Altair

Innovation Intelligence®

Entwicklungsprozess für die Industrialisierung der additiven Fertigung

Technologiesymbiose

Topologieoptimierung & 3D Druck

28.04.2016, Mirko Bromberger

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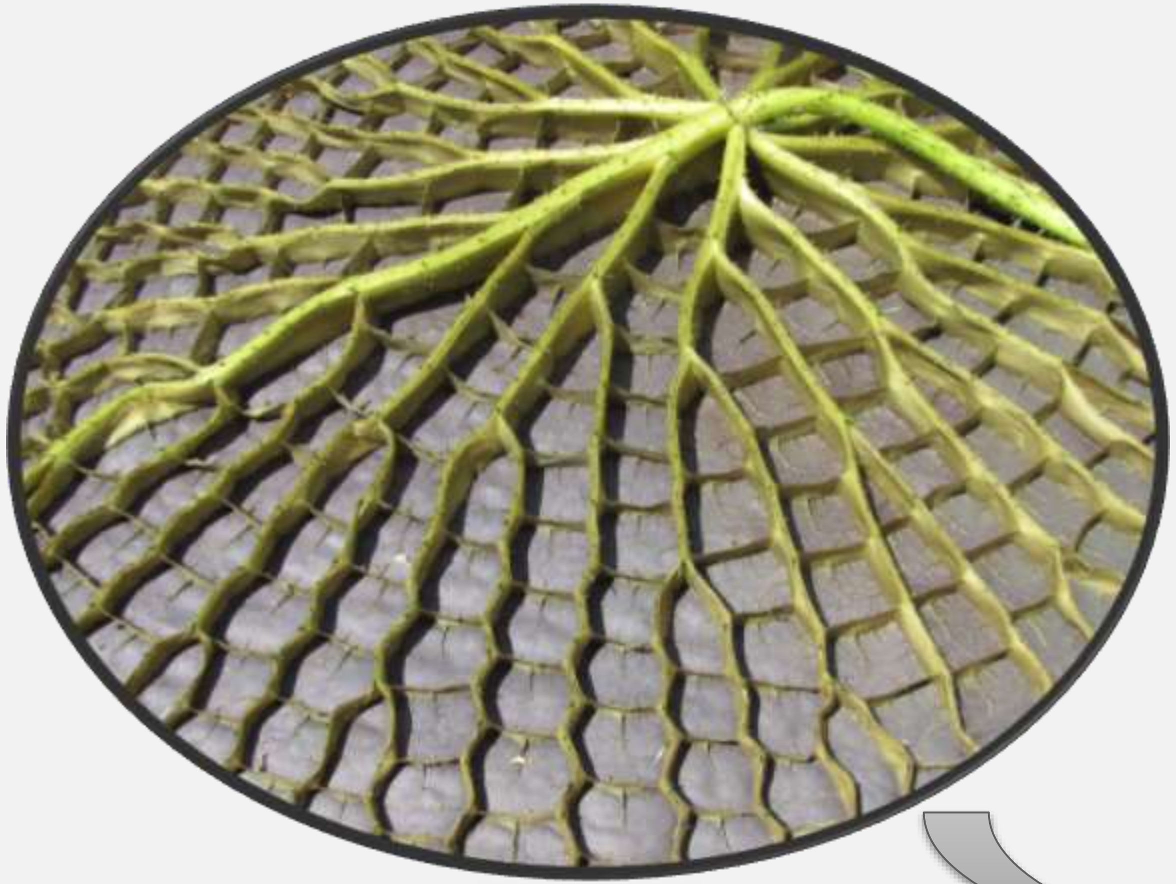
Key questions of the Industry:

Where is Additive Manufacturing suitable?

Where is it feasible to apply?

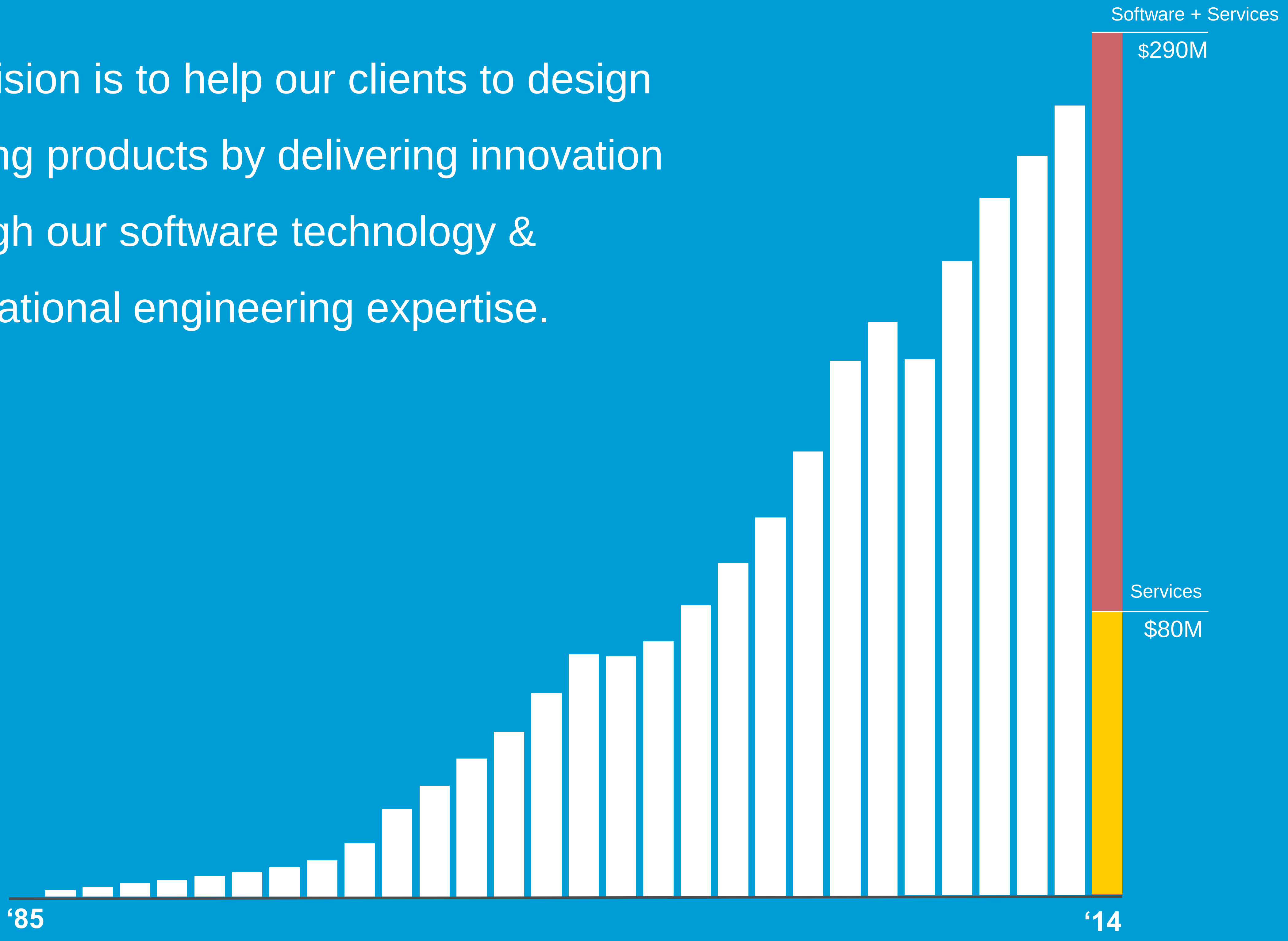
How to create an Added Value?

How to apply Bio principles in an Industrial application?



How to unlock the True Potential of Additive Manufacturing?

Our vision is to help our clients to design exciting products by delivering innovation through our software technology & international engineering expertise.



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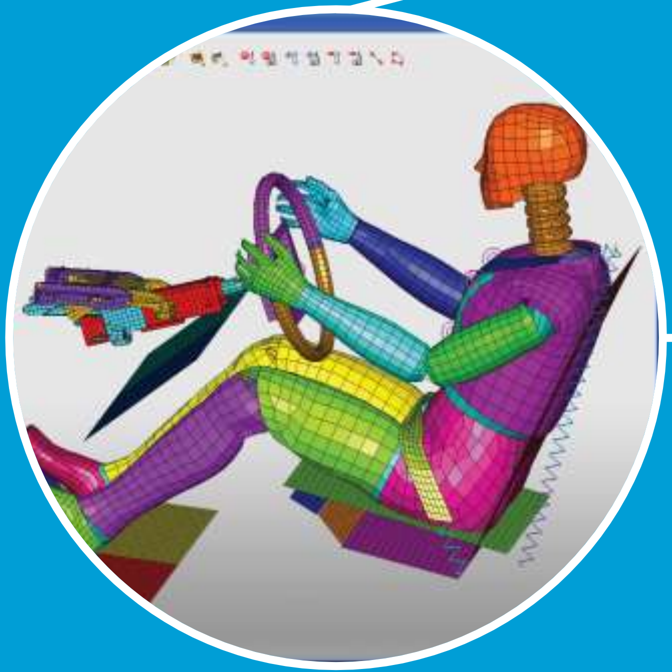
Business Units



HyperWorks

Industry’s broadest integrated Simulation Software Suite (Model Builders, Solvers, Optimisers Visualization)

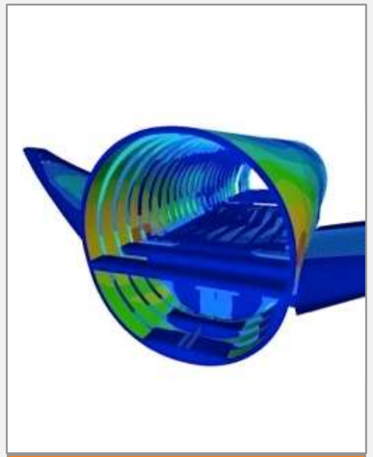
solidThinking

solidThinking Inspire enables Product Designers to quickly create and investigate structurally efficient concepts

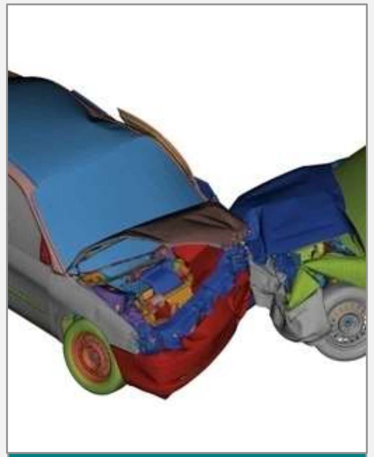
ProductDesign

A global engineering and design business delivering innovation to our clients

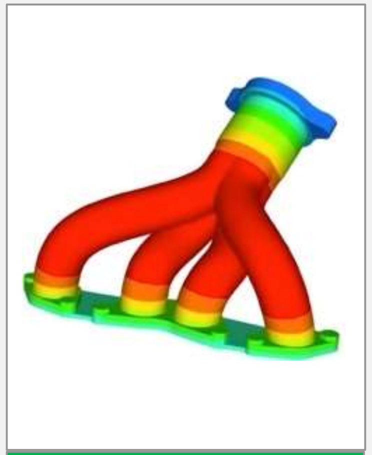
Who is Altair - solver technology



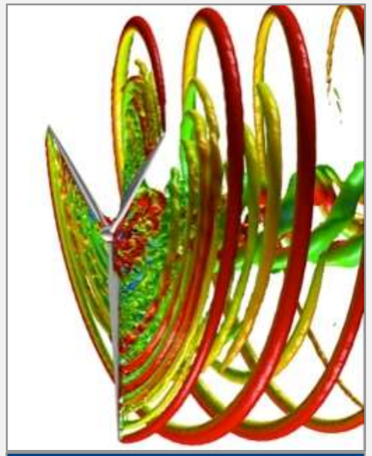
Structural Analysis



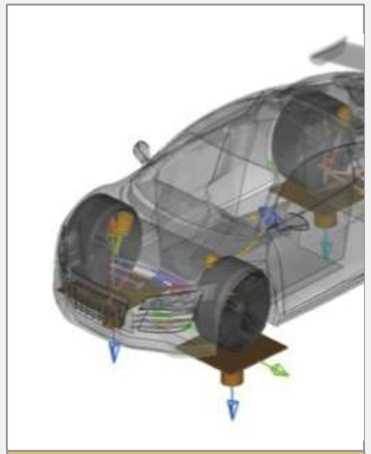
Crash, Safety, Impact & Blast



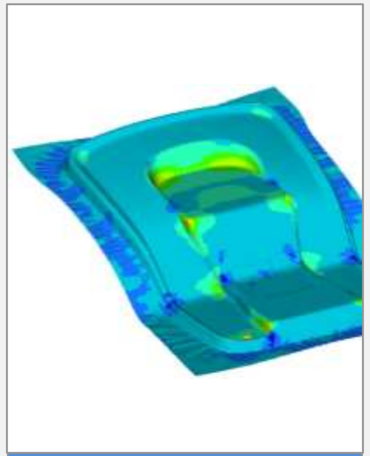
Thermal Analysis



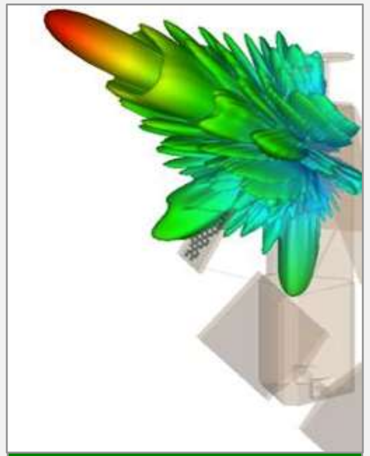
Fluid Dynamics



Systems Simulation



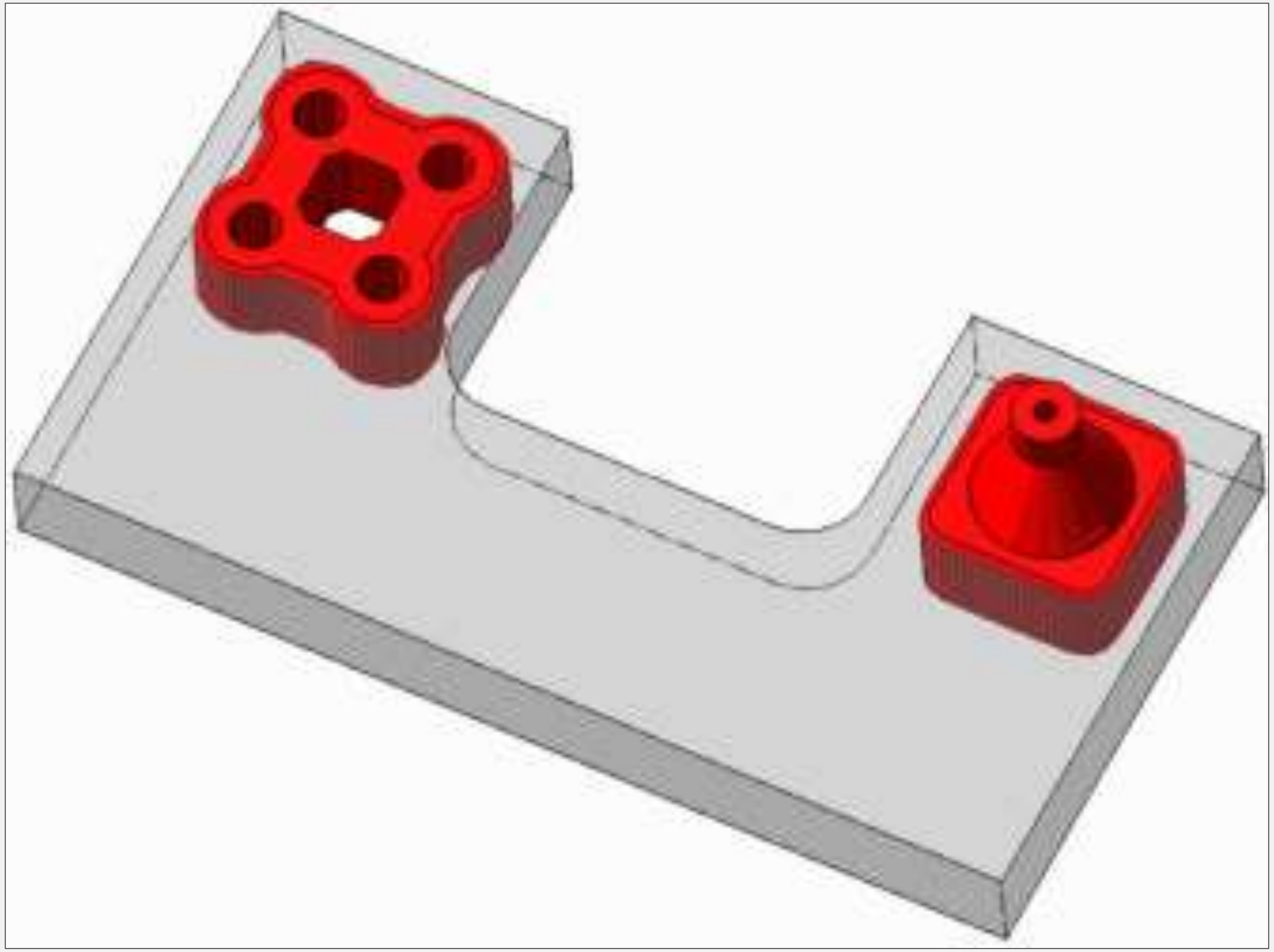
Manufacturing Simulation



Electro-Magnetics

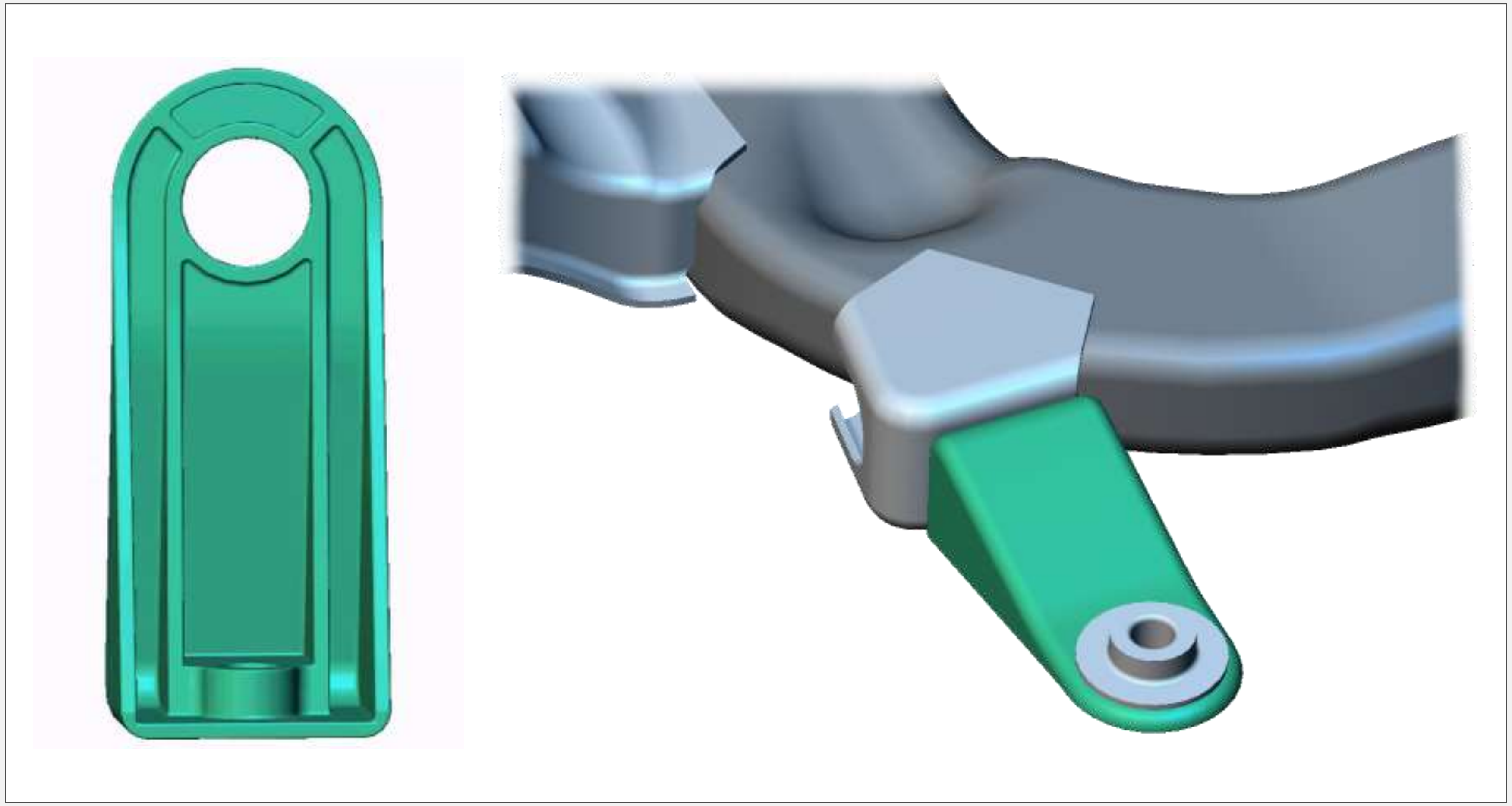
Multiphysics Analysis and Optimization

Intelligent Software Technology:
“Free Form Optimization”



Free Form Optimization History

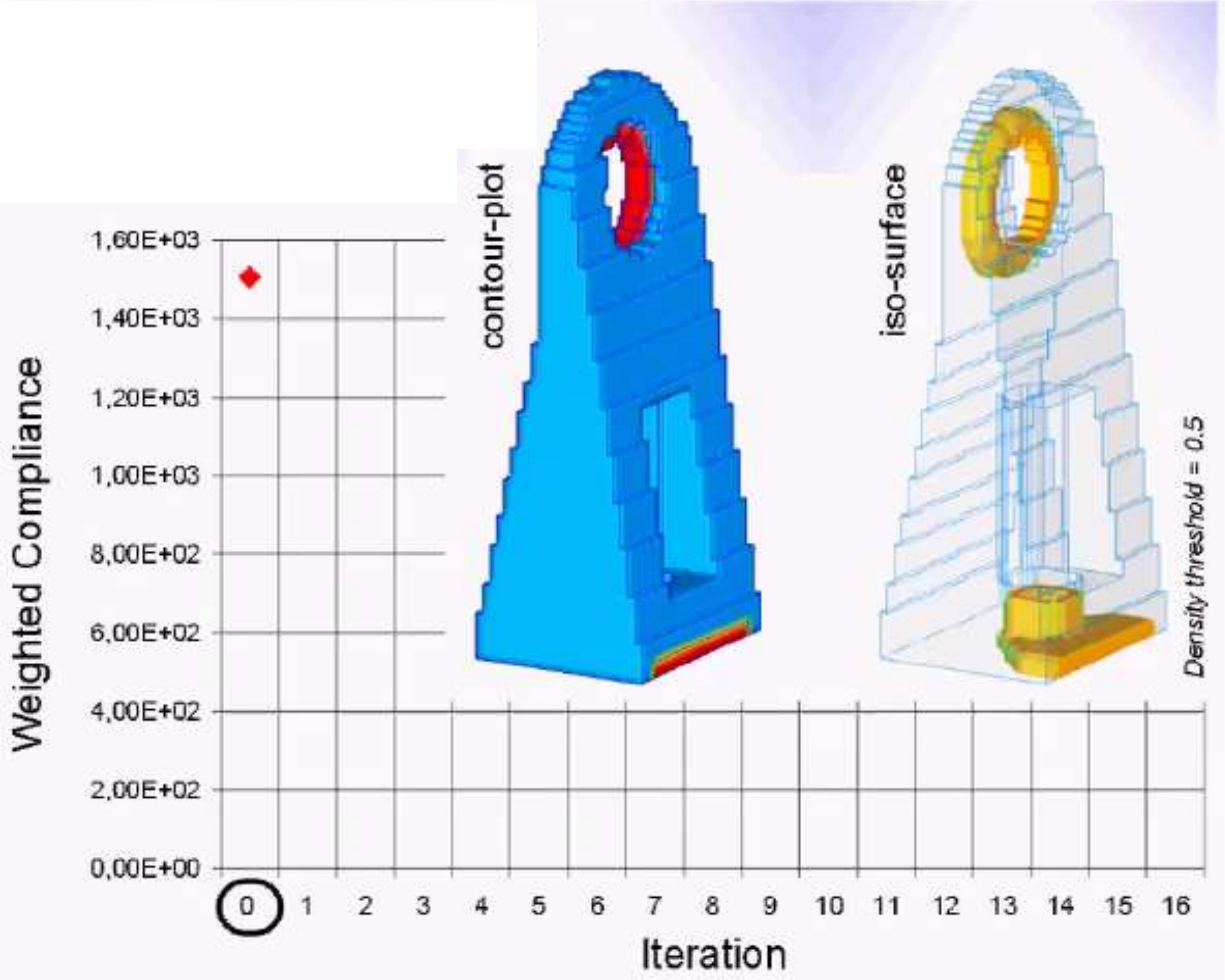
Radiator Bracket

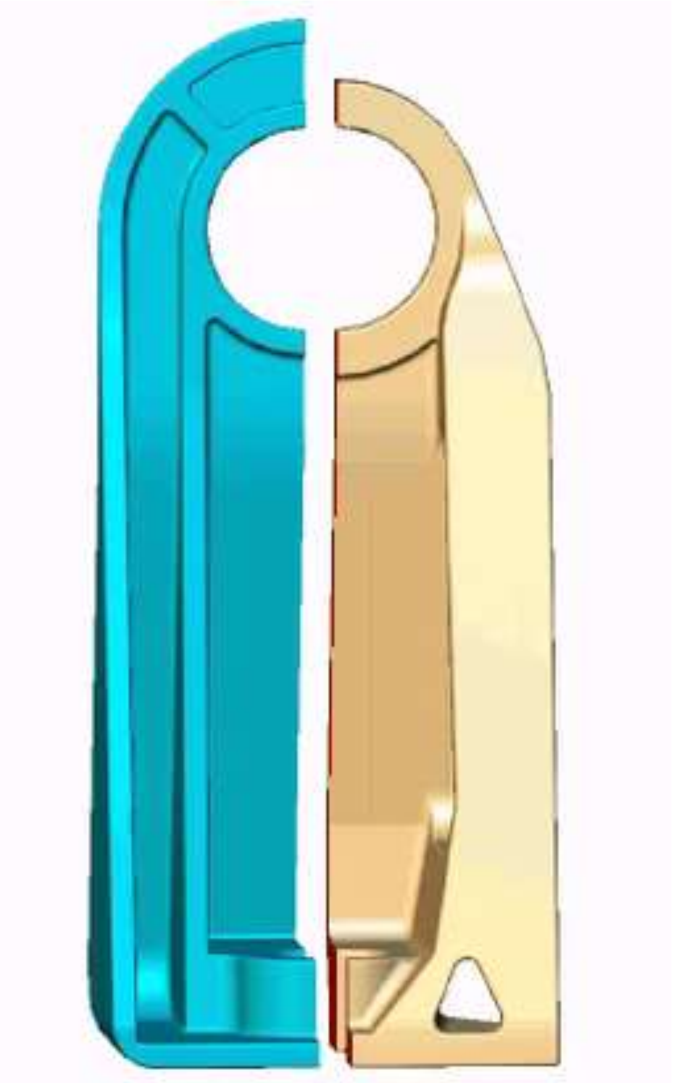


Original Bracket Failed

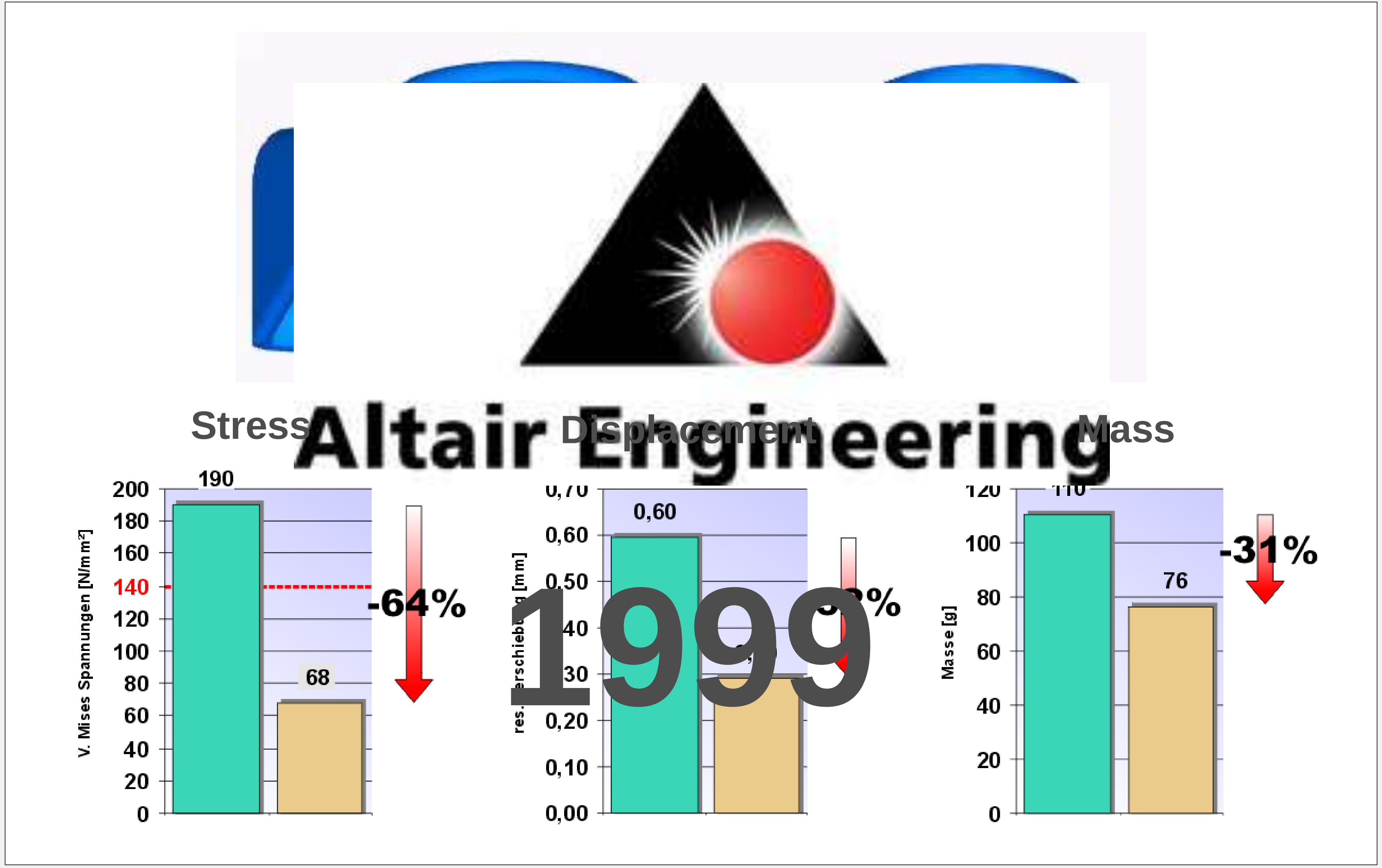
Redesign with Improved Performance / Weight

Radiator Bracket



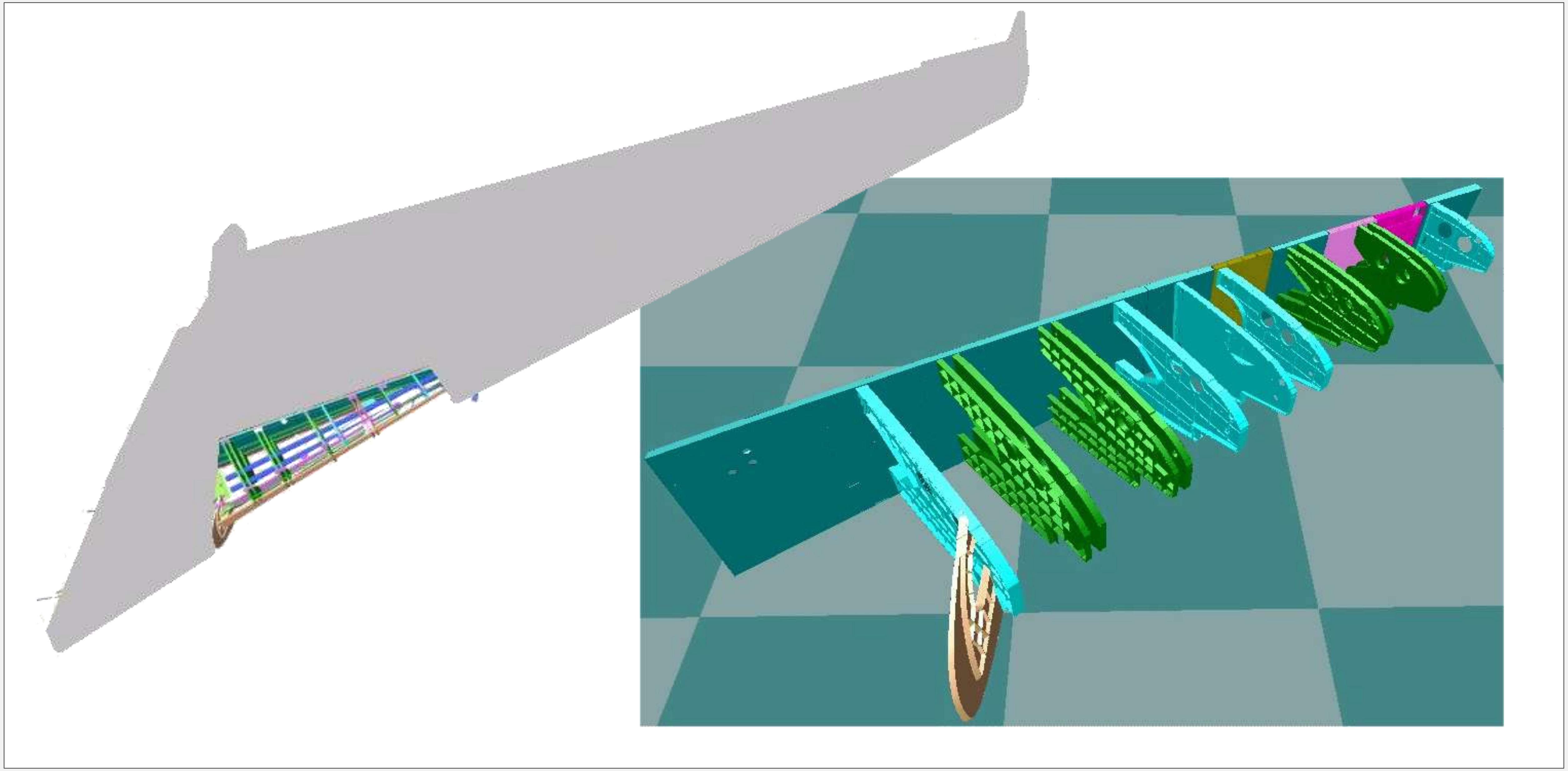


Radiator Bracket



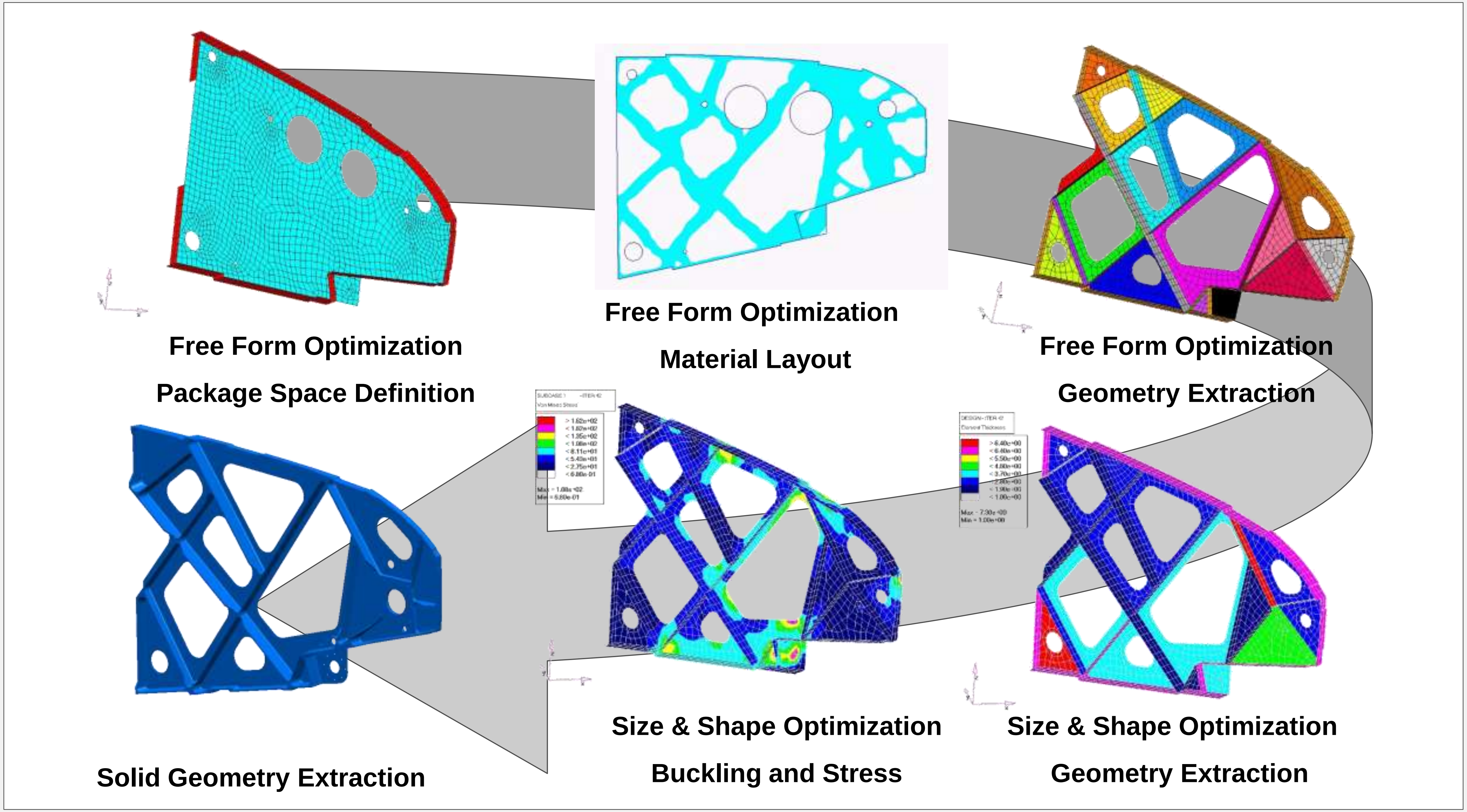
Significantly Increased Performance Characteristics

Airbus A380 Wing Rib



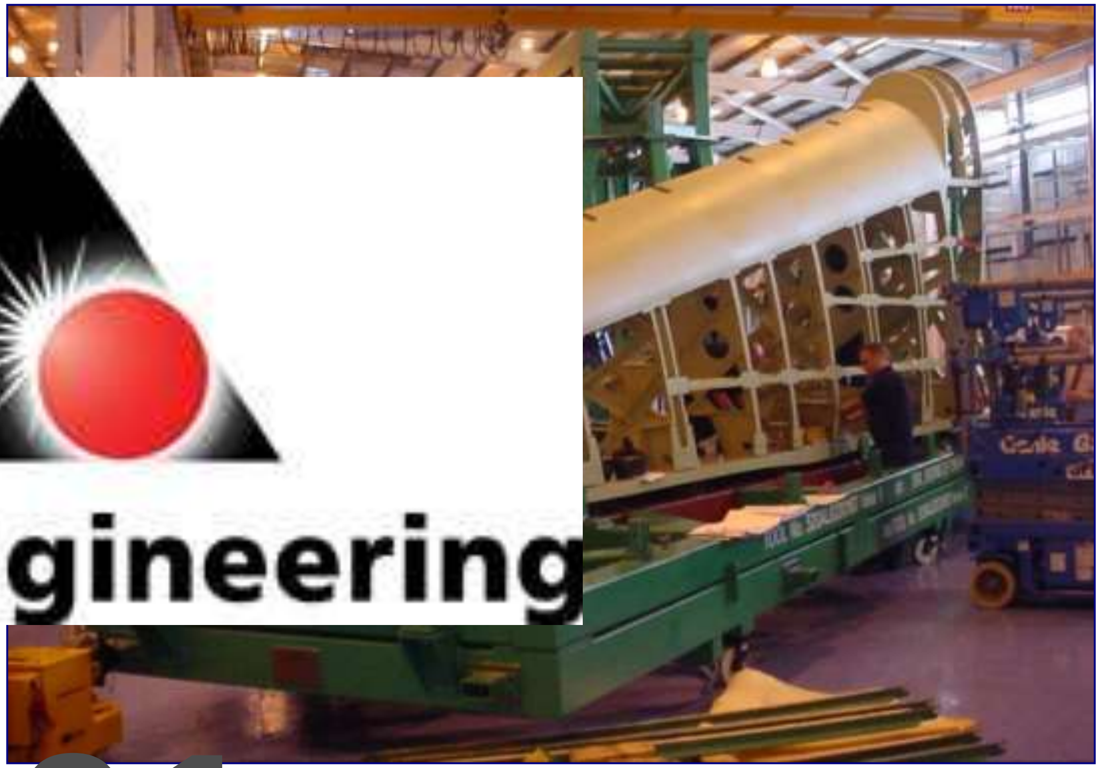
Traditional Design Delivered a Weight Challenge

Airbus A380 Wing Rib



Airbus A380 Wing Rib

Altair Engineering



2001

"Through collaborative partnerships with Altair, an innovative rib design resulted in **over 500kg saving per aircraft**"

BAE SYSTEMS **Press Release**

AM Product Development

Complimentary Technologies

Product Industrialization

AM Design Challanges

Differenciated View – „What is Additive Manufaccturing?“

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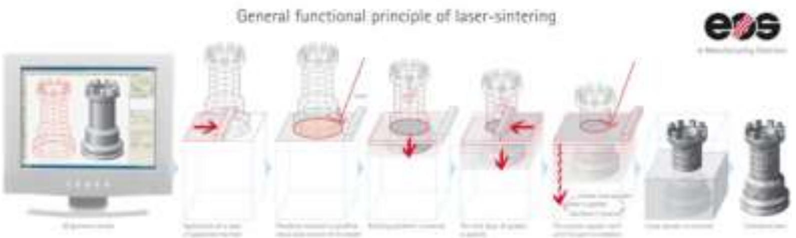
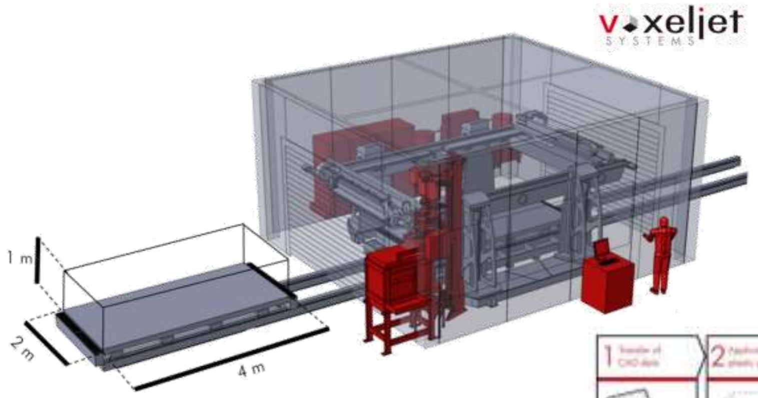
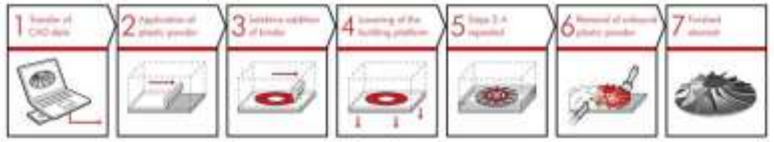
- Stereolithography
- Digital Light Processing
- **Fused Deposition Modeling - Thermoplastic extrusion (filament)**
- Inkjetted photopolymers
- wax deposition modeling
- Selective Laser Sintering plastics / metals
- **Selective Laser Melting of plastics / metals**
- Electronic Beam Melting
- Blown metal powder Welding
- **Sand binding**
- Binder jetted into metal powder (by ExOne)
- Smooth Curvature Printing (by Solidscape)
- Selective Deposition Lamination (by Mcor Technologies)
- Laminated Object Manufacturing
- **Hybrid CNC**
- …



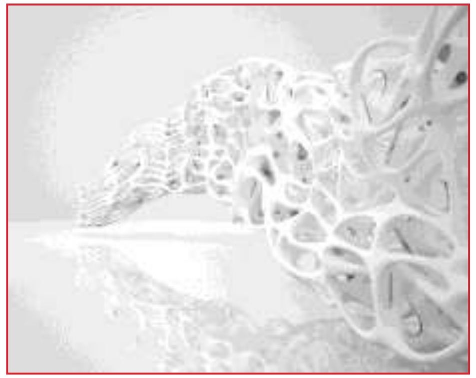




How to get an added value from 3D printing

Complexity for free!

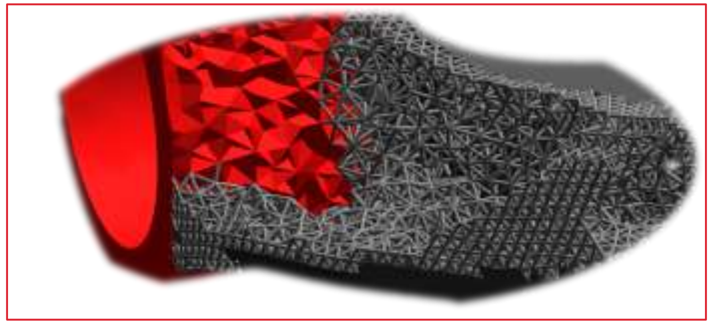
How to convert the freedom into performance?











When does a part qualify for Additive Manufacturing?

Laser Additive Manufacturing is only interesting when minimum one of the following criteria is fulfilled:

- Conventionally hard to manufacture
- Improvement of the product performance by utilizing the design freedom
- low quantity
- Possible integration of functionality
- High part complexity

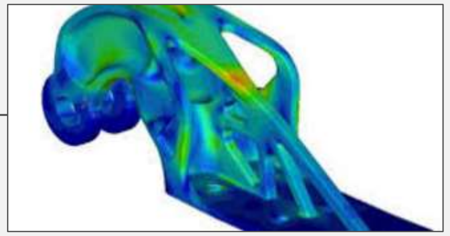
Quelle: autoneticind.com; forgingmanufacturer.com; masscustomization.blogscom; honeybuild.com; renishaw.com; os-gmbh.com; hrsflow.eu

content & pictures by courtesy of Laser Zentrum Nord

Complementary Technologies

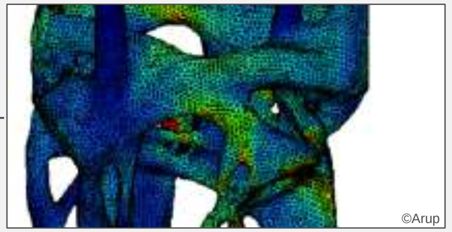
AM + **Topology Optimization**

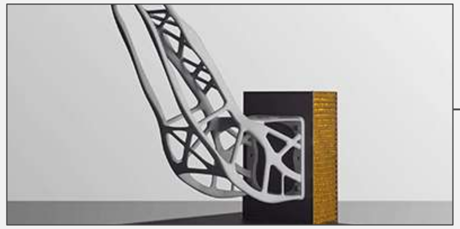
Geometric Freedom



Injects Innovation

Design Individuality

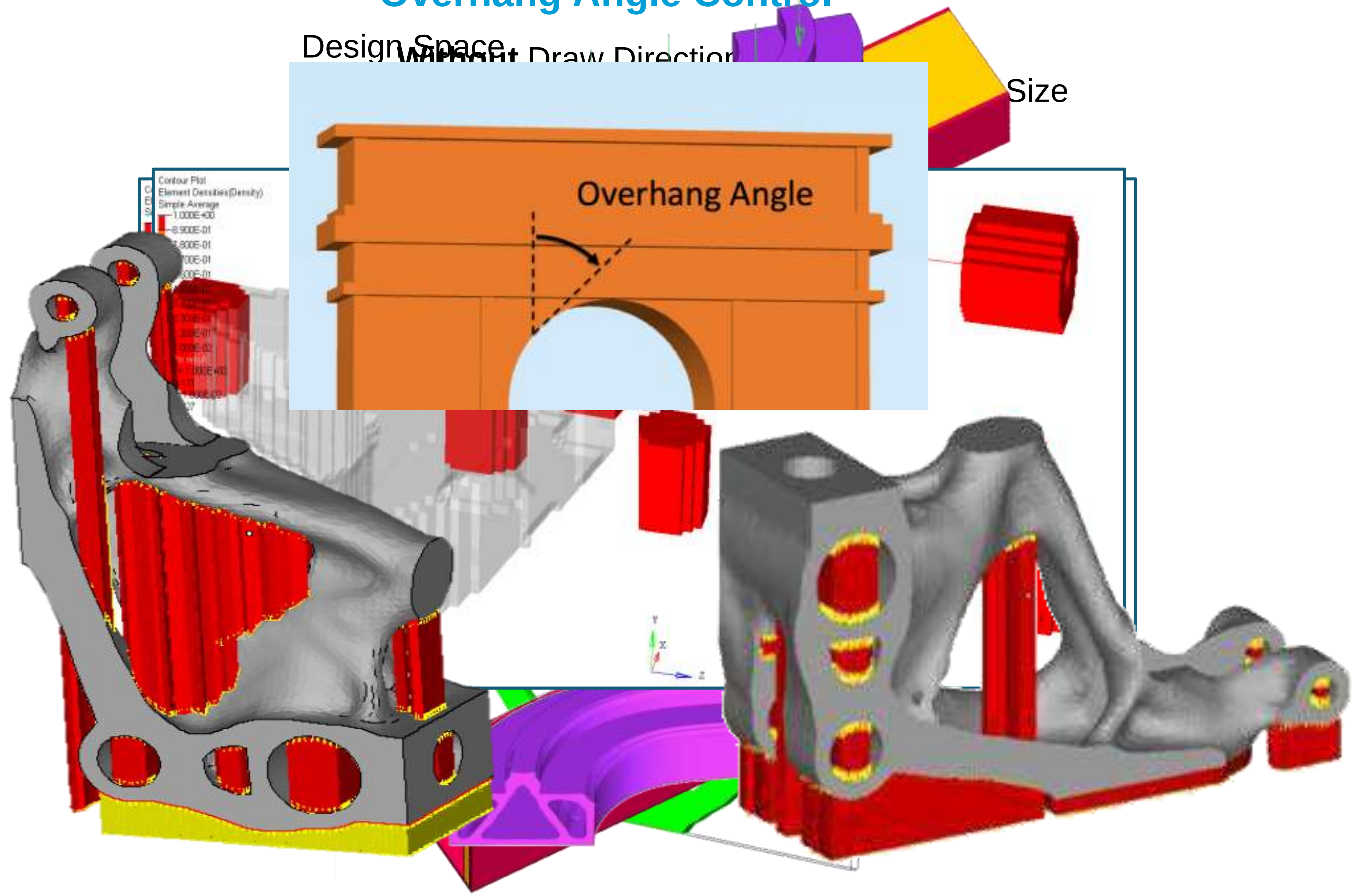




Accelerated Product Development

Product Industrialisation - Manufacturing

Minimise Support Structure by Overhang Angle Control



The Additive Manufacturing Design Challenge

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3

challenges when designing for AM

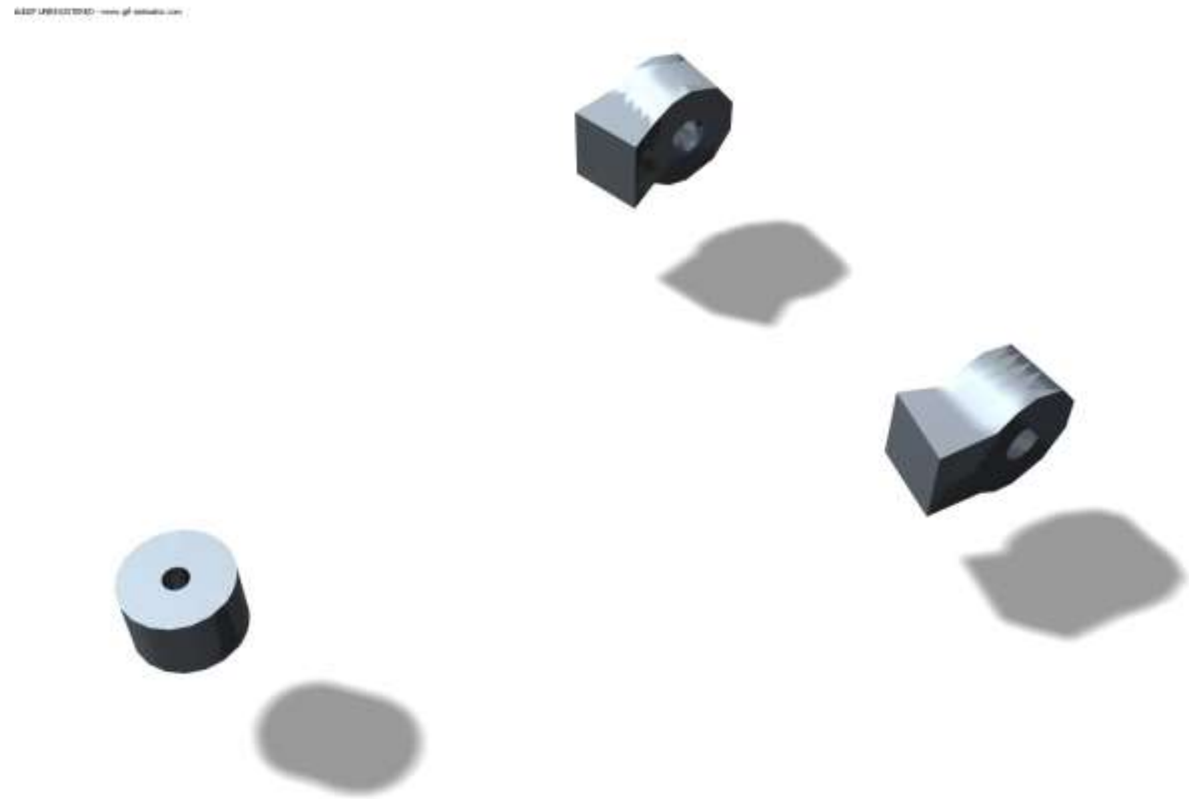
1

How can a designer come up with the best possible shape?

picture by courtesy of Laser Zentrum Nord

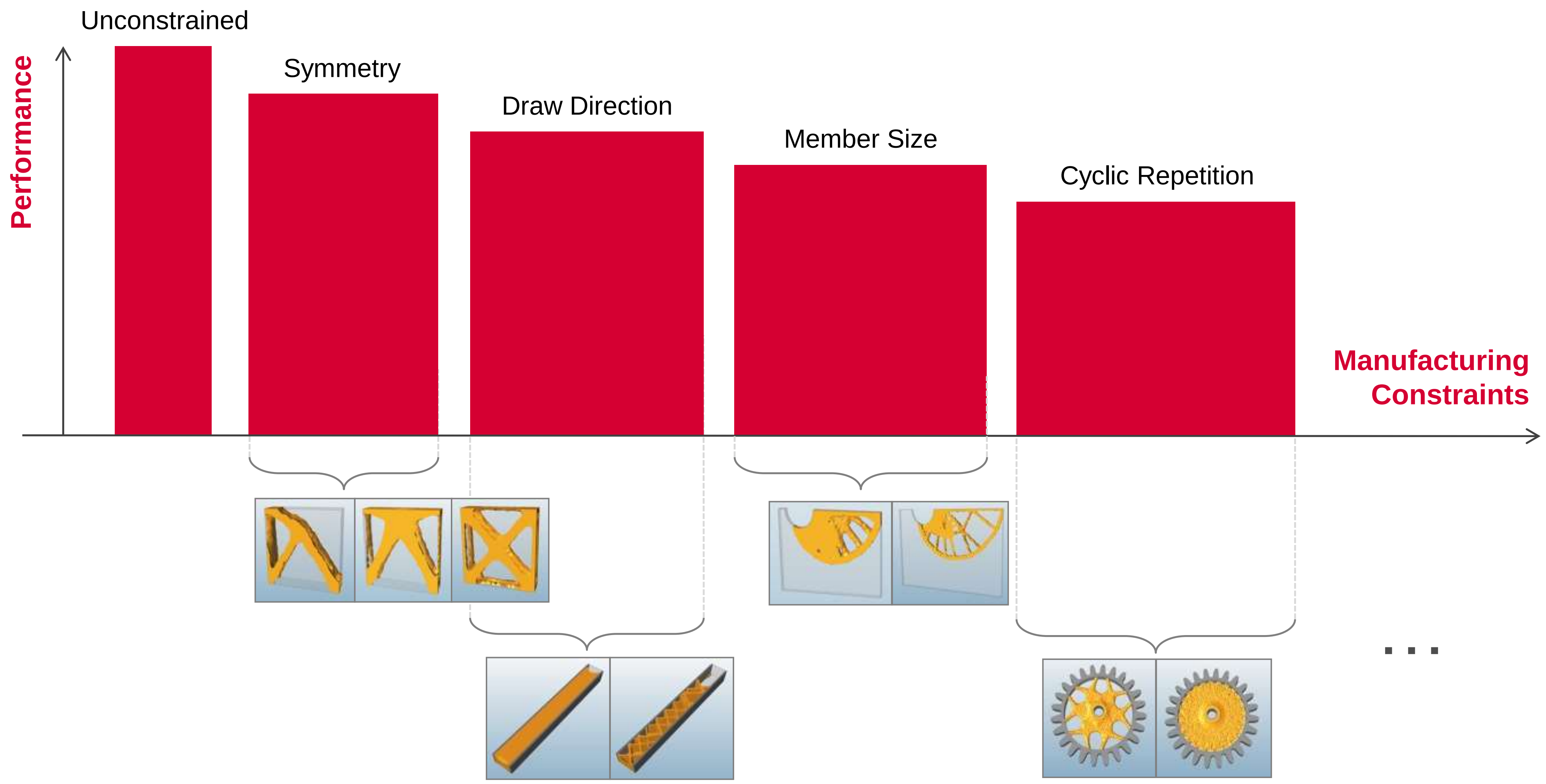
Solution #1:

Topology Optimization



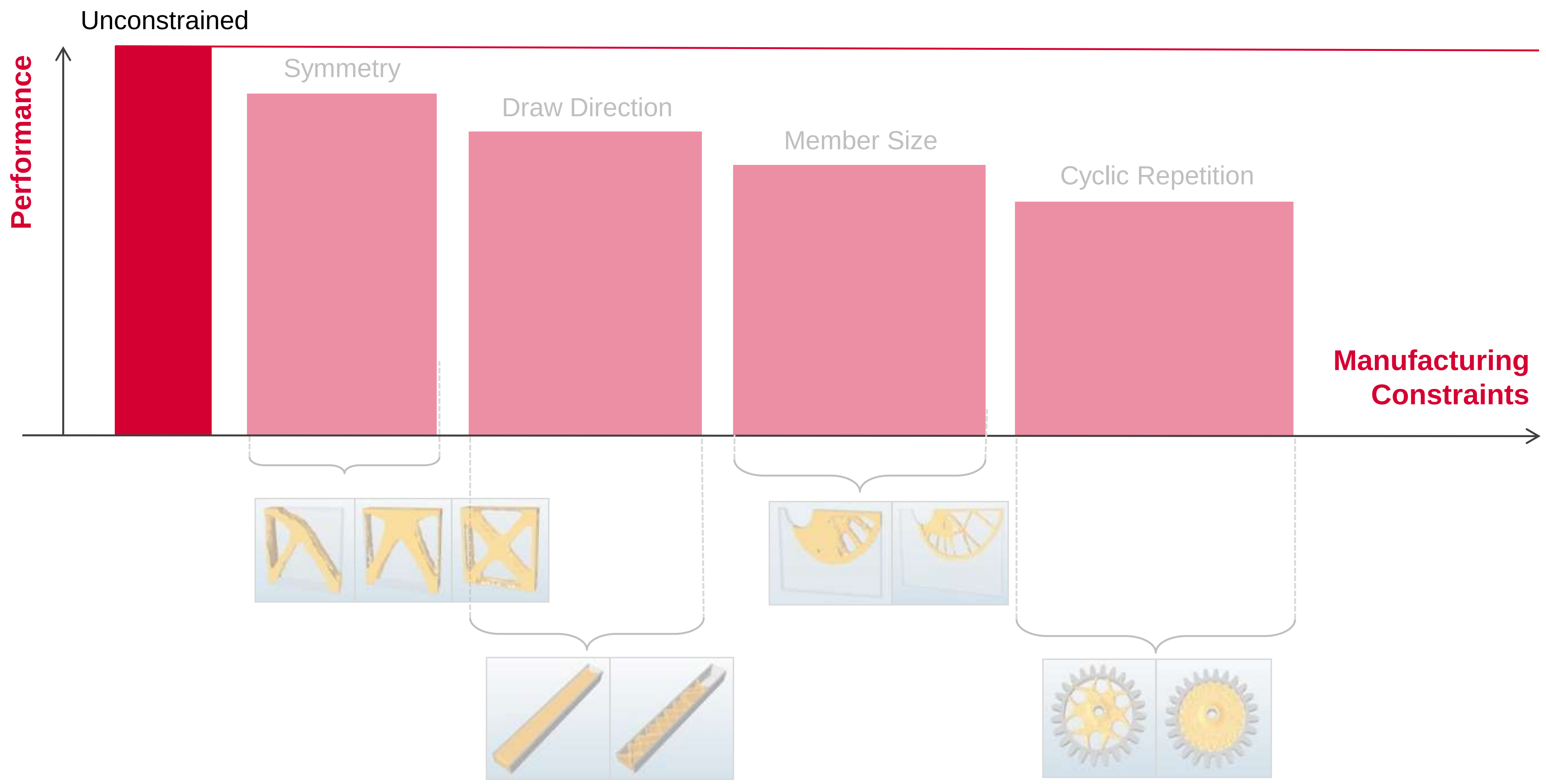
Technology symbiosis

Topology optimization provides the most efficient structure for a given load situation, but for traditional manufacturing designers always have to **trade performance for manufacturability**!



Technology symbiosis

Topology optimization provides the most efficient structure for a given load situation, with added manufacturing designers **no more** have to **trade performance for manufacturability**



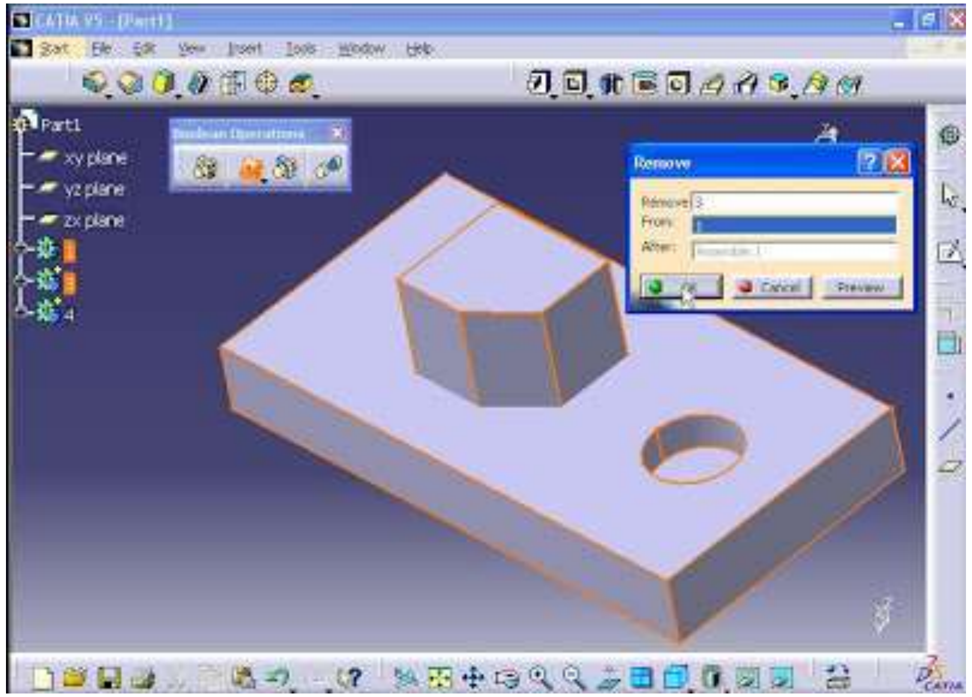
“Industrialization” of Topology Optimization

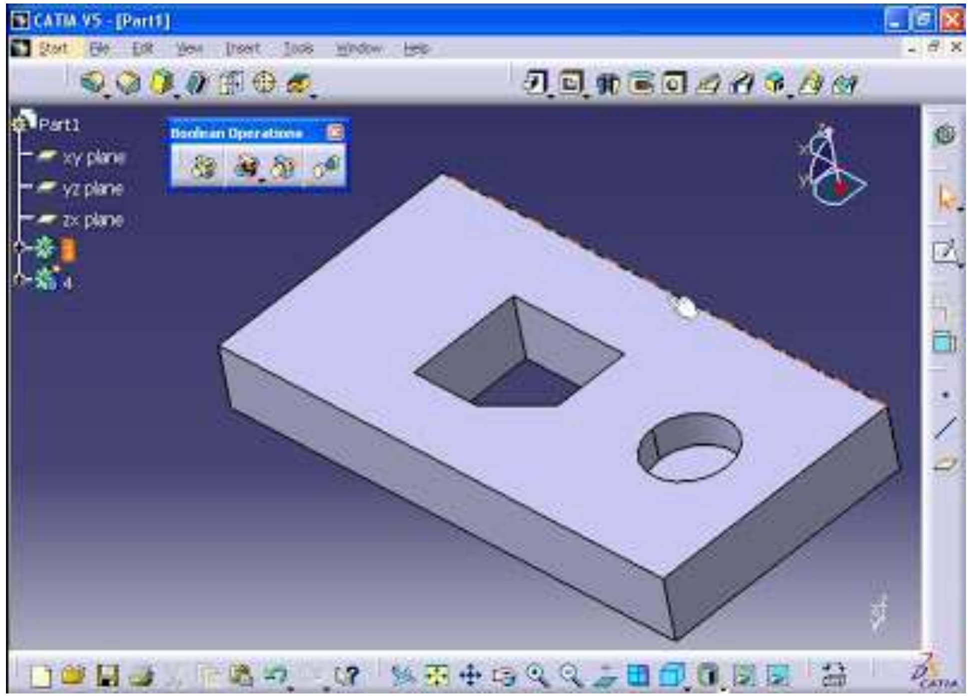
2

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

Valve Block Redesign

Nurmi / VTT Technical Research Centre of Finland

Topology Optimization with OptiStruct

Result Interpretation using OSSmooth

Materialise 3-matic STL Model

Analysis of the Redesign in OptiStruct

Optimal Fluid Flow

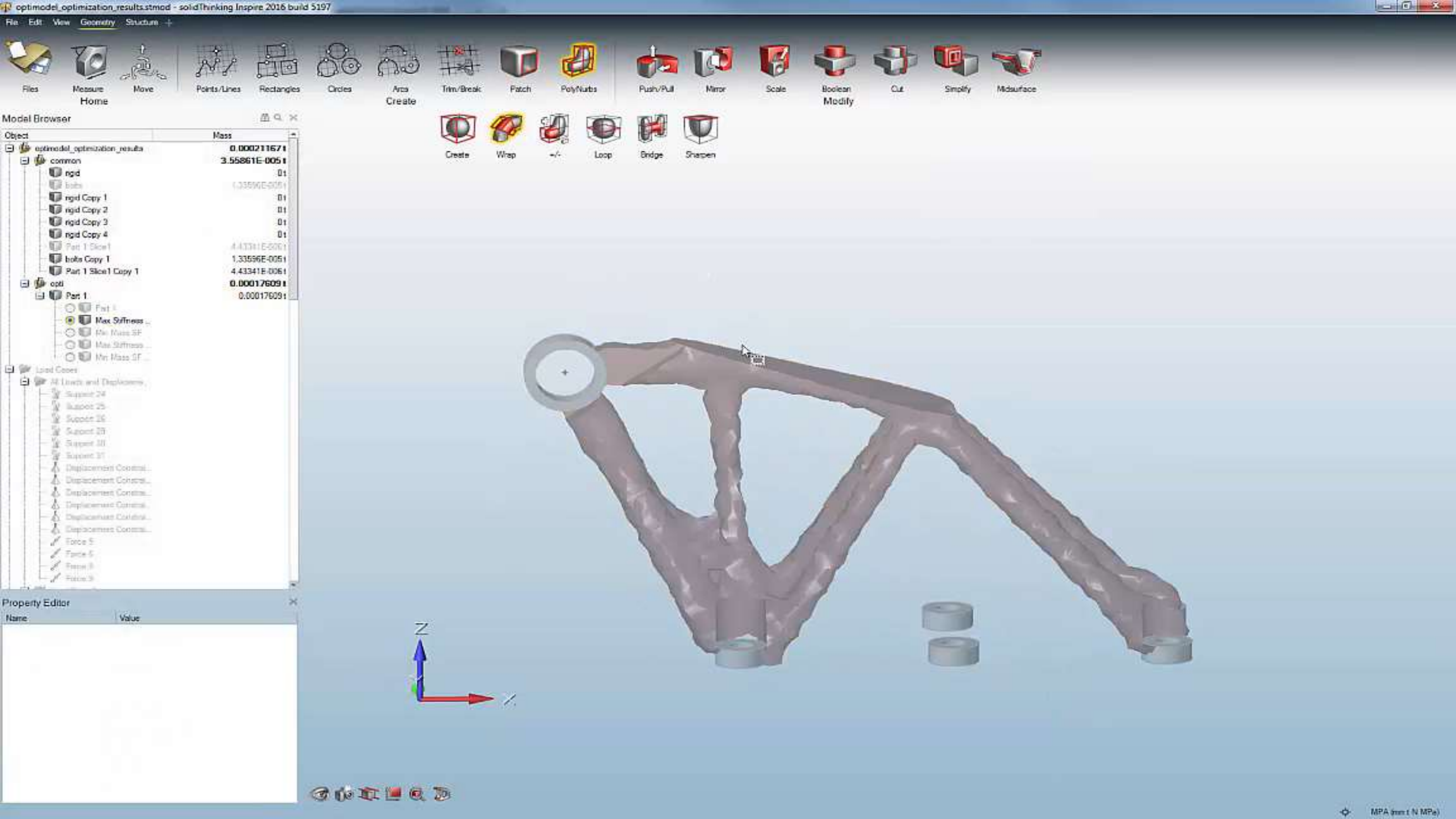
67 % Weight Reduction

„CAD Free“ _Realization

Solution #2:

Hybrid Modelling
Direct + Boolean

New
Polynurbs Design Technology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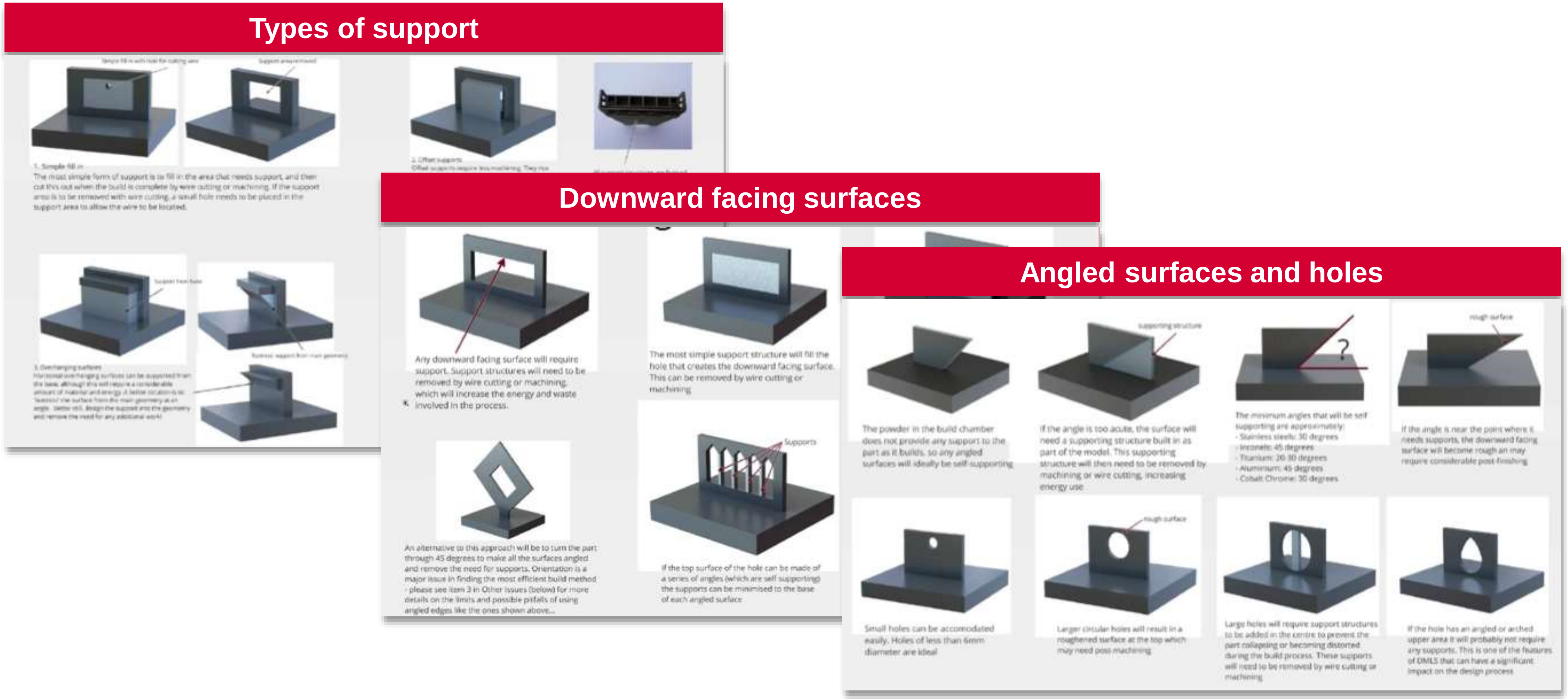
3

How to consider the NEW Manufacturing Constraints?

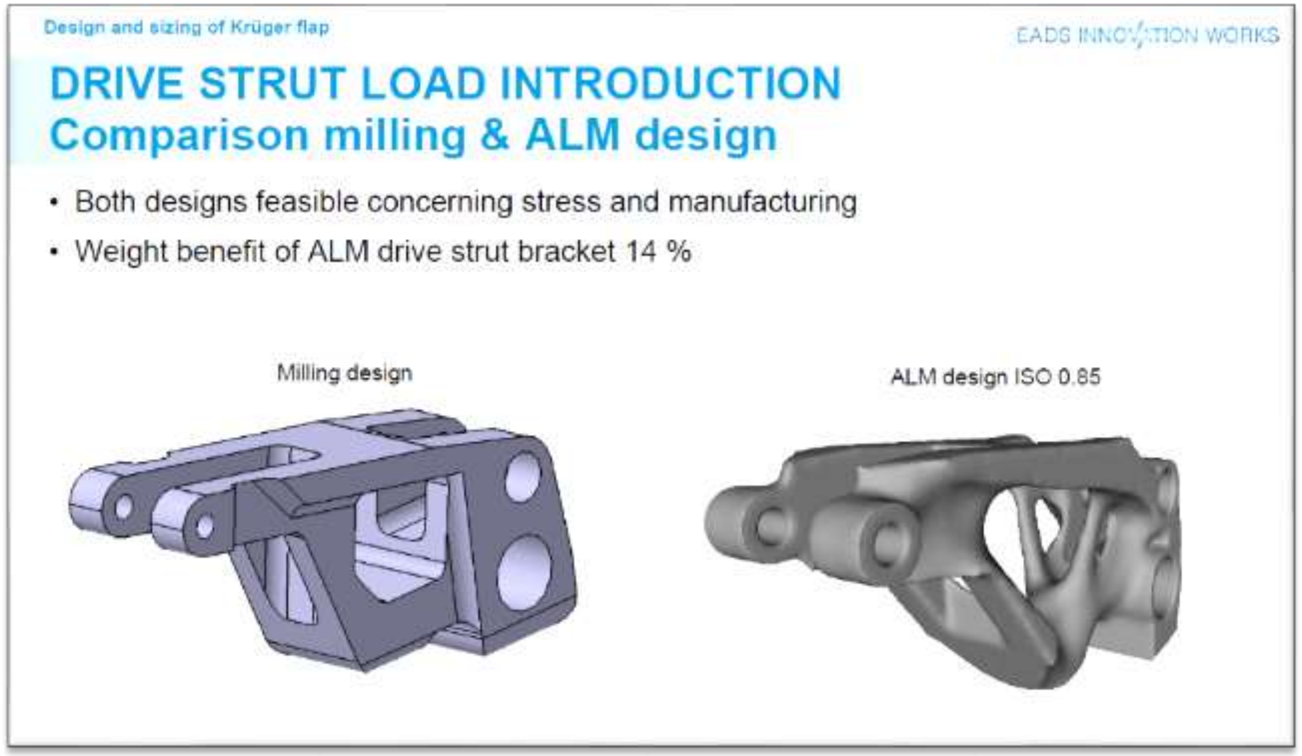


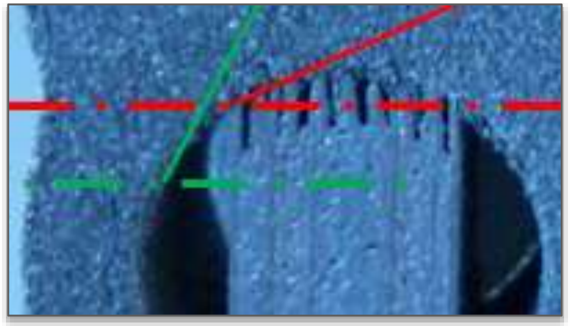
http://www.manufacturingthefuture.co.uk/design-guidelines/

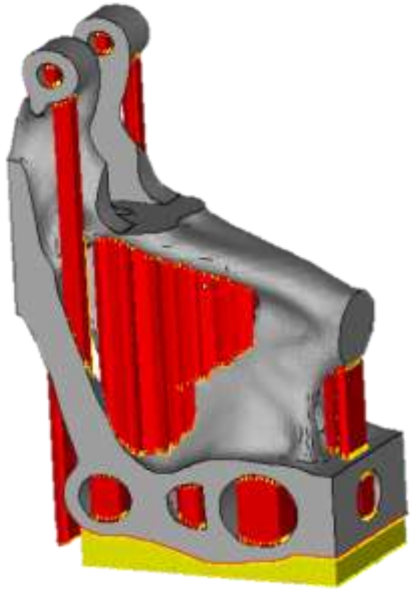
plunkett associates simpleware eos Delcam crucible UNIVERSITY OF EXETER

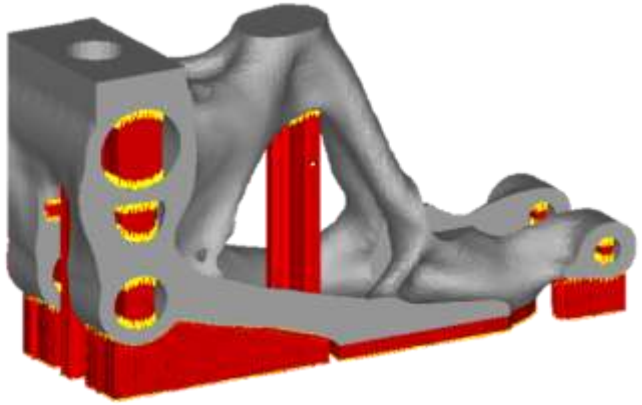
How to reduce support structures?

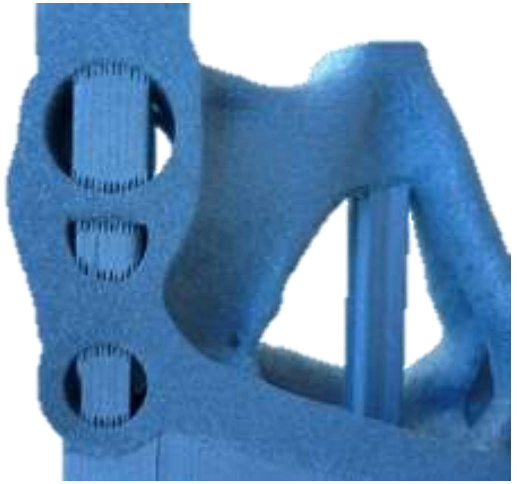
- **We are working on it!**











Wolfgang Machunze, EADS
Topology Design of a Metallic Load Introduction Bracket Manufactured by ALM
Altair Technology conference 2014, Turin

Solution #3.1. : design rule catalogues

Solution #3.2. : manuf. constraint implementation


AIP | Journal of Laser Applications
published in partnership with AIP Publishing

Design guidelines for laser additive manufacturing of lightweight structures in TiAl6V4

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

Citation: Journal of Laser Applications **27**, S14001 (2015); doi: 10.2351/1.4885235
View online: http://dx.doi.org/10.2351/1.4885235
View Table of Contents: http://scitation.aip.org/content/lia/journal/jla/27/S1?ver=pdfcov
Published by the Laser Institute of America

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Surface structuring by remelting of titanium alloy Ti6Al4V
J. Laser Appl. **27**, S29103 (2015); 10.2351/1.4906387

Mechanical response of TiAl6V4 lattice structures manufactured by selective laser melting in quasistatic and dynamic compression tests
J. Laser Appl. **27**, S17006 (2015); 10.2351/1.4888835

Mechanical stability of Ti6Al4V implant material after femtosecond laser irradiation
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Tolerances of joint gaps in Nd:YAG laser welded Ti-6Al-4V alloy with the addition of filler wire
J. Laser Appl. **23**, 012004 (2011); 10.2351/1.3554266

Effect of phase transformations on laser forming of Ti–6Al–4V alloy
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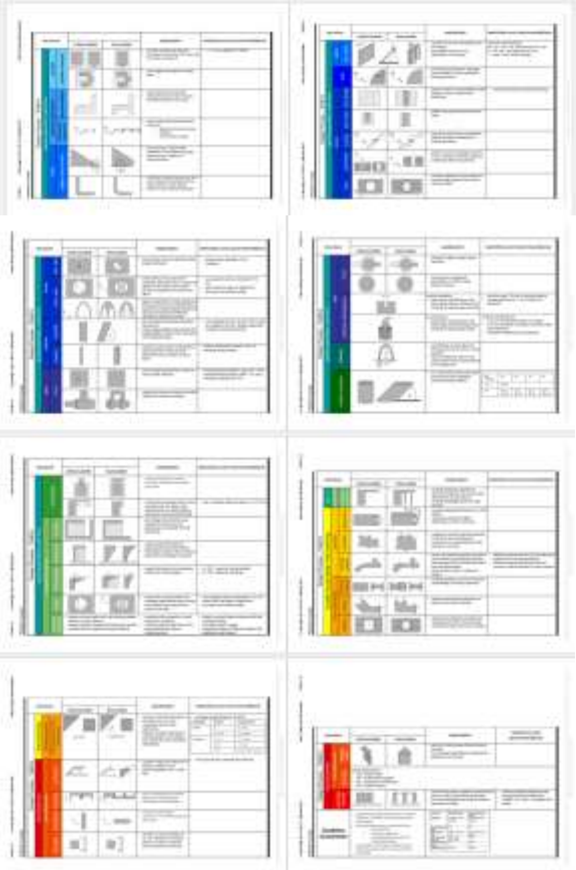
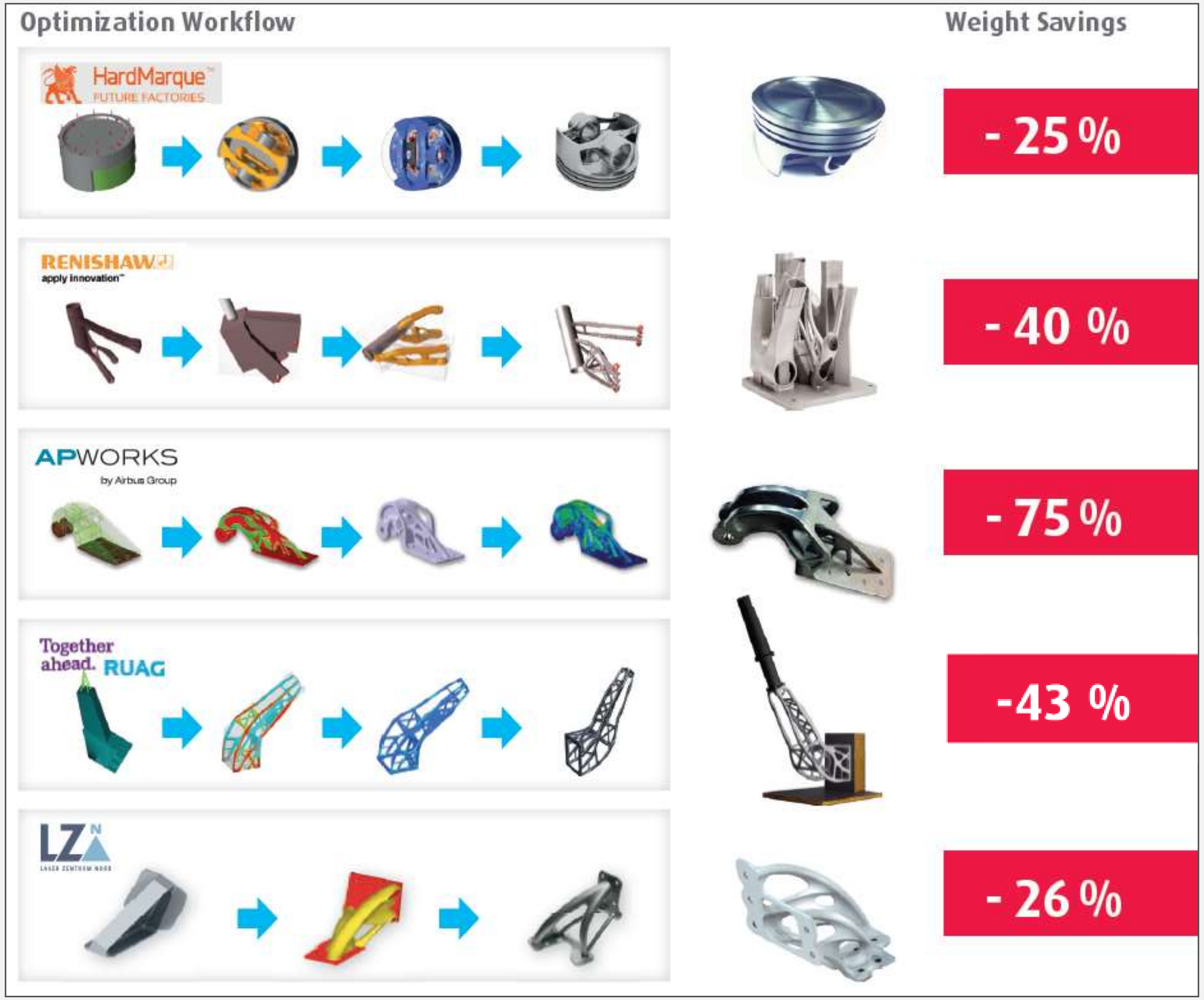


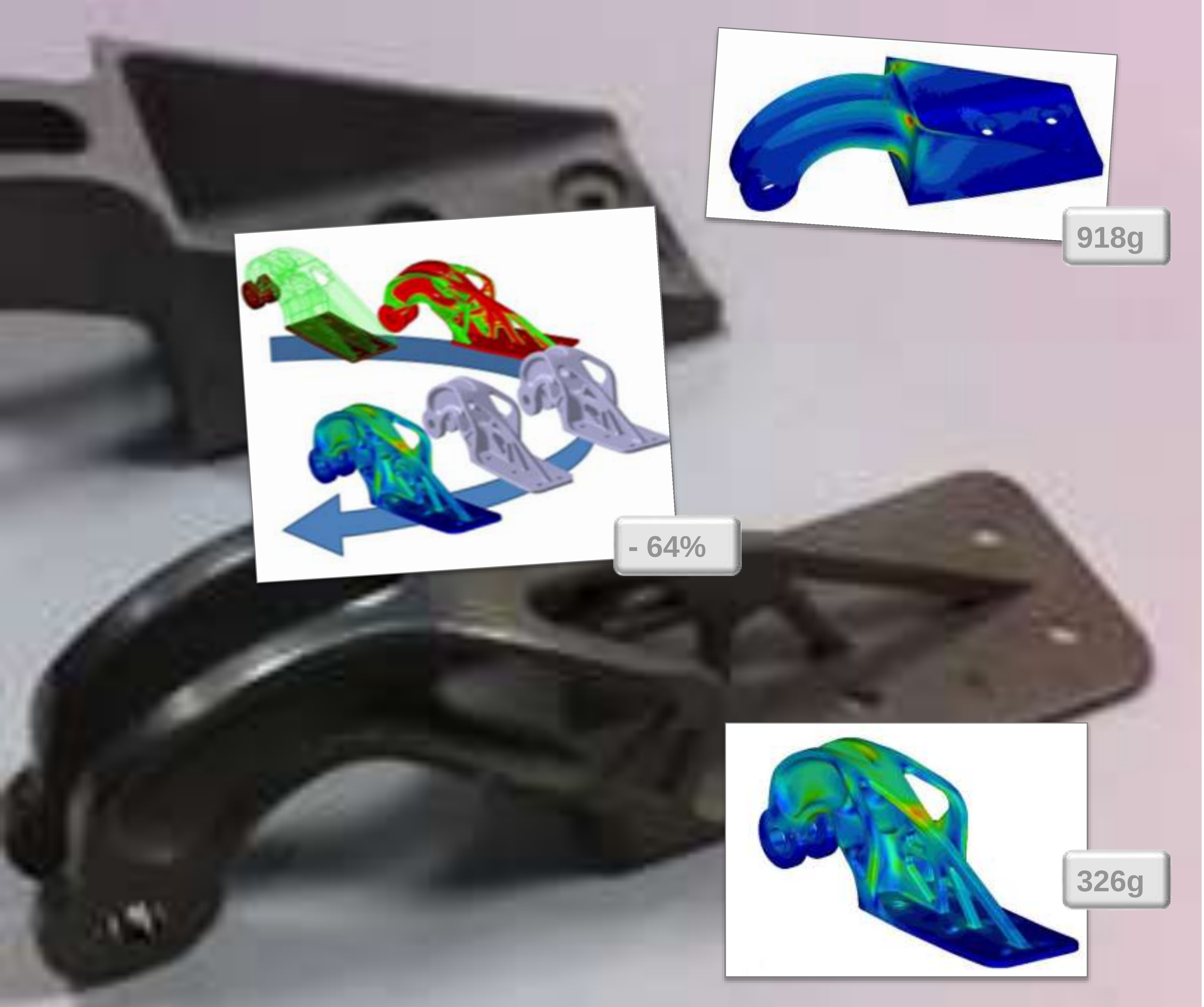
AM Overhang Angle constraint

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

Innovation Examples

A Partnership Delivering Product Innovation





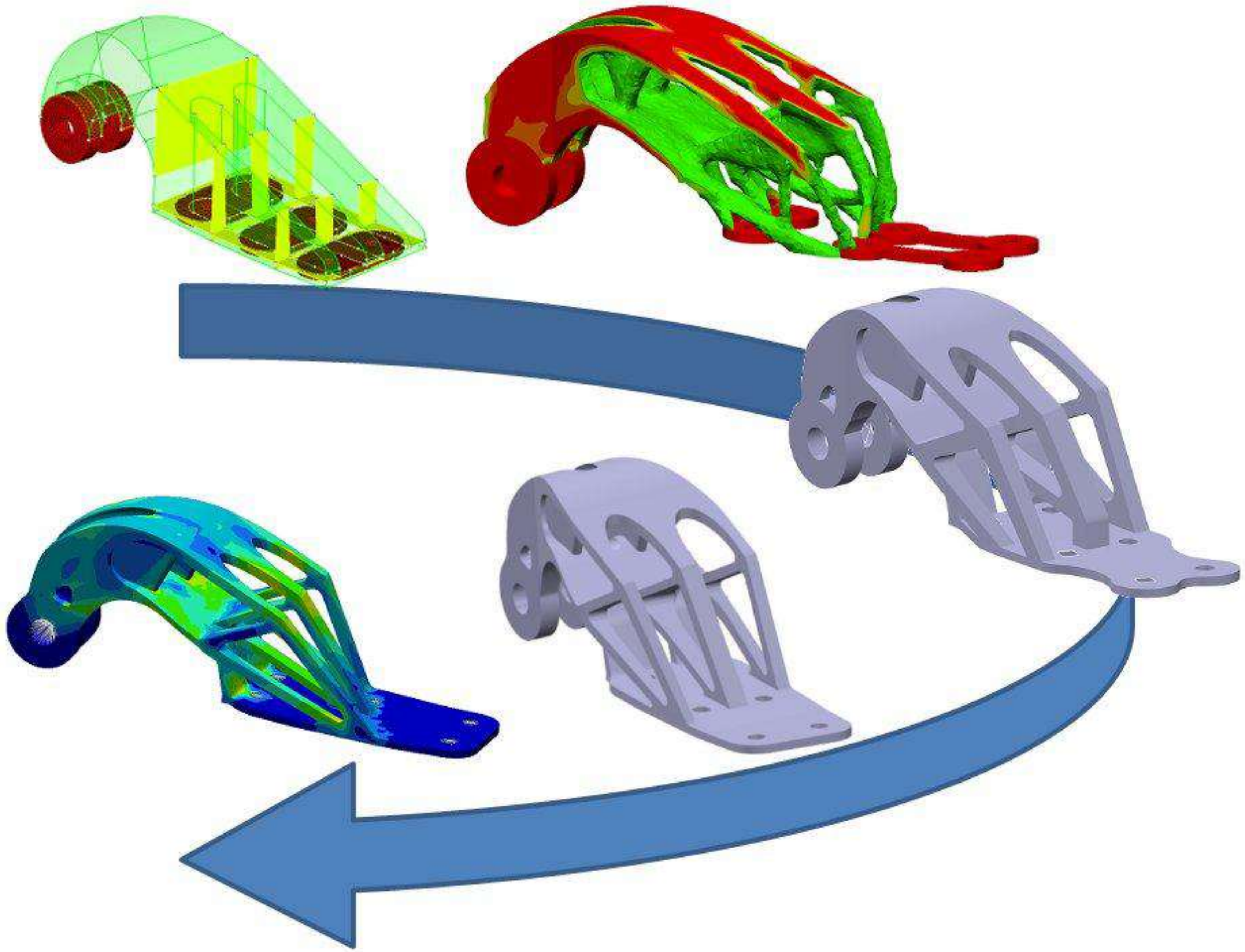
Unlock the ***lightweight*** *potential of* ***ALM*** *with* ***concept optimization*** *for* ***EADS IW***

"OptiStruct allowed us to maximize the weight saving benefits of the ALM process."

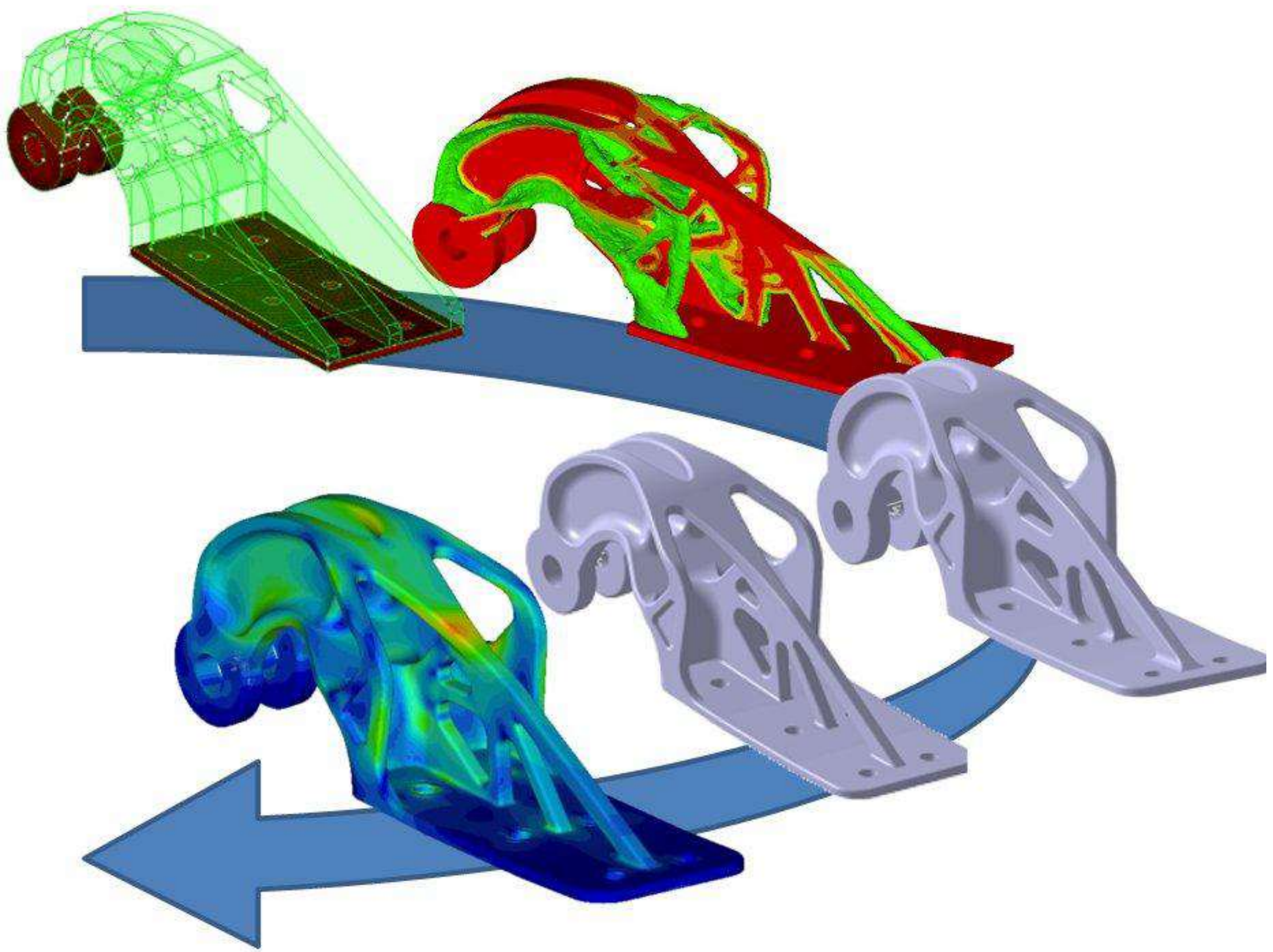
Jon Meyer EADS Innovation Works

Altair | HyperWorks®

Engineering ability

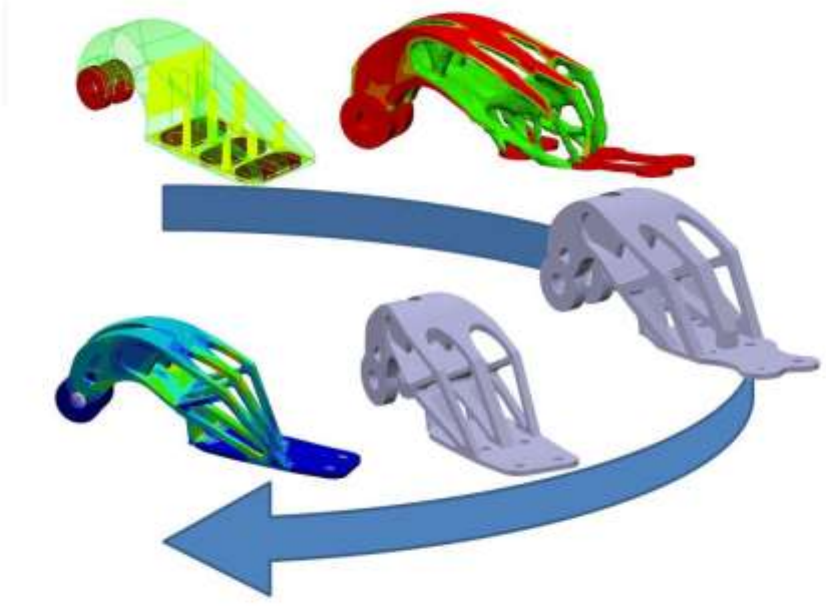


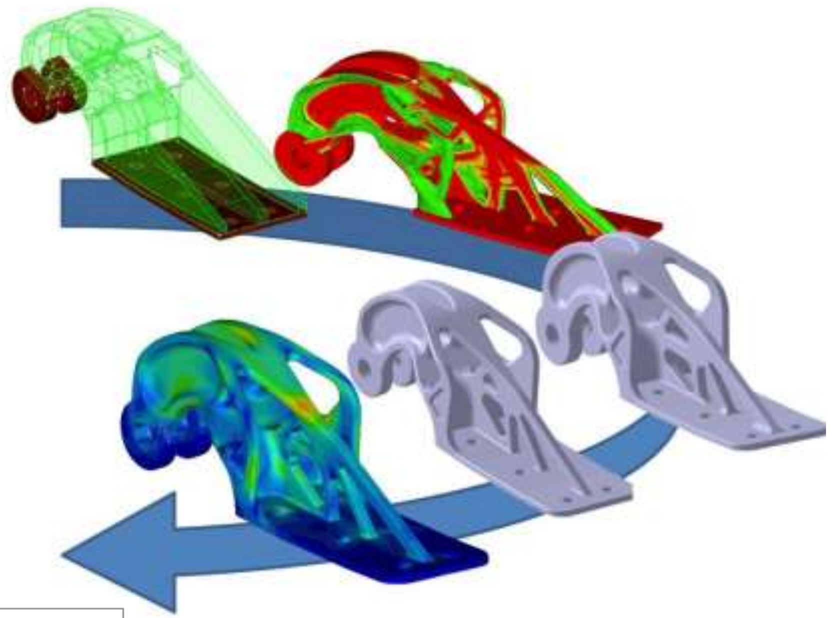
Engineering ability



Engineering ability

- Front loading
- Only the right assumptions lead to the desired result





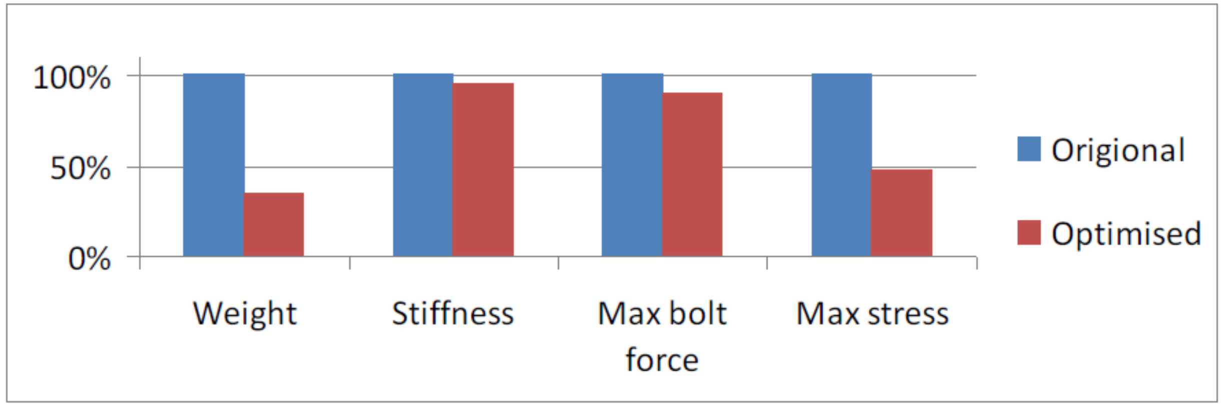


Figure 10: Performance comparison of original and new design

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

Matthew Tomlin
Intern, EADS Innovation Works

and

Jonathan Meyer
Research Team Leader, EADS Innovation Works

EADS

EADS

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.

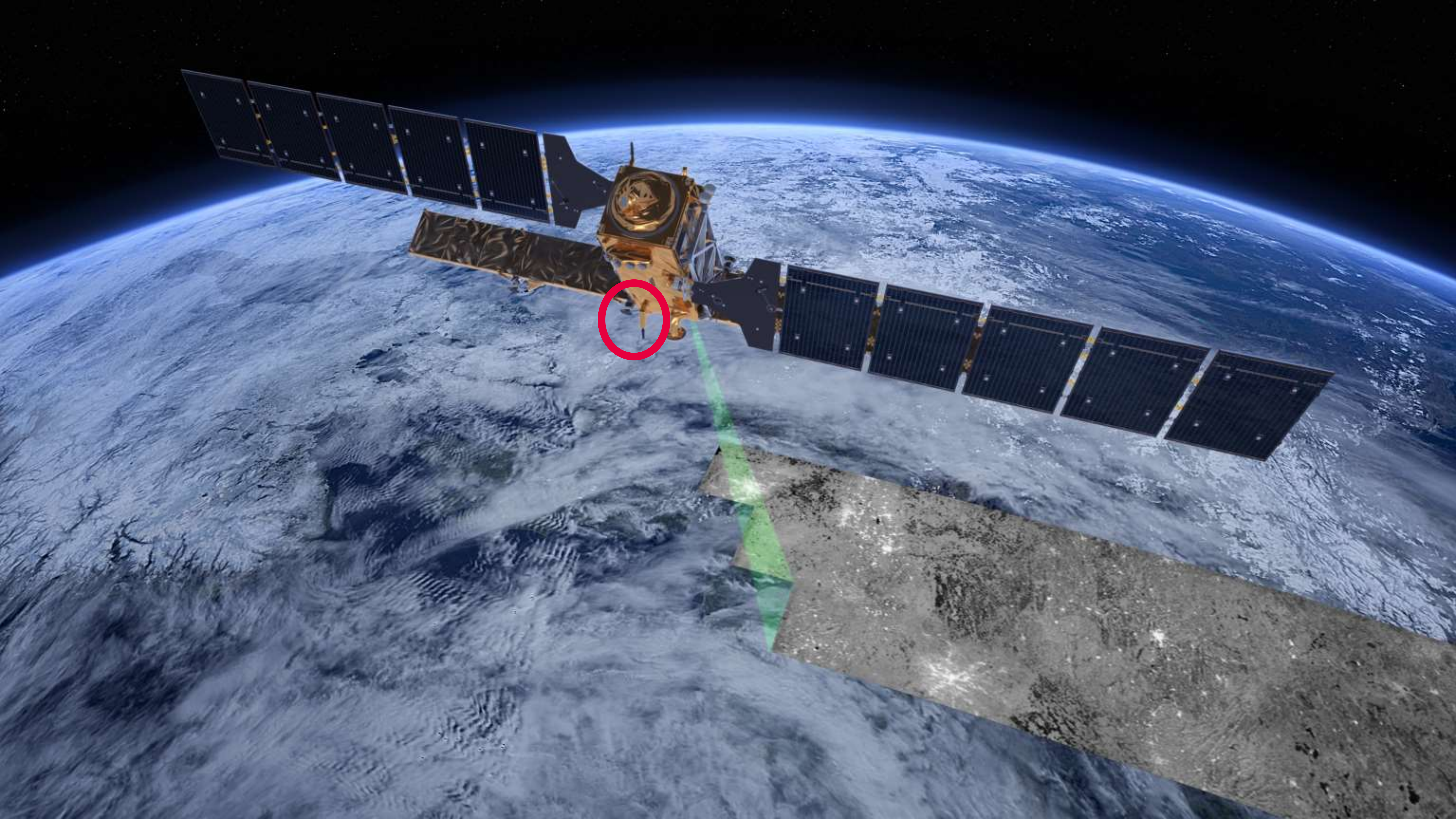
Keywords: Optimization, OptiStruct, topology

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

From the Printer into Space

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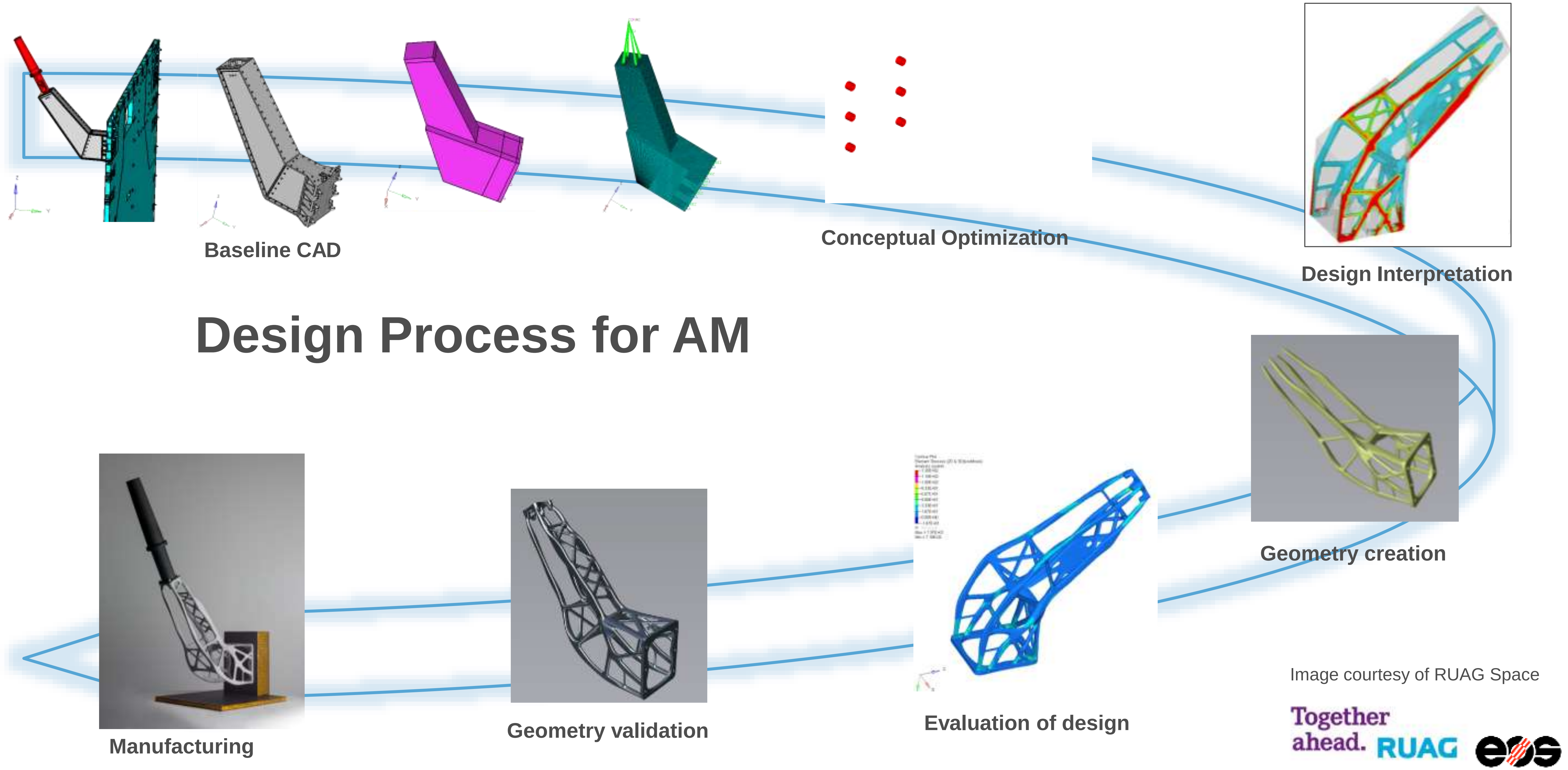
3D Printed Antenna Bracket for Sentinel-1 Satellite:

- **43% weight reduction** (from 1.626 kg to 0.936 kg)
- Increased Eigen frequency (70Hz → 90 Hz)
- Improved static behaviour, strength, stiffness, stability

Together ahead. RUAG

eos

From the Printer into Space



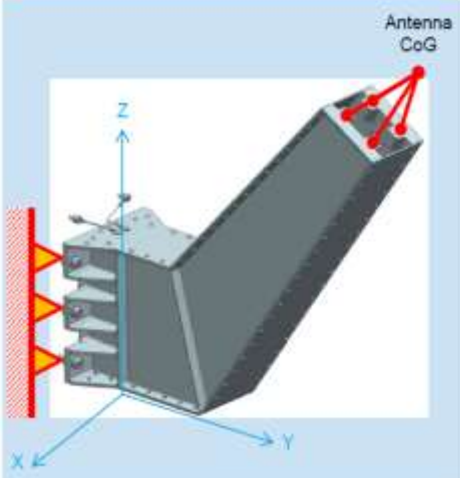
Model preparation

Model Preparation → Conceptual Optimization → Concept Interpretation → Concept Design → Detailed Optimization → Stress Verification → Additive manufacturing

Understand design requirements

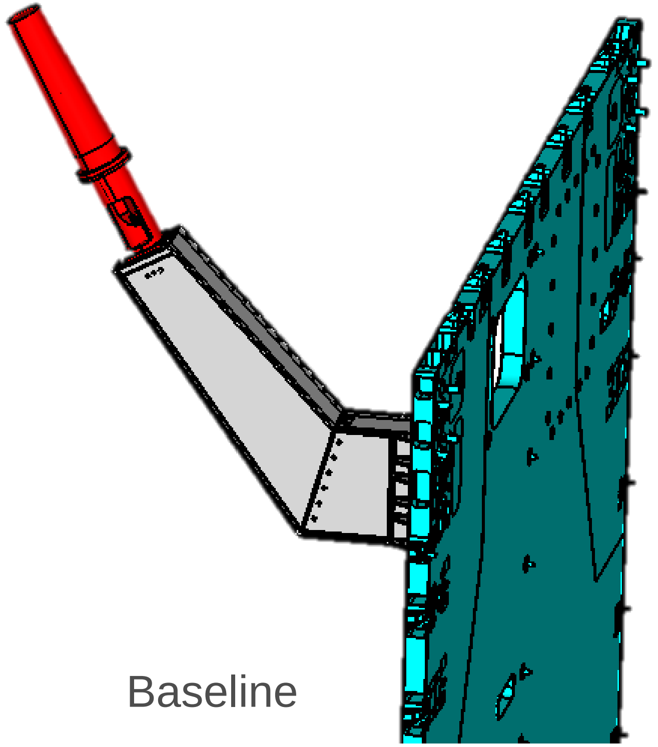
- Generation of Design Space
- Generate Optimization setup
  - Proper mesh
  - Proper BCs
  - Proper Optimization definition

Original Design

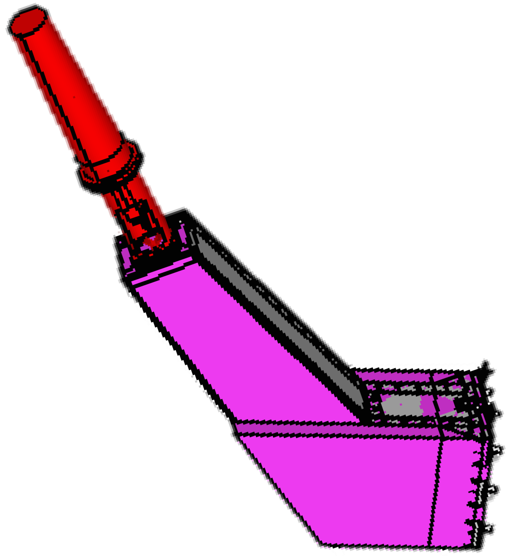


Specification

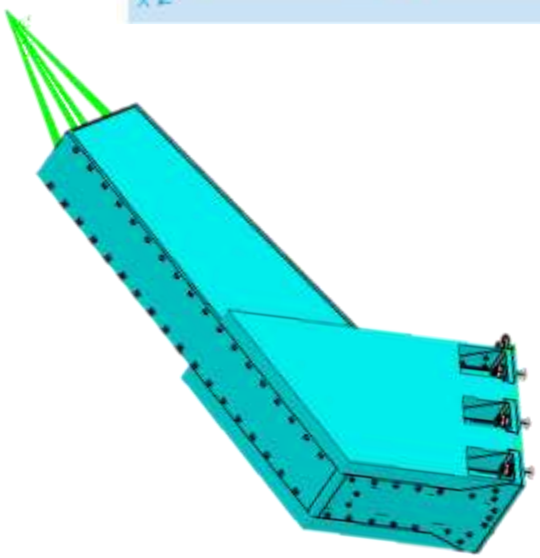
Eigenfrequency	> 70Hz
Boundary condition	Hard Mounted
Dimensions	385 x 345 x 115 mm3
Static Load (QL)	20g (X,Y) / 25g (Z)
S-Band Antenna	0.783kg
CoG Position	X = 436.2mm Y = -1091.8mm Z = 3330.6mm



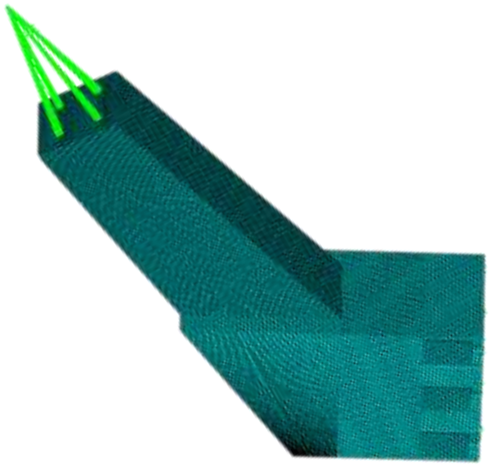
Baseline



Design Space Envelope



Design Space



Hexahedral Elements
Total Elements = 236004

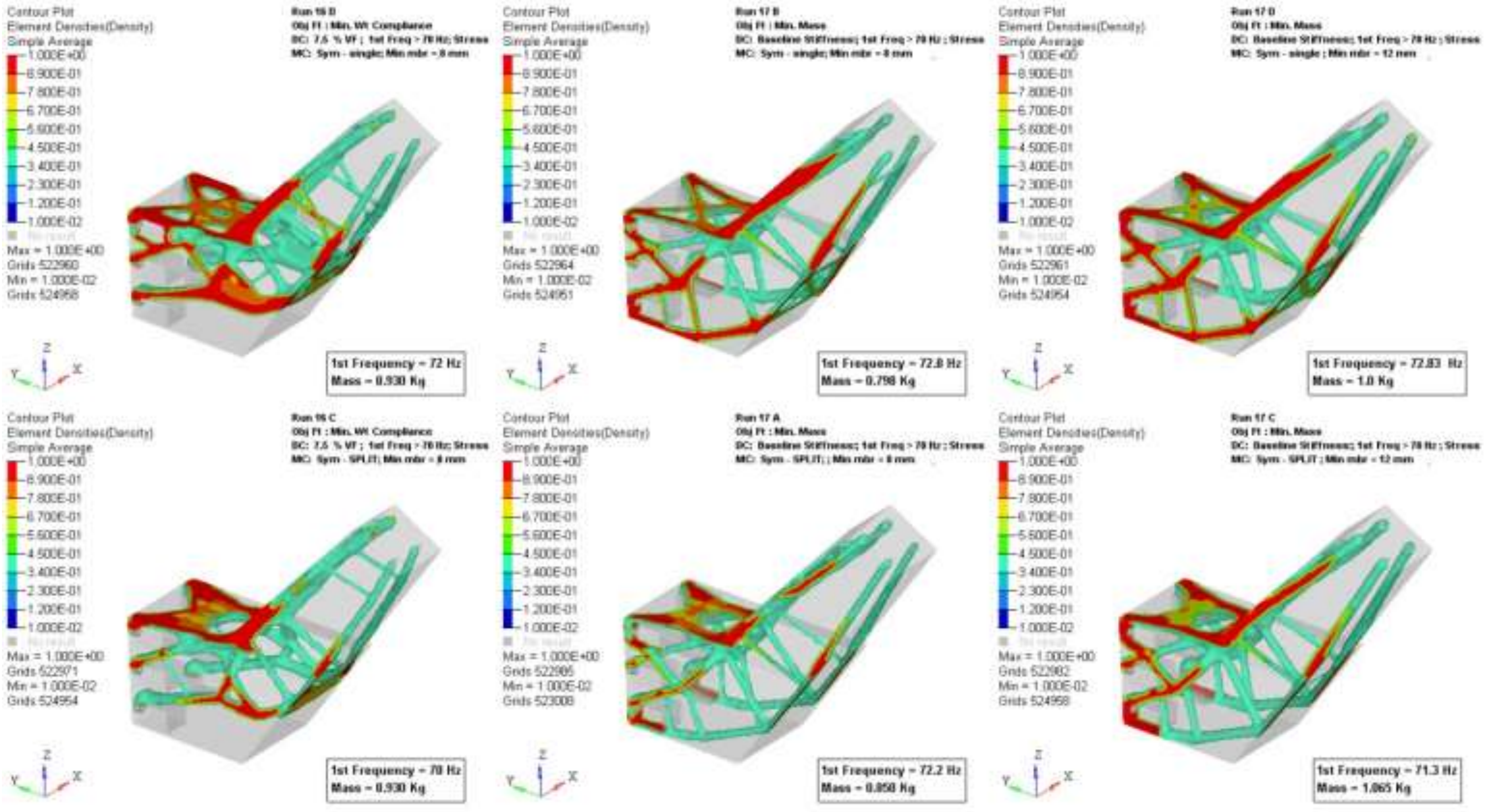
Conceptual Optimization

Altair

Model Preparation → **Conceptual Optimization** → Concept Interpretation → Concept Design → Detailed Optimization → Stress Verification → Additive Manufacturing

Optimization problem formulation:

- **Objective:** Minimize Mass or Compliance
- **Constraints:** Volfrac 20%, 10%, 7.5% / Stress (110MPa) / 1st mode > 70 Hz
- **Variables:** Element densities



Goals of multiple runs:

1. Understand tendency of the optimization
2. Which are the primary and secondary load paths
3. Numerical noise?
4. Explore different designs
5. Observe similarities

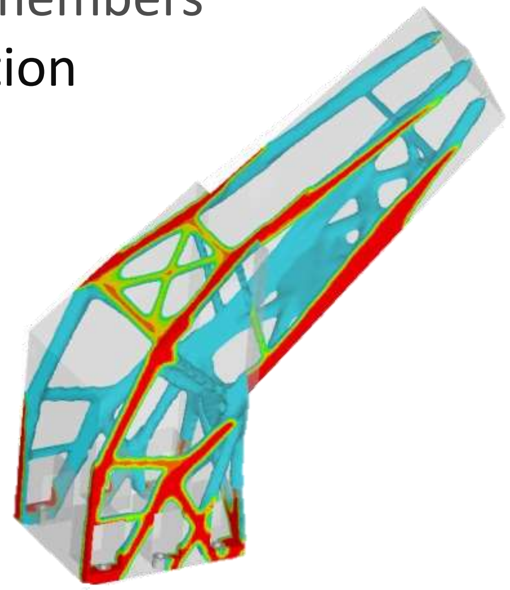
Conceptual Design

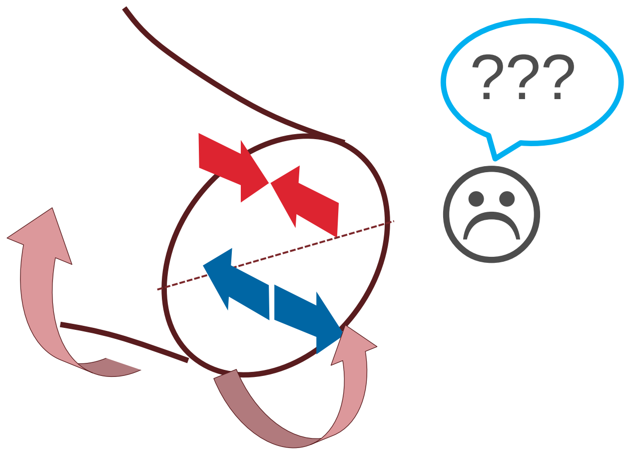
Model Preparation → Conceptual Optimization → **Concept Interpretation** → Concept Design → Detailed Optimization → Stress Verification → Additive Manufacturing

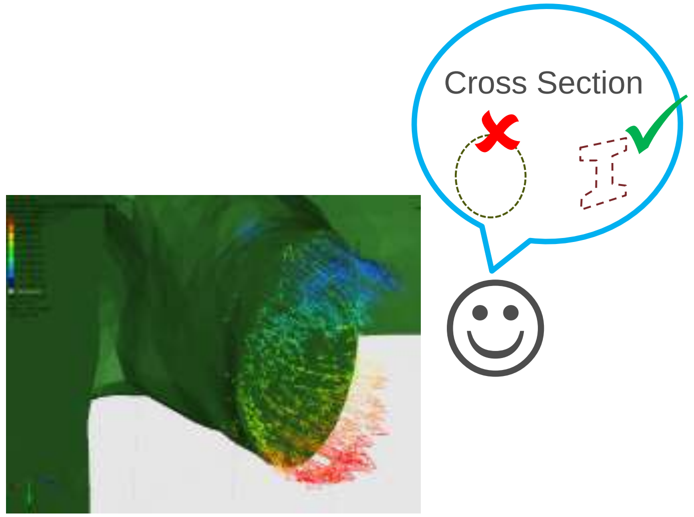
Goal = Obtain easily the right information from the optimization result to make the right decisions for realizing a design

Structural behavior:

- Understanding results of optimization
  - Primary and secondary load paths
  - Local vs Global optima
  - Discrete results
- Cross section behavior
  - Tension-Compression-Shear members
- Stress distribution after optimization
  - Uniform stress







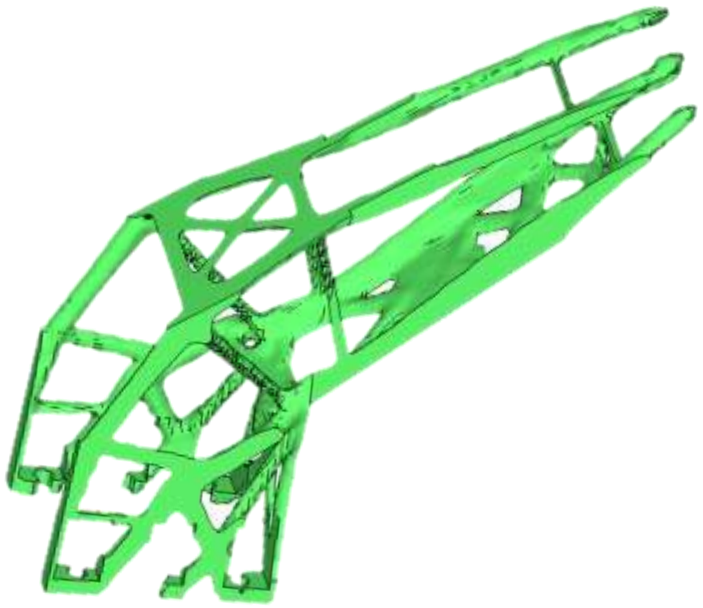
Conceptual Design

Altair

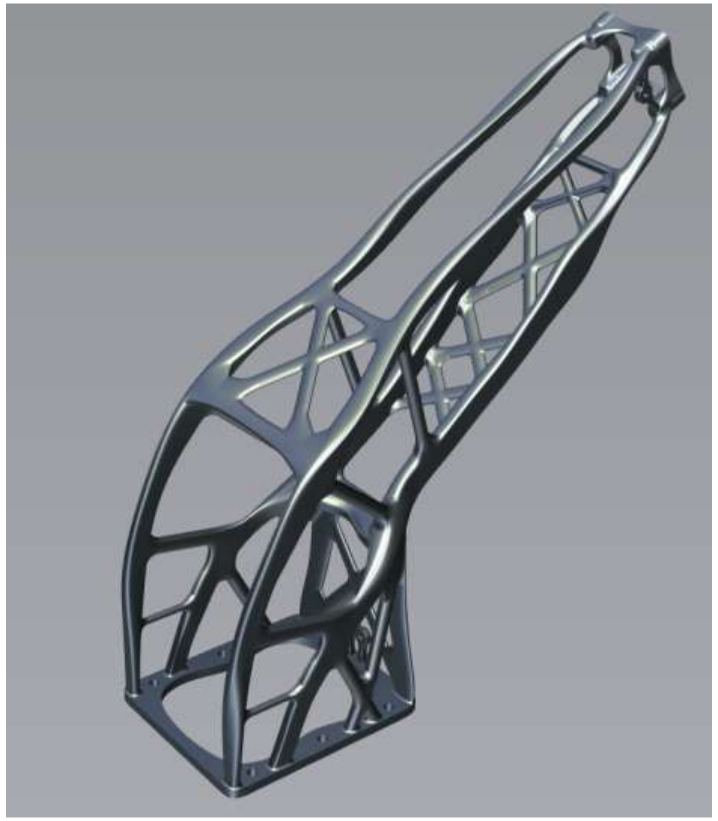
Model Preparation → Conceptual Optimization → Concept Interpretation → **Concept Design** → Detailed Optimization → Stress Verification → Additive Manufacturing

Concept freeze

- Evolve helps to realize the process of creating the CAD model **3x-4x faster** than traditional CAD tools
- Parametric modeling & Traditional surface modelling techniques (loft, sweep, etc…).



EVOLVE
solidThinking



Standard formats:
⇨ Parasolid
⇨ STEP
⇨ IGES

RUAG Space – Sentinel 1 Satellite Antenna Support

One more word on the topic support structures

From the Printer into Space

Altair

Model Preparation → Conceptual Optimization → Concept Interpretation → Concept Design → Detailed Optimization → Stress Verification → **Additive Manufacturing**

- Sentinel-1 AM Bracket **successfully completed its qualification test campaign!**

- Results exceed requirements:
  - 1st Eigenfrequency:

Requirement:	**> 70 Hz**
Simulation (OptiStruct)	91.44 Hz
Test:	90.9 Hz

  - 2nd Eigenfrequency:

Simulation (OptiStruct)	106.9 Hz
Test:	107.6 Hz

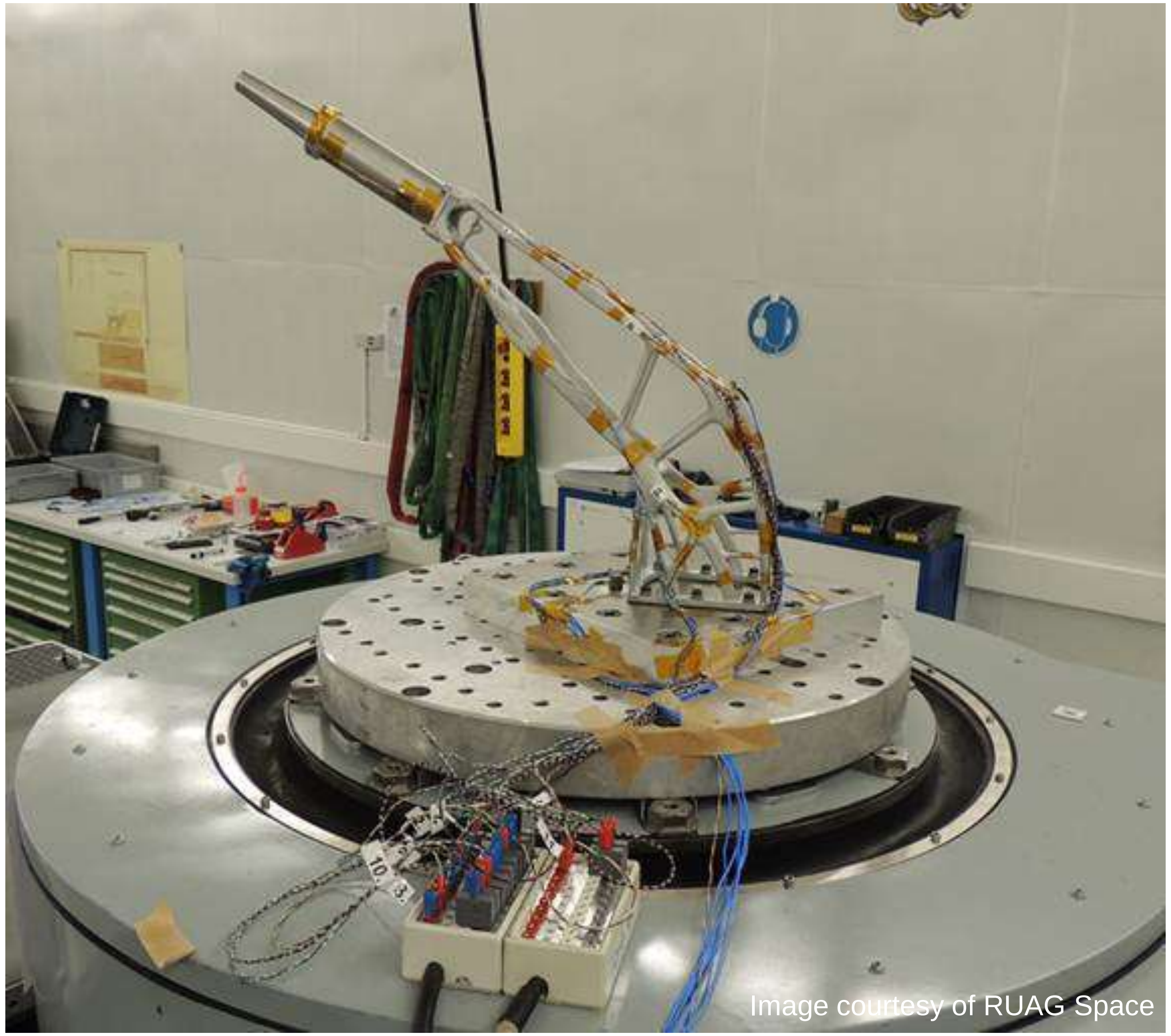


Image courtesy of RUAG Space

Key Aspects in Design for Additive Manufacturing

- **Additive Manufacturing requires new Designs to benefit from the design freedom!**

- **Topology Optimization is the best way to inject innovation in structural designs!**

  new concept generation, part consolidation projects, biomimicry adaption

- **The geometry complexity of ideal Designs for AM overexerts conventional CAD environments!**

- **Confidence in the Design is vital in all stages of the design process!**

- **Simulation Driven Design is the best way to convert the Design Freedom into Product Performance**

Meet us in Hall 7 Booth B32

pictures by courtesy
of Laser Zentrum Nord