Maritime GUIDE to 3D print

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3D print in Danish Maritime cluster

This baseline document is a reference work, collecting the learnings throughout the project process in 2016.

It holds documentation and analyses of the potential impact of 3D printing on the Danish maritime industry:

- Innovation
- Future value chain
- Future product development and design

It also document the state of the art of 3D printing in the maritime sector and related industries:

- Automotive
- Aeronautical
- Mechanical engineering

The state of art will be analysed in relation to:

- Rapid prototyping, for faster testing of solutions and design
- Additive manufacturing, where production is 3D printed
- Moulds for industry
- Tools for industrial machines
- Hybrid solutions where products are printed and subsequently milled
- Repairs using 3D printer technology

In this 3D print study analysis will be conducted into values and limitations.

Industrial revolution 4.0

Recall the hot and hyped technologies of each decade:

- PC in the 80'
- Internet in the 90'
- Smartphones in 00'
- 3D printers in the 10'

They were all introduced as game changers and they proved to be, but not instantly.

The term "Industrial Revolution 4.0" originates from high-tech strategy of the German government Presented at Hannover Fair 2012 the Working by Siegfried Dais (Robert Bosch GmbH) and Henning Kagermann (Acatech)

- 1st industrial revolution mobilised the mechanization of production using water and steam power.
- 2nd industrial revolution introduced mass production with the help of electric power
- 3rd industrial revolution was the digital revolution
- 4th industrial revolution use of electronics and IT to further automate production.

Smart Factories, cyber-physical systems monitoring physical processes, creating virtual copies of the physical world and make decentralized decisions. Internet of Things communicate and cooperate in real time, with the Internet of Services

Tremendous development

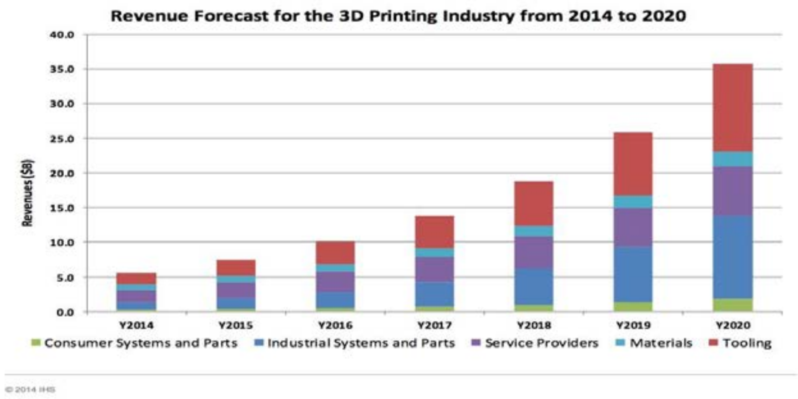
Within the previous decade:

- Costs have decreased a hundred times for the most inexpensive 3D printers
- Speed has increased more than a hundred times for the most professional 3D printers
- Revenue on printer hardware has increased ten times

We are now entering a decade of commercial 3D print mass production.

3D printers still have some serious limitations but the 3D printer industry is dealing with that.

The new technologies will disrupt the present ones. Professional 3D printers will mature from the handmade machines of today to mass production and maybe even 3D printing



Value

The strength and added value of 3D printing is:

- You get exactly what you design
- Fabrication of cavities
- Saving material weight and waste
- Single piece devices
- Complex geometry
- Fast molds with cavities
- Made to measure
- Just-in-time spare parts
- Instant repair
- 3D printing ceramic materials
- Faster product development
- Better products

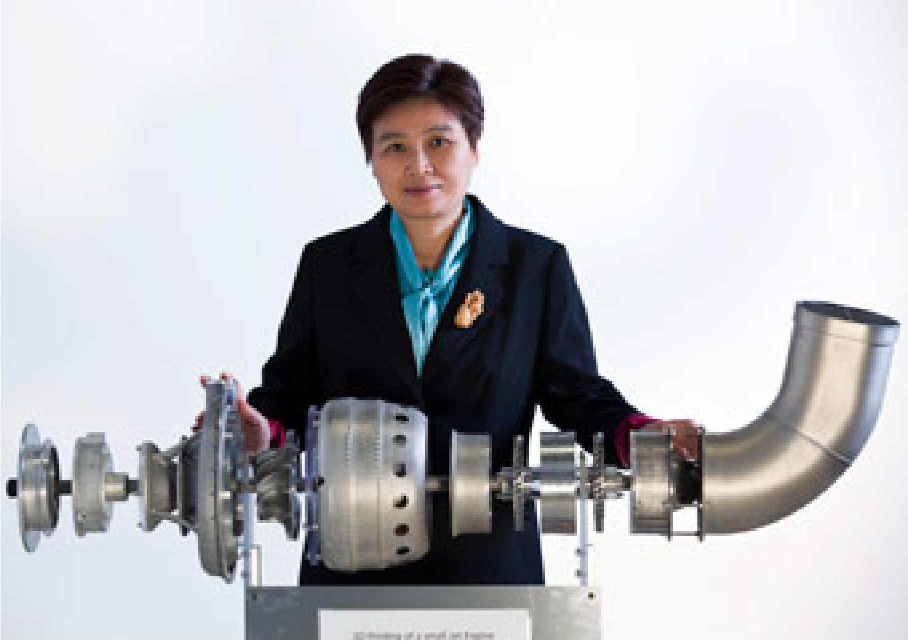
Value

Rules of thumb

The present 3D technology is only available for production of auxiliary components for ships and particularly components and spare parts for pumps, valves, heat exchangers, engines, propellers and catalysers. The photo shows the first 3D print jet engine that actually works.

3D print is competitive when the part printed is characterized by:

- High degree of customization
- Complex design
- High kg price of the component
- Leveraging value due to improved performance
- Urgency of delivery
- Consolidating many components into one



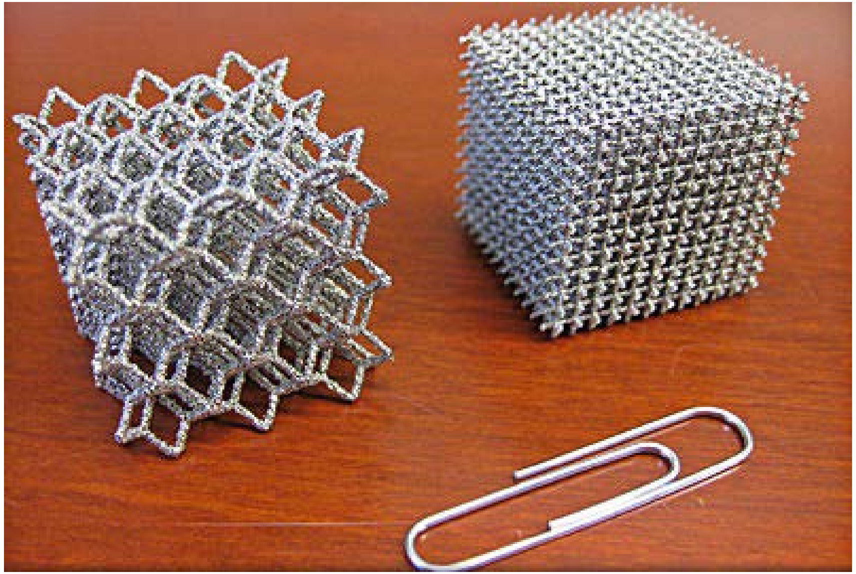
You get (almost) what you design

3D printing aims at giving you exactly what you design.

This eliminates human errors from interpretation of drawings and descriptions.

This is particularly valuable in processes where communication with subcontractors are difficult and consequences of bad communication impose significant risk.

In real life however, many printers deliver something a little smaller than designed as the material cool down and shrink after it is printed. It might also warp



Making impossible cavities possible

Only 3D printers can produce objects with cavities, and objects within cavities. A key question is what cavities can do for your product?

The fuel nozzle for General Electrics LEAP engine is legendary. The minus 50 degree jet fuel is spiralling behind the surface of the nozzle cooling it enough to allow higher temperatures in the combustion chamber, saving fuel consumption. This design is only possible with 3D printing, and the cost of such a small component is negligible compared to the savings.

Imagine a 3D printed engine

If you are developing a new engine you could start with questions like:

- Could 3D print save weight and thus fuel consumption of the car?
- Could the piston be almost completely hollow with a lot of bionic minimal structures within, supporting the load from the combustion to the connection rod?
- Could the water-cooling channels spiralling around the combustion chamber reduce the weight of the cylinder block and the volume of water?
- Could these cooling channels also cool the air channels coming from the supercharger?
- Could the catalyser be integrated in the cylinder block and the pistons, and be active in the combustion process, utilising the remaining energy within the combustion chamber while the exhaust gas is still super hot?
- Could the components be printed in ceramics and sintered afterwards?
- Could they be printed in catalyser ceramics?
- Could the entire engine be printed in one go with all the moving parts in position except the replaceable spark plugs and fuel injection?

Saving weight and material

The better you get at designing cavities, the more weight and material you save. This is particularly interesting if :

- The material is expensive
- Weight savings enable functionality
- Saving weight saves energy

Look for processes where weight is important. Maybe you can substitute aluminium with a 3D printed hollow steel part.

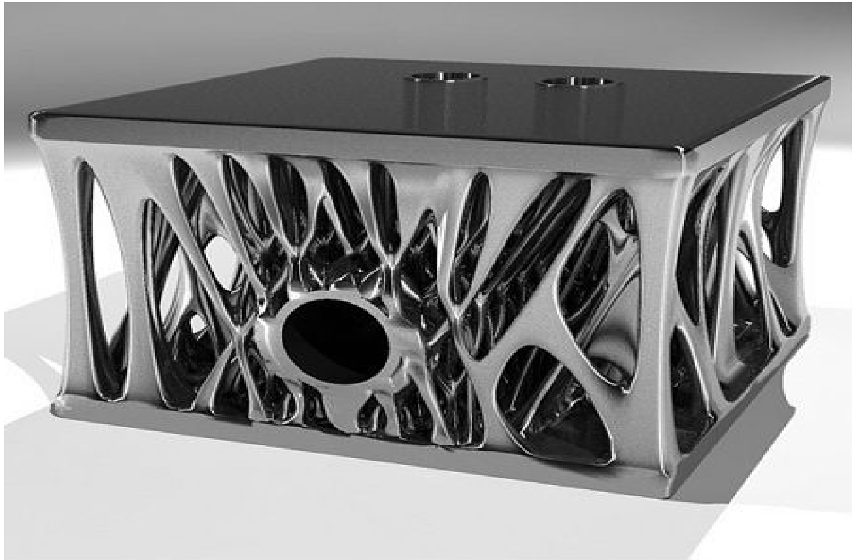
Imagine cavities within the propeller reducing the specific density enough to make it weightless in sea water. In that case you could switch propellers without dry-docking.

Single piece devices

You can save a lot of leaks and trouble if you 3D print one component instead of assembling a device from several components. This is particularly interesting if the device works with hydraulics, water or gasses under high pressure

Single piece devices also save assembly and processes justifying the extra cost of 3D print.

Heat exchangers and catalysers are good examples of devices which would benefit from 3D print.

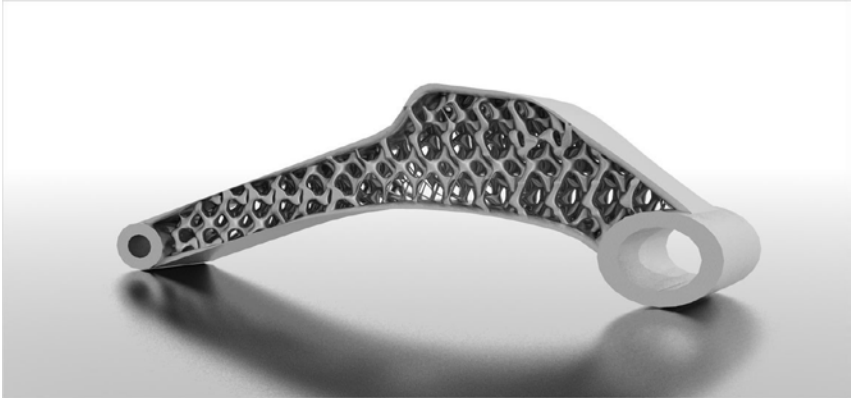


Complex geometry

3D print is a tool for complex geometries. You would never choose 3D printing if you want geometries you can extrude – like plates, cylinders, pipes, beams etc. or order from a shop.

3D printing is superior to milling for complex geometries where the volume of the finished component is small compared to the volume to be milled

- Shells
- Lattices
- Mesh and sieves
- Curved, wavy, hilly shapes that are stronger and more efficient than flat smooth surfaces.



Accurate cavity molds

Molds reverse the relation between volume kept and volume removed, so 3D printed moulds can often compete with milling.

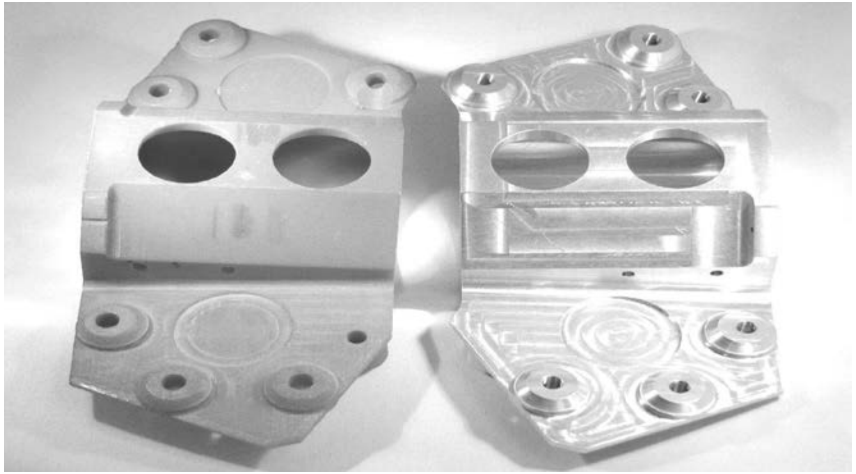
Sand-printing molds is actually one of the few technologies used for mass production with 3D printers.

Addition of multiple moulds could be the way to bridge the gap between the size of 3D printers and the size of ships.

Both 3D print and milling

Milling can finish the surfaces of the 3D print if very smooth surfaces are required.

The 3D printed component to the right is made with a welding metal 3D printer leaving a rather rough 3D print that need to be milled to become smooth.



Value

3D scanning & printing

Combining 3D scanning and 3D print is particularly successful for made-to-measure components

3D scanning of an existing tooth and 3D printing of the implant yields several benefits for both client and dentist and is large market for 3D printing industries:

- The implant fits exactly on first try
- The process is finished in one visit instead of two
- No temporary implant is needed.

All kind of statues, decoration and exhibits on cruise ships could also benefit from 3D scanning and printing

Just in time spare parts

It is of course easier to 3D print from digital files than from 3D scanning, so we expect to see an entreprise 3D scanning all spare parts to a 3D data base to be used by the 3D printer on board.

3D printing spare parts on board has several advantages:

- No inventory of spare parts on board
- No waiting for vital spare parts delaying the ship

Imagine that the spare parts are better than the original because they are updated

As prints shrinks and warp differently on different printers corrections from these distortions should be included in the printer file.

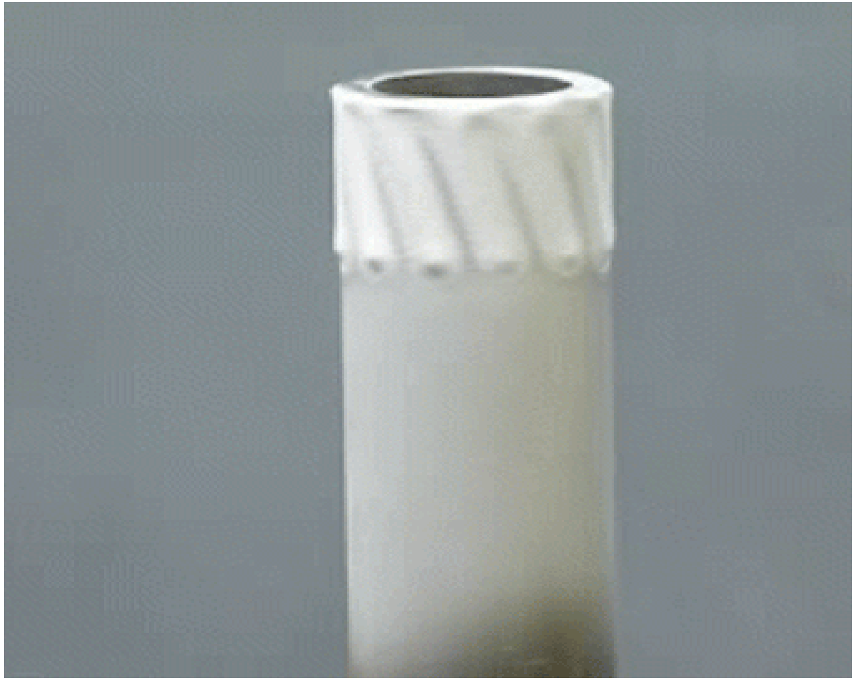
Value

Instant repair

Spray 3D printers can add material on the surface of existing components. This way existing components can:

- Be repaired
- Have new harder and more wear-resistant surfaces
- Have surfaces and coatings otherwise impossible to manufacture

Spray printers are expected on the market this year. A spray 3D printer can be a valuable tool in the workshop on board



3D printing ceramics

Everybody has talked about ceramic engine parts for decades but little has yet materialised on the market. Sintering of 3D print could be the very breakthrough for ceramic products the industry has waited for.

Faster product development

Ford, BMW, Audi and Airbus use 3D printing as a way to speed up the development process.

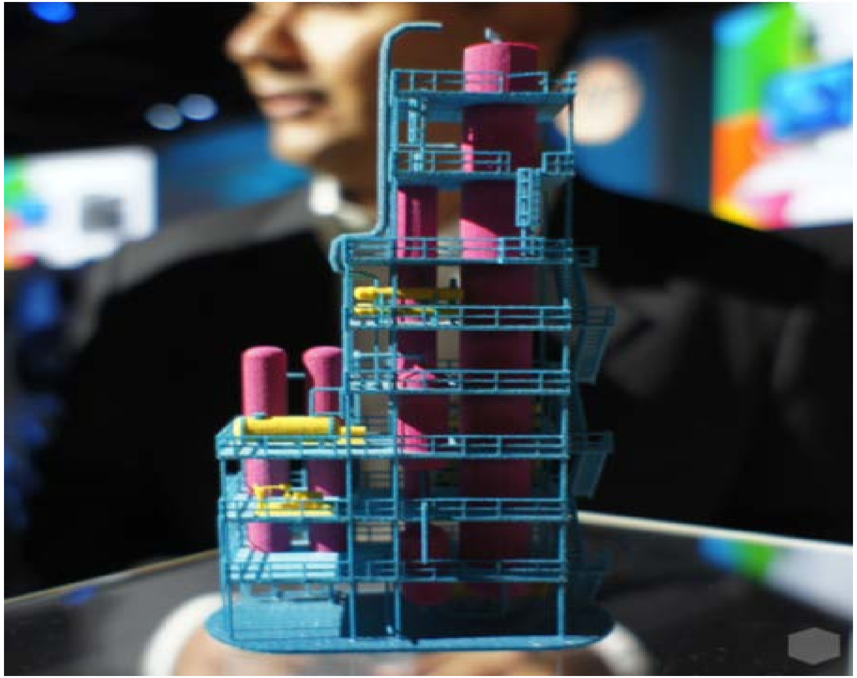
The entire prototype car can be made from 3D printed parts. It is much faster than producing handmade prototypes and the parts are much more like “the real thing”.

Late-ordered or delayed parts from subcontractors can be 3D printed tto meet deadlines.

These prototype 3D prints can later be substituted by mass produced traditional components.

Fail faster succeed sooner

- 3D printing is faster and less expensive than other prototypes
- Innovative designs and concepts become realistic options when prototyping is faster and less expensive
- More different solutions can be tested simultaneously
- More users and customers can be involved in the test
- Tested products reduce loss and liability from failed products



Value

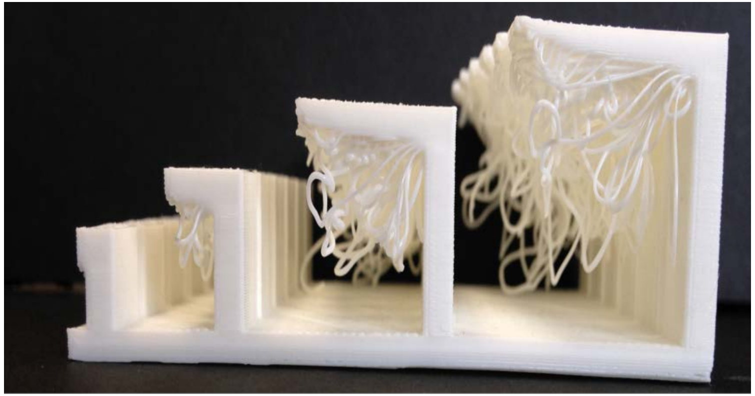
Confidentiality

It is easier to keep your development projects confidential if you are 3D printing within you own workshop– compared to parts and models manufactured by subcontractors

Limitations

The key limitations of 3D printers are:

- Particularly FDM printers are very slow compared to industrial processes but still fast compared to handmade components
- Polymer material cost is in the 100 $/kg range
- Direct metal printing material cost 3-600 $/kg
- Single piece object size is limited by printer size, which is often in the 30 x 30 x 30 cm range
- Strength in FDM 3D prints are inferior to solid materials
- Horizontal overhangs need support



Failed Horizontal Overhangs

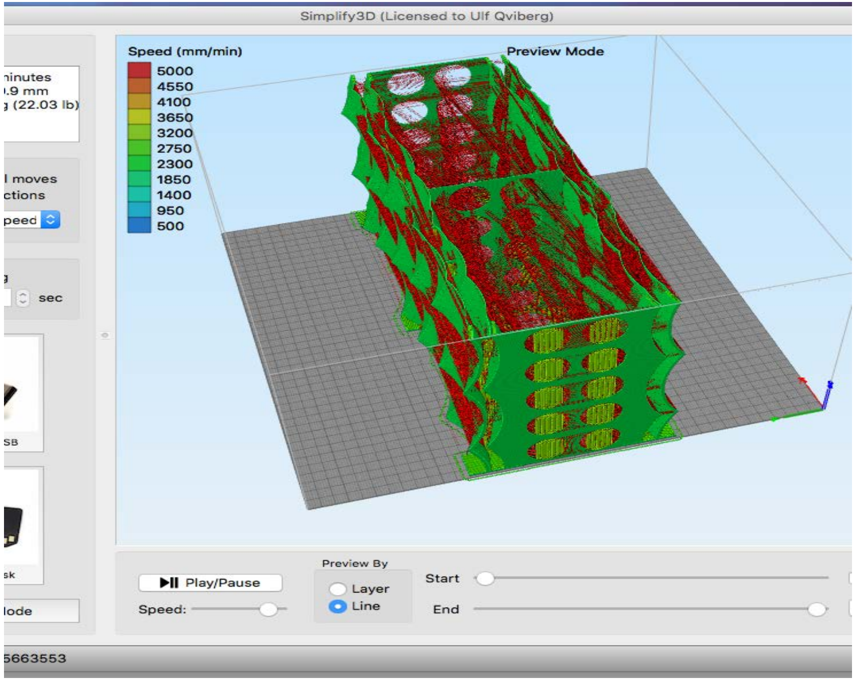
Limitations

Slow

So far most 3D printers are slow.

- Litre/h is the fair way of comparing metal and polymer printers as metal has a higher specific density than polymer.
- Kg/h is a better measure if you want to address the difference between the gross volume and the actual printed material.
- The most fair comparison between small and large printers is the growth in the z-axis, measured in layers/h because measuring in mm/h favours rough printers

The picture illustrate the movements of the FDM print head



Gross or net

The speed of FDM printers and all kinds of single nozzle 3D printers is almost independent of shape.

3D printers printing in a fluid or in a box filled with powder has a somewhat misleading print speed as it is assumed that the entire powder box turns into a print.

The litre/h is thus calculated for the outside dimensions without discounting the cavities. If you have 90% cavities you loose 90% of the speed advantage compared to single nozzle printers

Smooth or rough

The speed of the inexpensive FDM hobby 3D printer is starting at 0,01 litre/h. This speed is proportional to the thickness of the layers.

If you can accept an increase in layer thickness from 0,3 mm to 1 mm, the printer can handle 0,1 litre/h and if you accept 5 mm layers like in the worlds largest FDM printer from BAAM you can print 2,5 litre/h.

But what kind of industry will accept 5mm inaccuracy in their 3D prints?

Size maters

The large sand printers from Exone and Voxeljet 3D print simultaneously with nozzles in the full width of the print area with a 0,3 mm resolution. The maximum capacity is up to 400 litre/h measured from the gross volume at the periphery of the component rather than from the material volume of the component.

Material cost

The 3D printer industry charges 3D print by volume calculated in the STL 3D print file.

Charging the prints pr. litre has encouraged the filament industry to share profits. How much does the ink for your desk top printer cost pr. litre? You got the point? After one year you have paid more for the printer material than for the printer.

The cost of ABS and other thermoplastics for FDM printers are falling, because you can buy your own device to transform Cola bottles into filament by grinding it to powder, melting it and extruding it as filament.

Materials for most other polymer printers are in the 650 DDK/kg price range. Imagine 3D printing a ship or a house at that cost.

Sand printers consume sand and Furan binder. The sand has to be sieved and dried but still it is sand. And Furan is glue used in relatively small quantities

Sand prints are actually much less expensive with prices around 50 DDK/kg including the print process.

Metals are in the 1900-3900 DKK/kg range, because it is expensive to produce metal as a powder

Limited component size

If you want 3D prints larger than 1m^3 with a good accuracy, powder bed printing is the only commercially available technology.

It would be fabulous to print a large ship engine or even an entire ship in a giant 3D printer but that is very unlikely to happen.

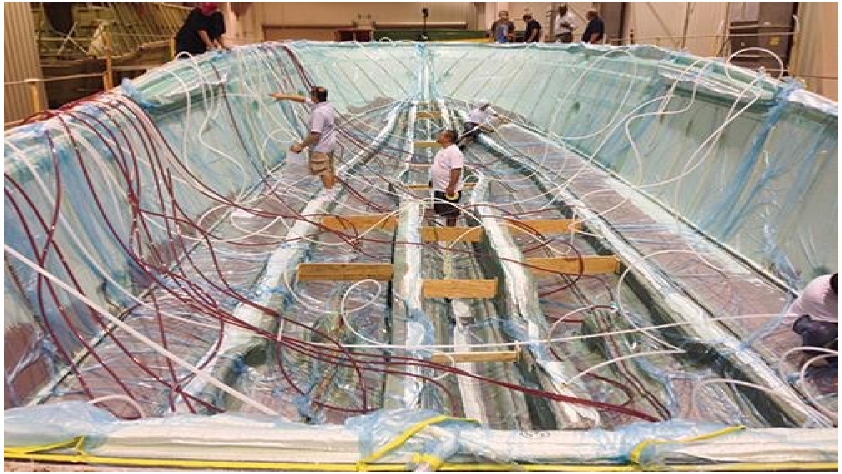
Size and speed is related. One large printer is much slower than a hundred smaller printers working simultaneously.

Any large prototype 3D printer is also more expensive than the many smaller mass-market 3D printers together.

Vacuum infusion molds

The most likely road to 3D printing of large constructions is to assemble them from components. This could lead to components designed to fit within the size limitations of the 3D printers and maybe even components optimised to fit into the void of each other in order to reduce cost of 3D print.

A lot of 3D printed molds could be combined with vacuum infusion fibre reinforced polymers in a process producing large ships.

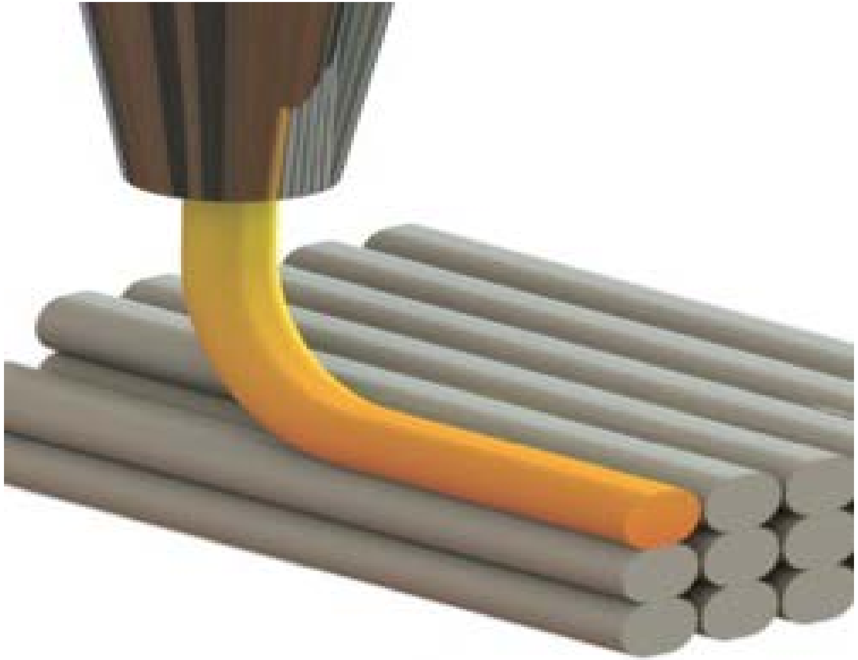


Limited strength in FDM print

A layered structure is mechanically weaker perpendicular to the layers than parallel to the layers.

Each layer of FDM prints and other printers curing by cooling are cooled enough to solidify before the next layer is applied.

The strength in the print and layer direction is as good as the solid material, but the perpendicular strength is limited by a poorer adhesion between the layers due to thermal stress and due to the cylindrical cross section of the fibres touching only at a limited surface.



Safety recommendations

The micron size powder is a health risk. Chose a closed printer with automatic post processing

Avoid cancer risk materials like PUR, polyacrylonitriles, PVC, epoxy, and styrenic copolymers

Photopolymer is a potentially harmfull material and skin contact and inhalation should be avoided. Chose printers delivering a finished dry product

Thermoplastic PLA is 30 times less toxic than ABS. Clean the nozzle to avoid the thermoplastic to burn on the extruder.

3D printers should never be on the desktop. It belongs in a room with exhaust ventilation and right next to the exhaust ventilation.

Wear non-permeable gloves and dust mask (P100) when accessing the stage area of the printer after printing

Uncured printing material is hazardous; wear neoprene or nitrile gloves when handling it

If material can splash, wear safety goggles.

In the event of leak or spill of printing material cartridges, use solvent-absorbent pads for model material and support material spills. Dispose clean up materials as hazardous waste.

Keep model and support materials away from areas where food and drink are stored, prepared or consumed

Different tool for different task

3D printers can be any:

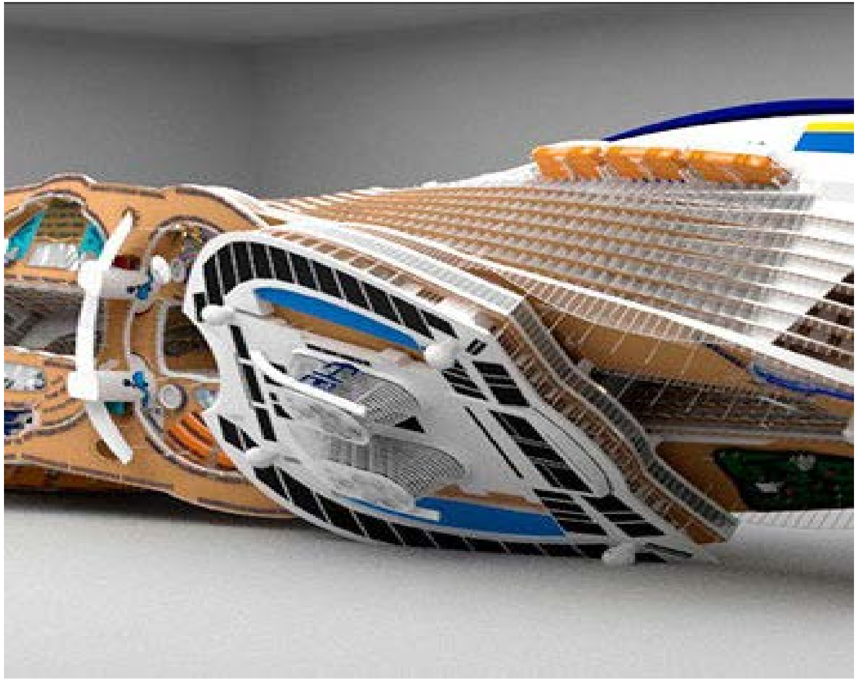
- Size from the nice CUBE 3D printer in your living room where the fireplace used to be, to the giant sand printers from Voxeljet and Exone the size of the entire living room.
- Speed from dreadfully slow inexpensive home and office printers to16.000 times faster large printers with thousands of nozzles.
- Material: plastic, rubber, sand, clay, steel, titaninium and it can be cured and sintered in many ways
- Strength from fragile FDM print to jet engine quality.
- Cost anything from 3.000 to 12.000.000 DDK

Ship models and device models

The key criteria for 3D printers for high quality ship models are:

- Full colour palette
- Very fine details
- Support for bridging structures
- Sufficient accuracy for modular addition without visible joints.

Only Jet technologies prints from Stratasys and 3D systems can meet these demands. It is expected that HPs new colour 3D printer will provide similar functionality in 2017 at a more competitive price. It can take weeks to 3D print a 1:200 model of a cruise liner



Superior performance metal components

The classic example is General Electrics fuel nozzle for the LEAP engine.

Several thousand of these components are produced every year on a large number of 3D printers. This nozzle can only be produced by laser sintered metal powder layer by layer in a powder bed type 3D printer, in this case from Stratasys

The component is approved by Federal Aviation Authorities. Each component is examined with CT scanning before it is approved.

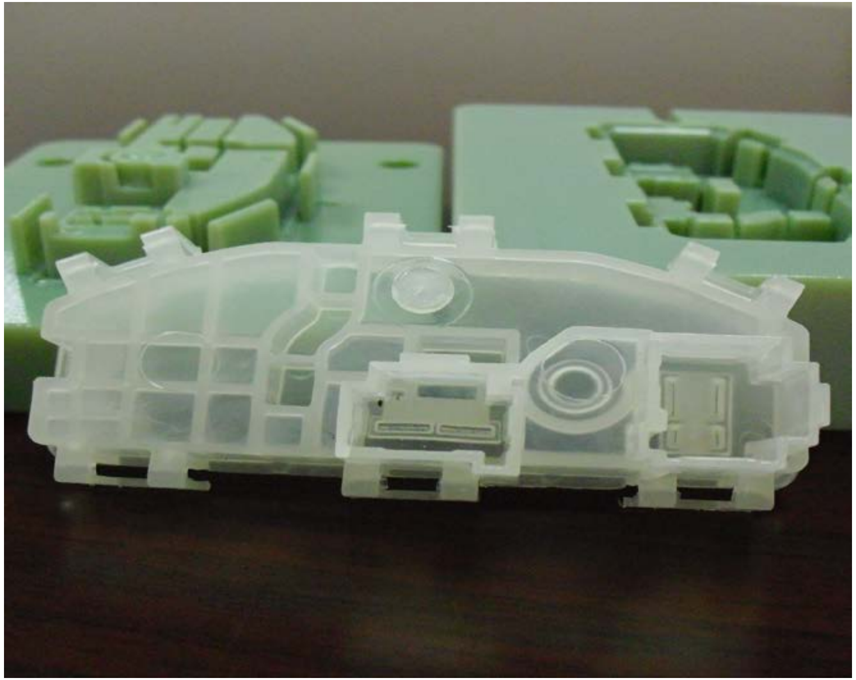
(b)

Real components

For the fast prototyping of components, you can 3D print a mold and cast the component in this mold. The 3D printed molds are often made from sand and organic glue. It is possible to cast cavities and complex geometries. After the metal is cured, the glue is burned away and the sand can be poured out.

Objects made with this technology are stronger, more acurate and more uniform than direct laser sintering. It is also less expensive and faster. This technology is interesting for engine and propeller parts.

Voxeljet and Exone produce very large and fast sand printers.



Tools for tasks

Repair

Spray surface treatments enhance the performance of surfaces that are vulnerable to wear and tear or exposed to corrosive environments.

If you combine this spray technology with a robot you can add ceramics and metals exactly where needed.

You can even repair broken cock wheels and revitalise engine parts. This technology could be useful in the workshop on board ships.

Watch this video https://www.youtube.com/watch?v=Ao319dj6kiM

Inexpensive

The market share for FDM 3D printers is massive in the inexpensive mass market segment.

Prices are down to 500 $ and that could lead to a 3D printer in every office similar to paper printers. The question is if there is a demand in every office for 3D prints, and if personal maintenance of the 3D printers is provided. It is not a trivial matter to keep 3D printers working.

Most FDM printers cannot print overhqnging structures automatically and many prints have defects and flaws or end up like candy floss

3D print technologies

The basic principle of 3D printers is to slice the digitalised object into thin layers and finish each layer before moving on to the next layer.

The 3 basic deposition processes are:

- Melted and then cured by cooling
- Fluid photo polymer cured with UV
- Powder glued together with binder

Most 3 D printers deposit the material with

- Linear x-y-z plotter
- Polar industrial robot

For large scale application a cable suspended technology is considered

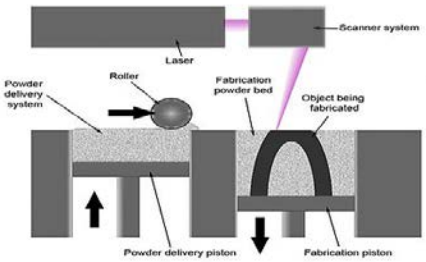
There are at least 5 different concepts

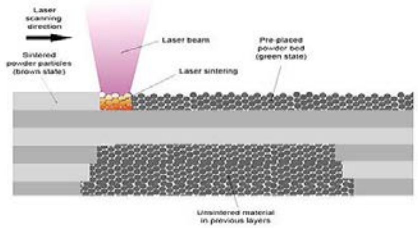
- **Powder bed** where a thin layer of powder like sand, sugar, gypsum, or metal is laid out in a “bed” or box and cured with UV, laser, glue, heat, microwaves or binder
- **Stereo Lithography** where UV light is curing a photo polymer within a pool of resin
- **JET** where small droplets of photo polymer are deposited and cured with UV
- **FDM** where thermoplastic or melted metal, ceramics or glass is extruded through a nozzle and cure it cooling
- **Spray** slamming fine particles into a surface, melting them by the impact energy and curing them by cooling

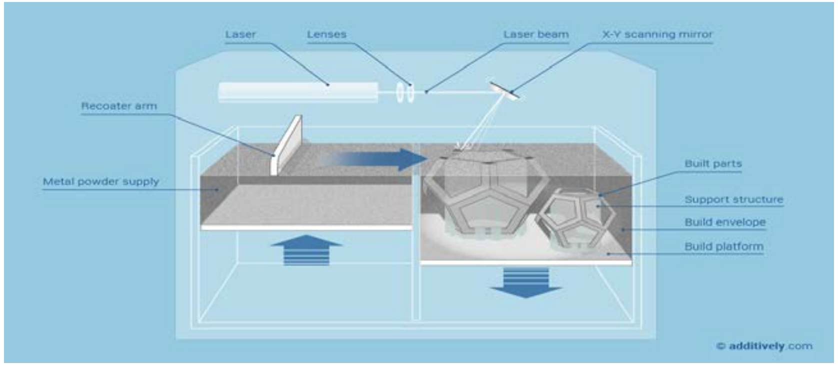
Powder bed

Power bed printer technology adds layers of powder in a box or “bed” and binds the particles to be kept. Many different versions of this technology is available:

- Materials cured with water like sugar, flour, gypsum and clay can be printed with water or ink as binder. A jet ink printer head from an ordinary paper printer can apply the ink finishing 10-15 layers a minute in colour print. (3D systems)
- Materials like sand glued together with Furan, epoxy or similar binders from a similar print head. This kind of print is not in colour. (Exone and Voxeljet)



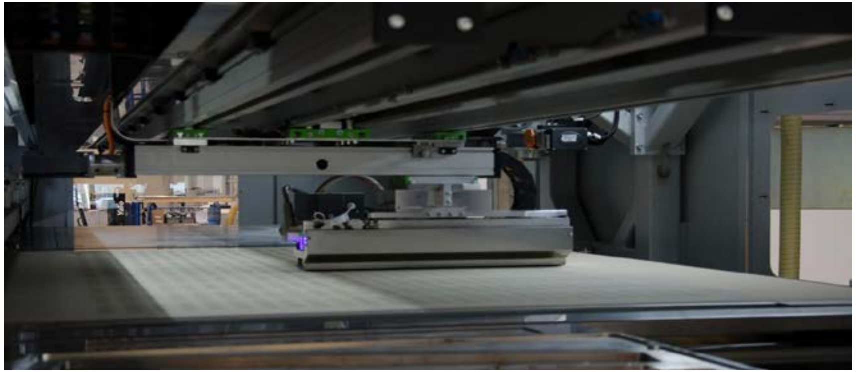




Technology

- Thermoplastic materials fused by melting with laser light.
- Metals sintered by melting with laser light (EOS) The prints made from this technology sell at 50 DKK pr. gram
- Polymer material sintered with UV cured photo plastic fluid. This fluid can be used for colour print (the coming 2017 HP 3D printer)

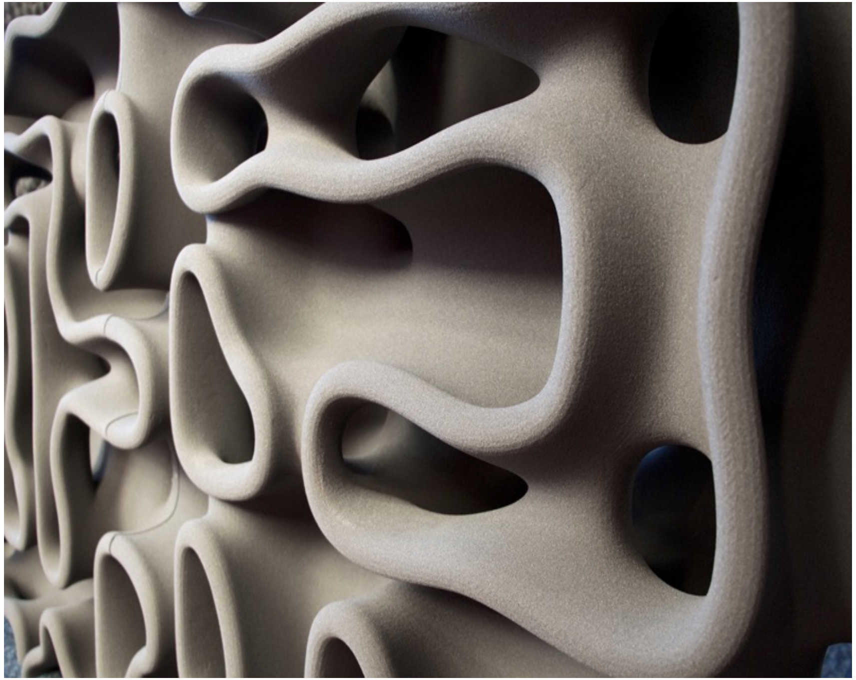
The printer adds thin layers of uniform size powder particles. The raw material is often inexpensive, but is has to be carefully sieved, kept dry and prevented from sticking together from static electrical forces etc. in order to be applied in thin layers.



Technology

The advantages of this kind of printer are:

- Largest professional 3D printer volume record is held by Voxeljet 4000 with a print box of 4 x 2 x 1 m.
- The fastest 3D printer record measured by volume/h is Exone Exerial with a printed volume of 400 l/h. The high speed is achieved with 2 print heads extending the entire width of the box with thousands of nozzles printing simultaneously as the print beam follows right behind the powder distributing beam.
- Objects within objects and any kind of cavities can be printed with this technology



Technology

- Laser sintered objects are almost as mechanical strong as the solid material

Several functionalities are available

- Eatable sugar and flour products
- 3D print sintered to ceramics
- A sand cast glued with a material that is burned away.
- Sand glued with sodium silicate produce a completely non combustible recyclable and non polluting object.

Any process melting the material introduces the risk of shrink and warp.

Powder printing is followed by a vacuum cleaning and dusting process and can be post processed with more binders, microwave curing, sintering etc. The sand prints need furthermore a casting process

Technology

The process of separating the powder and the printed object is quite messy and potentially harmful to the brittle objects and in the coming years automating this process is top priority as shown in this video
https://www.youtube.com/watch?v=jTjipJM8Bn0

Powder bed printers are in the expensive end with the largest and fastest 3D printer in the 4-12 million DDK range

Watch these videos
https://www.youtube.com/watch?v=kBHsfNDsbCs
https://www.youtube.com/watch?v=15AmryIYu4k
https://www.youtube.com/watch?v=LFGnjkoeDng
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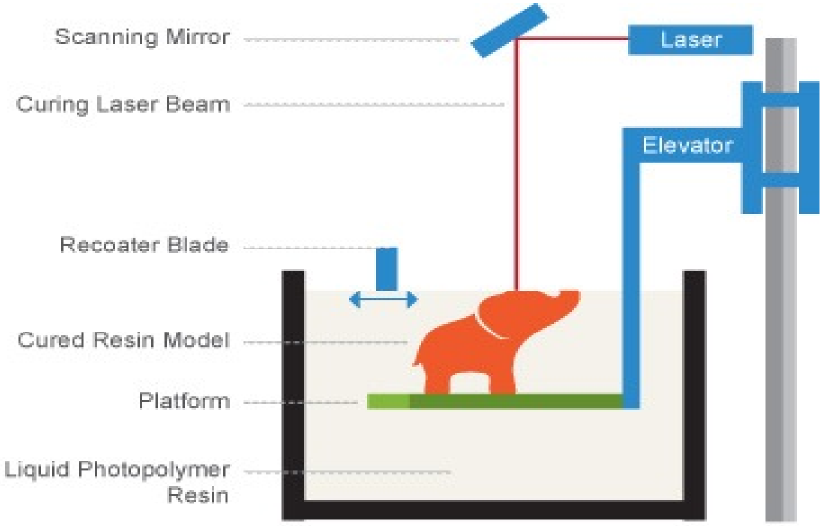
Stereo lithography

Stereo lithography was the first commercial 3D printing technology. It uses a scanning beam of UV laser light to photo cure the surface of a photo polymer resin. The advantage of stereo lithography is

- Any object within object, cavity and geometry can be printed because the print is floating.
- The process can be faster than FDM printers because it is faster to move a laser beam than to move a print head.



Technology

3D systems introduced this technology and still produce one stereo lithography 3D printer series, but has otherwise complete shifted to the JET technology.

Materialise has a giant 210×70×80 cm prototype stereo lithography 3D printer

The disadvantage of stereo lithography is that the process with a large basin of resin is messy and that the print comes out wet and sticky.

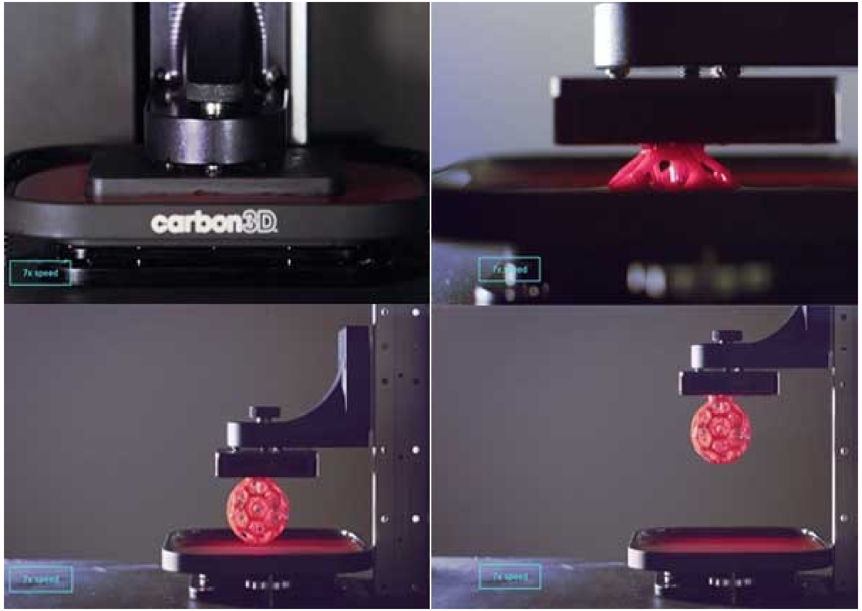
The resin should be used the same day as it cures after a few days in the basin. The resin is expensive and throwing it away adds to print cost and polution.

Stereo Lithography does not support the print in the same stable way as powder bed printers and need some support printed and removed.

Technology

Continuous Liquid Interface Production (CLIP) also uses photo polymerization cured by UV light, but:

- Instead of a laser beam, CLIP uses a DLP projector (known from the conference room) with a UV lamp. The best DLP 4K projectors projects 8 million pixels 25 times a second = 200 million voxels (spatial pixels) pr. second. The fastest sand printer produce 1 million voxels
- The process is continuous without distinctive layers in the product
- The 3D printed object is pulled up from the resin instead of being submerged in resin. The z-axis dimension is almost unlimited.



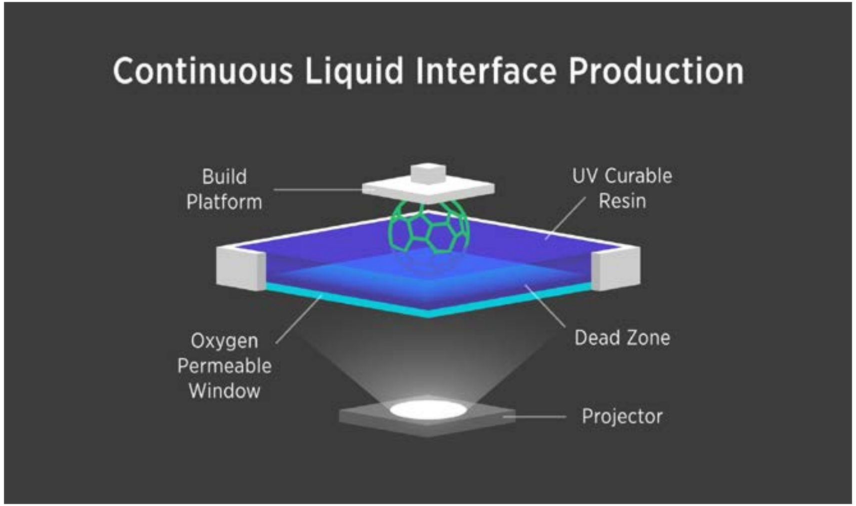
Technology

CLIP has an oxygen permeable membrane below the resin, creating a “dead zone” preventing the resin from attaching to the window. The 3D printed object rises slowly allowing resin to flow under and maintain contact with the bottom of the object.

CLIP can print rigid and flexible materials and a curing process can strengthen the objects beyond the strength of most polymers.

Bottom line is:

- Faster prints in the Z-axis direction than any other printer
- Very smooth prints without layers
- Very strong prints



Technology

Carbon 3D (www.carbon3D.com) has just introduced this CLIP technology to the market. Ford, BMW and major players like Autodesk and Google has invested a billion DDK bringing this technology to the market.

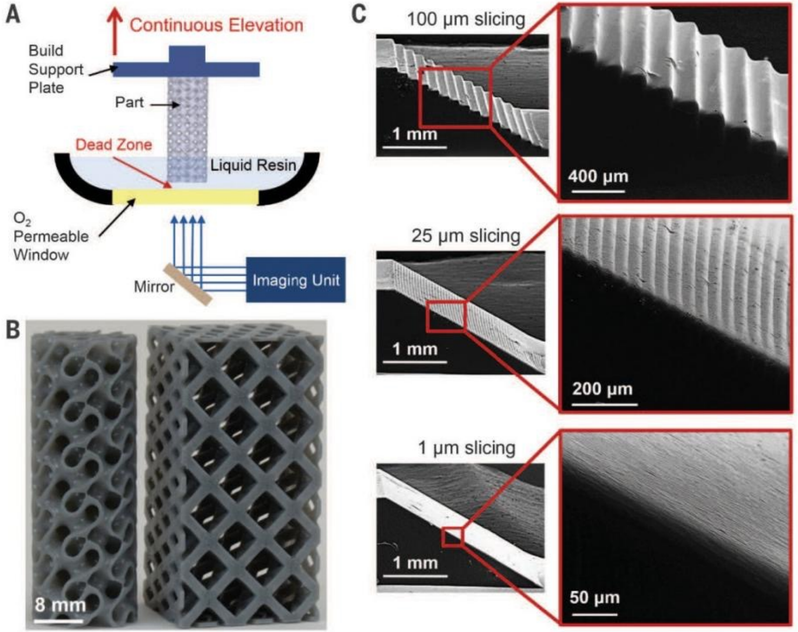
In this initial phase Carbon 3D printers are only available for lease at a cost of 260.000 DDK/year and the resin cost between 600 DDK and 2400 DDK pr. litre depending on functionality.

The limitation is that all parts of the print must be connected to the hoisted platform in a way where it is lifted rigidly and simultaneously. It is most likely not possible to print objects within objects or working machines.

Watch these videos

https://www.youtube.com/watch?v=UpH1zhUQY0c

https://www.youtube.com/watch?v=VTJq9Z5g4Jk



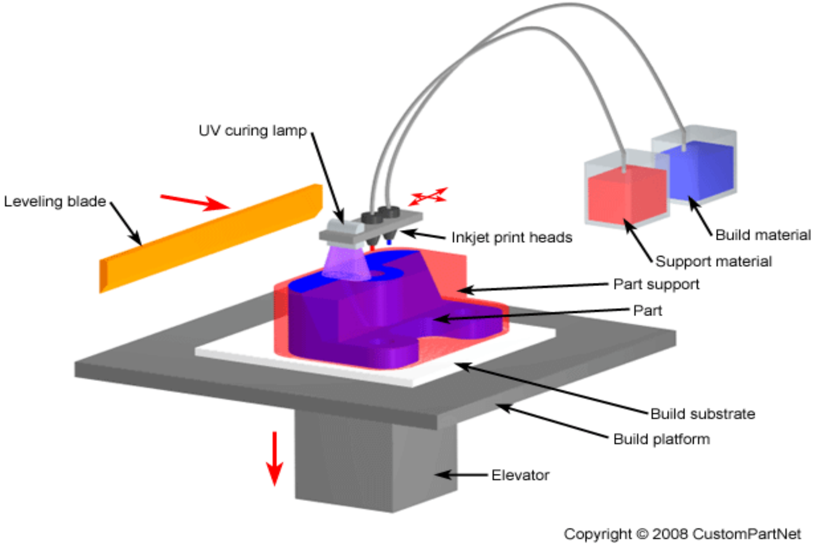
Jet

Jet printers deposit small droplets from multiple nozzles. The droplets are cured with UV light.

Jet technology is the choice if you need professional accurate working models in full colour without the risk of shrink or warp

The advantage of the Jet technology:

- Full colour
- Smooth surface (as the drops if softer than extruded thermoplastics)
- No thermal tension as the droplets are not heated, no shrink, no warp
- Integrated wax droplet support.
- Multiple nozzles increasing print speed about 10 times compared to FDM



Technology

The limitations of this technology is:

- High cost of proprietary resin
- Limited print size
- High cost of printer compared to print volume/capacity
- The Jet technology is not self supporting like the powder box solution. Overhanging construction are supported by printing wax and this wax is removed in a special dishwasher

Components are accurate enough to be added together to large structures.

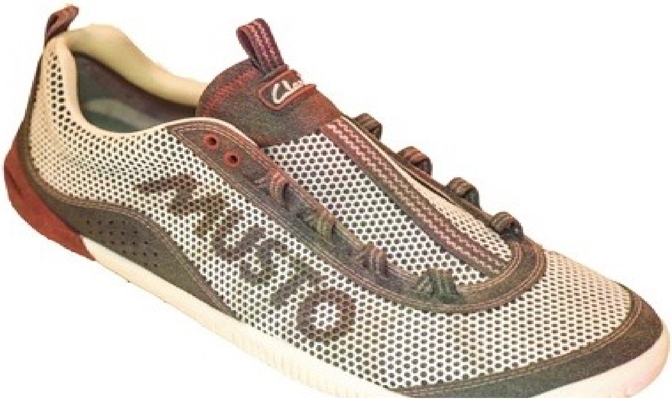
https://www.youtube.com/watch?v=sBRLrrM7DsY

The price tag for Jet printers is in the 0,5-1 million DDK range

Technology

Watch these videos

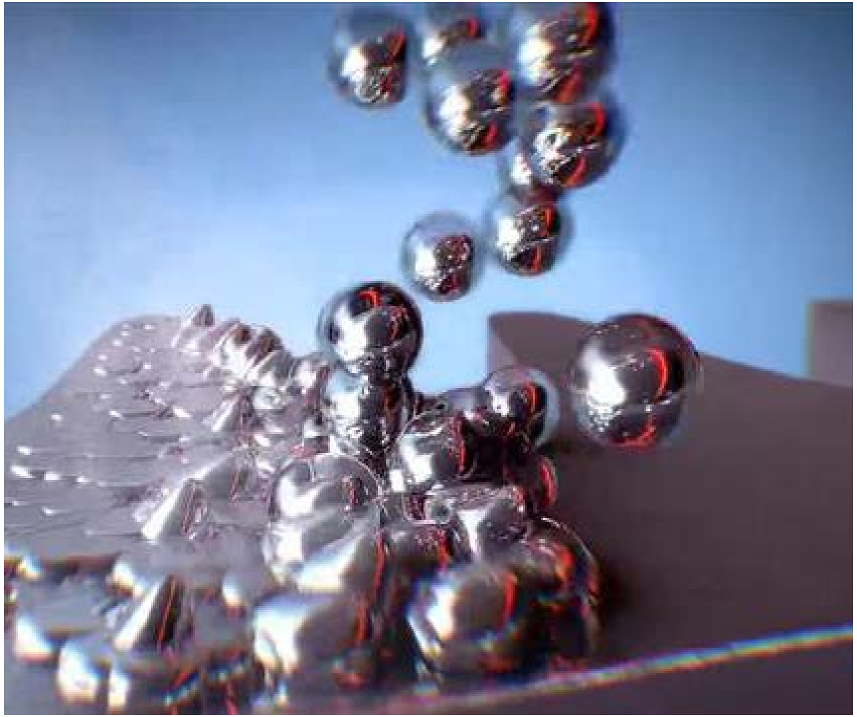
https://www.youtube.com/watch?v=lwEgjDj1wEA
https://www.youtube.com/watch?v=h-0266qG_2Y
https://www.youtube.com/watch?v=HMMJnn_gHWw
https://www.youtube.com/watch?v=qLV0hvA9Yhg
https://www.youtube.com/watch?v=8e--5u2LpHU
https://www.youtube.com/watch?v=FglwisdGMH8



Xjet

XJet's NanoParticle Jetting technology uses nano-sized metal particles suspended within a patented liquid formula. This formula can be jetted from standard printing heads, When put through high temperatures 300ºC, the liquid formula evaporates, leaving behind complex, precise, and strongly-bound metal components with layer thicknesses under 2 microns.

Thousands of nozzles cover the entire width of the print jet making the process up to 5x faster than laser sintering metal 3D printers. It also enables virtually any geometry to be designed, and is ideal for short run productions of precision, custom metal 3D printed parts in high-demand areas of production, such as aerospace, automotive, medicine, dental and more

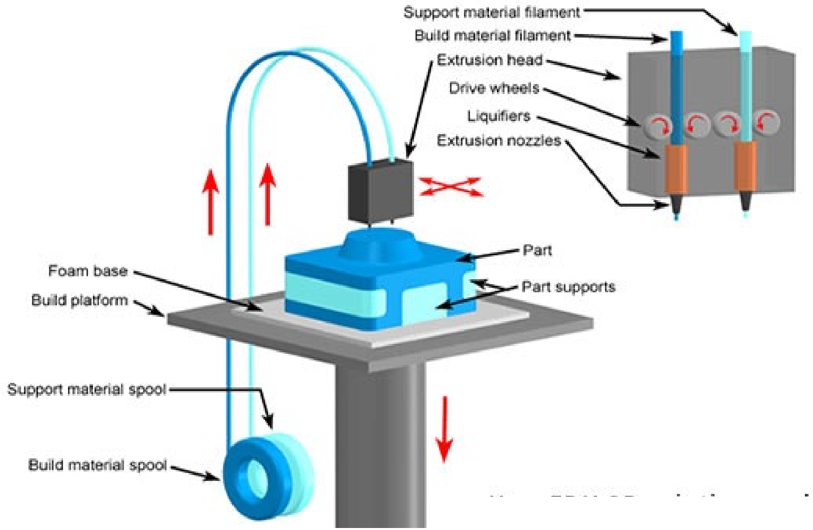


FDM

Fused deposition modelling (FDM) is extruding thin cylindrical fibres of thermoplastic material on top of the previous layers.

FDM printers have developed into a kind of "peoples printer". According to 3D hubs trend analysis https://www.3dhubs.com/trends as much as 90% of the printers are FDM printers.

The majority of the printers are using the RepRap open source concept with a lot of communality in software, components and printer filaments. It has become the industry standard for hobby printers.



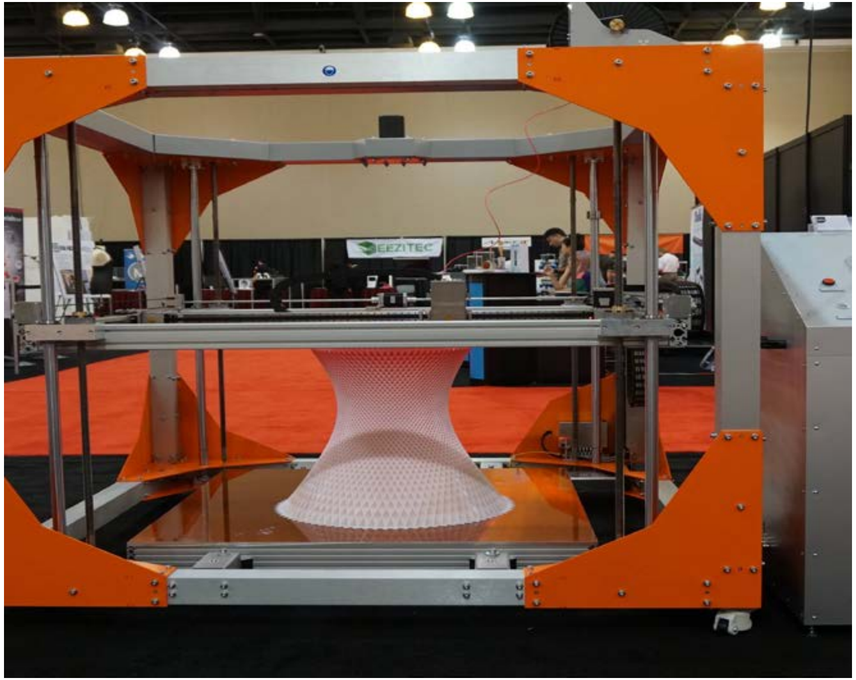
Technology

The advantage of FDM is that it is

- The most inexpensive printers starting at 3.000 DDK
- Printing with the most inexpensive filament in case you recycle ABS and produce your own filament.
- Low weight and small foot print of printer make FDM suitable for office and home use.

FDM printers can print with different thermoplastic filament materials and a mix of thermoplastic and clay, wood, metal. Thermoplastic combined with clay can produce ceramics.

FDM prototypes also print directly with concrete and PUR foam insulation



Technology

Industrial quality FDM printers are available but FDM printers have some serious limitation:

Each layer of thermoplastics is laid out at 200 °C and cools down to 20 °C. This build up tension in the printed material warping, bending, deforming and breaking apart larger prints. (se picture)

This tension straighten curved fibres and pulls them out of the printed object

It is difficult to print structures larger than 200 x 200 x200 m with ABS. BigRep use a PLA filament, which can print larger prints but size is an issue.

Technology

FDM print has difficulties bridging a gap of more than a few centimetres and cannot bridge curved gaps. The whole concept is to put one layer on top of the one below and if there is no material below there is nothing to print upon. FDM can only print things that are supported. It can print temporary support, but that support has to be cut away manually afterwards.

FDM printers have only 1-2 nozzles and covers some 300 mm/min so they are extremely slow. Most FDM printers have a capacity of 0,01-0025 l/h compared to the fastest printer are 16.000 times faster producing 400 l/h

As the fibres have a circular cross section they touch is other on a limited surface. The strength in the printed direction is good, put the strength perpendicular to the printed direction is significantly reduced.

Technology

FDM printers can be made very large for production of entire buildings http://www.wasproject.it/w/en/category/3d-printer-en/3d-big-delta-printer-en/ .

These mega printers extrude concrete and concrete cures rather slowly so it can only print 10-20 cm a day in height. The accuracy is very poor with extrusions in the 30-50 mm range which is about 100 times rougher than the other 3D printers.

BAAM has built a prototype 3D printer printing in 5 mm extrusions. The surface is very rough and the limitations from the small printers are also an issue here.

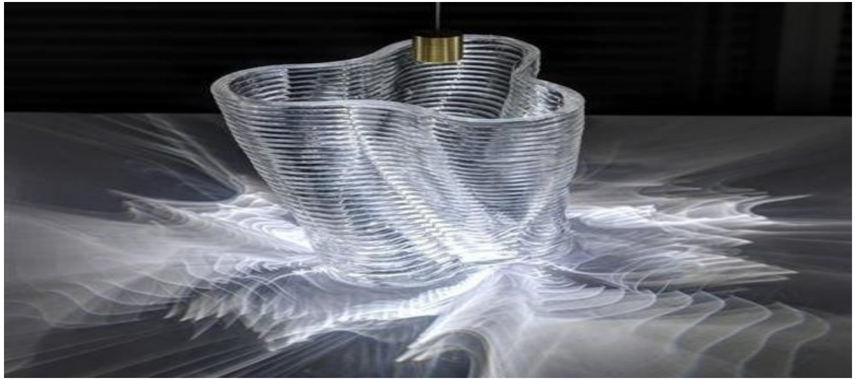
Technology

Wire Arc Additive Manufacturing (WAAM)
is a robot controlled welding process adding metal where needed. The movements are similar to FDM printers.
https://www.youtube.com/watch?v=Ao319dj6kiM
http://www.us.trumpf.com/en/products/laser-technology/solutions/applications/laser-welding/deposition-welding.html

Rapid Plasma Deposition builds by melting titanium wire in a cloud of argon gas
http://www.norsktitanium.com/
https://www.youtube.com/watch?v=sHfFERy6294

MIT has build a glass 3D printer extruding melted glass instead of melted thermoplastics.
http://matter.media.mit.edu/tools

Laval university is developing FDM print with PUR foam.
http://robot.gmc.ulaval.ca/en/research/research-thrusts/mecanismes-paralleles-entraines-par-cables/3d-foam-printer/



Caterpillar

Caterpillar is going to present this giant FDM 3D printer ultimo 2016.

It moves along tracks in the X direction, the print head moves in the Y direction on the portal and the portal moves in the Z direction by hydraulics turning at the hinges.

This machine is designed to print entire buildings with contour crafting concrete.

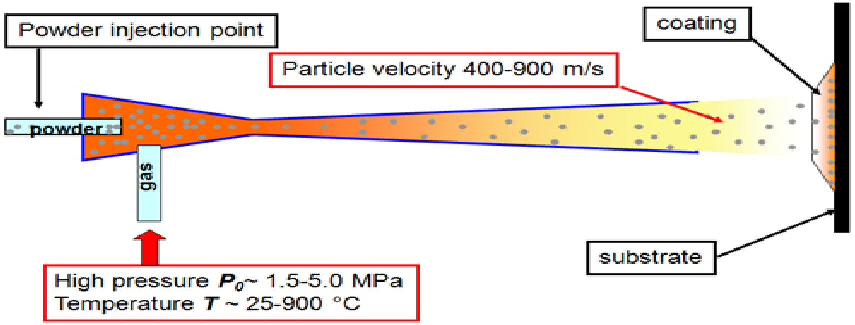
Technology

Spray

Accurately defined surfaces, texture and structure are spayed upon an object by a kind of spay paint material. It can recreate broken cogwheels, repair wear and tear, protect surfaces from chemicals and even build bridges over the canals of Amsterdam

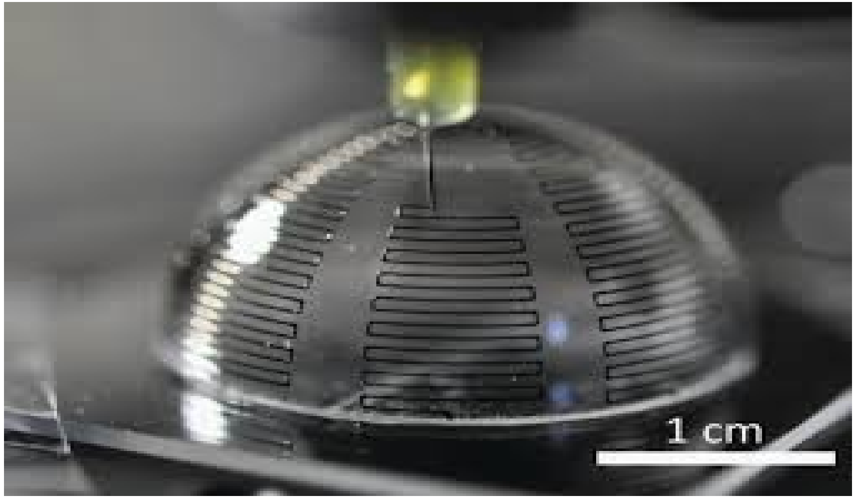
These prototype technologies use different concepts.

- High pressure accelerates fine titanium or other metal powder to a speed of 1.000 m/sec where it melts at impact with the object. https://www.youtube.com/watch?v=1AdKVTzfTc8



Technology

- Pressurised spray technology will be on the market end of this year http://www.hotendworks.com/
- Aerosol jet print can add electronic prints to any object. The technology is close to bubble jet technology used in 2D paper printers. http://www.optomec.com/resources/whitepapers-additive-manufacturing/
- MX3D is building a bridge in Amsterdam using a similar technology with steel instead of titanium. https://www.youtube.com/watch?v=NFF0QQIQDXE

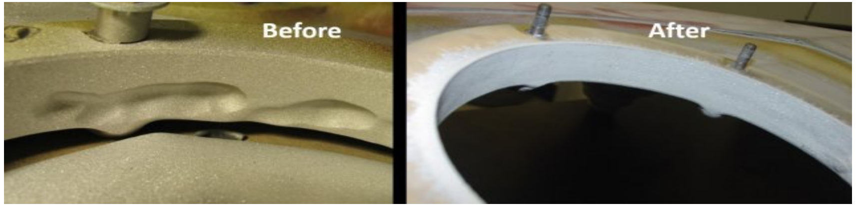


Technology

The advantages of this technology is that you can:

- 3D print on existing objects
- Repair objects
- Coat surfaces
- Obtain mechanical strength as a milled product
- Built completely unsupported structures because the high temperature material is cured instantly
- Build outdoors

Particularly the repair and surface treatment is a new functionality compared to other 3D printers.



Technology

The limitations are that

- The technology is slow like FDM printers because it only has one printing head pr. robot.
- The process is very energy consuming
- The equipment is expensive
- Few commercial spray printers are on the market.

Success cases

To be honest there are not many maritime success case yet. We are just in a moment of history where the snowball starts running.

Port of Rotterdam has initiated development of 3D print for maritime spare parts, China, US Navy and others have launched similar projects.

MAN has printed prototypes and turbo chargers and cylinders for ship engines

Hyundai has got a lot of money to 3D print components for ships.

But the martime sector is way behind General Electric. They are investing 36 billion DDK in 3D print, they already have more than 300 3D printers and they intend to 3D print 100.000 jet engine components by 2020

Port of Rotterdam & China CSIC

A project called "3D Printing of Maritime Spare Parts" by a consortium of 27 marine-related companies has been established by Innovation Quarters, Havenbedrijf Rotterdam, RDM Makerspace and AEGIR-Marine in order to share their expertise.

China Shipbuilding Industry Corporation (CSIC), the state-owned shipbuilder announced that it has achieved a breakthrough in 3D printing. In order to continue with its development of 3D printing technology, CSIC will expand its material manufacturing base in Kunming and establish a prototype technology centre in Yunnan province.

Success cases

MAN Diesel

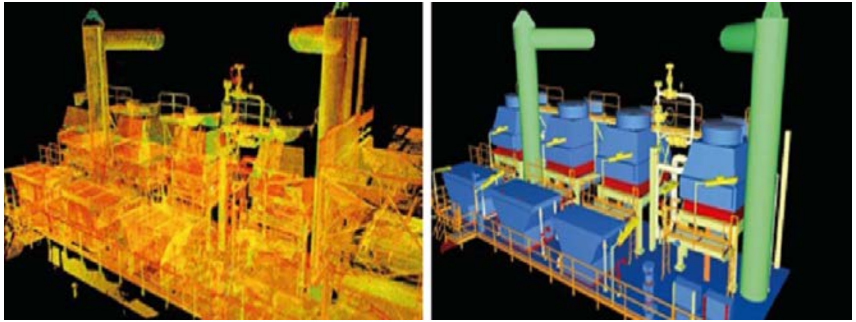
A cylinder head weighing several tonnes was produced at MAN B&W Diesel AG in Augsburg in record time, confirming the usefulness of the newest mold production technologies.

A company presentation by MAN B&W Diesel AG states as follows: "Diesel engines consist of 70% to 80% cast components, therefore our foundry is mainly concerned with the production of these components of the required quality and market-appropriate prices." It is possible to produce a large diesel cylinder head in two weeks

3D Scanning AS

3D Scanning AS, http://3dscanning.no/maritime-industry

Is a subsidiary of The Maritime Group of Norway has formed a partnership with 3Discovered of Chicago, a leading industrial 3D printing services platform, to supply 3D printed parts to its cruise/maritime ship repair and retrofit service business. The partnership will allow Miami, FL and Oslo, Norway based 3D Scanning to source a multitude of parts required for new and retrofitted equipment installations on vessels/cruise ships, in multiple locations without delays.



Success cases

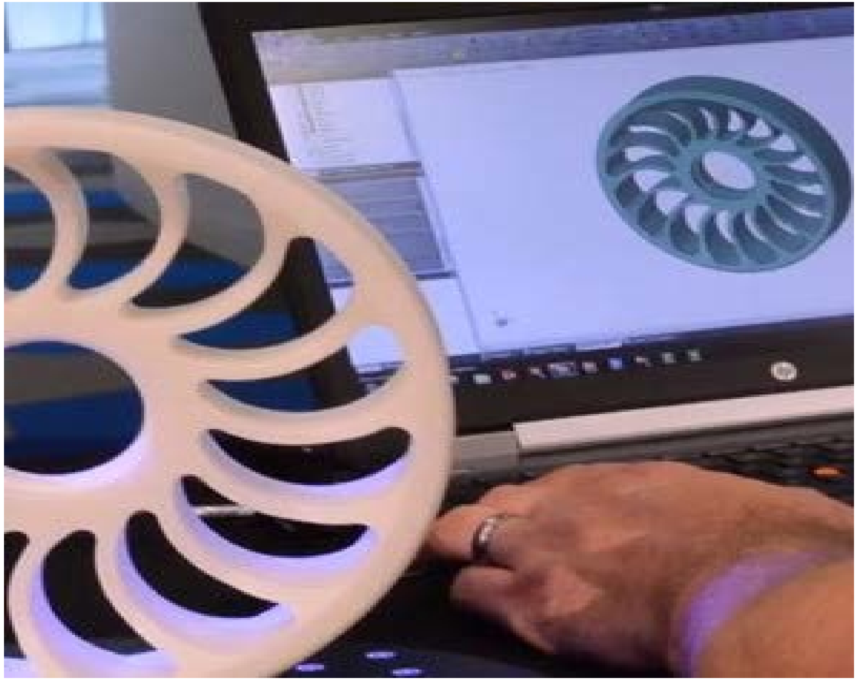
US Navy

Vice Admiral Philip H Cullom, Fleet Readiness and Logistics with the U.S. Navy, says

"It's my strong belief that 3D printing and advanced manufacturing are breakthrough technologies for our maintenance and logistics functions of the future". "We can gain new capabilities to make rapid repairs, print tools and parts where and when they are needed, carry fewer spares and, ultimately, transform our maritime maintenance and logistics supply chain."

Watch this video

https://www.youtube.com/watch?v=Hymam20SmqM



Success cases

3D Matters

3D Matters in Singapore is one of the longest established Additive Manufacturers in SE Asia with a strong track record of helping clients enter and grow their 3D printing needs.

3D Matters was started by Mark Lim and Hayden Tay in 2012 and is now in its next wave of growth developing a one-stop shop support through all stages of 3D printing from diagnostic and consulting, to design capture, right through to printing and finishing

http://3dmatters.com.sg/maritime.html


RITIME

tries ranging from consumer
ıcts to aerospace have already
ted and benefitted from 3D
ng technology. 3D printing can
ıelp the maritime, marine and
ore industry in multiple ways,
ding:

Improving spare parts manufacturing
Replicating scale ship, rig or equipment models with detailed features
Smoothening repair work flow
Speeding up performance testing
Minimizing errors in new products

e refer to our brochure for more
nation.

SHIP / EQUIPMENT MODEL

Imagine being able to demonstrate a fantastic new ship or new equipment design with an accurate full colour scale 3D printed model, highlighting those all-important design features that traditional model making is unable to reproduce.

VISUALISATION MODEL

We can produce sturdy and durable 3D-printed visualisers that help to speed up repair work by streamlining planning for issues such as access, emergency evacuations, material storage/offtake and more.

PROTOTYPES

While traditional prototyping can take weeks, or even months to complete, 3D-printed prototypes can be ready in a matter of days at a fraction of the cost.

We can produce accurate scale prototypes in a range of materials from highly accurate nylon to full colour sandstone.

PERFORMANCE TESTING

We can rapidly produce high-performing, strong prototypes of hulls, rudders, propellers and top sides for experimental tank testing of new designs helping shave critical days and dollars from the testing cycle.

SPARE PARTS

3D printing can design or reverse engineer obsolete or long lead time spare parts that can help extend equipment life or reduce equipment downtime.

With 3D printing, we can produce spare parts in a range of metals from Stainless Steel 316L to Titanium and Inconel. We are also able to provide certification of material compliance by international laboratories for the final printed part.

Qinetiq trend analysis

Britain's navy could be using a fleet of unmanned surface and underwater vessels and small 3D-printed ships within 15 years, according to a report from the former government defense-research laboratory, Qinetiq Group Plc.

Three-dimensional printing of craft up to 15-meters (50 feet) long and formed from layers of metal, plastic powder or graphene would permit cheaper and quicker production, according to the Global Marine Technology Trends 2030 report. Navies could also use the process to print mission-critical items at sea, allowing them to spend less time in dock.

https://www.qinetiq.com/media/news/releases/Pages/maritime-autonomous-systems-driving-the-biggest-advancement-in-maritime-security-in-over-a-century.aspx

Success cases

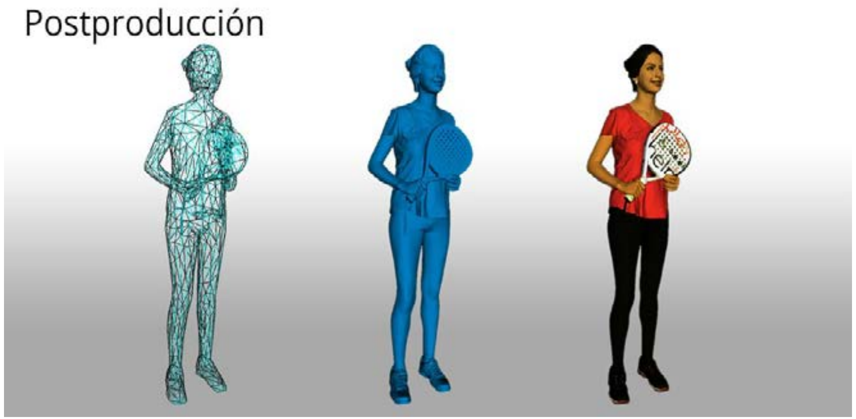
Hyundai

The Ministry of Trade, Industry and Energy South Korea has decided to invest $20M in a five-year plan (2017-2022) to research into 3D printing and 3D manufacturing of ships and offshore equipment.

Costa Cruises

Costa Cruises has partnered with 3D design studio Labs to offer passengers on board Costa Diadema the chance to purchase miniature 3D printed statuettes of themselves.

Described by Costa Cruises as a "quirky souvenir", the latest 3D technology is used on-board to capture a three-dimensional digital scale model. Experts on the ship complete a quick body scan, immortalising every detail of a figure, from hairstyle and clothing to arm position.



Success cases

First FAA approved 3D print

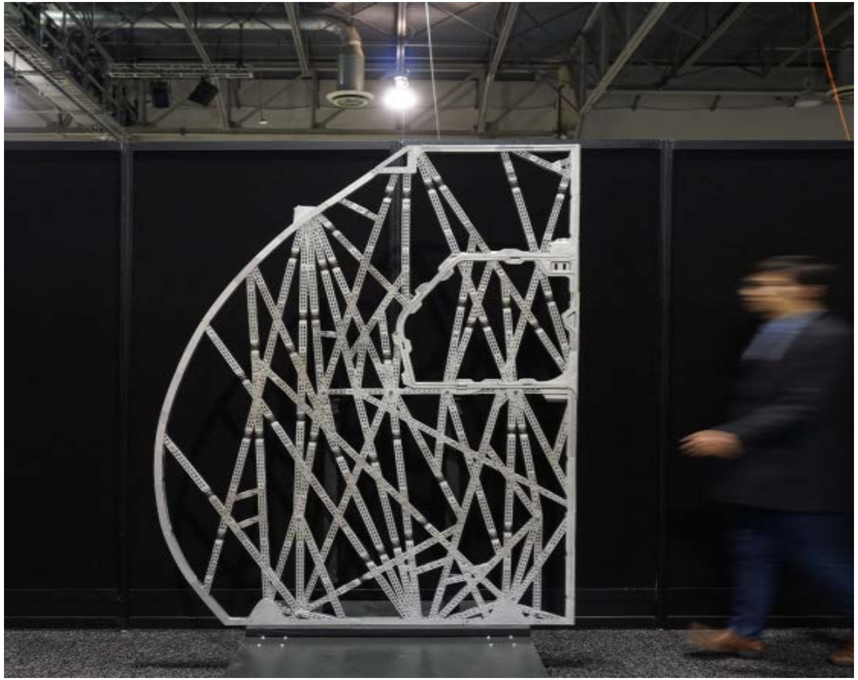
The fist piece of silver metal that houses the compressor inlet temperature sensor inside a jet engine is a part that’s a bit obscure even for many aviation aficionados. Starting now, however, it’s becoming a symbol of one of the biggest changes sweeping jet engine design.

The housing for the sensor, known as T25, recently became the first 3D-printed part certified by the U.S. Federal Aviation Administration (FAA) to fly inside GE commercial jet engines.

GE Aviation is currently working with Boeing to retrofit more than 400 GE90-94B jet engines – some of the world’s largest and most powerful – with the 3D printed part. The GE90 family of engines powers Boeing’s 777 planes.

Airbus

Airplane partitions are typically very heavy – and they need to be equipped with a cutout for emergency stretchers and a fold-down chair for cabin attendants. This creates a tricky puzzle for engineers looking to lighten the load. The new 3D-printed partition features a functional, yet artistic criss-cross design that turns out to be even stronger than its predecessor. Best of all, when you take into account the existing number of A320 planes, Airbus estimates that the new partition could save up to 465,000 tons of CO_2 emissions per year.



Success cases

BMW 4D print

BMW's Alive Geometry Technology, a physical 3D sculpture spread over the instrument panel, seats, and other car parts, consists of nearly 800 'moving triangles' that can shape-shift and communicate with the driver.

With Alive Geometry, BMW has tapped into the extremely forward-thinking concept of 4D printing, where 3D printed objects are able to re-shape or re-assemble themselves over time, leading to exciting applications in soft robotics or biomimetic devices. The system thus integrates novel materials, intelligent sensors, and interactivity to enhance every possible aspect of the driving experience.

Success cases

Audi

Already In 2004 Audi created a concept car manufactured in large part by 3D printers. The Audi RSQ was featured prominently in the sci-fi film I, Robot in 2011.

The car industry actually expects to 3D print a variety of personalised styling kits for your car.

Peugeot fractal

Inside Peugeot's gorgeous i-Cabin, 3D-printed panels present a never-ending feedback loop of geometric shapes, which are both visually stimulating and acoustically functional. With this near blank slate, a palette of silence, you can add music, conversation, or unique ambient noise.

Success cases

NASA

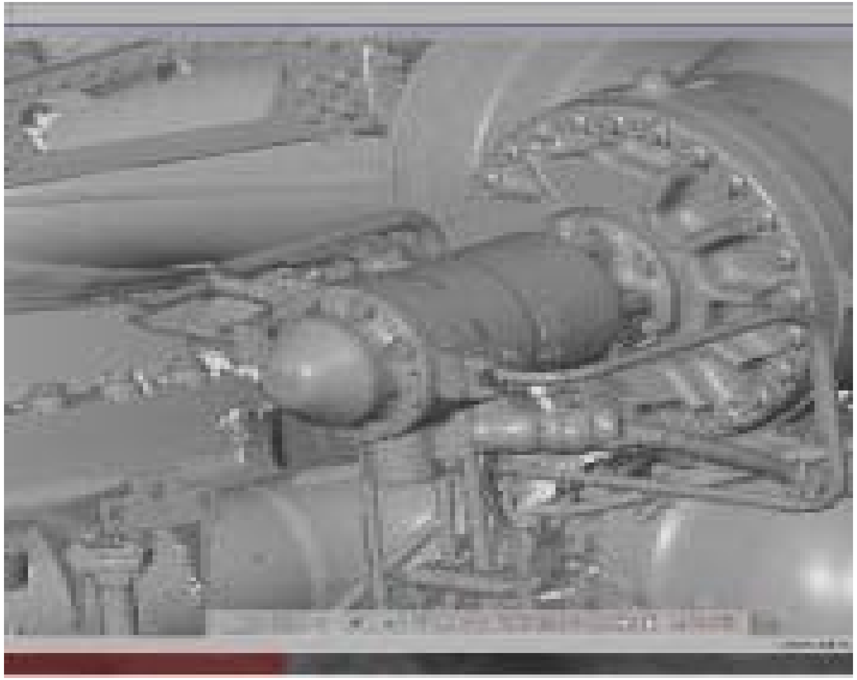
NASA needed to reduce the weight of satellite nozzles. The combustion chambers of compact in-space satellite engines typically consist of a convergent-divergent nozzle with an unsupported nozzle exit. The propellant reactions complete in the convergent section before the exhaust gases flow through the throat contraction into the divergent section where they are expanded supersonically. Existing chambers are designed to withstand the non-operational loads associated with the launch, with thicker walls reacting these transient loads. Once on station and operational the chambers do not need such thick walls

Success cases

NASA

NASA needed to reverse engineer their Apollo spacecraft engine in order to 3D print spare parts.

They used 3D Scanning and Point Cloud Processing. They started using Geomagic Solutions software for reverse engineering, combined with an ATOS Triple Scan and a TRITOP system for scanning, the team created a baseline scan, or Outer Mold Line (OML) model, of the entire engine. Then they methodically removed each part, scanned them individually, and processed them into accurate 3D data with Geomagic.



Success cases

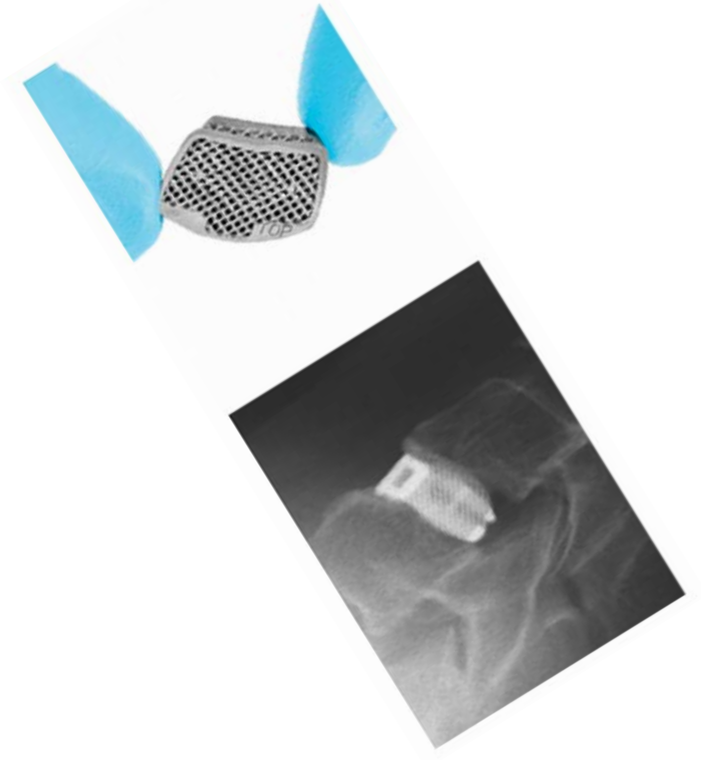
Heat exchanger

CEEE is working with Oak Ridge National Laboratory to develop the next generation of miniaturized air-to-refrigerant heat exchanges for HVAC and refrigeration applications.

For this project, funded by the US Department of Energy's Building Technologies Office1, only one type of manufacturing could satisfy CEEE's lean and green mandates: direct metal printing (DMP)

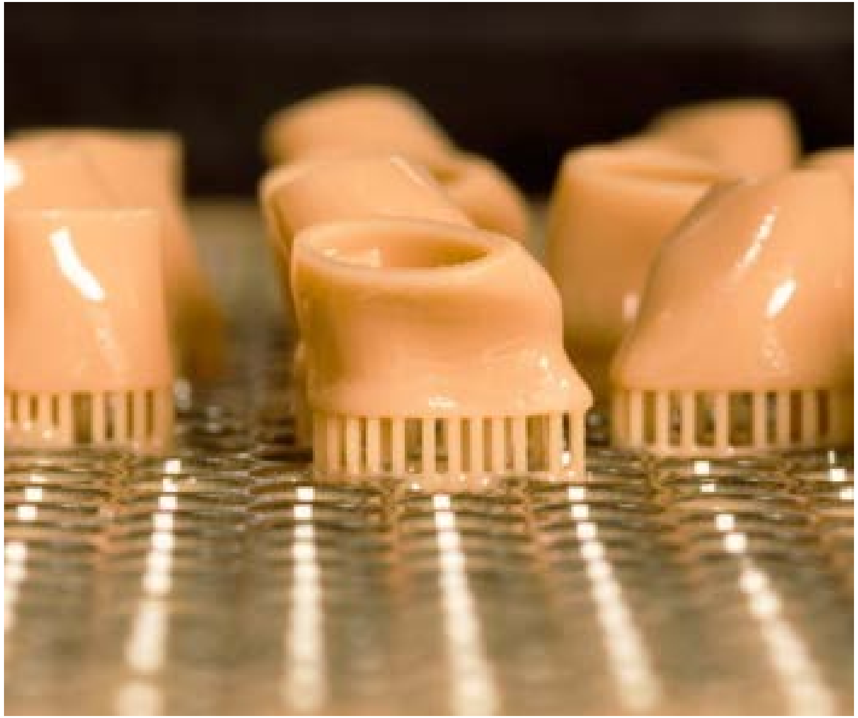
Medical implant

German medical device manufacturer Emerging Implant Technologies (EIT; www.eit-spine.de), the first European orthopedic implant maker to focus solely on manufacturing with 3D printing, recently demonstrated the vast potential of medical additive manufacturing by supplying the first anatomically adapted, 3D-printed titanium fusion implant to a patient with a degenerative cervical spine condition. The technology behind this pioneering effort was 3D Systems' Direct Metal Printing (DMP) technology, which is capable of building metal objects layer by layer in a variety of metals, in this case biocompatible titanium. Materialise produce 180.000 implants pr. year



20 million 3D printed hearing aids

Widex, a Danish hearing aid manufacturer won the sixth annual European Inventor Awards recognizing outstanding inventors with their CAMISHA, which means "Computer-Aided-Manufacturing-for-Individual-Shells-for-Hearing-Aids" CAMISHA injects liquid silicone in the ear to create an impression of the hearing aid user's ear canal. It is then scanned into a computer program and the information is converted into a 3D model. A 3D laser printer build the shell to fit the ear. Widex was the first company to produce some of the world's smallest, most comfortable hearing aids, that fits perfectly the individual ear canal. Now 20 million hearing aids are 3D printed every year



Success cases

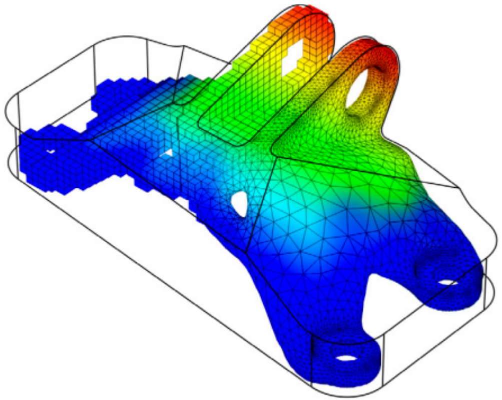
Hankook tire

Myungjoong Lee, CAD professional in Hankook Tire's design department, prints a tire design in the ProJet 660 before he leaves at the end of the day, and the final model will be waiting for him when he gets to work next morning. With the size of the models being created, it takes about seven to eight hours to build a finished mockup model overnight

Success cases

Bracket

GE's original design
The original design of the bracket used in the GE Aircraft challenge. The re-designed bracket was required to fit within this volume and meet load requirements while reducing the overall weight of the part.



Cloudmesh optimization
The topology optimized part design generated by Frustum's software.

Final DMP part
The GE Aircraft engine bracket redesigned by Frustum and manufactured by Quickparts on a 3D Systems ProX DMP 320 printer. The new part passed all the load condition requirements specified by the GE challenge and stayed within the same footprint while reducing weight by a staggering 70 percent.

Success cases

Impeller

In the conventional process, the file is sent to the tool shop where a tool is created in which wax patterns will be molded. For this impeller, the tool cost $40,000 and required 7-9 weeks to create.

For the Tech Cast process, the model is sent to 3D Systems where a QuickCast pattern is created. The cost of the pattern in this case is $3150 and requires one week.

Success cases

Lotus F1

Thomas Mayer, COO at Lotus F1 Team, is in no doubt of the added efficiency these technologies have brought to the team: “The first SLA® System parts were installed in a racecar in 2001 and following their success, we have continued to explore the boundaries of these materials. Since the launch of our Advanced Digital Manufacturing (ADM) Centre in 2002, 3D Systems’ technologies have become an effective new manufacturing process that enabled us to reduce both cycle times and cost, and has added invaluable benefit to the team.

Success cases

Cisco

Cisco uses the ProJet® 460 to create 10 models per week, on average, for design review. Models are printed directly from 3D CAD files that are submitted by Cisco designers around the world.

Success cases

Logitech

“We don’t need to think of the hassles that come with the standard prototyping and outsourcing of parts,” said Kevin Forde. “Using the Objet Eden, we can print any part deemed necessary. That fundamentally encourages people to try different design solutions.”

Keeping creative ideas confidential until a product is launched is critical in Logitech’s highly competitive market. Commented Kevin Forde: “We live in a very aggressive market environment, with a lot of competition, so reducing the number of contacts with the outside world is indispensable for our product’s success. Having Objet in-house helps us reduce exposure.”

Valves

The QuickPlastic™ cast urethane process gave Quickparts the ability to meet detailed critical feature requirements, satisfy post processing and assembly needs, and color-match the parts to specific MAC colors.

"The results are amazing," said Francis. "We were able to get highly detailed models of the valves at a fraction of the weight. We took a 75 lb. part down to a 9 lb. model and we didn't have to sacrifice on any of the small features."

Success cases

Drone

“The reason flying is still magical is because anytime an aircraft takes off for the first time, someone says I can’t believe it flies,” Dan said. “This was a magical moment. I absolutely love jet engines and seeing a 3D printed jet aircraft fly was amazing.

3D print service

Before you rush out and buy a 3D printer you should consider ordering your first 3D prints from a service provider. The service provider can help you with:

- Testing you design for design flaws that will make 3D print fail
- Suggesting the best possible material for your task
- Save you a lot of trouble with cleaning and maintenance

Or you can choose a hybrid version where you have an inexpensive FDM printer to do a lot of prototyping and ship the job to a service provider when your design gets serious.

For many corporations and institutions more than one type of printer may be necessary. You might need:

- Fast prototypes
- Convincing prototypes
- Production prototypes
- Mechanically strong prototypes.

Neither may you have the10 million DDK budget necessary to shop all kinds of 3D printers nor a 100 m2 workshop to place them in.

3D printing is about prototyping. Why not prototype you experience with 3D prints fro different printers before you start buying one?

3D providers

3D systems

3D Systems has e revenue of 4,5 billion DDK. 3D Systems produces 3D printers, print materials, and offers on-demand parts services and digital design tools. Its ecosystem supports advanced applications from the product design shop to the factory floor to the operating room. 3D Systems' precision healthcare capabilities include simulation, Virtual Surgical Planning, and printing of medical and dental devices as well as patient-specific surgical instruments. As the originator of 3D printing and a shaper of future 3D solutions, 3D Systems has spent its 30 year history enabling professionals and companies to optimize their designs, transform their workflows, bring innovative products to market and drive new business models.

http://www.3dsystems.com/

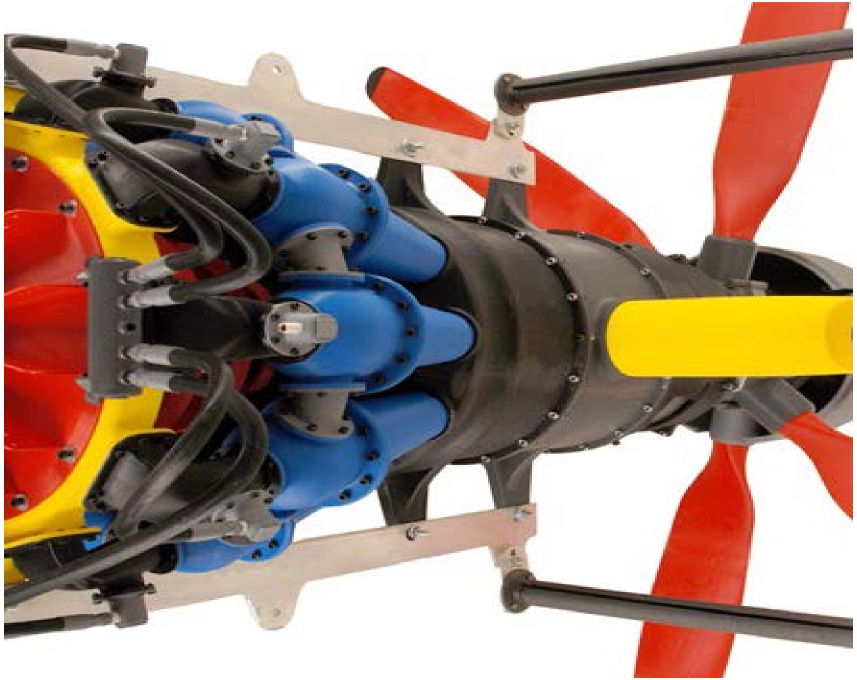
3D providers

Stratasys

Stratasys has a revenue of 1,1 billion DDK. For more than 25 years Stratays has offered the its own 3D printer technologies, deep industry expertise and flexible implementation options.

Statasys' mission is to find simpler, smarter approaches to stubborn design problems – and greater confidence to confront towering human and technological challenges. Less hindered by the usual constraints, they can imagine, design, iterate and replicate more freely than ever before. By providing the shortest possible path from idea to solid object, Stratasys empowers them to untangle complexity, tackle tough problems, uncover new solutions – and to do it all with the urgency our accelerating world demands.

http://www.stratasys.com/



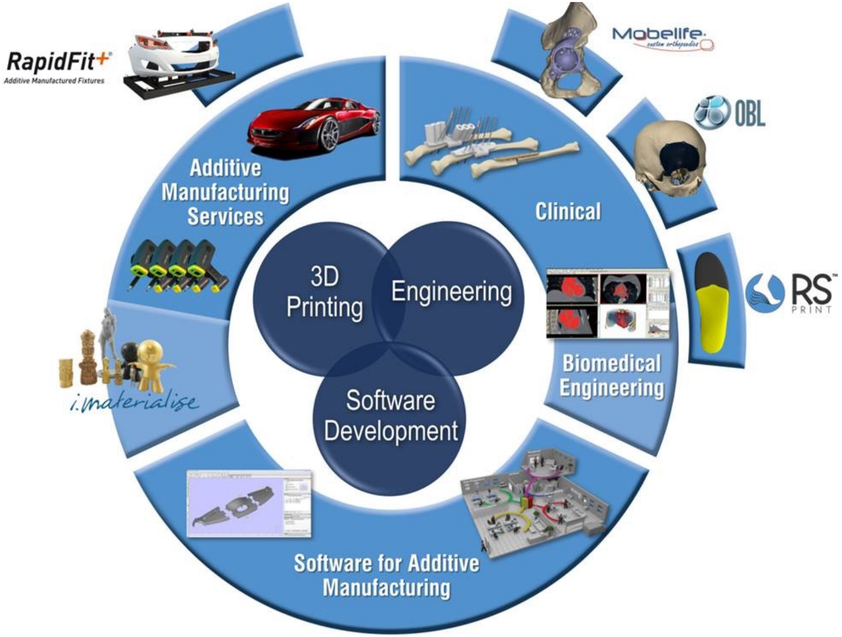
Materialise

Materialise has a revenue of 847 million DDK and was among the first in 3D printer services 26 years ago. Materialise are diversified into all kinds of 3D print on demand. offering everything from hardware and software to consultancy.

Materialise has also build consumer brands

- I materalise where you can order prints online
- MGX consumer products

http://www.materialise.com/
https://i.materialise.com/
https://mgxbymaterialise.com/



3D providers

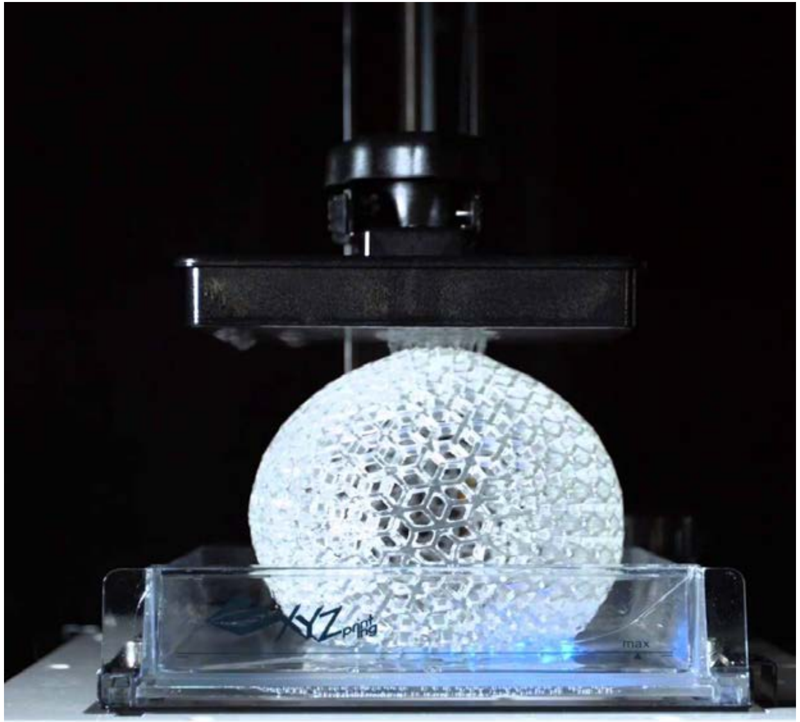
XYZ printing

Founded in 2013, XYZprinting is dedicated to bringing cost-effective 3D printing to personnel and business around the world. XYZ printing is growing several hundred pct. every year and has a revenue in 2015 of 450 million DDK. XYZ printing produces budget 3D printers at prices down to 3000 DDK.

XYZ new Nobel offers stereo lithography from around 13.000 DDK

http://us.xyzprinting.com/us_en/Product/Nobel-1.0

https://www.youtube.com/watch?v=lEUbJ9sccXc



3D providers

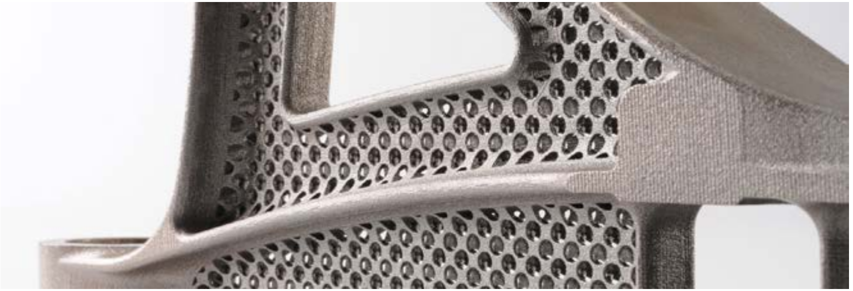
Exone

ExOne produces the fastest 3D printer in the world and has a revenue of around 300 million DDK

ExOne, provides 3D printing machines, 3D printed products and related services to industrial customers in multiple segments, including pumps, automotive, aerospace, heavy equipment and energy.

The ExOne® process, which utilizes Binder Jetting technology with industrial materials, gives traditional manufacturers an opportunity to reduce costs, lower the risk of trial and error and create opportunities for design innovation.

http://www.exone.com/



3D providers

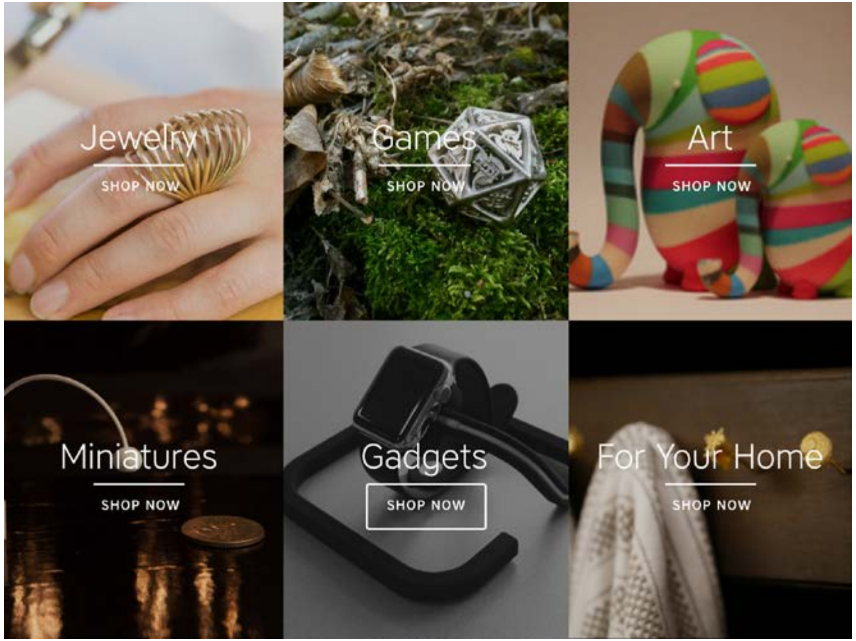
Shapeways

Shapeways is the Amazon of 3D printing with a platform for buying and selling designs and a platform for 3D printing. The revenue is around 260 million DDK. Instead of shopping in a real boutique you shop designs and personalise them.

Shapeways describe it this way:

“Founded in 2007, Shapeways is led by folks who've spent most of their careers in startups, and combine serious technical chops with an inspiring vision of what the world could be. We’re bringing together a passionate, dynamic team of game changers. We're having a great time working and playing harder than we ever have in our lives. It doesn’t hurt to know that what we do is changing the future as we know it.

http://www.shapeways.com/



3D providers

Ultimaker

Ultimaker started selling their products in May 2011 and has a revenue around 250 million DDK doubling every year. The company's foundation was laid at ProtoSpace Utrecht. Their first prototypes bore the name "Ultimaker protobox" but newer prototypes were just titled "Ultimaker". Since then they have kept improving quality and reliability making Ultimaker one of the most sold FDM 3D printer

https://ultimaker.com/

3D providers

Voxeljet

Voxeljet produces the largest industrial 3D printer in the world and has a revenue of 180 million DDK.

Voxeljet is a manufacturer of industrial 3D printing systems of the power bed concept. Besides the development, manufacturing and distribution of 3D printers, Voxeljet also operates service centers for the on-demand manufacture of molds and models for metal casting in Germany and abroad.

http://www.voxeljet.de/en/

3D providers

EOS

Founded In 1989, EOS is a pioneer and world leader in the field of Direct Metal Laser sintering (DMLS) and provider of a leading polymer technology. EOS is producing 3D printers, and provides software, services and consultancies. EOS has a revue of 164 million DDK.

http://www.eos.info/en

3D providers

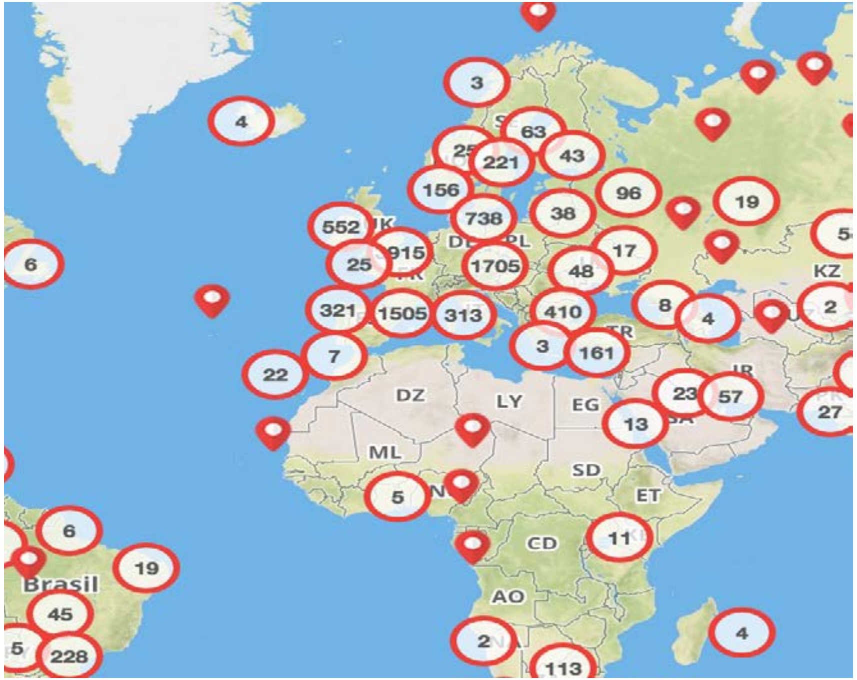
3D hubs

3D Hubs is the Airbnb of 3D printing taking a 15% commision of each 3D print and a fast growing revenue around 30 million DDK. 3D Hubs was founded out of frustration that the industry was not delivering on the promise of 3D printing to decentralize manufacturing.

Since 2013 3DHubs has connected 30.000 private 3D printers globally into one online platform and make them locally accessible.

Today, 3D hubs provide over one Billion people with access to 3D printing within 10 miles of their home.

Visit https://www.3dhubs.com/ and find trend reports, designs for 3D print, rating of printers and an online 3D print community



HP 3D printer

HP is now entering the market with a new 3D printer with:

- Mechanically strong prints
- Multiple material prints
- Colour prints
- 10 times faster prints
- Automatic post processing
- Less expensive filler material
- Reduced cost
- Smooth surface

HP has a annual revenue of 675 billion DKK and is thus more than 100 times larger than #1 3D printer company 3D systems. That could be disruptive in the 3D print business

Xjet

X jet offers break through metal prints with a new jet technology using nano metal powder.

It can basically the same as the polymer jet printers but this time for metal prints. The polymer jet printers disrupted the SLA professional printers and it is the same team who invented the jet printers who now has invented the metal jet printers

The advantages are:

- Speed
- Accuracy
- Smooth surface
- Minimal post processing

Carbon3D

The ultra fast Carbon 3D is finally here.

Continuous Liquid Interface Production (CLIP) is a superfast way of printing with a potential to be the fastest. The first Carbon 3D has a small print volume of only 14,4 x 8,1 cm and a height of 33 cm. But the accuracy is extreme at 0,075 mm and the z-axis print speed is 200 mm/h or 3000 layers/h. This is about 100 times more layers/h than other printers. Imagine what will happen when Carbon 3D is built in bigger dimensions. Already a 1 x 1 m printer will print 200 litre/h gross volume with 0,075 mm resolution

Business innovation model

Try to work you way through business innovation model and consider how 3D printing could change your business model.

- Profit model. Do you sell hardware parts, printer files or service contracts.
- Are they produced on you factory or from a network of OEM 3D print centre around the world.
- How is the structure of your company if you don’t have inventory, logistics or production
- What happens to the process if every product is a prototype
- How does it change the performance of your product
- How can you integrate systems
- How does print to customer change your service
- How does it change sales channels
- How does it change your brand and importance of brand
- How does it change your interaction with your customer that everything is tailor made

You will realise that it changes every single part of your business model

Business models

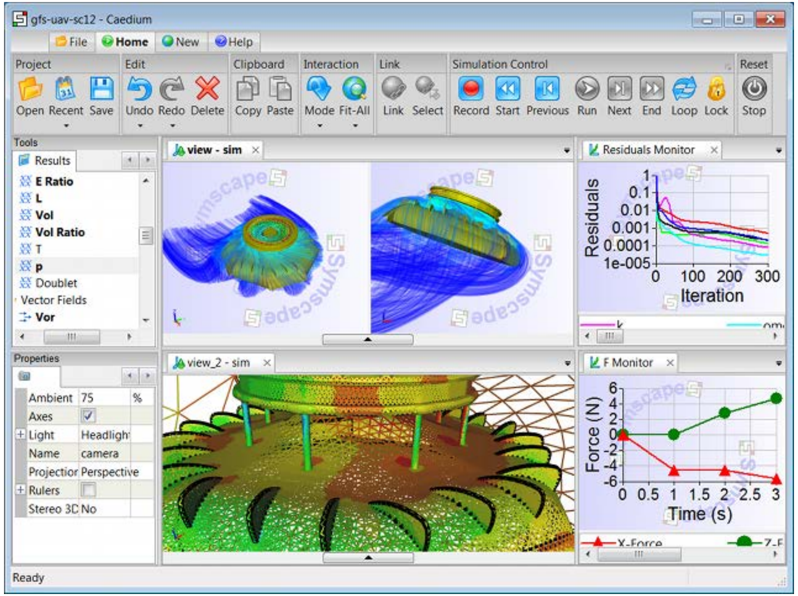
Usually the marine industry sell hardware.

- Selling 3D printed components is still hardware. That would only change an industry business model moderately
- Selling the file for 3D print is software. This business model is like selling music, e-books etc. An I-tunes business model
- Selling a customized 3D print file is consultancy
- Selling an Artificial Intelligence automatically generated and co-created customization of a 3D print based on Big data knowledge of the consumers preferences and needs is changing everything.

Value chain

Don't 3D print your normal components and don't keep the organisation. Start from scratch

1. Optimise the design and reduce the number of components and processes
2. Move the production close to the users to reduce lead time and logistics
3. Change the customer relation to customization and consultancy
4. Close the inventory and print just in time delivering spare parts to old machines with contemporary performance
5. Use ICT and AI where ever possible



IP

You can protect your 3D printer files legally by:

- Copyright (weak definition and coverage)
- Design protection by patent authorities (need to be visually distinctive)
- Trademark (needs to be very distinctive like a cola bottle)
- Non disclosure agreement with the printing company

You can also protect your files practically by encryption in a way where you pay to get an ever changing key to the encryption.

Or you can include 3D print in a service and warranty programme making copying irrelevant

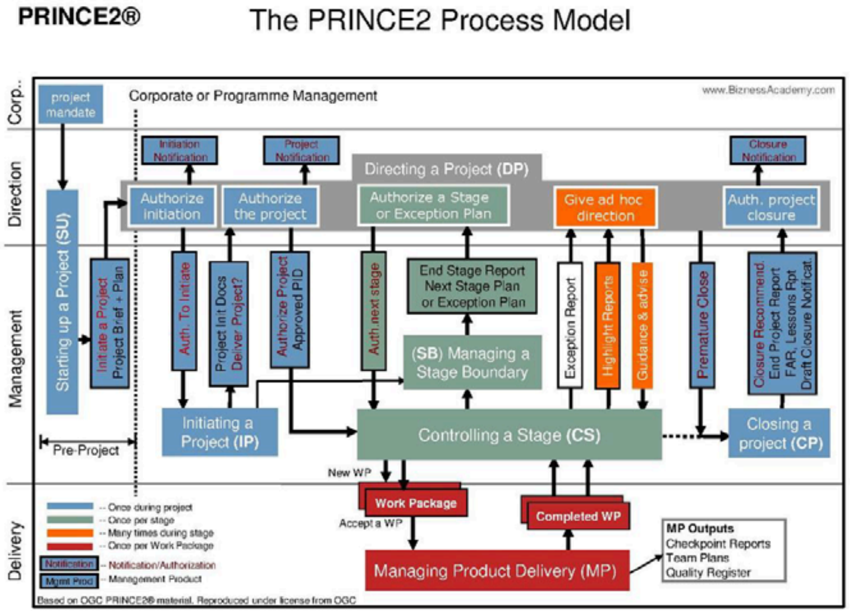
Project model

Work your way through PRINCE2 or any other project model you use in your organisation and make a strategy for implementation of 3D print .

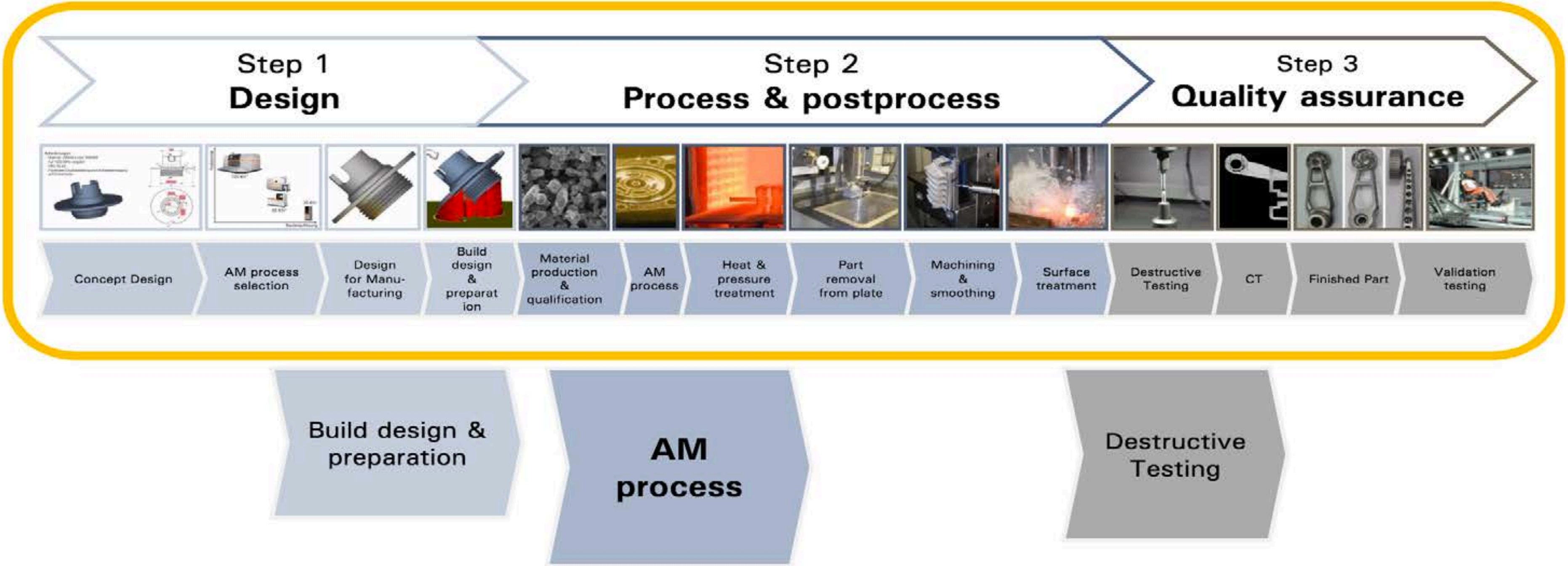
Start with the "why". What do you expect to achieve by 3D printing

Work you way through all the "how" and "who" in the rest of the model.

Involve the staff and unions in the process and convince them that 3D is about growing business rather than making them unemployed.



Process plan at Brose

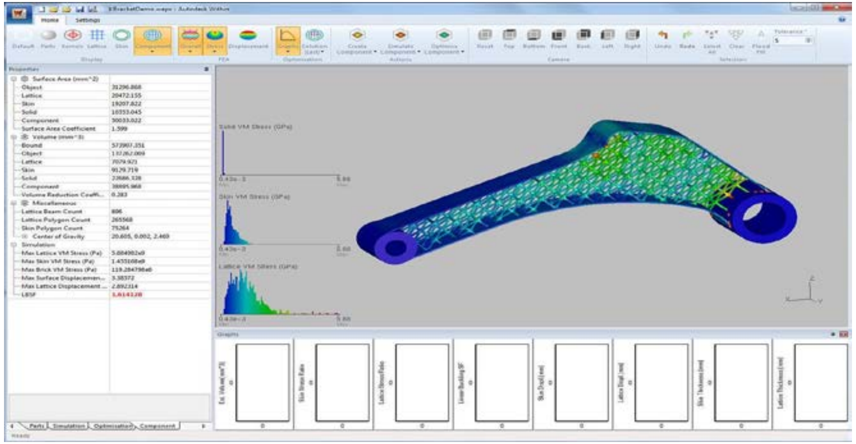


Really computer aided

Within (http://www.withinlab.com/) is a company specialised in software optimising shapes by functional optimisation using:

- Fluid dynamics to design the optimal flow in heat exchangers.
- Finite element software to design the optimal heat flow in a heat exchanger
- Finite element calculations of forces to minimise materials

This video explains this software in more detail https://www.youtube.com/watch?v=3KQfHBWEBg8



Supporting software

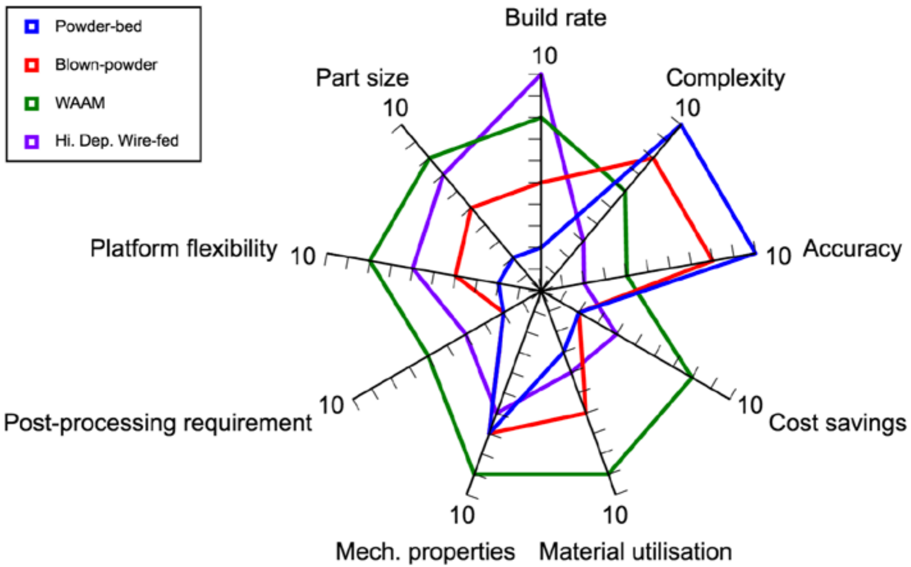
Materialise is one of the leading software suppliers in special tools:

- Combine different formats into one solid part or assembly
- Adjust wall thicknesses after scaling
- Thicken a-surfaces and make parts watertight
- Add ribs to reinforce walls
- Remove small features such as fillets and holes, and simplify assemblies
- Design fixtures directly on parts
- Split models into single pieces, and ensure fit with build platforms
- Cad import module reads the surface structure of your cad file and lets you create detailed surfaces by taking low-accuracy surfaces and reloading them with a higher resolution.
- Cad link module gives you the possibility to easily bring your file back to cad
- Texturing module: efficiently create textures, perforations and patterns
- Lightweight structures module reduce the weight of designs, replace solid volumes; create porous designs while minimizing costs and material usage
- Topology optimization reduces the weight of an indicated space, taking into account the material properties and a fixed set of loads on the design space. The organic-looking STL files, have very rough surface quality that is cleaned up
- Magics Reporting allows your account managers to access multiple file formats and exchange annotations and comments with the customer
- E-Stage increases Additive Manufacturing productivity by automating Stereolithography support generation, optimizing SL build process, and reducing finishing work.
- Build processor, bridge the gap between 3D software and printer
- Control Platform, take control over additive manufacturing, and filling of the box
- Streamics, manage & streamline your am production process
- Robot enables instant quoting and reduces the manual effort needed to prepare parts for building.

Process comparison chart

This process comparison chart is a way of mapping your demands versus the strength and weaknesses of different 3D printer technologies.

Technology shift very fast so be aware that the comparison to the right may well be outdated and that it anyway has to fit the size of the object you want to print and that the processing is highly dependant of the geometry of you object



Source: Cranfield University / waammat.com

Post processing

3D print most often needs post treatment:

1. FDM prints need to have supports and mishaps removed with a sharp knife
2. Jet prints need have the supporting wax removed
3. All box powder printing need to be unboxed, vacuum cleaned, and dusted
4. All fluid prints need to cleaned and dried
5. Both box powder and fluid printers need to have support and bottom plate cut off
6. Low accuracy metal prints need to be milled.
7. Some polymers need to be cured to have optimal strength
8. Some metal prints need to be heated to release thermally induced stresses.
9. Except for a few colour printers colours have to painted on the prints

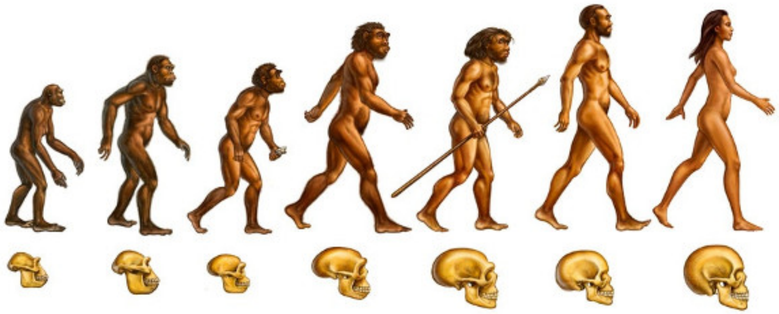
This post processing often double the cost because it is manual. Not everything is printable by the same printer. So some assembly is still necessary This means that the vision of home production of goods are decades away and production onboard ships are only partly feasible now

Implementation

Rome wasn't build in one day and you need to learn to crawl before you can learn to walk.

Your (or your teams) evolution will most likely follow this path:

1. Master disruptive design
2. Master solid 3D modelling CAD
3. Buy a desktop 3D printer and start playing
4. Experiment with co-design and user interaction iterations with the cheap printer
5. Move on to 3D print prototypes on a better 3D printer when you are getting closer to the final design
6. 3D print molds for casting or produce from direct prints



Training & competences

The 3D printing companies also provides training for their own staff an for the staff of their customers.

- Running the 3D printer course takes a week
- Servicing and repairing the 3D printer takes a few weeks
- Scanning and repairing the scan takes weeks
- Post processing 3D prints takes month
- Knowing how to turn and twist the object and supporting structure in order to avoid horizontal overhangs and warps takes month
- Designing objects optimized for the printer takes years
- Changing the mindset of your company takes many years. Start today

New comptetences

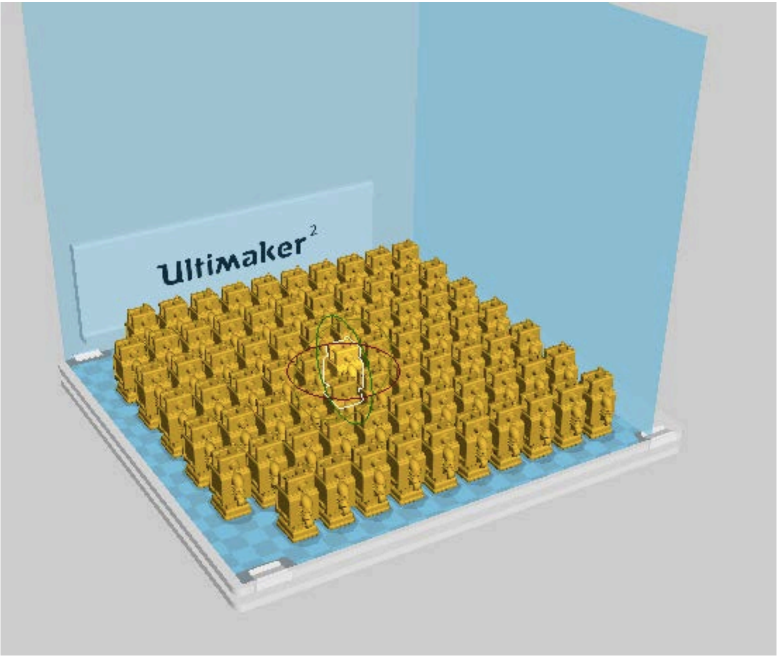
- **Disruptive mindset** (from Kodak to Instagram)
- **Business plan** (Platform economy)
- **3D value chain** (From producer to consultant)
- **IP** (I tunes)
- **Software** (from CAD to AI)
- **Design** (3D print optimized)
- **Scanning** (scanning and cleaning of data)
- **Configuration on parametric web order module** (Platform)
- **Production** (optimized for 3D print)
- **Operation** (3D printer)
- **Maintenance** (3D printer)
- **Post processing** (cleaning, toughening, milling, painting, assembly of products)
- **Non destructive validation** (test and quality control)

Non destructive validation

General Electric validate every single fuel nozzle for their Leap jet engine by CT scanning. That is a very safe and very expensive way. If the nozzle fail mechanically the jet is destroyed and might even explode.

But many components are not all that critical. They are validated by placing test components in the batch and testing them for chemical composition, strength, colour, volume, shape or whatever you want to test. The assumption is that if the test samples are good, the rest of the batch is good.

Some of the printers furthermore test while printing that powder, filament, glue, laser and other parts of the process is working well.



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Limitations
Tools for tasks
Technology
Success cases
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Business
Project partners

Partners

There are very few initiatives dealing with 3D print in the maritime industry contrary to automotive or aviation. Very few maritime stakeholders have invested in the technology or even considered how it might help solve some our future challenges. For that reason, a group of partners in Green Ship of the Future decided to initiate process in which they could work in depth with this an related technologies.

Partners include:

Create.dk

OSK-ShipTech A/S

DNV·GL

Maritime Development Center of Europe

ALFA LAVAL

Coordinated by

GREEN SHIP OF THE FUTURE

Sponsor

The project and this publication is kindly sponsored by the Danish Maritime Fund

Due to their support the process, activities and general findings are made open to all.
The general objective of this project is to increase the participants' knowledge to a level, where companies can consider how the technologies of the fourth industrial revolution particularly 3D printing and additive manufacturing can affect and develop their business model.

DEN DANSKE
MARITIME FOND

Partners

Create.dk

Ivar Moltke from Create.dk senses opportunities obscure to most people. He starts the innovation process by dismissing the assumptions people feel most secure about. He has tools to estimate when new technologies will be mature, when they will be implemented and what difference they will make. He can transform foresights into value propositions based on Stanfords NABC model.

Design is a fast holistic iterative process cycling between analysis, prototyping and testing. An evolutionary survival of the fittest process. This prototyping process opens for user co-design, and innovation all the way from idea to implementation. He can grind through the toughest design challenges with this process. www.create.dk