Unlocking the Design Potential of Additive Manufacturing

Dr. Robert Yancey

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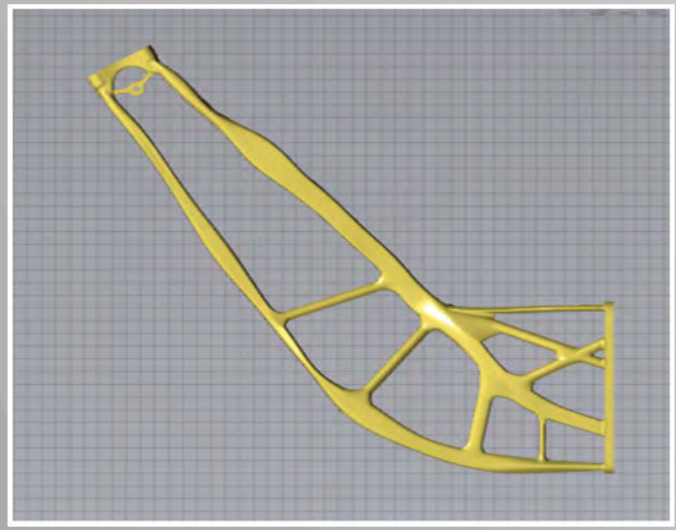
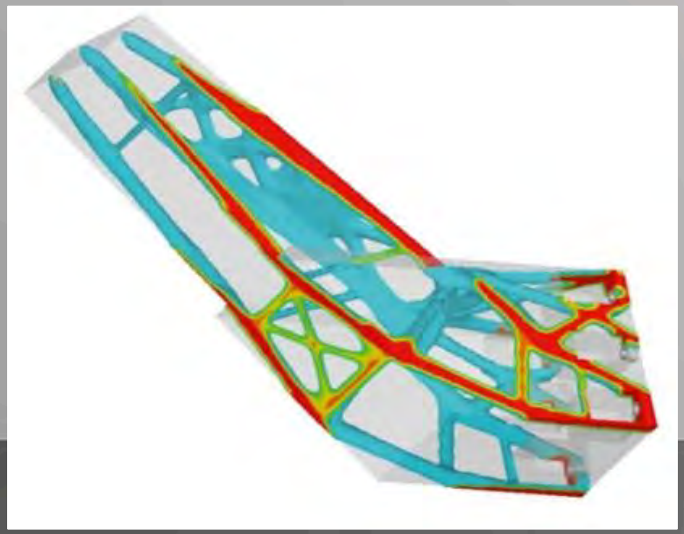
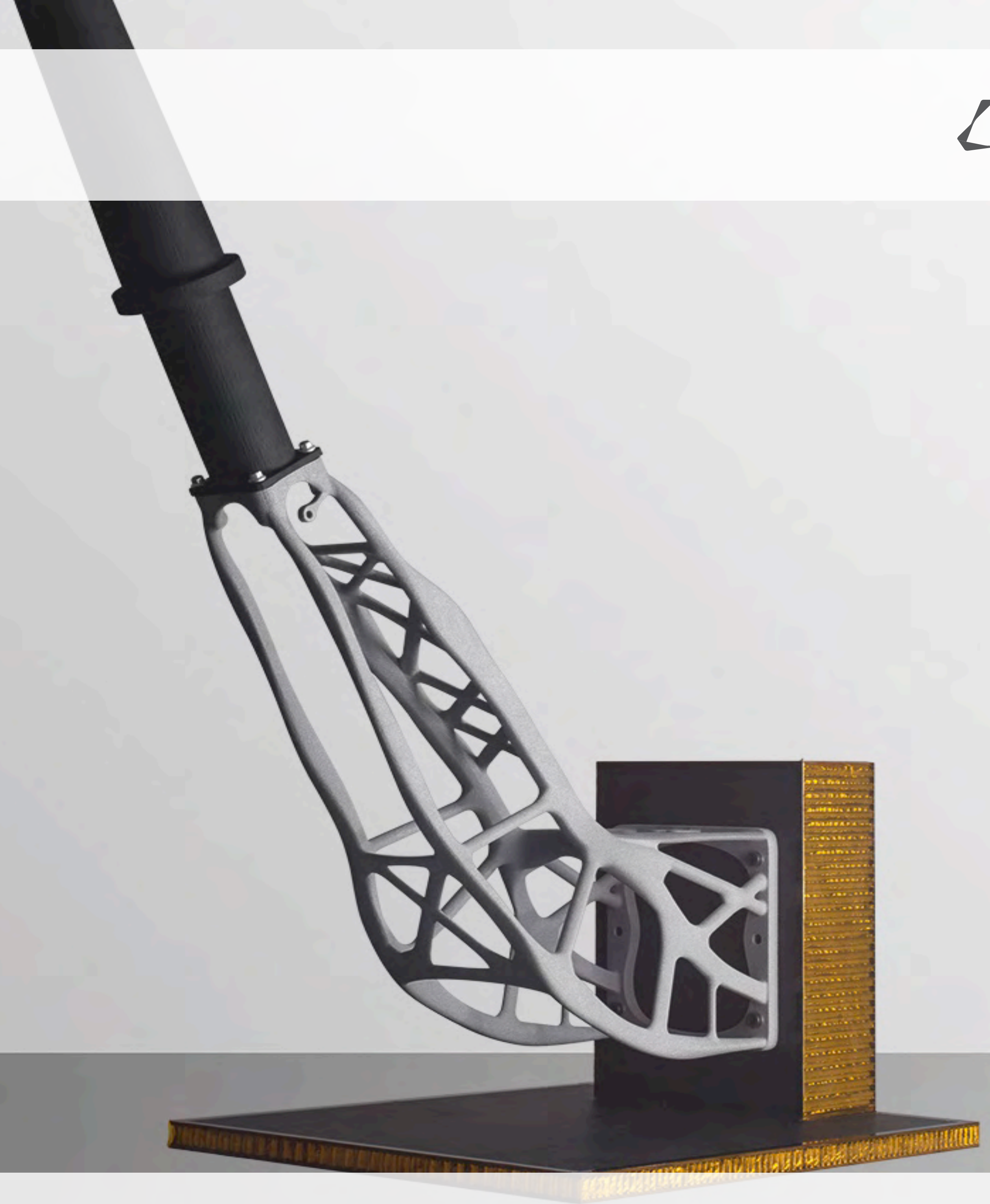
RUAG Space







Altair ProductDesign helps RUAG Space to design and optimize one of the longest components ever manufactured by industrial 3D printing for use in space – **50% weight reduction**

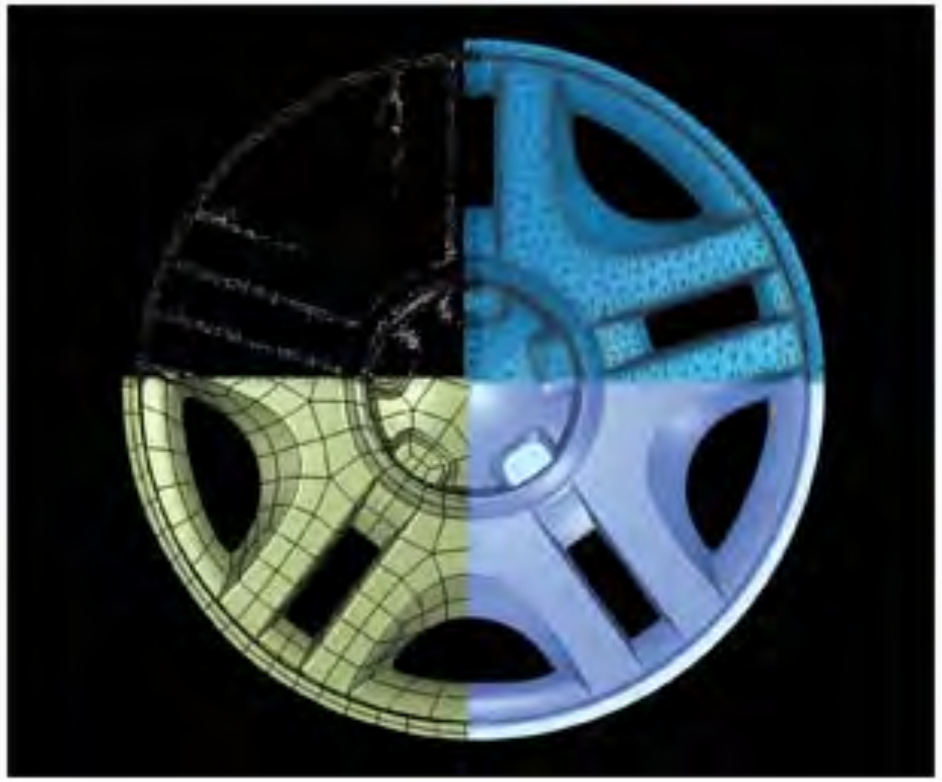
Major Challanges in the design process:

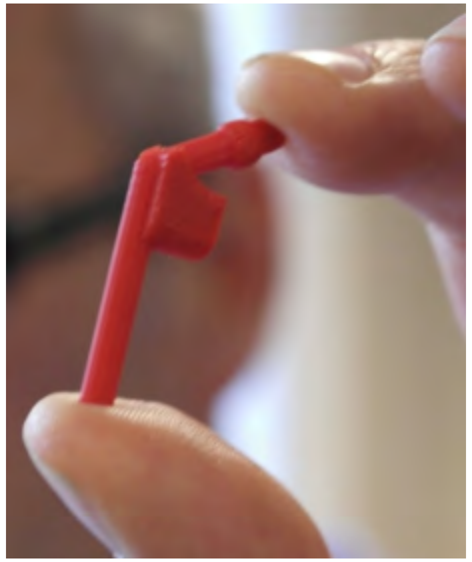
How to get the Digital File?

Reverse Engineering Geometry Capture – CT, Laser, CMM

Reverse Engineering

- Laser Scanning
- White Light Stereo Scanning
- CT
- Coordinate Measuring Machines





Major Challanges in the design process:

How to get the CAD?

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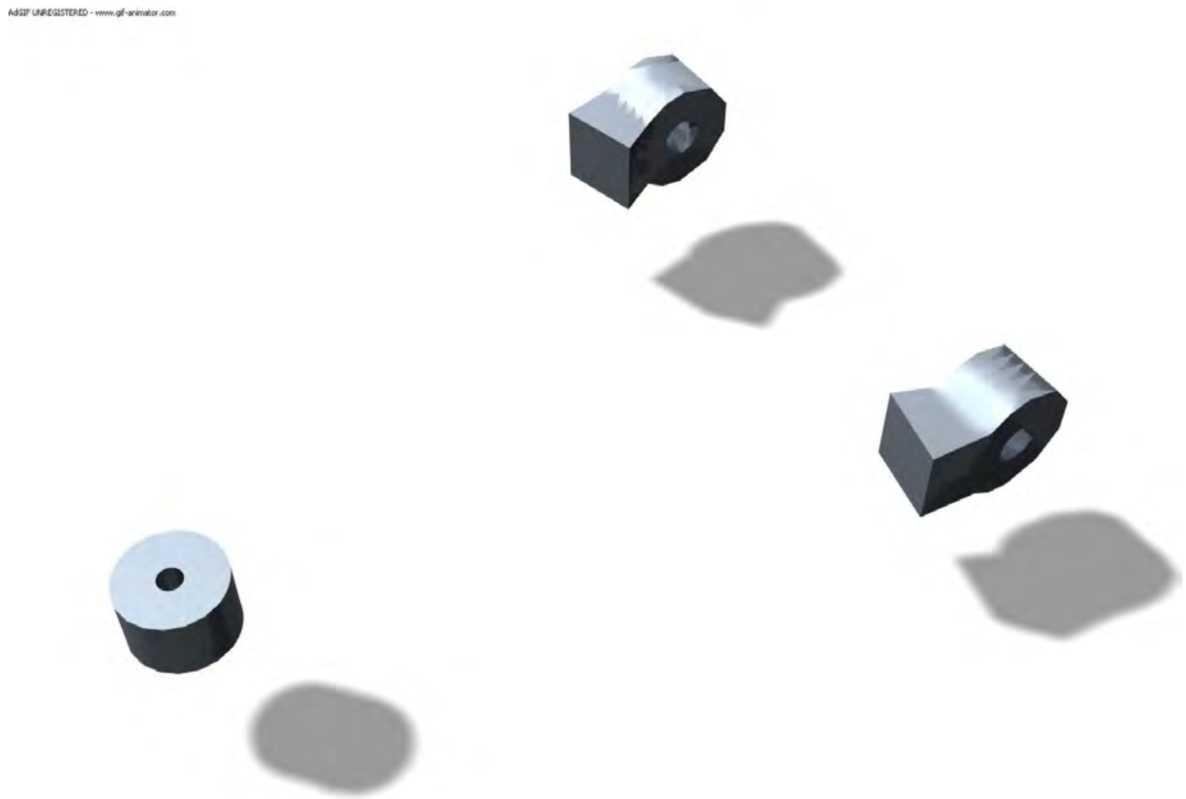
How to come up with the best shape possible?

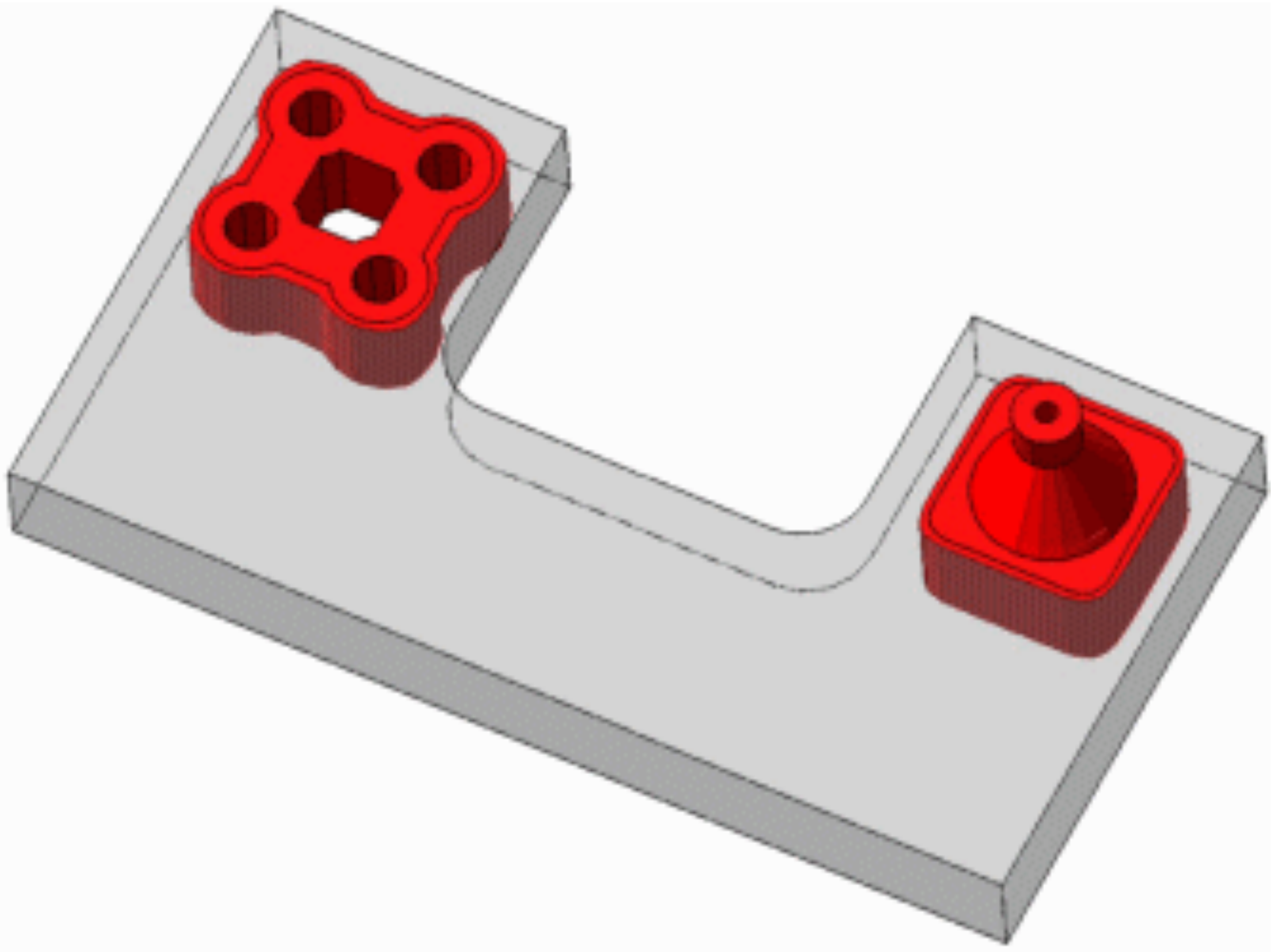
- Topology Optimization

Solution:

Biomimicry Software

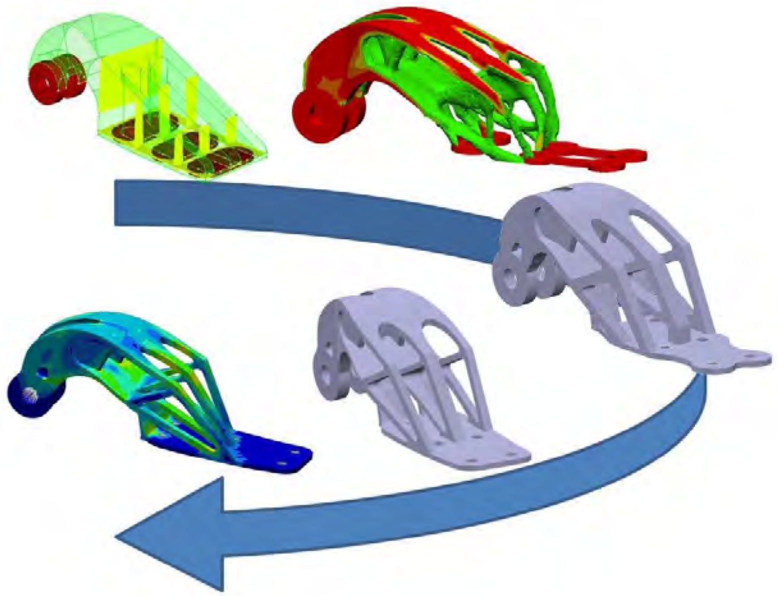


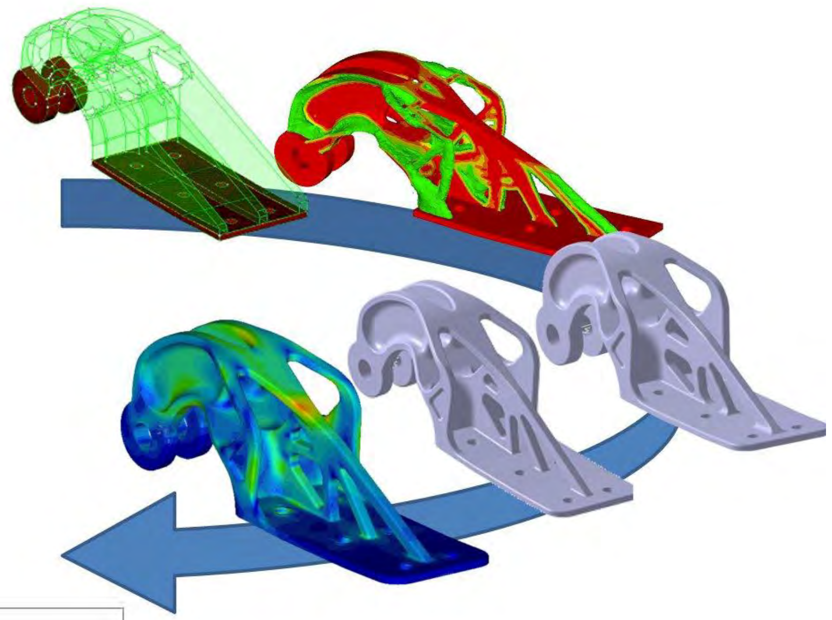
Underlying Technology:
"Topology Optimization"



“Industrialization” of Topology Optimization

Engineering ability – Topology Optimization





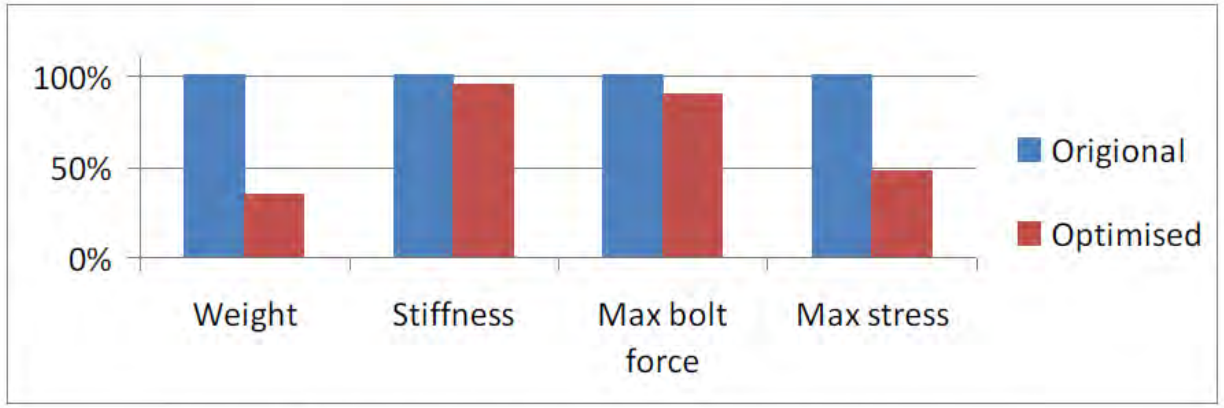
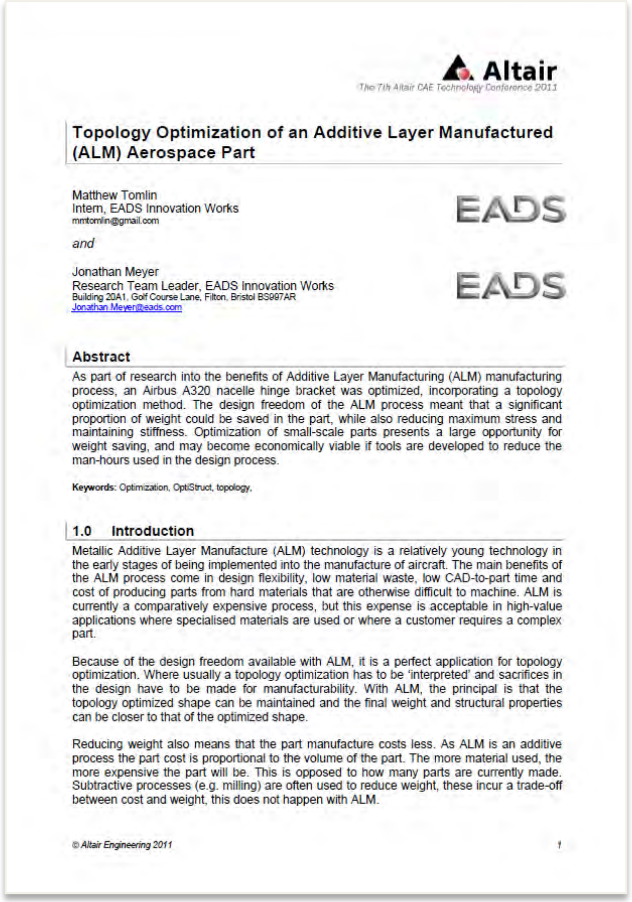


Figure 10: Performance comparison of original and new design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The 7th Altair CAE Technology Conference 2011

Topology Optimization of an Additive Layer Manufactured (ALM) Aerospace Part

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Abstract

As part of research into the benefits of Additive Layer Manufacturing (ALM) manufacturing process, an Airbus A320 nacelle hinge bracket was optimized, incorporating a topology optimization method. The design freedom of the ALM process meant that a significant proportion of weight could be saved in the part, while also reducing maximum stress and maintaining stiffness. Optimization of small-scale parts presents a large opportunity for weight saving, and may become economically viable if tools are developed to reduce the man-hours used in the design process.

Keywords: Optimization, OptiStruct, topology,

1.0 Introduction

Metallic Additive Layer Manufacture (ALM) technology is a relatively young technology in the early stages of being implemented into the manufacture of aircraft. The main benefits of the ALM process come in design flexibility, low material waste, low CAD-to-part time and cost of producing parts from hard materials that are otherwise difficult to machine. ALM is currently a comparatively expensive process, but this expense is acceptable in high-value applications where specialised materials are used or where a customer requires a complex part.

Because of the design freedom available with ALM, it is a perfect application for topology optimization. Where usually a topology optimization has to be 'interpreted' and sacrifices in the design have to be made for manufacturability. With ALM, the principal is that the topology optimized shape can be maintained and the final weight and structural properties can be closer to that of the optimized shape.

Reducing weight also means that the part manufacture costs less. As ALM is an additive process the part cost is proportional to the volume of the part. The more material used, the more expensive the part will be. This is opposed to how many parts are currently made. Subtractive processes (e.g. milling) are often used to reduce weight, these incur a trade-off between cost and weight, this does not happen with ALM.

© Altair Engineering 2011 1

Design Challenges

Major Challanges in the design process:

How to get the CAD?

- Reverse Engineering Geometry Capture – CT, Laser, CMM

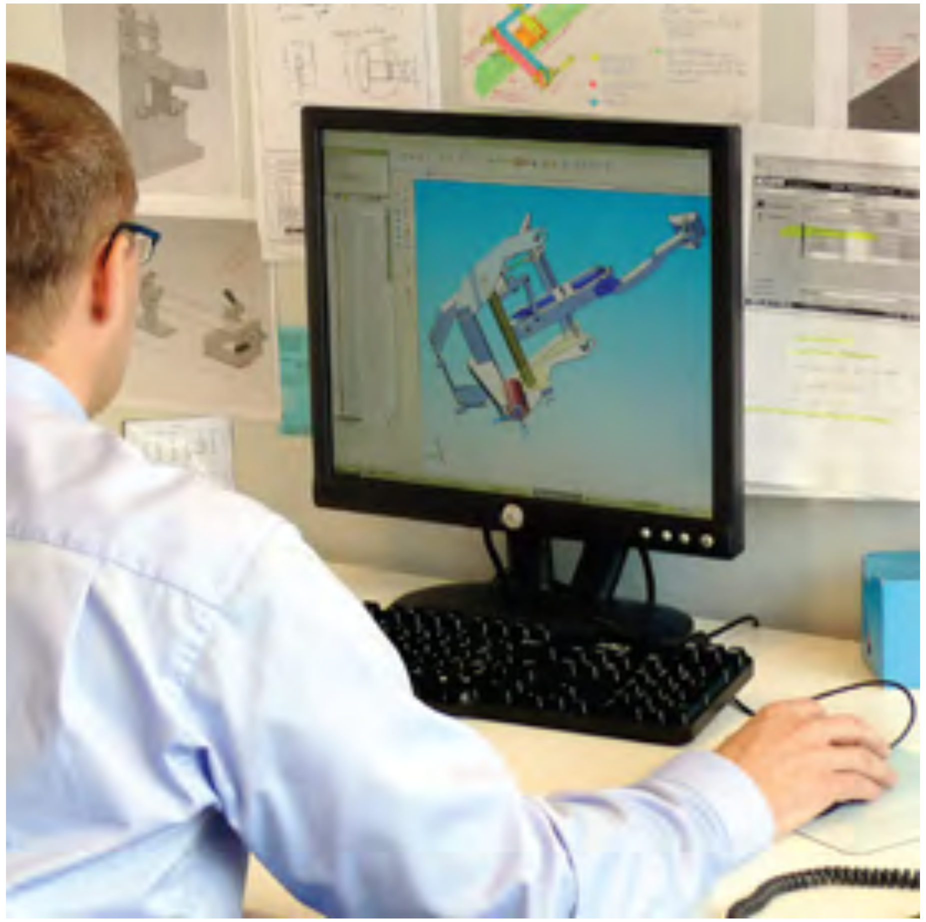
How to come up with the best shape possible?

- Topology Optimization

How the generate a geometry from the organic like structural concept?

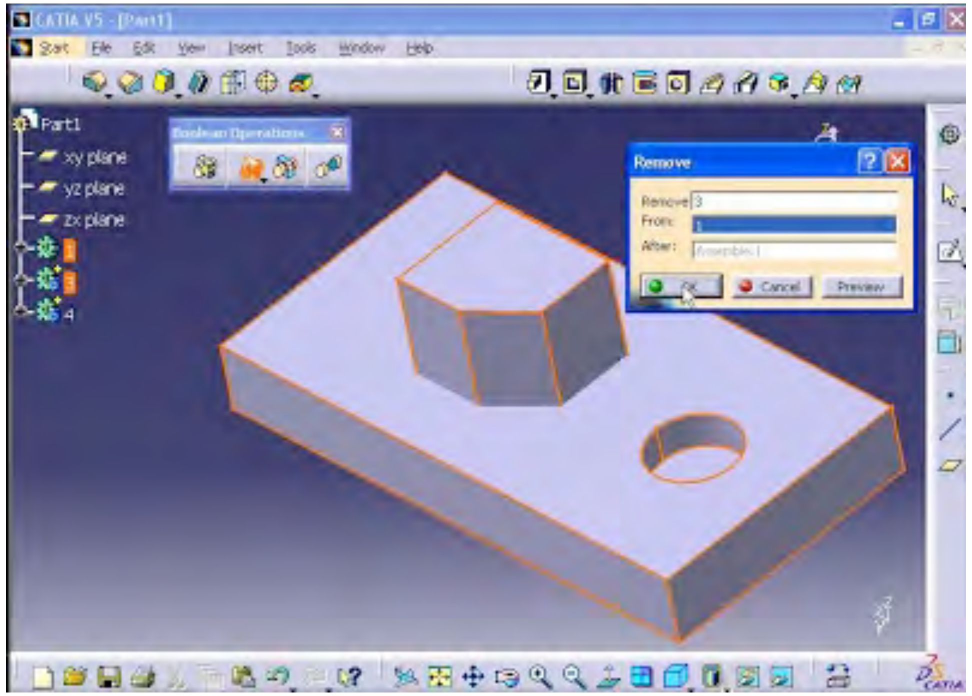
- Direct Modelling Tools instead of conventional CAD

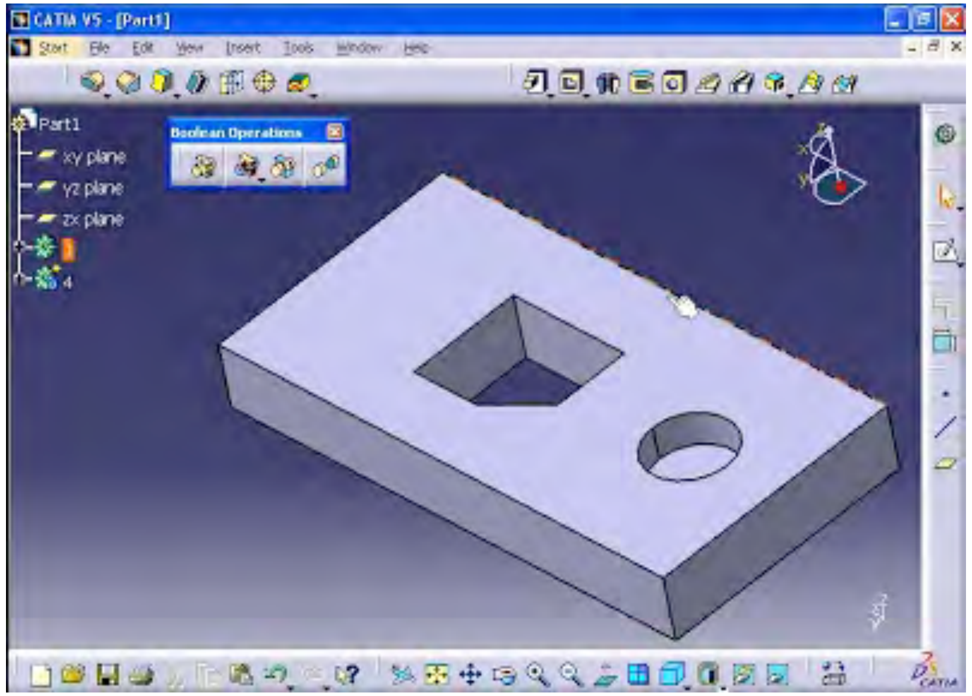
How can the engineer draw it in a CAD system?



Problem:

Conventional CAD systems rely on boolean operations of simple geometric entities





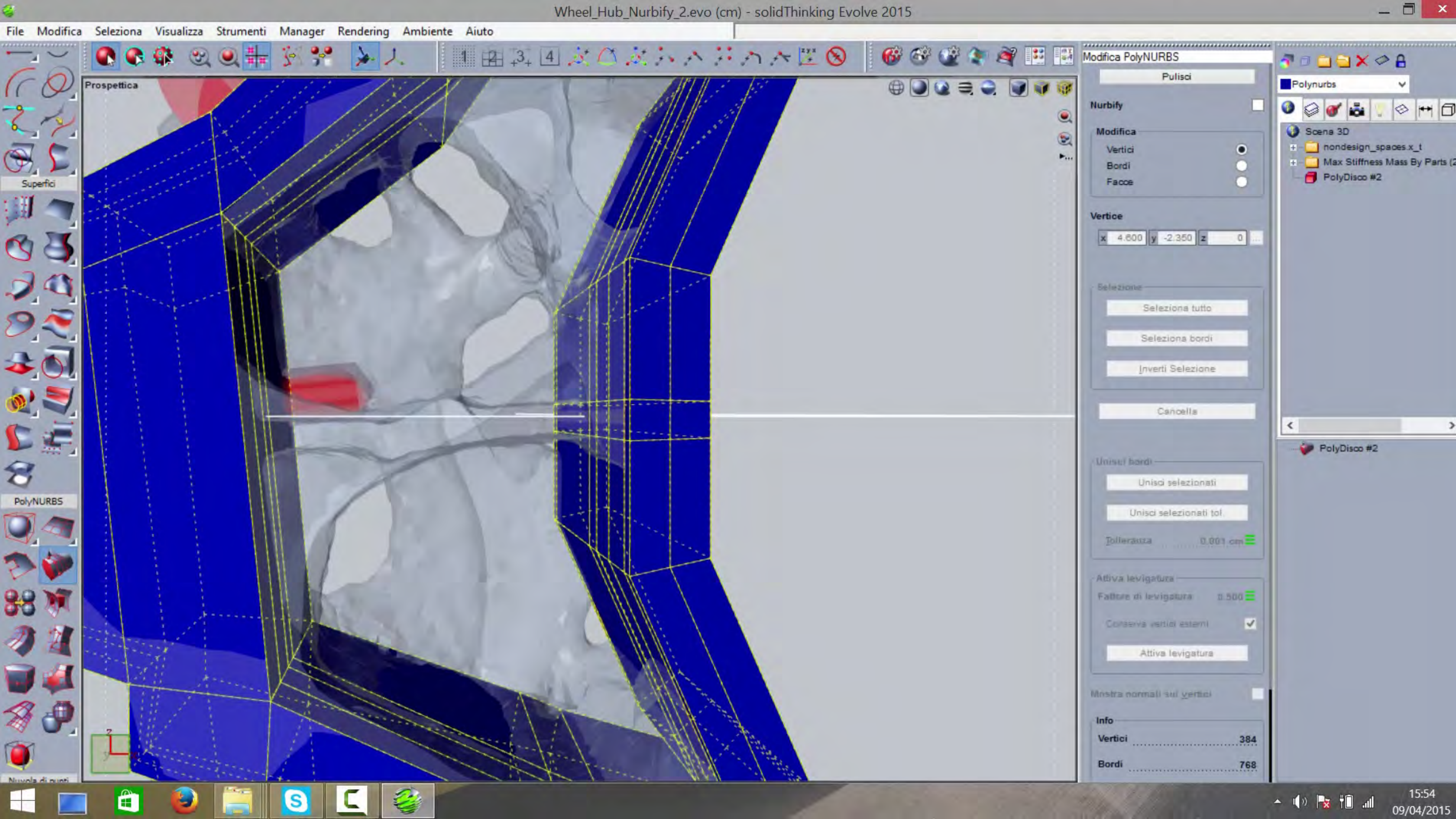
So “drafting” something like this can take weeks with a conventional system:

pictures by courtesy of Laser Zentrum Nord

Solution:

Direct Modelling

New
Polymesh Design Technology



Wheel_Hub_Nurbify_2.evo (cm) - solidThinking Evolve 2015
File
Modifica
Seleziona
Visualizza
Strumenti
Manager
Rendering
Ambiente
Aiuto
Prospettica
Superfici
PolyNURBS
Modifica PolyNURBS
Pulisci
Nurbify
Modifica
Vertici
Bordi
Facce
Vertice
x 4.600
y -2.350
z 0
Selezione
Seleziona tutto
Seleziona bordi
Inverti Selezione
Cancella
Unisci bordi
Unisci selezionati
Unisci selezionati tol
Tolleranza 0.001 cm
Attiva levigatura
Fattore di levigatura 0.500
Conserva vertici esterni
Attiva levigatura
Mostra normali sui vertici
Info
Vertici 384
Bordi 768
Polynurbs
Scena 3D
nondesign_spaces.x_t
Max Stiffness Mass By Parts
PolyDisco #2
PolyDisco #2
15:54
09/04/2015

Performance Comparison

Direct Modeling		Traditional CAD
363 Hz	1st Frequency	313 Hz
539 psi (3.72 MPa)	Max Stress	534 psi (3.68 MPa)
8.62e-5 in (2.19e-6 m)	Max Displacement	9.62e-5 in (2.44e-6 m)
.100 lb (.045 kg)	Weight	.108 lb (.049 kg)
8 hours	Design Time	24 hours

exactengineering

Design Challenges

Major Challanges in the design process:

How to get the CAD?

- **Reverse Engineering Geometry Capture – CT, Laser, CMM**

How to come up with the best shape possible?

- **Topology Optimization**

How the generate a geometry from the

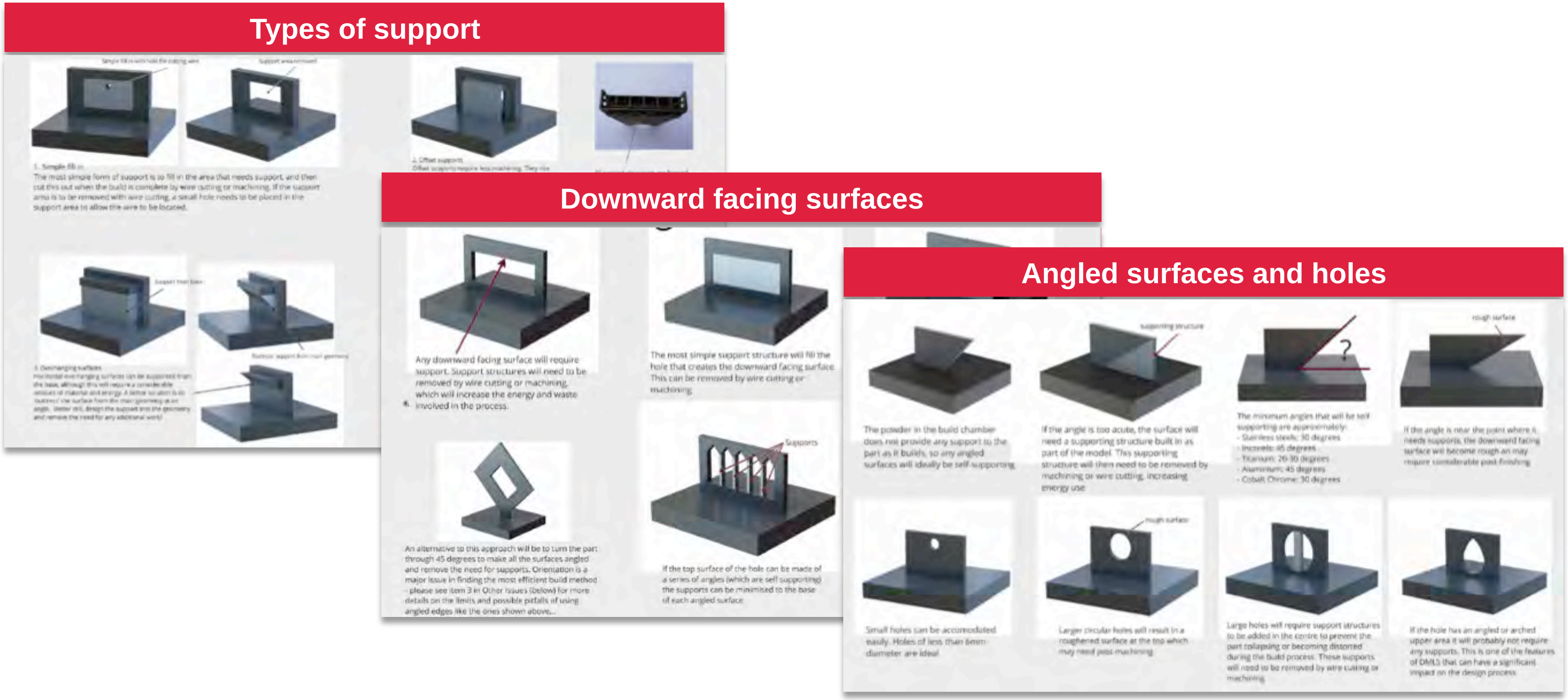
organic like structural concept?

- **Direct Modelling Tools instead**
  of conventional CAD

How to deal with the new manufacturing constraints?

- **Design rule catalouges**
- **Manufacturing constraint implementation in Design**

How to consider the NEW Manufacturing Constraints?



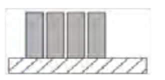
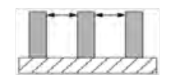
http://www.manufacturingthefuture.co.uk/design-guidelines/

plunkett associates simpleware EXETER

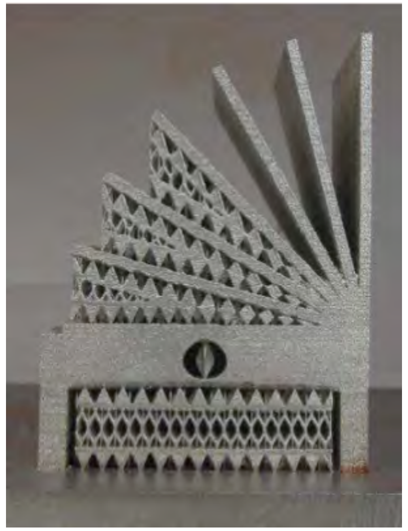
"Design guidelines for laser additive manufacturing of lightweight structures in TiAl6V4"

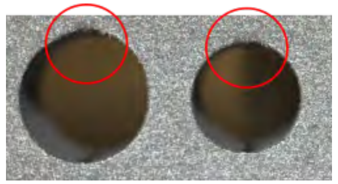
J. Kranz, D. Herzog, and C. Emmelmann

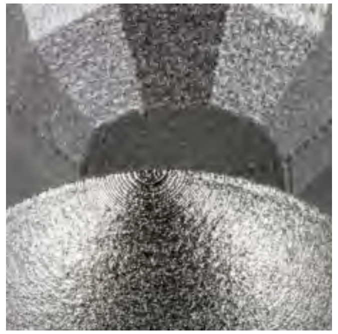
http://scitation.aip.org/content/lia/journal/jla/27/S1

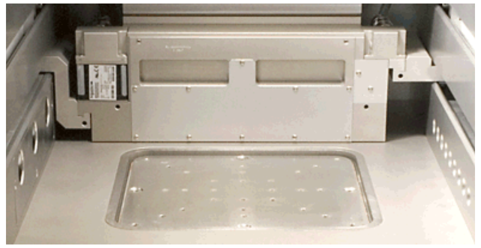
structure				unfavourable	favourable	explanation	restrictions and recommendations
Design Process – TiAl6V4	part placement	part alignment	filigree parts			• place thin walls perpendicular towards recoater • do not place large filigree crosssections parallel to the recoater	
			general	typical target figures: • max. support area • min. contact with supports • min. roughness of interfaces • min. support volume			
		package density				• consider free space between manufactured parts in order to ease final machining • to close packaging can lead to thermal interaction of parts	• sufficient ditance between parts minimizes thermal influences • TiAl6V4: ca. 5 mm; no powder bed heater

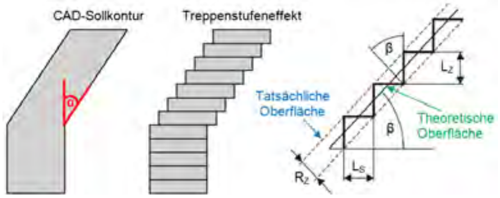
- Heat induced Stresses
- Support Structures
- Holes
- Overhangs
- Building Sizes
- Surface quality
- Building cost



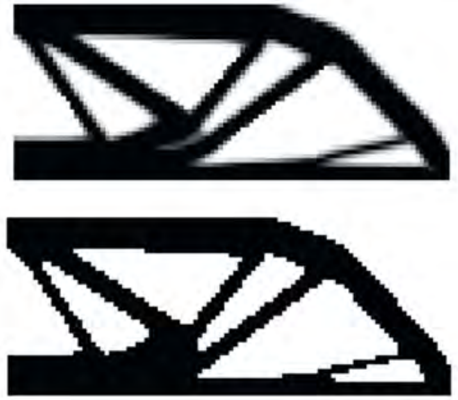


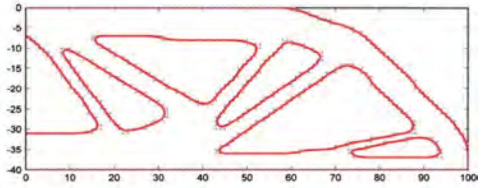


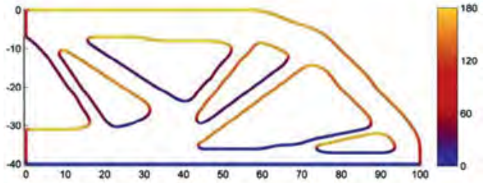


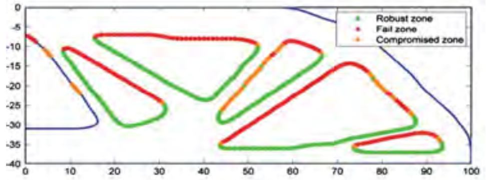


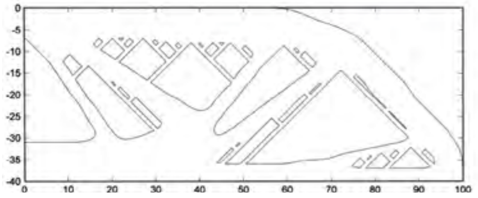
AM Overhang Angle – Fused Deposition Modelling (FDM)











Modification of topology design to enable support free AM structures

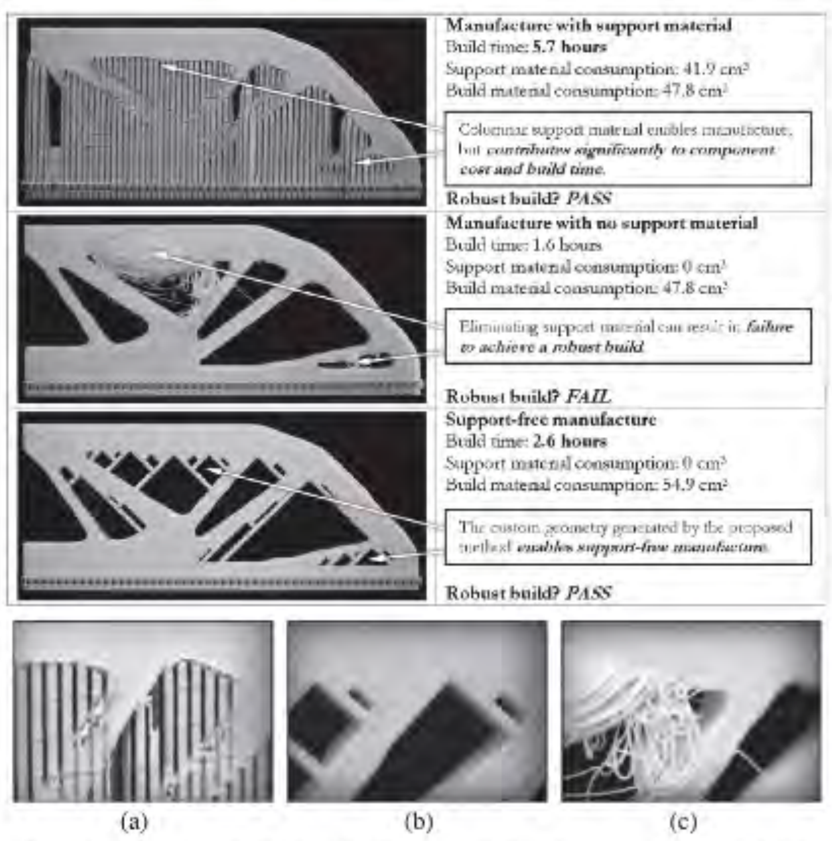


Fig. 16. Orientation 1 ($\Theta = 0°$). Details: (a) Machine support. (b) Optimal support. (c) No support – Failed.

Martin Leary, Luigi Merli, Federico Torti, Maciej Mazur, Milan Brandt – **"Optimal topology for additive manufacture: A method for enabling additive manufacture of support-free optimal structures", 2014**

AM Overhang Angle

Constraining topology design to allow optimal support free layout

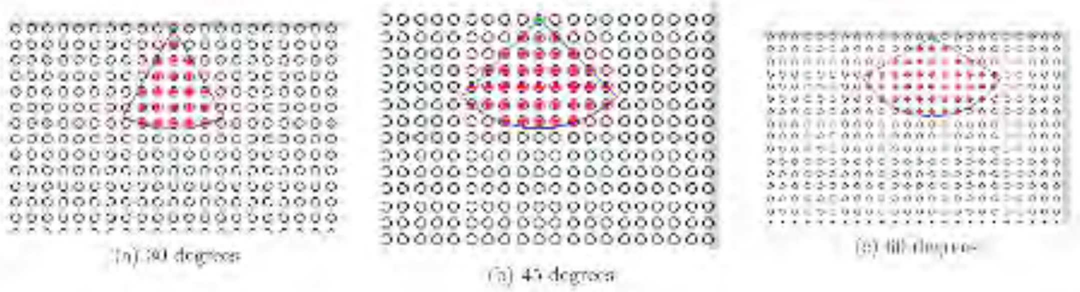
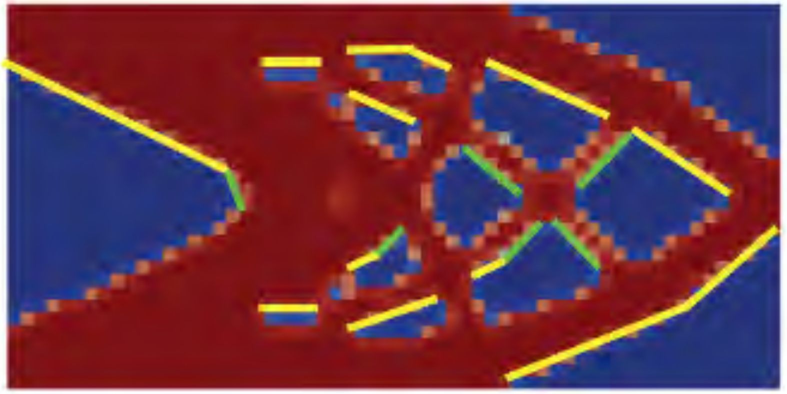
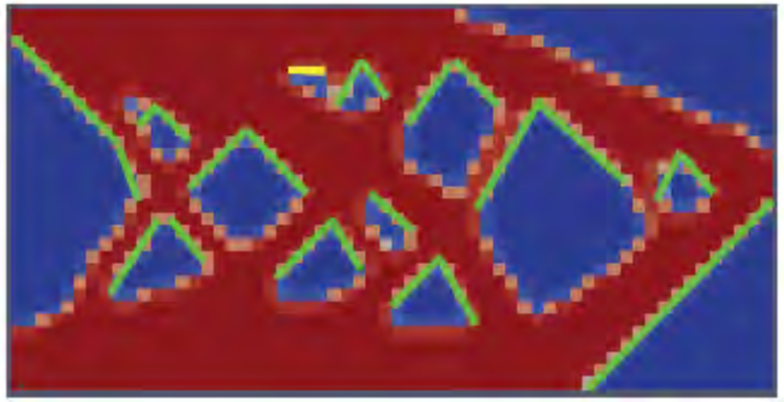


Figure 2: Overhang constraint: scanning range below e for various overhang angles.

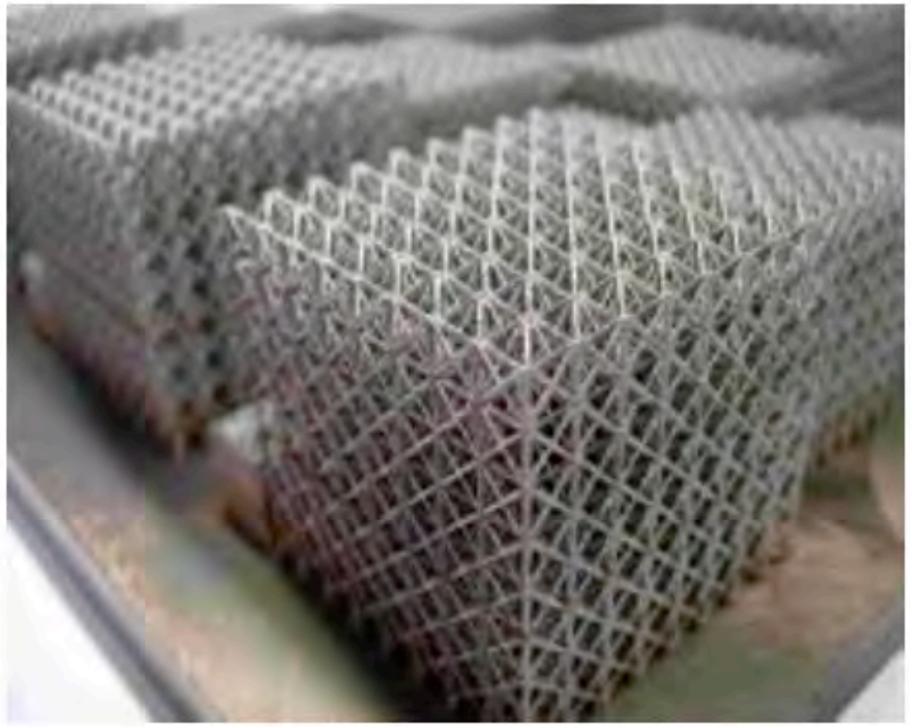




Andrew T. Gaynor and James K. Guest – “Topology Optimization for Additive Manufacturing: Considering Maximum Overhang Constraint”, 2014

What’s Next?

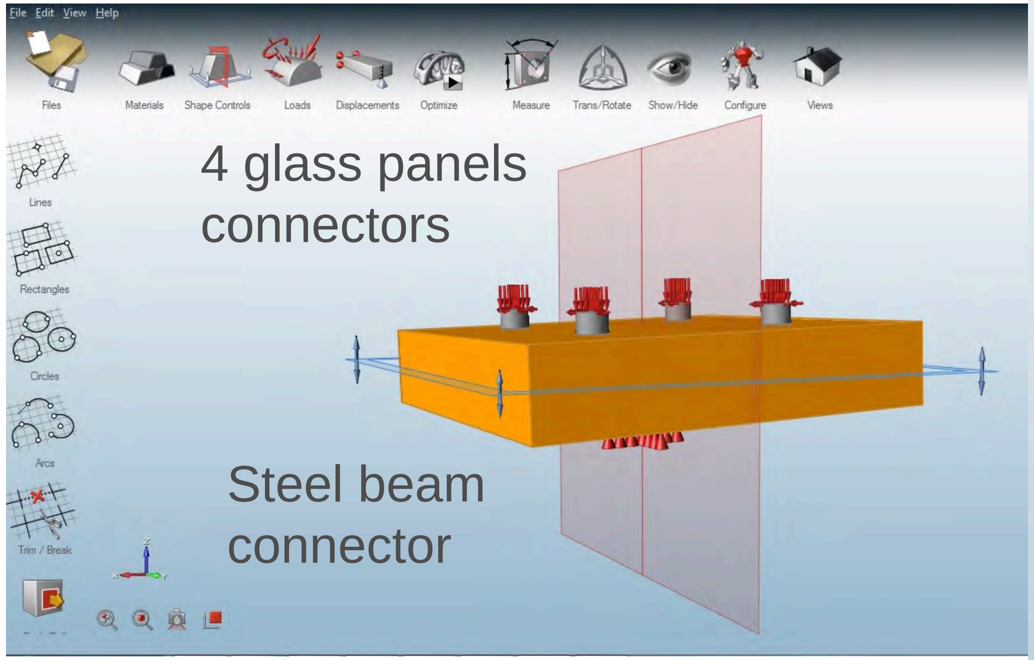
Topology optimized structures are pretty good, but lattice structures could be even better:

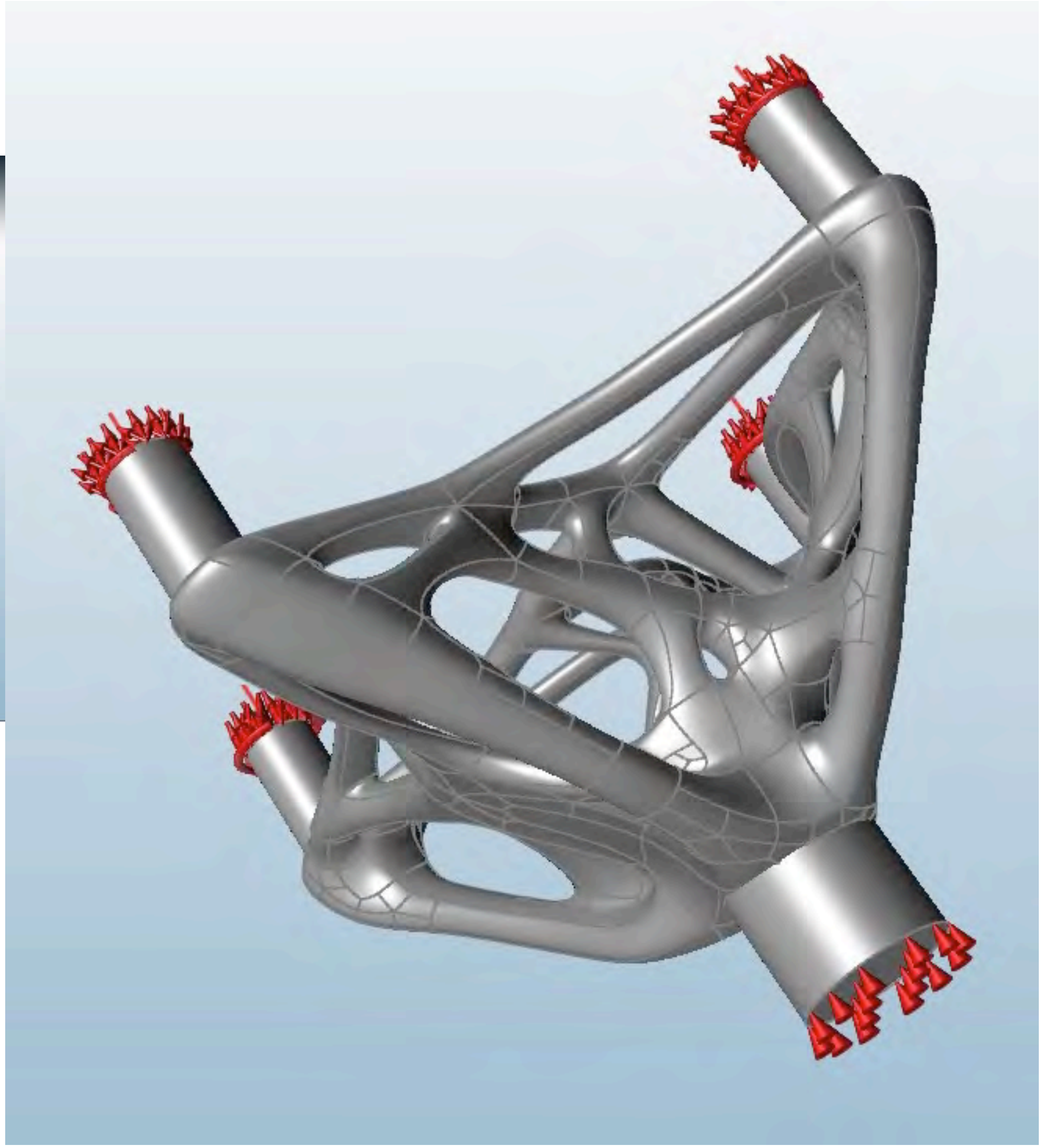


pictures by courtesy of Laser Zentrum Nord

So what if the design software could create lattice structures if needed?

Feasibility Study - Architectural Spider Bracket





Feasibility Study - Architectural Spider Bracket

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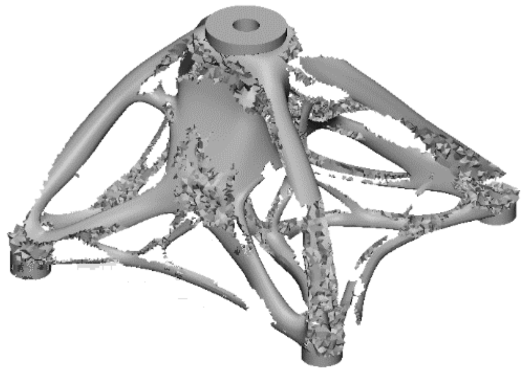
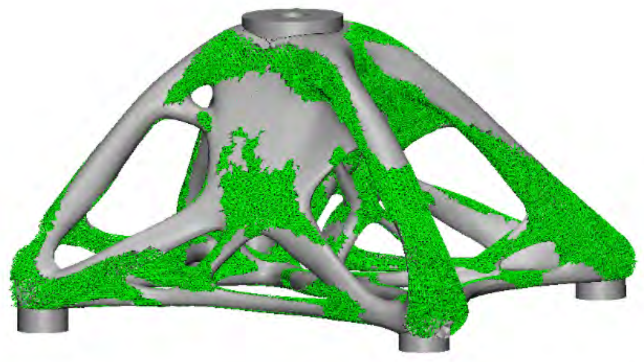
Materialise
innovators you can count on

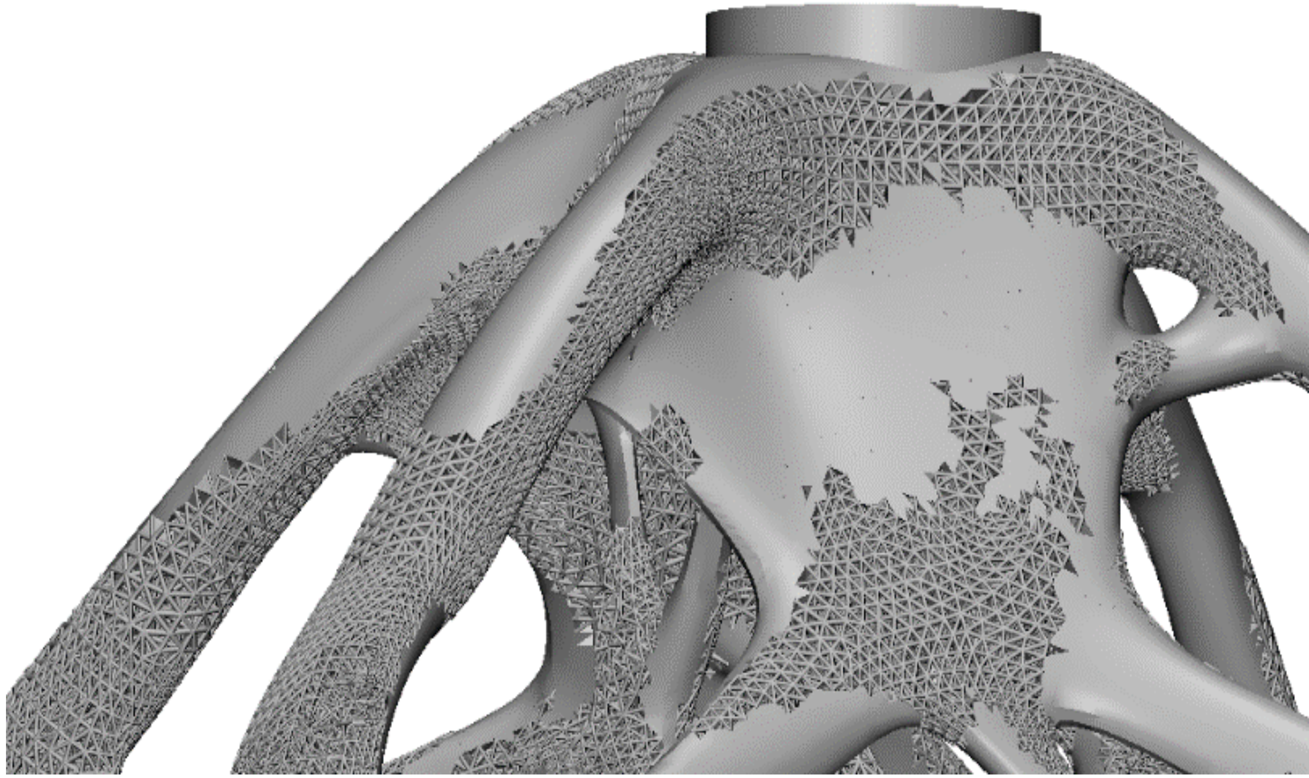
3-matic STL



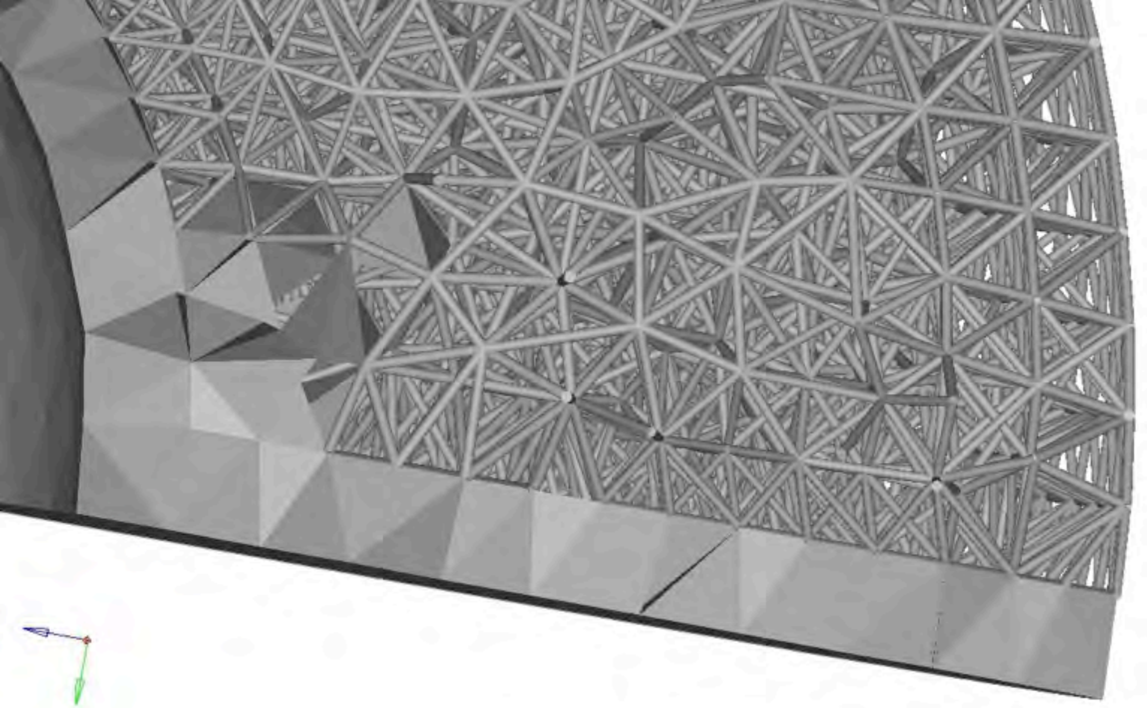
Optimized design with some zones of solid using OptiStruct

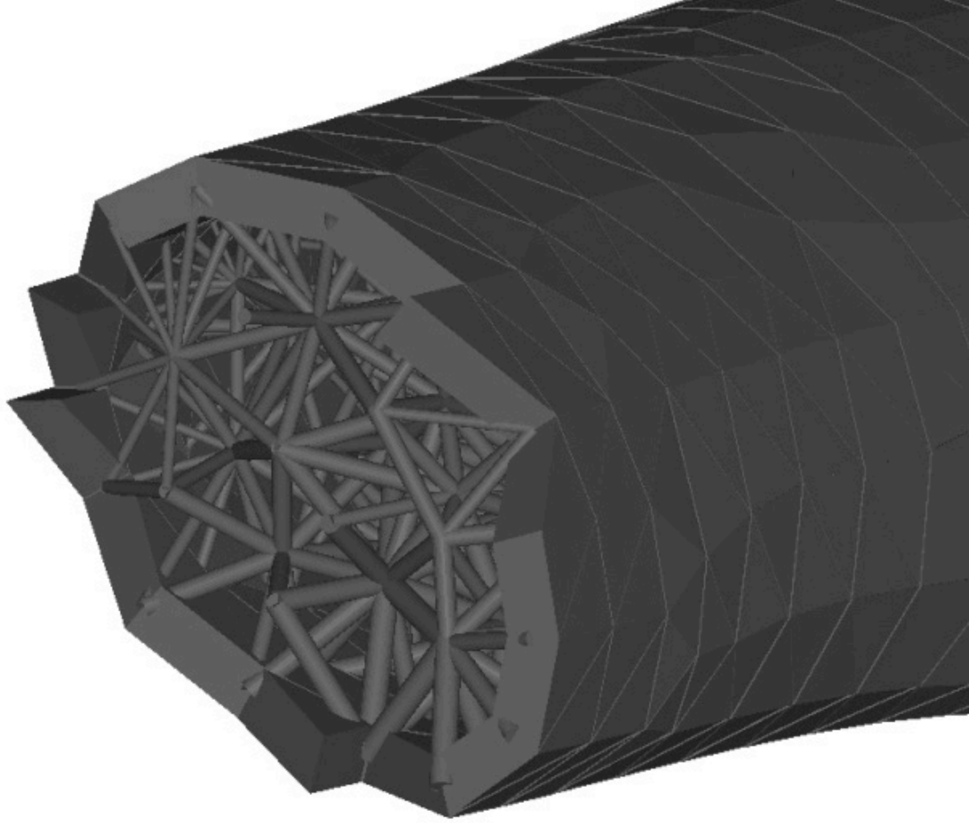


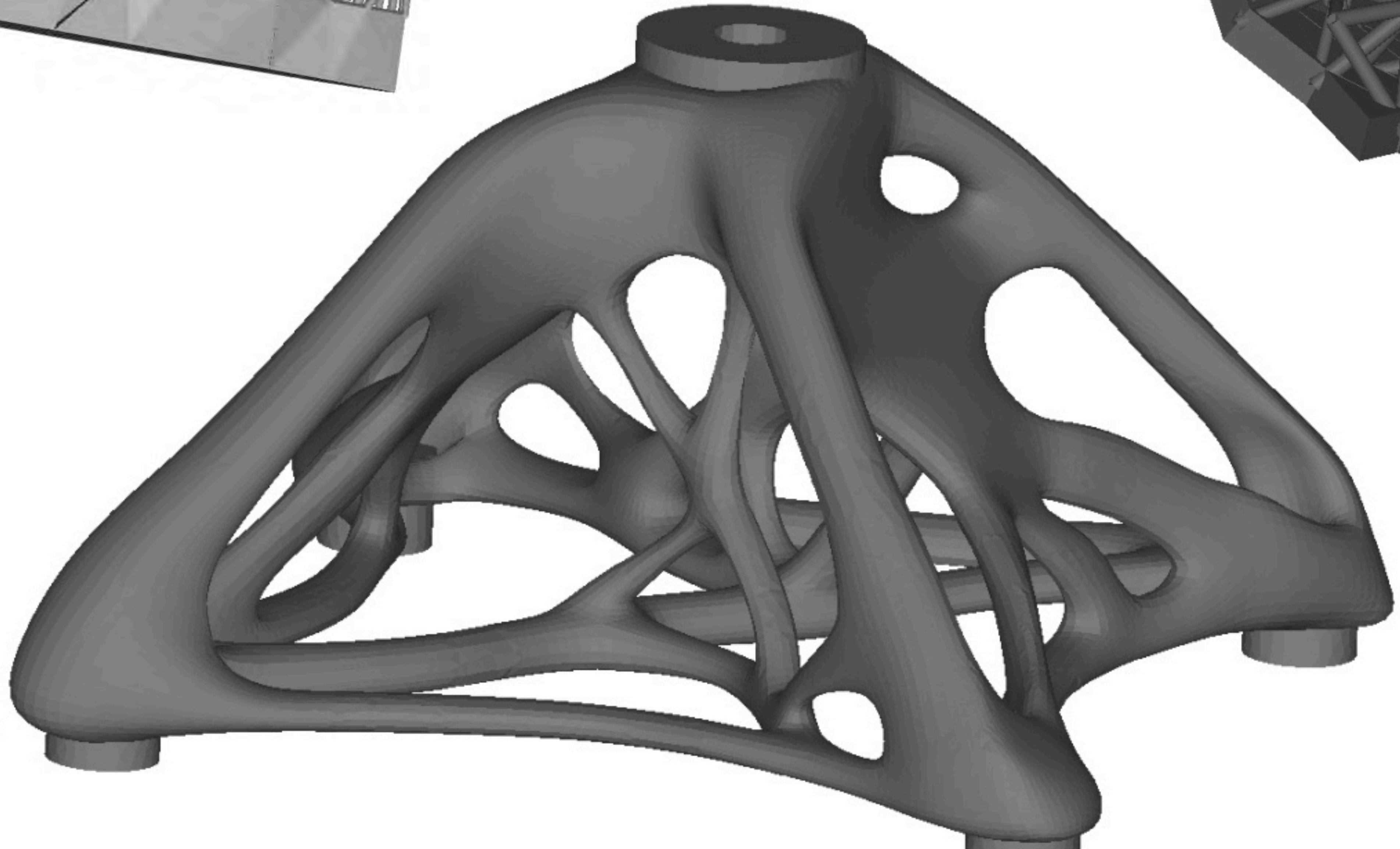
Optimized design with some zones of solid and some of structures using OptiStruct



Seamless export of structures from OptiStruct to 3-matic STL



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