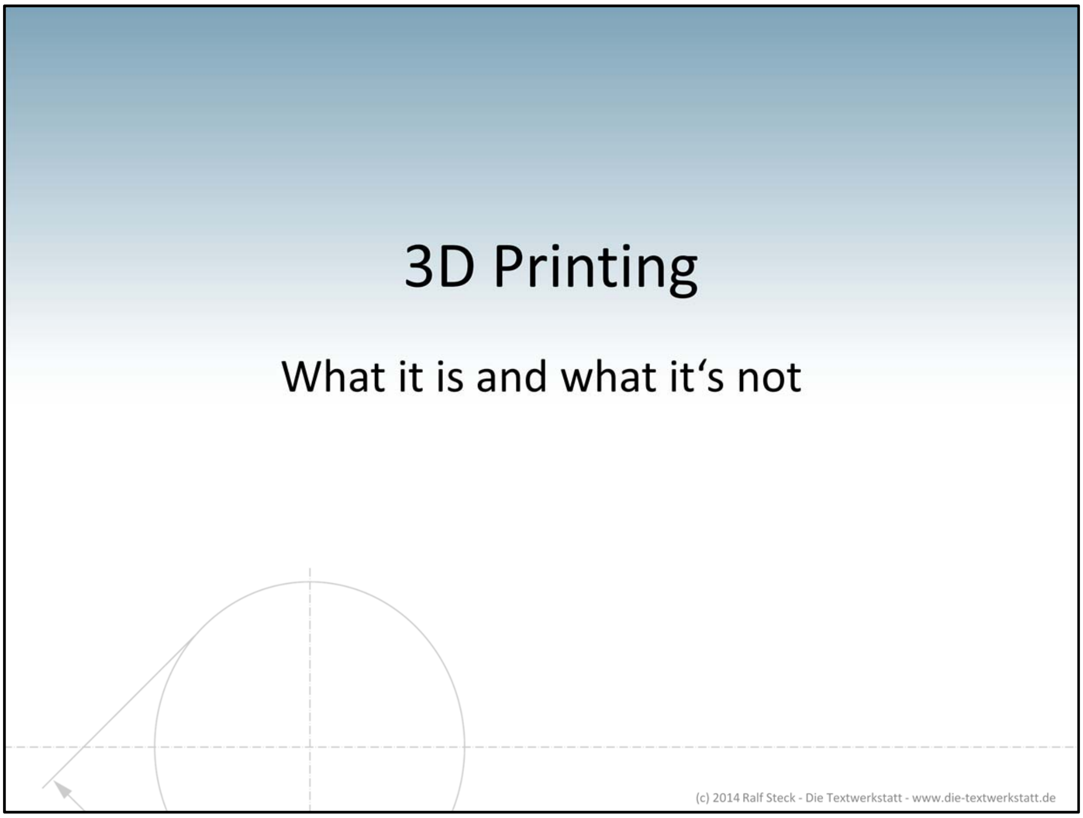
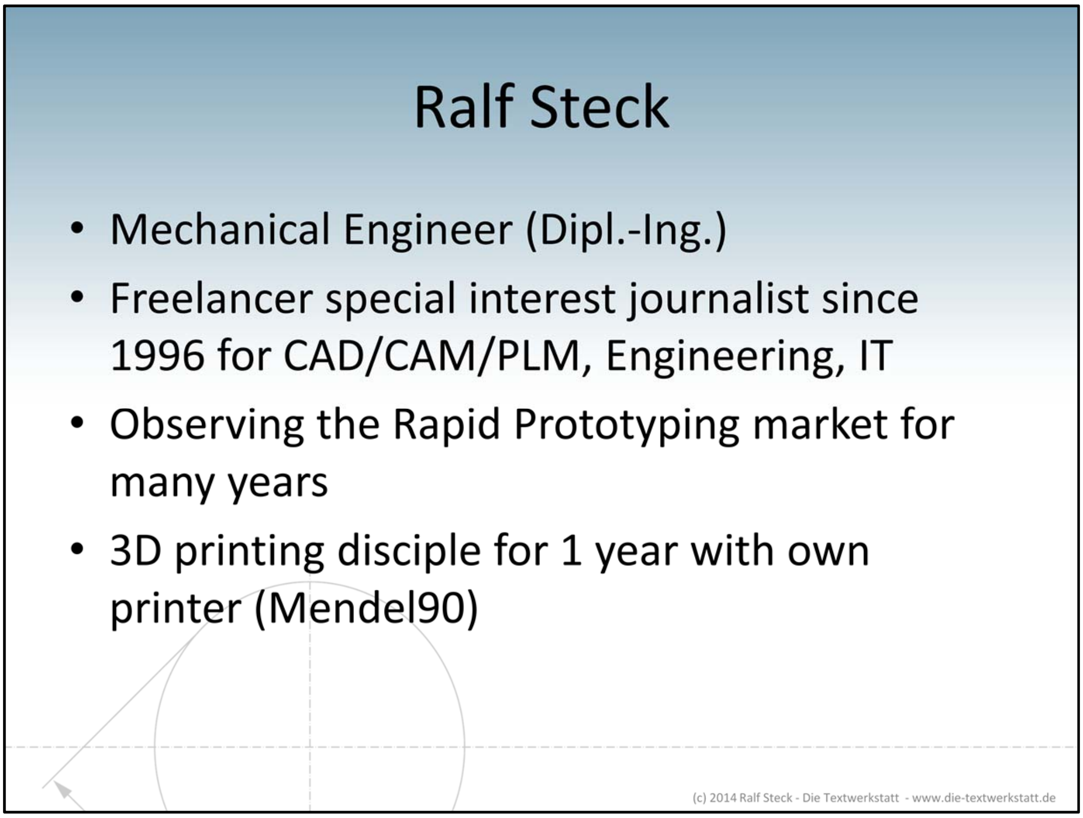
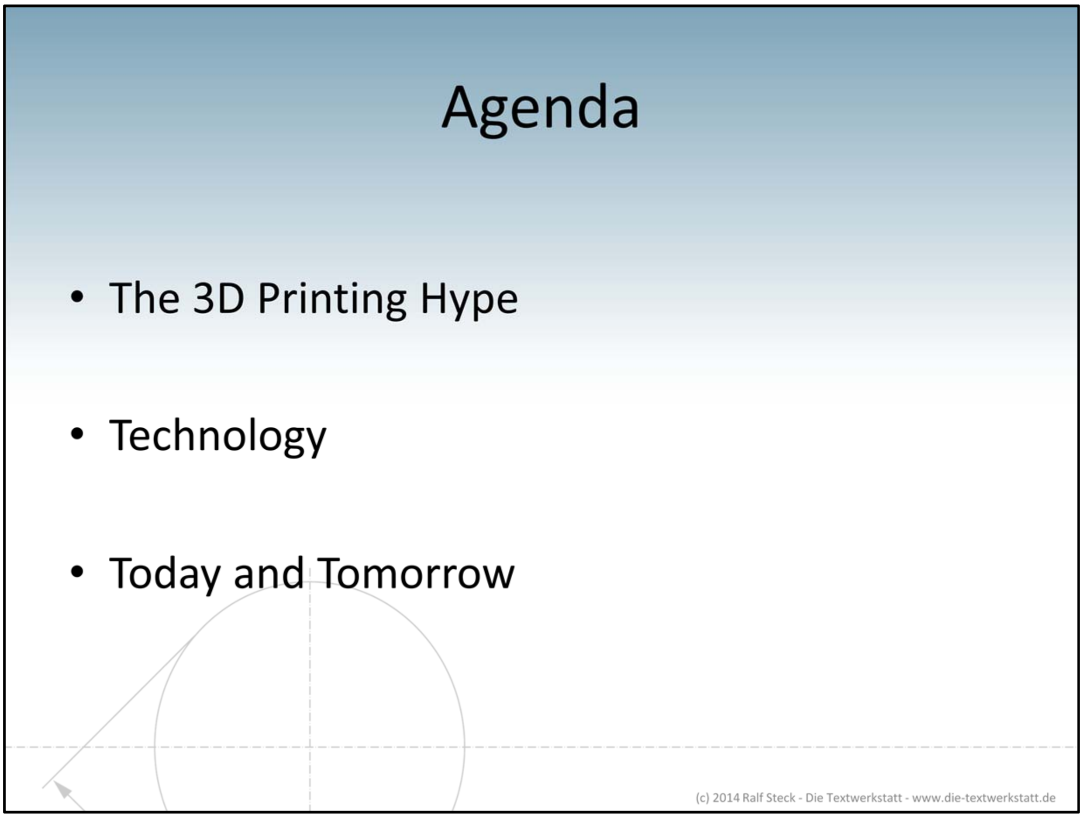


I heard 3D printing was elected as a theme for this event by you. That is nice and I hope I can live up to the expectations.

I named this talk “3D Printing – What It Is And What It’s Not” because I think there is a big demand for clarification between what is hype and what is reality. But let’s start with a short introduction.

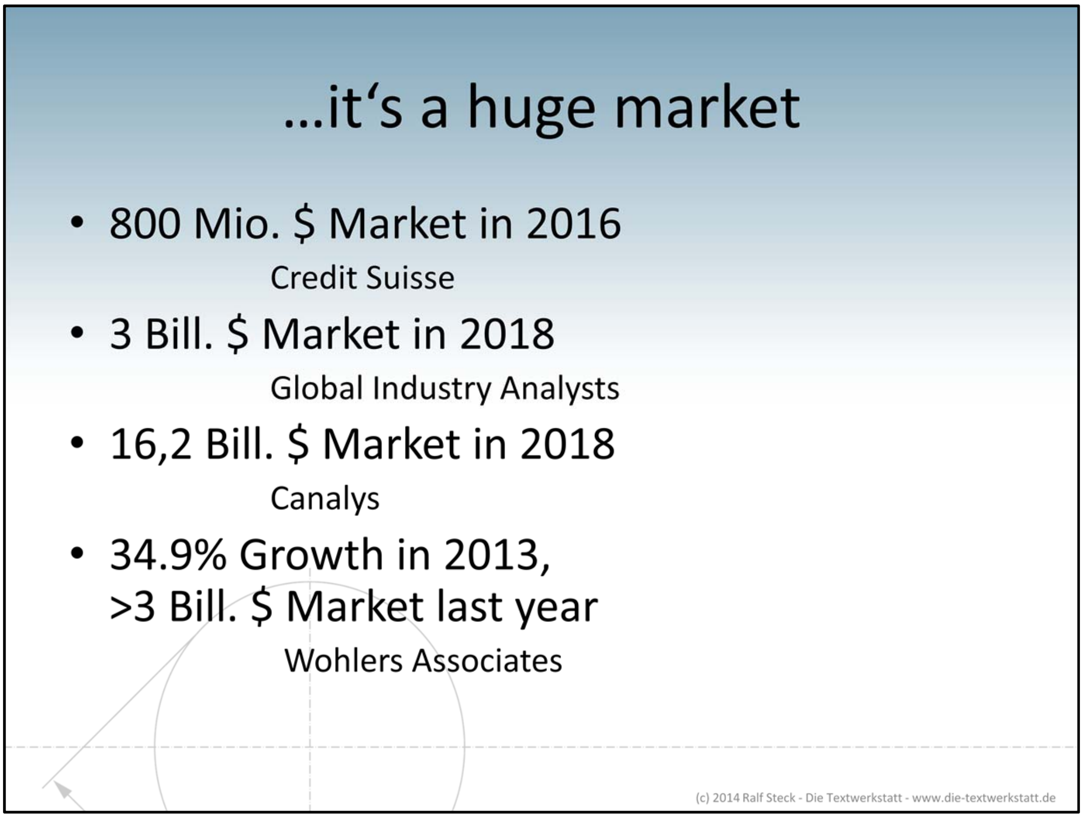


My name is Ralf Steck, I’m a mechanical engineer and got my degree in 1993. I then started working as a journalist in a publishing house that published a CAD CAM magazine about engineering software. I left that company in 1996 to work as a freelancer journalist which is what I’m doing till today. Quite early in my profession I came in touch with Rapid Prototyping as it was called back then. You see, 3D printing might well be the oldest “next big thing”. I dove into the world of open source 3D printers about a year ago and started to build my own Mendel 90 in December last year. This might not sound like a long time, but this is a young sector so the experts aren’t there for very long, too.



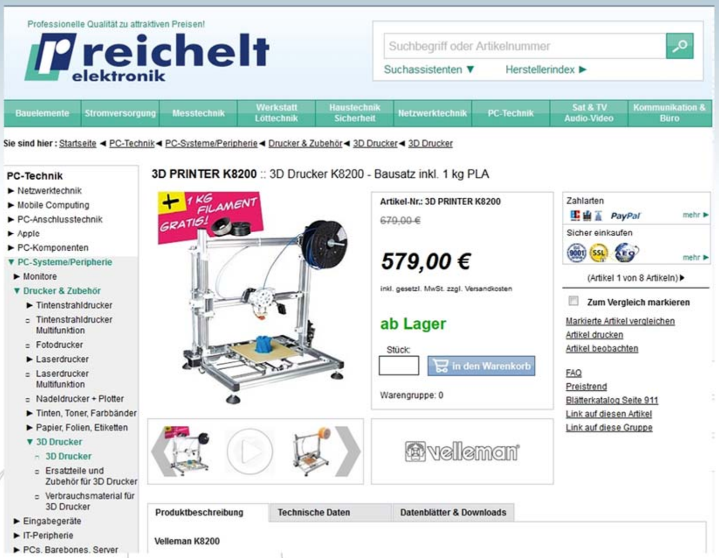
I have three items in my agenda. First, I try to show you a bit of the hype that has evolved in the last two years around 3D printing. This leads us to the technologies that are used, each of them having their own strengths and limitations. In the third part, I will show you practical uses of those technologies that are used today and in the future. Let’s start.

Nowadays, everybody seems to know everything about 3D printing. It’s in the media everywhere, every day we have news that we all soon print our own spare parts, houses, organs, or pasta. This is Mr Cody Wilson who wants to protect the right of every American to carry weapons with a 3D printed gun. And we even print our own, individual garment. Soon. In the near future.

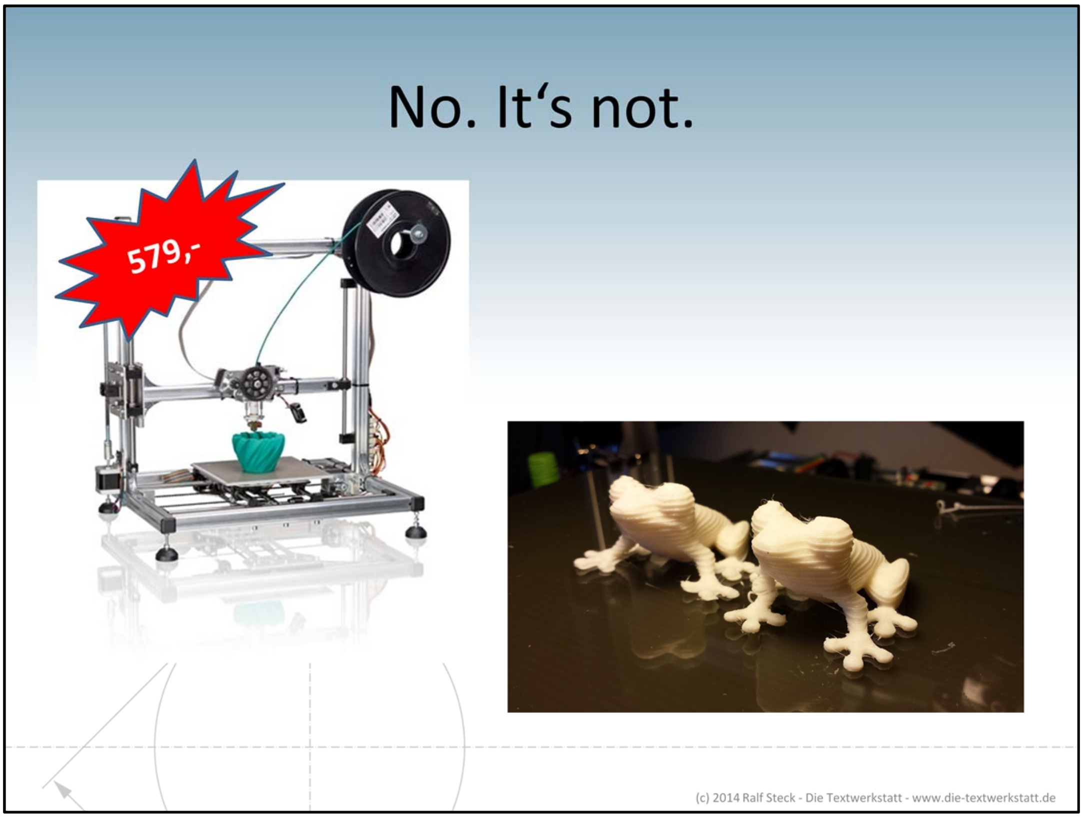


And it’s a huge market. Credit Suisse sees a market of 800 million Dollar in 2016. In 2018, according to Global Industry Analysts, we have 3 Billion Dollars from 3D printing. Canalys even foresees over 16 Billlion in that year. The only serious numbers I found are from Wohlers, that found a over 3 Billion market last year with a growth rate of 35 %. You see, there is a big uncertainty between the numbers and what counts as 3D printing market.

...and it‘s cheap!

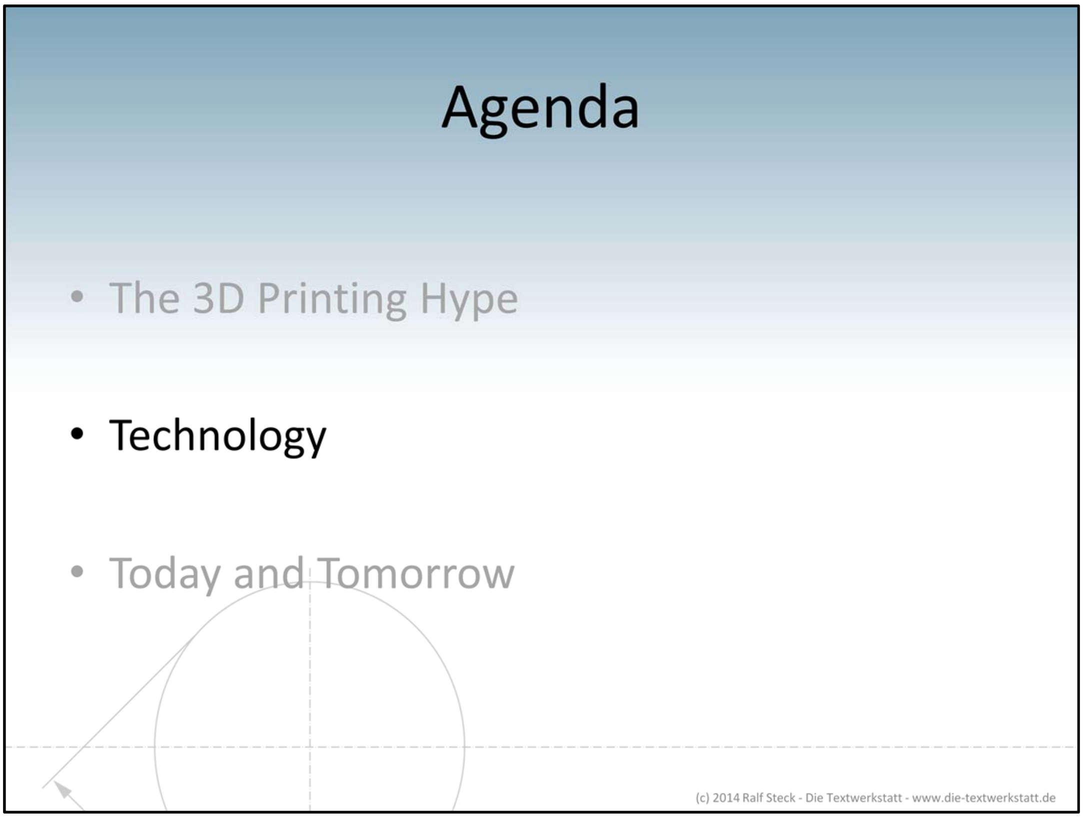


Oh, and 3D printing is cheap. You can buy a printer now for under 600 Euro! This fact is often connected with the fact that you can print metal, guns, organs and you know what.

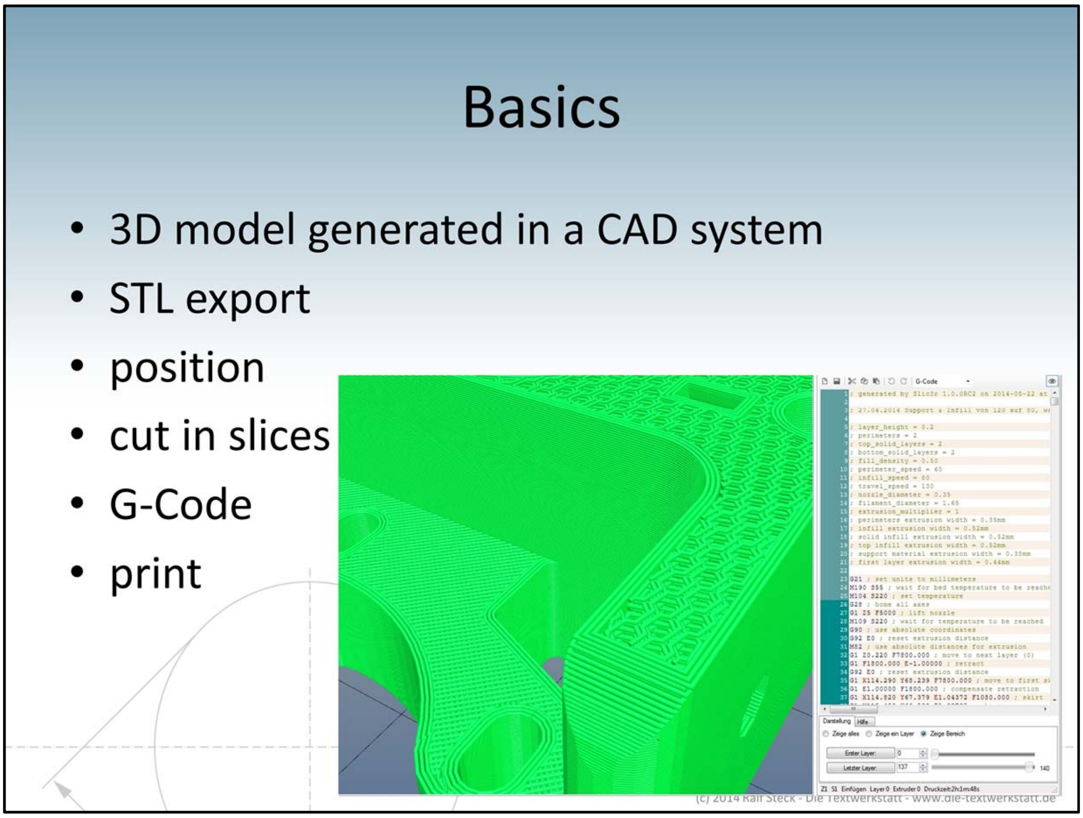


In reality, when you buy this printer, you get models like that. They might be better, but that needs much work and weeks of fine tuning. Believe me, I do that for months now. This is a experimental kit printer that you have to assemble first, and even after fine-tuning it, a substantial share of prints doesn’t succeed.

These are 3D printed prototypes of glasses, printed in one piece with transparent and rubber-like regions in them. This is extremely precise then it comes to dimensions and has a very smooth surface. But for prints like these, You need a Objet500 Connex3 machine, and that costs a bit more, around 250.000 Dollar. Machines for high-end printing like those from Voxeljet may even cost up to 2 Million Dollar. For that money, you get a build area of 4 times 2 meters and a machine that prints sand casting kernels, for example for prototype motor blocks.



You see, the technology has a big impact on what we really can expect from a 3D printer.

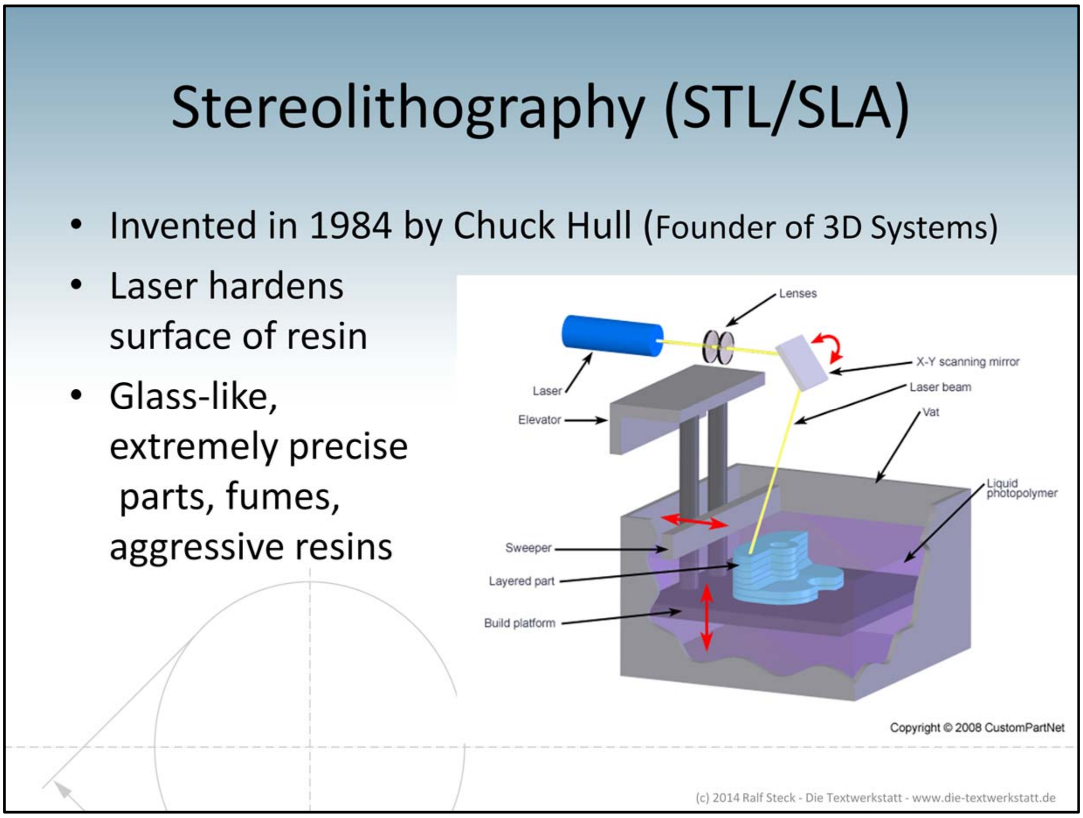


Let’s look at the basics. The beginning point of every 3D printed part is a 3D model. You can find odels on the internet, for example in Thingiverse, a website owned by Makerbot Industries that has over 100.000 models for free download – often in questionable quality or significance. Or you have to use a CAD system like SolidWorks to develop your own model. And that’s exactly the point why I don’t believe in this Hype: “Soon we will all have a 3D printer sitting on our desk, next to our inkjet.” You have to model in 3D and thatis much more complicated than writing a letter and printing it on paper.

Next step is the export to STL. STL is the lingua franca of 3D printing, a very easy to implement data format that describes three-dimensional triangles – the models are

very dumb, as the triangles have no logical connection to each other.
Then you import the model in a more or less printer specific software, where you position it in the build volume of the printer.
Next and most important step is slicing – You cut the model in very thin horizontal slices – these are the layers that are later printed one after the other. Here you tell the machine howfine the Z resolution is, how the object is printed and how much infill you want. You can decide which percentage of the object is filled with material, which in turn has an influence on the weight, the strength, but also on printing time and costs.
The software then generates G-Code, this is the code that really controls the printer. G1, for example, means go to these coordinates in work mode, extruding this much material. A G-ode viewer interprets these Codes. In the example, you see the infill here, 3 perimeters and the top filling pattern.

Now to the technologies that are mostly used in 3D printing. It’s only a few, with variations of the material and other parameters.

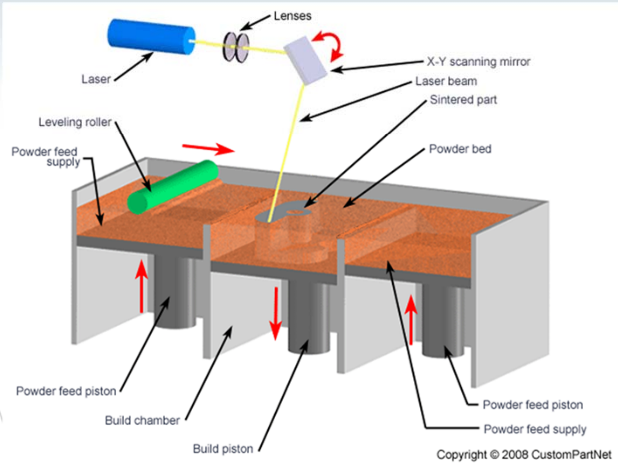


The oldest technology is Stereolithography. It was invented in 1984 by the founder of 3D systems, Chuck Hall. The technology is using a laser beam that is directed by this mirror. The laser beam draws the first layer on the surface of a resin that is in this basin. The resin hardens instantly when it is touched by the Laser light. After a layer is drawn, the build platform goes down one layer height and the next layer is printed.

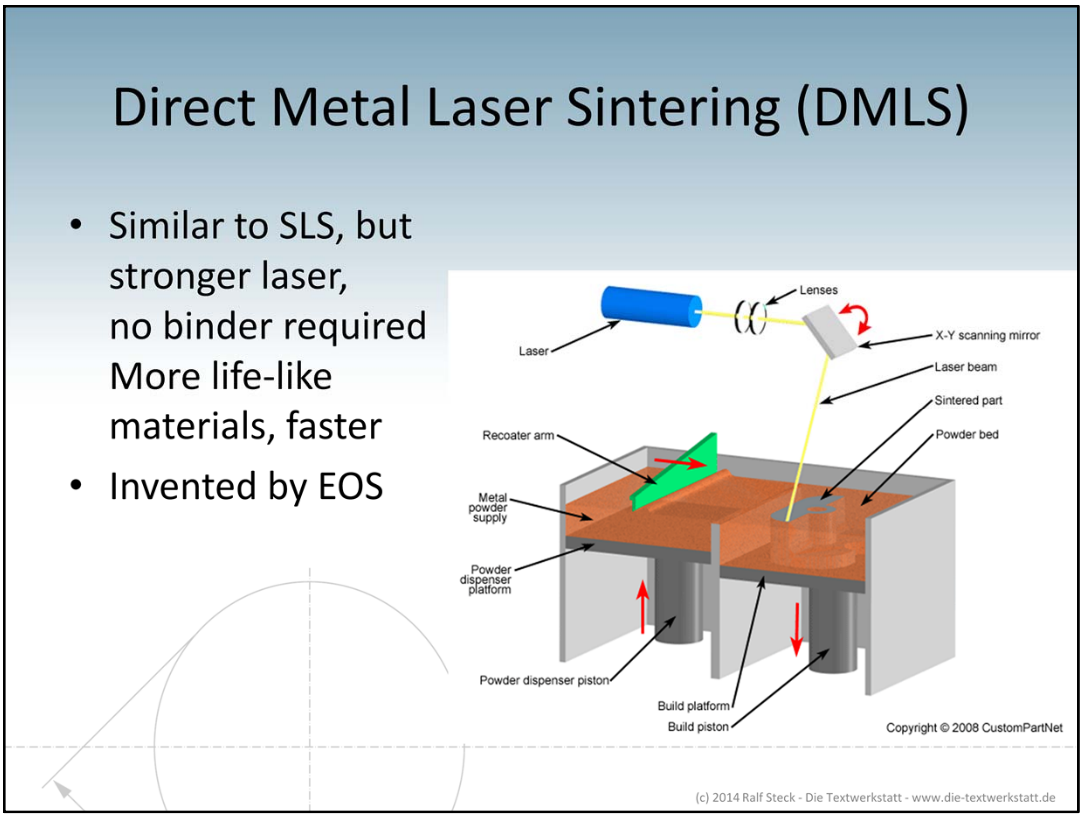
STL parts resemble brown glass and are similarly breakable, but very precise. The resin and the fumes are the negative sides of this technology. There is a new printer named Form1 that is printing upside down, the laser beaming through the bottom of the glass basin.

Selective Laser Sintering (SLS)

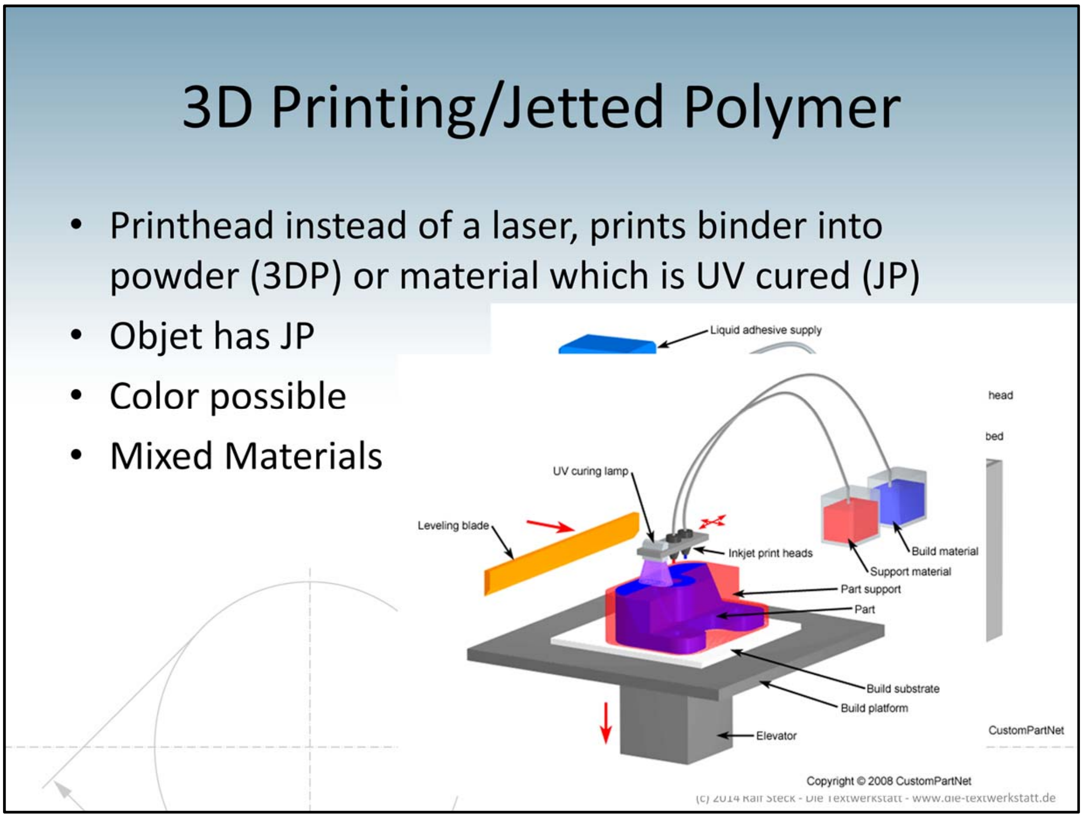
- Laser melts metal or polymer powder, then burn off binder
- Wide range of materials, metal parts



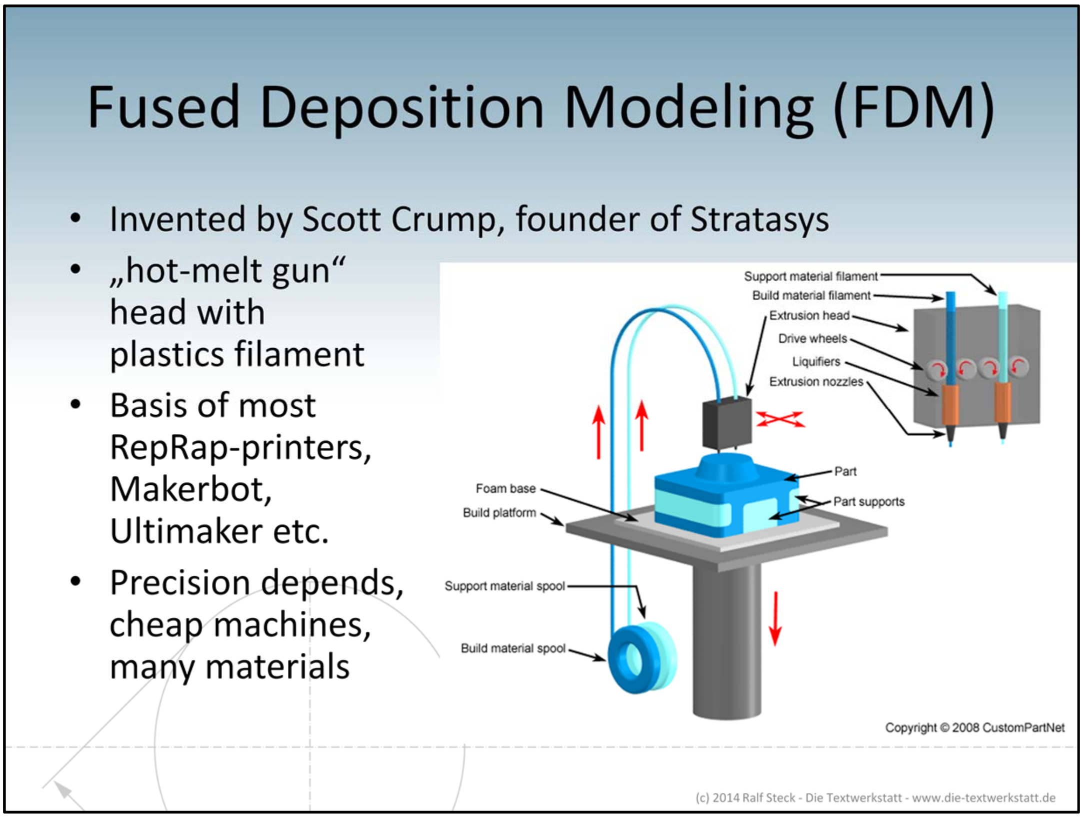
Next we have Selective Laser Sintering, SLS. This also uses a laser, but not a resin. The material is binder-coated plastics or metal powder. The laser melts the binder-coated particles together, after every layer the build platform goes down and a recoater puts the next layer of powder on top of the already printed part. After the printing process, the part is put into an oven and baked together at about 900 degrees Celsius.



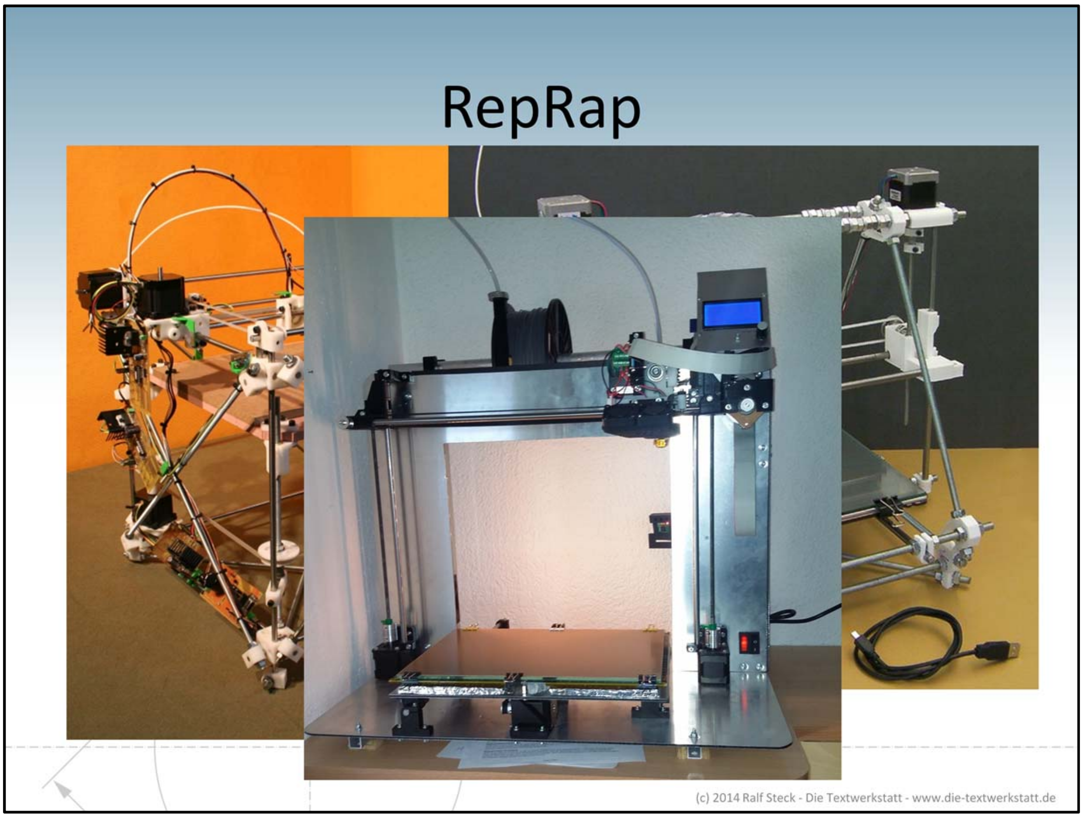
If you use a more powerful laser, you can melt metal powder directly. This has the big advantage that real-world materials like stainless steel can be used. And it's faster because the burning is removed. By the way, this technology was invented by EOS, a company from Gräfelfing, here in Munich.



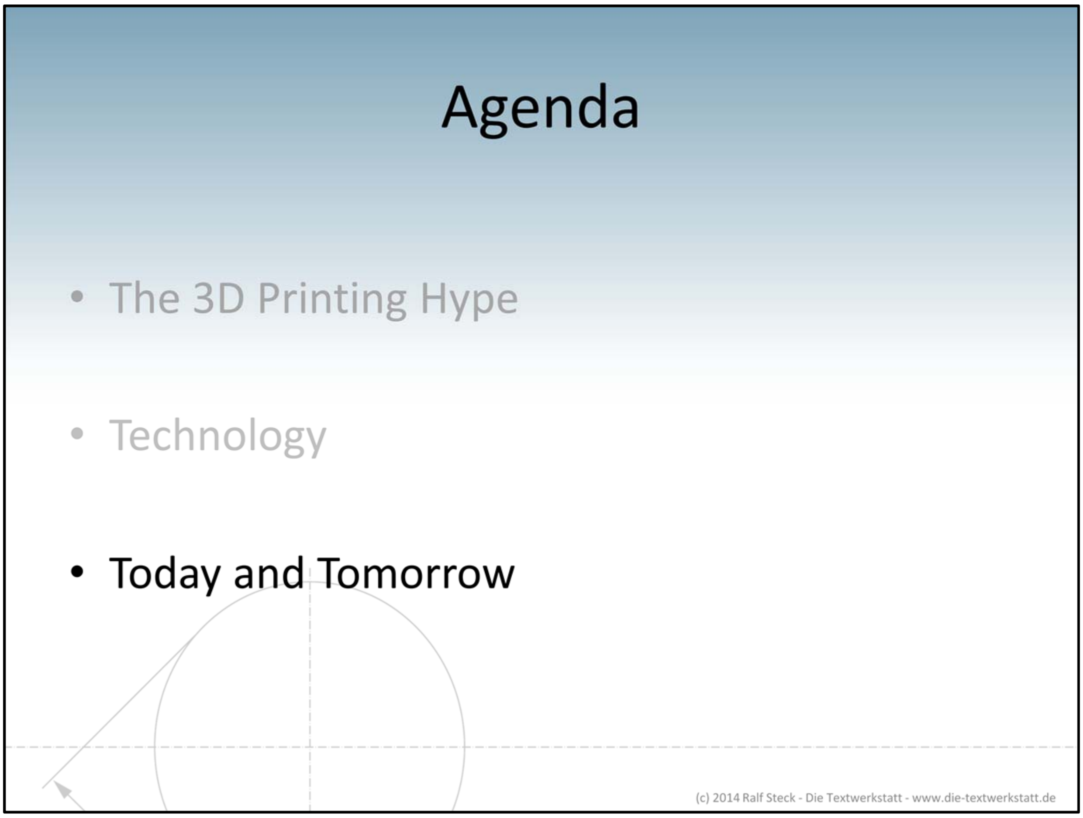
Then there are several similar technologies involving something like inkjet printheads. The ZPrinters print colored printer into a powder material which makes it possible to print full color, gypsum-like parts. Jetted polymer means that the material itself is coming out of the printhead. Objet uses this to generate Digital Materials, that means they print different materials instead of different colours. This makes it possible to influence for example the stiffness of a rubber-like material.



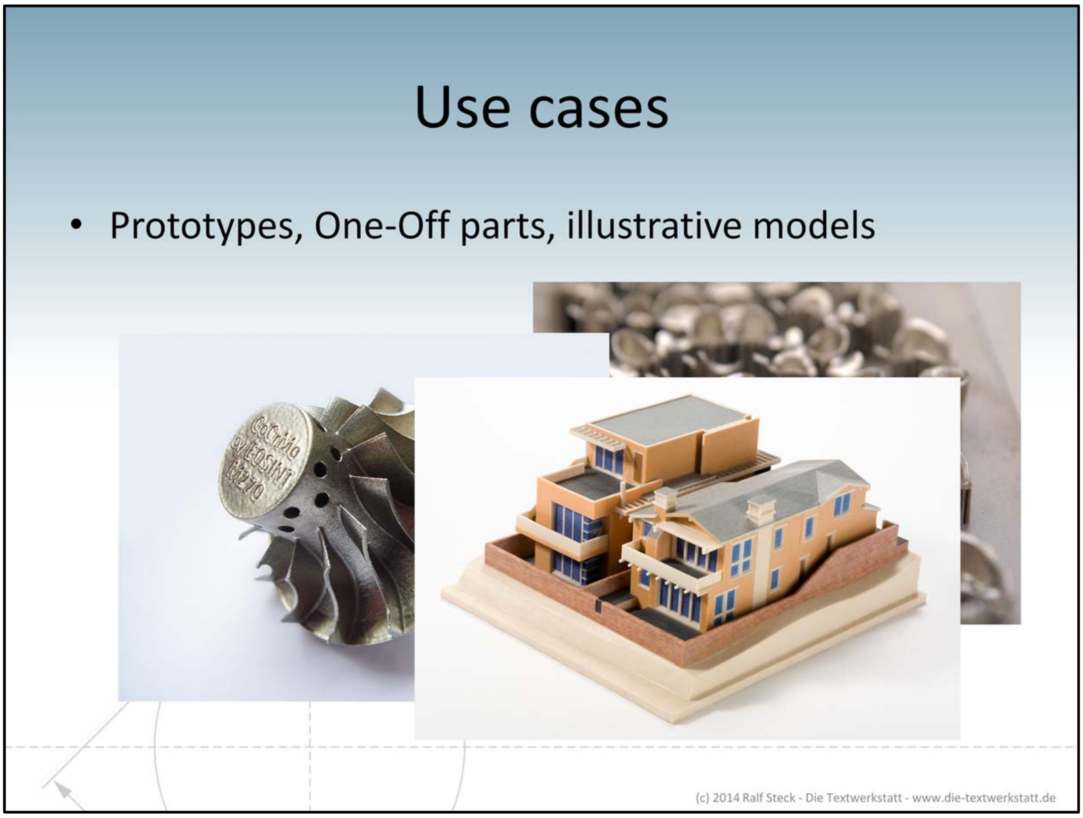
The last and, when it comes to cheap 3D printing, the most important technology is Fused Deposition Printing. Scott Crump invented it literally when he played with a hot-melt gun. It’s exactly that: Plastics filament is fed into a moving, hot nozzle that lays a bead of plastics on the print platform. It’s really easy to build such a printer so most of the cheap printers are using this technology, even if it’s not as precise as other technologies.



When we talk about FDM, we have to talk about RepRap. Adrian Bowyer was lecturer in mechanical engineering at the University of Bath in the UK, and he wanted to build a machine that replicates itself or at least the plastics parts, that are not sourceable such as motors or threaded rods. RepRap is Open Source and developed by a huge community of enthusiasts, it develops very fast and there are hundreds of models described at Reprap.org. You can even build the electronics by yourself. Adrian bowyer founded Makerbot, the most successful company in the low end sector.
These are examples of Reprap printers, here a Darwin, which was the first generation, this is a Mendel and here we have a Mendel 90. This is my own printer and more or less a Mendel with a different framework.



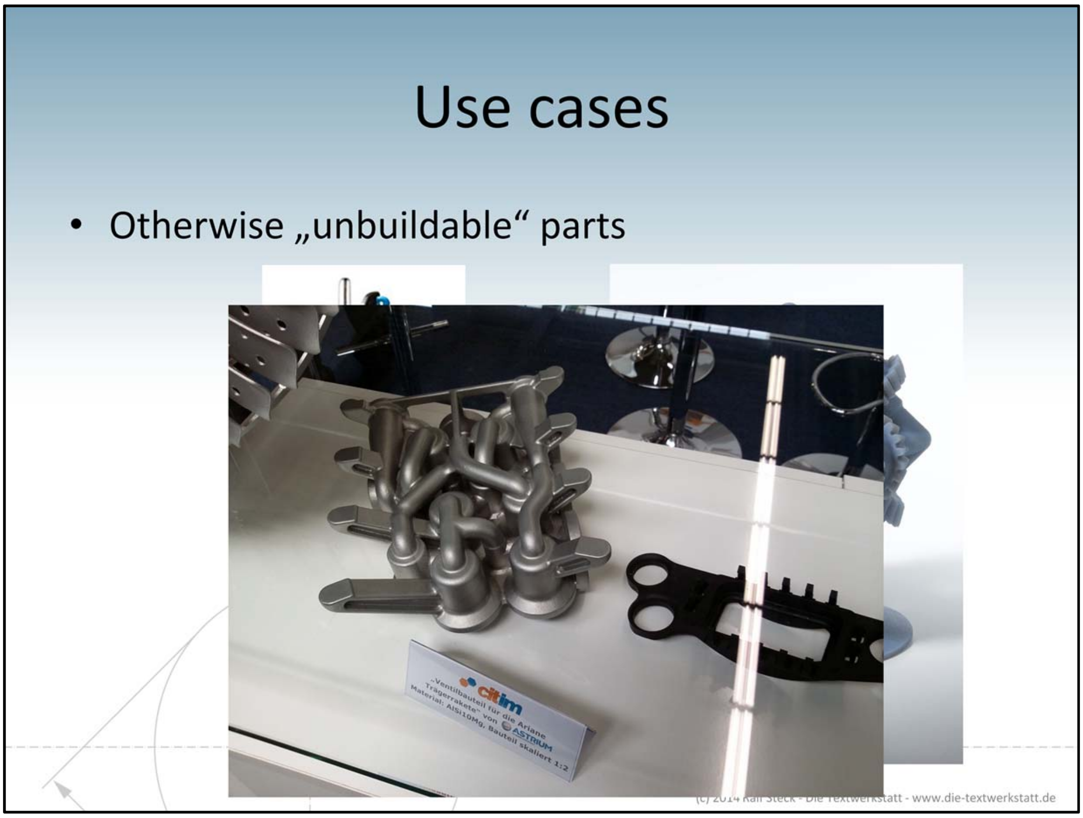
Now we come to the last part of my presentation, in which I want to show you some use cases, and when we have time left, I’ll talk about the future of 3D printing.



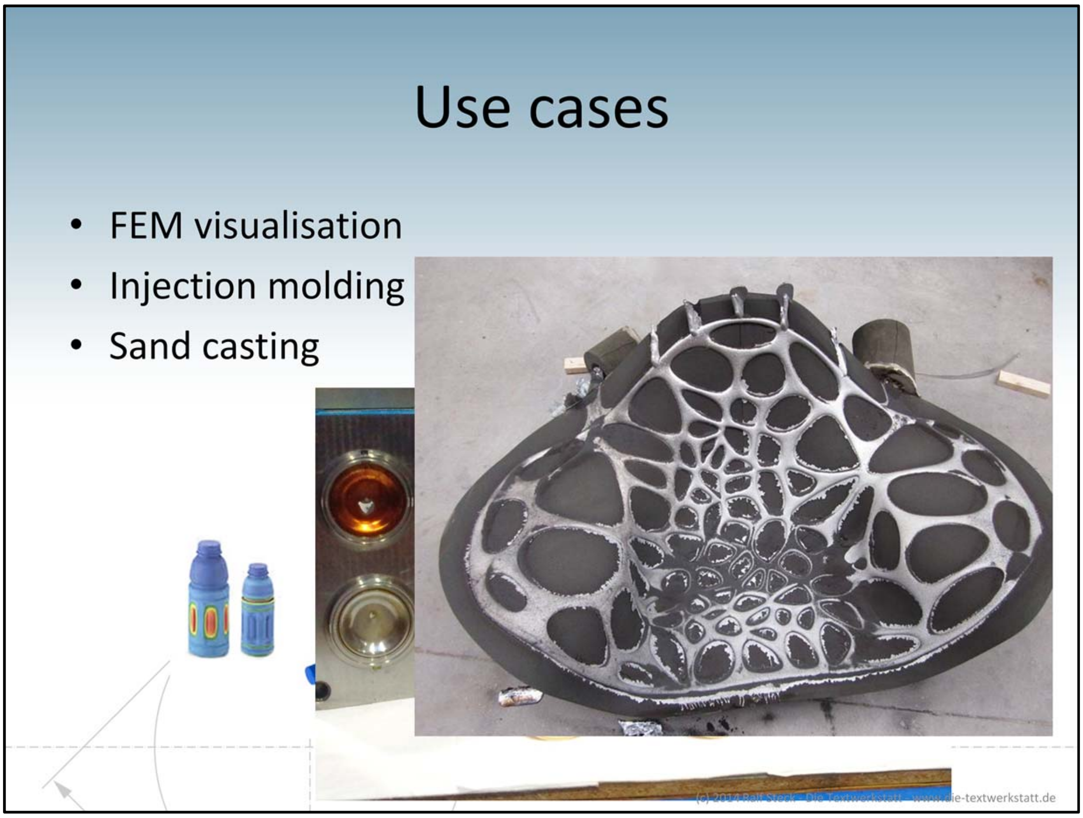
The first use case and where the technology comes from are prototypes, One-Offs or illustrative models. 3D printing is more or less useless for mass production, but when it comes to parts you need relatively fast and just one or a few, it's unbeatable. Another thing is Rapid manufacturing, this means mass production if individualized products.
Here we see a EOS build plate full of tooth implants. They are all different and individual for one person, but an EOS machine can build 600 of those in one build.

Next is a real prototype part of a small turbine. This is a full functional part that would days to be machines from a stainless steel block.

The third example is a printed model of a house, which says way more than the typical white cardboard models architects use.

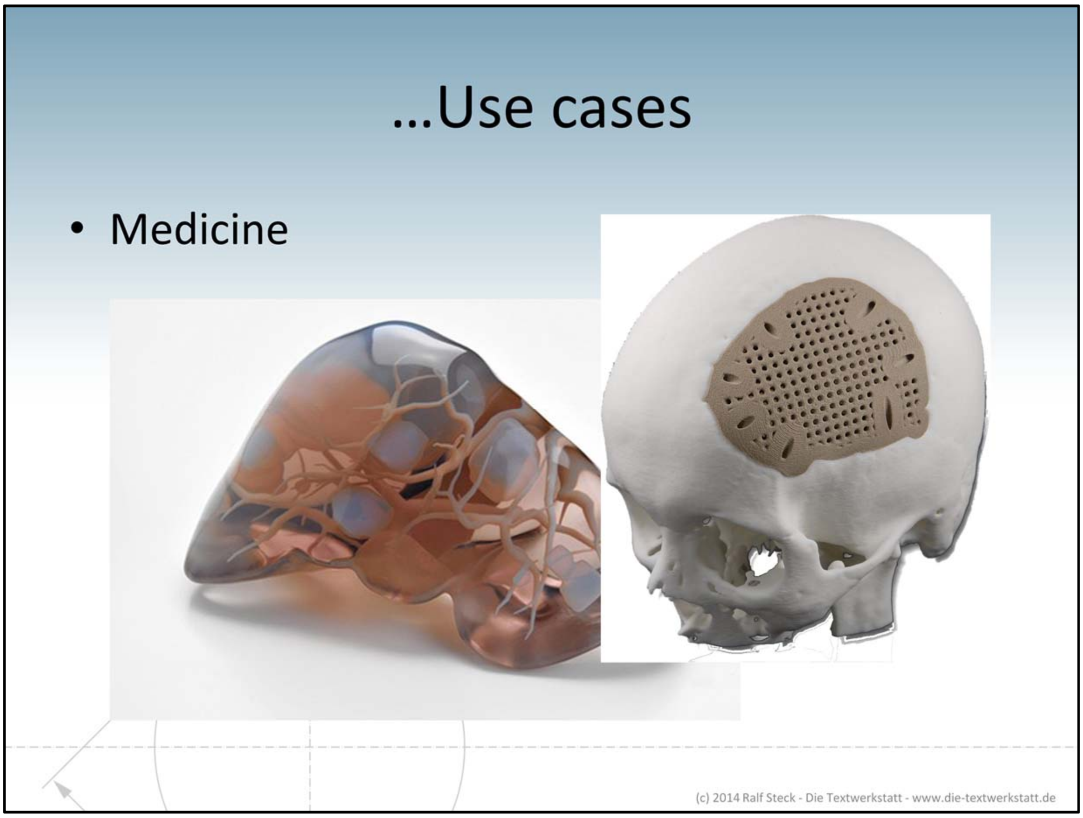


My seconds use case are otherwise unbuildable things like this braingear, that is printed in one part, You just use a water-solvable support material between the wheels and the axles and you get moving parts.
This snake nest is a valve manifold for the Ariane rocket. Valve manifolds are usually built from a massive steel block which is drilled in all directions to create the connections between the valves and the pipework. When you 3D print such a manifold, you place material only where needed – this ends in the shown piping mess. But you can imagine the weight difference between the massive block and this part. It costs between 300 and 400.000 Euro to lift a single kilo to the geostationary orbit, so you can compute yourself how much the 3D printed part saves.



The third use case are using 3D printing in a more indirect way, for example to show the stress in parts as simulated in a FEM computation. Very new is a material that can be used to print injection molds. In the foreground you see prototype membranes casted in the green molds. So it’s possible to evaluate the casting process before you make the very expensive production molds you see in the background.

Voxeljet builds printers that are able to print sand casts in which metal parts are casted, like this part of a chair.



Today, we can’t print a working liver, but how about a model that shows what is in a liver, for example the blood vessels? If you make such an object based on a CT model, a doctor can plan his cuts on the real anatomy of his patient.
And if you ever should happen to get a hole in your skull, ask for such a replacement. The conventional titanium plates make headache because their thermal conductivity is different to the bone. This plate is hollow so that new bone material can grow into it, closing the gap over the years.

And there is much more to come…