



A?

Aalto-yliopisto

Materials of Additive Manufacturing

Ville Kukko-Liedes

14.3.2019

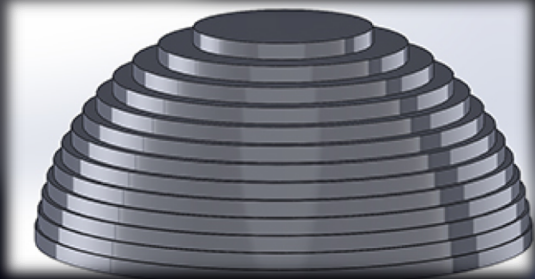
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What is 3D Printing?

Additive Manufacturing (AM):
Construction of physical
objects directly from 3D CAD
data – usually layer upon layer

(CAD = Computer Aided Design)



As opposed to e.g.
subtractive manufacturing
(milling, turning etc.)





Uses: Rapid Prototyping

- The original and still much used application of 3D printing
- Commercialized in the 80s (SLA by 3D Systems)
- Extremely popular in product development:
 - Fast testing of form, fit, function, ergonomics..
 - Accurate representation of intended material properties and function possible
 - Affordable and quick to produce prototypes provide early feedback
- Fail faster to succeed earlier!



- Concept wireless charging station for a plush toy / nightlight

Uses: Rapid Prototyping



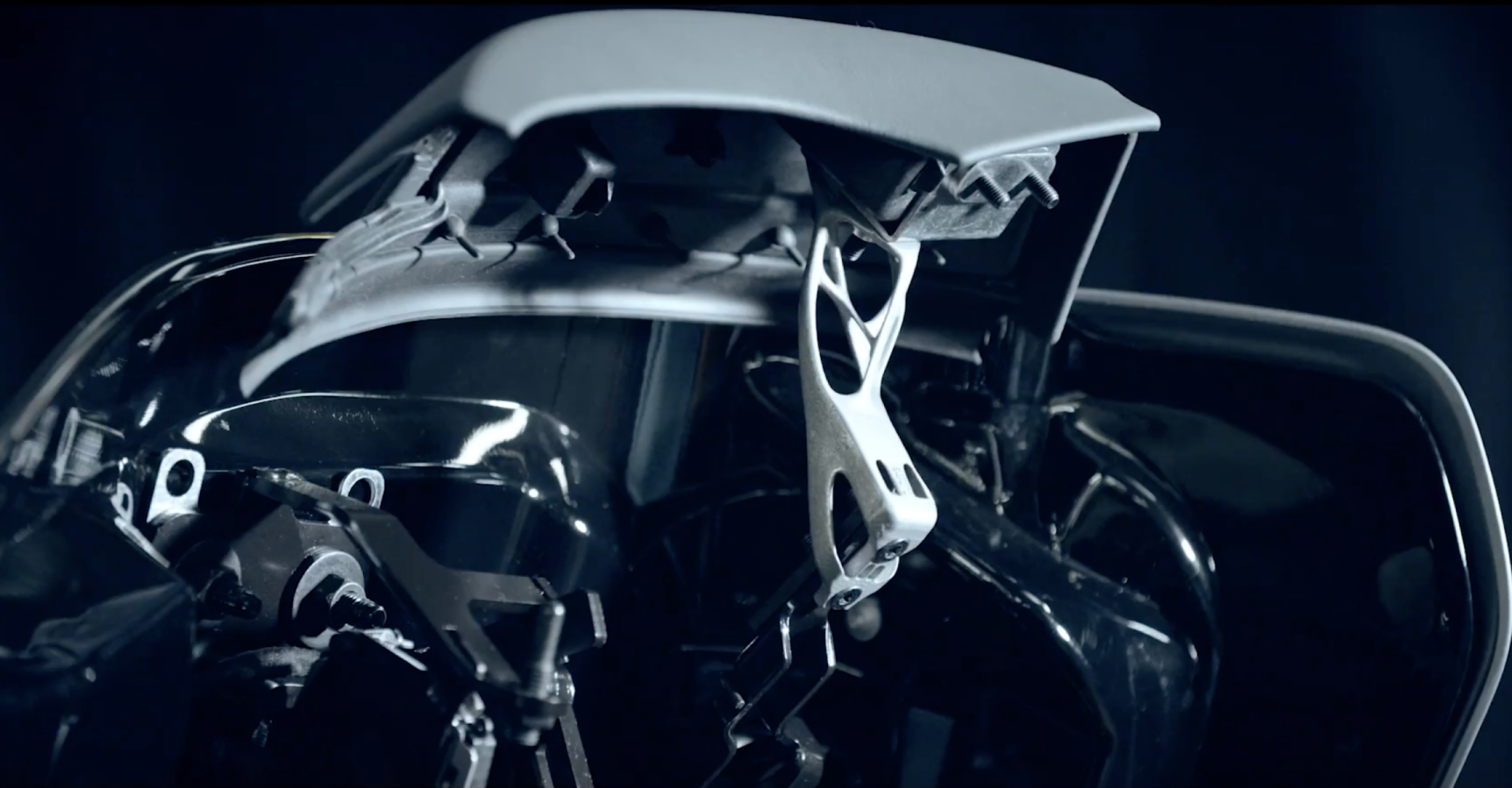


Uses: Rapid Manufacturing

- Use of AM to produce end-use parts and products
- Expansion during the last 13 years
 - From 4% (2003) to 35% (2014)
 - Result of process and material development & media hype
- Notable in medical and aerospace industries
 - Medical: Personalized solutions
 - Aerospace: Weight optimization
- Potential in multiple fields, but still restricted to low volume or customized production of high-end products
- Lacking standards & false assumptions hinder adoption

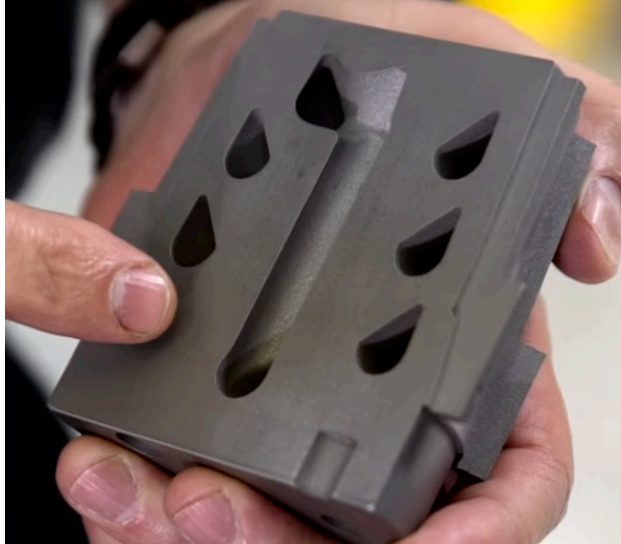


3D printed metal parts in BMW i8 convertible



Customized parts in MINI cars





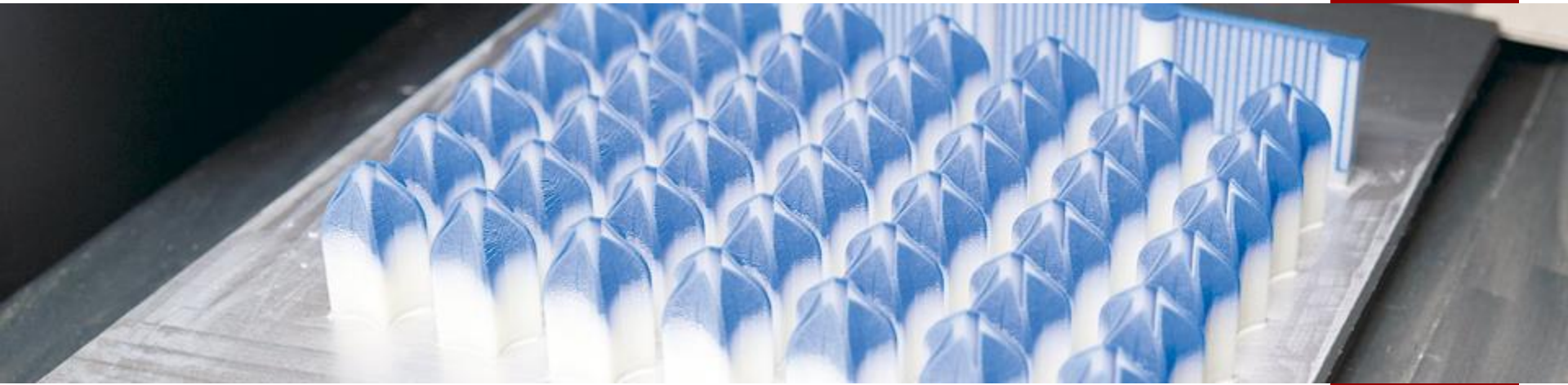
Uses: Rapid Tooling

- Use of AM for indirect production:
 - Masters for sand & silicon casting
 - Lost wax casting
 - Printing sand, metal & plastic molds
 - Fixtures for drilling
 - Jigs
 - Endless number of uses..
- For both prototypes & end-use parts
- Takes advantage of low investment cost, fast process, and AM introduced benefits such as contouring cooling channels in injection molds



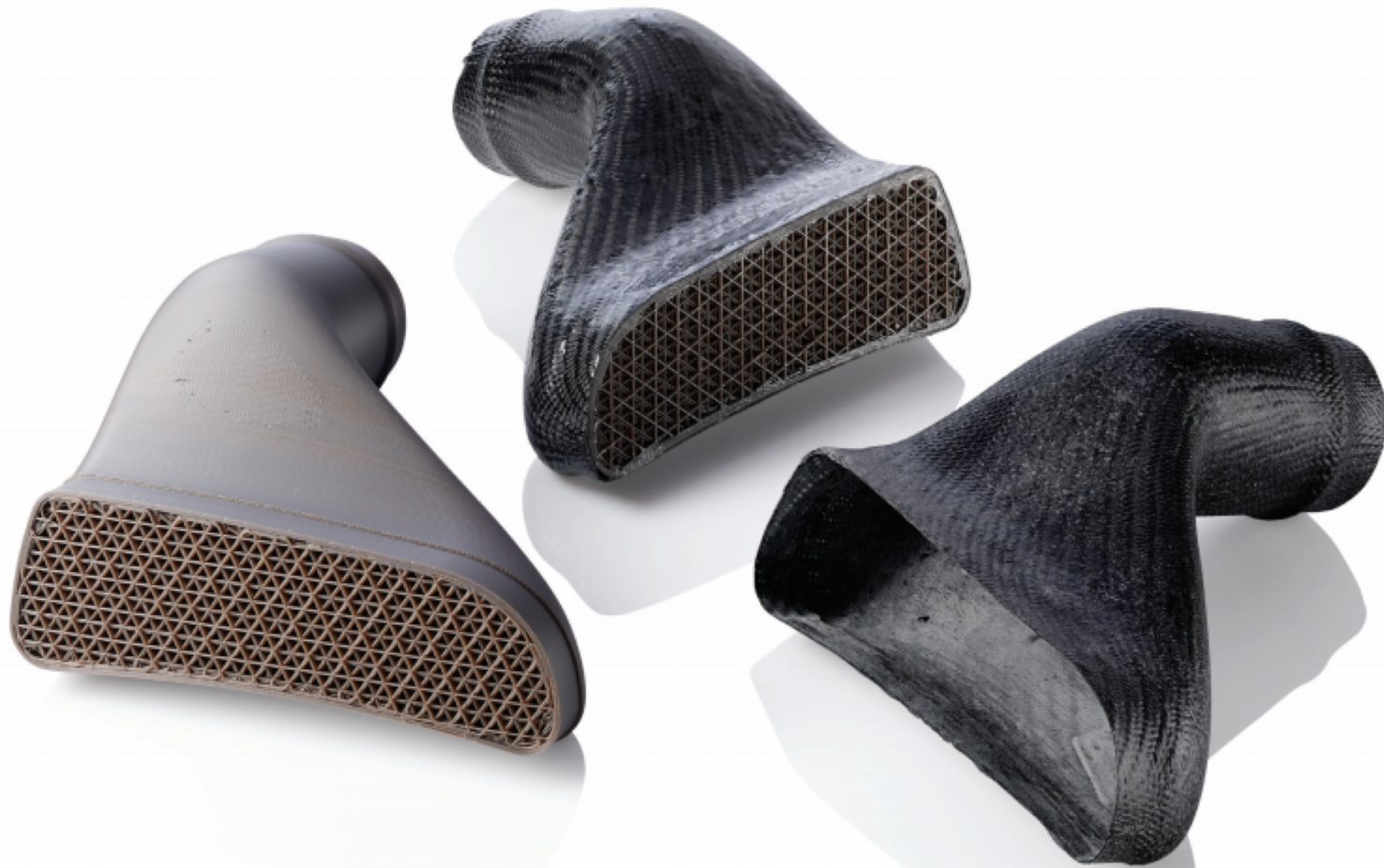


Masters for silicone casting

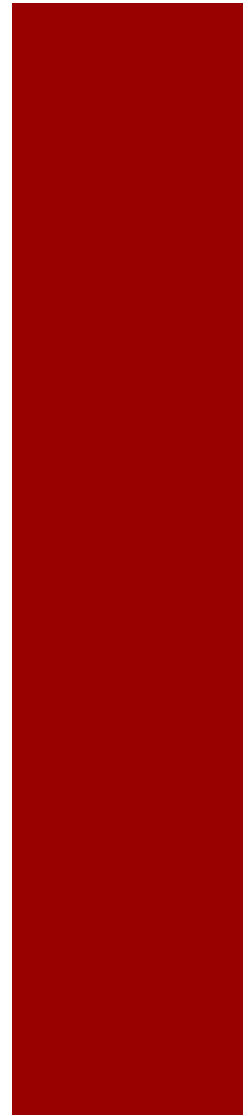


Printed wax masters for precision casting



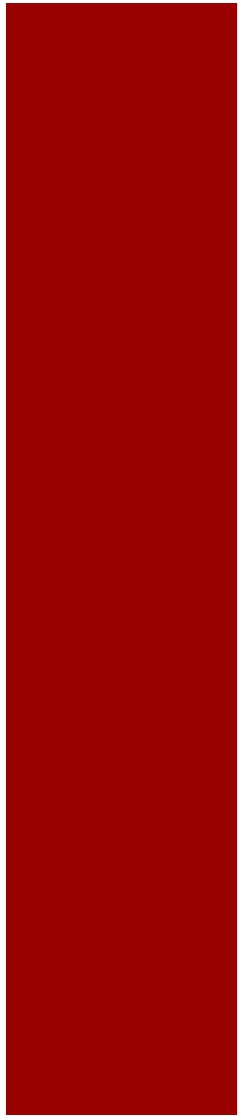
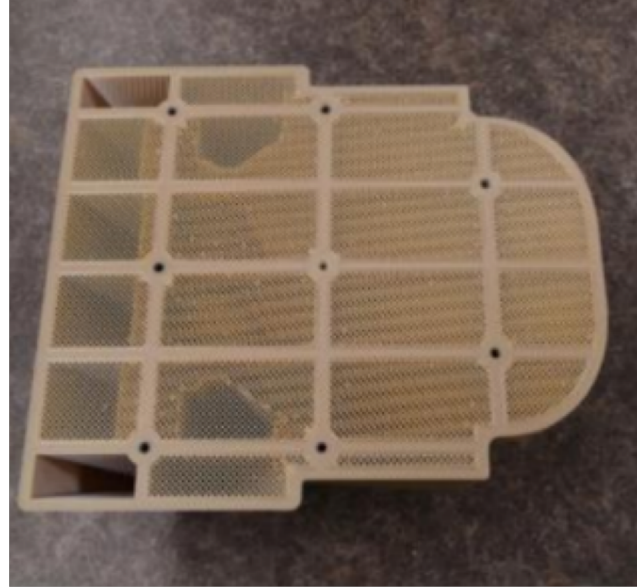


Cores for Glass/Carbon-fiber parts



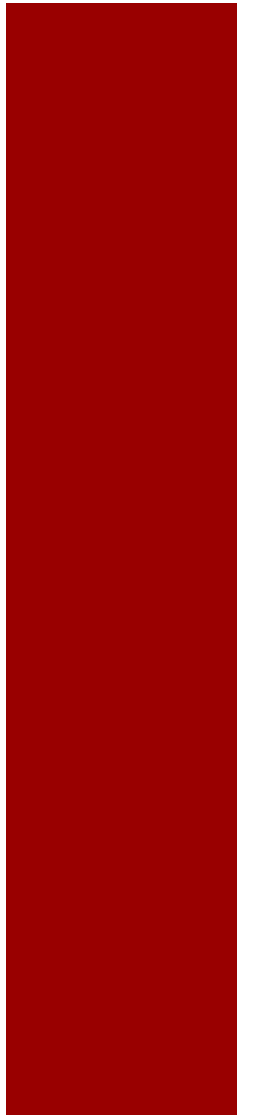


Vacuum forming cores





Injection molds printed with plastic



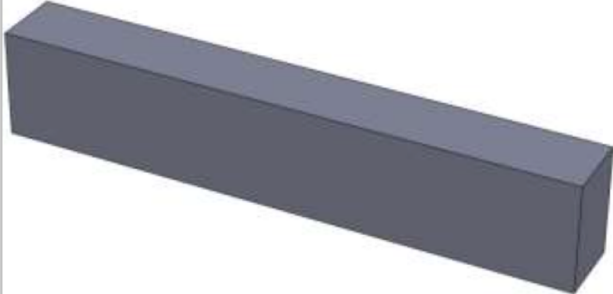
Freedom of design



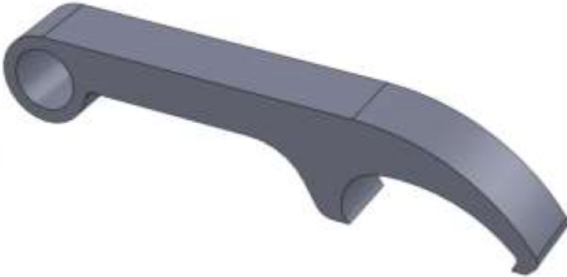
- No need to Design for Manufacturing & Assembly: Instead Design for Functionality, Weight, Strength etc
- Minimize part count while optimizing topology
- Pre-built assemblies – minimize labor time & QC
- Customization without additional cost – Every part can be different from the others, even in same batch



Design for AM – Case: bottle opener



Solid Billet: 10.39gms



Solid Machined/Cast: 4.22gms



Topology Optimised AM: 0.95gms

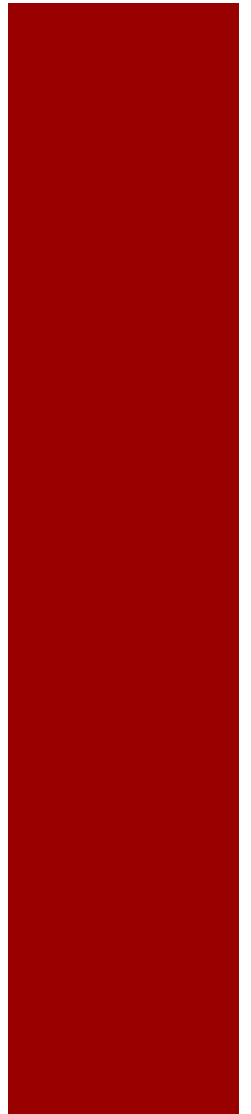
Design for AM – Case: Buckle



- Commercial aircraft can have anything up to 850 seat belt buckles
- Traditionally constructed, airline seat belt buckles weigh between
 - 155g (Steel)
 - 120g (Aluminium).



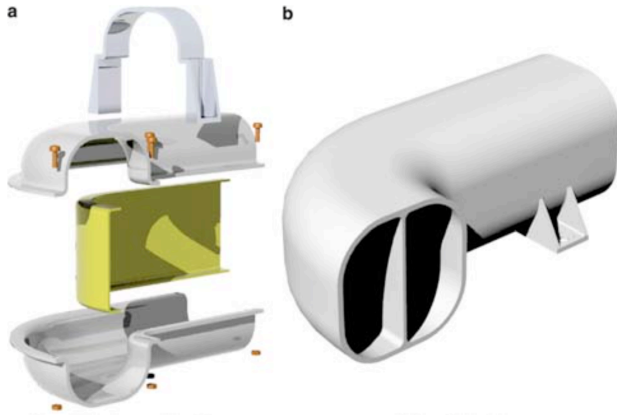
68 grams



Case: Boeing / F-18 air duct system re-design



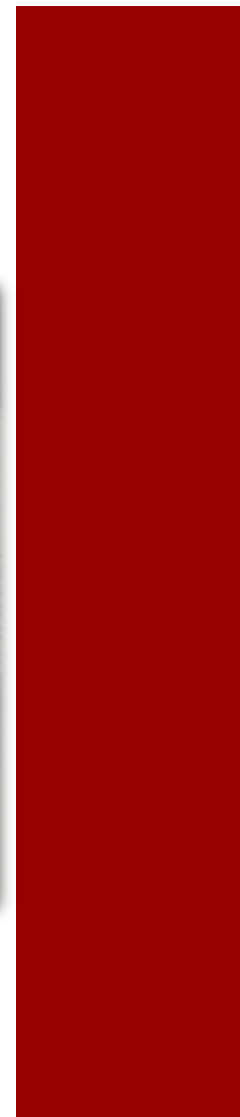
Case: F-18 cooling air system



- Complete re-design for functionality & weight
- This unit: part reduction from 16 to 1
- Improved air flow
- No assembly required
- No tooling required
- Future improvements with minimal cost
- Spare parts on demand and on location



Case: Align / Invisalign tooth retainers



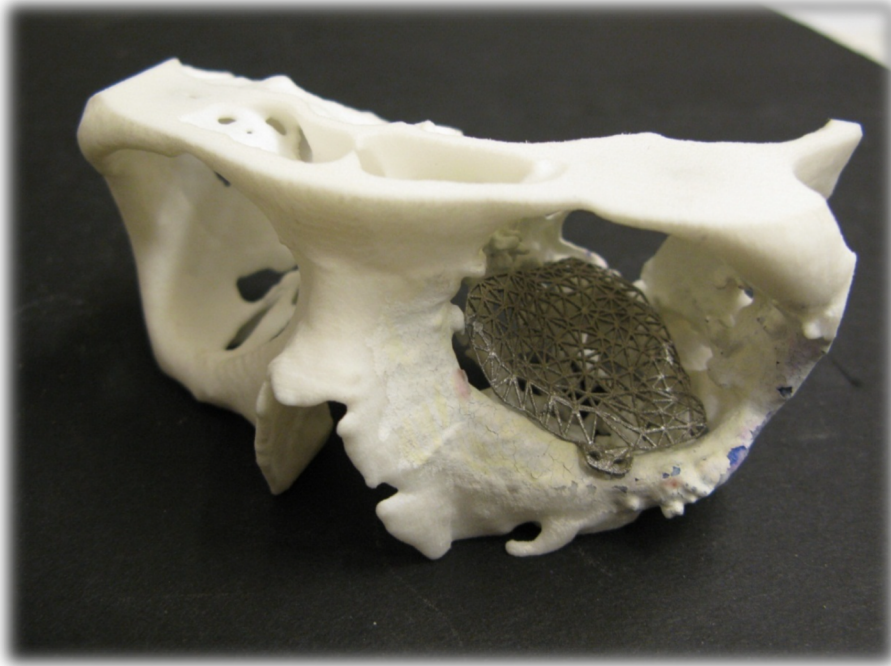
Case: Invisalign tooth retainers



- *Digital pre-planning of each unit, “digital inventory”*
- *Example of mass customization – 40,000 a day*
- *AM produced individual molds for thermal forming*
- *Innovative example of utilizing customizability*
- *RP machines & processes modified for excessive use*



Other medical uses



Inert implants

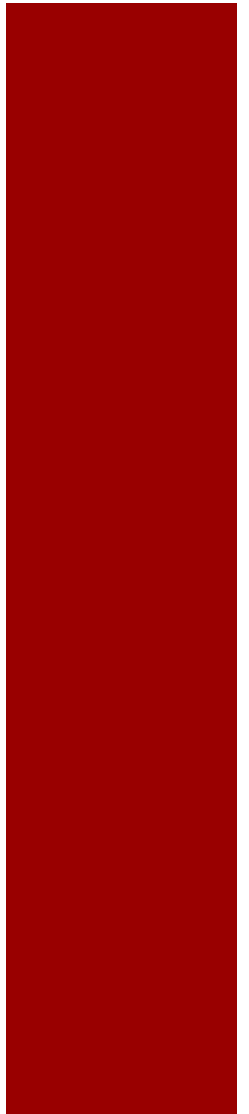


Hearing aids

- *Surgical planning, prosthesis, tooth crowns & bridges, tissue growth...*

Categories of 3D printing

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





Aalto-yliopisto

(THERMO)
PLASTICS



RESINS



METALS

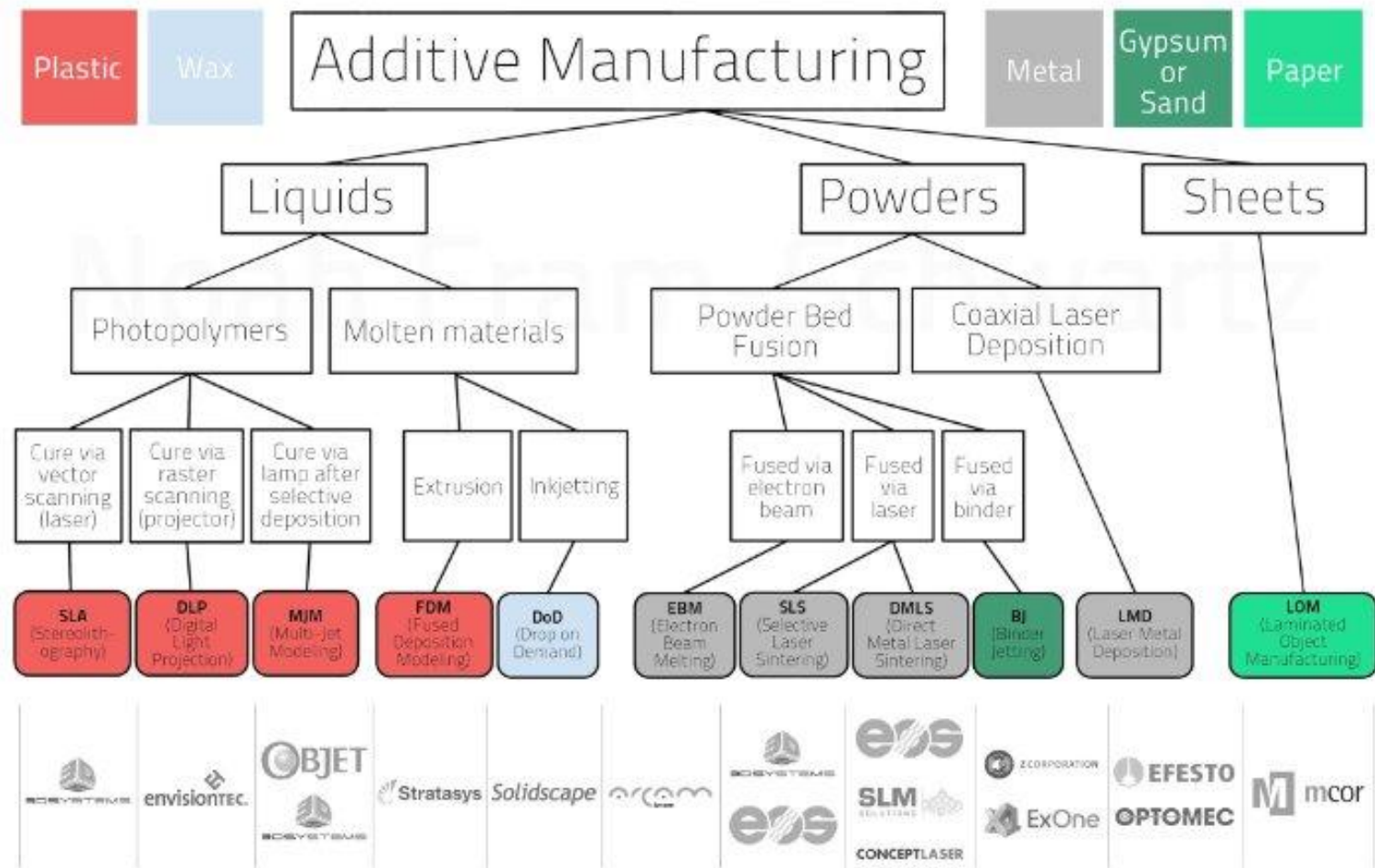


FULLCOLOR AND OTHERS



TYPES OF ADDITIVE MANUFACTURING

CREATED BY NOAH FRAM-SCHWARTZ



Plastics

Thermoplastics

- PA (Nylon)
- PA composites
- ABS
- PC
- ULTEM
- TPU
- TPE
- PEEK



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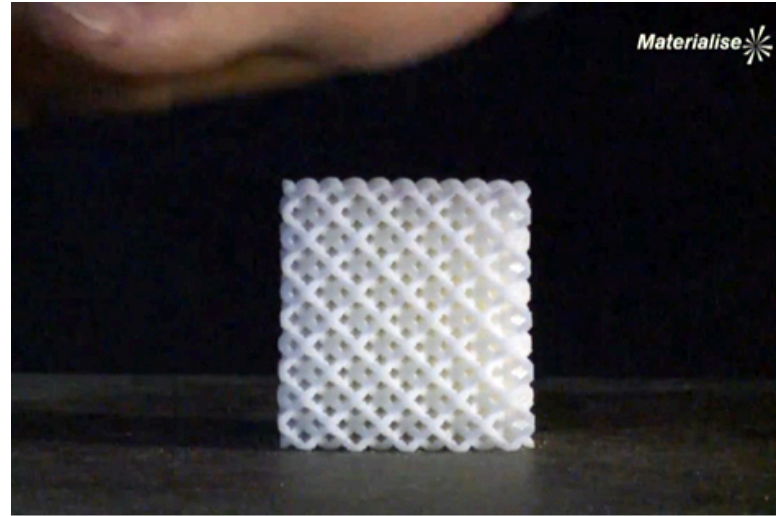
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Plastics

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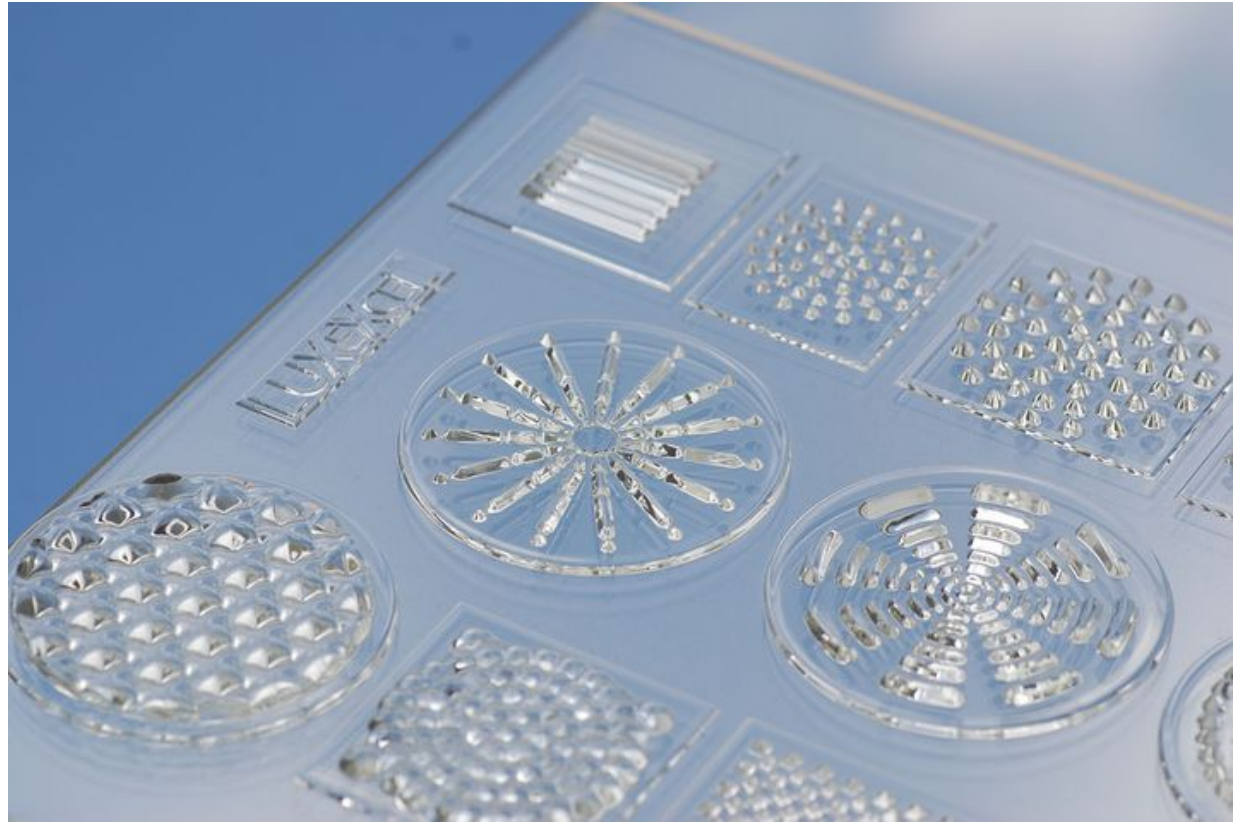
- Opaque
- Translucent
- Transparent
- Flexible
- Castable
- High temp
- High strength



Plastics

Resins

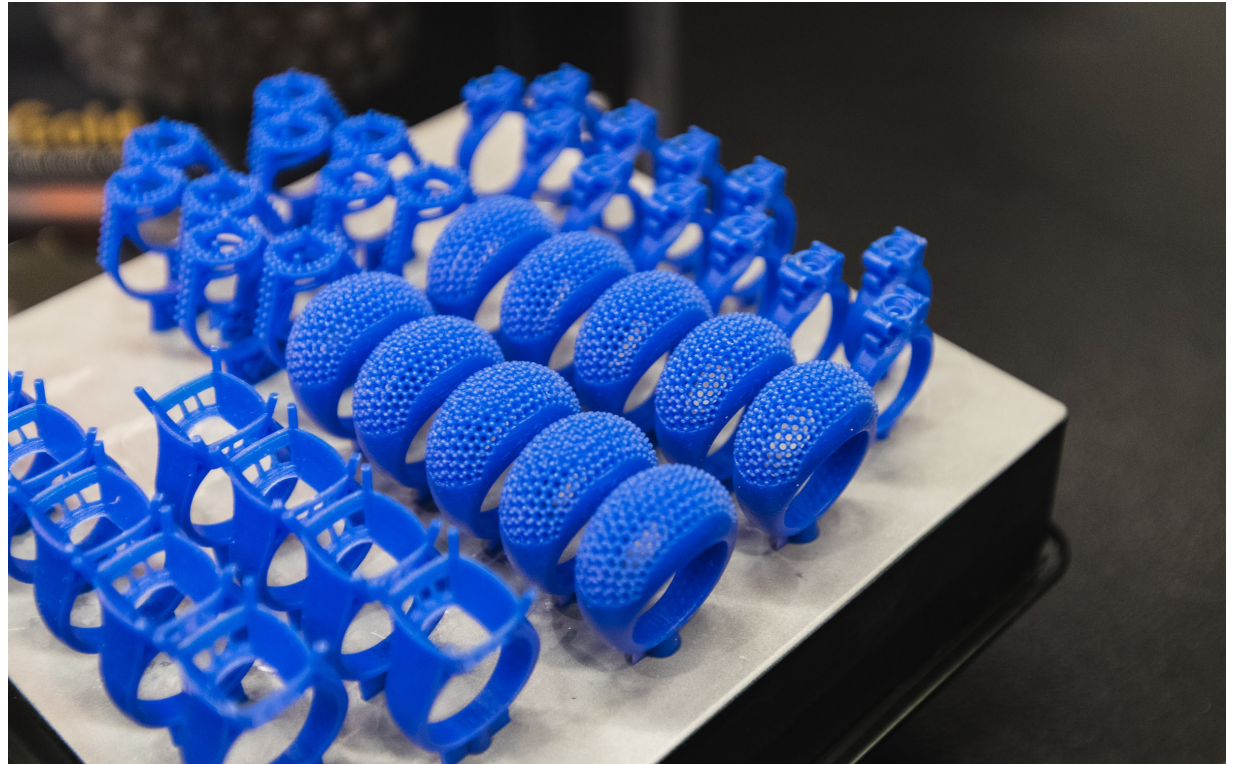
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DESIGN VERIFICATION

NAIL POLISH SET PROTOTYPES (TECHNOLOGY DEMONSTRATION ONLY)

This set of nail polish prototypes was created on the Stratasys J750 full color, multi-material 3D printer, in VeroClear material for the outer shell, in combination with VeroCyan, VeroMagentaV, VeroYellowV, VeroPureWhite, and VeroBlackPlus. In addition to vibrant and accurate colors, the models, for the first time, feature VeroClear in combination with VRML texturing. The stand assembly is created in VeroClear material.

System	Stratasys J750™
Material	VeroClear, VeroCyan, VeroMagentaV, VeroYellowV, VeroPureWhite, VeroBlackPlus
Build Time	2 hours, 21 min
Material Amount Used	22 g
Support Material Amount Used	6 g

stratasys



TRANSPARENT & TEXTURED GLOBE (TECHNOLOGY DEMONSTRATION ONLY)

This transparent globe with a textured surface was printed on the Stratasys J750 full color, multi-material 3D printer, in VeroClear material for the outer shell, in combination with VeroCyan, VeroMagentaV, VeroYellowV, VeroPureWhite, and VeroBlackPlus. In addition to vibrant and accurate colors, the models, for the first time, feature VeroClear in combination with VRML texturing. The stand assembly is created in VeroClear material.

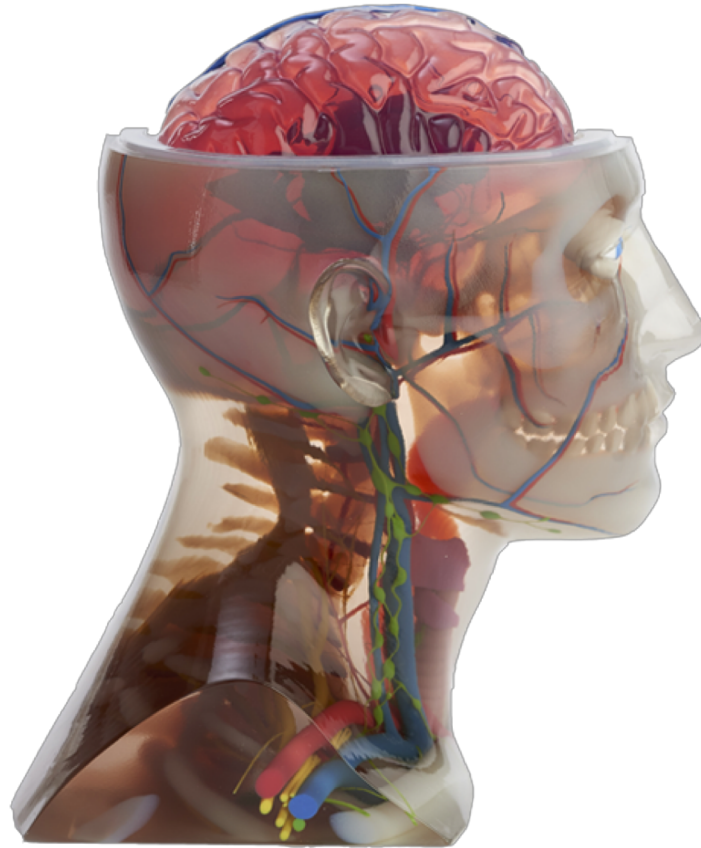
stratasys



Plastics

Resins

- Opaque
- Translucent
- Transparent
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Metals

- **Stainless Steel**
- **Bronze**
- **Aluminium**
- **Titanium**
- **Silver**
- **Gold**



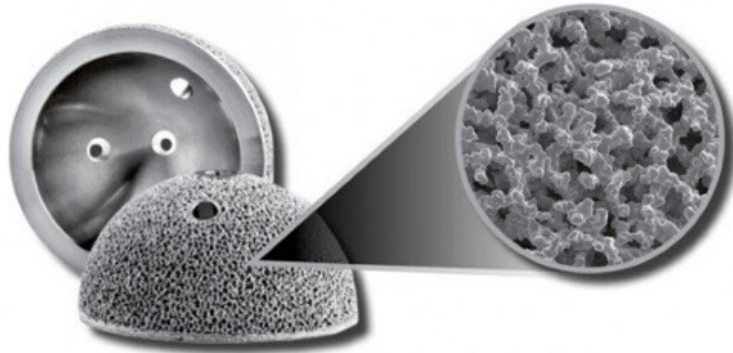
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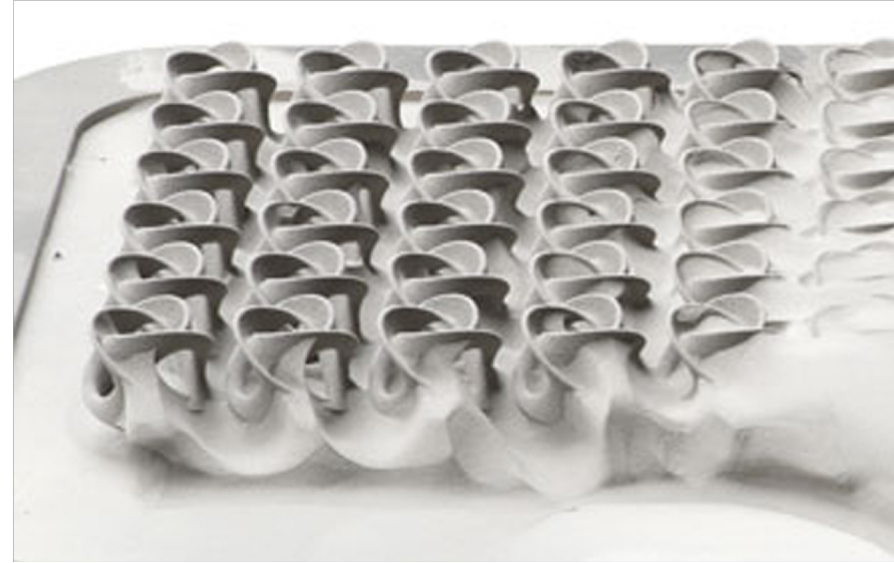
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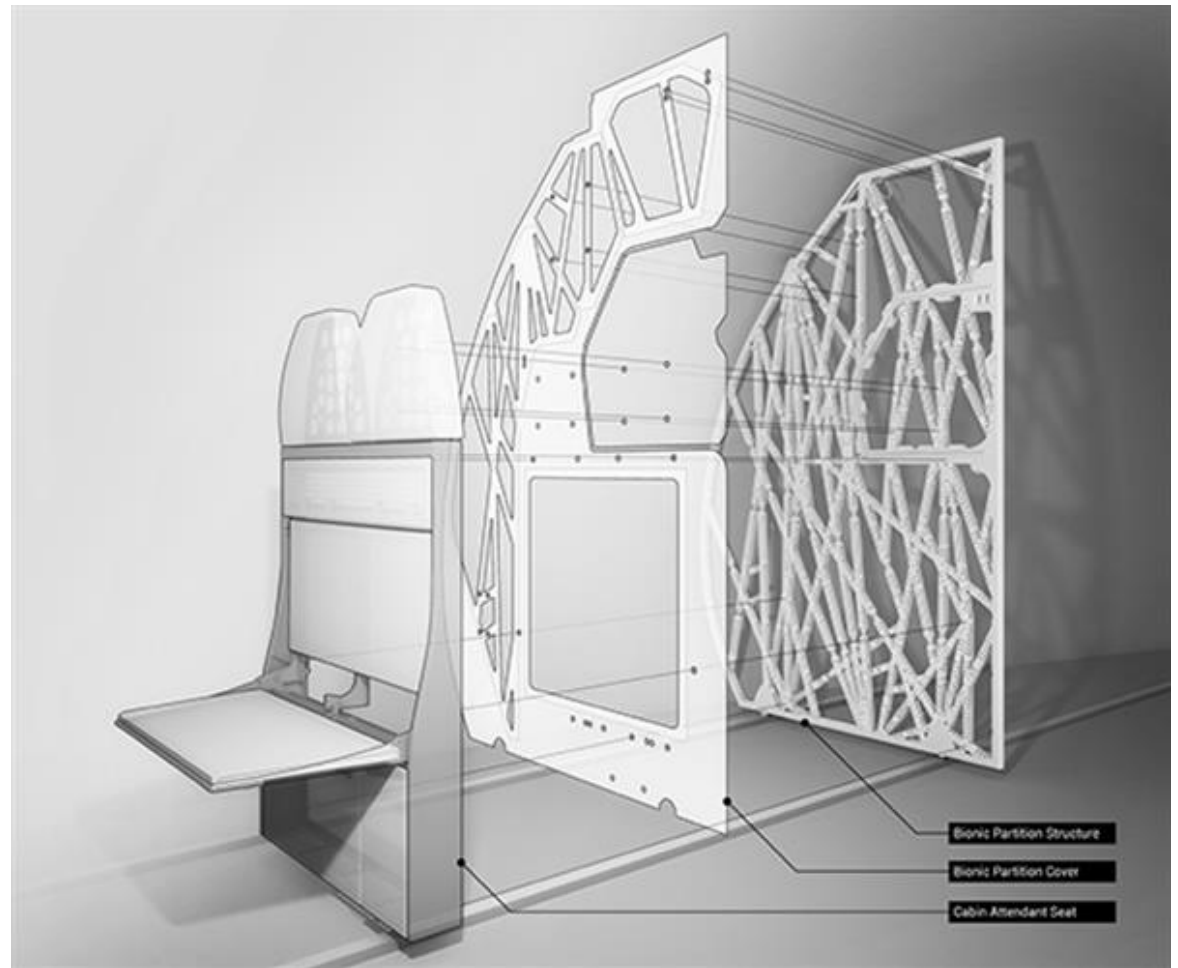
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Digital Metal – Höganäs, Sweden

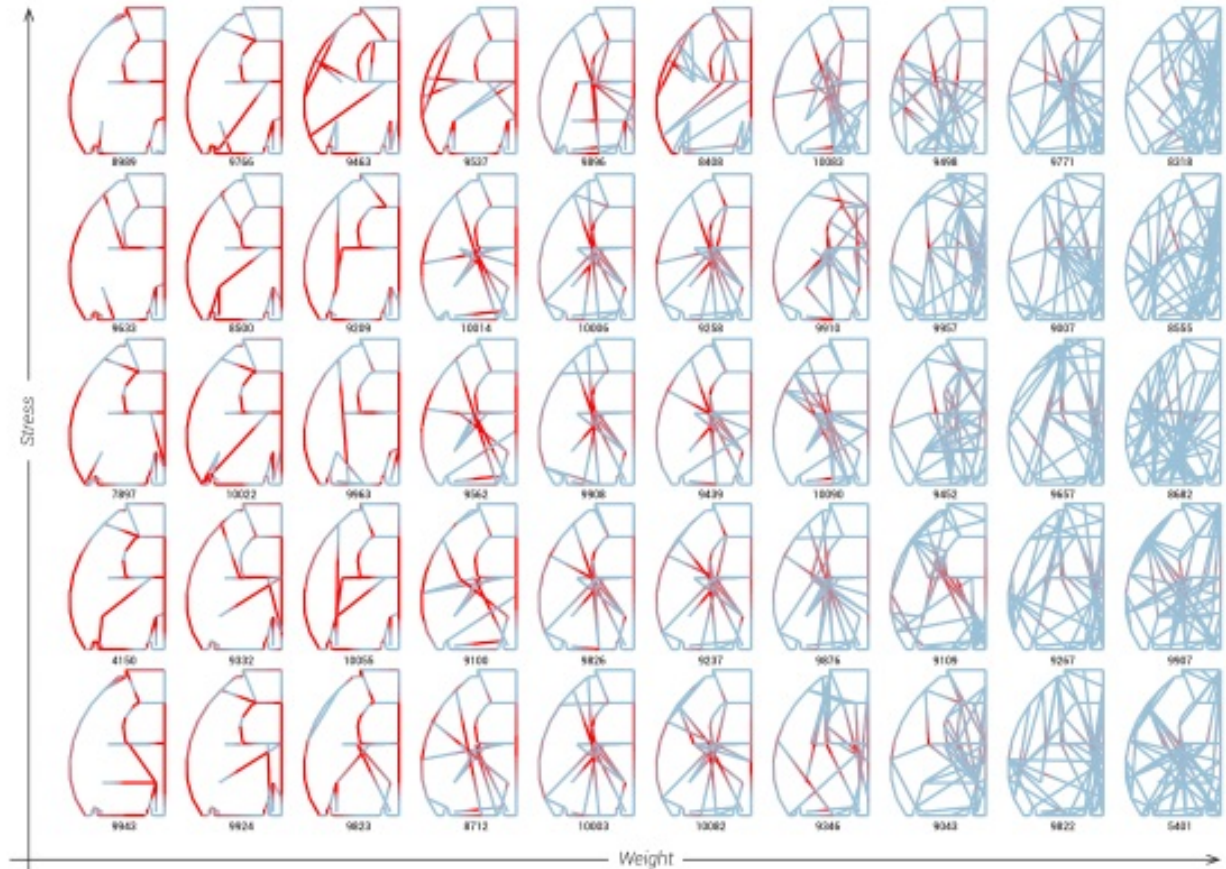
Case Airbus



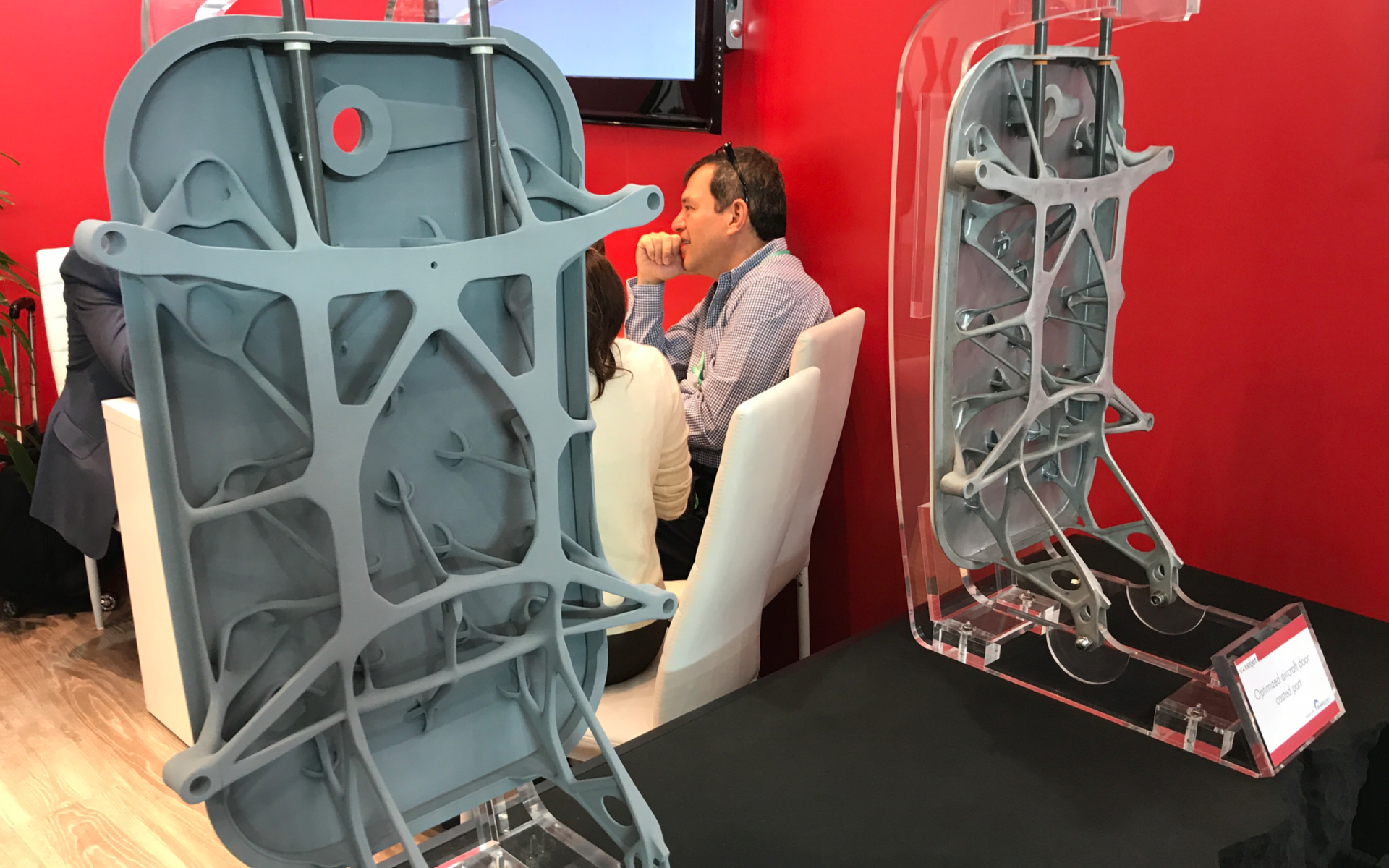
Case Airbus

Partition optimization via generative design

High stress  Low stress



High-performing results based on goals



Optimized aircraft seats created your

Others

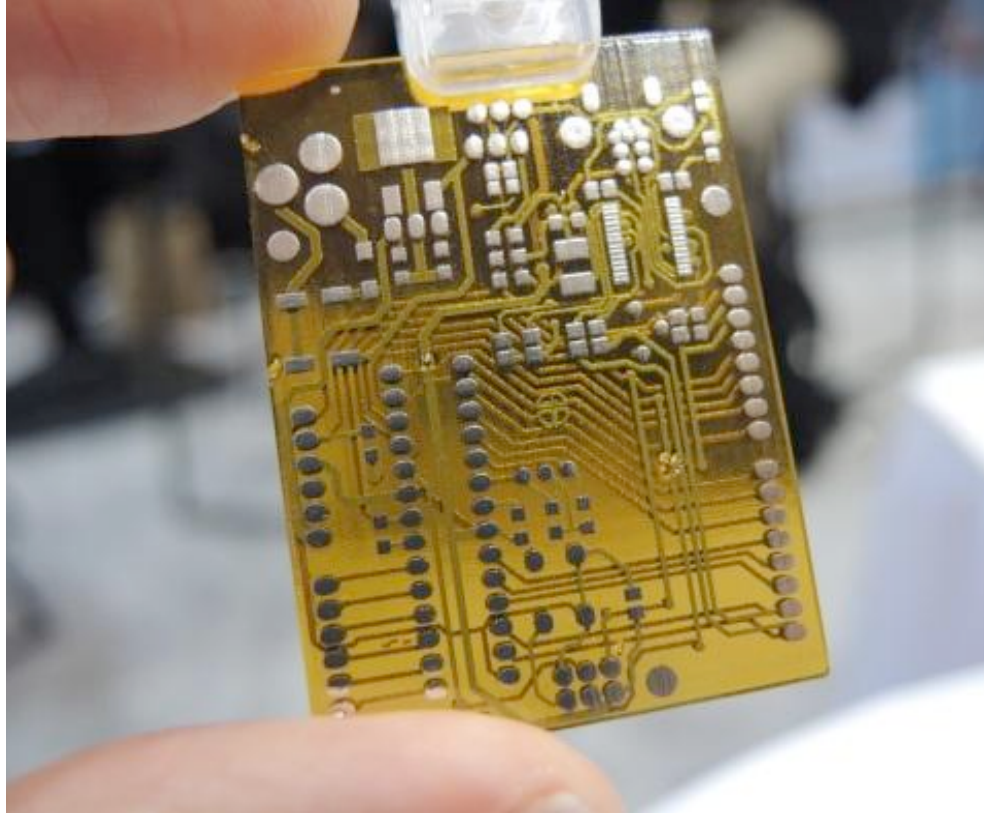
- **Ceramic**
- **Porcelain**
- **Sand (molds)**
- **Paper**
- **Concrete**
- **Cellular tissue**



Others

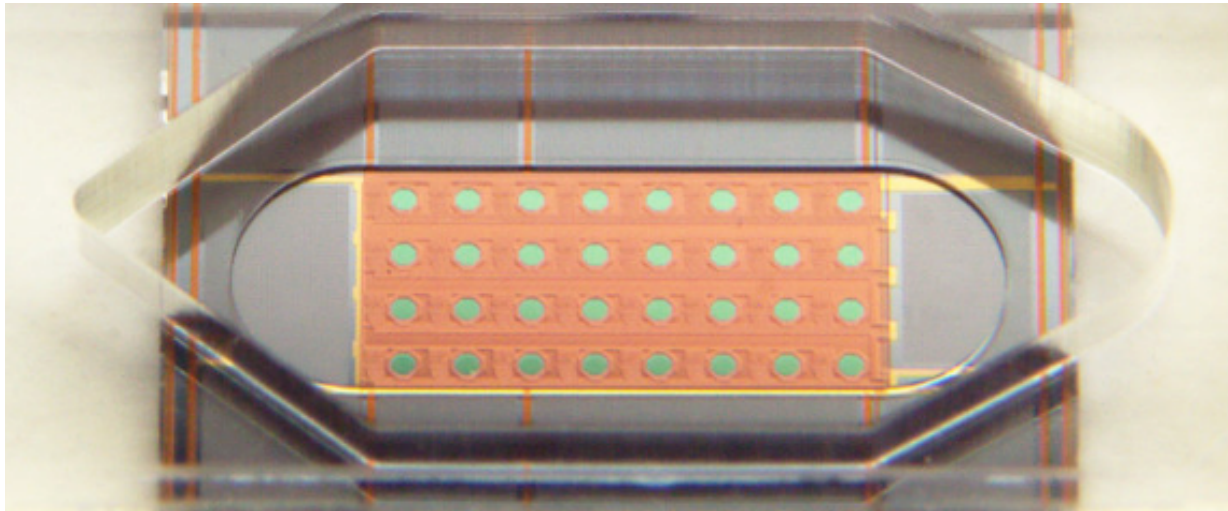
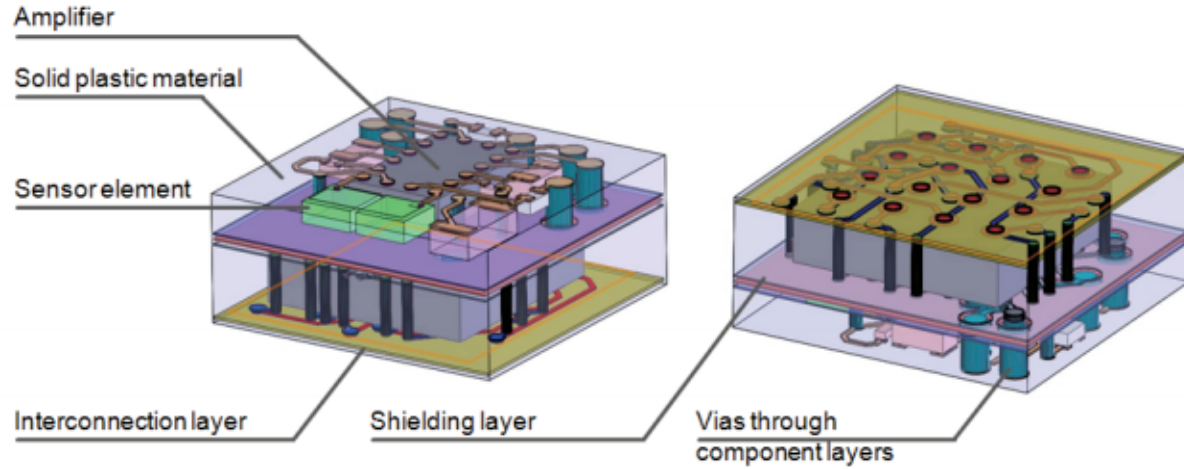
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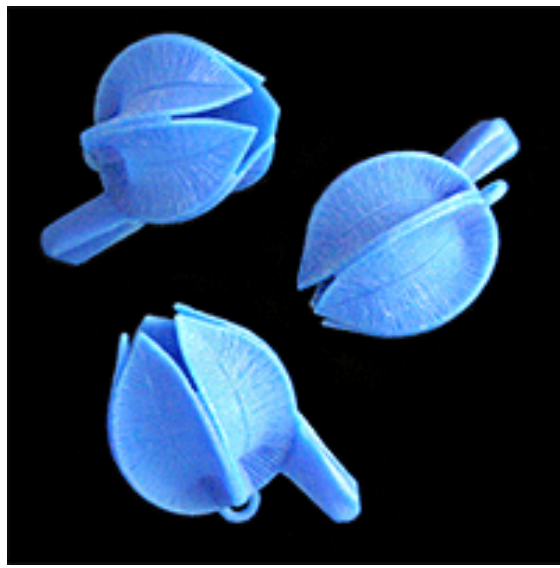




Dragonfly – PCB Prototyping

MicroTec – 3D Chip Sized Packaging





Kalevala – Jewelry
with wax investment casting





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