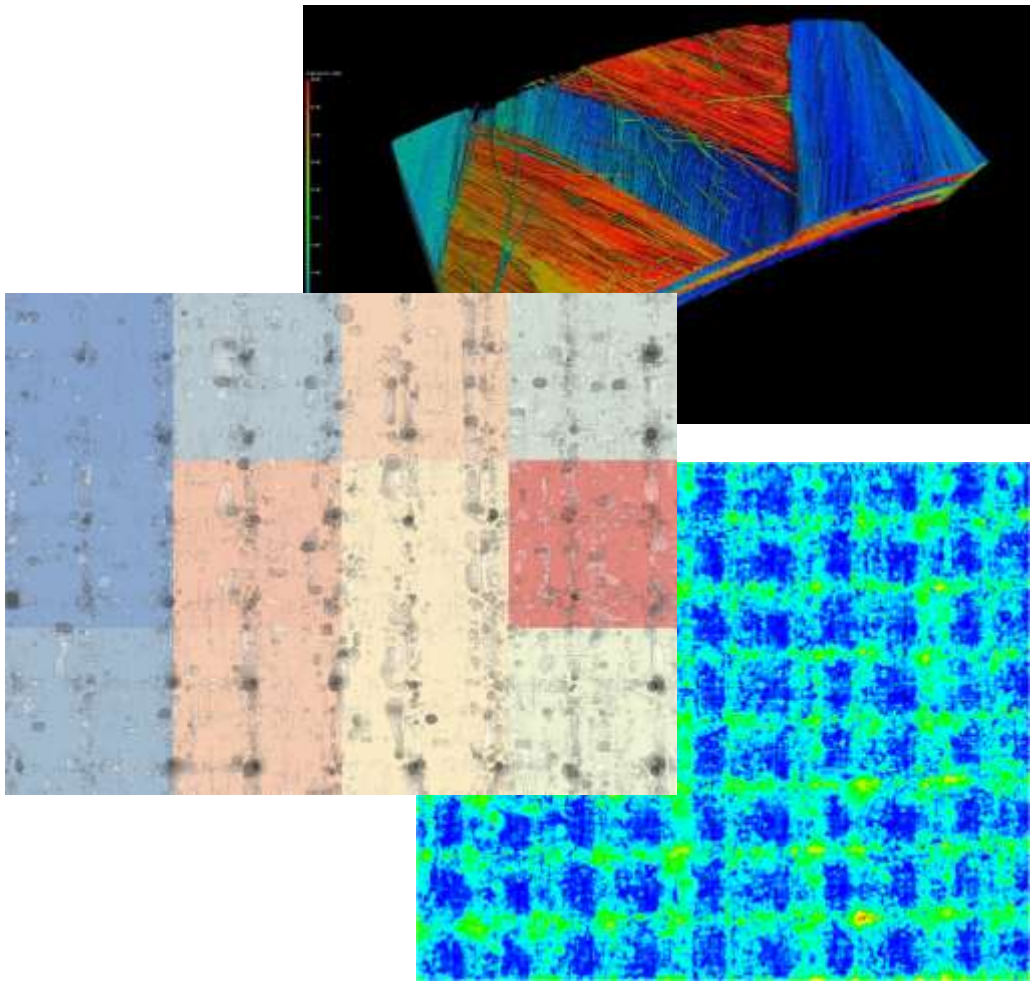
DECT reconstruction



QUICOM Technology Platform

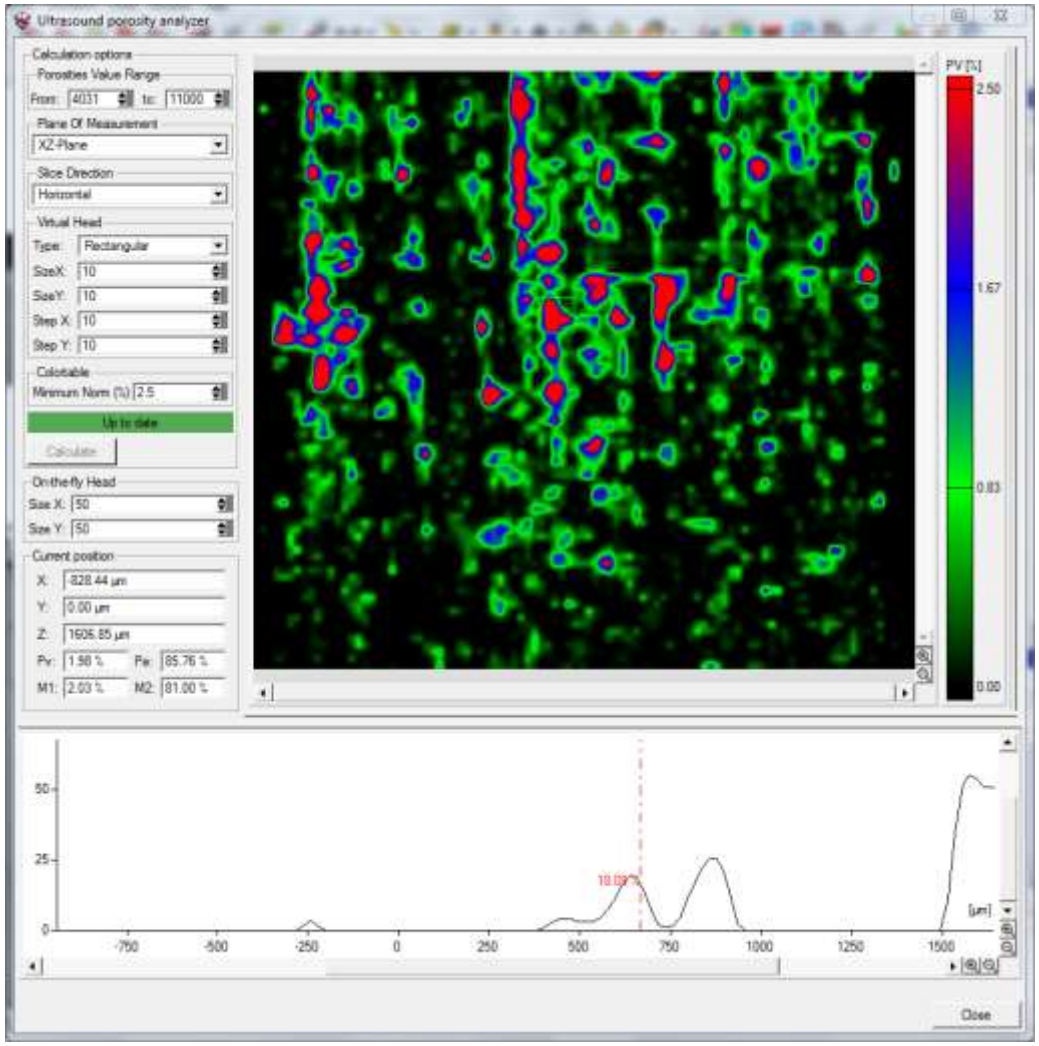
Hardware | **Software** | Simulation

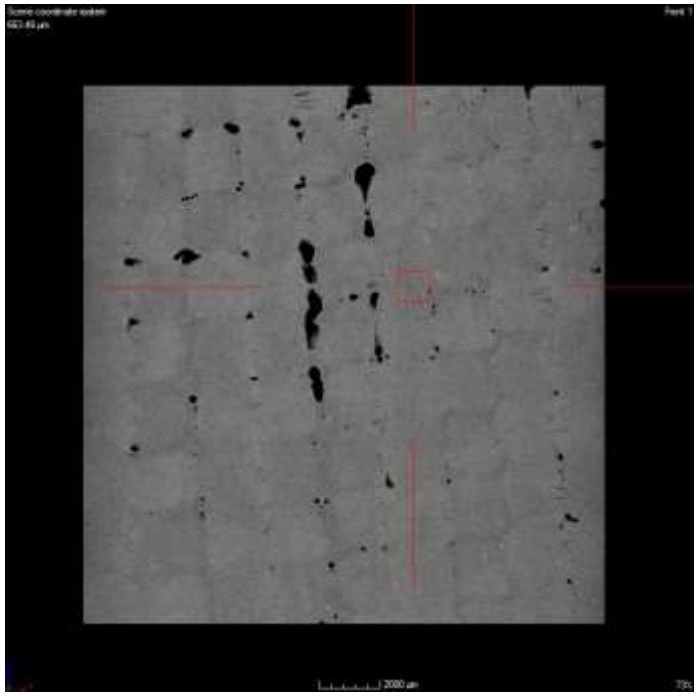
- **Material characterization** regarding fibers, fiber bundles, pores, voids etc.
- **Data analysis and interpretation of results**
- **Large data** analysis and visualization
- **Hardware accelerated** methods and techniques

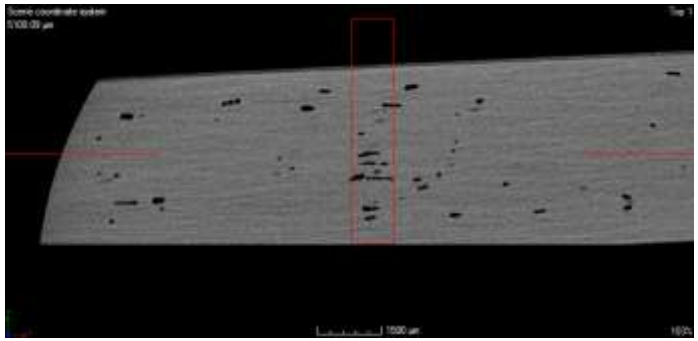


(images courtesy of VG, FHW)

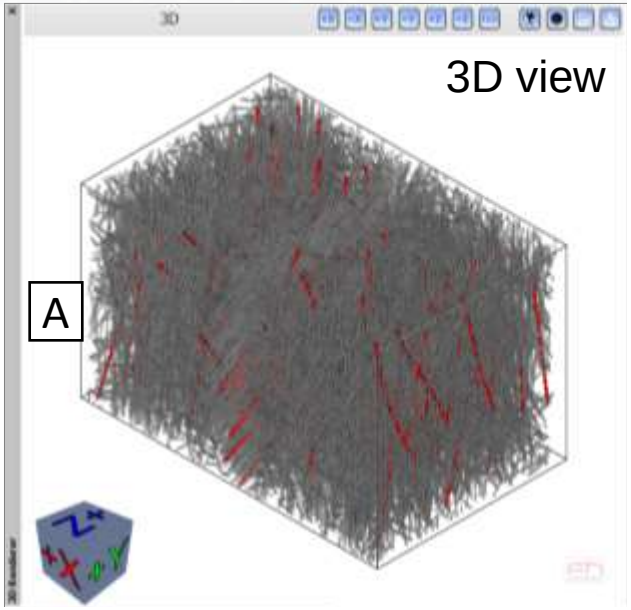
Comparison CT ←→US



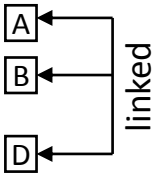




FiberScout

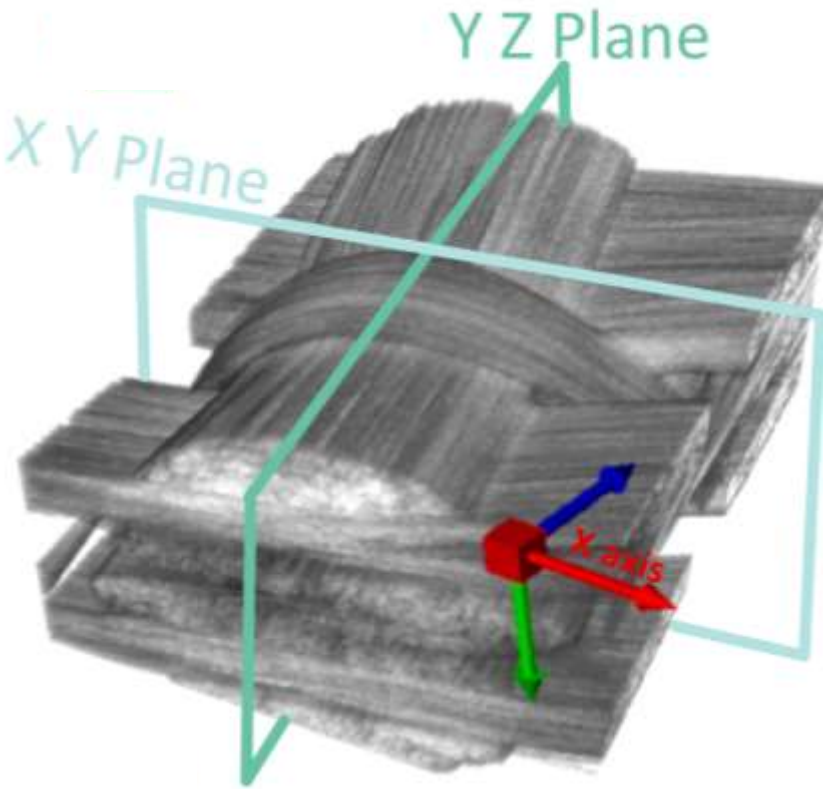


A. **3D Renderer**: fiber/pore visualization in the volume
B. **Scatterplot Matrix**: detailed fiber/pore selection according to their characteristics
C. **Polar Plot**: overview of fiber frequency distribution in volume
D. **Parallel Coordinates**: coarse fiber/pore selection according to their characteristics
E. **Class and Element Explorer**: fiber/pore class definition, browsing and statistics of fiber characteristics



MetaTracts

Original CT data



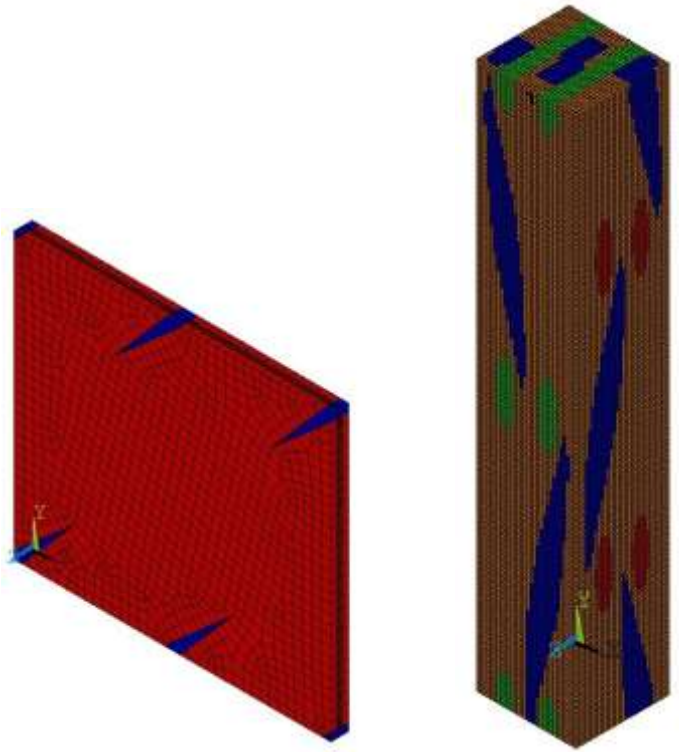
MetaTracts data

QUICOM Technology Platform

Hardware | Software | **Simulation**

- **X-ray simulation**
  Dedicated simulations for each of proposed part type for optimal XCT scans

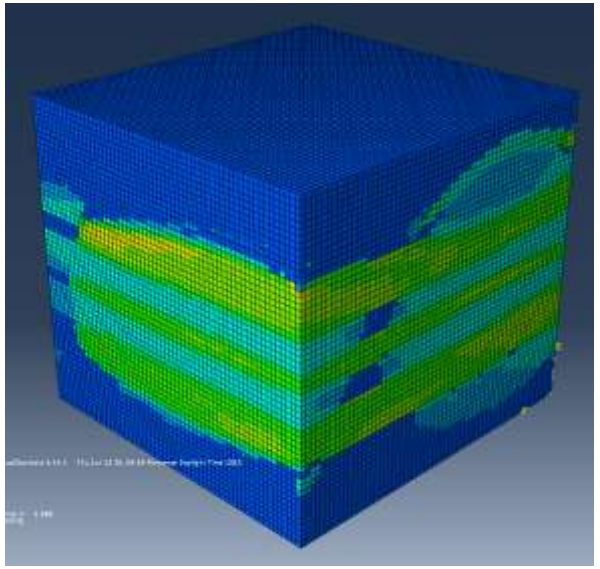
- **CFRP modeling and simulation**
  based on XCT data including flaws
  characterize precise mechanical properties



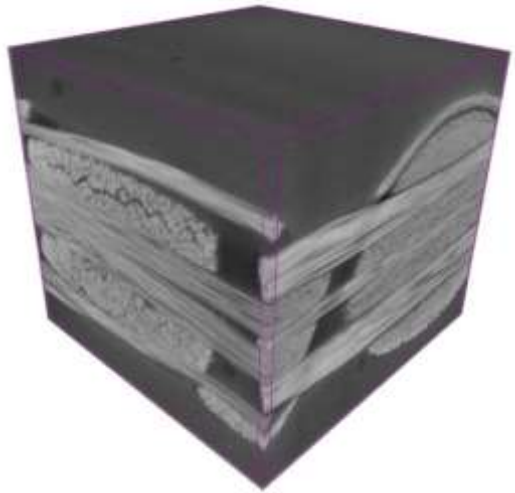
(images courtesy of UPAT)

Voxel-based modelling for textile composites

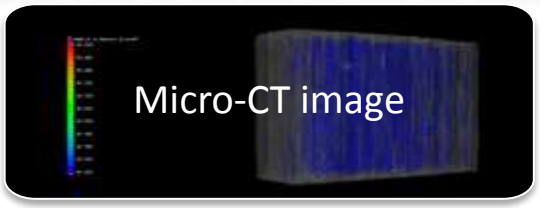
- **Advantages**
  - Geometrically simple – no need in triangulation / meshing of complex domains
  - Free from the problem of yarns interpenetration
  - Derivation from 3D CT images provides a way to model the material structure exactly as it is – hence no idealization



- **Applications**
  - Meso-level homogenization
  - Virtual testing for damage development
  - Preform permeability calculation



Multi-level Modeling of Porous CFRPs



Small Pores
- RVE
- Calculation of the Elastic Properties and Strength of the Matrix

Large Pores
- Unit Cell
- Calculation of the Elastic Properties and Strength of the Matrix

Macro Level- CFRP
- Progressive Damage Model

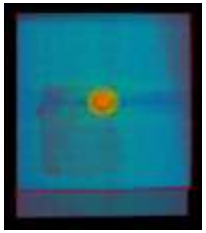
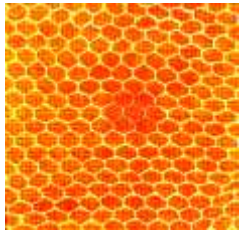
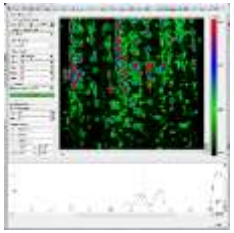
- **Basic features**
  - Models derived from Defect Analysis of CT images-Accuracy, Robust information
  - Distinguished impact of the effect of small and larger pores
  - Parametric RVEs regarding the Porosity Volume Fraction (V_f%), Pore size and Population → Adaptive to every porosity case
  - The progression of damage is simulated through the Progressive Damage Model at the Macro scale

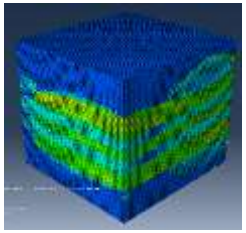
- **Main results**
  - Mechanical properties of the matrix in the presence of small and large pores
  - Mechanical properties of the CFRP laminate

Summary

Sneak peek into the **3 pillars** of the **QUICOM Technology platform**

- Hardware
  - **RobotCT**
  - **Fast process integrated CT**
- Software
  - **Comparison of CT with US** data
  - **FiberScout**, a visualization system for visual analysis of fiber, void, pore, crack etc., characteristics in FRPs.
- Simulation
  - **Voxel-based modelling** for textile composites
  - **Multi-level Modeling** of Porous CFRPs



This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n° ACP2-GA-2012-314562.

The project is endorsed by the European Aeronautics Science Network – EASN.

Thanks for your attention!

Questions?