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M.Tech.
Digital Manufacturing

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Guest Faculty

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DMZG521 – Design for Additive Manufacturing Session 3 & Lecture No. 5-6

Quick Recap

Session 1

- Need for DfAM
- Difference between DFM and DfAM
- Difference between AM and other machining operations
- Classification of AM processes
- AM Ecosystem

Session 2

- Machine configuration of AM processes
- Capabilities of different AM processes
- Materials used in different AM processes
- Science behind each AM process

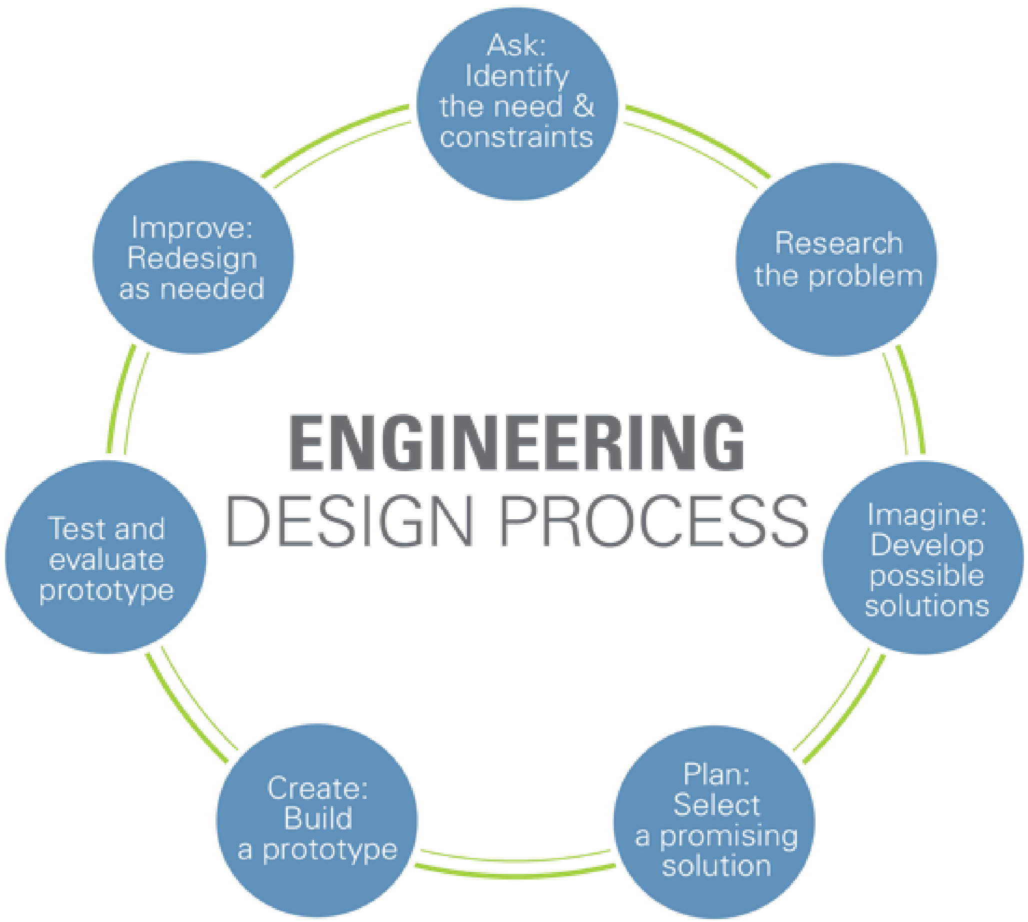
The best design
is the simplest one that
works.

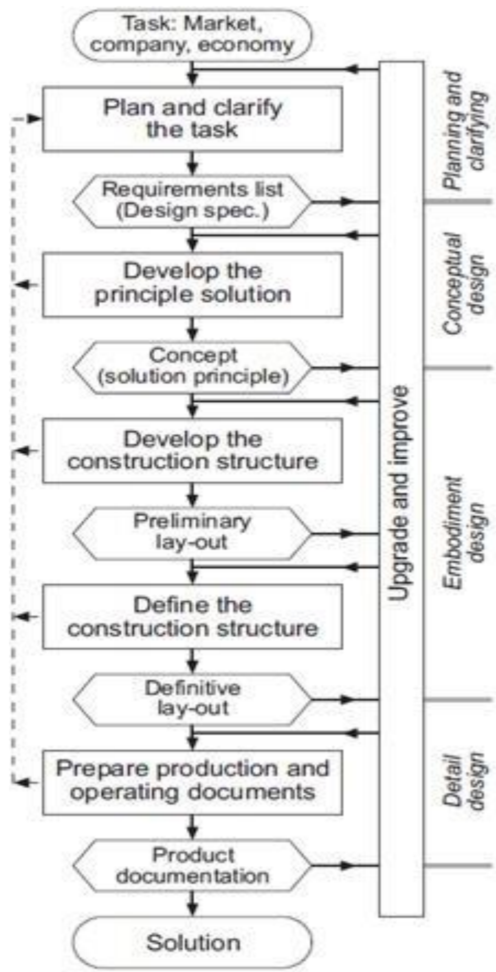
- Albert Einstein

What is ‘X’ in DFX?

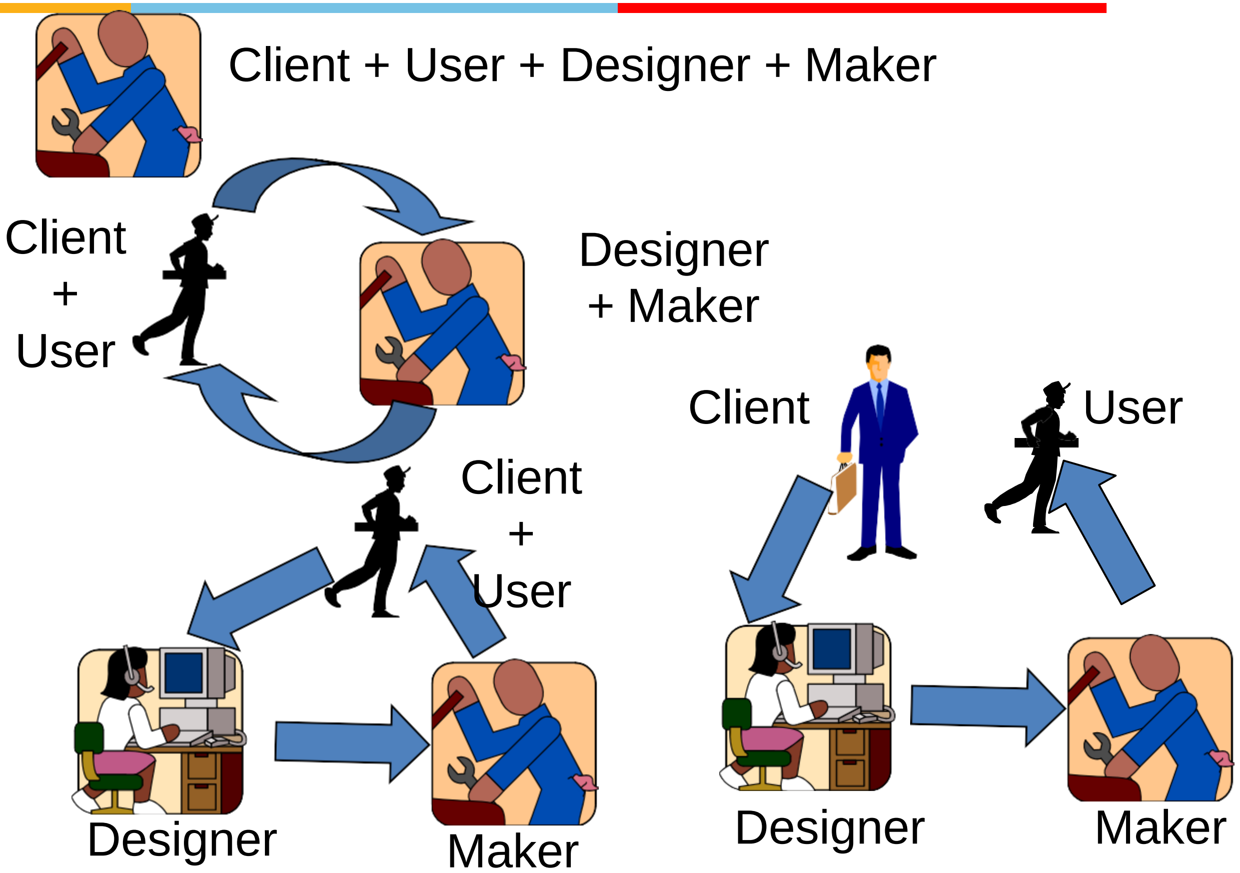
- Design for Manufacture
- Design for Assembly
- Design for Quality
- Design for Reliability
- Design for Serviceability/Maintainability
- Design for Safety
- Design for the Environment
- Design for User-Friendliness
- Design for Shorter Time-to-Market
- Design for Additive Manufacturing

Design Procedure





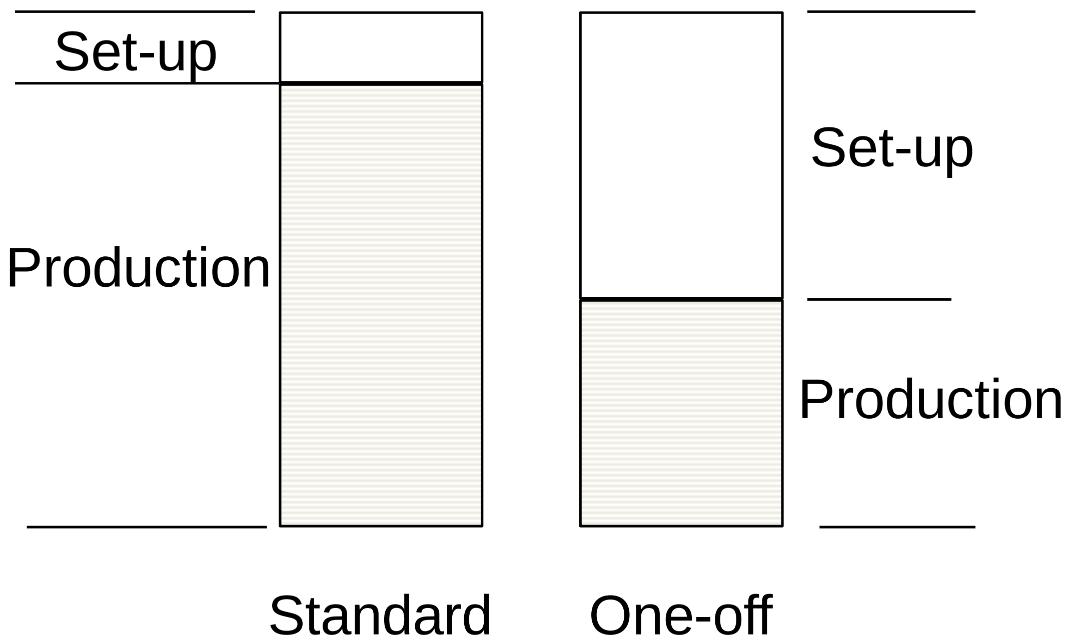
Stakeholders



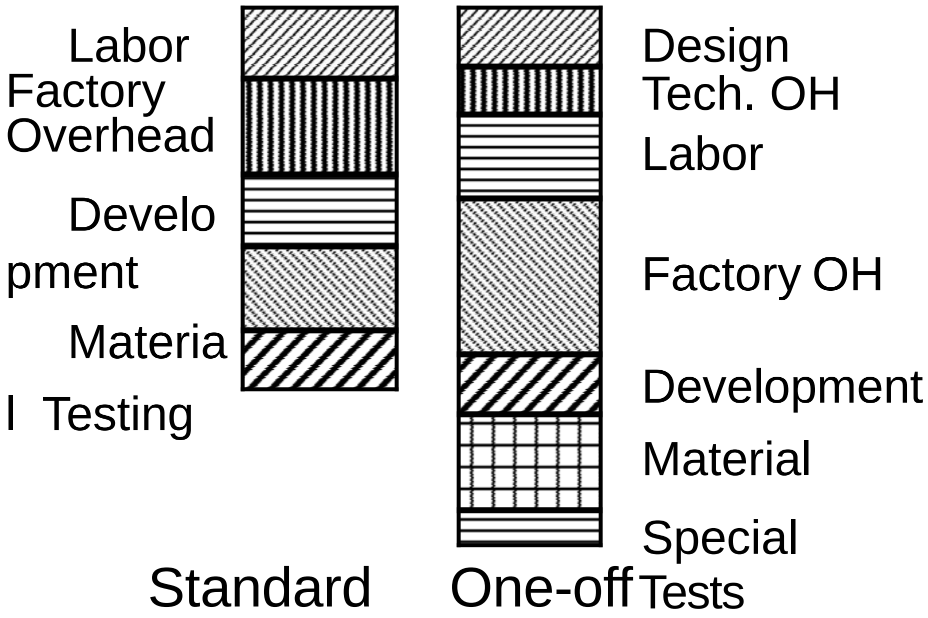
Standardization

- Development cost and training cost is reduced
- Fewer mistakes.
- Start-up costs reduced due to familiarity.
- Less debugging. Therefore, higher quality, lower lead time, and higher productivity.
- Tooling costs reduced since tools are already available.
- Production quantities higher because same parts are reused. Hence economies of scale and easier just-in-time (JIT) arrangements.

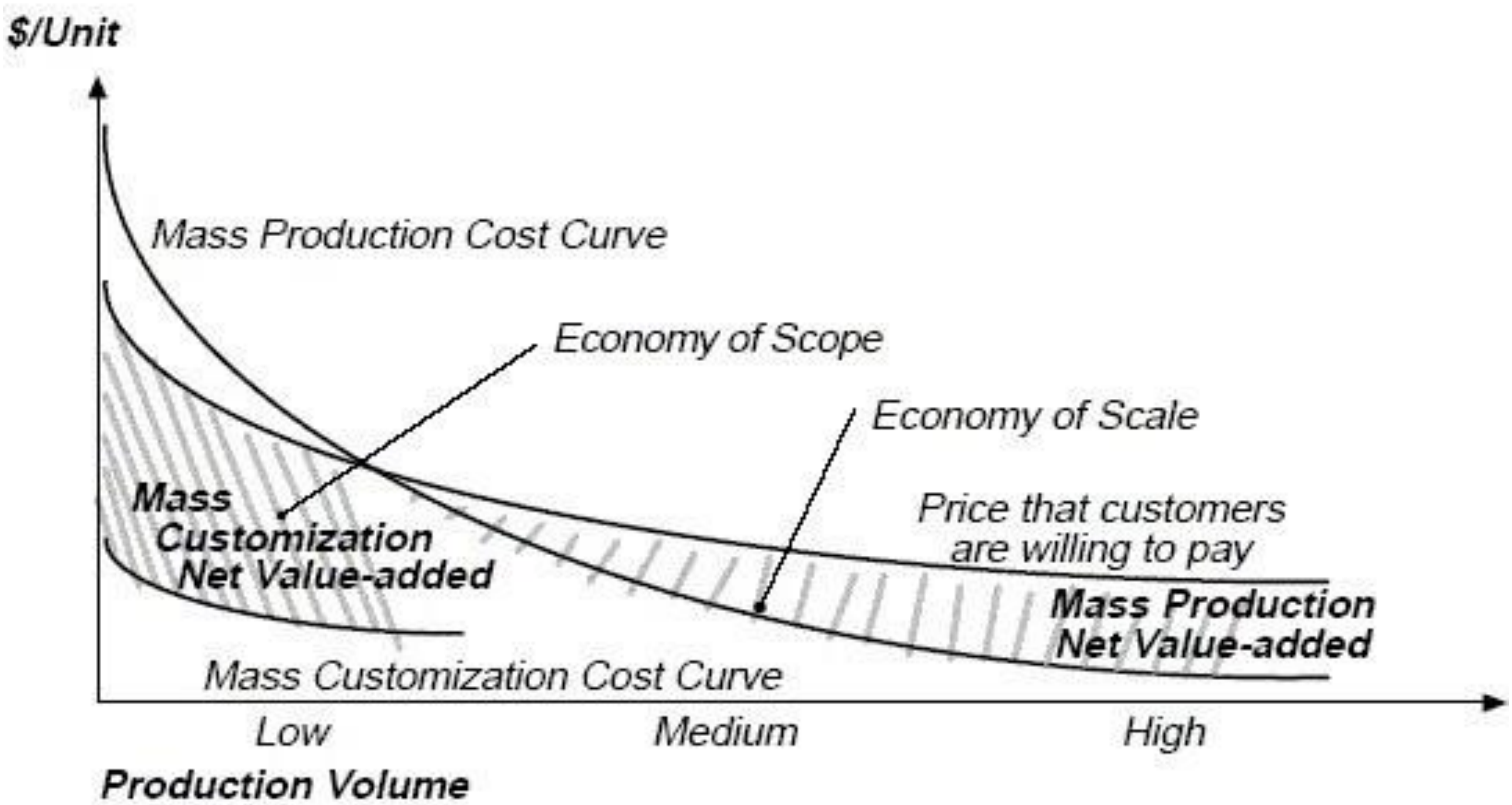
Standard v. One-off Design (Time Comparison)



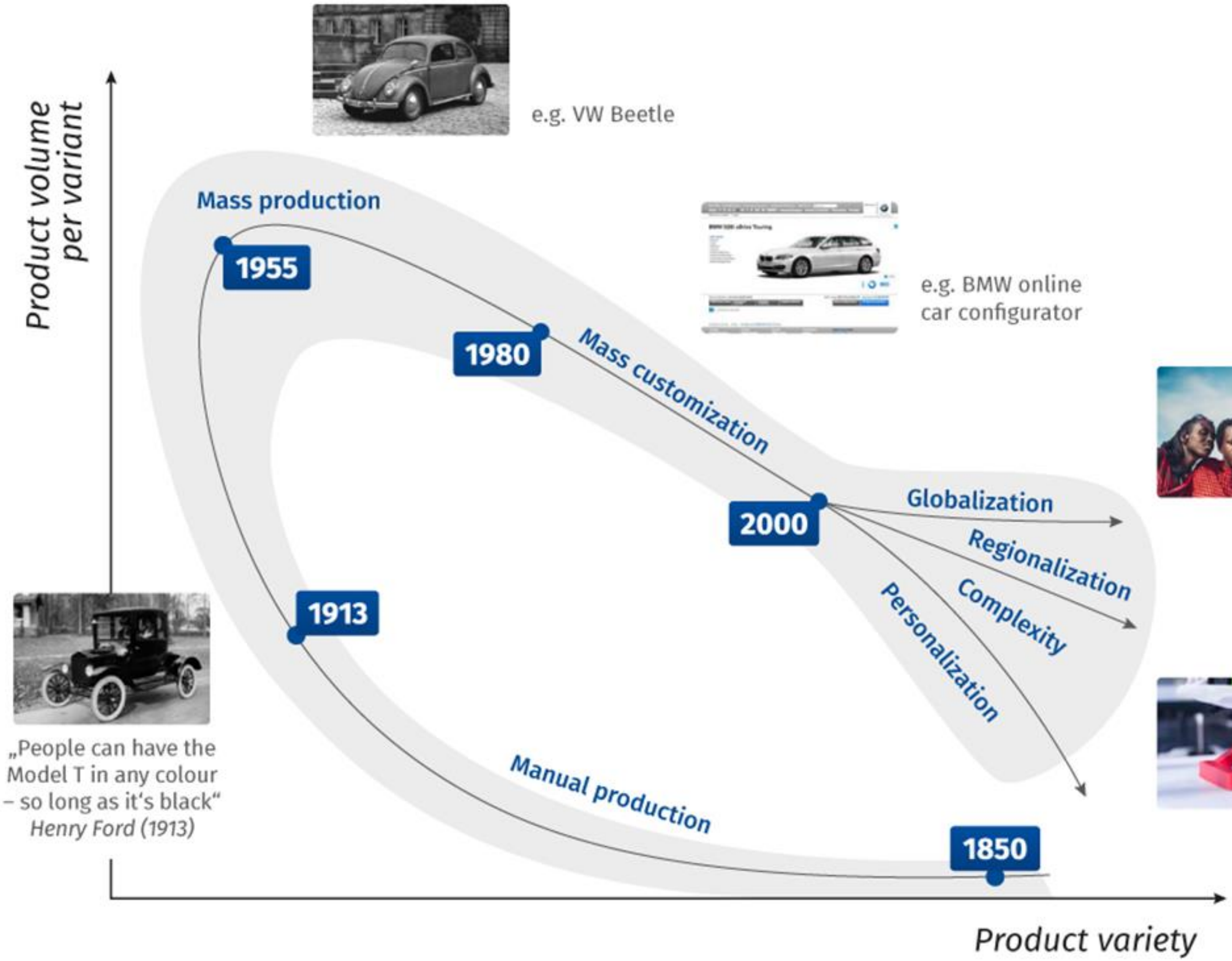
Standard v. One-off Design (Cost Comparison)



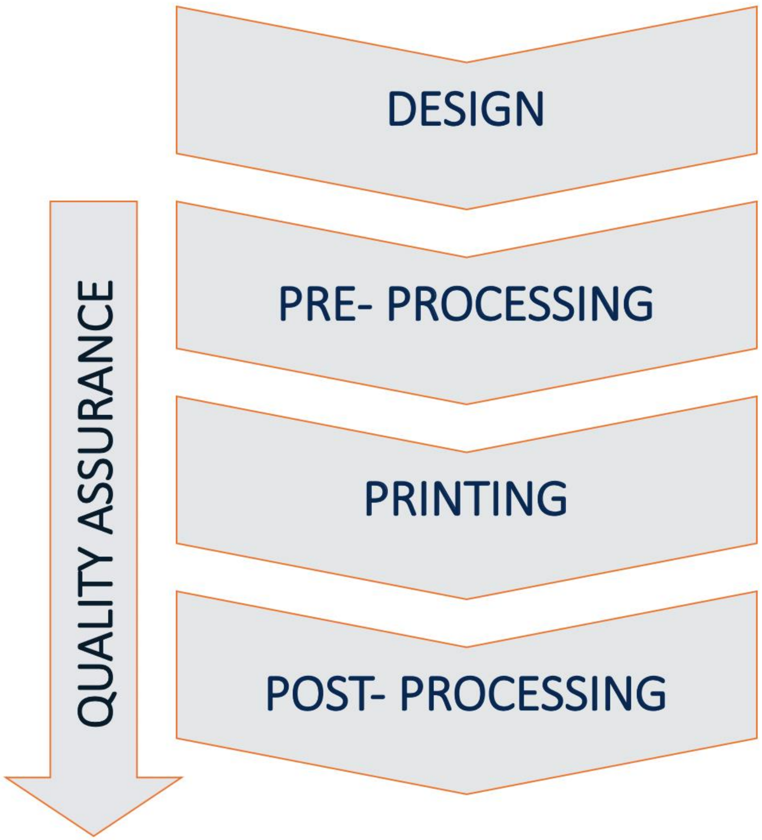
Mass Production Vs Mass customization



Mass Customization

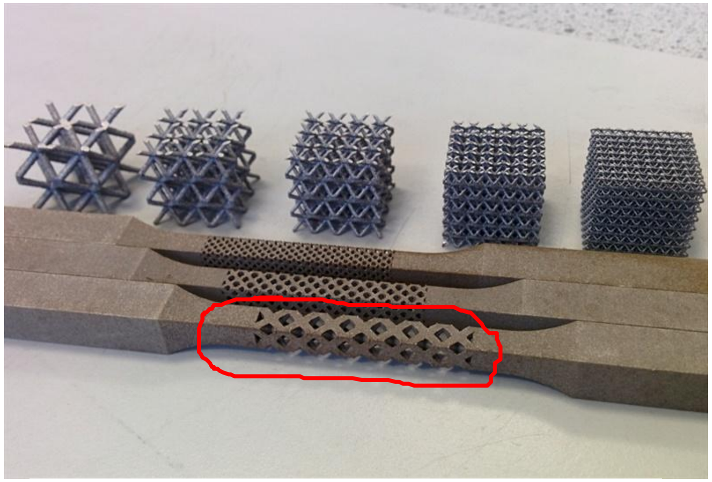


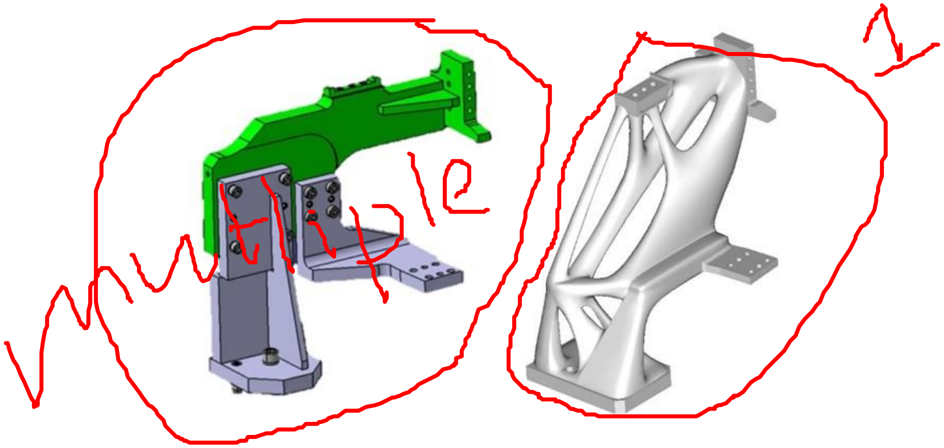
AM Process


DESIGN
PRE- PROCESSING
PRINTING
POST- PROCESSING
QUALITY ASSURANCE

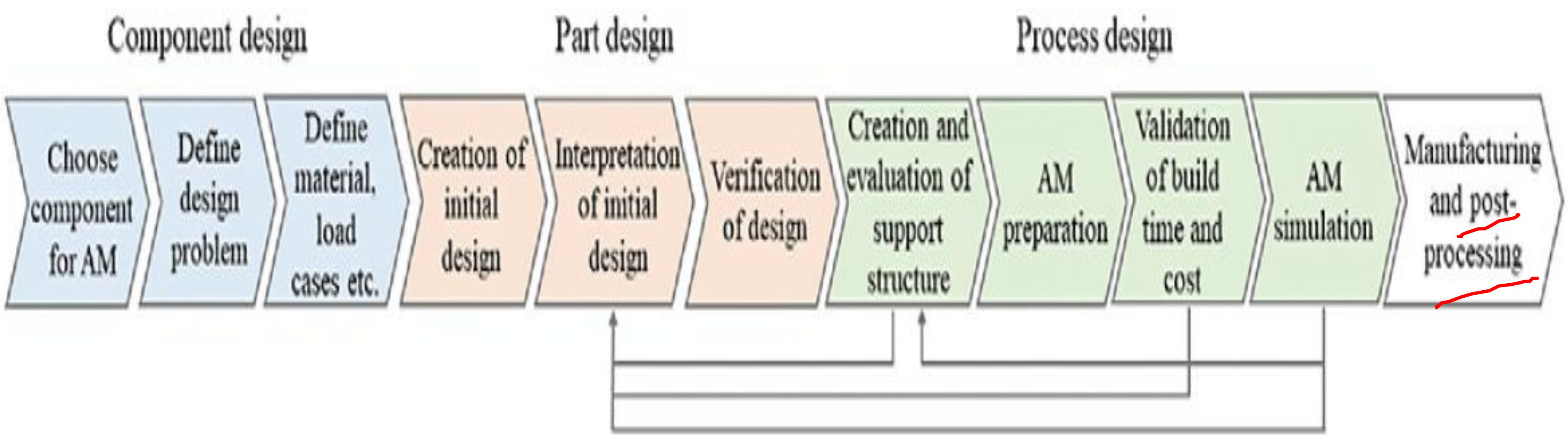
Design for AM

- Opportunistic DfAM
- Restrictive DfAM
- Redesign using DfAM



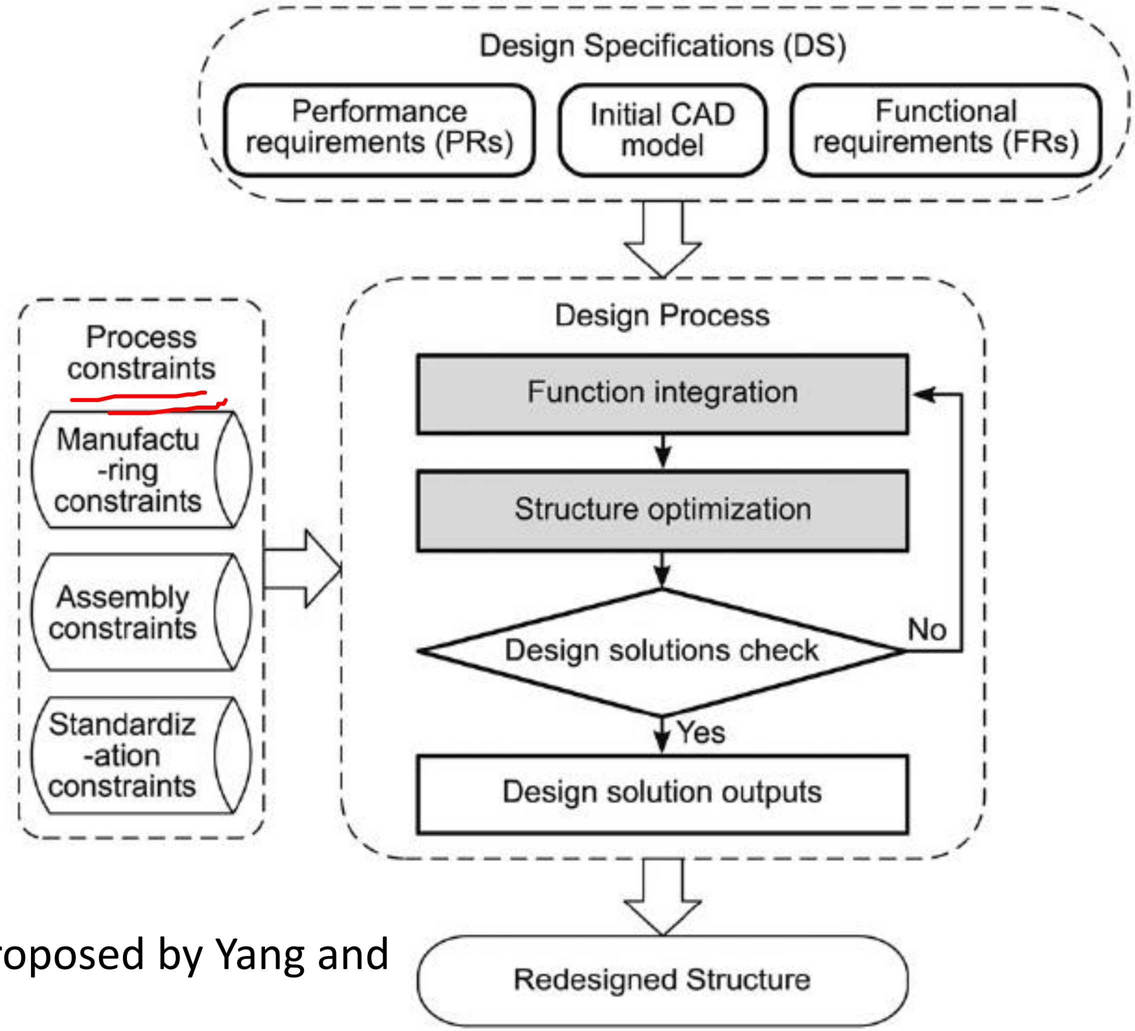


DfAM process today



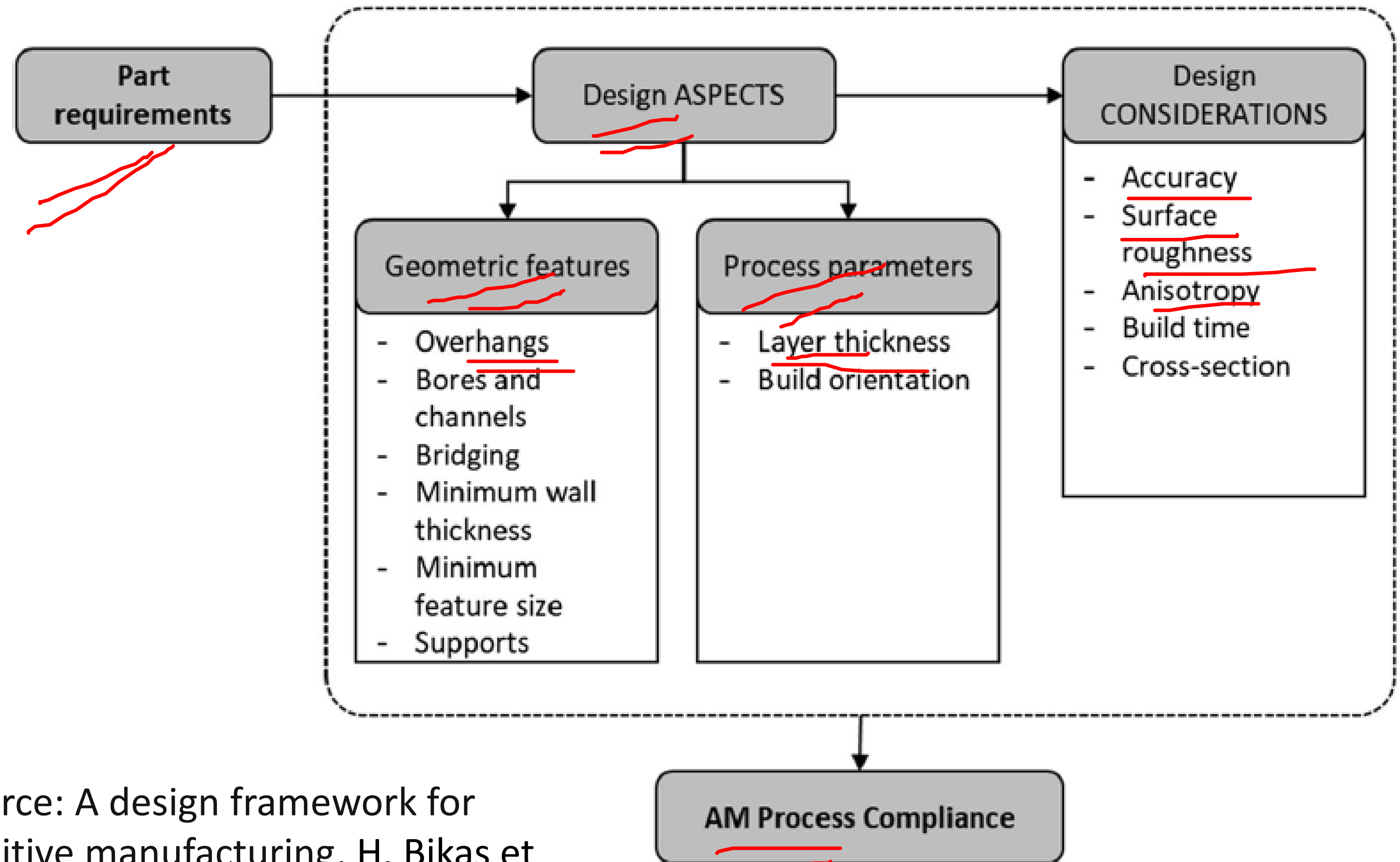
Source: DfAM-a review by Anton Wiberg et al.,

AM enabled design method



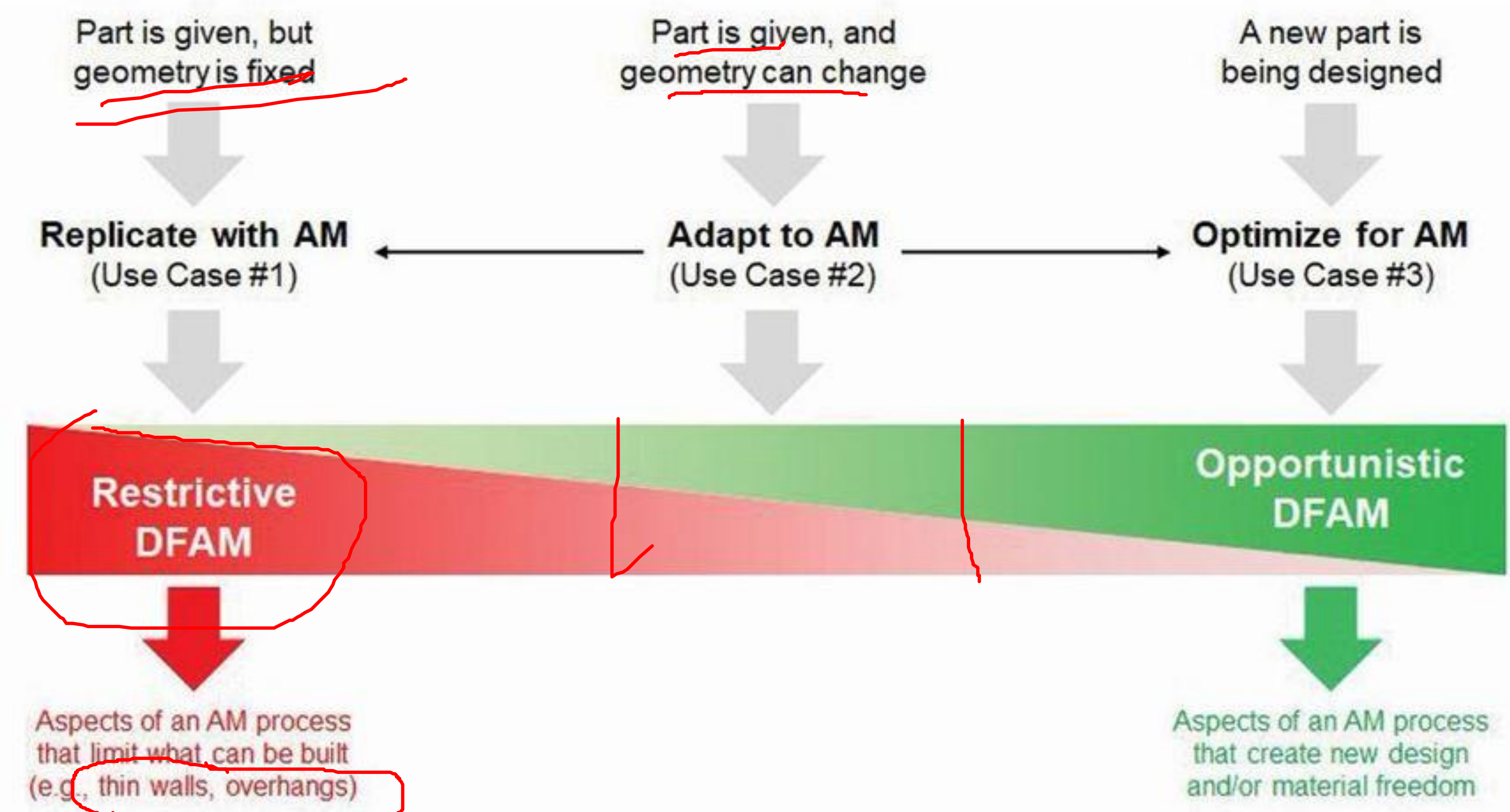
design method proposed by Yang and Zhao (2015).

Design Aspects and Consideration for AM

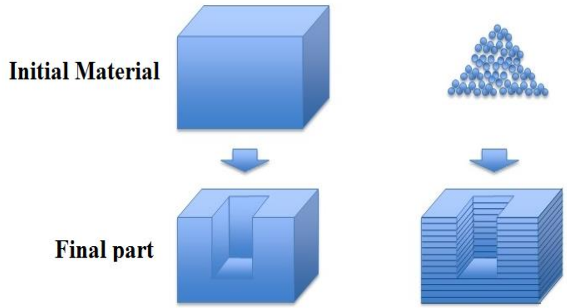


Source: A design framework for additive manufacturing, H. Bikas et al.,

AM enables Manufacturing for Design



Drivers of AM



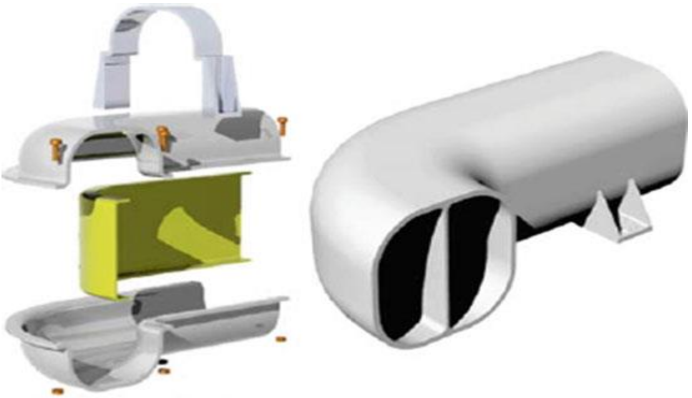
Material efficiency

Mass customization

Function integration

Flow optimization

Tailoring porosities and properties

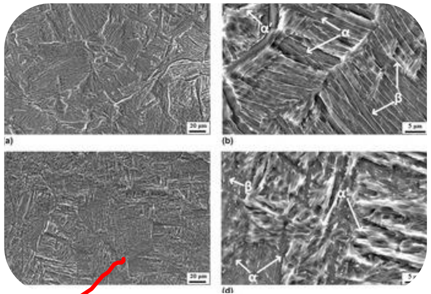


Part consolidation

Courtesy: google images

Drivers for DfAM

Shape complexity

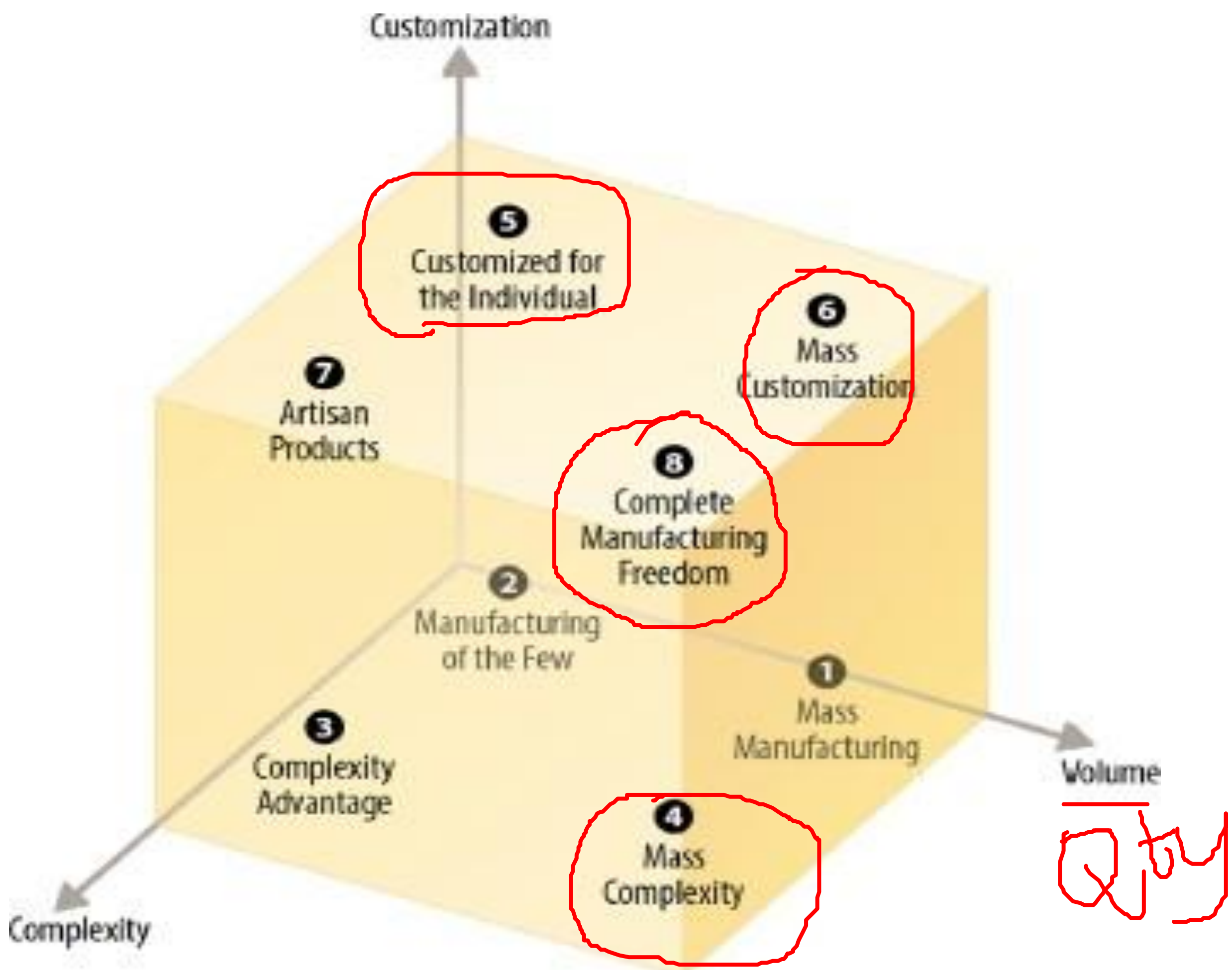


Hierarchical complexity

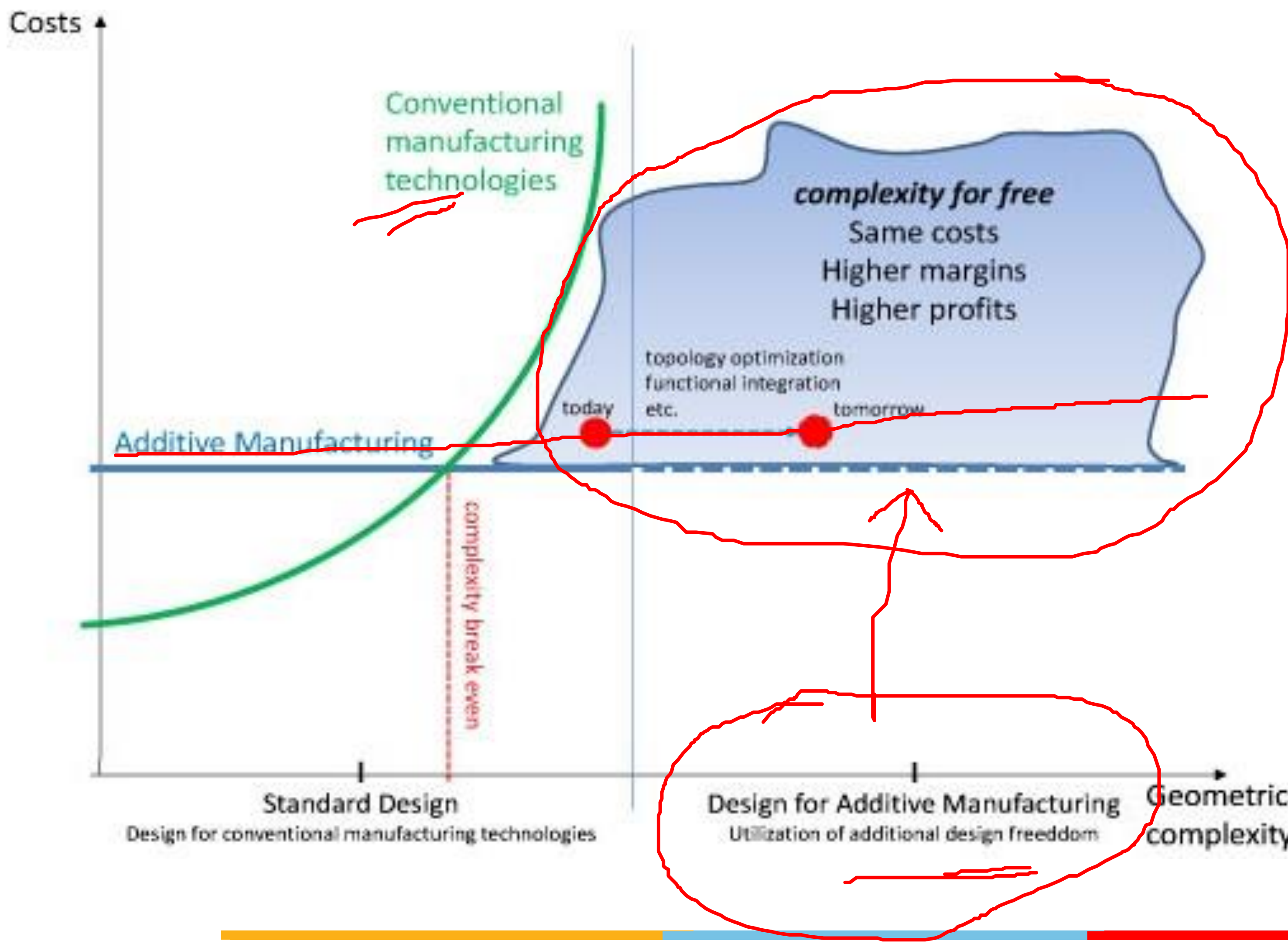
Material complexity

Functional complexity

Complexity of Geometry

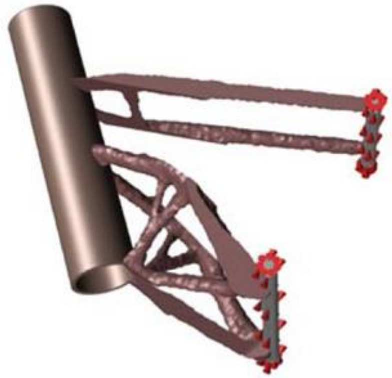


Shape Complexity



Shape complexity to reduce assembly issues

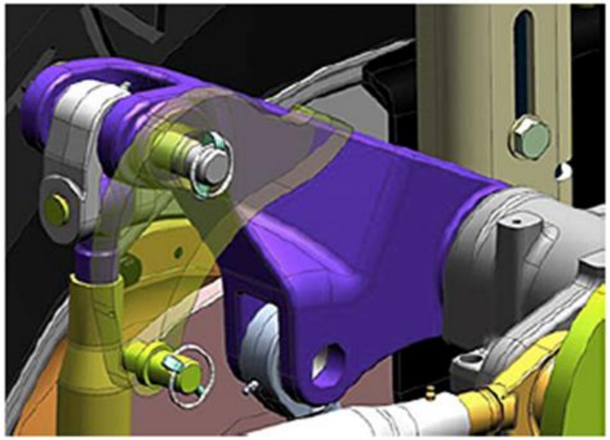
1. CAD model of seat post designed for aluminium alloy casting

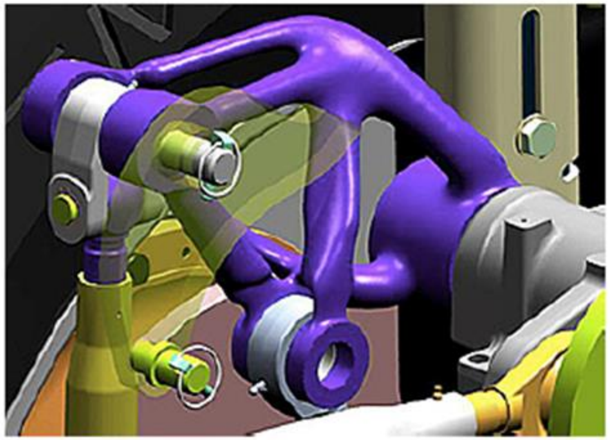


2. Topological optimisation using Altair's solidThinking Inspire® 9.5 software

3. Re-designed by Empire Cycles using the optimised CAD model as a template

4. Produce in titanium alloy on a Renishaw AM250 laser melting system

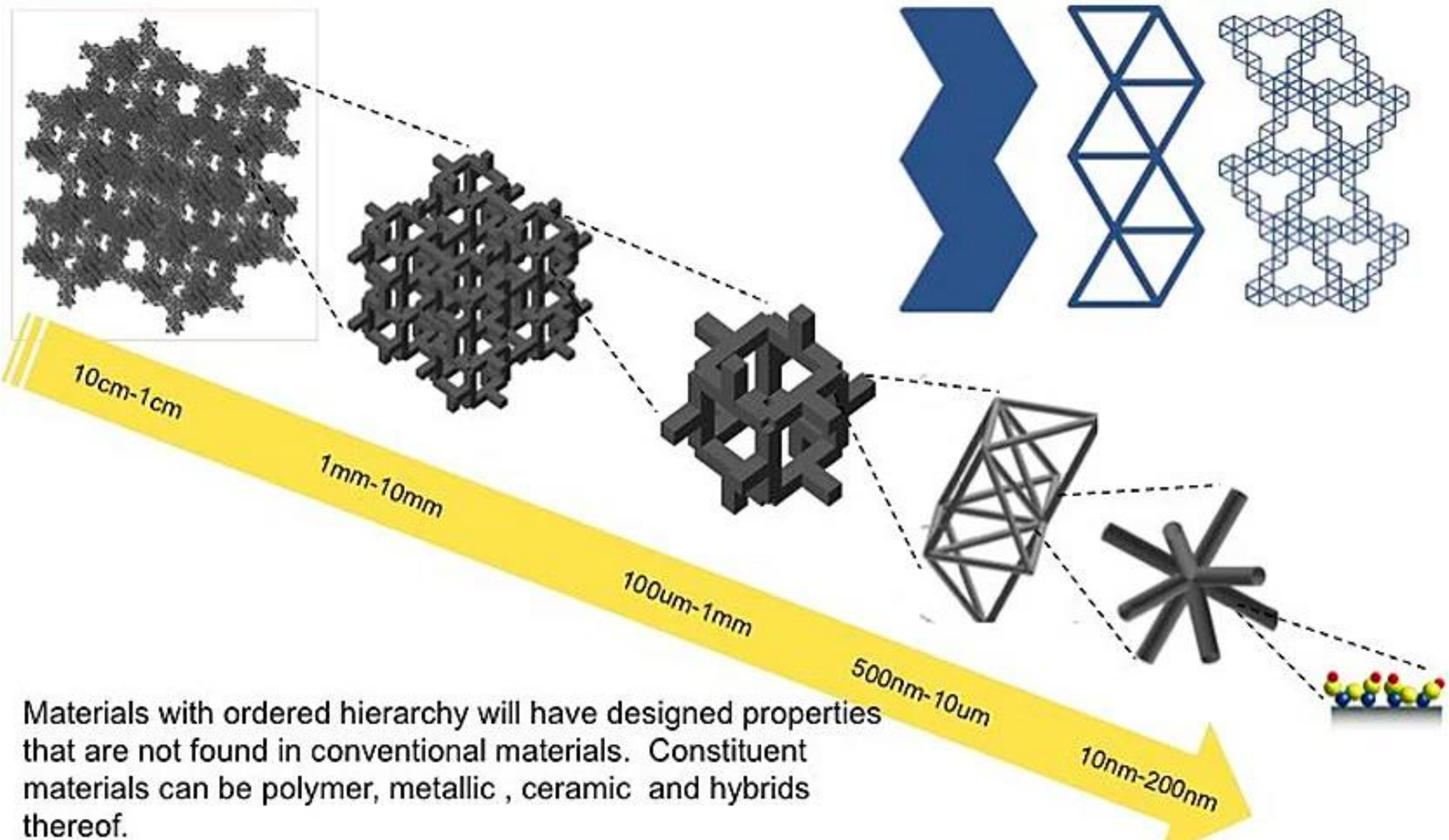




A component before and after weight optimization through the PLM software NX.

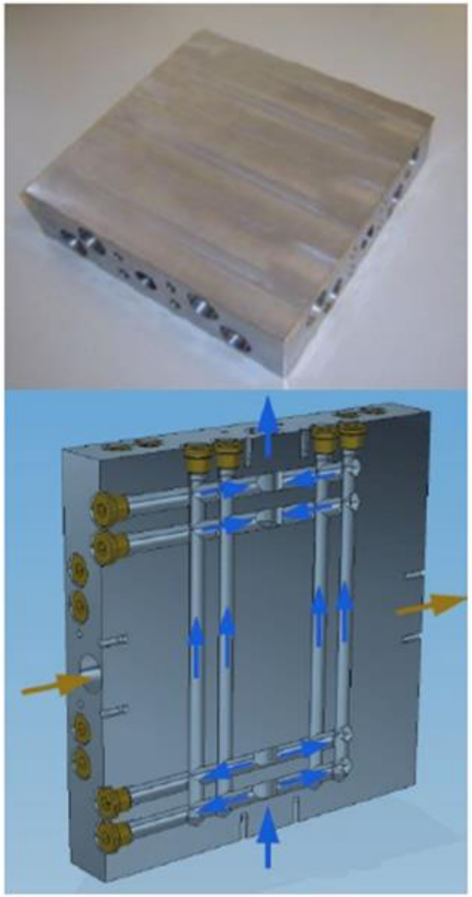
Courtesy: Renishaw and Empire cycles

Hierarchical complexity



Materials with ordered hierarchy will have designed properties that are not found in conventional materials. Constituent materials can be polymer, metallic , ceramic and hybrids thereof.

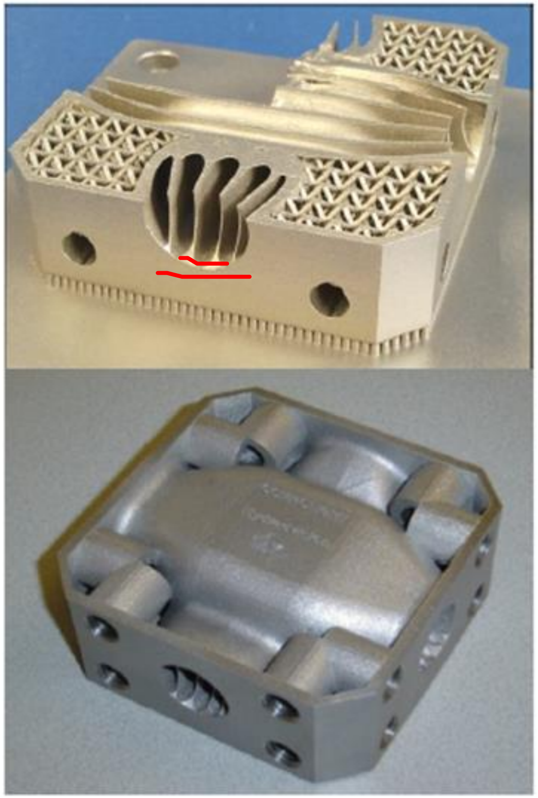
Functional Complexity

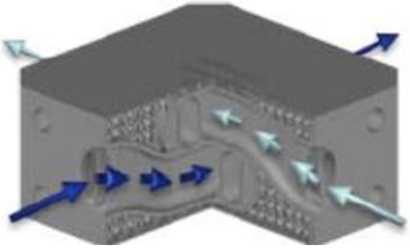


2.900 cm³ vs 244 cm³

19.2 kg vs 1,2 kg

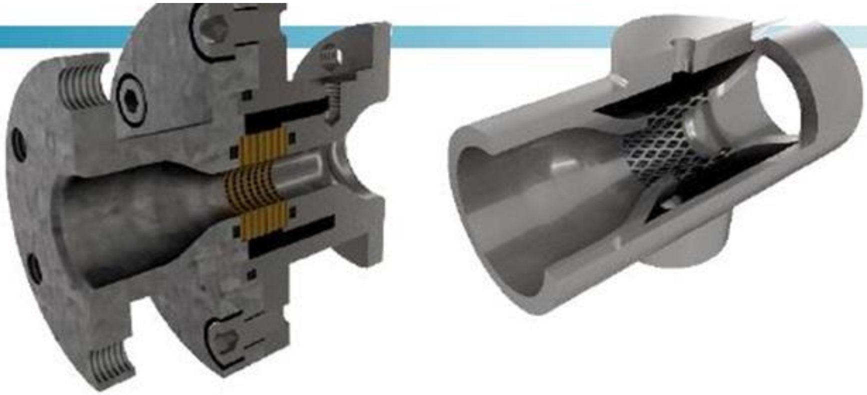
210 mm vs 85 mm





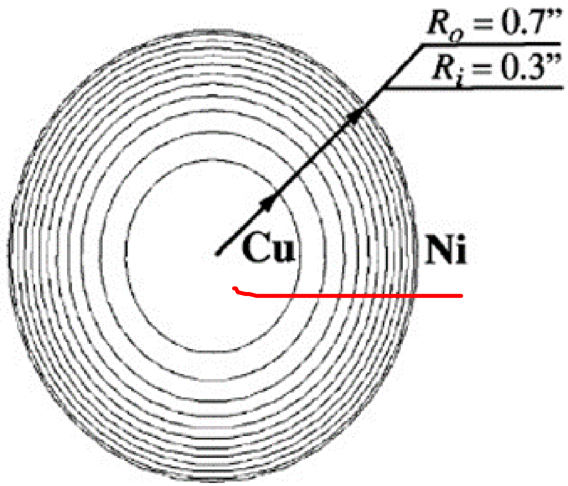
sirris

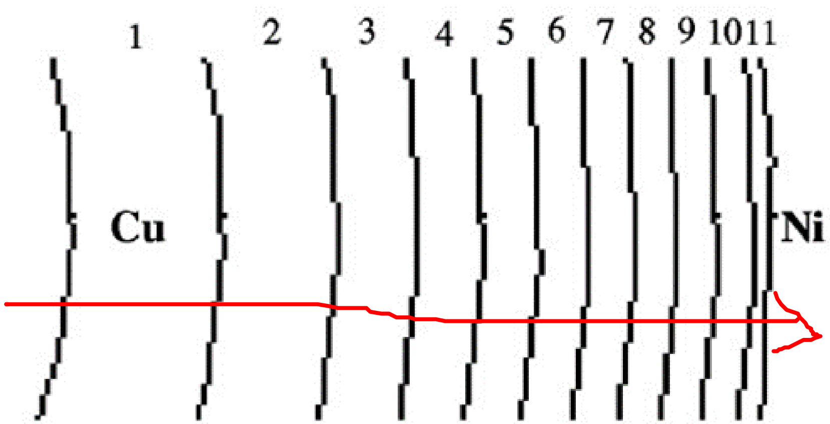
Functional Complexity



Aspect	Classic Design	Additive Design	Ratio
Number of parts	12	1	8%
Weight [kg]	1,3 kg	0,05 kg	4%
Volume [mm³]	401,920 mm³	45.263 mm³	11%
# of gaskets	3	0	0%
Maunufacturing time [min]	720	360	50%
Assembly time [min]	35	0	0%
Throughput time [shifts]	18	2	11%
# involved departments	4	2	50%
Manufacturing cost [€]	1.250	340	27%

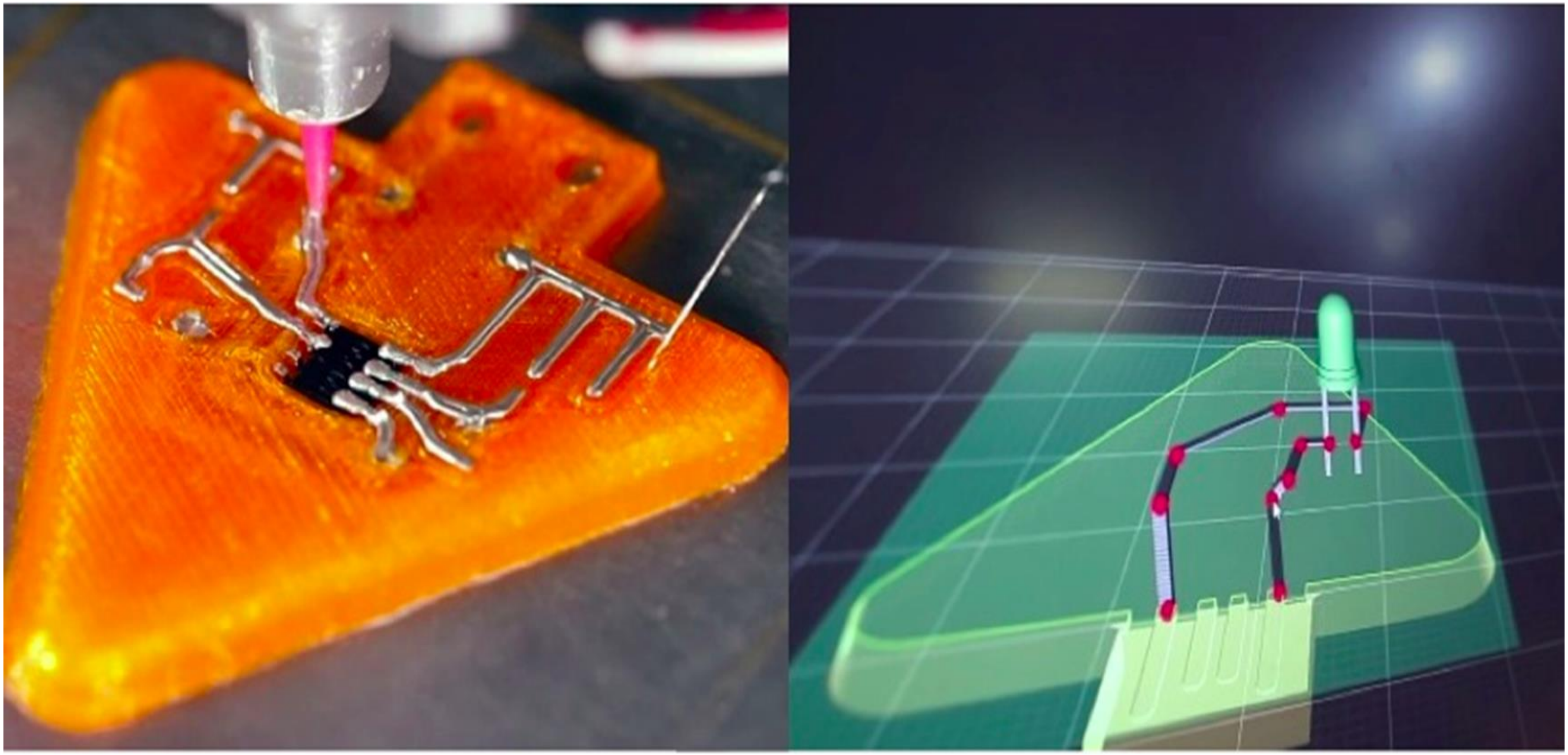
Material Complexity



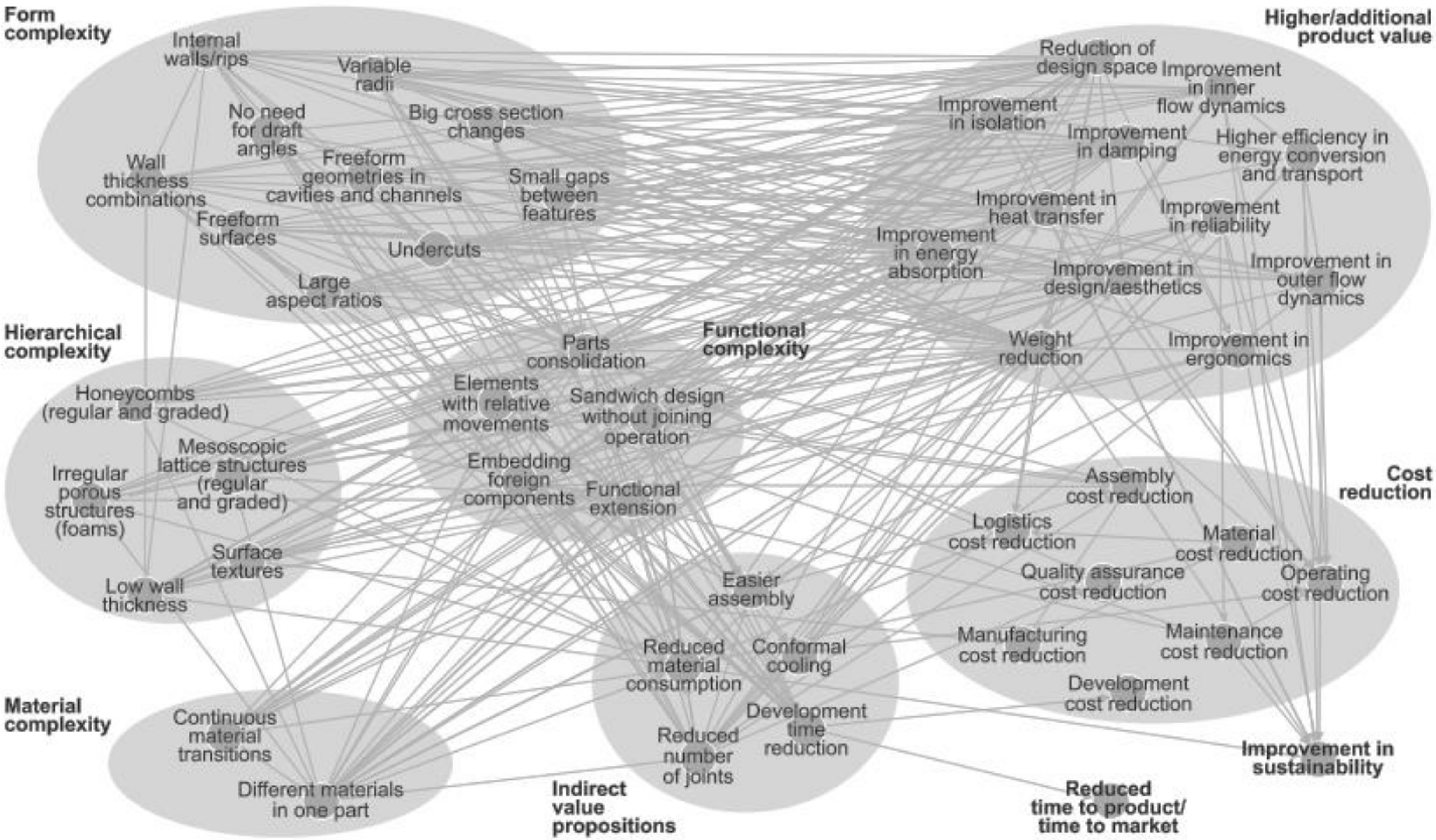


Material compostion	Radius
1: 100 % Cu	0.39"
2: 90% Cu + 10% Ni	0.45"
3: 80% Cu + 20 % Ni	0.50"
4: 70% Cu + 30% Ni	0.54"
5: 60% Cu + 40% Ni	0.57"
6: 50% Cu + 50% Ni	0.60"
7: 40% Cu + 60% Ni	0.62"
8: 30% Cu + 70% Ni	0.64"
9: 20% Cu + 80% Ni	0.66"
10: 10% Cu + 90% Ni	0.68"
11: 100% Ni	0.70"

Material Complexity



DfAM Potentials

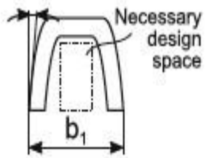
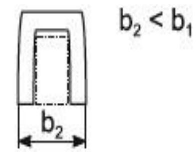
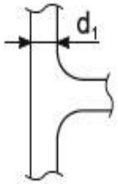
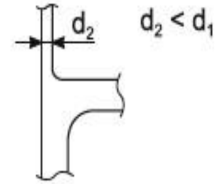
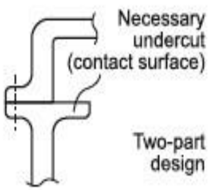
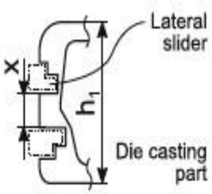
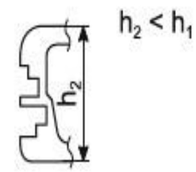


Other Design Freedoms in AM

- Part consolidation
- Weight reduction
- Functional integration / customization
- Superior aesthetics
- Manufacturing footprint reduction

DFM

Comparison of Restrictive and Opportunistic DfAM

Die casting design rule		Similar SLM design rule	Degree of new design freedom	Exemplary benefit	
	Add draft angles	No	Very high		Reduction of design space
	Aim for uniform wall thickness	No	Very high		Weight reduction
	Avoid undercuts	Partly (due to removal of support structures)	High (restriction less crucial)		Parts consolidation
	Avoid small distances between features	No	Very high		Reduction of design space

Core DfAM Concepts and Objectives

- AM enables the usage of complex geometry in achieving design goals without incurring time or cost penalties compared with simple geometry.
- As a corollary to the first guideline, it is often possible to consolidate parts, integrating features into more complex parts and avoiding assembly issues.
- AM enables the usage of customized geometry and parts by direct productionfrom 3D data.
- With the emergence of commercial multimaterial AM machines, designers should explore multifunctional part designs that combine geometric and material complexity capabilities.
- AM allows designers to ignore all of the constraints imposed by conventional manufacturing processes (although AM-specific constraints might be imposed).

Next Sessions

1. Part consolidation
2. Mass customization
3. Lightweighting
4. Topology Optimization
5. Generative Design
6. Heterogenous modelling
7. Hierarchical structures
8. Modelling for Hybrid AM
9. Multi-Materials
10. Functional Integration

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End of Lecture 5-6