Image Based Modelling:
New Tools for Design and Analysis

From 3D Images to Models –

Philippe Young– Professor University of Exeter/ R and D Director Synopsys
pyoung@synopsys.com

Sept 05 2018 SWANSEA

Synopsys / Simpleware Intro

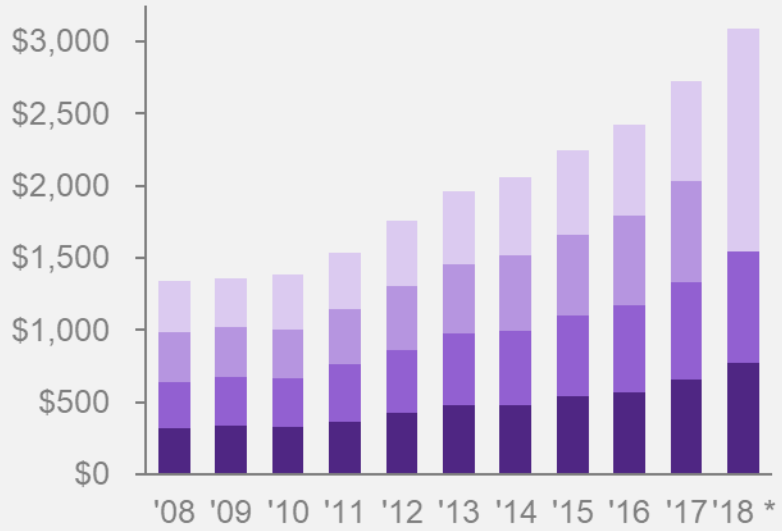
SYNOPSYS®

Synopsys Today

FY17 Revenue: ~$2.7B

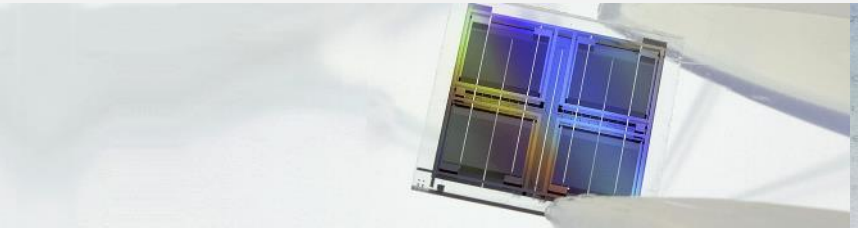
Employees: >12,590

Years: 30+



* Note: FY2018 guidance midpoint provided May 23, 2018

- **#1** electronic design automation tools & services
- **Broadest IP portfolio** and **#1** interface, analog, embedded memories & physical IP
- **'Leader'** in Gartner's Magic Quadrant for application security testing

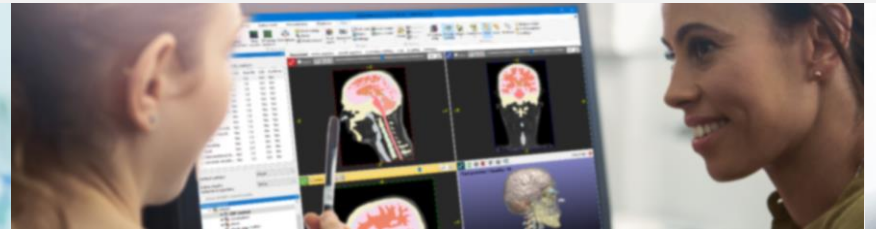


SYNOPSYS®

Simpleware Product Group

- Developers of high-end 3D image processing software
- Dedicated sales, support and service teams
- Global presence
- Customer base in life sciences, materials and manufacturing applications

SYNOPSYS® | SIMPLEWARE PRODUCT GROUP

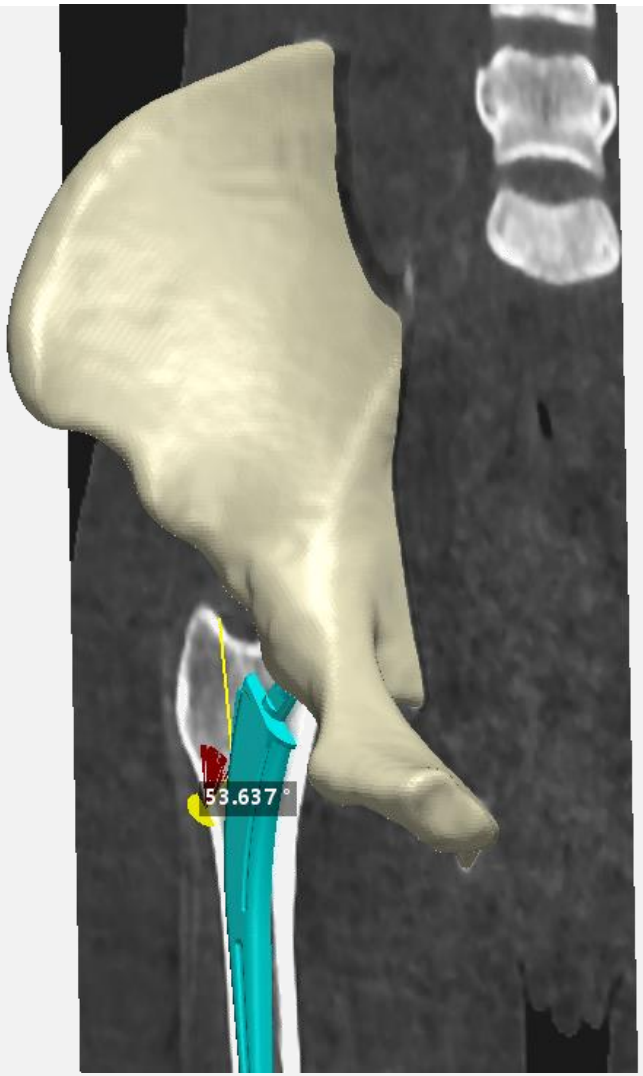

SYNOPSYS®

What Does Image Based Modelling Offer

Medical/Clinical Industry Example:

Cut down on intra-operative time and improve clinical outcomes

- Based on pre-operative scans (e.g. CT, MRI)
- Take pre-operative virtual measurements
- Carry out virtual planning, e.g. resect bone, virtually check fit of implant or stent within artery
- 3D print: obtain a physical model of femur or aorta for pre-surgical planning/training



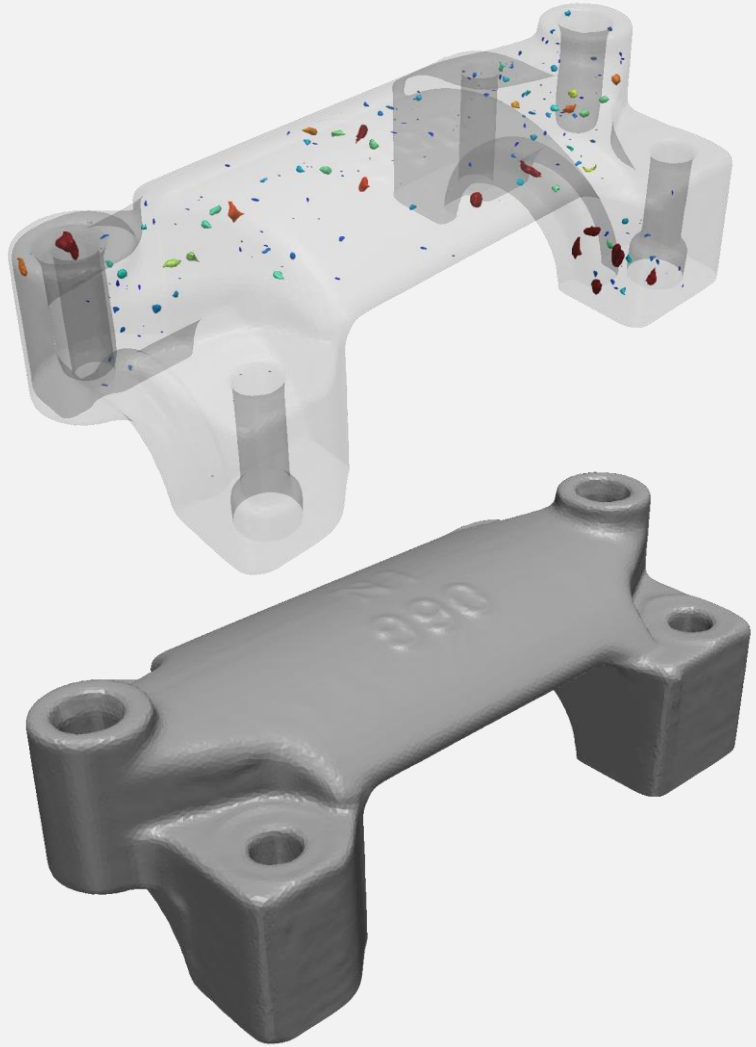
SYNOPSYS®

What Does Image Based Modelling Offer

Industrial Reverse Engineering Example:

Inspect and validate as-built parts and compare to designs

- Take scans of a manufactured part, e.g. casting, ALM, injection moulding…
- Non destructive 3D visualisation, e.g. to quantify defects
- Carry out geometric metrology, measurements, compare to original CAD
- Facilitate simulation on as built or damaged part to check still fit for purpose



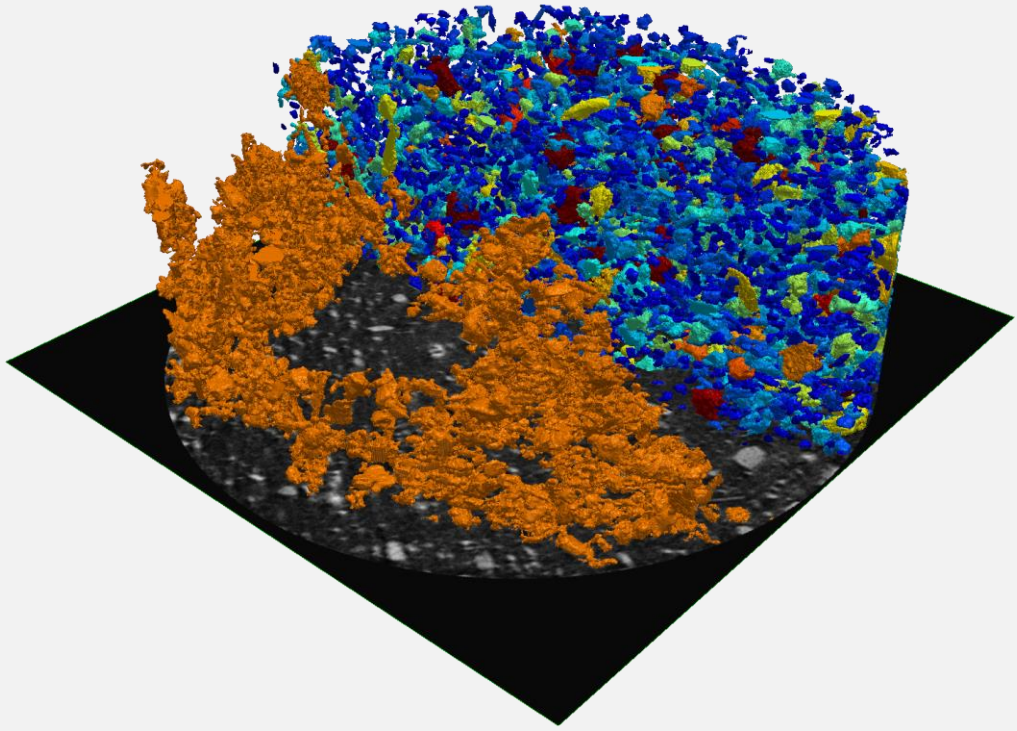
SYNOPSYS®

What Does Image Based Modelling Offer

Materials Industry Example:

Understand or improve performance of a microstructure, e.g. filter, foam, composite, textile, soil, asphalt…

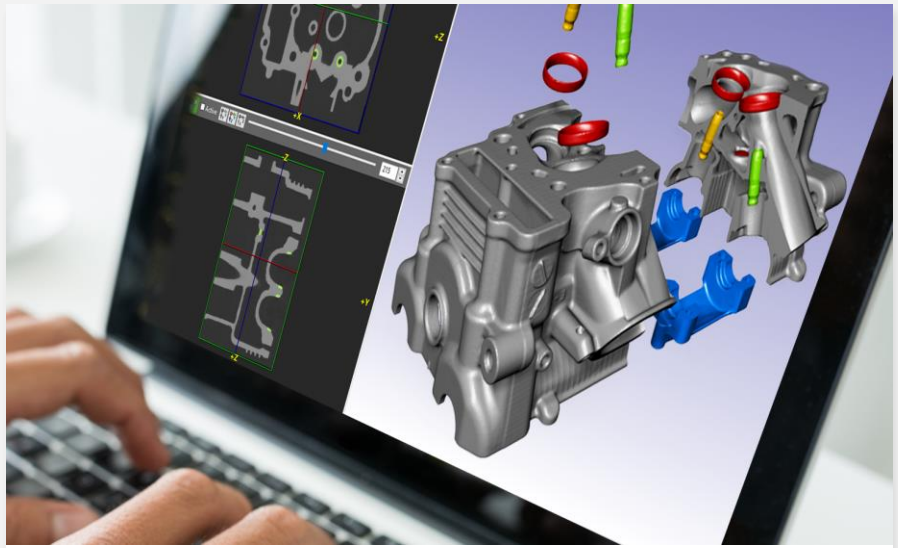
- Visualise internal structure from scans or synthetic data
- Calculate porosity, surface area, pore/particle distribution, fibre orientation…
- Analyse network structures, e.g. centrelines, shortest routes…
- Obtain homogenised material properties, e.g. effective permeability, Young's Modulus…



Simpleware Product Group

Customer Applications

Life Sciences



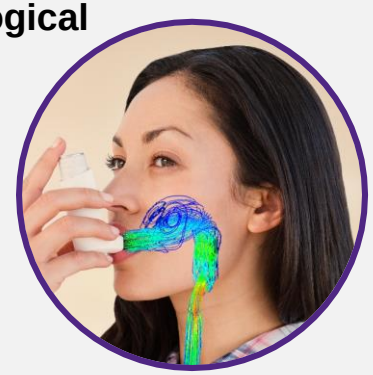
Manufacturing & Materials

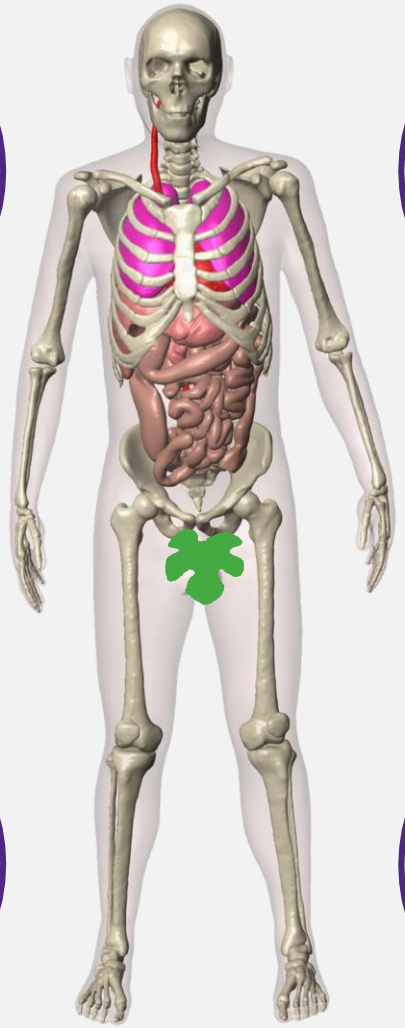
SYNOPSYS®

Applications in Life Sciences / Product Integration

3D Printing

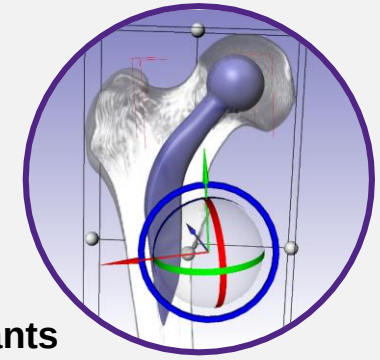
Physiological Flows





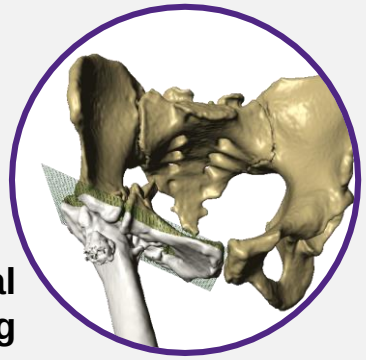
Protective Gear

Wearable Electronics

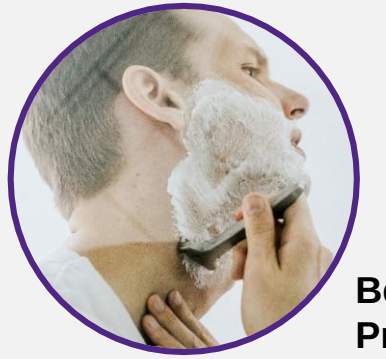


Implants

Pre-Surgical Planning



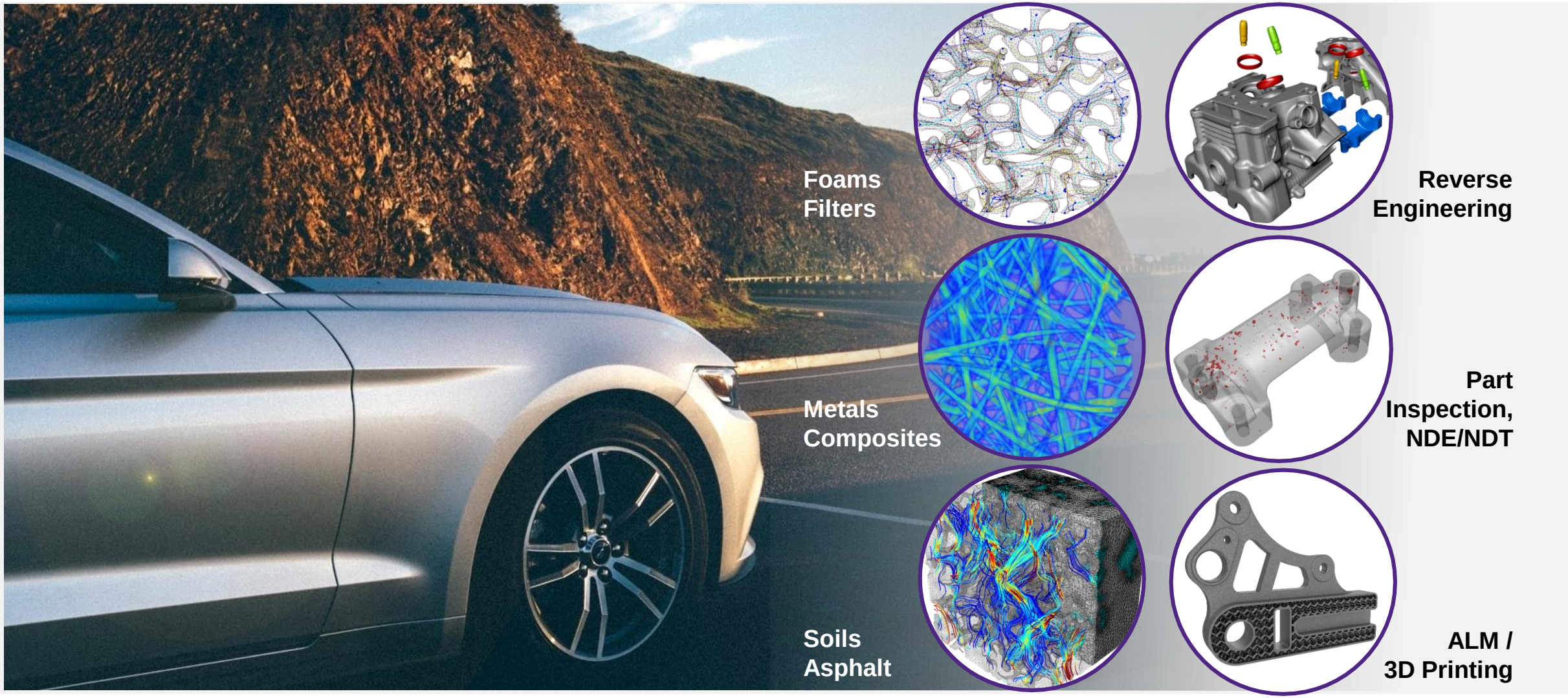
Shoes / Clothing



Beauty & Care Products

SYNOPSYS®

Applications in Materials & Manufacturing



SYNOPSYS®

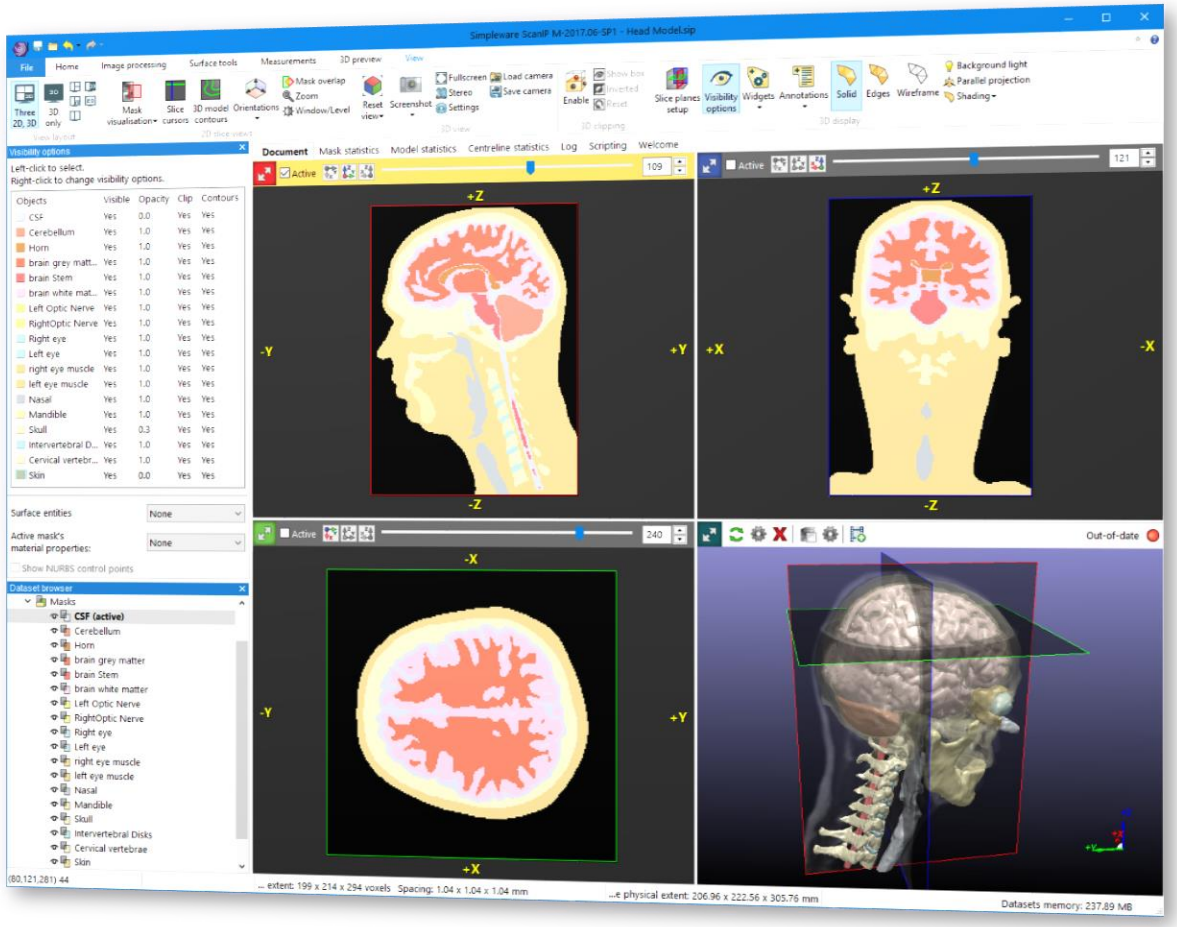
Simpleware Software Solutions

SYNOPSYS®

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 and quantification
- CAD and image integration
- 3D print, CAD and FEA/CFD model export



SYNOPSYS®

Simpleware Software Solutions

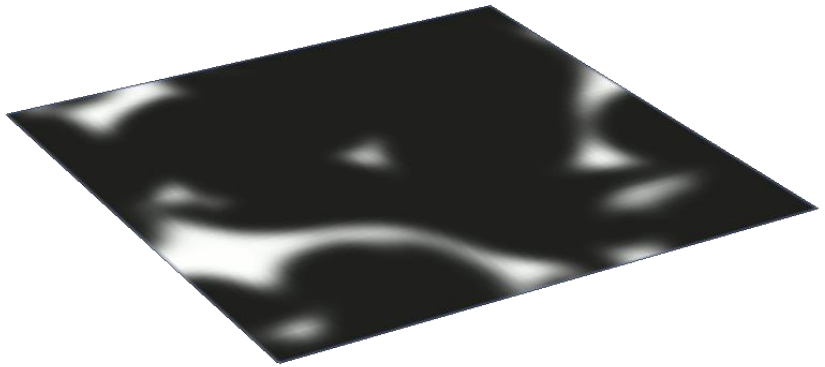
3D Image Import & Visualization

Segmentation & Processing

Measurements & Analysis

CAD & Image Integration

Model Generation



SYNOPSYS®

Simpleware Software Solutions

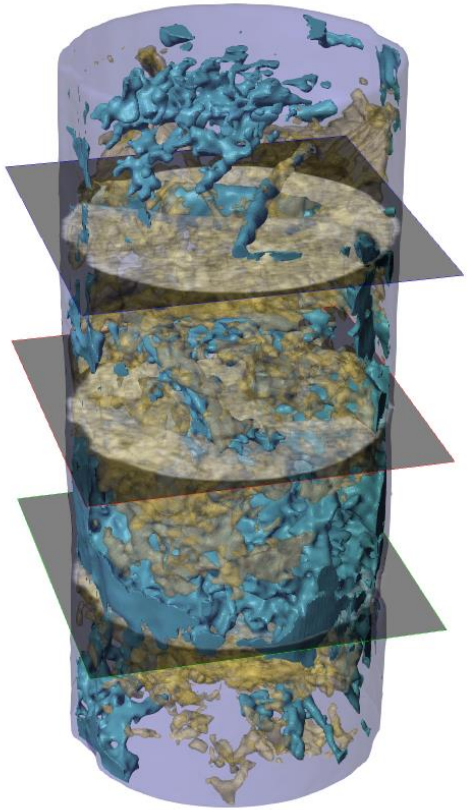
3D Image Import & Visualization

Segmentation & Processing

Measurements & Analysis

CAD & Image Integration

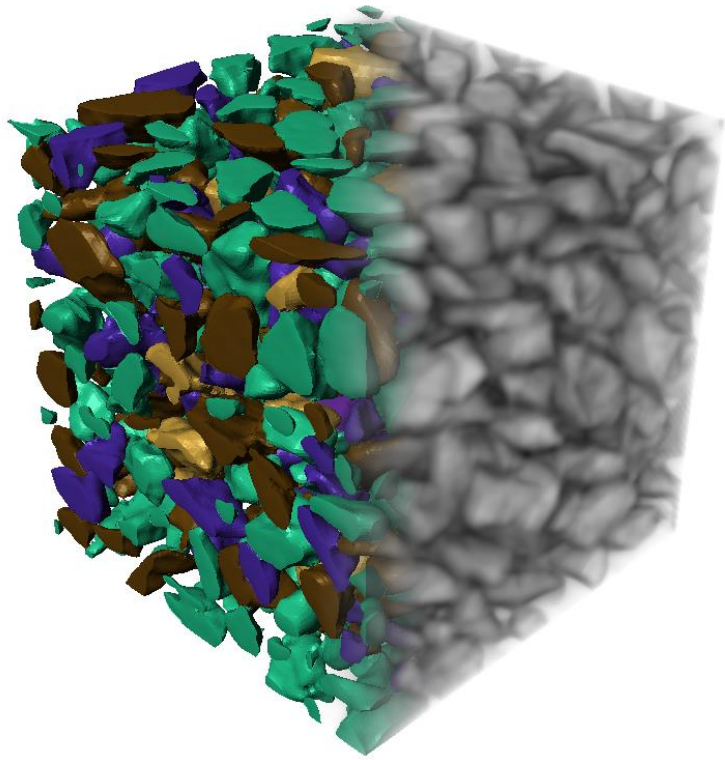
Model Generation



SYNOPSYS®

Simpleware Software Solutions

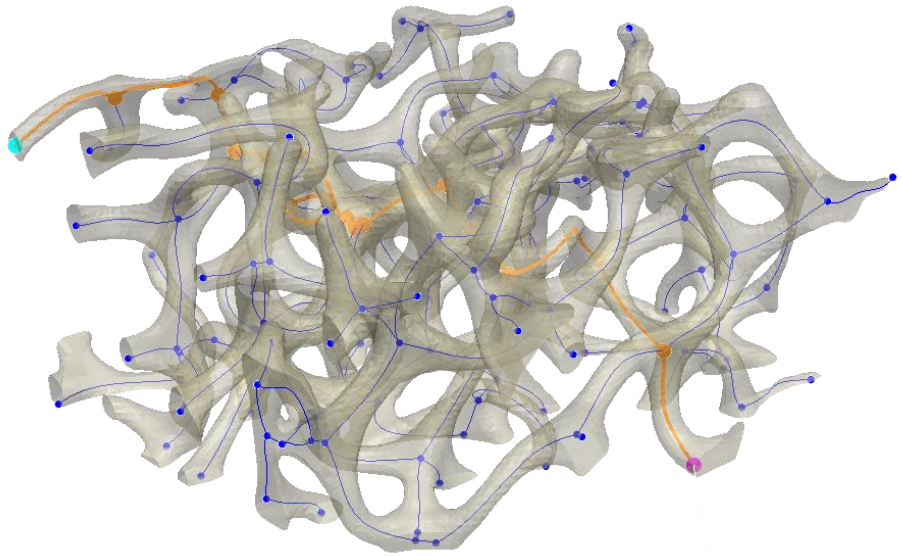
- 3D Image Import & Visualization
- **Segmentation & Processing**
- Measurements & Analysis
- CAD & Image Integration
- Model Generation

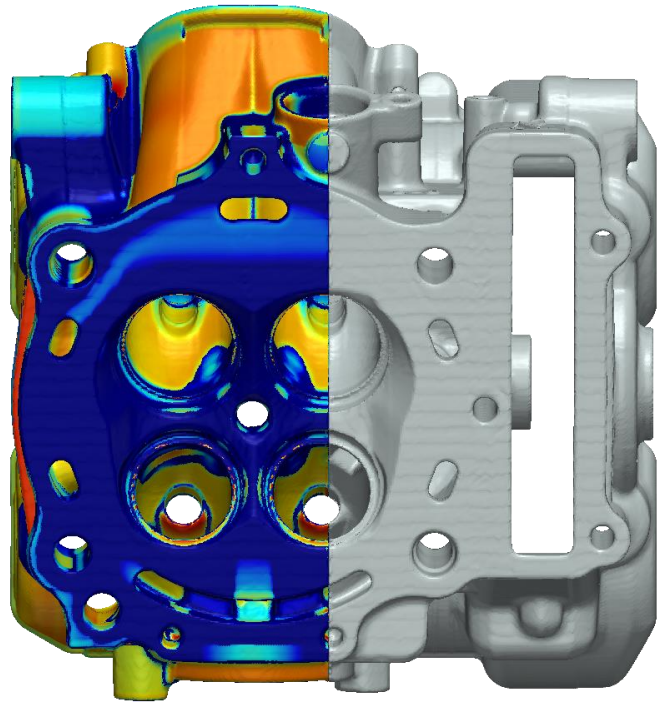


SYNOPSYS®

Simpleware Software Solutions

- 3D Image Import & Visualization
- Segmentation & Processing
- **Measurements & Analysis**
- CAD & Image Integration
- Model Generation

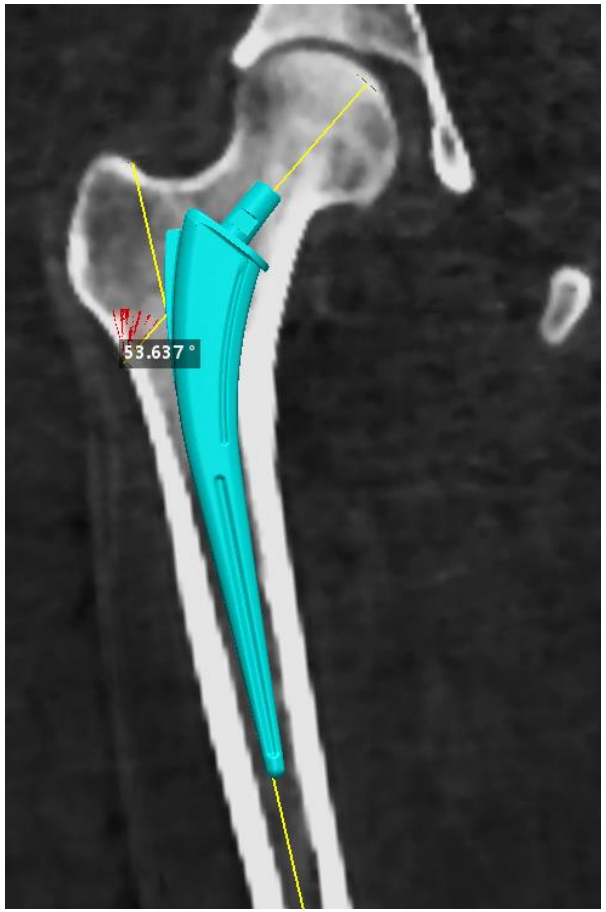


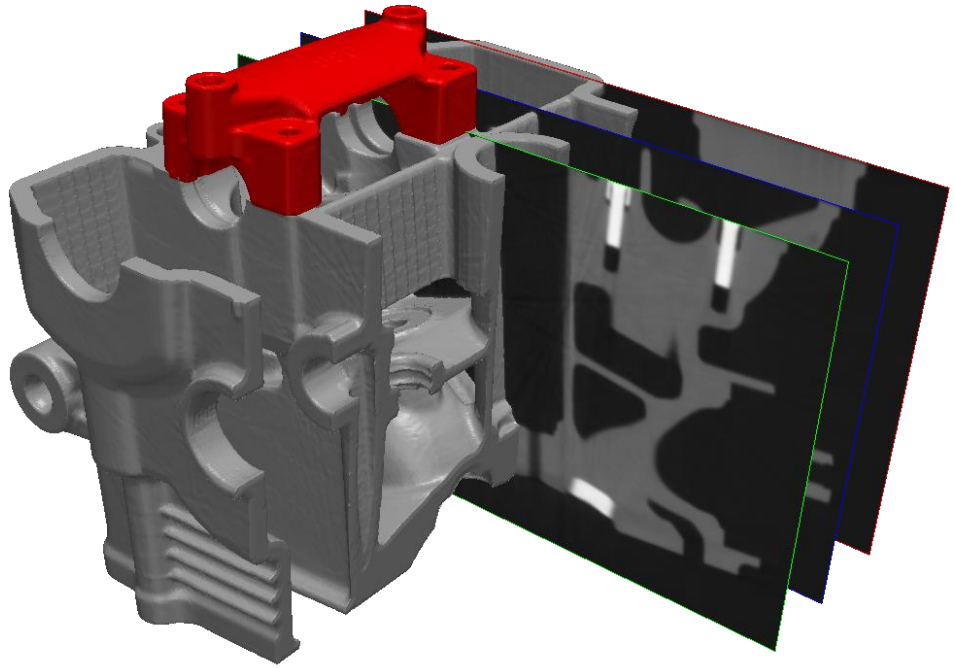


SYNOPSYS®

Simpleware Software Solutions

- 3D Image Import & Visualization
- Segmentation & Processing
- Measurements & Analysis
- **CAD & Image Integration**
- Model Generation

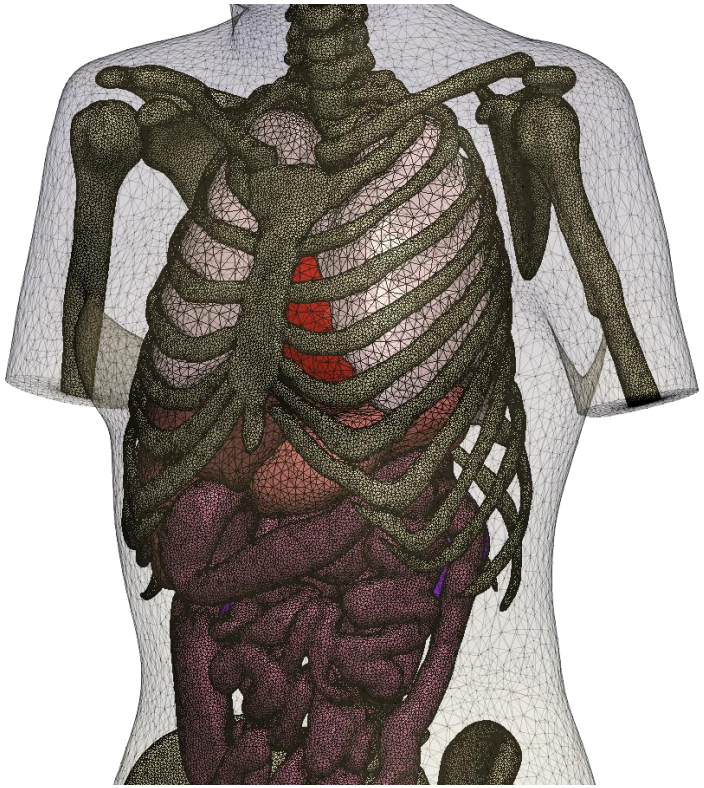


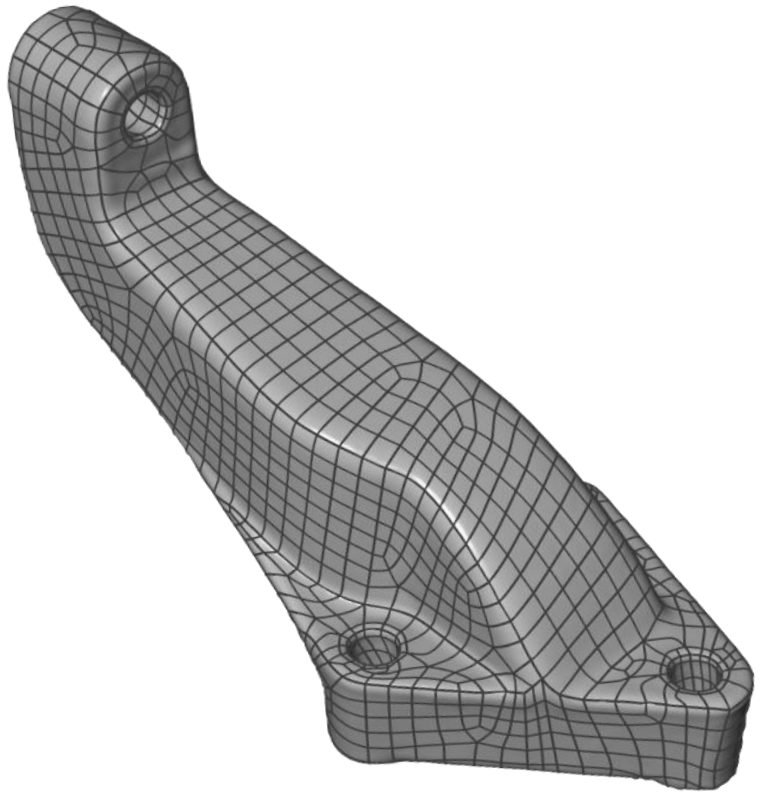


SYNOPSYS®

Simpleware Software Solutions

- 3D Image Import & Visualization
- Segmentation & Processing
- Measurements & Analysis
- CAD & Image Integration
- **Model Generation**





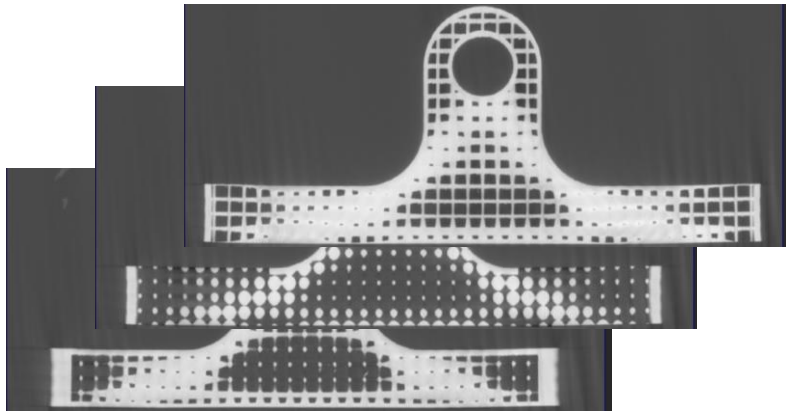
SYNOPSYS®

Simpleware Image-based modelling workflow

SYNOPSYS®

CT Scan of Part

North Star Imaging (NSI) CT Scanner



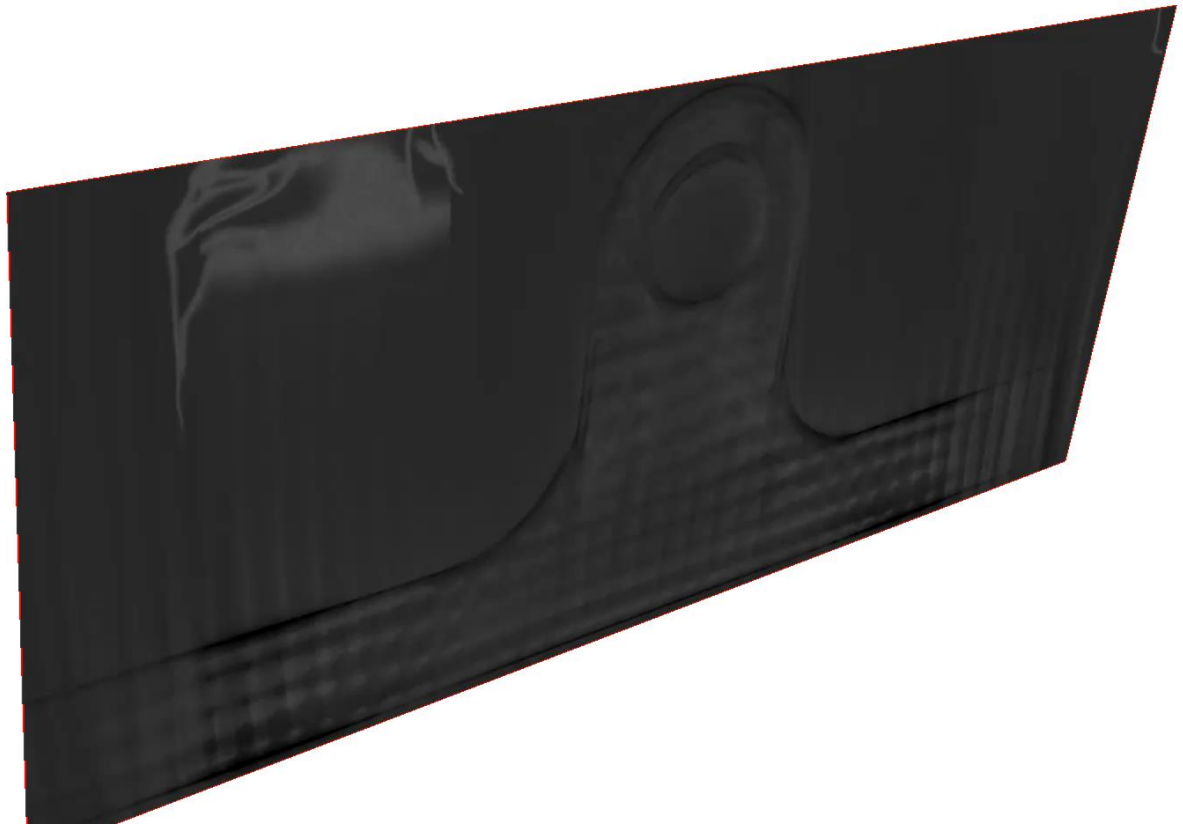
Exported Slices

Content Courtesy of NORTH STAR IMAGING NSI AN ITW COMPANY

SYNOPSYS®

Image-based modelling workflow

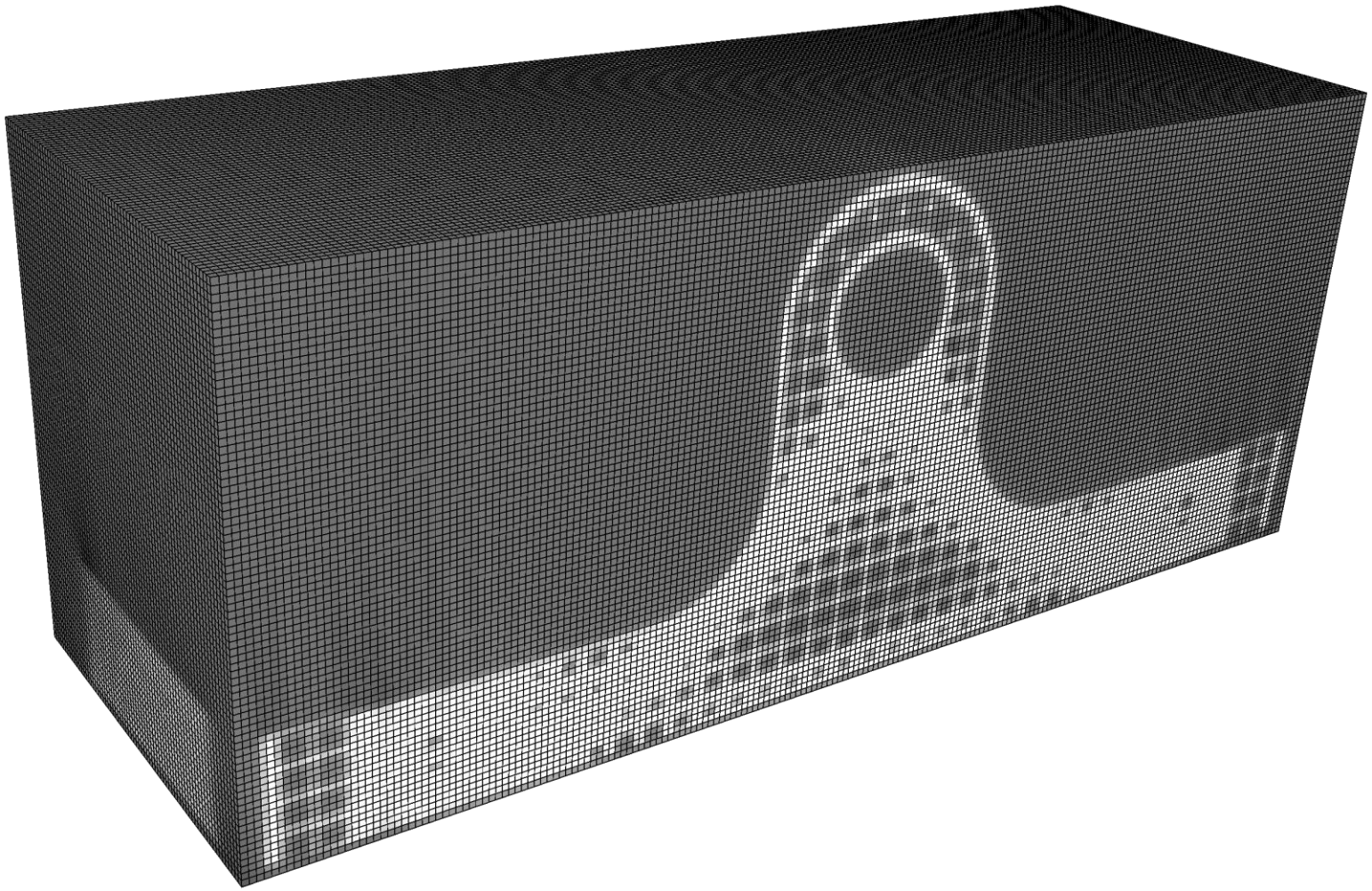
Import volume image data



SYNOPSYS®

Image-based modelling workflow

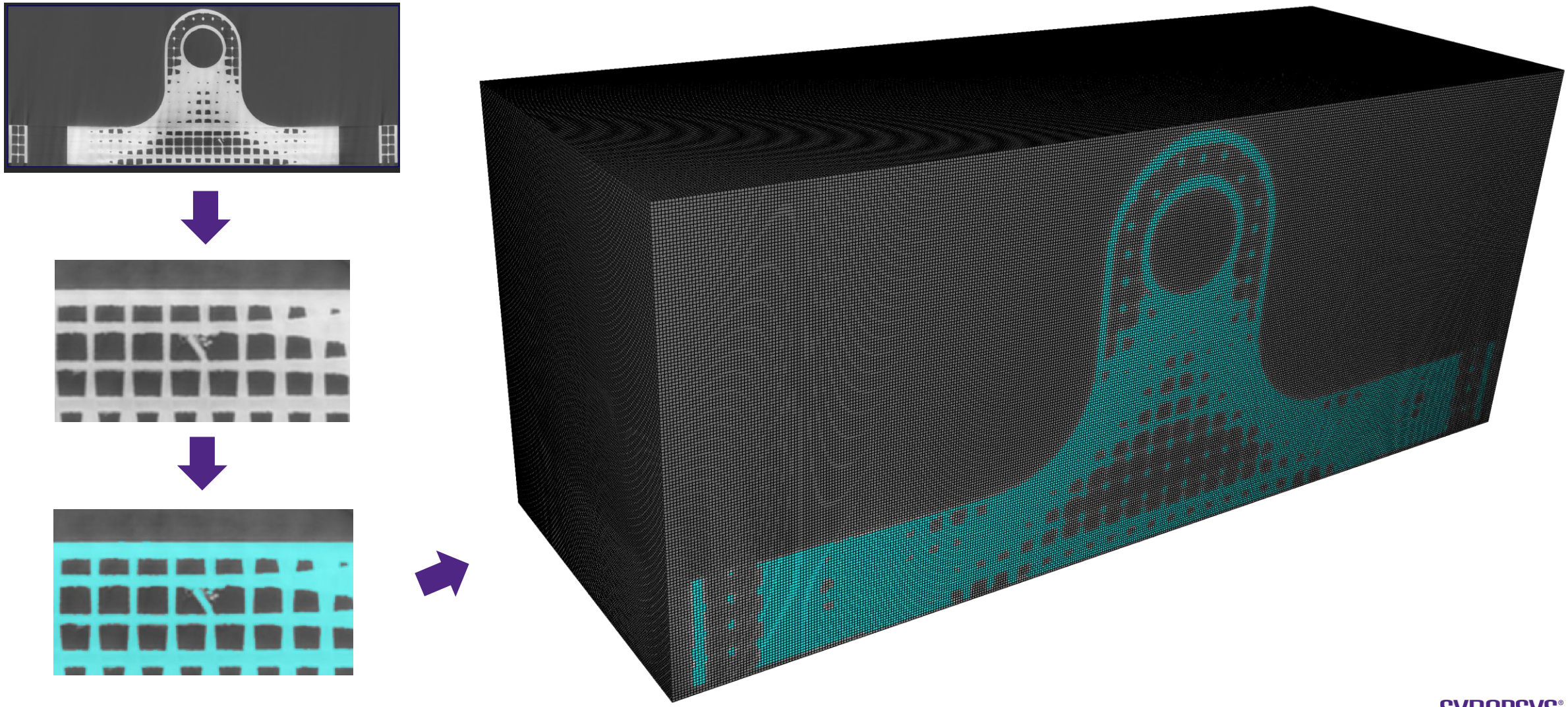
Voxel Grid Formed



SYNOPSYS®

Image-based modelling workflow

Segmentation of regions of interest



SYNOPSYS®

Image-based modelling workflow

*Create surface mesh (**STL**)*

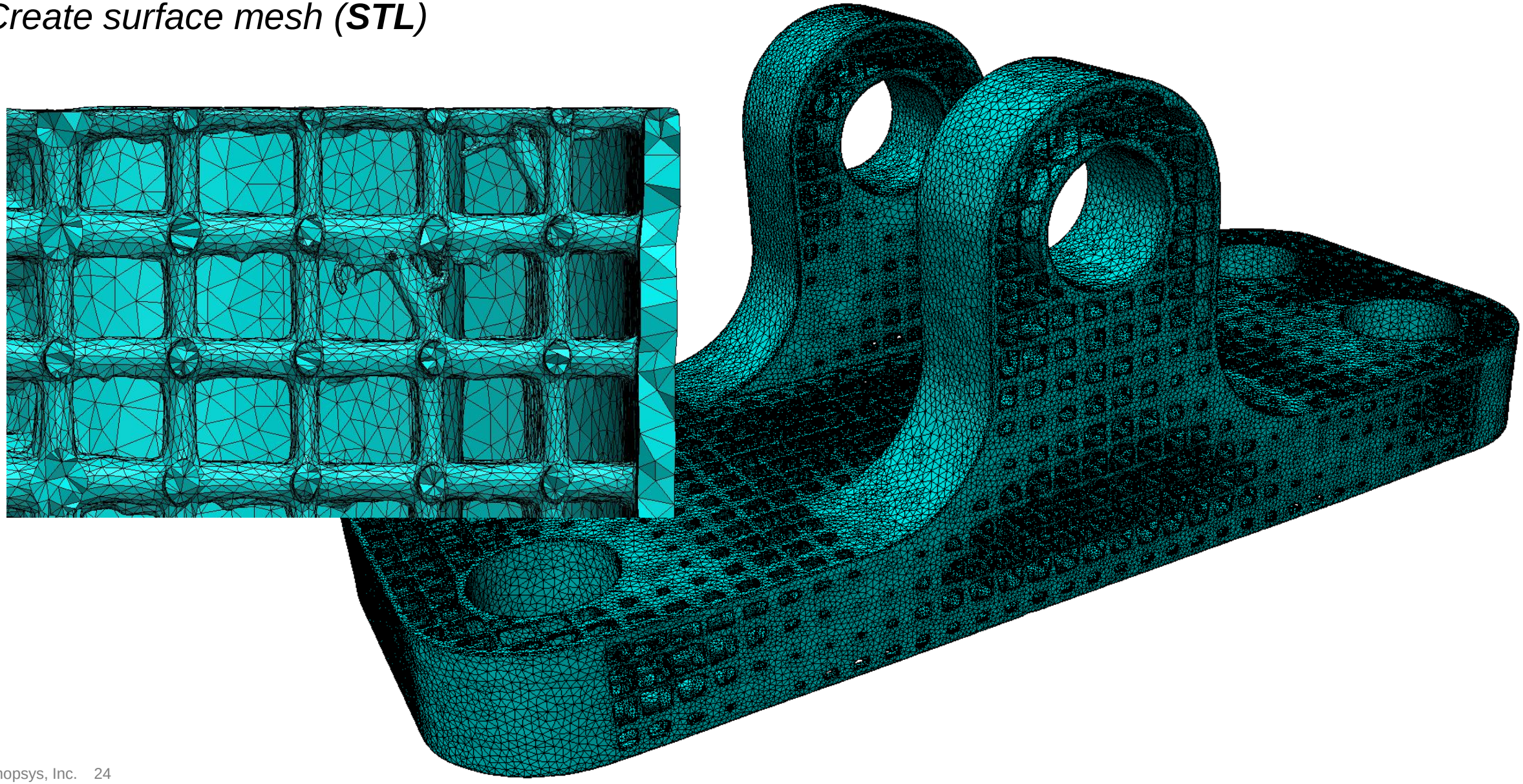
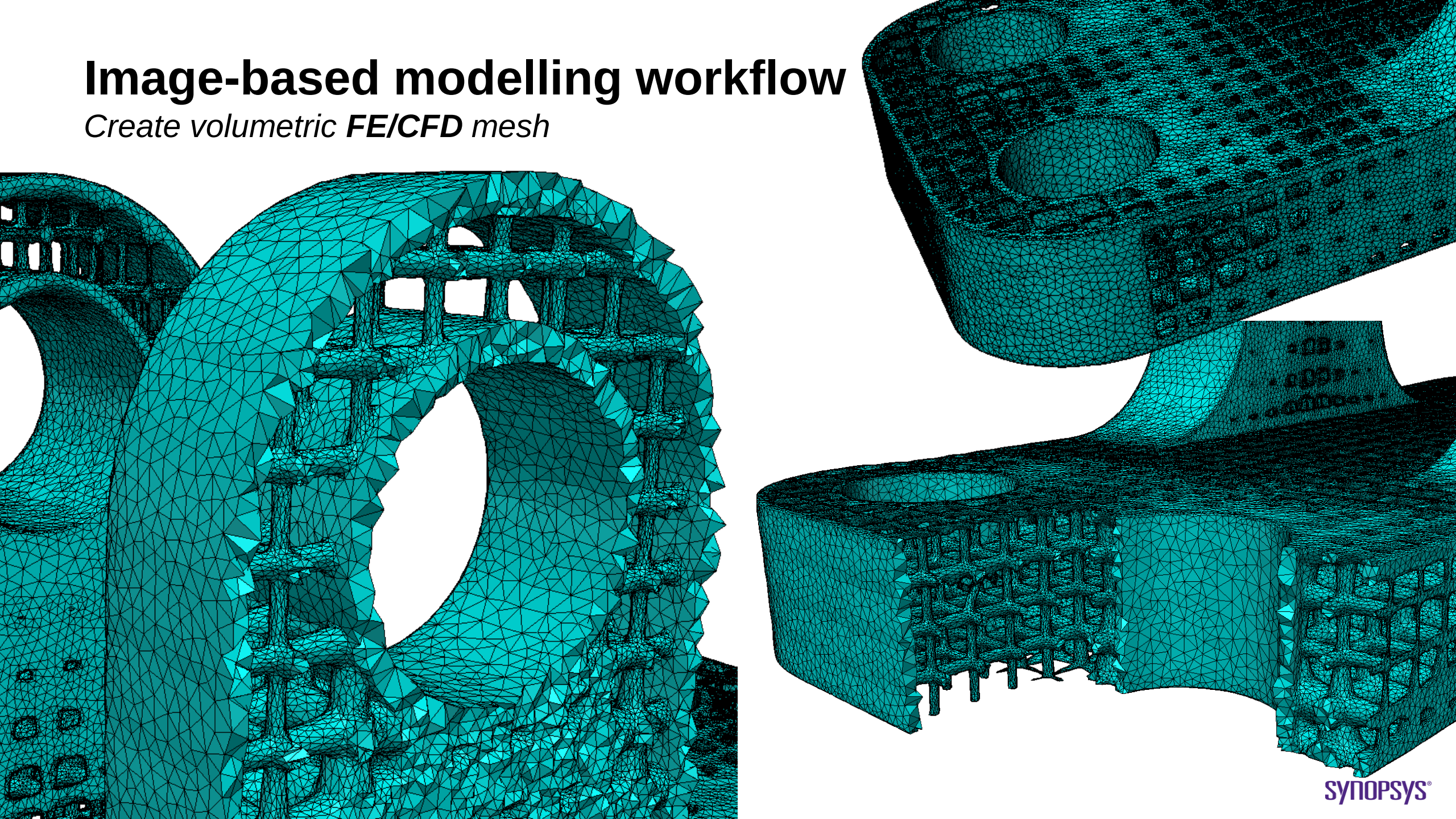


Image-based modelling workflow

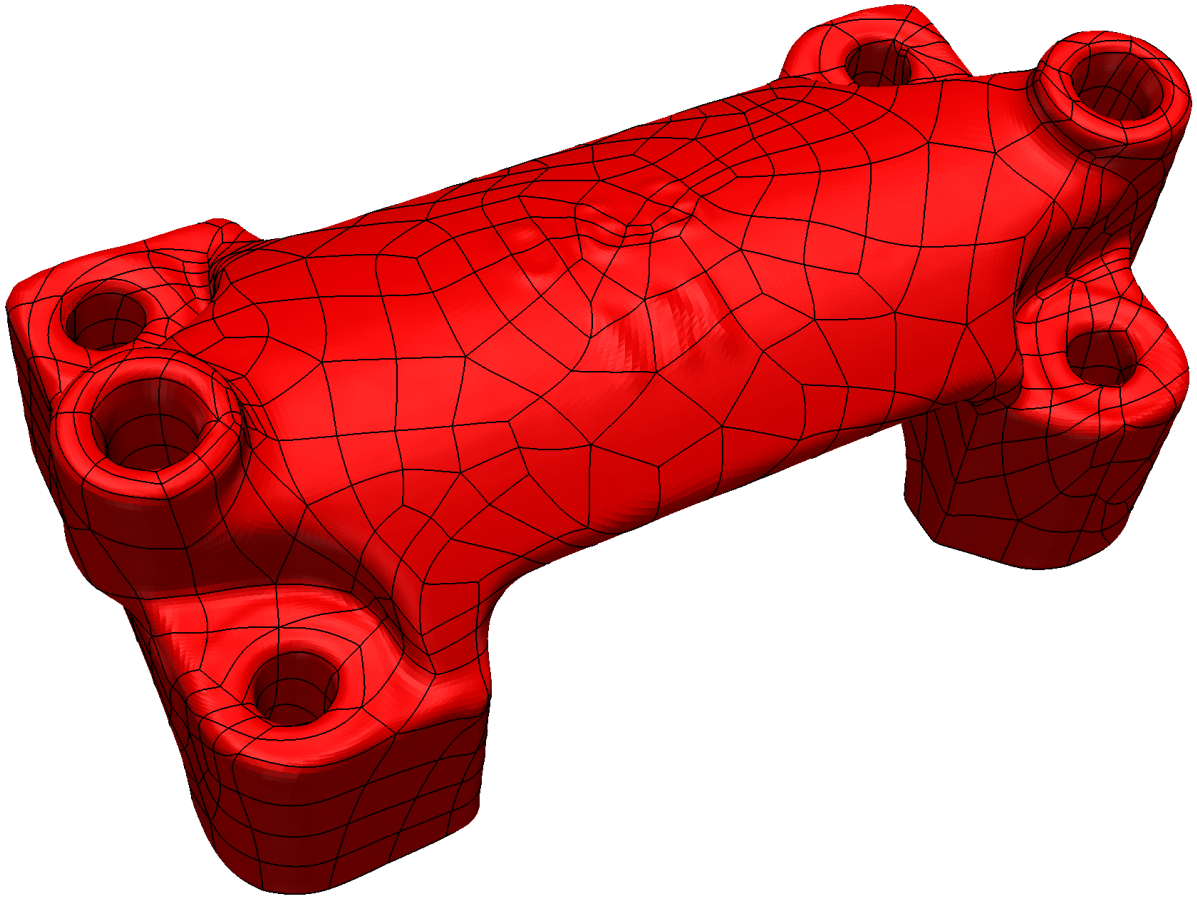
*Create volumetric **FE/CFD** mesh*

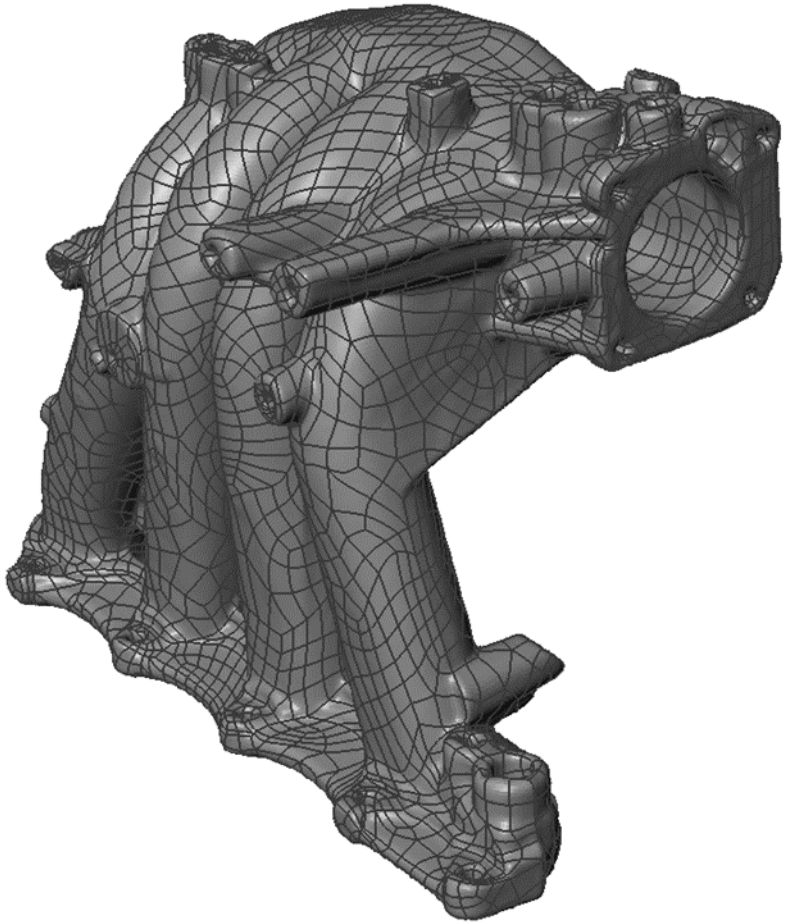


SYNOPSYS®

Image-based modelling work

NURBS generation – (IGES / STEP)





SYNOPSYS®

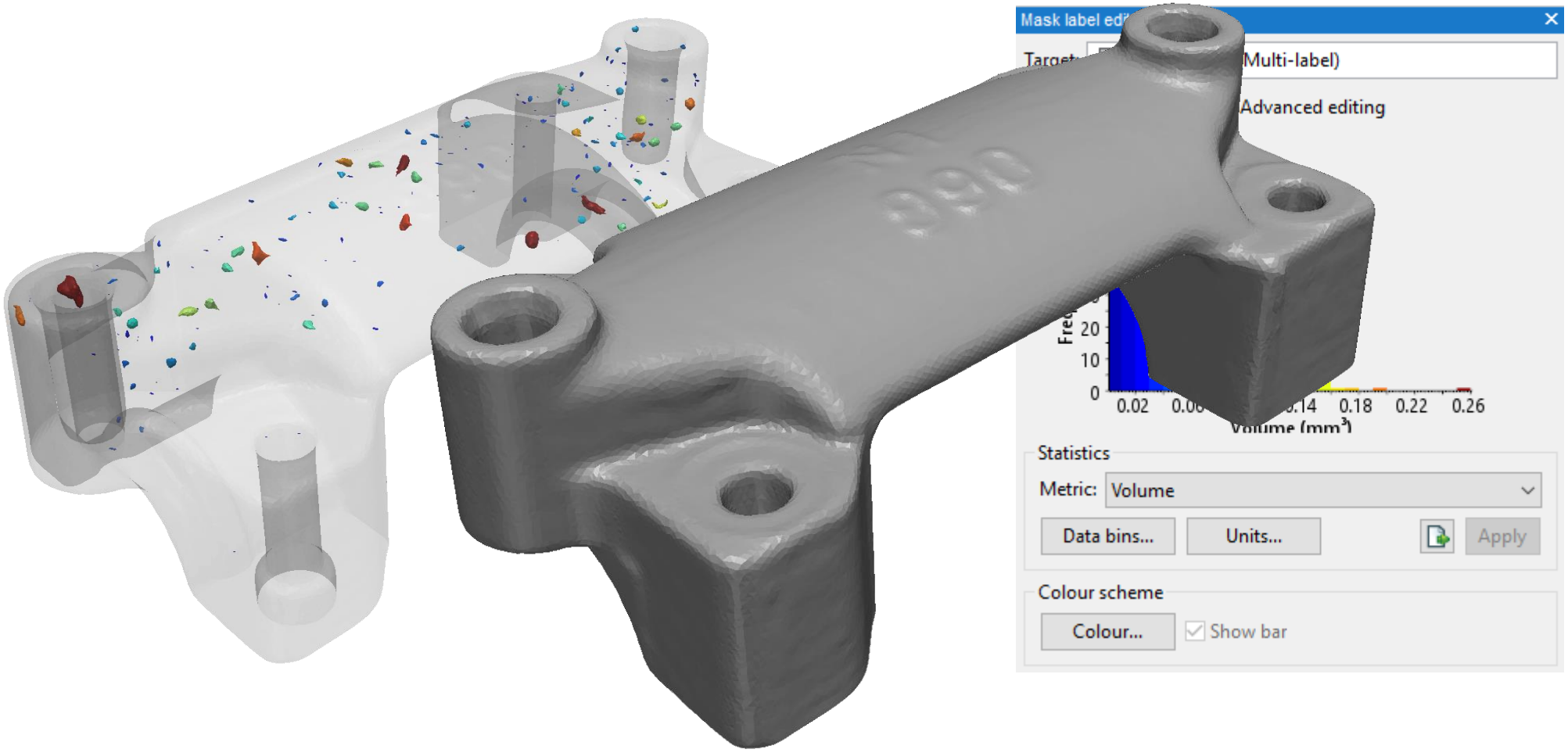
Inspection workflows

Determining the “as-built” deviations from design

SYNOPSYS®

Defect Quantification

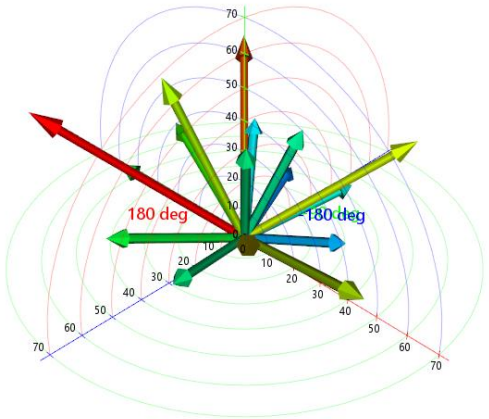
Pore / Void / Particle analysis

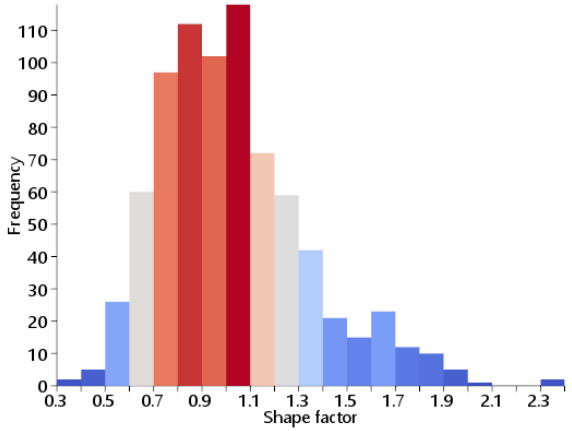


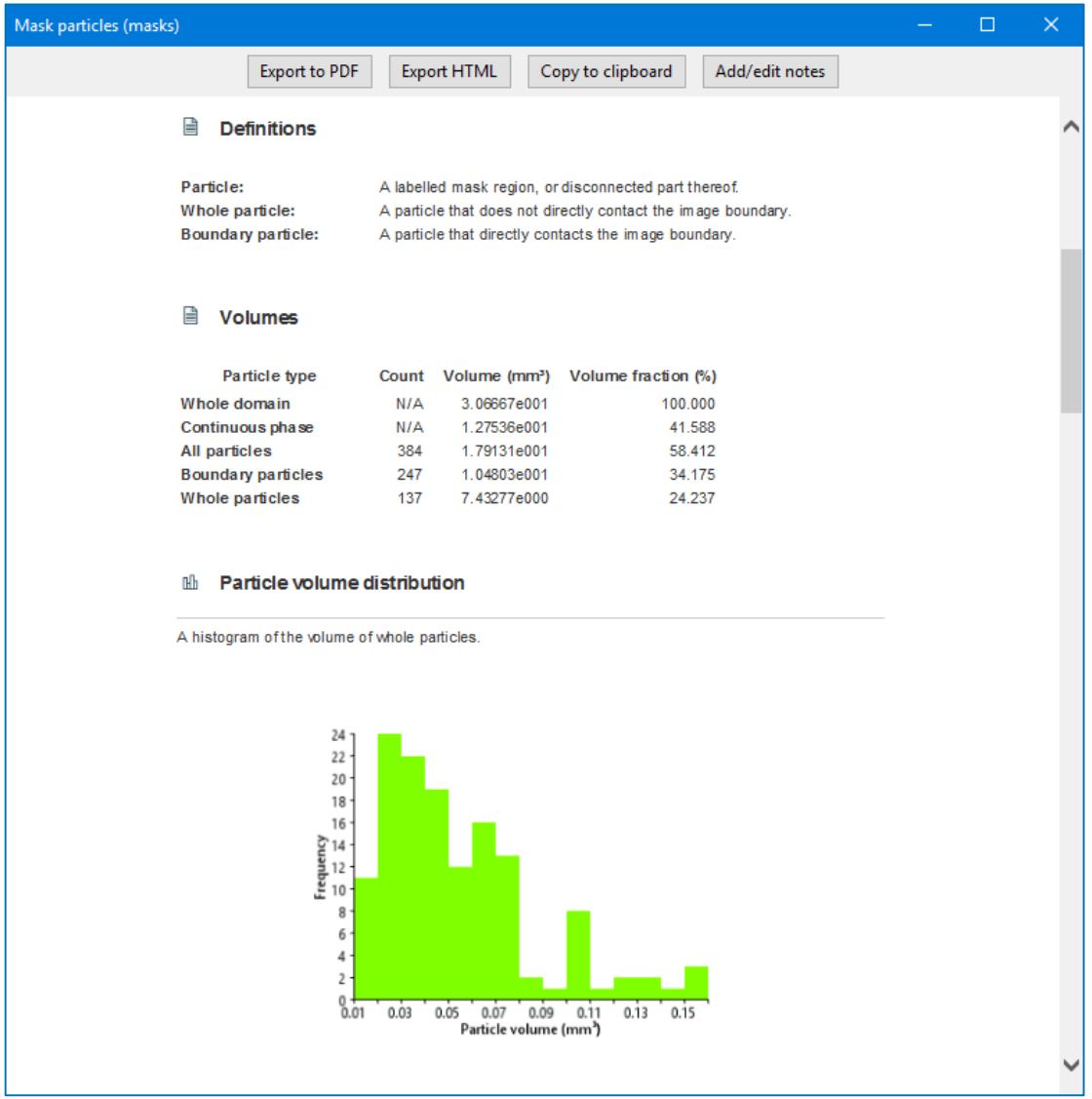
SYNOPSYS®

Automatic Reports

- Pre-set reports for pores and particles
- Customisable graphs
- Export to PDF, HTML or Clipboard



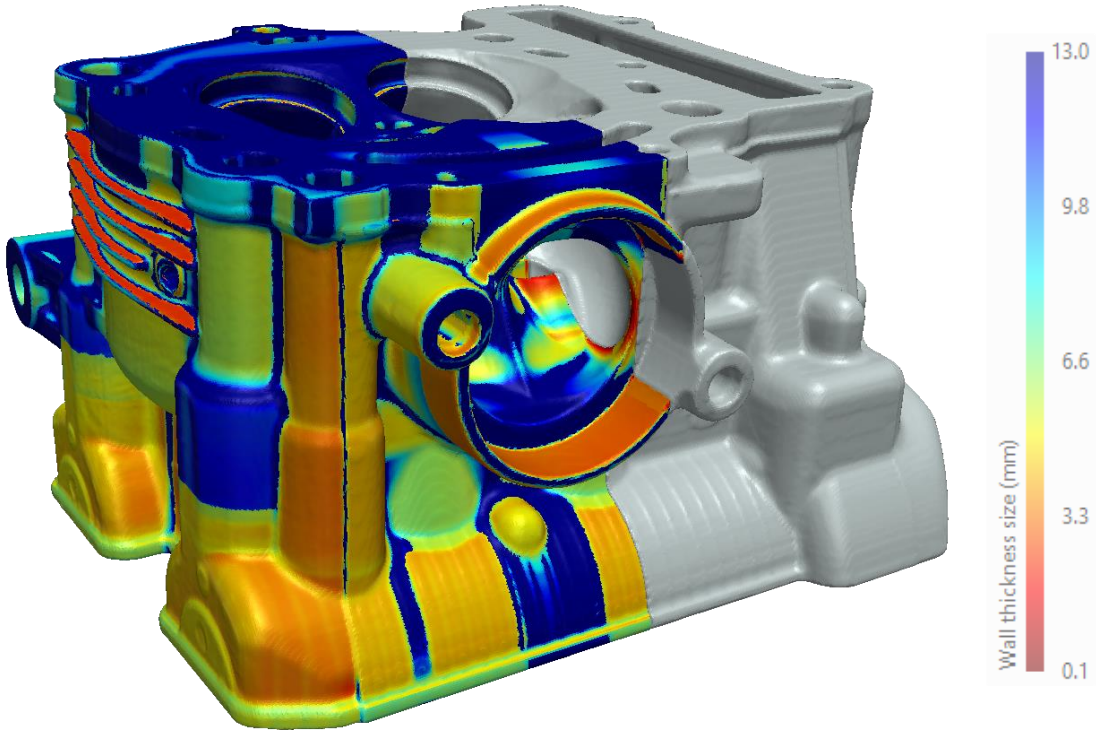




SYNOPSYS®

Wall Thickness Analysis

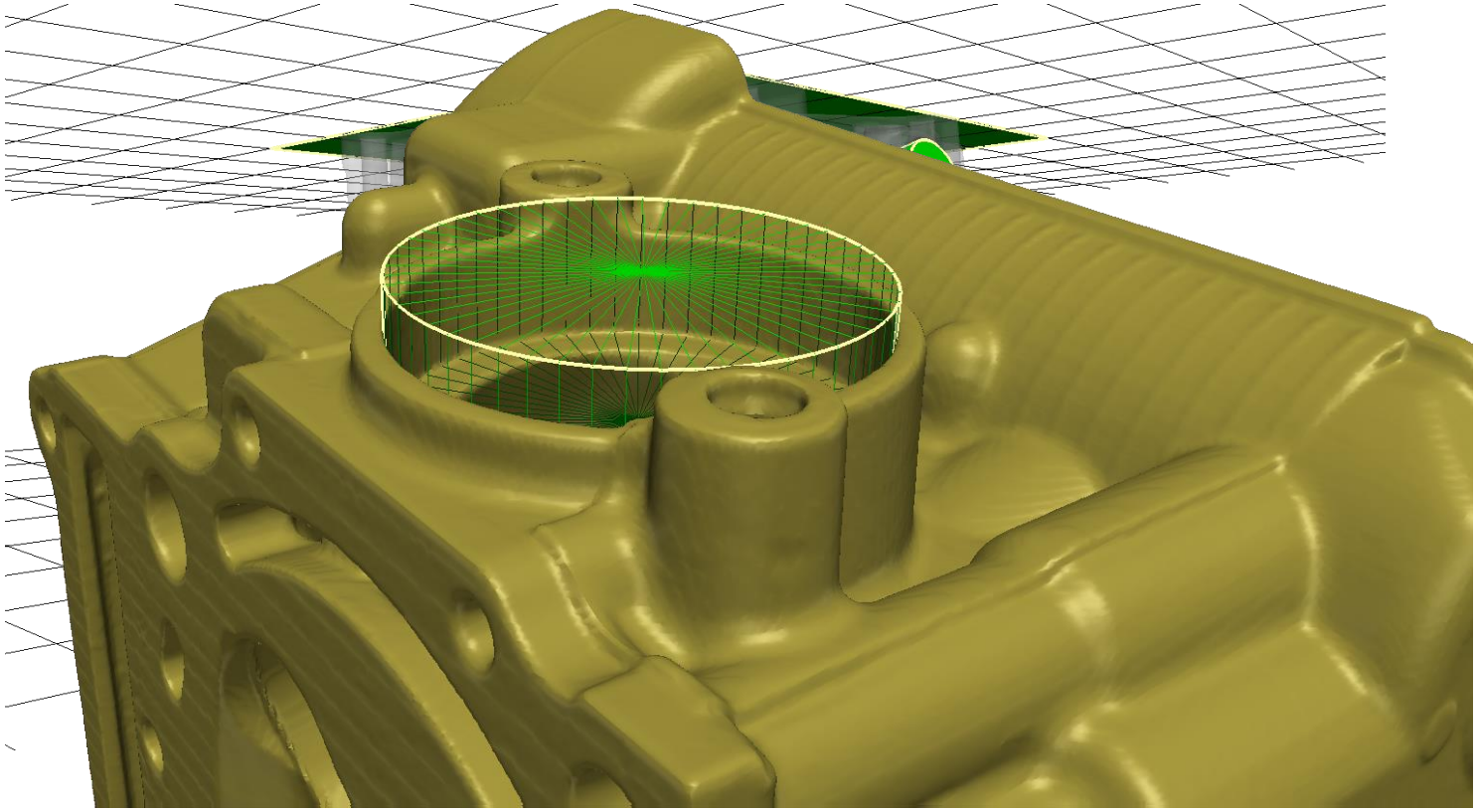
- Analyse the thickness of any segmented mask or surface object
- Visualize results in 3D with a colour map to identify critical regions
- Probe the 3D model to inspect local results in more detail
- Statistics on the minimum, maximum and average thickness



SYNOPSYS®

Shape Creation, Fitting and Analysis

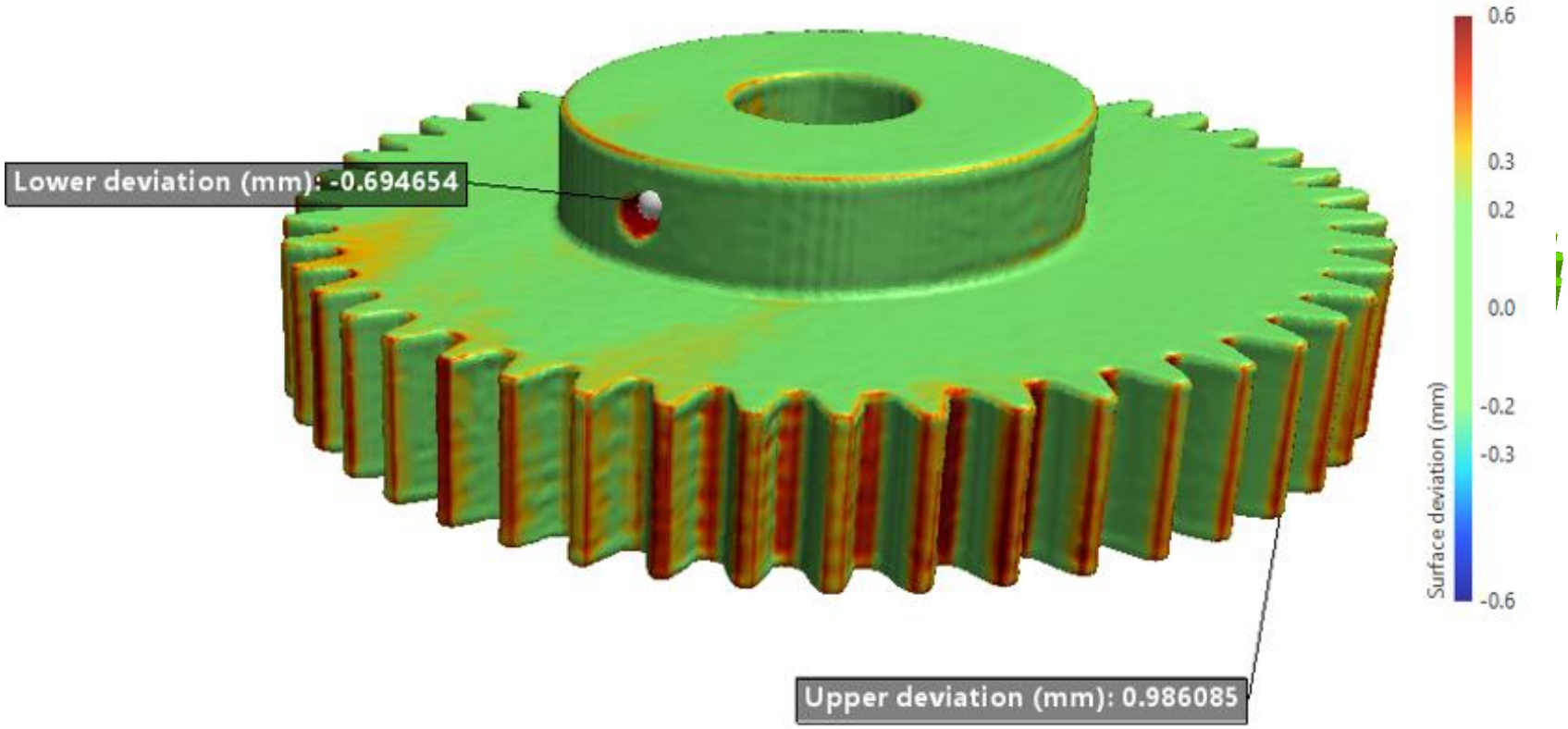
- Tools for the creation and fitting of shapes, incl. planes, spheres, cylinders …
- Surface painting selection tools to easily and quickly identify regions of interest
- Obtain statistics and measurements for each shape or between shapes



SYNOPSYS®

Snap Registration and Surface Deviation

- Snap registration offers an automatic alternative for registration of alike surfaces by landmarks
- Align scanned objects with the intended design part from STL/CAD
- Obtain visual feedback of differences and export many more statistics



SYNOPSYS®

Success stories

Inspection and simulation-based NDE

SYNOPSYS®

Quality Control of ALM Aerospace Part

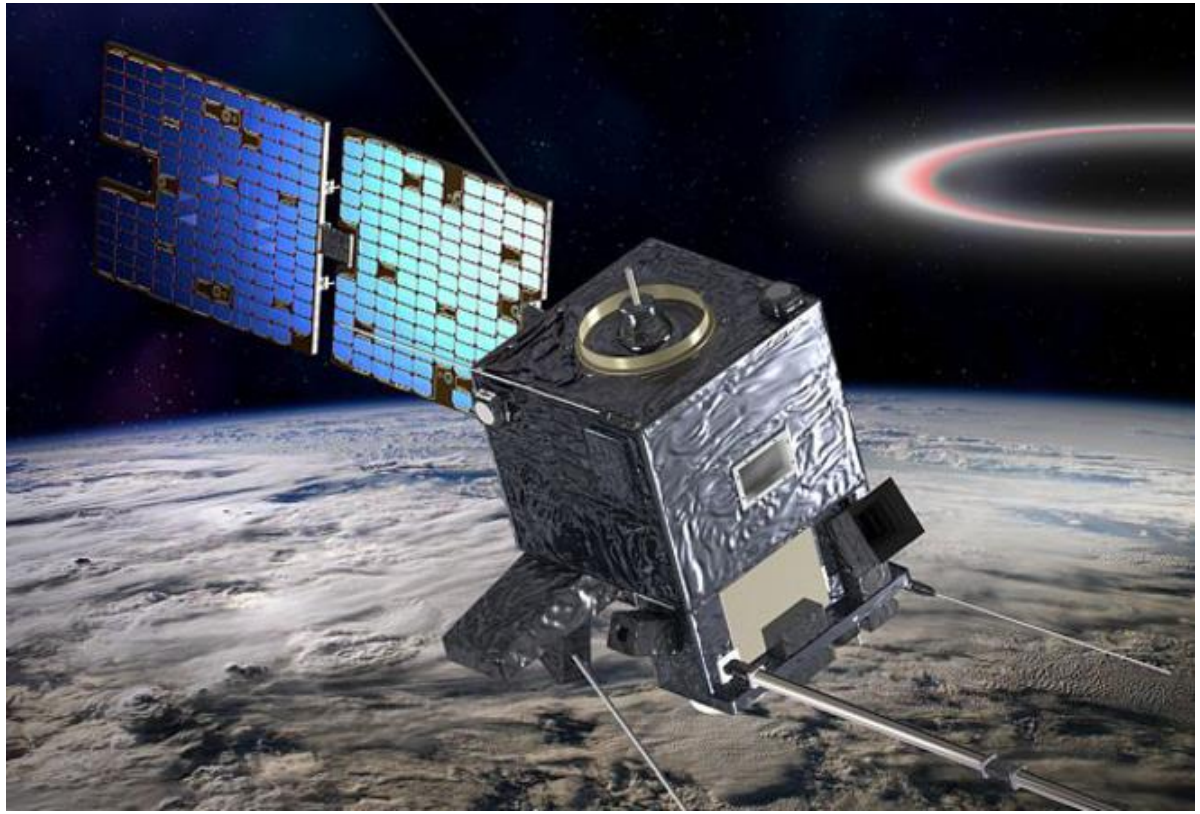
ELEMCA & CNES

SYNOPSYS®

Quality Control of ALM Aerospace Part

Highlights

- ALM part used for the TARANIS satellite was analyzed to identify the location of porosities within the material
- Simpleware software was used to generate models for FEM to validate its structural integration
- Results validated ALM method for comparing CAD models and designed part, with space mission applications



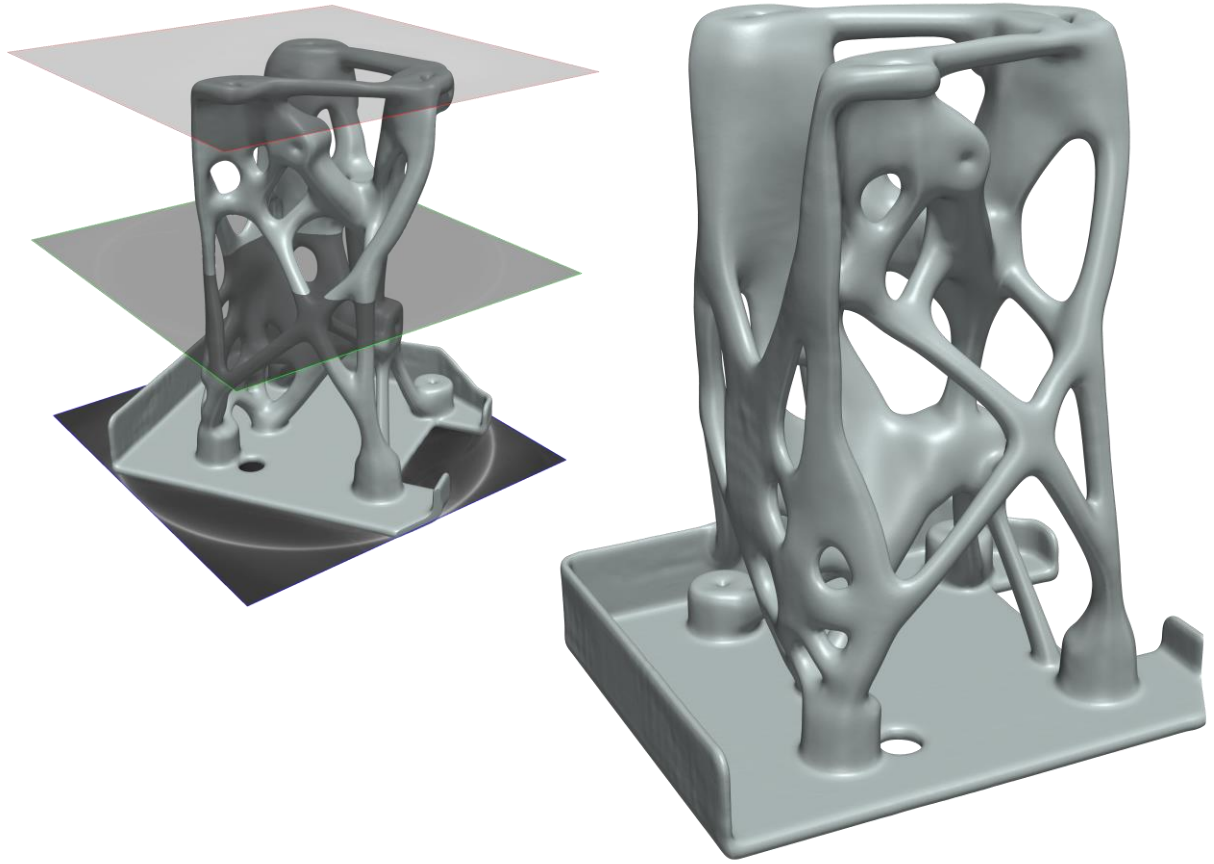
ELEMCA, CNES

SYNOPSYS®

Quality Control of ALM Aerospace Part

Workflow

- X-ray CT data of aluminium part part used for the TARANIS satellite were processed in Simpleware ScanIP



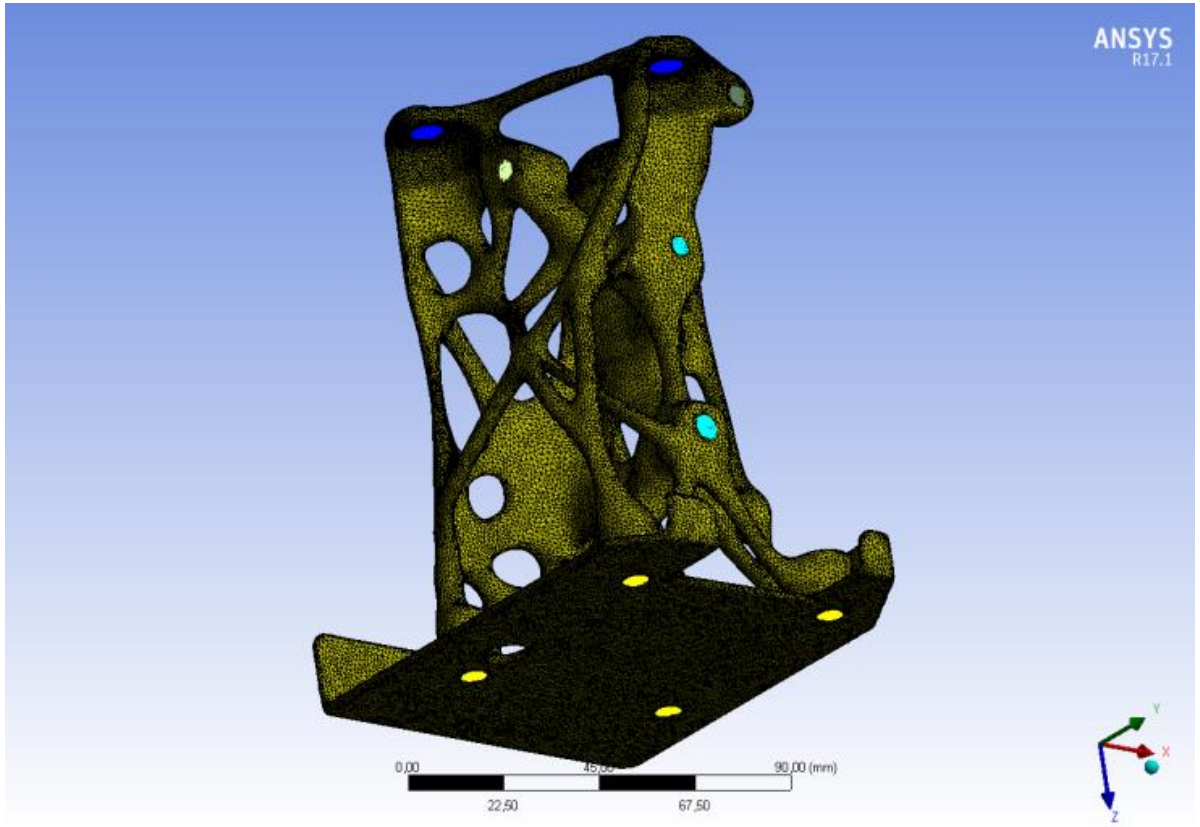
ELEMCA, CNES

SYNOPSYS®

Quality Control of ALM Aerospace Part

Workflow

- X-ray CT data of aluminium part part used for the TARANIS satellite were processed in Simpleware ScanIP
- The model was simulated in ANSYS to analyze defects and compare scan data to previous simulations based on idealized CAD data



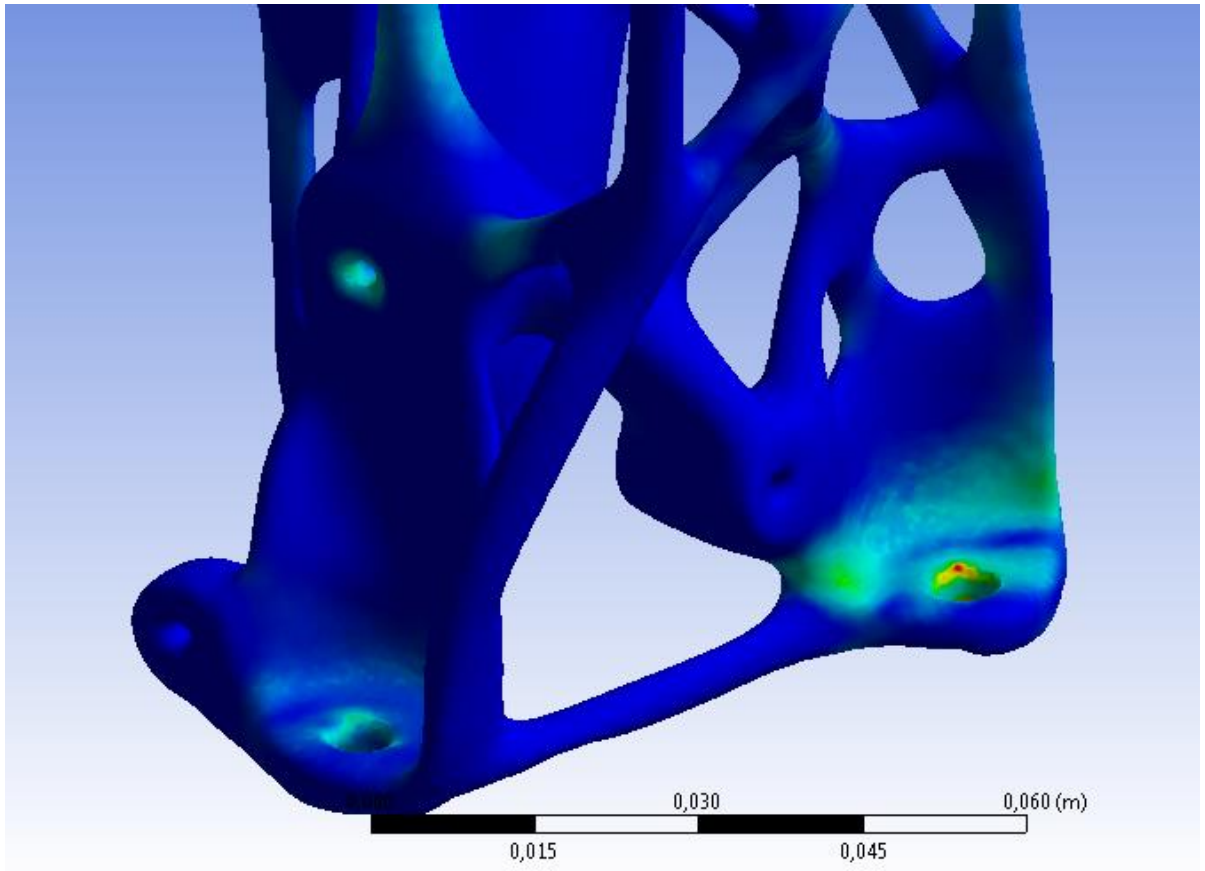
ELEMCA, CNES

SYNOPSYS®

Quality Control of ALM Aerospace Part

Workflow

- X-ray CT data of aluminium part part used for the TARANIS satellite were processed in Simpleware ScanIP
- The model was simulated in ANSYS to analyze defects and compare scan data to previous simulations based on idealized CAD data
- This workflow is useful for adding new levels of quality control and analysis to AM processes within the space industry. The part has been successfully tested, and may now be integrated into the space mission



ELEMCA, CNES

SYNOPSYS®

Giving Arthritis the Finger (Prosthetic Finger Joint)

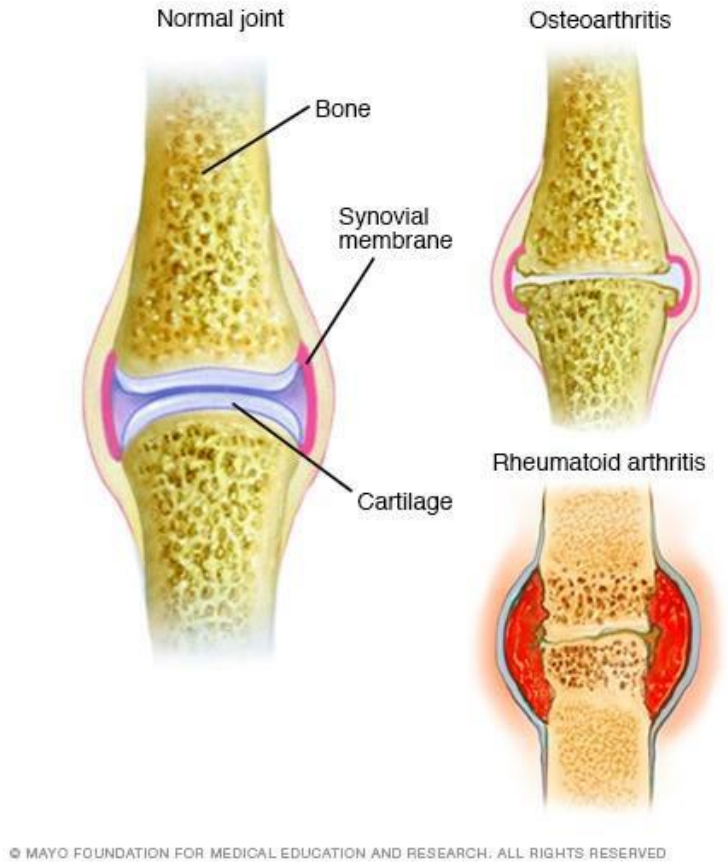
Optimal Device, Endurica

SYNOPSYS®

Giving Arthritis the Finger (Prosthetic Finger Joint)

Highlights

- Total joint replacement can alleviate pain for rheumatoid arthritis; surgery involves removing the swollen joint tissue and replacing with an off the shelf prosthetic
- For development of a patient-specific silicone finger joint implant, Simpleware software was used to segment CT scan data of the hand
- Workflow describes why and how to leverage patient-specific anatomical data, non-linear structural simulation, fatigue simulation and shape optimization to enhance device design



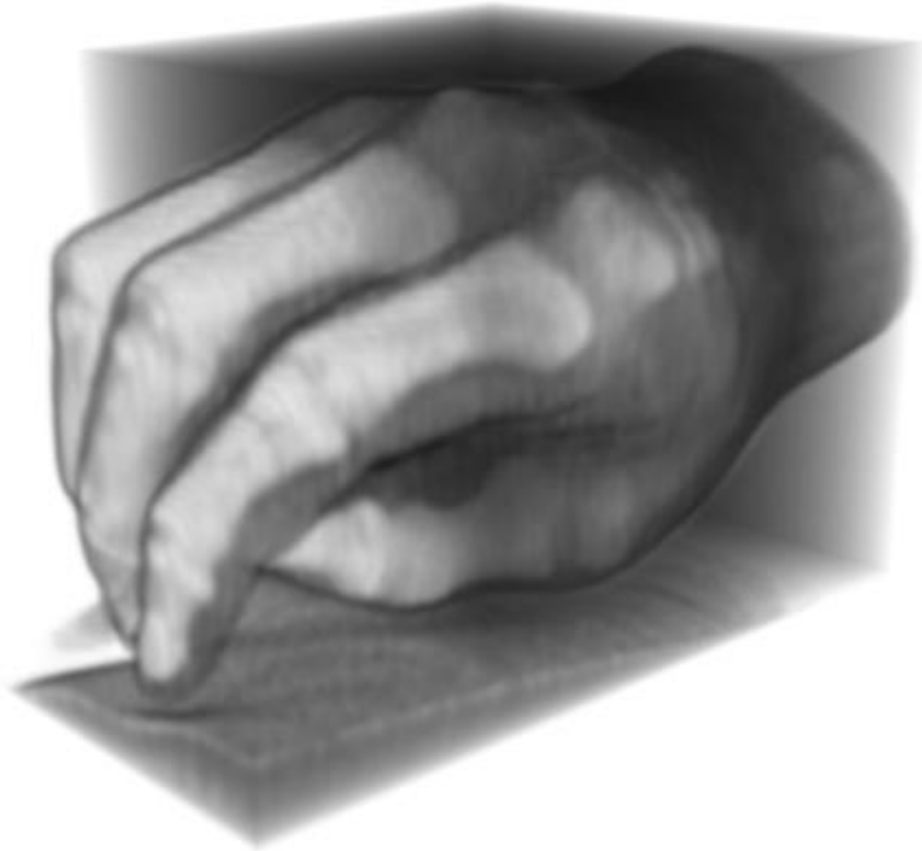
Optimal Device, Endurica

SYNOPSYS®

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP



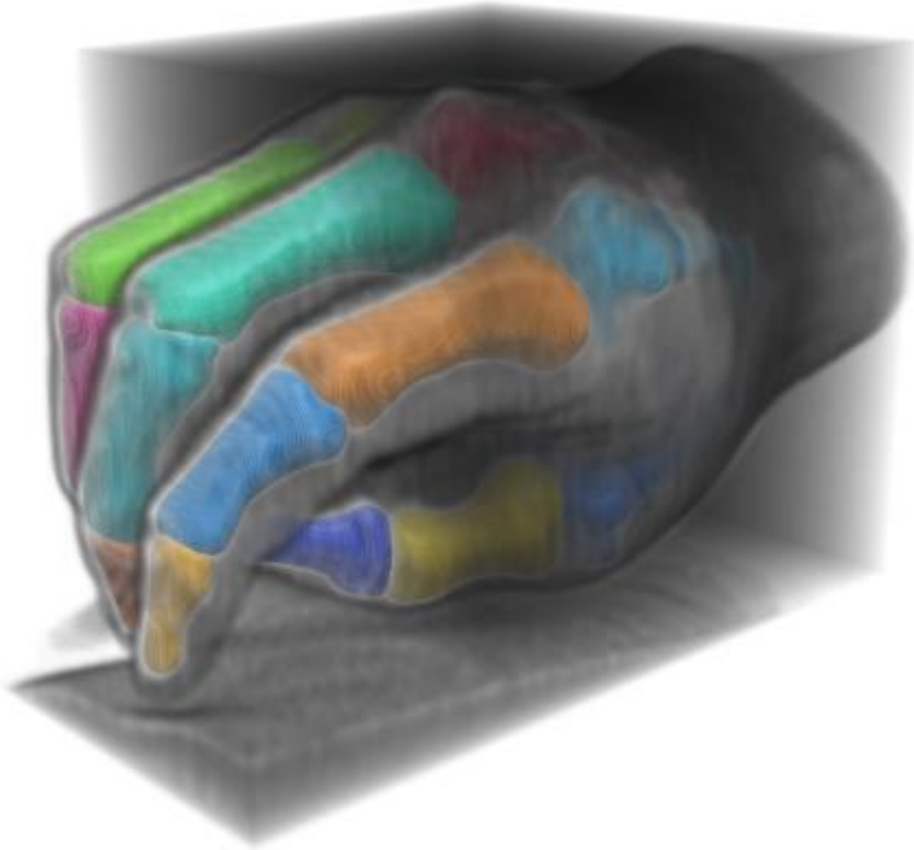
Optimal Device, Endurica

SYNOPSYS®

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP

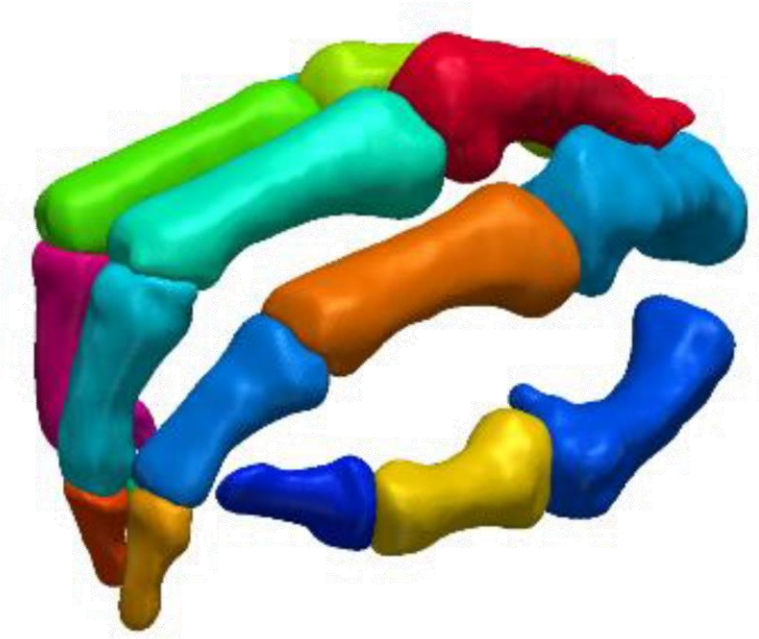


Optimal Device, Endurica

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP

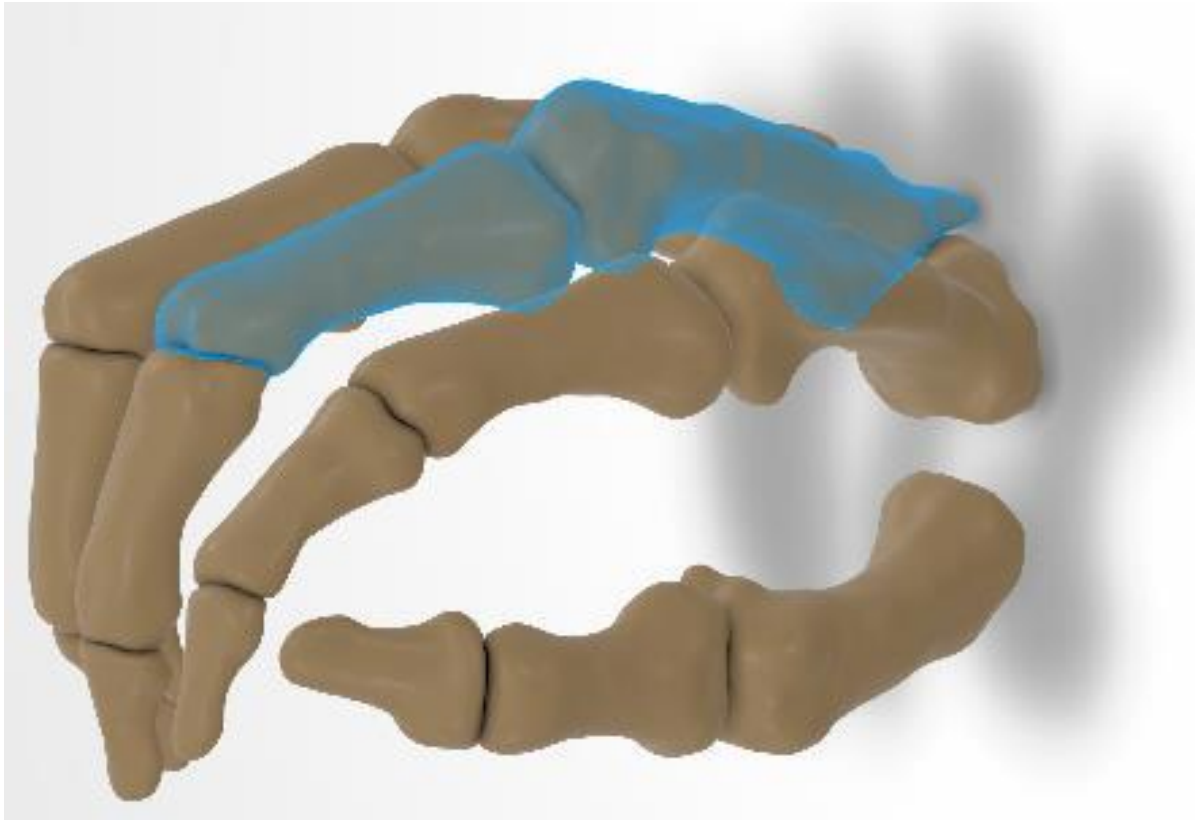


Optimal Device, Endurica

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP
- Implant design in CATIA into middle metacarpal and proximal phalange

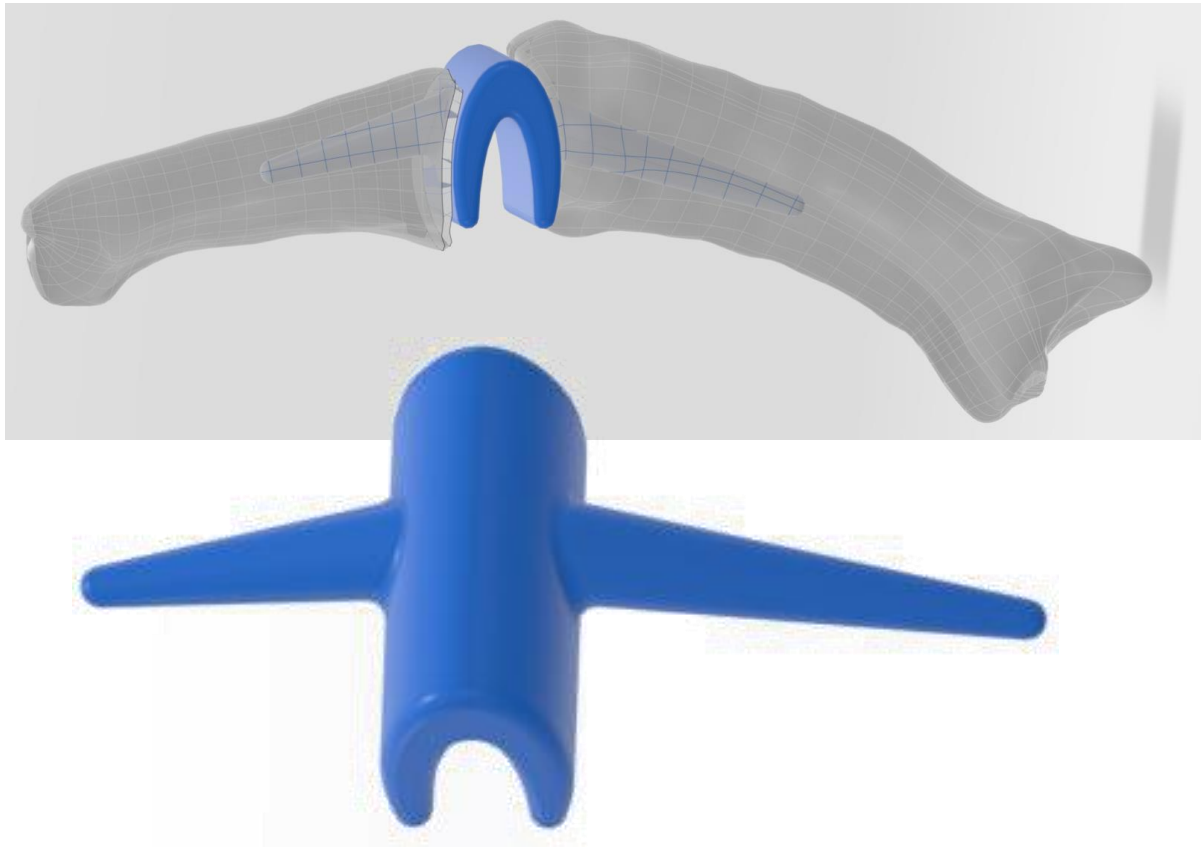


Optimal Device, Endurica

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP
- Implant design in CATIA into middle metacarpal and proximal phalange



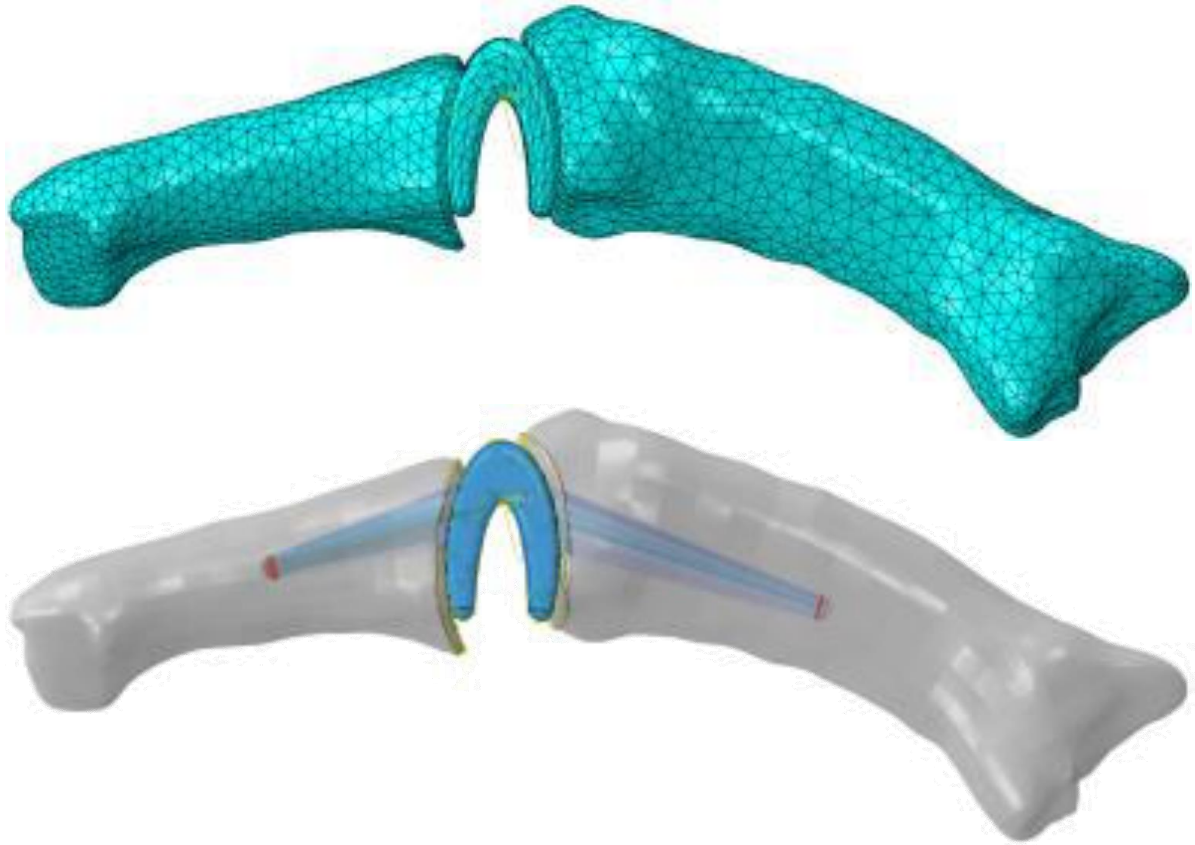
Optimal Device, Endurica

SYNOPSYS®

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP
- Implant design in CATIA into middle metacarpal and proximal phalange
- Non-linear finite element model created in Abaqus/CAE that included large deformation, contact and a 3rd order Ogden hyperelastic material properties

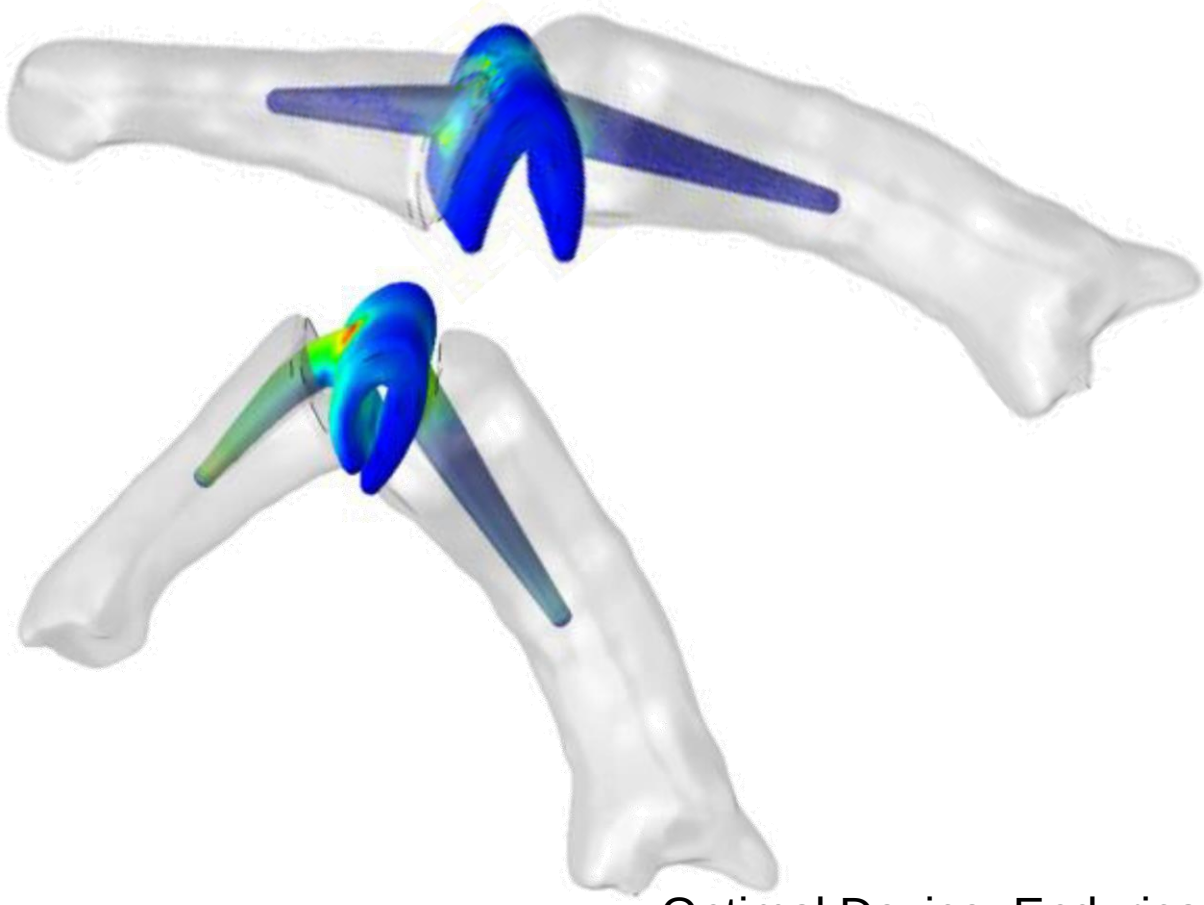


Optimal Device, Endurica

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP
- Implant design in CATIA into middle metacarpal and proximal phalange
- Non-linear finite element model created in Abaqus/CAE that included large deformation, contact and a 3rd order Ogden hyperelastic material properties
- Durability analysis in fe-safe/Rubber to calculate maximal strain locations for 20° extension and 70° flexion



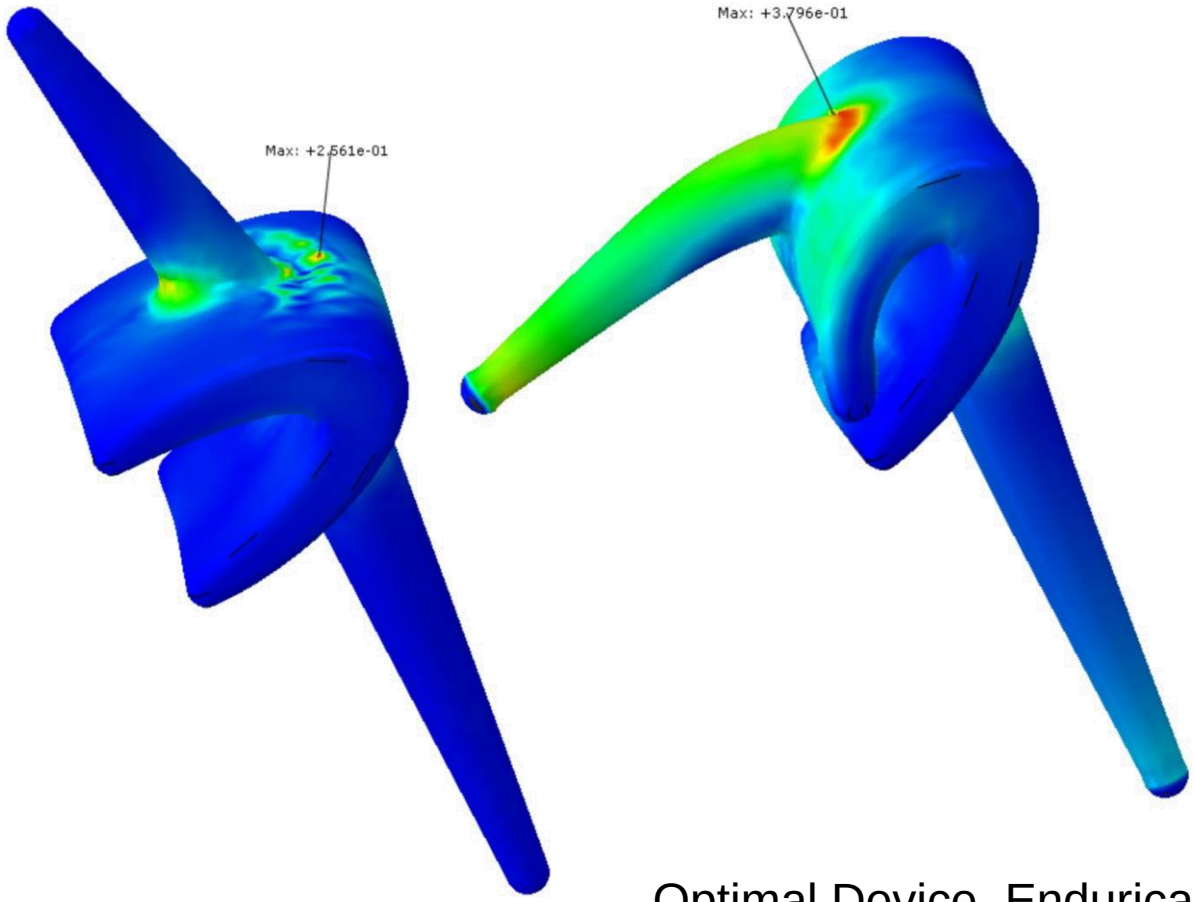
Optimal Device, Endurica

SYNOPSYS®

Giving Arthritis the Finger (Prosthetic Finger Joint)

Workflow

- CT scan data of the right hand from the Visible Korean dataset used to segment bones from soft tissue in Simpleware ScanIP
- Implant design in CATIA into middle metacarpal and proximal phalange
- Non-linear finite element model created in Abaqus/CAE that included large deformation, contact and a 3rd order Ogden hyperelastic material properties
- Durability analysis in fe-safe/Rubber to calculate maximal strain locations for 20° extension and 70° flexion



Optimal Device, Endurica

SYNOPSYS®

High-performance Computation in Solid Oxide Fuel Cell Microstructures

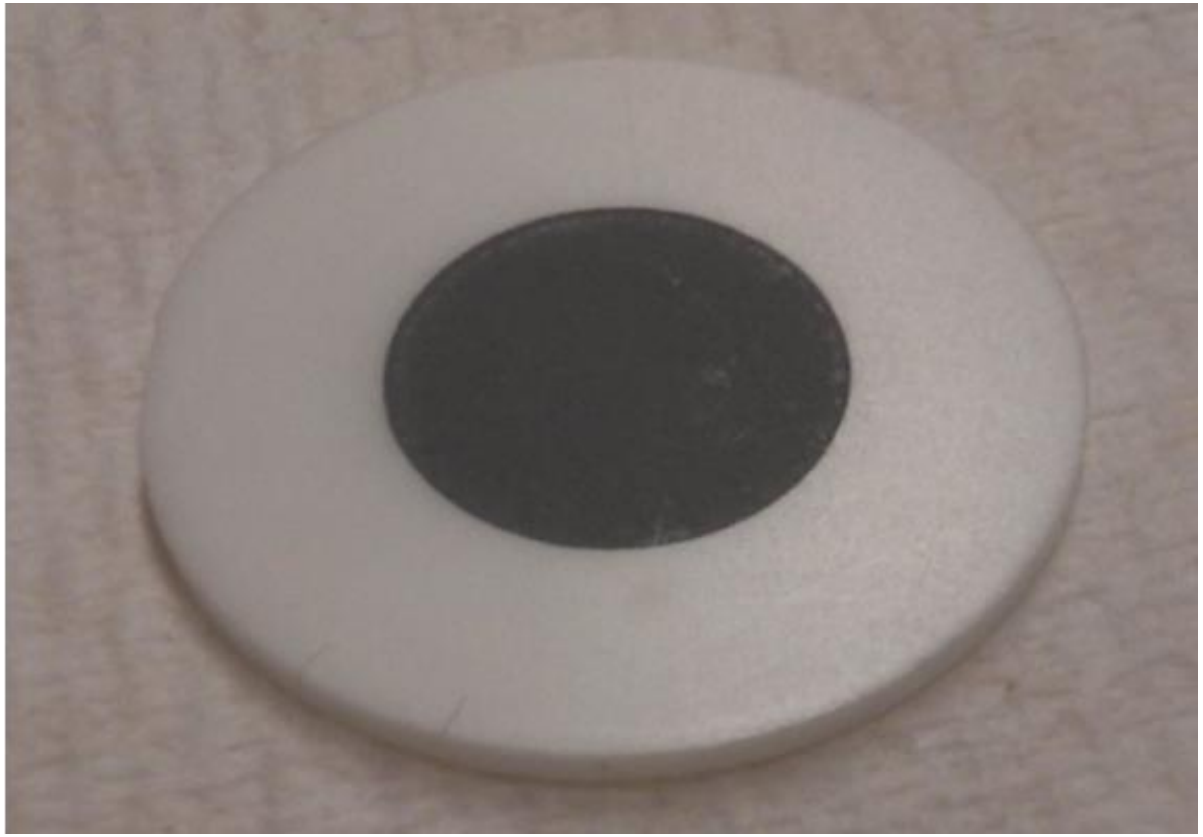
Carnegie Mellon University

SYNOPSYS®

High-performance Computation in Solid Oxide Fuel Cell Microstructure

Highlights

- High-performance methods using meshed 3D microstructures allows for quantification of local distributions of electrochemical properties from FIB-SEM data
- Simpleware software provides straightforward one-step conversion of microstructure data to meshes, speeding up previously time-consuming tasks for large meshes by using scripting
- Simulated local electrochemical performance throughout microstructure can provide insight into electrode degradation and failure behavior



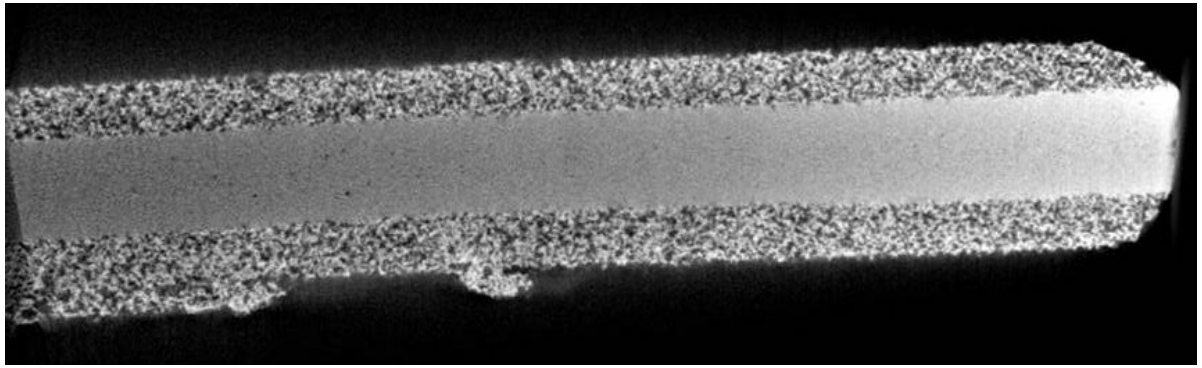
Carnegie Mellon University

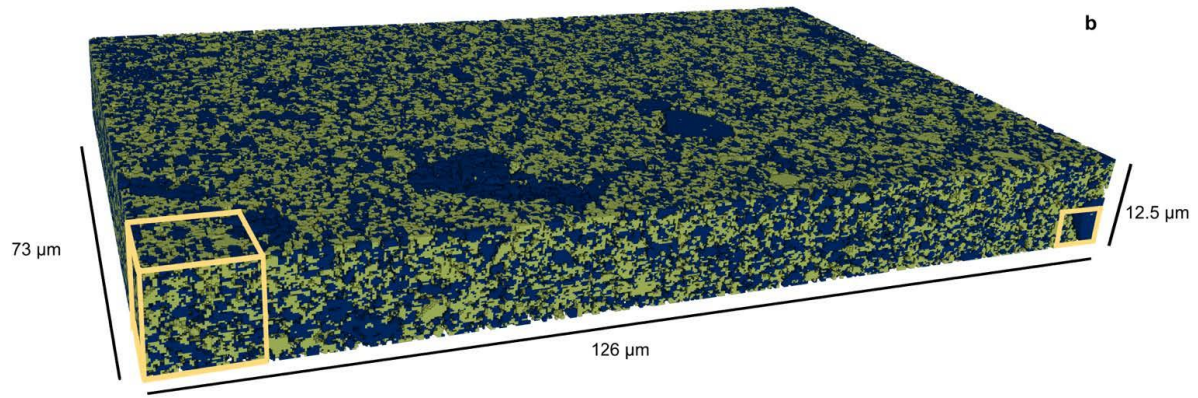
SYNOPSYS®

High-performance Computation in Solid Oxide Fuel Cell Microstructure

Workflow

- Electrode microstructures obtained using Xe-plasma FIB-SEM serial sectioning to capture length scales on the order of 100-200 µm





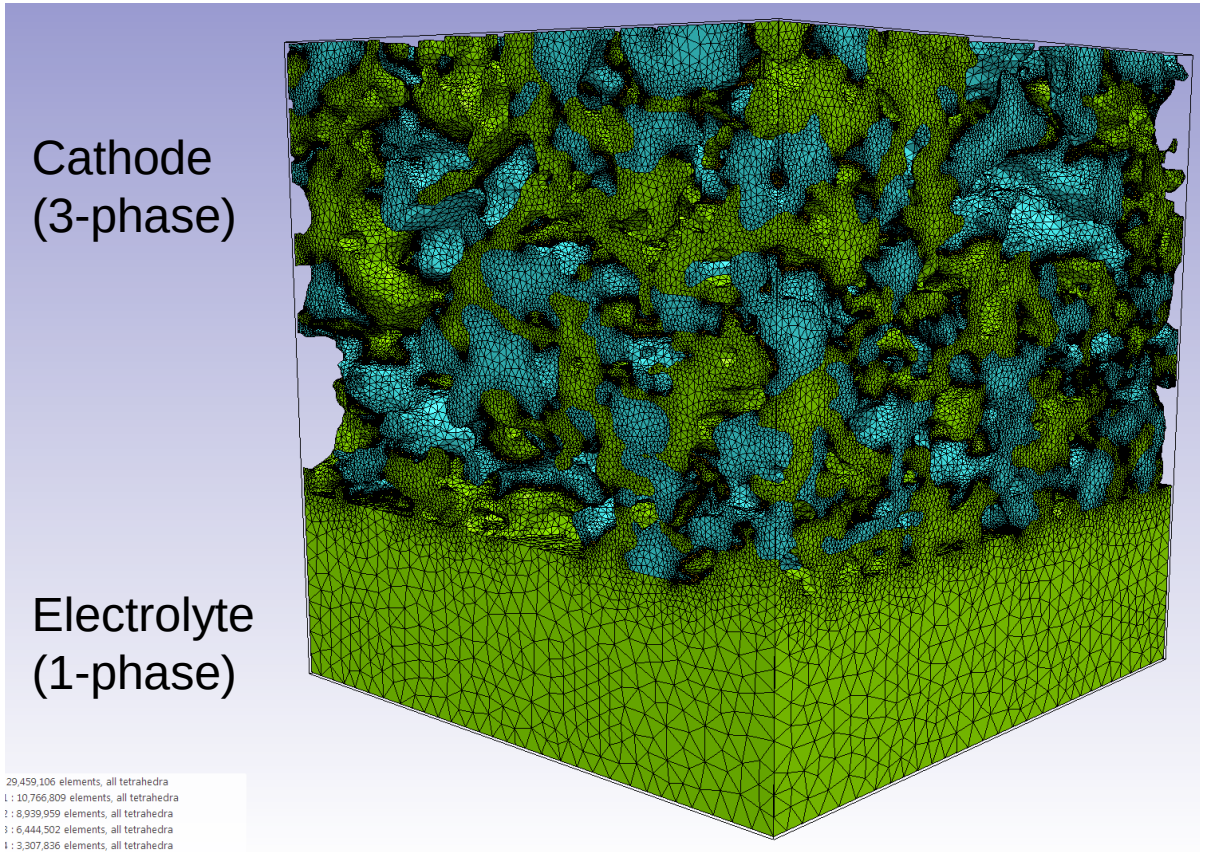
Carnegie Mellon University

SYNOPSYS®

High-performance Computation in Solid Oxide Fuel Cell Microstructure

Workflow

- Electrode microstructures obtained using Xe-plasma FIB-SEM serial sectioning to capture length scales on the order of 100-200 µm
- Simpleware software used to convert 3D scan data into microstructural, multi-domain and simulation-ready FE meshes. These models preserve the complex surface morphologies in three-phase SOFC electrodes



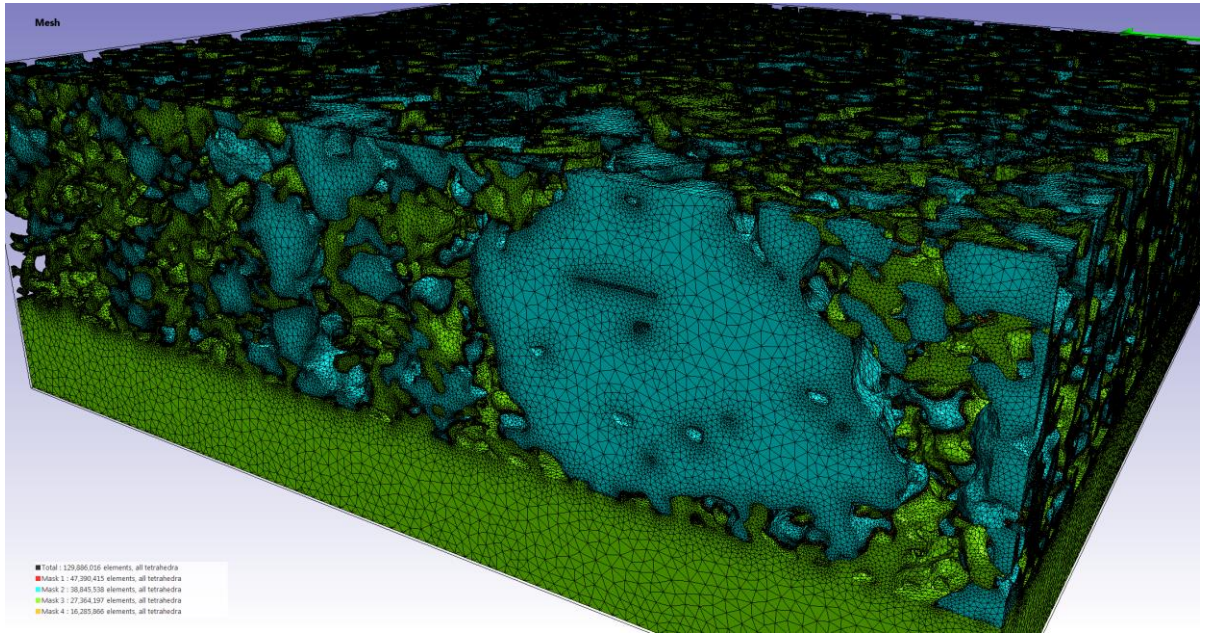
Carnegie Mellon University

SYNOPSYS®

High-performance Computation in Solid Oxide Fuel Cell Microstructure

Workflow

- Electrode microstructures obtained using Xe-plasma FIB-SEM serial sectioning to capture length scales on the order of 100-200 µm
- Simpleware software used to convert 3D scan data into microstructural, multi-domain and simulation-ready FE meshes. These models preserve the complex surface morphologies in three-phase SOFC electrodes



Large-scale meshing:
30 x 30 x 10 [µm], 130 million mesh elements

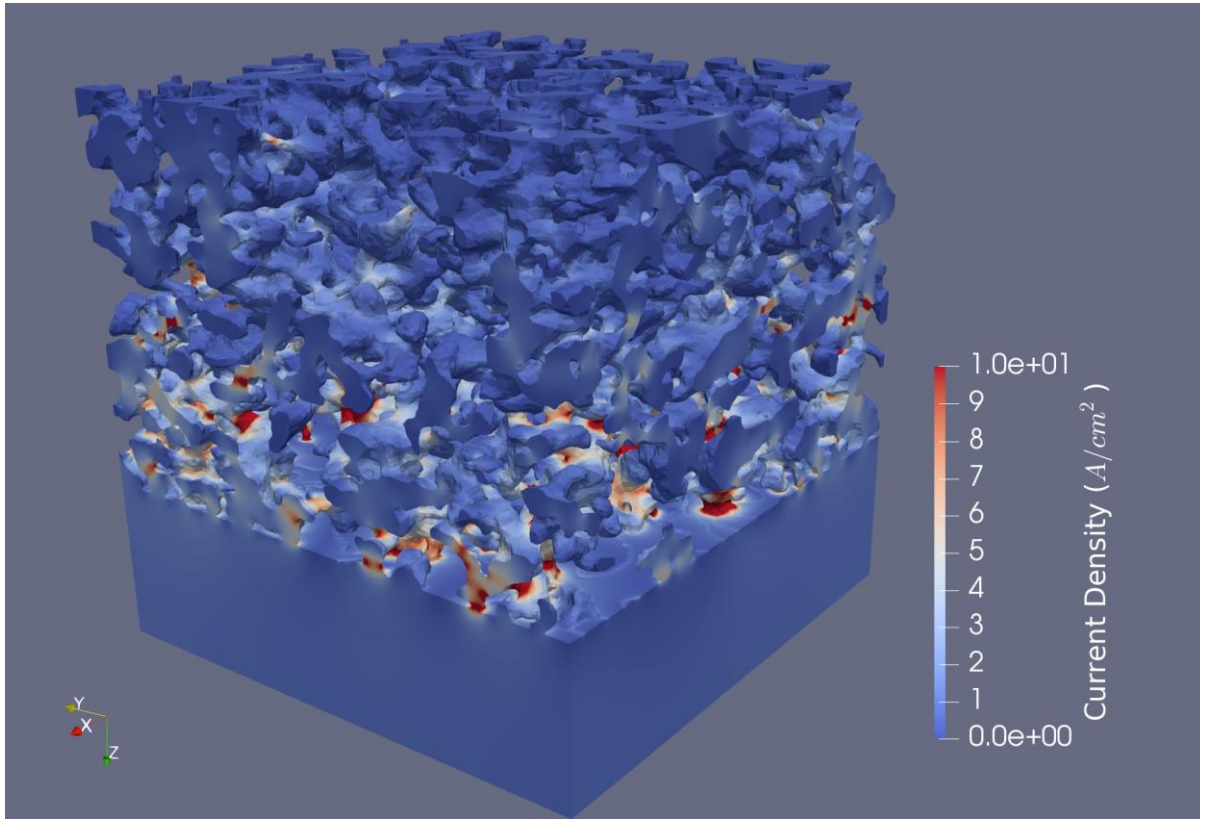
Carnegie Mellon University

SYNOPSYS®

High-performance Computation in Solid Oxide Fuel Cell Microstructure

Workflow

- Electrode microstructures obtained using Xe-plasma FIB-SEM serial sectioning to capture length scales on the order of 100-200 µm
- Simpleware software used to convert 3D scan data into microstructural, multi-domain and simulation-ready FE meshes. These models preserve the complex surface morphologies in three-phase SOFC electrodes
- High-performance simulations produced a collection of computed scalar or vector fields of electrochemical variables. Results showed promising insights into the distribution of local electrochemical parameters that can aid future research into SOFC performance



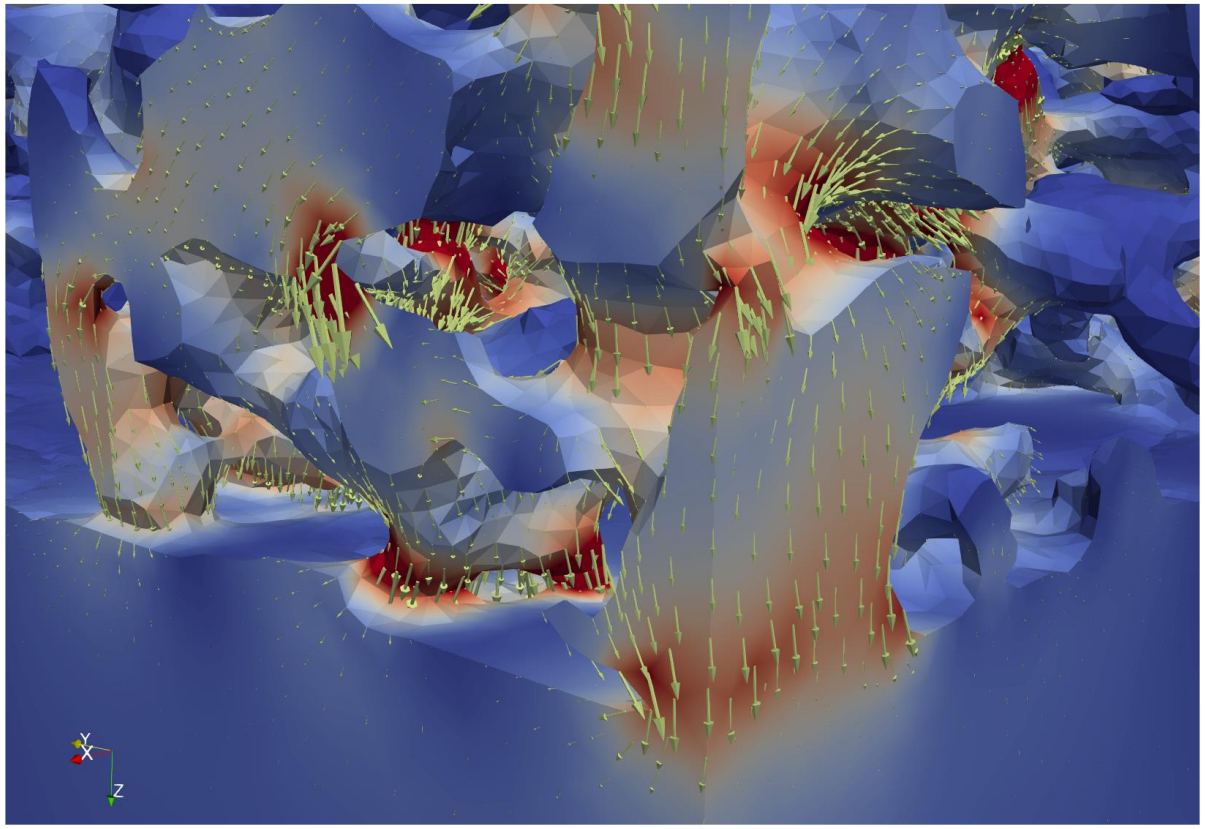
Carnegie Mellon University

SYNOPSYS®

High-performance Computation in Solid Oxide Fuel Cell Microstructure

Workflow

- Electrode microstructures obtained using Xe-plasma FIB-SEM serial sectioning to capture length scales on the order of 100-200 µm
- Simpleware software used to convert 3D scan data into microstructural, multi-domain and simulation-ready FE meshes. These models preserve the complex surface morphologies in three-phase SOFC electrodes
- High-performance simulations produced a collection of computed scalar or vector fields of electrochemical variables. Results showed promising insights into the distribution of local electrochemical parameters that can aid future research into SOFC performance



Carnegie Mellon University

SYNOPSYS®

Inspecting Deviation from Design in Manufactured Part

North Star Imaging, Ansys, MOOG

SYNOPSYS®

Inspecting Deviation from Design in Manufactured Part

Highlights

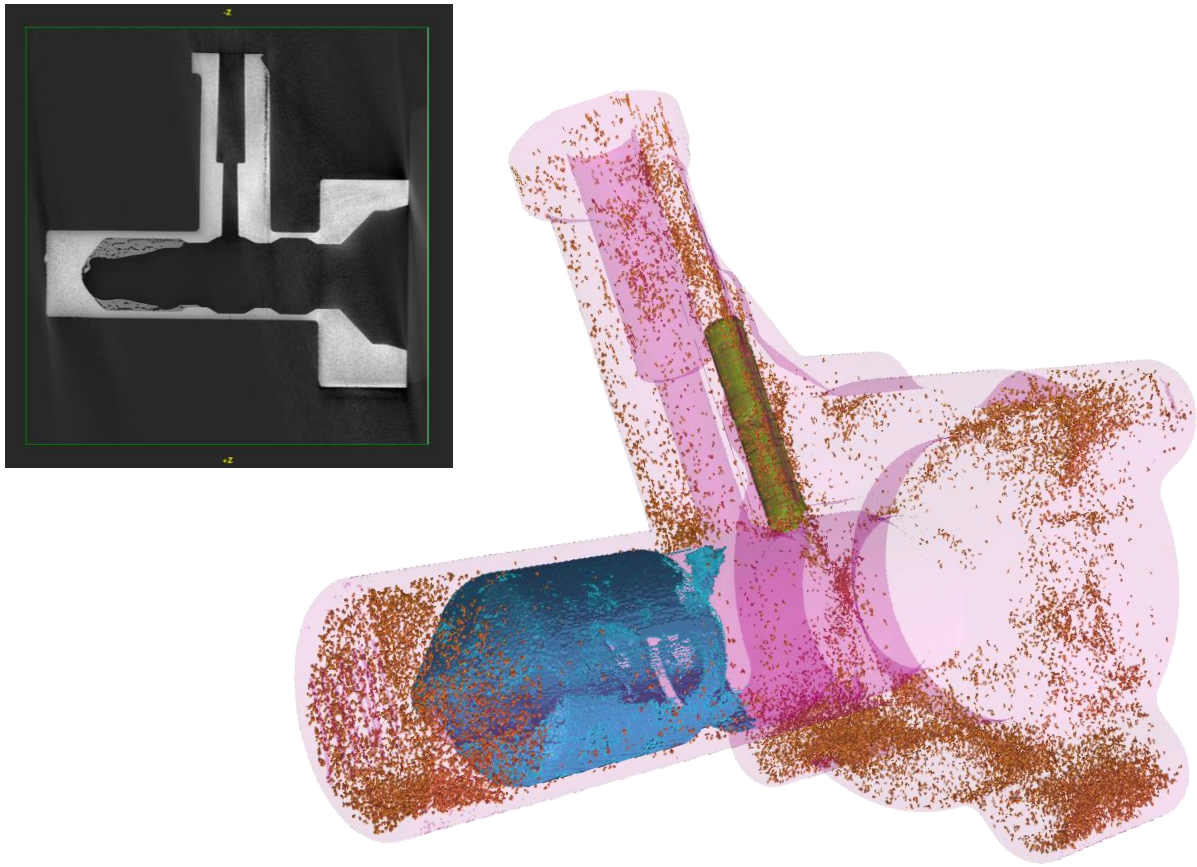
- Optimizing the design of an internal test manifold for a specific material and hydraulic configuration
- Simpleware software 3D image processing enabled visualization of defects, and comparison of the as-built part from the original CAD
- Simulation of maximum principal stress in ANSYS. The workflow enabled MOOG to quantify the fitness-for-purpose of the part and evaluate performance uncertainty

North Star Imaging, Ansys, MOOG

Inspecting Deviation from Design in Manufactured Part

Workflow

- CT scan data from NSI imported into Simpleware software. Visualization of pores, cracks and residual powder



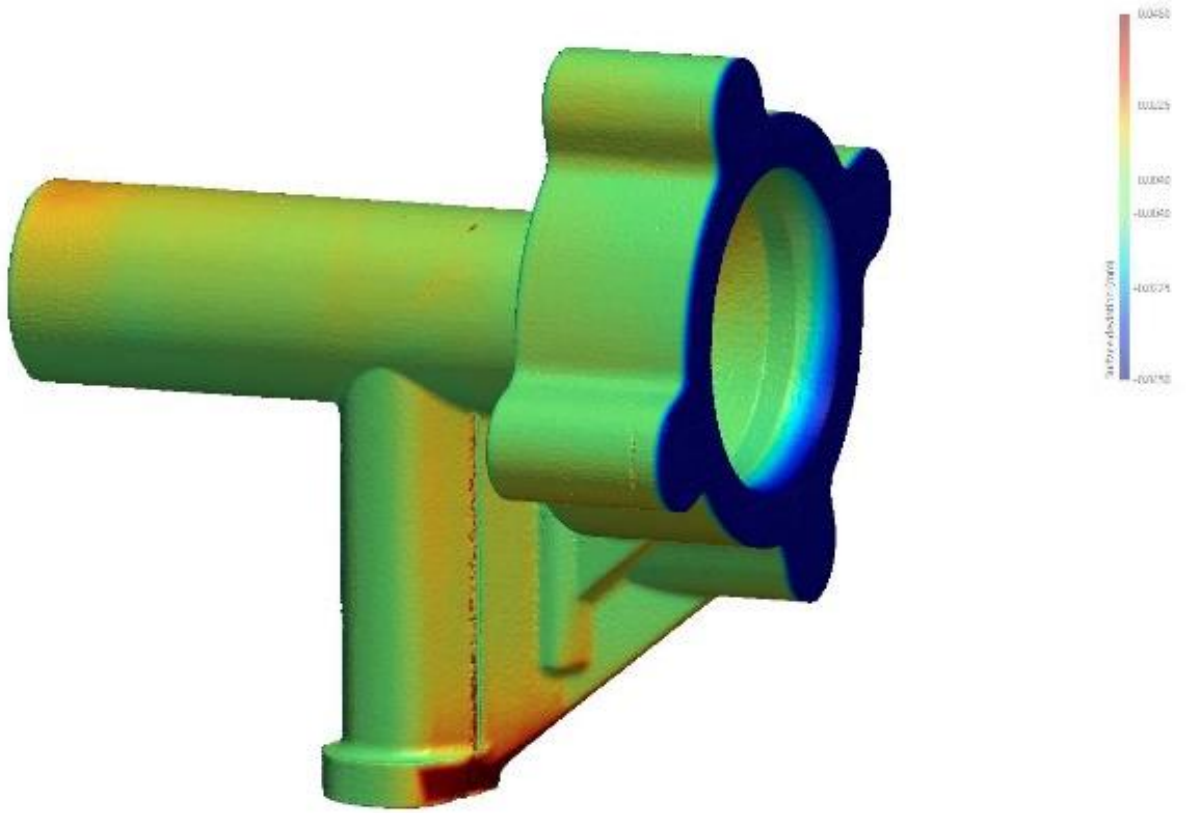
North Star Imaging, Ansys, MOOG

SYNOPSYS®

Inspecting Deviation from Design in Manufactured Part

Workflow

- CT scan data from NSI imported into Simpleware software. Visualization of pores, cracks and residual powder
- Simpleware software used to import original CAD and compare with as-built part to identi geometric deviations, for example in part porosity



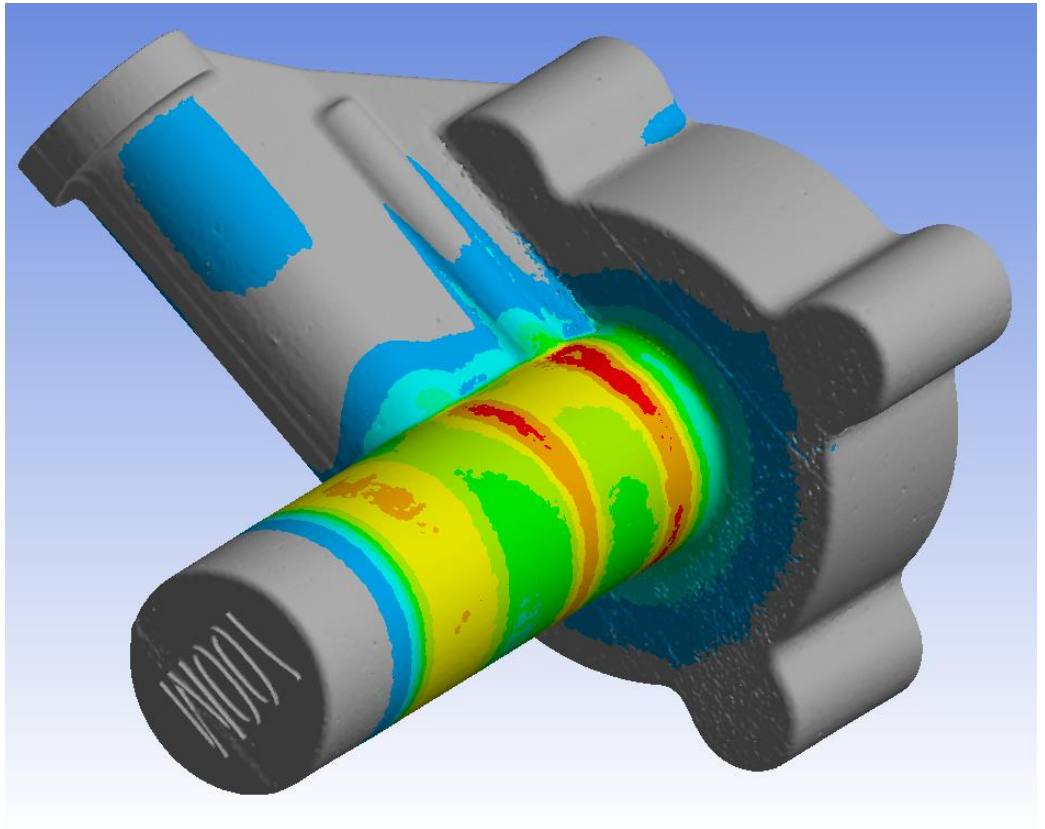
North Star Imaging, Ansys, MOOG

SYNOPSYS®

Inspecting Deviation from Design in Manufactured Part

Workflow

- CT scan data from NSI imported into Simpleware software. Visualization of pores, cracks and residual powder
- Simpleware software used to import original CAD and compare with as-built part to identify geometric deviations, for example in part porosity
- Simulation results in Ansys showed that between the CAD and image-based model there was a 23.18% increase in maximum principal stress, likely due to cracks and pores in the as-built geometry



North Star Imaging, Ansys, MOOG

Simpleware Human Body Models

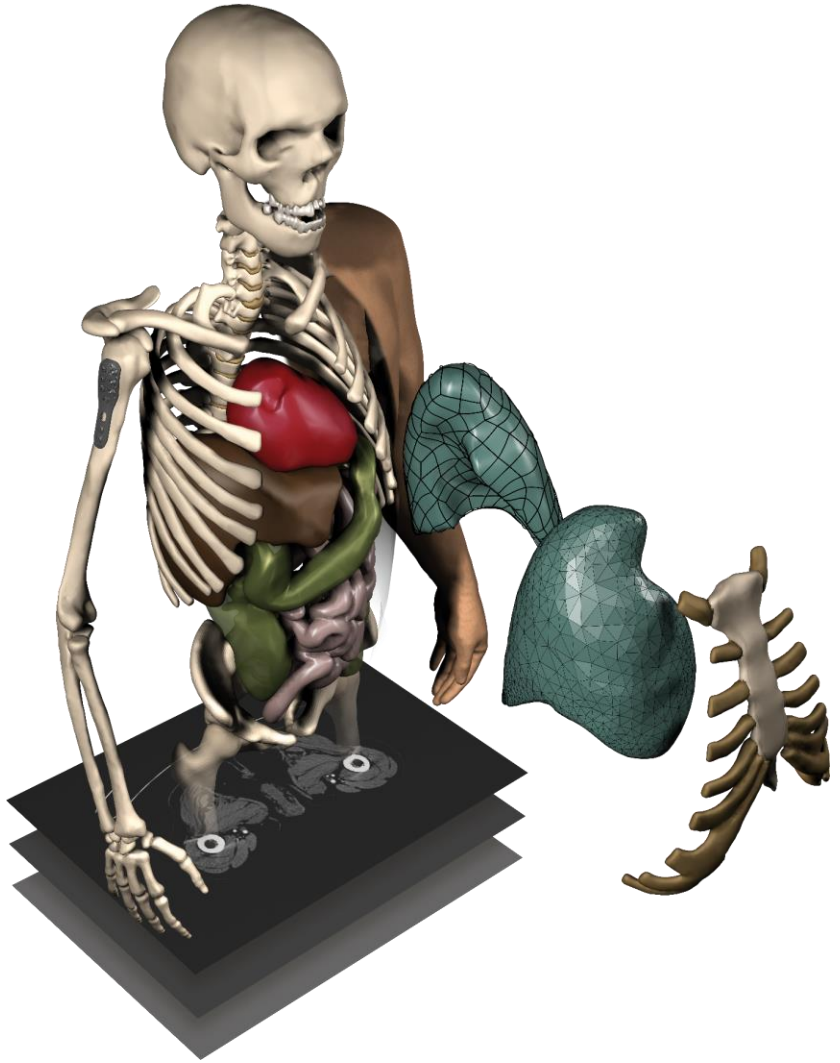
SYNOPSYS®

Simpleware Human Body Models

- **To Design Better Products:**
  (e-wearables, shoes, sports clothing, helmets)

  Currently designers and engineers of products that interact with the human body make limited use of anatomically correct CAD/CAE models to analyze their performance in use.

- **Provision of Off-the-shelf or Fully-customized Models for:**
  - 3D printing / ALM (STL)
  - CAD (NURBS)
  - Simulation (FE and CFD meshes)

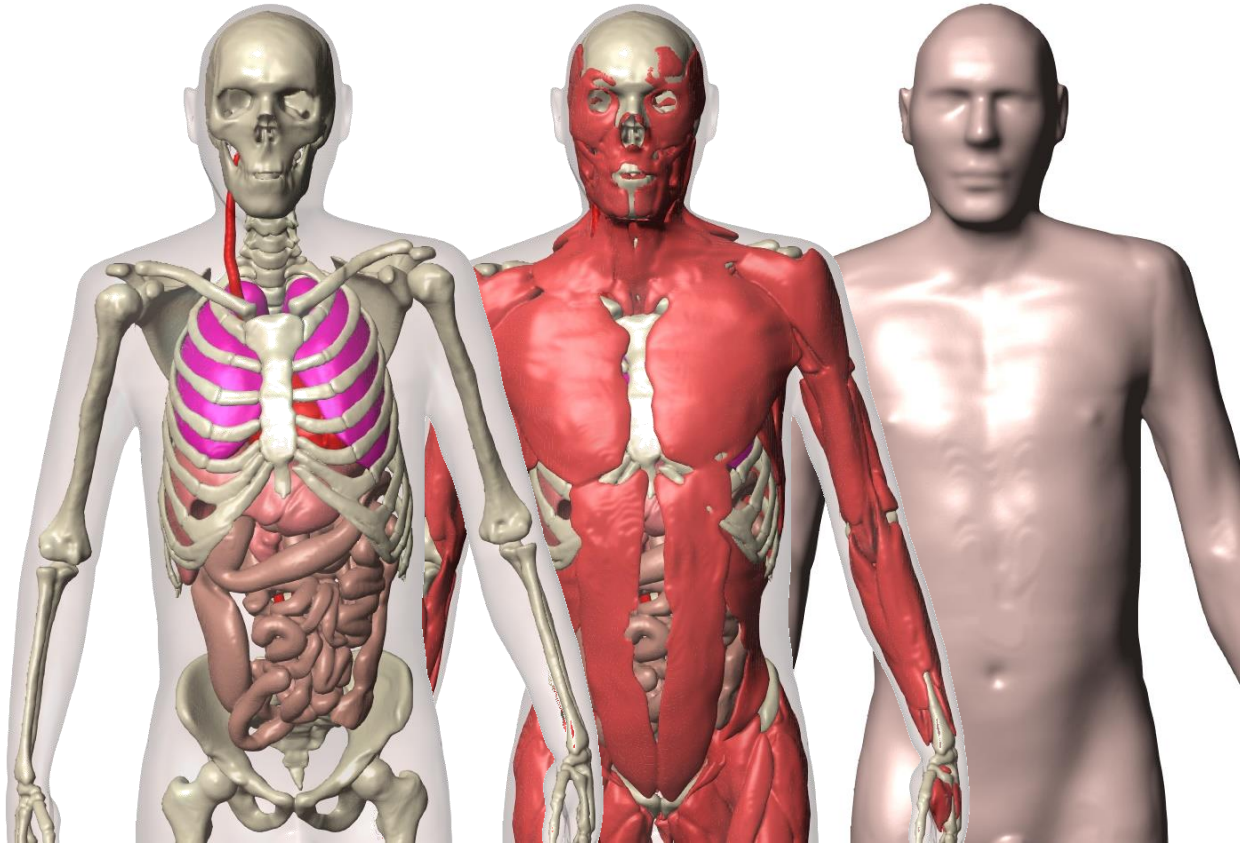


SYNOPSYS®

Simpleware Human Body Models

Our Datasets:

- Large collection of anatomical datasets from high-resolution MRI and CT scans
- Models offer outstanding levels of detail and geometrical accuracy
- Select generic models or configure models to your requirements
- Models can be customized to combine CAD with image data
- Scans and models can also be commissioned



SYNOPSYS®

Simpleware Services

SYNOPSYS®

Simpleware Services

- **Consultancy Services:**
  - Image processing, segmentation, analysis and animations
  - Model and mesh generation
  - Scanning and 3D printing facilities

- **Customized Script, Plug-ins and Software Development:**
  - Get the best from the software's functionalities and beyond
  - Develop standalone personalized applications

- **Software Training:**
  - Classroom training at local Synopsys offices or at your place of work
  - Web-based training at your desk

SYNOPSYS®

SYNOPSYS®
Silicon to Software™

Thank You