Additive manufacturing for mass manufacturing

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Contents

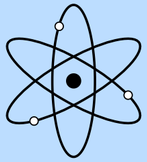
1. Comparing AM and mass production traditional techniques
2. Design for AM
3. Study cases of AM in mass production
4. Challenges in scaling AM
5. Future trends

AM and mass production techniques

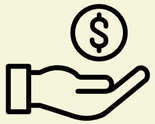
Comparison 

Presented by Thomas Roulet

Comparison



Mechanical properties

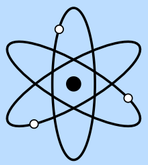


Cost efficiency

Design complexity

Sustainability factors

Comparison



Mechanical properties

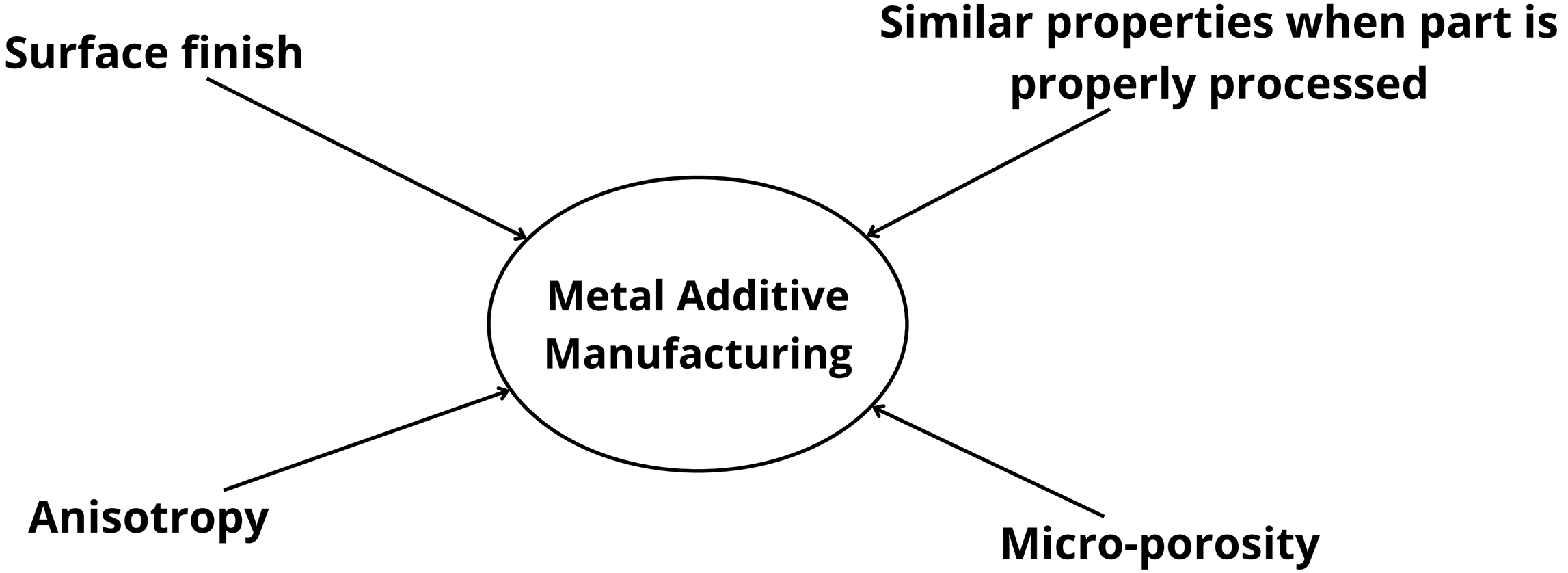
Cost efficiency

Design complexity

Sustainability factors

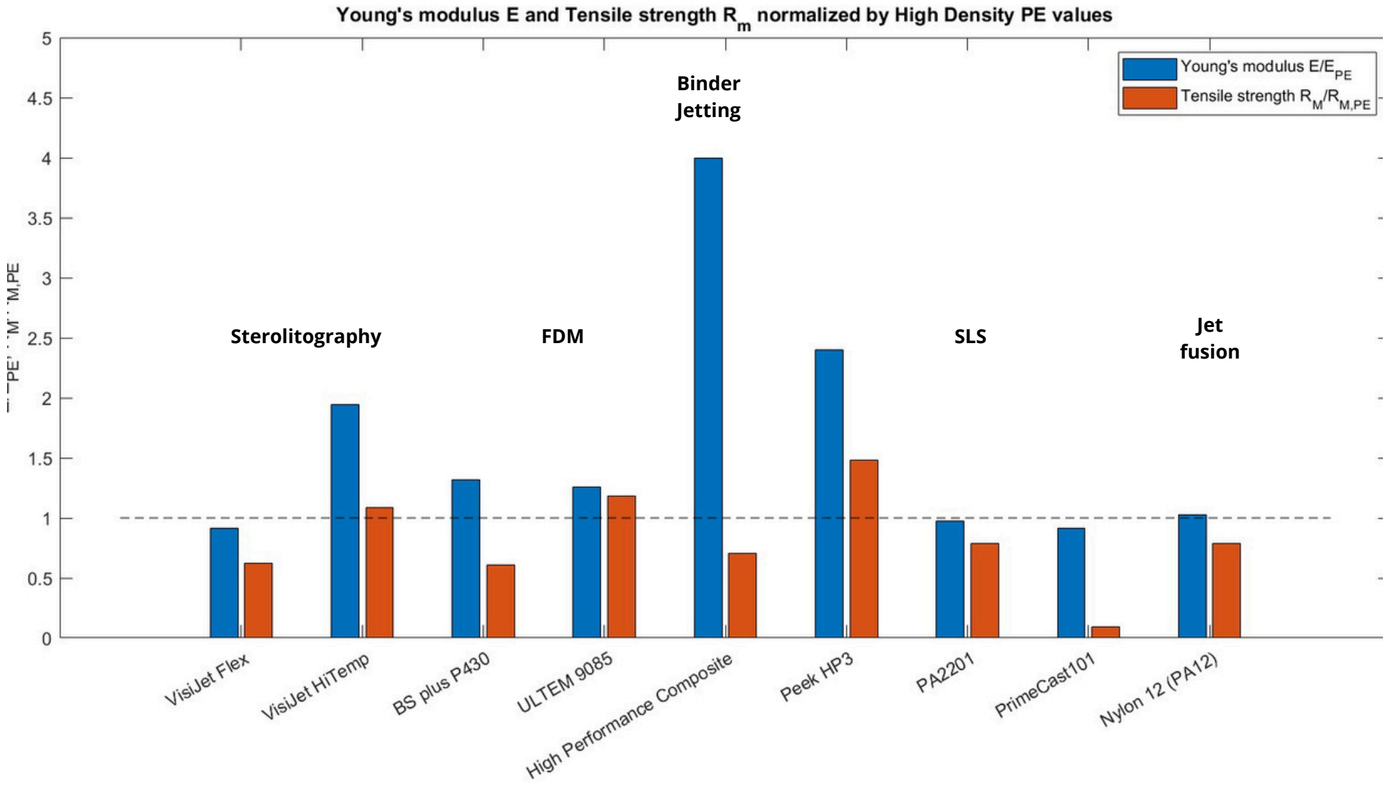
Mechanical Properties

Metal based AM



Mechanical Properties

Polymer based AM



Distortion

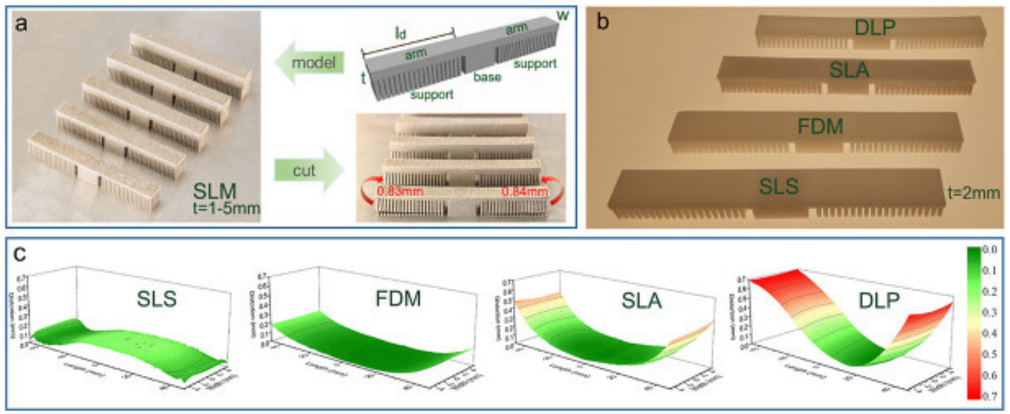
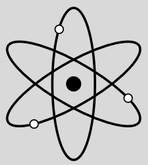


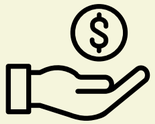
Image source: Deqiao Xie, Et al.,2022,A Review on Distortion and Residual Stress in Additive Manufacturing,Chinese Journal of Mechanical Engineering: Additive Manufacturing Frontiers, URL : https://www.sciencedirect.com/science/article/pii/S2772665722000216

Data source: Eric Boillat, J. Brugger, and C. Moser. Cours: Introduction to Additive Manufacturing., PE values : https://www.matweb.com/index.aspx

Comparison



Mechanical properties



Cost efficiency

Design complexity

Sustainability factors

Cost efficiency

AM advantage / Disadvantage

- ✓ Less wasted material
- ✓ Linear price ⟶ Cost Advantage to small batches
- ✓ Reduced price for complex parts

- ⊗ Need additional development to be economically viable for all types of part

Cost efficiency

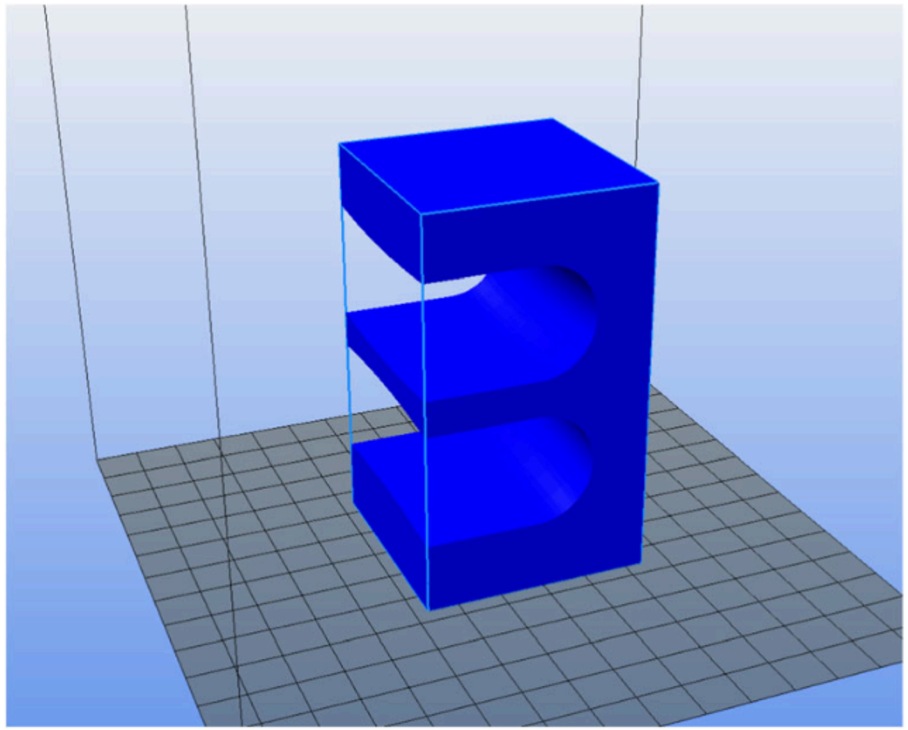


Fig. 1 Drawing of automotive housing used for case study

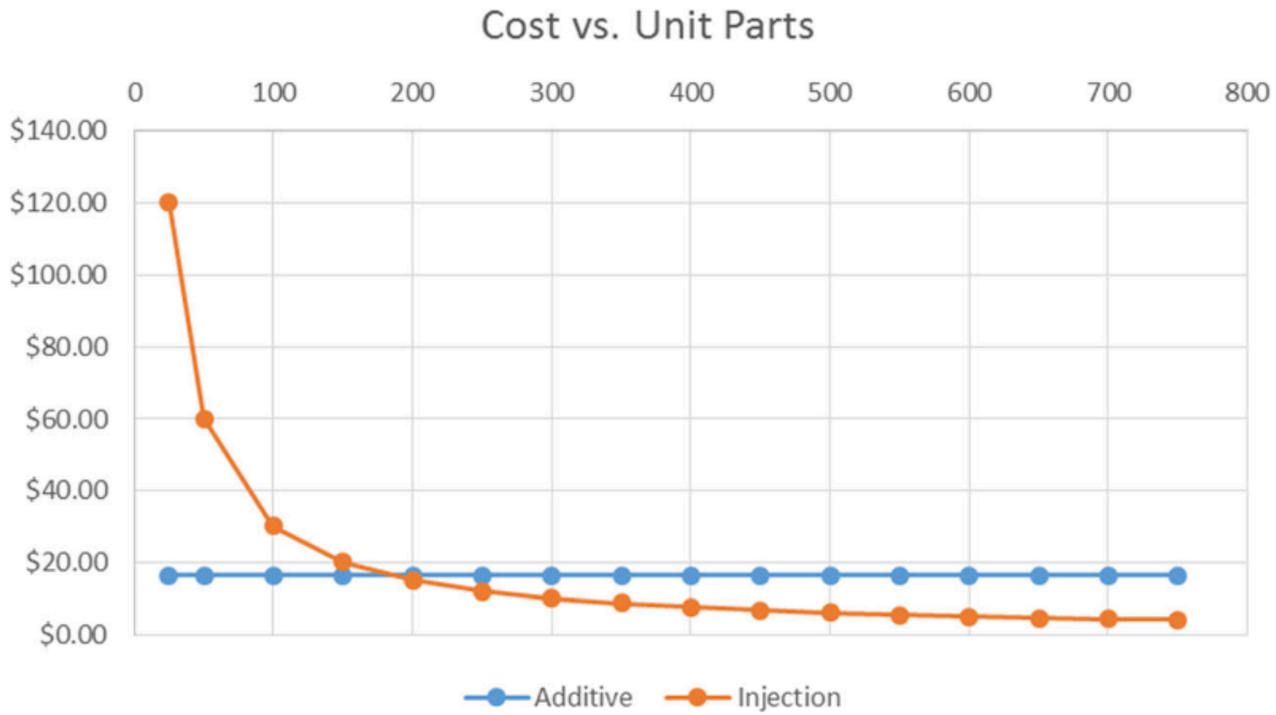
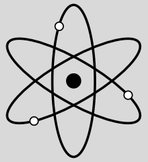


Image source: 2016, Matthew Franchetti, Connor Kress, An economic analysis comparing the cost feasibility of replacing injection molding processes with emerging additive manufacturing techniques, URL : https://link.springer.com/article/10.1007/s00170-016-8968-7

Comparison



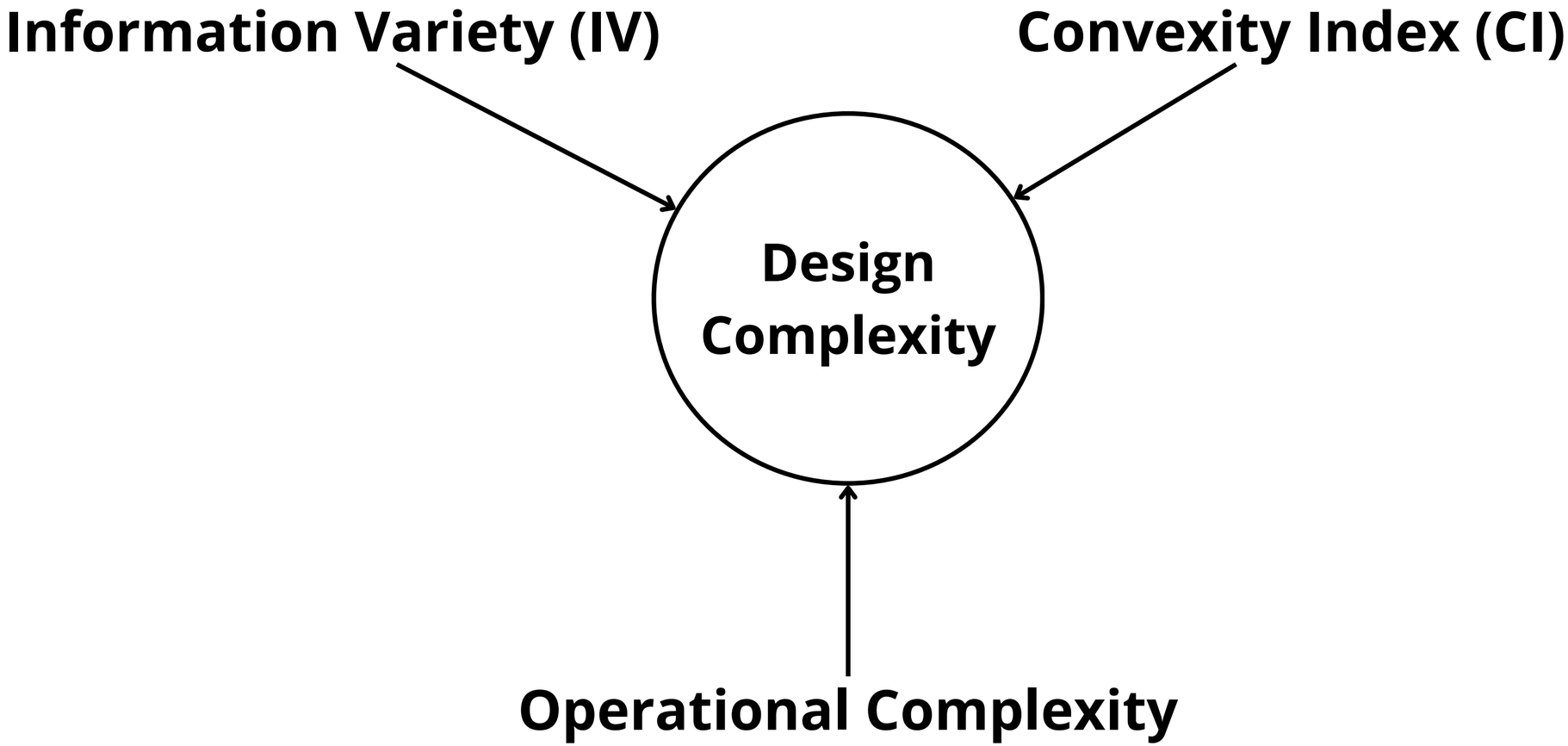
Physical properties

Cost efficiency

Design complexity

Sustainability factors

Design complexity



Design complexity

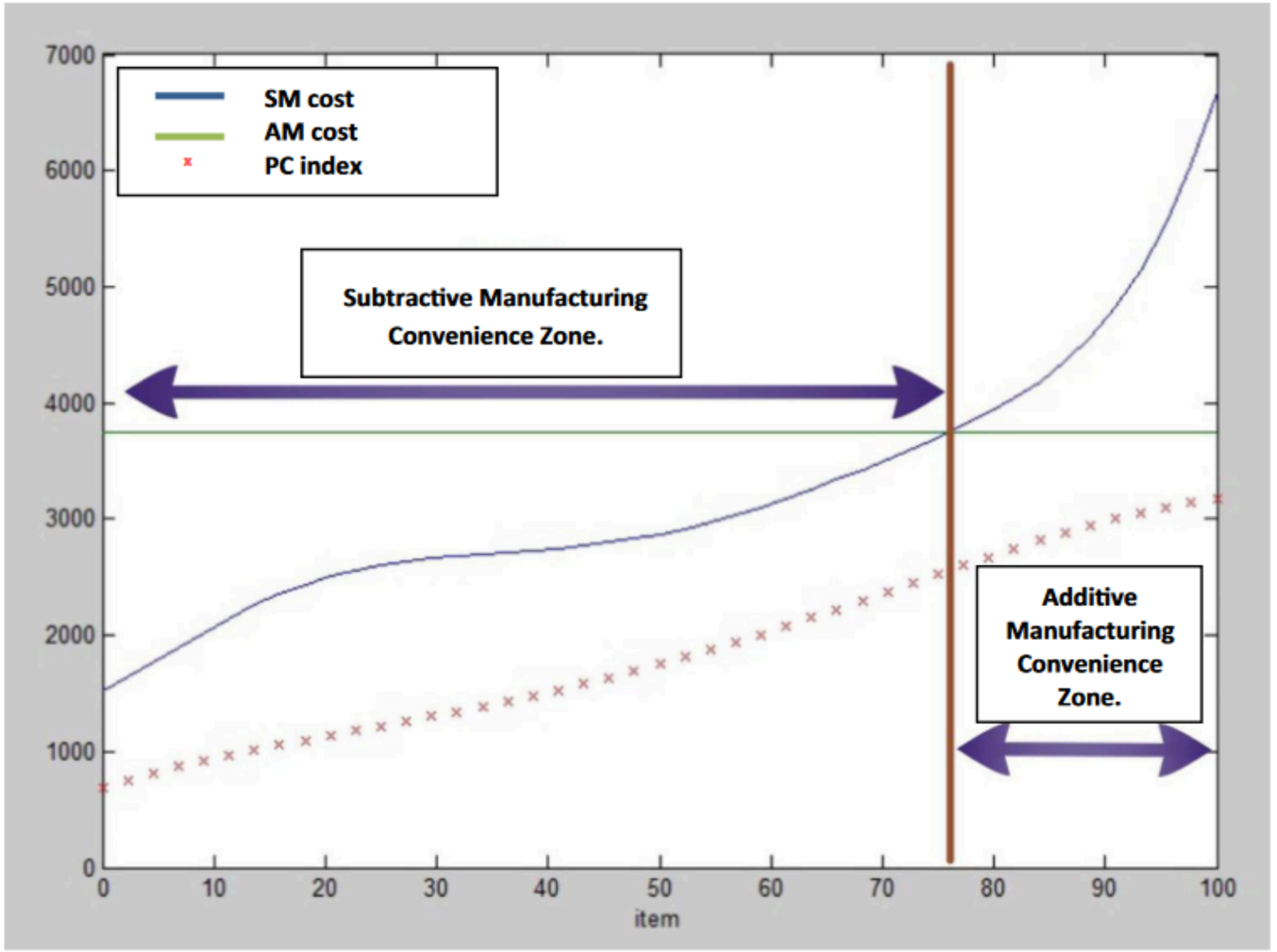
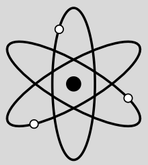


Image source: M. Fera & R. Macchiaroli & F. Fruggiero & A. Lambiase, 2017, A new perspective for production process analysis using additive manufacturing—complexity vs production volume URL : https://link.springer.com/article/10.1007/s00170-017-1221-1#preview

Comparison



Mechanical properties

Cost efficiency

Design complexity

Sustainability factors

Sustainability factors

Classical Mass manufacturing

High Waste
From 4:1 to 20:1
material to part ratio
for 5 axis CNC machine

Overproduction

Less Waste
From 1:1 to 3:1
material to part ratio
for AM*

Part on demand
Part is produced when needed

Additive Manufacturing

Decentralized logistics

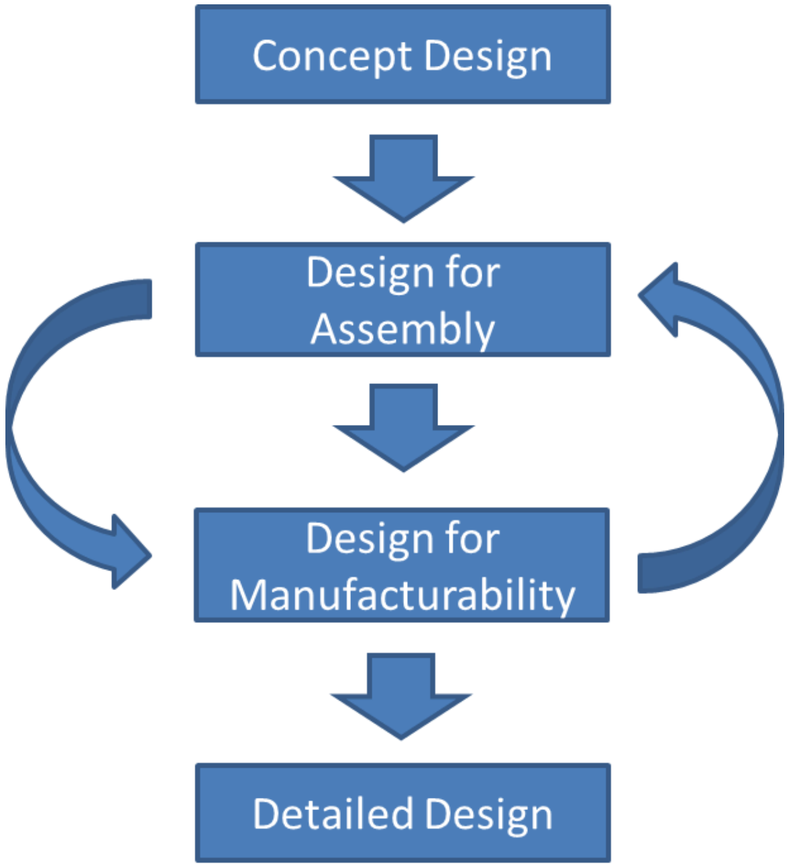
Optimised Design
Better performance leads to savings in ressources

Source *: A. Barz, T. Buer, H.-D. Haasis, 2016, A Study on the Effects of Additive Manufacturing on the Structure of Supply Networks
URL : https://link.springer.com/article/10.1007/s00170-017-1221-1#preview

Design for Additive Manufacturing (DfAM)

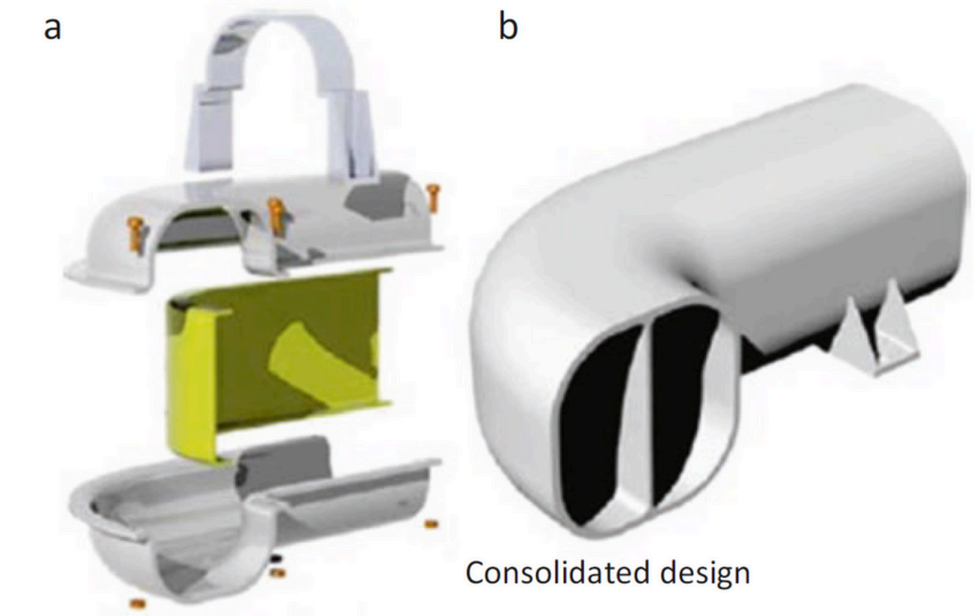
Presented by Sebastian Schüpbach

Design for manufacture and Assembly



- Design for manufacture
- Design for Assembly
- Why is DfM important?
- In mass production process optimization is crucial.

The need for Design for Additive Manufacturing



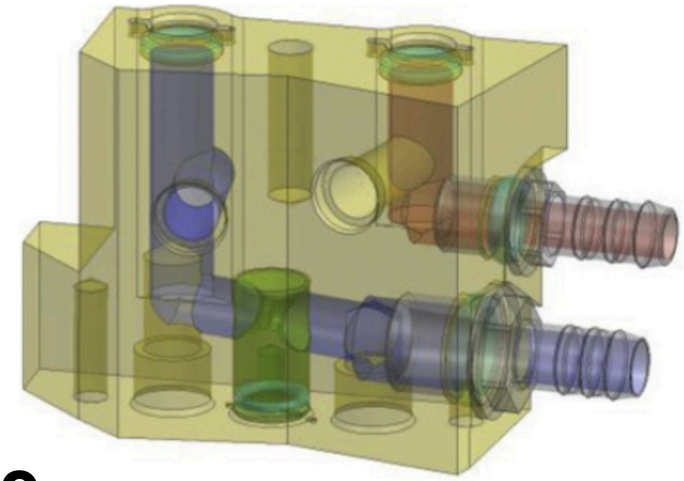
- AM processes have very different constraints
- ➡ need for new methods and rules!

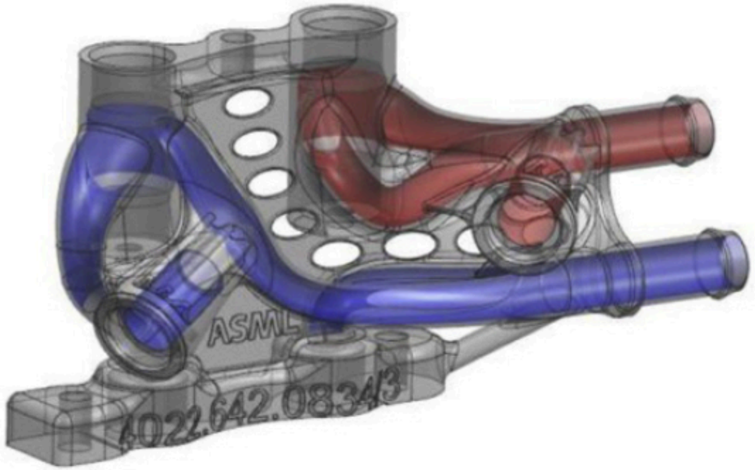
Image source: Brent Stucker, Mahyar Khorasani, Ian Gibson David Rosen. “Direct Digital Manufacturing”. In: Additive Manufacturing Technologies. 3rd. Springer, 2021, p. 531., doi: 10.1007/978-3-030-56127-7.

Additive Manufacturing unique capabilities

- Shape complexity
- Hierarchical complexity
- Functional complexity
- Material complexity

➡ Mass customization





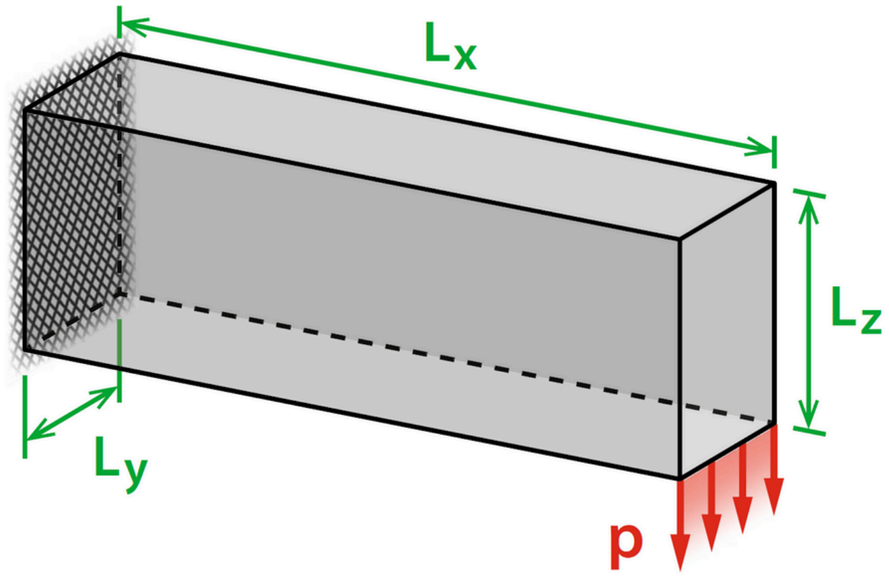
Thompson et al. (2016), Design for Additive Manufacturing: Trends, opportunities, considerations, and constraints, CIRP Annals - Manufacturing Technology 65(2016): 737–760.

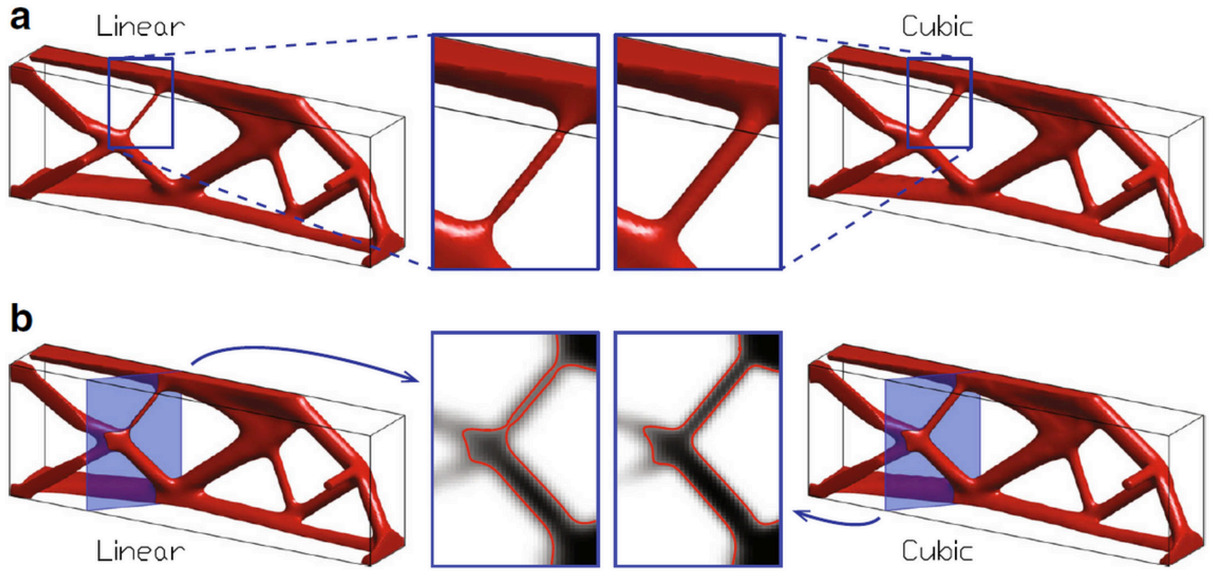
DfAM

- Take advantage of AM unique capabilities!
- Ensure AM constraints are respected
- The main challenge of DfAM: think of products in new ways!

Optimization Methods

- Topology Optimization (TO)
- TO in Product Design
- Synergy between TO and AM





Zegard, T., & Paulino, G. H. (2016). Bridging topology optimization and additive manufacturing. Structural and Multidisciplinary Optimization, 53, 175–192. https://doi.org/10.1007/s00158-015-1274-4

Optimization Methods

- Generative Design (GD)

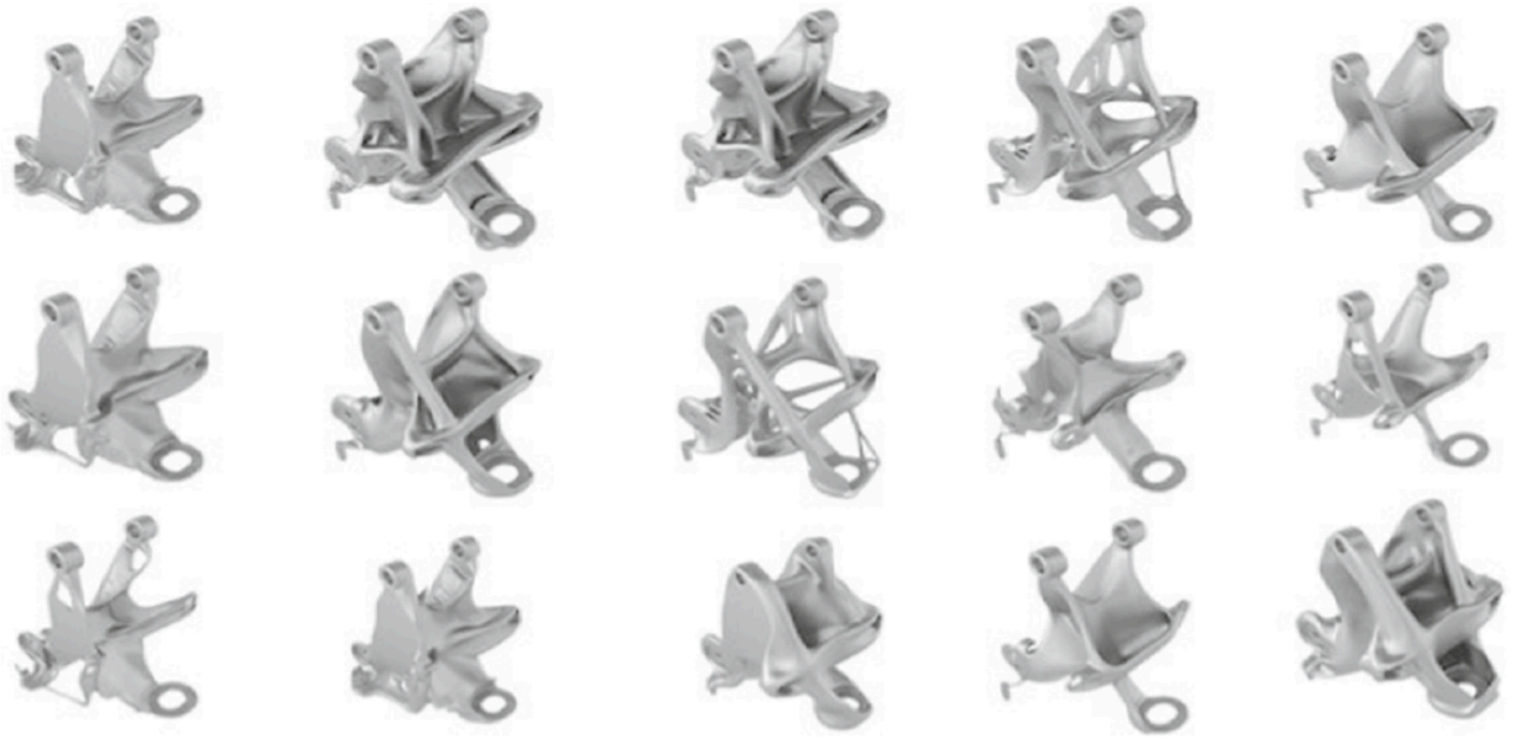
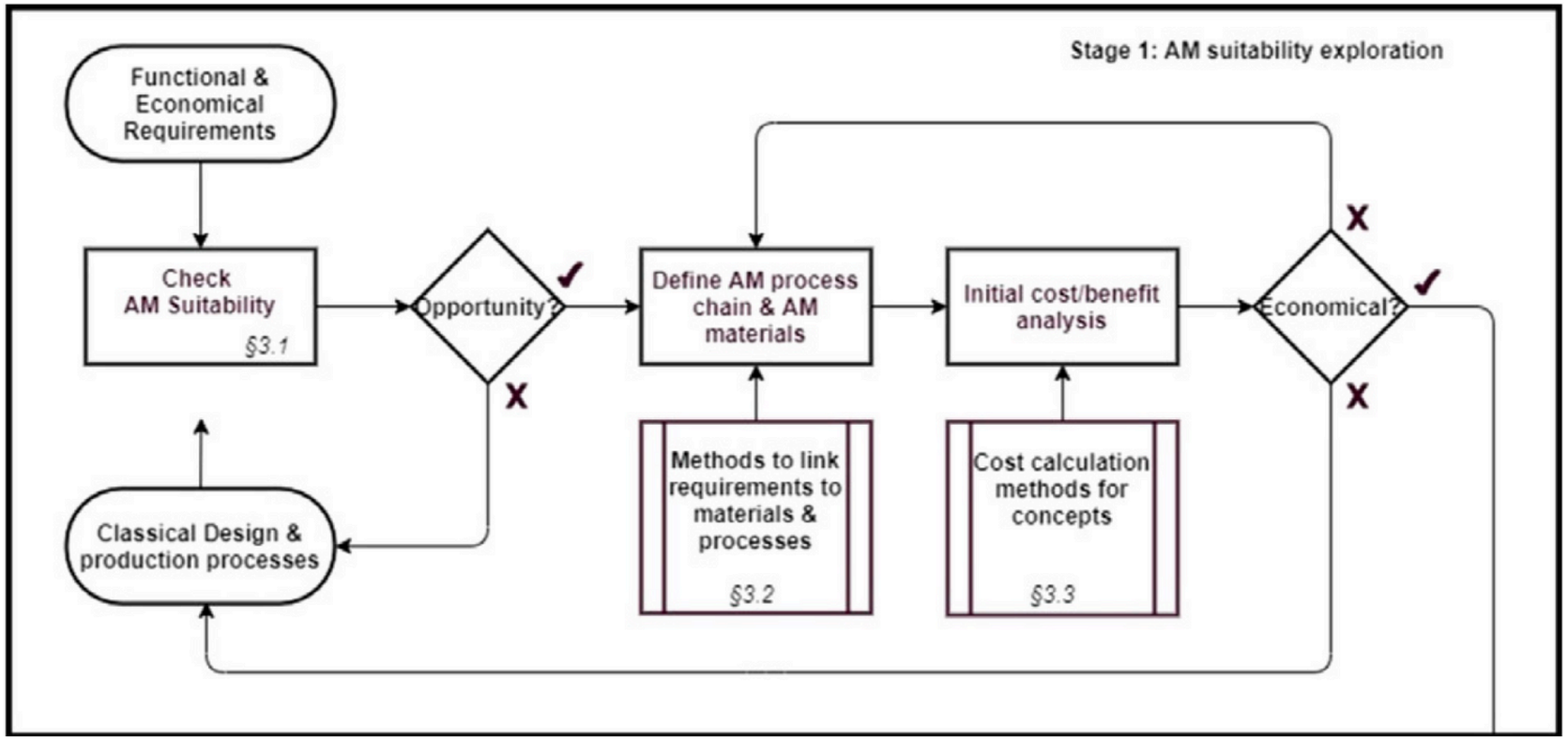
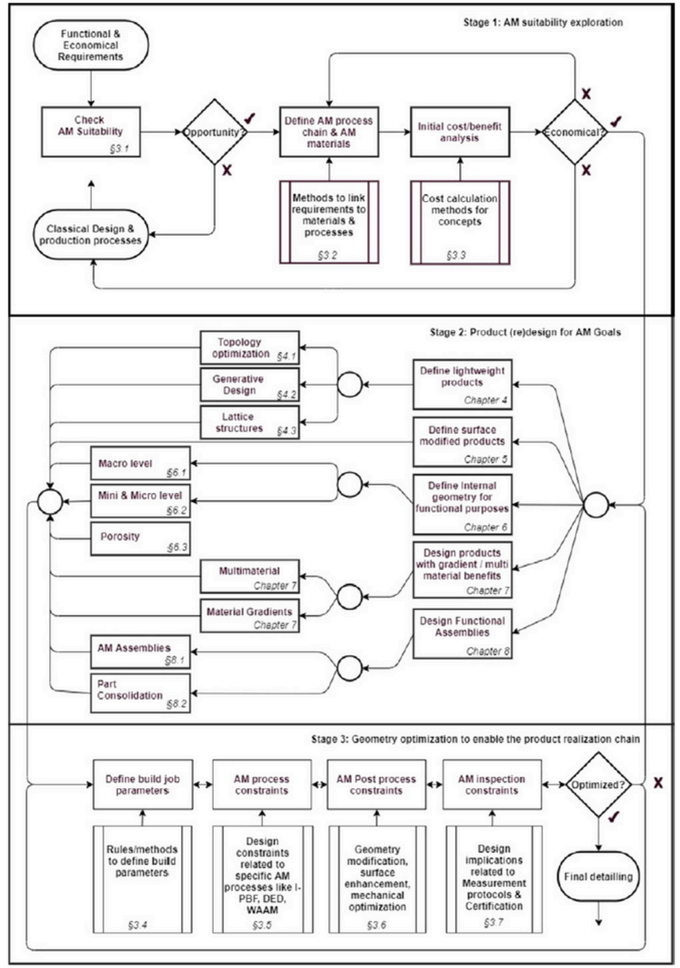


Figure source: Briard, T., Segonds, F., & Zamariola, N. (2020). G-DfAM: A methodological proposal of generative design for additive manufacturing in the automotive industry. International Journal on Interactive Design and Manufacturing (IJIDeM), 14, 875–886. https://doi.org/10.1007/s12008-020-00669-6

DfAM framework

Stage 1: AM suitability exploration

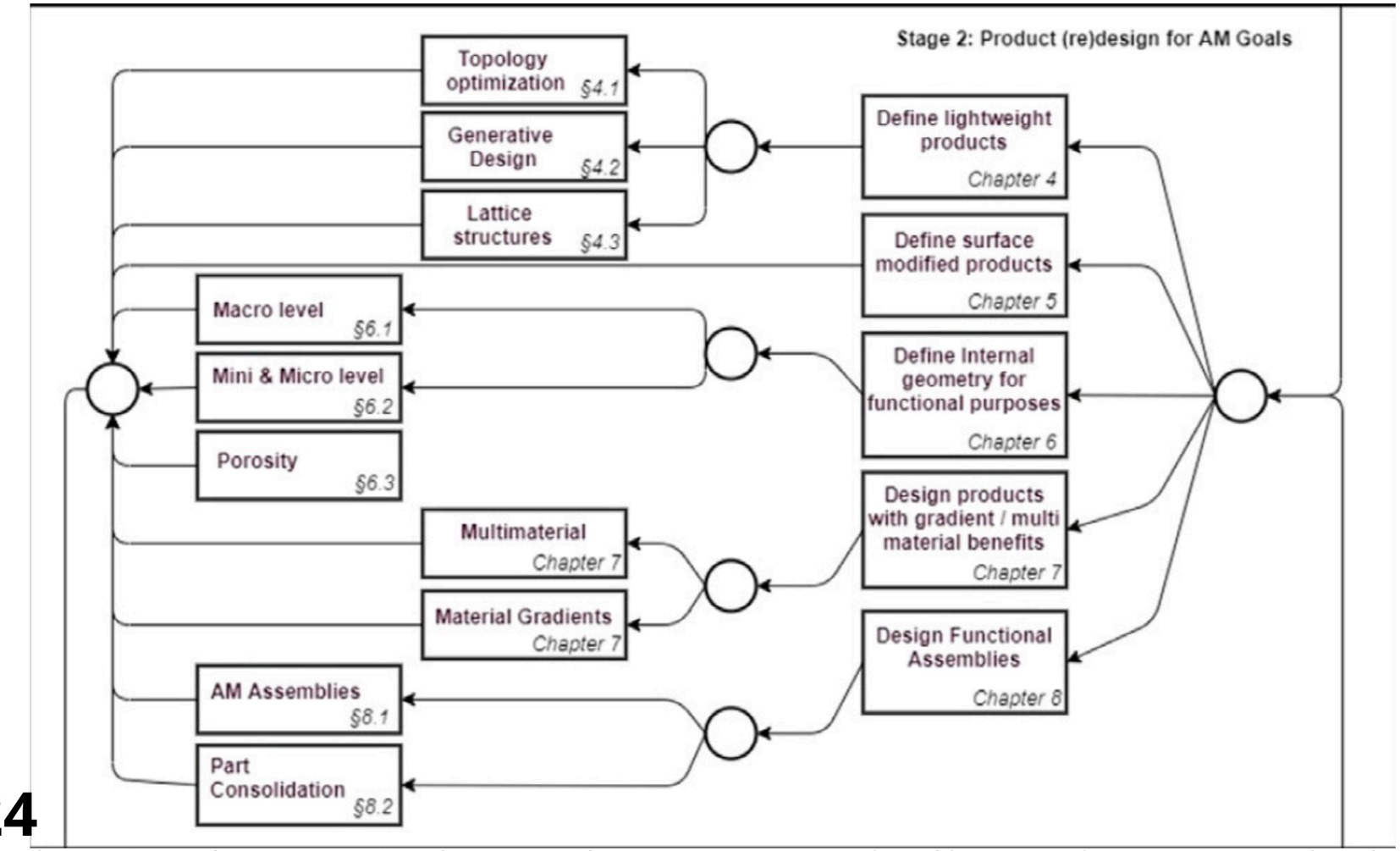


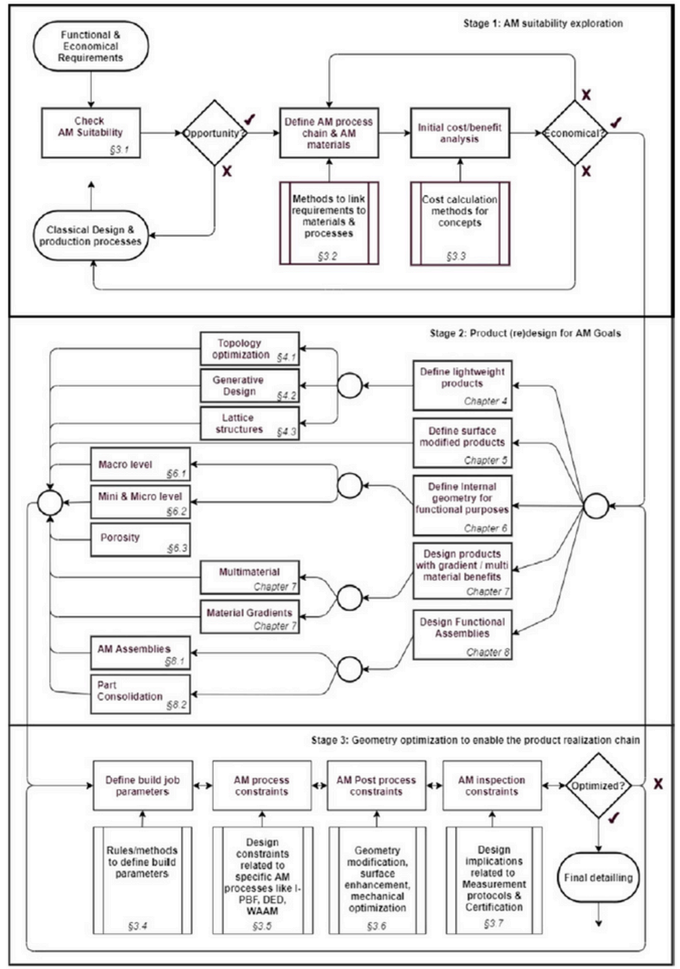


Vaneker, T., Bernard, A., Moroni, G., Gibson, I., & Zhang, Y. (2020). Design for additive manufacturing: Framework and methodology. CIRP Annals - Manufacturing Technology, 69(1), 578–599. https://doi.org/10.1016/j.cirp.2020.05.006

DfAM framework

Stage 2: Product (re)design for AM





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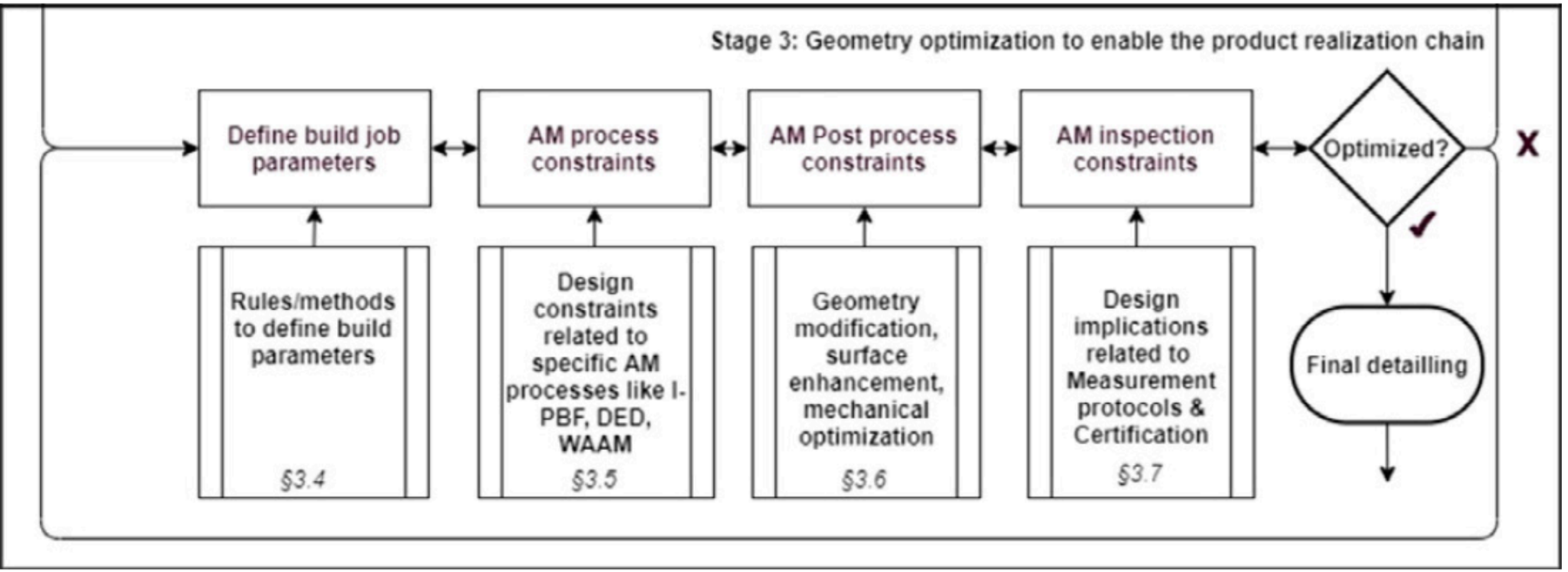
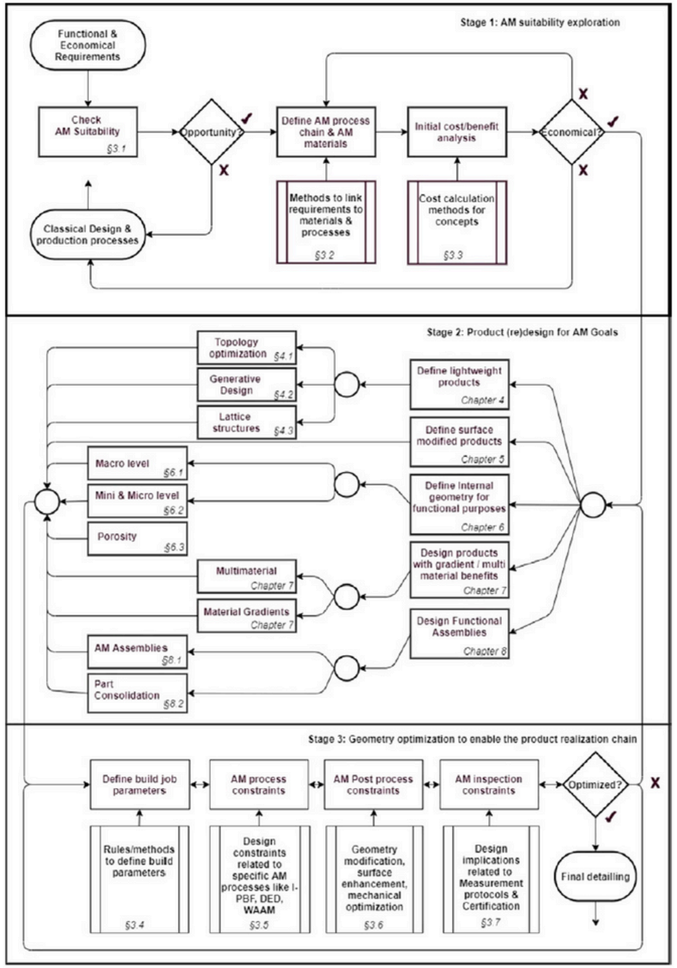
DfAM framework

Stage 3: optimization of the production chain





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Case studies

Presented by Maia Migliaro

1 - Climamog shoes

1 - Climamog shoes by Adidas

Image source:

1 - Climamog shoes by Adidas

- Adidas' CLIMACOOL line for more breathable footwear
- Slip-on shoes

Image source:

1 - Climamog shoes by Adidas

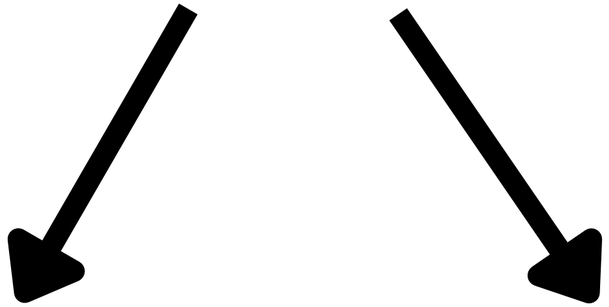
Design choices

- Mesh-lattice structure
- Single, continuous piece
- Polyurethane

1 - Climamog shoes by Adidas

Direct Ink Writing

Photopolymerization

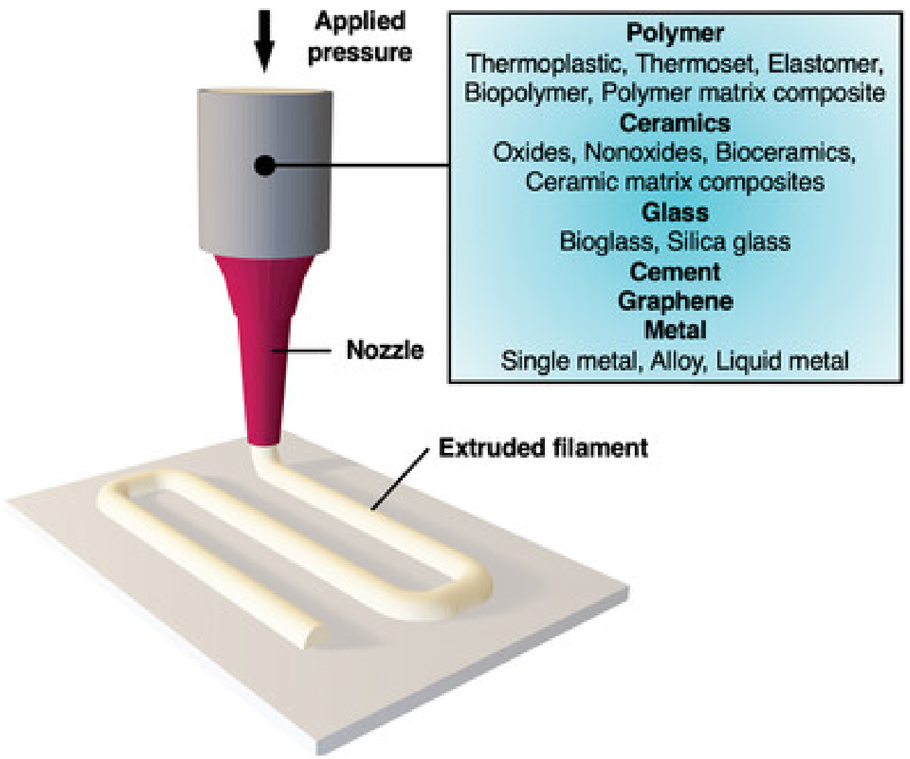


DLP

Stereolithography

1 - Climamog shoes by Adidas

Direct Ink Writing



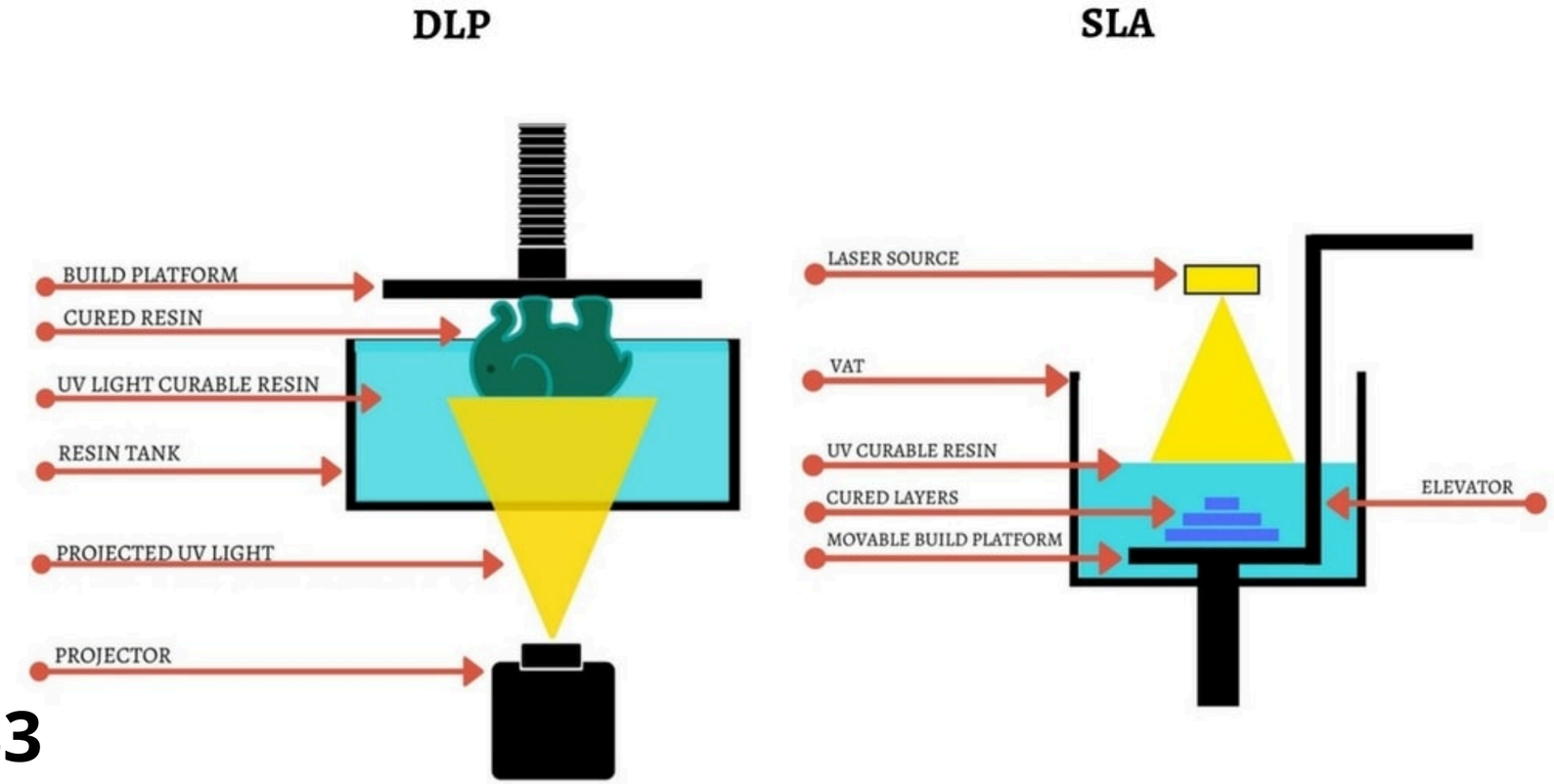
- A mixing nozzle extrudes the liquid PU layer by layer

1 - Climamog shoes by Adidas

Photopolymerization

DLP

Stereolithography

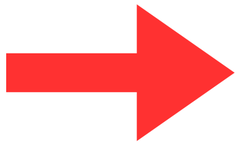


- Curing the material layer by layer with light or heat

1 - Climamog shoes by Adidas

Costs

- Costs of production: 28$ per pair
- Retail price: 140-170$



15-20% cost of retail

Similar ratio to other shoes

2 - FLAMTRÄD Line

2 - FLAMTRÄD Line by Ikea

2 - FLAMTRÄD Line by Ikea

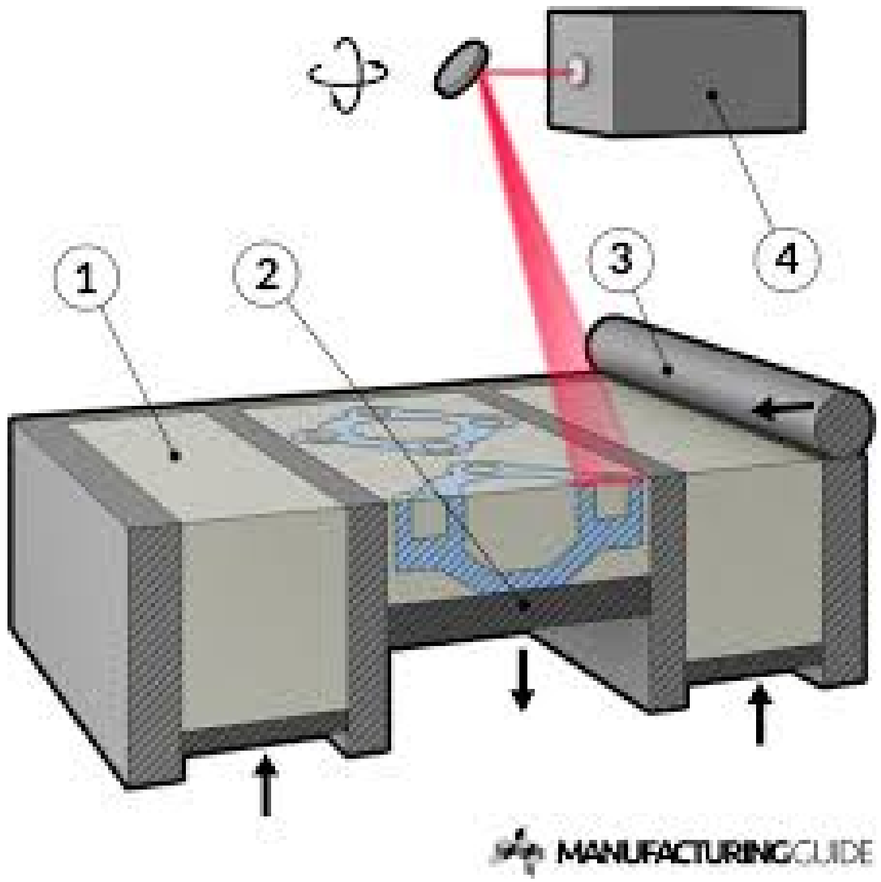
2 - FLAMTRÄD Line by Ikea

Design choices

- Mesh-lattice structure
- Polyamide 12 “Nylon”

2 - FLAMTRÄD Line by Ikea

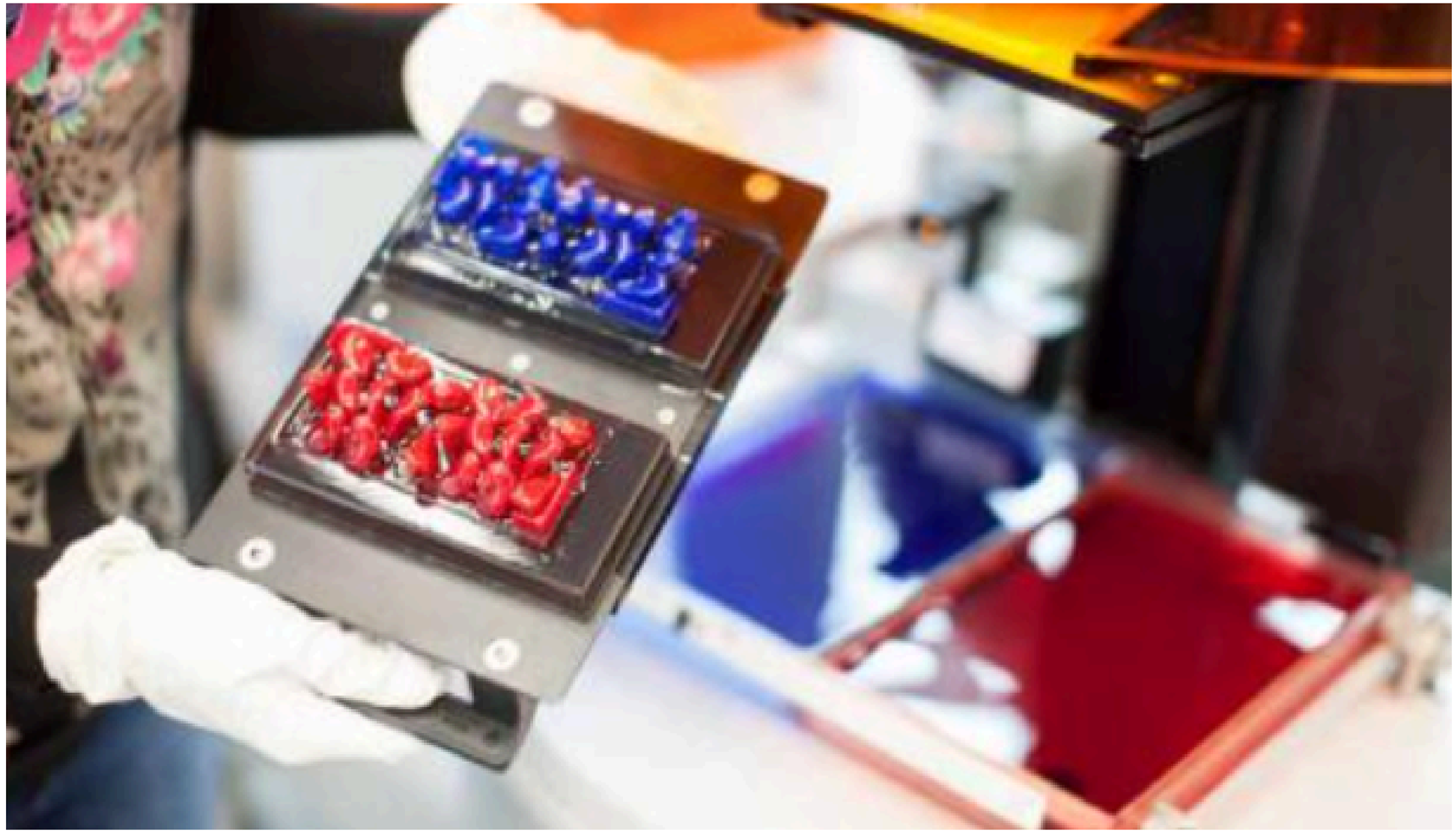
Selective Laser Sintering



- Uses a laser to selectively sinter polymer powder layer by layer,

3 - Hearing-aids

3 - Hearing-aids by Sonova



3 - Hearing-aids by Sonova

The process

1. Taking silicone impressions

3 - Hearing-aids by Sonova

The process

1. Taking silicone impressions
2. Scan impressions and create digital files

3 - Hearing-aids by Sonova

The process

1. Taking silicone impressions
2. Scan impressions and create digital files
3. Send files to printer

3 - Hearing-aids by Sonova

The process

1. Taking silicone impressions
2. Scan impressions and create digital files
3. Send files to printer
4. Clean printed shells and assembled with electronics

3 - Hearing-aids by Sonova

The process

1. Taking silicone impressions
2. Scan impressions and create digital files
3. Send files to printer
4. Clean printed shells and assembled with electronics
5. Quality testing

3 - Hearing-aids by Sonova

Advantages

- Mass customization
- Large volumes at reduced costs

3 - Hearing-aids by Sonova

Advantages

- Mass customization
- Large volumes at reduced costs

Challenges

- Precision
- Material selection

3 - Hearing-aids by Sonova

EnvisionTEC Perfactory 3D printer

- Digital Light Processing (DLP) technology
- Resolution of up to 25 microns

4 - Airplane brackets

4 - Airplane brackets for Airbus

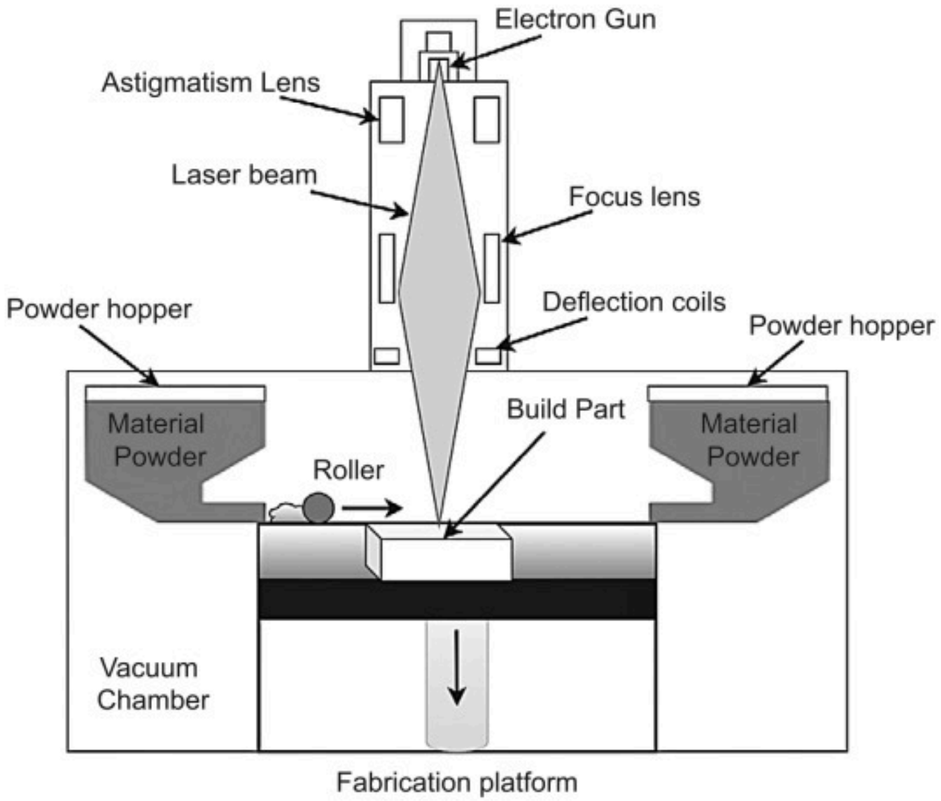
4 - Airplane brackets for Airbus

Design choices

- In series element
- Stainless steel powder

4 - Airplane brackets for Airbus

Electron Beam Melting



- Powder bed fusion methods
- A beam of electrons, guided by a magnetic field, melts metal powder to build layer-by-layer
- Specific for metal parts

4 - Airplane brackets for Airbus

Advantages

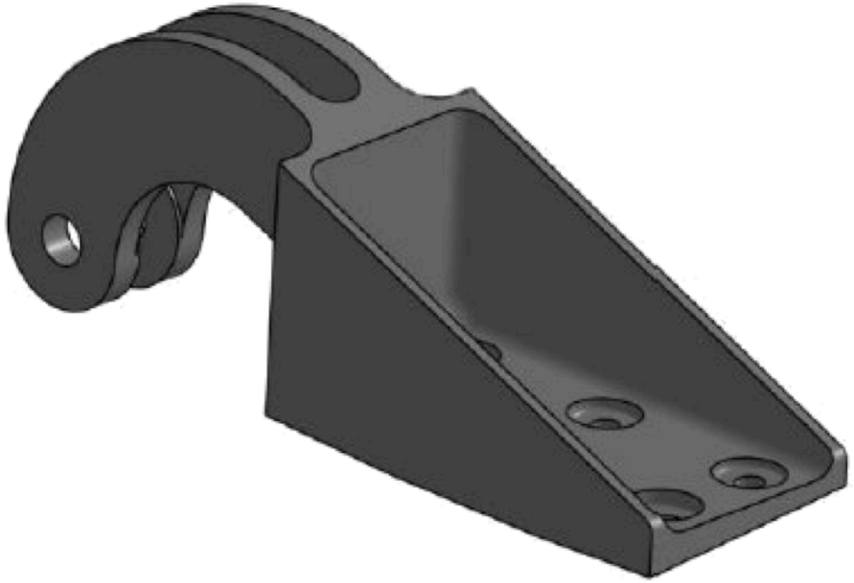
- Optimal strength-to-weight ratio
- Reducing weight and CO2 emissions

Challenges

- Quality testing

Limitations

Presented by Guillaume Keusch



source: EADS innovation team

Economical Limitations

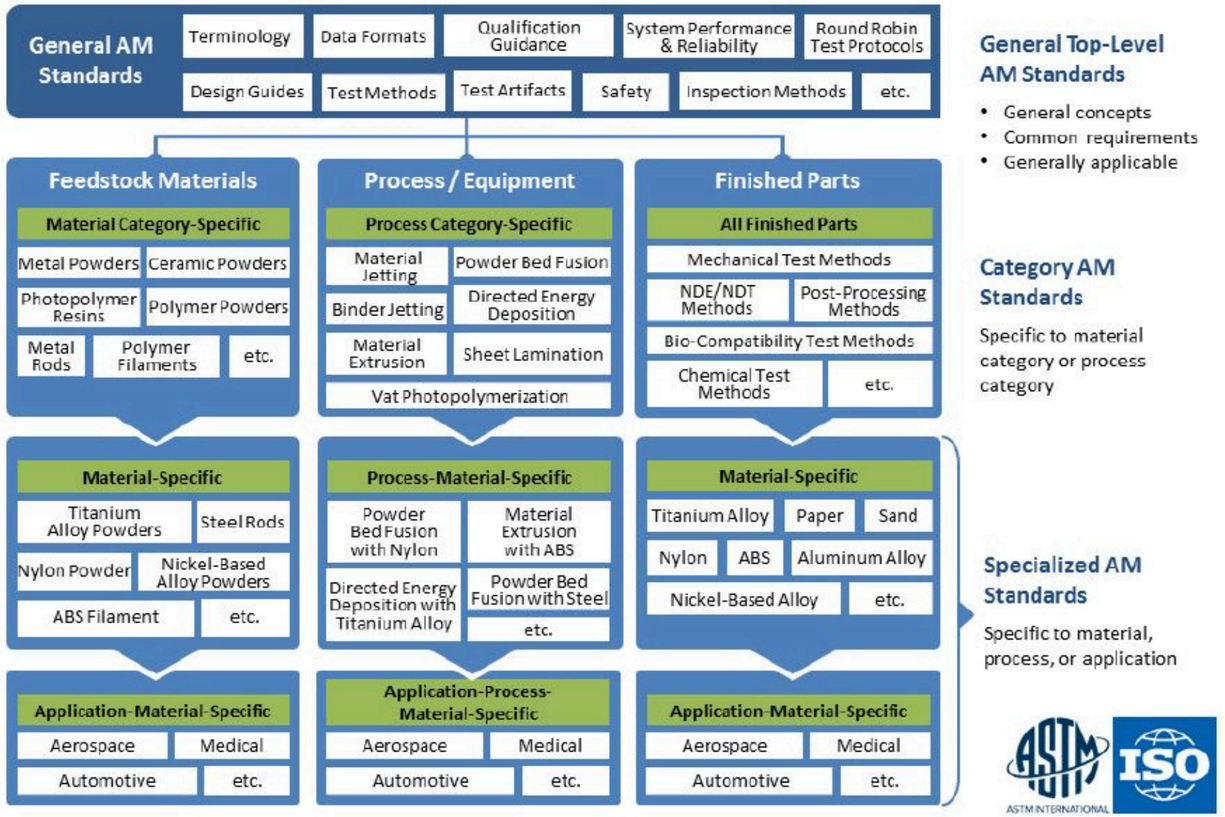
What are the big investments?

- Cost of re-equipement
- New staff
- New design philosophy

Technical Limitations

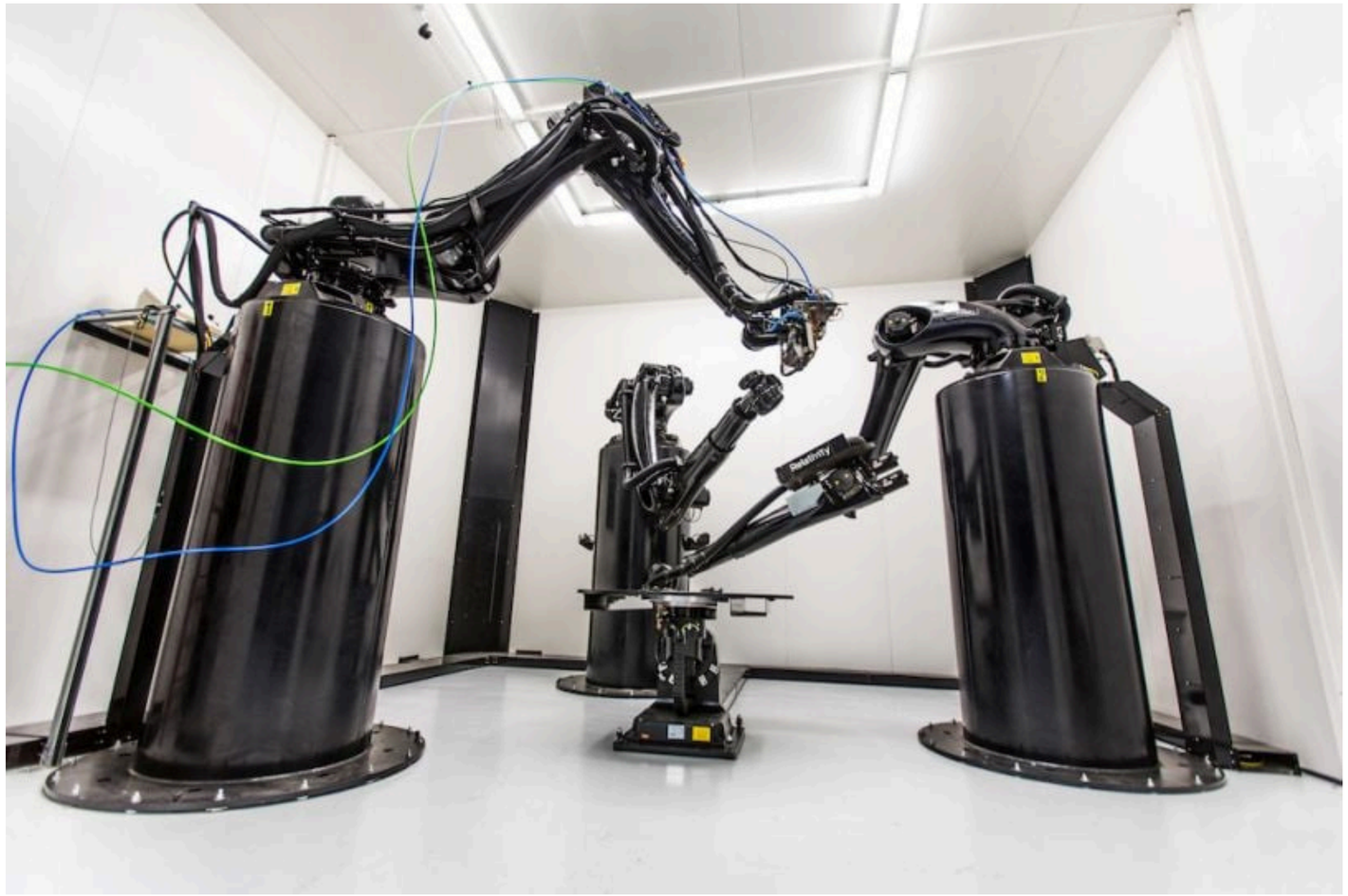
What needs to be developed?

- Norms
- Materials
- Quality control
- Post-processing



Future Trends

Presented by Mathieu Zysset

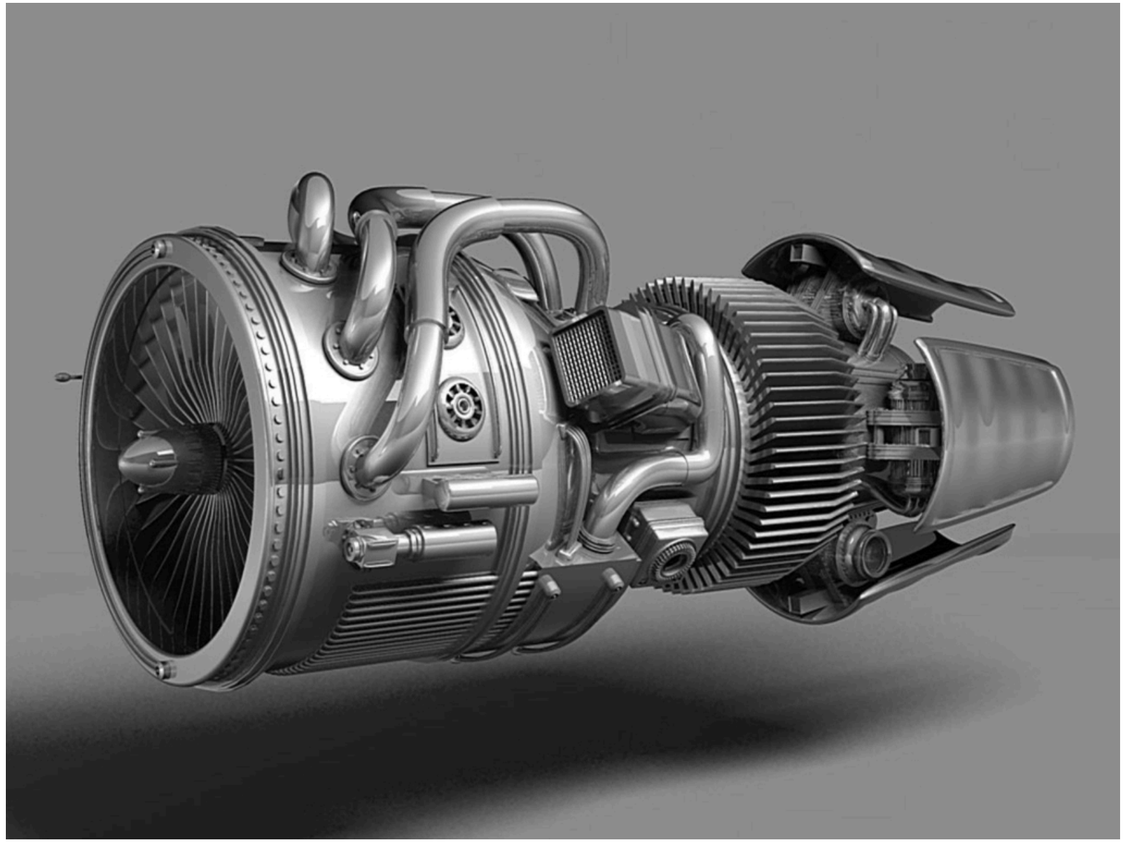


Source Relativity Space

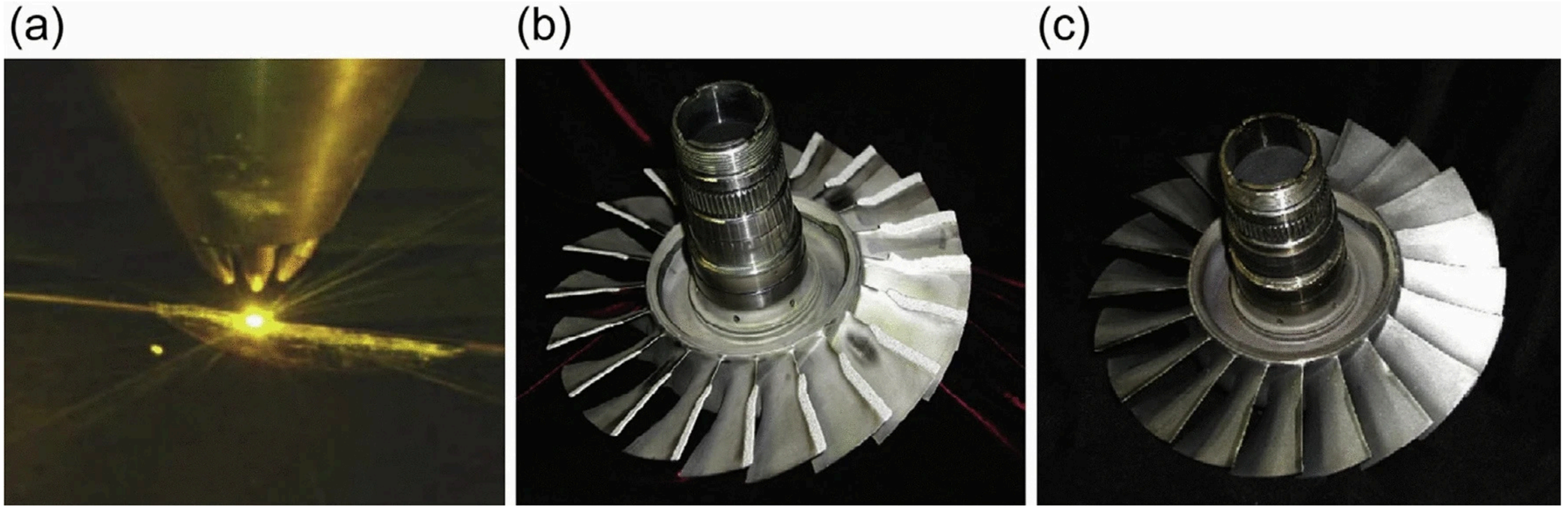
Growing Existing Sectors

Aerospace

- Complex, custom parts
- Small volumes
- 3/4 of jet engine in AM
- Relativity Space project
- Repair work by AM



Growing Existing Sectors



Repair of T700 blisk by laser engineering net-shaping (a) Lead edge in-process repair for Ti64 airfoil, (b) post deposit blisk, and (c) blisk after finishing. Courtesy: Optomec

Growing Existing Sectors

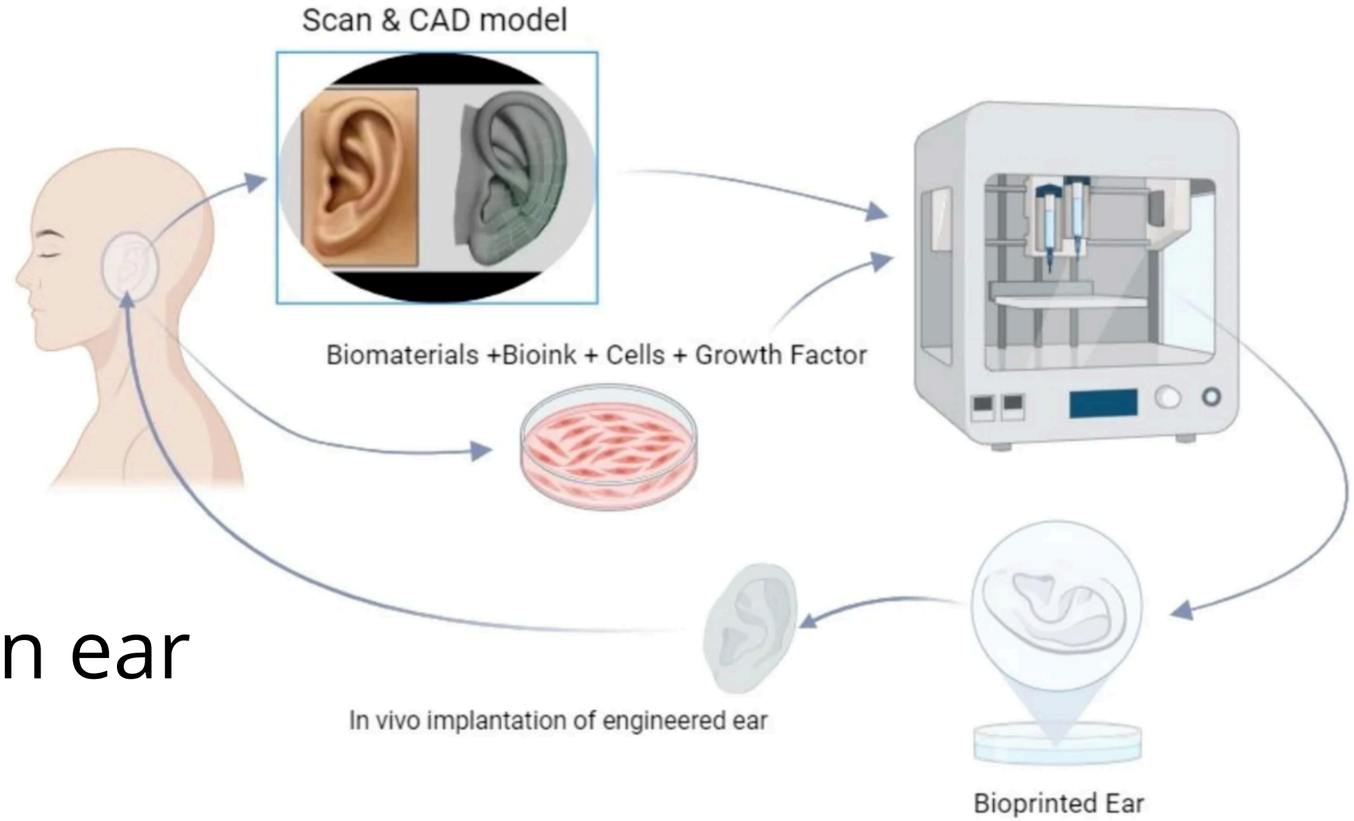
Automobile

- Drive shafts, gear boxes, exhausts by AM
- Motorsport interest for reduced mass and joints
- CRP Technology : air inlet by SLS

Growing Existing Sectors

Medical Sector

- Complex, Custom parts
- Implants, prostheses
- Scaffolds, equipments
- Education
- 3D bioprinting of human ear



Source Paper “A Comprehensive Literature Review on Advancements and Challenges in 3D Bioprinting of Human Organs: Ear, Skin, and Bone”

Growing Existing Sectors

Construction Industry

3D Printed houses

- Complex design
- Reduced Labor
- Reduced Waste
- Reduced time

↓

Greatly reduced costs

Source WinSun

Growing Existing Sectors

Source : Icon Technology

Link : https://www.iconbuild.com/our-story

Growing Existing Sectors

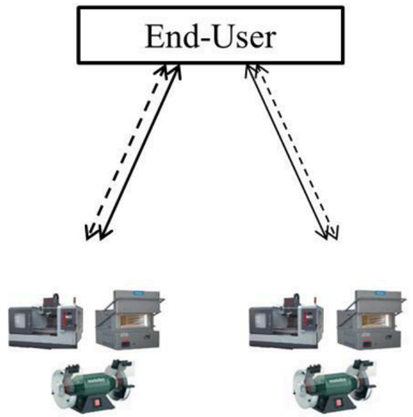
Source Icon Technology

- Most Recent robot - “Phoenix”
- Capable of multi-story
- Precision challenge
- Potential for mass customization

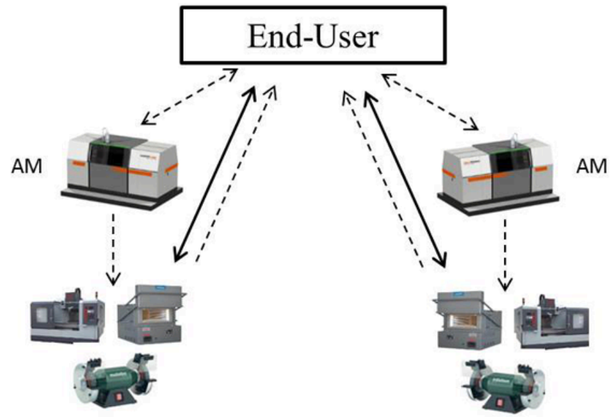
Hybrid AM

- What is hybrid ?
- Traditional process + AM
- Reduce Limitations
- Interface challenges

Hybrid AM for Mass Production

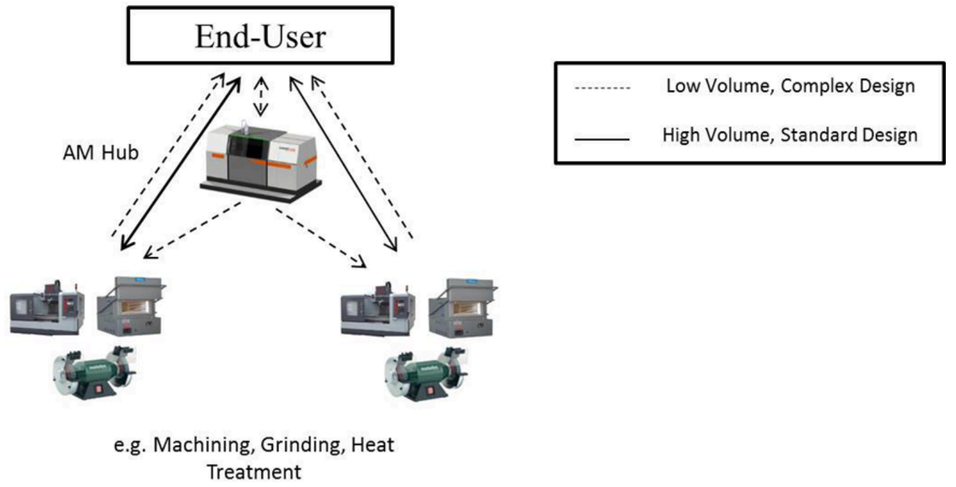


(a)



(b)

- AM added in supply chain
- Low Volume
- Complex Design
- 2 scenarios (b) and (c)



(c)

Source Paper “Current state and potential of additive – hybrid manufacturing for metal parts”

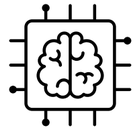
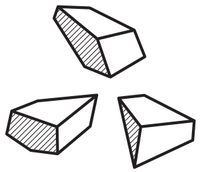
Artificial Intelligence driven AM processes

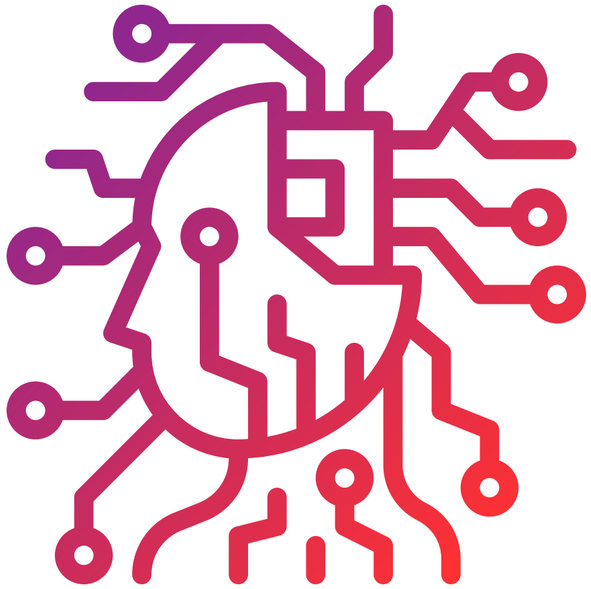
A.I. for design customization

- Challenges : quality, performance, time and cost
- Fast design solutions
- Part Geometry optimized

1. Desired Properties
2. Mass minimization
3. Minimal use of support

A.I. for materials in AM

- A.I. accelerates development 
- Data mining for new Al-alloys for LBPF 
- Avoiding grain nucleation causing hot-cracking 
- Finding right nucleant among 4500 candidates 



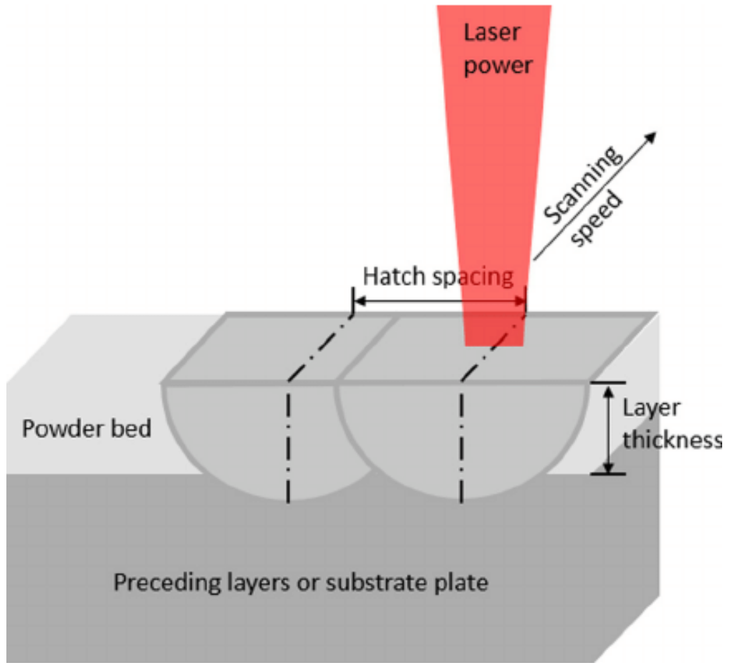
A.I. for process optimization

Optimization of :

- Slicing parameters
- Build orientation
- Layer thickness
- Printing paths
- Laser power
- Laser scanning speed
- Hatch spacing

Using :

- Data-driven approach
- Accelerated optimization
- Supervised Machine learning



Discussion

- Better competitiveness with traditional methods
- Potential of increasing volume production
- Lot of high-quality data needed
- AM for mass production ?

Thank you for your attention !

Questions ?