An Industrial Workflow for Non-Destructive Testing and Simulation of a Heat Exchanger

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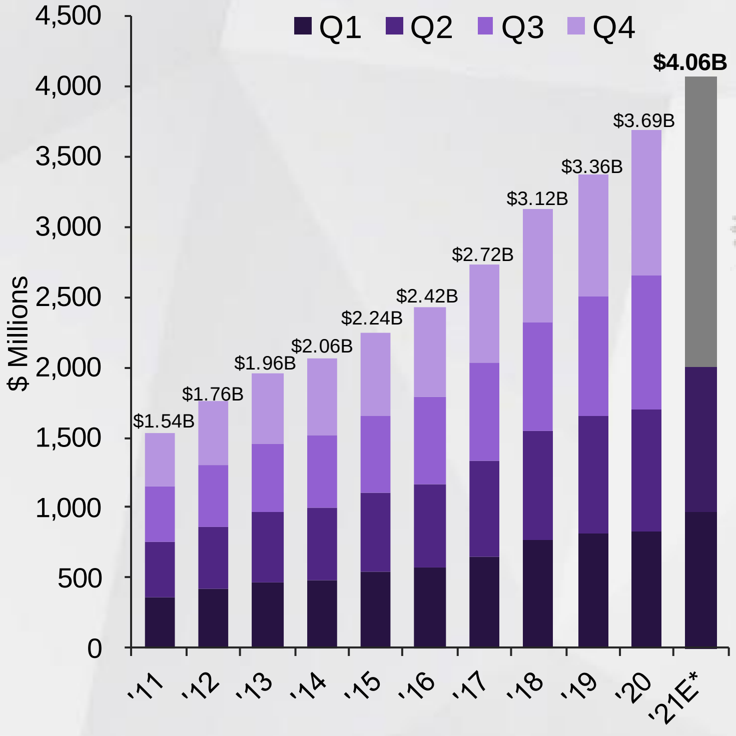
Synopsys Today: From Silicon to Software

FY20 Revenue: ~$3.7B

Employees: 15,556

Patents: 3386

Offices: 122



#1 electronic design automation tools & services

Broadest IP portfolio and **#1** interface, foundation & physical IP

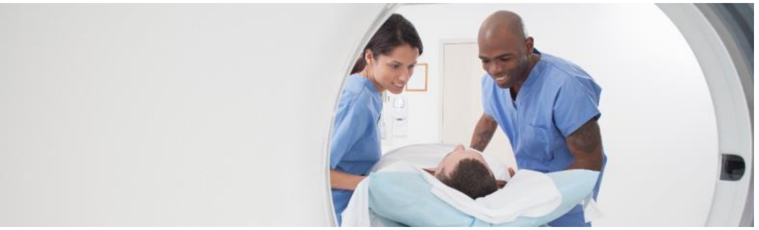
'Leader' in Gartner's Magic Quadrant for application security testing

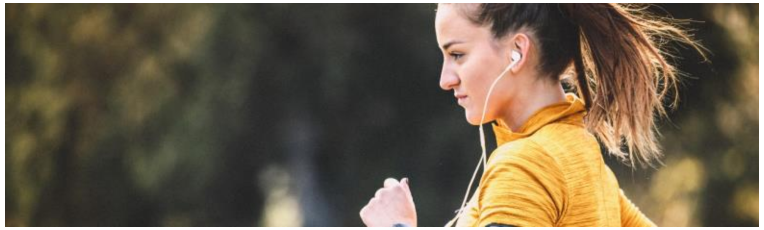
* FY21E reflects the midpoint of FY21 guidance

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…

SYNOPSYS® | SIMPLEWARE PRODUCT GROUP





What does the Simpleware Product Group offer for me?

Industrial Reverse Engineering Example:

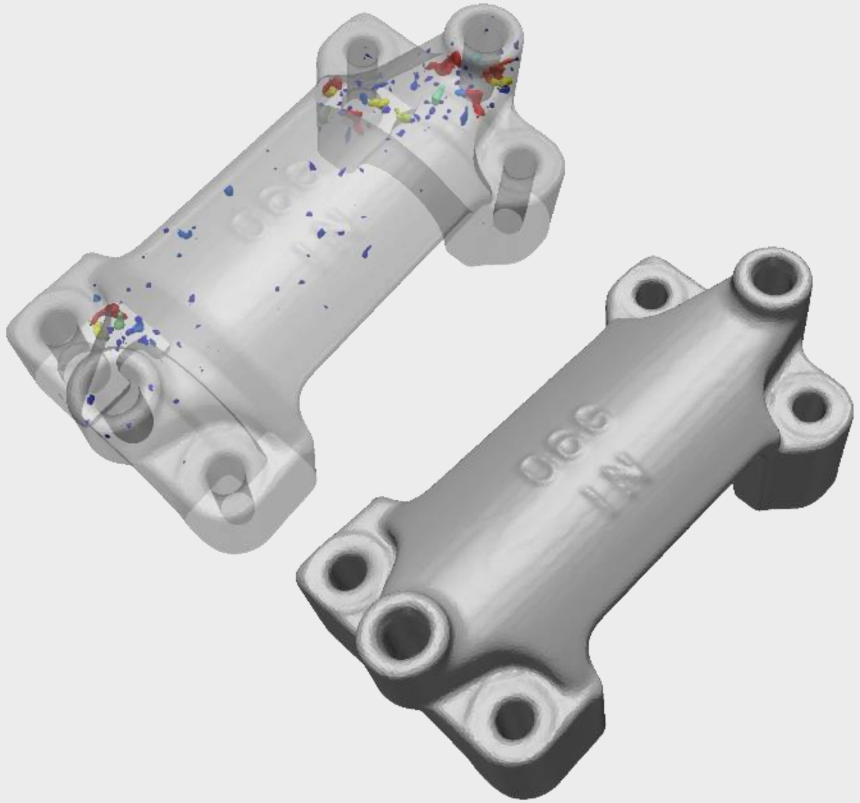
Based on industrial CT scans

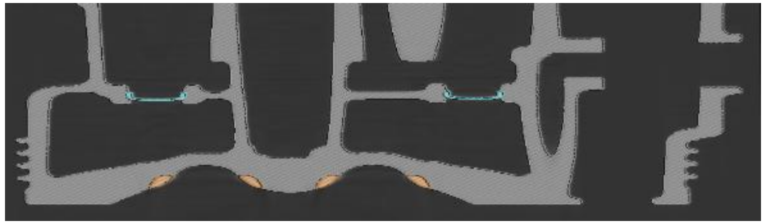
– Take scans of a manufactured part, e.g. casting, AM, injection moulding…

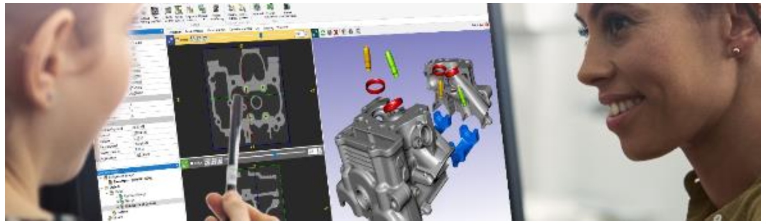
– Register CAD to scanned parts, to perform metrology, measurements, and deviation analysis

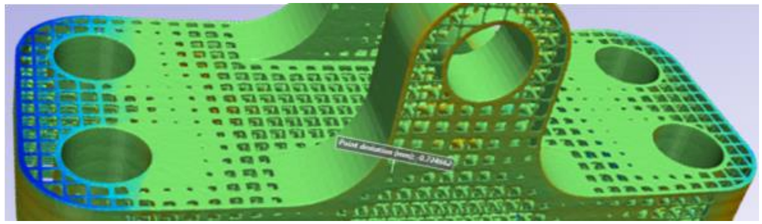
– Facilitate simulation on as built or damaged part to check performance and fit for purpose

→ *Improve quality assurance and reduce time to market*



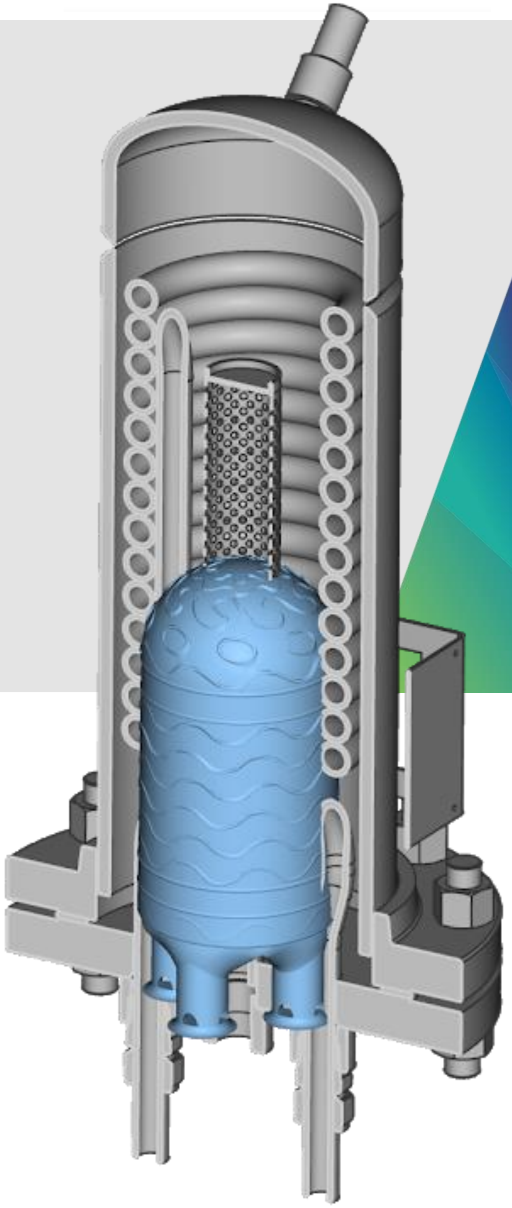






Overview -

Six industry leaders took on the challenge to develop a clean slate rapid design of an advanced heat exchanger leveraging each of the advanced capabilities that their companies offer.



Legacy Heat Exchanger Designs

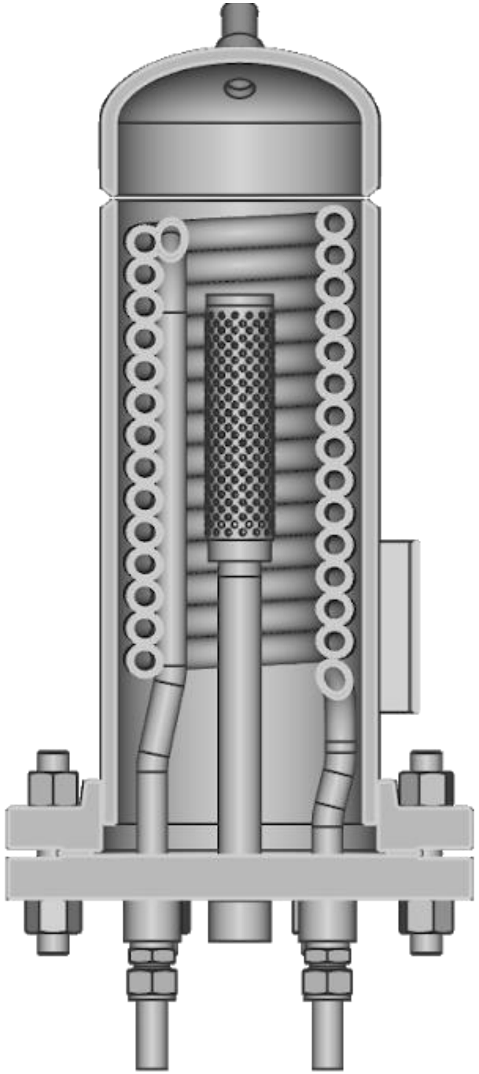
- Today's most advanced applications are **space constrained** and rising thermal requirements are driving the need for smaller and more efficient designs

- There has been relatively **little innovation** in the geometries of the most common heat exchanger designs

  - Most liquid-liquid heat exchangers are dominated by in-efficient **tube and shell** geometry designs

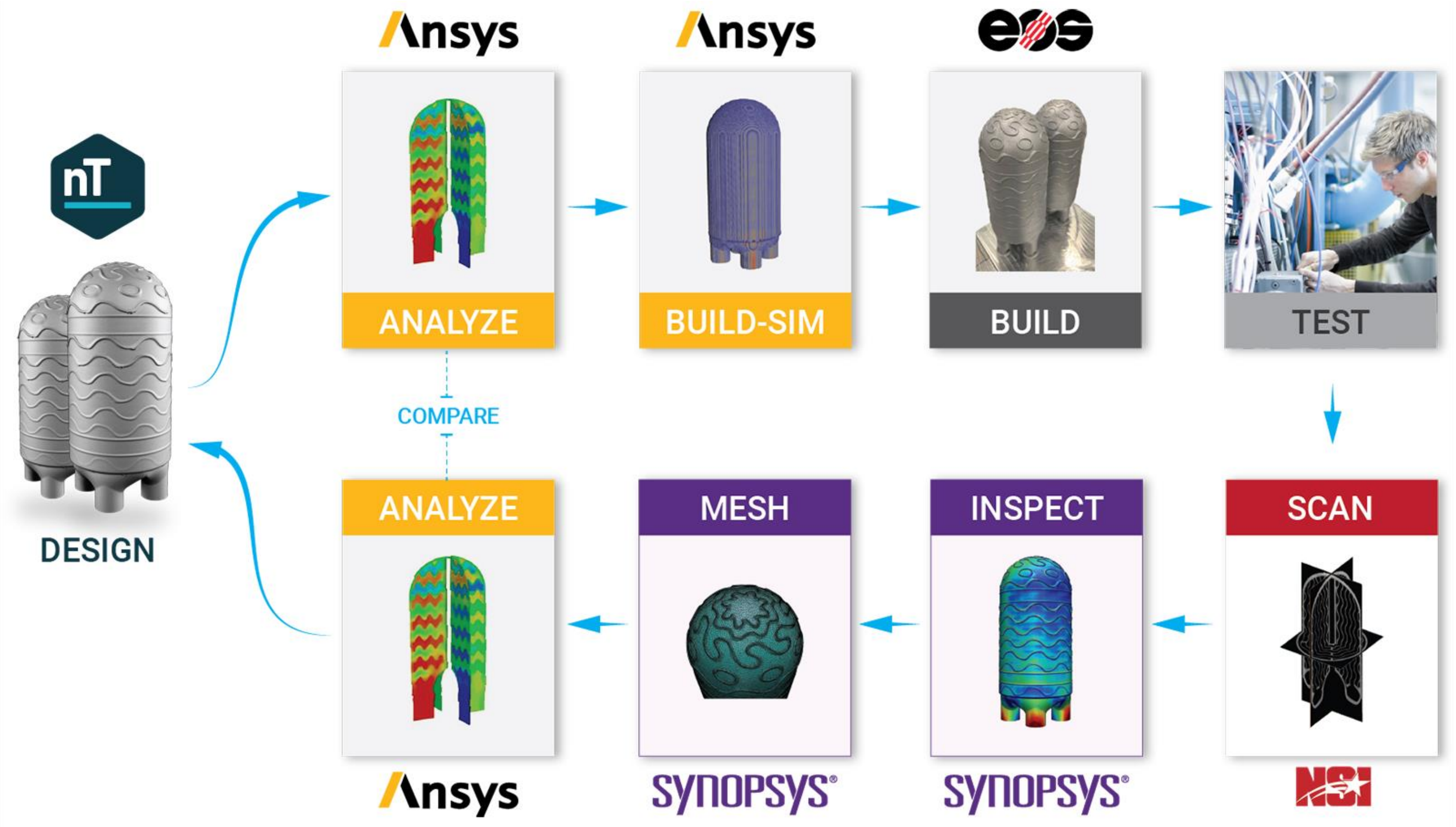
- With Advanced Manufacturing a designer can make a heat exchanger with higher energy efficiency and system performance and is fundamentally able to move **larger amounts of heat around using less material in less space**

- Well-known techniques for convective **heat transfer enhancement** include the use of structures that induce **mixing and swirling** can offer large heat transfer increases



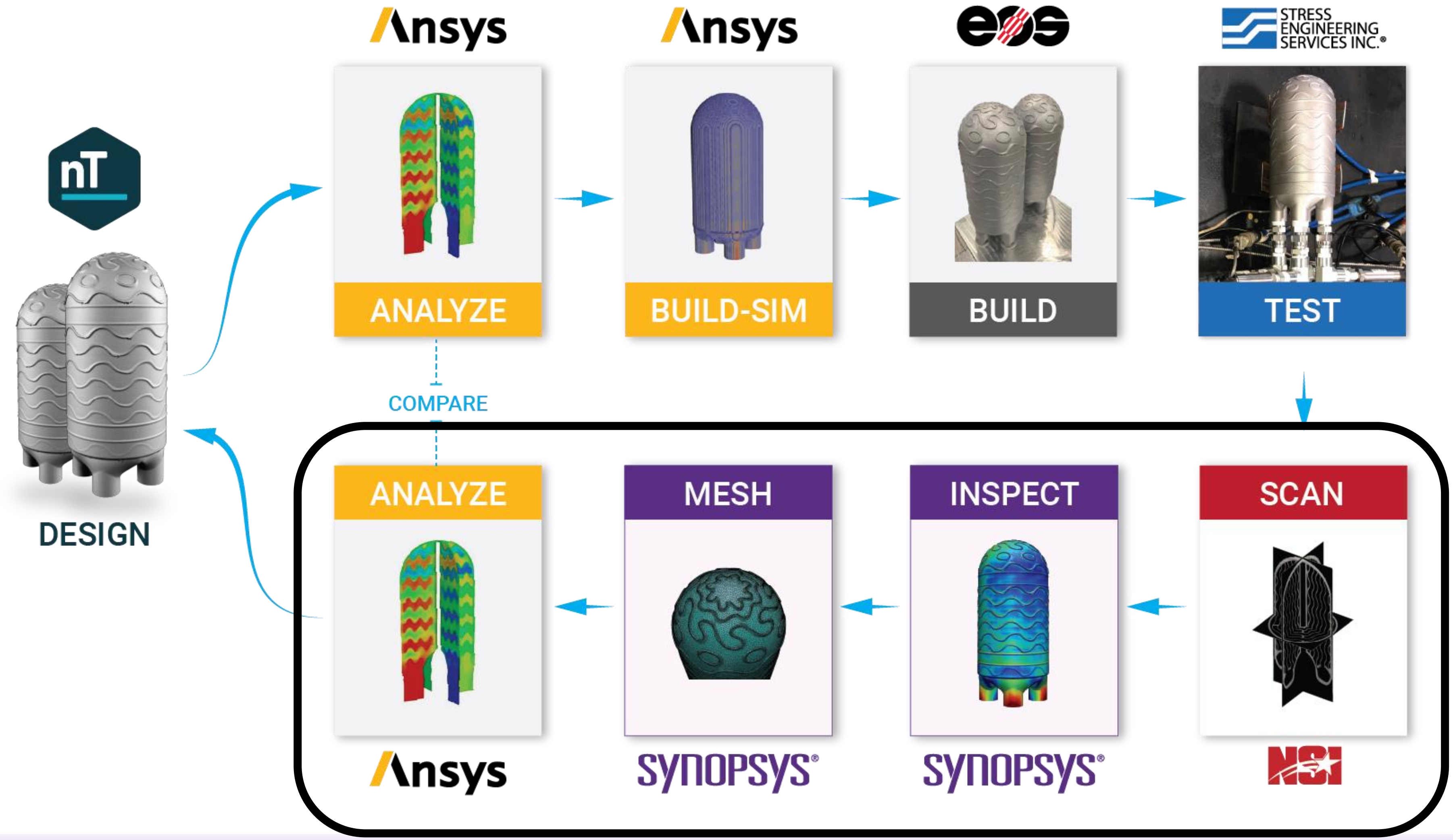
We will demonstrate how implicit geometry can be used to drive the future of heat exchanger design using complex surfaces that provide incredible gains in heat exchanger performance

Overall workflow



Reduce risk while leveraging advanced manufacturing techniques for innovation

Key Technologies



Reduce risk while leveraging advanced manufacturing techniques for innovation

Quality Inspection

- Differences
- Internal Intricate Structures
- Porosity
- Manufacturing Tolerances

As-Designed **VS** **As-Built**

How will these differences affect **performance** in the real world?

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Computed Tomography (CT)

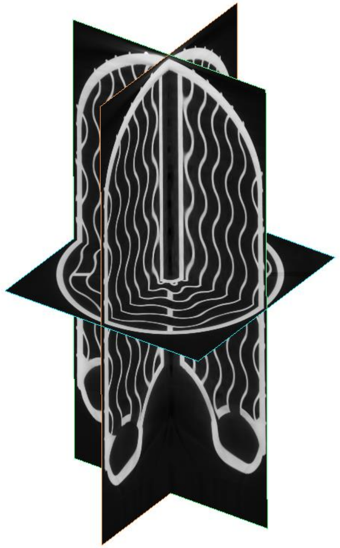
How to capture the internal structure of your part

High Value Part

Example:
- Turbine Blades
- AM Parts
- Composites
- Ceramics etc.

Industrial CT Scanner

- R&D groups examining Materials or AM
- Production workflows for QA

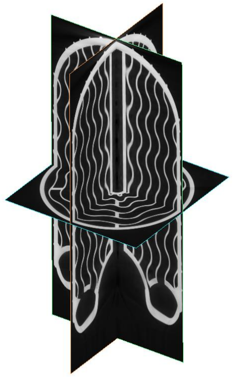


3D Image Data

Visualize internal structures for various analysis workflows.

Converting 3D Images to Models

3D Image Data



Simpleware Software Platform

Model

Reverse Engineering
Non-Destructive Analysis
Metrology & CAD Comparison
As-Built Simulation

Automation

Typical Bottleneck of scaling up workflow from R&D to production level efficiency is image segmentation and landmarking

Simpleware AI-based solution for complete automation

- Process hundreds to thousands of CT scans per month
- Scaling up is only limited by compute power

Simpleware Software - What Does It Do?

Model Generation

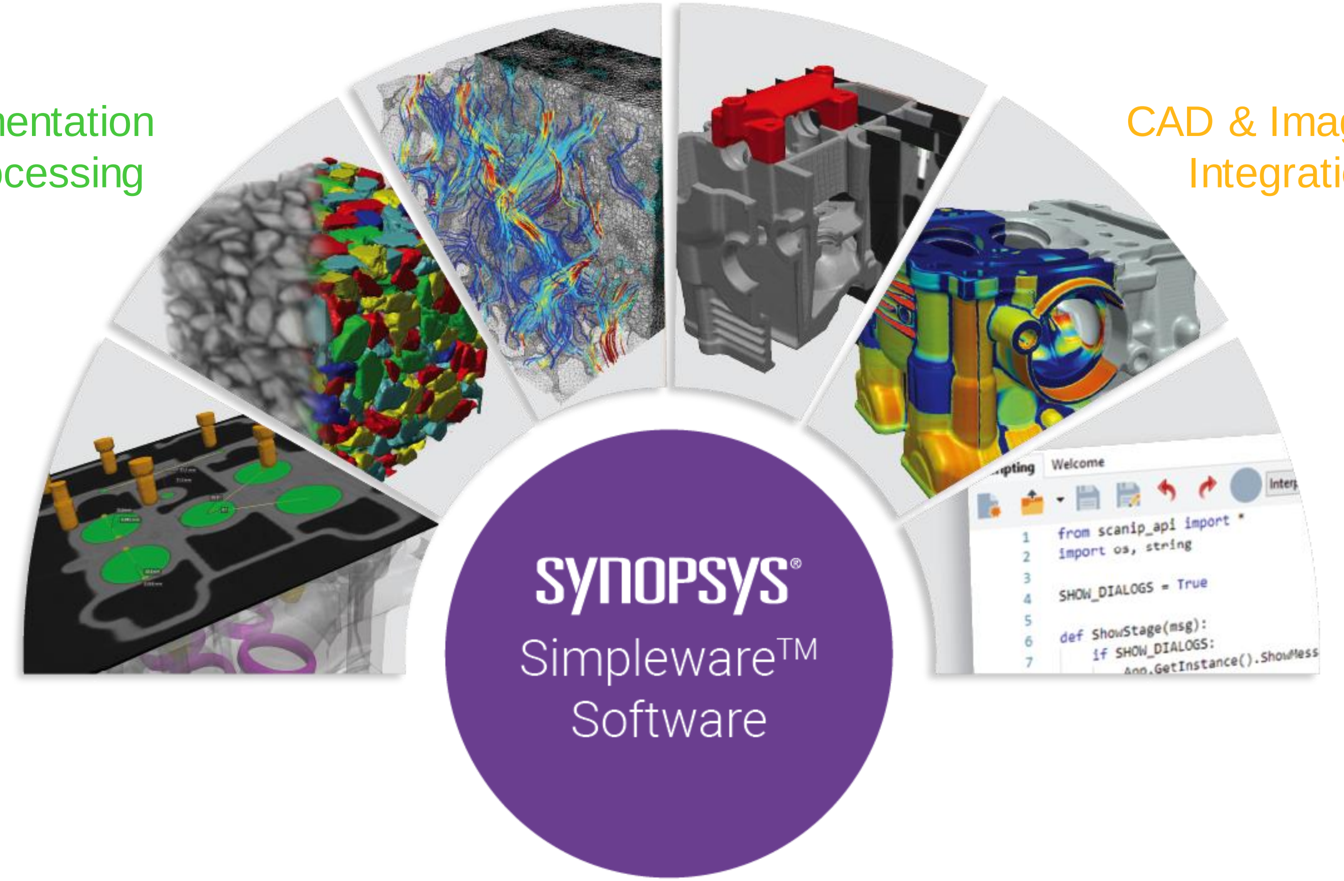
3D Image Import & Visualization

Segmentation & Processing

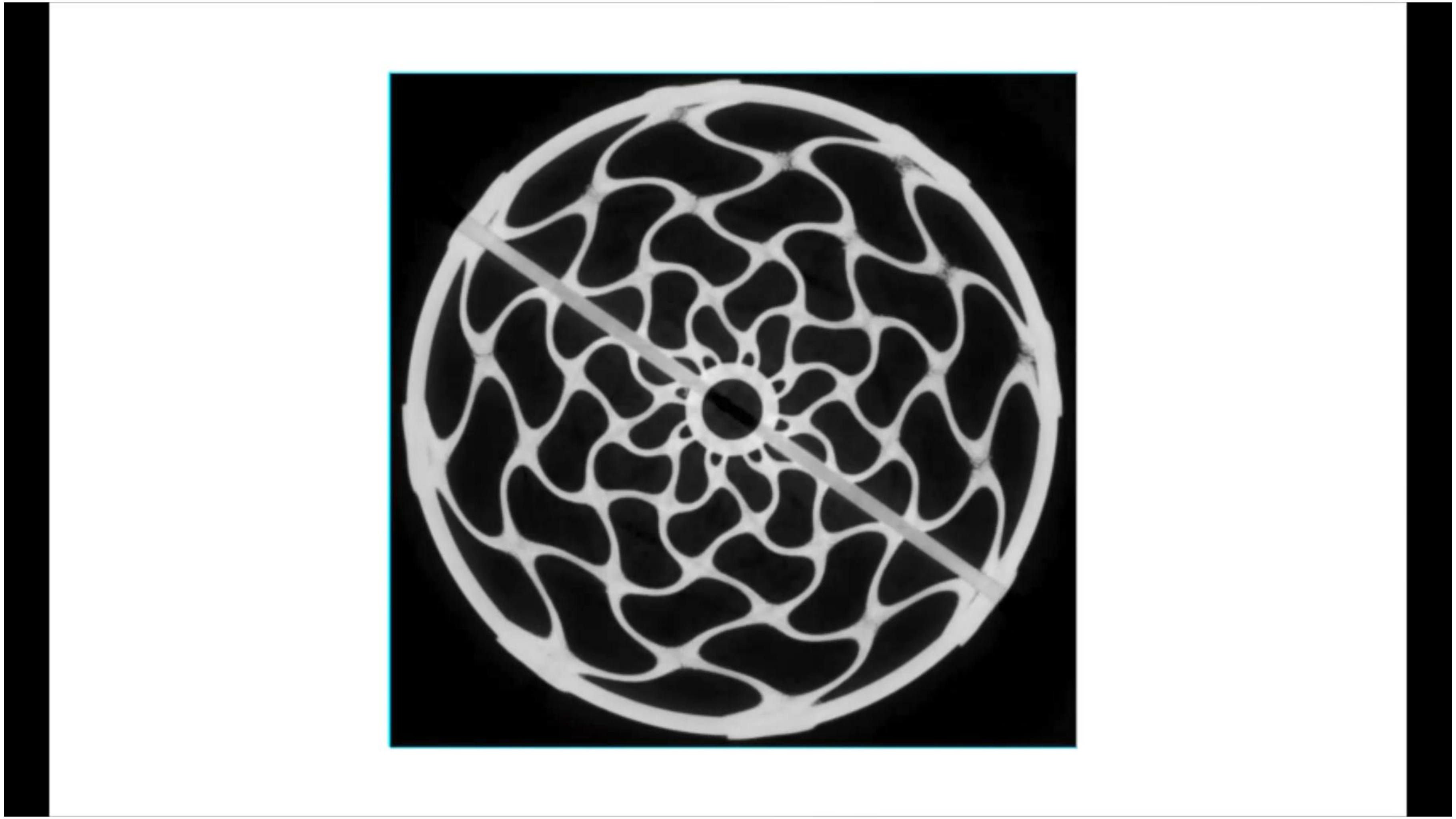
CAD & Image Integration

Measurements & Analysis

Scripting & Automation

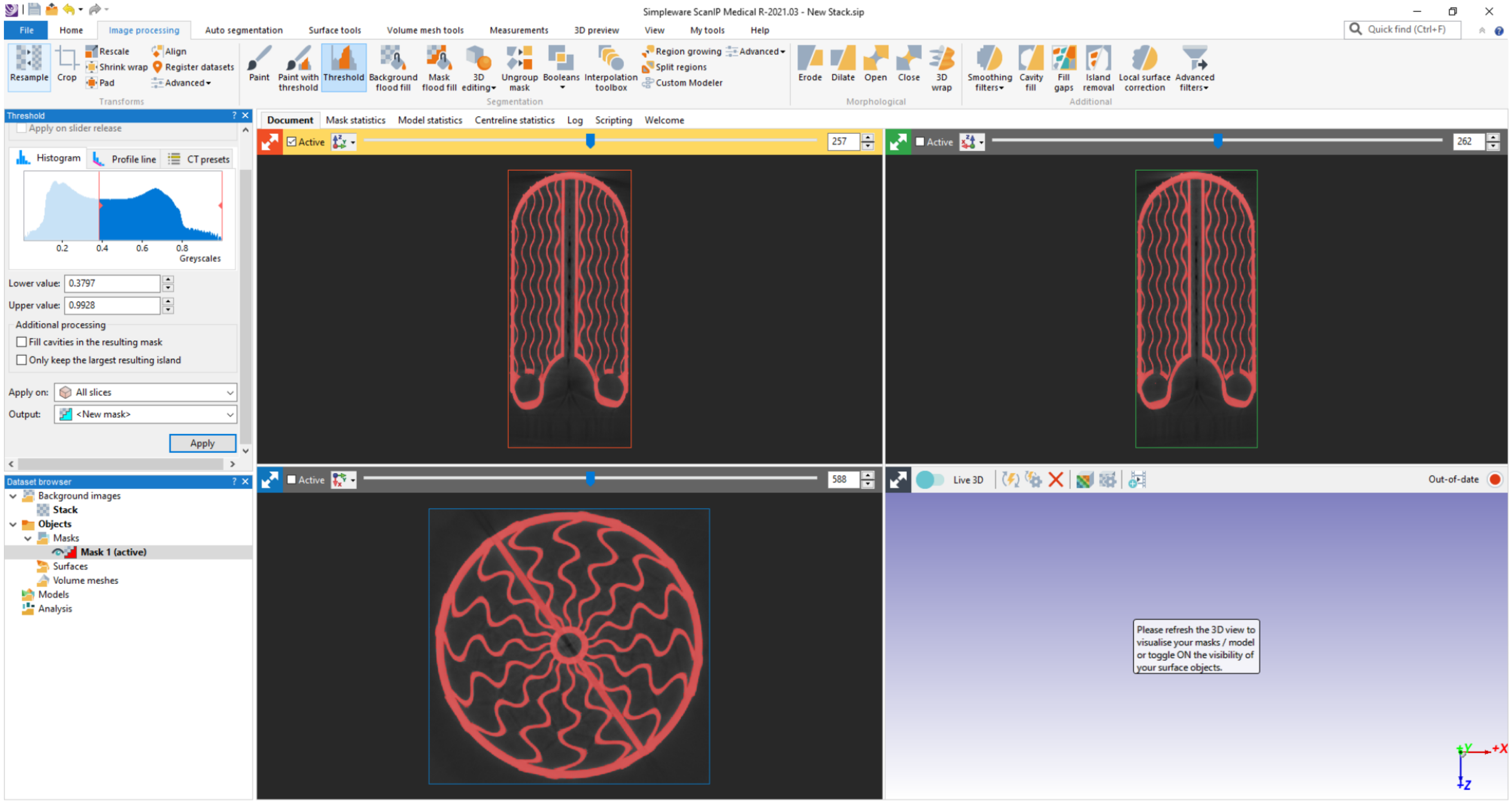


Images as received from North Star Imaging

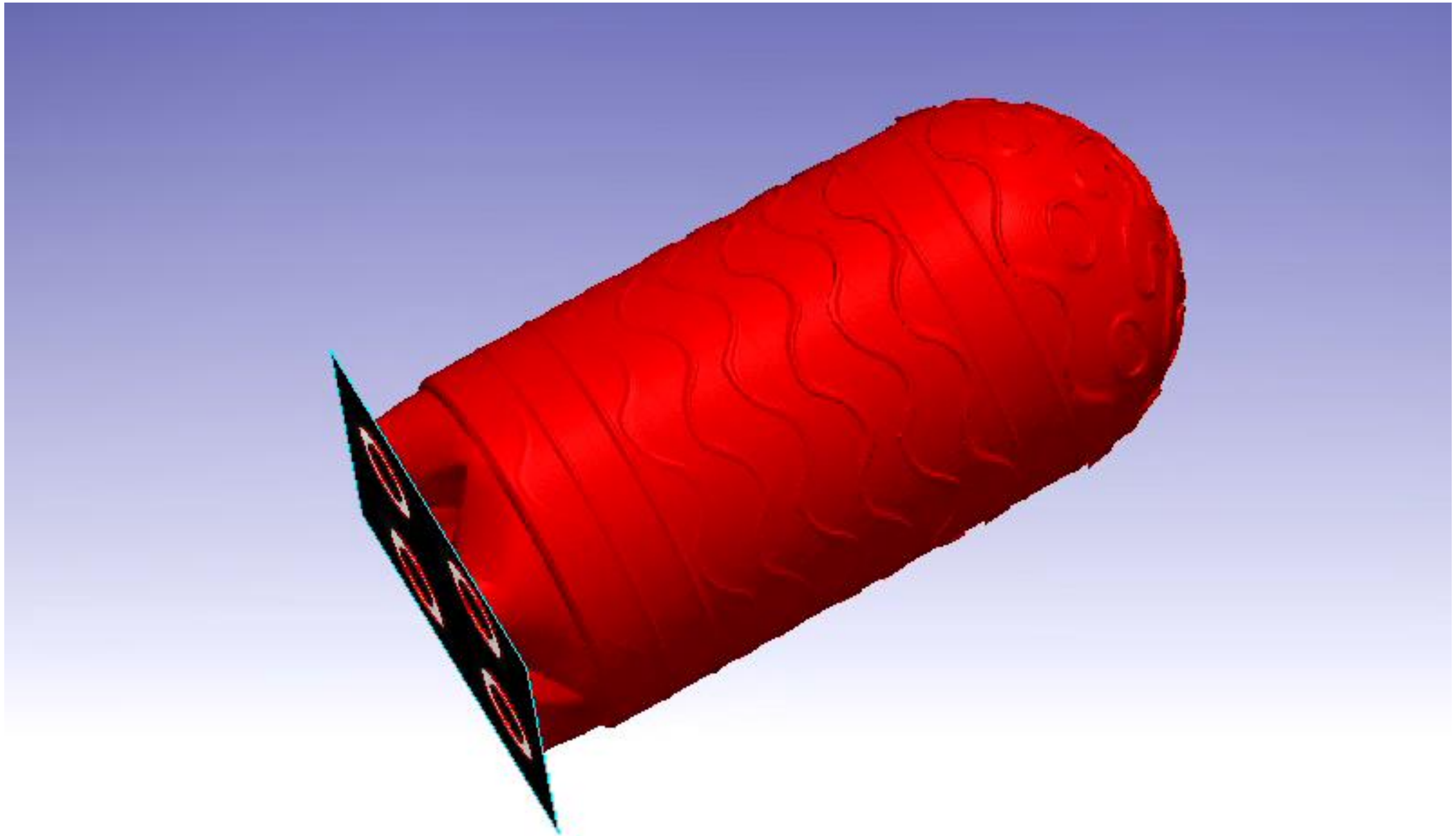


Segment the Images (Identify which voxels in the images correspond to which structure)

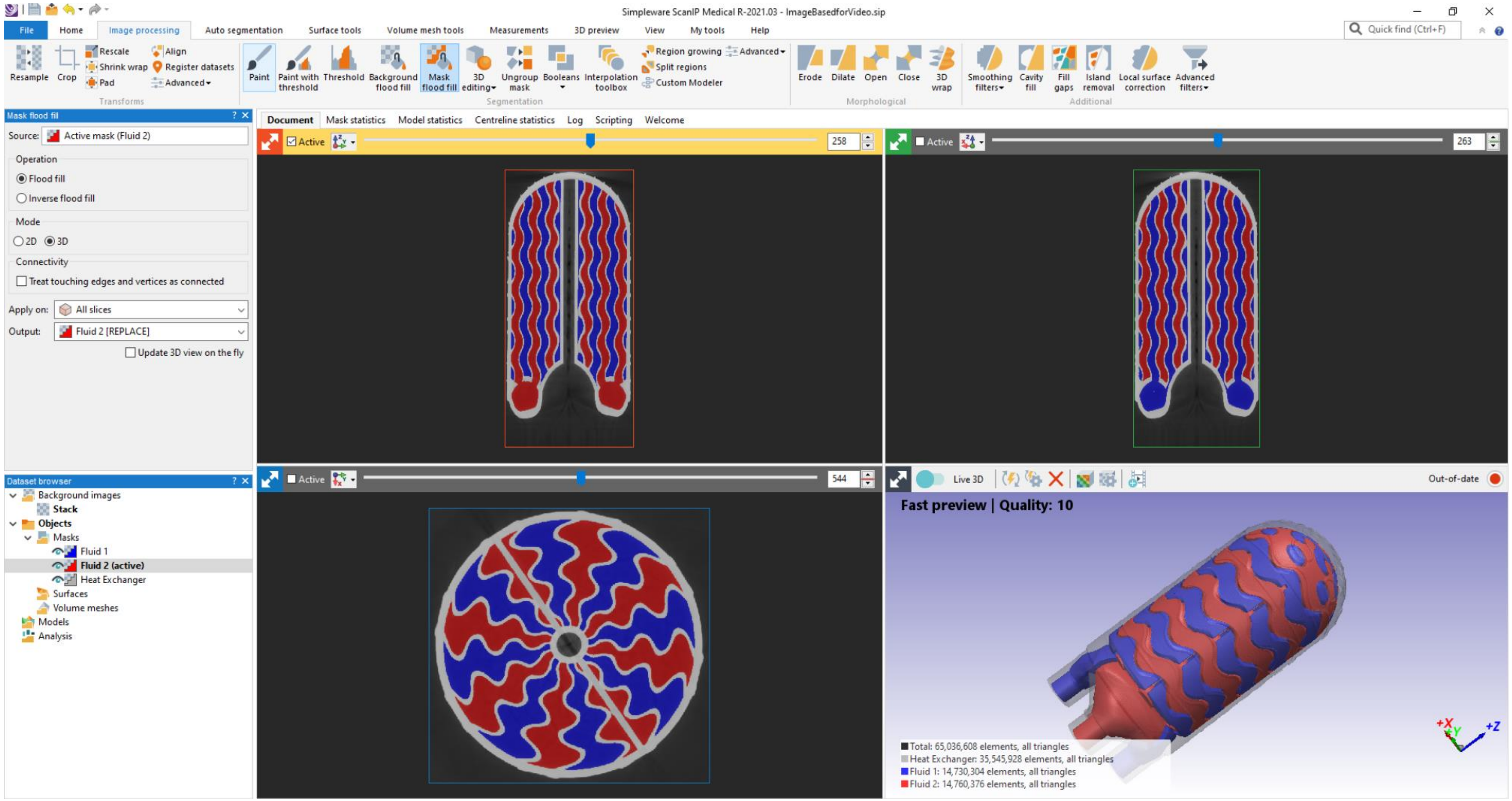
MESH



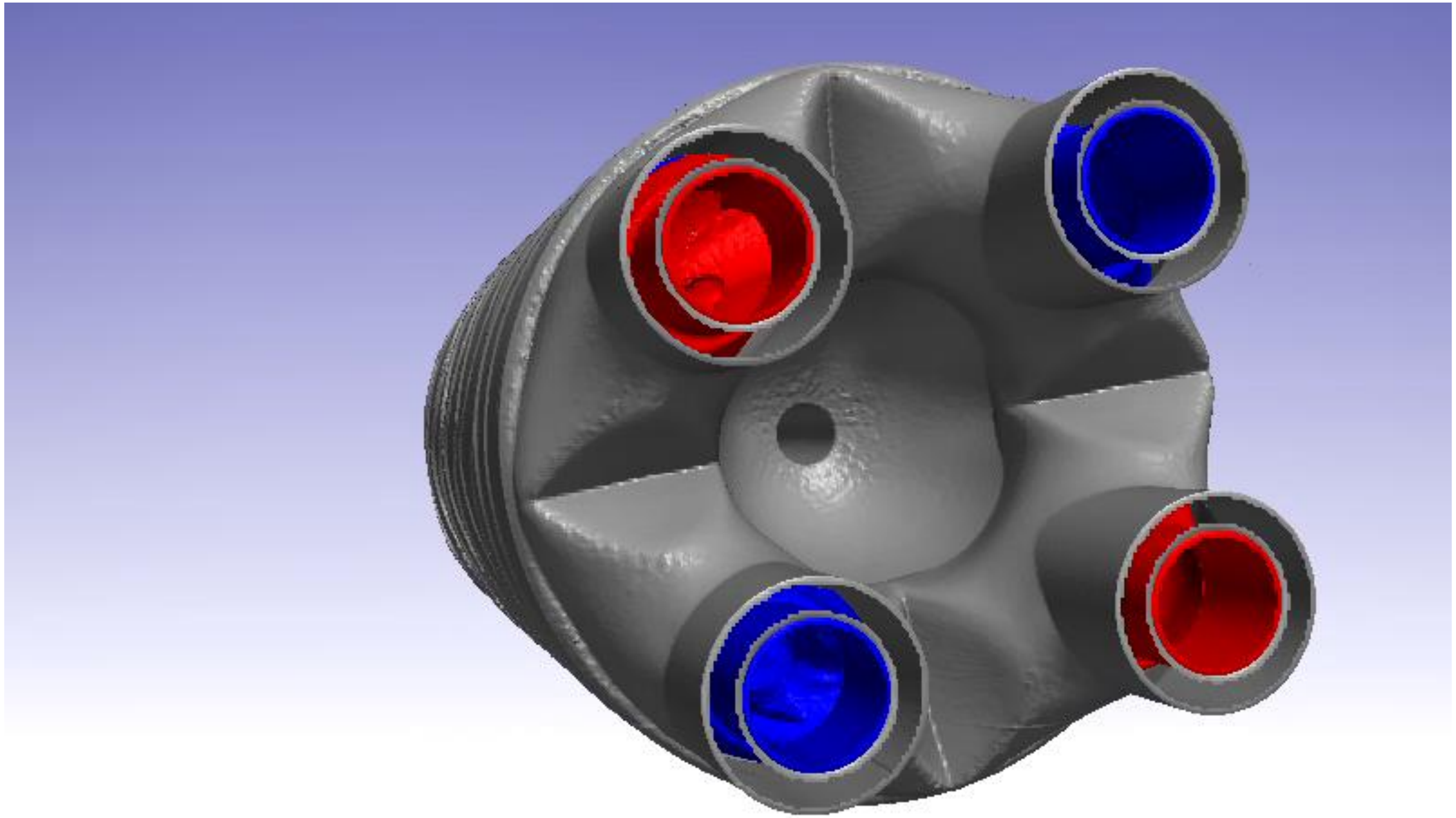
Segment images to create model(s) of imaged object



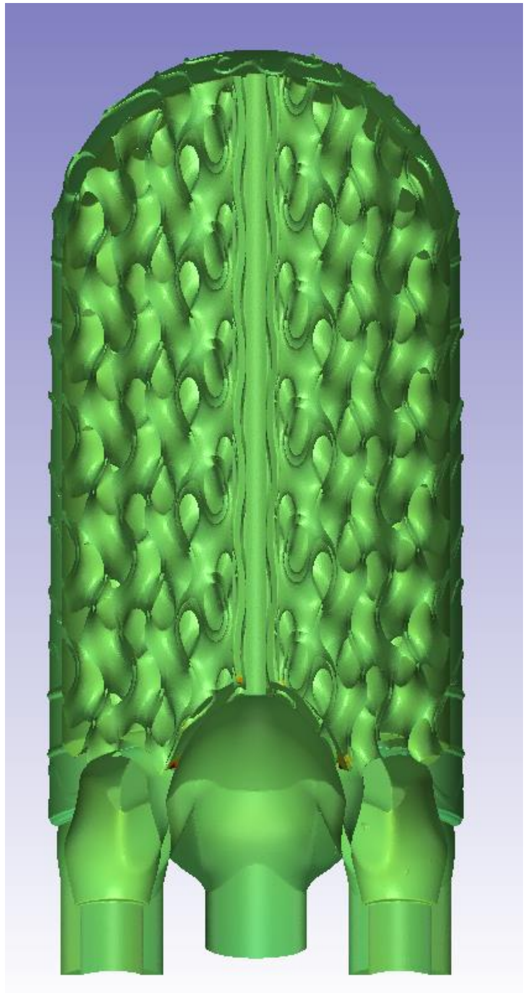
Segment images to create model of fluid regions (3 Step Process – Duplicate, Invert, and Flood Fill)

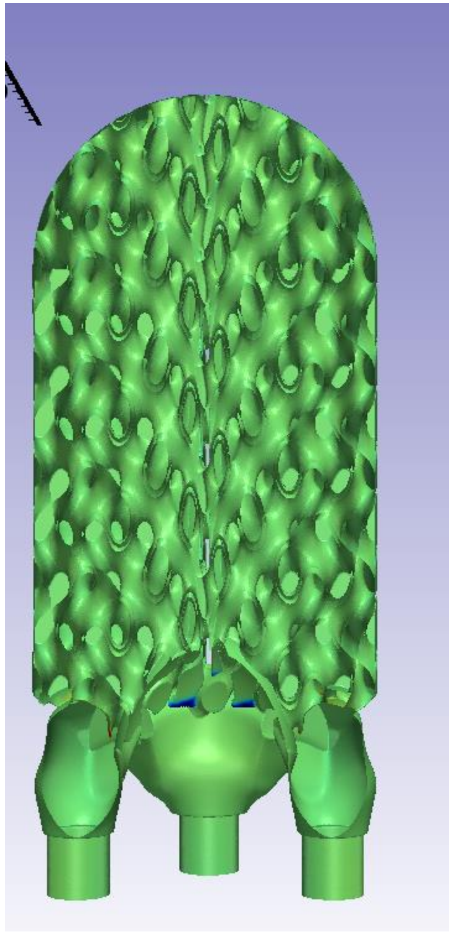


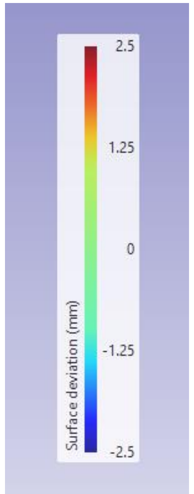
Visually Check for Defects (Holes, Cracks, Porosity)



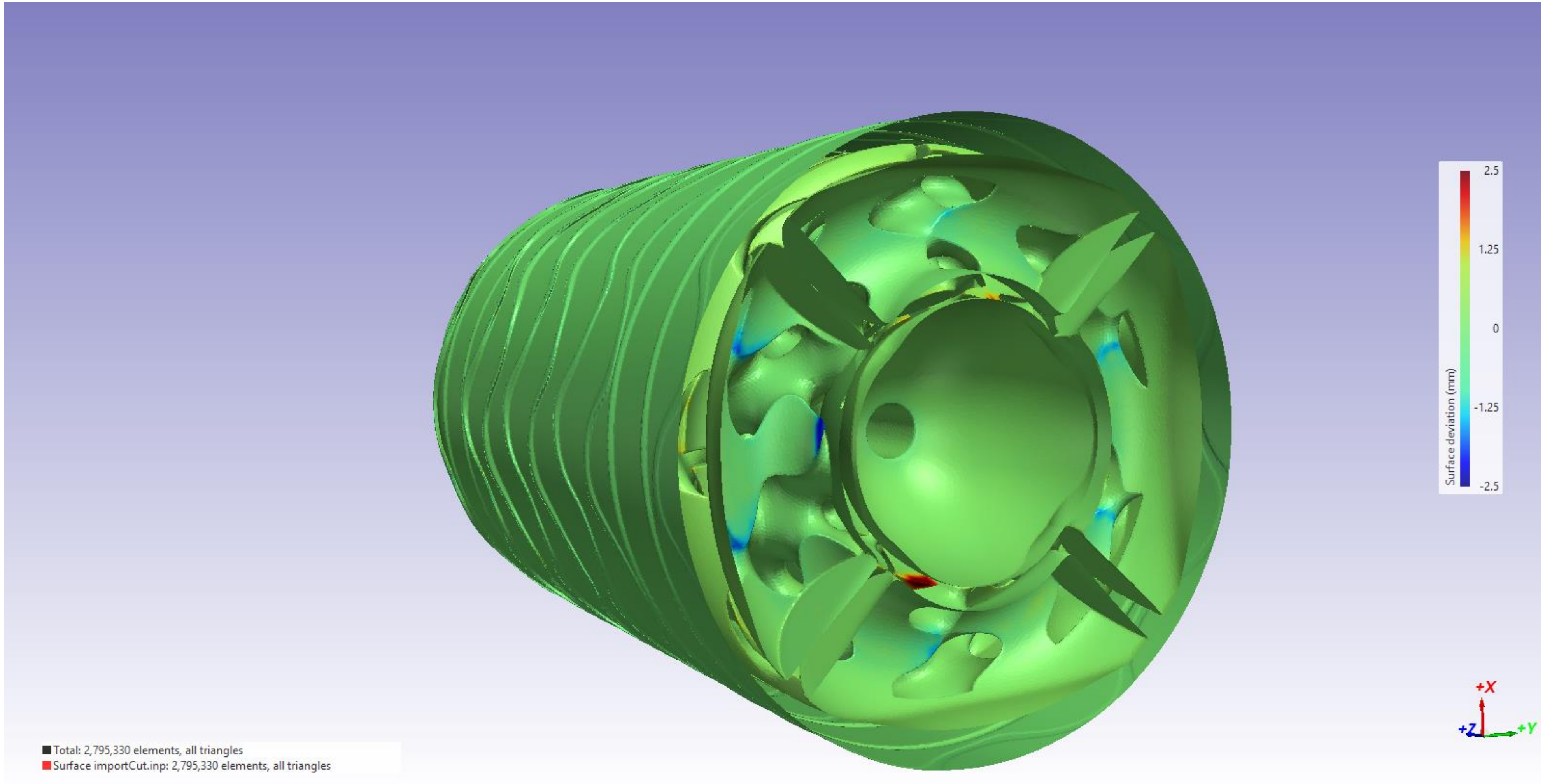
Fluid Space Comparison Cross Section
Note: CAD STL set as standard.







Close Up of Regions of Highest Deviation

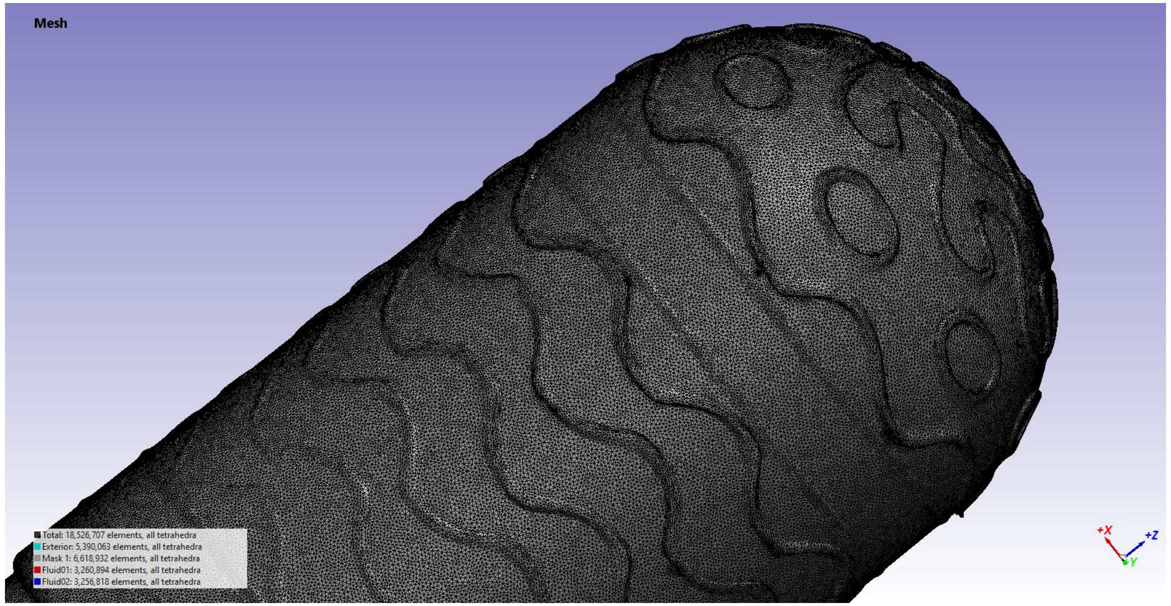


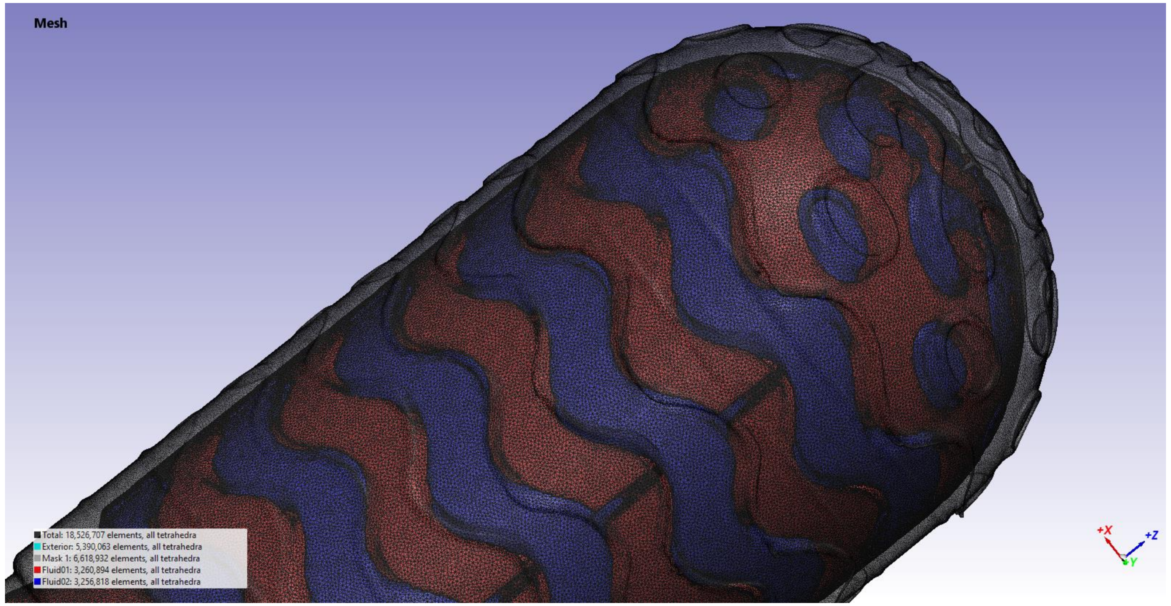
Statistics: As Built compared to As Designed

- Upper deviation 3.15 mm
- Lower deviation -2.28 mm
- Mean 0.08 mm
- Mean positive 0.09 mm
- Mean negative -0.02
- Root mean square error 0.152
- % Above critical positive deviation 0.001
- % Above nominal positive deviation 0.02
- % Below nominal negative deviation 0.01
- % Below critical negative deviation 0

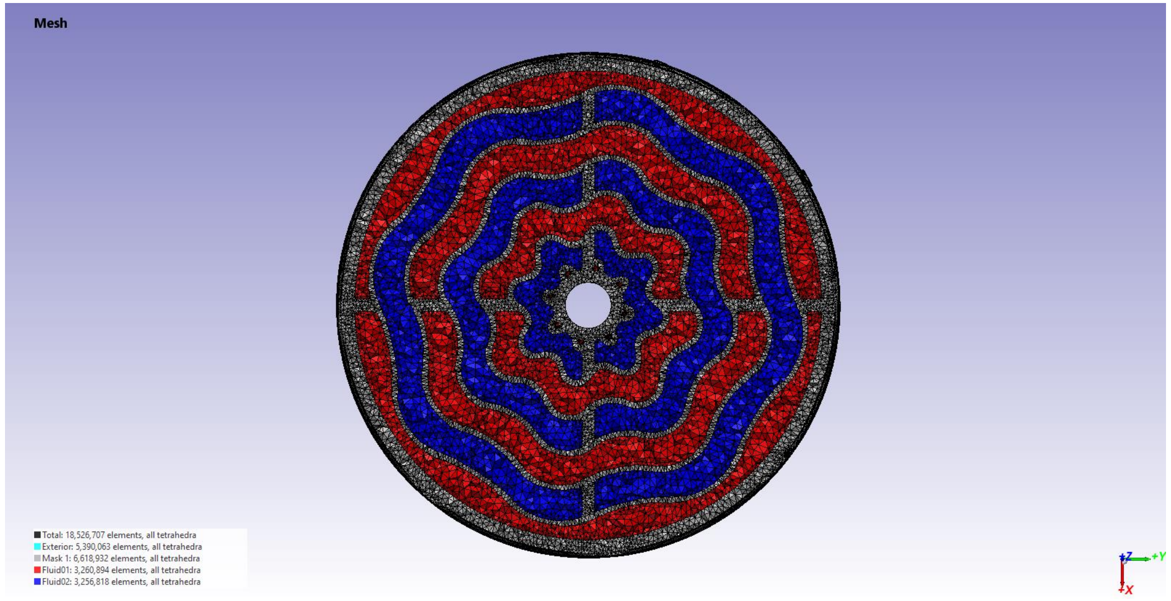
Overall Excellent Print!!

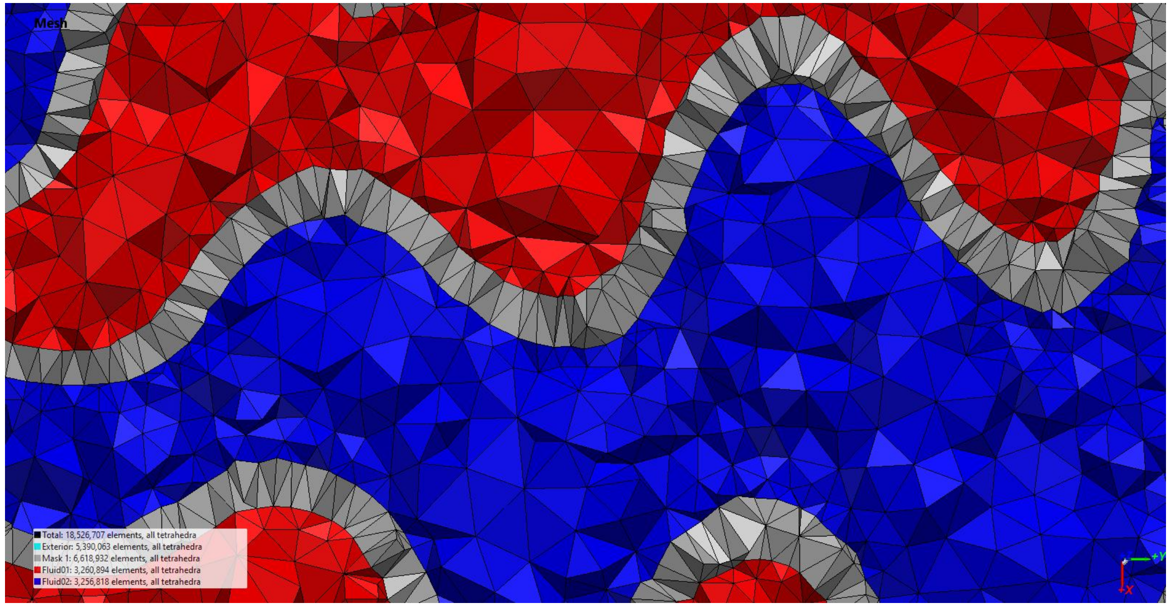
Generate Mesh





Automatically Generate Multi-Domain FE Mesh





ANALYZE

Ansys

Burst Pressure Validation Requirements

Aerospace heat exchangers must not only perform heat transfer operations, but also survive structural loading requirements.

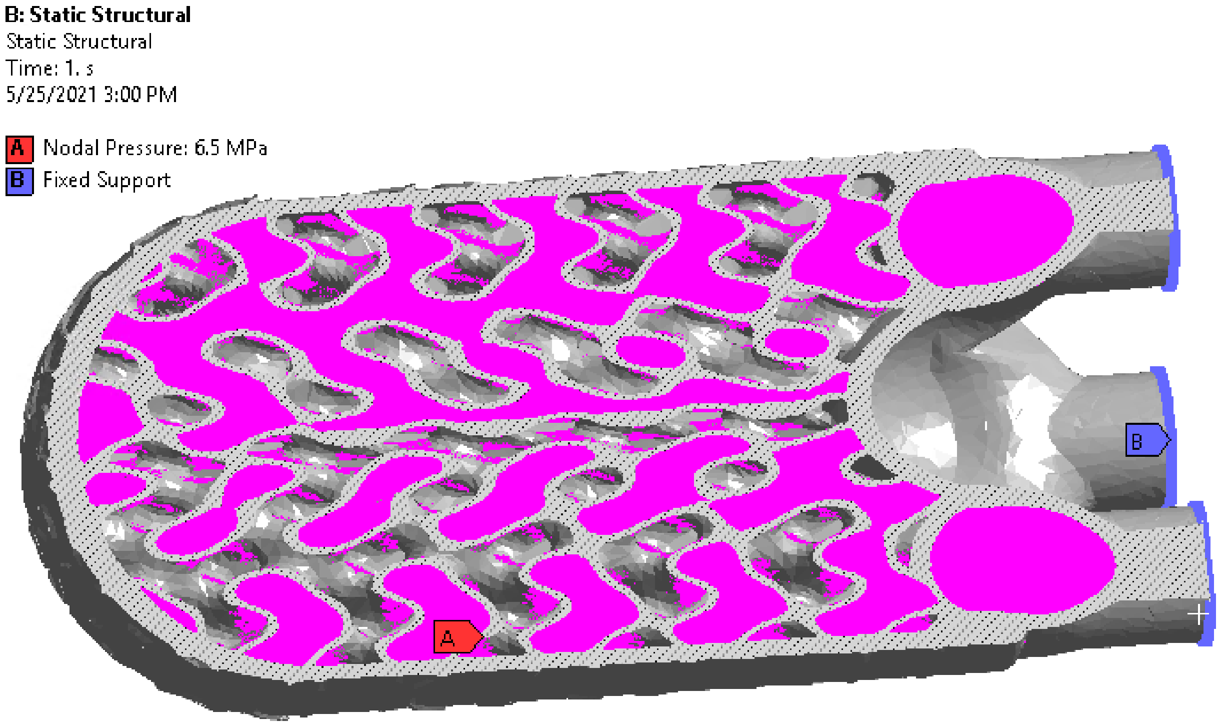
A critical requirement is to meet burst pressure requirements that exceed normal operating conditions due to external loads.

Structural requirements may have a larger impact on the wall thickness of the heat exchanger rather than heat transfer requirements.

Heat Exchanger Design is often driven by requirements beyond pure heat transfer

SYNOPSYS

Burst Pressure Test Simulation



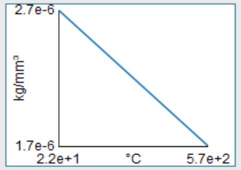
- Mesh import easily into ANSYS Workbench Mechanical
  - Alterative :STL import -> ANSYS Meshing Tools
- As- Built vs As-Designed comparison
- Boundary Conditions:
  - 6.25 x operating pressure on the cold-side
  - Fixed at the base
- Large Deformation plasticity Analysis

Material Properties

AlSi10Mg

Sample data representative of AlSi10Mg

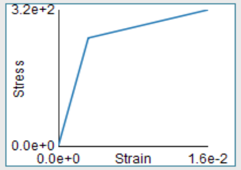
Density



Structural

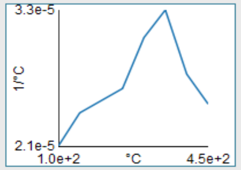
Isotropic Elasticity

Bilinear Isotropic Hardening



Isotropic Secant Coefficient of Thermal Expansion

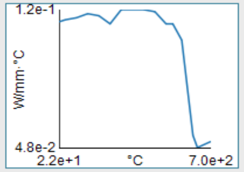
Coefficient of Thermal Expansion



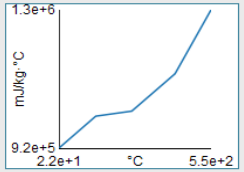
Zero-Thermal-Strain Reference Temperature | 22 °C

Thermal

Isotropic Thermal Conductivity



Specific Heat Constant Pressure



Other

Melting Temperature | 570 °C

AlSi10Mg properties from Additive Materials library
Bilinear Isotropic Plasticity

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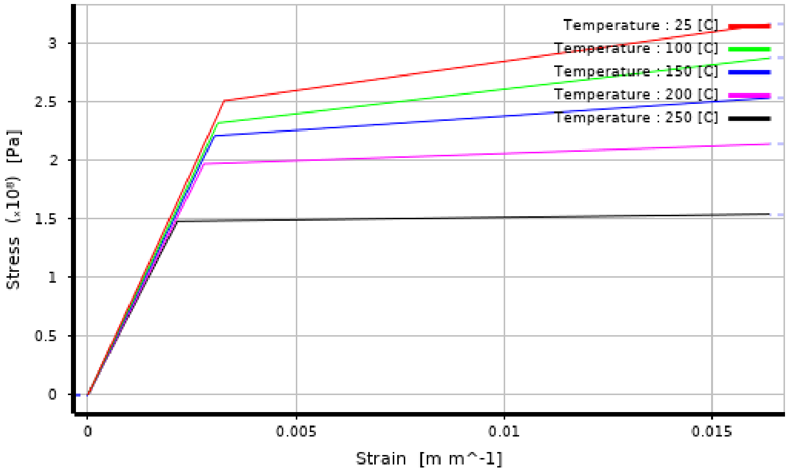

	A	B	C
1	Temperature (C)	Yield Strength (Pa)	Tangent Modulus (Pa)
2	25	2.51E+08	5E+09
3	100	2.32E+08	4.18E+09
4	150	2.21E+08	2.43E+09
5	200	1.97E+08	1.25E+09
6	250	1.48E+08	4.3E+08
*			

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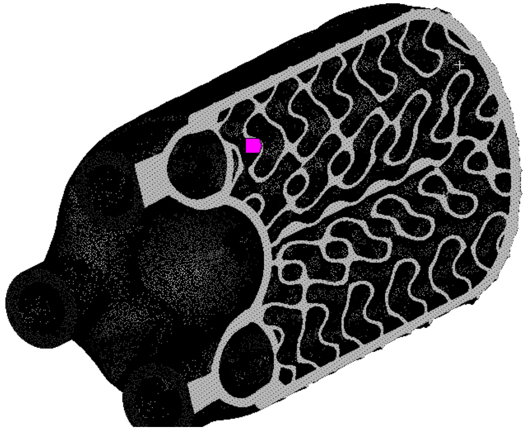
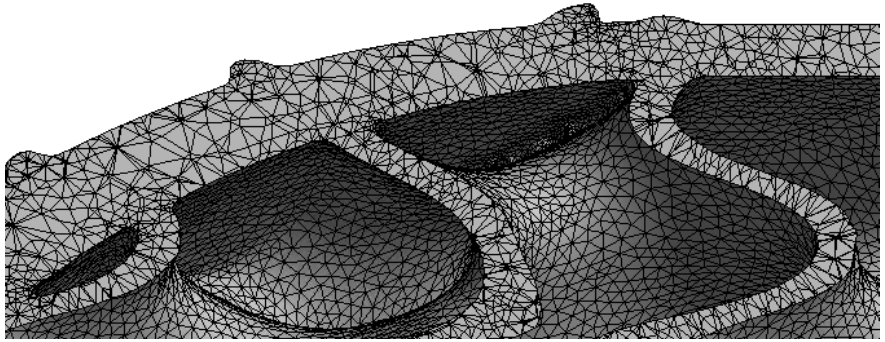
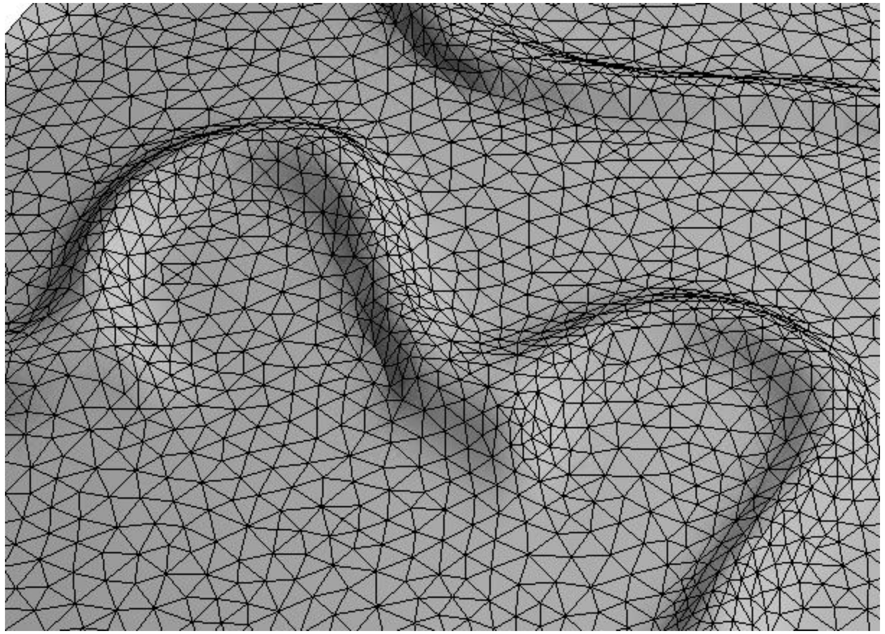
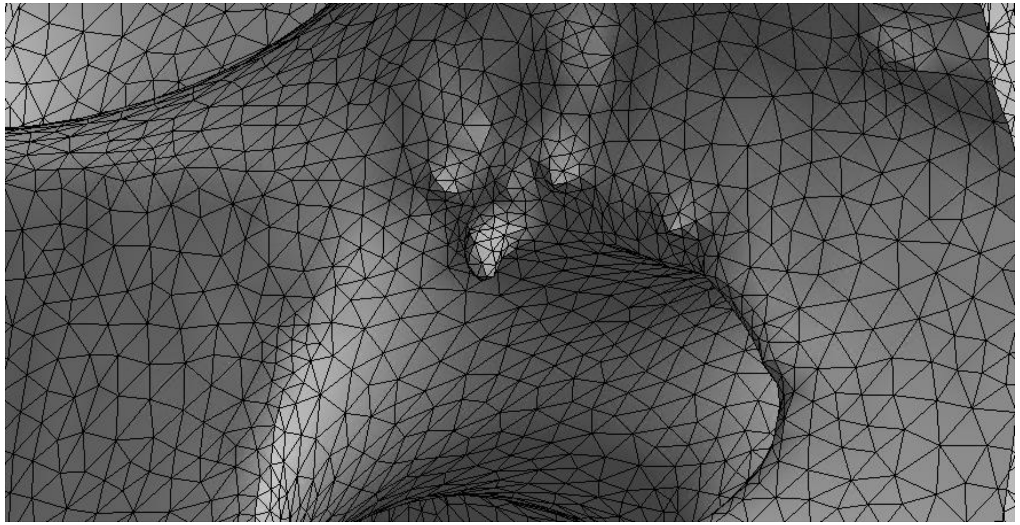
Mesh Details





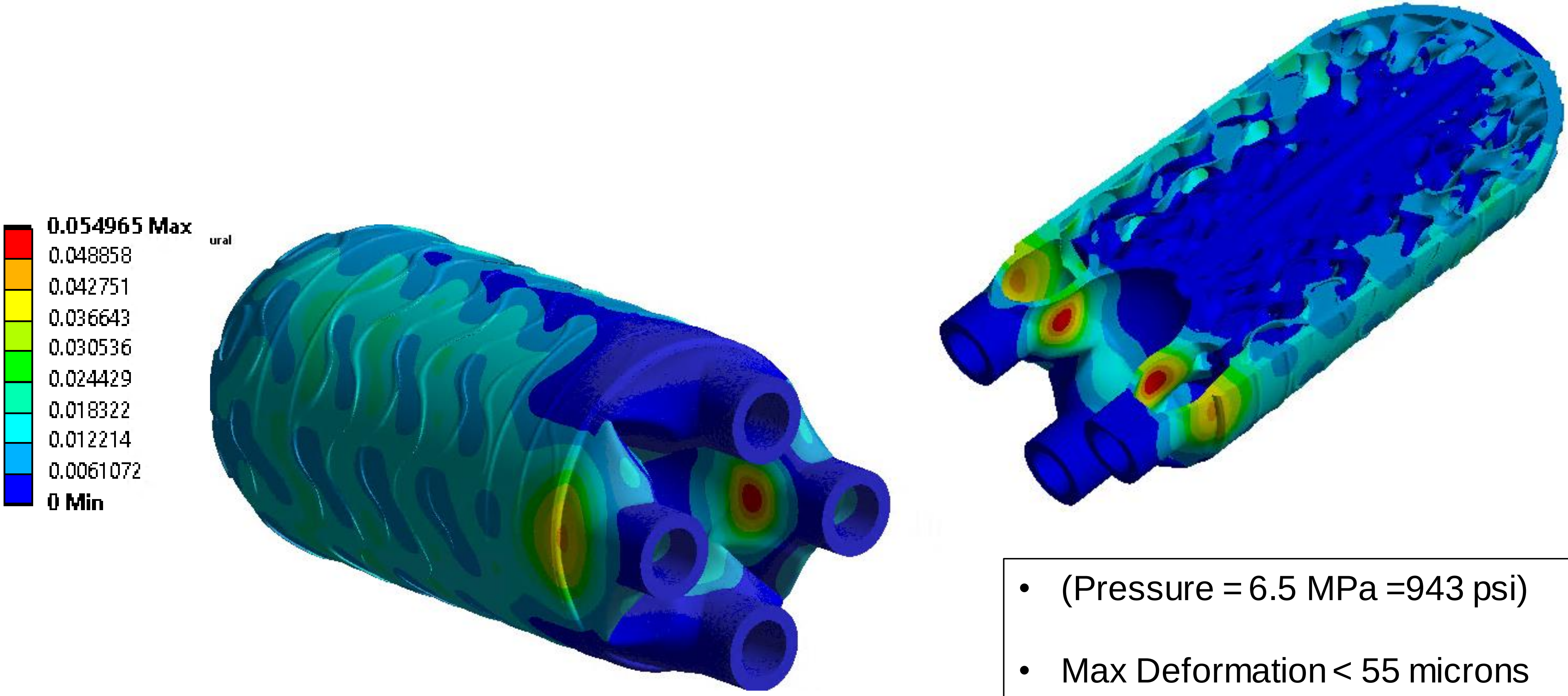
Nodes	1782742
Elements	6618932





Quadratic Elements
Mesh captures build imperfections for the As-built model

Deformation : As Designed



- (Pressure = 6.5 MPa =943 psi)
- Max Deformation < 55 microns
  - near inlet/outlet
  - around 10 microns elsewhere

Von Mises Stresses : Designed

ANALYZE

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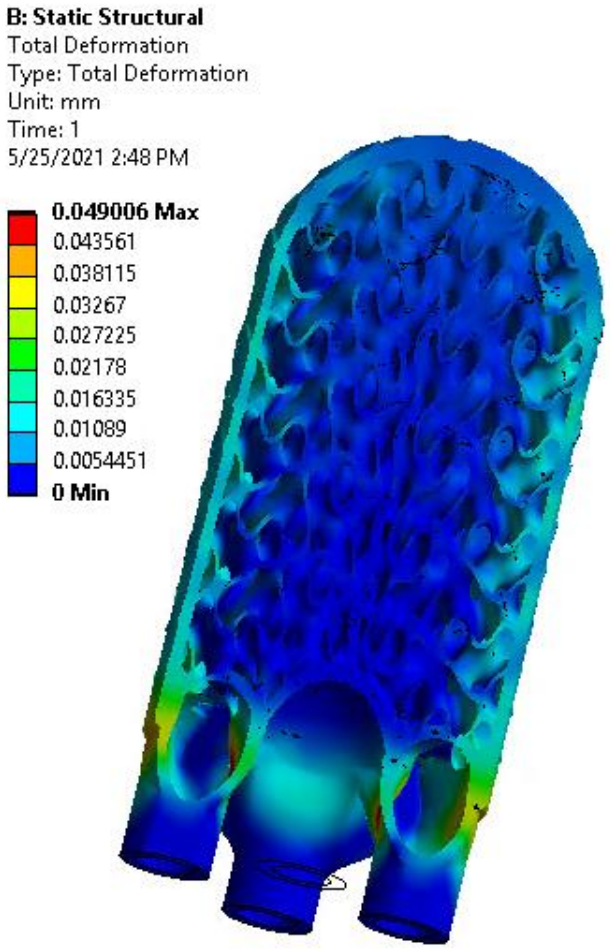
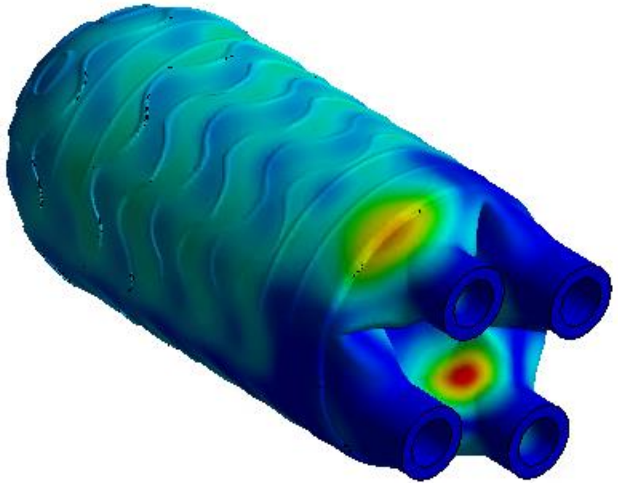
- (Pressure = 6.5 MPa =943 psi)
- Max stress ~ 267MPa
  - Highly localized
  - Well below Ultimate Tensile Strength
  - 0.37% Plastic Strain

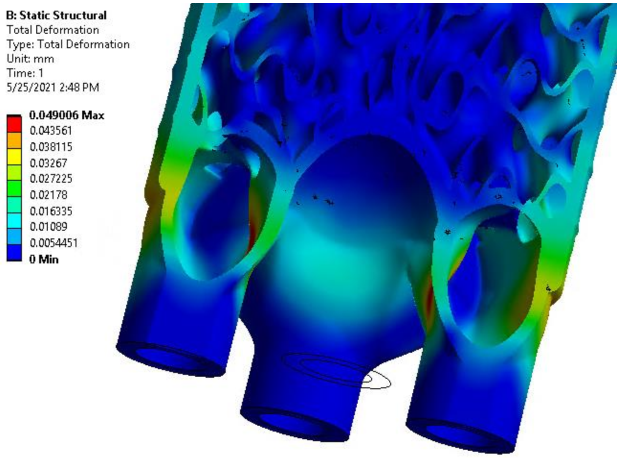
Deformation : As Built

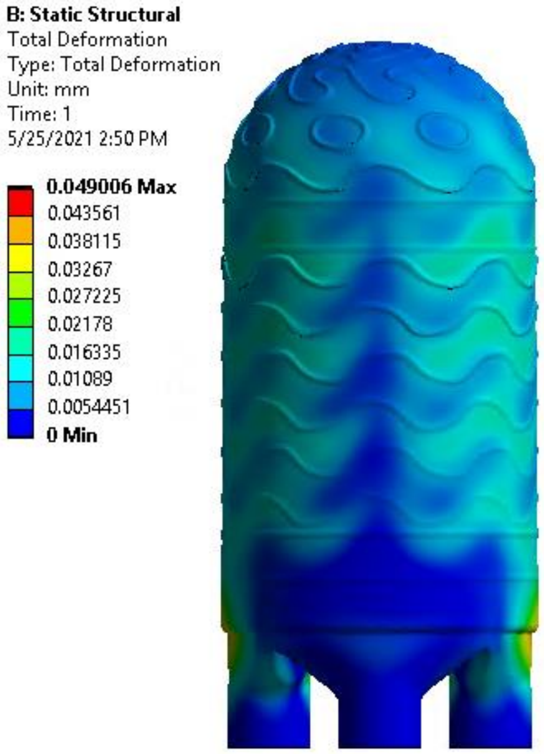
ANALYZE

Ansys



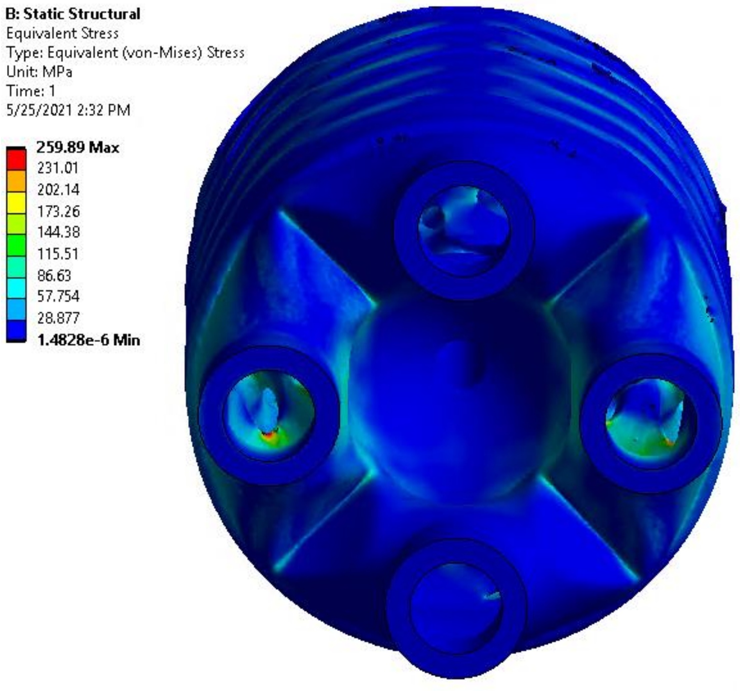


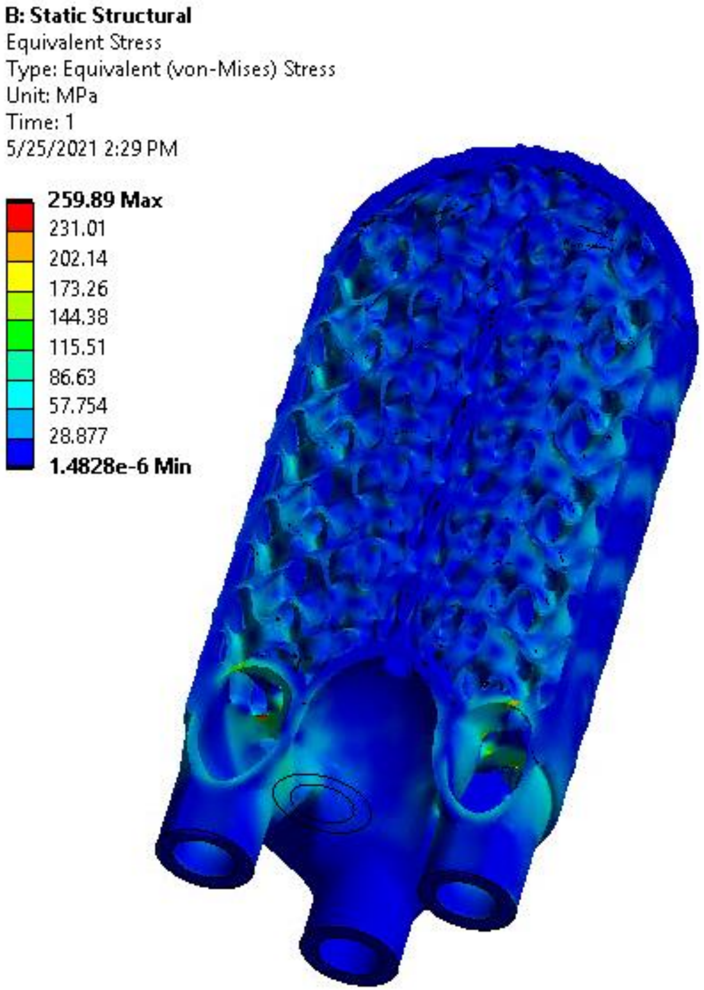


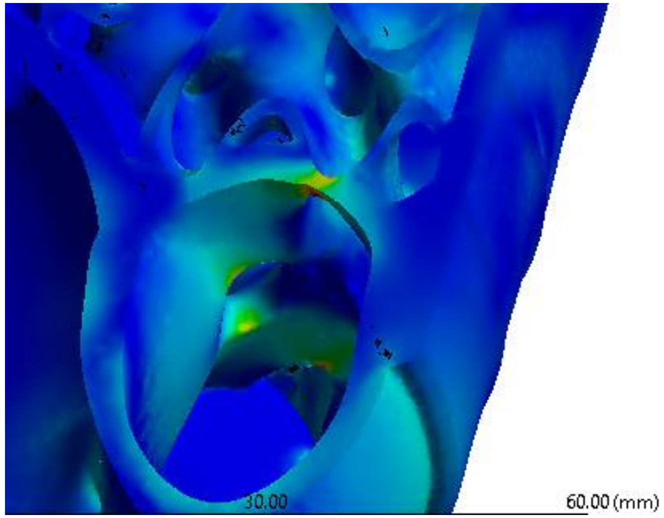


- (Pressure = 6.5 MPa =943 psi)
- Max Deformation < 50 microns
  - near inlet/outlet
  - around 10 microns elsewhere

Von Mises Stresses : As Built







ANALYZE

Ansys

- (Pressure = 6.5 MPa =943 psi)
- Max stress ~ 260 MPa
  - Highly localized
  - Well below Ultimate Tensile Strength
  - 0.23% Plastic Strain

As Designed vs As Built Comparison

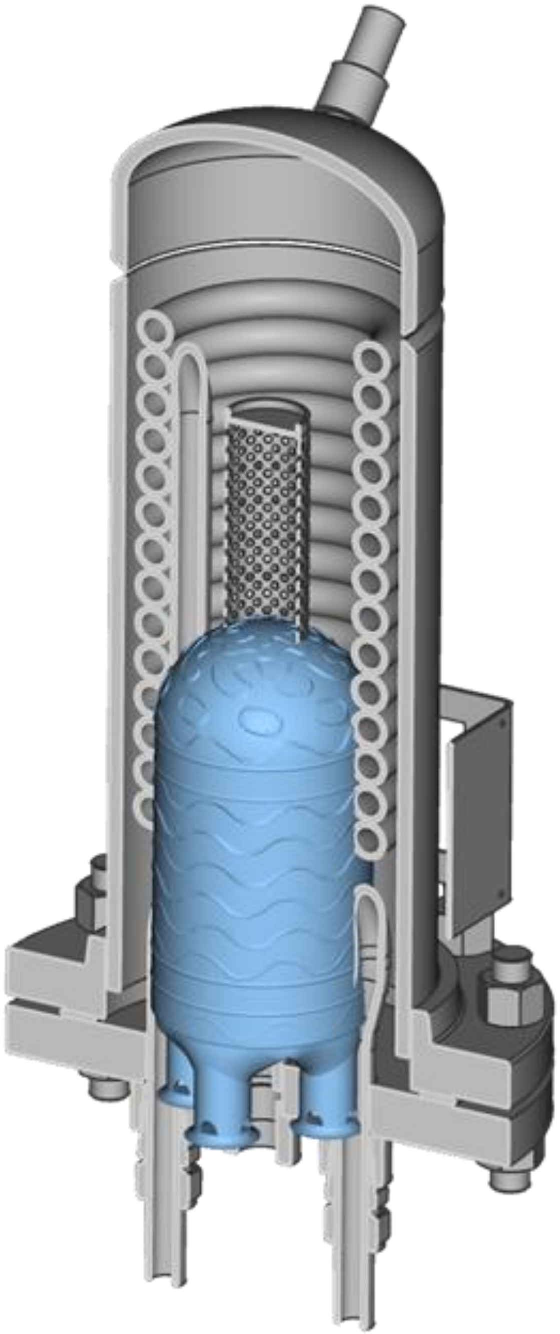
Quantities	As Designed	As Built
Max Deformation	~ 55 Microns	< 50 Microns
Max V M Stress	~ 267 MPa	~ 260 MPa
Max Plastic Strain	~0.37%	~ 0.23%

- As Built performance is very similar to as designed performance
  - Marginal improvement in deformation may be from local thickening

This Scan and Simulation Solution gives the Design Team the confidence that **the part will perform as intended** and that testing should proceed

Compact Heat Exchanger ReDesign Conclusions

Coupled with Real-time Sim/Conjugate Heat Transfer Analysis



Given the design space….

Goal: Redesign the liquid to liquid HEX using Triply Period Minimal Surfaces (TPMS) with minimal increase in comparable surface areas while maintaining the inlet and outlet ports as best as possible.

Cold TPMS surface area: - 2.5%

Hot TPMS surface area: + 23.5%

Legacy Design vs. TPMS Design

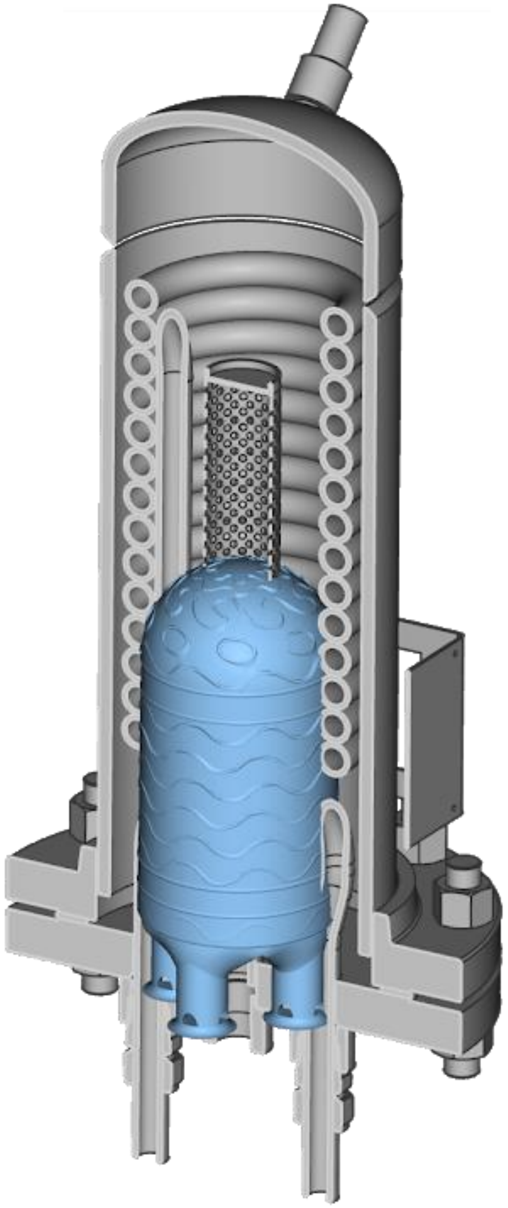
- 85% reduction in volume
- 81% reduction in total mass
- 40+ parts to 1 part

- 11.7x increase in heat transfer per unit volume
- 9.4x increase in heat transfer per unit mass
- 7.9x increase in surface area per unit volume
- 9.1x reduction in pressure drop on hot side
- 1.16x increase in pressure drop on cold side

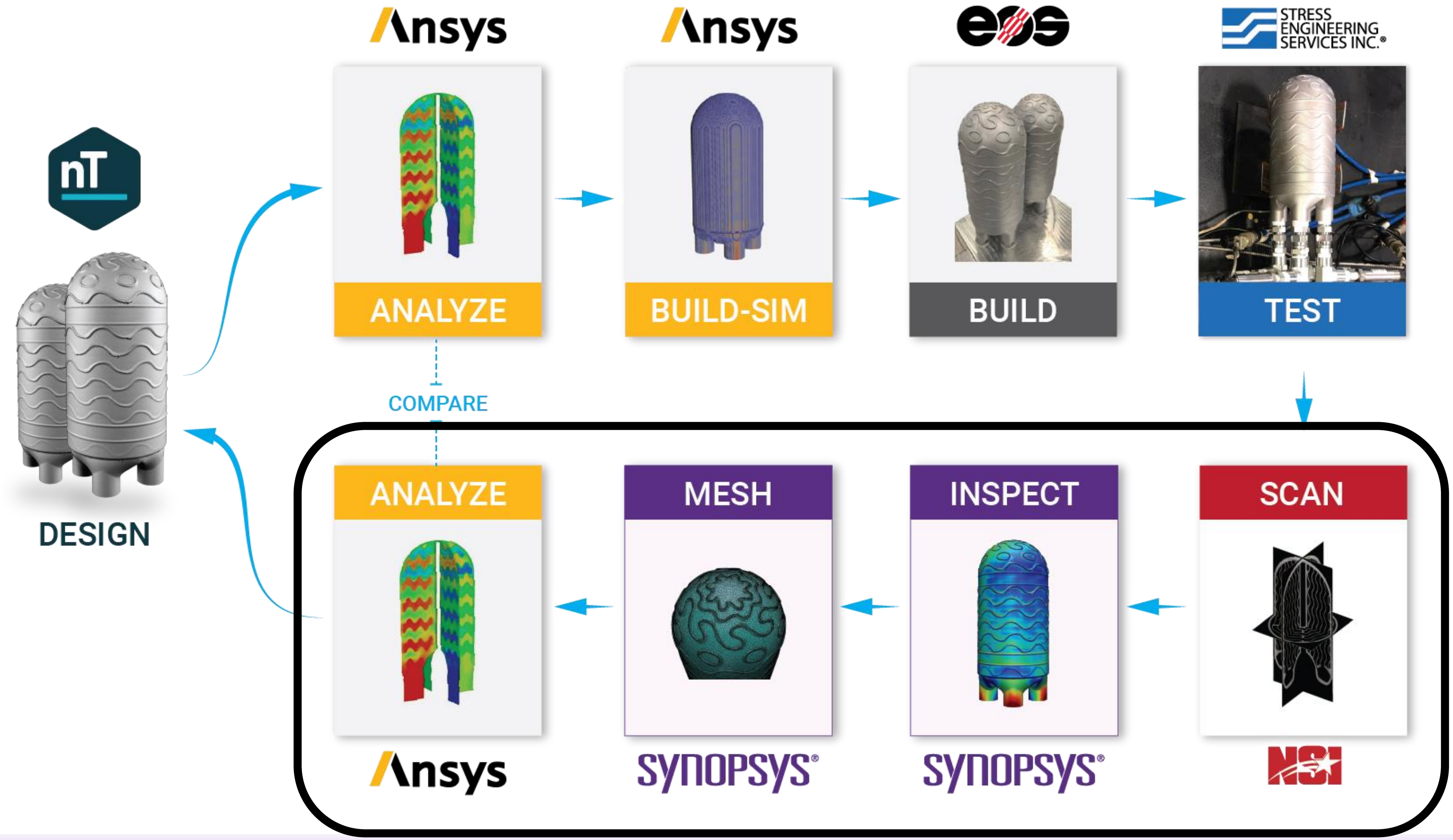
Webinar Series Overview

Results:

Part Reduction	- 40 parts → 1 part
Heat Transfer	- Doubled Heat Transfer in 20% of the volume
Pressure Drop	- 9.1x Reduction in Pressure Drop
Manufacture	- Successful Print on First Attempt
Inspection	- Full NDE Inspection with Zero Defects
Validation	- Structural Sim of As-Built Part



Key Technologies



Reduce risk while leveraging advanced manufacturing techniques for innovation

See and Try Simpleware Software

- **Get a 30-day Free Trial:**
  - Receive a fully functional trial version of the full Simpleware product suite
  - Contact support with any questions, for advice or help in setting up your workflow

- **Arrange a Personal Software Demonstration:**
  - Arrange a personalized software demonstration via WebEx
  - With our expert Application Engineers using your own or our data

- **Watch Product Videos, On-demand Webcasts, Download Datasheets:**
  - See our extensive library of product information: www.synopsys.com/simpleware/resources.html

- **Contact Us:**
  - Email: simpleware@synopsys.com
  - Website: www.synopsys.com/simpleware

Thank You

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