Additive Manufacturing

The MDH Way

21 August 2020

Who am I?

Name: Christopher Gustafsson

Work description: Research Engineer

Research interests: Additive Manufacturing (3D Printing), Product Development, Product Design, Product Innovation, Innovation and Design

Other interests: Ice hockey, Basketball, Art and Design, Statistics, Mathematics, Physics, Solid Mechanics, Food

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Agenda

This seminar will present an introduction to the emerging technology called **Additive Manufacturing (AM), also known as 3D printing**, which is a **key aspect in Industry 4.0**. **Production systems, supply chains, business models, and many more aspects** are being **transformed and reimagined** due to the potential that AM possess.

The seminar will also present some **AM related activities/projects at Mälardalen university** as well as **exploring the current challenges, limitations and opportunities with AM** from **different research perspectives**.

What is Additive Manufacturing?

Additive manufacturing (AM) is the official industry standard term (ASTM F2792) for all applications of the technology, however, it is most commonly known as 3D printing.

It is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies.

Synonyms are additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication. Other related terms are desktop manufacturing, rapid prototyping, rapid manufacturing, rapid production, rapid tooling.

Many standards in AM regarding design, materials, processes, terminology, test methods, and more.

Source: https://wohlersassociates.com/additive-manufacturing.html & https://www.astm.org/Standards/additive-manufacturing-technology-standards.html

Why AM?

Additive manufacturing (AM), considered a disruptive technology of Industry 4.0 and the efforts of digital transformation, has been implemented in several industries particularly in prototyping. However, a road map to successful implementation and leverage of AM in manufacturing remains blurred.

- Jirsak and Brunet-Thornton (pp. 179, 2019)

AM is considered to be a landmark digital manufacturing technology with strong effects on industry structure.

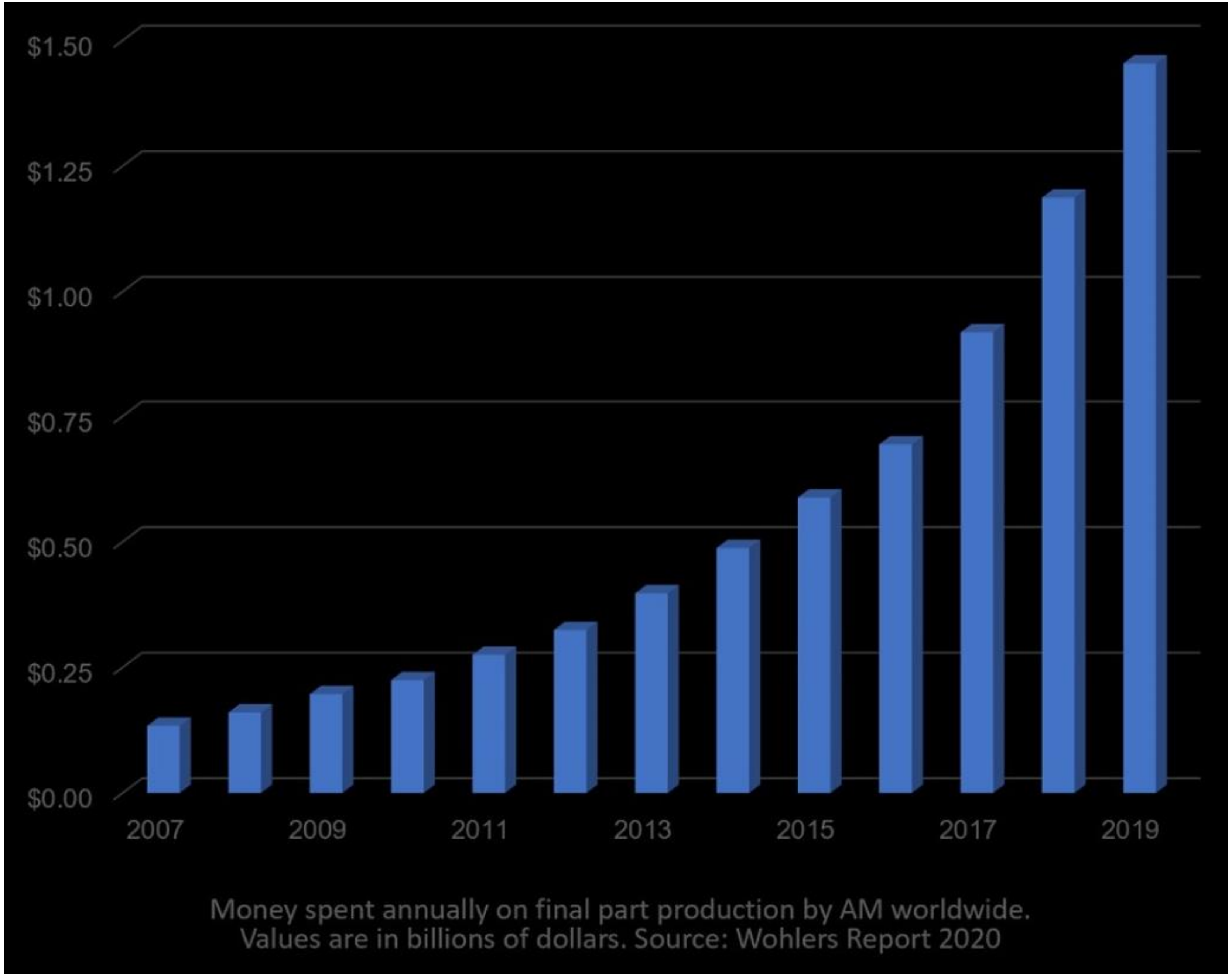
- Kleer and Piller (pp. 33, 2019)

We propose that to benefit from the opportunities AM offers, firms should focus on the product they would like to create, irrespective of its complexity, and also on the material best suited to making that product. In addition, we suggest that firms will only regard AM as a competitive manufacturing method if they move from calculating costs on a per part basis, to doing so over the lifetime of the product.

- Maresch and Gartner (pp. 2, 2020)

It can challenge traditional removal and molding-centric manufacturing and either revolutionize entire processes or complement traditional manufacturing.

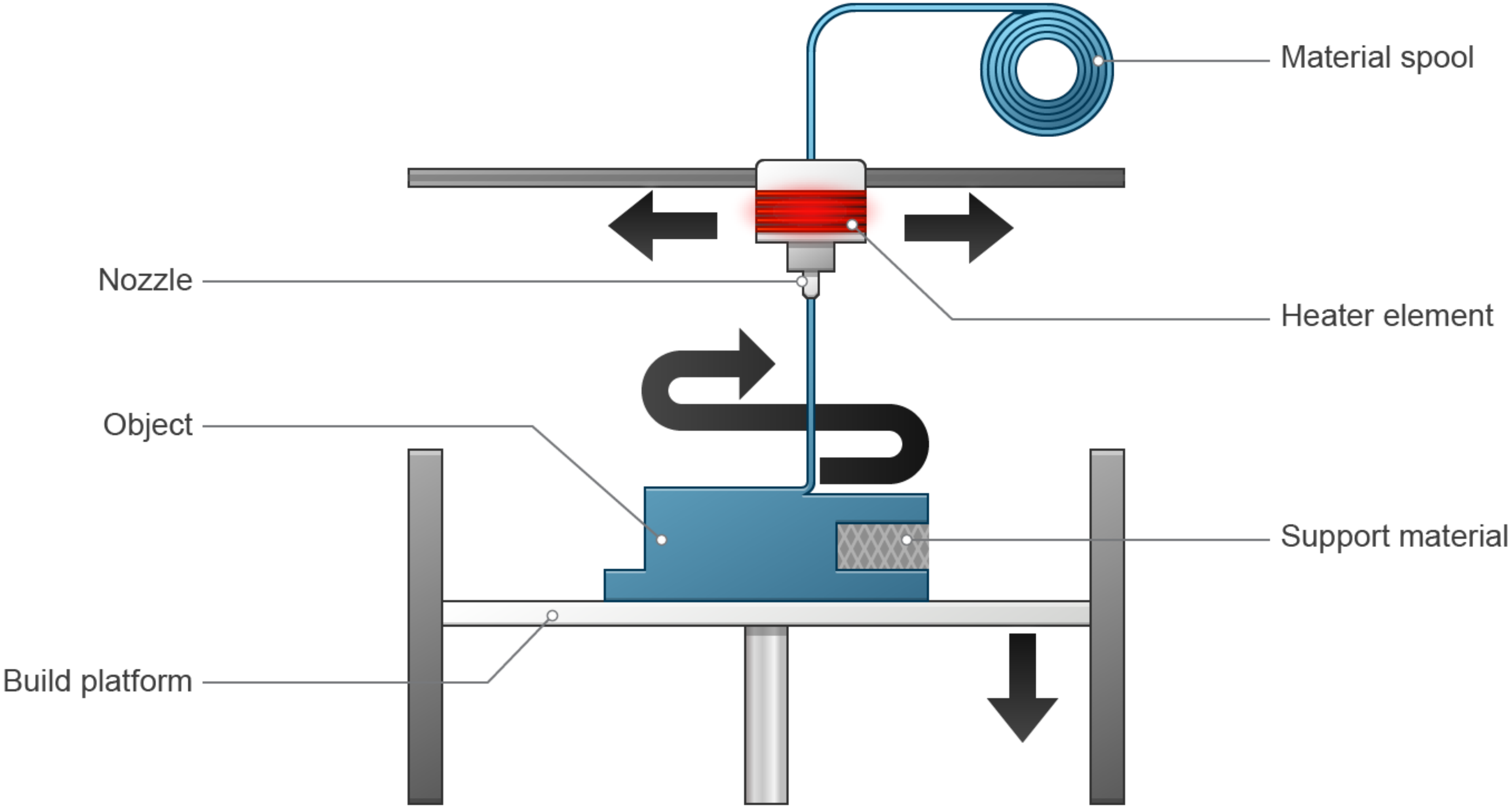
- Luomaranta and Martinsuo (pp. 54, 2020)



Source: https://wohlersassociates.com/

AM processes and their technologies

- **Material Extrusion**
- Powder Bed Fusion
- Material Jetting
- Binder Jetting
- Directed Energy Deposition
- Photopolymerization
- Sheet Lamination



Source: https://make.3dexperience.3ds.com/processes/introduction-to-additive-processes

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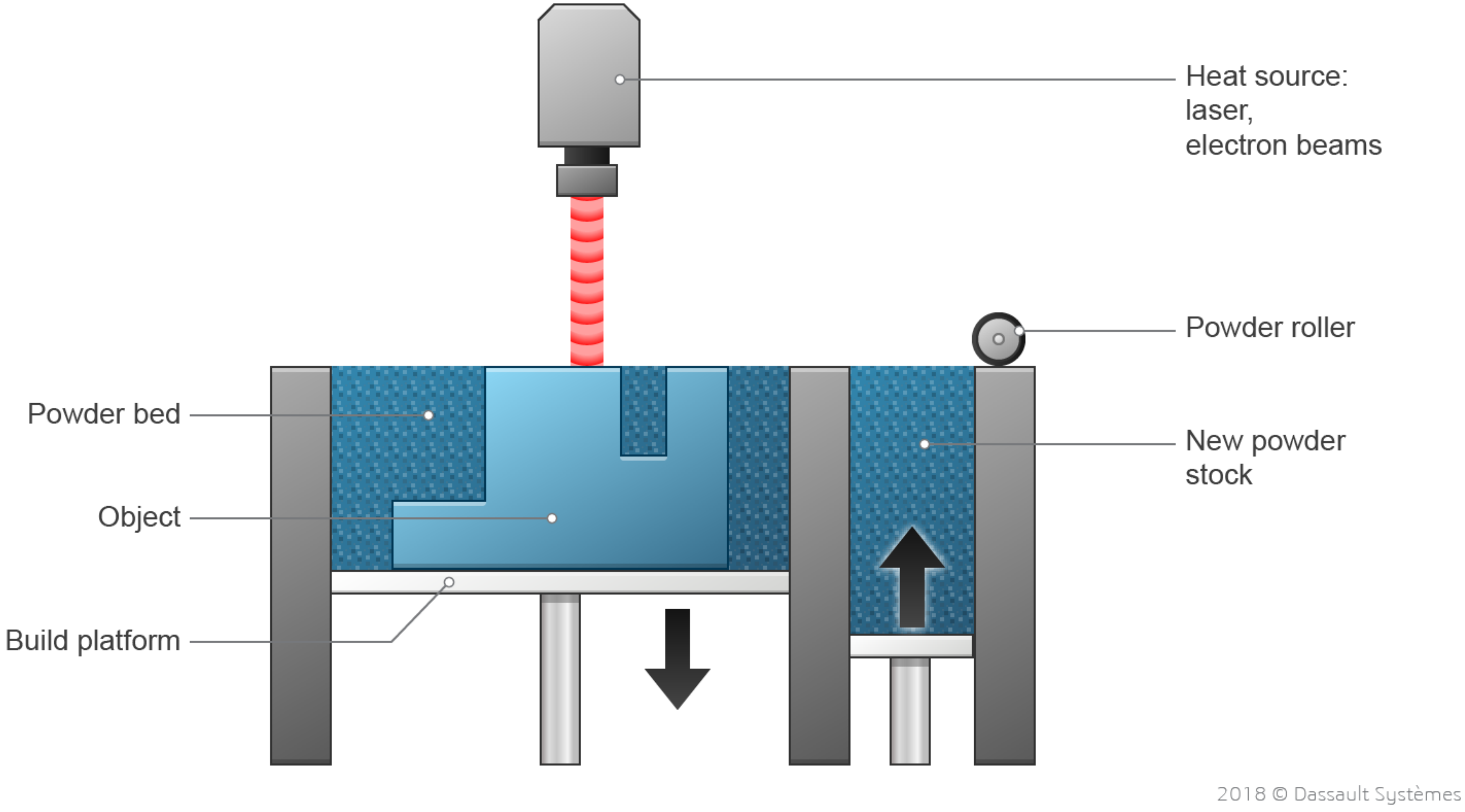

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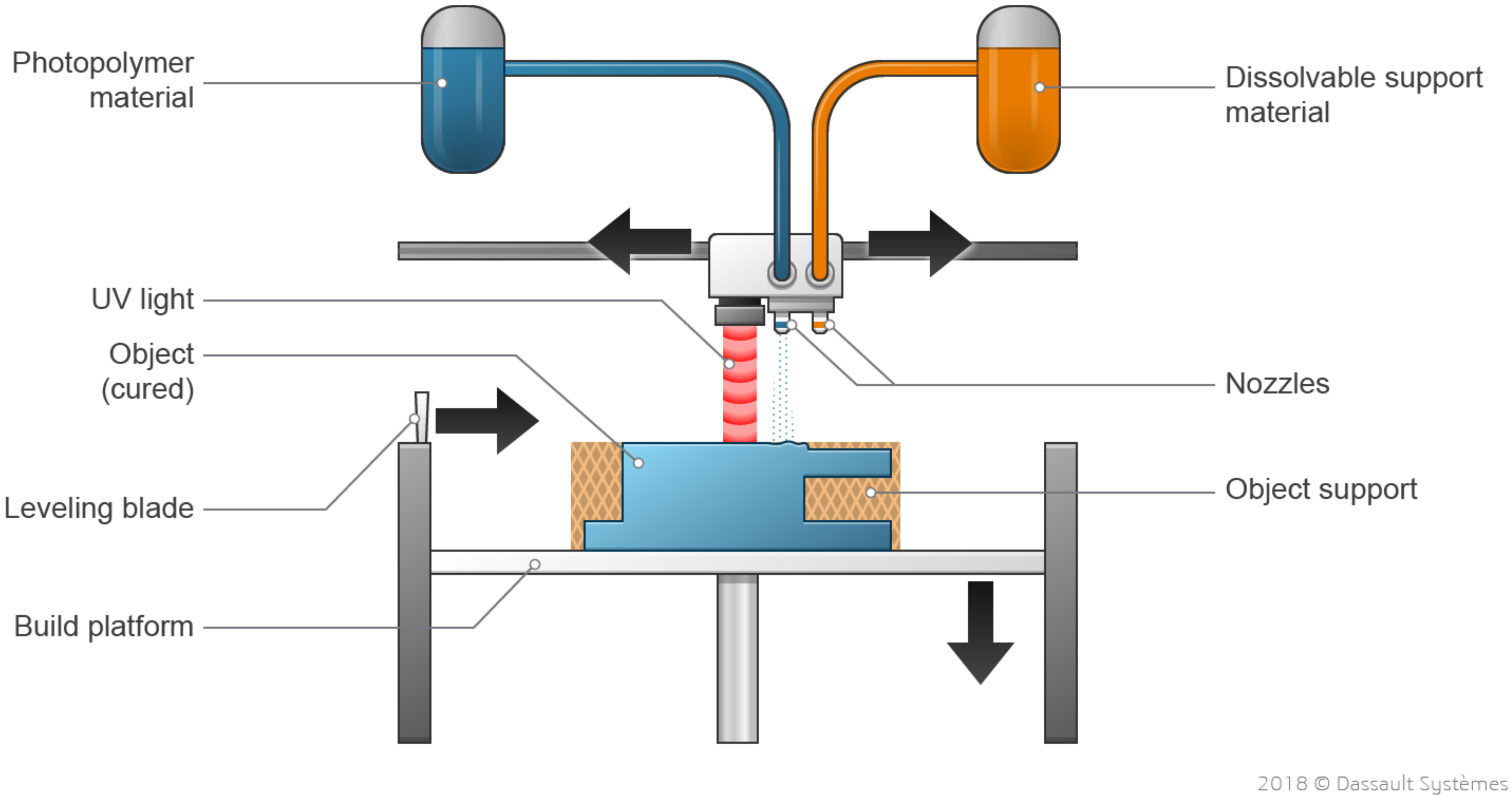

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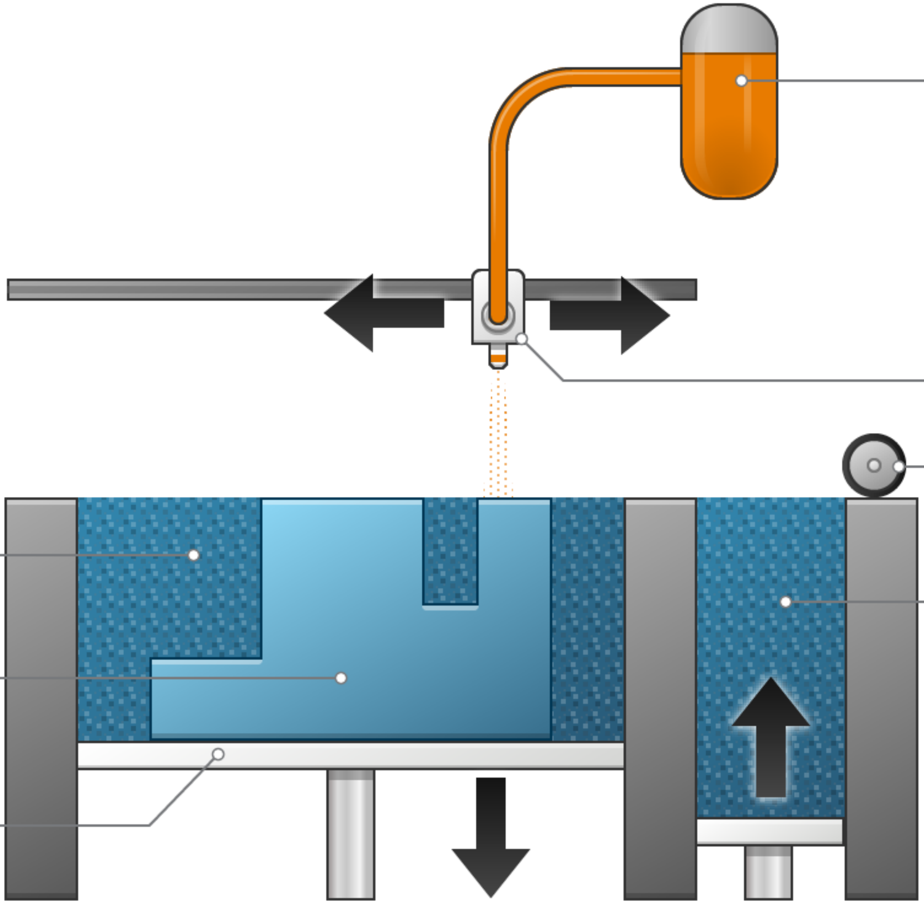

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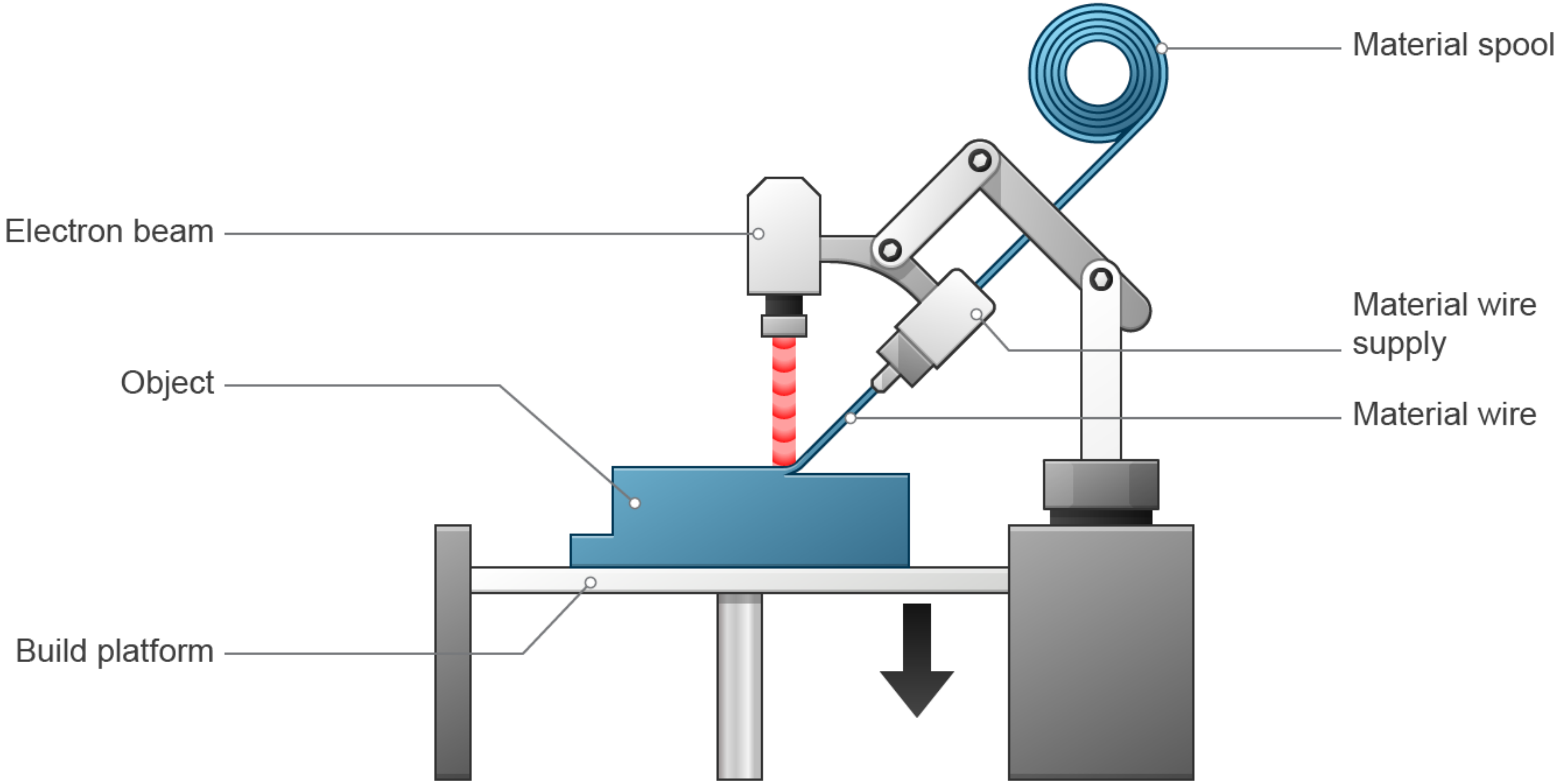

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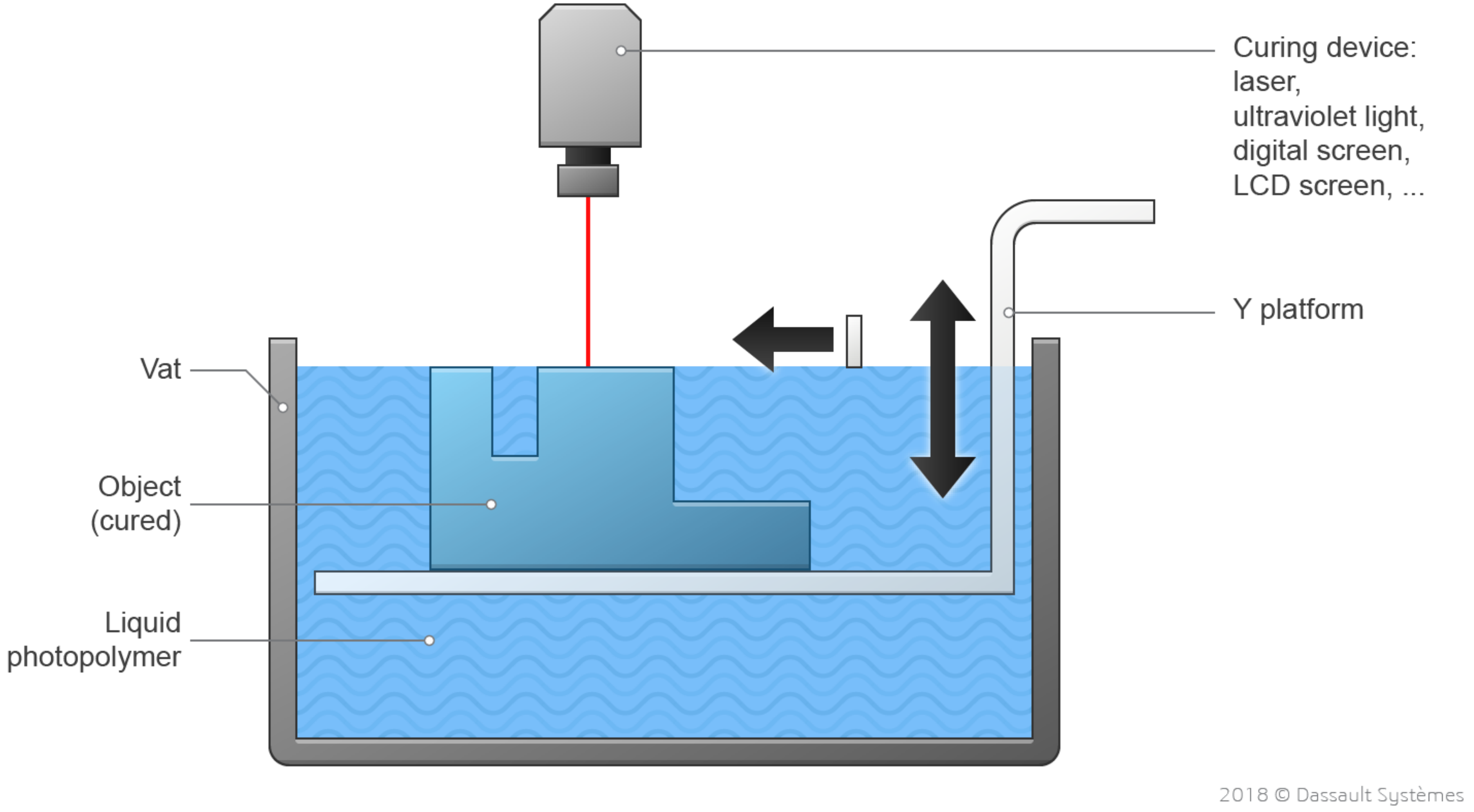

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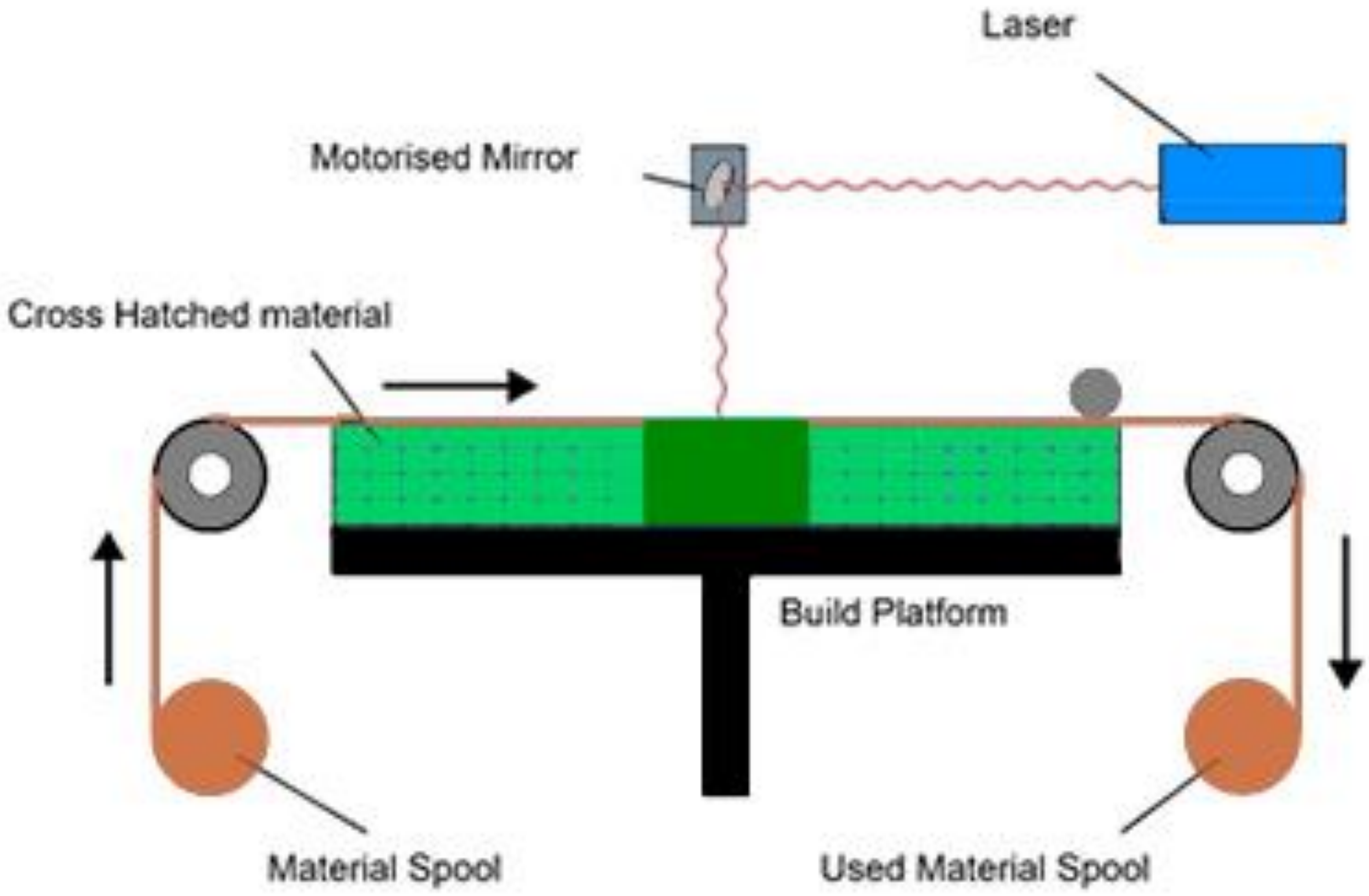


Source: https://www.engineersgarage.com/tech-articles/3d-printing-processes-sheet-lamination-part-8-8/

Materials used in AM

Plastics (e.g. ABS, PLA, SLA)

Metals (e.g. aluminum alsi10mg, maraging steel 1.2709, titanium alloy Ti6Al4V)

Ceramics (e.g. silica/glass, porcelain, silicon-carbide)

Composites (e.g. ABS, epoxy resin, nylon)

Food (e.g. chocolate, meat, pasta)

Wood (e.g. PLA base material combined with cork, wood dust, or other)

Biomaterials (e.g. organs, human tissue, cells on macro and micro levels)

More materials are being developed as we speak!

AM characteristics

- Costs
- Weight
- Complexity
- Individuality
- Speed
- Sustainability

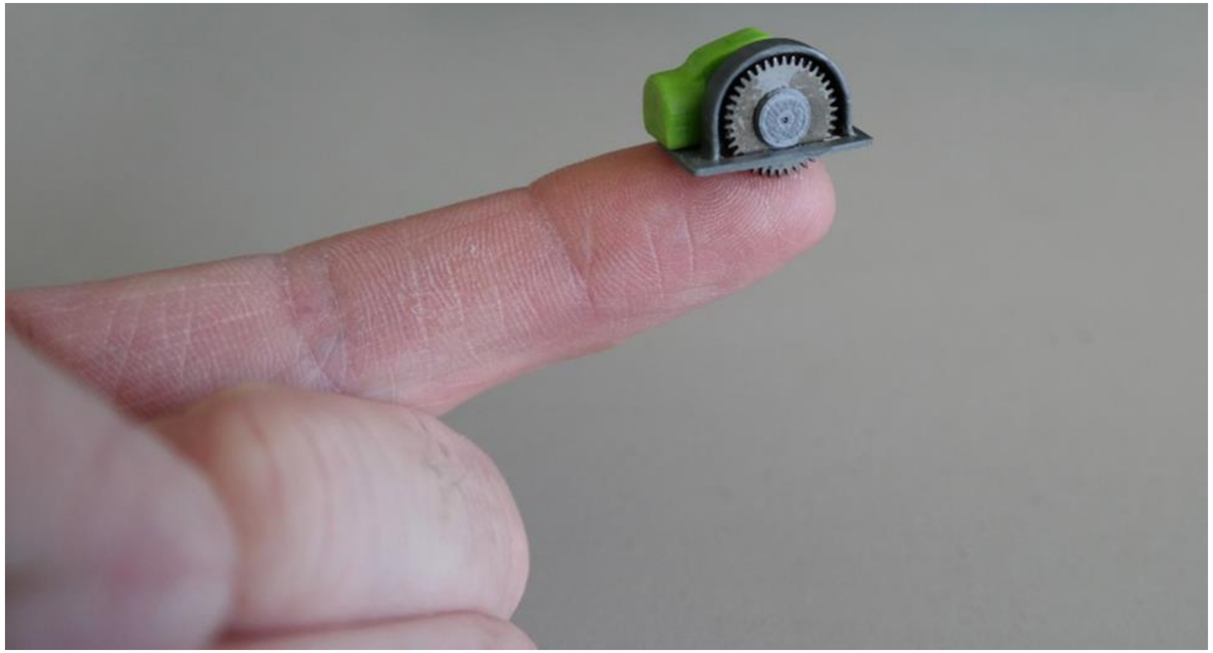
Daniela Maresch and Johannes Garter (2020). Make disruptive technological change happen – The case of additive manufacturing. Technological Forecasting & Social Change. 155: 119216. doi: 10.1016/j.techfore.2018.02.009

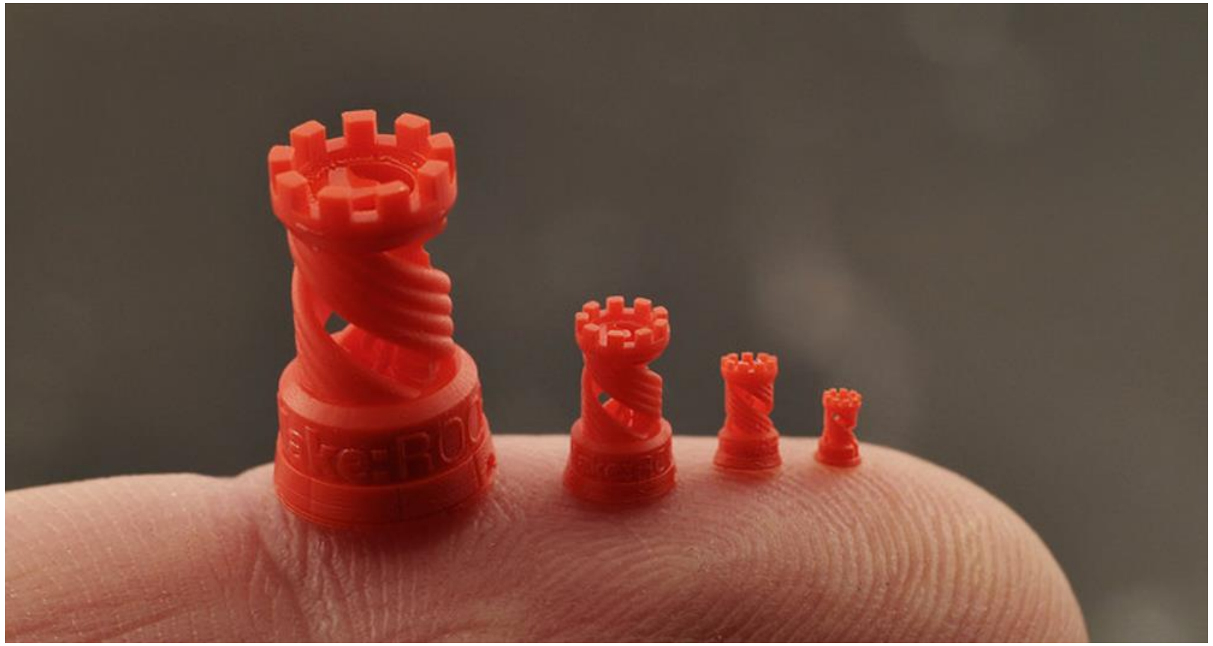
AM characteristics

Costs	Firms first have to invest a lot in the printer at the beginning and the printer should pay off within three years. The question is if printers are easy enough to apply to fulfil this requirement.
Weight	The main sales argument for AM is to have less weight and more efficiency.
Complexity	Most people expect to be able to print complex designs when buying a 3D printer.
Individuality	I am surprised that individuality does not play a bigger role, but maybe this is because the AM way of thinking is not yet well established. I think that individuality provides the possibility to create new business models.
Speed	In addition to the possibility to produce locally, AM also offers the possibility to produce on demand.
Sustainability	Particularly in the field of polymer, sustainability will become a topic. At the moment, quantities are too low, a few tons of additively manufactured polymer simply disappear when comparing them to the waste produced by the packaging industry.
Other Dimensions	There are many more other types of dimensions to consider, for example innovation, value, manufacturability, to name a few.

Examples on fields of application with AM

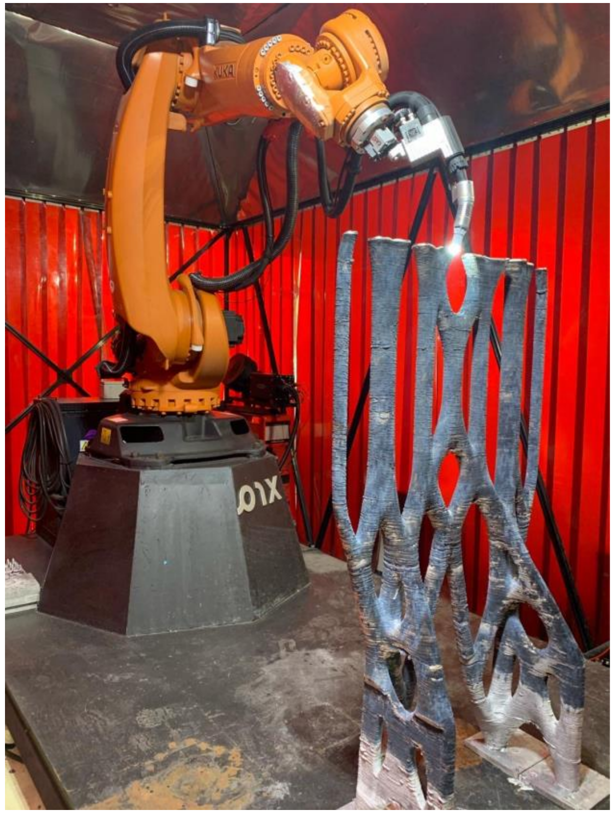
- Prototyping
- Medicine
- Industry
- Tooling
- Art
- Aerospace
- Service provider
- Retailer
- Education
- Research
- Hobby
- Construction
- Fashion
- Food
- Automotive
- Jewelry
- Dental
- Other fields

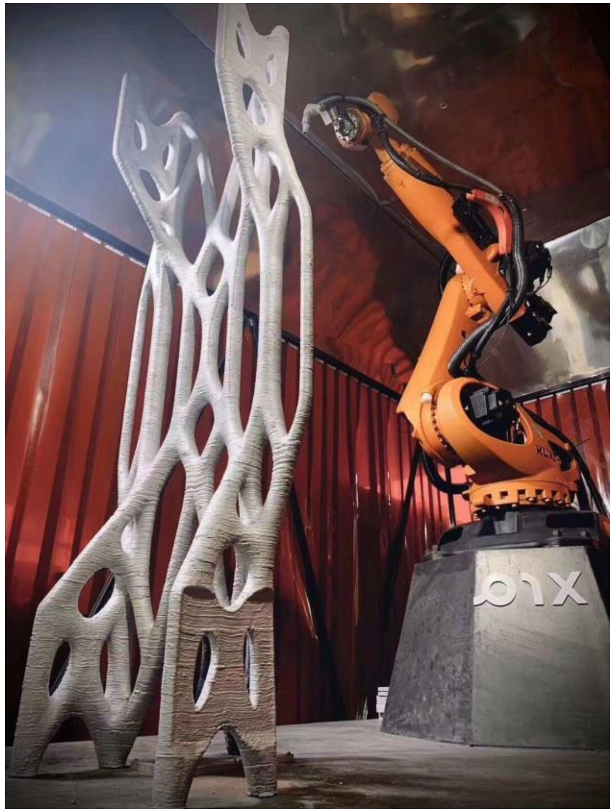


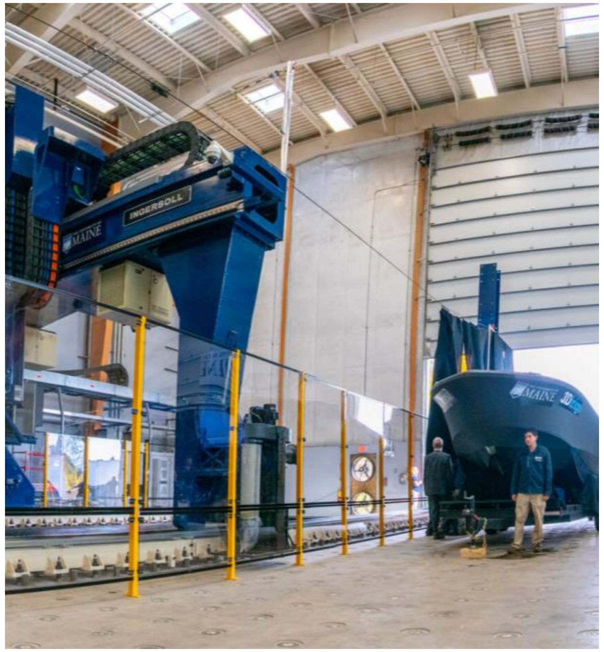


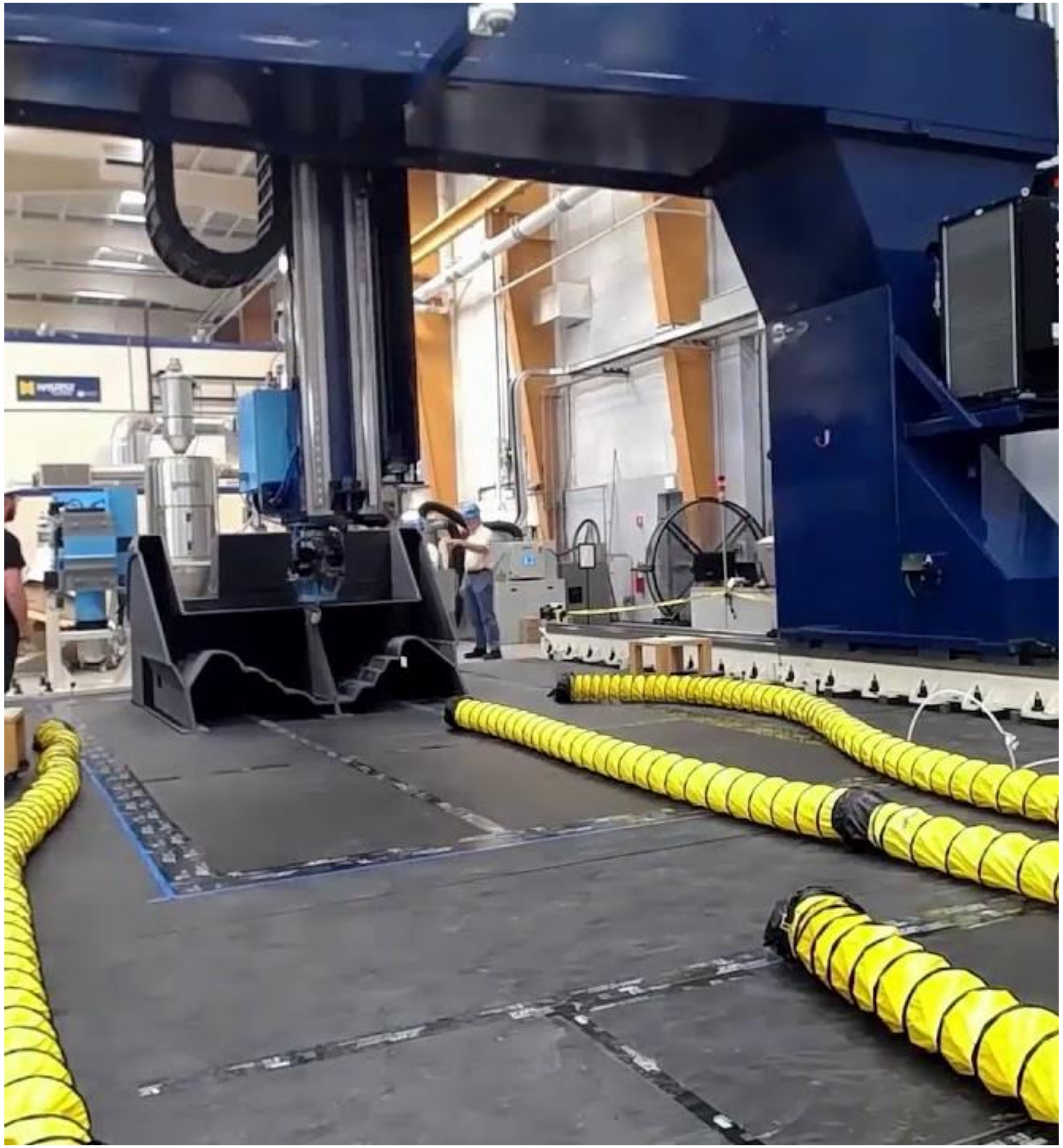
Source: https://all3dp.com/2/the-smallest-3d-printed-things/


KUKA









Source: https://umaine.edu/news/blog/2019/10/10/umaine-composites-center-receives-three-guinness-world-records-related-to-largest-3d-printer/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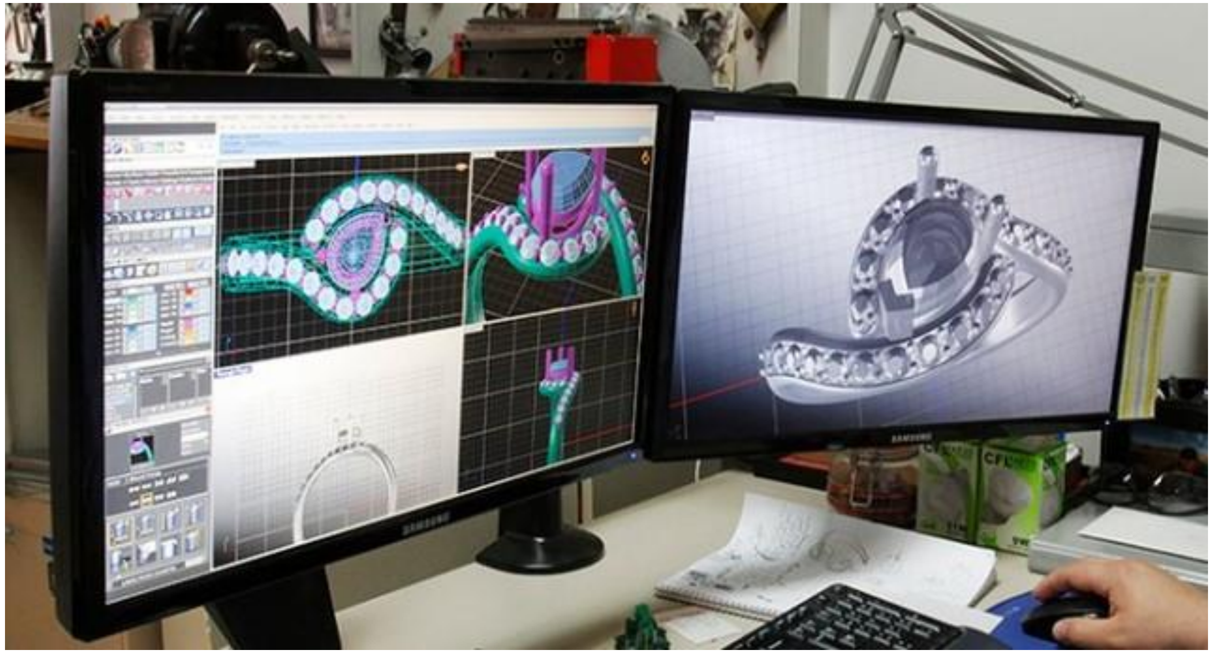
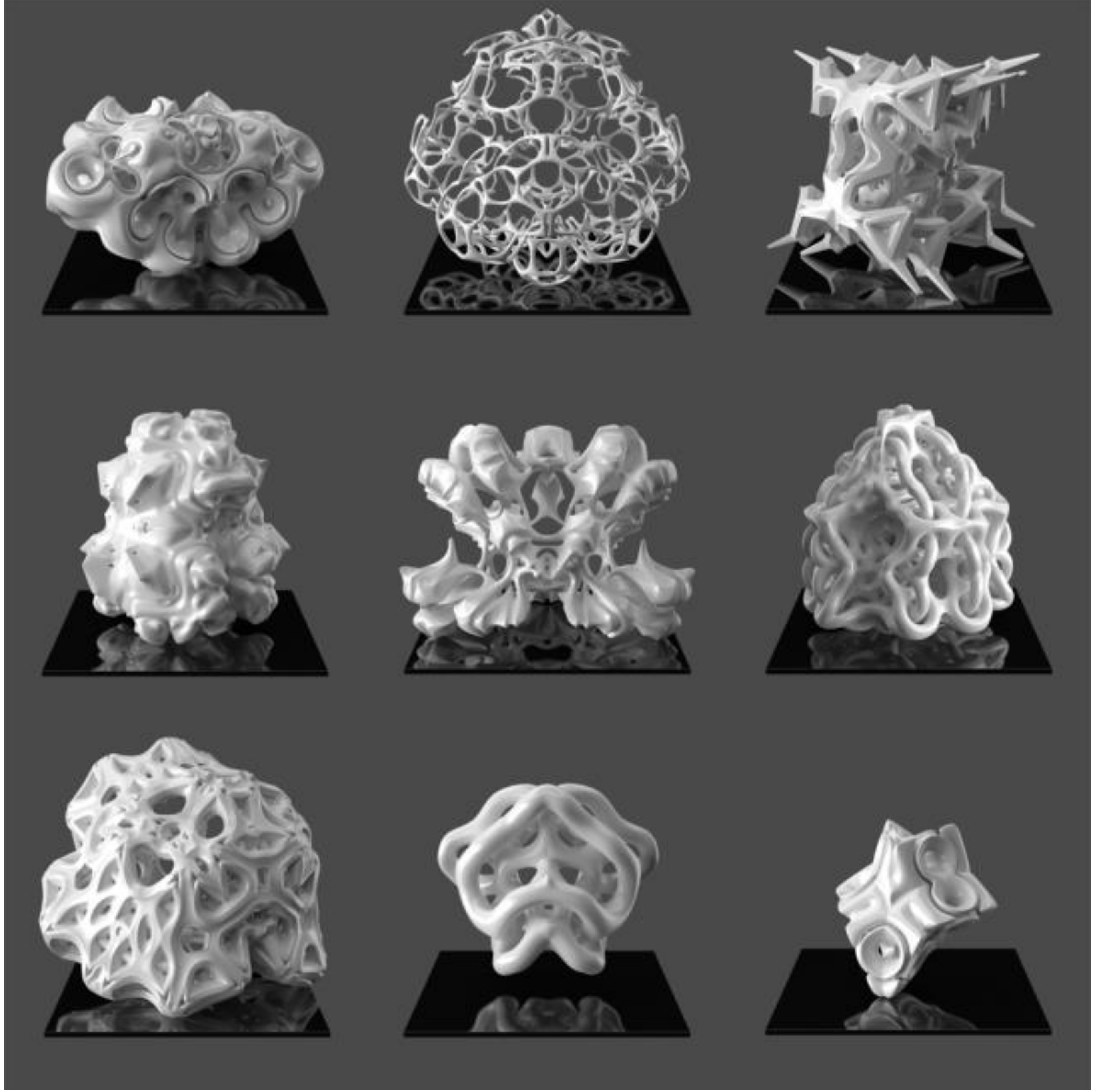
EPAL





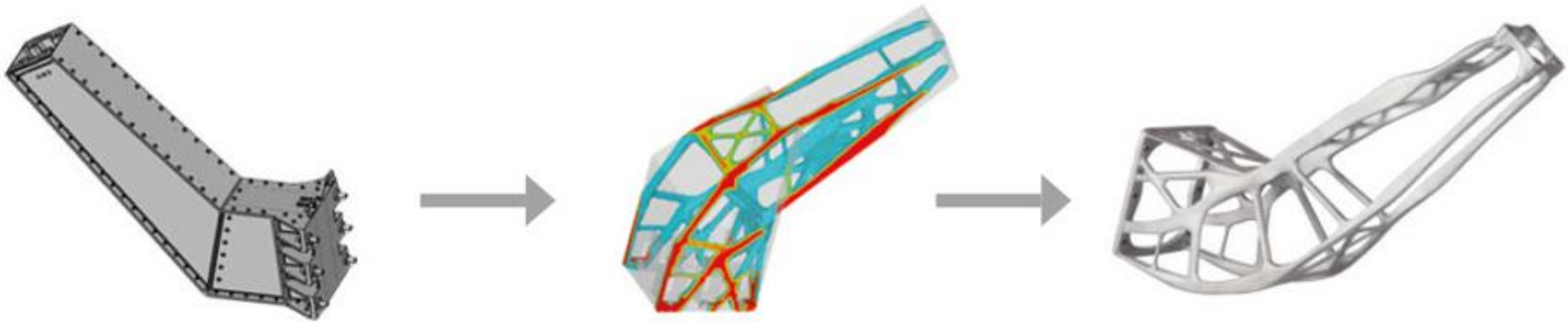
Source: https://all3dp.com/2/how-to-3d-print-jewelry-tips-for-designers/

Source: https://www.pinterest.se/pin/470274386063896583/



Source: https://www.pinterest.se/pin/323837029429395560/

Source: https://wohlersassociates.com/



Original design

Optimized topology

Redesigned antenna bracket

Source: https://www.eos.info/case_studies/additive-manufacturing-of-antenna-bracket-for-satellite/ & https://www.digitalalloys.com/blog/business-value-of-metal-additive-manufacturing/

AM in times of crisis

Source: Photo by [cottonbro] from [Pexels]

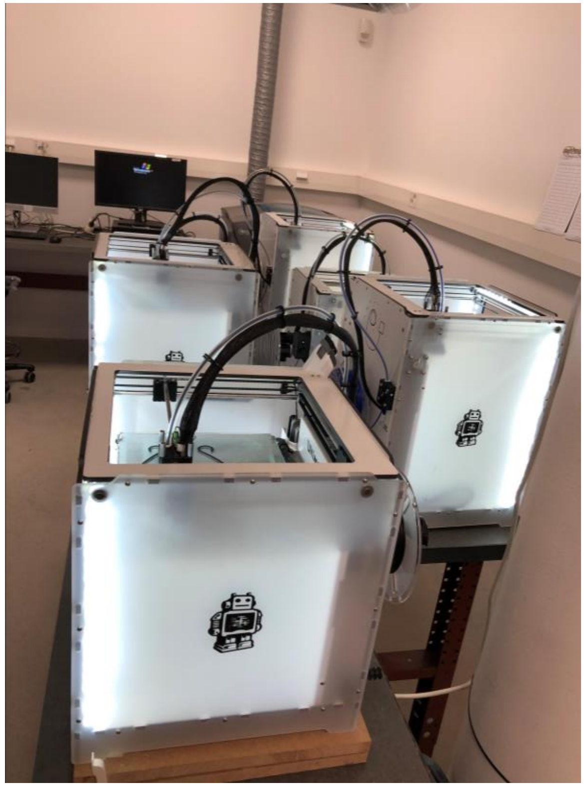
EDITORS' PICK | 77 365 views | Mar 19, 2020, 03:57pm EDT

Meet The Italian Engineers 3D-Printing Respirator Parts For Free To Help Keep Coronavirus Patients Alive

Amy Feldman Forbes Staff
Manufacturing

Source: https://www.forbes.com/sites/amyfeldman/2020/03/19/talking-with-the-italian-engineers-who-3d-printed-respirator-parts-for-hospitals-with-coronavirus-patients-for-free/#66bea94e78f1

MDH + AM = True!



Heroic employees at MDH joined the fight against COVID-19.

All 3D printers were up and running.

With our knowledge, experience and life-long learning here at MDH.

We can AM in times of crisis!

Source: https://www.mdh.se/artiklar/2020/april/har-tillverkas-skyddsutrustning-till-varden

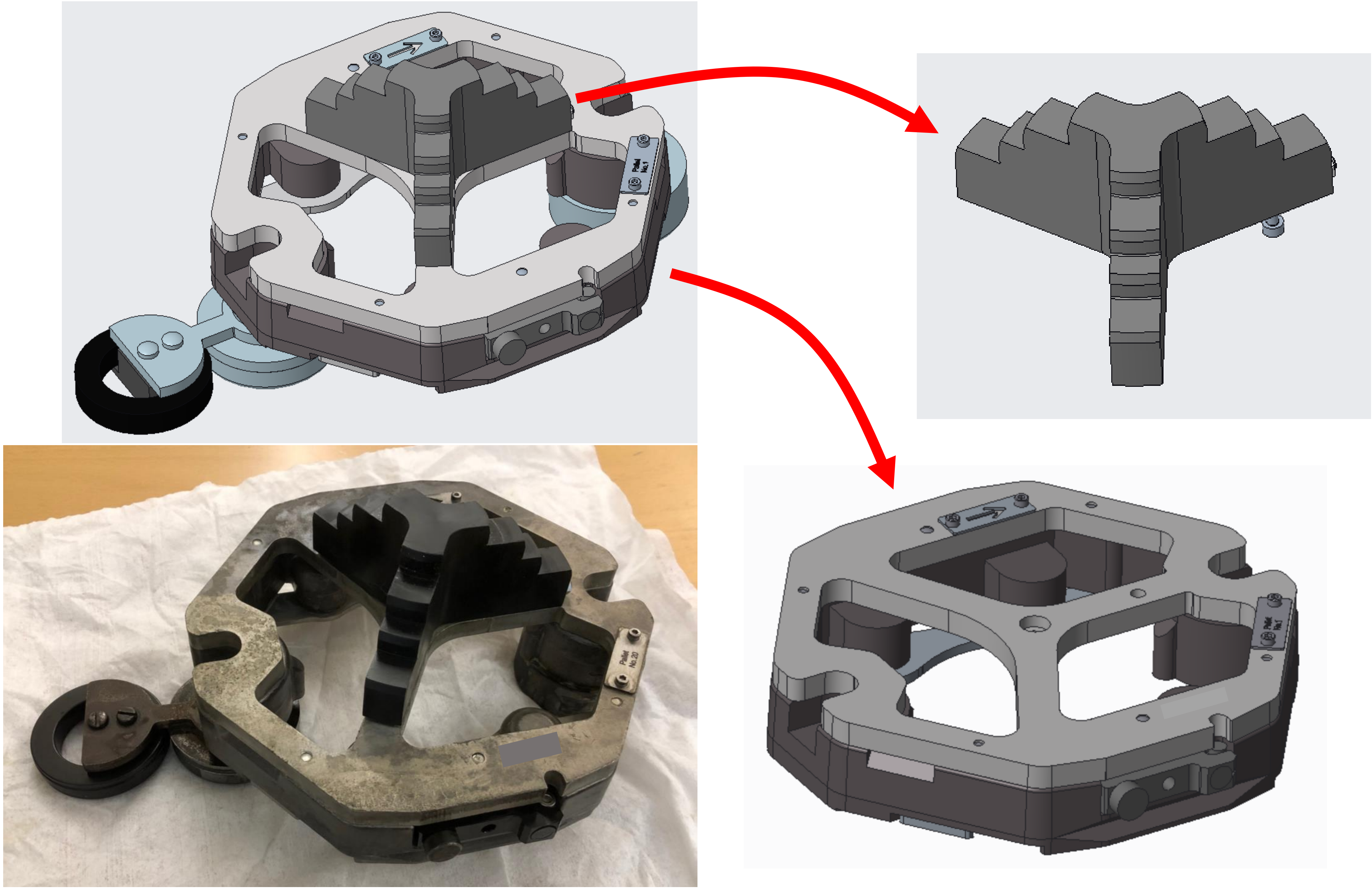
Name	Year	Level	Title	Conclusion
Anna Bousquet	2017	MSc	Additive manufacturing in metal and topology optimization	Results show potential in weight reduction through the use of topology optimization aimed for metal additive manufacturing in industrial specific articles.
Tobias Bäckman	2018	MSc	Investigation on design and calculations for additive manufacturing – Markforged	Results show significant cost and time reduction by replacing traditional manufacturing with additive manufacturing on redesigned industrial tools.
Philip Ragnartz & Axel Staffanson	2018	MSc	Improving the product development process with additive manufacturing	Results show significant improvements to the product development process with the use of additive manufacturing, especially to cost and time.
Barrett Sauter	2019	MSc	Ultra-light weight design through additive manufacturing	Results show potential to ultra-light weight design of industrial articles and signs of improved performance through the new design aimed for additive manufacturing.
Christopher Gustafsson	2019	MSc	Lead-time reduction and rapid prototyping of tools and fixtures, therefore I AM: A case study about additive manufacturing in the automotive industry	Results show significant lead-time reduction through rapid prototyping activities, however, to achieve profitability the "best" design for additive manufacturing concept needs to be chosen.

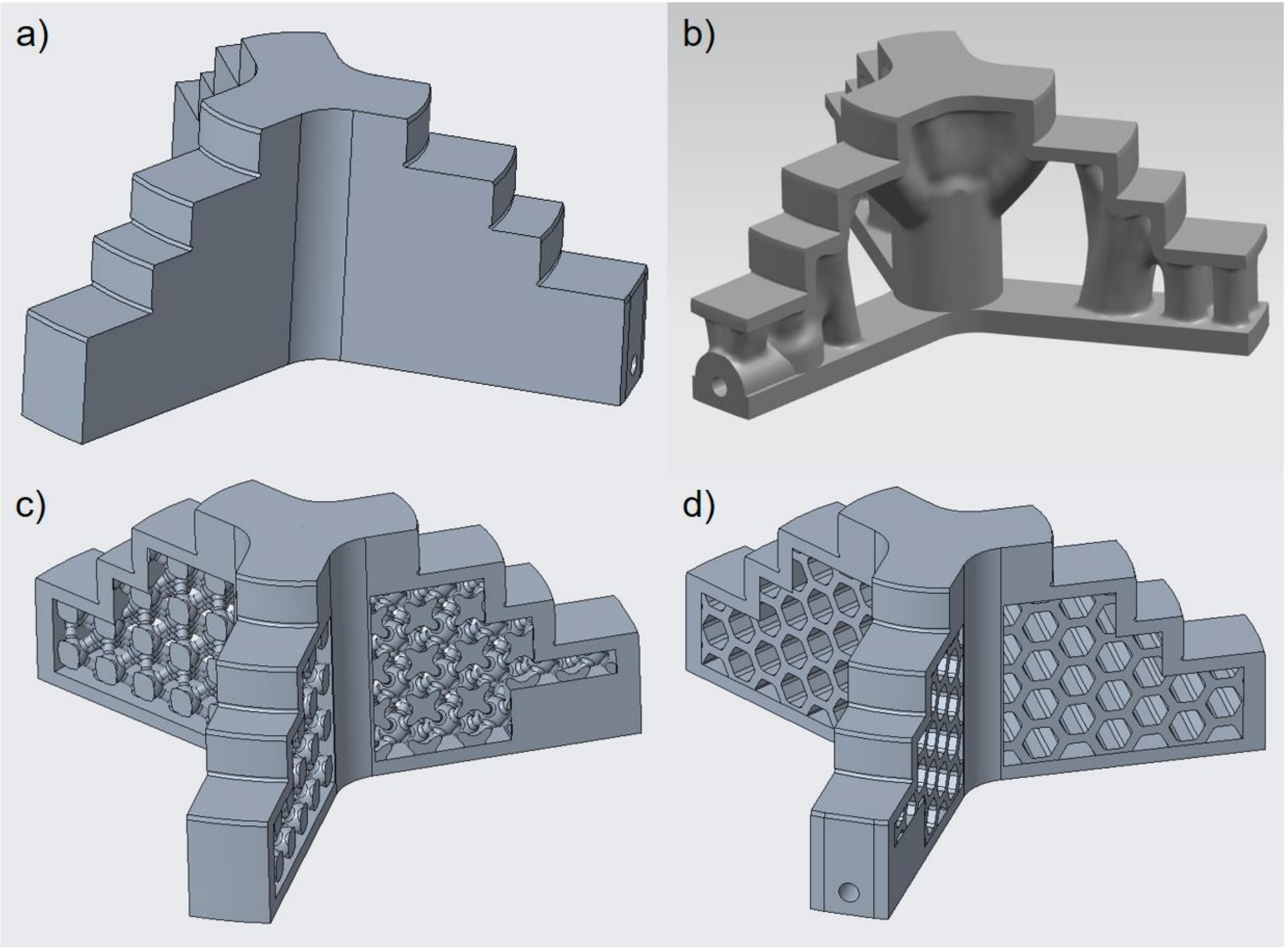
Source: http://www.diva-portal.org/smash/search.jsf?dswid=766

MDH + AM = True!

Thesis examples related to additive manufacturing.

Through industrial projects and thesis opportunities, our engineering students are well equipped with knowledge, experience and life-long learning in any engineering field, especially the AM field.



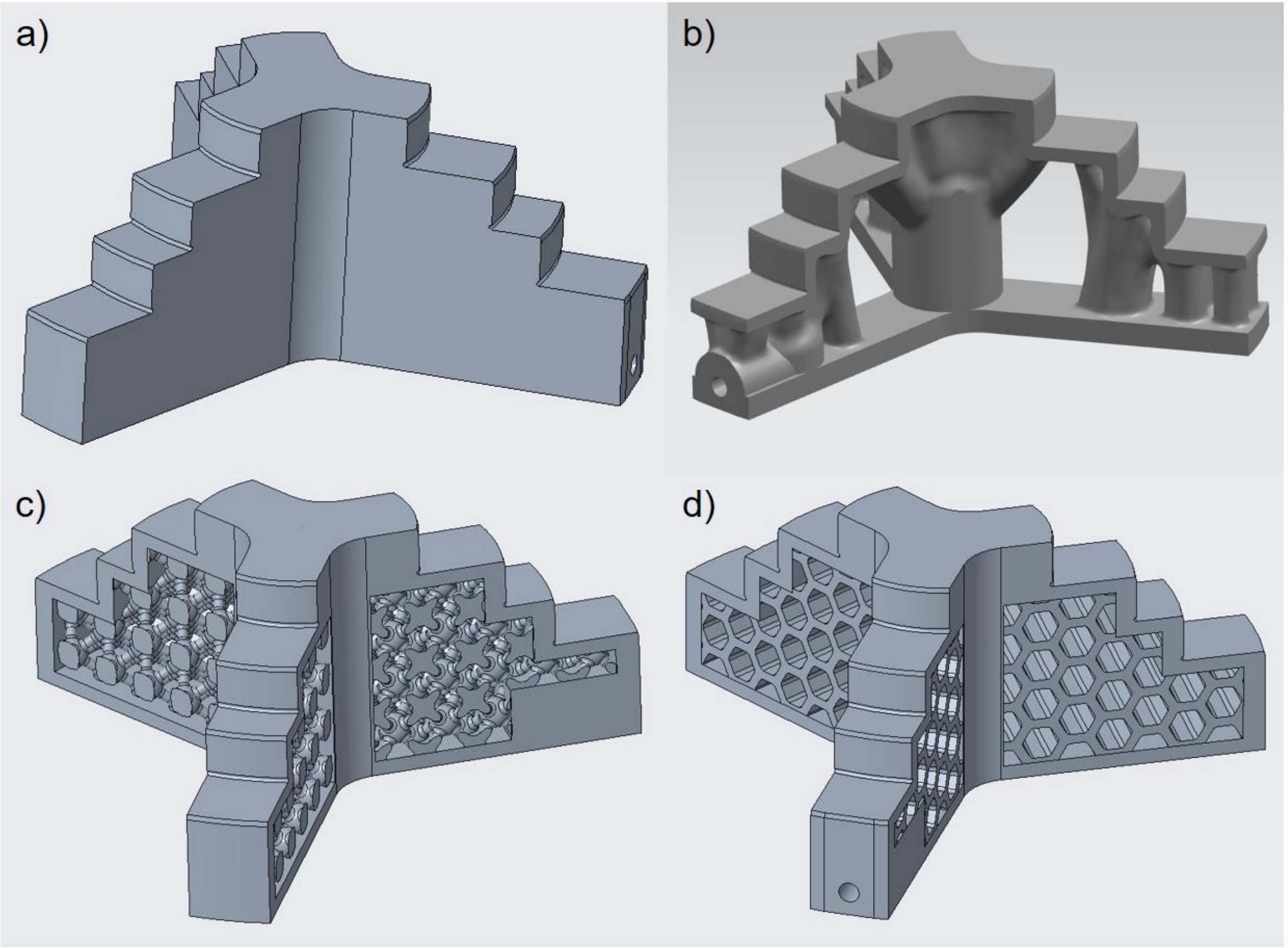


Are these design changes good or bad?

In terms of reducing costs?

Reducing lead-time?

Increased performance?



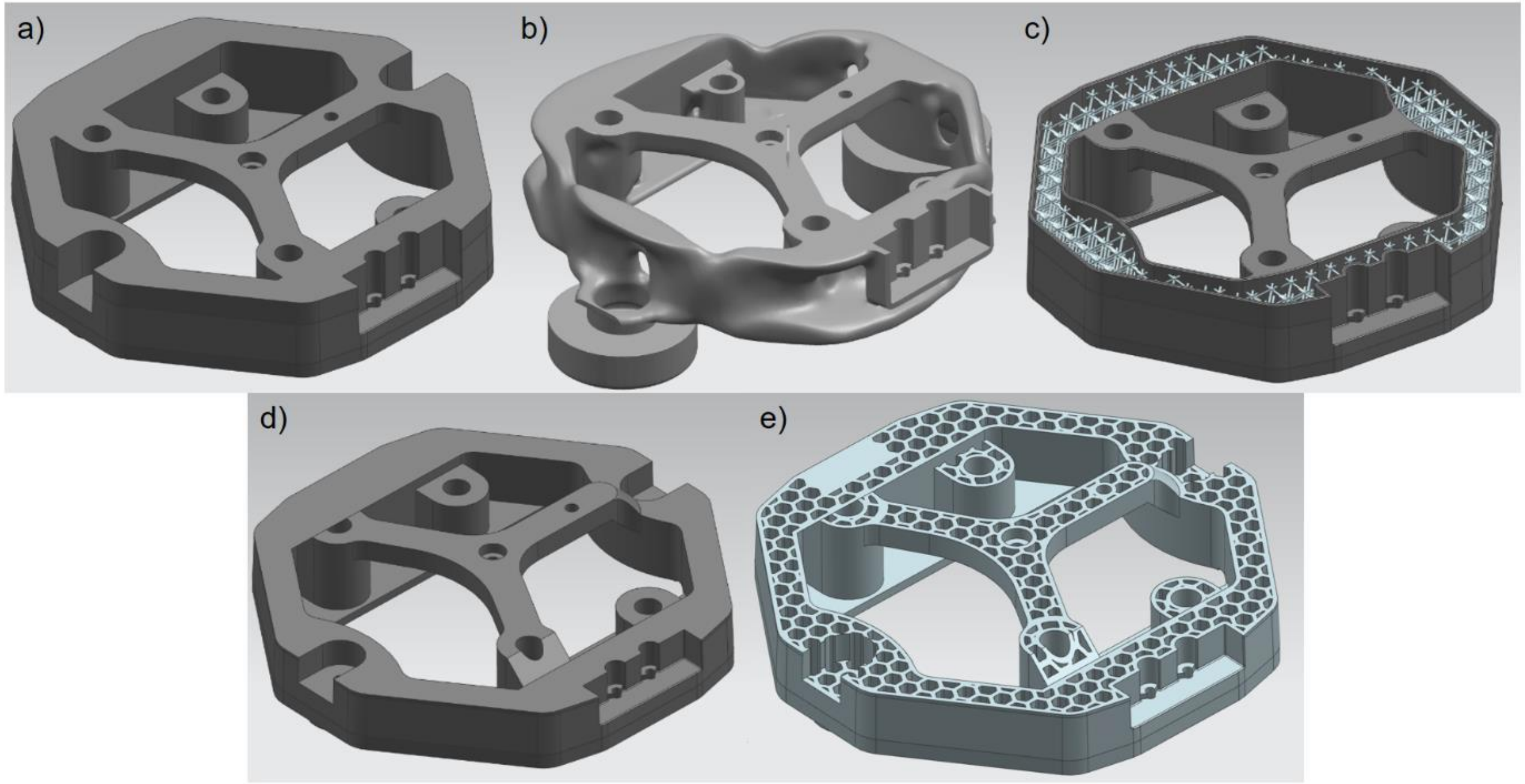
If the designs were to be 3D printed…

a) Cost could be reduced, lead-time could be increased, performance could be maintained.

b) Cost is reduced, lead-time is increased, performance is maintained.

c) Cost is reduced, lead-time is increased, performance is maintained.

d) Cost is reduced, lead-time is increased, performance is maintained.



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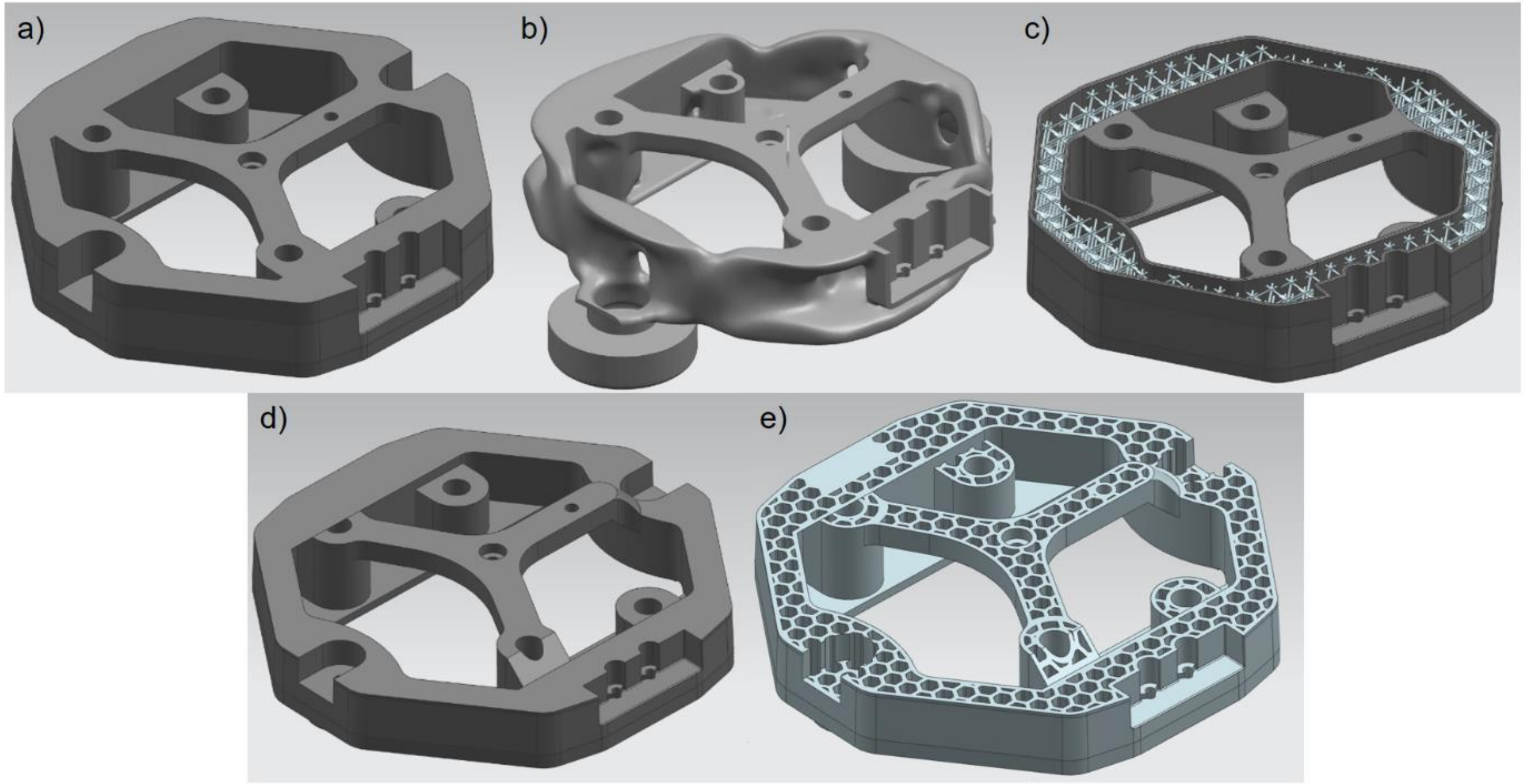


a) Cost is increased, lead-time is reduced, performance is maintained

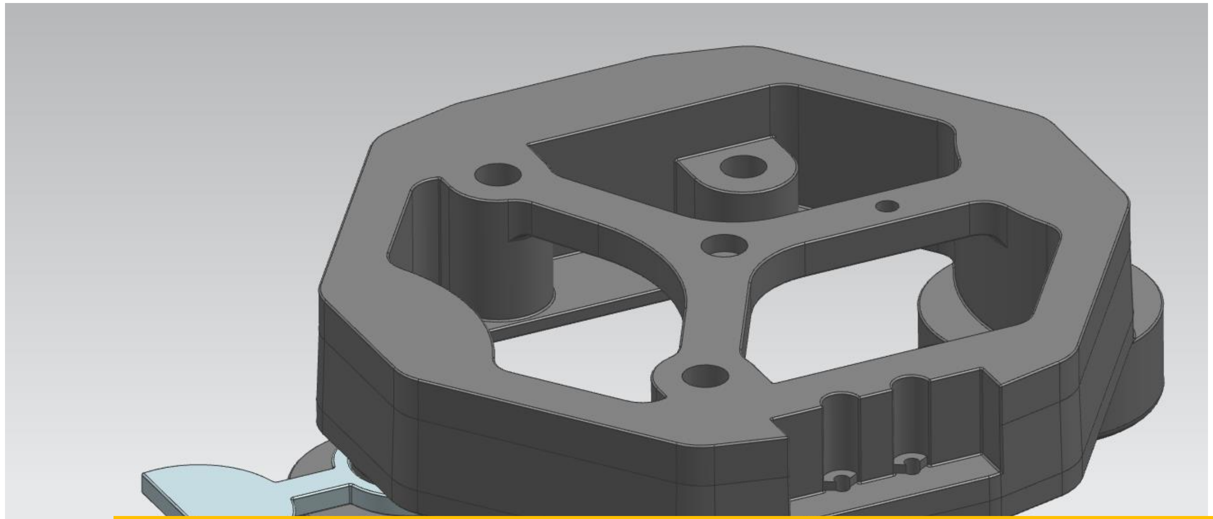
b) Cost is increased, lead-time is reduced, performance is maintained

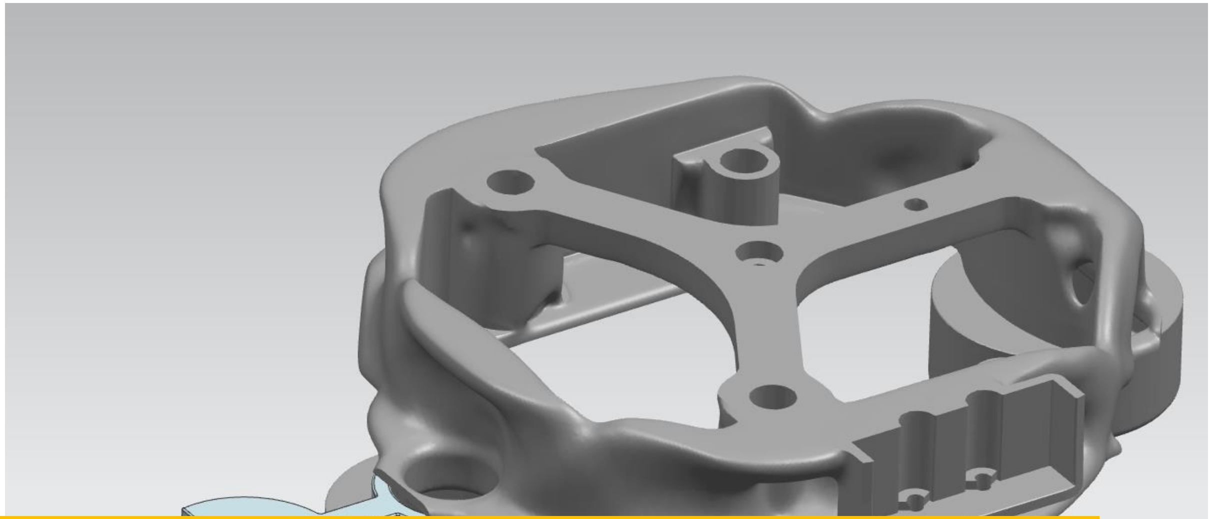
c) Cost is increased, lead-time is reduced, performance is maintained

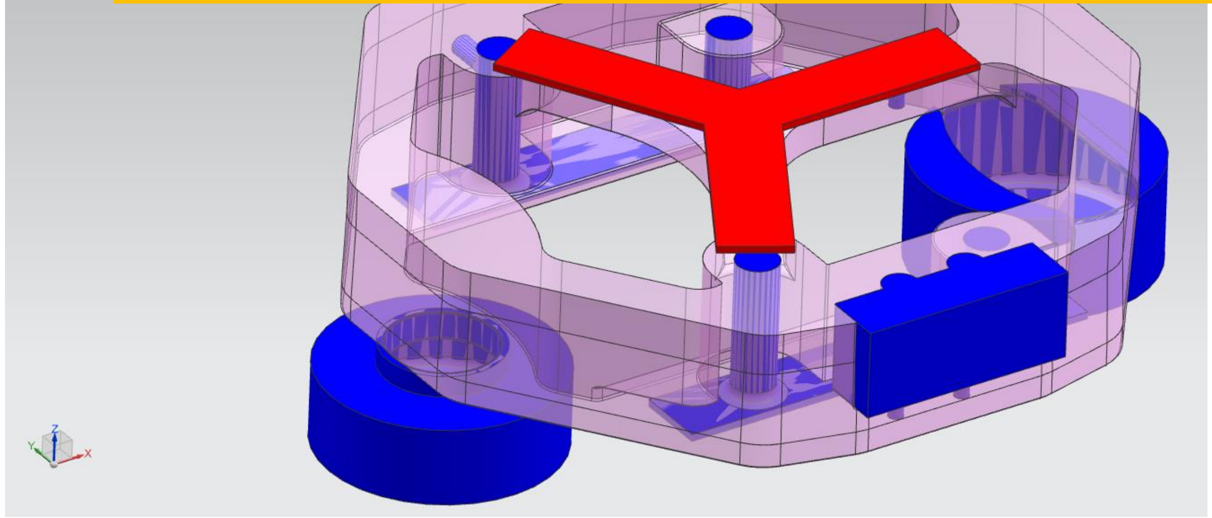
d) Cost is increased, lead-time is reduced, performance is maintained

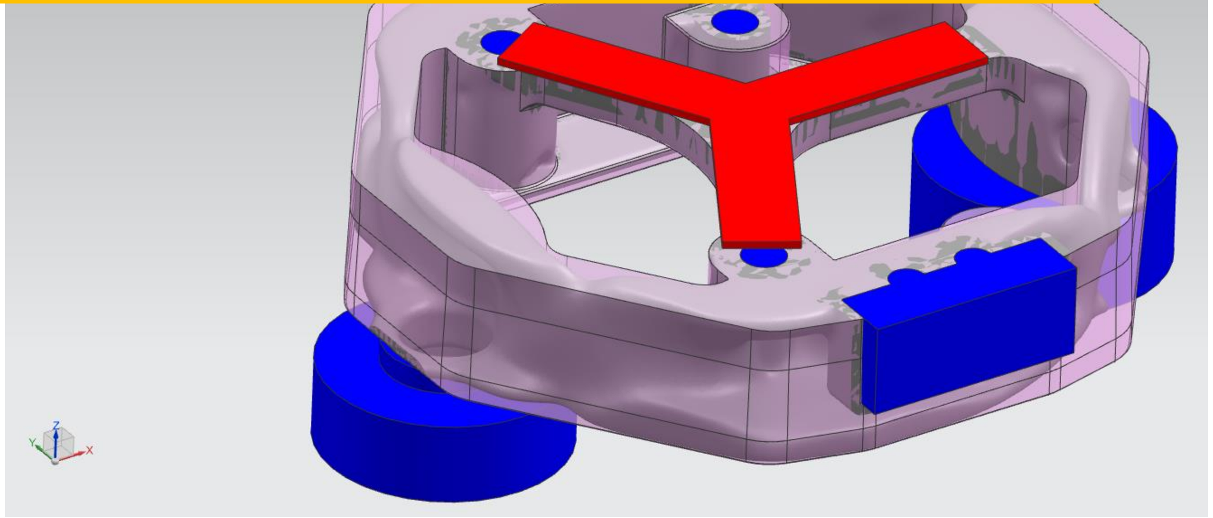
e) Cost is increased, lead-time is reduced, performance is maintained

Design Change using Topology Optimization

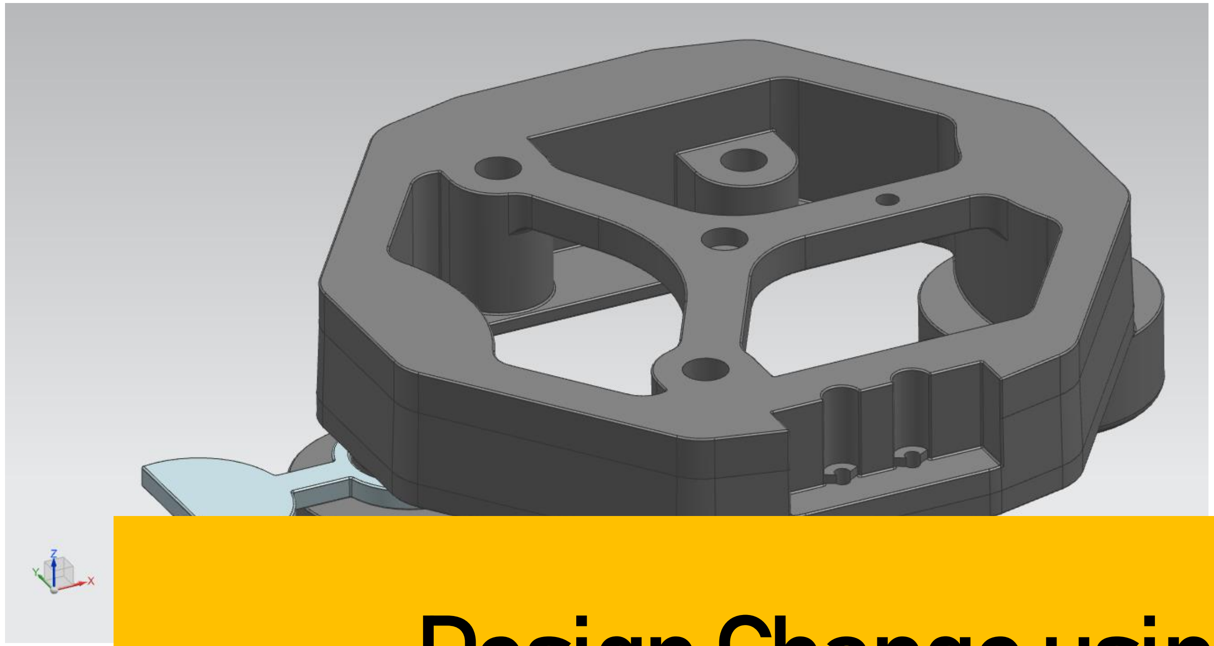


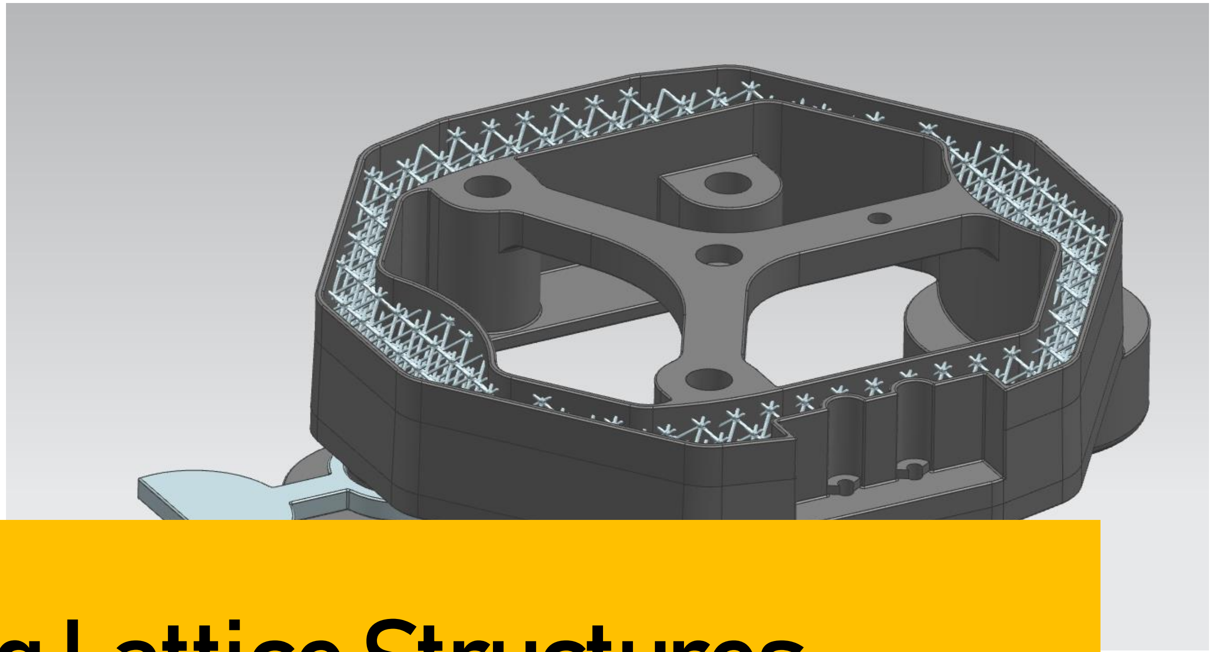


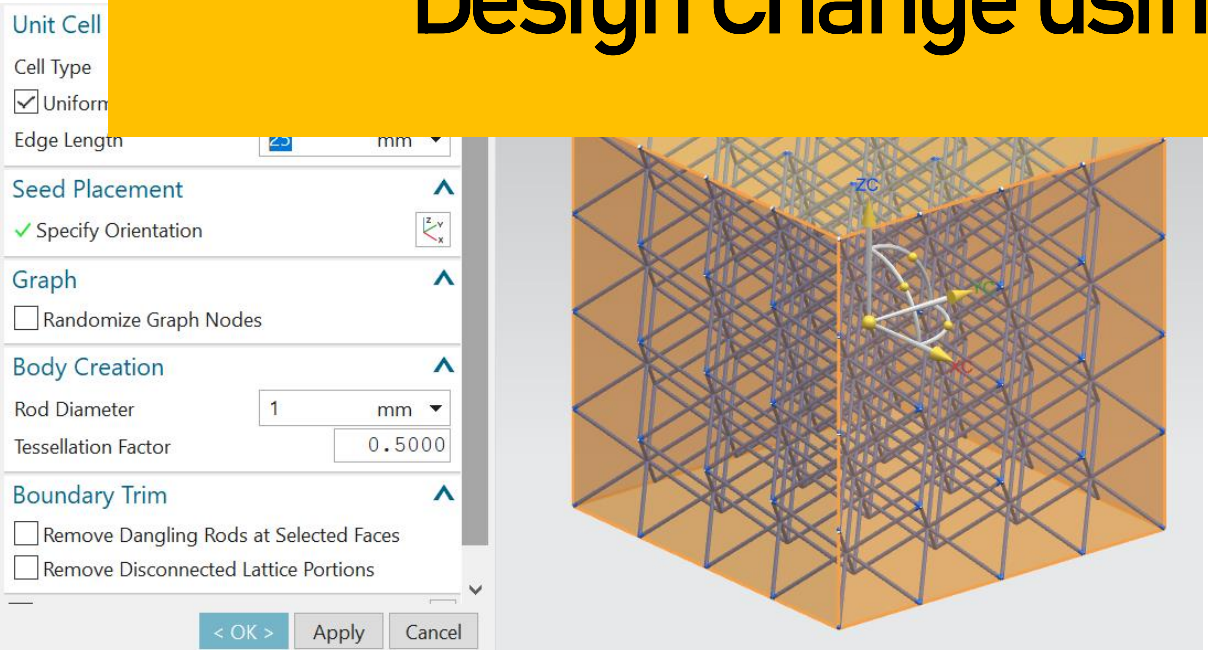


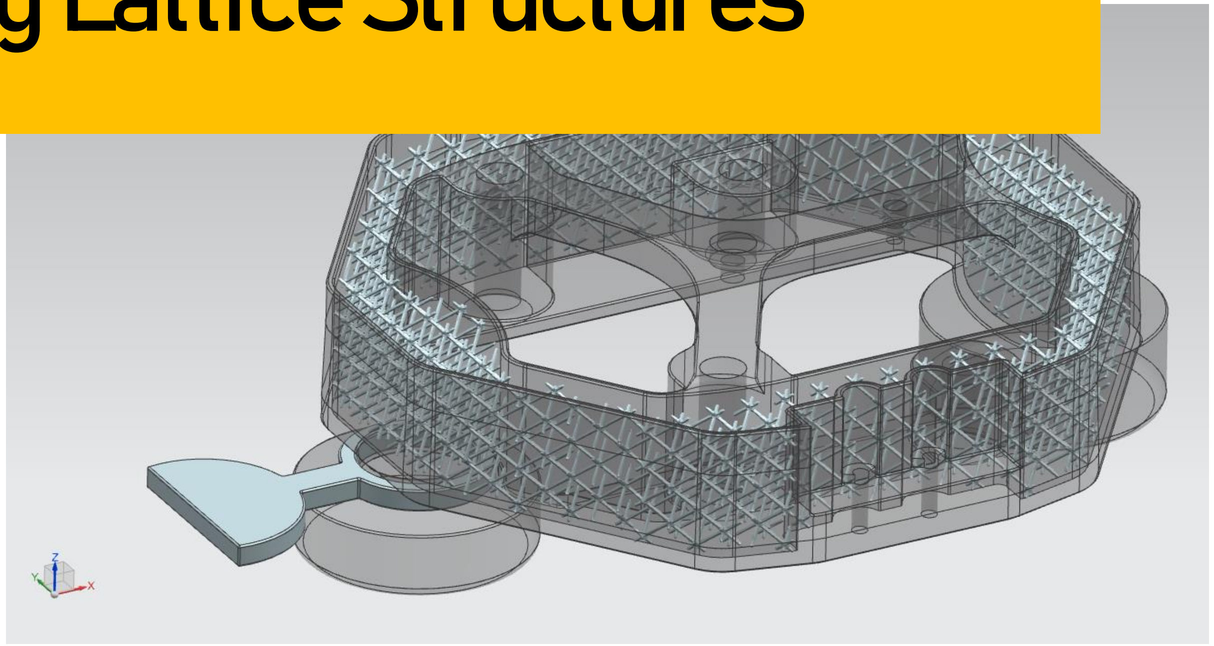


Design Change using Lattice Structures









Adopting AM in SME: Main challenges

Technology	Strategy	Supply chain	Operational	Organizational	External
AM technology and material uncertainties	Strategy and economic situation	Digital data transfer, software	Design, R&D, innovation	Current skills and practices; lack of knowledge	Customer and subcontractor relationships and marketing

The benefits of AM on a large scale will likely be reaped in the context of machine manufacturing and process industries if the entire supply chain adopts AM technology and its consequences.

Adopting AM in SME: Potential solutions

To advance the progress of AM, SMEs should take strategic actions to overcome the challenges in AM adoption, including:	To advance the progress of AM, SMEs should take operational actions to overcome the challenges in AM adoption, including:
Developing strategies by identifying the benefits of AM, selecting the focal application areas and deciding on "make or buy". Scouting and collaborating to accumulate AM information, and advancing digitalization. Starting with lead customers, creating demand through prototypes and activating supply chain partners.	Reducing technical and material uncertainties through learning, small-scale experiments and research. Giving resources to designers to learn and experiment, scaling up AM deliveries in selected niche products and markets. Creating new assessment criteria and metrics for AM manufacturing.

Future trends of 2020 and beyond

The industrialization of AM continues – many industrial applications have potential to deliver impactful business value.

Controlling the AM chain from material over machines to certified parts is base for successful AM projects.

Design engineers have to be trained on thinking additive because AM designs are key to benefit from the technology.

Digitalization & automation are essential to get the full potential out of industrial AM in serial production.

AM is key for the transition towards greener energy because it enables the development of eco-friendly technological solutions.

Thank you!
Questions?

For those who are interested, please feel free to contact us at Mälardalens högskola.

Lifelong Learning at Mälardalen University

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- ✓ Gives university credits.
- ✓ Developed in close cooperation with industry.
- ✓ Free-of-charge for employees in Sweden and EU/EEA and Swiss citizens.

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Software Test

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Circular Economy
Climate Change
Sustainable Development

Innovation Management
Trendspotting and
Scenario Design
Innovation Management

Applied AI
Big Data
Machine Learning
Predictive Analytics

Production Engineering
Industry 4.0
Lean Production
Simulation

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Seminar series Industry 4.0

Date	Title	Teacher
August 14	Is maintenance value adding?	Antti Salonen
August 21	Additive Manufacturing – The MDH way	Christopher Gustafsson
August 28	Robots in collaborative applications	Mikael Hedelind
September 4	Optimization of Production Systems	Konstantinos Kyprianidis & Yuanye Zhou & Stavros Vouros
September 11	Industrialization: multiple perspectives and the role of digitalization	Koteshwar Chirumalla

Production engineering courses autumn 2020

(5 credits/course)

Lean production
Study period 2020-08-31 - 2020-11-08

Internet of Things for the manufacturing industry
Study period 2020-08-31 - 2020-11-08

Simulation of production systems
Study period 2020-08-31 - 2020-11-08

Big Data and Cloud Computing for Industrial Applications
Study period 2020-11-09 - 2021-01-17

Industrial maintenance development
Study period 2020-11-09 - 2021-01-17

Optimization of production systems
Study period 2021-01-18 – 2021-03-28

Visualization for industrial applications
Study period 2021-01-18 – 2021-03-28

Industry 4.0 – Introduction
Study period 2021-03-29 - 2021-06-06

Industry 4.0 – Realisation
Study period 2021-03-29 - 2021-06-06

Industrialization and Time-to-Volume
Study period 2021-03-30 - 2021-06-08

For more information, visit mdh.se/premium

Extra reading

Al-Makky, M. and Mahmoud, D. (2018). THE IMPORTANCE OF ADDITIVE MANUFACTURING PROCESSES IN INDUSTRIAL APPLICATIONS. Proceedings of the 17th International Conference on Applied Mechanics and Mechanical Engineering, 19-21 April, 2016.

Attaran, M. (2019). The rise of 3-D printing: The advantages of additive manufacturing over traditional manufacturing. Business Horizons 60: 677-688. doi: 10.1016/j.bushor.2017.05.011

Bourell, D., Kruth, J.P., Leu, M., Levy, M., Rosen, D., Beese, A.M. and Clare, A. (2017). Materials for additive manufacturing. CIRP Annals 66:2 659-681. doi: 10.1016/j.cirp.2017.05.009

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Gao, W., Zhanga, Y., Ramanujana, D., Ramania, K., Chenc, Y., Williams, C.B., Wange, C.C.L., Shin, Y.C., Zhanga, S. and Zavattieri, P.D. (2015). The status, challenges, and future of additive manufacturing in engineering. Computer-Aided Design 69: 65-89. doi: 10.1016/j.cad.2015.04.001

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Wohlers Associates Inc. (2020). Wohlers report. Fort Collins, CO: Wohlers.

Astm standard f2792, standard terminology for additive manufacturing technologies. 2013. URL: http://www.astm.org/Standards/F2792.htm

https://www.stratasys.com/

https://ultimaker.com/

https://www.ptc.com/en/products/cad/3d-design/design-for-additive-manufacturing

https://www.plm.automation.siemens.com/global/en/products/mechanical-design/design-for-additive-manufacture.html

https://www.mckinsey.com/business-functions/operations/our-insights/additive-manufacturing-a-long-term-game-changer-for-manufacturers#

https://www.youtube.com/watch?v=FSu19nz7NlE (17 Incredible 3D Printed Objects)