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3D Inspection Of AM Components Using CT:

From Defect Detection To Thermal Simulation In COMSOL Multiphysics®

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COMSOL Conference 2020

Simpleware Product Group

- Developers of high-end 3D image processing software
- Dedicated sales, support and service teams
- Global presence
- Working with customers in clinical, life sciences, materials, manufacturing and more…

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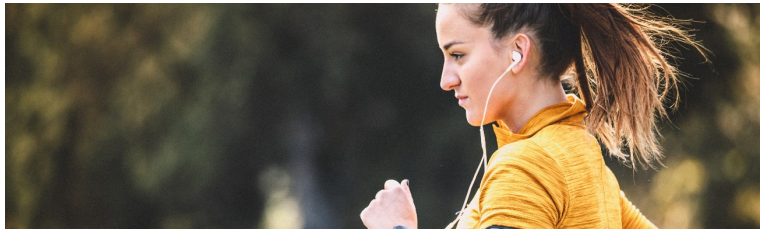
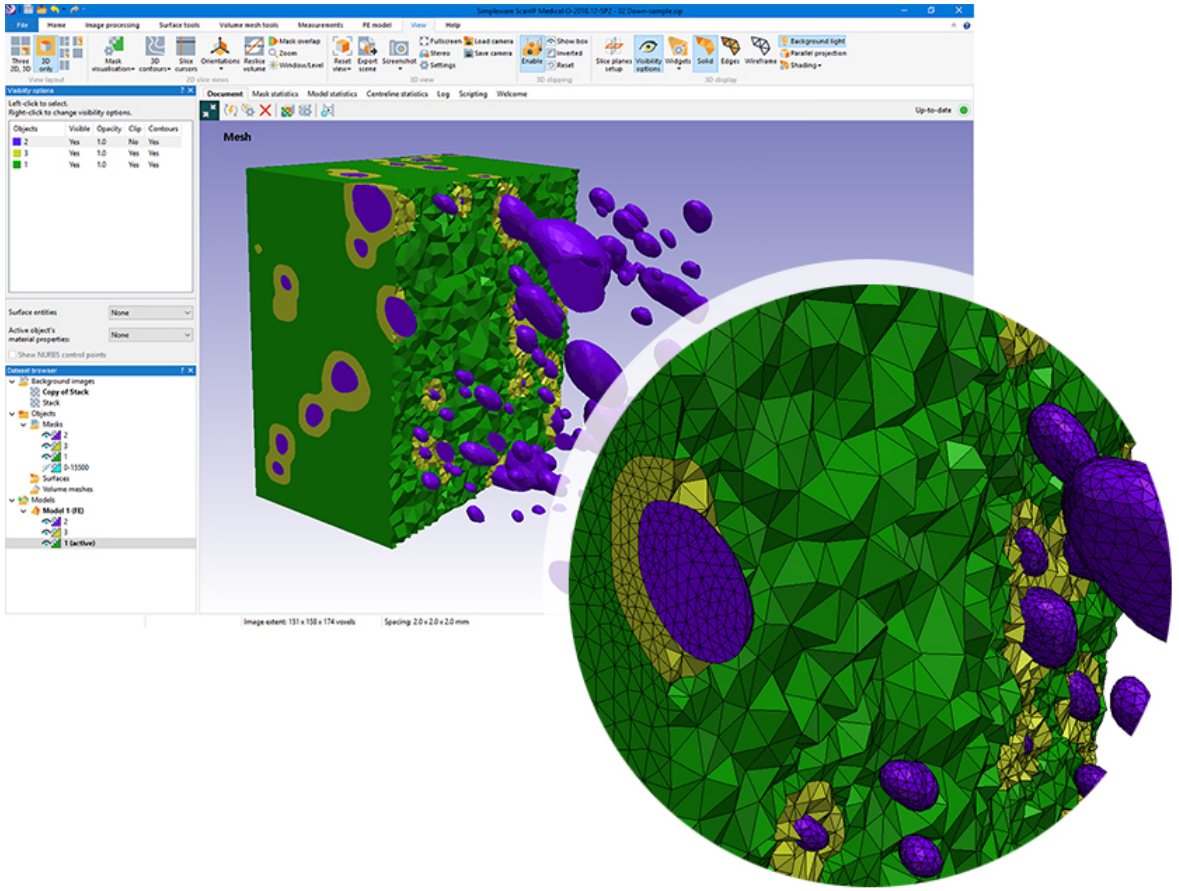


Simpleware Software Solutions

GUI-based high-end 3D image processing platform which provides comprehensive range of tools for:

- Visualization including animations
- Filtering and segmentation
- Measurement, quantification and statistics
- CAD and image integration
- 3D print, CAD and FEA/CFD model export
- Scripting and automation

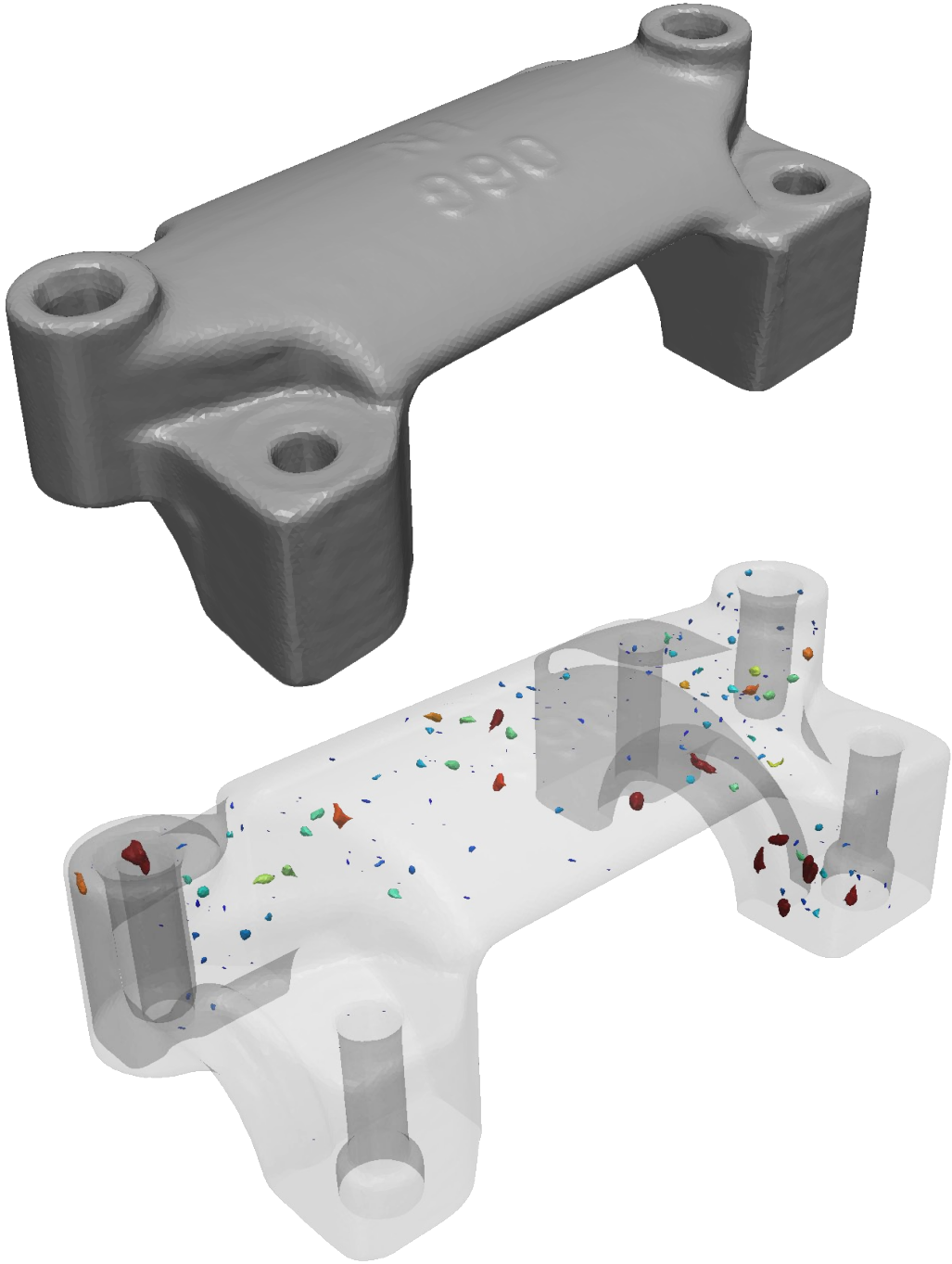


How to inspect complex AM parts?

"What are the differences between my design and the part that is actually produced by AM?"

"How will these differences affect real world performance?"

These questions can be answered using 3D image-based modelling & simulation



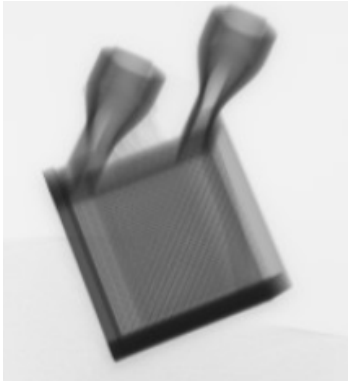
What is image-based modelling & Simulation?

AM part

&

Nikon MCT225 metrology X-ray CT

Scan



Radiographs

Reconstruction

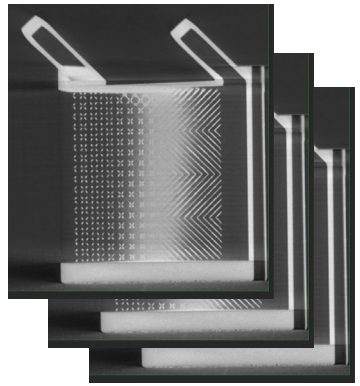


Image slices

What is 3D image-based modelling?

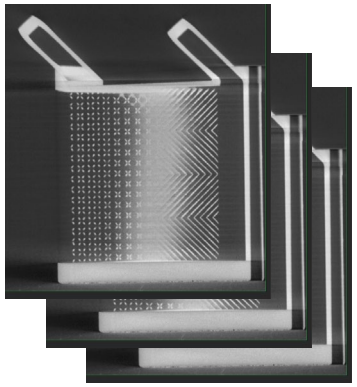
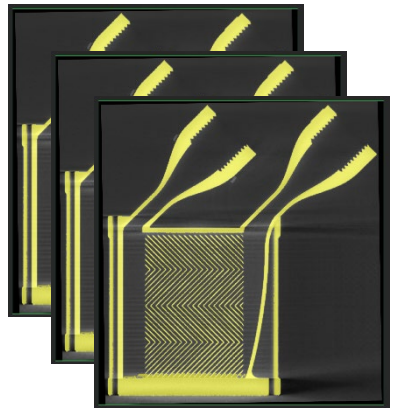


Image slices

3D image processing

Visualise

Segment



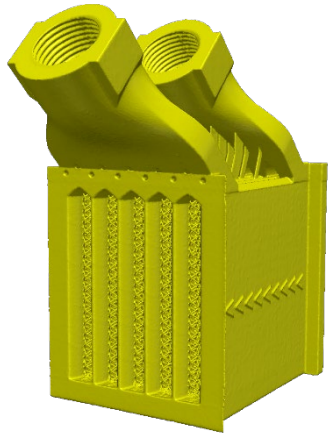
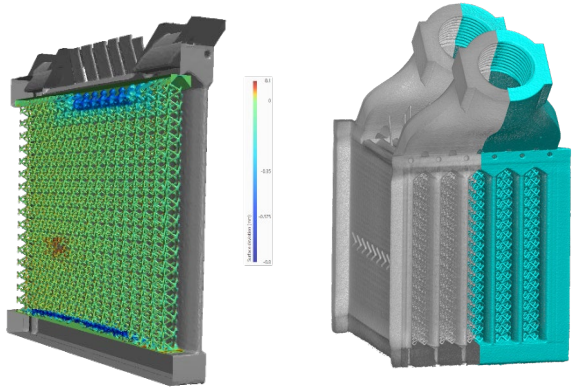


Image-based model

Compare to CAD

Inspect



Find and characterise defects

What is 3D image-based simulation?

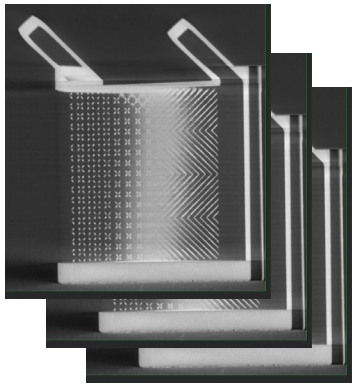
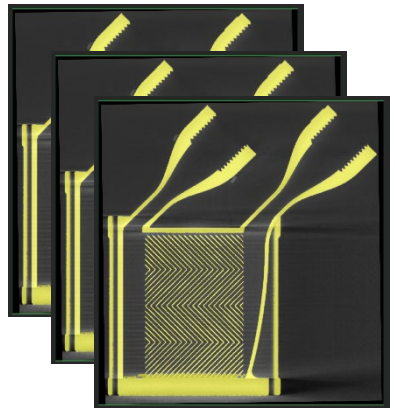


Image slices

3D image processing

Visualise

Segment



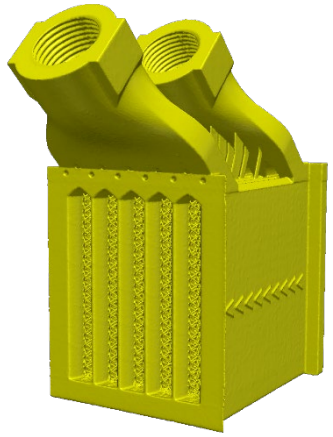
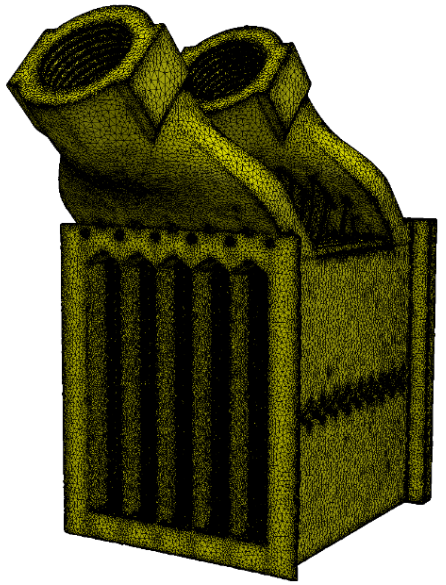
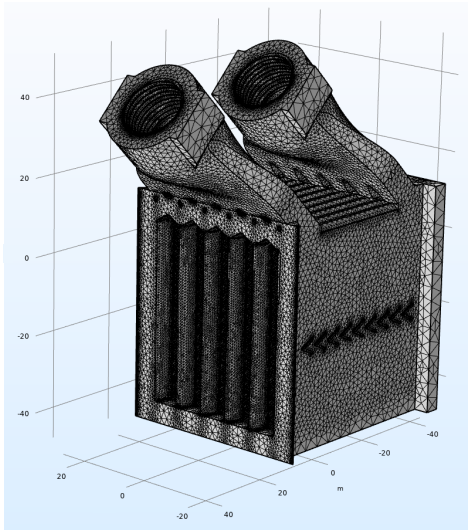


Image-based model

Mesh



Simulate



The “Hot Box”

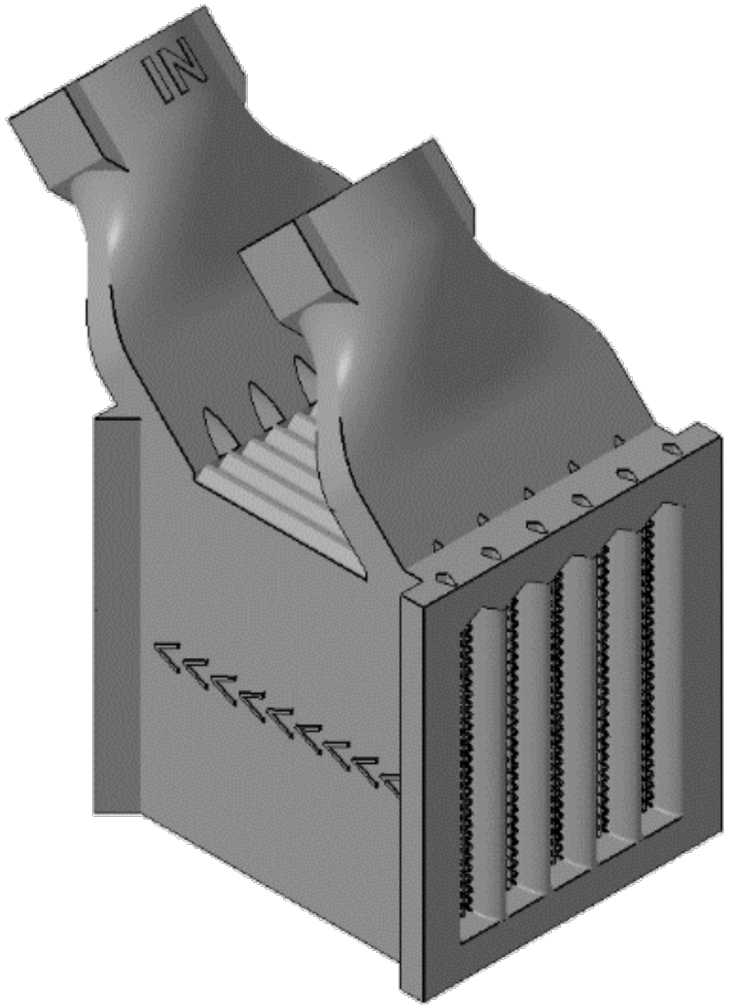
- Test jig designed to test performance of topologies before being integrated into bespoke heat exchangers.

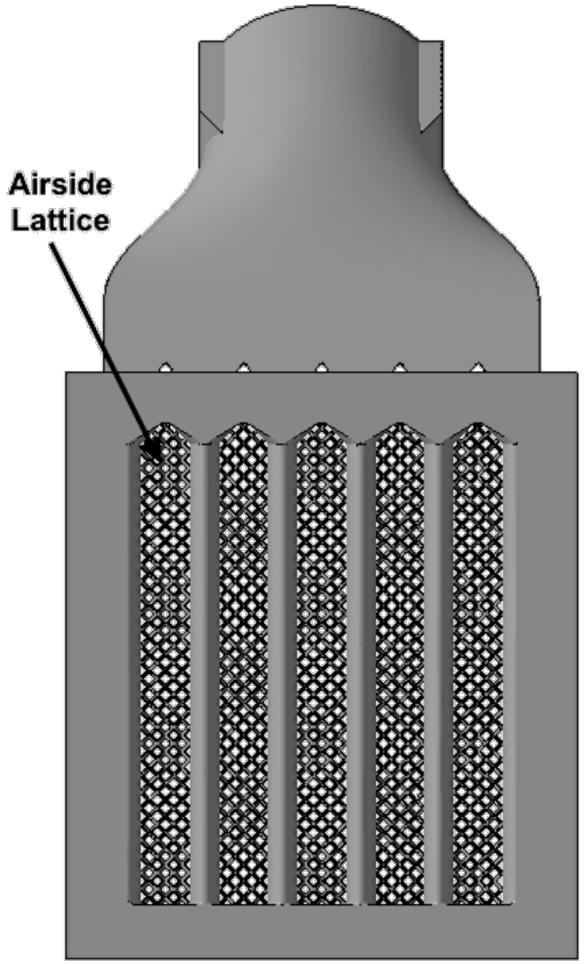
- Design includes:
    1. Five sections of lattice structure which air flows through separated by six fins
    2. Liquid coolant flows through cross corrugated channels within the six fins

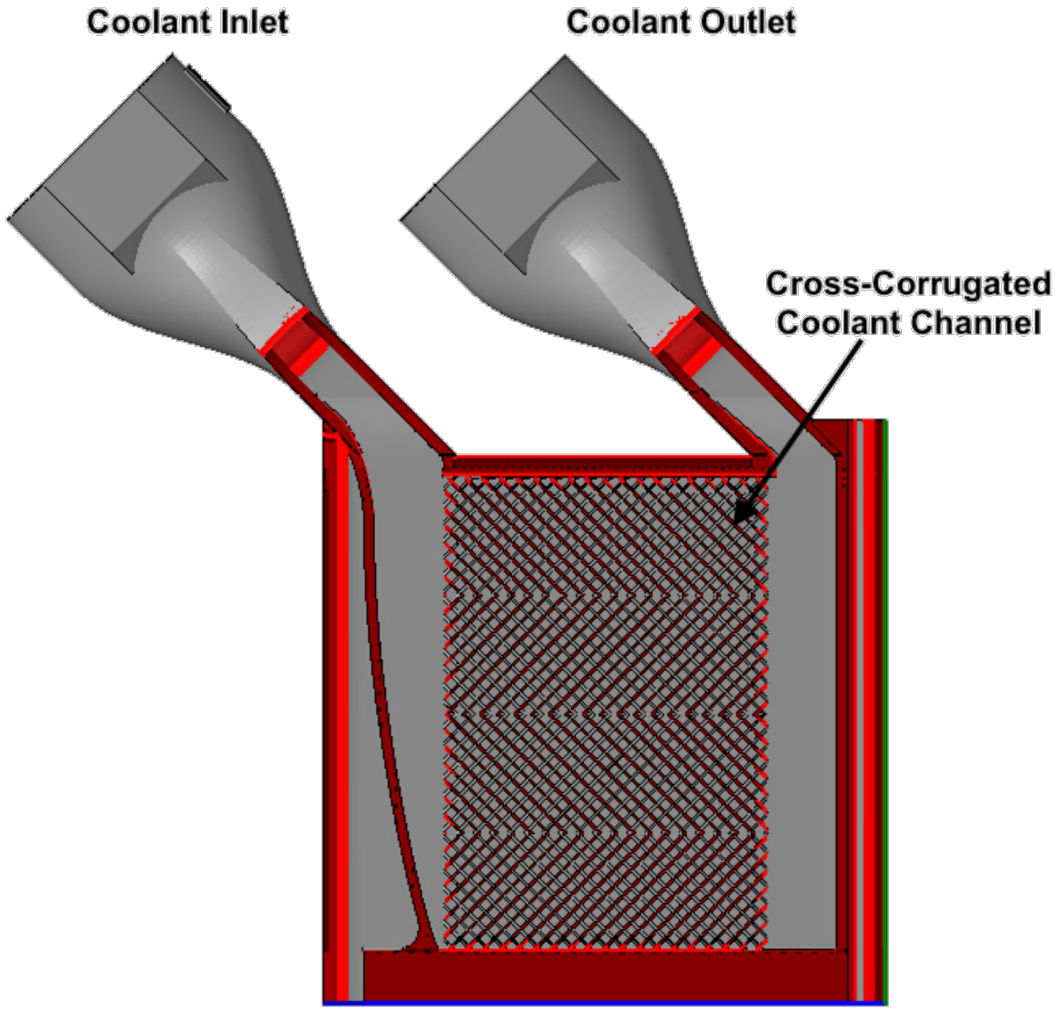
- Designed and manufactured by Hieta Technologies Ltd (UK)

- Manufactured in AlSi10Mg

The “Hot Box” Design



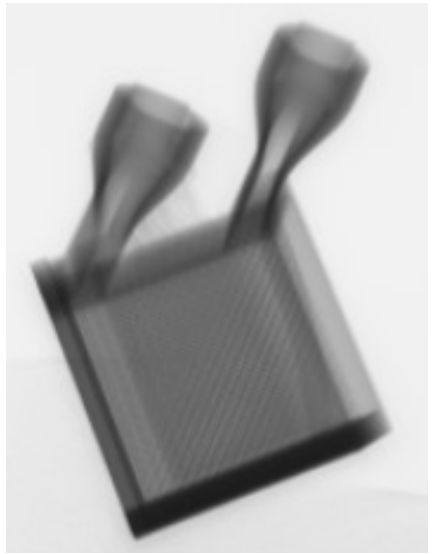




Scanned and reconstructed

- Hot box scanned and reconstructed using Nikon MCT225 metrology X-ray CT System at the Manufacturing Technology Centre (UK)
- Scan parameters shown below
- Reconstructed into a stack of images

Component	Al Hotbox
System	XT H 225 ST
Voltage	192 kV
Current	85 μA
Filtration	1 mm Al
Voxel Size	67 μm
Scan Time	3540 s



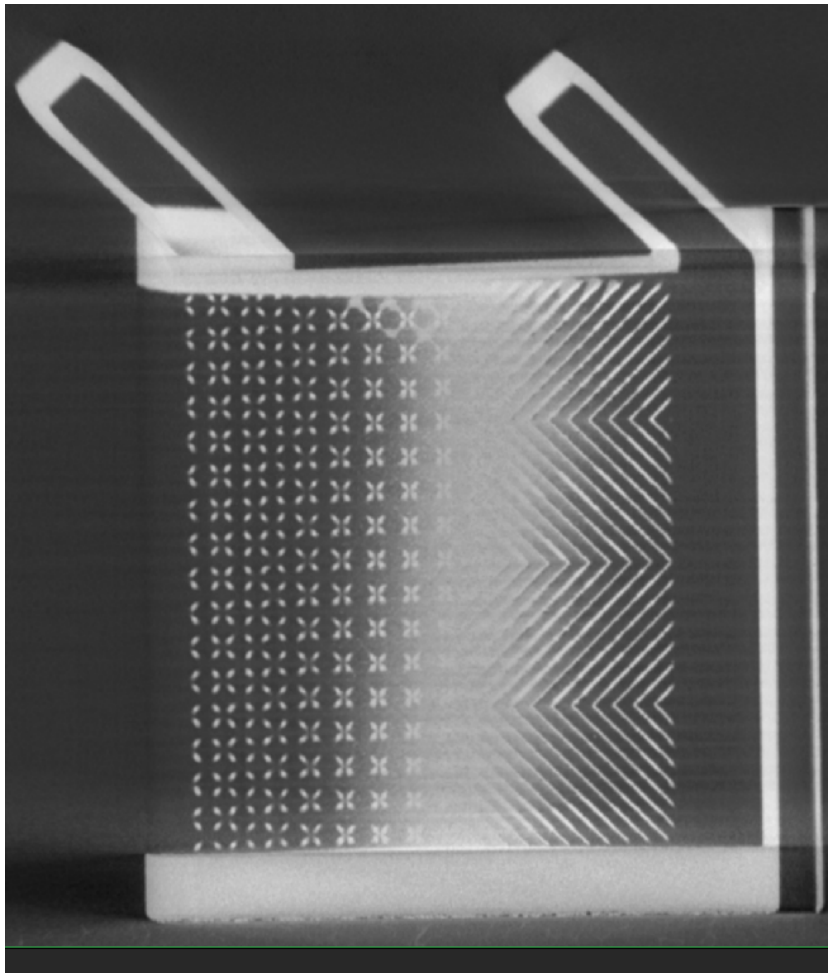
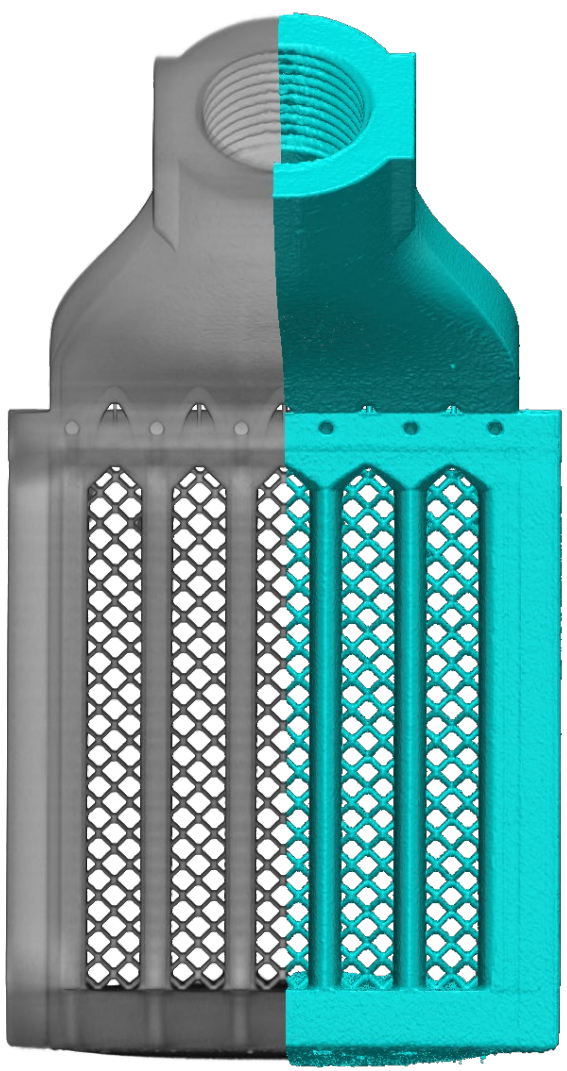
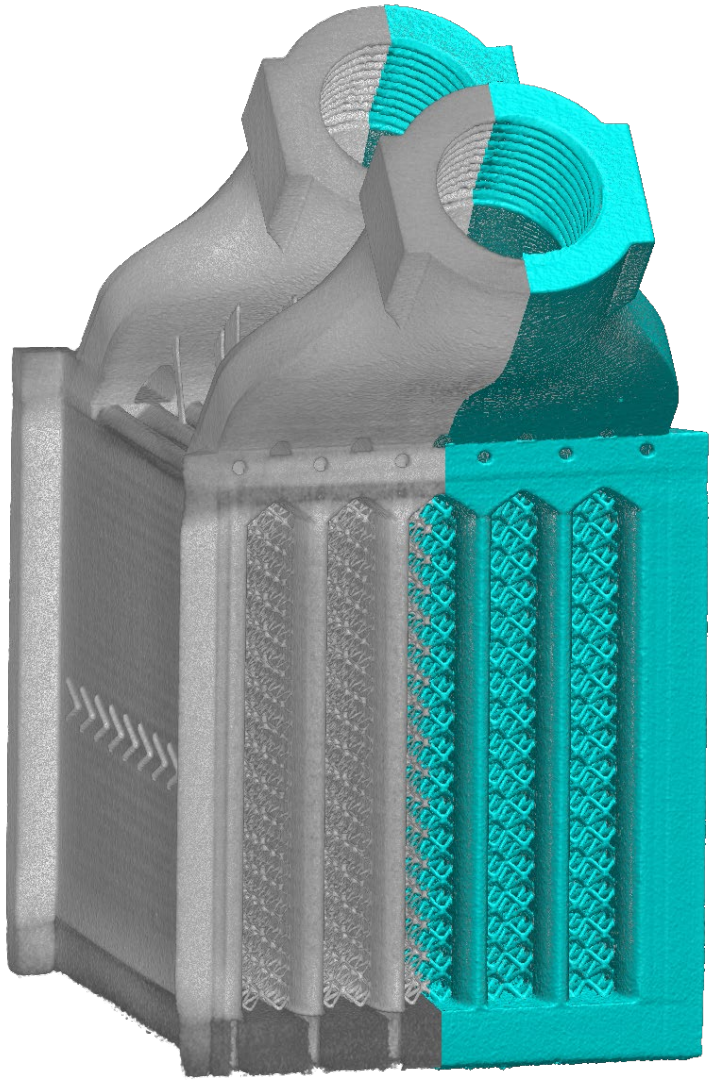


Image based model in Simpleware ScanIP

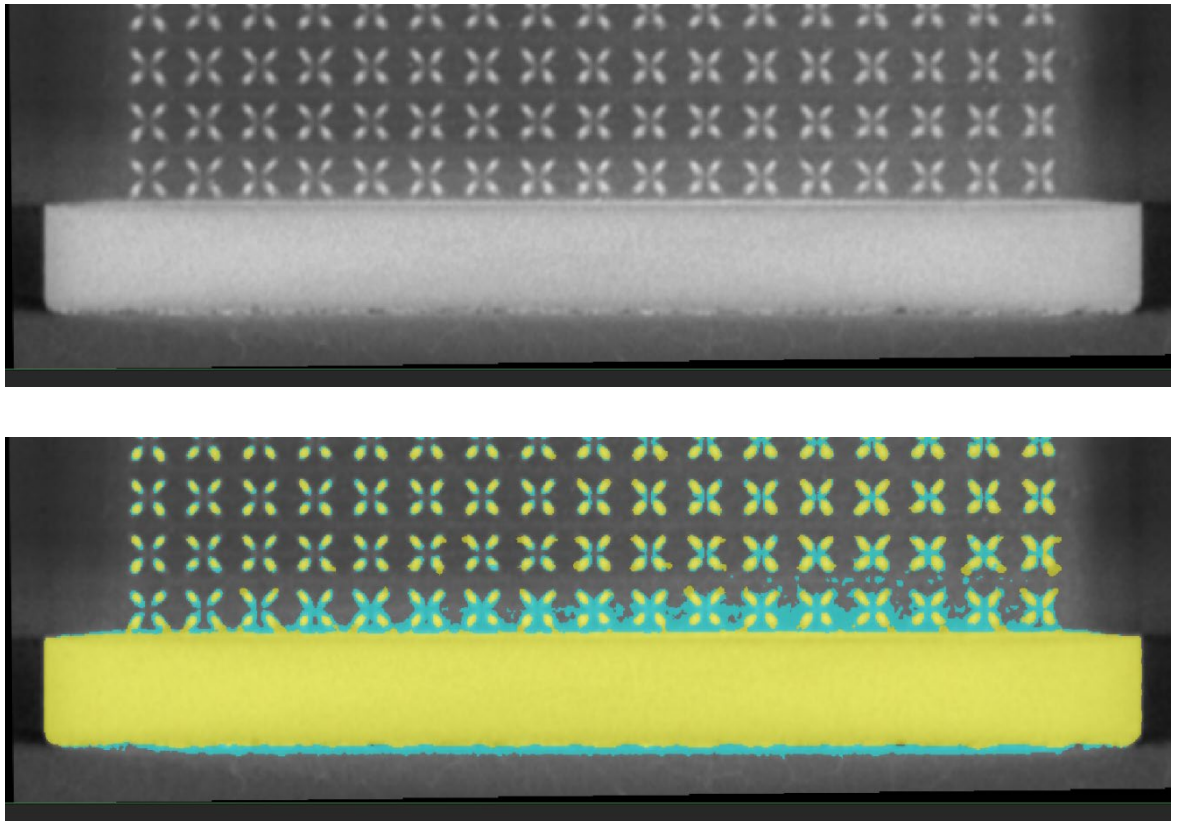
- Stack of image imported into Simpleware ScanIP
- Volume rendering (grey) used for initial inspection showing powder build up in the base of the Hot Box.
- Automated Segmentation tools used to generate the initial Image-based model (blue)





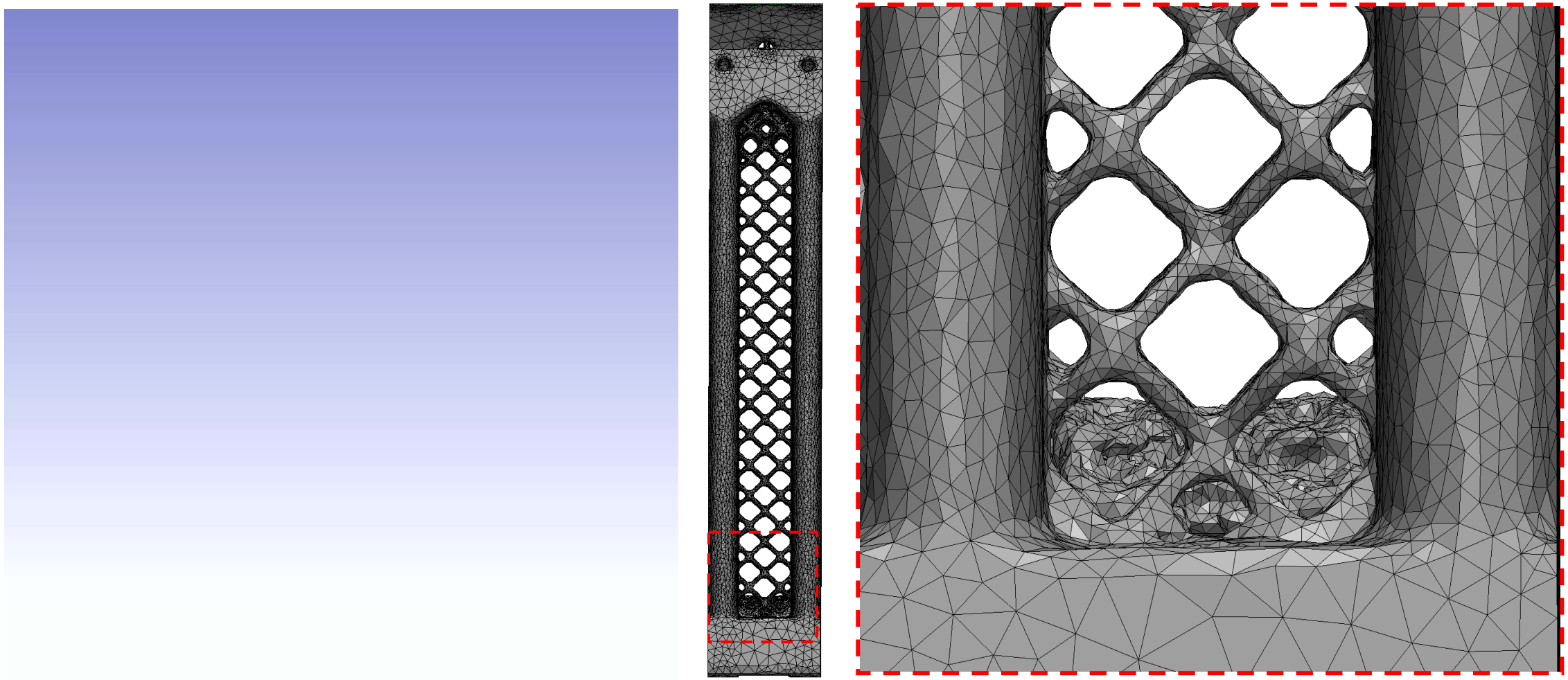
Segmentation

- To generate an accurate Image-based model a series of automated segmentation tools were used.
  - OTSU (blue)
  - Local surface correction (yellow)
  - Light smoothing
- The local surface correction filter is used to overcome problems caused by image artifacts such as:
  - Beam hardening
  - Streaking
  - Ring artifacts



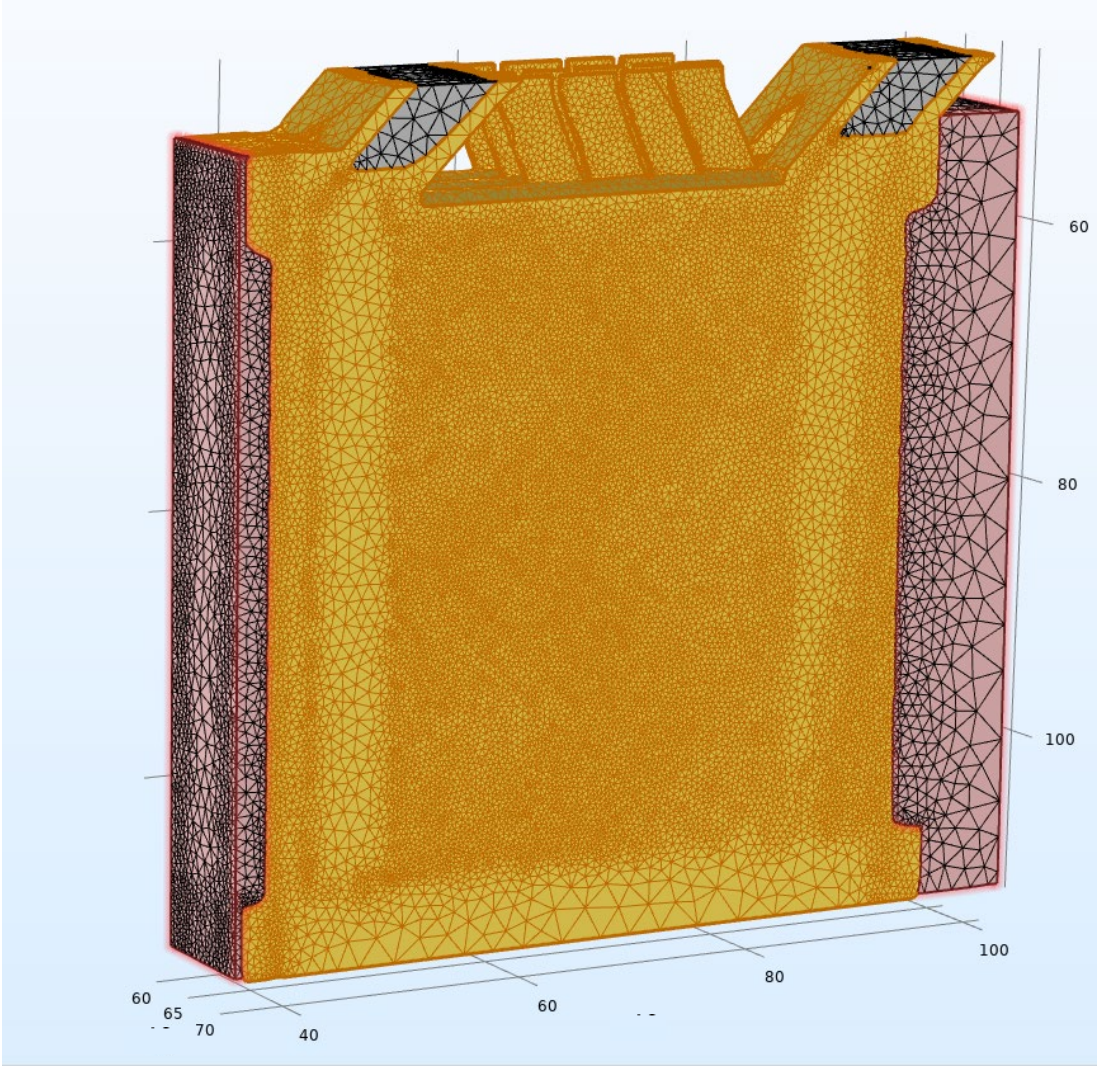
Top: section of greyscale image data, Bottom: section of greyscale image data overlaid with OTSU (fully automatic) segmentation (blue), and OTSU + local surface correction (yellow).

Image-based Finite Element Meshing



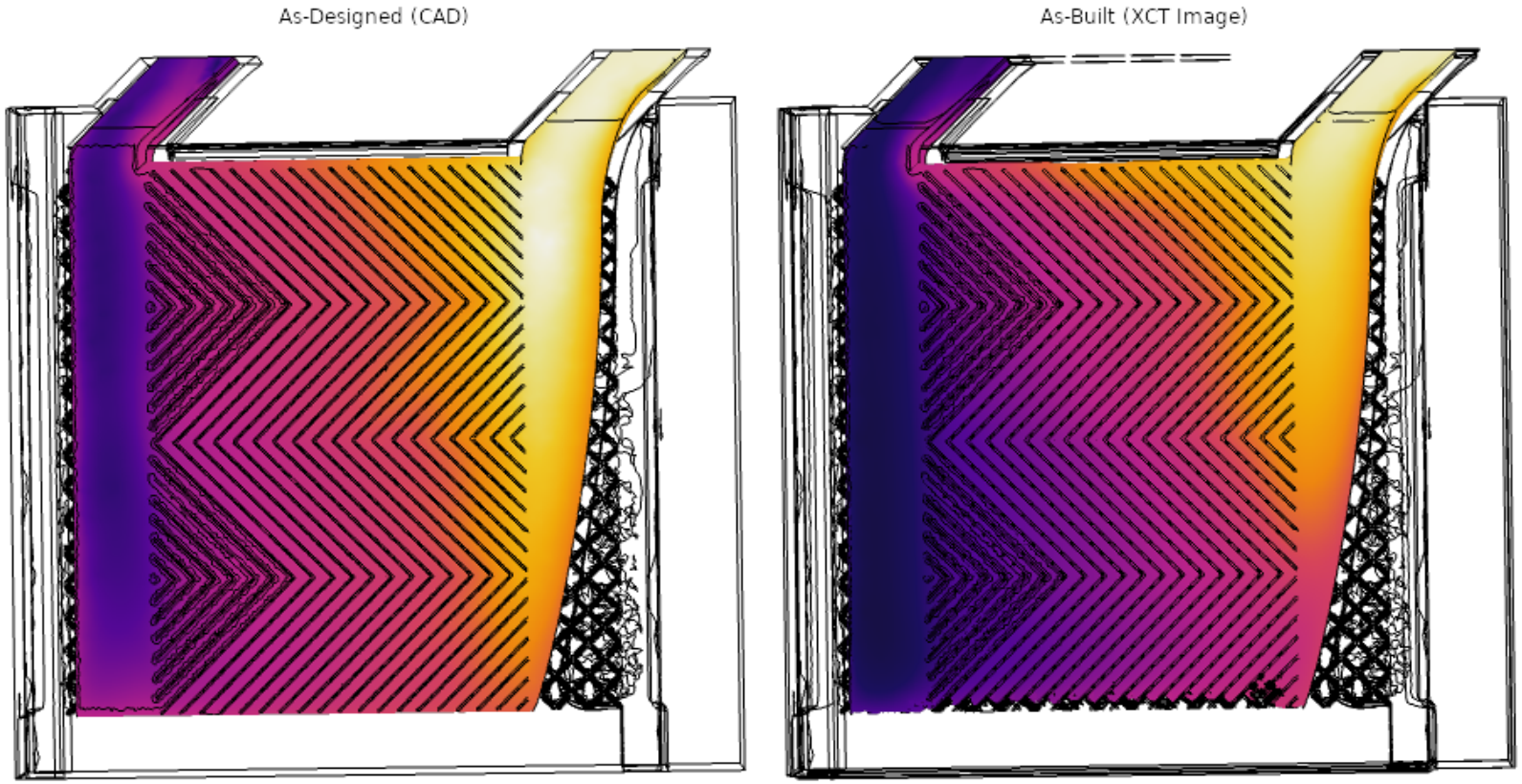
Thermal simulation in COMSOL

- Subsection of full design chosen
- Centre lattice and two fins containing cross corrugated channels
- 3 Phases modelled:
  - Metal (yellow)
  - Air (red)
  - Fluid (grey)
- Full volumetric mesh exported from Simpleware ScanIP to COMSOL Multiphysics
- Simulation of thermal behavior, coupled heat transfer and laminar flow.



Thermal simulation results

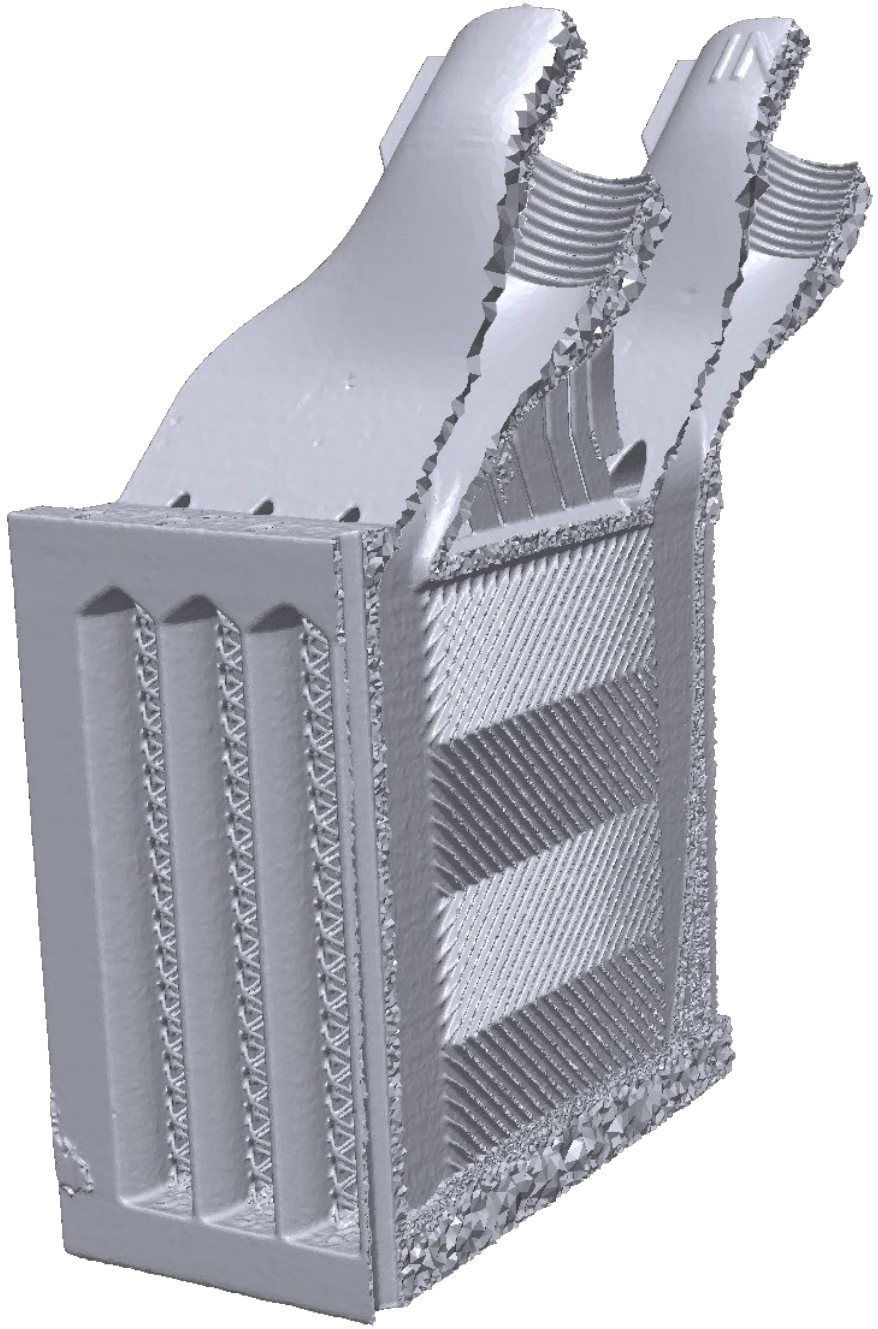
- Thermal simulation of “As-built” image shows less uniform heat dissipation.
- “As-built” part performs worse than the “as-designed” due to geometrical deviations (blocked channels, imperfect lattice)
- This means the “as-built” part is not as efficient at heat dissipation compared to the initial design.



Left: Heat map from thermal simulation of “As-designed” part (from CAD part)
Right: Heat map from thermal simulation of “As-built” part (image-based simulation)

Conclusion

- This workflow demonstrates how to use X-ray CT and image-based modelling and simulation as a non destructive test method to:
  - find defects in the manufactured part
  - determine the impact on real world performance
- This allows better allocation of time and physical test resources



Project partners

Innovate UK: 3in1 X-ray CT Inspection

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Thank You

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