

# End-to-end workflow for generative design and lattices for the automotive and aerospace industry

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Senior Technical Consultant – Advanced Consulting

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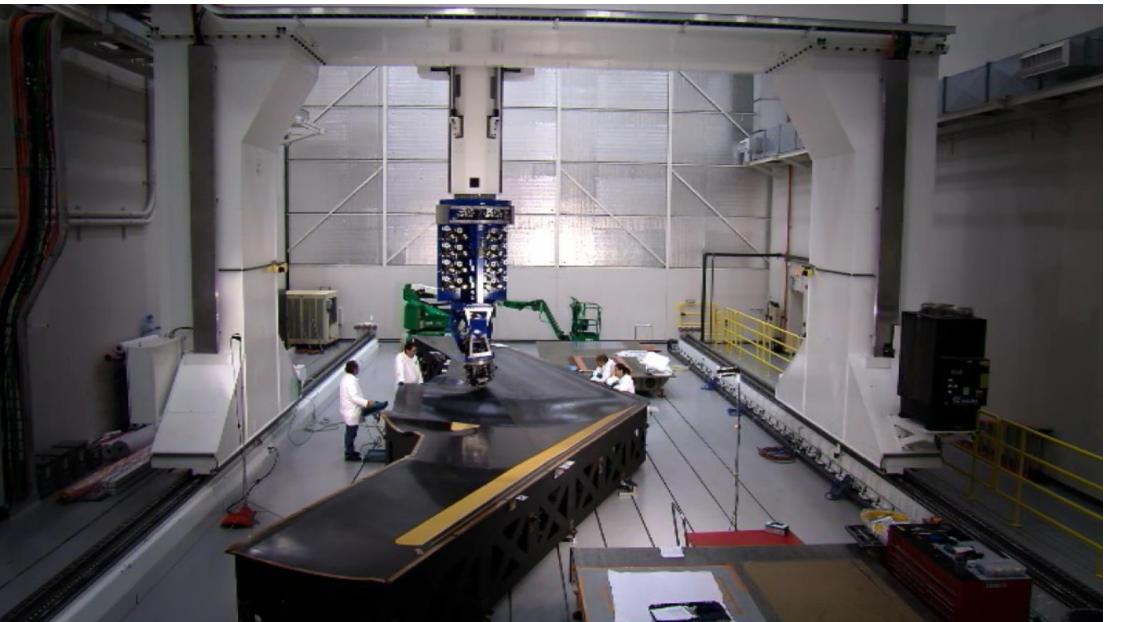
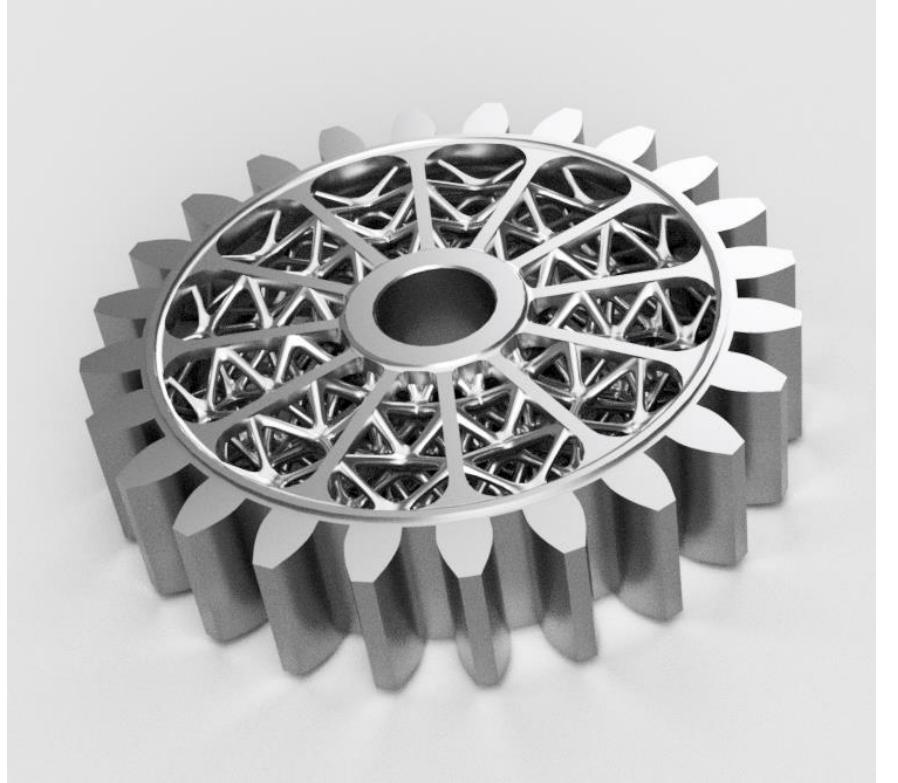
The background features a complex, abstract wireframe pattern composed of numerous thin, light gray lines forming a organic, flowing structure. It has several large, irregularly shaped holes or openings of varying sizes throughout the design.

# Autodesk Advanced Consulting

# Autodesk Advanced Consulting

We work in Partnership with our Clients to :

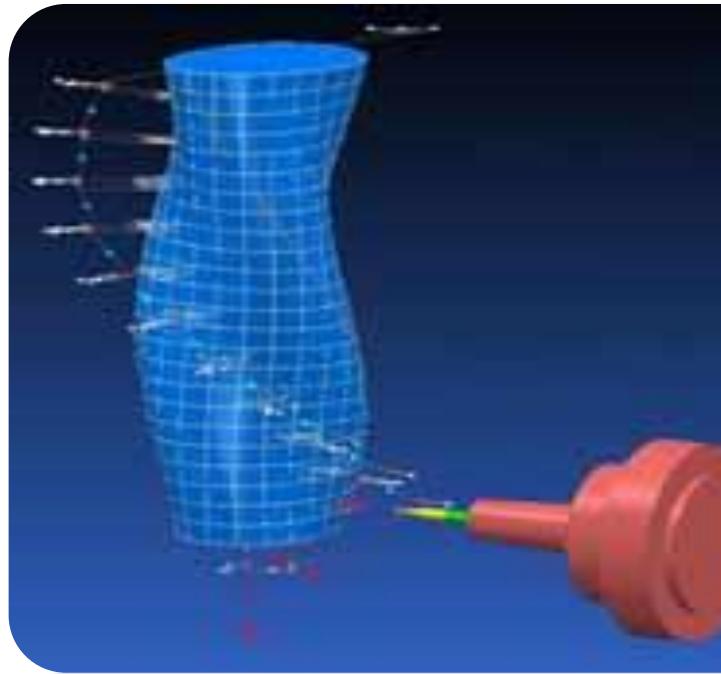
- *Deliver Innovative Design Solutions*
- *Deliver High Performance Products*
- *Increase the Efficiency of their Designs*
- *Effectively Implement AM Technology*
- *Help them improve their knowledge of AM*
- *Exploit New Opportunities*



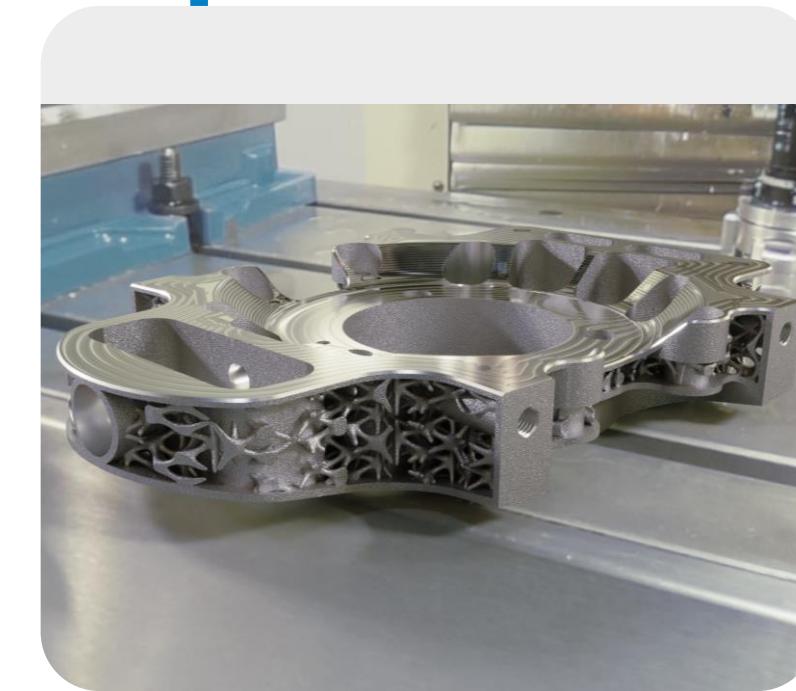
# DMG: Advanced Manufacturing Capabilities



Adaptive Manufacturing



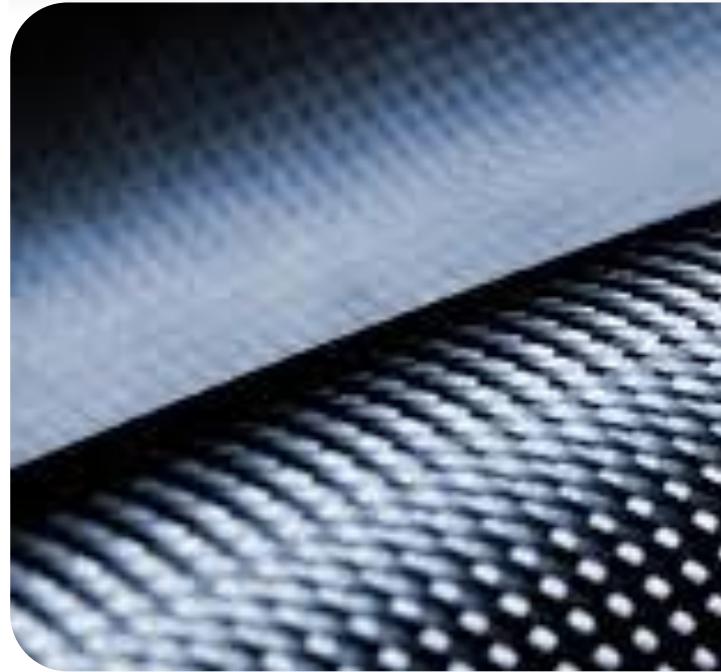
Robotics Programming



Additive Manufacturing



Build Verification & Inspection



Composites Design & Manufacturing



Sheet Metal Nesting

The background features a complex, organic geometric pattern composed of numerous thin, light gray lines forming a mesh of triangles and larger polygons. This pattern is set against a solid white background at the top and a solid blue background at the bottom, which has a subtle gradient effect.

# Current Additive Manufacturing Techniques

# AM Background: Techniques

- Stereolithography (SLA)
  - UV curing
  - Polymer
  - 0.1 mm feature size



# AM Background: Techniques

- Fused deposition modeling (FDM)

- Heated deposition of wire
- Polymer
- 0.125 mm feature size



# AM Background: Techniques

- Selective laser sintering (SLS)
  - Laser heating of powder
  - Polymer and metal (DMLS)
  - 0.1 mm feature size



\*Autodesk Advanced Consulting



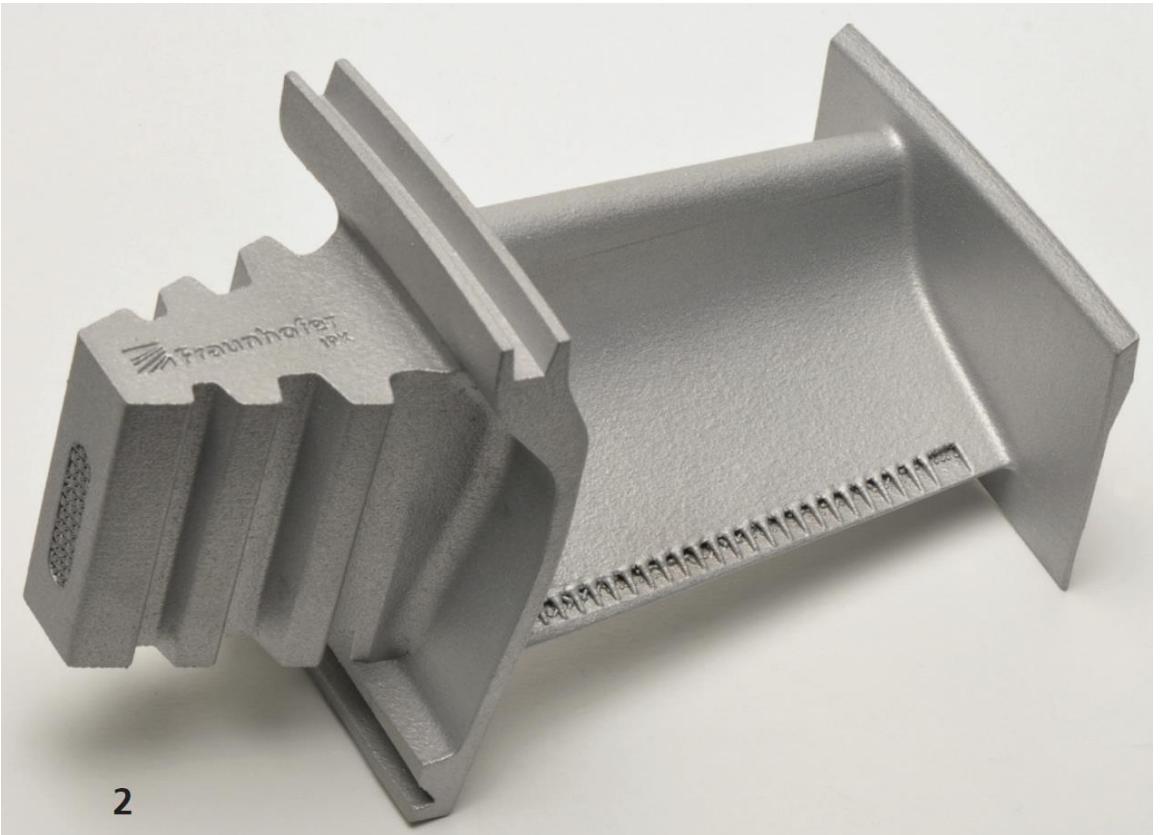
\*Autodesk Advanced Consulting



\*Autodesk Within Medical

# AM Background: Techniques

- Selective laser melting (SLM)
  - Laser heating of powder
  - Polymer and metal
  - 0.1 mm feature size



\*Fraunhofer



# AM Background: Techniques

- E-beam (EBM)
  - Electron beam heating
  - Metal
  - 0.13 mm feature size



\*Autodesk Within Medical



# AM Background: Techniques

- Direct metal deposition (DMD)
  - Laser heating of directed powder
  - Metal
  - 0.5 mm feature size

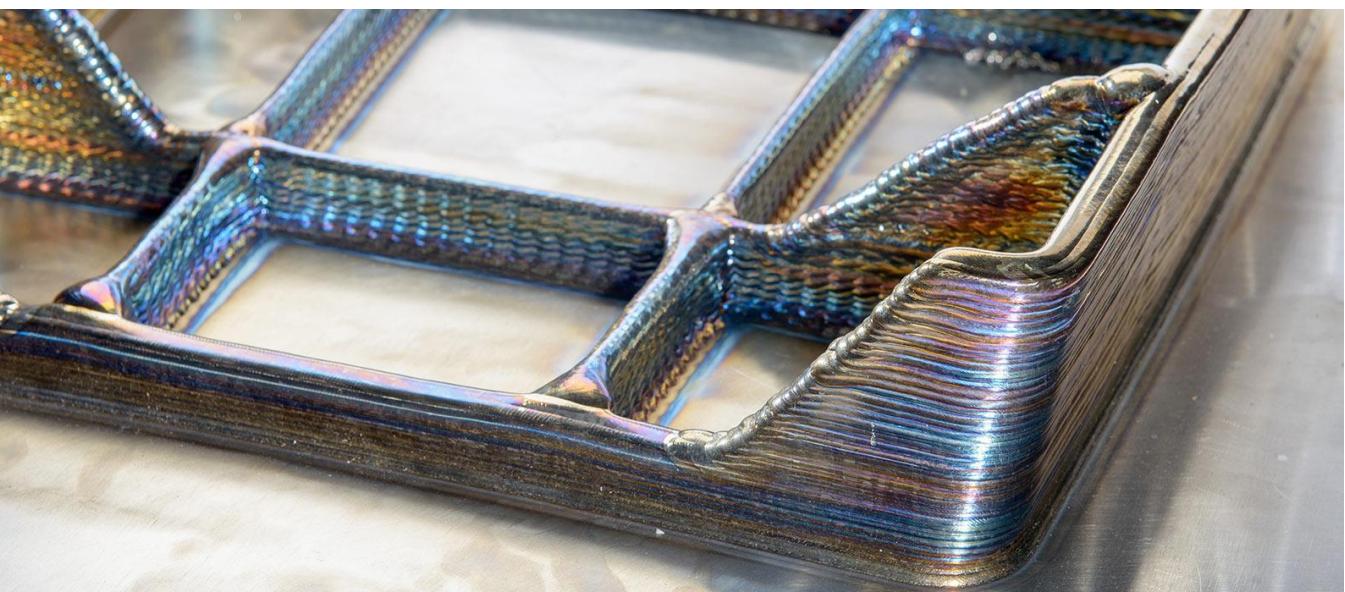
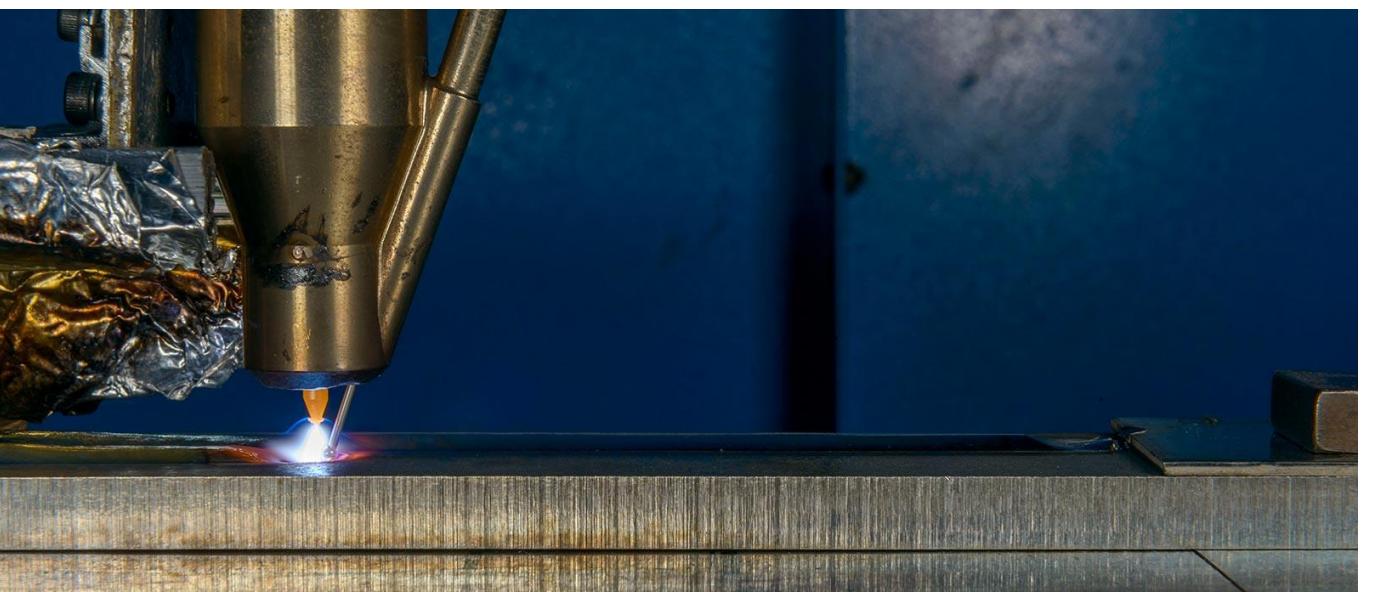


\*Fraunhofer



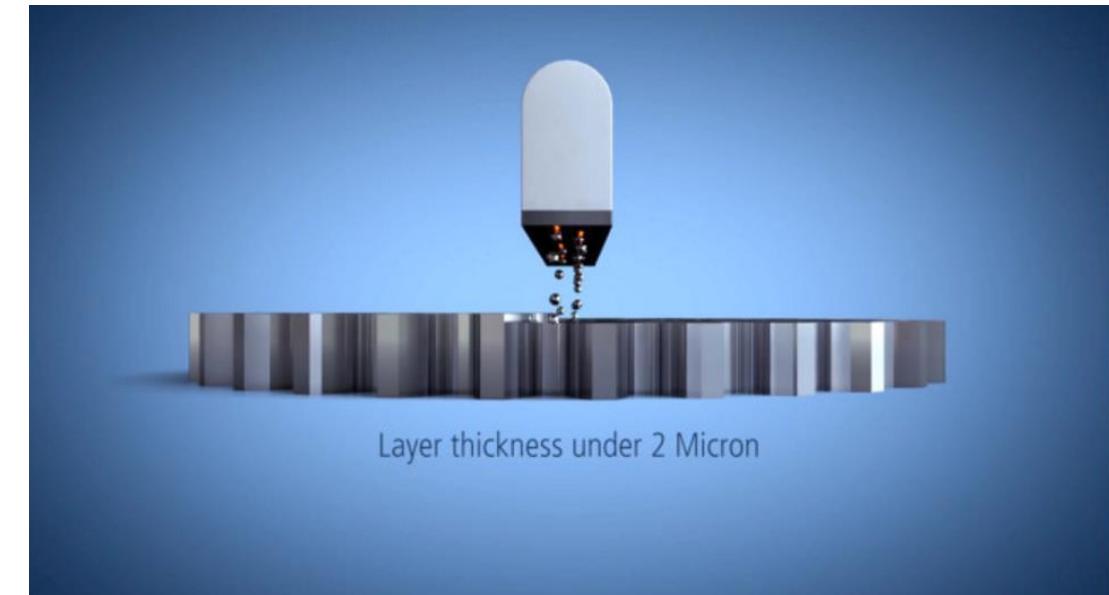
# AM Background: Techniques

- Wire and arc additive manufacturing (WAAM)
- Heated deposition of wire
- Metal
- 2 mm feature size
- Up to 250 mm<sup>3</sup>/s build speed



# AM Background: Techniques

- 3D metal jetting (binder jetting)
- Polymer binder
- Nano size metal particles
- No laser or e-beam, part is sintered after building
- ~30  $\mu\text{m}$  feature size
- No thermal stress/distortion
- Up to  $8 \text{ mm}^3/\text{s}$  build speed (~5x faster than laser)

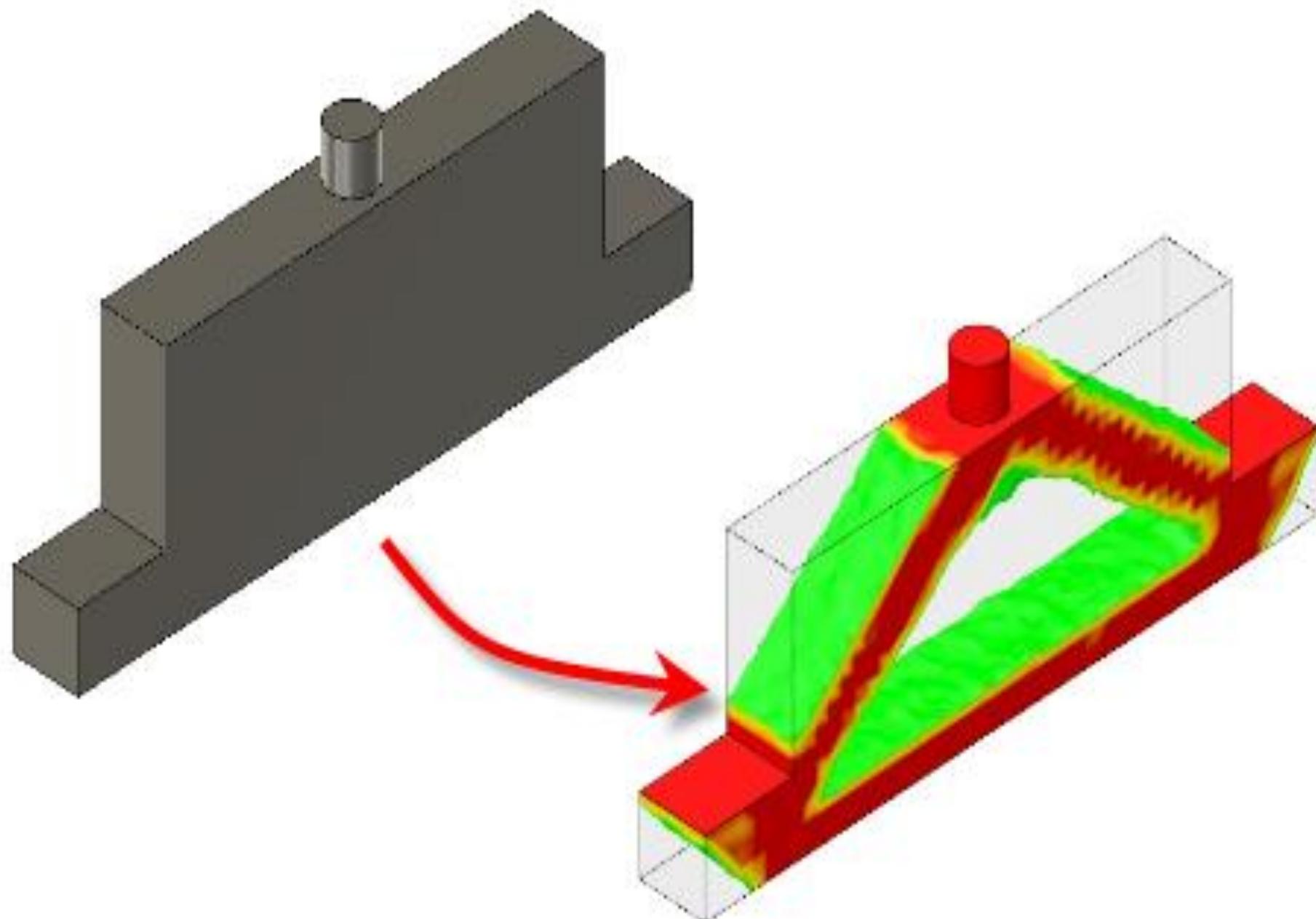


The background features a complex, abstract geometric pattern composed of numerous thin, light-grey lines forming a wireframe mesh. This mesh is organized into several large, overlapping spherical structures that appear to be in motion or interconnected. The overall effect is organic and futuristic.

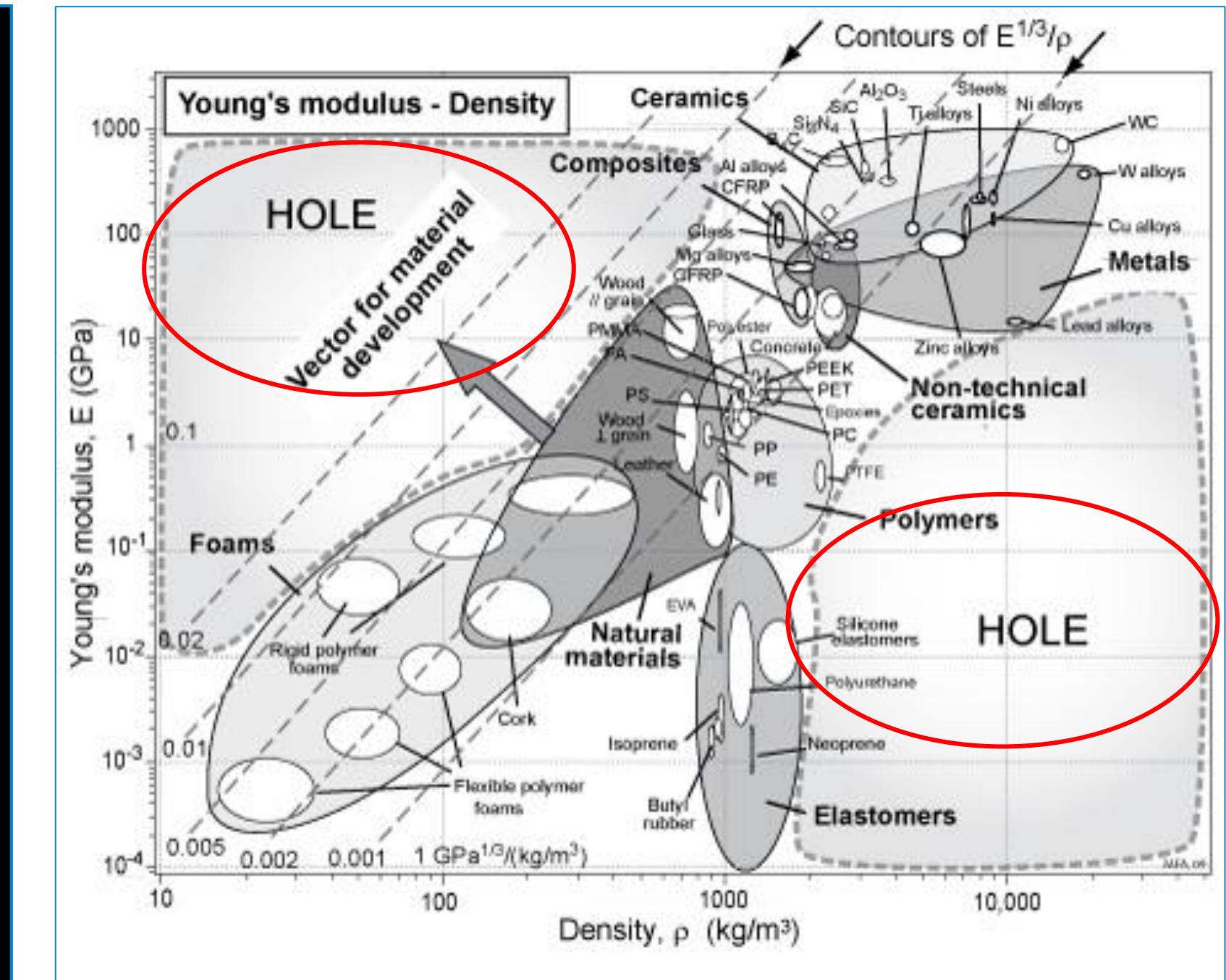
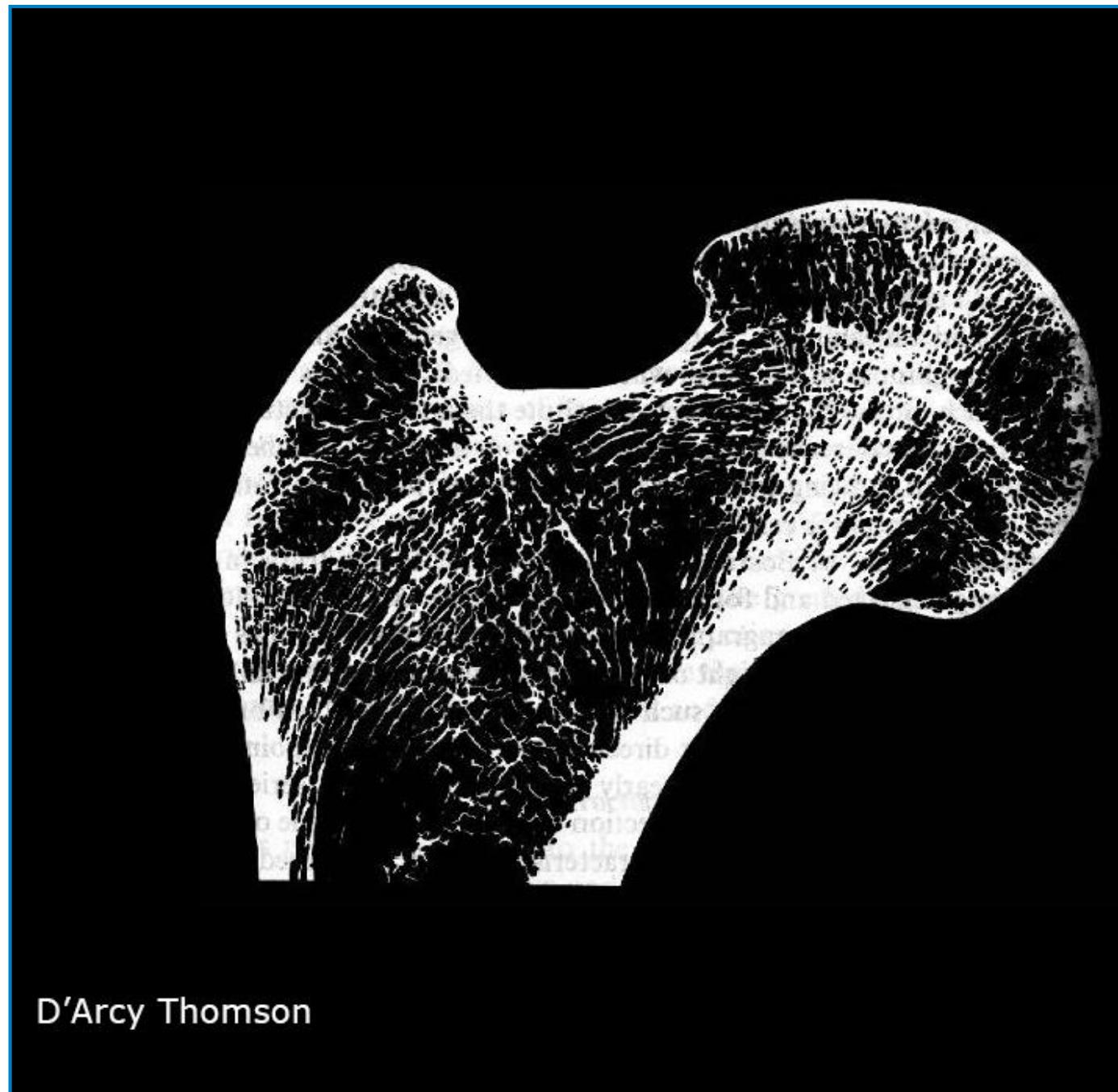
# Design Optimisation

# Topology Optimisation

- Structural
  - Stress
  - Displacement
  - Modal frequency
- Thermal
  - Temperature
  - Heat flux
- Combinations



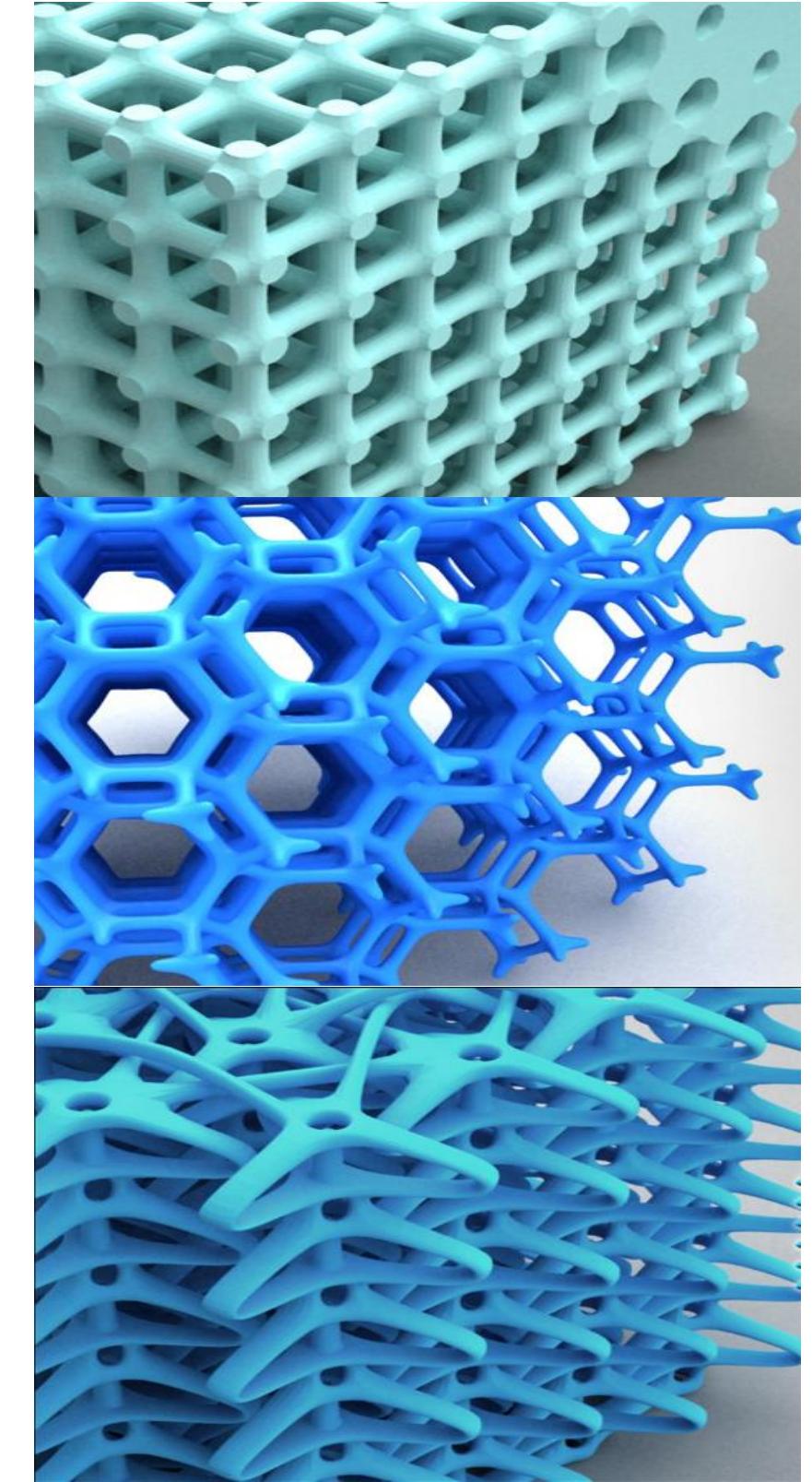
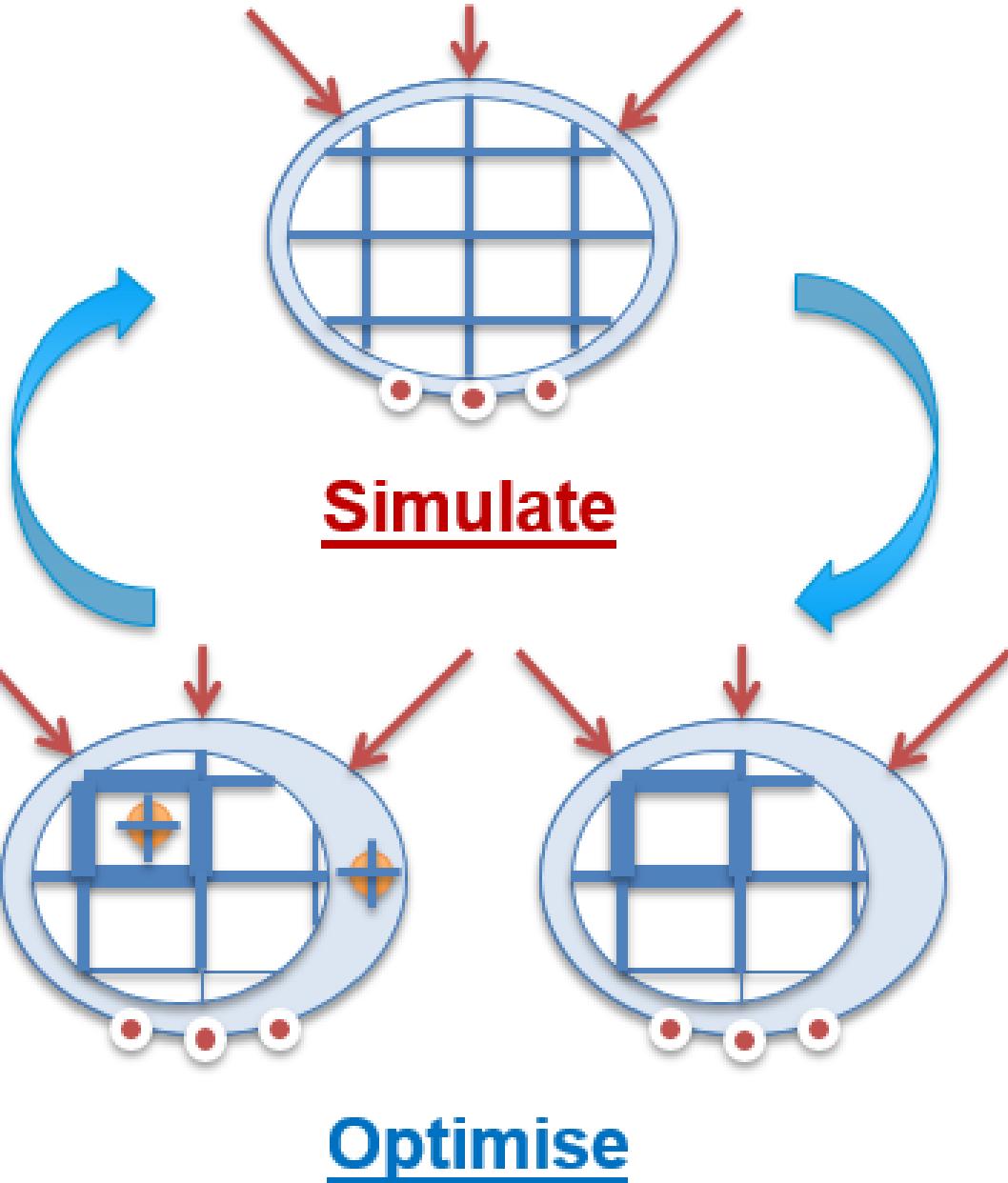
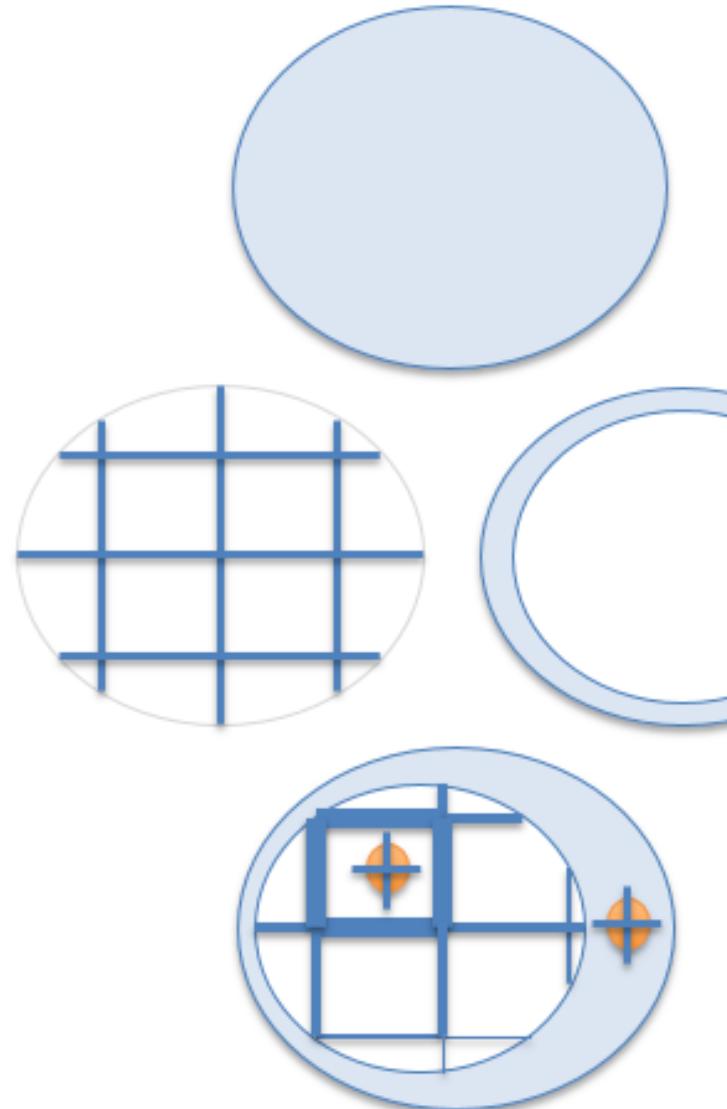
# Lattice Optimisation



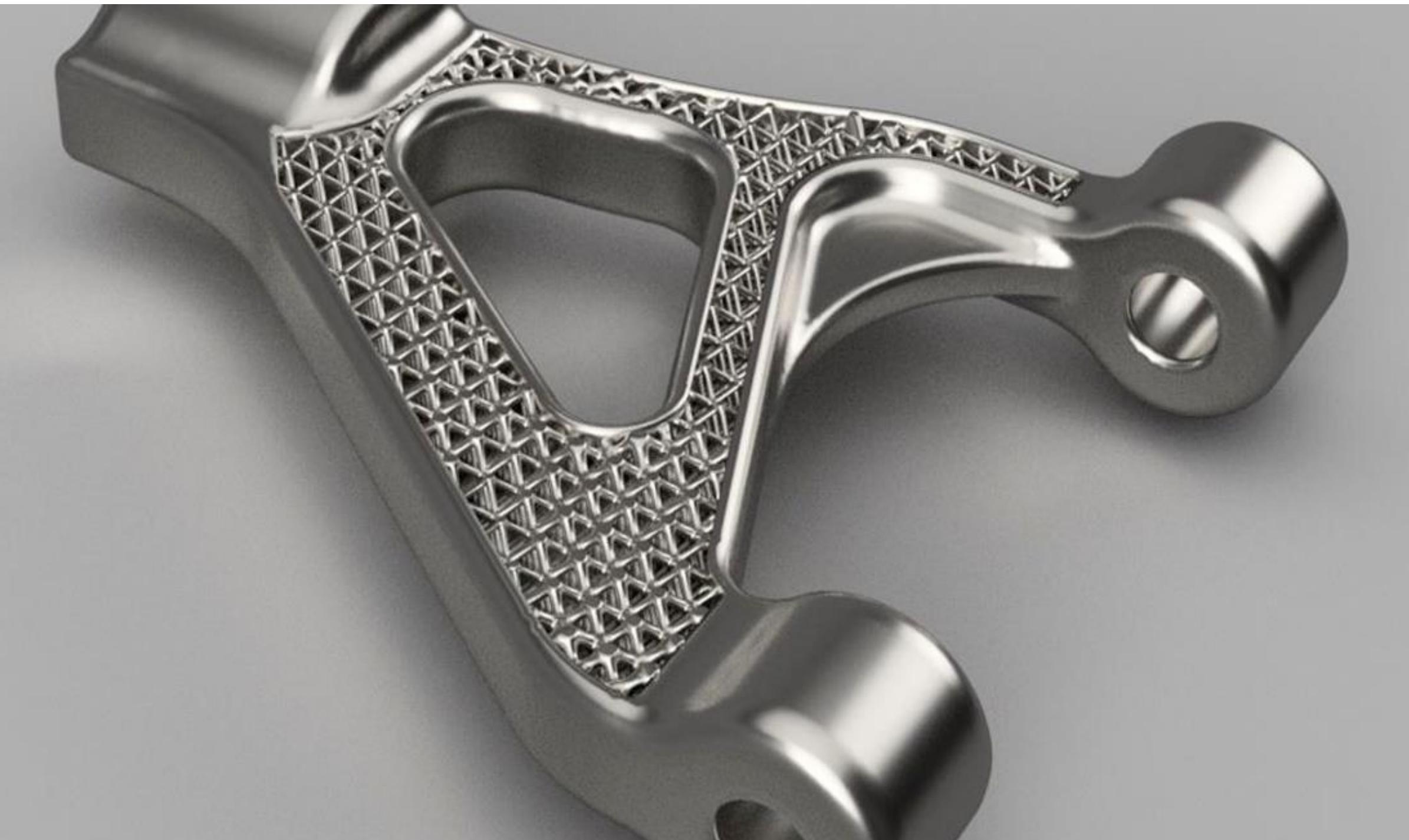
*Inspired by Nature*

*Potential of Lattice Structures*

# Lattice Optimisation

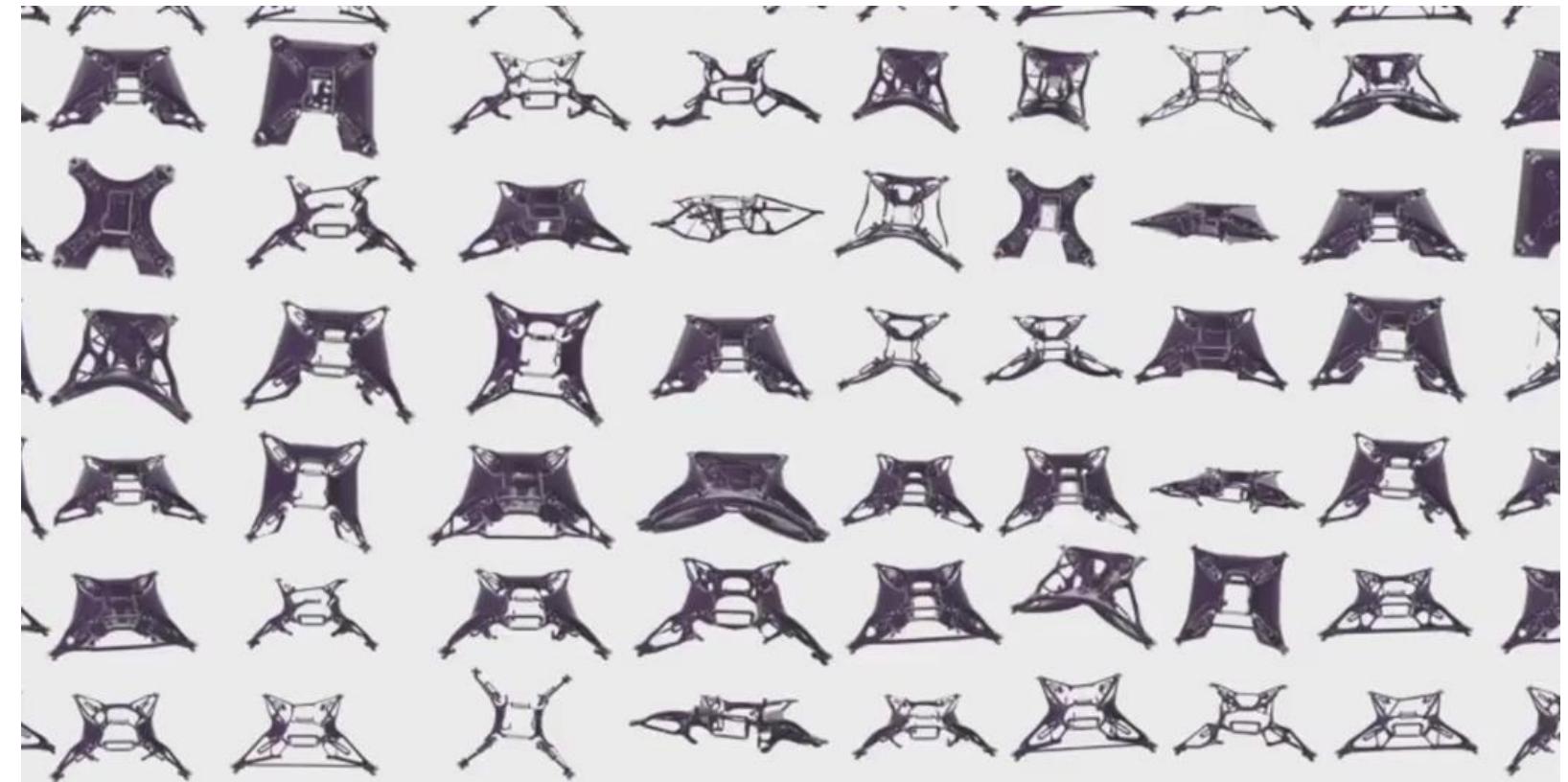


# Design for Additive Manufacturing



# Generative Design

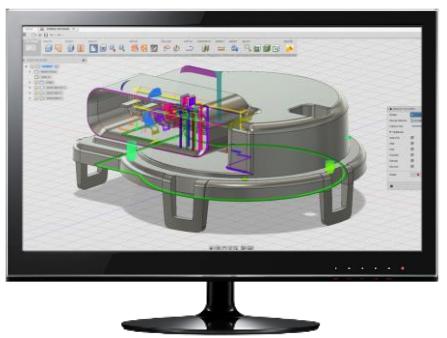
- Design of experiments
- Make comparisons between designs
- Vary parameters and understand how they influence the design



Allows the computer to help you design!

# The End-To-End Process

## Design creation



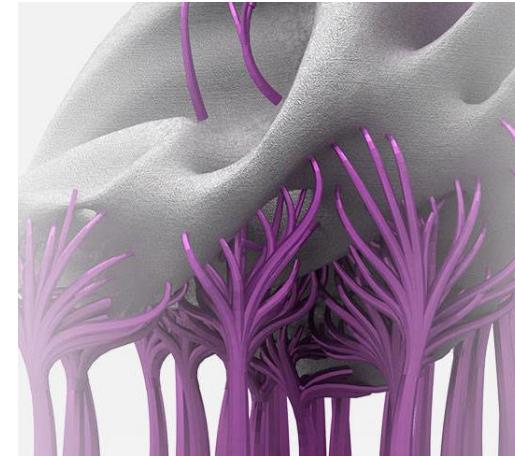
**F** FUSION 360™  
**I** INVENTOR®  
**C** CFD

## Design optimization



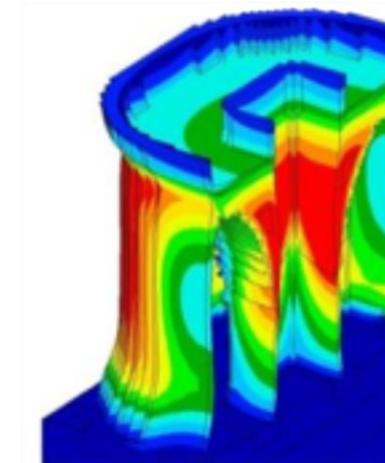
**N** NETFABB®  
**M** MOLDFLOW  
**F** FUSION 360™  
**I** INVENTOR®

## Build preparation



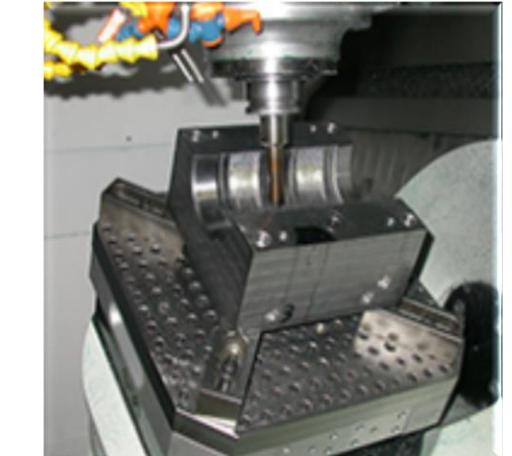
**N** NETFABB®  
**P** AUTODESK® POWERSHAPE®

## Build simulation



**N** NETFABB®

## Machine finishing

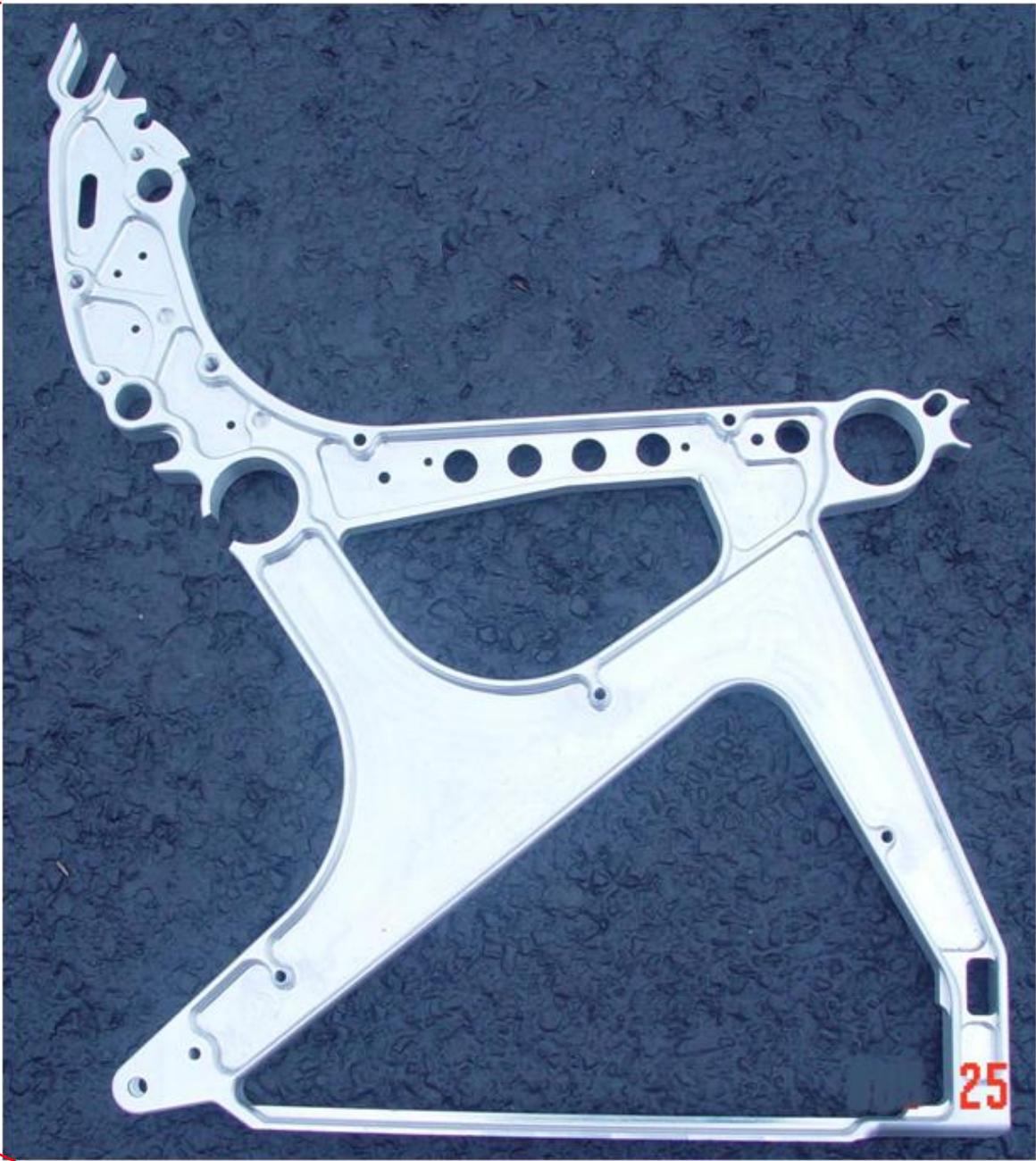


**P** AUTODESK® POWERMILL®  
**F** AUTODESK® FEATURECAM®  
**F** FUSION 360™  
**P** AUTODESK® POWERINSPECT®

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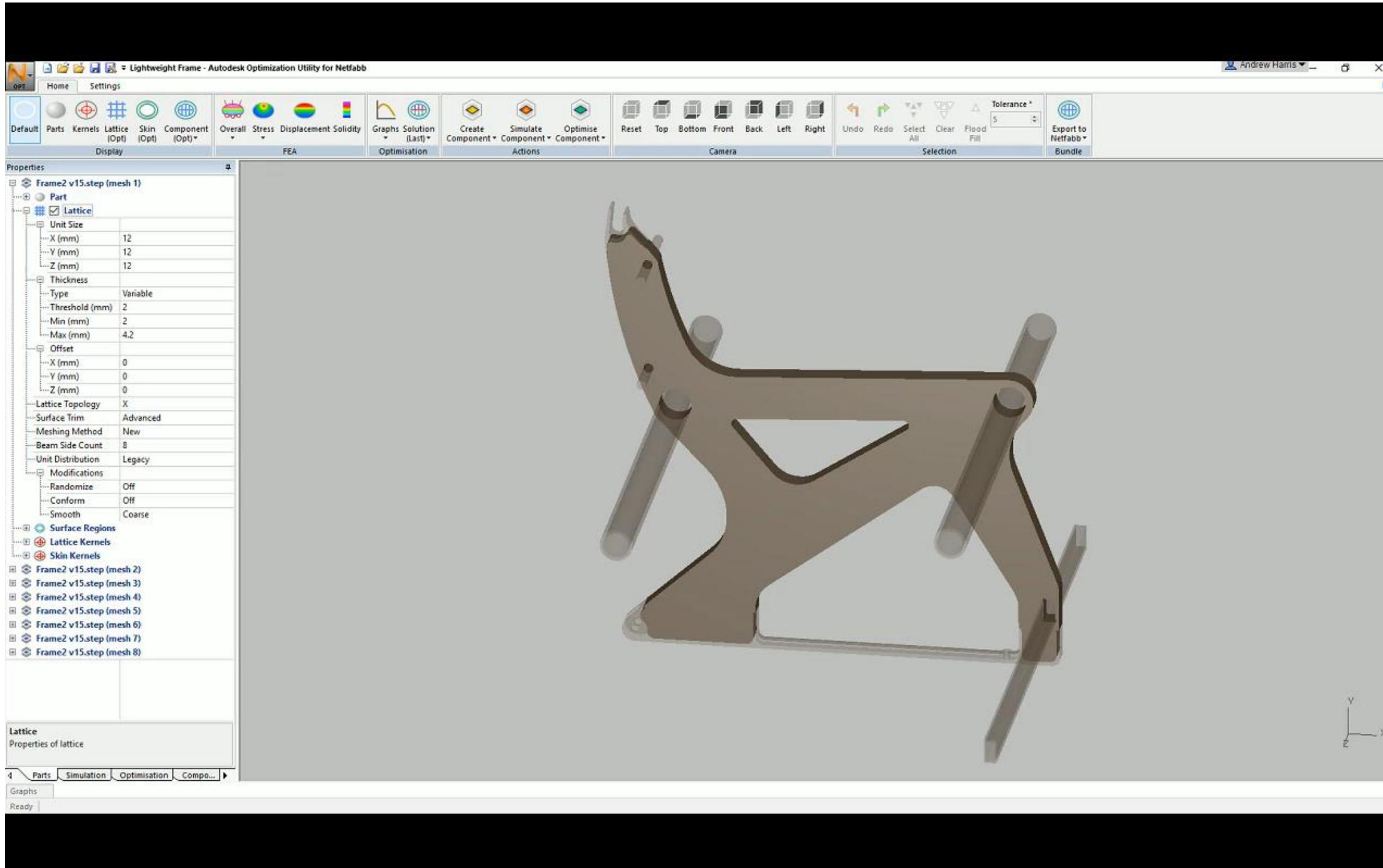
# Aerospace Case Study

# Case Study: Aircraft Seat Bracket



- Structural component within the seat
- Manufactured from a single billet of material resulting in high material wastage

# Netfabb Optimisation



# Additive + Casting Process



# Assembled Patterns



# Ceramic Slurry Coating



# Dry

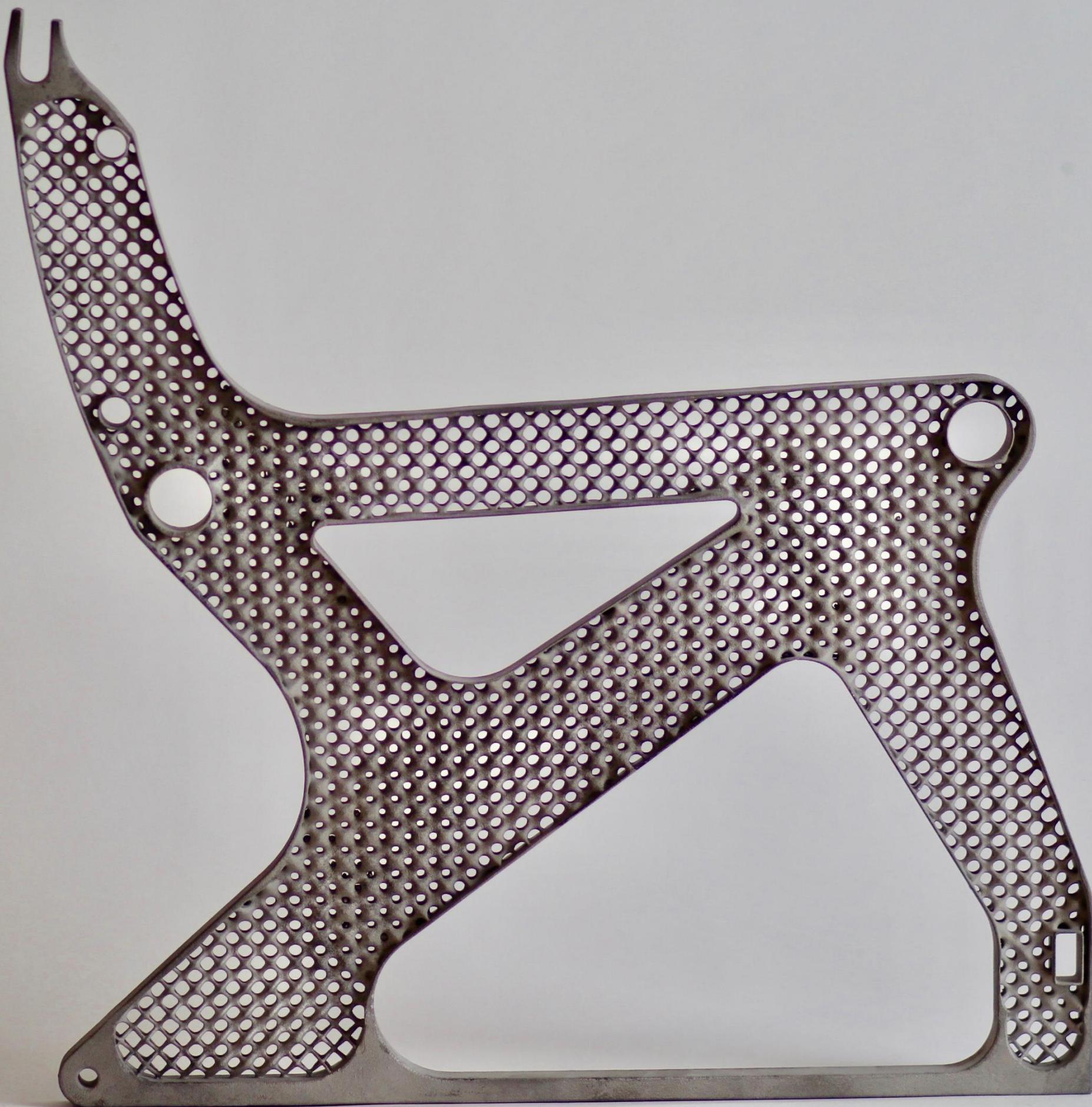


# Pattern Removal



# Pour Metal





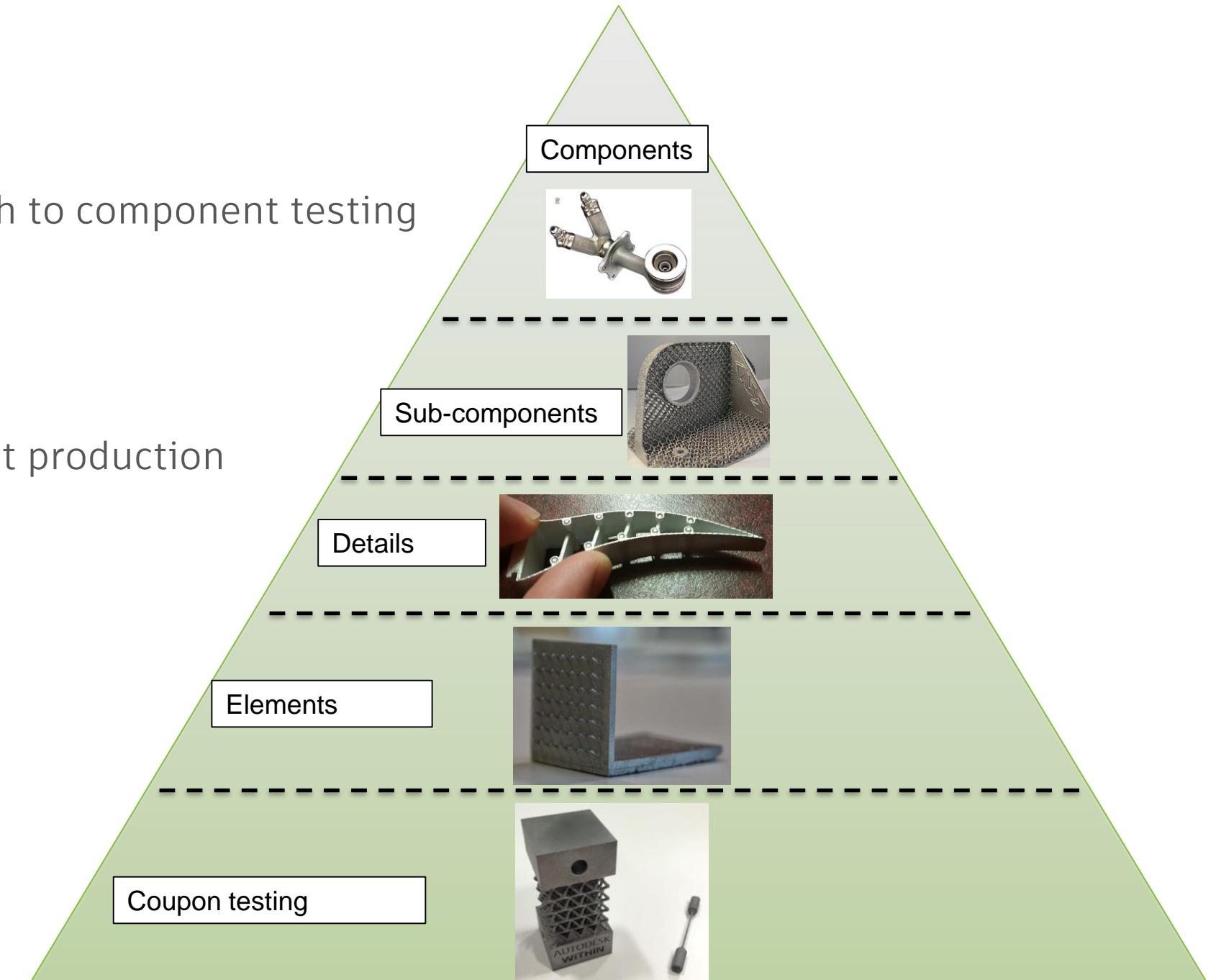
# Aerospace Certification

- **Certification**

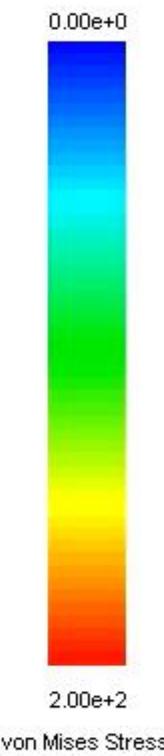
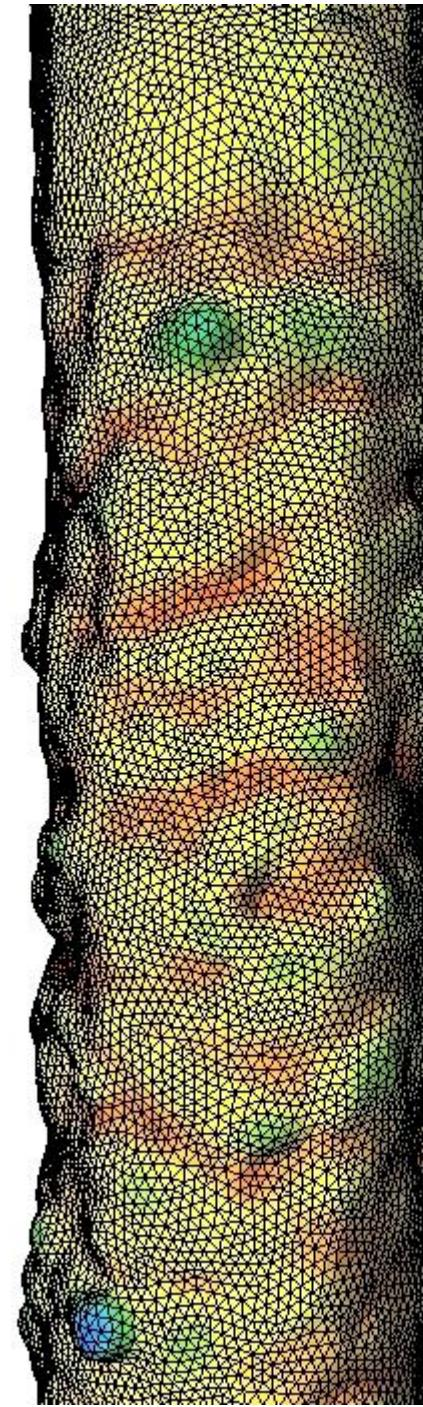
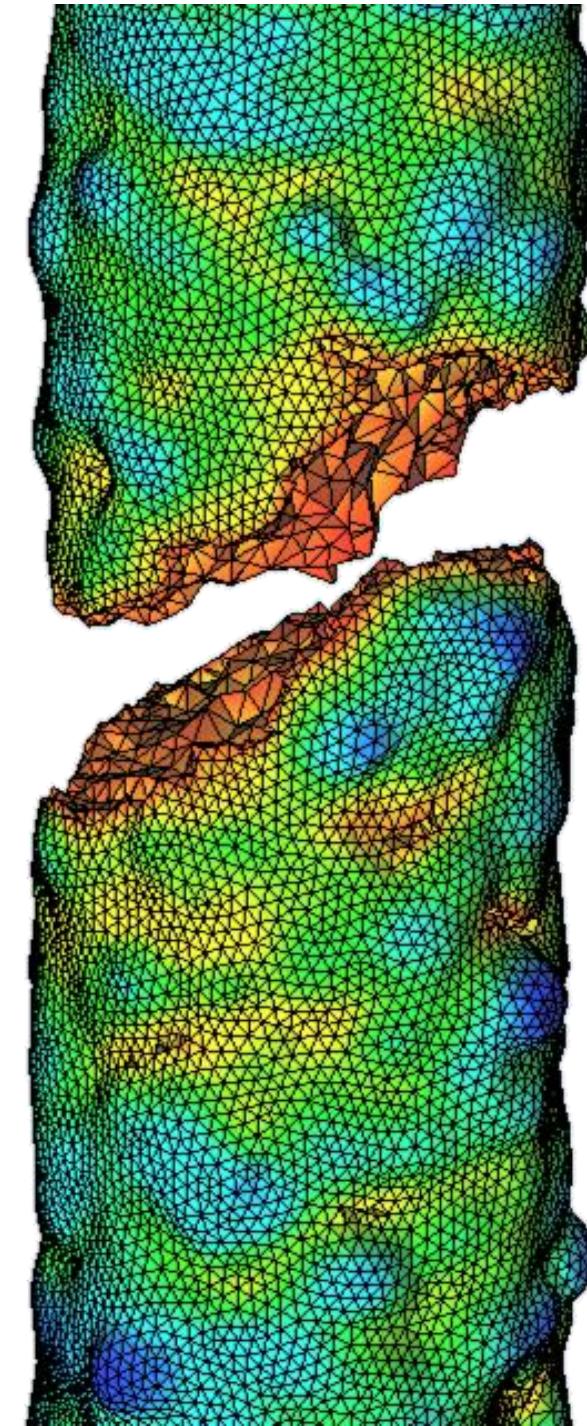
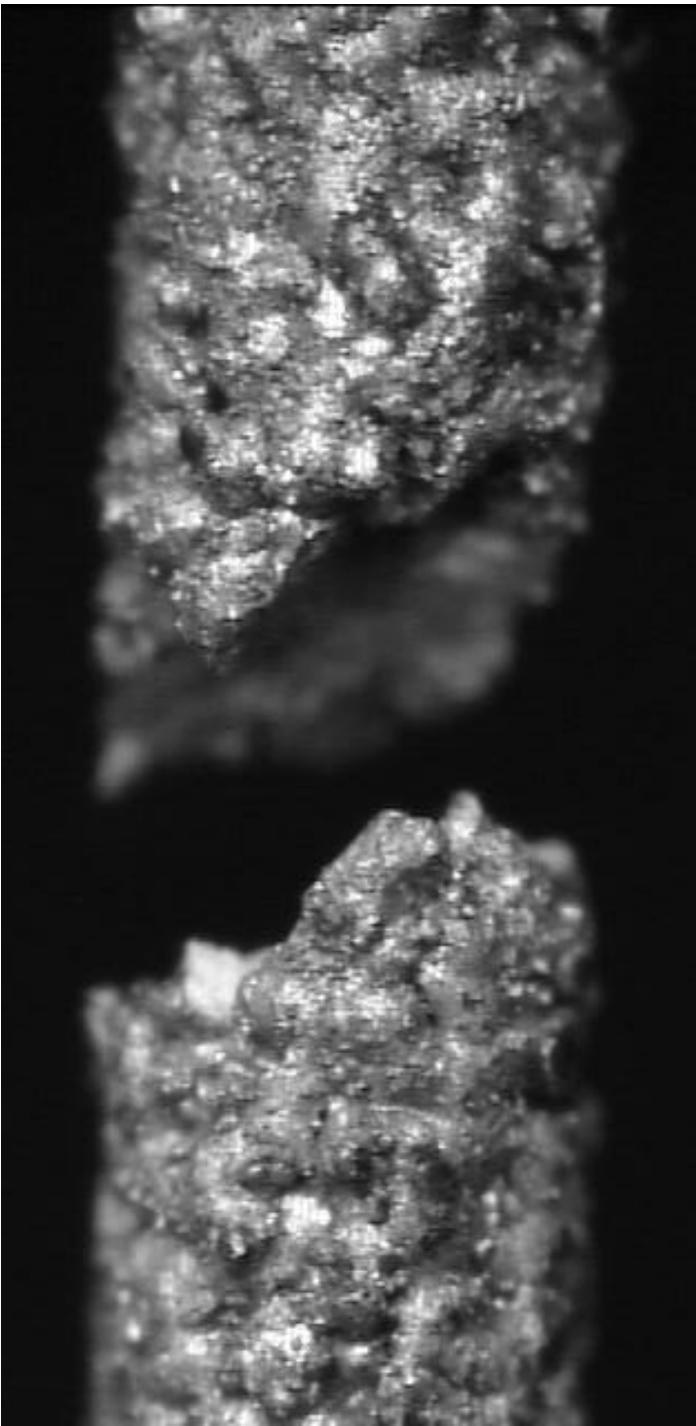
- Analysis supported and validated by coupon through to component testing
- Compliance with FAA/EASA/JAA
- Build knowledge and experience towards component production

- **Validate**

- Materials data for coupon through to component
- Manufacturing processes
- Analysis (FEA etc.)



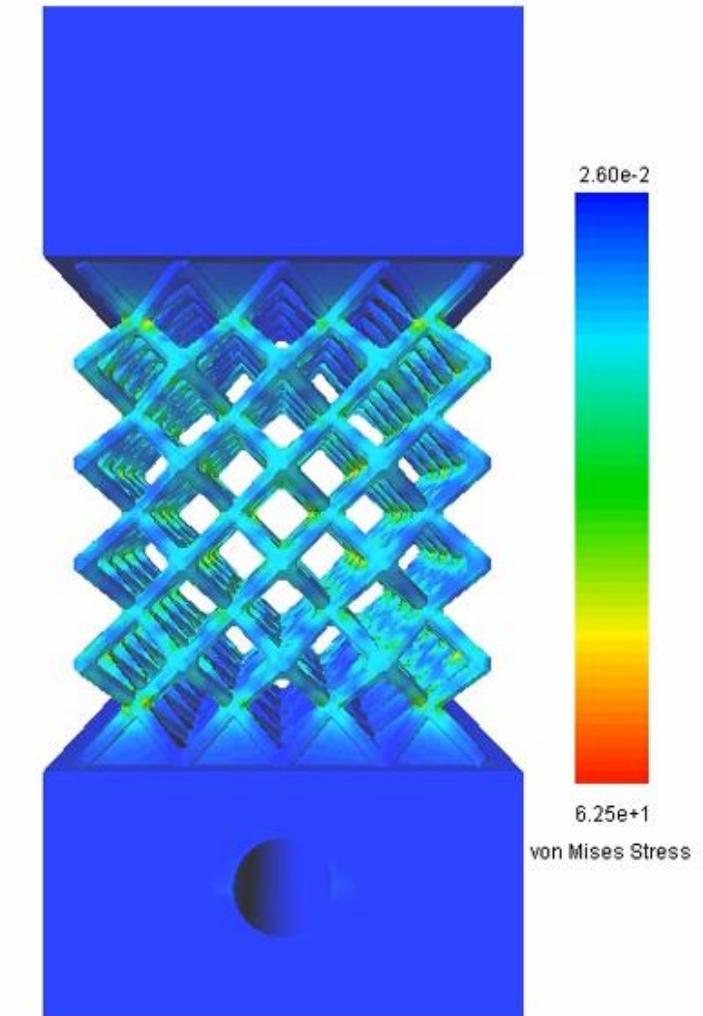
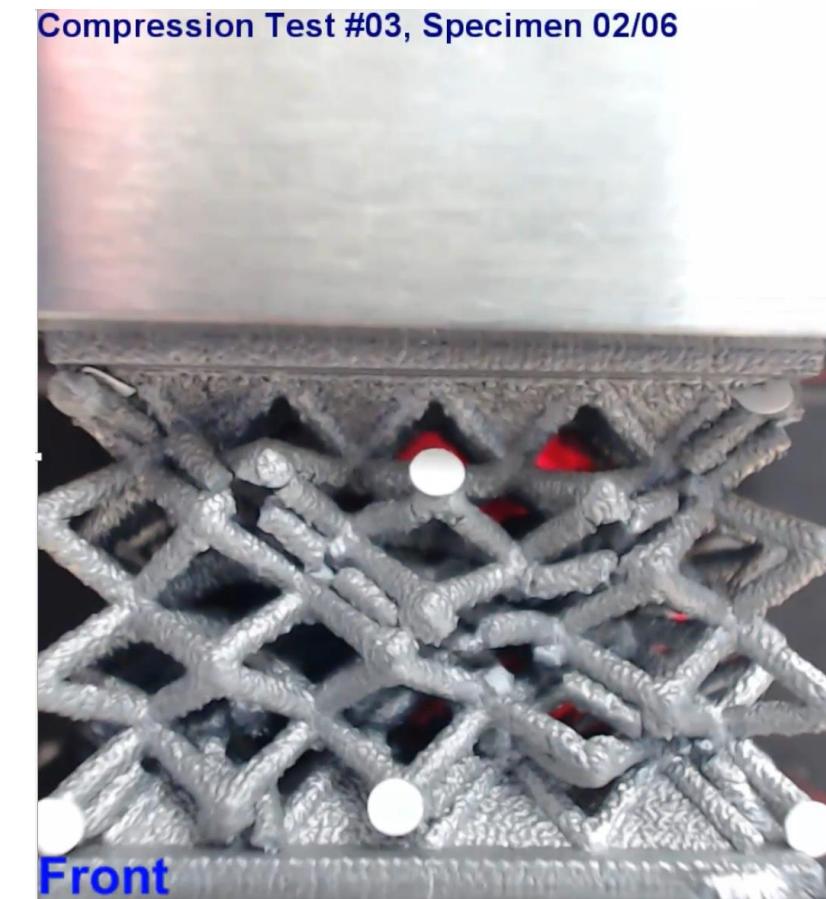
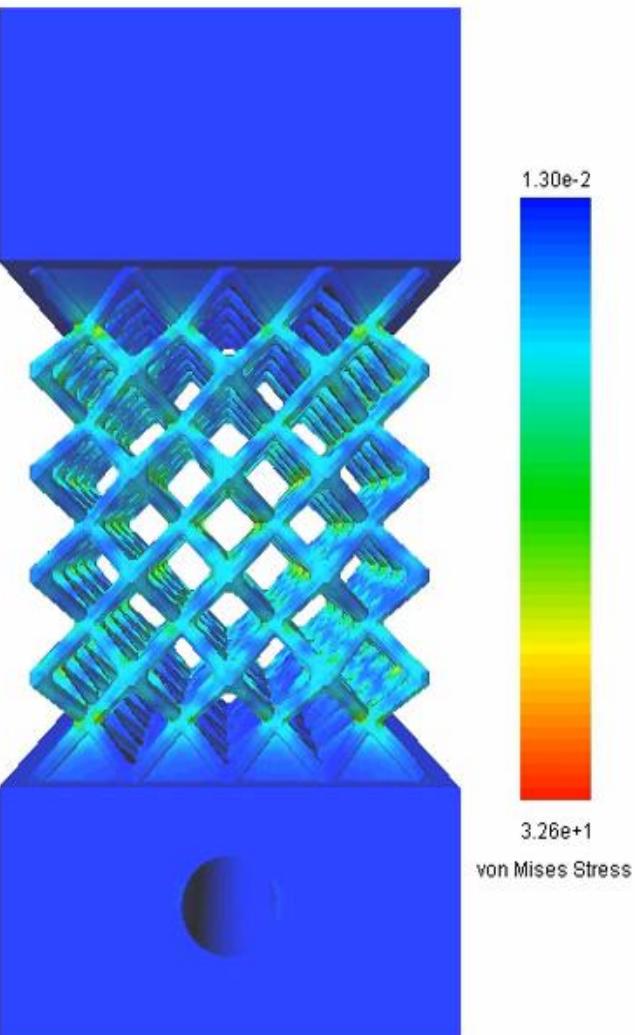
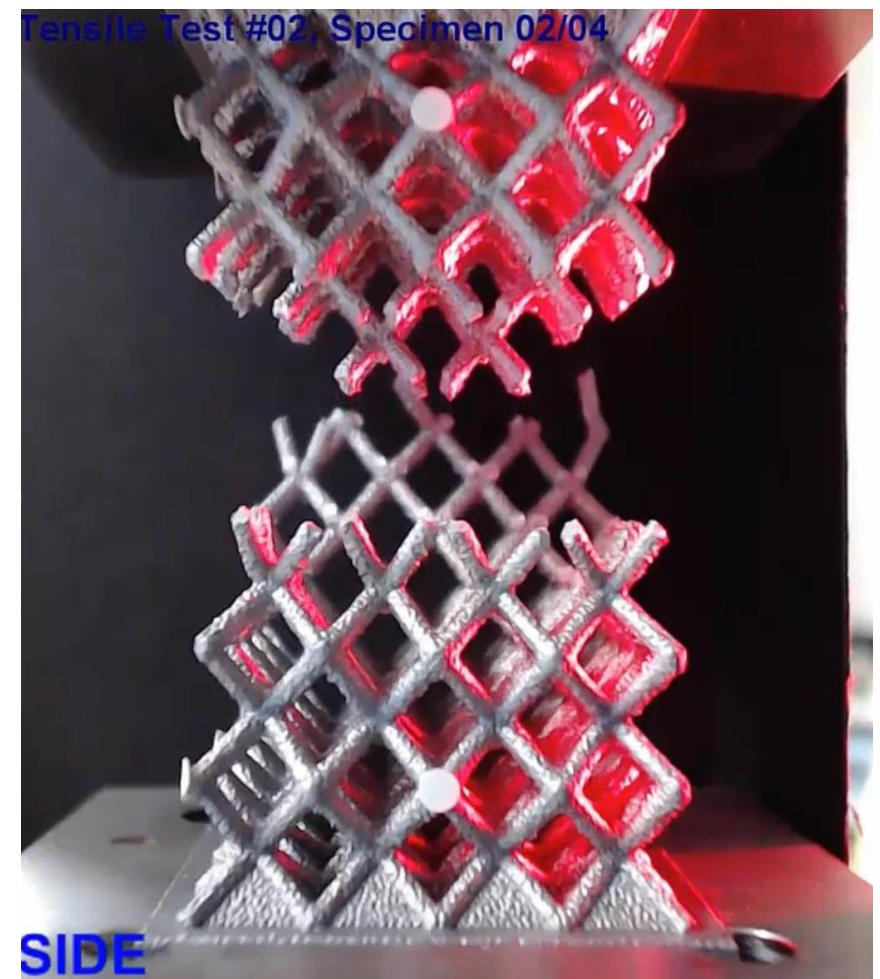
# Materials Testing



2.00e+2

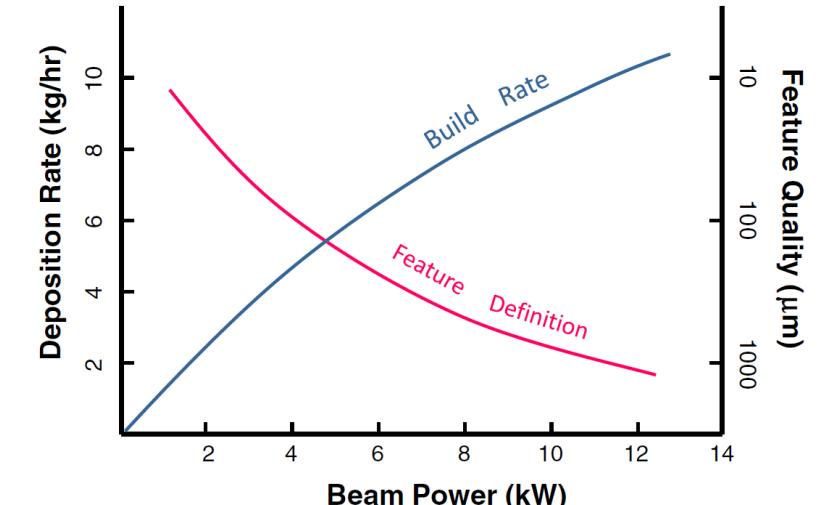
von Mises Stress

# Materials Testing



# Aerospace Certification – Additive Manufacturing

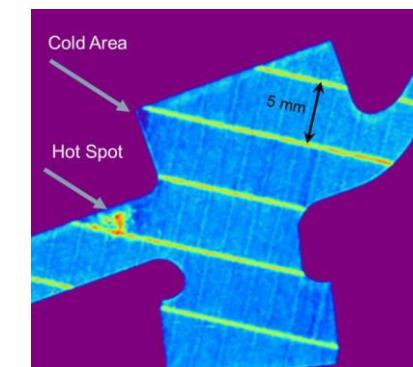
- Additively manufactured parts featuring in non-primary structures in aircraft
- Knowledge and understanding is enabling greater use
- Enable assembly size reductions and cost savings
- Often requires post manufacturing treatments such as HIP
- Quality assurance during and after build
- Support manufacturing of tooling



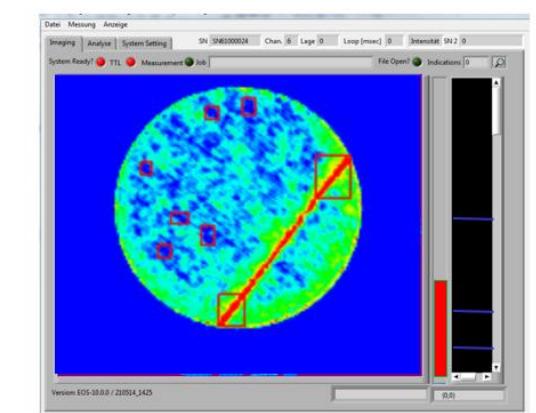
\*Frazier, 2014, Metal Additive Manufacturing- A review



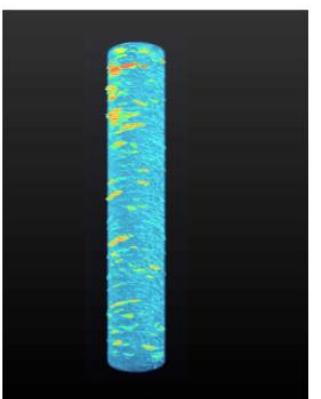
\*Honeywell and Sigma Labs



\*Zenzinger, Bamberg, Ladewig, Hess, Henkel, Satzger, MTU Aero Engines, Process monitoring of additive manufacturing by using optical tomography

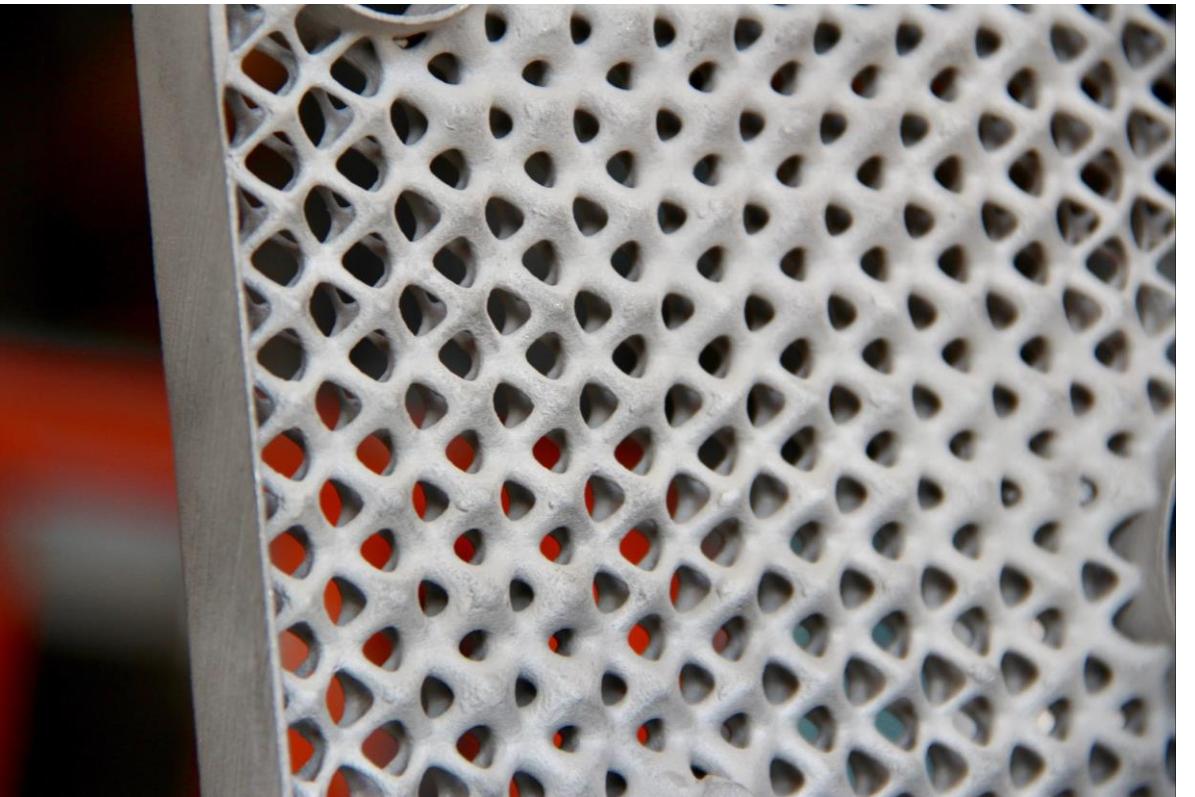


\*Volker Carl, Monitoring system for the quality assessment in additive manufacturing



# Aerospace Certification – Investment Casting

- Already established process in aerospace
- Can be supported by additive manufacturing
- Allows structures not possible with other casting techniques
- Allows a greater range of materials and geometry size than AM
- Can utilise certified magnesium alloys (e.g. Elektron 21)

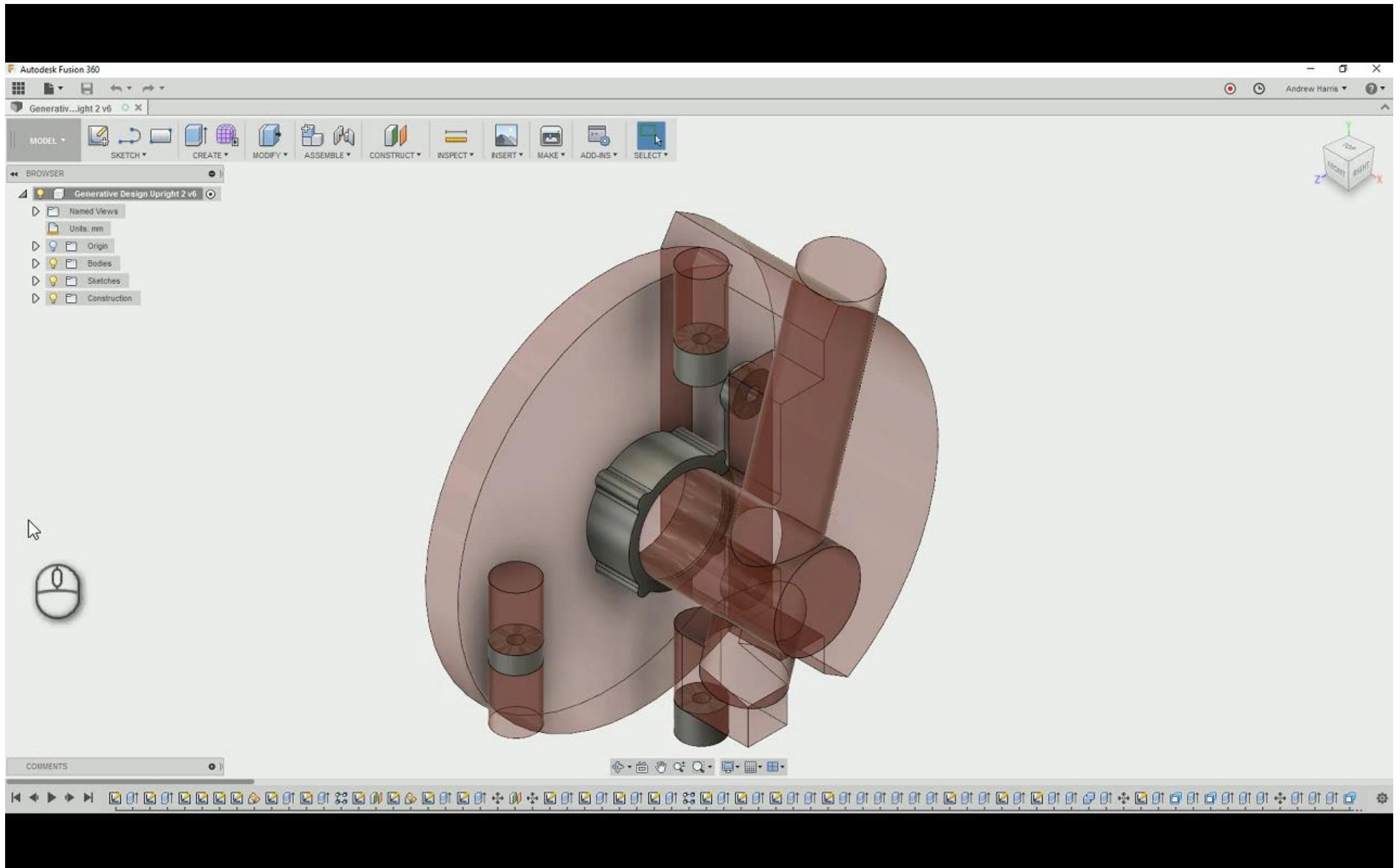




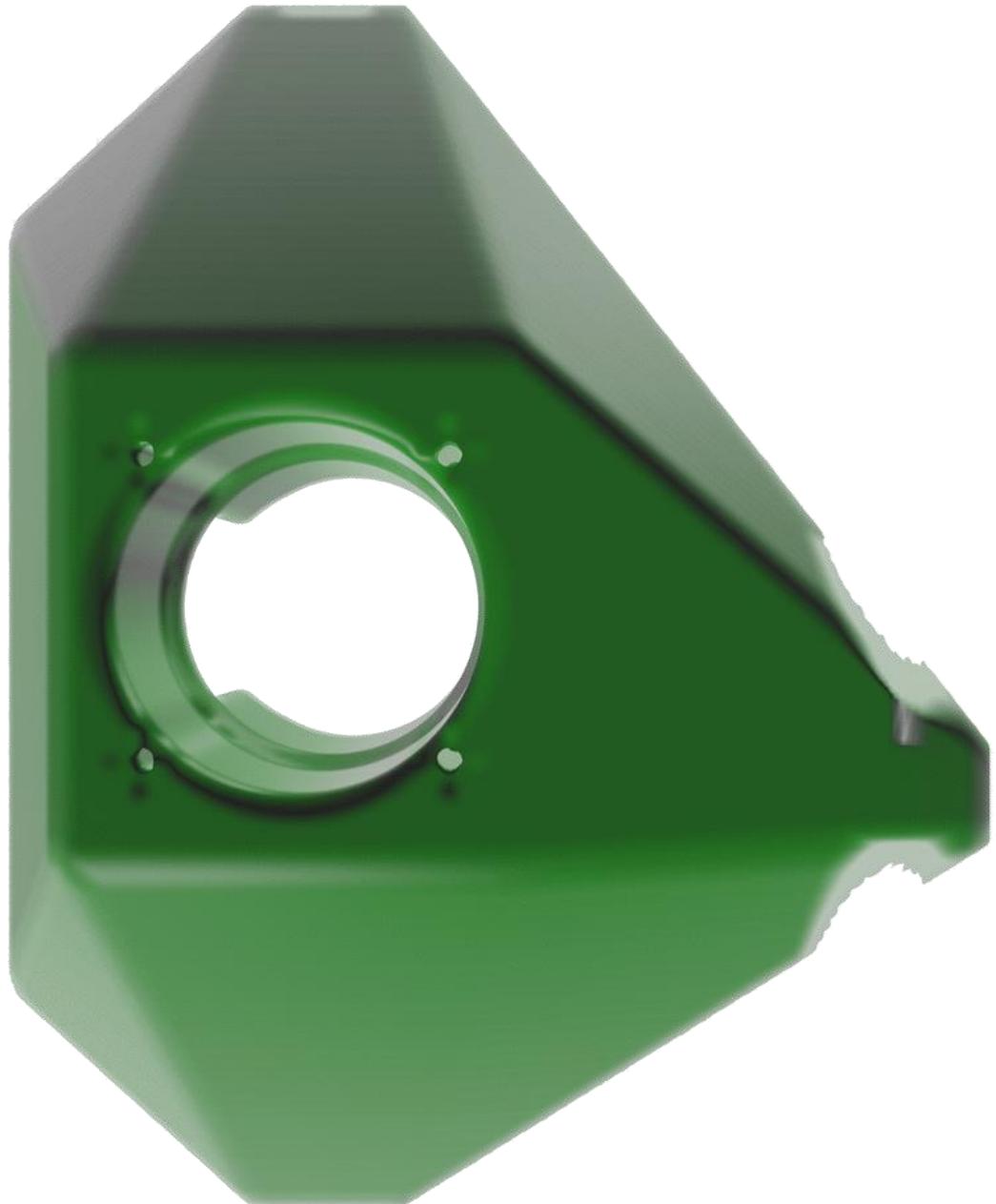
# Automotive Case Study



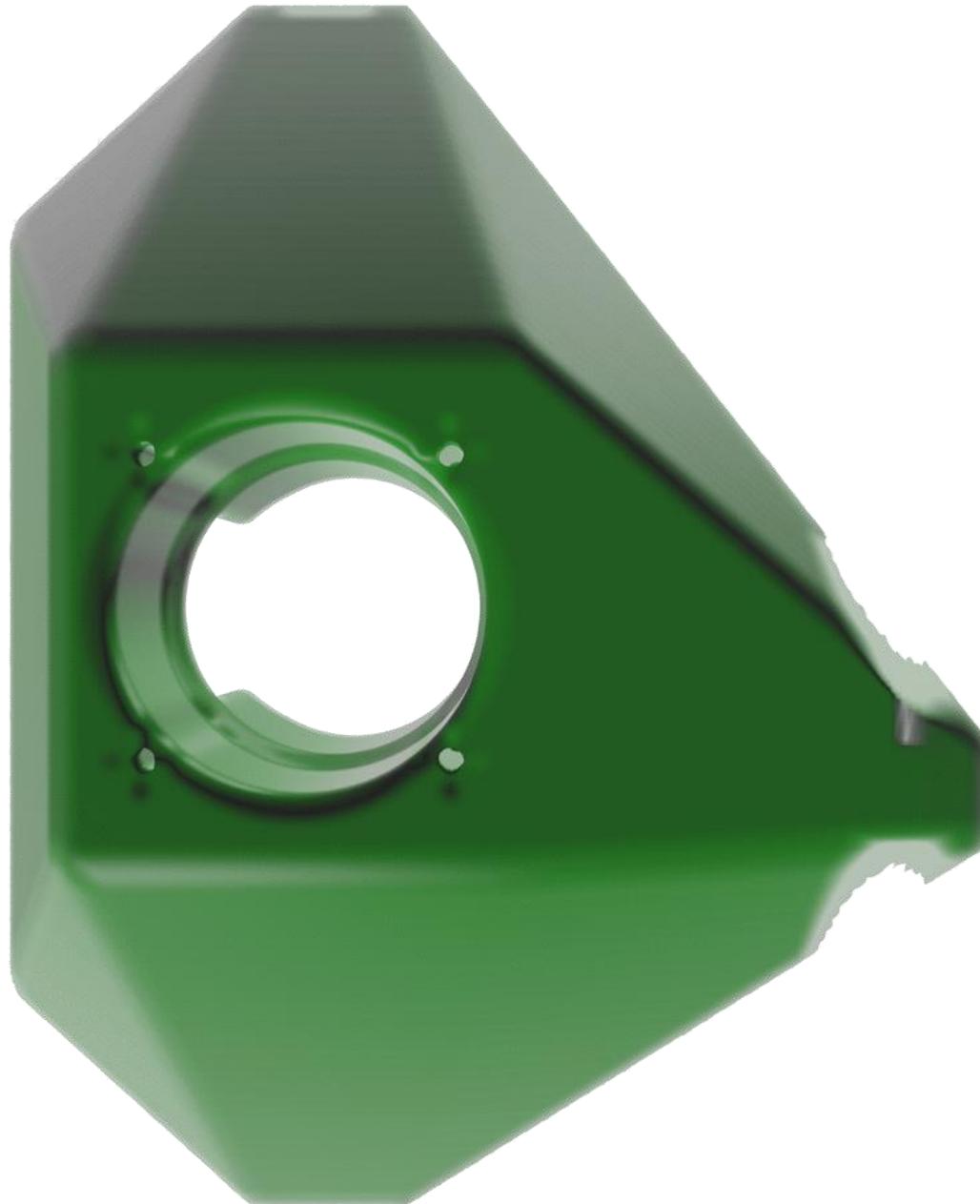
# Autodesk Fusion CAD



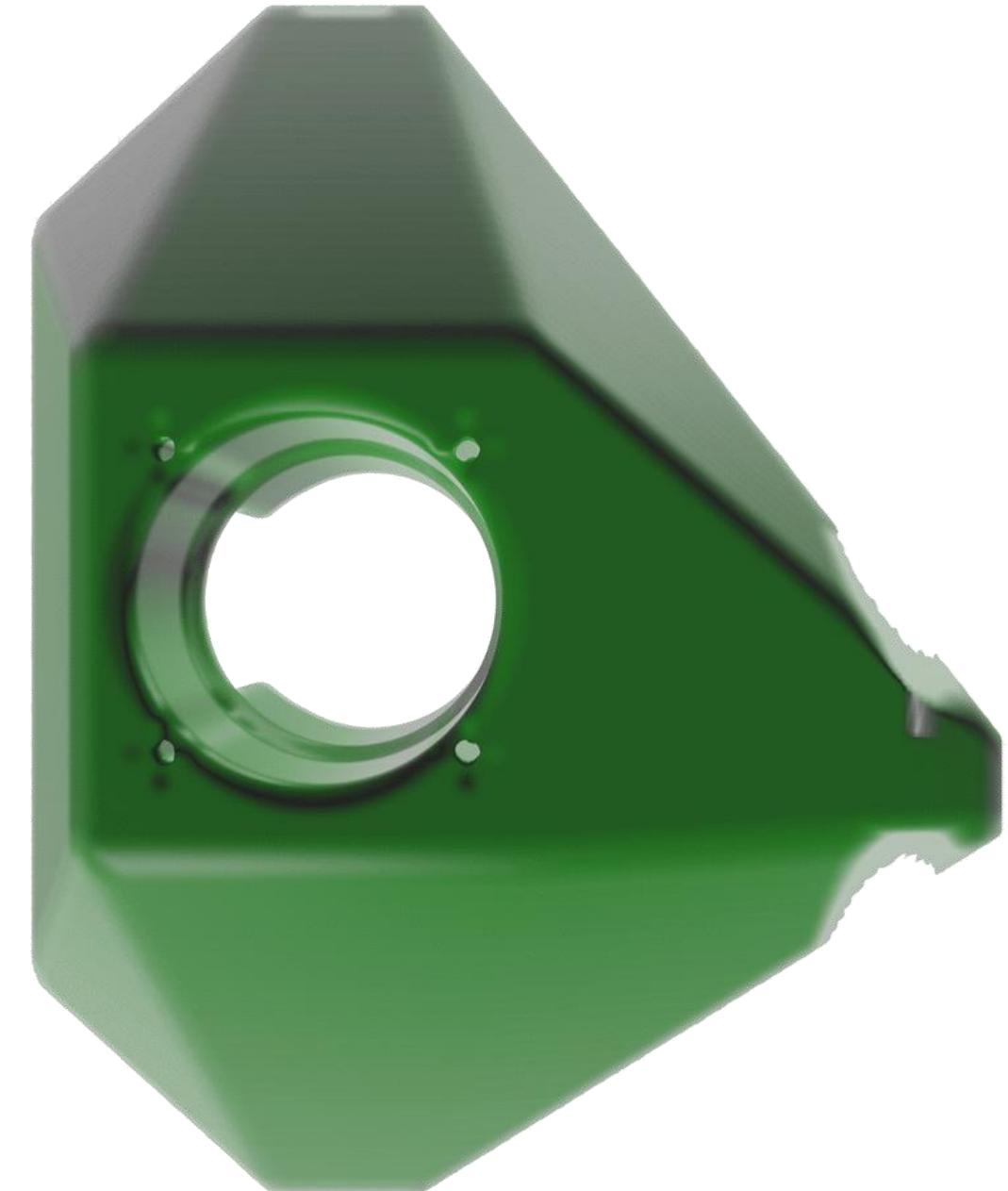
# Generative Design



Aluminium

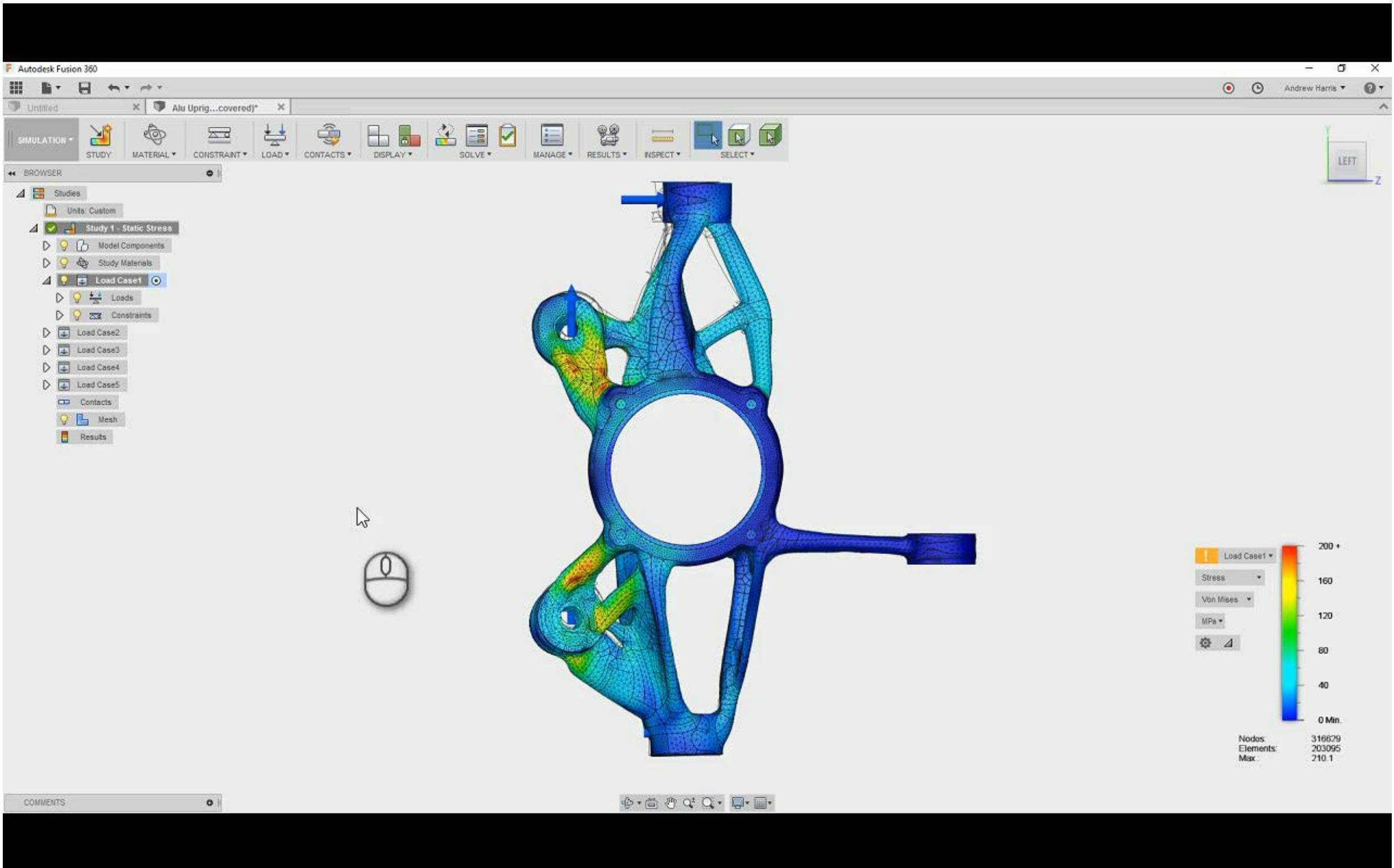


Steel

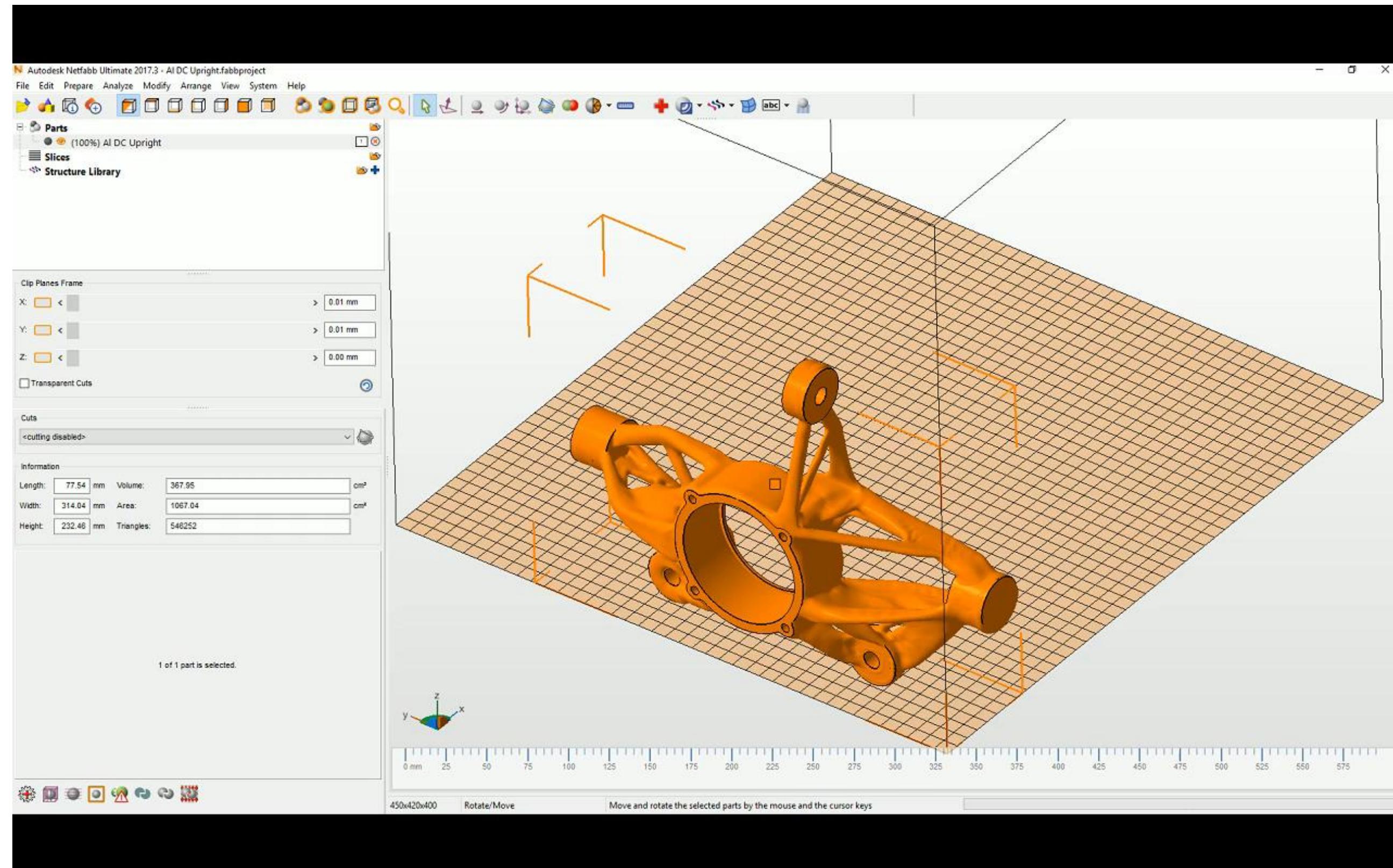


Titanium

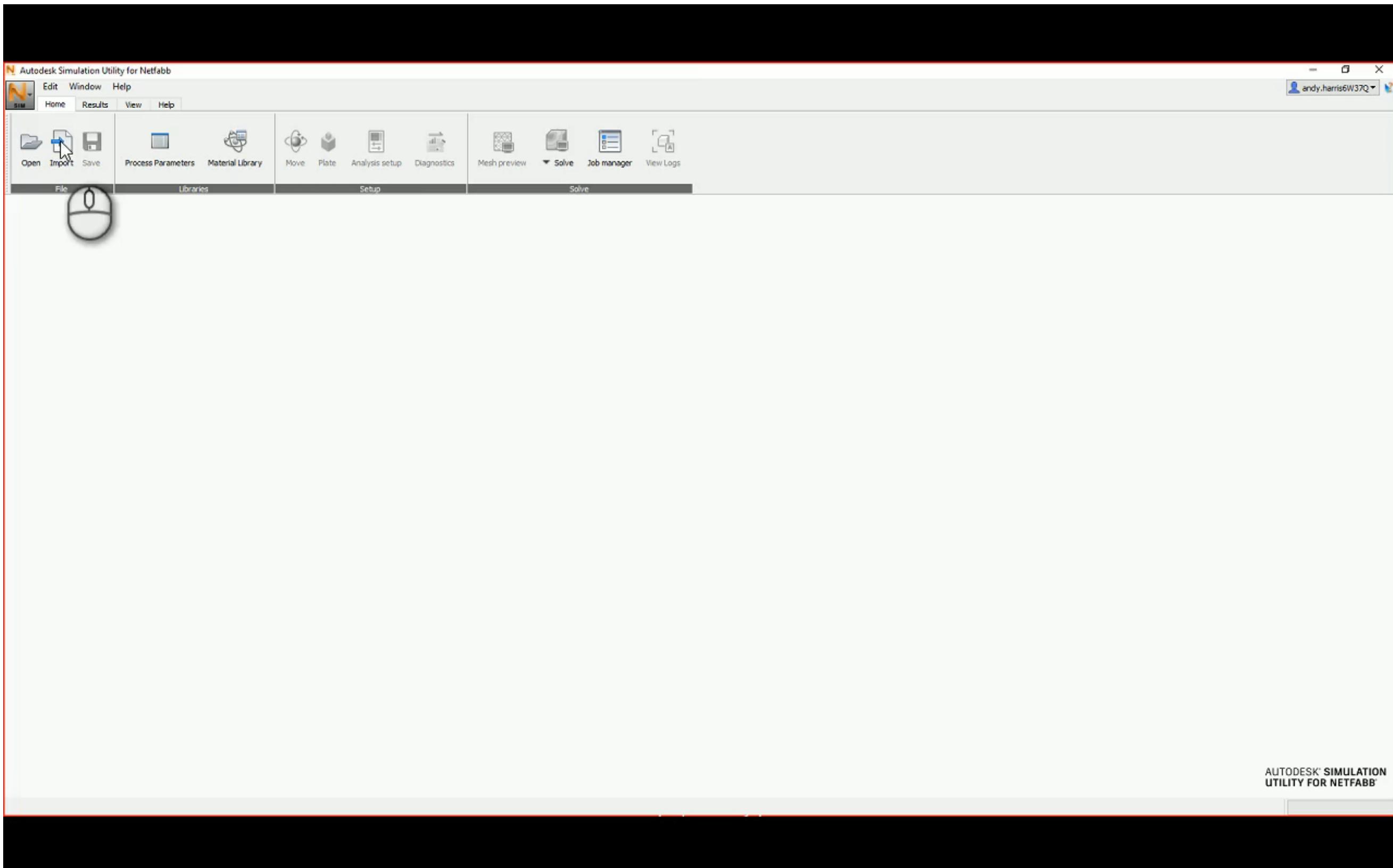
# Nastran Verification



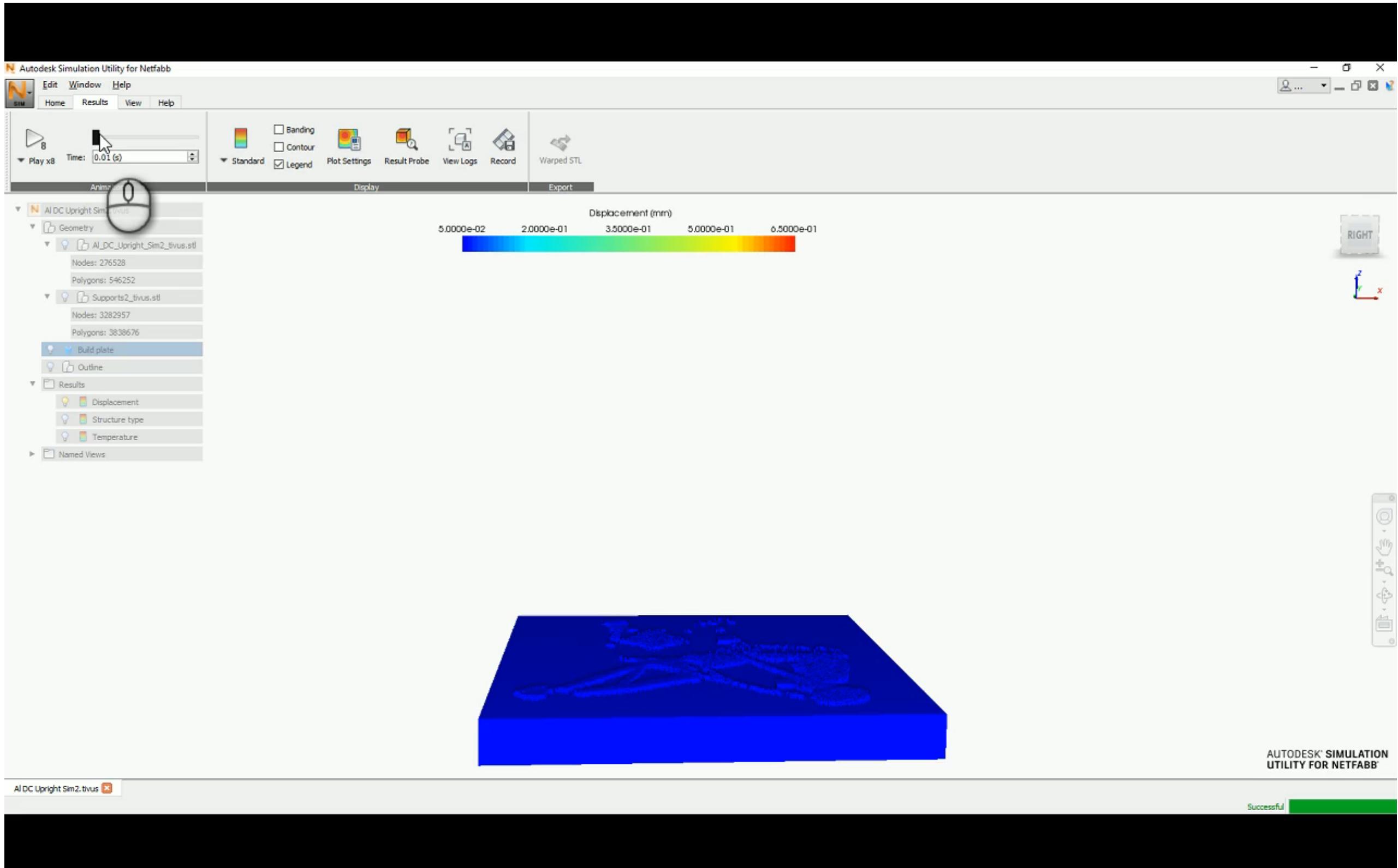
# Prepare

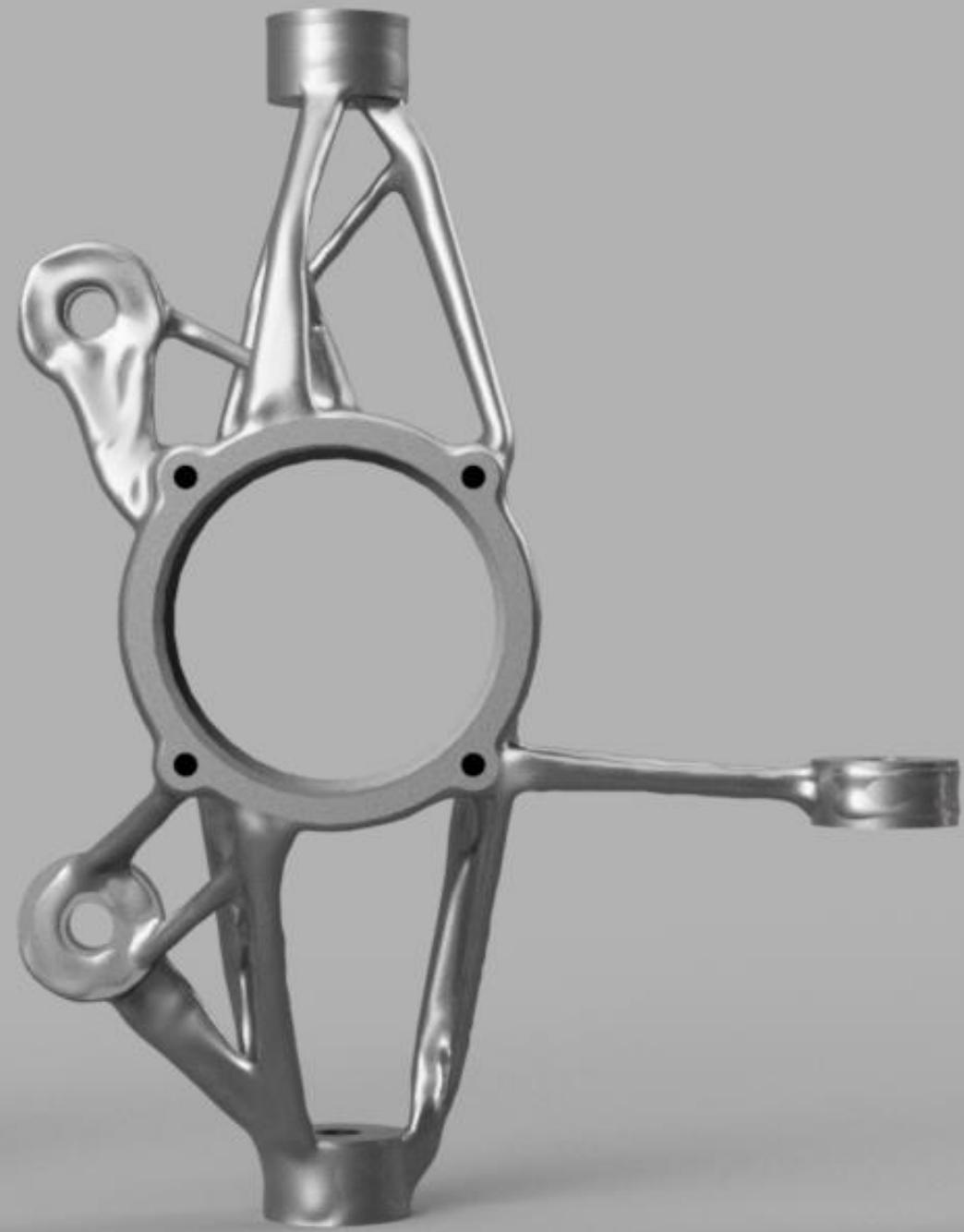


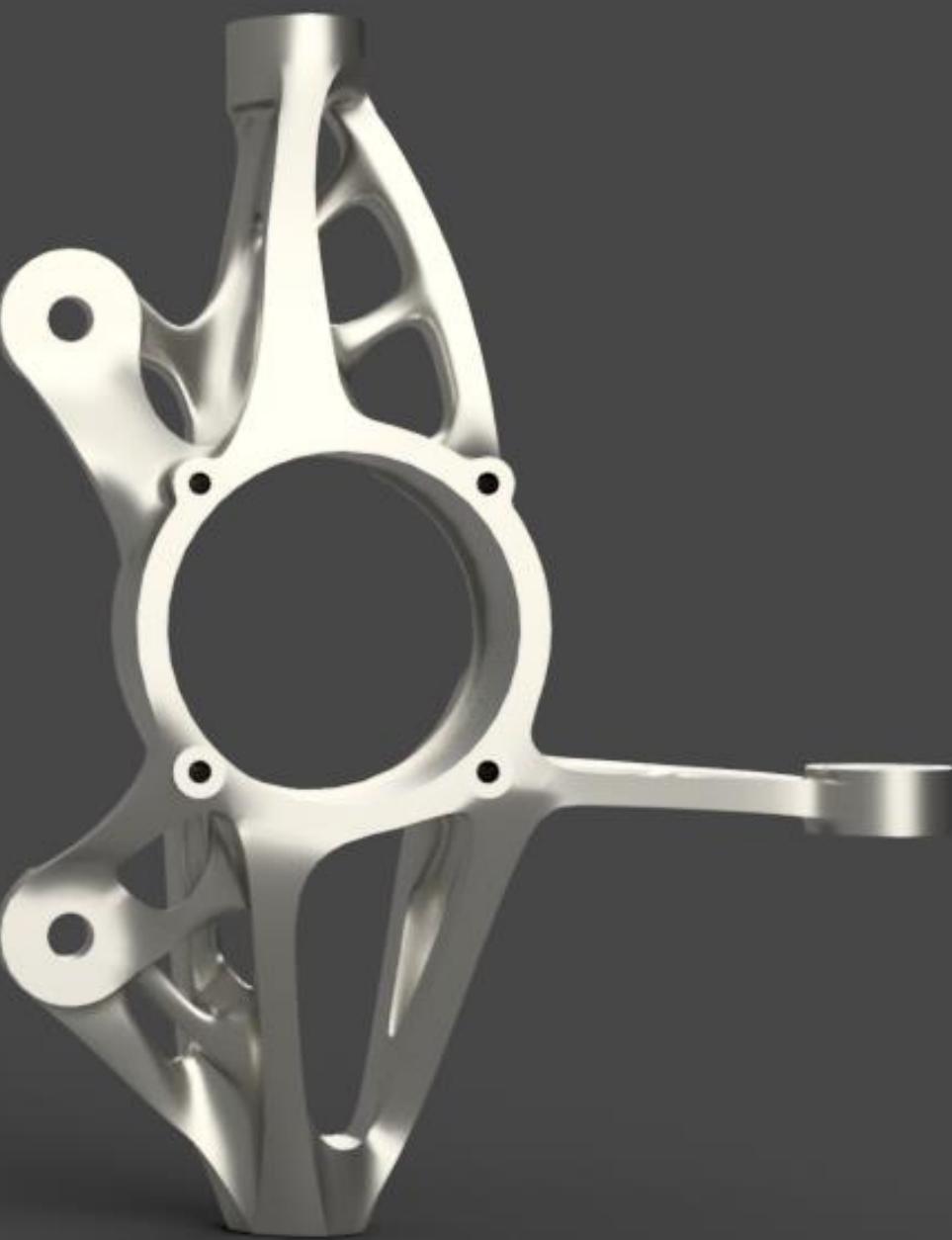
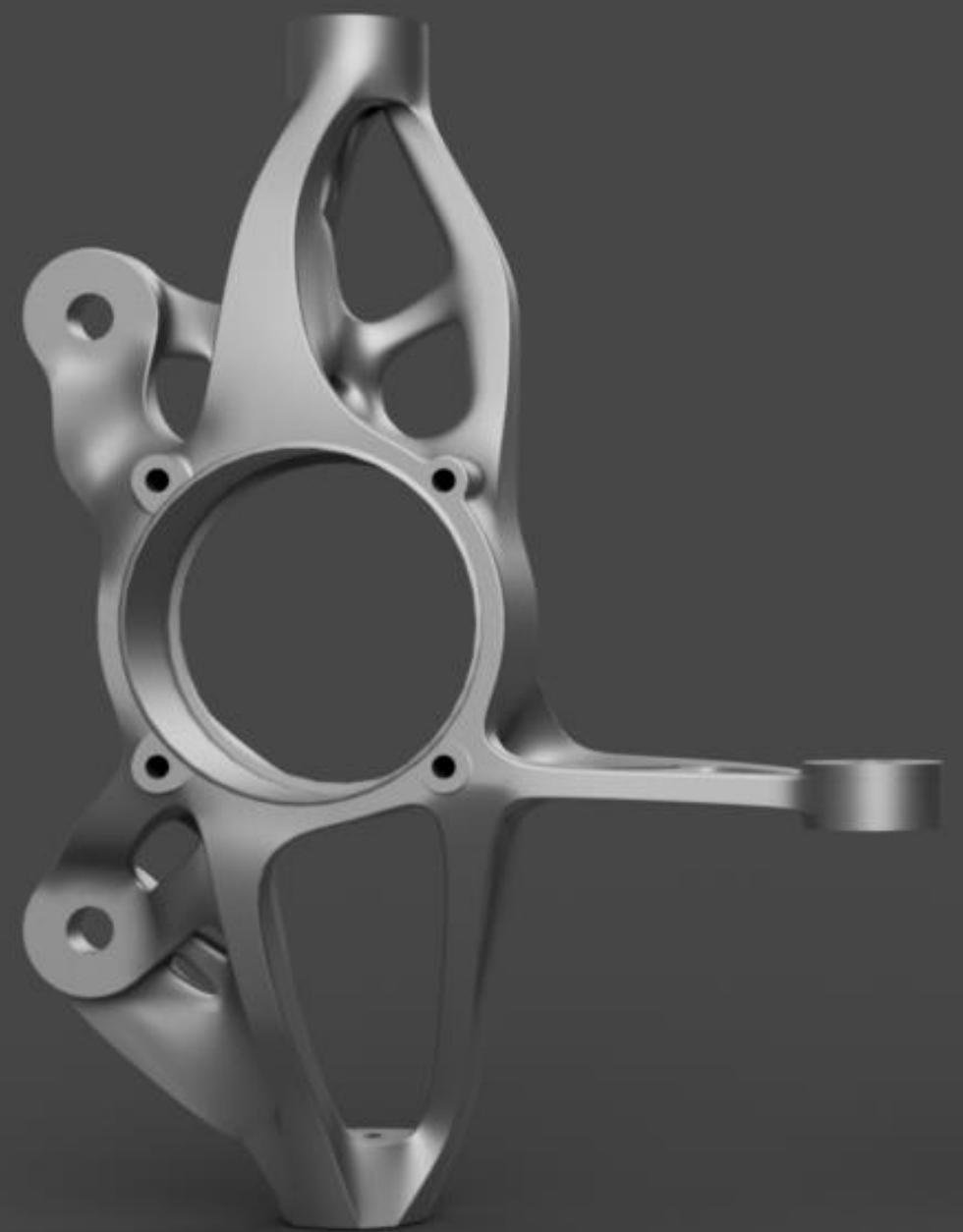
# Build Simulation

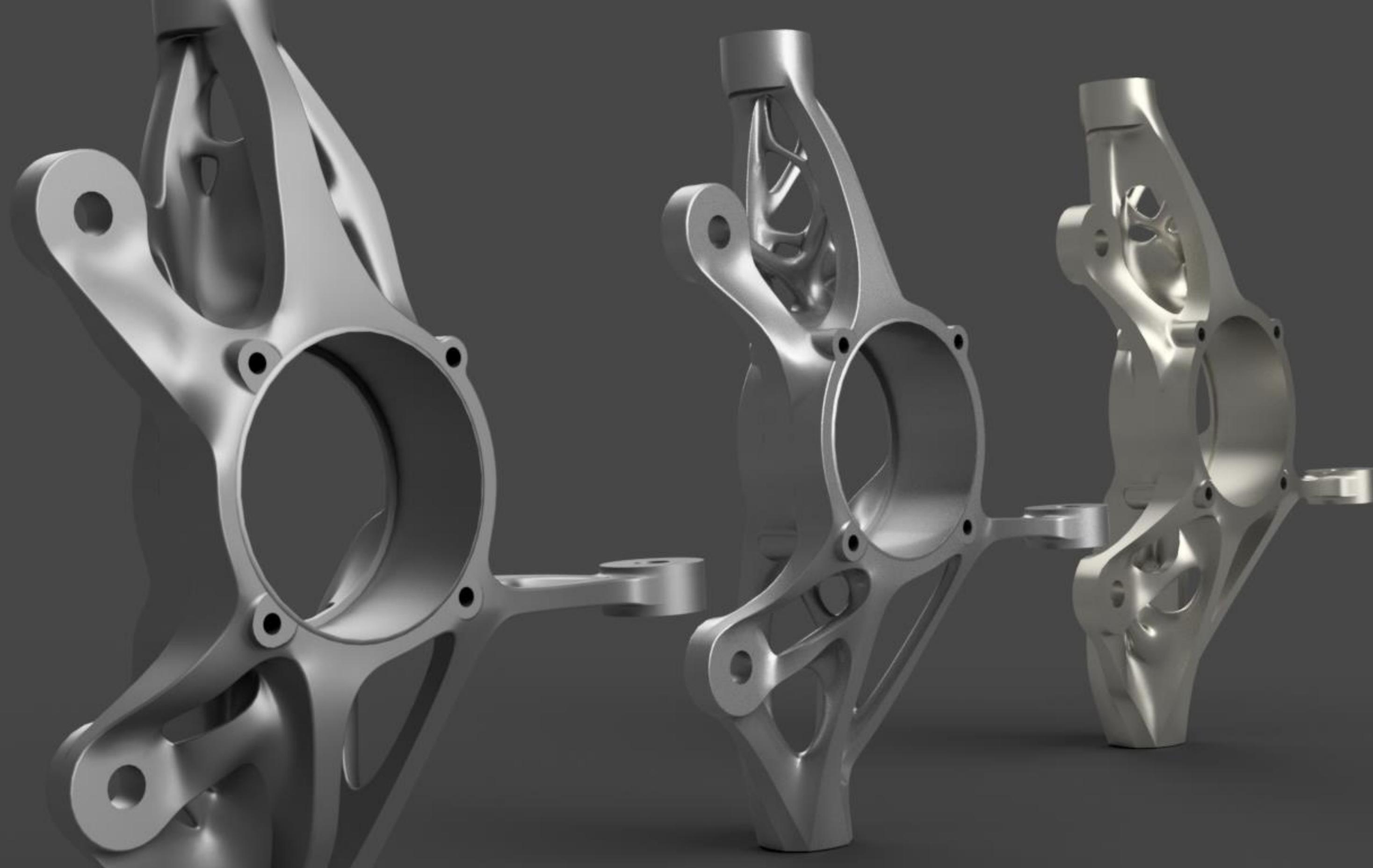


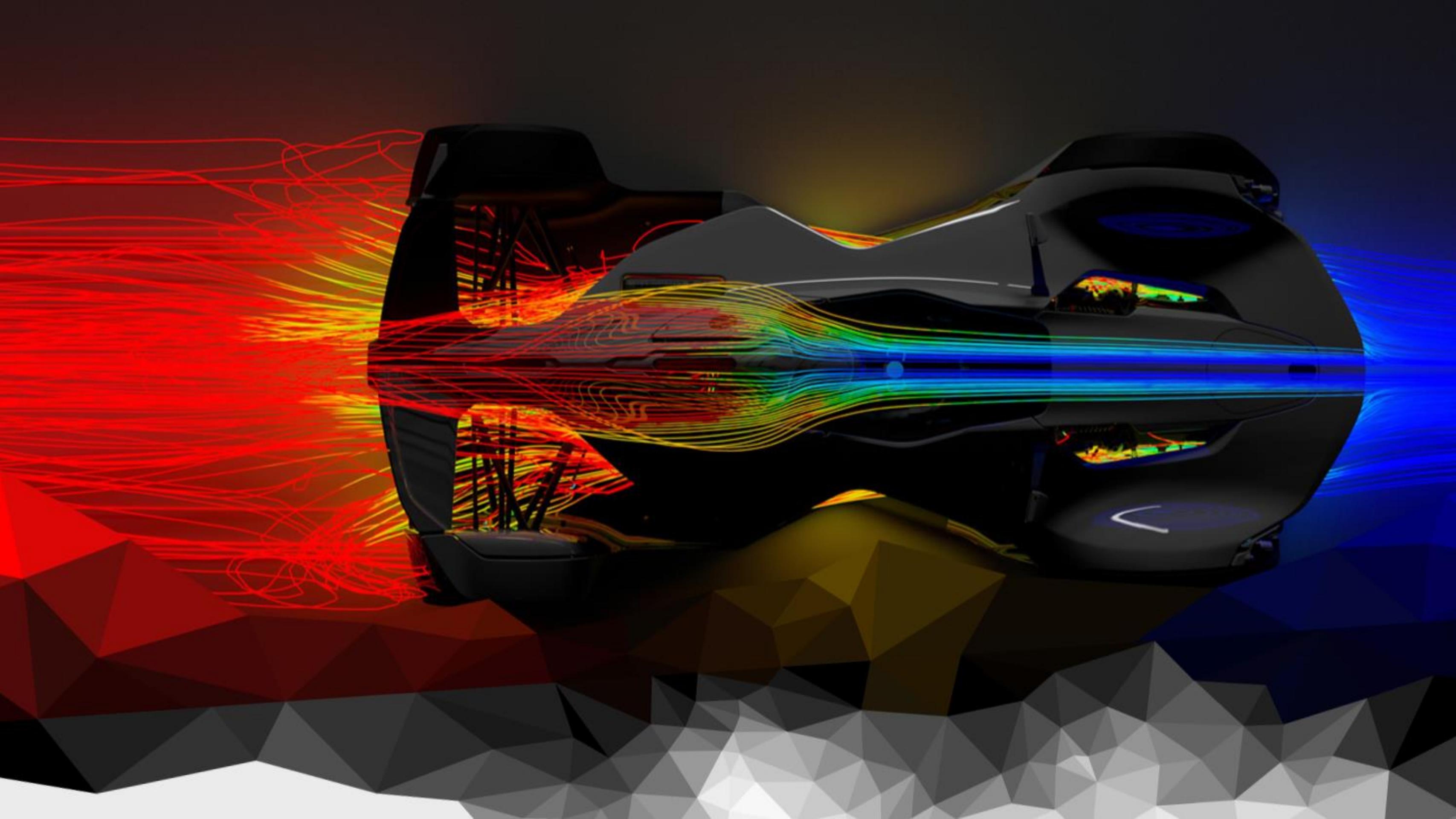
# Displacement Results

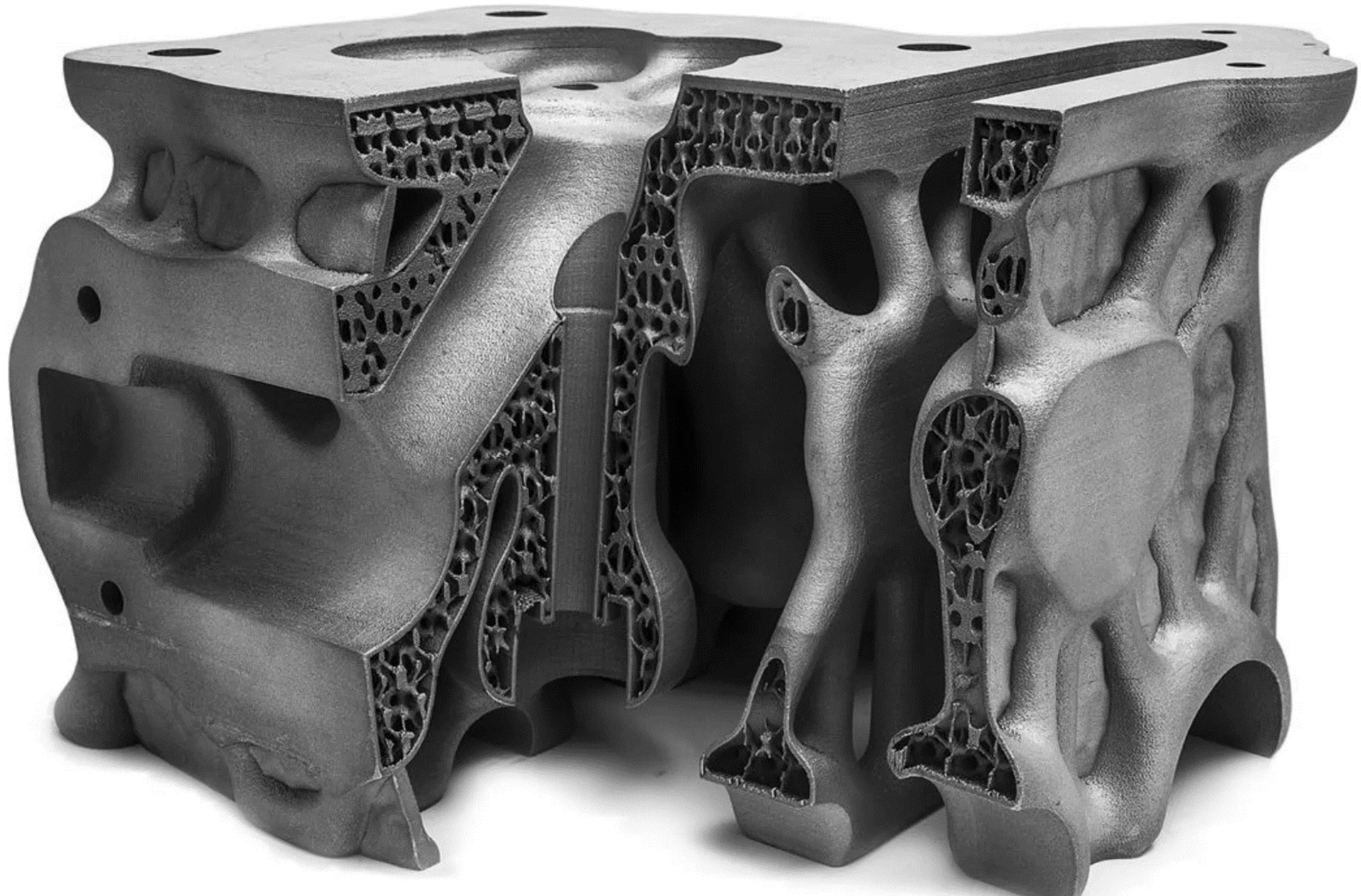
















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