

The EPFL logo is displayed in a bold, red, sans-serif font in the top left corner. The background of the slide is a grayscale photograph of a jagged, snow-capped mountain peak rising above a layer of clouds.

EPFL

ME-413 Introduction to additive manufacturing

AM in the Swiss Industry

Guillaume FASQUELLE

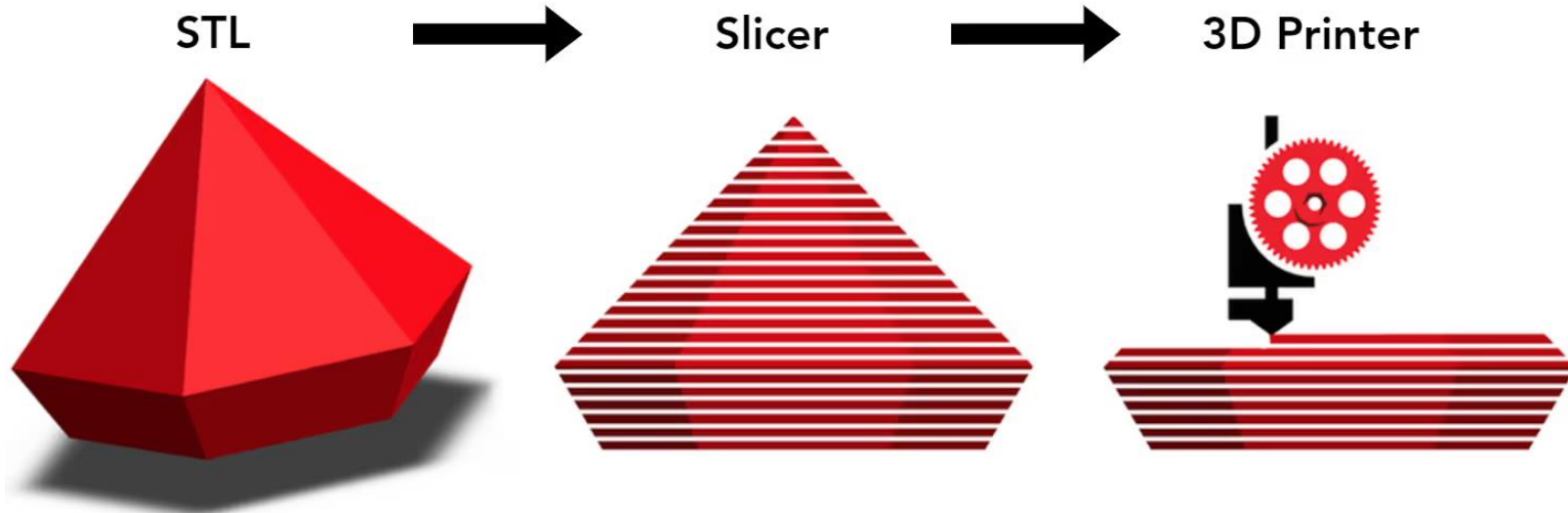
Burak KARAGÖZ

Joseph PRIEUR

Luca MARTENON

Introduction

Guillaume Fasquelle

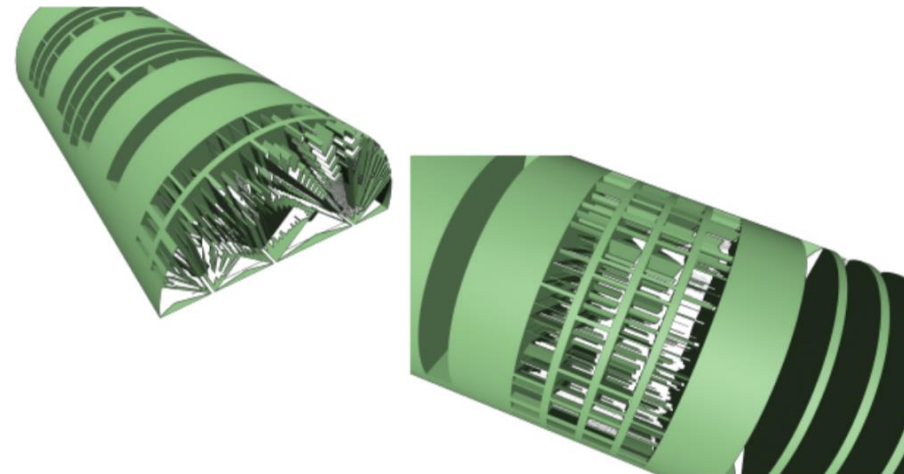


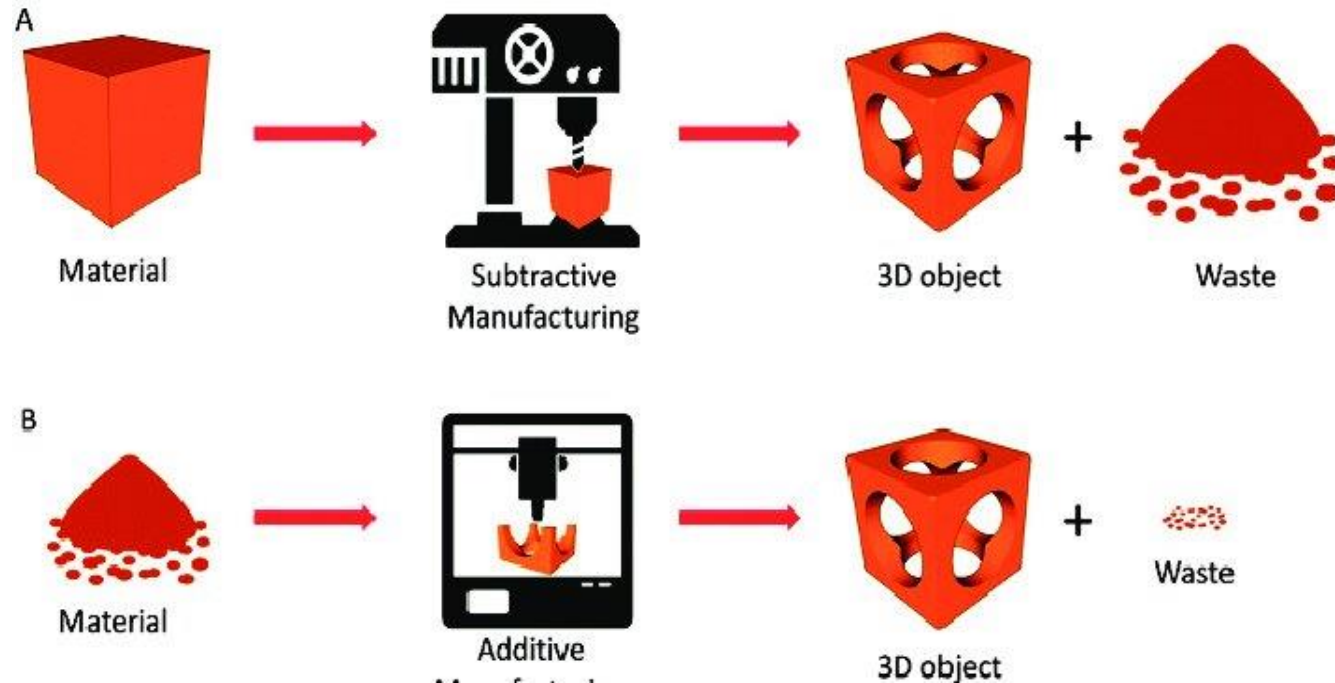
- Steps from CAD model to printed part
- The STL file is sliced into layers and sent to the 3D printer for fabrication.

Analog sundial (classic)



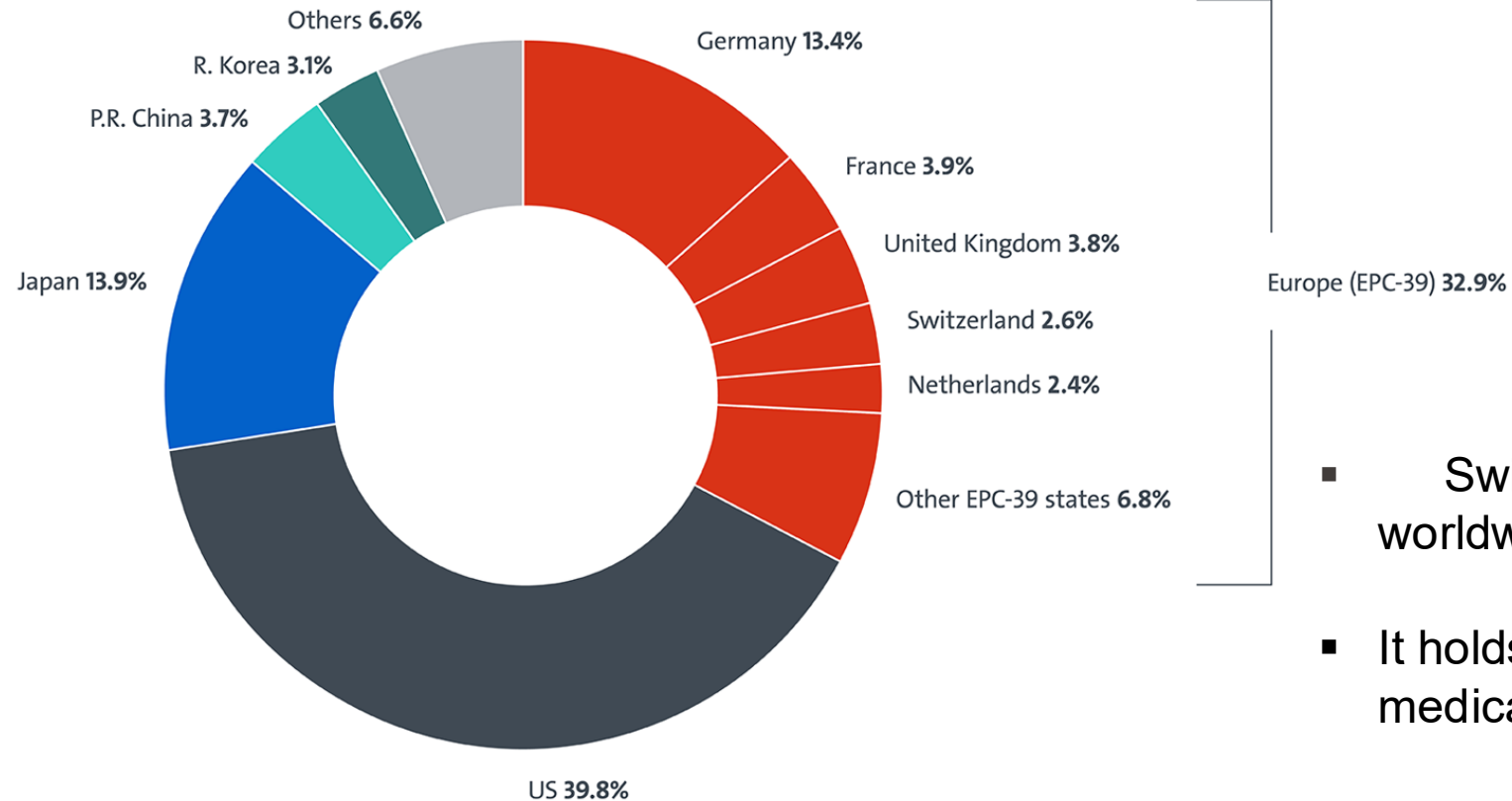
Digital sundial (3d-printed)





- Comparison between subtractive and additive manufacturing
- subtractive methods remove material from a solid block and generate significant waste
- additive manufacturing builds the part layer by layer with minimal material loss.

Countries of origin for international patent families in 3D printing technologies, 2001-2020



- Switzerland ranks 8th worldwide in 3D printing patents.
- It holds the 4th position in the medical sector.
- This reflects the country's strong innovation capacity despite its small size.

Sauber Technologies

Guillaume Fasquelle





1993 – Sauber's first season in Formula One.



3D printed brake cooling duct.
VCARB team



- Hinwil Factory – headquarters of Sauber Motorsport AG

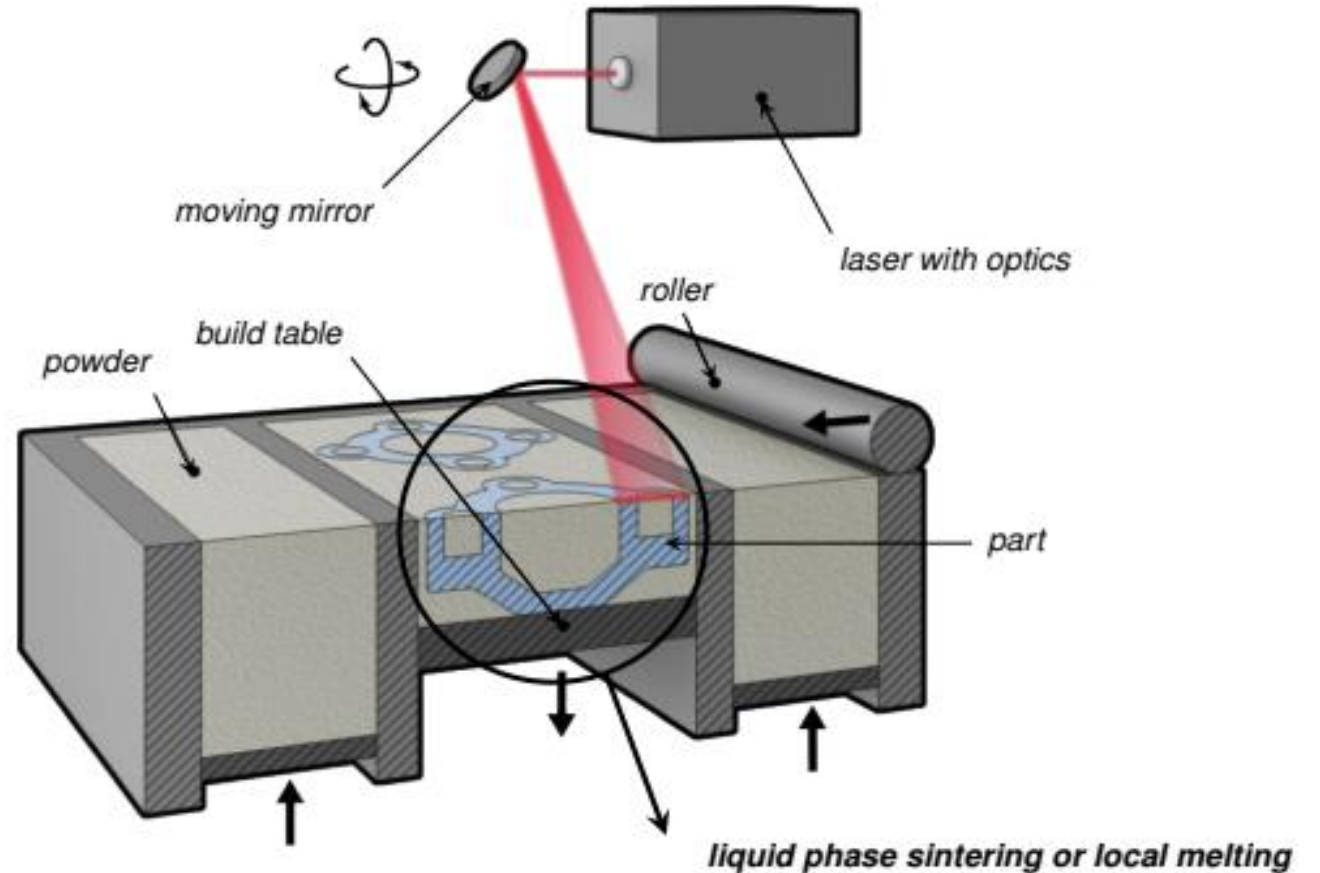


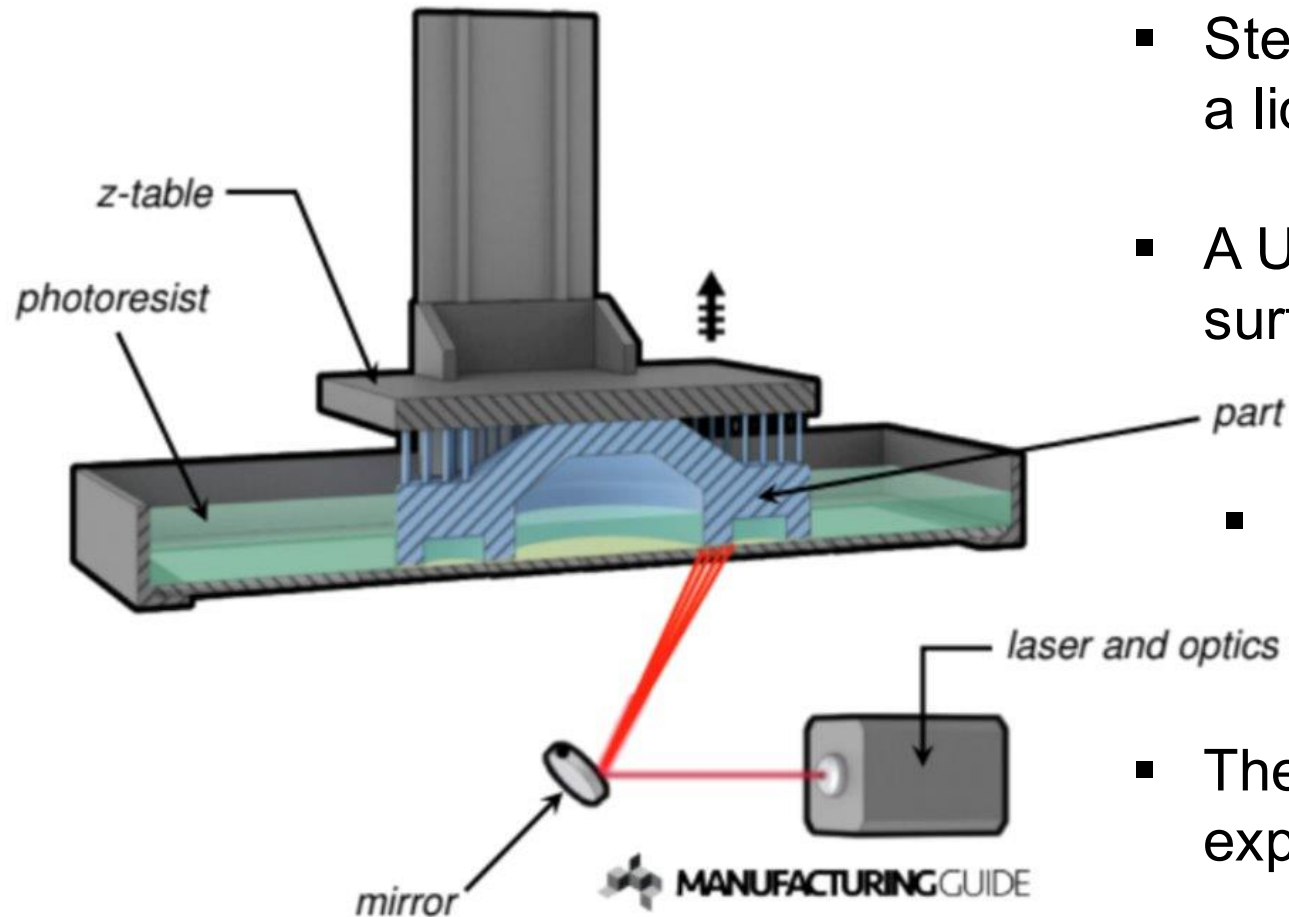
- Sauber's Wind Tunnel



- SLA 3D printing machines (ProX 800)

- Laser Powder Bed Fusion (L-PBF) process for metallic parts.
- A thin layer of metal powder is pushed on the build platform.
- A laser beam, guided by mirrors, melts selected regions according to the part's cross-section.
- The platform lowers, and a new layer of powder is added.
- The process occurs in an inert atmosphere (argon or nitrogen).
- Produces fully dense parts with mechanical properties comparable to forged metals.





- Stereolithography (SLA) – laser-based curing of a liquid photopolymer resin.
- A UV laser selectively cures the resin surface layer by layer.
 - The build platform moves vertically after each layer.
- The photoinitiator triggers polymerisation when exposed to UV light.
- Produces parts with high precision, smooth surfaces, and fine details.
- A final UV post-curing step improves mechanical properties.



The Wheelchair Project
– development of the OT
FOXX M1 racing
wheelchair in
collaboration with
Orthotec AG and Sauber
Technologies.

Swiss Watchmaking Industry

Burak Karagöz

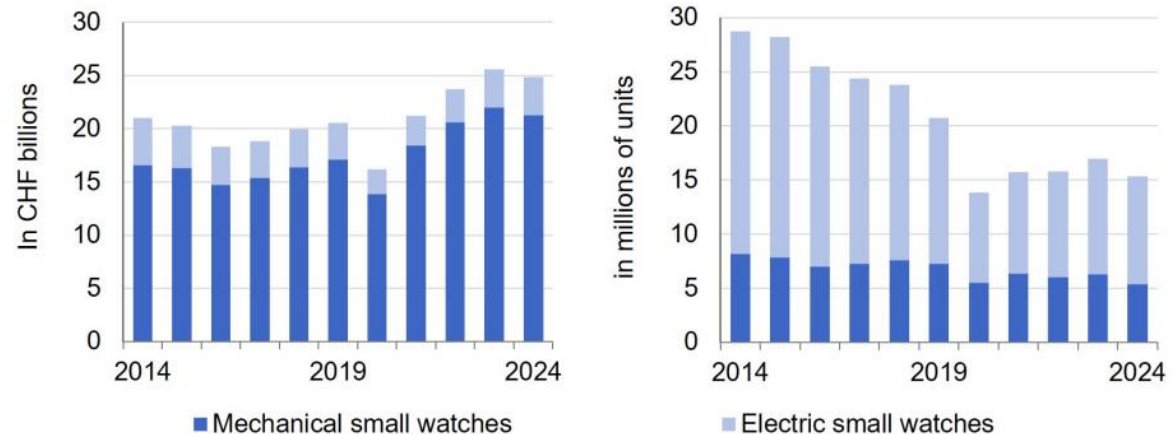
The Importance of Watchmaking in Switzerland

- The watchmaking industry is one of the most significant and historically influential sectors in Switzerland.
- It contributes approximately 4% to the country's GDP and exceeded CHF 24 billion in 2022.
- The sector ranks as Switzerland's third-largest exporter, after the chemical, pharmaceutical, and machinery industries.



Source: DFAE, Présence Suisse (2024) – aboutswitzerland.org

Evolution of small watches export, 2014–2024



Source: BAZG – Swiss Foreign Trade Statistics Annual Report 2024

Innovation in a Traditional Industry

- The watchmaking industry is traditionally known for its use of classic manufacturing techniques and methods.
- Conventional equipment such as lathes, milling machines, and manual finishing tools have long been used to produce watches.
- Despite this strong attachment to tradition, the industry remains highly innovative, especially in terms of manufacturing.
- Major watch brands use state-of-the-art manufacturing techniques to achieve both high precision and high production volumes.



Source: Panerai Manufacture, Movement Components Production (Panerai Official Website).



Industrial Scale and Need for Advanced Methods

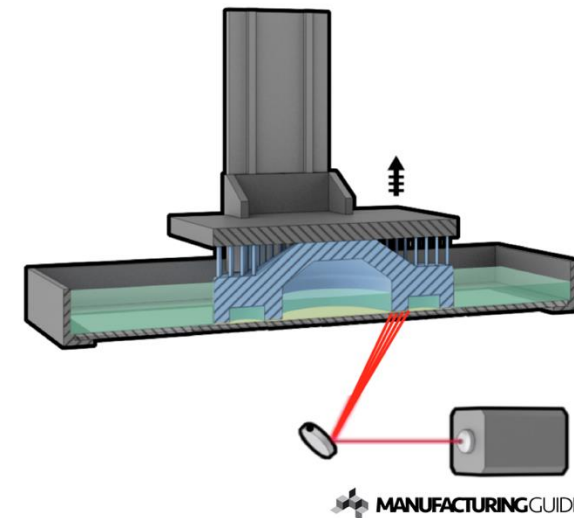
- The amount of manufacturing required in the watch industry should not be underestimated.
- For example, Rolex, one of the largest watch producers in Switzerland and worldwide, produced approximately 1.24 million watches in 2023.
- Achieving such production volumes while maintaining the highest levels of precision and quality would be very difficult using only traditional techniques.
- As a result, the use of innovative manufacturing methods has become a necessity.

Emergence of Additive Manufacturing (AM)

- With the ongoing search for innovative technologies, additive manufacturing (AM) has emerged as a transformative technology in watch production.
- AM enables enhanced design flexibility, precision, and material efficiency in the manufacture of watch components.
- A leading company in this field is **Mimotec SA**, which specializes in the production of high-precision micro-components for watch movements.
- These components include escape wheels, anchors, springs, cams, and other intricate mechanical elements produced using the **UV-LIGA** process.



Source: Mimotec SA – About Us

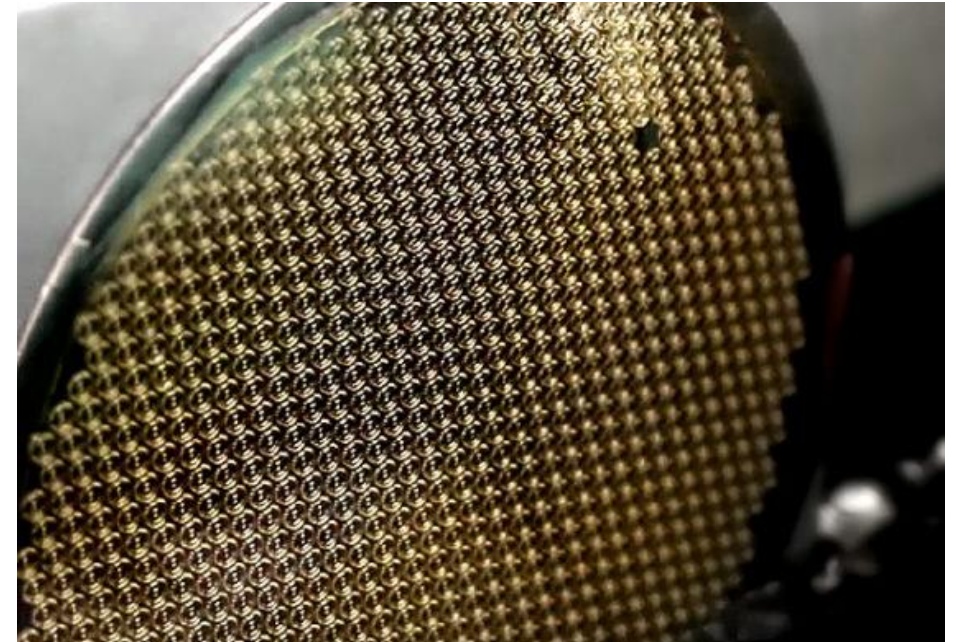


MANUFACTURINGGUIDE

Source: Manufacturing Guide – Stereolithography (SLA)

UV-LIGA as an Additive Manufacturing Process

- The primary additive manufacturing technique used by **Mimotec SA** is **UV-LIGA**.
- This process enables new possibilities in the miniaturization of components and the microstructuring of surfaces.
- It allows the fabrication of high-precision geometries that are difficult or impossible to achieve with conventional methods such as milling, stamping, or laser cutting.
- UV-LIGA is cost-effective, can be implemented rapidly, and is suitable for both rapid prototyping and large-scale production, while offering micrometric precision and excellent surface finish quality.



Source: Mimotec SA – UV-LIGA technology

UV-LIGA Process: Step 1

- The UV-LIGA process combines photolithography with material deposition in a galvanic bath.
 - **Wafer(Substrate) Preparation:** A thin layer of gold is first deposited on the wafer to create an electrically conductive surface, followed by a photoresist layer that is slightly thicker than the final component.

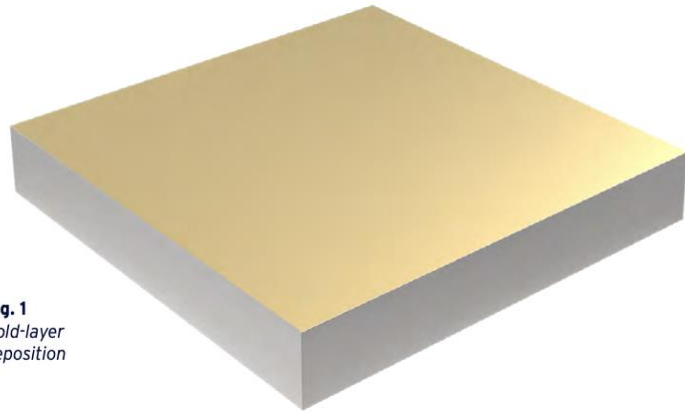


Fig. 1
Gold-layer
deposition

Source: Mimotec SA – Whitepaper

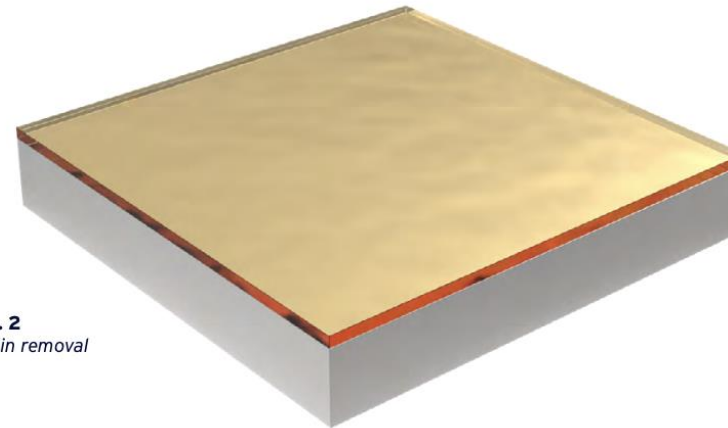


Fig. 2
Resin removal

Source: Mimotec SA – Whitepaper

UV-LIGA Process: Step 2

- **Photolithography/Development:** The photoresist is exposed to collimated UV light through a photomask, and when the wafer is immersed in a solvent, the non-illuminated regions dissolve, forming the mould for the part.

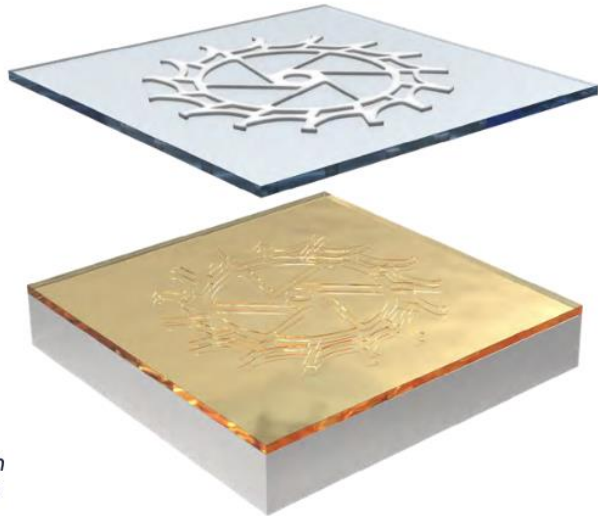


Fig. 3
*Illumination
of the resin*

Source: Mimotec SA – Whitepaper

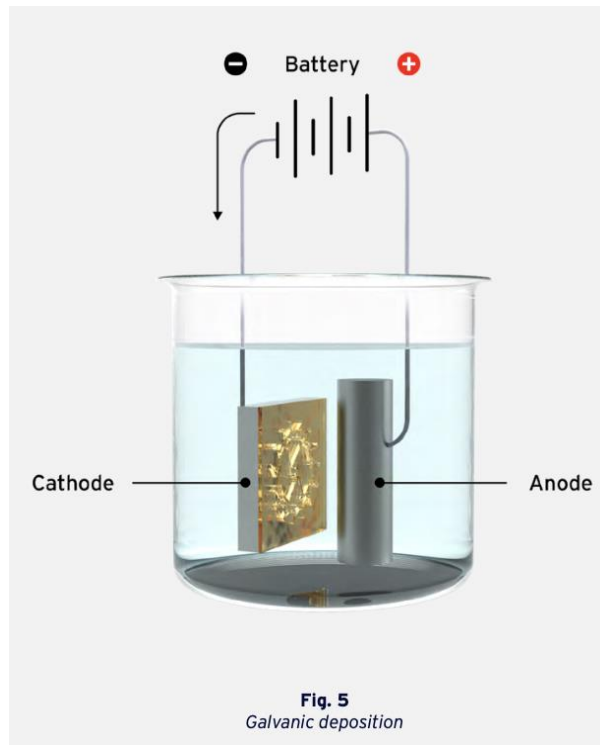


Fig. 4
*Dissolution of the
uncured resin*

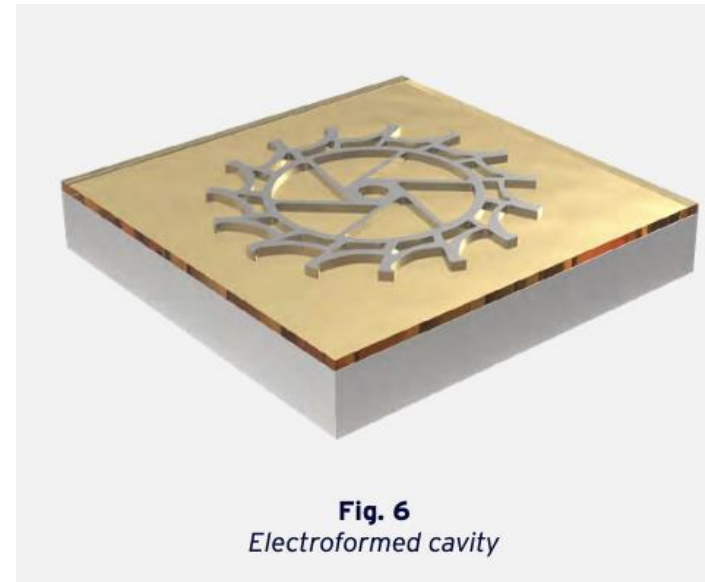
Source: Mimotec SA – Whitepaper

UV-LIGA Process: Step 3

- **Galvanic Deposition:** The structured wafer is then immersed in a galvanic bath for electroforming, the cavity is filled with metal, the upper surface is machined to the required thickness.



Source: Mimotec SA – Whitepaper



Source: Mimotec SA – Whitepaper

UV-LIGA Process: Step 4

- **Dissolution of the Mould:** Finally, the resin and substrate are chemically removed to release the finished micro-components.



Source: Mimotec SA – UV-LIGA technology



Source: Mimotec SA – UV-LIGA technology

Application: Rolex Calibre 4130 Chronograph Wheel



Source: SJX Watches – Rolex Daytona Cal. 4130 LIGA Technology

Evolution of Case Manufacturing Techniques

- Traditionally, master case makers produced cases by dividing the parts and manufacturing them individually.
- Cases were made on the lathe, while the lugs were manufactured separately and then attached to the case.
- In today's watch industry, production techniques have evolved to meet higher demand and tighter tolerances.



Source: A Collected Man – Casemaking with Jean-Pierre Hagmann

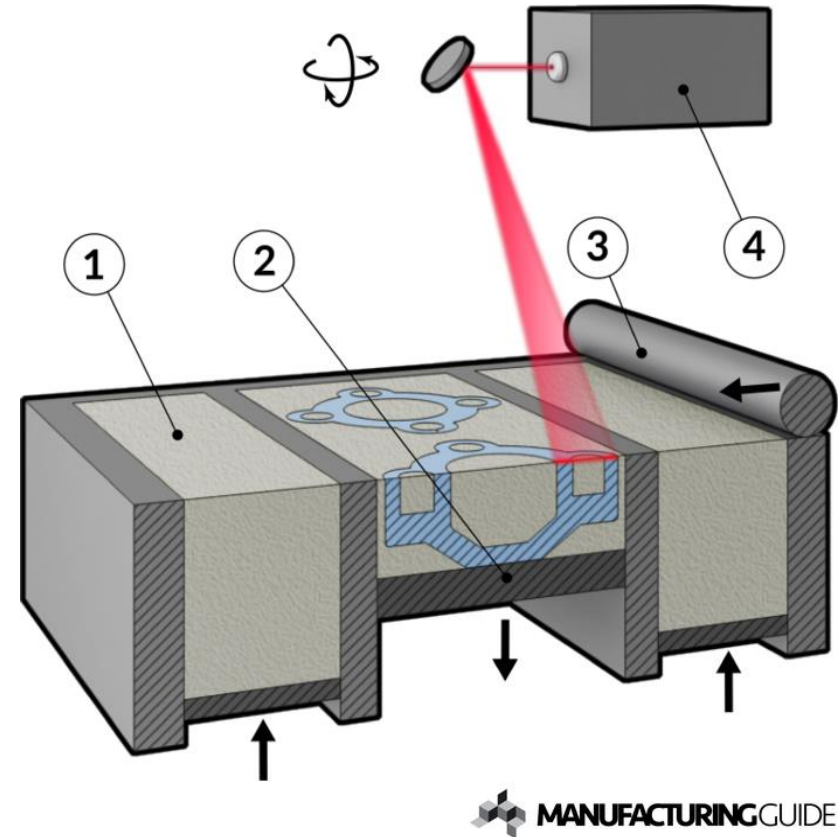
Modern Case Manufacturing Techniques: TUDOR



Source: TUDOR Official YouTube – Savoir-Faire: Shaping the Case

Selective Laser Melting and 3D Précision SA

- Another additive manufacturing technique that has begun to be used in the watch industry is Selective Laser Melting (SLM).
- 3D Précision SA, founded in 2014 in Delémont, Switzerland, manufactures watch cases using SLM.
- SLM is a powder-bed fusion process in which a laser beam selectively melts and consolidates metal powder in a controlled manner, layer by layer, in an inert gas atmosphere such as nitrogen or argon.
- Materials used in this process include titanium, aluminium, stainless steel, cobalt-chromium, copper, and tungsten, making it suitable for high-performance watch cases.



Selective Laser Melting (SLM) Technology in Watchmaking

Source: HOROPEDIA – Technologie de fusion sélective par laser (SLM)

Swiss Aerospace industry

Joseph PRIEUR

Aerospace in Switzerland

- Founding member of the ESA in 1975
- Subsystems for space applications
- Satellites know-how
- 130 Swiss aerospace-related companies
- 3000+ qualified people employed



Source : CSEM's CRRM made in AM – csem.ch



Source : SWISSto12's HummingSat satellite - swisst012.com



Source : ESA headquarters – esa.int

RUAG Space

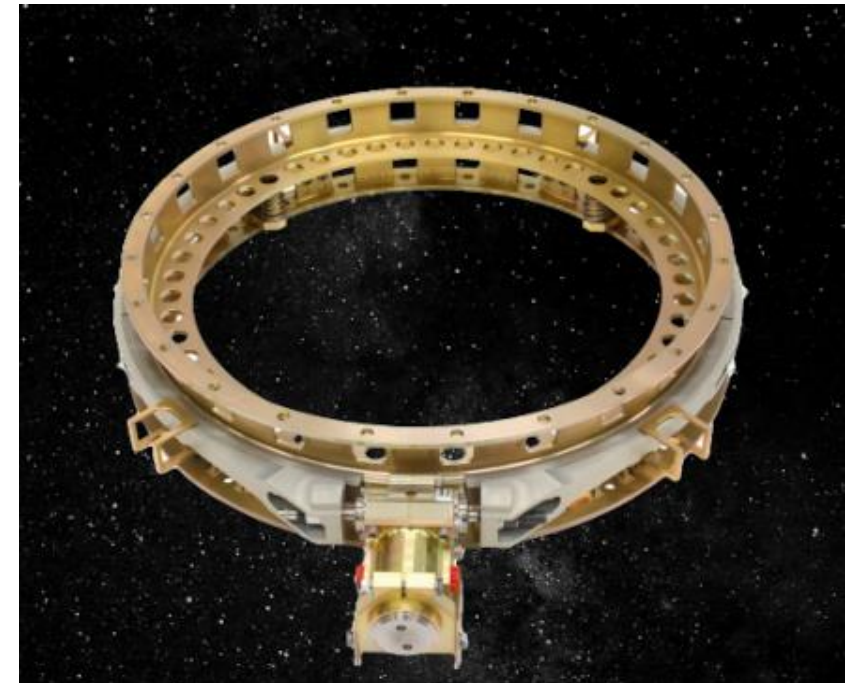
- Leading supplier for space industry
- Key products : Satellite structures and thermal control systems
- Pioneering in lightweight materials
- Expert know-how in separation and pairing systems for satellites
- Strong international presence



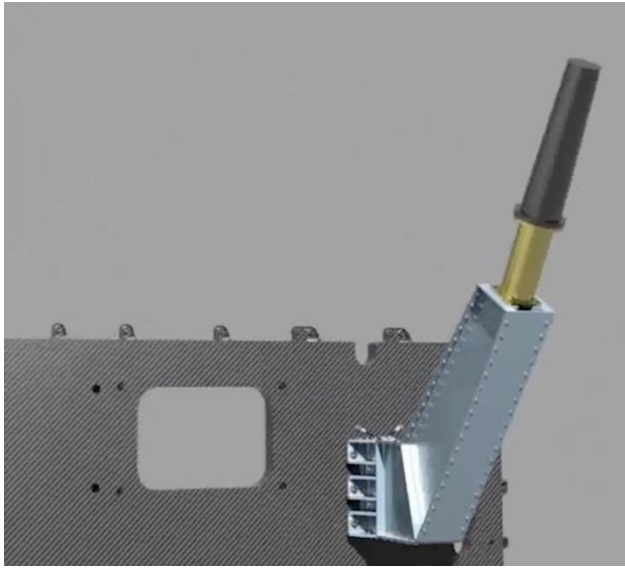
Source : RUAG employee working on a satellite part – ruag.com



Source : RUAG premises - 24heures.ch



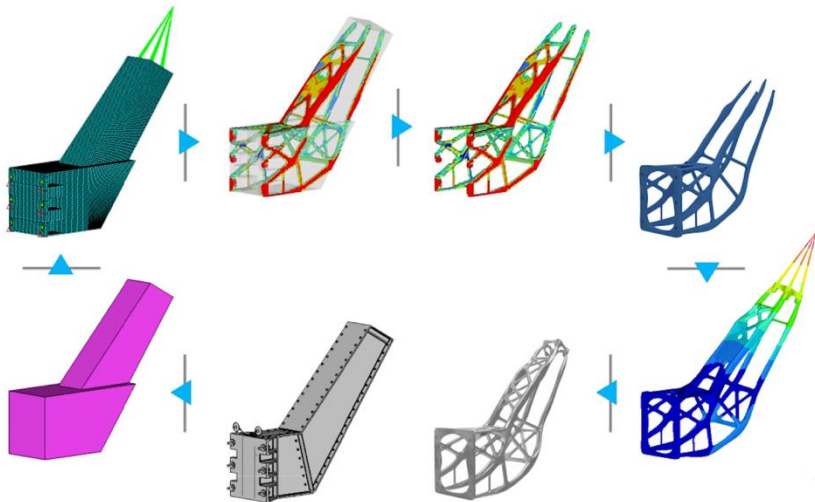
Source : RUAG's PA610 low shock separation system – satnow.com



Source : Incumbent antenna bracket – altair.com



Source : Sentinel 1B satellite in orbit – esa.int

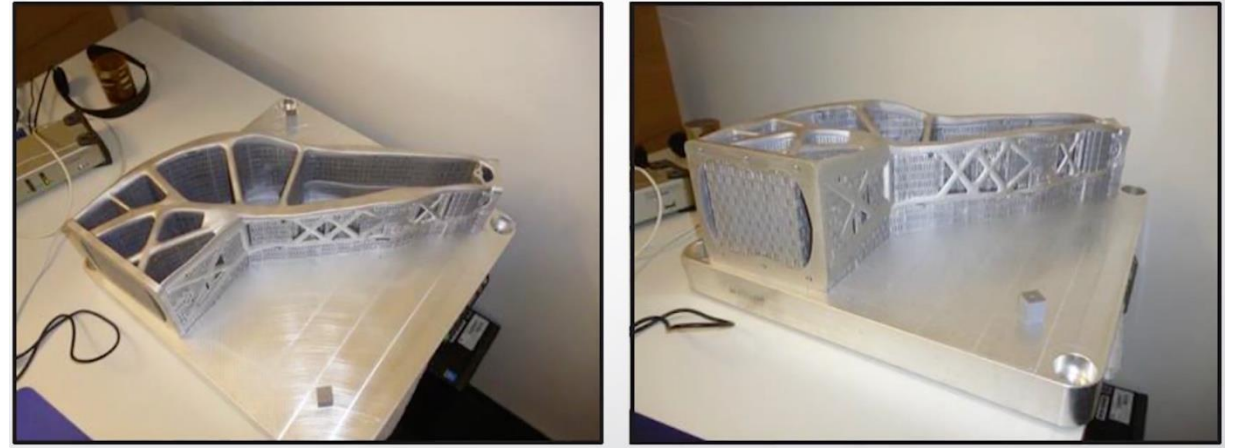


Source : Structural optimization process – altair.com

- Sentinel 1B for Copernicus program
- 20'000 .- per kg of transported payload
- The antenna bracket is a critical component
- Incumbent antenna bracket is 1.6kg
- Topology optimization with OptiStruct software



Source : EOS M400 LPBF machine – eos.info



Source : Untrimmed antenna bracket – altair.com

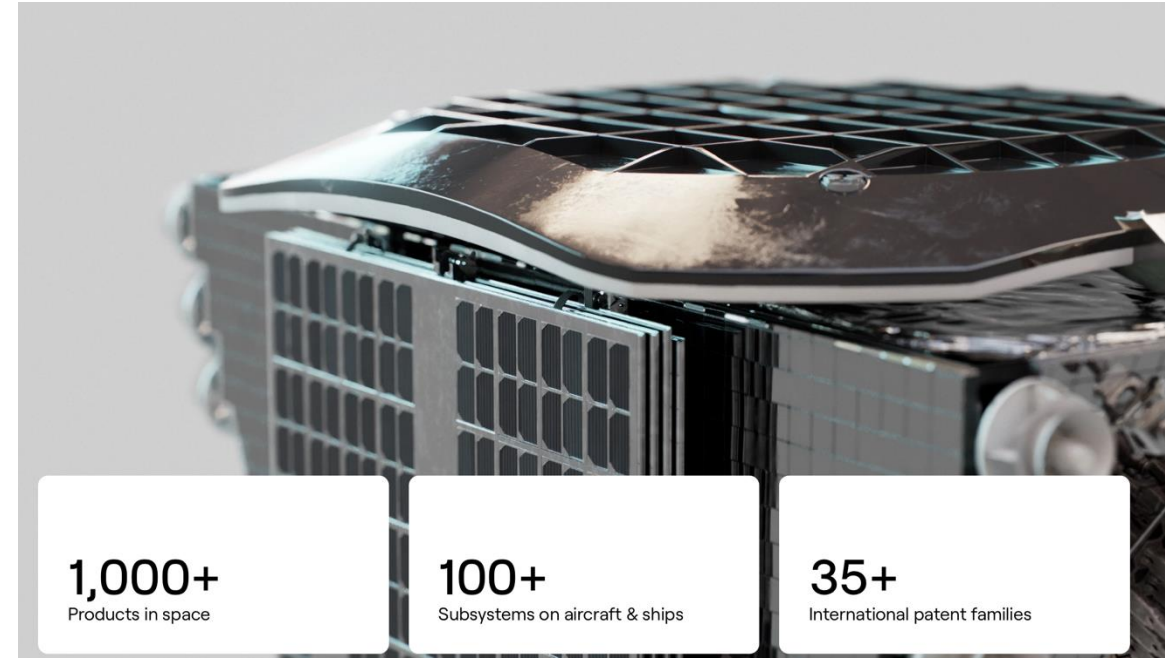
- Laser Powder Bed Fusion (L-PBF)
- AlSi10Mg alloy
- EOS M400 machine (400x400x400mm)
- 1.6kg → 0.94 kg (>10'000.- savings !)
- Achieved 130% of the required rigidity !
- Full success for RUAG, ALTAIR and EOS !



Source : Final AM antenna bracket and assembly – esa.int

SWISSto12

- Co-founded in 2011 as a spin-off from EPFL
- Specialized in RF and SATCOM
- Fastest growing swiss aerospace company



Source : SWISSto12 presentation – swissto12.com



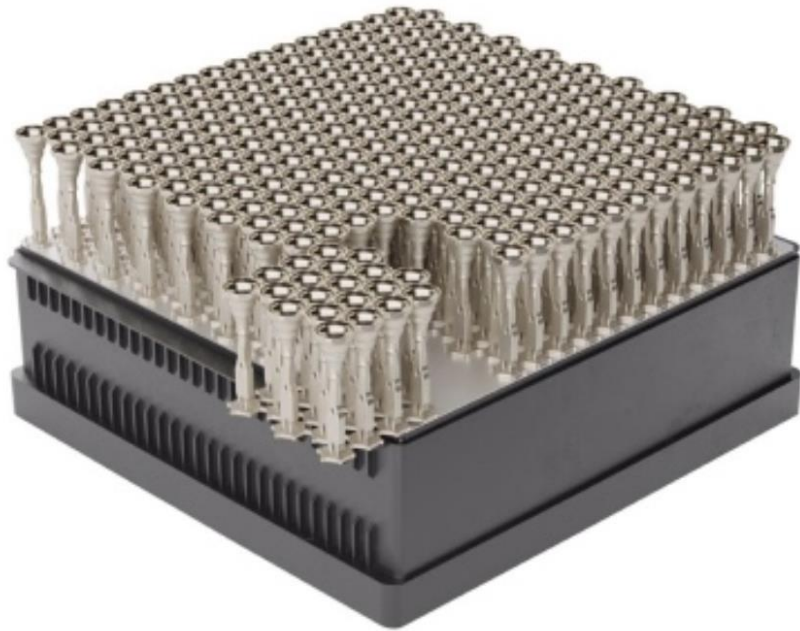
Source : MetalFabG2 machine – additiveindustries.com

- Recent purchase : 4 MetalFabG2 L-PBF
- Compatible with most high-performance alloys (Ti, Al, SS, Inconel, ...)
- Equipped with 4 full-field 1'000W lasers
- Automated powder handling, sieving, and extracting process

Horn antennas with integrated brackets



Source : Horn antennas with integrated brackets – swissto12.com

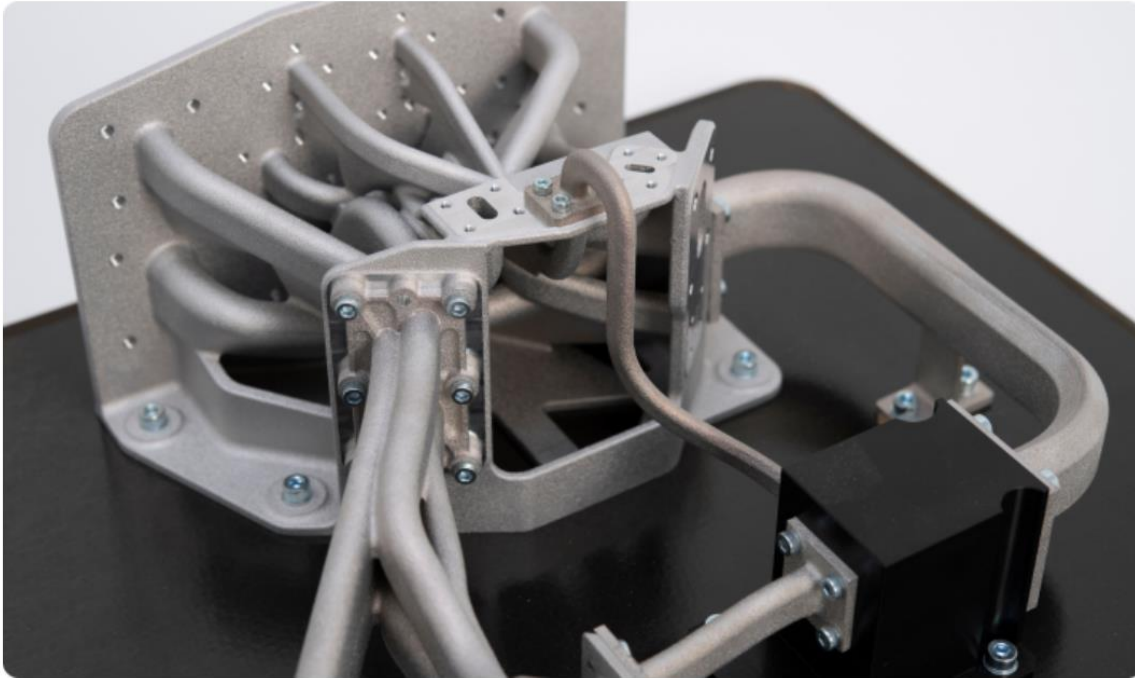


(a) Geostationary satellite AESA

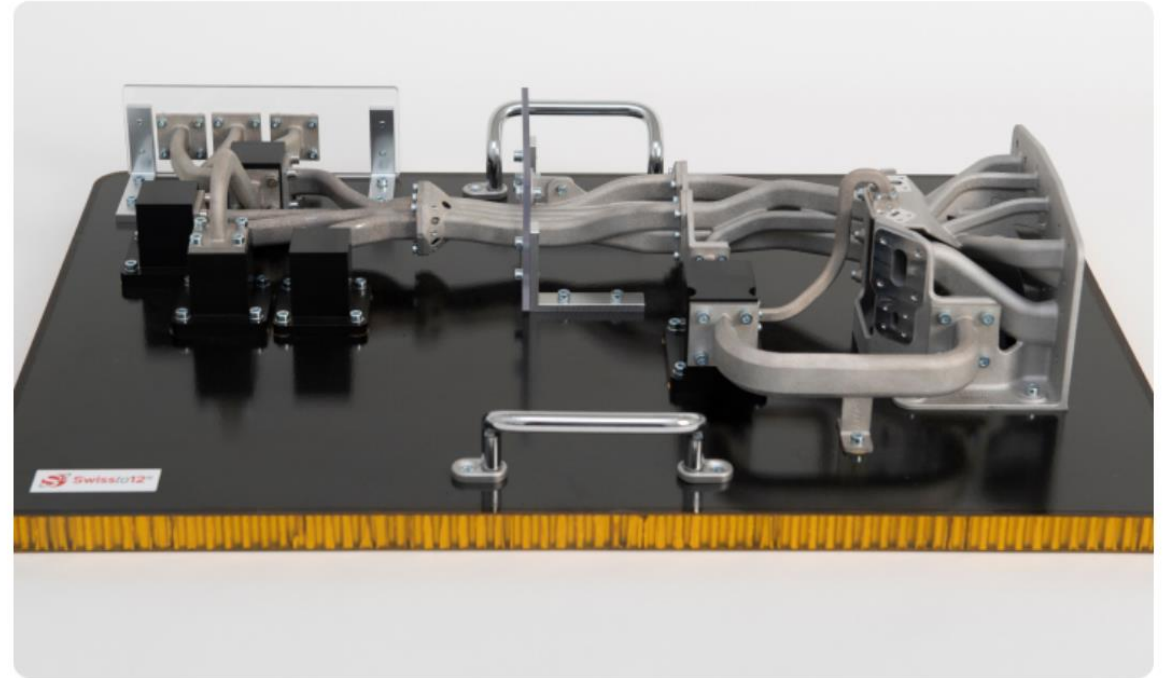


(b) Low earth orbit AESA

Waveguide routing solutions



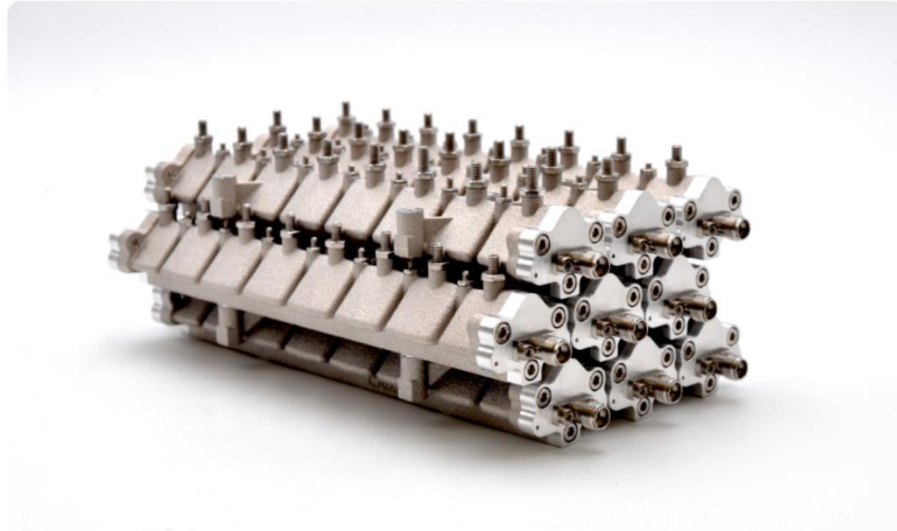
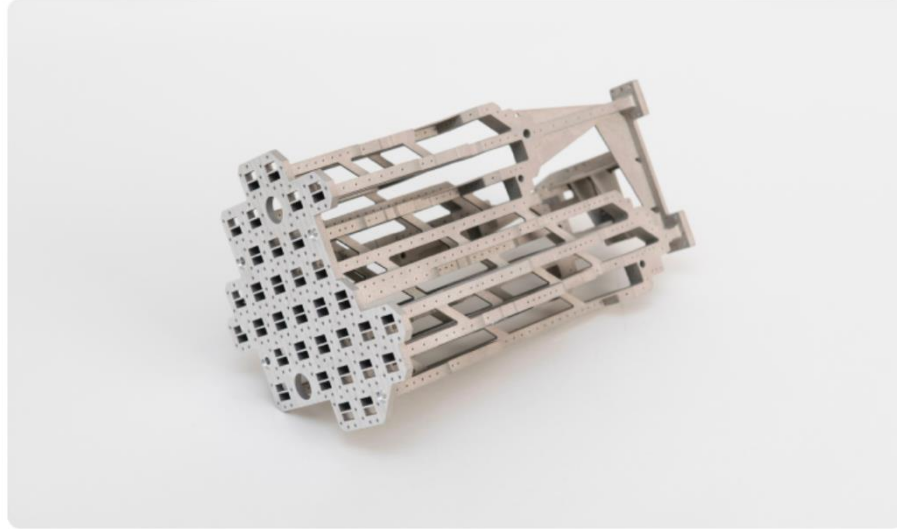
(a) Radiofrequency wave detangler



(b) Waveguide routing and brackets

Source : Waveguide routing solutions by SWISSto12 – swissto12.com

Passive components for SATCOM



Case study of a Swiss start-up : Nu Glass



Overview

- Scope of the case study
- Presentation of Nu Glass
- Applications of AM at Nu Glass
- Limitations faced with AM
- Other technologies to overcome the limitations
- Conclusion
- Interview with Cyril CTO of Nu Glass



Scope of the case study

- AM processes are relatively new
- Are they mature enough to benefit a start-up
- Are start-up using AM at its full potential ?

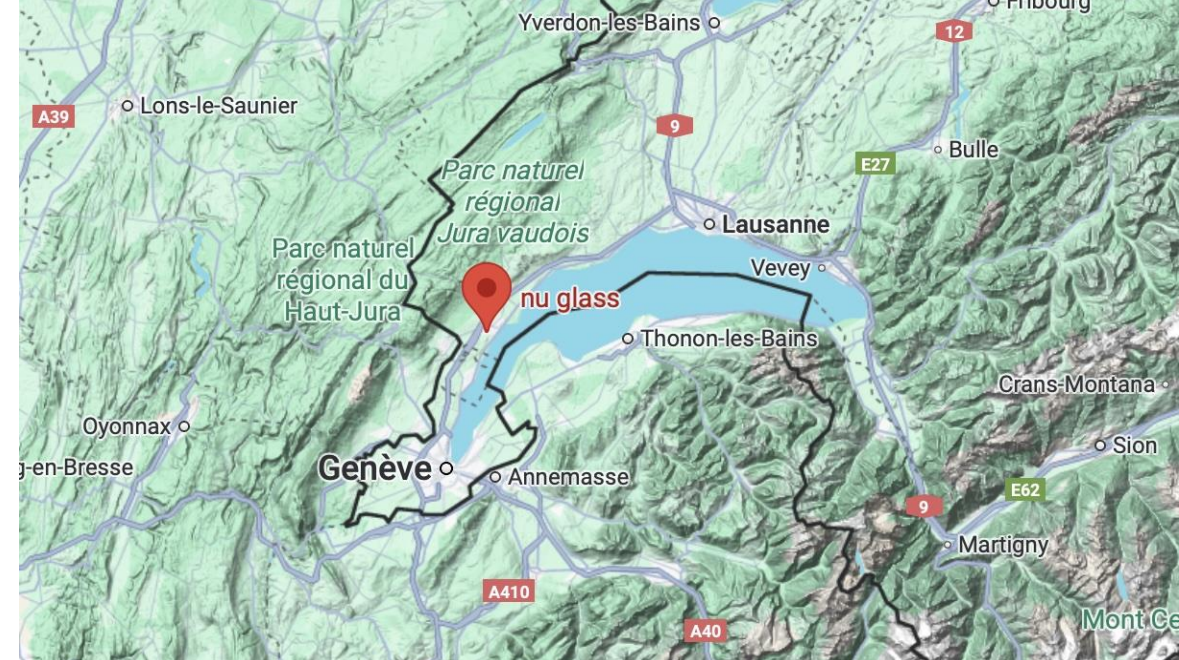


EPFL

Nu Glass



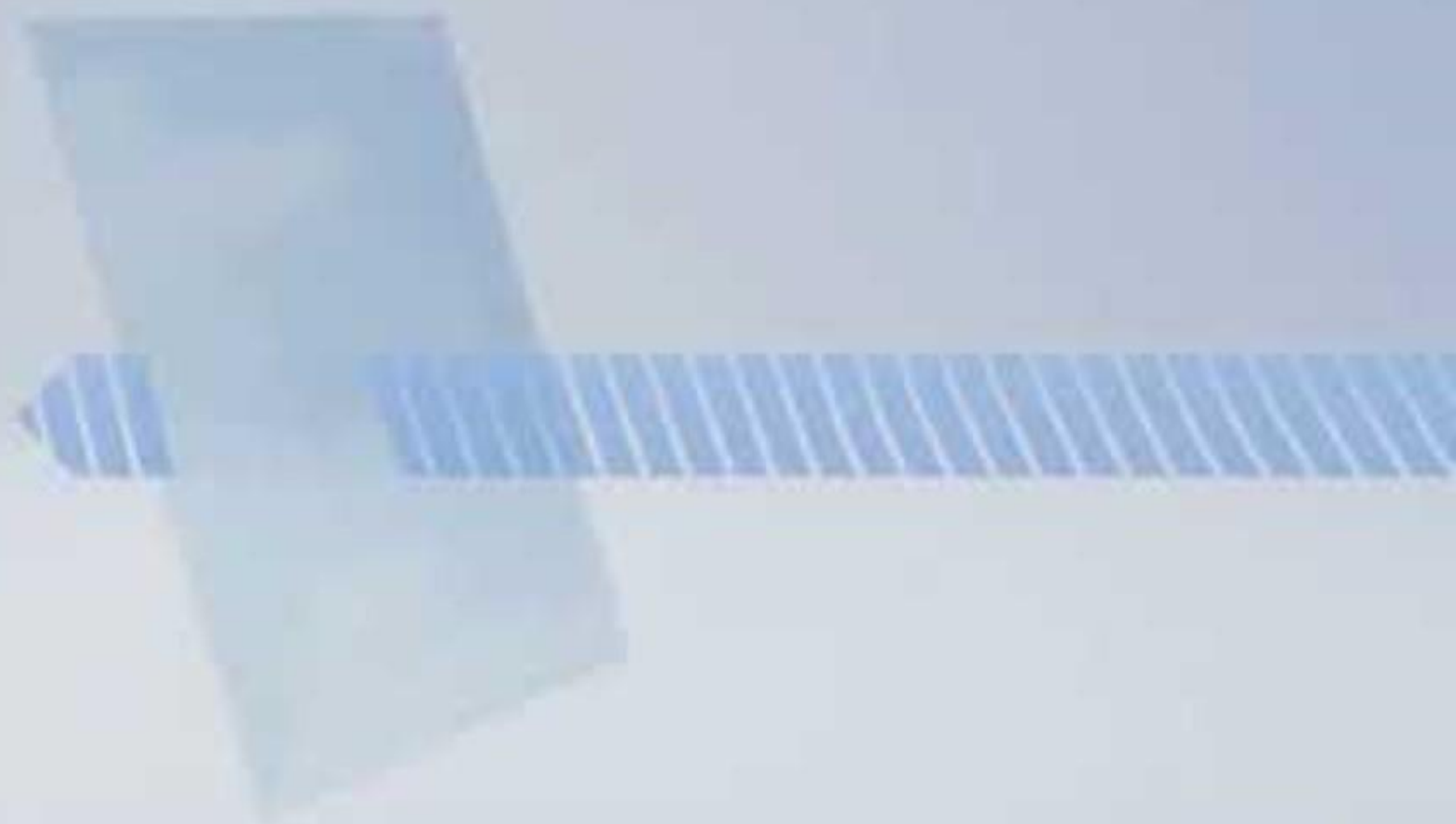
- Created in 2021
- EPFL spin-off
- Over 20 employees
- Fast growing start-up



What they do

- Laser treatment on trains and buildings
- Improve connectivity inside the trains
- Making glass permeable to mobile phones
- Improve connectivity by x1000
- Reduce insulation by 2%





designed to let frequencies pierce through freely, and forever

How Nu Glass uses additive manufacturing

- Rapid prototyping
- Complex shape parts
- Often changed parts
- Equipment

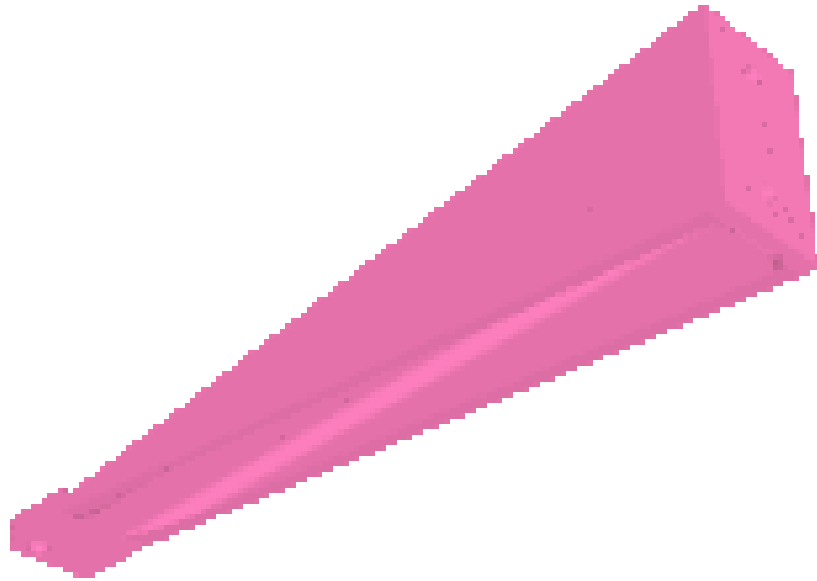


Rapid prototyping

- Allows super fast implementation on the robot
- It had to leave the next day
- Designed and manufactured in few hours
- The robot could leave on time
- Impossible with machining (except if you have it at the work shop)

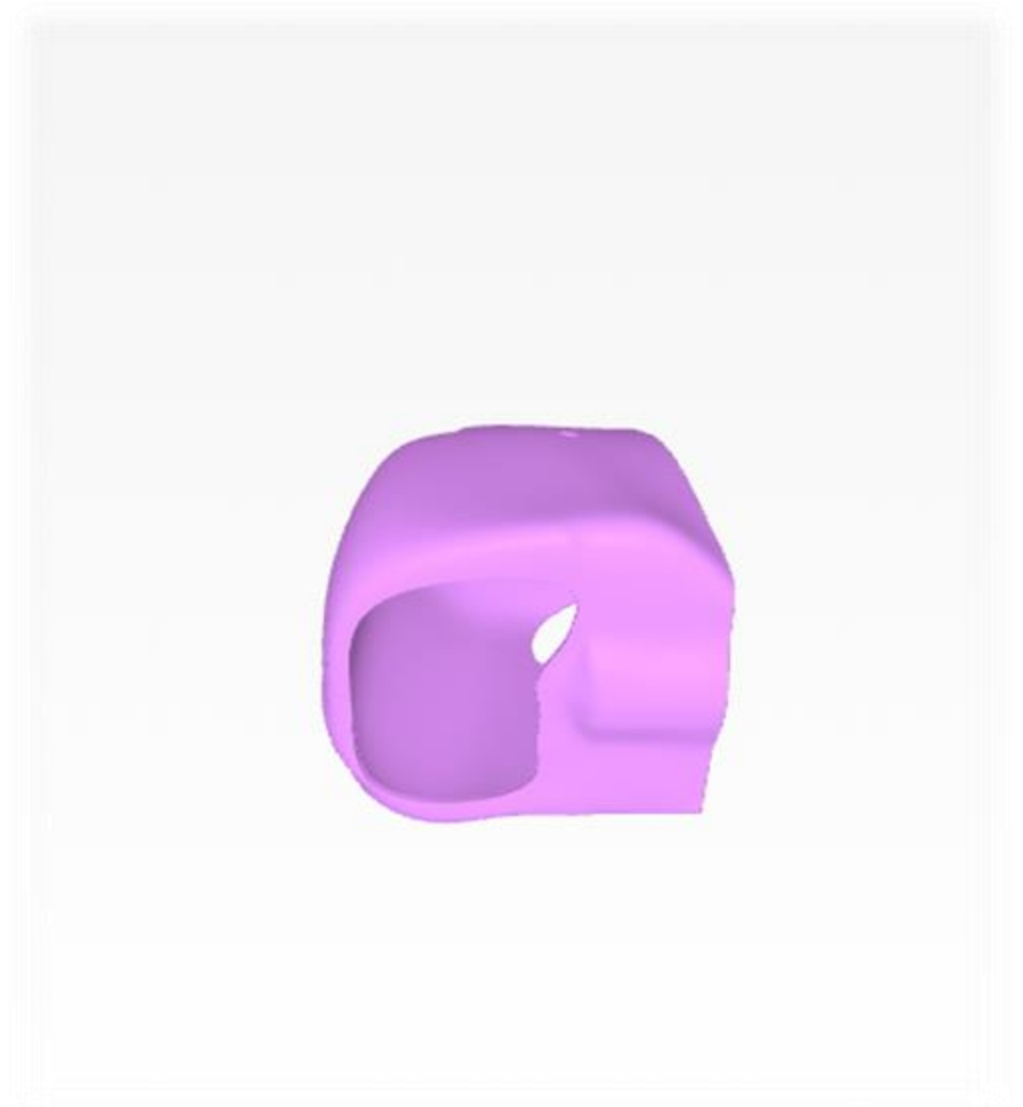


Rapid prototyping other example



Complex shape parts

- Shape that would be impossible to do with machining
- Small series that wouldn't be worth molding
- Complex shape that suits your needs
- Get the maximum use of each part



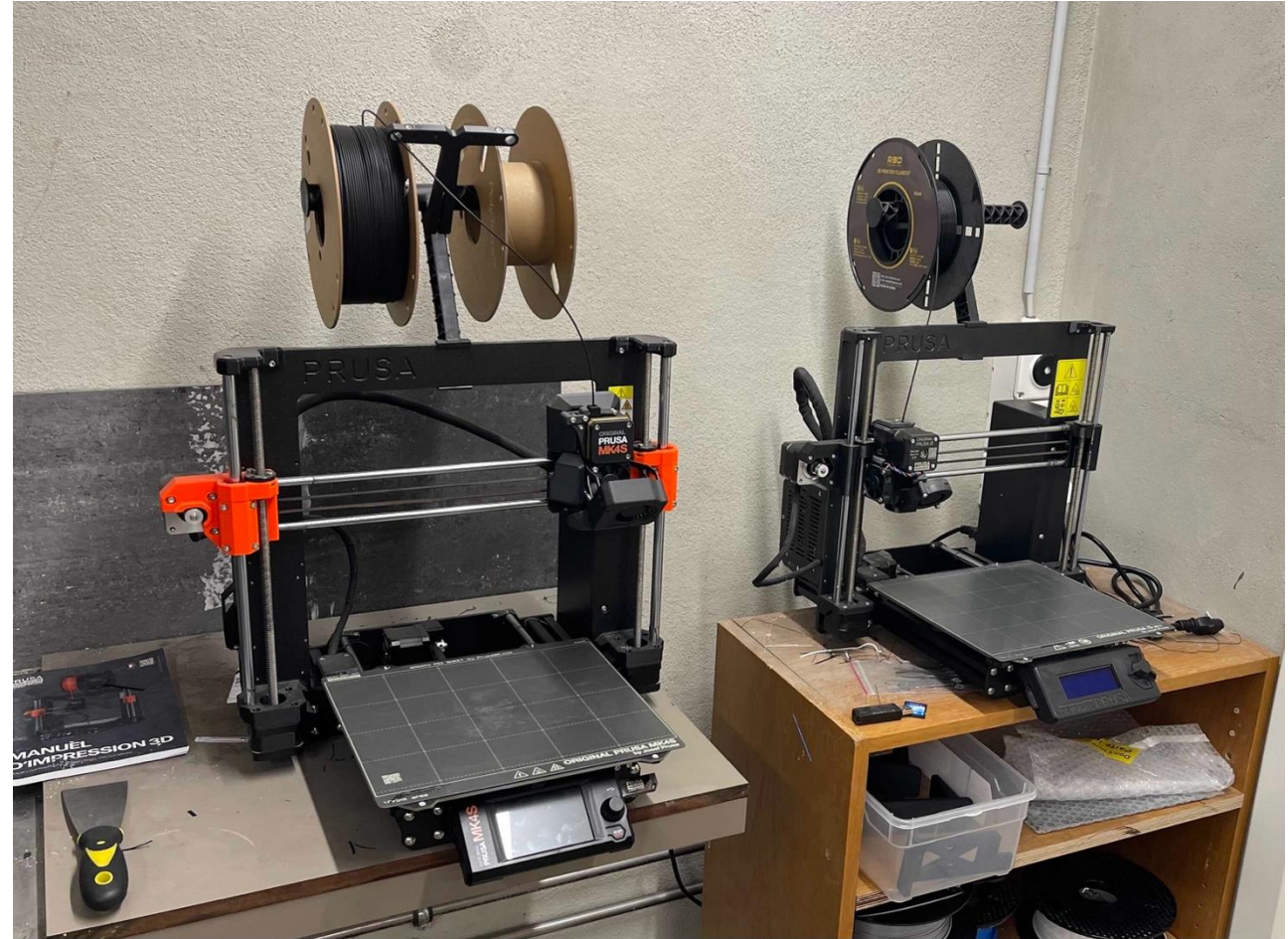
Often change parts

- Parts that need to be adapted to each train
- Design is changing every week and old designs aren't useful
- Molding and machining would be too expensive



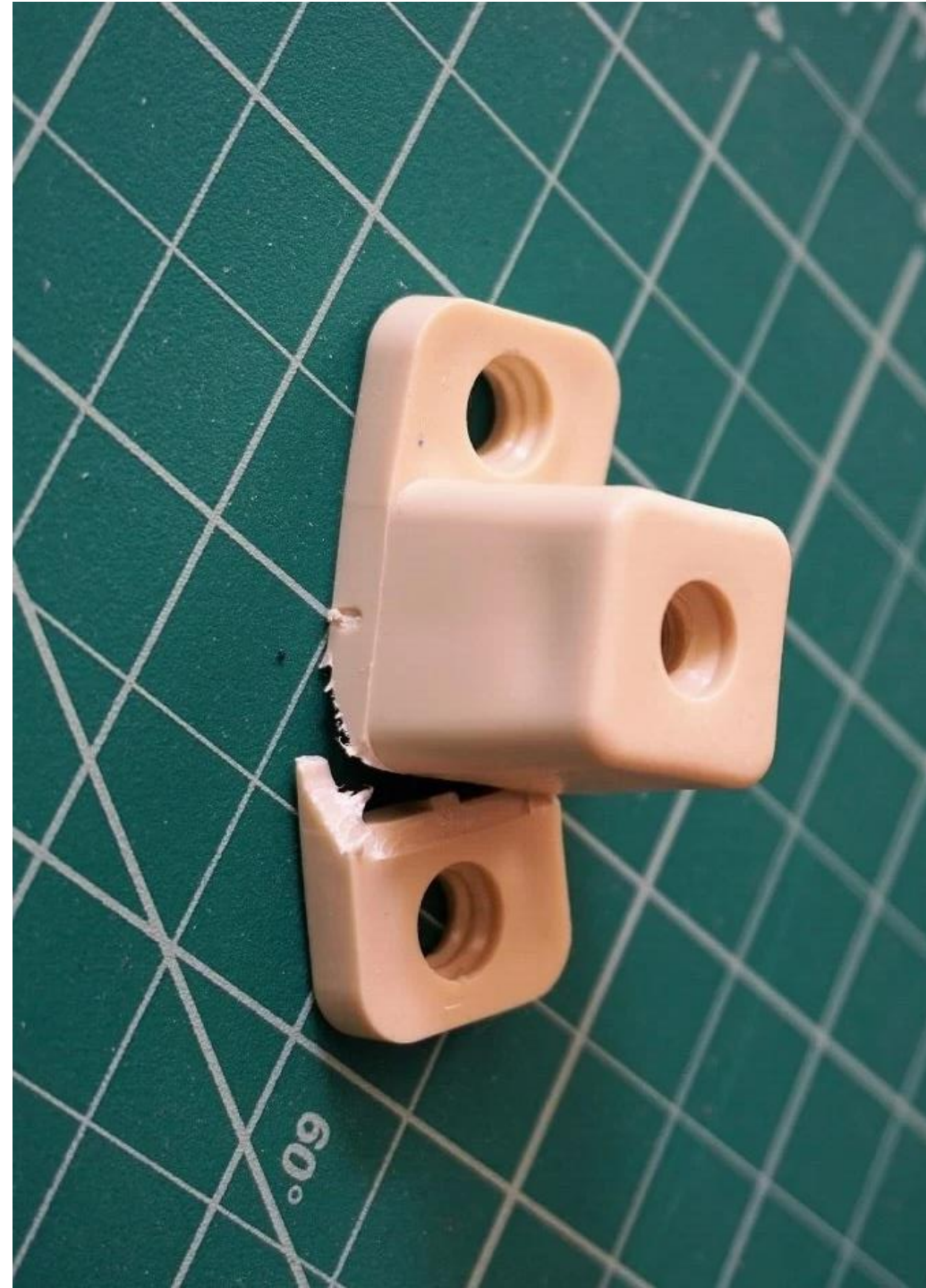
Equipement

- Prusa MK4
- Prusa MK3
- PLA
- Carbon-reinforced PLA



Limitations faced with AM

- Precision
- Mechanical properties
 - Stress resistance
 - Heat resistance
- Scalability



Precision

- The laser path needs a precision around 10 μm
- FDM printers are precise about 100-300 μm
- Why not using SLA ?



Stress resistance

- Low tensile strength with FDM
- Depends on the layer orientation
- Anisotropic parts
- Can be a good thing sometimes
- What about metal AM ?



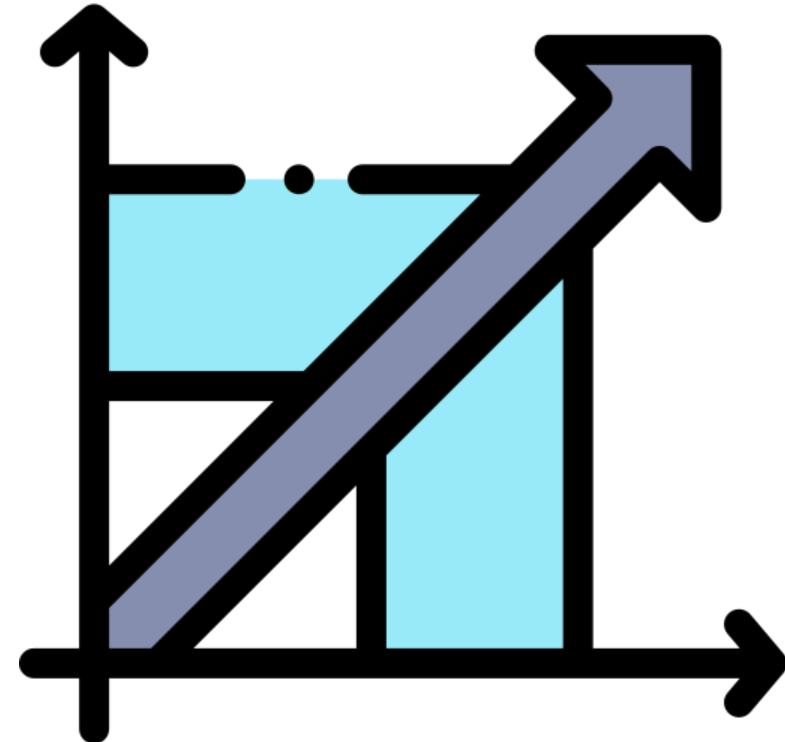
Heat resistance

- Low heat resistance with PLA
- What about metal AM ?
- What about engineering filaments ?



Scalability

- Nu Glass has currently about 15 robots
- This number is about to grow
- AM processes aren't compatible with high scale production



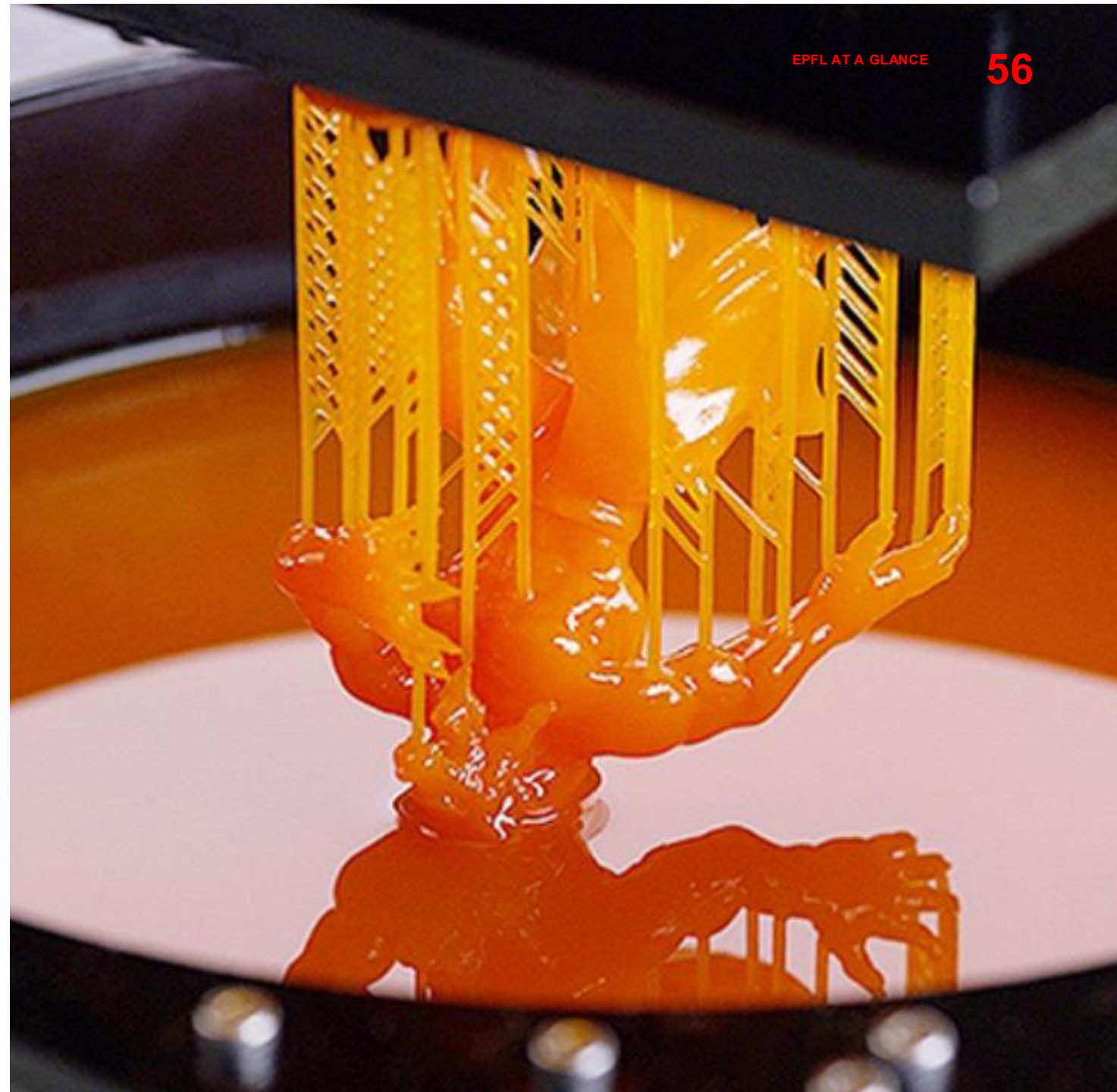
Other AM processes to face the limitations

- SLA
- Metal AM
- Engineering FDM



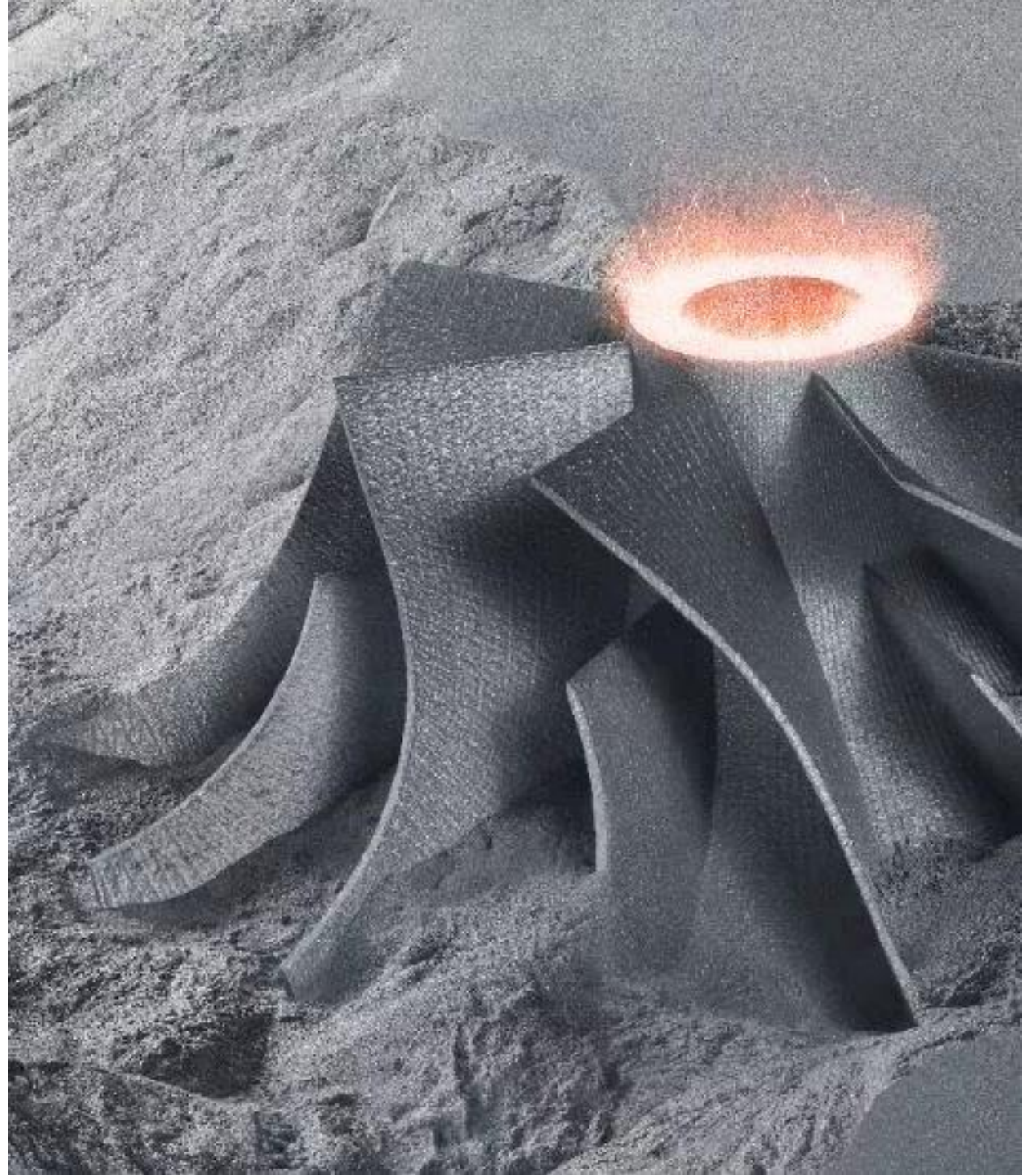
SLA

- Precision of 50 to 100 μm
- Need ventilated space
- Need UV curing after printing
- Harder process than FDM



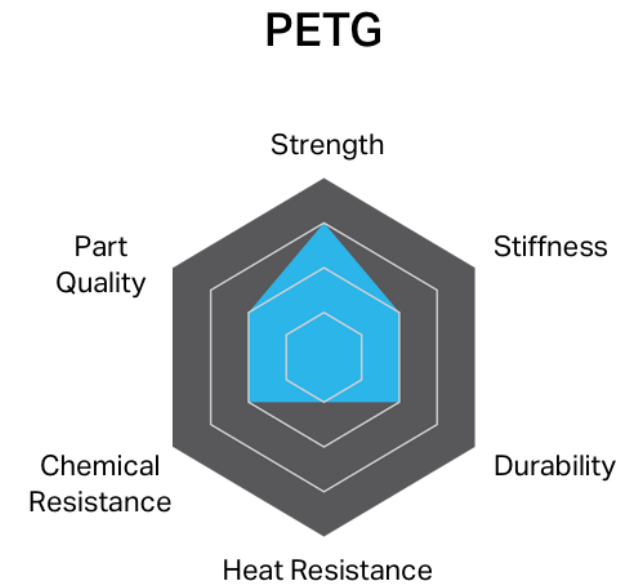
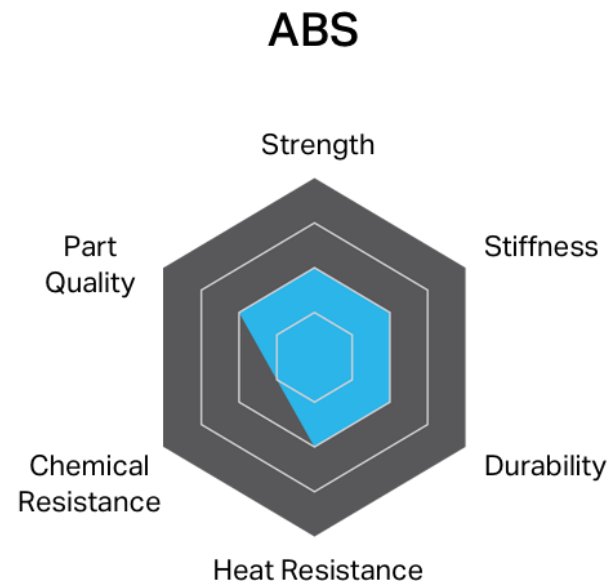
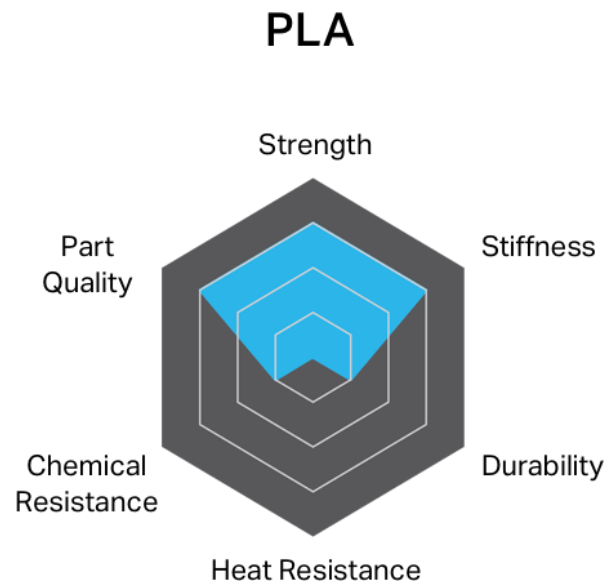
Metal AM

- Better stress resistance
- Better heat resistance
- Huge investment for start-ups
- Complex process
- Can be outsourced (as Nu Glass did)



Engeneering FDM

- Heat resistant filament
- Flexible filament
- Large format printers



Is AM mature enough for start-ups ?

- Basic AM can be easily implemented in a start-up
- Enables their creativity and production skills
- Some processes are still complex and need post processing
- Huge investment for more advanced technologies
- Cheaper technologies would lead to broader use of AM

Are start-ups using AM at it's full potential ?

- New ways of designing using AM
- Machining remains the default option
- Need to use AM as a full process and not as an option B
- Schools like EPFL can play a big role in bringing AM into mainstream manufacturing

CONCLUSION