

L'OTTIMIZZAZIONE TOPOLOGICA, ELEMENTO ESSENZIALE NELLA PROGETTAZIONE DI COMPONENTI REALIZZATI IN ALM

Giulio Turinetti, Mar 10 2016

Fields of application



Automotive

Rapid prototyping, Tooling, first experiments with mold making for metal casting

Aerospace

Rapid prototyping,

Air ducts in plastic in operation since a while, spare parts

first flight-critical production parts in metal in the air

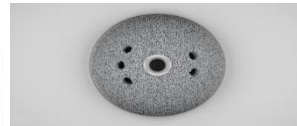


Medical:

Dental, implants

Turbomachinery:

blade Cooling, fuel nozzles, Heat exchangers

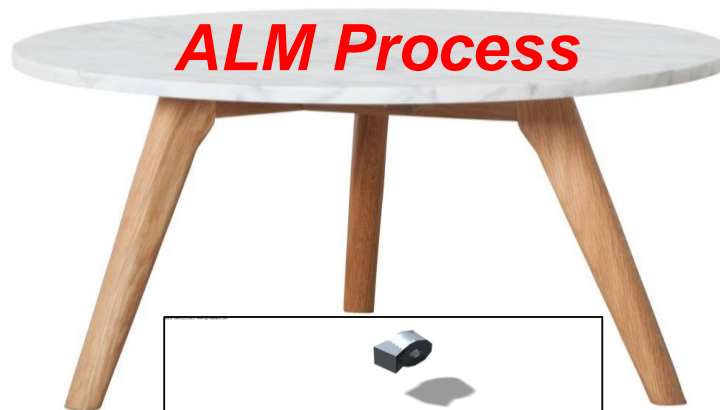


General:

Jewelry, Art, consumer products, Edutainment, Modelling



The ALM Process – 3 Main elements



Metallic Powders

- Final material strenght
- External roughness
- Chemical properties



Topology Optimization

- Load path based design
- Minimum material
- Designed by performances



3D printing Machines

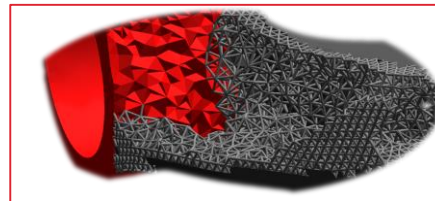
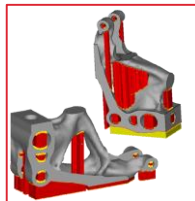
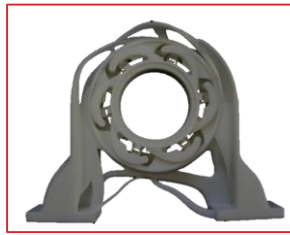
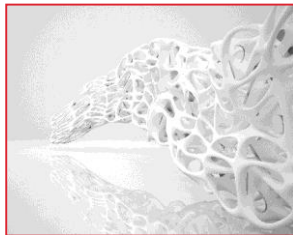
- Production time
- Process controls
- Hybrid capabilities

How to get an added value from 3D printing

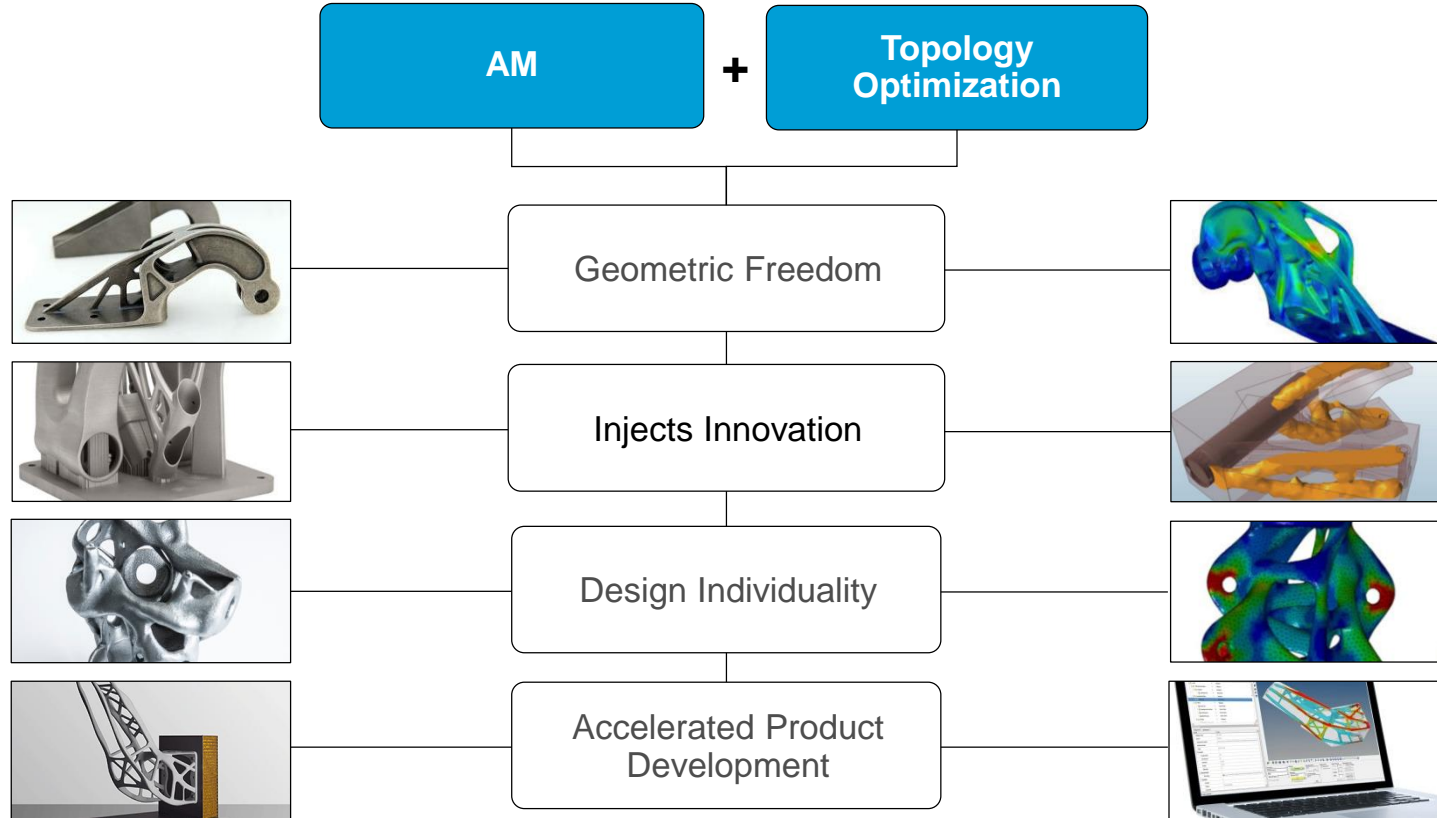


Complexity for free!

How to convert the freedom into performance?



Complementary Technologies

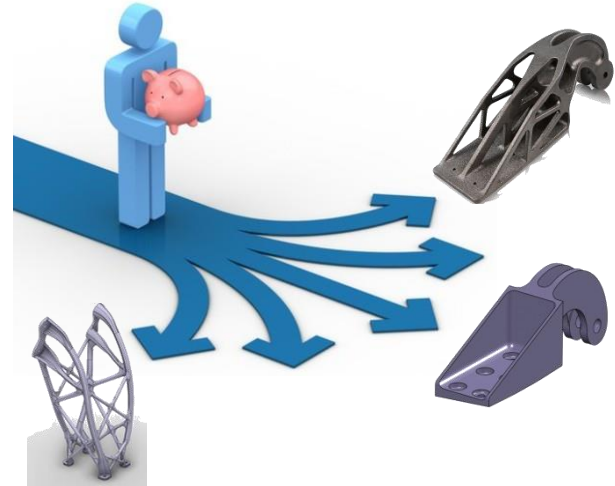


Why Topology Optimization?



ALM offers a broad range of possibilities in shape design

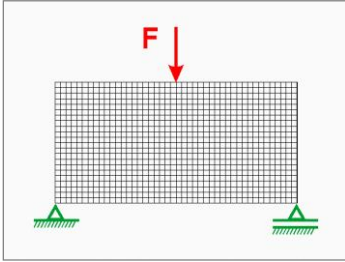
How can a designer come up with the best possible shape?



Helping to choose the technology, Traditional Vs. ALM

In ALM reducing the volume parts means saving time

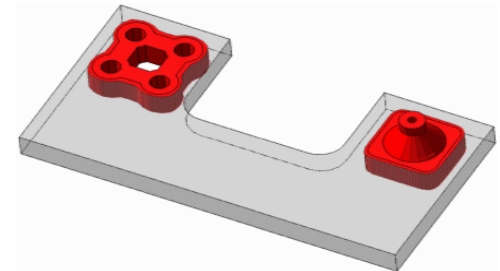
Topology Optimization



Topology optimization is a mathematical approach that optimizes material layout within a given design space under given operating conditions.

IDENTIFYING THE LOAD PATHS

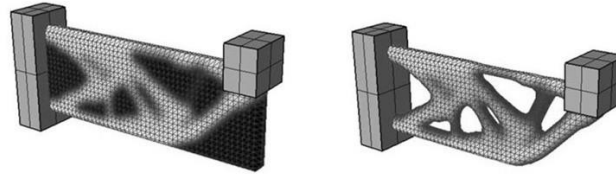
CHOOSE THE BEST MASS DISTRIBUTION



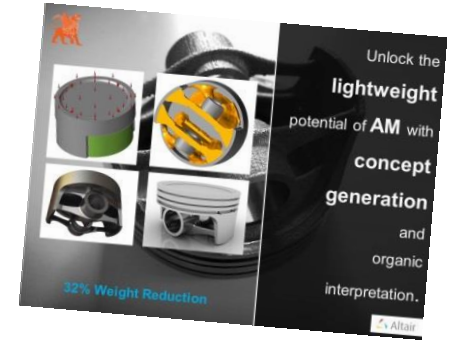
Altair Topology Optimization is OptiStruct



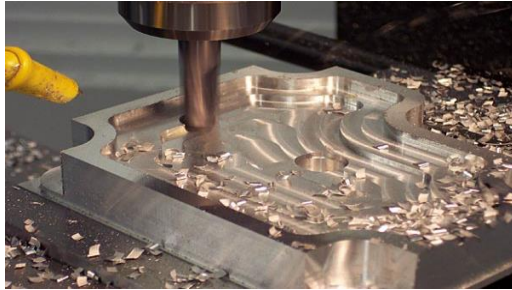
Altair is the premier provider of design optimization software, driving design processes of leading manufacturers for over 20 years



Not just an exercise



Classical Manufacturing methods



Milling



Extrusion



Casting



Metal Forming

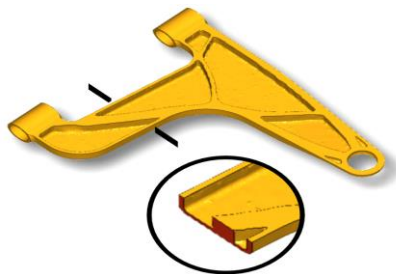
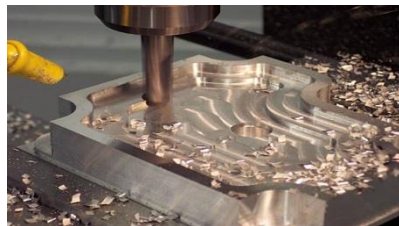


Injection Molding

Optistruct Classical Manufacturing Constraints



Draw direction



Extrusion



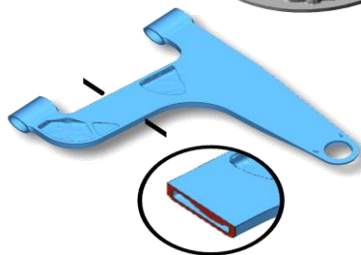
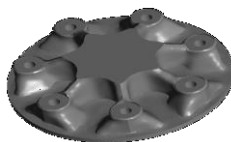
Free / no Holes



Max member dimension



Min member



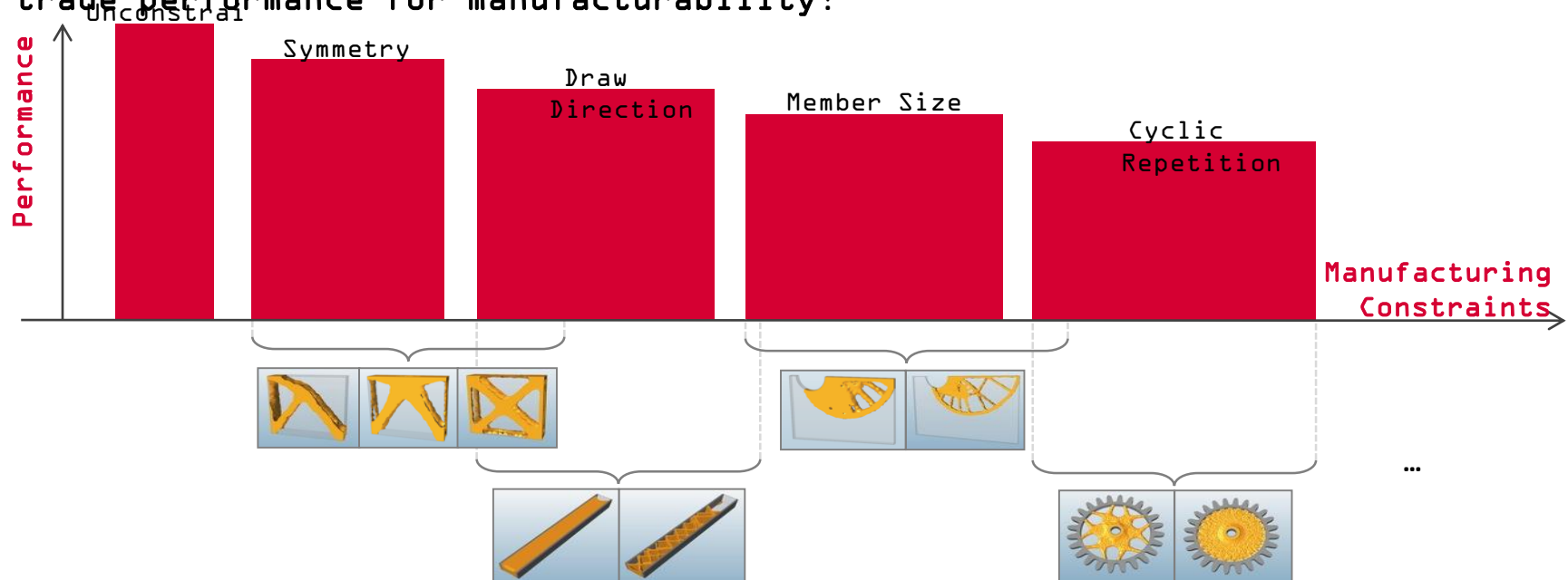
Draw + Member



Technology symbiosis



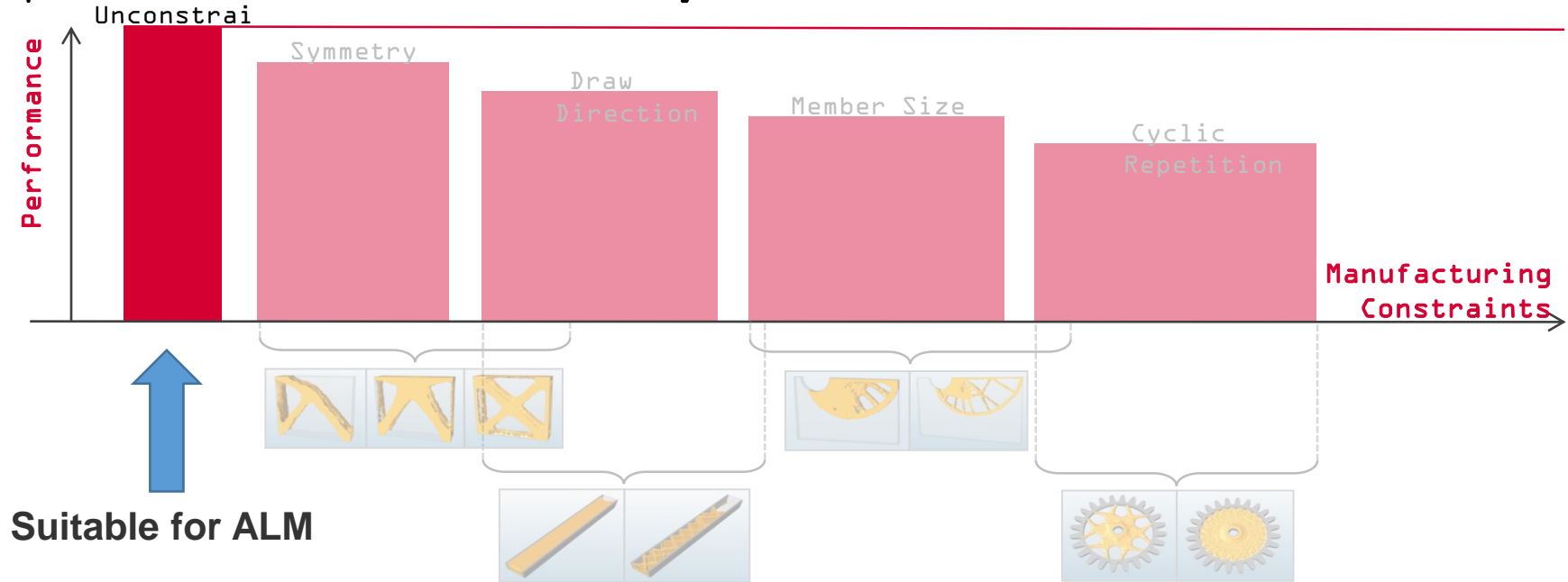
Topology optimization provides the most efficient structure for a given load situation, but for traditional manufacturing designers always have to **trade performance for manufacturability!**



Technology symbiosis



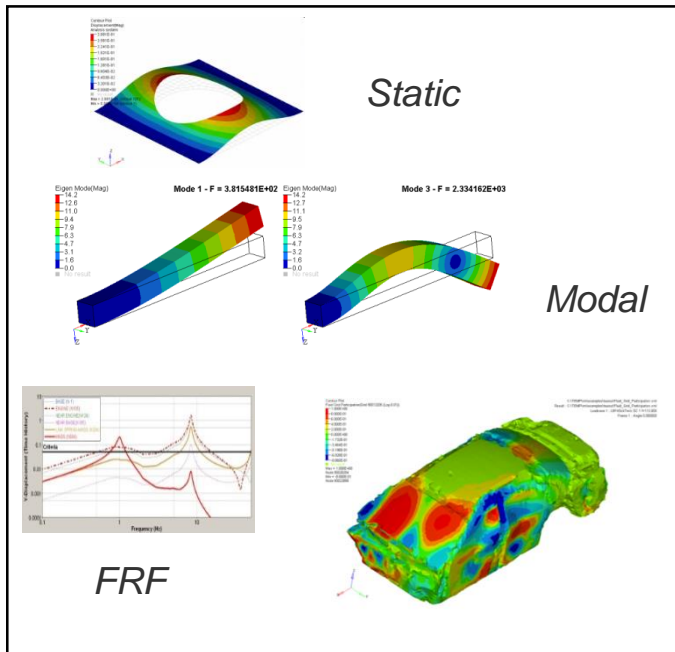
Topology optimization provides the most efficient structure for a given load situation, with added manufacturing designers **no more** have to **trade performance for manufacturability**



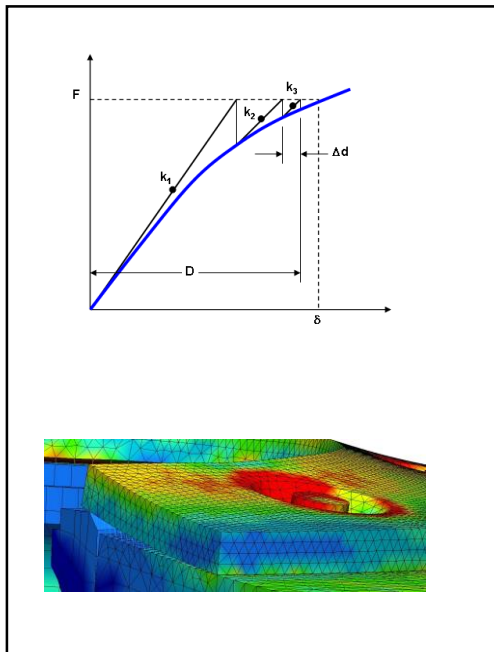
Optimization - Advanced features



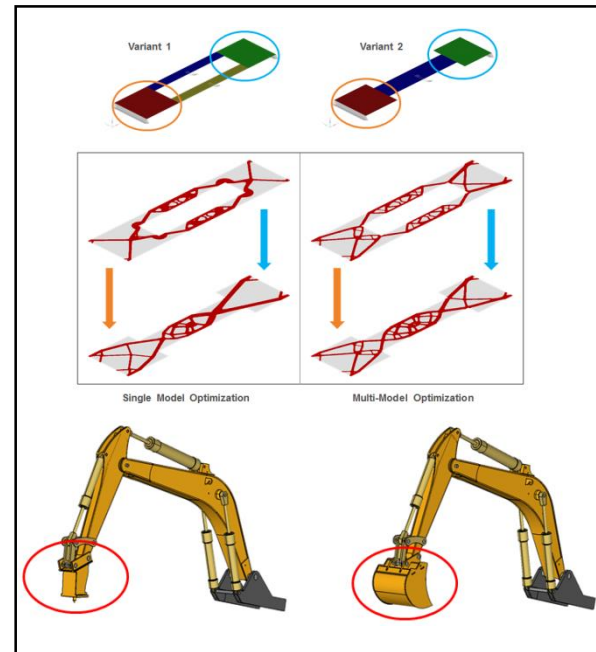
Different Physics in a single analysis



Non-Linear Optimization



Multi-model Optimization



The Additive Manufacturing Design Challenge



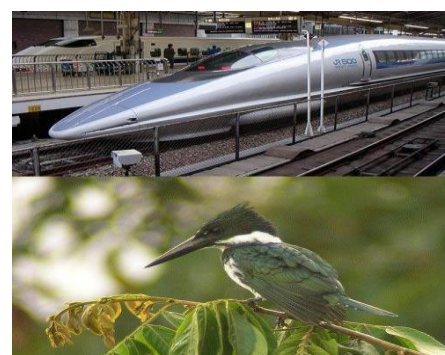
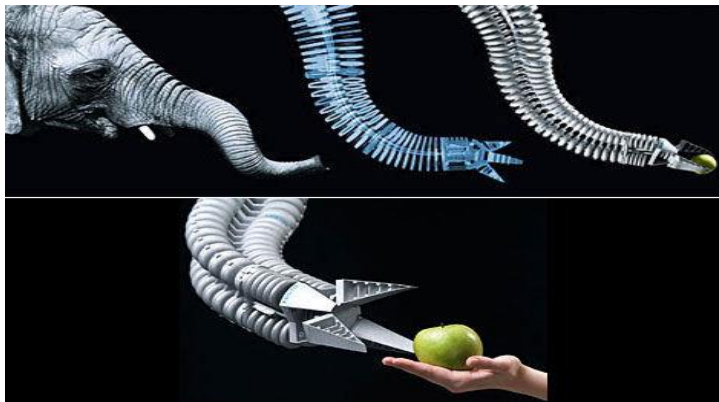
How can a designer come up with the best possible shape?



picture by courtesy of Laser Zentrum Nord 



Inspiration by Nature



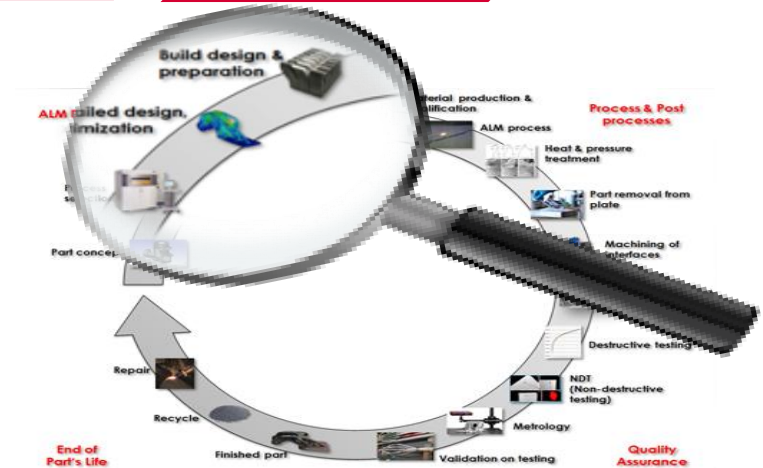
Process chain



How does the digital process chain look like at the moment



Where to get the structural inspiration?

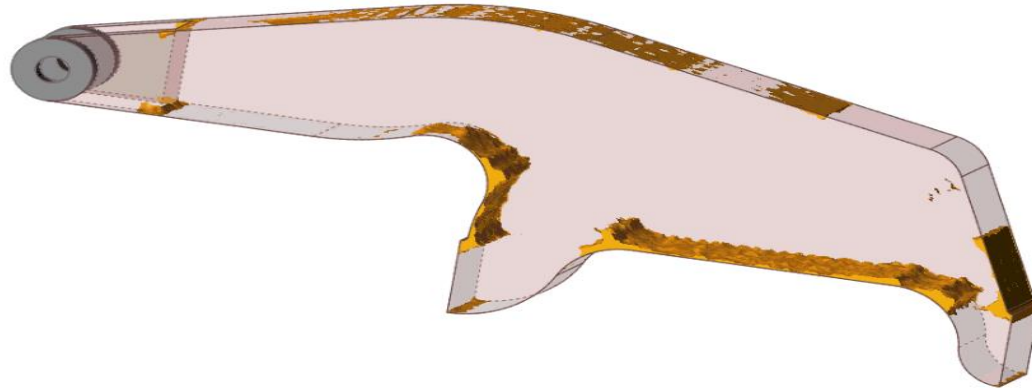


For Design Engineers



INSPIRE
solidThinking®

helps design products:

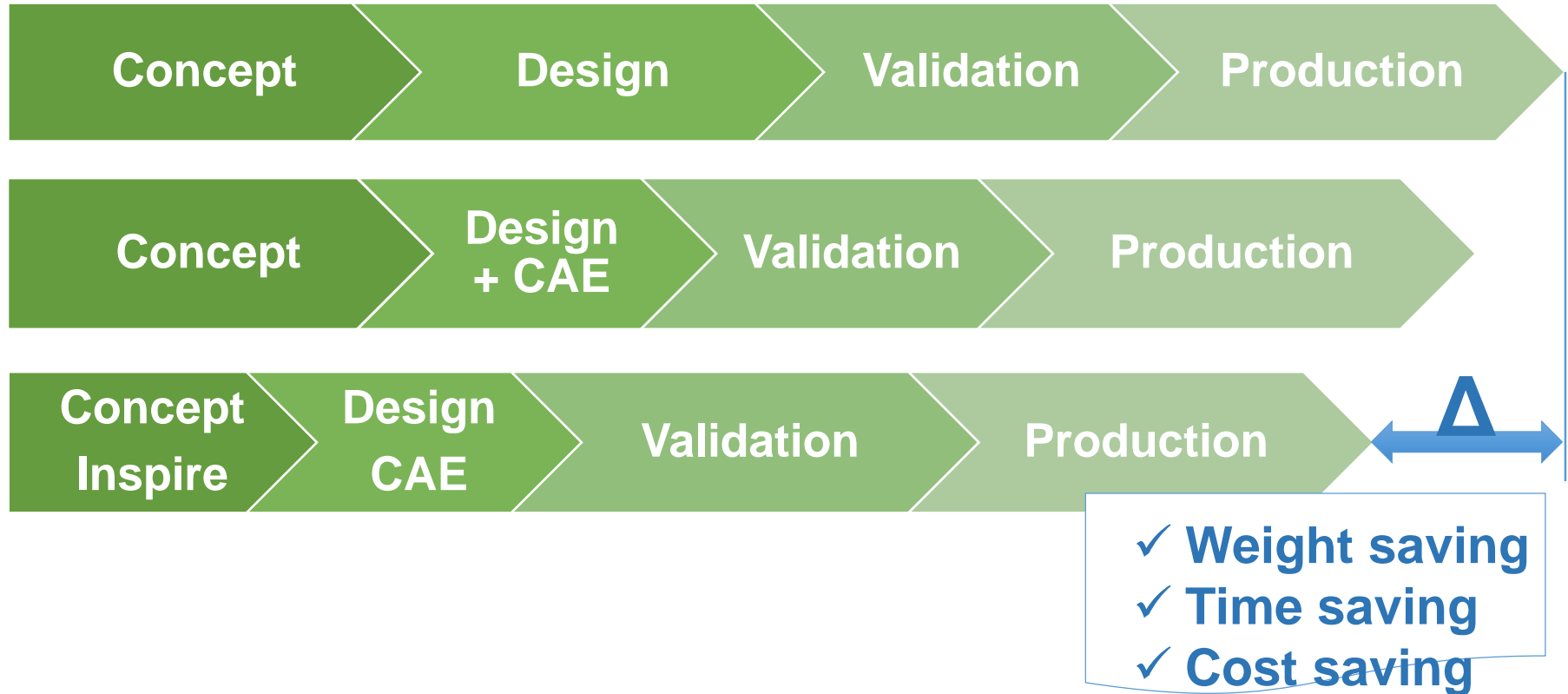


Faster

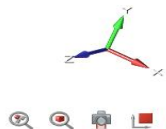
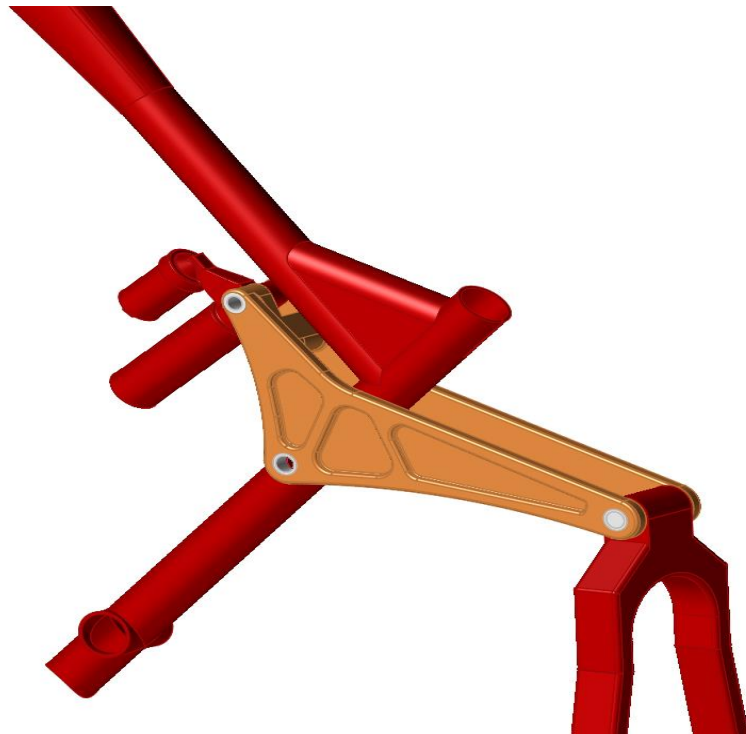
Smarter

Lighter

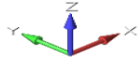
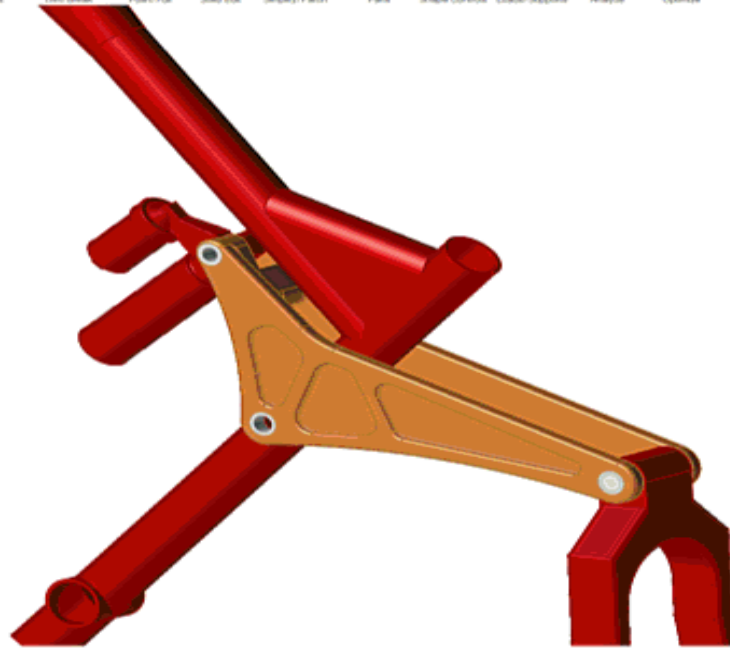
Never too soon to optimize



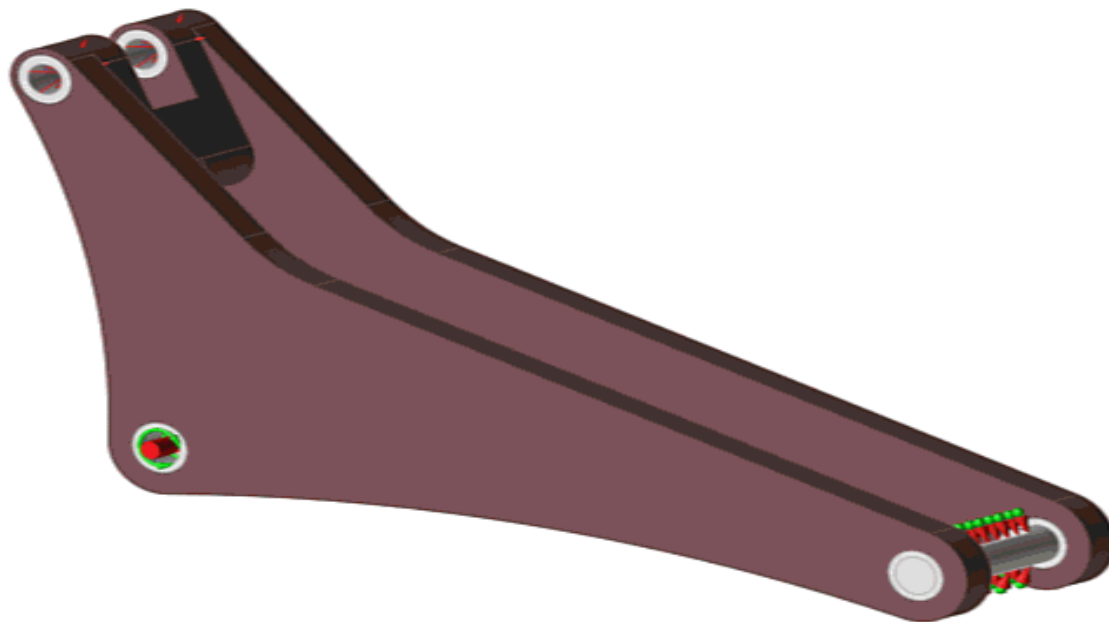
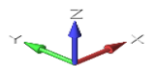
Start with original CAD design



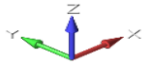
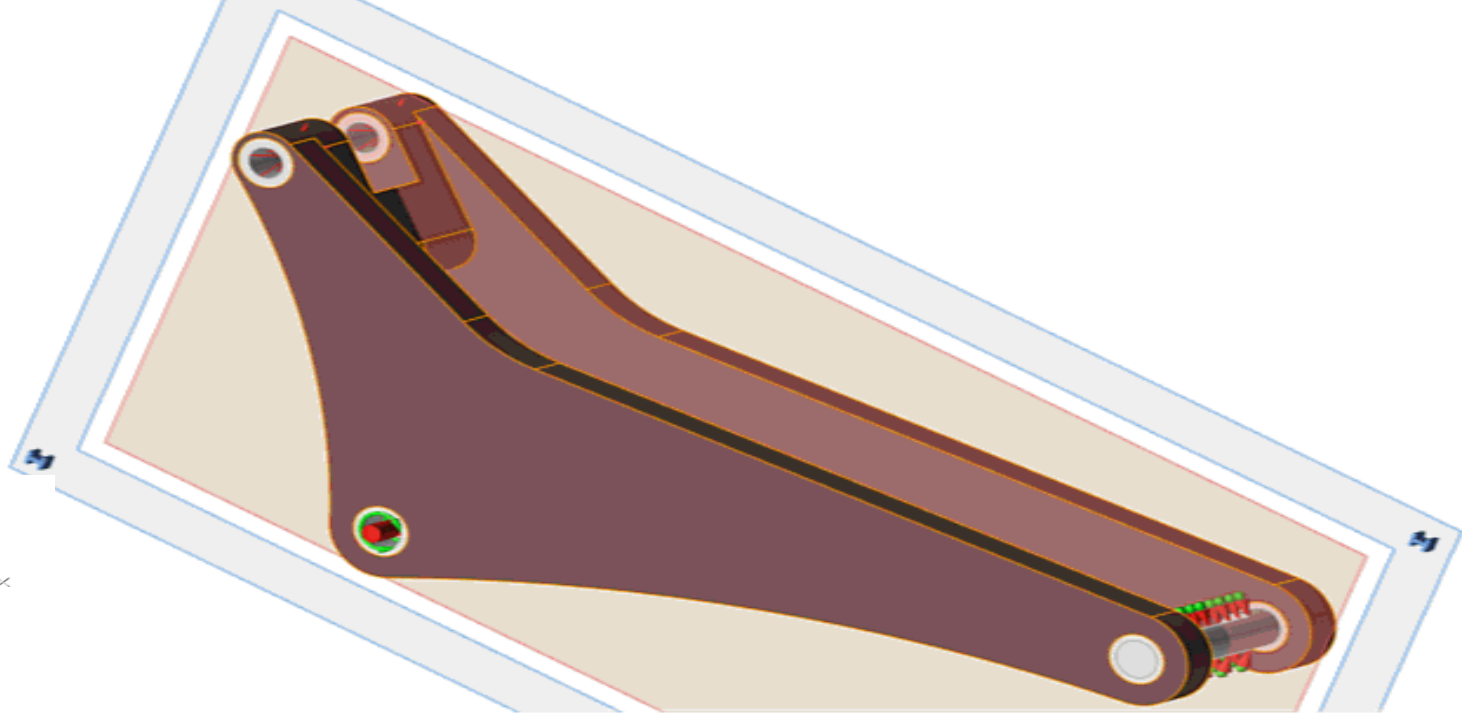
Create Package Space and Load Cases



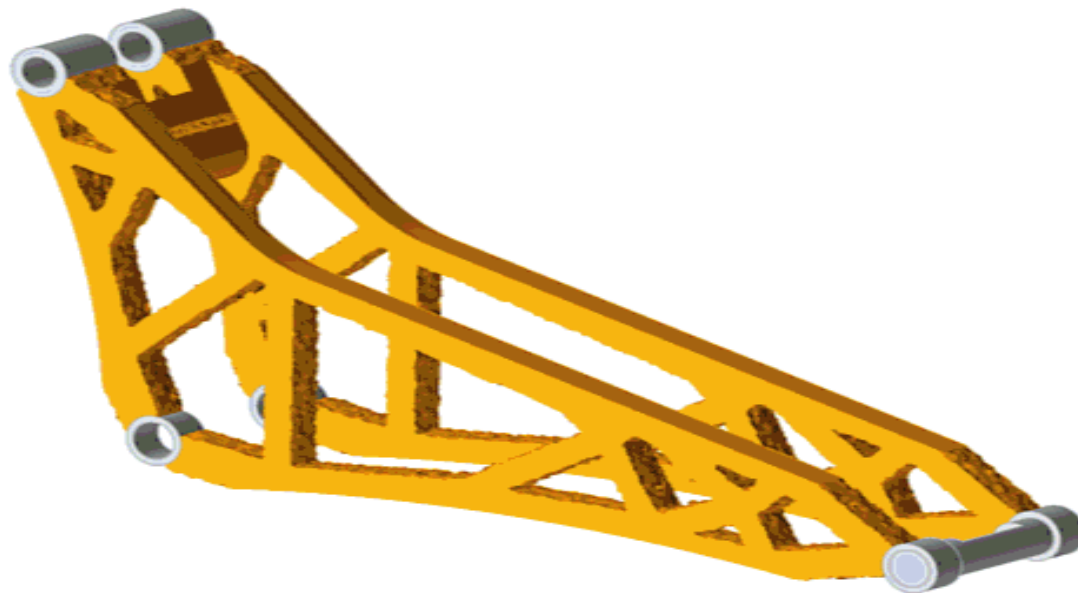
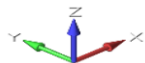
Inspire Concept Shape



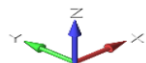
Explore Different Designs / Shapes



Validate Inspire Concept Shape / Proposal



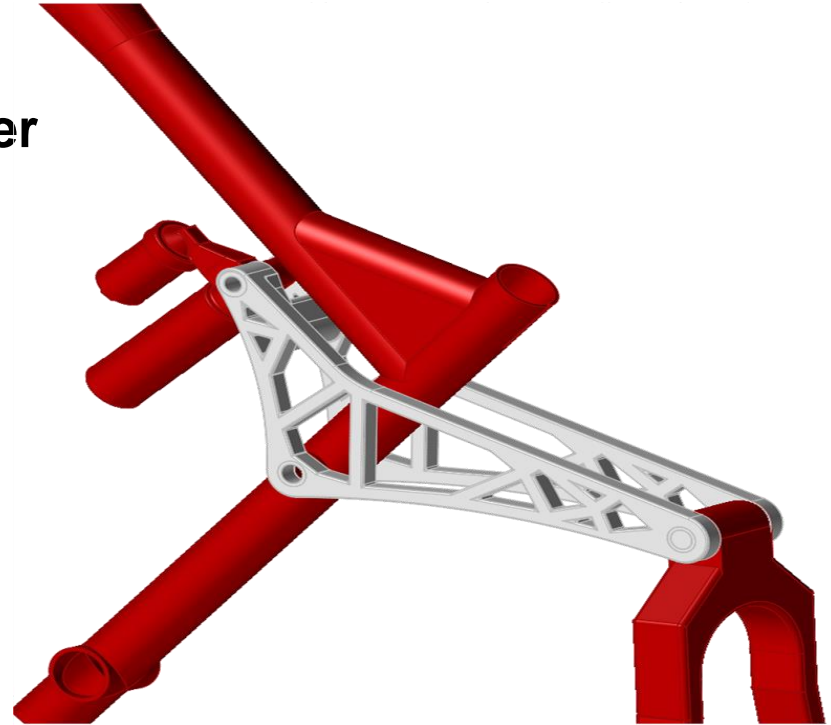
Inspire Results back into CAD



Original Design vs. Inspire Design



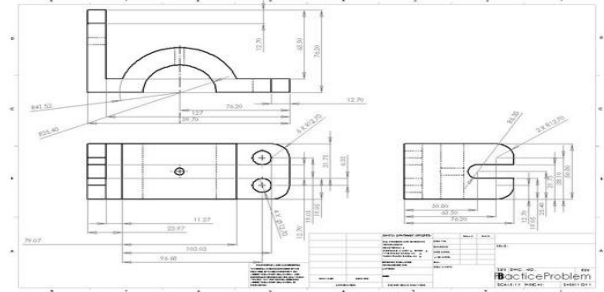
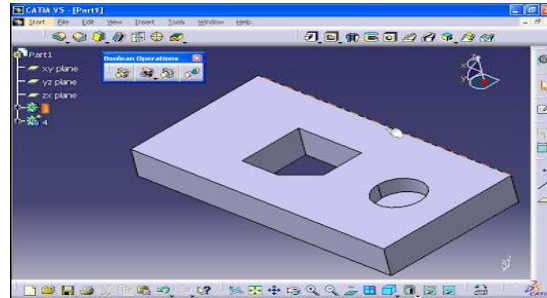
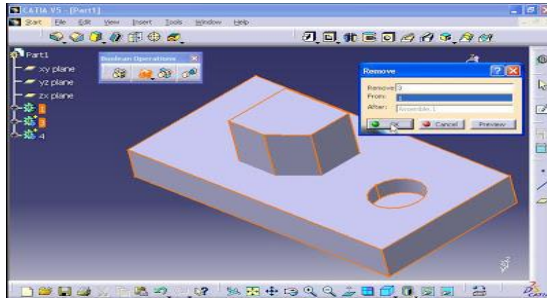
New Design: 25% Lighter



How can the engineer draw it in a CAD system?



Conventional CAD systems rely on boolean operations of simple geometric entities



Too Complex



Organic shape

How can the engineer draw it in a CAD system?



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



Nurbify – Evolve technology



Topology Optimization Workflow from Altair to Materialise



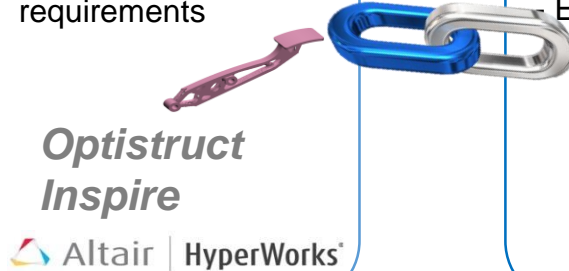
Design Space Preparation

- CAD assembly
- CAD to FEM export
- Indicate Loads on part



Topology Optimization

- Mesh Optimization
- Linear stresses
- Design requirements



*Optistruct
Inspire*



Design for AM

- STL Cleanup
Based on **Digital CAD (STL)**
- Lattice design
- Export to FEA/CAD



3-maticSTL



Altair
Partner Alliance

AM production

- CAM software for 3D printing
- Supports
- Positioning
- Platform validation
- Scan profiles

Magics RP

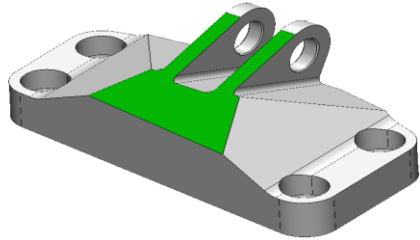


[not in APA]

Design flow for Topology Optimization

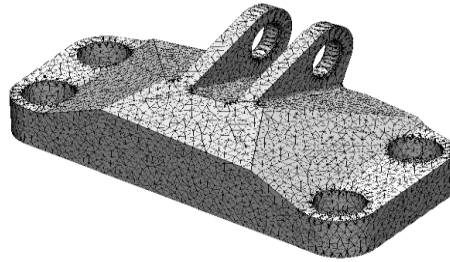


Design Space



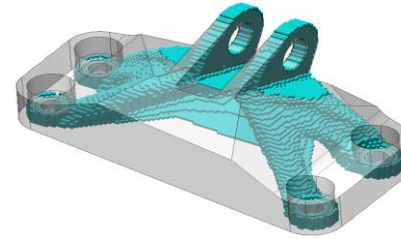
- *Designed in CAD*
- *Fits in assembly*
- *Loads are known*

FEM Model



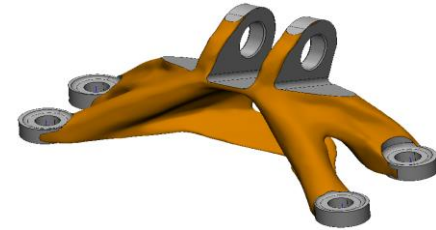
- *FE Model*
- *Apply loads*

Topology
optimization



- *Optimize*

3-maticSTL



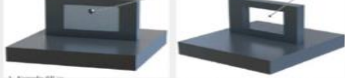
- **STL Studio**
- *FEA check*
- *owards AM*

Topology Optimization software

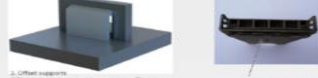
Post-process

Is ALM technology Limitless?

Types of support

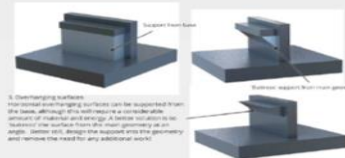


1. Simple fill-in
The most simple form of support is to fill in the area that needs support, and then cut this out when the build is complete by wire cutting or machining. If the support area is to be removed with wire cutting, a small hole needs to be placed in this support area to allow the wire to be located.



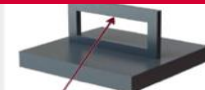
2. Offset supports

Offset supports are used to support a top surface.



3. Overhanging surfaces
Overhanging surfaces can be supported from the base, although this will require a considerable amount of material and energy. A better solution is to support the surface from the main geometry at an angle. (See item 4).

4. Angled supports
Angled supports are used to support a top surface from the main geometry at an angle. (See item 4).



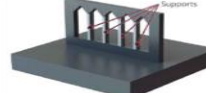
Any downward facing surface will require support. Support structures will need to be removed by wire cutting or machining, which will increase the energy and waste involved in the process.



The most simple support structure will fill the hole that creates the downward facing surface. This can be removed by wire cutting or machining.



An alternative to this approach will be to turn the part through 45 degrees to make all the surfaces angled and remove the need for supports. Orientation is a major issue in finding the most efficient build method - please see item 3 in Other Issues (below) for more details on the limits and possible pitfalls of using angled edges like the ones shown above...



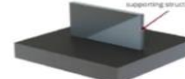
If the top surface of the hole can be made of a series of angles (which are self-supporting) the supports can be minimised to the base of each angled surface.

Downward facing surfaces

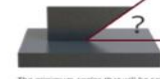
Angled surfaces and holes



The powder in the build chamber does not provide any support to the part as it builds, so any angled surfaces will ideally be self-supporting.



If the angle is too acute, the surface will need a supporting structure built in as part of the model. This supporting structure will then need to be removed by machining or wire cutting, increasing energy use.



The minimum angles that will be self-supporting are approximately:

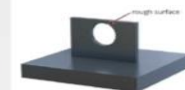
- Stainless steel: 30 degrees
- Inconel: 45 degrees
- Titanium: 20-30 degrees
- Aluminum: 45 degrees
- Cobalt Chrome: 30 degrees



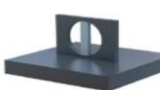
If the angle is near the point where it needs supports, the downward facing surface will become rough and may require considerable post finishing.



Small holes can be accommodated easily. Holes of less than 6mm diameter are ideal.



Larger circular holes will result in a rougher surface at the top which may need post-machining.



Large holes will require support structures to be added in the centre to prevent the part collapsing or becoming distorted during the build process. These supports will need to be removed by wire cutting or machining.



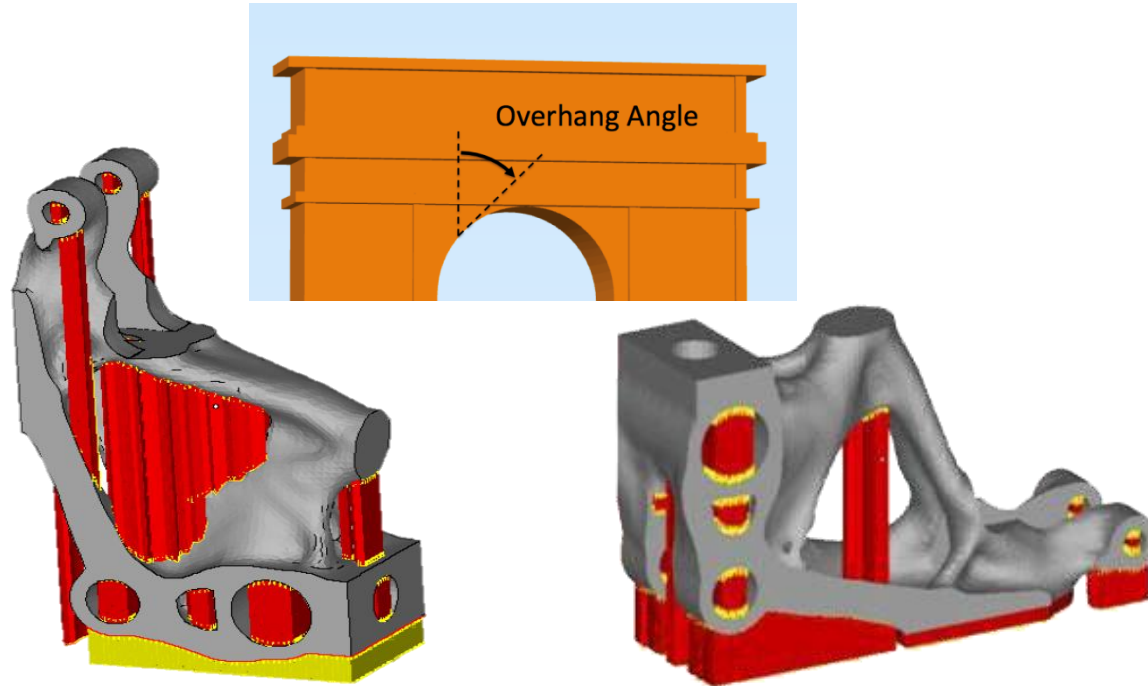
If the hole has an angled or arched upper area it will probably not require any supports. This is one of the features of DMLS that can have a significant impact on the design process.

How to consider the NEW Manufacturing Constraints?

Product Industrialisation - Manufacturing



Minimise Support Structure by Overhang Angle Control



How to reduce support structures



We are working on it!

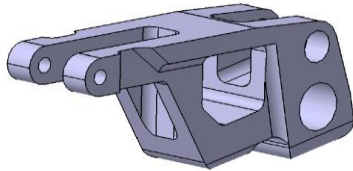
Design and sizing of Krüger flap

EADS INNOVATION WORKS

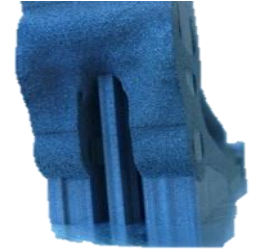
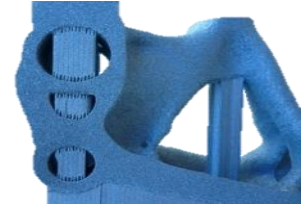
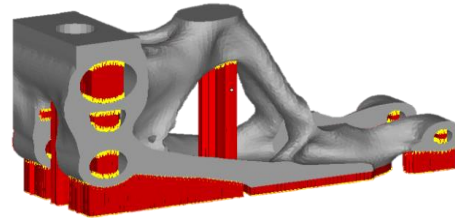
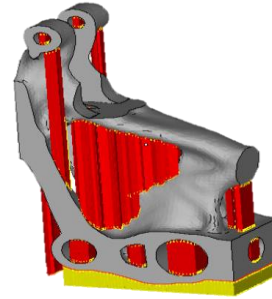
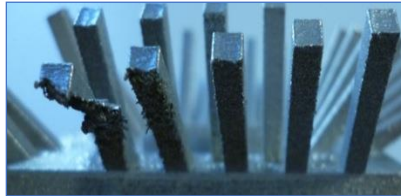
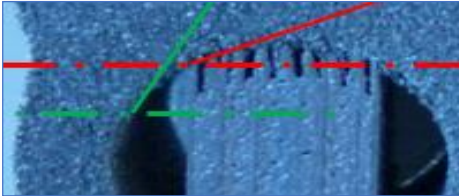
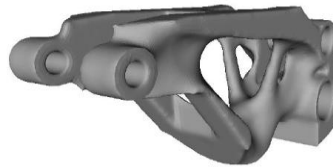
DRIVE STRUT LOAD INTRODUCTION Comparison milling & ALM design

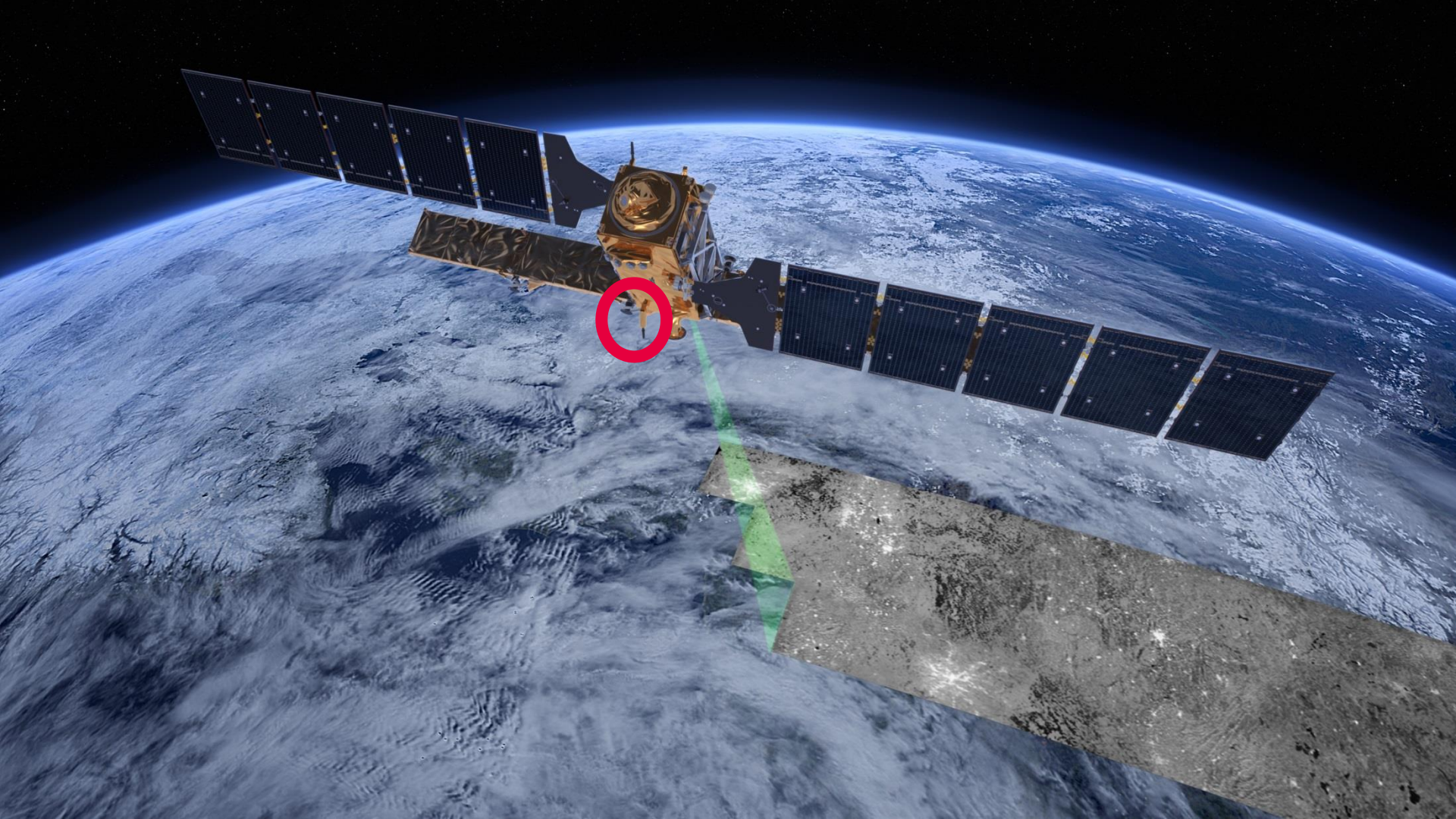
- Both designs feasible concerning stress and manufacturing
- Weight benefit of ALM drive strut bracket 14 %

Milling design



ALM design ISO 0.85







Altair

From the Printer into Space



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

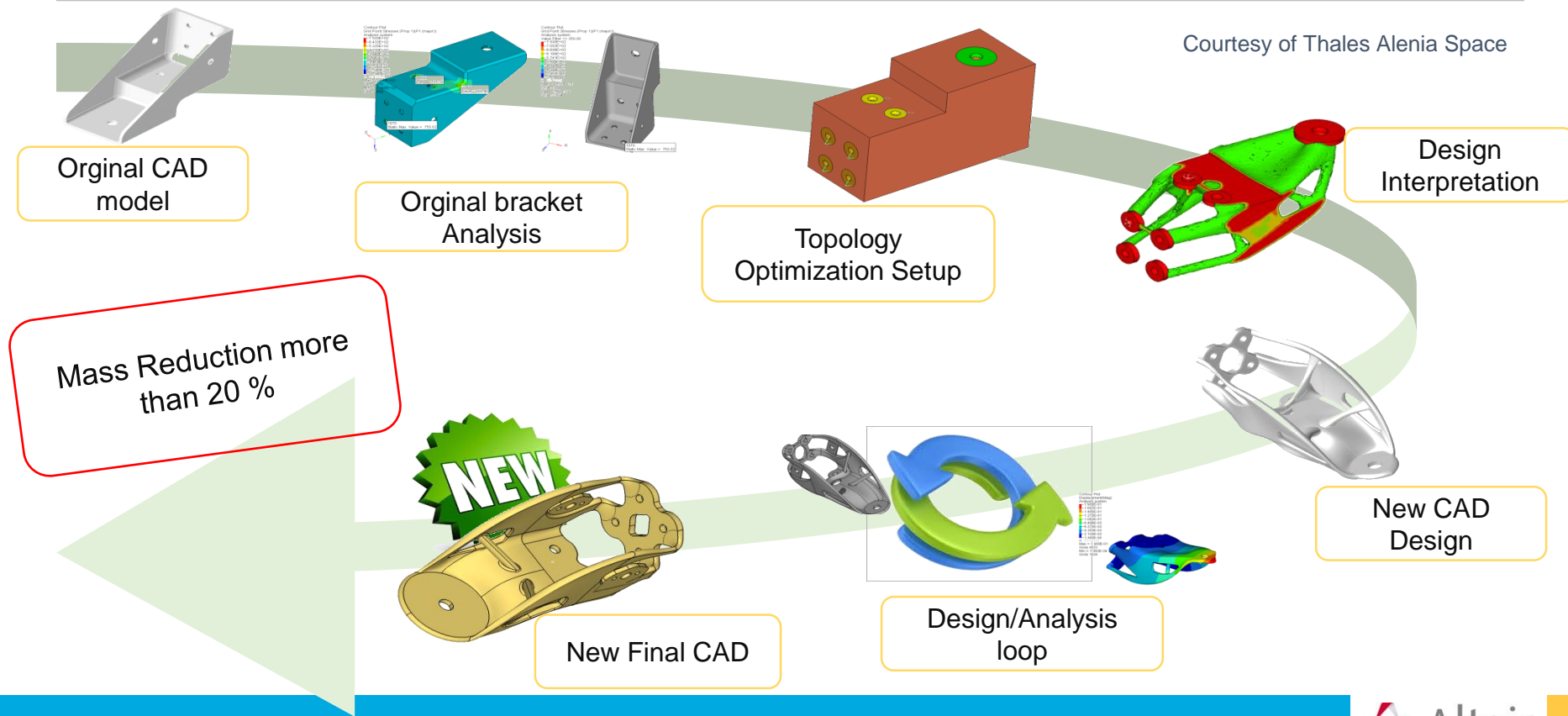
Together
ahead. **RUAG**



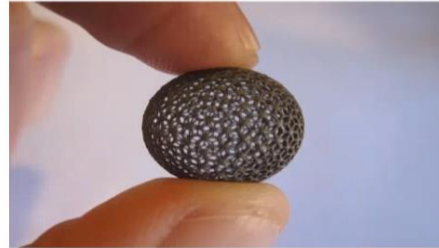
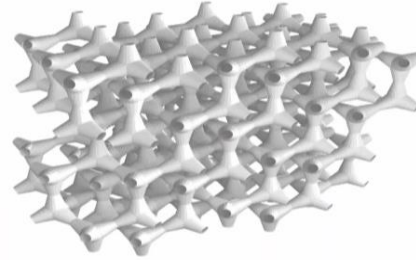
Optimization Aided Design - Process



Courtesy of Thales Alenia Space



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



Lattice structure : Example



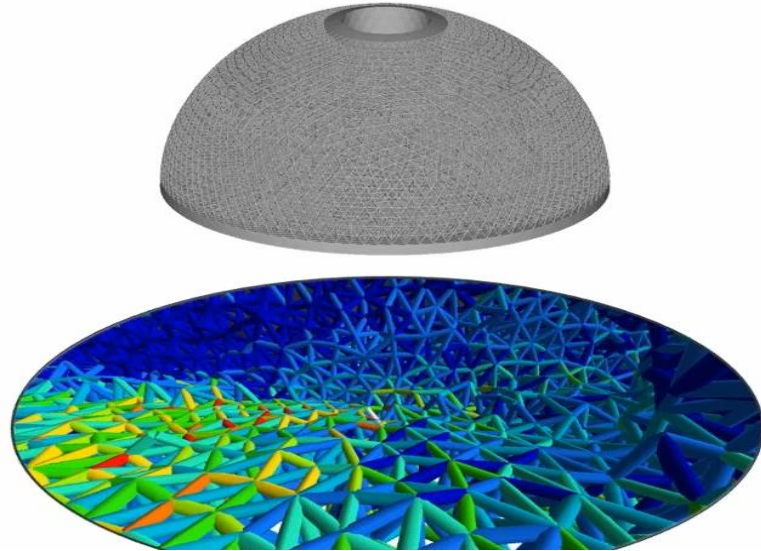
Lightweight structures are inspired by nature:

1. Minimize the weight while maintaining the stiffness
2. Create a better bone ingrowth for medical purposes

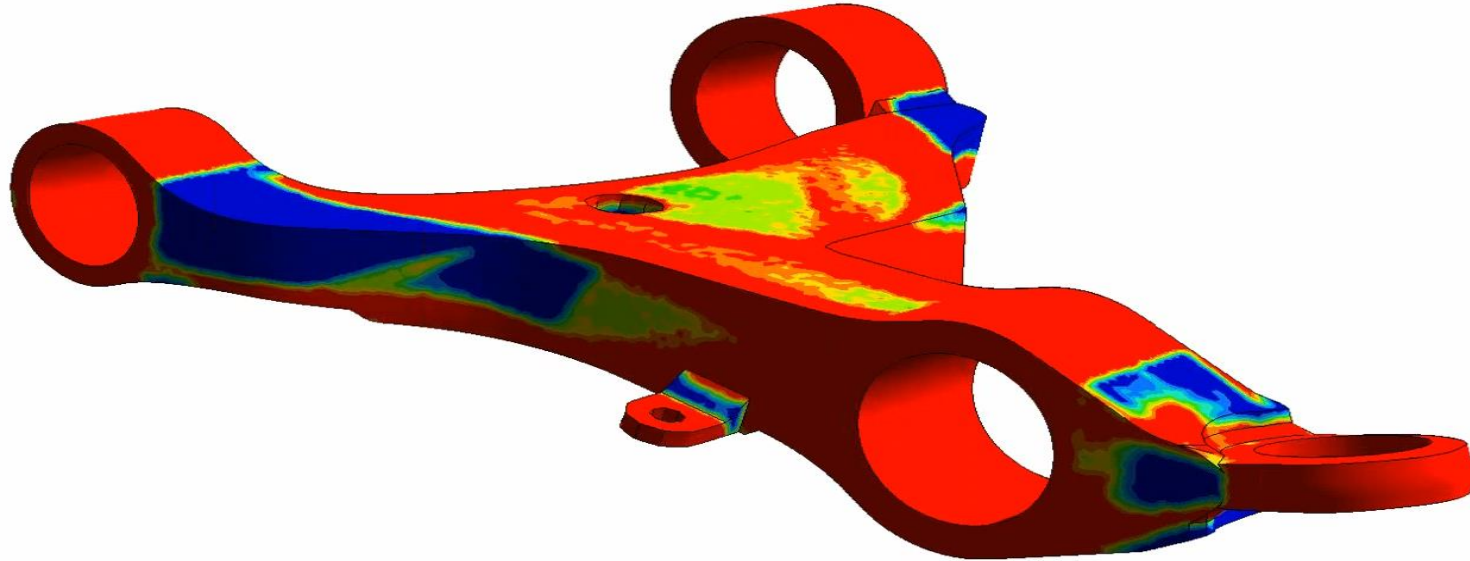
Lattice structure Design Characteristics



- Usually less stiff when compared to free topology based structures
- Can be stiffer when topology is used with manufacturing constraints
- Better performance for stability, thermal behavior, vibrations, etc.
- Specialized applications such as biomedical, e.g. implants



Control Arm – Concept Design (Phase 1)



Void

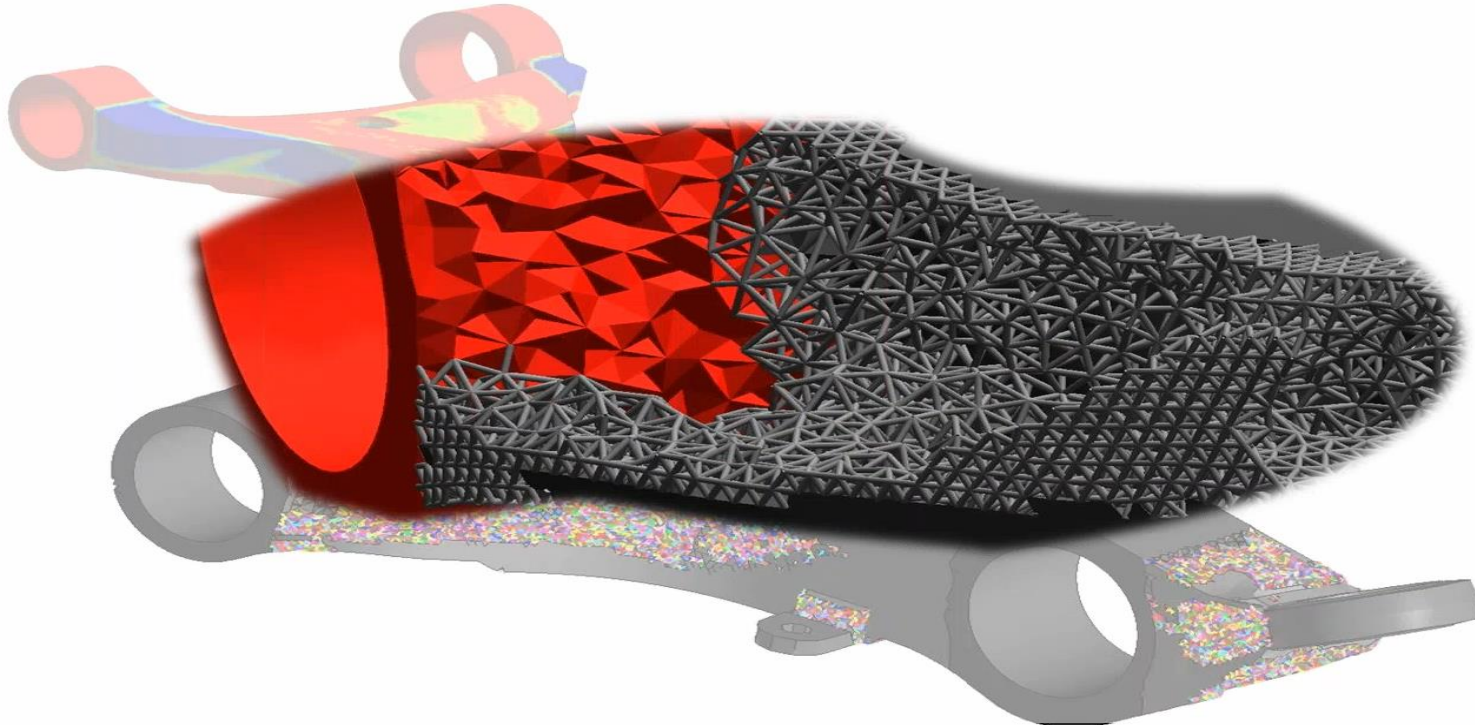


Lattice

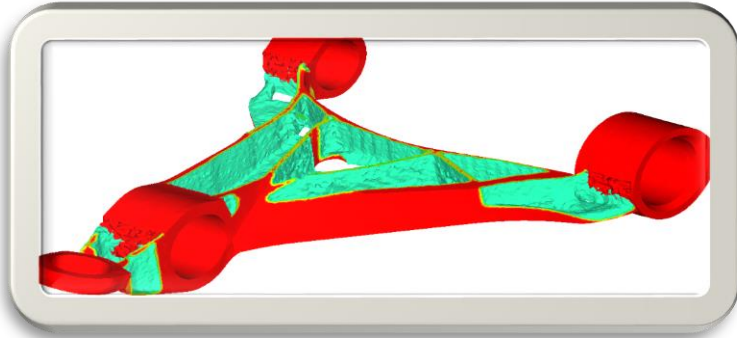


Solid

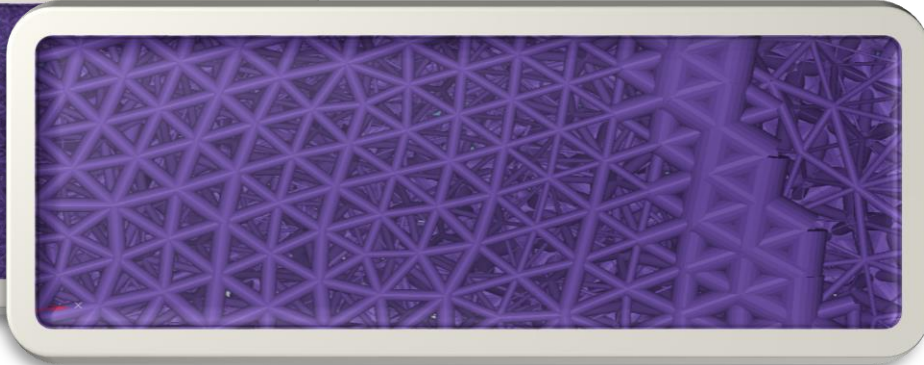
Control Arm – Concept Design to Lattice Design



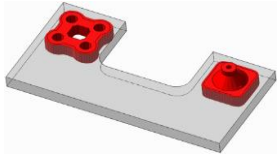
Demouldable Design vs. Lattice Structure



3% Stiffer



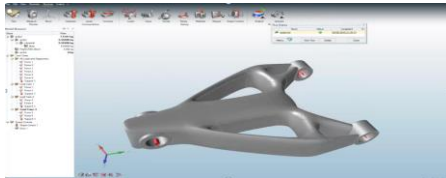
Summary



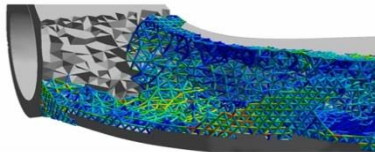
Topology Optimization is the technology behind the scene



Inspire is the easy to use software to take shape inspiration



Nurbify can easy draw organic shapes

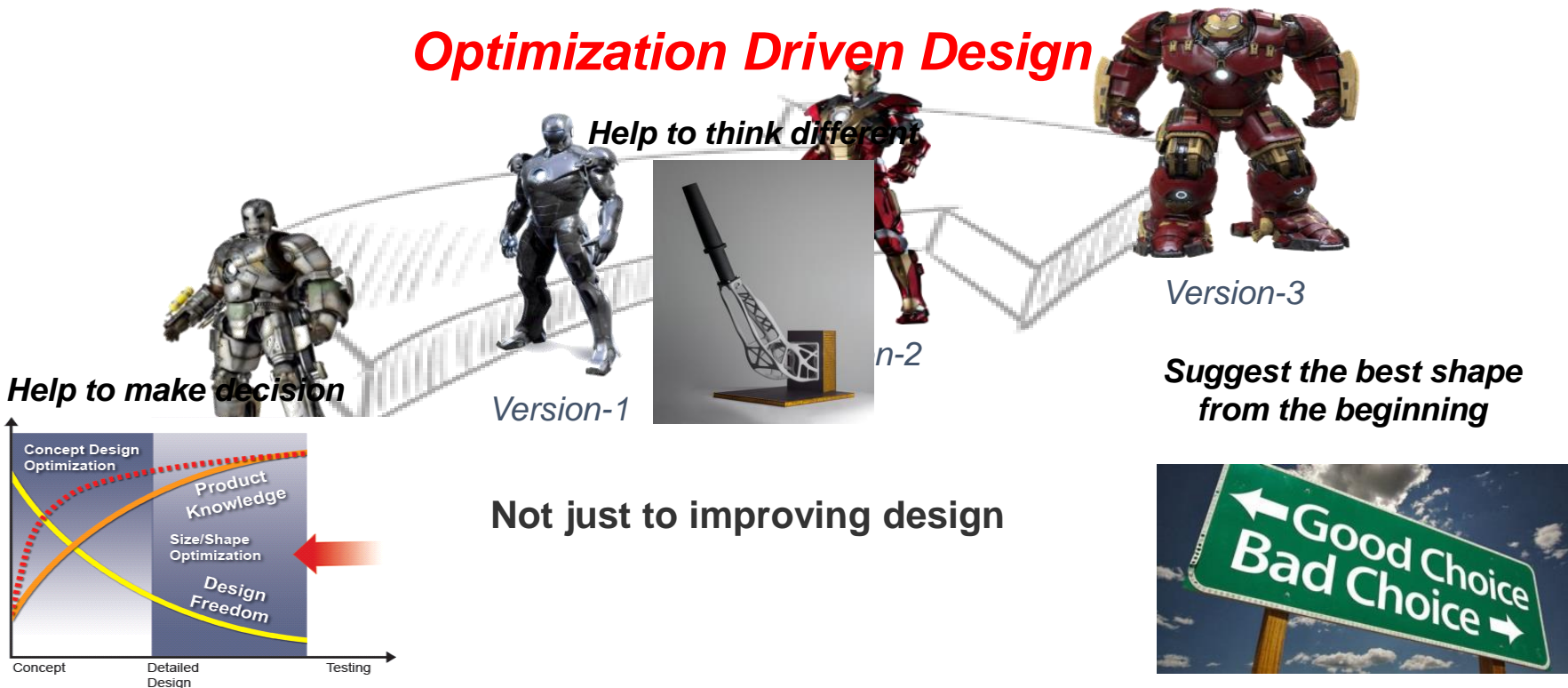


Lattice can even improve the design

Altair Vision - Not a traditional Optimization tool



Optimization Driven Design



Awards



DesignNews



Materialise

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RAPID 2014



Thank you for your attention!