Additive manufacturing in the Swiss industry

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Image source : [1]

Abstract
Additive Manufacturing (AM), has emerged as a transformative technology across various sectors of the Swiss industry. This report delves into the implementation of AM in aerospace, automotive, healthcare, watchmaking, and other industries, showcasing its potential to revolutionize design, prototyping, and production processes. The Swiss industry has been at the forefront of AM innovation, with companies like Sauber Technologies, 3D Precision SA, and others leveraging its capabilities for lightweight, complex, and custom components. Healthcare applications range from patient-specific prosthetics to bioprinting for regenerative medicine, while the luxury sector employs AM for intricate designs in jewelry and watches. Despite its benefits, such as reduced material waste and increased design freedom, AM faces barriers including high costs, limited material options, and challenges in scaling for mass production. Switzerland's leadership in AM-related patent applications highlights its commitment to research and innovation. This report underscores the current advancements, challenges, and future potential of AM, positioning it as a pivotal tool in shaping sustainable and efficient manufacturing solutions.

Contents

1 Introduction

As the industry evolves, companies must adapt to meet the demands of new customers and embrace innovative manufacturing methods. This may involve reducing production costs or enabling the creation of products and designs that were previously impossible to achieve. With advances in technology, new manufacturing techniques have emerged to enhance production capabilities. One notable example is additive manufacturing, which has been around since the late 20th century, incorporating methods such as binder jetting, directed energy deposition, material extrusion, and powder bed fusion, among others.

Despite the technology being in its early stages when compared to traditional techniques that are currently used in manufacturing, it has shown promising possibilities and numerous advantages. Additive manufacturing remained primarily within academic research for a long time. However, as the technology matures, it is gradually making its way into industry and finding practical applications. According to the European Patent Office[2], in 2018 alone 4072 patent applications were filled and between 2013 and 2020, patent applications for additive manufacturing grew at 26.3% per year compared to 3.5% to the overall applications. Most applications are unsurprisingly dominated by industry giants, primarily based in the US. Notable examples include General Electric, with 875 applications between 2000 and 2018, and United Technologies, with 810. However, Europe also holds a significant share, accounting for 45% of all patents. Furthermore, Switzerland represents 3.6% of all applications. This number might seem negligible, however when putting into context in respect to economy size, we notice that Switzerland is world leader in additive manufacturing patent applications per economic output. The Swatch Group being one of the companies with one of the most patents in additive manufacturing for customer goods.

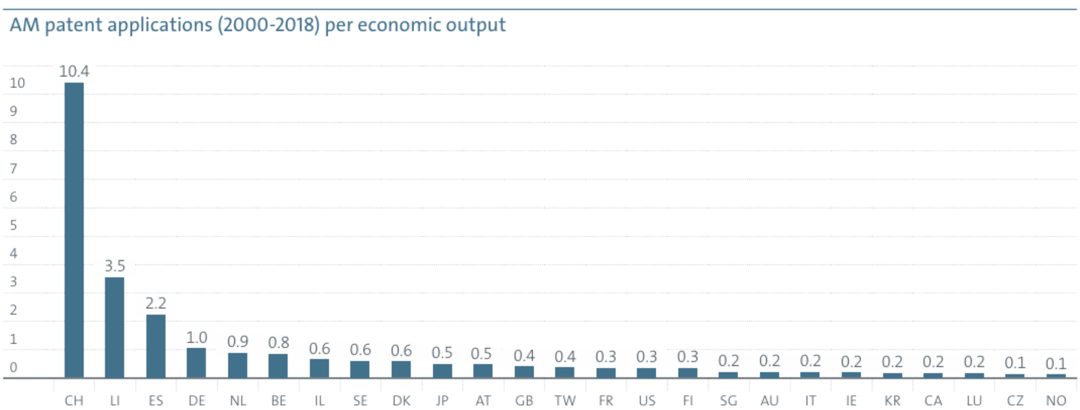


Figure 1: AM patent applications (2000-2018) per economic output [3]

In the following sections we have compiled some companies and applications of additive manufacturing in Swiss industry. It is important to note that this list is non-exhaustive and the impact and extent of AM techniques reaches beyond what is written in this report.

2 Aeronautic, automotive and spatial sectors - written by Martin

In the aeronautics and space sectors, additive manufacturing has become essential for enhancing the performance of various types of aircraft, from commercial planes to satellites. The Swiss industry, renowned for its technological advancements, employs highly qualified engineers and companies that deliver additive manufacturing services to clients worldwide.

Additive manufacturing processes enable manufacturers to produce lighter parts while maintaining robust mechanical properties and achieving complex shapes necessary for high-performance applications. Initially, as in many other industries, additive manufacturing has been widely used for rapid prototyping, which allows for creating and testing various model stages in different conditions, depending on specific needs, even thought it is now used and considered fully as a production process.

One prominent example is Sauber Engineering, a high-tech company originally specializing in Formula 1, which employs additive manufacturing processes such as Selective Laser Sintering (SLS) for polymers and Selective Laser Melting (SLM) for metal alloys. Sauber has developed its own polymer powder called “HiPAC” for SLS applications, combining the advantages of standard SLS processes with Sauber’s in-depth knowledge of composites technology. This material is based on PA12, or Nylon 12, a polyamide widely used in Fused Deposition Modeling (FDM) when in filament form and in SLS when in powder form. By adding carbon fibers — a material they have used for over thirty years in Formula 1 racing — Sauber has created a polymer that can be sintered into complex shapes using SLS. The “HiPAC” polymer exhibits remarkable mechanical properties, such as a maximum Young’s modulus of 6.7 GPa, 3.5 GPa, and 2.9 GPa depending on the direction of load, as well as a tensile strength of 65 MPa in the direction of interest. In contrast, PA12 alone achieves a Young’s modulus of only 1.8 GPa and a tensile strength of 50 MPa. This advancement allows SLS to be used for complex parts subject to high loads, providing an alternative to metal alloys when weight reduction is essential.

For parts not intended to endure high loads, Sauber also uses standard PA12 powder in the SLS process.
In addition, Sauber Technologies employs the Stereolithography (SLA) process developed by 3D SYSTEMS through the ProX 800 printer (cf. Figure 2), using two materials: Accura HPC PIV (cf. Figure 3) and Accura Xtreme (cf. Figure 4).

Figure 2: ProX 800 printer from 3D SYSTEMS

Accura HPC PIV, recognizable by its purple color, is optimized for wind tunnel testing and airflow analysis, offering enhanced surface quality that contributes to more efficient wind tunnel economics. Meanwhile, Accura Xtreme is used to replace components traditionally made from Acrylonitrile Butadiene Styrene (ABS) and Polypropylene in CNC machining. Thanks to its strong physical properties, Accura Xtreme is used for prototypes that must meet form, fit, and function requirements while enduring high loads, as well as for creating master patterns in room temperature vulcanizing (RTV) and silicone molding.

Figure 3: Accura HPC PIV material

Figure 4: Accura Xtreme material

The SLA process by 3D SYSTEMS provides the advantage of producing isotropic parts, which may be preferred over SLS with HiPAC material for certain applications where uniform material properties are essential.

On the metal side, Sauber produces intricate metal components through the Direct Metal Laser Sintering (DMLS) process. Despite its name, DMLS involves melting metal powder rather than sintering, making it quite similar to Selective Laser Melting (SLM); both processes are part of the Powder Bed Fusion (PBF) technology category. The primary differences include laser point diameter — approximately 40 microns for DMLS compared to 80-160 microns for SLM — and layer thickness adjustability, which is possible in SLM but not in DMLS. Sauber also performs in-house post-processing, including automated support removal, sandblasting, and CNC machining, to ensure optimal productivity and quality.

To enhance its metal additive manufacturing capabilities, Sauber has partnered with Additive Industries, a Dutch company specializing in metal additive manufacturing systems. This collaboration enables Sauber to provide clients with top-notch solutions tailored to their specific needs. A noteworthy example of the DMLS process in action is the restoration of a rare Ferrari 340 America Barchetta. The owner of one of the last two remaining models, originally imported to Switzerland in the early 1950s, had a broken rear axle transmission. Using AlSi10Mg alloy through DMLS, Sauber was able to fabricate a new, stronger transmission axle (as shown on Figure 5 and Figure 6), allowing this historic car to return to the road and racetracks.

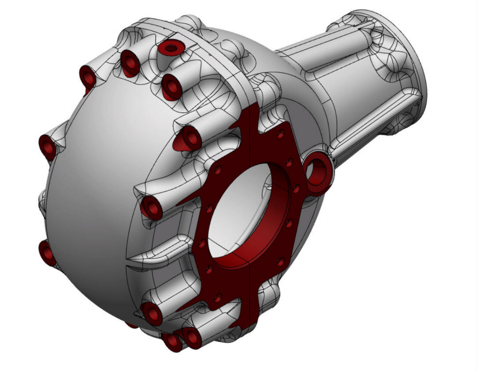


Figure 5: CAD model of the Ferrari 340 Barchetta's rear transmission

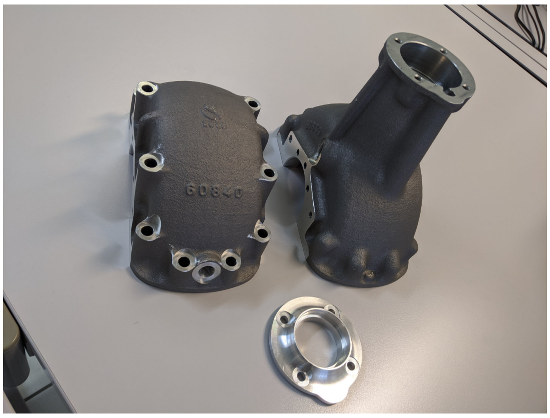


Figure 6: New Ferrari 340 Barchetta's rear transmission made by SLM

Another key player in the Swiss aerospace and aeronautics industries is 3D Precision SA, an emerging company founded in 2014 and based in the Swiss Jura region. Specializing in Selective Laser Melting (SLM) for metal parts, 3D Precision SA has been certified to ISO 9001 and ISO 13485 standards since 2016, ensuring high-quality processes across its operations.

3D Precision SA supports clients throughout the entire project lifecycle, from designing metal parts to manufacturing and finishing. The SLM process provides designers with the freedom to create complex geometries that traditional subtractive methods cannot achieve. This capability allows 3D Precision SA to compete effectively by offering highly complex and precise components. The company also provides reverse engineering services by using 3D scanning to replicate existing parts, making it possible to manufacture replacement components.

Using advanced software such as Magics from Materialise, a leader in additive manufacturing software, 3D Precision SA can optimize designs, including internal honeycomb patterns that reduce weight while retaining essential mechanical properties. Their SLM chamber measures 250 x 250 x 280 mm, and they employ specialized software to segment larger parts, enabling assembly after manufacturing. With a minimum layer thickness of 20 micrometers, which is exceptionally thin for SLM, 3D Precision SA can achieve high precision, further enhanced through post-processing where needed. These post-processing operations include milling, turning, heat and surface treatments, polishing, sandblasting, bead blasting, and ultrasonic cleaning.

3D Precision SA works with a broad range of metals and alloys, including Ti6Al4V, pure titanium, AlSi10Mg, two types of stainless steel, maraging steel, CoCr alloy, pure copper, pure tungsten, and special alloys upon request. Variations of AlSi10Mg, such as CL 30AL and CL 31AL, are used in lightweight applications that demand high mechanical strength and dynamic load resistance. Pure titanium and

Ti6Al4V alloy are particularly suitable for prototypes, single parts, or series production of functional components, including those requiring internal cooling channels.

A notable application of these processes is the design of compliant mechanisms for space applications. Compliant mechanisms rely solely on the flexibility of the material to transmit forces and enable movement. The advantages of such mechanisms include the absence of rigid mobile parts that would otherwise rub against each other, thereby eliminating wear due to friction, allowing for highly precise positioning, and often requiring only a single-piece construction. These qualities make compliant mechanisms particularly well-suited for space applications, such as precise mirror positioning.

This is why, in 2020, the European Space Agency (ESA) commissioned the Centre Suisse d'électronique et de microtechnique (CSEM) to develop a compliant mechanism known as the Compliant Rotation Reducer Mechanism (CCRM), shown on Figure 7. To accomplish this project, CSEM collaborated closely with 3D Precision to design the components and then manufacture them.

Figure 7: Compliant Rotation Reducer Mechanism

Additive manufacturing played a critical role in this project, as it enabled the optimization of the part's design through multiple iterative stages, some of which are shown on Figure 8:

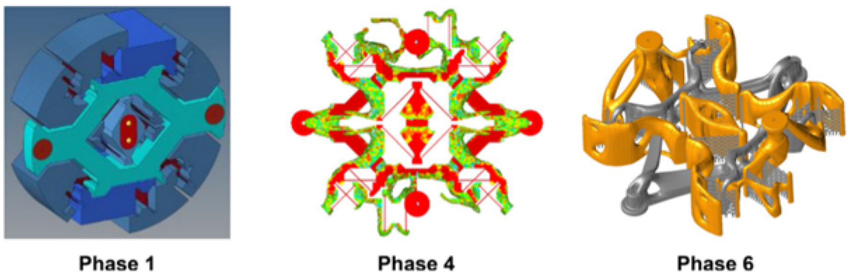


Figure 8: Optimization steps of CCRM's design

The entire manufacturing process is illustrated in the Figure 9.
A complete production plate includes two CCRMs along with several tensile test samples, all produced in CL 92PH stainless steel using Selective Laser Melting (SLM). The post-processing sequence consists of three main steps. First, the parts undergo a thermal treatment called Hot Isostatic Pressing

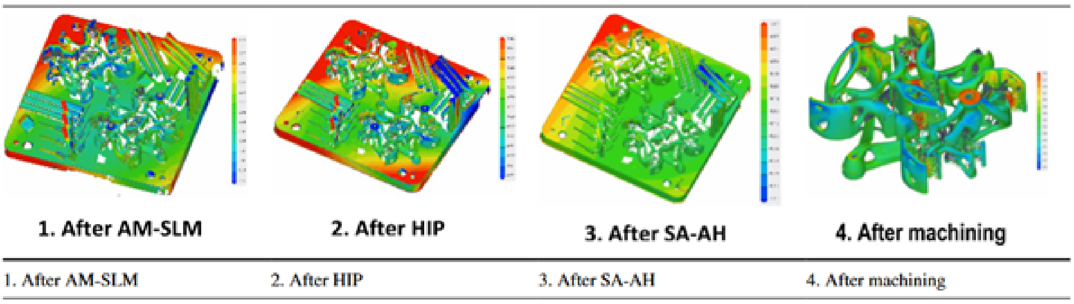


Figure 9: Manufacturing steps of CCRM

(HIP) to reduce metal porosity. Next, a Stress Annealing–Age Hardening (SA-AH) process is performed to relieve internal stresses and achieve the required mechanical properties. Finally, the plate is machined to obtain the desired final parts. All these steps are shown on Figure 10 and Figure 11:

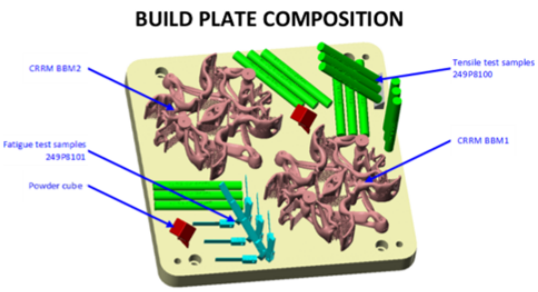


Figure 10: Description of all parts printed on a single plate

Figure 11: Plate after SLM process

Another example of additive manufacturing processes in the space industry is the "Additive Manufacturing of a Slipring Assembly Rotor" (AMAR) project, a collaboration between CSEM and Ruag Space Switzerland. This project involved the manufacturing of a slipring assembly rotor, a component used in electrical and mechanical systems that enables the continuous transmission of electrical signals between a rotating part and a stationary part of the system. The aim was to design this component using Selective Laser Melting (SLM) to eliminate the need for the successive assembly of machined parts with tight tolerances, which could result in inaccuracies in the final assembly.

To achieve this, they enlisted 3D Precision SA to produce the additive-manufactured parts. Once produced, resin was cast over the parts before they were machined one final time to achieve the precise shape required for the slipring assembly rotor, as shown on Figure 12.

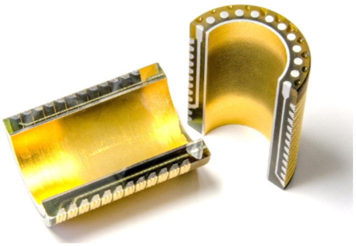


Figure 12: First prototype made with Additive Manufacturing

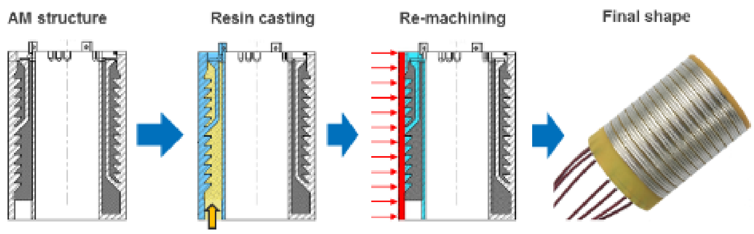


Figure 13: Full manufacturing process

One final example is the flexible pivot patent registered by Almatech in 2016 (Figure 14). Flexible pivots are mechanisms used as an alternative to lubricated bearings in oscillatory applications. Prior to this patent, the main limitation of flexible pivots was their angular range, typically restricted to plus or minus 10 degrees. However, thanks to additive manufacturing, Almatech succeeded in producing a flexible pivot capable of handling rotations of plus or minus 90 degrees for an impressive 125,000,000 cycles — an endurance that can be considered "infinite" when compared to the cycle lifespan of a traditional lubricated bearing. This breakthrough opens up a wide range of potential applications in the space industry, including Antenna Pointing Mechanisms, Laser Terminals for optical communications, and Earth Observation payloads in low Earth orbit (LEO).

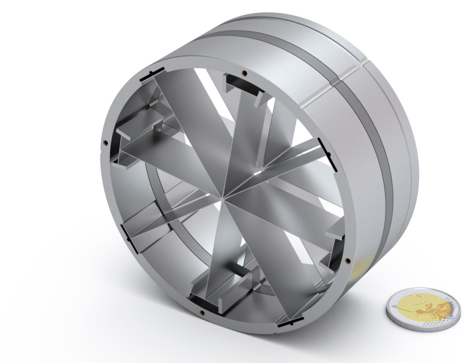
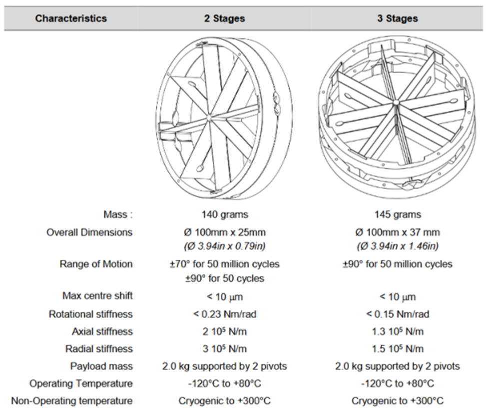


Figure 14: Flexible pivot from Almatech



Characteristics	2 Stages	3 Stages
Mass :	140 grams	145 grams
Overall Dimensions	Ø 100mm x 25mm *(Ø 3.94in x 0.79in)*	Ø 100mm x 37 mm *(Ø 3.94in x 1.46in)*
Range of Motion	±70° for 50 million cycles ±90° for 50 cycles	±90° for 50 million cycles
Max centre shift	< 10 µm	< 10 µm
Rotational stiffness	< 0.23 Nm/rad	< 0.15 Nm/rad
Axial stiffness	2 10^5 N/m	1.3 10^5 N/m
Radial stiffness	3 10^5 N/m	1.5 10^5 N/m
Payload mass	2.0 kg supported by 2 pivots	2.0 kg supported by 2 pivots
Operating Temperature	-120°C to +80°C	-120°C to +80°C
Non-Operating temperature	Cryogenic to +300°C	Cryogenic to +300°C

Figure 15: Table of main properties of flexible pivot

3 Machinery - written by Paul-Antoine

Metal additive manufacturing (AM) has offered new perspectives on the feasibility of metal parts. For machinery in the industry and the automation world, the recent performances of metal AM allows the industry to evaluate the role it could play to enhance quality or efficiency of production. The AM technology is not considered as a production tool due to its low rate of production, however it can be used to design parts, tools to enhance actual machinery. As the technology has been growing lately, it is common for most companies to look into these processes. Companies with the means tend to invest on an R&D branch, while most companies contact external resources such as research labs (ed. the "Laboratoire de technologie des poudres et matériaux avancés" of the HES-SO) or other startups and established companies of metallurgy AM.

3.1 Products made for machinery

By asking what was the extent of the impact of Metallurgical AM in main companies, Dr. Samuel Rey-Mermet from the AM powder lab in Sion answered: "We do not know, it's just hidden". Meaning that, companies with intern R&D branches or contractors agencies are less likely to share they usage of AM in the field of enhancing production. Companies, with the means, tend to invest in private research. On the other hand, research labs like his, have public research in collaboration with smaller companies. They are used as consultant for companies that want to evaluate the extent of possibilities those processes would have to offer. Public research such as the ones made by university labs allows to investigate on some examples AM has to offer in that field.[4]

One of the examples we can find in Swiss industry is the manufacturing tools. Additive manufacturing offered the feasibility to manufacture tools with specific properties. In the case of drill bits, they undergo extraordinary stresses to be able to extrude matter from a metal part. Optimal materials that would ideally be used to elaborate this part of the tools need to have specific properties. The material used to make a drill bit has always been a compromise to allow the feasibility of the manufacturing, putting aside requirements such as long lasting tools or fatigue resistivity. Now, with metallic 3D printing, companies can access drill bits with harder materials. The process allows the making of low thermal expansion and shape memory alloys, both good properties for a drill bit to have. It elongate durability and consistency of the tool over time. Another advantage of Metal AM is the local variations of the alloy. A one body part can indeed have local variations of the phase printed on the layer which allows to selectively chose the required local properties depending on the usage. Drill bits can be welded on helical flute or can be specifically designed for complex drillers such as rock driller that have a complex shape not suitable for conventional manufacturing.

As mentioned in the article "Three-dimensional printing of hard materials" (E. Carreño-Morelli, et al. International Journal of Refractory Metals & Hard materials 87 (2020) 105110): "Until now, it has not been possible to process reliable parts in WC-Co based hard materials using laser-based AM techniques. High energy density achieves close to full densification through cobalt re-melting and evaporation, but also results in thermally induced cracks and embrittlement due to the formation of undesirable phases. On the other hand, low energy density leads to high residual porosity". With “Solvent on granule 3DPrinting” (SG-3DP) Figure 16, a slightly different process than "binder jetting 3D-Printing" (BJ-3DP), highly efficient drill bit can be obtained with well controlled phases and mechanical properties.[5]

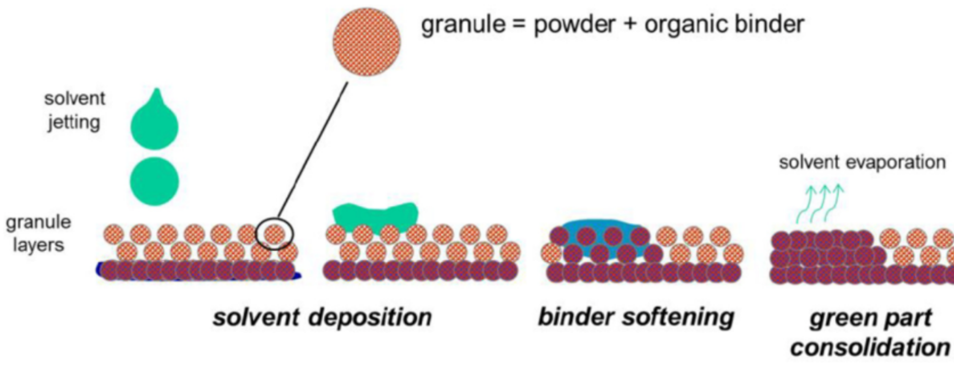


Figure 16: Principle-of-Solvent-on-granules-3D-printing-SG-3DP [5]

Another example of 3D printing part to enhance machinery is concerning air flow. For most processes, surface condition stays not sufficiently good for designing a smooth metallic part, however the main advantages are the feasibility of complex shapes. Especially concerning internal structure that can not be manufactured. In this case, metal 3D printing becomes more than useful. As mentioned by Dr. Samuel Rey-Mermet, they are able to create air or liquid filters. Those filters are printed in metal for the efficient properties metal has to offer. Depending on the internal design of the filter, many uses can be found for such a product. With help of fluidics and topology sciences, the internal structure can be established to optimize specific conditions. The metal printing of such a filter can offer efficient thermal dissipation. The porosity of the structure can also be modulated as required offering unique behavior of the filter.

Figure 17: Velo3D printed heat exchangers featuring 320 µm leak-tight walls and 220 µm turbulators that resulted in lower pressure drop [6]

Other structure can also optimize the commingling of different gazes or liquids. With even more complex topology, some filters are also able to segregate gases due to several cavities, allowing really specific applications. It is difficult to evaluate how common those filter would be in the swiss industry. However, beside filters, some other machinery parts require complex specifications that cannot be achieved with traditional manufacturing technics such as part in the need of a channels allowing air or liquid to flow, as Bühler AG would testify later in this paper. For these kind of parts, we can easily acknowledge the widespread of occasional tailor made parts ordered by companies.

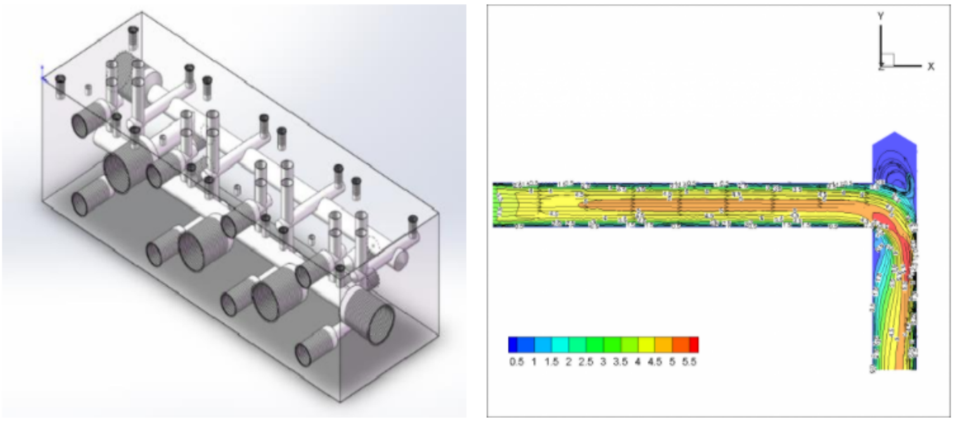


Figure 18: Hydraulic Manifolds manufactured in traditional method / Hydrodynamic analysis of right-angle flow channels [7]

Figure 19: 3D printed metal hydraulic manifolds, optimizing weight and volume [7]

On the Figure 18 we can see for an hydrolic manifold, how the right angle and the blind holes made through traditional manufacturing methods are not optimizing the flow. The 3D printed part Figure 19 offers many advantages such as laminar flow but also an optimization in term of mass, volume and quantity of raw material. This is an example of a tailor made part for a specific task that companies would order to a 3D printing agency.

3.2 3D Printing Machinery

Despite the inaccessibility to evaluate the presence of Metallic AM in the swiss industry, there are multiple companies such as ProtoShape 3D Printing AG [8], 3D Precision SA [9] and 3D Technology

SA [10] based in the canton of Berne, Jura, Valais respectively. They offer consulting and services to elaborate metallic 3D parts for other companies. Acknowledging also the presence of EOS GmbH [11], Trumpf [12] and SLM Solutions Group AG [13] that as of today sell 3D printers for metallic parts in Switzerland, we can hardly ignore the presence of these processes in the industry. Their presence on the market strongly suggest a flourishing demand. We can also mention companies like AMiquam located at Gland who offers a variety of sensors to enhance and analyze metallic 3D printers. Their devices are an upgrade to add to the printer to measure precisely the consistency of microstructure in a printing. For metal AM, it is not possible to assure consistent grain size and phases appearing layer by layer due to multiple uncontrolled behavior such as heat dissipation and others. AMiquam offers a range of sensors allowing to measure specifically microstructure being made during the printing to better assess the mechanical properties of the product that are uncertain without such a device. AMquam, living only on the market of enhancing metallic 3D printing, reinforce the idea of the presence of the process in the swiss industry.

4 Electrical industry - written by Daniel

More recently, additive manufacturing in electronics has also been used in order to integrate more sensors into a smaller factor. Indeed, with conventional techniques, making a device that uses several sensors results in heavy and bulky devices that cannot be used everywhere. Notably, CSEM plays a significant role in pushing additive manufacturing (AM) into the industry, as they help to turn experimental technology into practical applications. Indeed, they work closely with companies to create real-world solutions for specific needs that cannot or are not easily solved with current manufacturing techniques. And although it is more of a research center than industry, in 2023 alone CSEM had 245 active contracts with industrial clients.

For instance, in 2022 CSEM [14] started developing a smart thermal control system that integrates sensors and energy harvesting into a single component using AM for customers such as Thales Alenia Space and CERN. This shows how they're combining traditional manufacturing techniques with AM to make products that are lighter, more efficient, and packed with extra functionality, which is something that industries like aerospace and telecommunications need.
To achieve something like this, CSEM uses laser powder bed fusion with stainless steel, the process is then stopped at a specific point to add the sensors. Then Aerosol jet printing is used to place conductive and insulating inks on these components and finally insulation is applied after removing supporting structures. Aerosol Jet printing is an additive manufacturing process that uses an aerosolized mist of micro-sized droplets to precisely deposit materials onto a substrate. It enables high-resolution, multi-material printing for complex, three-dimensional structures, making it ideal for applications in electronics, sensors, and medical devices.

Furthermore, additive manufacturing techniques can also be used as alternative method for PCB fab-

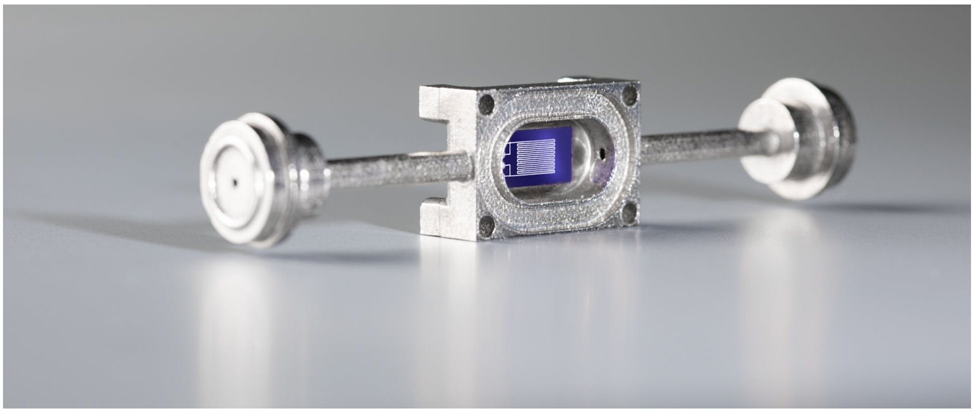


Figure 20: CSEM's HEAD project result

rication. Such an exemple is Nano Dimension who has established a presence in the Swiss electronics industry. The company, based primarily in the United States, is known for its innovative 3D printing technology, especially the DragonFly IV 3D printer [15]. Although Nano Dimension is not based in Switzerland, it operates internationally and more specifically in Switzerland, through it's SMT division, Essemtec, which specializes in surface mount technology and automation solutions for electronics manufacturing which allows them to integrate its innovative 3D printing technologies with local manufacturing processes and support the growth of additive manufacturing in electronics in the region. Traditional PCB production can be quite slow and involves several steps like lamination, drilling, and etching, which can delay the design process and often times companies do not do this on site. In contrast, Nano Dimension's approach enables quicker prototyping and makes it easy to modify designs on the fly as it allows manufacturers to produce multilayer circuit boards and complex electronic components in-house, offering a compelling alternative to traditional PCB manufacturing methods. Additive manufacturing techniques such as this allows mid-sized businesses to enhance time efficiency and enabling continuous improvements, instead of relying on external manufacturers and wait for delivery. Additionally, as most additive techniques, their method minimizes waste by using only the materials needed for each print, which is an important consideration as the industry moves toward more sustainable practices.

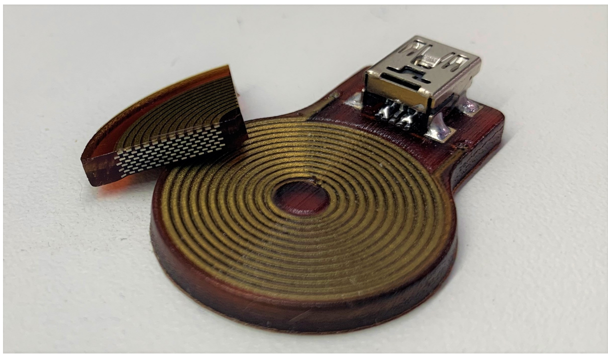


Figure 21: 3D printed electromagnetic coil using Nano dimension's DragonFly [16]

Finally the last big competitor we will discuss in this section is Cicor. Cicor's a Swiss company based in Boudry (Neuchâtel) and has numerous production sites in Europe and Asia. They develop high-quality electronics solutions, namely designing and manufacturing of PCB's for numerous industries and have two technology centers for printed electronics, one of wich is located in Bronschhofen (St. Gallen). Much like CSEM, Cicor's goal when using additive manufacturing for electronics is to achieve structures and performances that are not reachable with traditional manufacturing. As shown on figure 22, they can integrate circuitry into the housing to make space for other circuits or reduce overall volume of the piece. One of the techniques employed by Cicor for printed electronics is Aerosol Jet Printing [17], which unlike traditional PCB manufacturing techniques does not require etching of the parts we want to get rid of, but instead works by directly depositing functional inks onto a given substrate this technique allows companies, such as Cicor, to precisely print circuits in 2D but also in 3D. Some of the advantages are: wide variety of materials (metals, conductors insulator, carbon based materials, polymers, etc...), line precision of up to 10μm and a printing thickness from a few hundreds of nanometers to tens of micrometers.

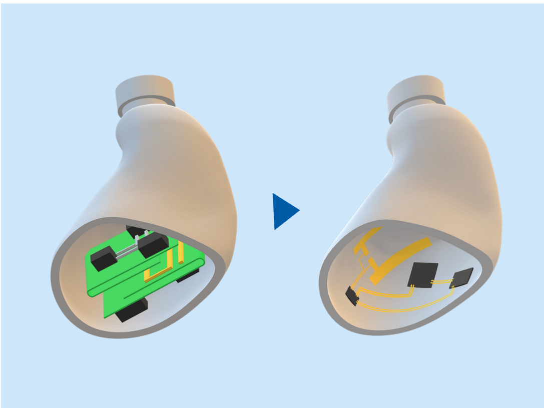


Figure 22: Miniaturization

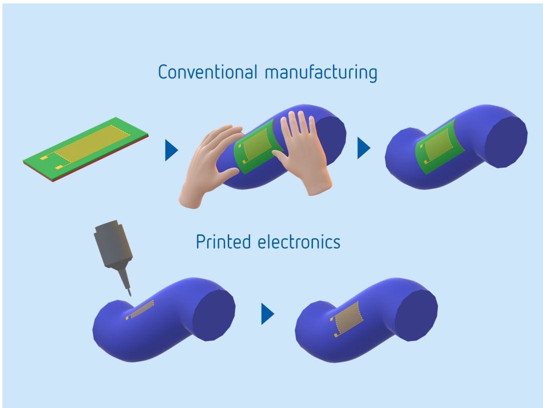


Figure 23: Reducing assembly complexity

5 Packaging industry - written by Daniel

One example of a packaging firm is BOBST, a Swiss company established in Mex that is a global leader in packaging and label solutions, indeed 59%[18] of the packaging sold worldwide is done by companies that use BOBST machines. By incorporating AM into their processes, companies may improve the performance and efficiency of their packaging equipment, meeting industry demand for more complex, dependable, and cost-effective solutions. An important aspect to note is that BOBST mentions additive manufacturing is already commonly used across all their entities, although it is difficult to determine the exact extent, as it is standard practice within the industry to keep most internal manufacturing techniques closely guarded.

At an internal level, they use additive manufacturing to build particular parts for some of their equipment from a variety of materials. They work with metals like stainless steel and titanium, as well as polymers like Nylon and PLA, using both powder-based methods for metal and polymer components and fused deposition modeling (FDM) for polymer parts.

The adoption of additive manufacturing has also changed the way BOBST designs its machine components. The freedom given by AM enables them to create geometrically complex components that were previously hard or impossible to manufacture with conventional methods or at a much lower cost.

Despite the advantages AM offers, BOBST acknowledges the challenges of integrating it into a traditional manufacturing environment. One of the challenges is changing the mindset of experienced mechanics and engineers who are accustomed to conventional manufacturing techniques. Cost competitiveness with traditional methods is another challenge; AM can be more expensive, but it becomes viable when the value lies in the complexity of the design, such as integrating multiple functions into a single part or simplifying assembly by replacing multiple components with one printed piece. For this reason, currently their goal in respect to AM is not to replace all of their conventional manufacturing by AM but instead to improve their overall manufacturing by integrating AM when a specific need is not met by conventional techniques.

Size limitations of current AM techniques also restrict the range of applications, as large components cannot easily be printed. Moreover, understanding the mechanical properties of printed materials, such as their fatigue performance, remains a challenge. Currently, AM accounts for less than 1% of BOBST's overall production. This modest numer shows how AM is still in early stages relative to BOBST's history and more generally conventional manufacturing techniques. Furthermore, most machines that BOBST manufactures use very simple pieces and don't cost much to produce, which gives very little reason to manufacture them with AM.[19]

To give a concrete exemple of one of BOBST's successful integration of additive manufacturing, not only for internal R&D but also for consumer-oriented products, we can cite the development of the cluster system within BOBST's digital inkjet technology, which is used for printing on various types of packaging solutions. In this application, they manufacture a 3D-printed titanium structure for ink conditioning, which precisely manages the ink's viscosity, temperature, and amount of ink in the printhead. In the same way, the temperature control layer is also produced through additive manufacturing. This layer features complex internal channels that let the ink flow and regulate the temperature, a design such as this one would be hard to achieve using conventional manufacturing methods. The advantage of AM in creating such components is evident, as it enables the production of intricate internal pathways that are essential for optimizing performance.
This example shows how AM contributes to creating more efficient and effective machinery. The

Figure 24: 3D printed conditioning layer[20]

Figure 25: 3D printed temperature layer [20]

company's use of AM extends across all its entities, integrating the technology throughout the organization to foster innovation and maintain a competitive edge.

6 Healthcare - written by Clémence

AM has revolutionized the healthcare sector in Switzerland by enabling customized, complex medical devices. Its precision, material efficiency, and speed have made it indispensable in fields such as prosthetics, surgical guides, bioprinting, and dentistry. AM is applied to create patient-specific solutions that traditional methods struggle to achieve.

6.1 Prosthetics

NEO3D AG[21] is a Swiss company based in Kriens (Lucern) that specializes in the use of AM to create custom prosthetic limbs. The process starts with a 3D scan of the patient's limb (cf. Figure 26), enabling precise digital modeling that captures the unique shape and features of each individual. Using GeoMagic Freeform, an advanced CAD software (cf. Figure 27), the company customizes the design to meet the patient's specific anatomical needs. The final prosthetic is produced using either Selective Laser Sintering (SLS) or Multi Jet Fusion (MJF) technologies, which enable fast production and design flexibility. Post-processing involves surface smoothing and applying a color finish for both comfort and visual appeal. The company operates two AM machines: the Formlabs Fusible 1 for SLS and the HP Multi Jet Fusion 4200 for MJF. Additionally, they offer project development services.

Another company in prosthesis is Spectroplast AG [22]. Based in Schlieren (Zurich), this company specializes in silicone AM, using Stereolithography (SLA) technology to produce customized medical and industrial products. By utilizing TrueSil, a high-resolution resin, Spectroplast creates isotropic silicone parts with excellent mechanical properties, smooth surface finishes similar to human tissue, such as elasticity, softness, and translucency. This makes the material particularly suitable for applications like facial prostheses and soft-tissue replacements. The company's process allows for the direct fabrication of end-use products without the need for molds, eliminating waste and reducing

Figure 26: Scanning process using "Calibri mini"

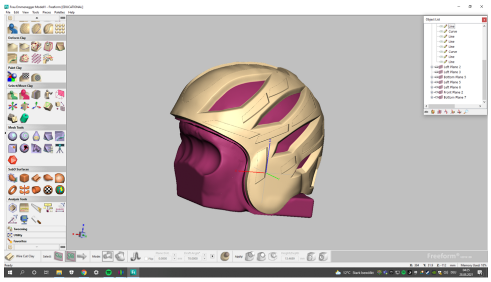
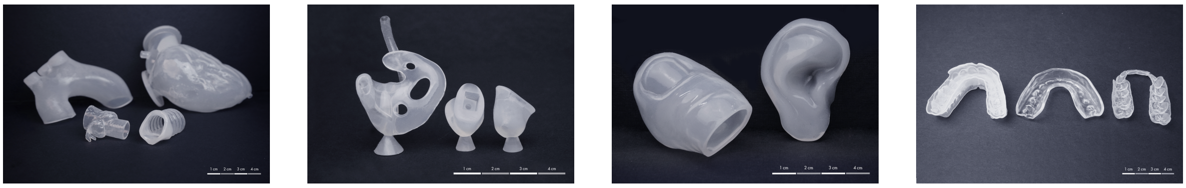


Figure 27: Geo-Magic Freeform

production time. Spectroplast's AM capabilities are scalable, supporting both small-batch and serial production.
Spectroplast's applications include anatomical models, implants, hearing aids, earplugs, headphone tips, prostheses, orthoses, and dental products like mouth guards, positioners, and liners (cf. Figure 28).



(a) Anatomical model (b) Hearing aids (c) Epithesis (d) Dental positionners

Figure 28: Non-exhaustive overview of Spectroplat's applications

6.2 Surgical guides

Symbios [23], based in Yverdon-les-Bains, specializes in the production of personalized orthopedic implants, particularly the ORIGIN® knee prosthesis. Using 3D imaging and AM, Symbios customizes implants to match the patient's skeleton, ensuring better alignment and functionality compared to traditional off-the-shelf prostheses. Traditional methods often require selecting a standard prosthesis, which may need adjustment during surgery, leading to alignment issues. In contrast, Symbios uses CT scans to create digital models and patient-specific cutting guides (cf. Figure 29) that ensure precision during surgery, improving patient outcomes and reducing recovery times.
The process allows for faster, more efficient surgeries with fewer instruments, reducing both operating costs and infection risks. Additionally, the use of AM enables complex geometries, leading to enhanced knee function and patient satisfaction.

6.3 Bioprinting and Regenerative Medicine

Bioprinting is a key technique in regenerative medicine, where the goal is to repair, replace, or regenerate damaged tissues and organs.

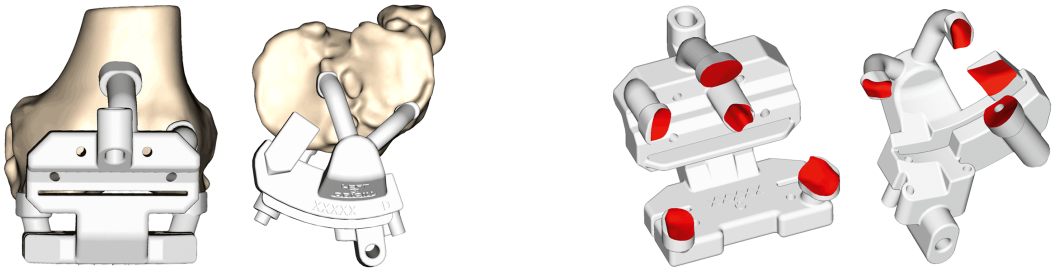


Figure 29: (left) KNEE-PLAN® cutting guides simulated on the femur's end
(right) KNEE-PLAN® cutting guides with support point in red

Readily3D [24], a young Swiss company based in Renens, pioneers volumetric bioprinting with its tomographic 3D printer, *Tomolite* (cf. Figure 30). This light-based technology simultaneously solidifies photosensitive bioinks, rapidly creating centimeter-scale biological structures. Unlike extrusion-based methods, this process avoids shear stress, making it cell-friendly.

Figure 30: Tomolite bioprinter

Extrusion	Volumetric bioprinting
Shear stress < 60% Viability	No shear stress Increased viability > 90%
Limited design freedom	Freeform, No support struts
Low-throughput <0,1cm³/min	High-throughput >10cm³/min

Figure 31: Specs comparison between extrusion and volumetric bioprinting

Volumetric bioprinting enables high-throughput production, creating over 10 cm³ of material per minute, compared to less than 0.1 cm³ for extrusion (cf. Figure 31). The method allows support-free printing of complex geometries (cf. Figure 32), offering greater precision for patient-specific implants. This technique also allow to print organoids which is used in drug testing and tissue regeneration.

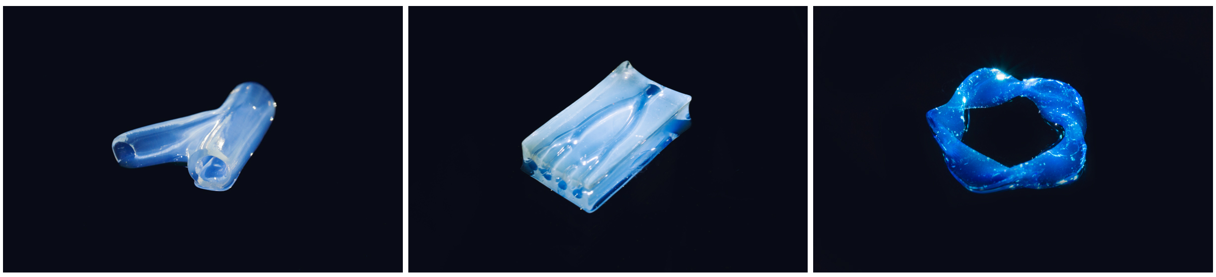


Figure 32: Example of printable part using the Tomolite

regenHU [25] is also a leading innovator in the field of 3D bioprinting for tissue engineering and regenerative medicine. This company, based in Villaz-St-Pierre (Fribourg) utilizes advanced inkjet and extrusion techniques to produce human tissue models for medical research, drug testing, and potential organ regeneration. In inkjet bioprinting, tiny droplets of bioinks, often made from living cells, are precisely deposited onto a substrate to create tissue-like structures. On the other hand, extrusion-based bioprinting involves extruding bioinks through a nozzle to build larger tissue scaffolds. These techniques enable the precise deposition of living cells to create biologically accurate models that mimic human tissues.

One of regenHU's primary goals is to help accelerate medical research by providing reliable in-vitro models for drug testing, which can help reduce reliance on animal models. These models are used for testing drug interactions and developing therapies more efficiently, especially in the fields of cancer research and tissue regeneration. The company's work also holds significant promise for organ transplantation. By printing complex tissues, regenHU is advancing the development of functional tissues that could one day be used for organ regeneration, helping to address critical shortages of donor organs.

6.4 Dentistry

The Swiss company Swiss M4M [26] based in Bettlach (Soleure) specializes in dental AM, focusing on the creation of custom dental and orthodontic devices. They employ state-of-the-art 3D printing technologies to produce high-precision parts like crowns, splints, and frameworks, primarily using metals such as titanium and cobalt-chrome. These materials offer excellent biocompatibility and strength, making them ideal for dental applications (cf. Figure 33). The company's approach to AM involves advanced processes that can deliver products based on STL files provided by the customer. This allows for a high level of customization, where each piece is tailored to the specific needs of the patient. Swiss M4M's methods enable the rapid production of complex geometries without the need for additional tooling or support structures, which reduces both time and cost.

(a) Splint   (b) Removable partial denture   (c) Plate for oncological mandibular treatment

Figure 33: Example of parts produced by Swiss m4m using SLM

One of the key advantages of their technology is the high resolution and accuracy achieved through Selective Laser Melting (SLM). This method melts metal powders with a laser to create precise parts, and the post-treatment process improves the mechanical properties of the parts. Additionally, the flexibility of AM allows for mass customization, where multiple personalized devices can be produced in one batch, enhancing manufacturing efficiency and scalability. By integrating AM into their production, Swiss M4M offers significant benefits over traditional methods. These include faster prototyping, reduced lead times, and the ability to create highly detailed and patient-specific dental products at competitive prices.

7 Luxury and watchmaking - written by Aude

Over the past decade, additive manufacturing has increasingly been integrated into the luxury and watchmaking industries, where these advanced processes are used to fabricate components or, in some cases, entire objects.

In Switzerland's jewelry sector, for instance, the Swiss-Italian company Digimorphé[27] exemplifies this trend. Founded in 2013 by Consuelo Keller, an archaeologist turned digital artisan, Digimorphé was created to explore the potential of creative coding in jewelry design and to bring these designs to life using advanced manufacturing technologies.

Figure 34: Digimorphé jewelry

For Consuelo Keller, the ability to hold a tangible prototype of her designs is central to her creative process. To achieve this, she primarily uses material extrusion techniques, such as Fused Deposition Modeling (FDM), for prototyping. This method is cost-effective, versatile, and accessible, supporting rapid prototyping, functional testing, and small-scale production. FDM also allows her to test the fit and proportion of her jewelry on the body whenever needed, making it easy to transition from digital designs to physical prototypes.

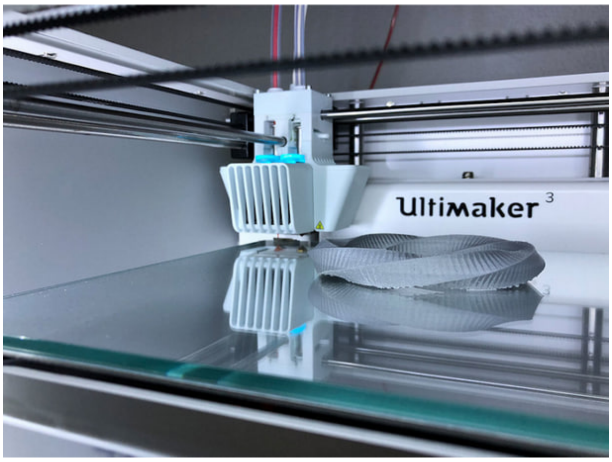


Figure 35: Prototyping of a bracelet by FDM - Digimorphé

For final production, Keller employs different additive manufacturing processes depending on the material used in each piece. For polyamide or aluminum blends, she relies on Selective Laser Sintering (SLS), a process that fuses powdered materials layer by layer with a precision laser, ideal for creating small series of complex parts. For other metals, she uses Metal Binder Jetting (MBJ), which bonds metal powder with a binder before a bronze infiltration. MBJ is faster than selective laser melting or electron beam melting, as the binder is applied across the entire powder bed rather than in precise steps. This method allows for complex geometries without the need for support structures, while maintaining high precision. For bronze, silver, and gold, Keller employs stereolithography combined with lost-wax casting. High-quality gold, silver, and bronze powders can be expensive and challenging to source for MBJ, raising the cost of raw materials. Lost-wax casting, however, uses molten metal and is more economical and manageable when working with precious metals. Each of these methods may require finishing steps, such as polishing, coating, or applying a patina, depending on the techniques.

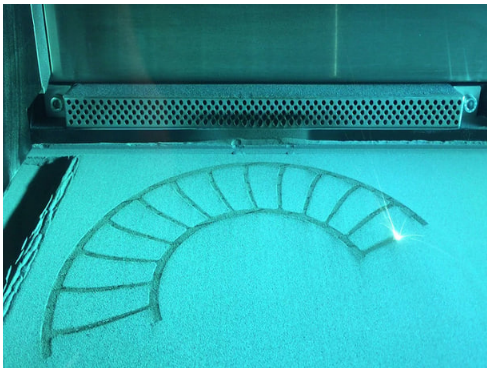


Figure 36: Selective laser sintering of a bracelet by Digimorphé

In a further evolution of her craft, Consuelo Keller has transformed her jewelry design into art[28]. Using Laser Powder Bed Fusion (LPBF), she creates intricate designs from titanium powder (Ti-6Al-4V) in the form of complex gyroid patterns, and from aluminum in different noise-based textures. In this process, the titanium is selectively melted in ultra-thin 0.03 mm layers using a computer-controlled laser, producing intricate, highly detailed art pieces. These artworks are presented in custom FDM-printed boxes, offering a simple yet effective way to personalize packaging for her creations.

Figure 37: Jewelry made into art by Digimorphé - Gyroides (left) - Noise (right)

Another example is Mimotech[29], a Swiss company that primarily uses UV-LIGA and Liga Plus (a hybrid of UV-LIGA with conventional machining) techniques to manufacture microcomponents for the Swiss watchmaking industry. Their production includes essential watch parts like escape wheels, anchors, and darts, as well as a variety of other microcomponents such as anti-backlash gears, springs, and cams. They also produce specialized parts like micro-sieves, micro-molds, and MEMS probes.

The watch industry requires extremely small, customized parts to facilitate the intricate movements of watches, making UV-LIGA an ideal process. It enables the creation of complex shapes without the need for additional surface treatment or improvements in material quality. Parts can be produced within extremely tight tolerances, even at very small dimensions, with consistently high quality. UV-LIGA is also well-suited to small and medium production series, as it uses a single reusable mask for each component type, making it both economical and highly competitive with traditional machining. This additive process typically utilizes pure metals rather than alloys, which is compatible with the requirements of the watchmaking industry. Mimotech offers a range of durable, nickel-based stainless materials, such as nickel-phosphorus, which is non-magnetic and ideal for regulating components within a watch. They also use LigaFlex™ (NiFe), which has exceptional elasticity for parts requiring flexibility, such as jumper springs, return springs, and date finger springs. For components like gear trains, pinions, cams, discs, and chronograph cores, hard nickel (Ni) is the material of choice.

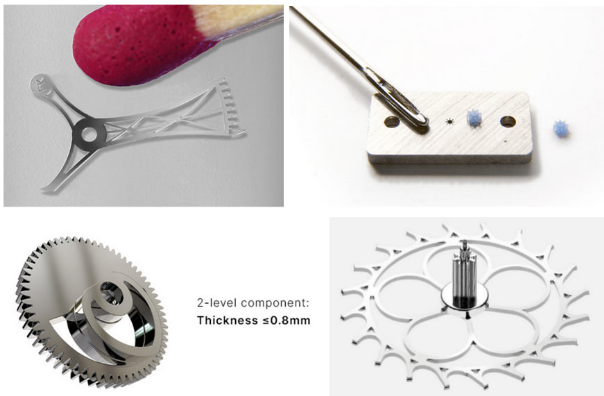


Figure 38: Different objects made by Mimotec

Rado[30], a Swiss watchmaking company within the Swatch Group, was one of the first luxury watchmakers to use Ceramic Injection Molding (CIM) for watch components. This technique is primarily used for mono-bloc cases and bracelets. CIM can produce highly complex geometries with exceptional precision, making it a perfect fit for the watchmaking industry's strict tolerance requirements. Ceramic parts made through CIM are often stronger and more durable than those produced by other methods, offering Rado's watches notable advantages.

The high-tech ceramics used by Rado offer lightness, scratch resistance, and skin-friendly qualities. These ceramics are created from high-purity powders with a uniform grain size, resulting in compact, high-density material with significant advantages over conventional ceramics. Additionally, ceramic is an excellent color carrier, allowing Rado to produce various color models through a single process.

Figure 39: High-tech ceramic bracelet by Rado

3D Precision SA[9], as referenced in section 2, uses Selective Laser Sintering (SLS) to produce parts across various industries, including luxury and watchmaking. SLS enables the production of complex parts that are challenging to manufacture with traditional material-removal processes, delivering rapid production times. These qualities cannot be overlooked when producing objects in those industries.

Figure 40: Objects made by 3D Precision SA

Panerai[31], another watchmaker under the Swiss luxury group Richemont, introduced the Lo Scienziato, a watch crafted with cutting-edge technology. The watch case was made using direct metal laser sintering (DMLS), also known as selective laser melting (SLM). DMLS is similar to SLS, with the difference that the laser fully fuses the metal powder, making their advantages for production very similar. By using titanium for this watch, Panerai achieved a 40% weight reduction compared to steel. And like many watchmakers, Panerai relies on FDM for prototyping, allowing quick and iterative testing and adjustments before final production.

Figure 41: Lo Scienziato by Panerai

8 Barriers to adoption and future potential of AM - written by Daniel

While it may seem that most companies use additive manufacturing in their production, this is not always the case. Indeed, we have also had the opportunity to approach companies like Bühler AG, that are a Swiss company based in Uzwill and that manufacture plant equipment specially for the food industry worldwide and who upon inquired about the use of AM within the company they informed us that it is "nowhere within the company".

Indeed they use AM manufacturing for rapid prototyping scaled down versions of machines that they develop during R&D using fused deposition modeling with consumer grade Prusa 3D printers. However when it comes to using additive techniques for manufacturing the pieces for machines, they very rarely use it. The estimations are that only about a 100 pieces are manufactured using additive techniques and these pieces are simply manufactured by an external supplier and are usually parts that cannot be achieved with traditional techniques because they need for example to have inner channels to allow for air or liquid flow.

Bühler highlighted, several interesting points concerning the lack of additive manufacturing within the company. Firstly, engineers do not think to use it because it's not integrated into their processes, yet without being used, it never becomes a standard consideration in design and manufacturing and as Bühler representative put it : "it is like chicken and the egg problem". The second point is that, even if engineers were to circumvent this initial mindset and were to think additive design, the initial investment required for buying the required material to be able to manufacture additively in-house is hard to justify to the management as it does not present any clear economical advantage. Lastly, given that Bühler operates in the food industry, when manufacturing new parts they need to make sure that every part that comes in contact with food has to be food safe which means for example that the surface has to be as smooth as possible. This is simply not possible with AM, as the layer-by-layer process results in a surface texture with ridges and irregularities, meaning that even if they manufacture the pieces using AM, post-processing will have to be done to the piece and depending on the geometry of the pieces it is not an easy process, for instance if the part has inner channels that are hard to reach.

Despite this, Bühler thinks that the degrees of freedom given by AM represent true potential and that it is simply a question of time and hopes that within 10 to 15 years it will be able to integrate AM more into their processes.[32]

9 Conclusion

In conclusion, this report highlights the growing role of additive manufacturing (AM) in the Swiss industry across sectors such as aerospace, luxury, healthcare, electronics, and more. Swiss companies are leveraging AM's capabilities to produce lightweight, complex, and customized components, driving innovation and improving efficiency.

Despite these advantages, challenges such as material limitations and integration into traditional processes make it difficult to rely on AM exclusively. Switzerland's leadership in AM patent applications relative to its economic size underscores its strong focus on R&D and technological advancements. Overcoming current barriers will be essential for broader adoption of AM in industrial practices. Its potential to enhance sustainability and precision ensures that AM will remain a pivotal force shaping the future of Swiss industry.

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