# How does 3D printing effect the way we produce and consume products in the future?

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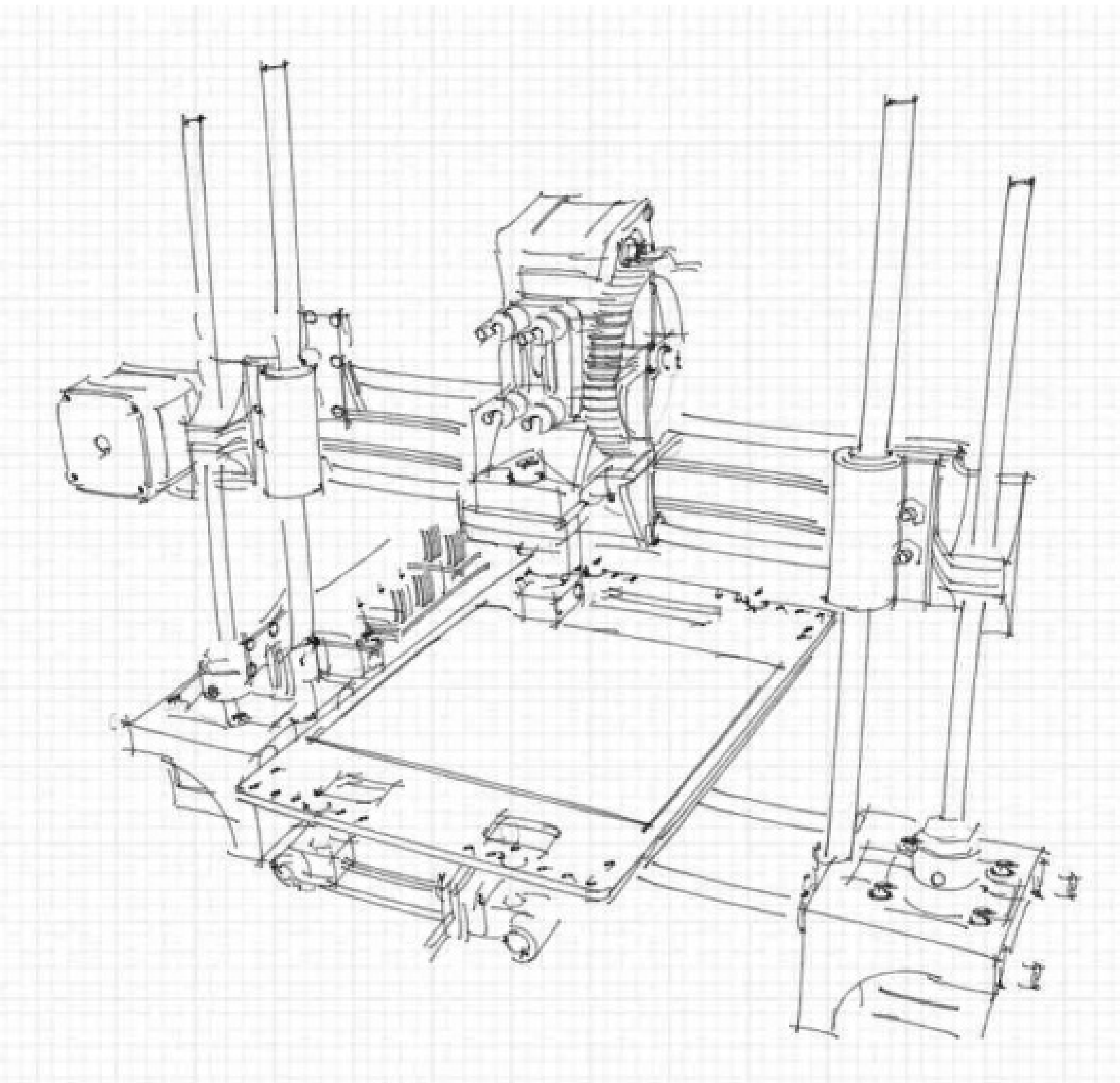
**2nd year - Product Design**

# History

In the late 1980′ the first 3D printing technologies became visible under the name Rapid Prototyping technologies. By using the method, the product development industry was much faster and more cost-effective in creating prototypes.
The first patent application was filed in 1986 for Charles Hull's SLA (stereolithography apparatus) machine, that he had invented 1983. Later on it was Hull who co-founded the "3D Systems Corporation", which is one of the largest organizations operating in the 3D printing sector today.
The first commercial Rapid Prototyping was the SLA-1 and was introduced in 1987 and first sold in 1988.
While SLA was the first starting point in the 3D printing industry, it wasn't the only one at that time. In 1987 Carl Deckard filed a patent for Selective Laser Sintering (SLS) and in 1989 that Scott Crump (co-founder of Stratasys Inc.) filed a patent for Fused Deposition Modelling (FDM). The FDM technology is represented by many entry-level machines that are based on the open source RepRap model.
A major rise in companies that filed patents and developed new technologies and methods for Rapid Prototyping was experienced in the early 1990's. Technologies as Ballistic Particle Manufacturing (BPM), Laminated Object Manufacturing (LOM), Solid Ground Curing (SGC) and "three dimensional printing (3DP) count as an example for those too.
The new technologies were still focused wholly on industrial applications and more companies conducted their R&D into more specific manufacturing e.g. for specific tooling and casting. As a result, new terminologies found their way into the sector: Rapid Tooling (RT), Rapid Casting and Rapid Manufacturing (RM). Later on, as commercial operations began to set up, the terminology evolved to a term for all of the processes and was called Additive Manufacturing (AM).
A few years later, the sector divided itself into two specific areas. The first was high end 3 D printing. Very expensive systems that were meant for producing highly engineered and complex parts of high value. This has today become visible in production applications across the medical and fine jewelry sector, the aerospace and automotive sector.
The other part was more focused on 3D printers that improved concept development and functional prototyping. Those machines were specifically being developed to be user- and office-friendly and were the kick start to today's desktop machines.
All in all, these machines were all very much for industrial applications.
That time can be acknowledged as the calm before the storm and in 2007 the first system under $10,000 was brought into the market by 3D Systems. Eventually, the product never hit the market as it was expected. As told from insiders in the industry the ultimate goal was to build a 3D printer for under $5,000 to open the 3D printing technology to a much wider audience.
The RepRap movement by Dr. Bowyer has its roots in the same year and showed a concept of an open source, self-replicating 3D printer, which was labeled as a phenomenon in the sector.
It wasn't until the beginning of 2009 that the first commercially available 3D printer, based on the RepRap concept hit the market. The BfB Rapman 3D printer, was closely followed by a printer from a team that was heavily involved in the development of RepRap, but departed from the open source philosophy to commercialize 3D printing as Makerbot Industries.
The RepRap phenomenon has given a rise to the new sector of commercial, entry-level 3D printers although it is focusing on creating a community around 3D printing and containing commercialization.

In 2012, the first alternative 3D printing processes were introduced at the lower side of the market. The B9Creator, using the DLP technology was released in June, followed by the stereolithography printer Form1 in December. Both printers were advertised and a huge success on Kickstarter (Crowdfunding Platform).
Due to the divergence of the market, there was room for significant advances at both the industrial level and the low market systems. A boost in awareness and popularity that was enabled by various mainstream media channels picking up on the technology led to a major boost in awareness and a growing maker movement.
In 2013, Stratasys acquired Makerbot which was one of the most notable acquisitions in the industry.
3D printing has been called as the 2nd or even 3rd Industrial Revolution by some and its impact on the industrial sector and a tremendous potential for the future and consumers cannot be denied.



## How does it work?

The 3D printing process has its starting point in a digital 3D model, which can be created choosing from a variety of various software programs. 3D CAD (Computer-aided drafting) are used in the industry and way simpler and more accessible programs are being offered for consumers.
An existing object can also be scanned by a 3D printer and then imported into 3D software. A CAD designed object is then being sliced into layers and converted into a 3D printer readable file by the 3D printer's specific software. The processed material is then going to be layered matching to the design and the process.
As stated there are various types of 3D printers that involve a different technology and process different materials.Thus, it is important to understand the basic limitation in 3D printing. Learning the use of one, doesn't mean you can use the other, there is no solution that fits every section of the technology. Some 3D printers process polymer resin materials and use a laser to solidify resin in thin layers, others use heat to melt powdered materials such as plastic, nylon, ceramic and metal. Some even are processing similar to the inkjet printer, fine droplets of a superior material than ink that is combined with a binder to create small layer and eventually an object.
The most common processing technology nowadays might be the extrusion which is employed by a variety of entry-level 3D printers. The process extrudes melted plastics, most common PLA and ABS, to form layers and create the designed shape. The material is here injected as filament.

Stereolithography (SL) print on the left vs. extrusion (FFF) on the right

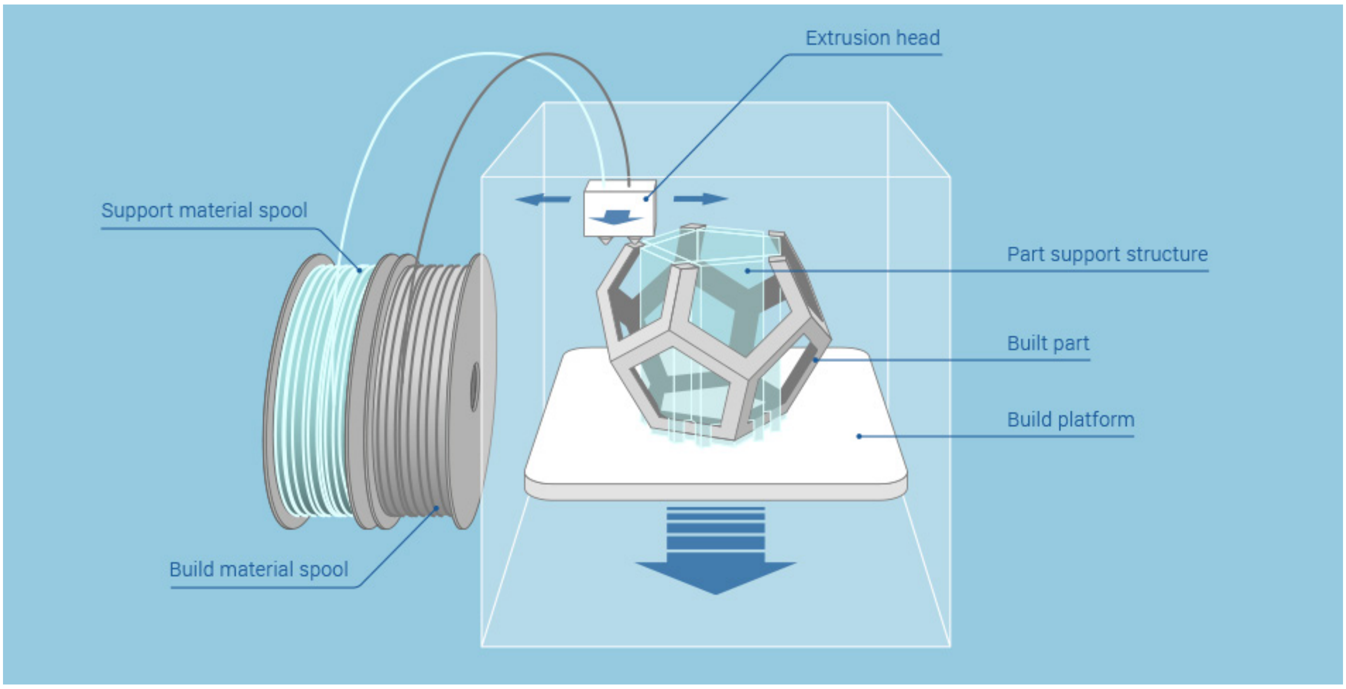
## Extrusion

As stated above the extrusion of a thermoplastic material is the most common and recognizable process in the 3D printing sector. It exists since the early 1990's under the name Fused Deposition Modelling (FDM) and is quite known in the industry and a trade name registered by Stratasys. FDM has been originally developed by Scott Crump who then started Stratasys to commercialize his invention. Due to the patents held by Stratasys the Fused Filament Fabrication (FFF) process has emerged. It is a more basic form of the FDM process and is being utilized by the entry-level 3D printers that entered the market in 2009. Extrusion technology has been utilized by the earliest RepRap printers and all following machines, open source and commercial. The process works by melting plastic filament that is deposited by a heated extruder and one layer at a time. The layers are placed onto a build platform (usually heated) and each layer hardens as it cools down and bonds with the previous layer eventually creating the object that has been supplied as a 3D model to the printer.

The most common materials used in the process by entry-level printers are PLA (Polylactic acid) and ABS (Acrylonitrile butadine styrene). Though, ABS and PLA are the most common, there is an increasing number of thermoplastic composites that are available as filament. Thermoplastics mixed with metals, wood, carbon fiber and more.

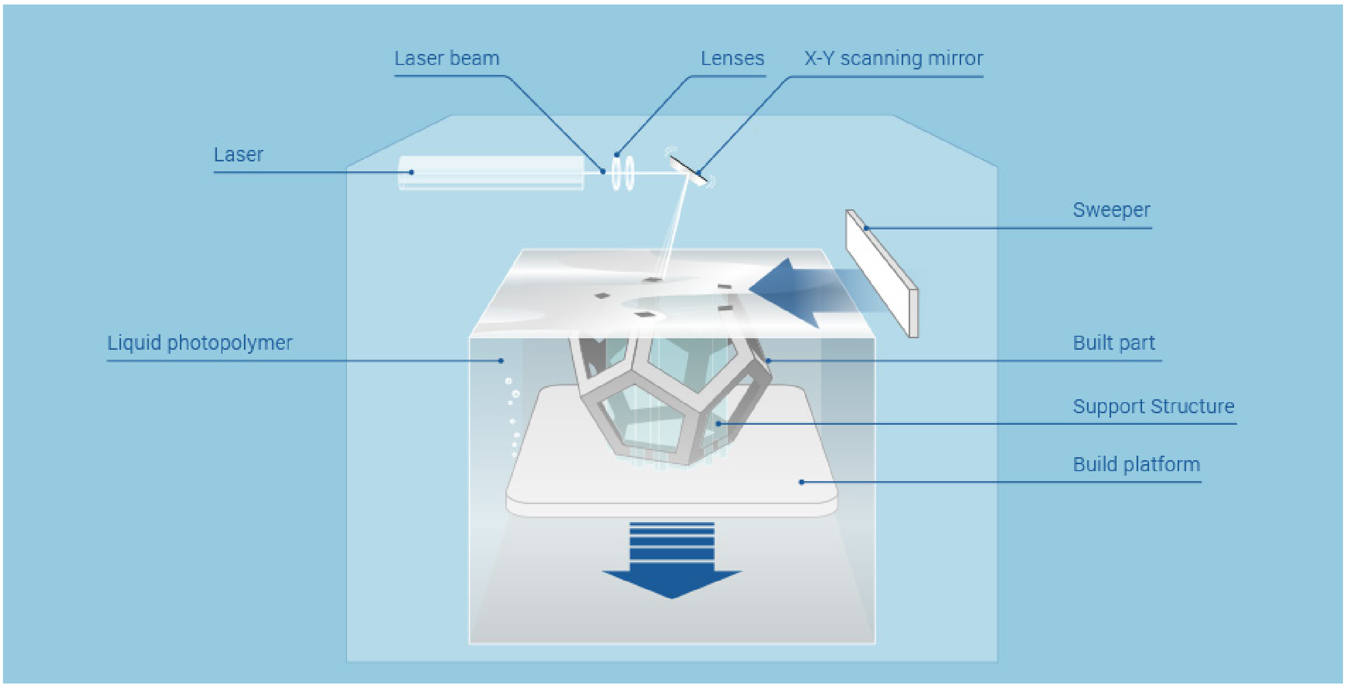
Both the FDM and the FFF method need support structures for overhanging geometries. A support can be printed as breakaway or water-soluble structure. Breakaway support needs to be removed manually by "breaking" it off the 3D printed object. Support printed with a water-soluble material can be easily washed away after the print is finished.

With the extrusion process, layer-to-layer adhesion can be problem, causing the objects to not be watertight and it can be slow for some geometries. Post-processing is sometimes needed and can resolve some issues, using Acetone to make the object watertight as an example.



Stereolithography (SL or SLA)

This 3D printing process is laser-based and works with photopolymer resins that react to the laser and form a solid. SL was the first 3D printing process that has been commercialized and it is a more complex process. The resin is being held in a vessel with a movable platform inside and a laser beam that is being guided by the X- and Y-axis and according to the data supplied to the printer on the surface of the resin. The laser hardens the resin and as soon as a layer has been completely hardened, the platform within the vessel moves down the Z-axis by a fractional part. Layer after layer is being hardened until the object is completed and the platform is being moved out of the vessel to remove the object.
To fully harden the resin, the object needs to be cleaned and cured by subjecting it to intense light (e.g. in an oven like UV light box).
The SL process does in some cases need support structures especially involving undercuts and overhangs. The structures need to be manually removed after printing.
Due to its fine surface finish, SL is considered to be one of the most accurate 3D printing processes, although limitation is caused by the post-processing necessity and the stability of the materials.



# Global Effects & Value

It is not a secret that 3D printing has already changed sectors in manufacturing and has a lot of potential to change the way we consume and produce as well as effecting our global economy.
In terms of manufacturing, 3D printing stimulates new ways of thinking considering social, environmental and economic aspects. A key factor here is the relationship between production and the end user or consumer. 3D printing has the potential to reduce the current supply chain restrictions and due to the high value of customization, it has the ability to engage consumers by producing small batches of a product on demand which could cause a reduction in inventories and stock piling.
A wider adoption could bring 3D printers to basically every community or even household and would eradicate e.g. the shipping of spare parts from the other side of the globe as there would be a chance to 3D print them on site. This would have impact on how small and large businesses and consumers interact and engage on a global scale.
To go a step further and ask what could happen if 3D printing would be adopted worldwide. A shift between production and distribution from the model that exists today to a localized on-demand based production that happens on site could reduce the imbalance between import and export countries. On top of that, 3D printing could have the impact and create new industries and new professions (is already happening today) and not just related to the production of 3D printers. New product designers, printer operators, material suppliers will emerge and there are existing services in many cities that offer their machines as “rent” to let your own objects be printed. The impact 3D printing could have on the developed world is huge. Talking about its use in the medical sector or the shifting of age demographics that makes it an aged society which has been a concern in relation to work force and production in general. The impact on the developing world is rather debatable. An upside would be lowered manufacturing costs by using recycled and regional materials, but a downside the reduction of manufacturing jobs, which could hit certain developing countries severely.

3D printing comes with more than a few advantages. It allows to customize products to maximize the value and individual use of a product in a specific situation. This means that various products can be produced without any additional process cost. This will on a bigger scale reduce our mass production of products no one might find use for.
By designing models for the 3D printing process, new and more complex objects can be designed by the use of a modelling software and with the technology of a 3D printer also printed. Those levels of complexity cannot be matched by traditional methods.
In terms of sustainability and environmentally friendly, 3D printing is emerging as an energy-efficient technology that can contribute to a more sustainable future. In many ways it is more efficient in creating less waste by utilizing up to 90% of standard materials and using recycled materials in the process. In the corporate landscape 3D printing contributes greatly to reduce waste in manufacturing by improving development processes.
Nonetheless, it is not to say that 3D printing is overly positive in terms of environmentally friendly and more sustainable processing. For example, in some 3D printing processes the printed object is smaller than the deposited material, support material that will be thrown away, the dissolving of chemicals (fumes that can’t recycled) etc.
Overall it is to say that sustainability and 3D printing not always have to get along. There are printers existing without special disposal of build or post-processing material, no disposable build platforms and 100% recyclable build material.

## Closing remarks

As a prospective designer, I find 3D printing equal to a lot of new possibilities especially for rapid prototyping when designing a product. When quality doesn't matter so much, but a rough form of a design to test it as an actual object that can be iterated quickly.
Another upside of the technology is its huge community that goes cross-disciplinary around the world. It is only a matter of time that entry-level printers will get more advanced and create even more possibilities for the consumer to download a file of a part that is broken and print it out. I see a lot of potential in the technology and am curious what the fast progression of technology brings us in the coming years.
During my studies I want to experiment with a DIY-3D printer to understand the assembly of the machine. This will lead to a better understanding of the functions and problems that will occur during the use. Furthermore, I want to find the boundaries of such a printing by modifying it and experimenting with all sorts of materials and techniques in printing.

The very first 3D printer by Chuck Hull

Today's DIY Kossel Delta 3D printer

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