Short Introduction to the AM Technology

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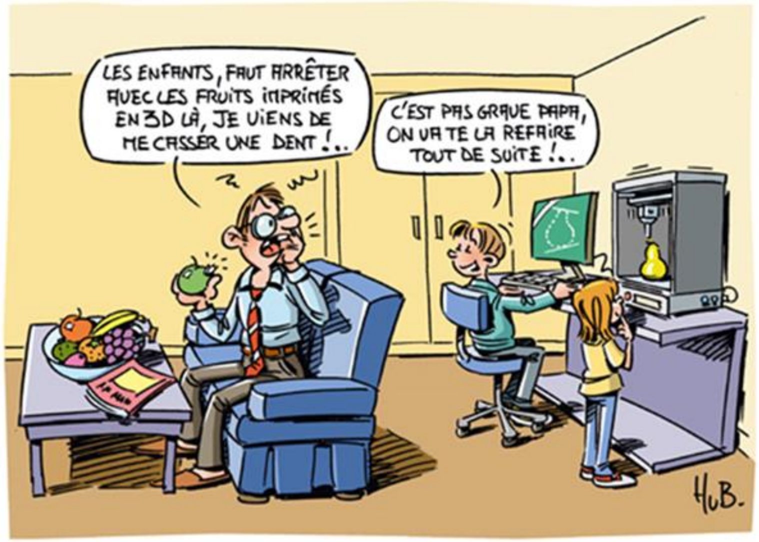
INTRODUCTION



Additive Manufacturing

Short introduction to the technology

INTRODUCTION:

WHAT IS IT:

Additive Manufacturing by ASTM (American Society for Testing and Materials): “Process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining”

NAMING:

Rapid Prototyping: This term was used in the beginning of the professional use of the technology because the main application was the manufacturing of prototypes, mock ups and sample parts.

Todays most common terminologies are:

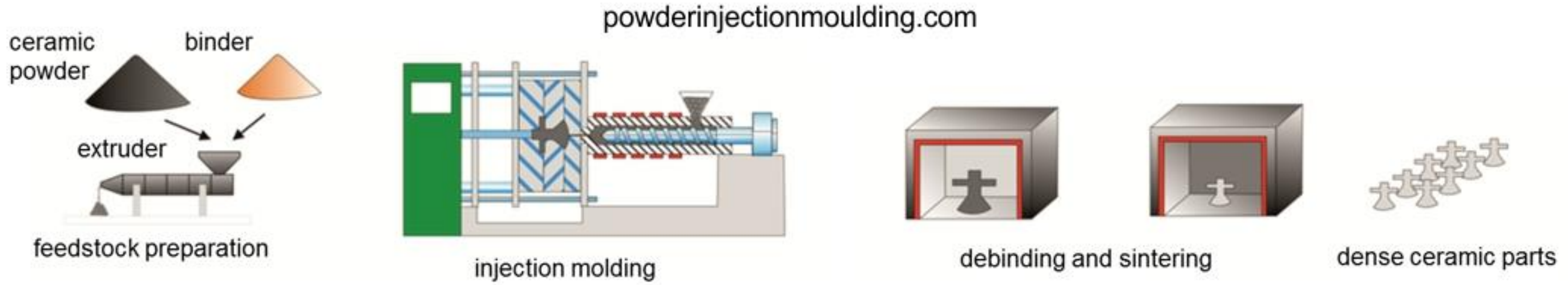
ADDITIVE MANUFACTURING (AM) or **3D PRINTING**

“I GUESS THE TWO DEFINITIONS ARE VALID”

INTRODUCTION:

But:
Additive Manufacturing (AM) concerns as well some other technologies

Powder Injection Moulding (PIM), comprising Metal Injection Moulding (MIM) and Ceramic Injection Moulding (CIM), is an advanced manufacturing technology for the production of complex, high volume net-shape components.



INTRODUCTION:

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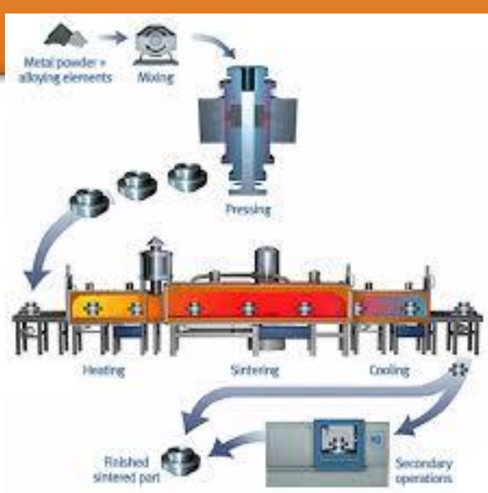
Powder sintering is the process of blending fine powdered materials, pressing them into a desired shape or form (compacting), and then heating the compressed material in a controlled atmosphere to bond the material (sintering). The powder metallurgy process generally consists of four basic steps: powder manufacture, powder blending, compacting, and sintering. Compacting is generally performed at room temperature, and the elevated-temperature process of sintering is usually conducted at atmospheric pressure. Optional secondary processing often follows to obtain special properties or enhanced precision.



INTRODUCTION:

But:
Additive Manufacturing (AM) concerns as well some other technologies

Hybrid (Additive and Subtractive manufacturing)
Laser Cladding Process with traditional machining
Laser Cladding Process description
In laser cladding, the laser beam is defocused on the workpiece with a selected spot size. The powder coating material is carried by an inert gas through a powder nozzle into the melt pool. The laser optics and powder nozzle are moved across the workpiece surface to deposit single tracks, complete layers or even high-volume build-ups.

History of 3D Printing:

1980-2000

- 80 — First patent application for RP technology was filed by a Dr Kodama, in Japan, in May 1980.
- 86 — The first patent was issued to Charles Hull for stereolithography apparatus (SLA).
- 87 — SLA-1, was introduced.
- 89 — SLS patent was issued to Carl Deckard.
- 90 — EOS sold its first 'Stereos' system.
- 92 — FDM patent was issued to Stratasys.
- 96 — Sanders Prototype (later Solidscape) and ZCorporation were set up.
- 97 — Arcam was established.
- 98 — Objet Geometries launched.

The earliest 3D printing technologies first became visible in the late 1980's, at which time they were called Rapid Prototyping (RP) technologies. This is because the processes were originally conceived as a fast and more cost-effective method for creating prototypes for product development within industry.

1983 Charles Hull invents Stereolithography (SLA) Charles 'Chuck' Hull was the first to develop a technology for creating solid objects from a CAD/CAM file, inventing the process he termed 'stereolithography' in 1983. SLA works by curing and solidifying successive layers of liquid photopolymer resin using an ultraviolet laser. The field that came to be known variously as 'additive manufacturing', 'rapid prototyping' and '3D printing' was born.

2000-

- 00 — MCP Technologies introduced the SLM technology.
- 02 — EnvisionTec was founded.
- 04 — Dr Bowyer conceived the RepRap concept of an open source, self-replicating 3D printer.
- 05 — ExOne was established as a spin-off from the Extrude Hone Corporation.
- 07 — The first system under $10,000 from 3D Systems.
- 08 — Desktop Factory was acquired by 3D Systems.
- 09 — The first commercially available 3D printer – in kit form, based on the RepRap concept.
- 12 — Alternative 3D printing processes were introduced at the entry level of the market.
- 13 — Stratasys acquires Makerbot.

Additive Manufacturing

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The AM value chain consists of five steps – AM system providers are active in most areas of the value chain

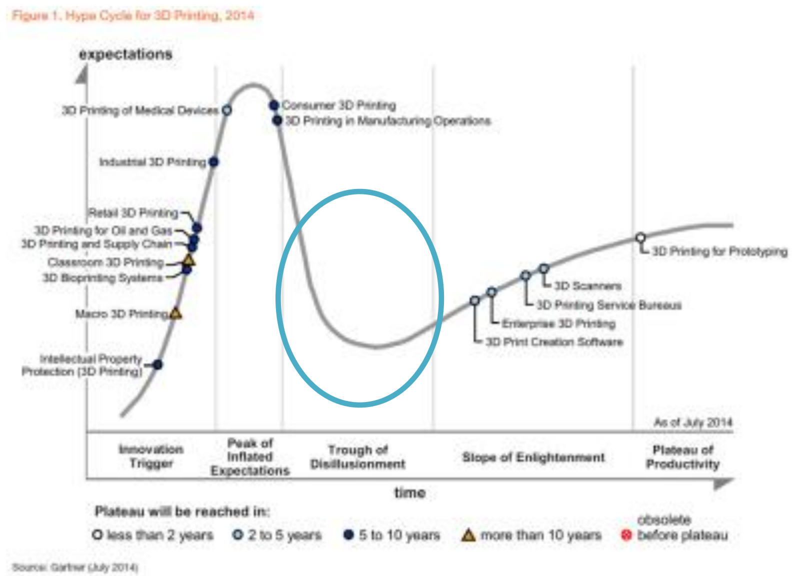
Material	System	Software	Application design	Production
Mainly: Creation of metal powder > Powder with high purity and a very narrow distribution of the granular size (usually 30µm) > Hard to get from large providers due to small orders >Usually sold by AM system providers	>Usually stand-alone powder bed fusion systems > System providers with low levels of vertical integration, standard components usually made by contract manufacturers > Providers integrate components system & software	>Differentiation between process control and enhancement software > Process control from system prov. > Add-on software such as automatic support generation, design optimization By specialized companies	> Support for end customers > Can be complex and demanding > Done by system providers, software developers and/or service providers > Not every service provider is able to design applications	>Different production scenarios: - Large OEM - Contract manufacturer/service provider - Specialized part manufacturer > Production is normally not done by AM System providers
Players: > Höganäs > TLS Technik > San > etc.	Players: > EOS > SLM Solutions > Concept Laser > etc.	Players: > Materialise > netfabb > With > etc.	Players: > 3T PRD > Concept Laser > EOS > etc.	Players: > 3T PRD > Janke Engin. > Layer Wise > etc.

"3D PRINTING'S POTENTIAL TO REVOLUTIONIZE MANUFACTURING IS QUICKLY BECOMING A REALITY."

Global 3D printing market

Estimates and forecast of market value to 2018, in USD

Category	2013 estimates	2014 forecast	2018 forecast
Total	$2.5b	$3.8b	$16.2b

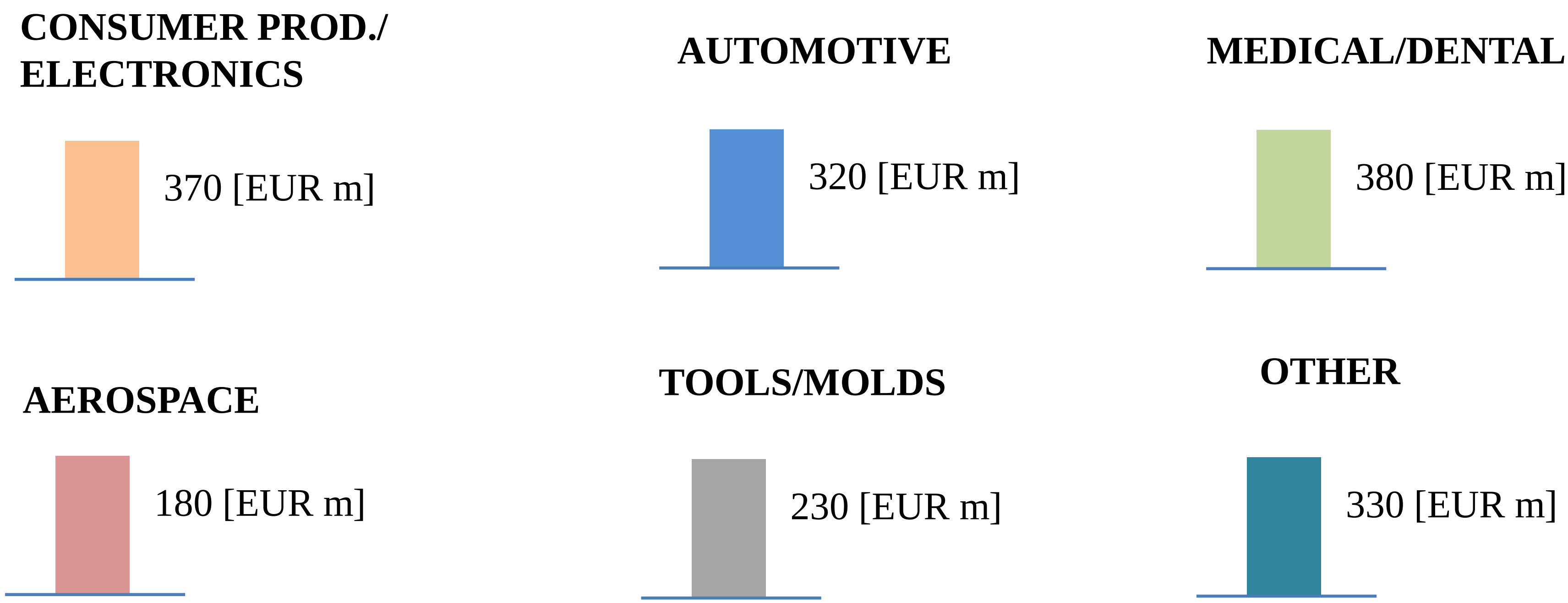


In the frame of the Horizon 2020 project many European and National Networks are founded to see the potential of the technology.

President Obama announced his plan to invest $1 billion to catalyse a national network of up to 15 manufacturing innovation institutes… Pilot institute : National Additive Manufacturing Innovation Institute (NAMII) with a budget of 30 M$ in 2013

As of today, AM applications have been developed in various industries

AM Revenues per industry segment (2012)



Source: Wohlers Associates; Expert interviews; Roland Berger

Advantages:

Design complexity and freedom:
The advent of 3D printing has seen a proliferation of products (designed in digital environments), which involve levels of complexity that simply could not be produced physically in any other way. While this advantage has been taken up by designers and artists to impressive visual effect, it has also made a significant impact on industrial applications, whereby applications are being developed to materialize complex components that are proving to be both lighter and stronger than their predecessors.

Speed:
You can create complex parts within hours , with limited human resources. Only machine operator is needed for loading the data and the powder material, start the process and finally for the finishing. During the manufacturing process no operator is needed.

Customisation
3D printing processes allow for mass customisation — the ability to personalize products according to individual needs and requirements. Even within the same build chamber, the nature of 3D printing means that numerous products can be manufactured at the same time according to the end-users requirements at no additional process cost.

Tool-less
For industrial manufacturing, one of the most cost-, time- and labour-intensive stages of the product development process is the production of the tools. For low to medium volume applications, industrial 3D printing — or additive manufacturing — can eliminate the need for tool production and, therefore, the costs, lead times and labour associated with it. This is an extremely attractive proposition, that an increasing number or manufacturers are taking advantage of. Furthermore, because of the complexity advantages stated above, products and components can be designed specifically to avoid assembly requirements with intricate geometry and complex features further eliminating the labour and costs associated with assembly processes.

Extreme Lightweight design
AM enable weight reduction via topological optimization

Advantages:

Sustainable / Environmentally Friendly

3D printing is also emerging as an energy-efficient technology that can provide environmental efficiencies in terms of both the manufacturing process itself, utilising up to 90% of standard materials, and, therefore, creating less waste, but also throughout an additively manufactured product's operating life, by way of lighter and stronger design that imposes a reduced carbon footprint compared with traditionally manufactured products.

No storage cost

Since 3D printers can "print" products as and when needed, and does not cost more than mass manufacturing, no expense on storage of goods is required.

Increased employment opportunities

Widespread use of 3D printing technology will increase the demand for designers and technicians to operate 3D printers and create blueprints for products.

Disadvantages:

Questionable Accuracy
3D printing is primarily a prototyping technology, meaning that parts created via the technology are mainly test parts. As with any viable test part, the dimensions have to be precise in order for engineers to get an accurate read on whether or not a part is feasible. While 3D printers have made advances in accuracy in recent years, many of the plastic materials still come with an accuracy disclaimer. For instance, many materials print to either +/- 0.1 mm in accuracy, meaning there is room for error.

Support material removal
When production volumes are small, the removal of support material is usually not a big issue. When the volumes are much higher, it becomes an important consideration. Support material that is physically attached is of most concern.

Limitations of raw material
At present, 3D printers can work with approximately 100 different raw materials. This is insignificant when compared with the enormous range of raw materials used in traditional manufacturing. More research is required to devise methods to enable 3D printed products to be more durable and robust.

Considerable effort required for application design and for setting process parameters
Complex set of around 180 material, process and other parameters and specific design required to fully profit from the technology

Material cost:
Today, the cost of most materials for additive systems (Powder) is slightly greater than that of those used for traditional manufacturing .

Material properties:
A limited choice of materials is available. Actually, materials and there properties (e.g., tensile property, tensile strength, yield strength, and fatigue) have not been fully characterized. Also, in terms of surface quality, even the best RM processes need perhaps secondary machining and polishing to reach acceptable tolerance and surface finish.

Disadvantages:

Intellectual property issues
The ease with which replicas can be created using 3D technology raises issues over intellectual property rights. The availability of blueprints online free of cost may change with for-profit organizations wanting to generate profits from this new technology.

Limitations of size
3D printing technology is currently limited by size constraints. Very large objects are still not feasible when built using 3D printers.

Cost of printers
The cost of buying a 3D printer still does not make its purchase by the average householder feasible. Also, different 3D printers are required in order to print different types of objects. Also, printers that can manufacture in color are costlier than those that print monochrome objects.

Unchecked production of dangerous items
Liberator, the world's first 3D printed functional gun, showed how easy it was to produce one's own weapons, provided one had access to the design and a 3D printer. Governments will need to devise ways and means to check this dangerous tendency.

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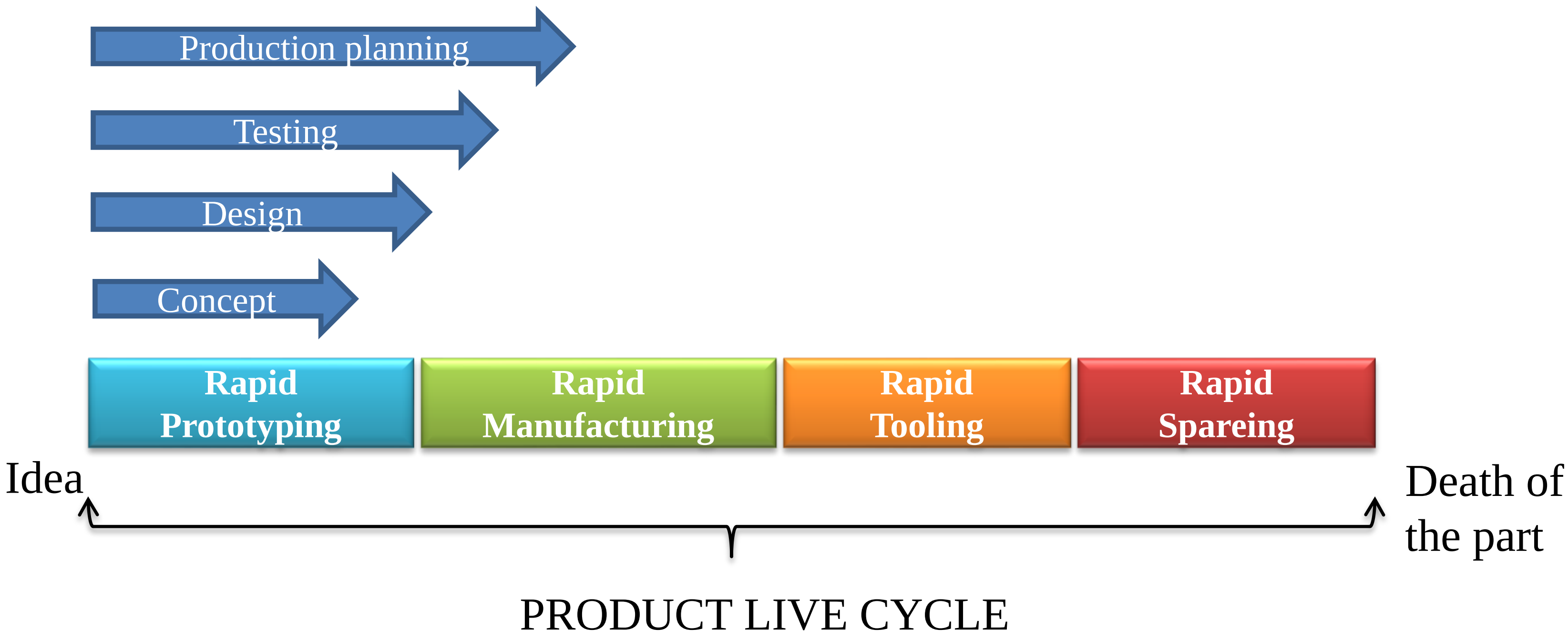
Over the last years AM technology became valid for the hole lifecycle of a product



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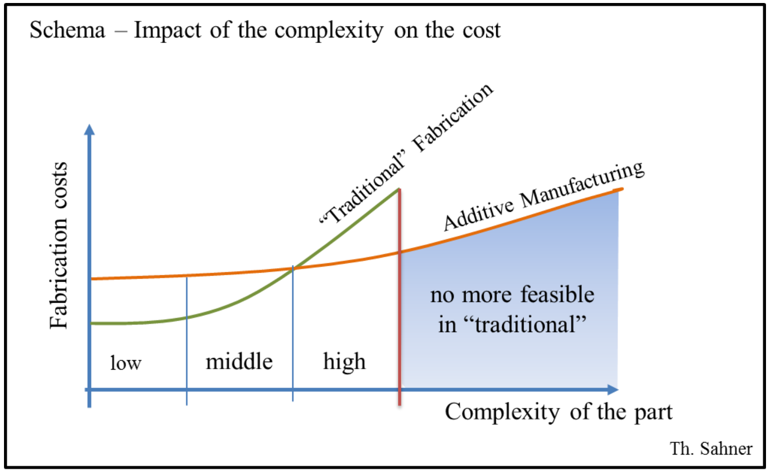

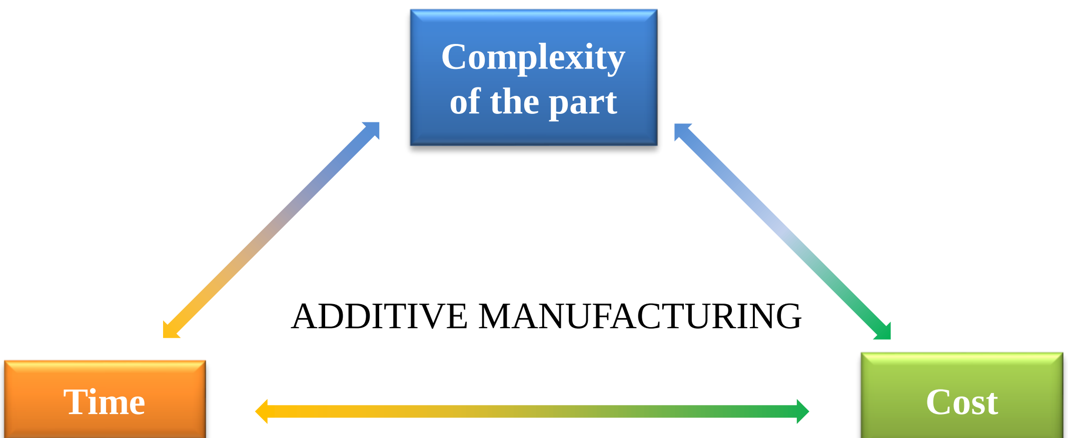

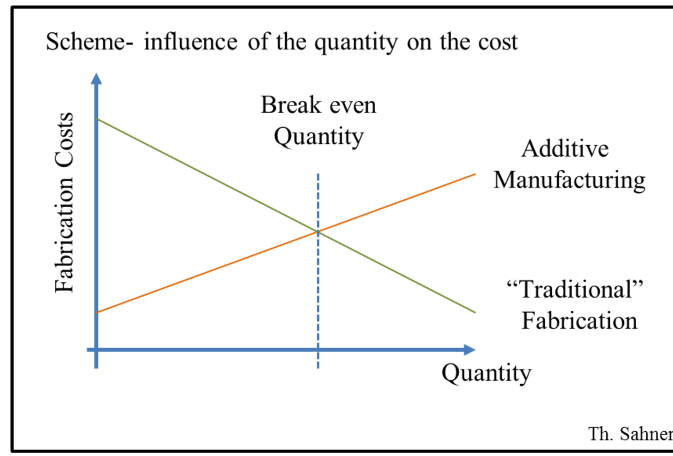

Conventionally designed and produced cast steel nacelle hinge bracket for an Airbus A320 (top) and optimised titanium version of the nacelle hinge bracket made by additive manufacturing technology.

"SEE THE DIFFERENCE IN THE CONCEPTION OF THE PART"

Commercial airplanes can have up to several hundred seed belt buckles. A standard buckle weight is around 155g in St. and 120g in Al. With AM the weight was reduced to 68 g in Ti.
Saving over the lifetime of an A380:
Fuel: 3.300.000 l
CO_2 emission: 0,74Mt

Part manufacturing

- Advantage for sport shoe manufacturer is the data exchange between development and production over night. e.g. ADIDAS with the development in Germany an the production side in China.

Example for medical application

- 3D printing can be personalised
- Giving back life quality

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The assembly can be personalised and printed in one process.

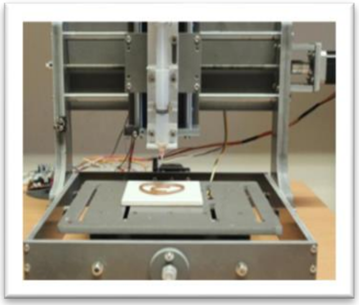
NASA has carried out parabolic flights that mimic microgravity to test "additive manufacturing“

Many other applications for printing on-site

The fast packaging solution, French postal

The part is scanned in the post office and a cutter is cutting the different layer on site.

For her Spring/Summer 2015 collection, presented in Paris, Dutch fashion designer Iris van Herpen unveiled 3D-printed garments and accessories "grown" that explores the interplay of magnetic forces. Her inspiration of this collection came after she visited CERN, and the Large Hadron Collider

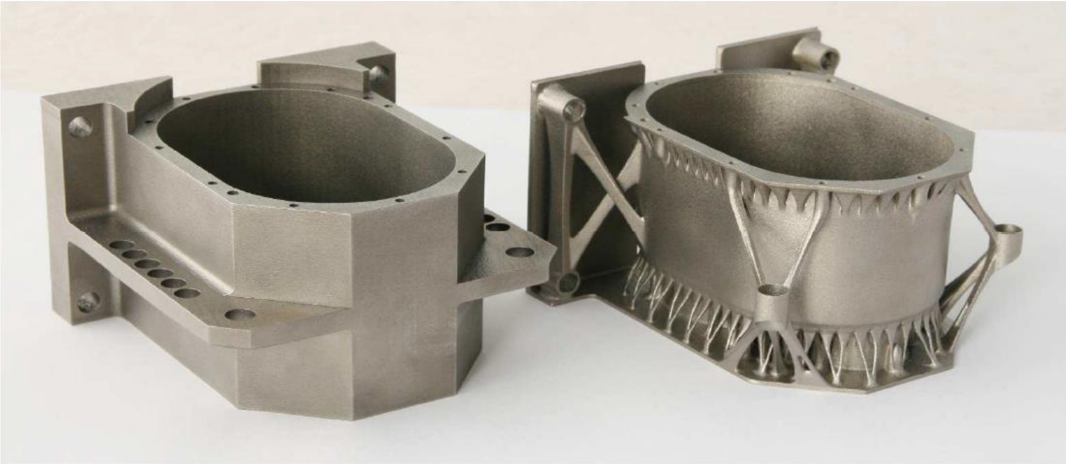


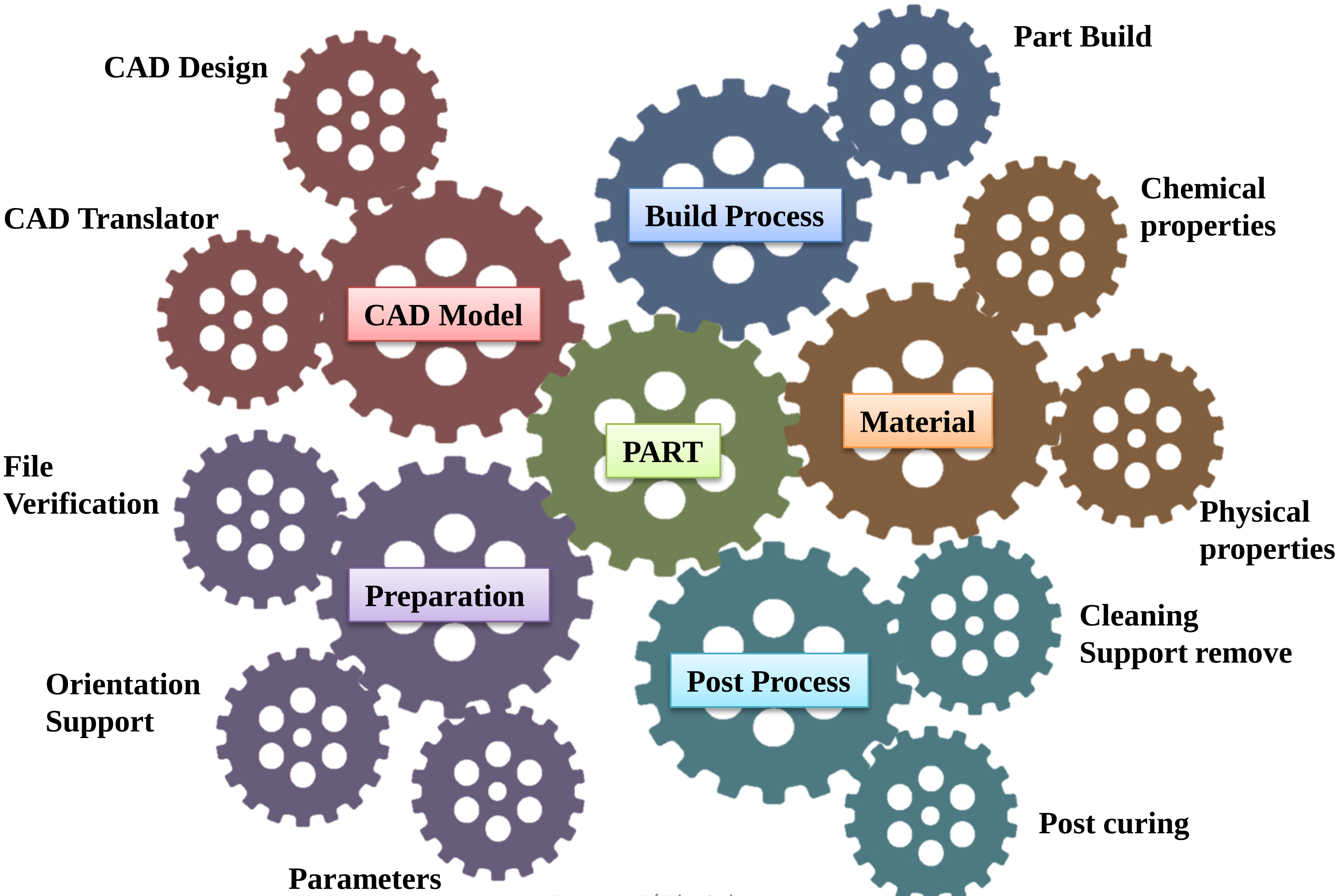

Chocolate printer

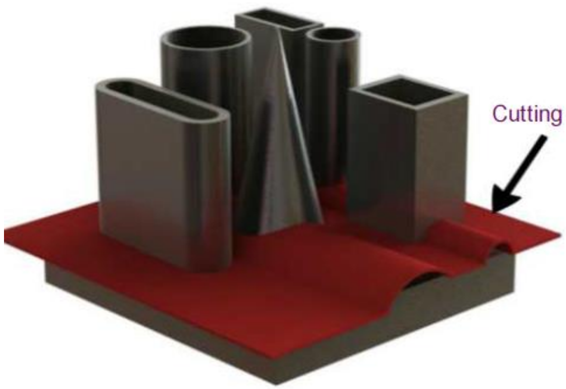
Figure Print

Concrete Printer

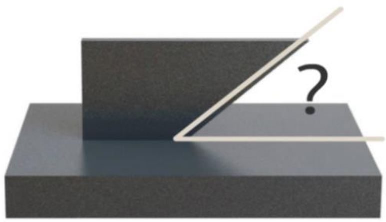
APPLICATION DESIGN

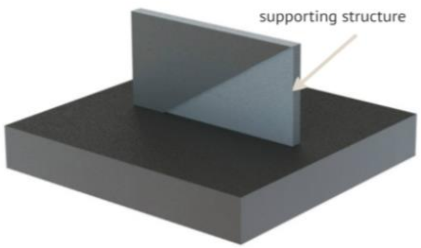


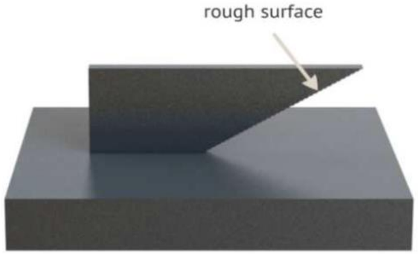

CAD Design
CAD Translator
CAD Model
File Verification
Preparation
Orientation Support
Parameters
Build Process
Part Build
PART
Material
Chemical properties
Physical properties
Post Process
Cleaning Support remove
Post curing



Easy Cutting Path

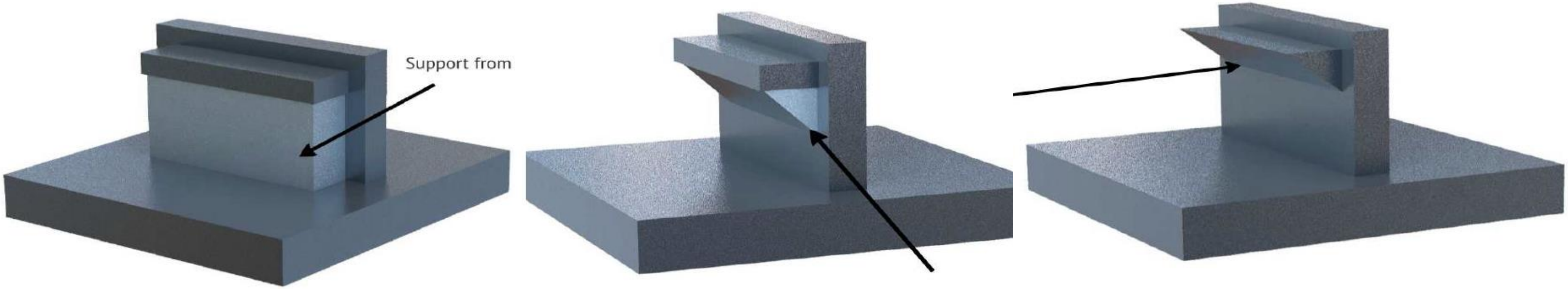


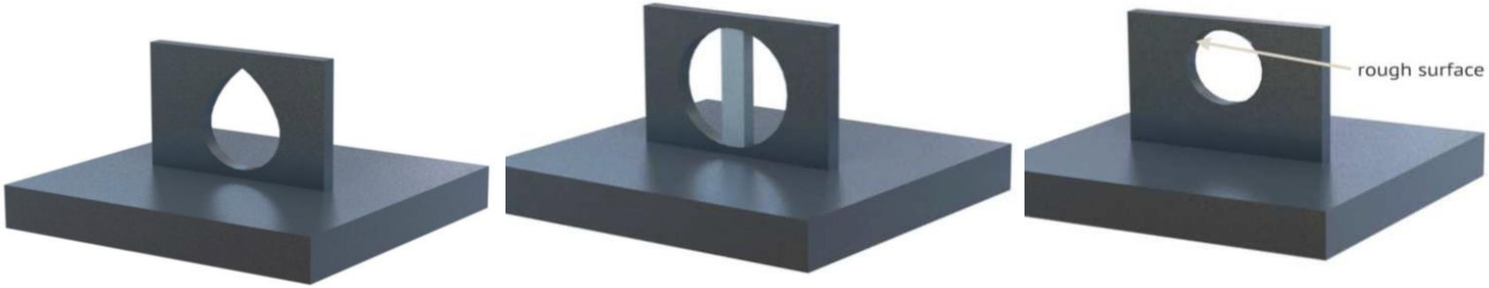




Angled surfaces

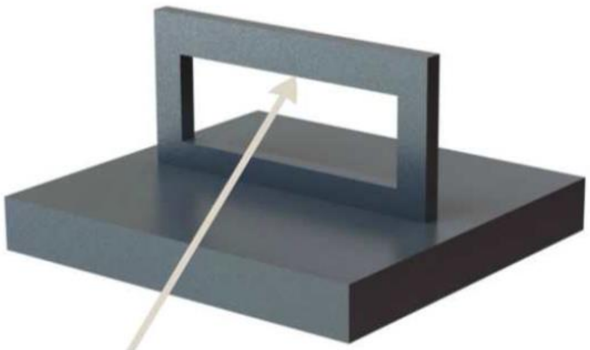
Supports

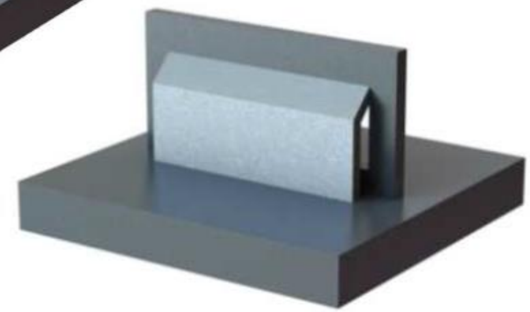


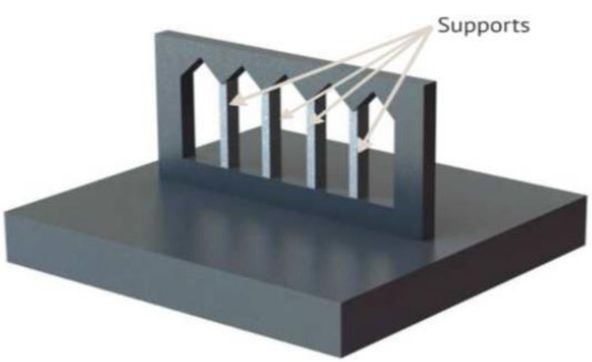


Holes

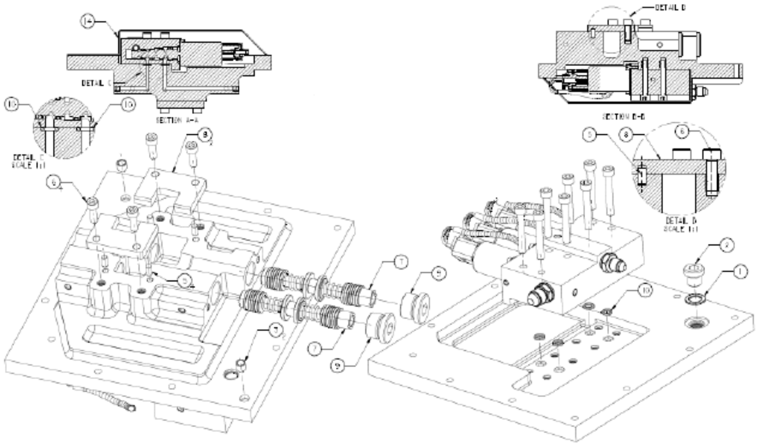
Down Ward Facing Surfaces

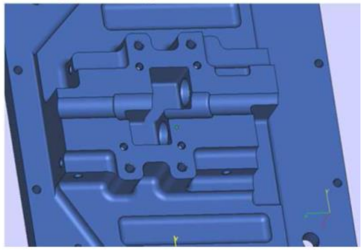






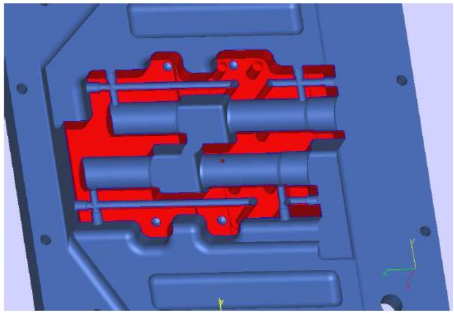
Increased Performance of a Hydraulic Actuator



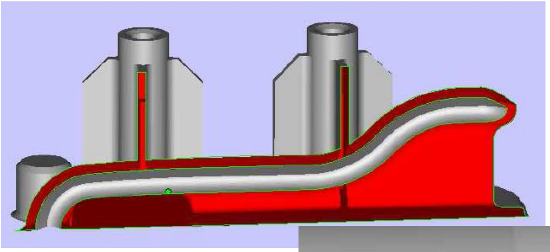


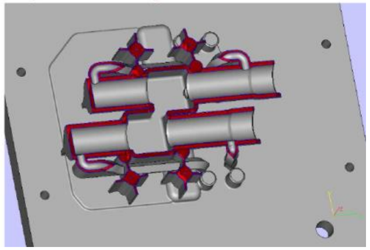
Original design

Building cavities



Redesign of supports and channels
With new channel shape





Optimized design

PROCESSES

Major AM processes based on Hopkinson and Dickens' classification

AM Processes

Liquid Based

- Stereolithography
- Jetting Systems
- Direct Light Processing

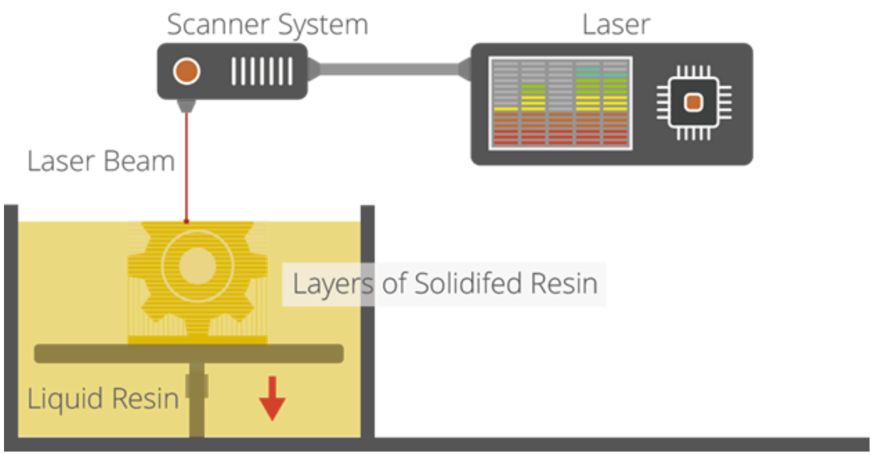
Powder Based

- Selective Laser Sintering
- Three-Dimensional Printing
- Fused Metal Deposite Systems
- Electron Beam Melting
- Selective Laser Melting
- Selective Masking Sintering
- Selective Inhibition Sintering
- Electro photographic Layered Manufacturing
- High Speed Sintering

Solid Based

- Fused Deposition Modelling
- Sheet Stacking Technologies

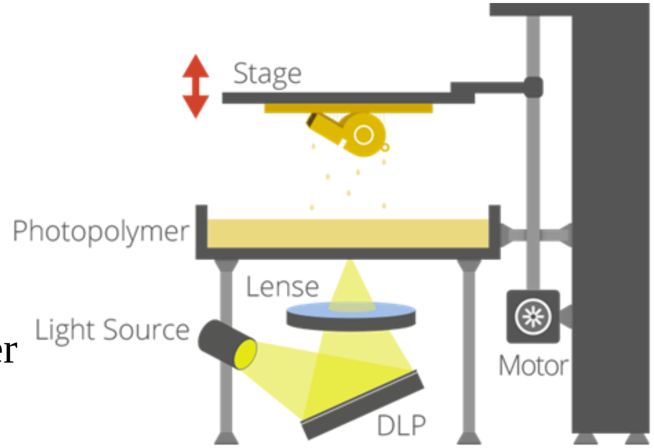
Stereolithography (SL)



is widely recognized as the first 3D printing process; it was certainly the first to be commercialised. SL is a laser-based process that works with photopolymer resins, that react with the laser and cure to form a solid in a very precise way to produce very accurate parts.
It is a complex process, but simply put, the photopolymer resin is held in a vat with a movable platform inside. A laser beam is directed in the X-Y axes across the surface of the resin according to the 3D data supplied to the machine (the .stl file), whereby the resin hardens precisely where the laser hits the surface. Once the layer is completed, the platform within the vat drops down by a fraction (in the Z axis) and the subsequent layer is traced out by the laser. This continues until the entire object is completed and the platform can be raised out of the vat for removal. Because of the nature of the SL process, it requires support structures for some parts, specifically those with overhangs or undercuts. These structures need to be manually removed. In terms of other post processing steps, many objects 3D printed using SL need to be cleaned and cured. Curing involves subjecting the part to intense light in an oven-like machine to fully harden the resin. Stereolithography is generally accepted as being one of the most accurate 3D printing processes with excellent surface finish. However limiting factors include the post-processing steps required and the stability of the materials over time, which can become more brittle.

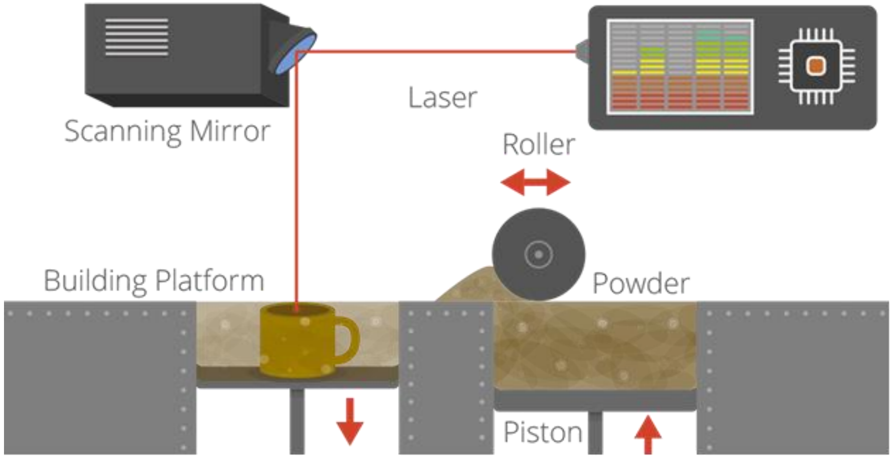
Digital Light Processing (DLP)

is a similar process to Stereolithography in that it is a 3D printing process that works with photopolymers. The major difference is the light source. DLP uses a more conventional light source, such as an arc lamp, with a liquid crystal display panel or a deformable mirror device (DMD), which is applied to the entire surface of the vat of photopolymer resin in a single pass, generally making it faster than SL.



Also like SL, DLP produces highly accurate parts with excellent resolution, but its similarities also include the same requirements for support structures and post-curing. However, one advantage of DLP over SL is that only a shallow vat of resin is required to facilitate the process, which generally results in less waste and lower running costs.

Laser sintering and laser melting (SL, SLM)



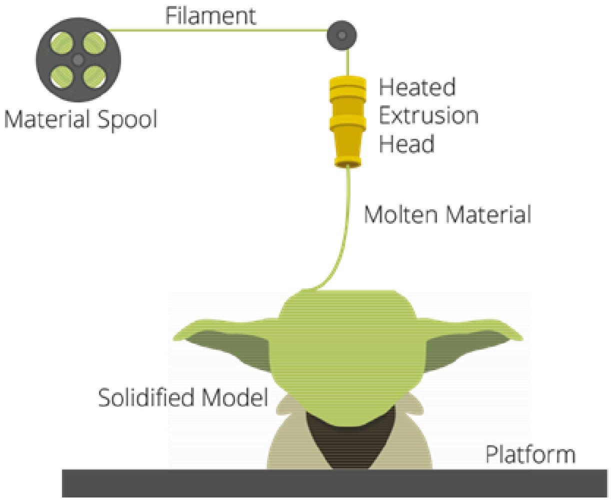
are interchangeable terms that refer to a laser based 3D Printing process that works with powdered materials.
The laser is traced across a powder bed of tightly Compacted powdered material, according to the 3D data fed to the machine, in the X-Y axes.
As the laser interacts with the surface of the powdered material it sinters, or fuses, the particles to each other forming a solid. As each layer is completed the powder bed drops incrementally and a roller smoothes the powder over the surface of the bed prior to the next pass of the laser for the subsequent layer to be formed and fused with the previous layer.
The build chamber is completely sealed as it is necessary to maintain a precise temperature during the process specific to the melting point of the powdered material of choice. Once finished, the entire powder bed is removed from the machine and the excess powder can be removed to leave the 'printed' parts. One of the key advantages of this process is that the powder bed serves as an in-process support structure for overhangs and undercuts, and therefore complex shapes that could not be manufactured in any other way are possible with this process.

Laser sintering and laser melting (SL, SLM)

However, on the downside, because of the high temperatures required for laser sintering, cooling times can be considerable. Furthermore, porosity has been an historical issue with this process, and while there have been significant improvements towards fully dense parts, some applications still necessitate infiltration with another material to improve mechanical characteristics.

Laser sintering can process plastic and metal materials, although metal sintering does require a much higher powered laser and higher in-process temperatures. Parts produced with this process are much stronger than with SL or DLP, although generally the surface finish and accuracy is not as good.

Fused Deposition Modelling FDM & Freeform Fabrication FFF

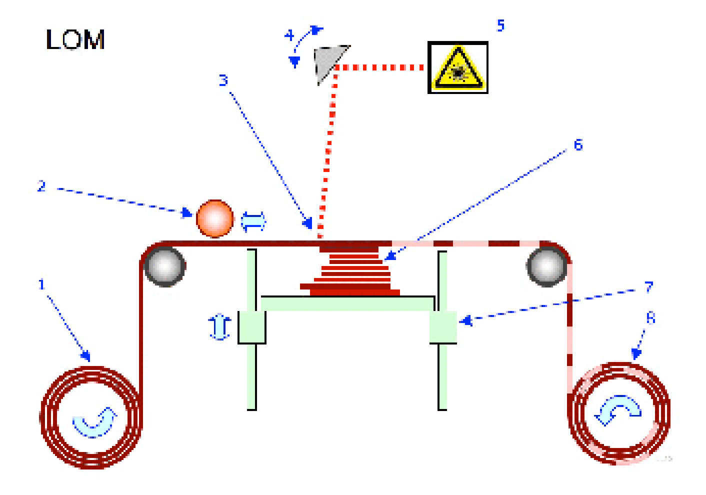


3D printing utilizing the extrusion of thermoplastic material is easily the most common — and recognizable — 3DP process. The most popular name for the process is Fused Deposition Modelling, due to its longevity, however this is a trade name, registered by Stratasys, the company that originally developed it. Stratasys' FDM technology has been around since the early 1990's and today is an industrial grade 3D printing process. However, the proliferation of entry-level 3D printers that have emerged since 2009 largely utilize a similar process, generally referred to as Freeform Fabrication, but in a more basic form due to patents still held by Stratasys. The earliest RepRap machines and all subsequent evolutions — open source and commercial employ extrusion methodology. However, following Stratasys' patent infringement filing against Afinia there is a question mark over how the entry-level end of the market will develop now, with all of the machines potentially in Stratasys' firing line for patent infringements. The process works by melting plastic filament that is deposited, via a heated extruder, a layer at a time, onto a build platform according to the 3D data supplied to the printer. Each layer hardens as it is deposited and bonds to the previous layer.

Fused Deposition Modelling FDM & Freeform Fabrication FFF

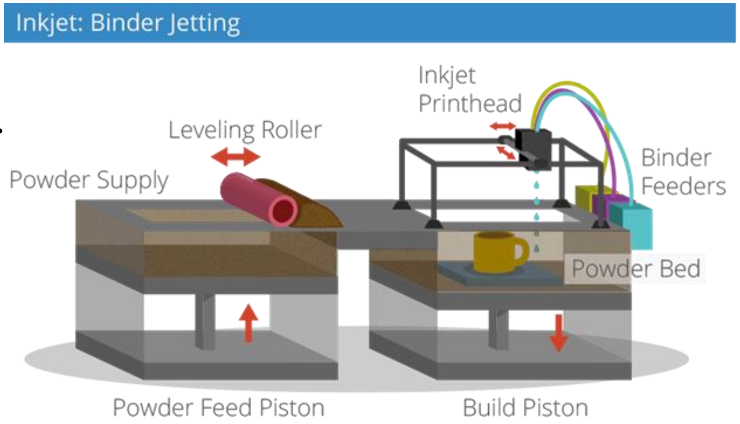
Stratasys has developed a range of proprietary industrial grade materials for its FDM process that are suitable for some production applications. At the entry-level end of the market, materials are more limited, but the range is growing. The most common materials for entry-level FFF 3D printers are ABS and PLA.
The FDM/FFF processes require support structures for any applications with overhanging geometries. For FDM, this entails a second, water-soluble material, which allows support structures to be relatively easily washed away, once the print is complete.
Alternatively, breakaway support materials are also possible, which can be removed by manually snapping them off the part.
Support structures, or lack thereof, have generally been a limitation of the entry level FFF 3D printers. However, as the systems have evolved and improved to incorporate dual extrusion heads, it has become less of an issue.
In terms of models produced, the FDM process from Stratasys is an accurate and reliable process that is relatively office/studio- friendly, although extensive post-processing can be required. At the entry-level, as would be expected, the FFF process produces much less accurate models, but things are constantly improving.
The process can be slow for some part geometries and layer-to- layer adhesion can be a problem, resulting in parts that are not watertight. Again, post-processing using Acetone can resolve these issues.

Laminated object manufacturing (LOM)



is a rapid prototyping system developed by Helisys Inc. In it, layers of adhesive-coated paper, plastic, or metal laminates are successively glued together and cut to shape with a knife or laser cutter. Objects printed with this technique may be additionally modified by machining or drilling after printing.
Typical layer resolution for this process is defined by the material feedstock and usually ranges in thickness from one to a few sheets of copy paper.

Binder Jetting



There are two 3D printing process that utilize a jetting technique.
Binder jetting: where the material being jetted is a binder, and is selectively sprayed into a powder bed of the part material to fuse it a layer at a time to create/print the required part.
As is the case with other powder bed systems, once a layer is completed, the powder bed drops incrementally and a roller or blade smoothes the powder over the surface of the bed, prior to the next pass of the jet heads, with the binder for the subsequent layer to be formed and fused with the previous layer.
Advantages of this process, like with SLS, include the fact that the need for supports is negated because the powder bed itself provides this functionality. Furthermore, a range of different materials can be used, including ceramics and food. A further distinctive advantage of the process is the ability to easily add a full colour palette which can be added to the binder.

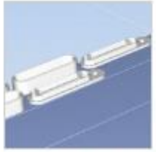
The parts resulting directly from the machine, however, are not as strong as with the sintering process and require post-processing to ensure durability.

Voxeljet

voxeljet is one of the leading manufacturers of industrial 3D printing systems and operates service centres in Germany, USA and UK for the "on-demand production" of molds and models for metal casting.

voxeljet SYSTEMS business division focuses on the development, production and distribution of the fastest and most powerful 3D printing systems in the market. Today, voxeljet has a well-coordinated product range that reaches from smaller entry models to large-format machines, and therefore offers the perfect 3D print system for many application areas.

Tooling



STL models in Objet Studio, ready to print.

3D printed mold for plastic injection.

Cavities of the digital mold.

Digital mold in place in the support plates.

Digital mold in the injection machine

Detail of the core side in the injection machine

Detail of the injected part

Injected plastic part.

Injected plastic part.

3D printed tool inserts in polymer to print plastic parts which can not printed directly with 3D printers (e.g. PP)

MATERIALS

AM Materials

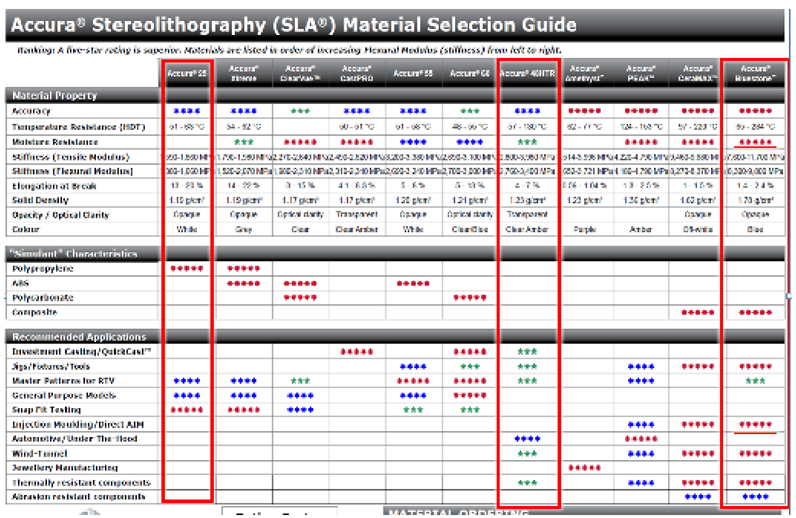
However, there are now way too many proprietary materials from the many different 3D printer vendors to cover them all here.
Instead, we will look at the most popular types of material in a more generic way. And also a couple of materials that stand out.

Liquid Based **Powder Based** **Solid Based**

What do we have at CERN:

Today we are only able to manufacture some polymers
The planning is to get a metall machine in 2015 in our main workshop

SLA® Viper si2 system



Accura® Stereolithography (SLA®) Material Selection Guide

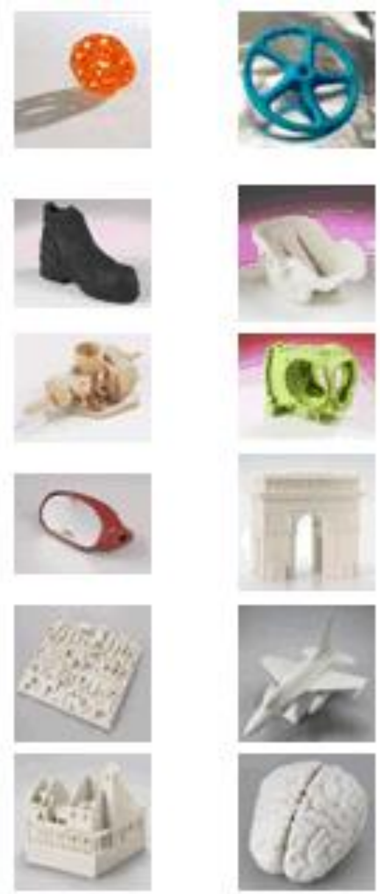
Ranking: A five-star rating is superior. Materials are listed in order of increasing Flexural Modulus (stiffness) from left to right.

	Accura® 25	Accura® Xtreme	Accura® ClearVue™	Accura® CastPRO	Accura® 55	Accura® 60	Accura® 48HTR	Accura® Amethyst™	Accura® PEAK™	Accura® CeraMAX™	Accura® Bluestone™
Material Property											
Accuracy	★★★★	★★★★	★★★	★★★★	★★★★	★★★	★★★★	★★★★★	★★★★★	★★★★★	★★★★★
Temperature Resistance (HDT)	61 - 65 °C	54 - 62 °C		60 - 61 °C	61 - 68 °C	48 - 55 °C	57 - 130 °C	62 - 77 °C	124 - 168 °C	57 - 220 °C	65 - 284 °C
Moisture Resistance		★★★	★★★★★	★★★★★	★★★★	★★★★	★★★		★★★★★	★★★★★	★★★★★
Stiffness (Tensile Modulus)	[illegible]	1,790-1,590 MPa	2,270-2,640 MPa	2,450-2,620 MPa	3,200-3,380 MPa	2,690-3,100 MPa	[illegible]	[illegible]	4,220-4,790 MPa	[illegible]	7,600-11,700 MPa
Stiffness (Flexural Modulus)	[illegible]	1,520-2,070 MPa	1,980-2,310 MPa	2,310-2,340 MPa	2,620-3,240 MPa	2,700-3,000 MPa	[illegible]	[illegible]	[illegible]	[illegible]	8,300-9,800 MPa
Elongation at Break	13 - 20 %	14 - 22 %	3 - 15 %	4.1 - 6.3 %	5 - 8 %	5 - 13 %	4 - 7 %	0.56 - 1.04 %	1.3 - 2.5 %	1 - 1.5 %	1.4 - 2.4 %
Solid Density	1.19 g/cm³	1.19 g/cm³	1.17 g/cm³	1.17 g/cm³	1.20 g/cm³	1.21 g/cm³	1.23 g/cm³	1.23 g/cm³	1.36 g/cm³	1.63 g/cm³	1.78 g/cm³
Opacity / Optical Clarity	Opaque	Opaque	Optical clarity	Transparent	Opaque	Optical clarity	Transparent			Opaque	Opaque
Colour	White	Grey	Clear	Clear Amber	White	Clear/Blue	Clear Amber	Purple	Amber	Off-white	Blue
"Simulant" Characteristics											
Polypropylene	★★★★★	★★★★★									
ABS		★★★★★	★★★★★		★★★★★						
Polycarbonate			★★★★★			★★★★★					
Composite										★★★★★	★★★★★
Recommended Applications											
Investment Casting/QuickCast™				★★★★★		★★★★★	★★★				
Jigs/Fixtures/Tools					★★★★	★★★	★★★		★★★★	★★★★★	★★★★★
Master Patterns for RTV	★★★★	★★★★	★★★		★★★★★	★★★★★	★★★		★★★★		★★★
General Purpose Models	★★★★	★★★★	★★★★		★★★★	★★★★★					
Snap Fit Testing	★★★★★	★★★★★	★★★★		★★★	★★★					
Injection Moulding/Direct AIM									★★★★	★★★★★	★★★★★
Automotive/Under-The-Hood							★★★★		★★★★★		
Wind-Tunnel							★★★		★★★★	★★★★★	★★★★★
Jewellery Manufacturing								★★★★★			
Thermally resistant components							★★★		★★★★	★★★★★	★★★★★
Abrasion resistant components										★★★★	★★★★

Acura Bluestone

3D Printer

Binder Jetting



For simple models, the purpose is in the rapid prototyping and 3D Mock-ups.
The mechanical properties can be improved by epoxy impregnation

AM Materials

Nylon, or ***Polyamide***, is commonly used in powder form with the sintering process or in filament form with the FDM process. It is a strong, flexible and durable plastic material that has proved reliable for 3D printing. It is naturally white in colour but it can be coloured — pre- or post printing. This material can also be combined (in powder format) with powdered aluminium to produce another common 3D printing material for sintering Alumide.

ABS is another common plastic used for 3D printing, and is widely used on the entry-level FDM 3D printers in filament form. It is a particularly strong plastic and comes in a wide range of colours. ABS can be bought in filament form from a number of non- propreitary sources, which is another reason why it is so popular.

PLA is a bio-degradable plastic material that has gained traction with 3D printing for this very reason. It can be utilized in resin format for DLP/SL processes as well as in filament form for the FDM process. It is offered in a variety of colours, including transparent, which has proven to be a useful option for some some applications of 3D printing. However it is not as durable oras flexible as ABS.

AM Materials

LayWood is a specially developed 3D printing material for entry- level extrusion 3D printers. It comes in filament form and is a wood/polymer composite (also referred to as WPC).

A growing number of metals and metal composites are used for industrial grade 3D printing. Two of the most common are ***aluminium*** and ***cobalt*** derivatives.

One of the strongest and therefore most commonly used metals for 3D printing is ***Stainless Steel*** in powder form for the sintering/ melting/EBM processes. It is naturally silver, but can be plated with other materials to give a gold or bronze effect.
In the last couple of years ***Gold*** and ***Silver*** have been added to the range of metal materials that can be 3D printed directly, with obvious applications across the jewellery sector. These are both very strong materials and are processed in powder form.
Titanium is one of the strongest possible metal materials and has been used for 3D printing industrial applications for some time.

Supplied in powder form, it can be used for the sintering/melting/ EBM processes.

AM Materials

Ceramics

Ceramics are a relatively new group of materials that can be used for 3D printing with various levels of success. The particular thing to note with these materials is that, post printing, the ceramic parts need to undergo the same processes as any ceramic part made using traditional methods of production - namely firing and glazing.

Paper

Standard A4 copier paper is a 3D printing material employed by the proprietary SDL process supplied by Mcor Technologies. The company operates a notably different business model to other 3D printing vendors, whereby the capital outlay for the machine is in the mid-range, but the emphasis is very much on an easily obtainable, cost-effective material supply, that can be bought locally. 3D printed models made with paper are safe, environmentally friendly, easily recyclable and require no post-processing.

Bio Materials

There is a huge amount of research being conducted into the potential of 3D printing bio materials for a host of medical (and other) applications. Living tissue is being investigated at a number of leading institutions with a view to developing applications that include printing human organs for transplant, as well as external tissues for replacement body parts. Other research in this area is focused on developing food stuffs - meat being the prime example.

AM Materials

Bio Materials
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Food
Experiments with extruders for 3D printing food substances has increased dramatically over the last couple of years. Chocolate is the most common (and desirable). There are also printers that work with sugar and some experiments with pasta and meat. Looking to the future, research is being undertaken, to utilize 3D printing technology to produce finely balanced whole meals.

Other
And finally, one company that does have a unique (proprietary) material offering is Stratasys, with its digital materials for the Objet Connex 3D printing platform. This offering means that standard Objet 3D printing materials can be combined during the printing process — in various and specified concentrations to form new materials with the required properties. Up to 140 different Digital Materials can be realized from combining the existing primary materials in different ways.

Concrete

RIKS

Safety features

Powder handling & changing - The following risks may be experienced while working with the systems:

Risk or damage to respiratory tract and lungs when handling metal powders and filter dust and suspected carcinogenic effect of the metal powder and filter dust. It is strongly recommended to wear breathing protection (respiratory mask; particle filter P2D or P3D) and NEVER inhale the dust when filling, emptying and cleaning the build envelope (build module, dosing chamber, coater, powder overflow) and when emptying the collecting container and filter cartridge of the extraction and filter unit.

Risk of eye damage when handling metal powder and filter dust. It is strongly recommended to wear eye protection (close-fitting safety goggles) when filling, emptying and cleaning the build envelope (build module, dosing chamber, coater, powder overflow) and when emptying the collecting container and filter cartridge of the extraction and filter unit.

Risk of compressed air outlet. Compressed air can escape if compressed air lines and union joints are opened or damaged. It is strongly recommended to wear safety gloves due to risk of skin damage. The toxic nickel in the metal powder and filter dust can cause irreversible damage or a sensitisation through skin contact (allergic reaction).

Risk of suspected carcinogenic effect of the metal powder and filter dust. A longer period inhaling of powder dust may cause accumulation of powder in lungs, blood and other organs which has a strong carcinogenic effect.

Laser system

The principal risks of the laser system are the following:

Laser is “invisible” (Class 1). This means that the human eye cannot detect the beam if it impacts the eye. It is highly recommended to activate the laser only when the door is closed due to protective action of the door crystal.

Special precaution should be made with docking/undocking of the build chamber. The laser may impact with the part and suffer severe damage.

3D printers are energy hogs

When melting plastic with heat or lasers, 3D printers consume about 50 to 100 times more electrical energy than injection molding to make an item of the same weight, according to research by Loughborough University. In 2009, research at MIT's Environmentally Benign Manufacturing program showed that laser direct metal deposition (where metal powder is fused together) used hundreds of times the electricity as traditional casting or machining. Because of this, 3D printers are better for small batch runs. Industrial-sized 3D printers may not be the answer to lessening our use of coal power any time soon.

Unhealthy air emissions

3D printers may pose a health risk when used in the home, according to researchers at the Illinois Institute of Technology. The emissions from desktop 3D printers are similar to burning a cigarette or cooking on a gas or electric stove. The 2013 study was the first to measure these airborne particle emissions from desktop 3D printers. While heating the plastic and printing small figures, the machines using PLA filament emitted 20 billion ultrafine particles per minute, and the ABS emitted up to 200 billion particles per minute. These particles can settle in the lungs or the bloodstream and pose health risk, especially for those with asthma.

Reliance on plastics

One of the biggest environmental movements in recent history has been to reduce reliance on plastics, from grocery bags to water bottles to household objects that can be made from recycled materials instead. The most popular—and cheapest—3D printers use plastic filament. Though using raw materials reduces the amount of waste in general, the machines still leave unused or excess plastic in the print beds. PLA is biodegradable, but ABS filament is still the most commonly used type of plastic. The plastic byproduct ends up in landfills. If 3D printing is going to be industrialized, that byproduct or other recycled plastic needs to be reused.

IP and licensing deals

In January, 3D Systems acquired Gentle Giant Ltd., which owned the licensing rights to toy franchises such as The Hobbit, The Walking Dead, Harry Potter, Alien, and Star Wars. Gartner has said that companies may lose at least $100 billion in four years to licensing or IP owners. 3D printing will change the business market—and the black market for these items—and the legislation will have to rush to catch up. This potential digital piracy situation is comparable to the way the internet challenged the movie and music industries for copyrights, trademarks, and illegal downloads.

Gun control loopholes

The first successful 3D printed gun is old news, but its ramifications are very important. Companies are popping up around the world, attempting to sell these guns and/or the CAD designs for them. Engineering firm Solid Concepts has even fired rounds out of the first 3D printed metal gun. Congress' Undetectable Firearms Act, which bans guns that can't be detected by metal detectors or x-ray scanners, was renewed for 10 years. It left a loophole in the law, however: 3D printed guns with a tiny piece of metal aren't banned by the Act. Legislators are attempting to close that loophole now, after Congress ignored the issue for quite some time, with special requirements for printed guns.

Responsibility of manufacturers

Weapons can be 3D printed. So can safety equipment such as helmets, wheels for bikes, and toys for small children. Of course there is the issue of intellectual property and trademark, but the larger issue involves responsibility. If a person shoots a gun and harms or kills someone, stabs someone with a 3D printed knife, or breaks their neck while riding on a bike with a 3D printed helmet, who is held accountable? The owner of the printer, the manufacturer of the printer, or the irresponsible person who thought it was a good idea to produce and use an untested product?

Bioprinting ethics and regulation
Cornell bioengineers and physicians created an artificial ear that looks and acts like a natural one.
The conversations about the ethics of bioprinting have already begun. Organovo is printing liver cells as well as eye tissue cells in a partnership with the National Eye Institute and National Center for Advancing Translational Sciences. Scientists have also proposed mixing human stem cells with canine muscle cells to create enhanced organ tissue. Printing cartilage is still the most realistic type of bioprinting, and printing whole organs is still many years away, but 3D printing is growing in medicine quite rapidly. Conversations about the moral, ethical, and legal issues surrounding bioprinting have started, but they will inevitably cause a lot more controversy as it becomes more commonplace.

Possibility of 3D printed drugs
Assembling chemical compounds on a molecular level using a 3D printer is possible. A researcher at the University of Glasglow created a prototype of a 3D "Chemputer" that makes drugs and medicine. He wants to revolutionize the pharmaceutical industry by allowing patients to print their own medicine with a chemical blueprint they get from the pharmacy. Of course, this is a very long way off, but it stands to enable DIY chemists to create anything from cocaine to ricin.

Safety of items that come into contact with food
Kitchenware is popular to 3D print, but the safety of the materials used is questionable.
You can print out a fork or spoon with your MakerBot, but if you use ABS plastic, it is not BPA-free. Luckily, new filaments that are safer to put in your mouth are being created for this specific reason, but they aren't widely available yet. Many 3D printers have spaces where bacteria can easily grow if they aren't cleaned properly, as well. In order to more safely-produced 3D printed food and kitchenware, there may be a need for an FDA-approved machine. People probably don't want to eat genetically-engineered pizza off of toxic plates.

Some commercial aspects

The costs of RM Fabrication depends basically on:

Part fabrication costs

The costs of RM parts depends on these parameters:

- Volume of the part.
- Cost of materials.
- Cost of consumables.
- Height of the part.
- Height of supports
- Number of slices

Man Power

0,1-0,5 FTE

Space requirements

Approx. 25-30m2 for the machine, container, generator stocking room

Auxiliary equipment (temporary)

Electro erosion, milling machine and compressed air

Peripherals & Consumable

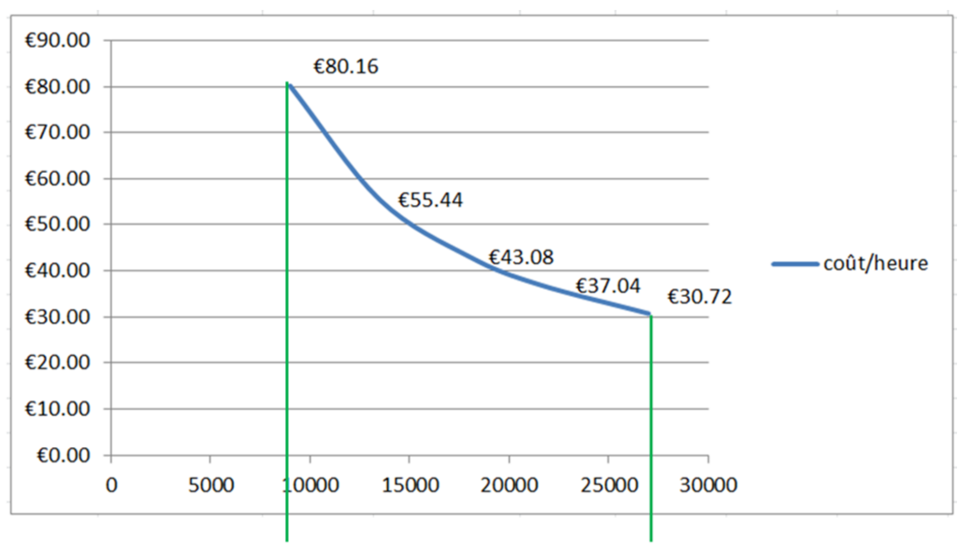
Powder materials
Lifting and transportation device for material handling
Build platform (first set is delivered with the order)
Cleaning and handling: hand sieves , brush, gloves filter mask shovel….
Recoaster blades
Antistatic waste bags

Maintenance

Software maintenance
Machine maintenance

Coût machine						
	Années	Semaines activées par année	Pièces par semaine	Heure de construction par pièce	Nombre d' heures de construction en 5ans	
	5	45	2	20	9000	heures
Prix de la machine					Prix de la machine par heure	
485000	Euro				53.89	Euro/heure
Maintenance						
	Années	Active mois par année	Prix par mois		Prix maintenance en 5ans	
	5	11	€1`910.00		105`050.00	Euro
					Prix maintenance par heure	
					11.67	Euro/heure
Con sommables						
Laser		Durée de vie en heures	Prix Laser		Laser/heure	
		10000	€60`000.00		6.00	Euro/heure
Racleur		Racleur par semaine	Prix racleur		Racleur/heure	
		1	€45.00		1.13	Euro/heure
Plaque de base		Plate/semaine	Prix Plaque de base		Plate/heure	
		0.2	€50.00		0.25	Euro/heure
Logiciel		Licence & Maintenance	L&M/année		L&M/heure	
			€13`000.00		7.22	(Euro/heure)
		Cout estime par heure de construction			80.16	(Euro/heure)

heures/5ans	9000	13500	18000	21500	27000
coût/heure	€80.16	€55.44	€43.08	€37.04	€30.72



5ans a 45semaines x40h/semaine = 9000h

5ans a 45semaines x120h/semaine = 27000h

Tableau 3 : Comparaison de coût total (Cas1 fabrication maison/ Cas2 fabrication externe)		
Comparaison de coût total	Cas 1 int. Imprimante 3D	Cas 2 ext. par service
Coût des actifs amortissables (€)	485.000	
Valeur résiduelle (€)	48.500	
Durée de vie en années	5	
Capital engage moyen (€) [C_{em}]	266.750	
Prévision de production d’unités par an	60	60
Capital et autres coûts fixes :[KF]		
Intérêt moyen du capital engage moyen(€) [KZ_{AB}]	26.675	
Taux d’amortissement par an (€) [AB]	87.300	
Autres coûts fixes, contrat de maintenance (€)	21.010	
Total des coûts fixes (€)	***134.985***	
Coûts variables par an: [KV]		
Frais de personnel (€)	3.600	
Matériau (€)	12.000	
Coût du service (€)	0	120.000
Total des coûts variables (€)	***15.600***	120.000
Coût total par an (€) ***[KG]***	**150.585**	**120.000**

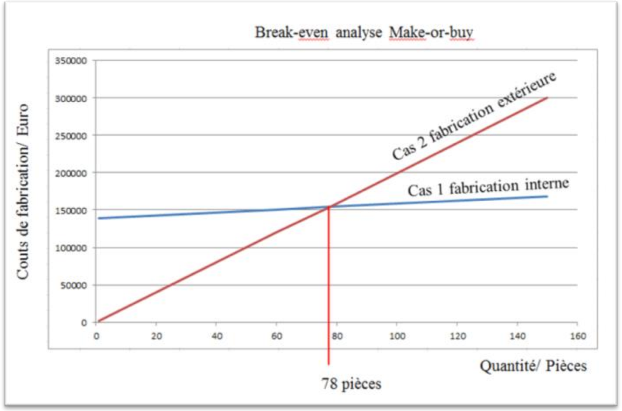
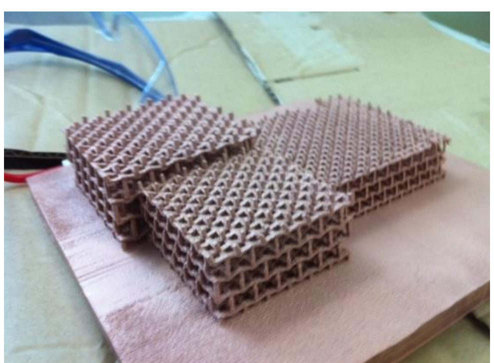


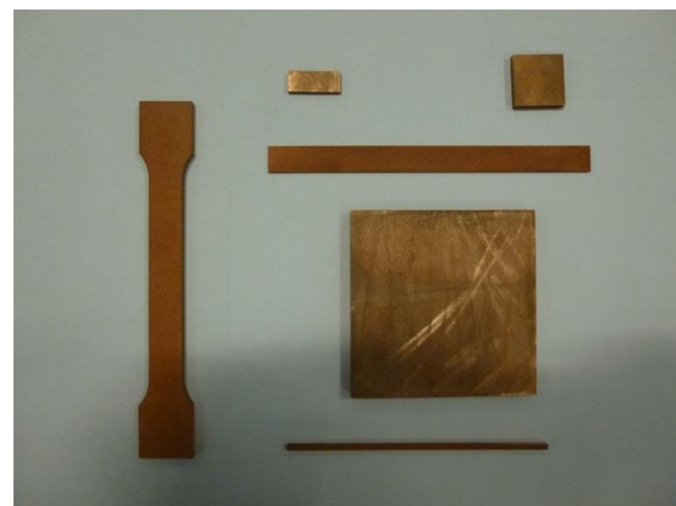
Tableau 1 : Supposition Cas 1	
Coût d’investissement de l’imprimante 3D	485.000 €
La durée d’utilisation	5 ans
Produit de la liquidation ou valeur résiduelle	48500 €
Maintenance - et coûts de réparation pour 1 an	21.010 €
Coûts du matériel au cm3	0,20 €
Volume moyen par unité	1000 cm3
coûts des pièces à l'unité	200,00 €
Frais de personnel par pièce	60,00 €
Pièces fabriquées par mois	5 pièces
Pièces fabriquées par an	60 pièces
Taux d'intérêt implicite (I)	10 %

Future

What we are doing at CERN:

Printing models in some polymer materials at CERN
Subcontracting parts in polymer
Subcontracting parts in metal
Exploring ceramic materials
Exploring the installation of an 3D metal printer
Several collaboration agreements in 3D printing
R&D to print pure Copper and Niobium
Further R&D of materials
Contact to universities and other organisations





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Many exiting examples can be found under: http://www.3ders.org/applications.html

Thank you for your attention
Merci pour votre attention