ptc

# LIVEWORX

A NEW ERA IN PRODUCT LIFECYCLE INNOVATION

**SESSION ID:** CA1522C

# ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES


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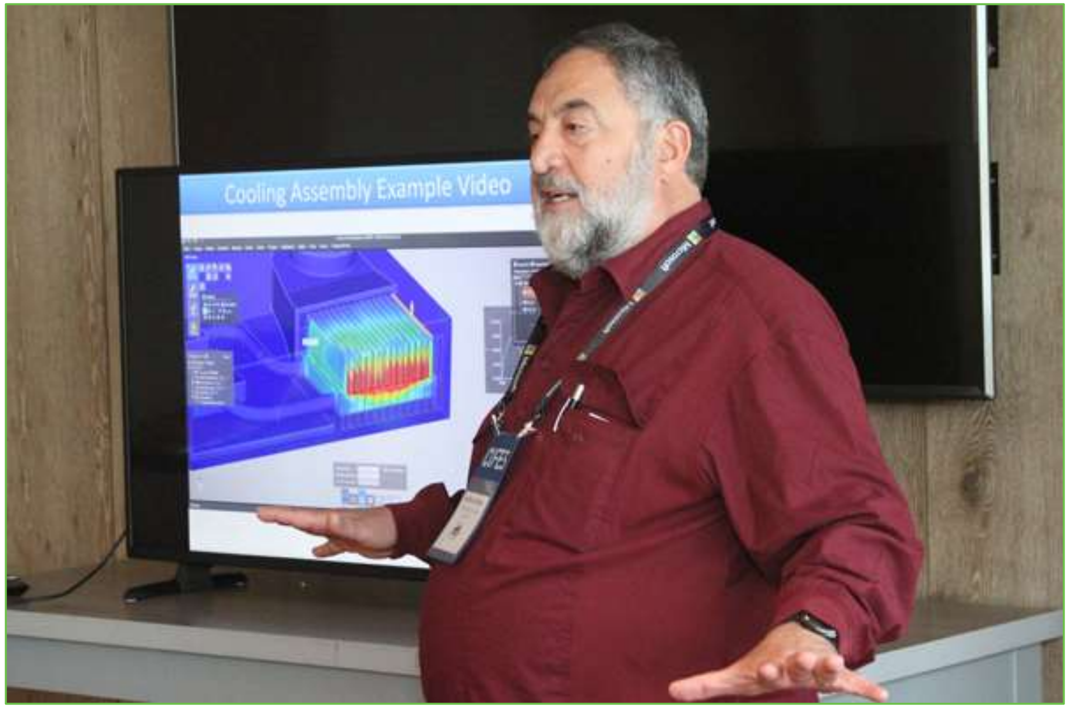
CTO, Advanced Engineering Solutions

**Jose Coronado**
Product Management Director, PTC


MAY 15, 2023

# ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

## Andreas Vlahinos



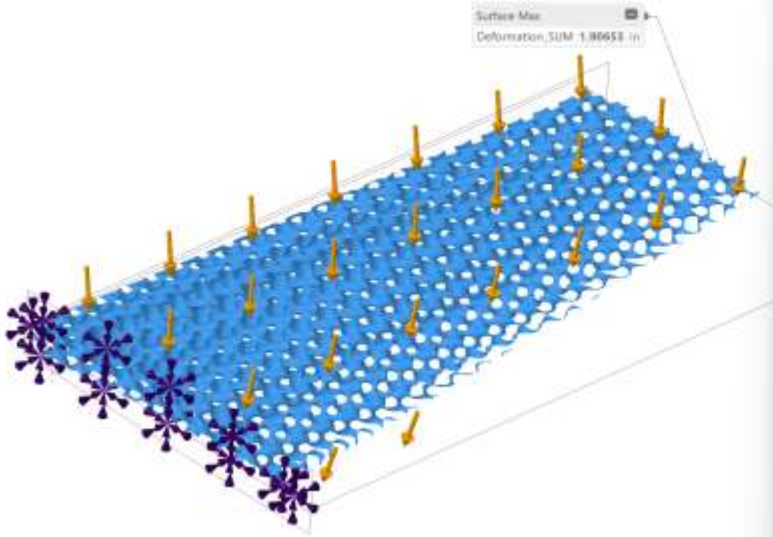

*CTO, Advanced Engineering Solutions*

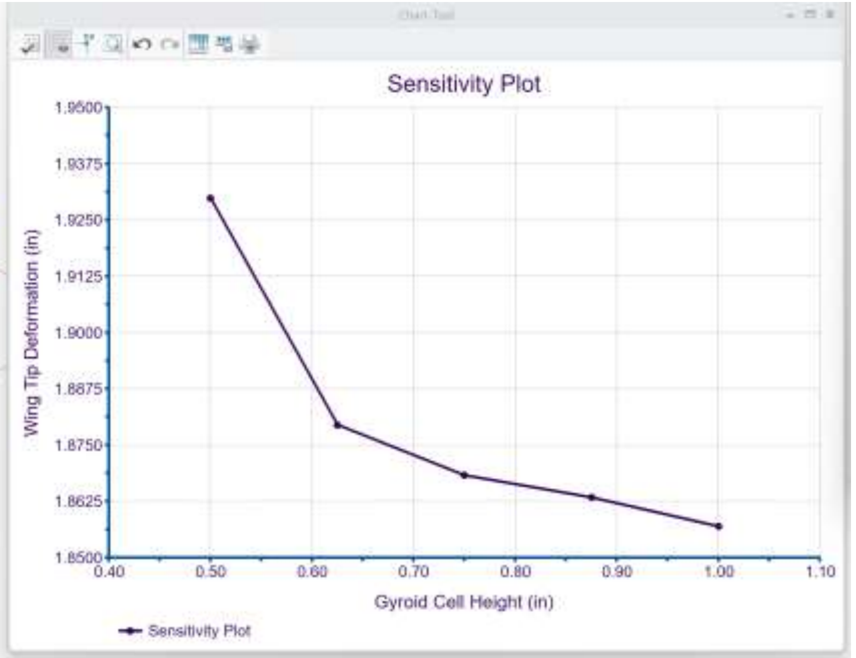
## Jose Coronado

*Product Management Director, PTC*

# ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

- Taxonomy of Lattice Structures
- Optimization Workflow
- Simulation-driven lattices in Creo
- Special cases





# ART OF POSSIBLE: GENERATIVE DESIGN AND LATTICE STRUCTURES

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- Optimization Workflow
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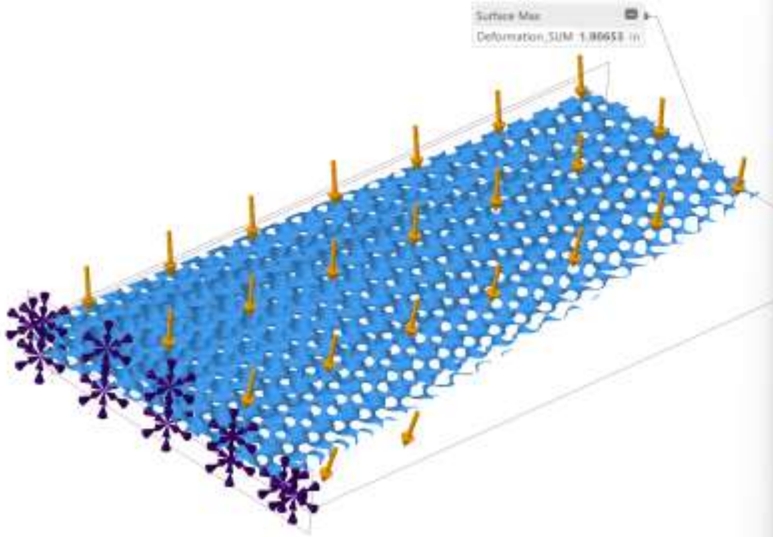
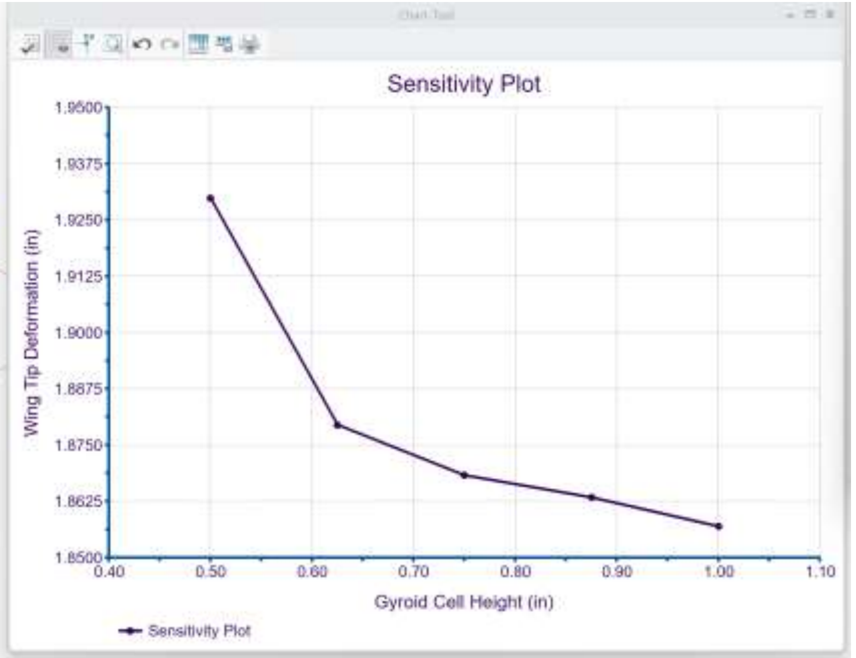
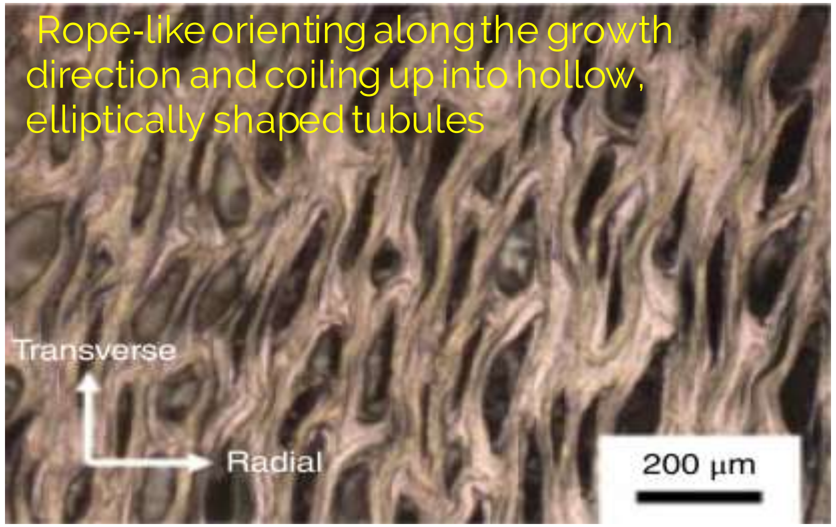
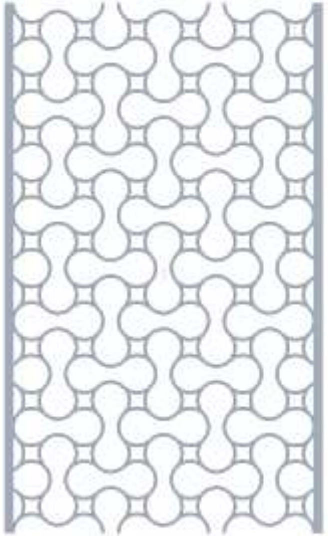
- Special cases

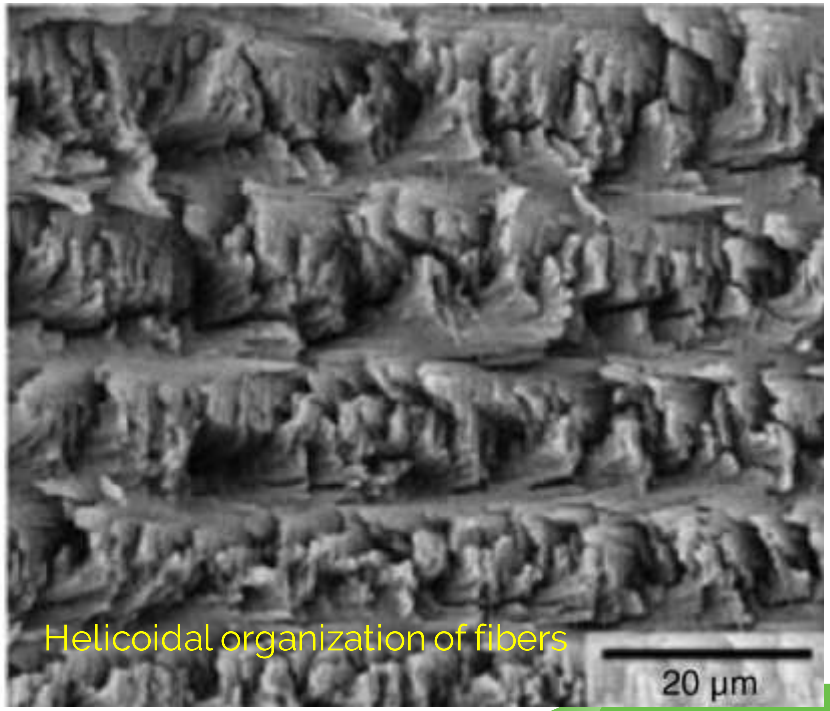


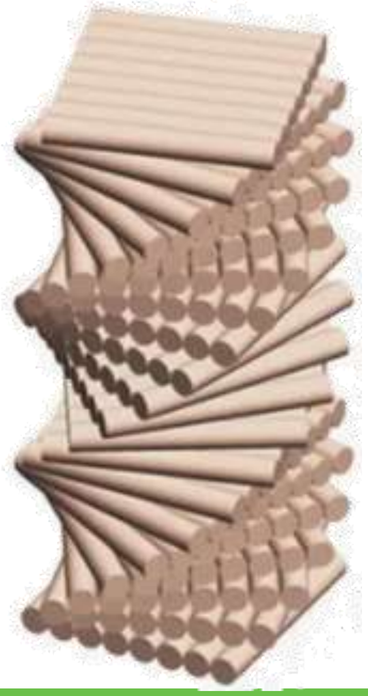


# WHAT NATURE CAN TEACH US ABOUT STRENGTH, ENERGY ABSORPTION AND LIGHT WEIGHING ?



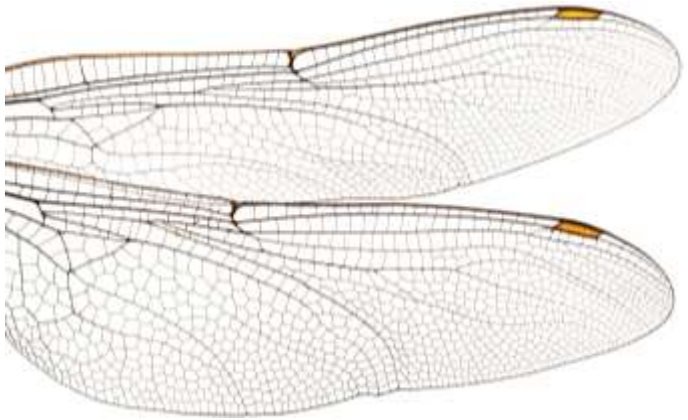



# TAXONOMY OF LATTICE STRUCTURES IN NATURE

## On Surface Lattice

Periodic
- Triangle, Square, Hexagon, Octagon, etc.

Stochastic
- Voronoi Tessellation
- Delaunay Triangulation
  - Uniform
  - Spatially Varied



Dragonfly Wings

## 2 ½ D Lattice

Periodic
- Cartesian Trimmed
  - Triangle, Square, Hexagon, Octagon, etc.
- Cartesian Conformal Edge

Polar

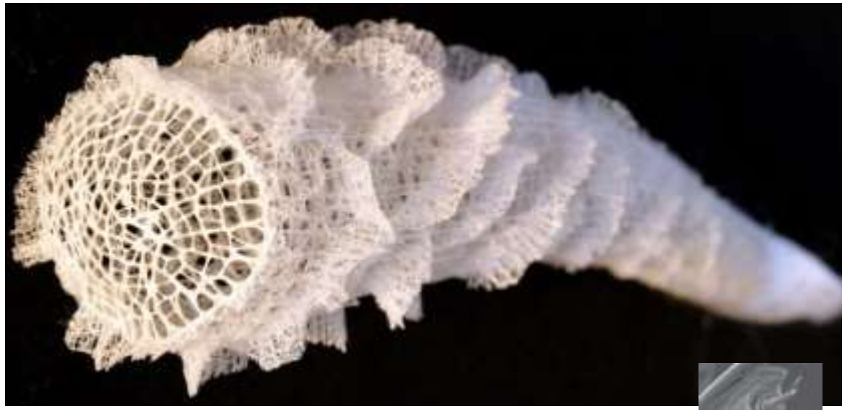
Herringbone

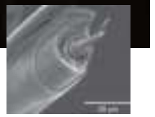
Honeycomb

## 3D Beam Lattice

Periodic
- Cartesian,
- Triangle, Square,,
- Octagon, etc.
- Polar

Stochastic
- Voronoi
- Delaunay
- Uniform
- Spatially Varied





Venus flower basket glass sponges

## 3D Surface Lattice TPMS

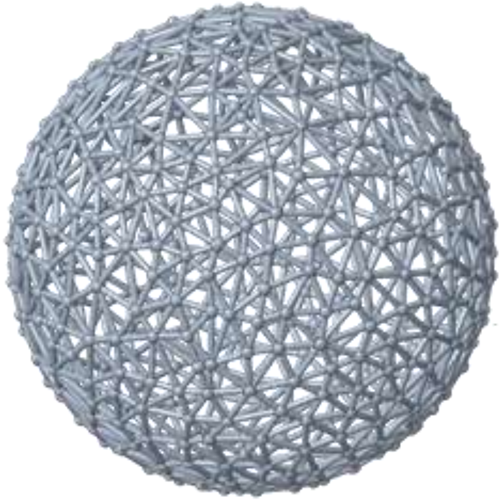
Periodic
- Uniform thickness
- Variable thickness
- Variable cell size
- Spatially Varied

Examples:
Gyroids, Diamonds, Octets, Lidinoid, Schwarz D, Schwarz P, Neovius, ...

Butterfly gyroid nanostructures

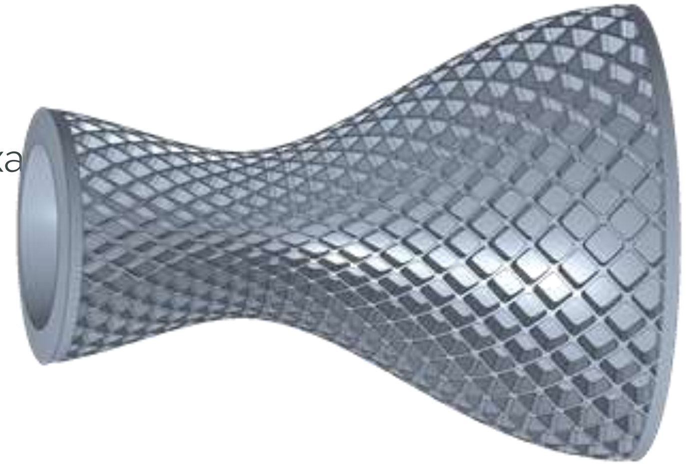
# TAXONOMY OF LATTICE STRUCTURES IN CREO

**On Surface Lattice**
Periodic
Triangle, Square, Hexagon, Octagon, etc.
Stochastic
Voronoi Tessellation
Delaunay Triangulation
Uniform
Spatially Varied



Surface Delaunay Triangulation

**2 ½ D Lattice**
Periodic
Cartesian Trimmed
Triangle, Square, Hexa
Octagon, etc.
Cartesian Conformal Edge
Polar
Herringbone

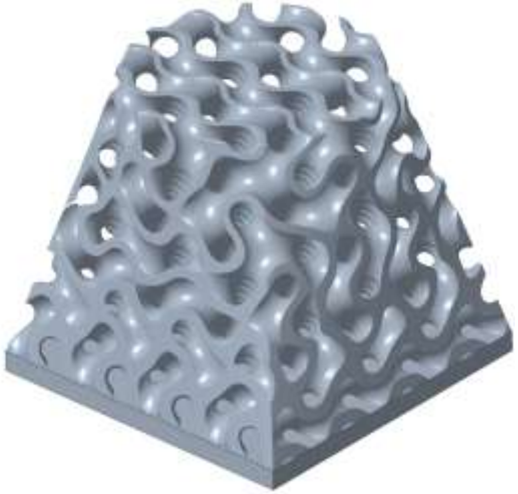


Rocket Nozzle with Ribs

**3D Beam Lattice**
Periodic
Cartesian,
Triangle, Square, Hexag
Octagon, etc.
Polar
Stochastic
Voronoi Tessellation
Delaunay Triangulation
Uniform
Spatially Varied

High Performance Heat Exchanger

**3D Surface Lattice TPMS**
Periodic
Uniform thickness
Variable thickness
Variable cell size
Spatially Varied
Examples:
Gyroids, Diamonds, Octets, Lidinoid, Schwarz D, Schwarz P, Neovius, ...

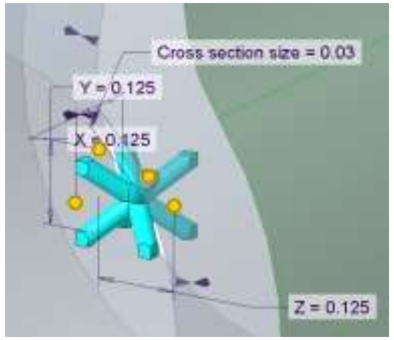


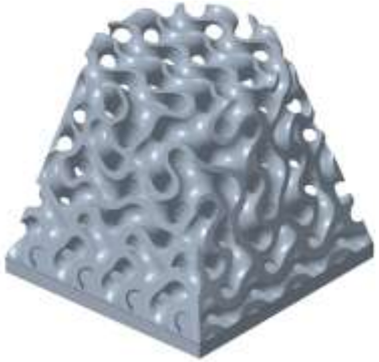
TPMS High Performance Heat Exchanger

# WHAT ARE THE CHALLENGES IN SIMULATING LATTICE GEOMETRIES?

## Challenges

- Massive tet element size
  - Required to capture the small geometry details
- Interoperability
  - TPMS are using explicit or voxel-based kernels not (B-rep) without neutral file format (STEP, Parasolid) exports
- Integration with Generative Design
  - GD tools can't use a TPMS geometry as a design space



## Solutions

- Geometric Representation
  - Full Geometry
  - Simplified
  - Homogenized
- Real Time Simulation
  - Use & Understand Voxel geometry
- Generative Design
  - Use Homogenized Material properties,
  - Simulation Driven lattice sizing

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- **Optimization Workflow**
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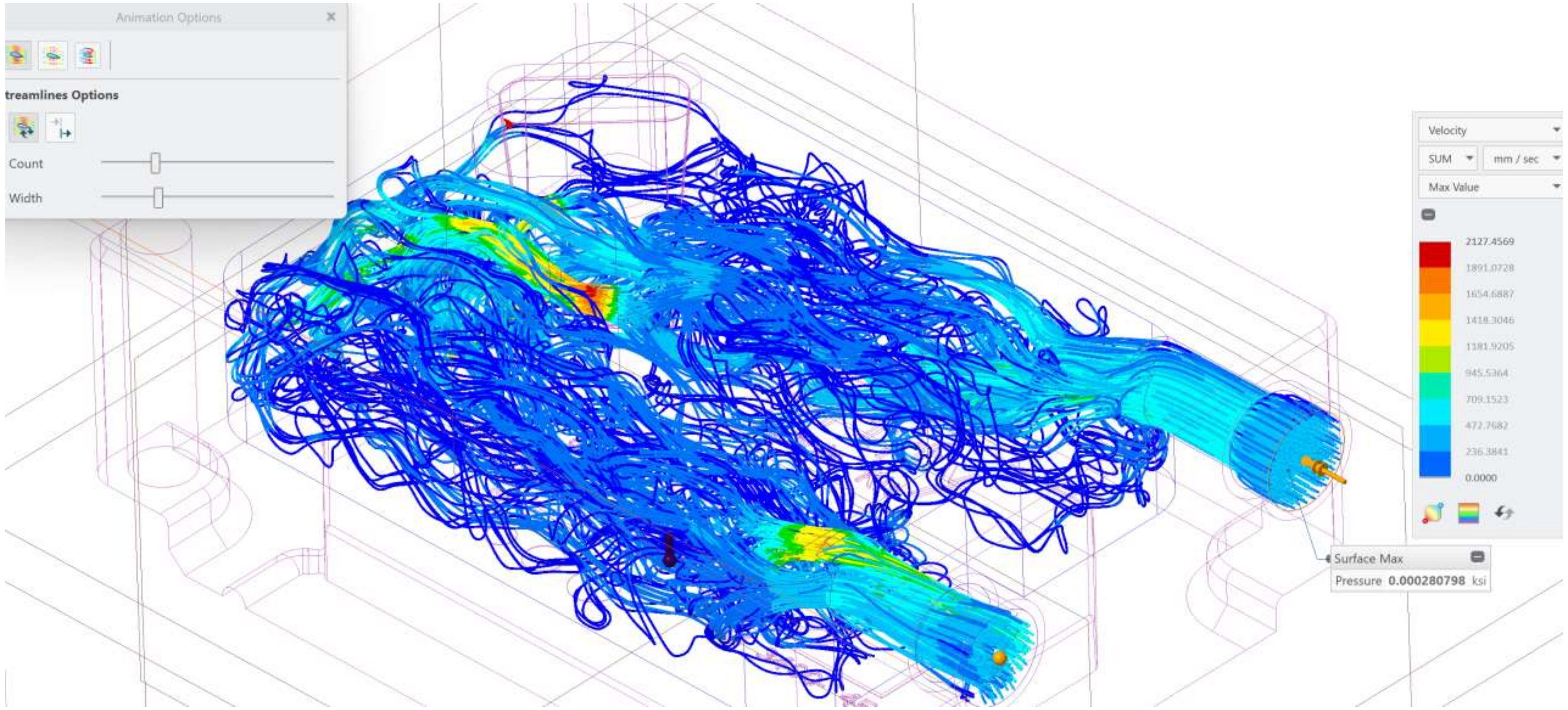
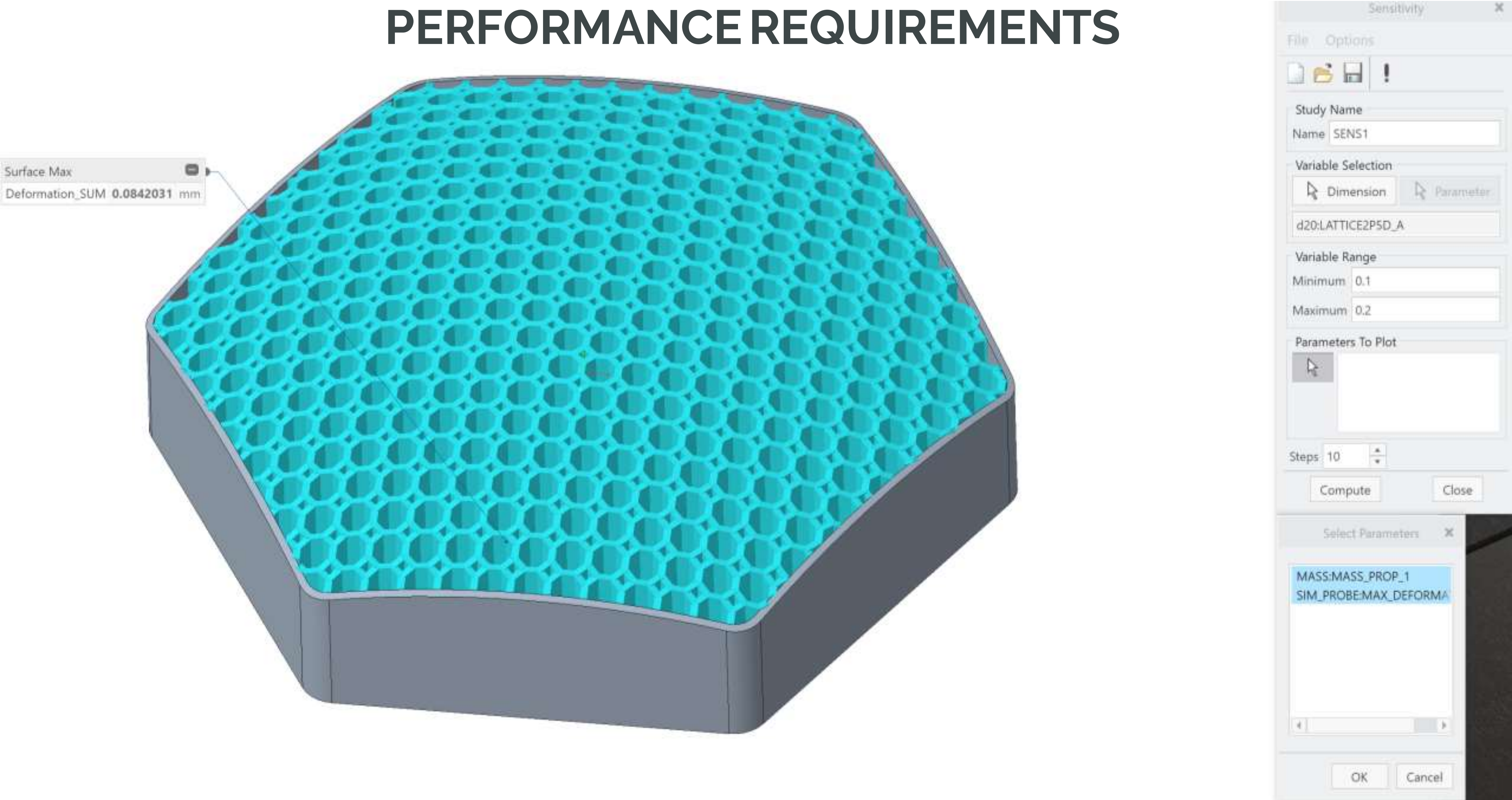
- Special cases

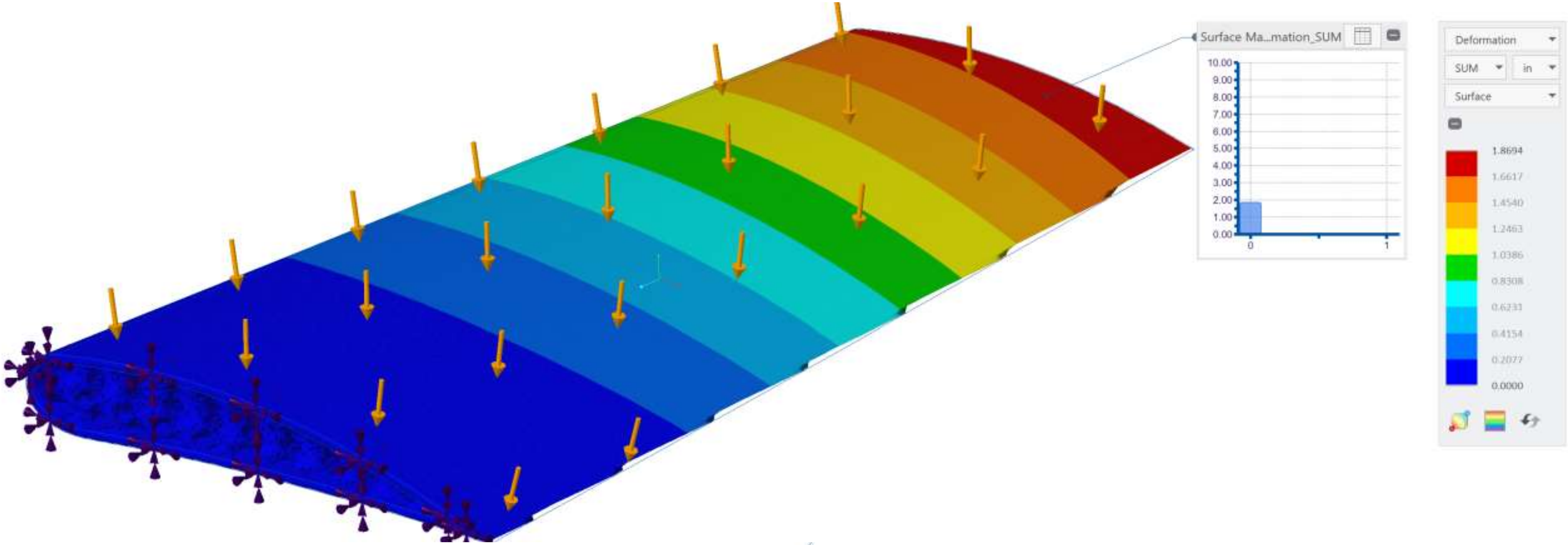


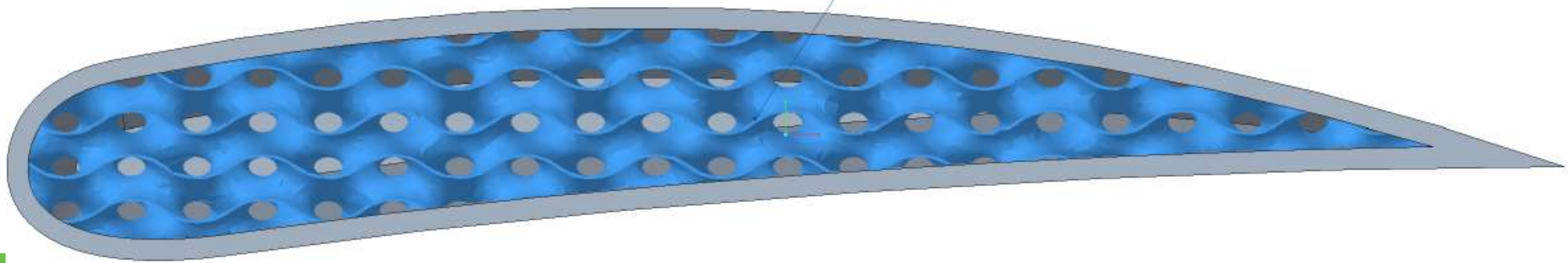
# OPTIMIZATION WORKFLOW TO MINIMIZE WEIGHT AND MEET PERFORMANCE REQUIREMENTS



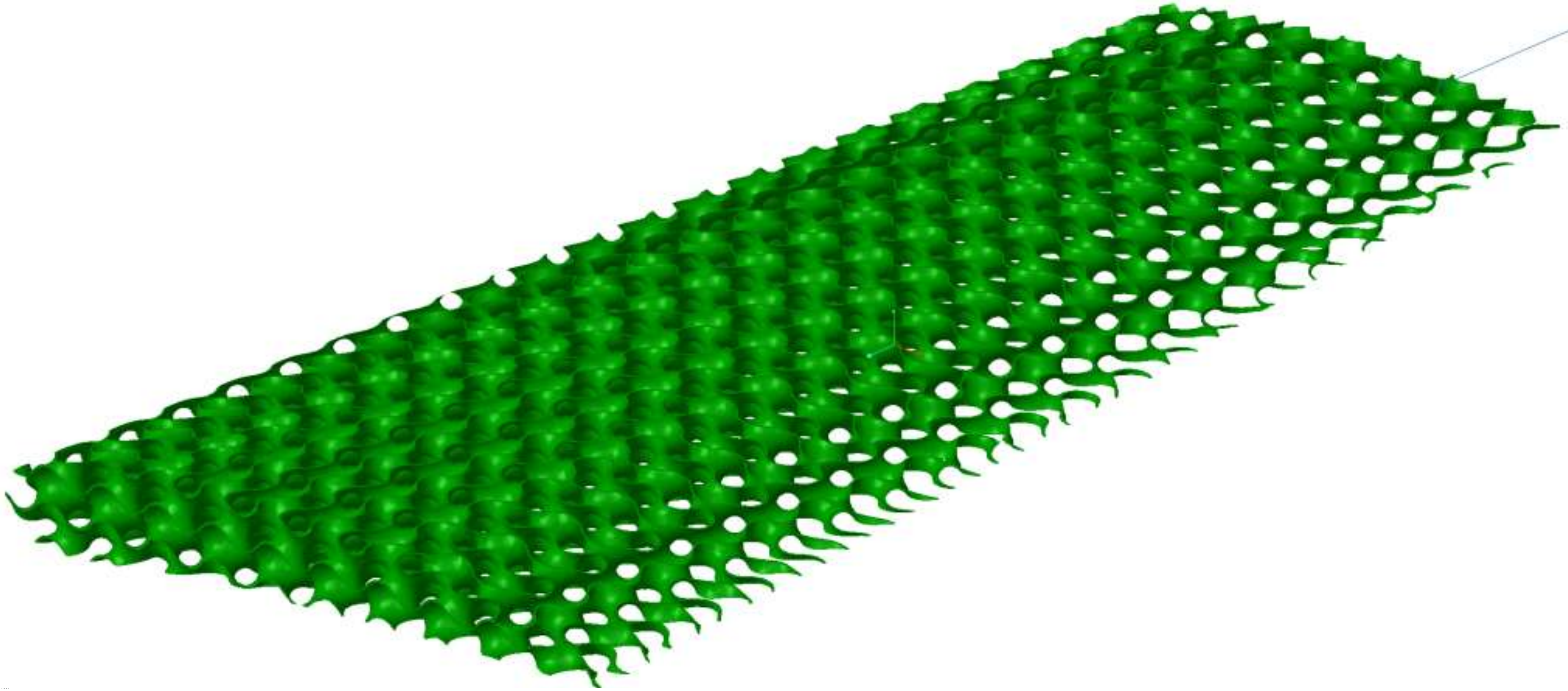
# PERFORM A SENSITIVITY ANALYSIS TO DETERMINE
## THE REQUIRED CELL THICKNESS
## TO MINIMIZE THE DEFLECTION TO 0.1 MM

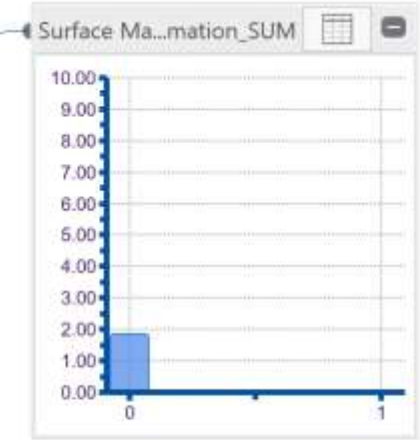
# COMPARE DISPLACEMENTS FOR VARIOUS LATTICES - GYROID



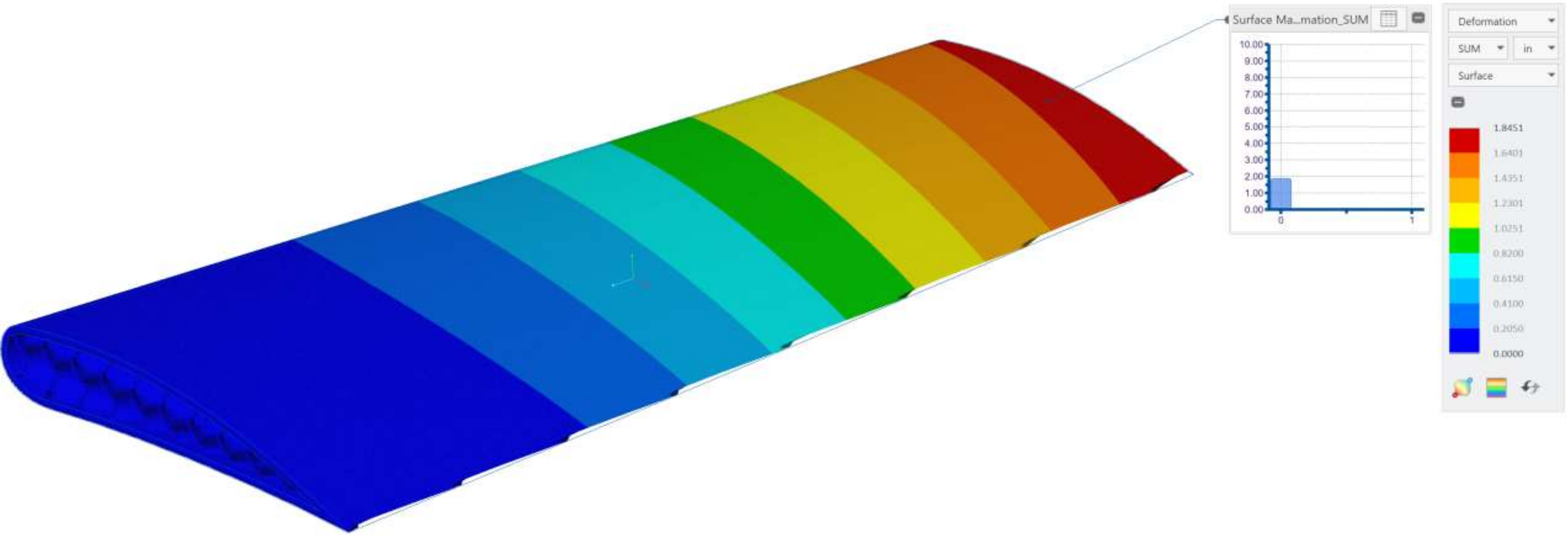



# THE GYROID INFILL

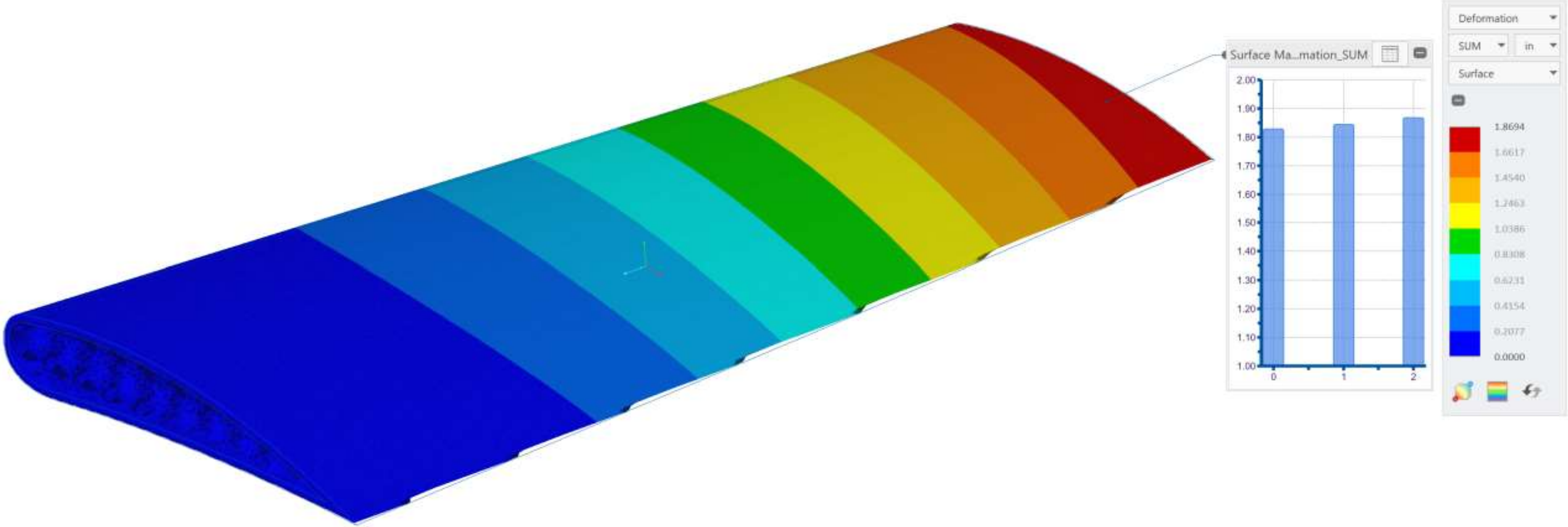




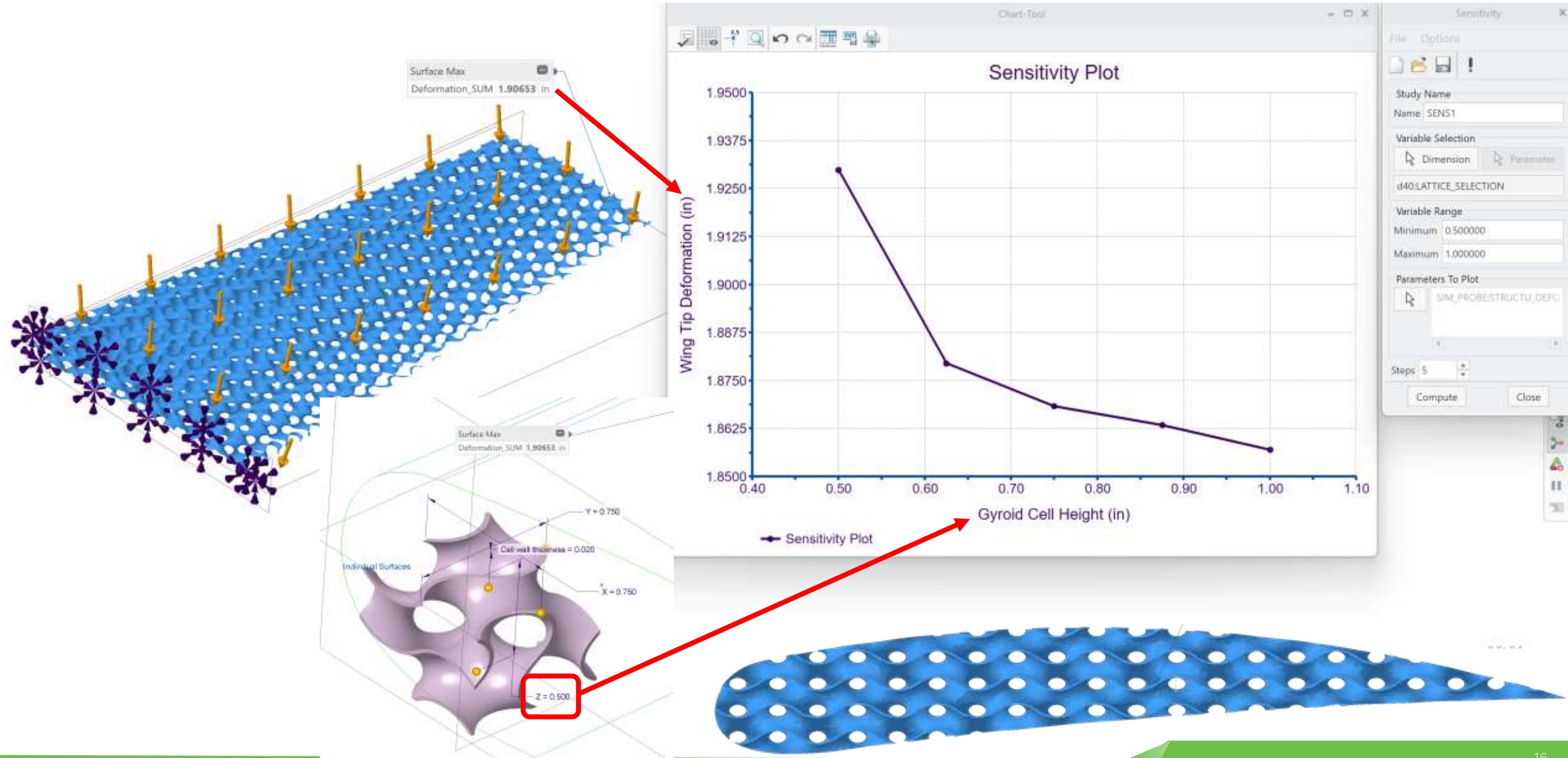
# COMPARE DISPLACEMENTS – PRIMITIVE LATTICE



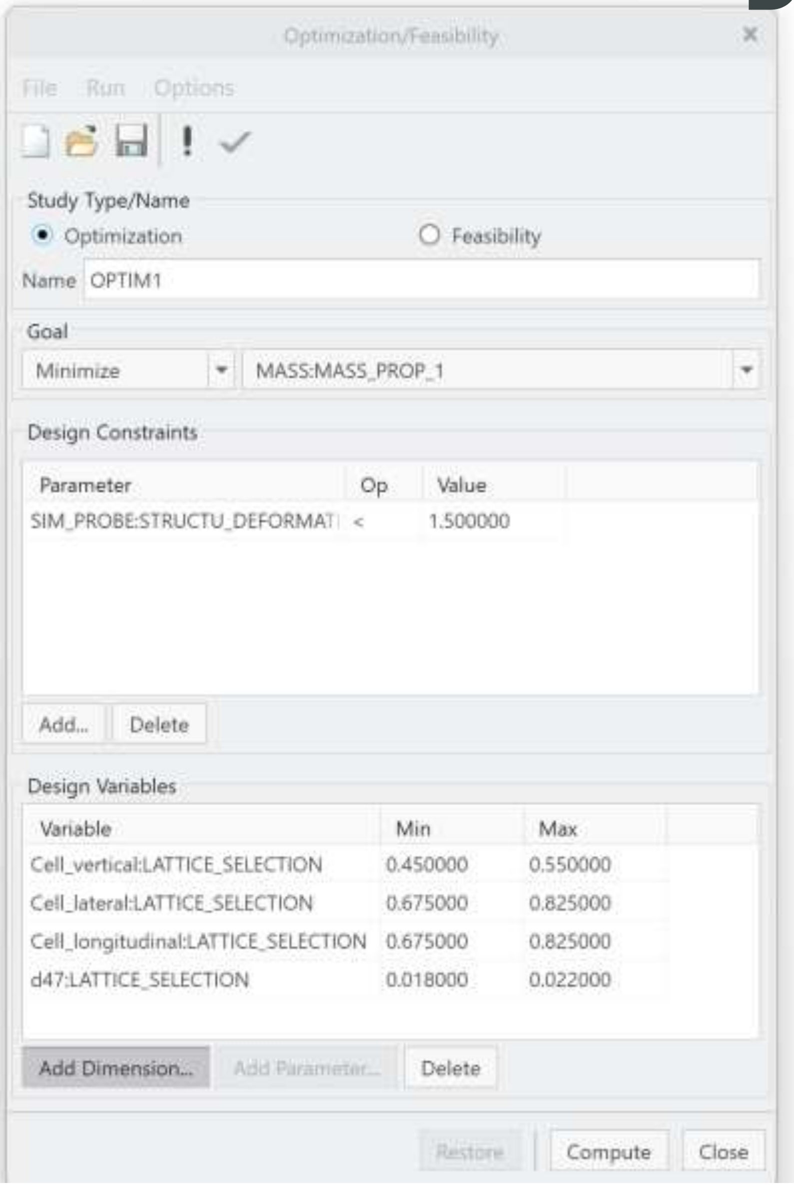
# COMPARE DISPLACEMENTS - DIAMOND LATTICE

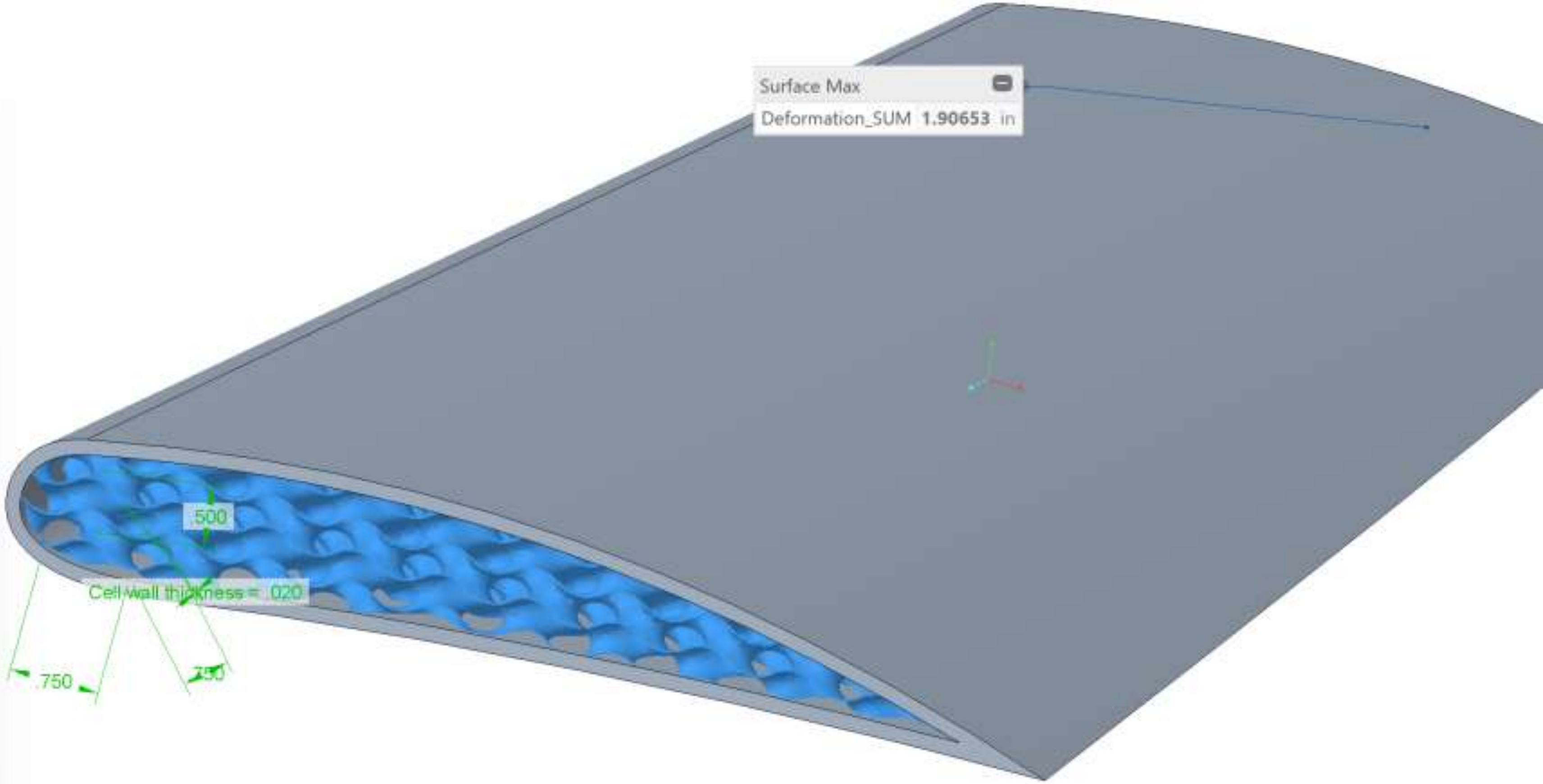


# SENSITIVITY OF WING TIP DEFLECTION TO VERTICAL GYROID CELL HEIGHT



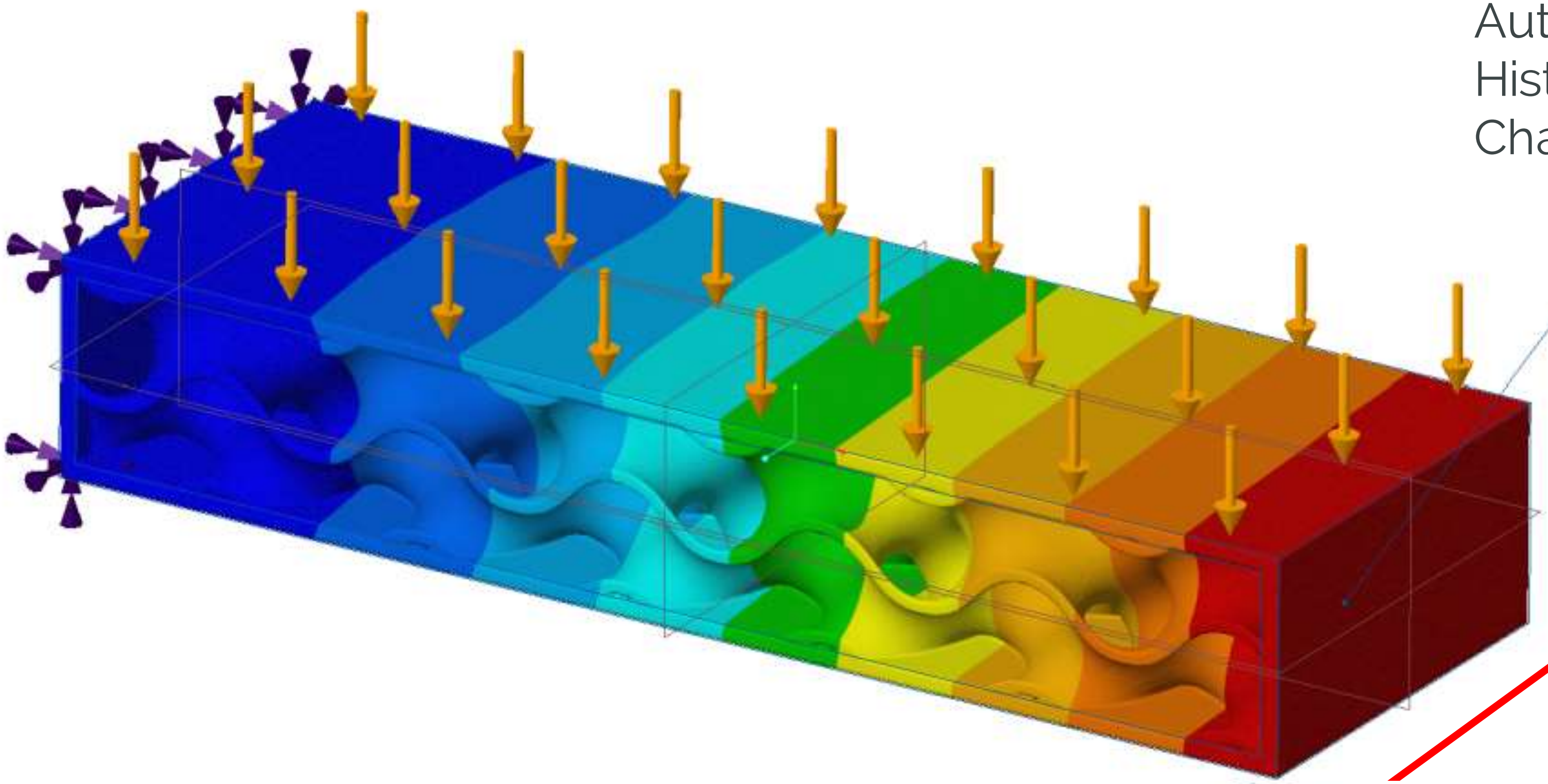
# OPTIMIZATION SETUP MINIMIZE WEIGHT WITH DEFLECTION CONSTRAINT



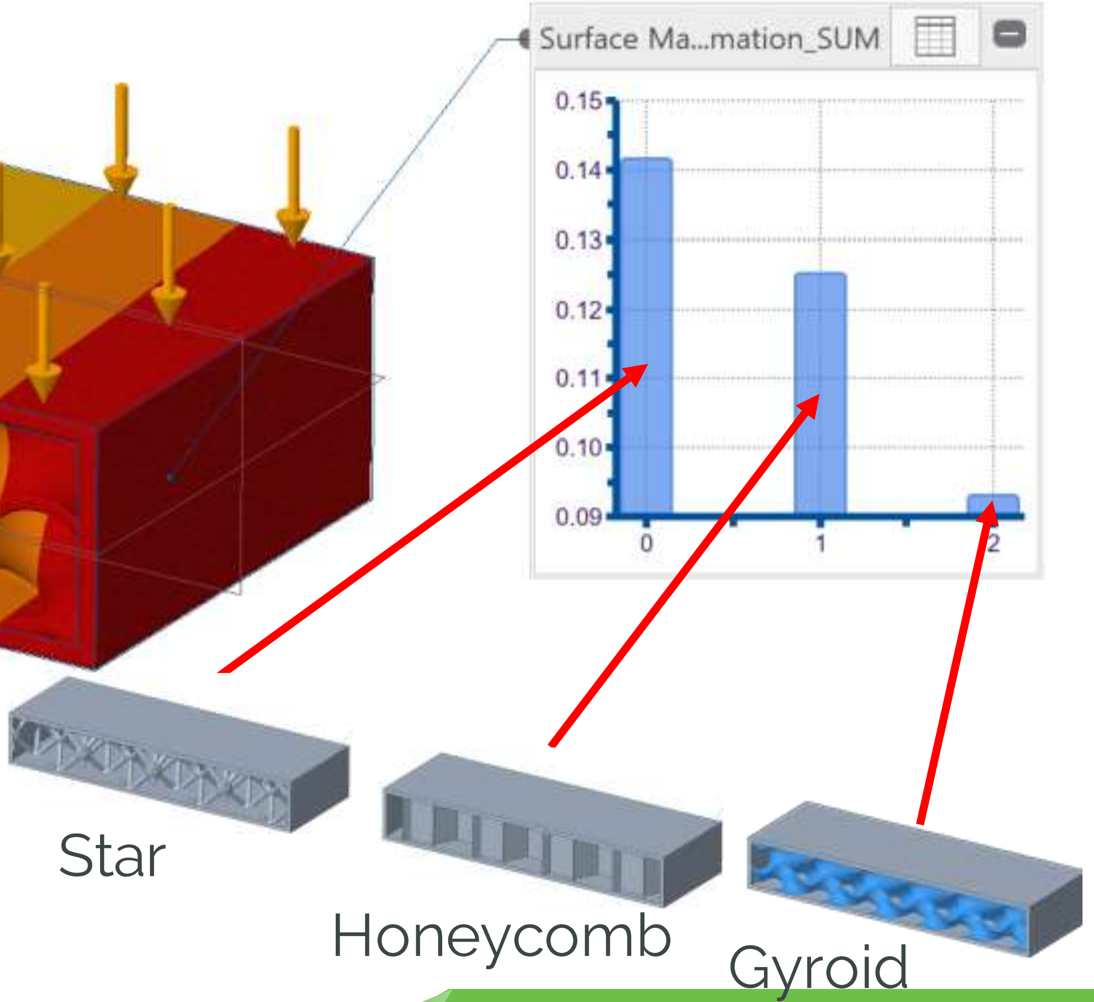




Design Variables are the 4 dimensions of the unit cell

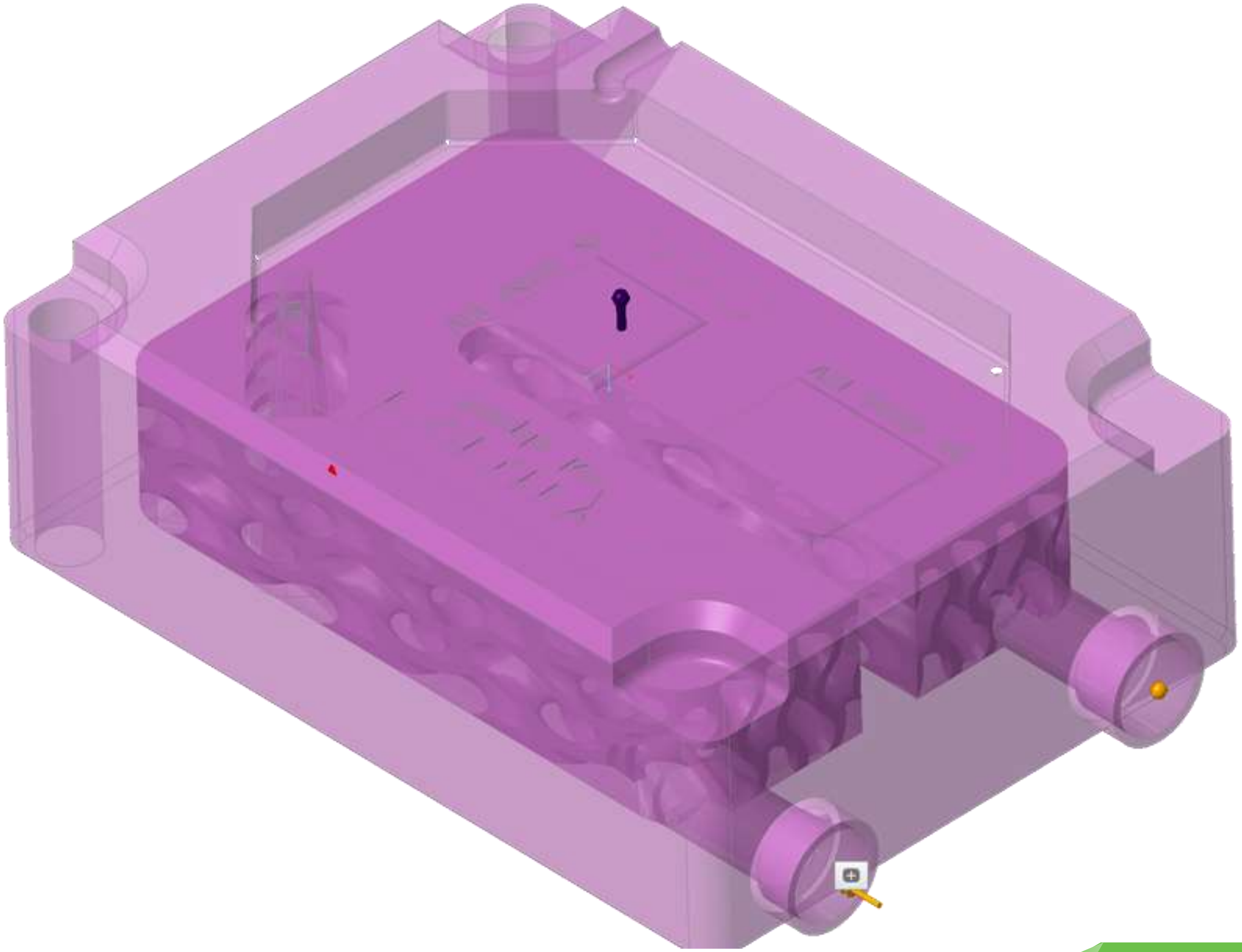
# LIVE DEMONSTRATION – DESIGN EXPLORATION



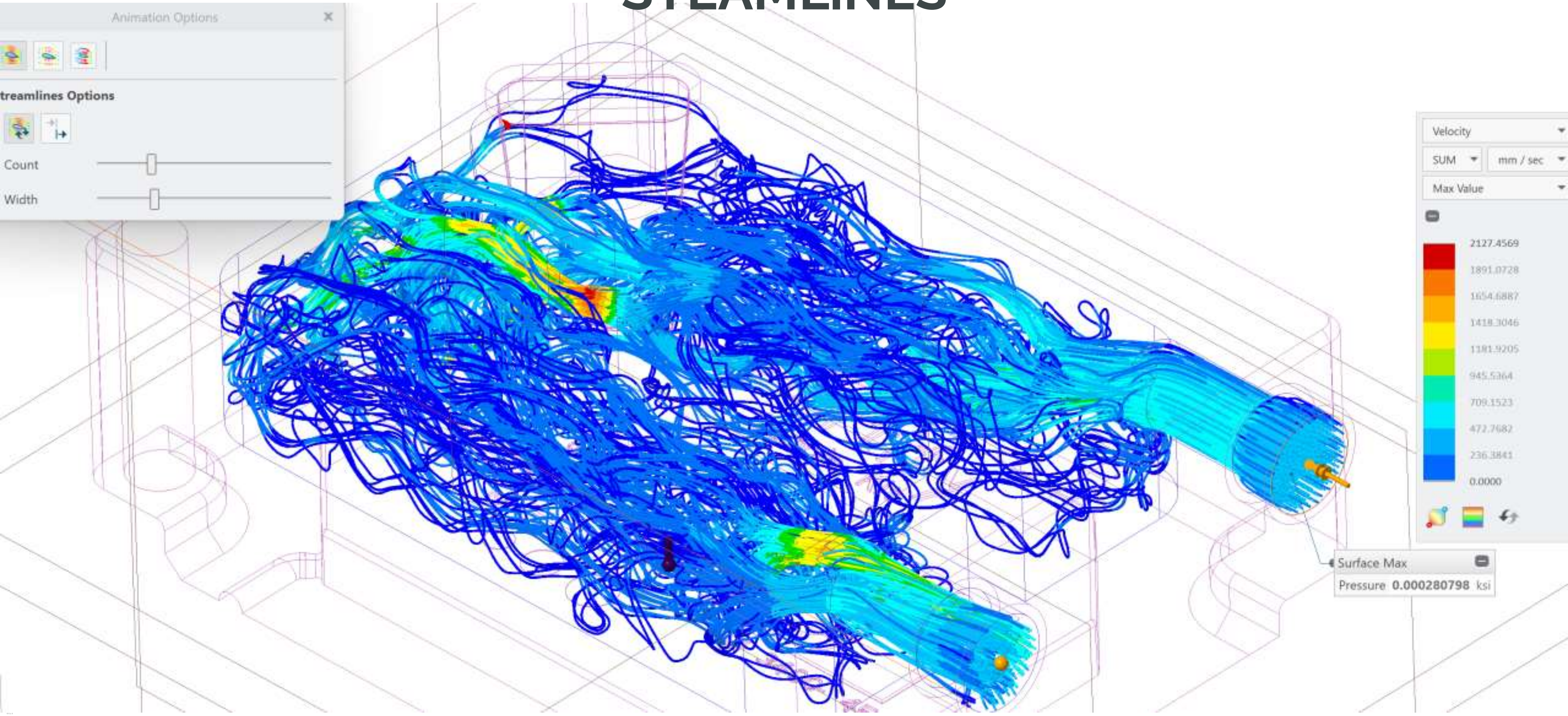
Capturing Automatically Historical Data in a Bar Chart



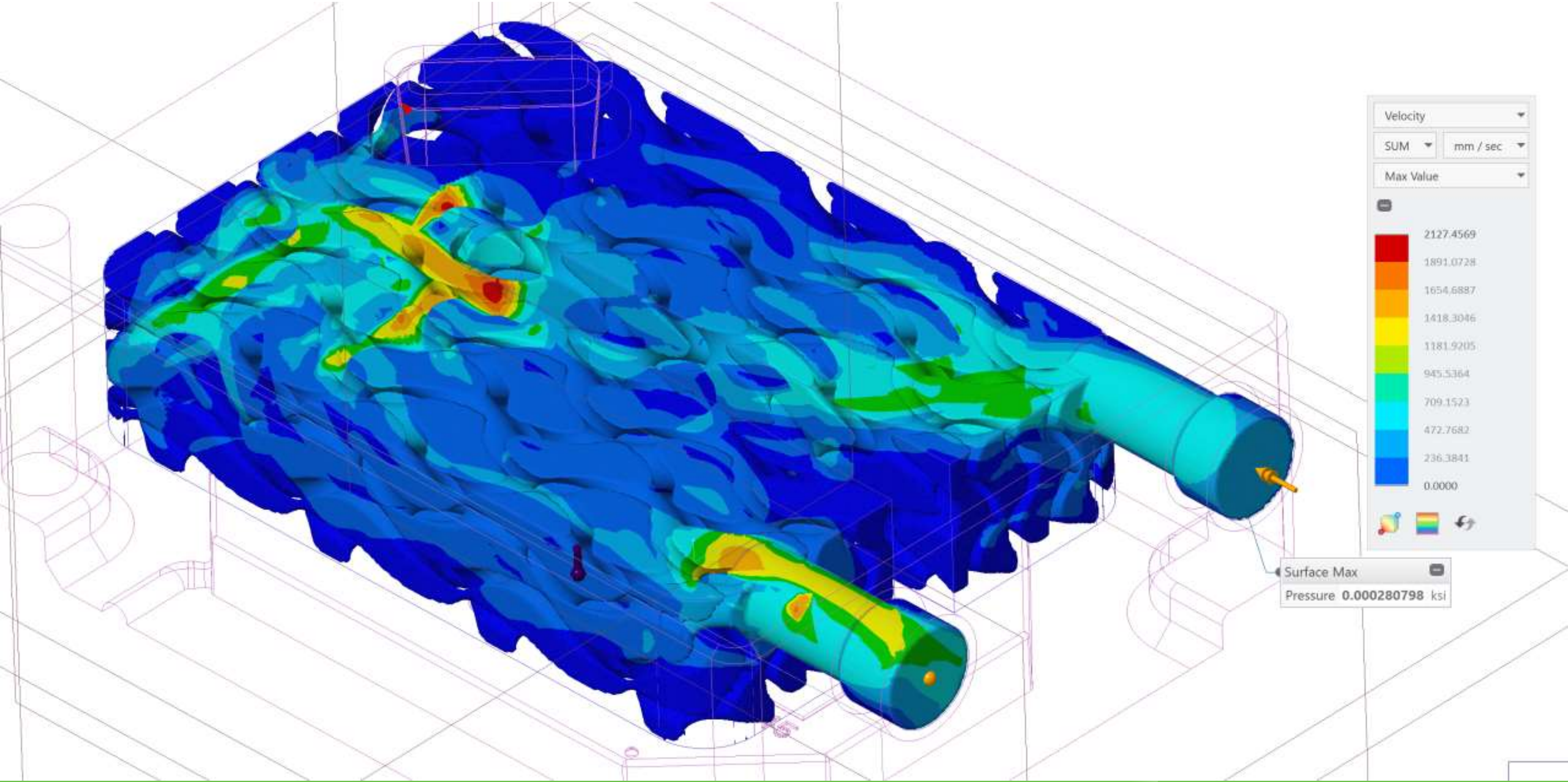
# PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY



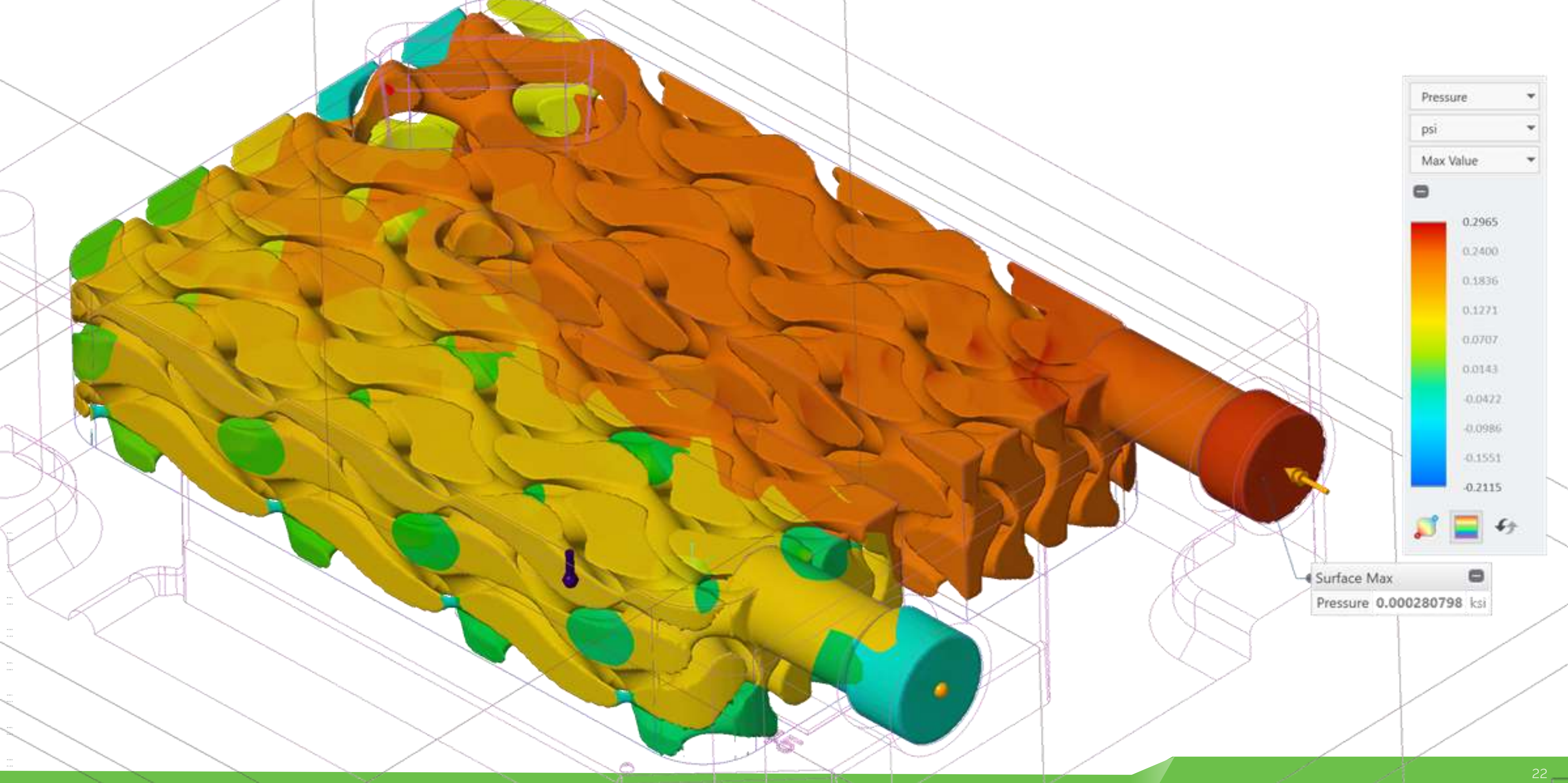
# PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY STEAMLINES



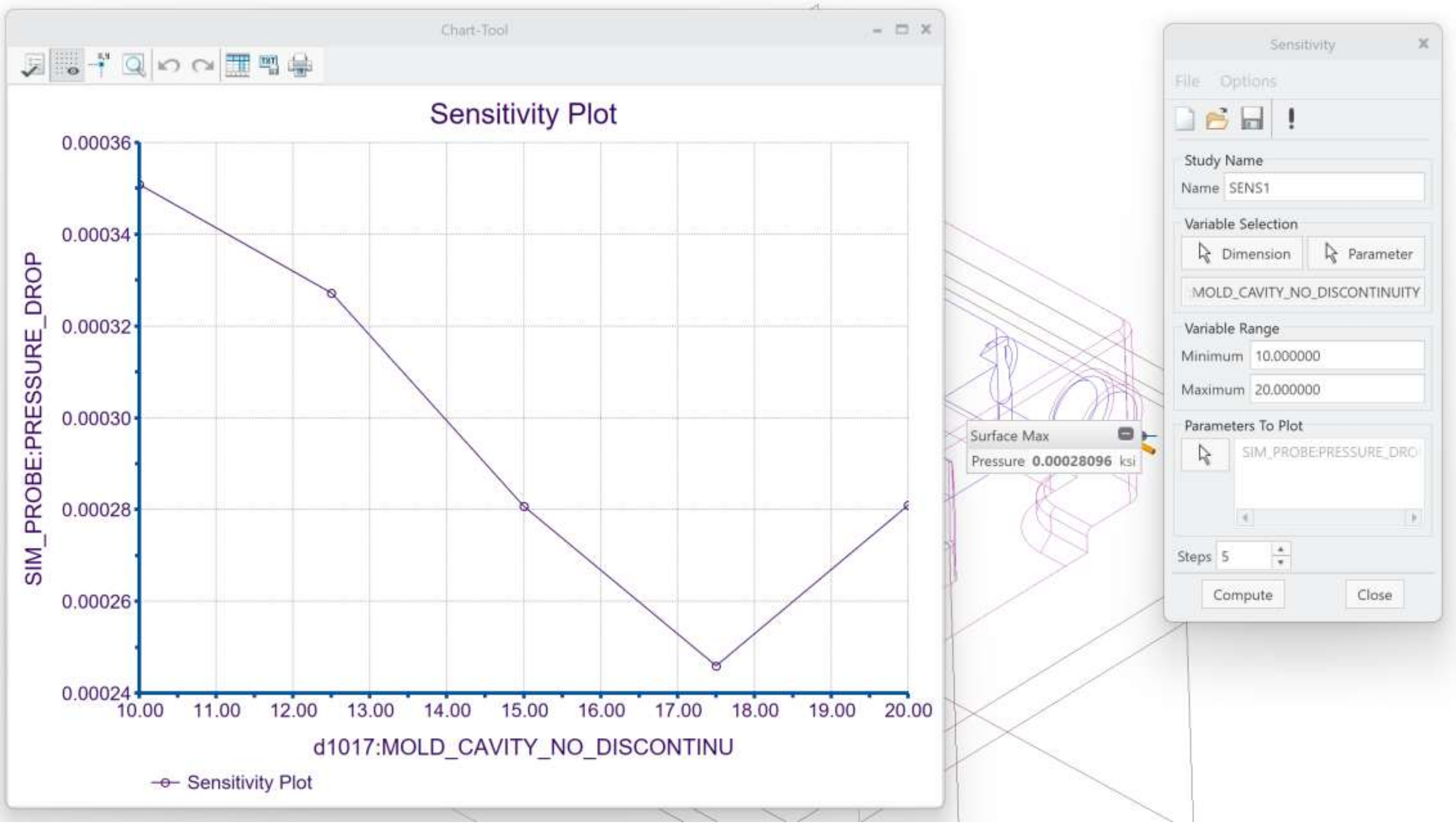
# PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY
# VELOCITY DISTIBUTION



# PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY PRESSURE DISTRIBUTION



# PRESSURE DROP OPTIMIZATION OF A MOLD CAVITY



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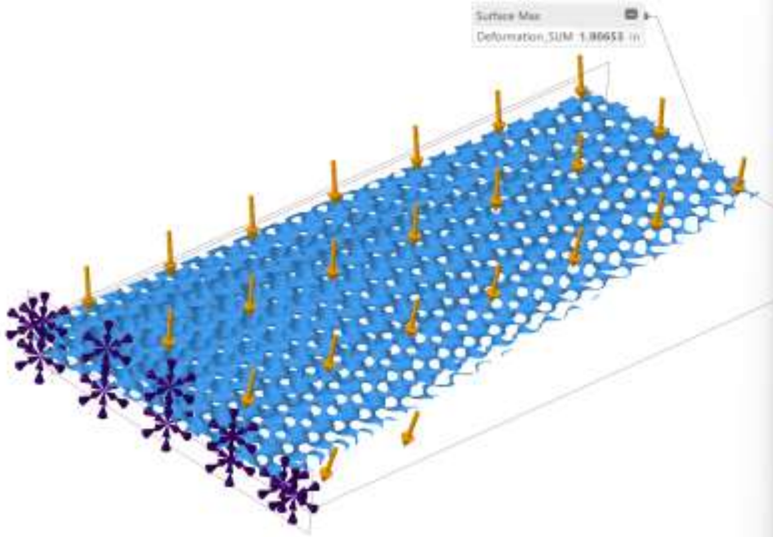
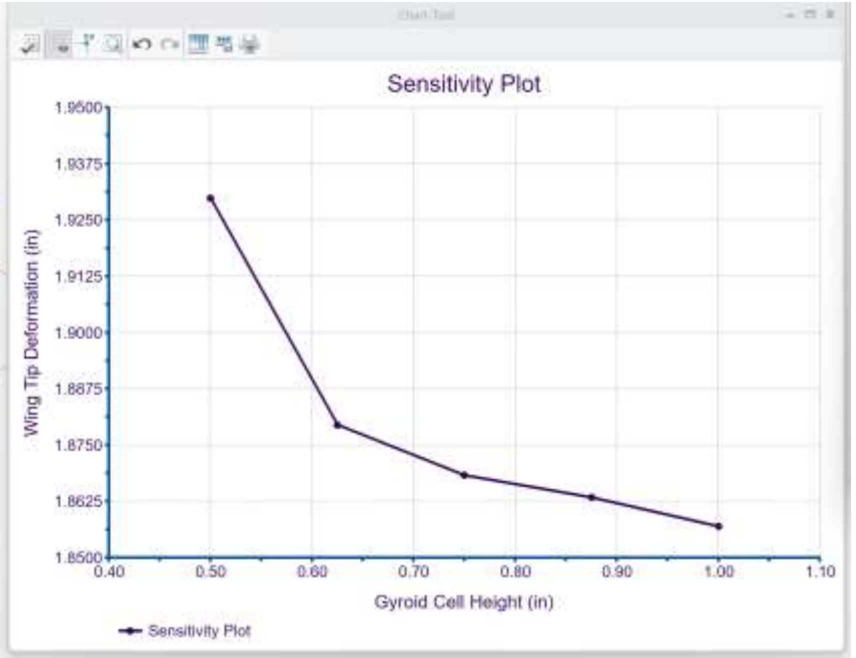
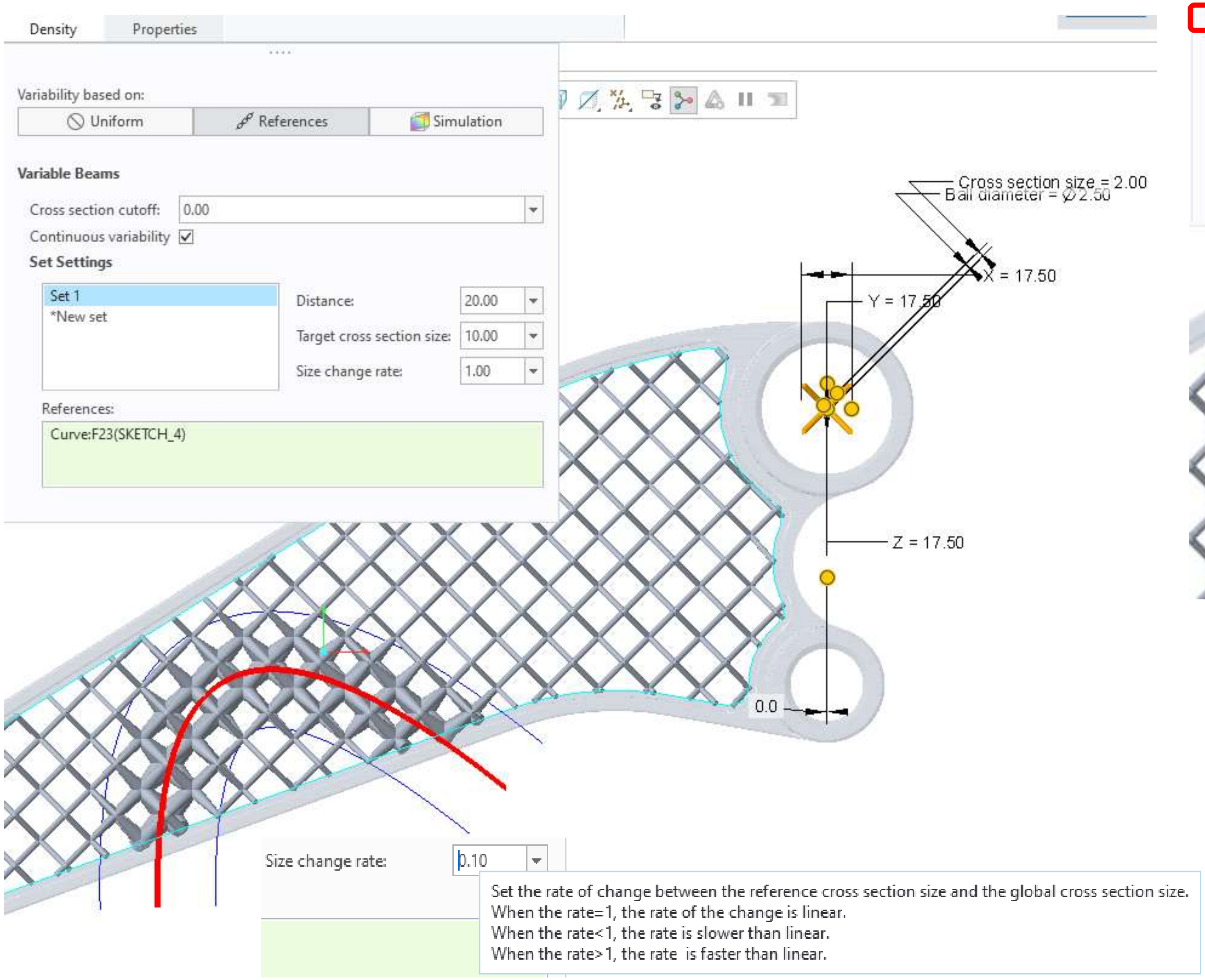
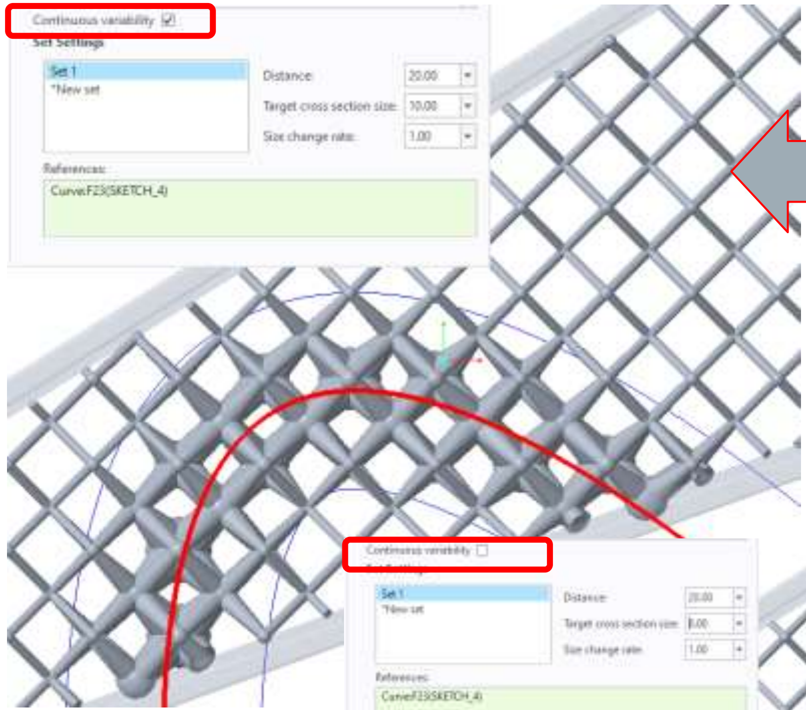
- Optimization Workflow
- **Simulation-driven lattices in Creo**
- Special cases





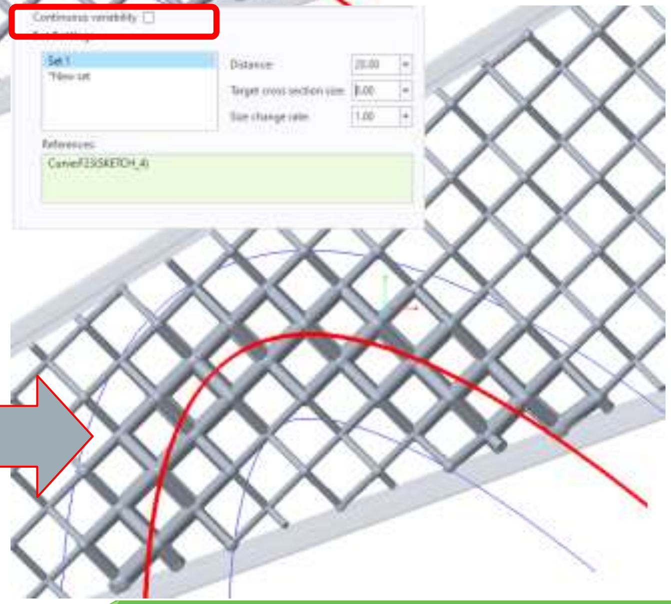
# LATTICE VARIABILITY USING GEOMETRIC REFERENCES



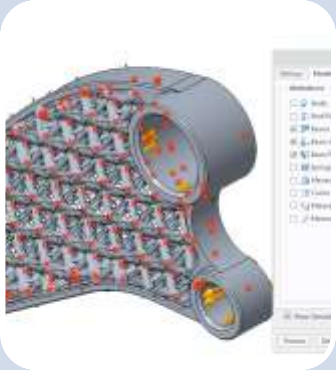
Transitioning with conical beams

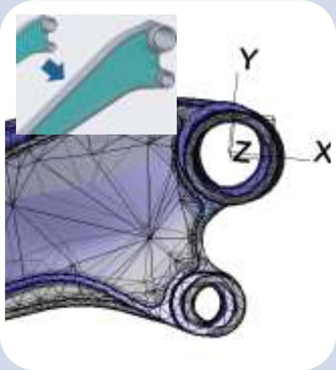
Transitioning with cylindrical beams

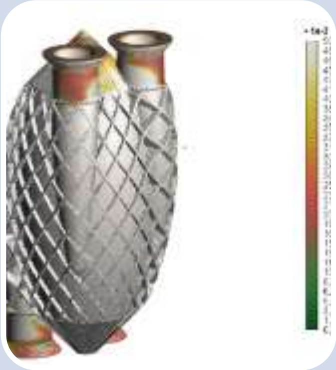


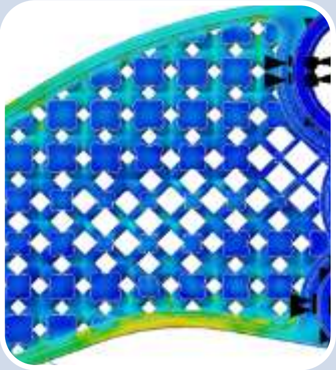
# EVOLUTION OF SIMULATION-DRIVEN LATTICE MODELLING

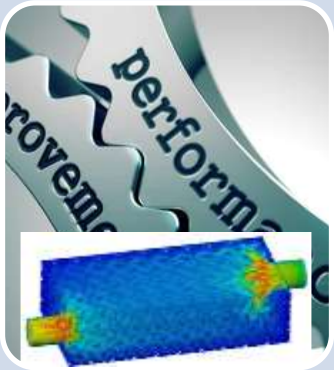
*CREO CONTINUES TO FOCUS ON INNOVATING LATTICE MODELLING*

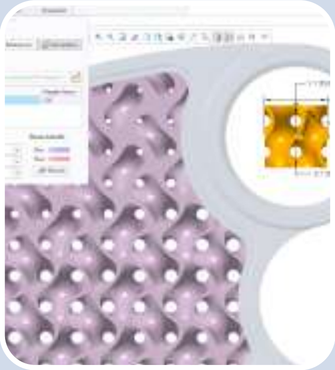










## Creo 5

**Simulation and optimization of lattices using idealizations in Creo Simulate**

- Beams, Shells and Masses

## Creo 6

**Material homogenization**

- For uniform lattices, uniformly propagated

- Creo Simulate solver only…

**Real-time simulation**

- Using Creo Simulation Live

## Creo 7

**Additive process simulation** (3rd party)

- Simulation of parts, lattices and supports

- Creation of compensated models

## Creo 8

**Automatic Lattice variability** based on simulation results

- for beam-based lattices

## Creo 9

**Real-time simulation**

- FDL Lattice support for CSL Fluids

Regular performance improvements projects

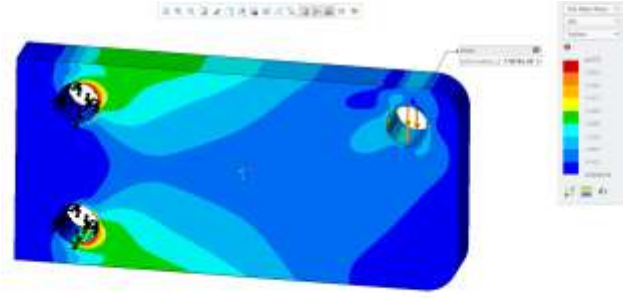
## Creo 10

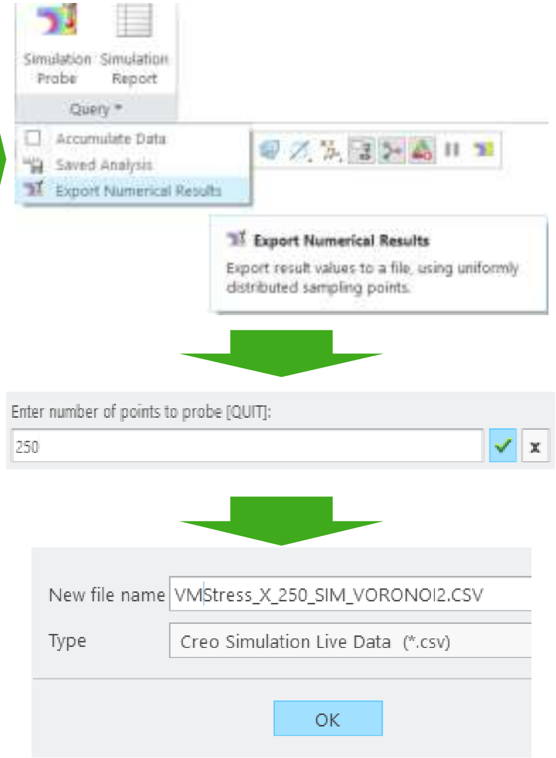
**Automatic Lattice variability** based on simulation results

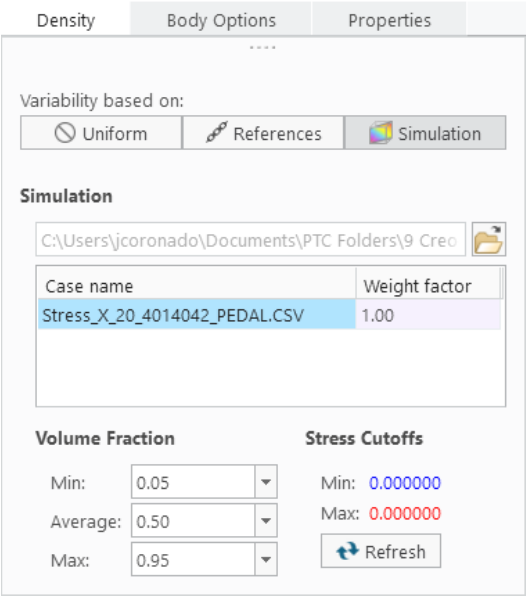
- for formula-driven lattices

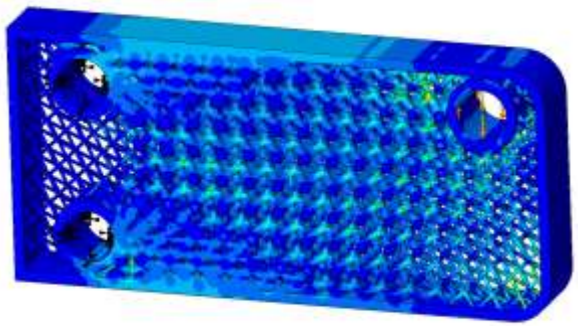
# LATTICE VARIABILITY BASED ON SIMULATION RESULTS.
# - PROCESS -

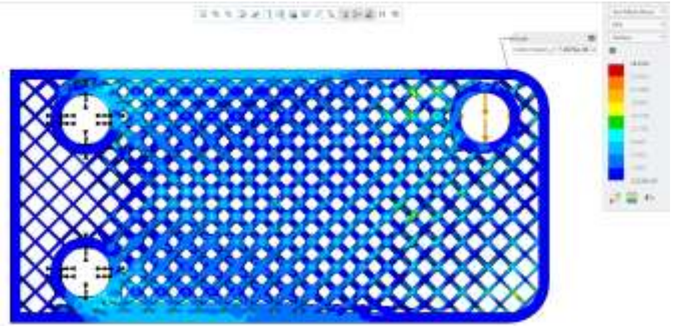
- Simulate a part
- Export simulation results
- Add lattice with variability based on simulation results
- Get a smart infill and validate results using simulation







# SIMULATION SUPPORT FOR LATTICE

| Lattice type | Lattice representation | Creo Simulate | CSL | Ansys Simulation | Creo Flow Analysis |
|---|---|---|---|---|---|
| Beams | Full geometry | ✓ | ✓ | ✓ | ✓ |
| | Simplified | ✓ | ✓ | X | ✓ |
| Beams | Homogenized | ✓ (static and modal analysis) | X | X | X |
| 2.5D | Full geometry | ✓ | ✓ | ✓ | ✓ |
| | Simplified | ✓ | ✓ | X | ✓ |
| Formula Driven | Voxelized | X | ✓ | X | ✓ |
| Custom | Full geometry | ✓ | ✓ | ✓ | ✓ |
| | Simplified | X | ✓ | X | ✓ |

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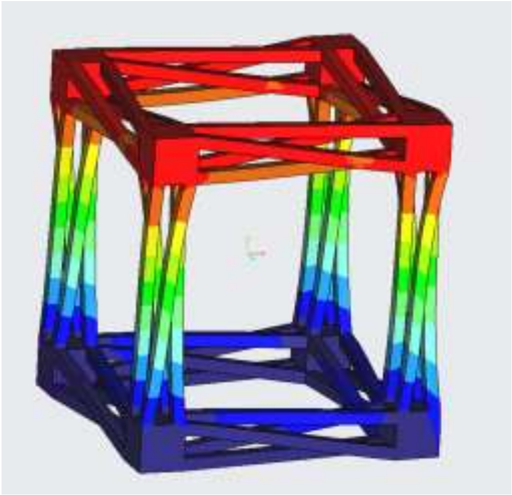
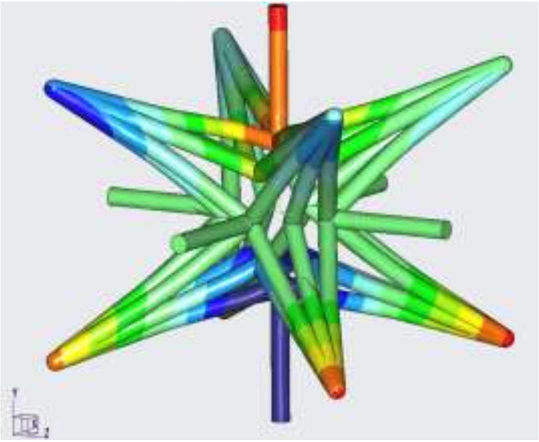
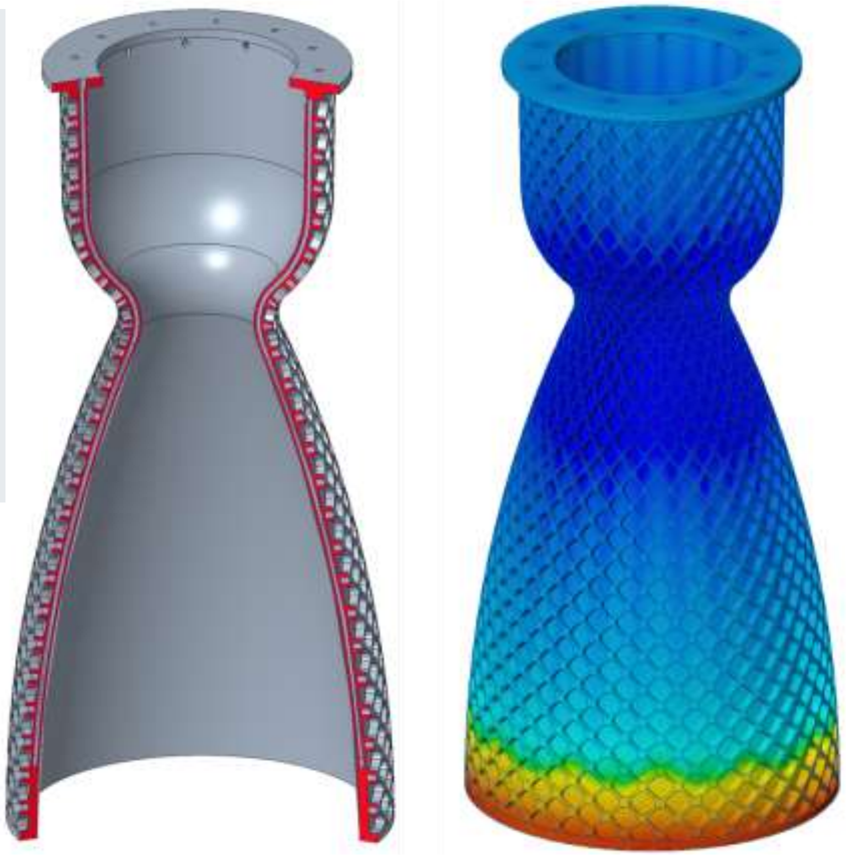
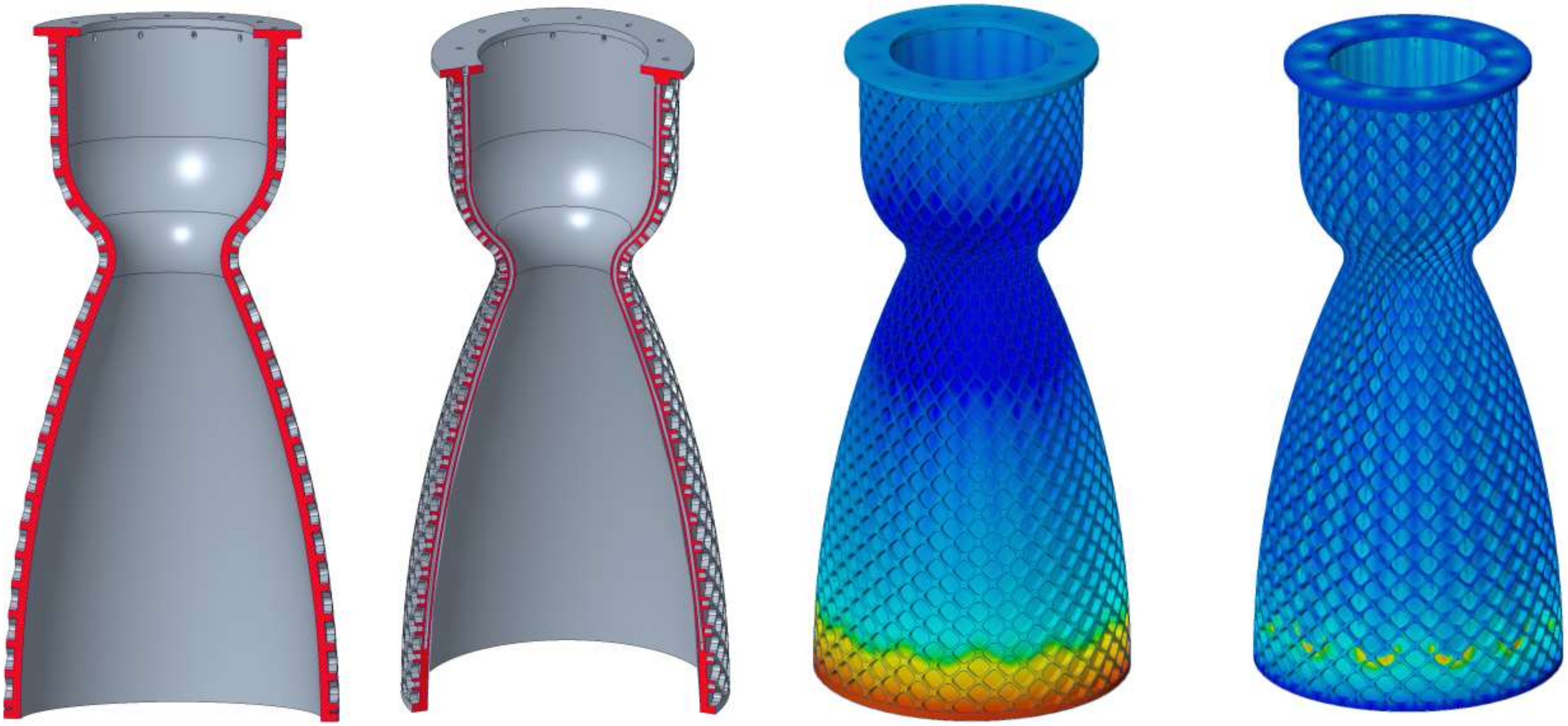
- Taxonomy of Lattice Structures
- Optimization Workflow
- Simulation-driven lattices in Creo
- **Special cases**



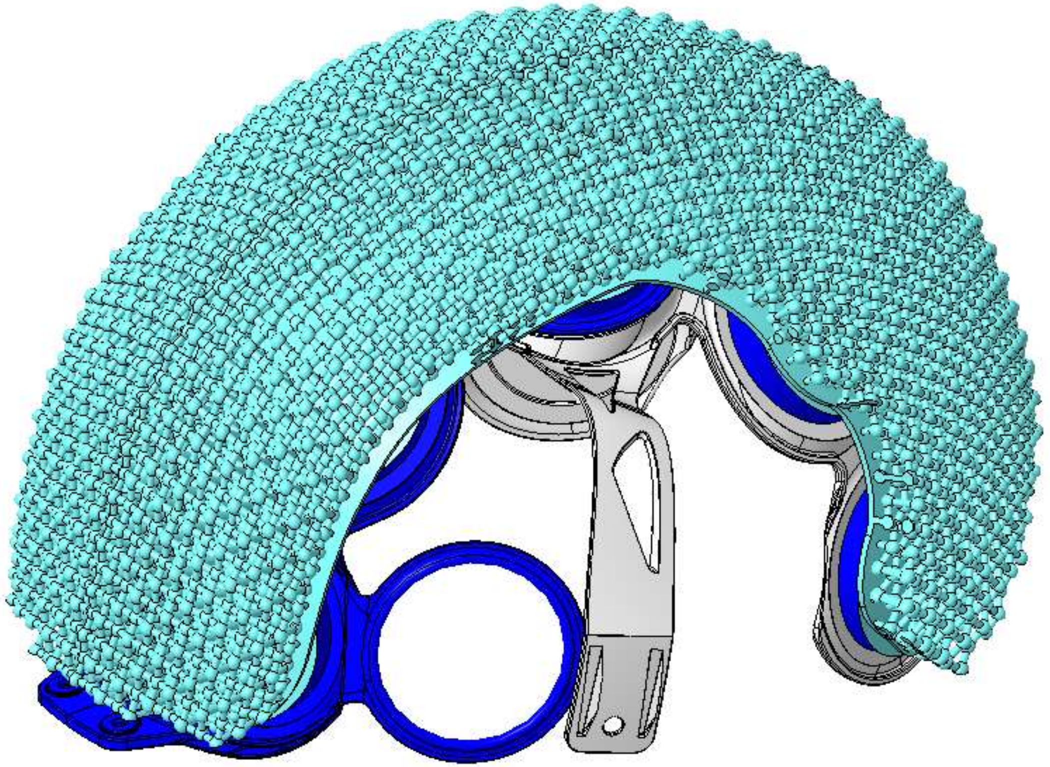




# ROCKET NOZZLE WITH COOLING CHANNELS

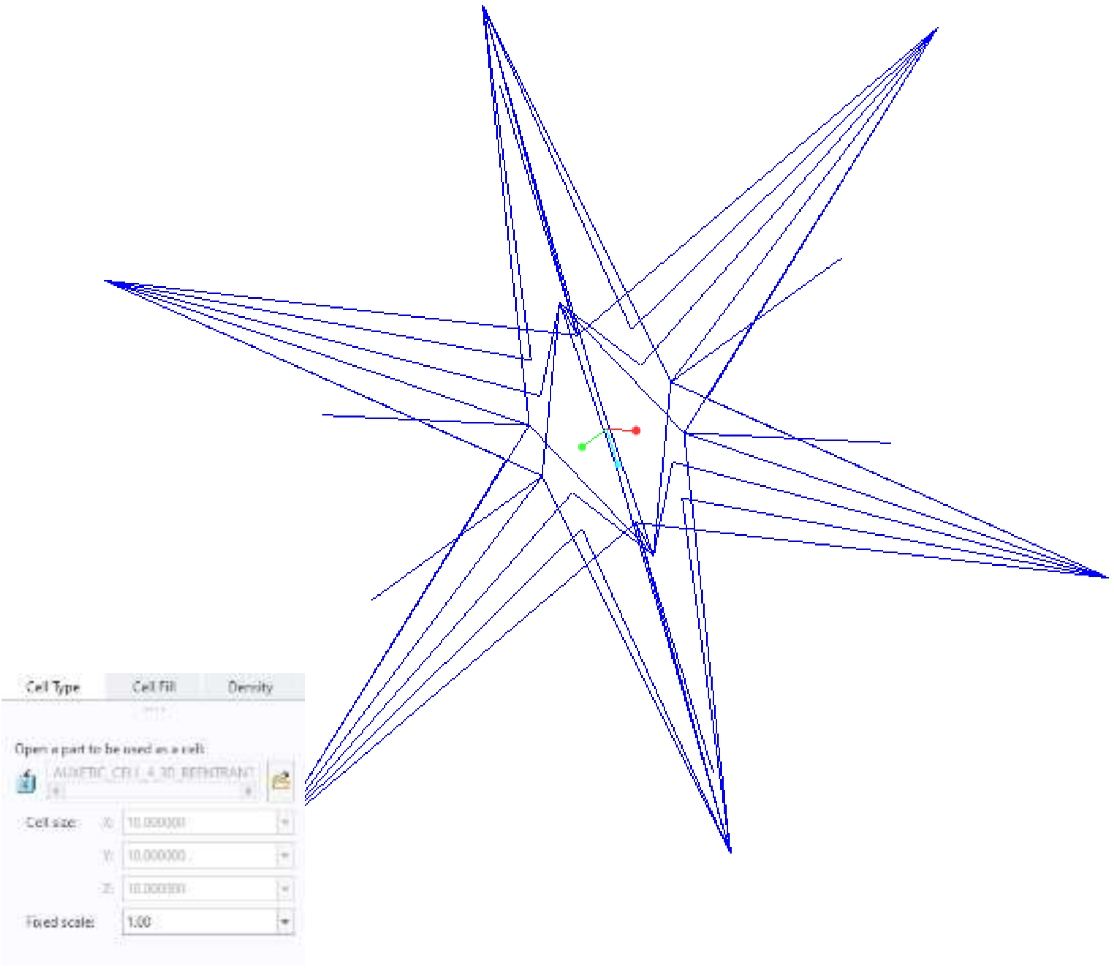


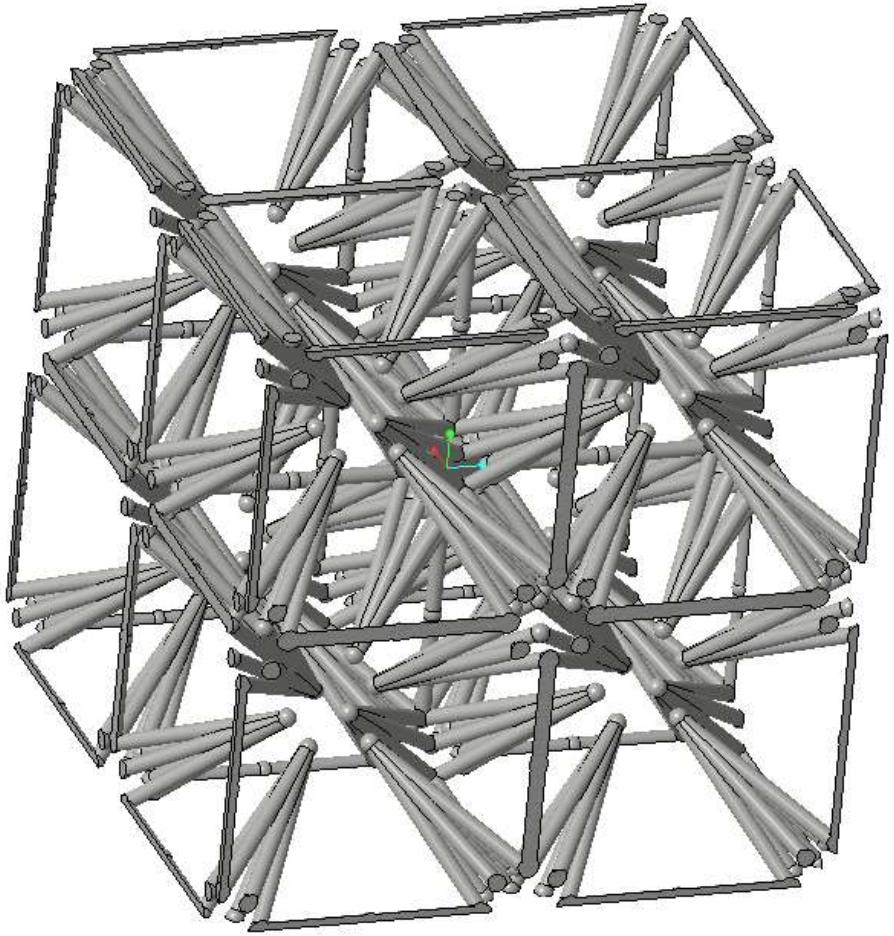
# THE NEW AUXETIC LATTICE, NORMAL TO THE SURFACE



# CUSTOM CELL

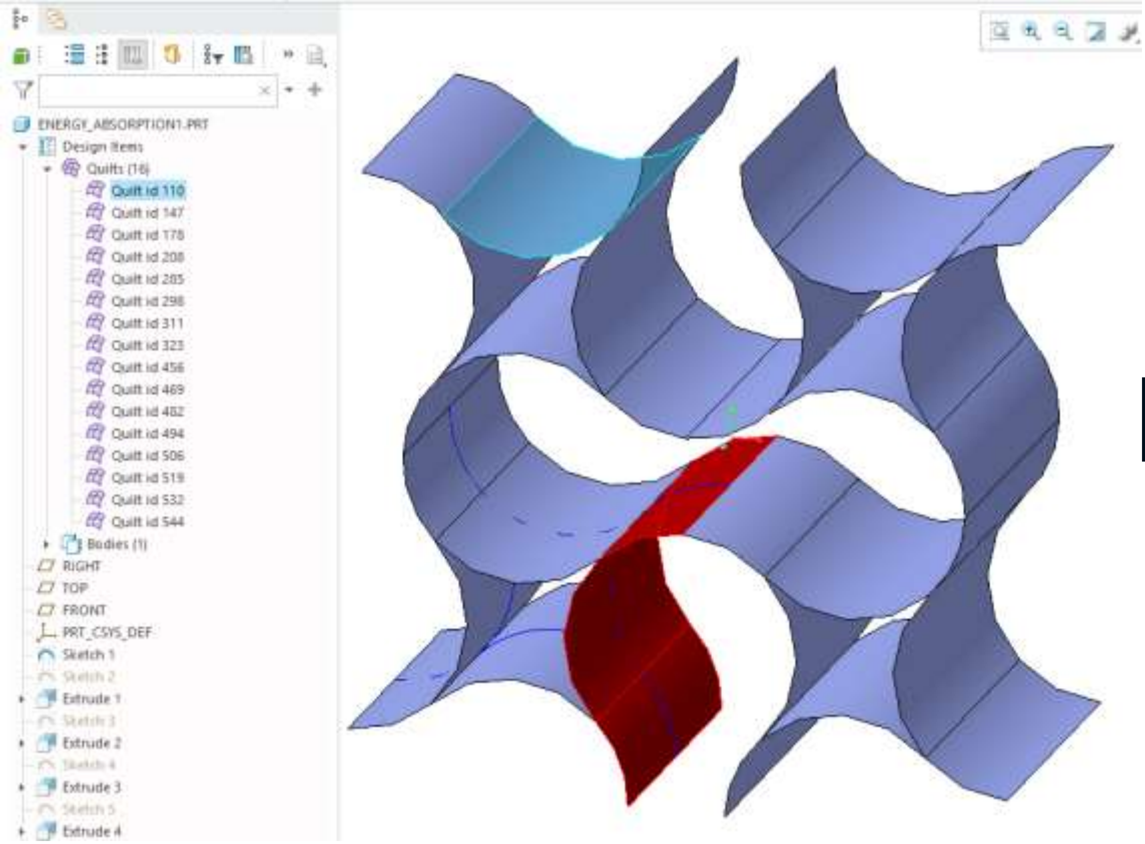
A Creo model with only straight lines



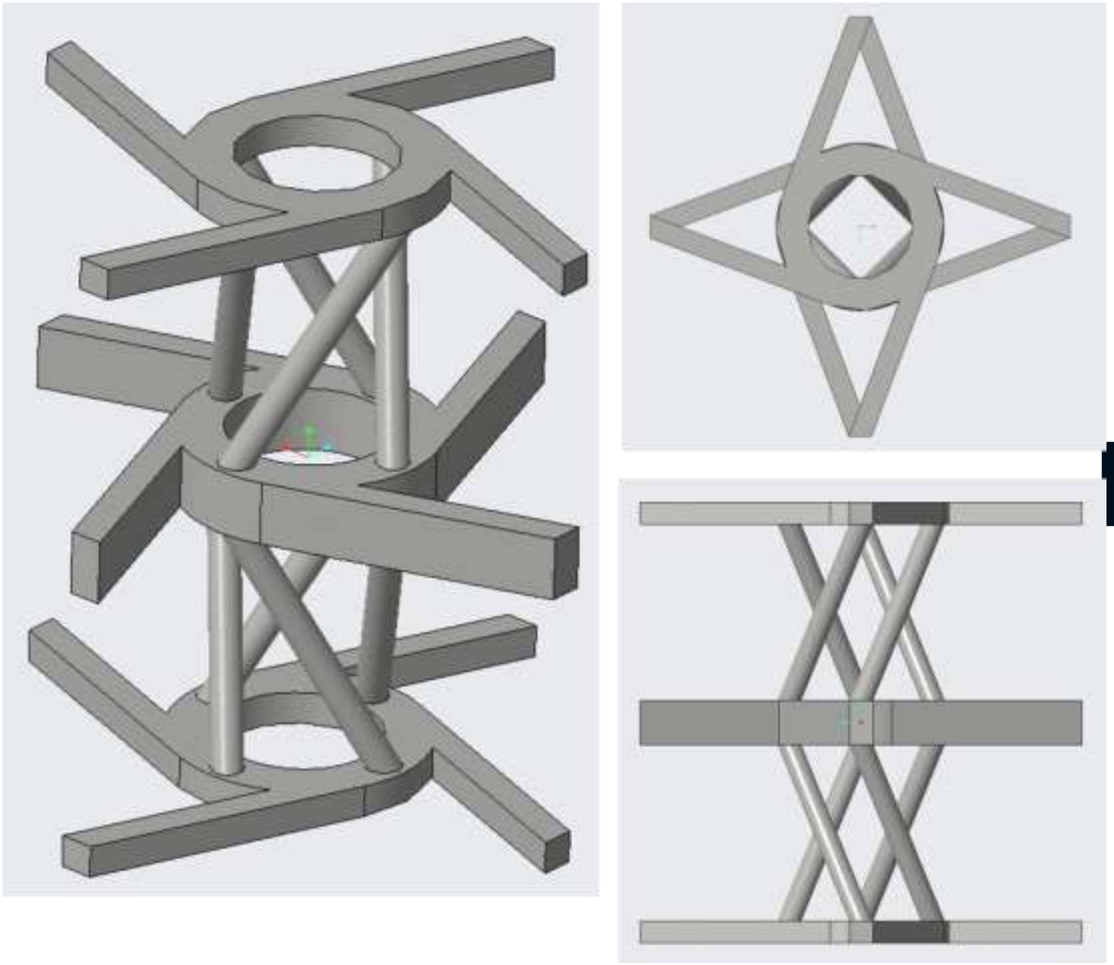
# CUSTOM CELL

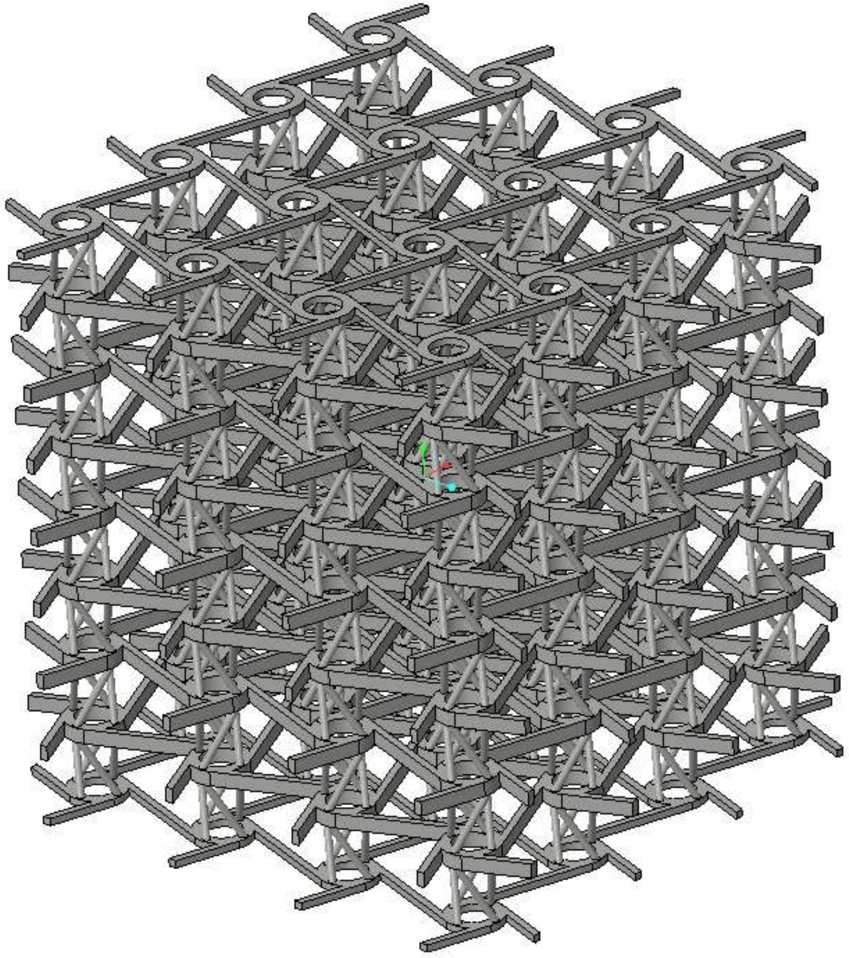
A model with quilts




# CHIRAL. LOOP-LIKE CELL

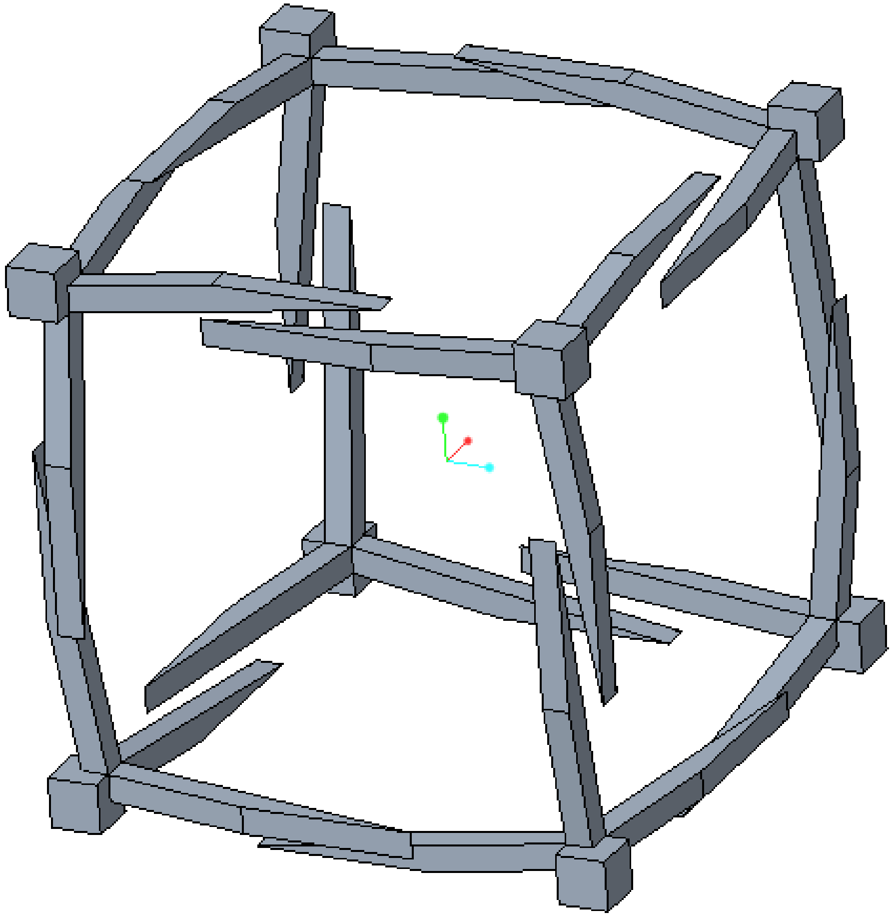
A Creo Solid Model

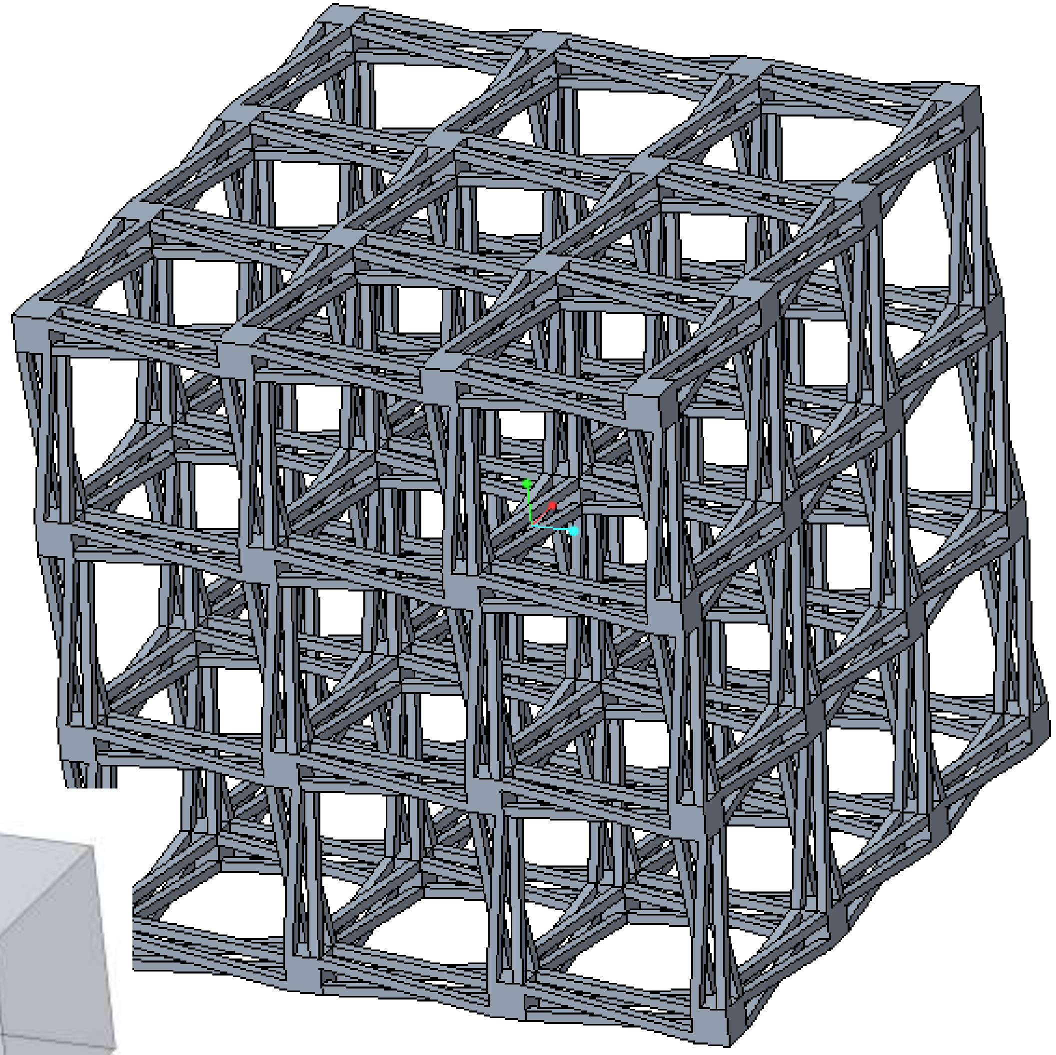


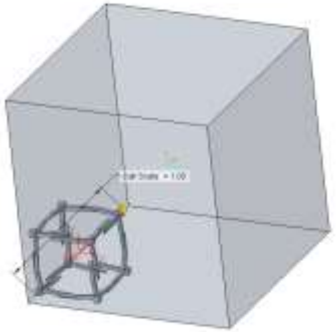


# CUSTOM CELL

A Creo Solid Model

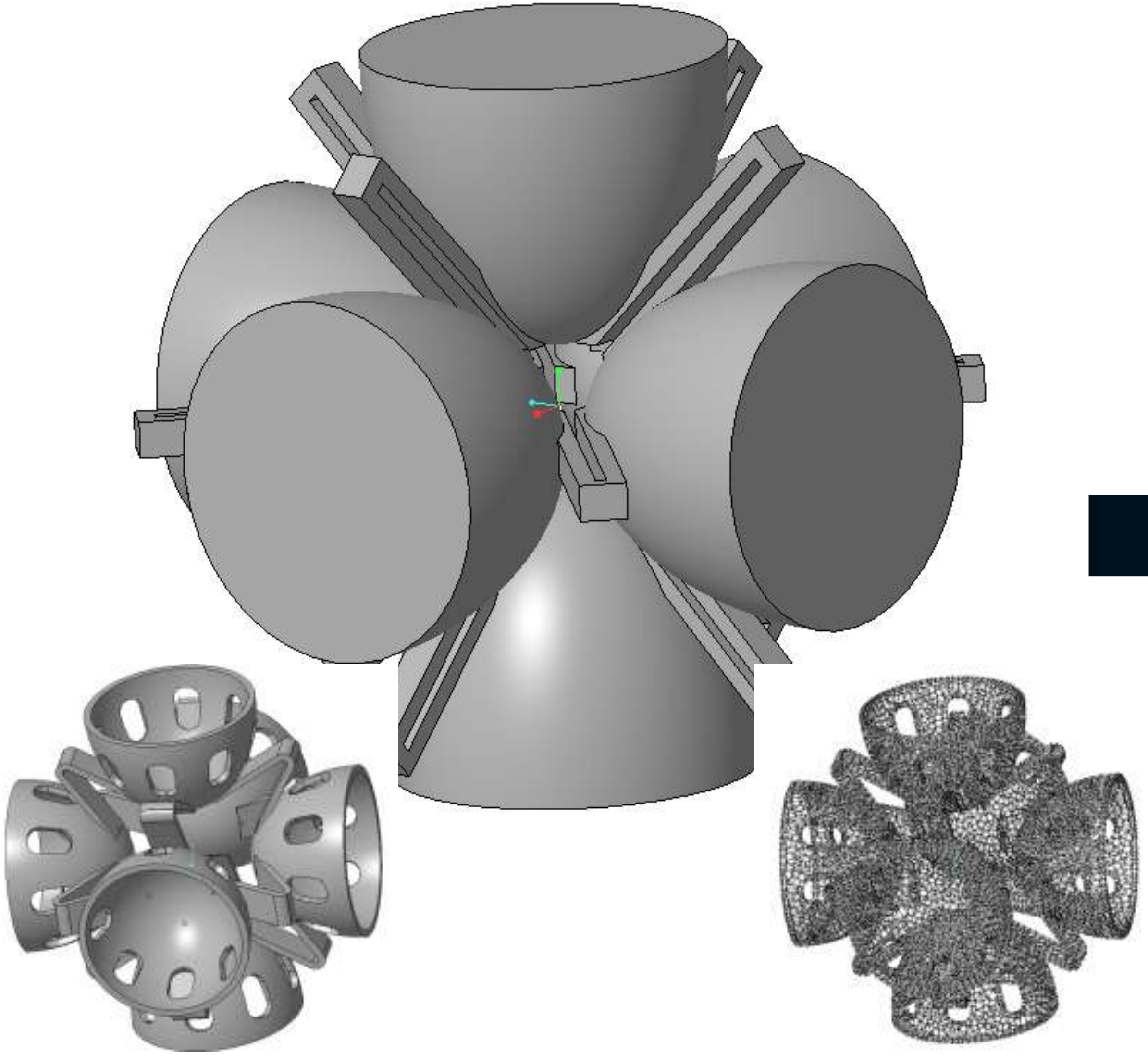


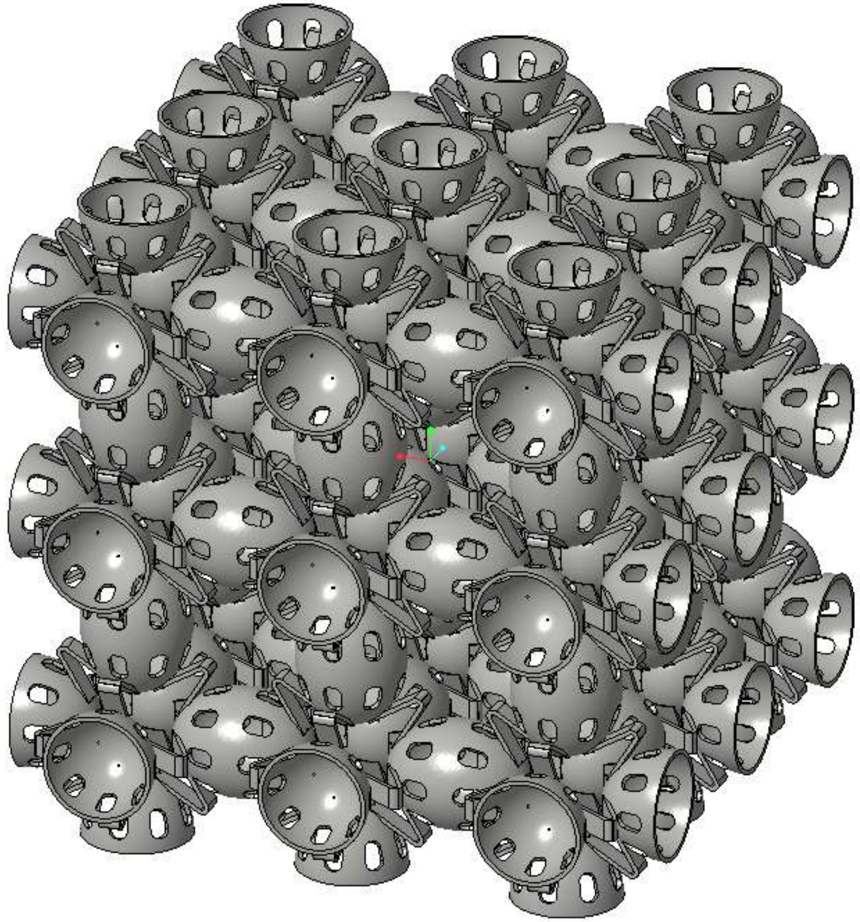


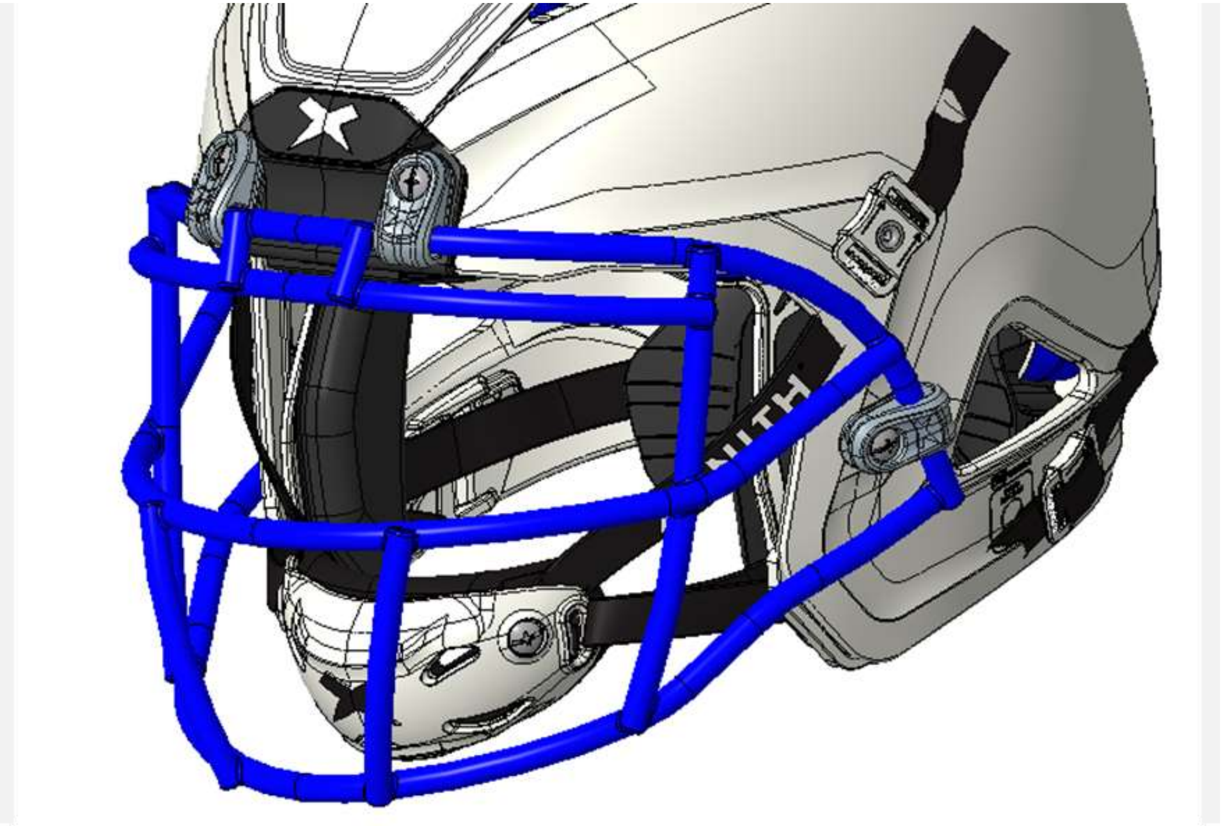


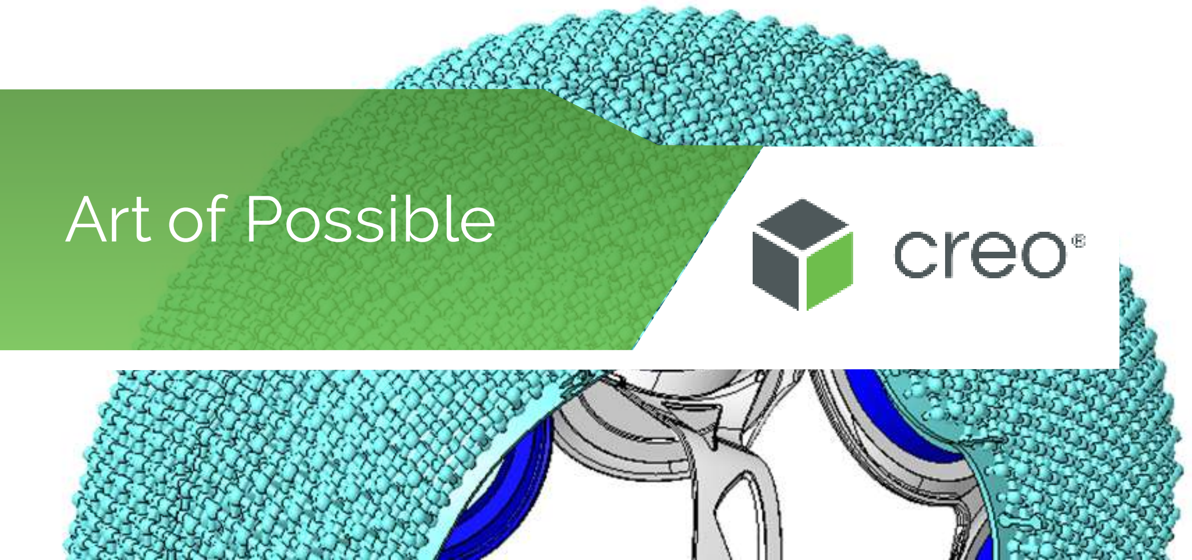
# CUSTOM CELL

A Creo Solid Model










# METAMATERIALS WITH CREO LATTICE MODELLING

- A metamaterial (from the Greek word μετά meta, meaning "beyond" or "after", and the Latin word materia, meaning "matter" or "material") is any material engineered to have a property that is not found in naturally occurring materials.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