HEI MAKERS

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Technical creativity in 3D printing module

Co-funded by the Erasmus+ Programme of the European Union
2017-1-LT01-KA203-035231

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LESSON #1
FUNDAMENTALS OF 3D PRINTING

Technical creativity in 3D printing module

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OUTLINE OF THE LESSON #1

- Topic 1.1 Definitions
- Topic 1.2 3D printing processes and technologies
- Topic 1.3 3D printing advantages and limitations
- Topic 1.4 3D printing materials
- Topic 1.5 3D printing work flow
- Further learning
- Tasks for reflection

1.1. DEFINITIONS

- In this lesson you will learn about the most relevant definitions related to 3D printing (3DP).
- Expected learning outcomes: understanding the most relevant terms used in 3DP.

Duration	1 academic hrs
Author / Lecturer	Doru Cantemir, Ludor Engineering
Delivery methods	Individual / Teamwork / P2P
Evaluation methods	Test / Report / Feedback / Exam etc.

WHAT IS 3D PRINTING?

- 3D printing (3DP), also known as Additive manufacturing, is a general term for some technologies that build 3D physical objects from a digital file by successively adding material. 3D printing is, in fact, an umbrella term covering a group of distinct 3DP processes.

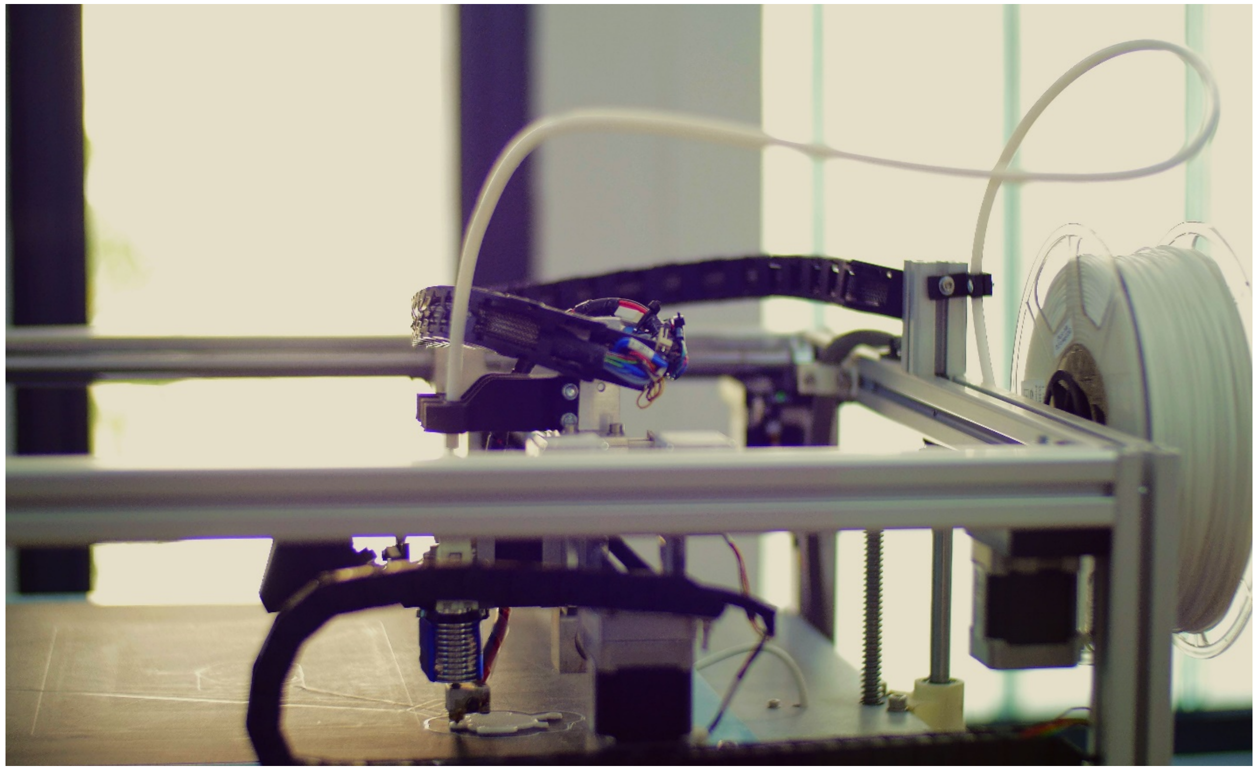


Figure 1.1.1. 3D printing. Source: Ludor Engineering

WHAT IS RAPID PROTOTYPING?

- Rapid prototyping (RP) is a technique that uses 3D computer aided design (CAD) data to fabricate a prototype. Although the terms “rapid prototyping” and “3D printing” are occasionally used interchangeably, 3DP is the process and RP is the end result. RP is one of many applications under the 3DP umbrella.

Figure 1.1.2. Rapid prototyping. Source: Ludor Engineering

STL FILES

- STL is a file format widely used for 3D printing, usually generated by a computer-aided design (CAD) program, as an end product of the 3D modelling process. STL files stores information about 3D models, describing only their surface geometry without any representation of colour, texture or other common CAD model attributes.

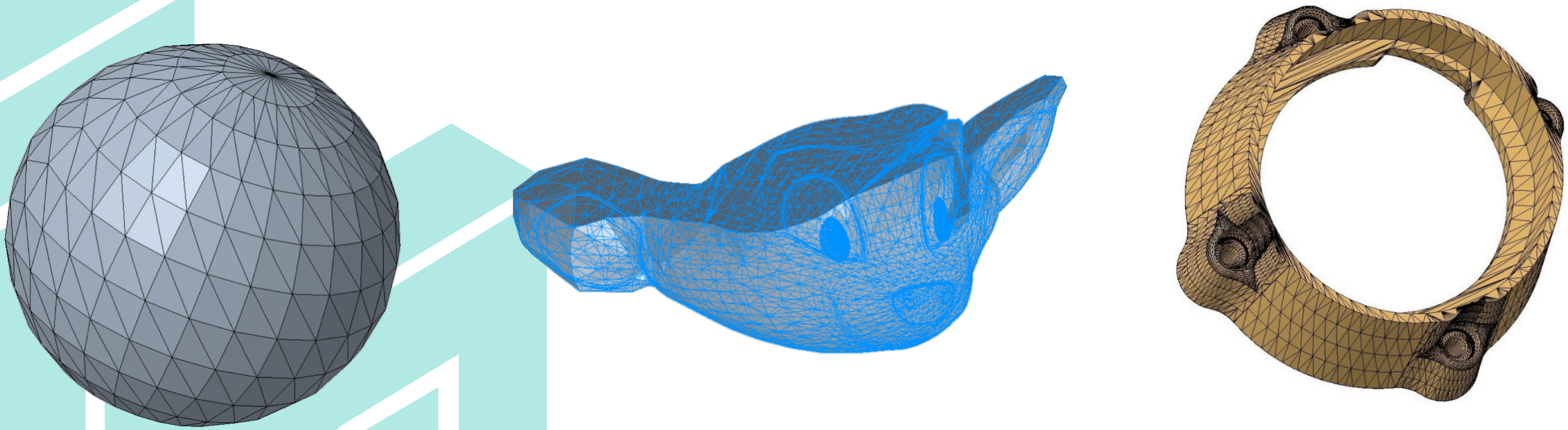
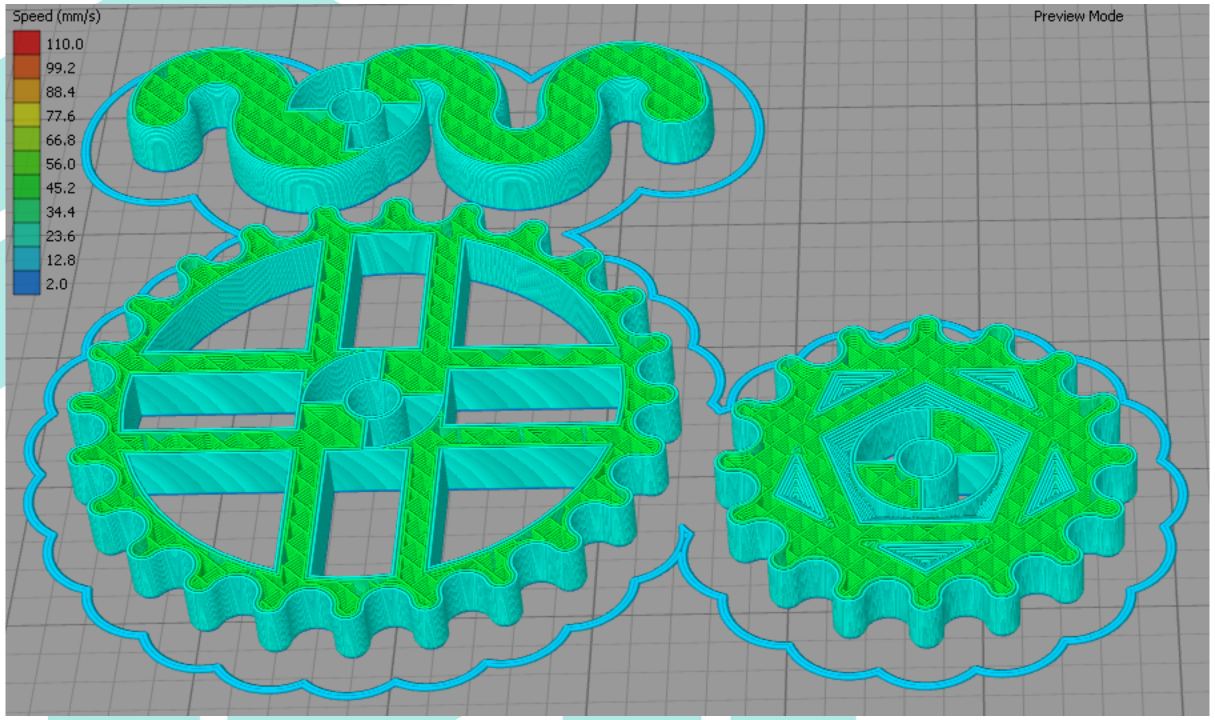


Figure 1.1.3. STL files. Source: Ludor Engineering

SLICING

- Slicing is the translation of 3D models into G-code (a generic name for a numerical control language) that a 3D printer can understand and print. Slicing software will cut the 3D models in many horizontal layers and create a path a print head can follow – line by line, layer by layer.



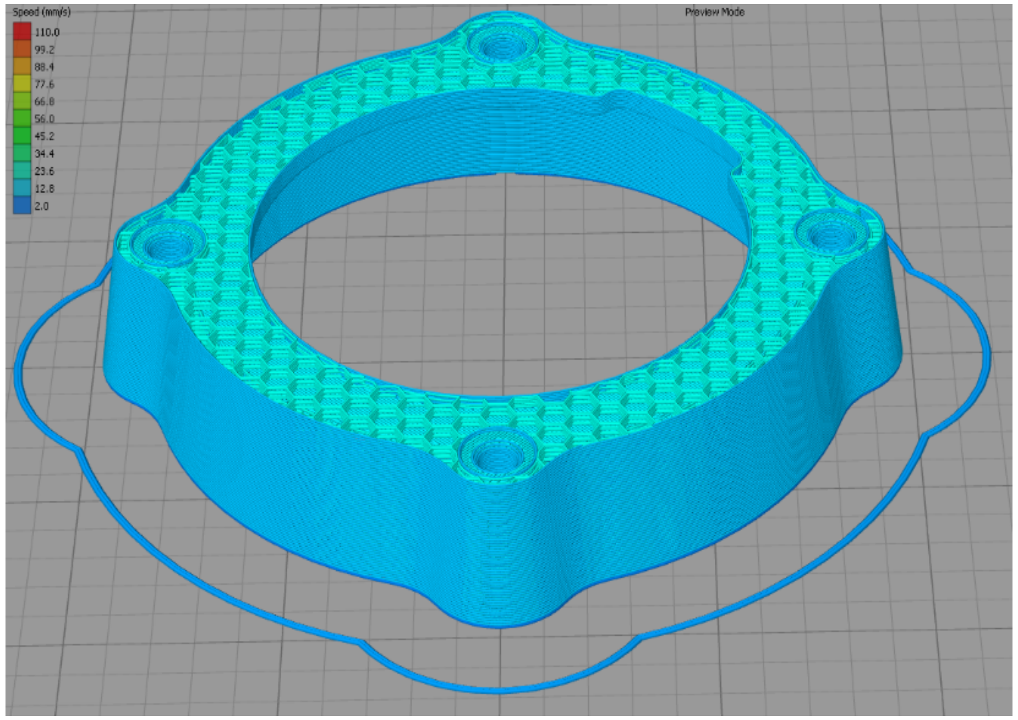
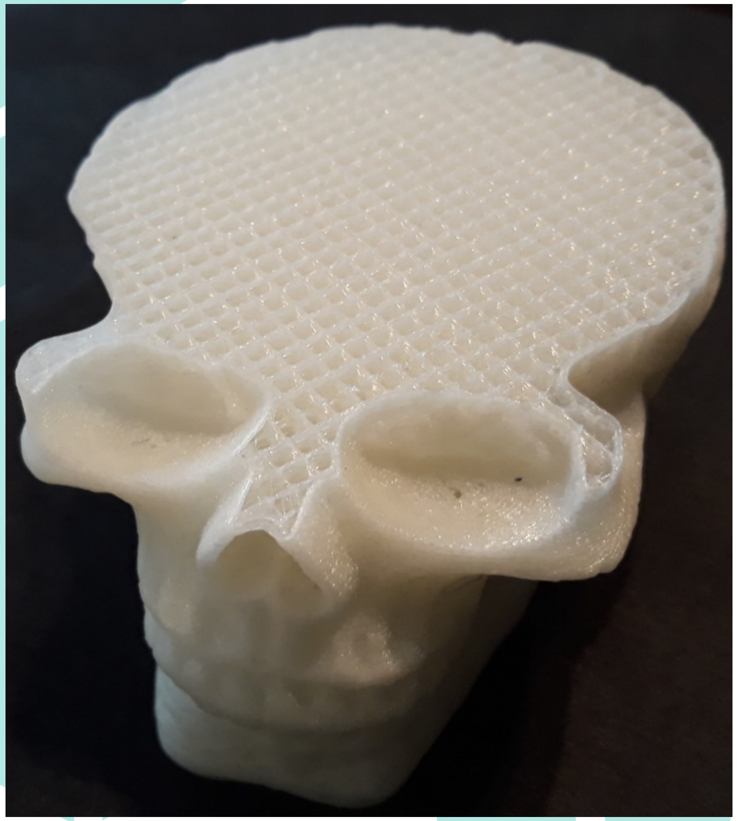


Figure 1.1.4. Slicing. Source: Ludor Engineering

INFILL

- Infill is a repetitive structure used to take up space inside an otherwise empty 3D print. The most important parameter of infill is its density (the amount of plastic inside the print). A higher infill density means that there's more plastic on the inside of your print, leading to a stronger object.



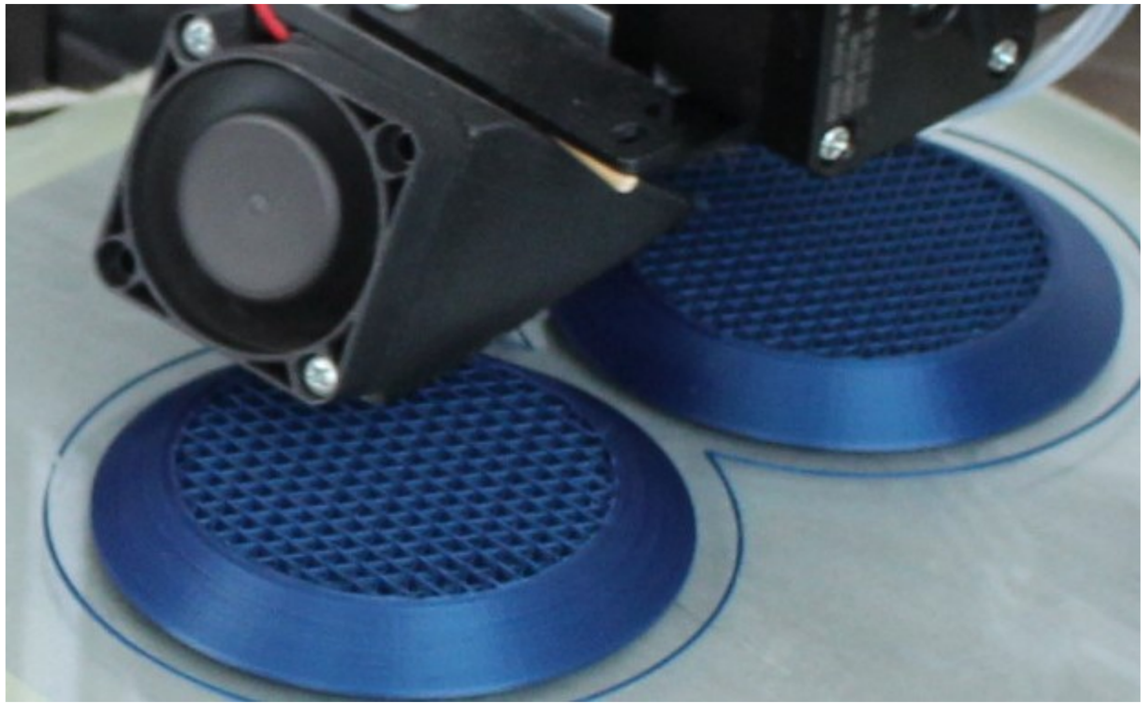


Figure 1.1.5. Infill. Source: Ludor Engineering

SUPPORT STRUCTURES

- 3DP is an additive process, in which each layer is consecutively added to the previous layer, so each new layer must be supported by the layer beneath it. Therefore, each layer can only be slightly larger than the previous layer without failing. When this is not the case (there are steep overhangs or unsupported areas) support structures are used. They act as scaffolding for the part during 3D printing and should be removed after the print is completed.

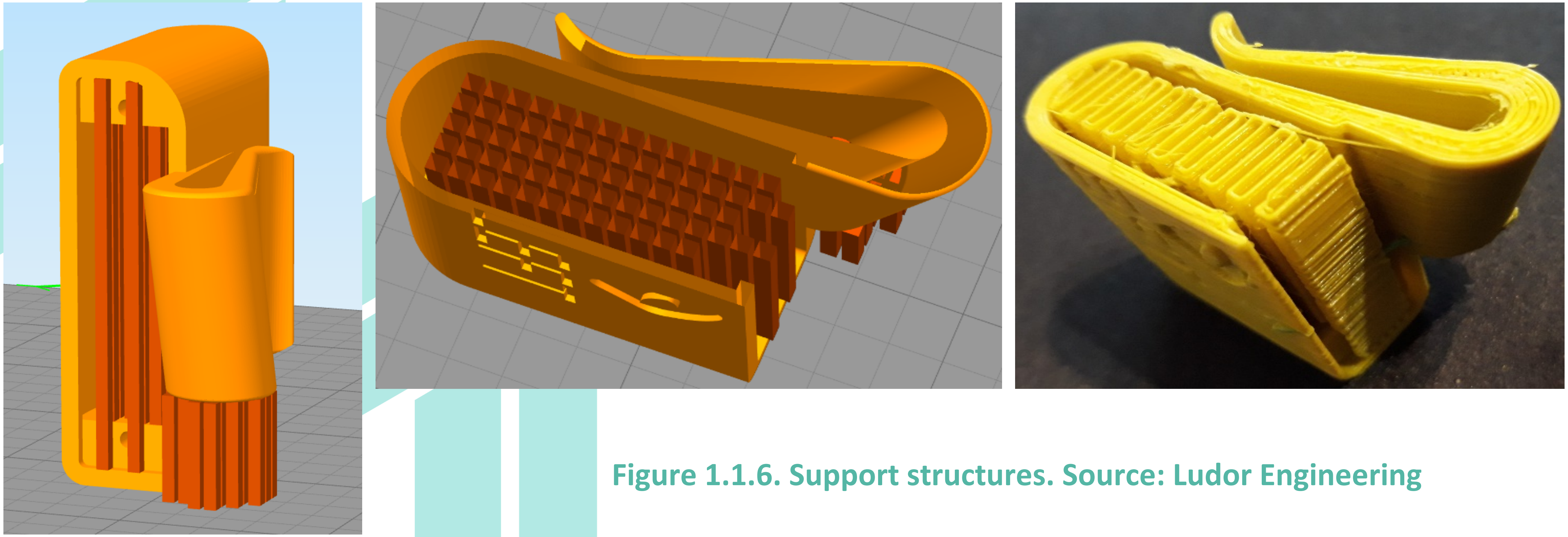


Figure 1.1.6. Support structures. Source: Ludor Engineering

FURTHER LEARNING

3D printing glossary
https://www.3dhubs.com/knowledge-base/definitive-3d-printing-glossary

About STL files
https://en.wikipedia.org/wiki/STL_(file_format)

Slicer settings for beginners
https://all3dp.com/3d-slicer-settings-beginners-8-things-need-know/

Infill – what is it and how to use it
https://all3dp.com/2/infill-3d-printing-what-it-means-and-how-to-use-it/

Support structures – all you need to know
https://all3dp.com/1/3d-printing-support-structures/

1.2. 3DP PROCESSES AND TECHNOLOGIES

- In this lesson you will learn about the existing 3D printing processes and technologies
- Expected learning outcomes: basic knowledge about the main 3DP processes and technologies, with a focus on the technologies most accessible for makerspaces (FDM and SLA)

Duration	1 academic hrs
Author / Lecturer	Doru Cantemir, Ludor Engineering
Delivery methods	Individual / Teamwork / P2P
Evaluation methods	Test / Report / Feedback / Exam etc.

3D PRINTING PROCESSES

- According to the ISO/ASTM 52900 standard[1], the 3DP processes can be divided into 7 categories.

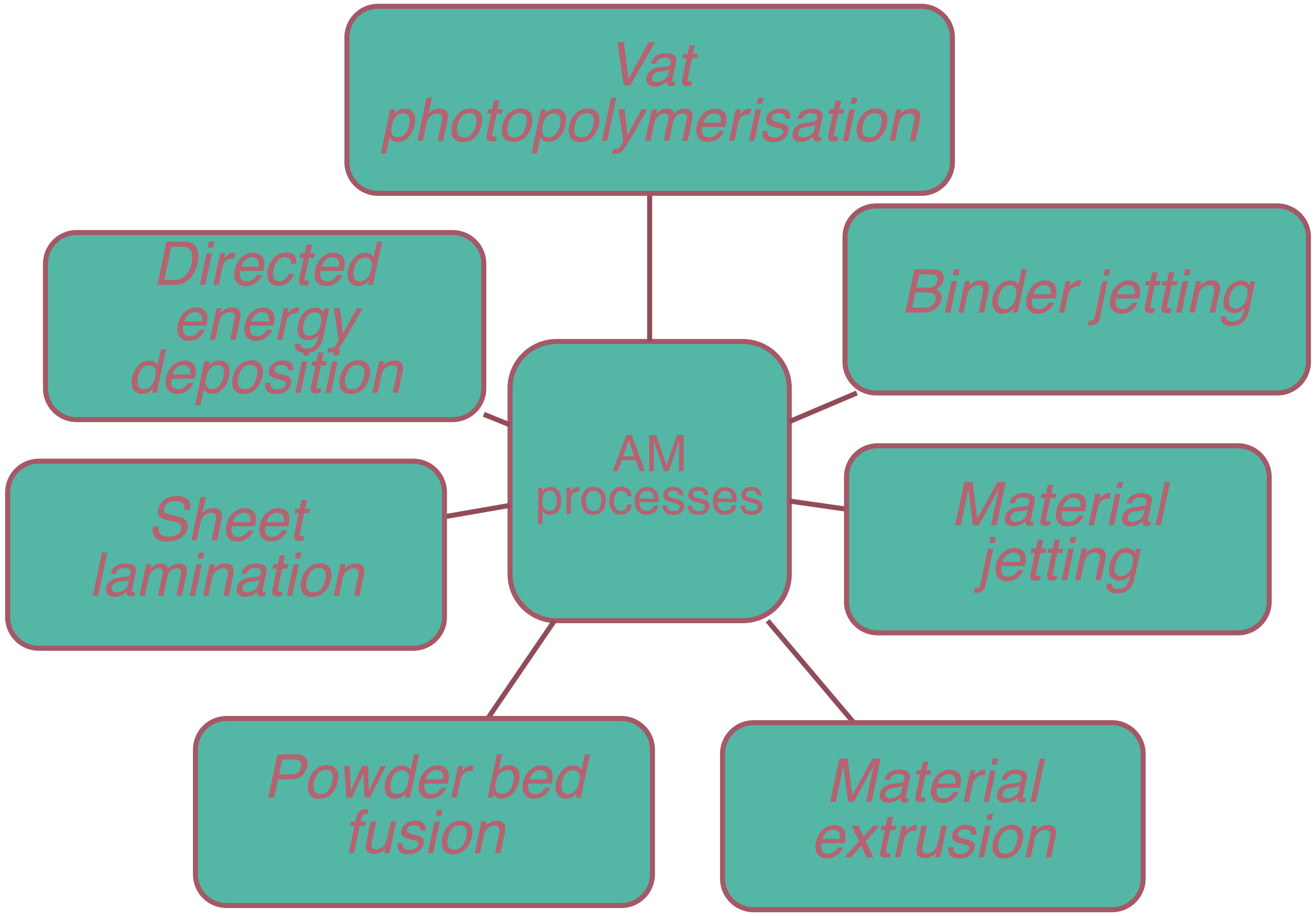


Figure 1.2.1. 3DP processes. Source: Ludor Engineering

1 *ISO/ASTM 52900-15, Standard Terminology For Additive Manufacturing – General Principles – Terminology– General Principles – Terminology, 2015*

3D PRINTING TECHNOLOGIES

- Based on each process category, many different 3DP technologies have been developed and are available today. Some of the more widespread are listed below.

Fused Deposition Modelling (FDM)
- Stereolithography (SLA)

Digital Light Processing (DLP)
- Selective Laser Sintering (SLS)

Material Jetting (MJ)
- Drop on Demand (DOD)

Sand Binder Jetting
- Metal Binder Jetting

Direct Metal Laser Sintering (DMLS)
- Selective Laser Melting (SLM)

Electron Beam Melting (EBM)
- Digital Light Synthesis (DLS)

Bound Metal Deposition (BMD)
- Single Pass Jetting (SPJ)

Wire + Arc Additive Manufacturing (WAAM)

Figure 1.2.2. 3DP technologies. Source: Ludor Engineering

FDM / FFF TECHNOLOGY

- Fused filament fabrication (FFF), also called fused deposition modelling (FDM), is a 3DP process which works by laying down consecutive layers of material at high temperatures, allowing the adjacent layers to cool and bond together before the next layer is deposited.

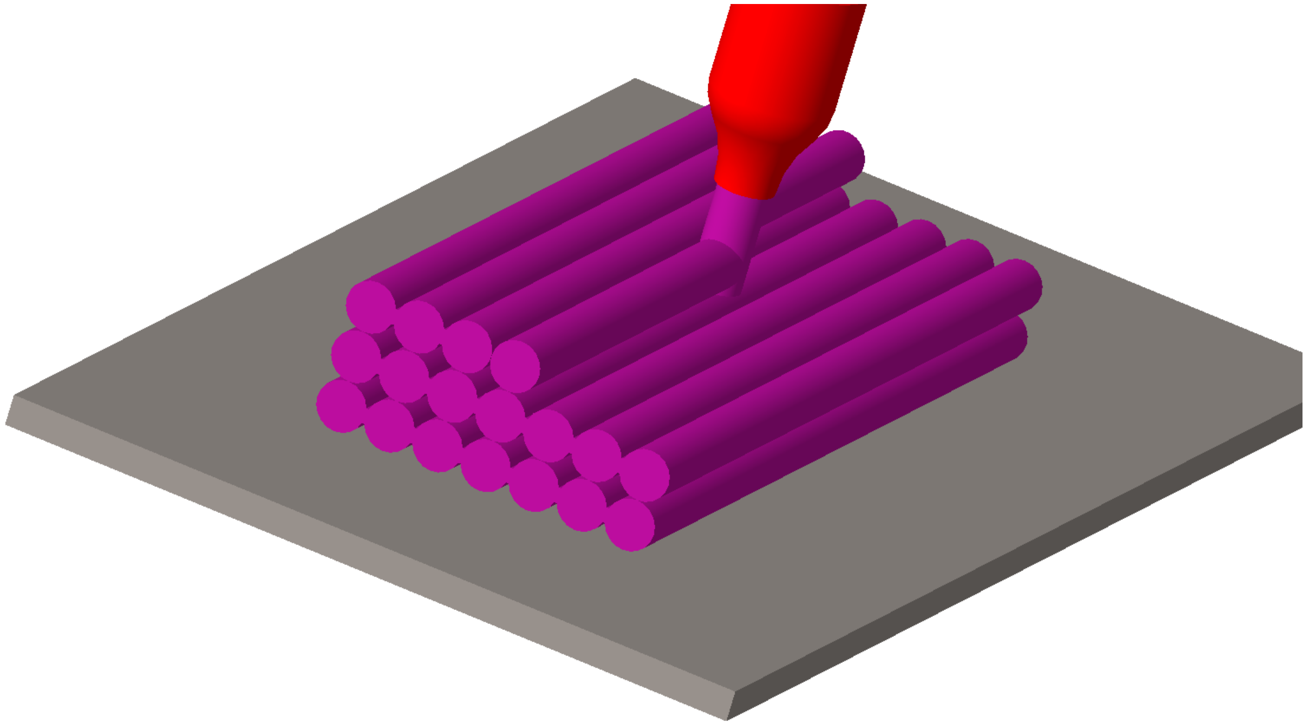


Figure 1.2.3. FDM technology. Source: Ludor Engineering

FDM / FFF TECHNOLOGY

- FDM is the most common 3D printing technology and can use many types of materials, including thermoplastics, chocolate, concrete, pastes, thermoplastic infused with metal, wood, carbon fibre, etc.

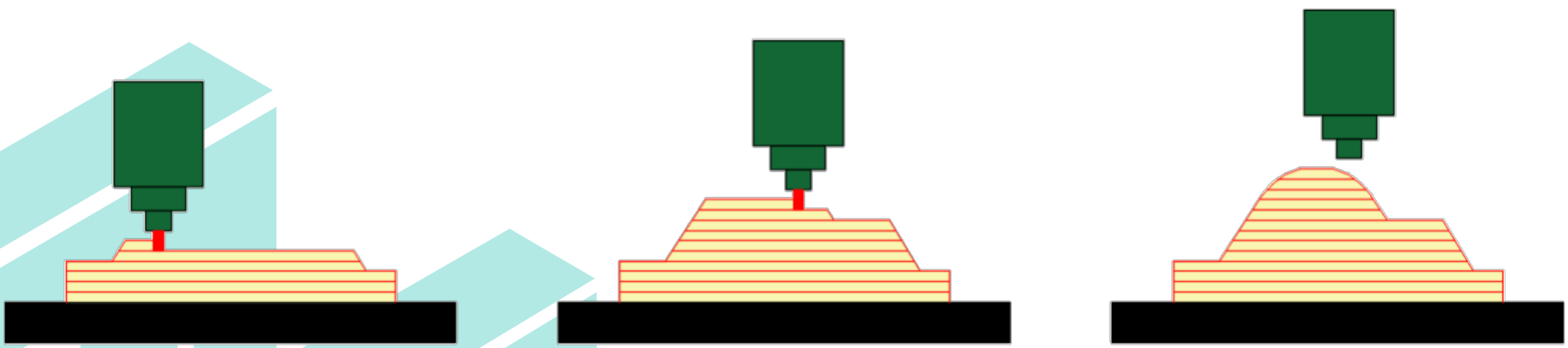


Figure 1.2.4. FDM technology. Source: Ludor Engineering

FDM / FFF TECHNOLOGY

- A variety of designs of FFF/FDM printers are available:
  - different mechanisms used to move the print head
  - different extruders, using filament, pellets, or paste

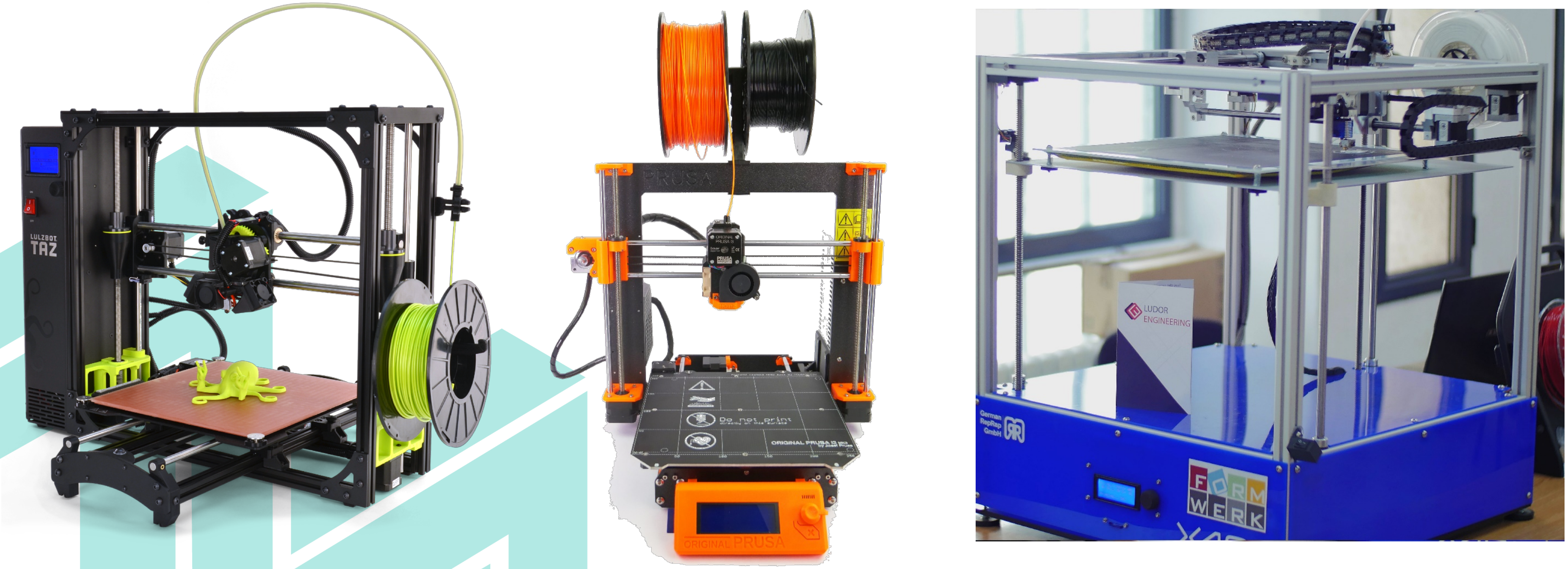


Figure 1.2.5. FDM 3D printers. Source: ALEPH OBJECTS, INC., Ludor Engineering and Prusa Research

SLA TECHNOLOGY

- Stereolithography (SLA) is a 3DP process which create objects by selectively curing a liquid thermoset polymer resin layer-by-layer using a light source. It is the world's first 3DP technology.

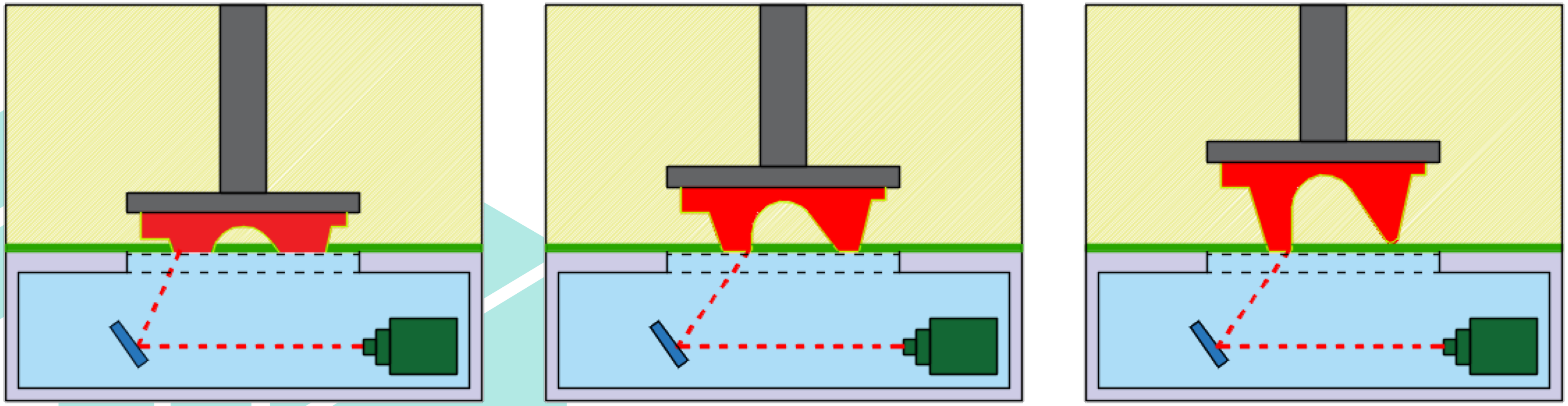


Figure 1.2.6. SLA technology. Source: Ludor Engineering

SLA TECHNOLOGY

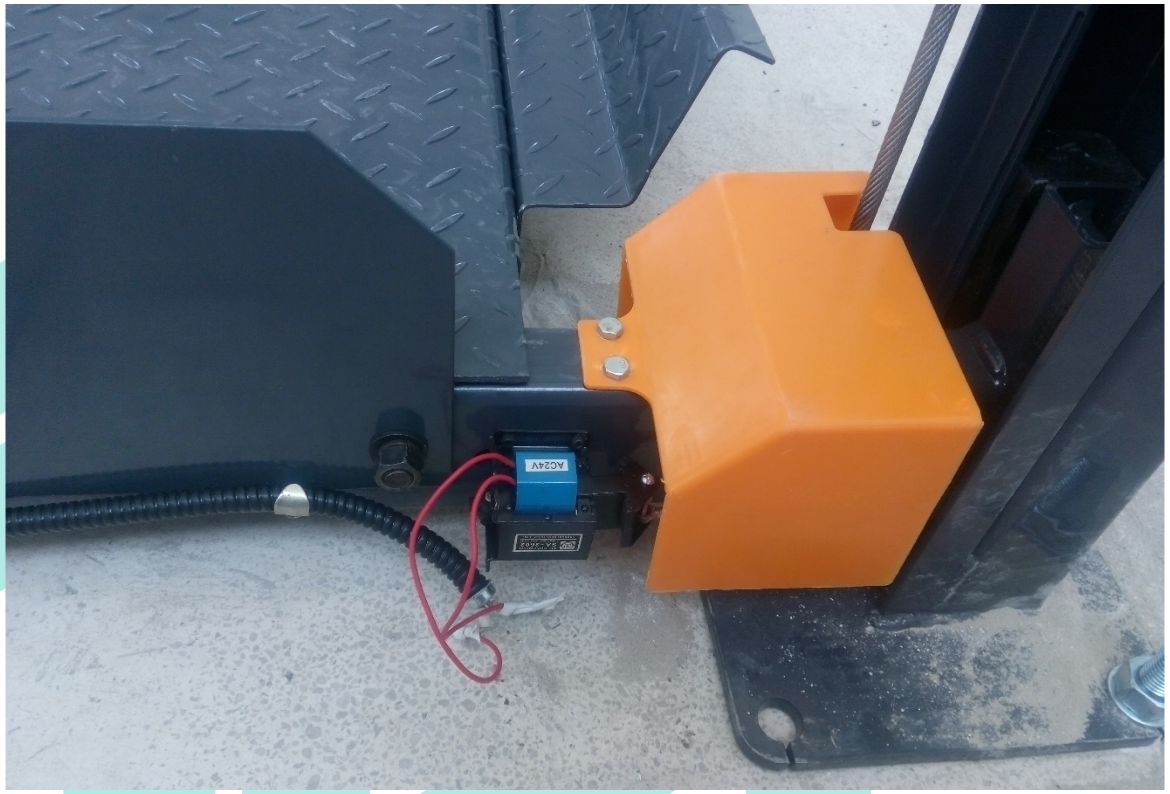
- SLA can produce objects with high resolution, fine details, and a smooth surface finish. There is a wide range of SLA resins available, including engineering, dental and castable resins.

Figure 1.2.7. SLA 3D printers. Source: Formlabs, Prusa Research and SprintRay

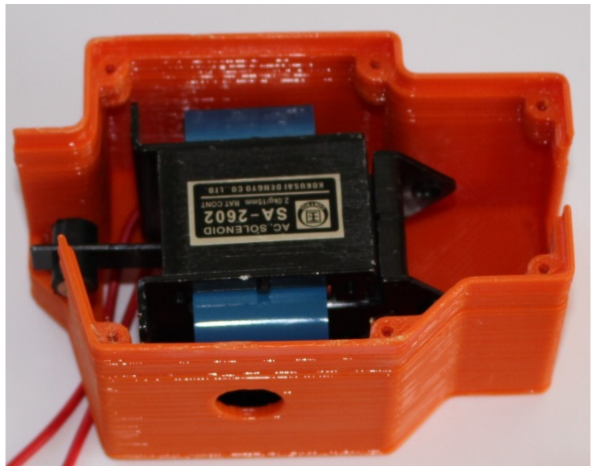
CASE STUDY

- Exploiting FDM 3D printing for fabricating a custom relay box

The relays of an outdoor parking lift needed a protective cover. Custom boxes were designed and made in ABS using a FDM 3D printer. This proved to be a very good solution: functional, cost effective and completed in a short time.



(a)



(b)

(c)

Figure 1.2.8. Using FDM for custom products fabrication. (a) A relay to be protected; (b) and (c) The custom made relay box. Source: Ludor Engineering

FURTHER LEARNING

3DP technologies
https://all3dp.com/1/types-of-3d-printers-3d-printing-technology/

3D Printers and 3DP: Technologies, Processes and Techniques
https://www.sculpteo.com/en/3d-printing/3d-printing-technologies/

SLA 3D Printing
https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/

FDM 3D Printing
https://www.3dhubs.com/knowledge-base/introduction-fdm-3d-printing

Animation demonstrating FDM process
https://youtu.be/ROE2ni5xg88

1.3. 3DP ADVANTAGES AND LIMITATIONS

- In this lesson you will learn about the main advantages offered by 3DP as well as the limitations.
- Expected learning outcomes: basic knowledge needed to evaluate the opportunity of using 3DP for making different parts of your prototype.

Duration	1 academic hrs
Author / Lecturer	Doru Cantemir, Ludor Engineering
Delivery methods	Individual / Teamwork / P2P
Evaluation methods	Test / Report / Feedback / Exam etc.

3DP ADVANTAGES

- 3DP provides several key advantages over traditional manufacturing techniques, in terms of cost and time efficiency, complexity of design, sustainability, etc.

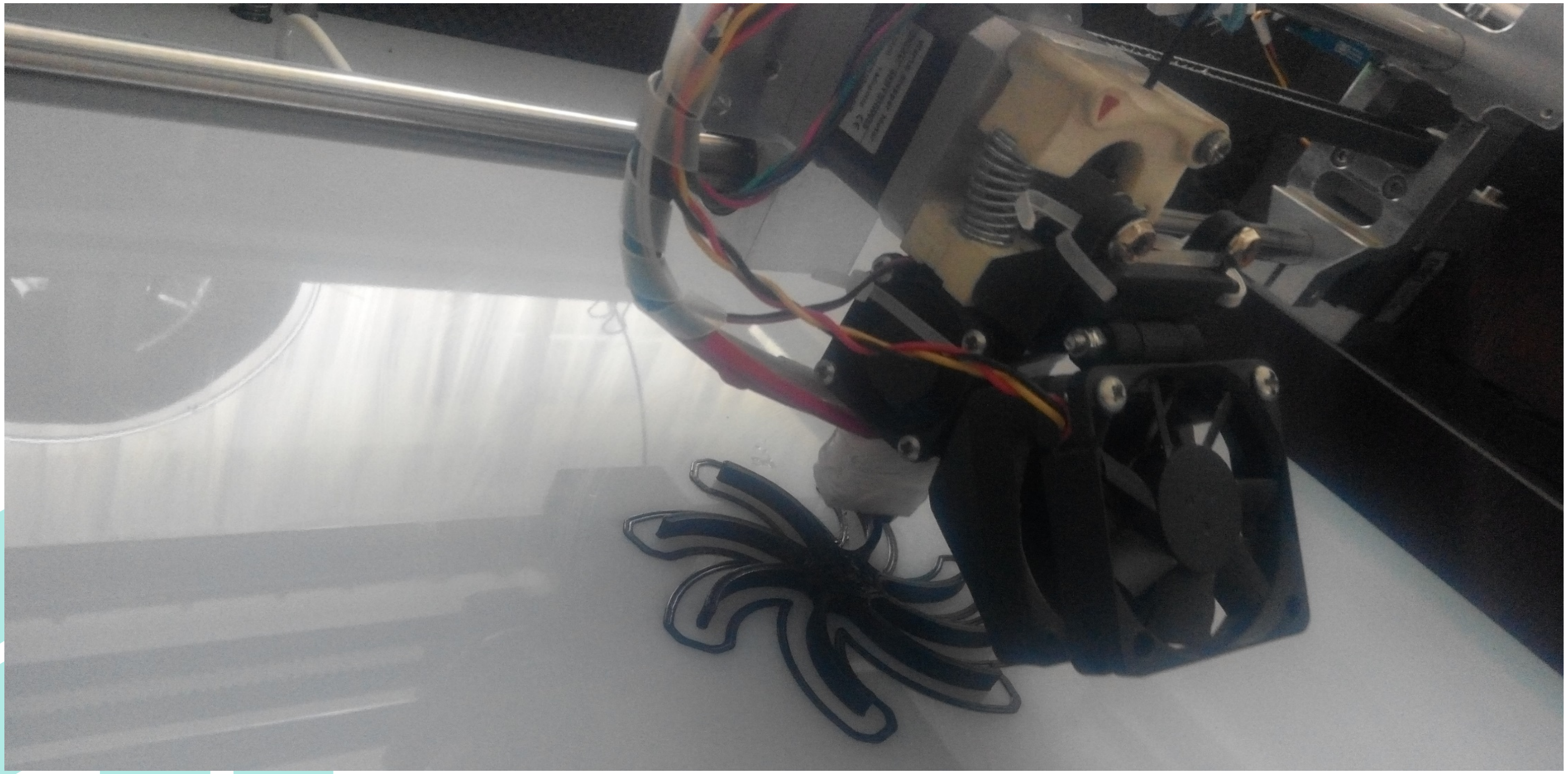


Figure 1.3.1. 3D printer at work. Source: Ludor Engineering

3DP ADVANTAGES

- ***Freedom of design and complexity***

Very complex shapes and geometry are made possible by 3DP. This allows designers to be much more creative as they are no longer limited by the traditional manufacturing restrictions.

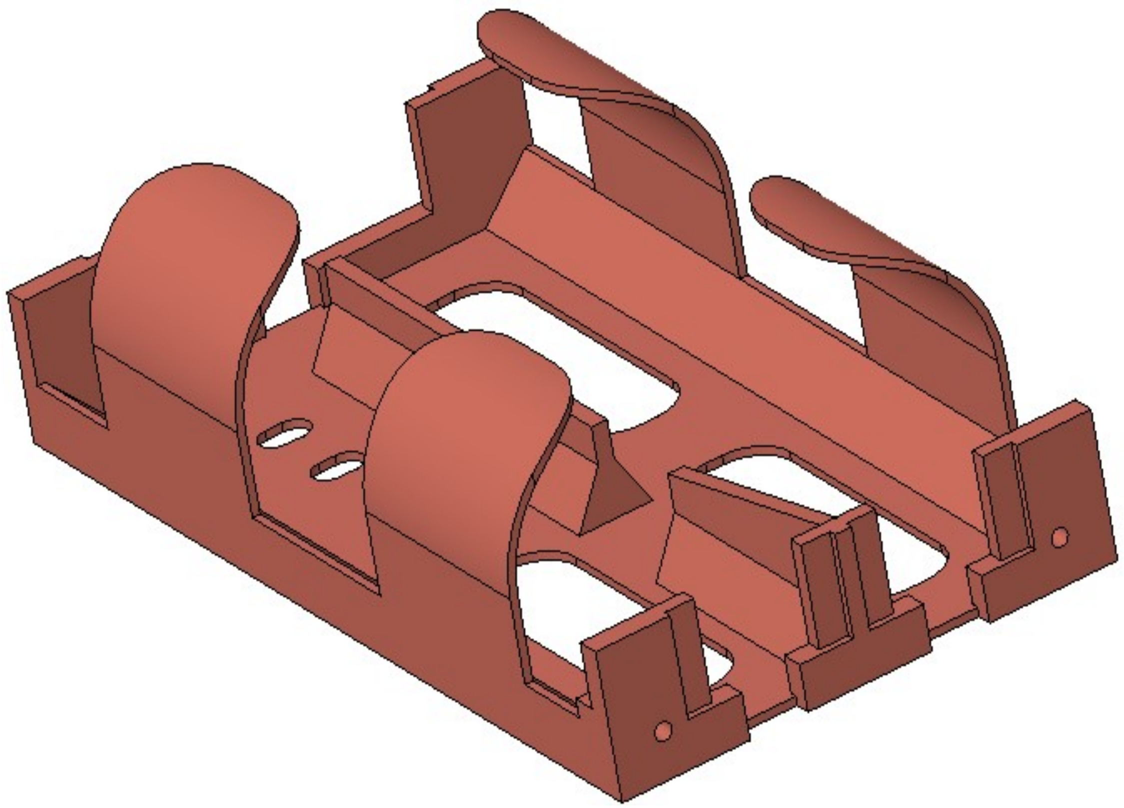


Figure 1.3.2. Complex part designed for 3DP. Source: Ludor Engineering

3DP ADVANTAGES

- ***Customization***

3DP allows customisation of produced parts without added costs. To create different products is enough to update their 3D file so the price of production is the same for 1 or 1,000 3D printed parts. Thus, to produce 1,000 identical parts or 1,000 slightly personalised parts it comes at virtually the same cost.

Figure 1.3.3. Customised part designed for 3DP. Source: Ludor Engineering

3DP ADVANTAGES

- ***No need for tooling***

In contrast with traditional manufacturing techniques, 3DP doesn't require the initial cost of moulds and specific tooling. This makes 3DP very effective for unique or small batch production as well as for mass customization.

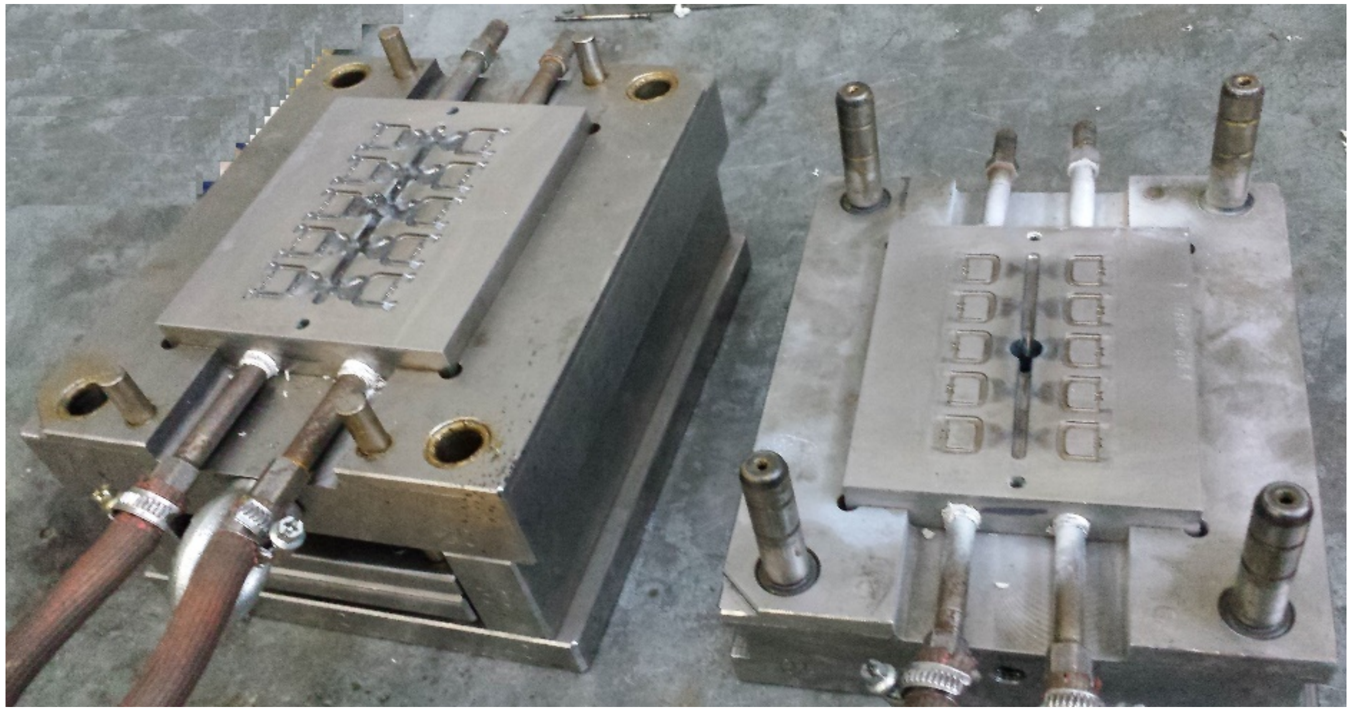


Figure 1.3.4. Mould used for traditional manufacturing. Source: Ludor Engineering

3DP ADVANTAGES

- ***Prototyping costs savings***

Prototyping with 3DP is, most of the times, faster, cheaper and easier than with traditional technologies.

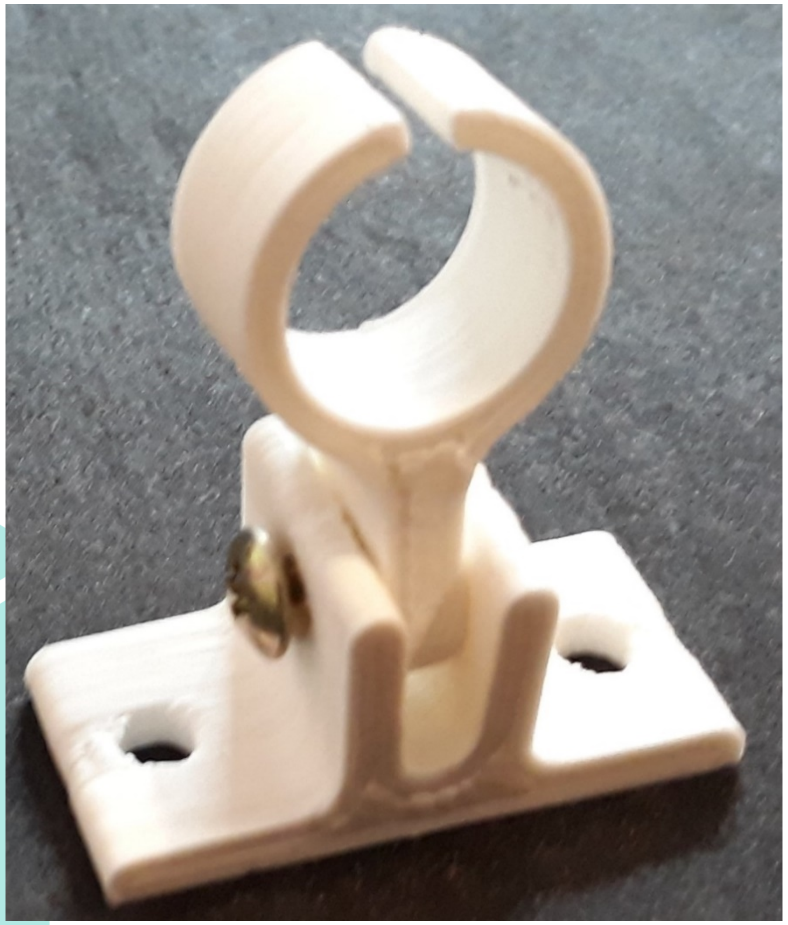


Figure 1.3.5. 3D printed prototypes. Source: Ludor Engineering

3DP ADVANTAGES

- ***Faster product development***

Product development involves a cyclic process of prototyping, testing, analysing, and refining an idea. With 3DP, prototypes are quick and easy to produce thus allowing for rapid design iterations and faster product development.

Figure 1.3.6. Successive product development stages.
Source: Ludor Engineering

3DP ADVANTAGES

- ***Less risky route to market***

A 3D printed production-ready prototype is a great verification tool that reduces the risk of investing in expensive manufacturing equipment for a faulty product.

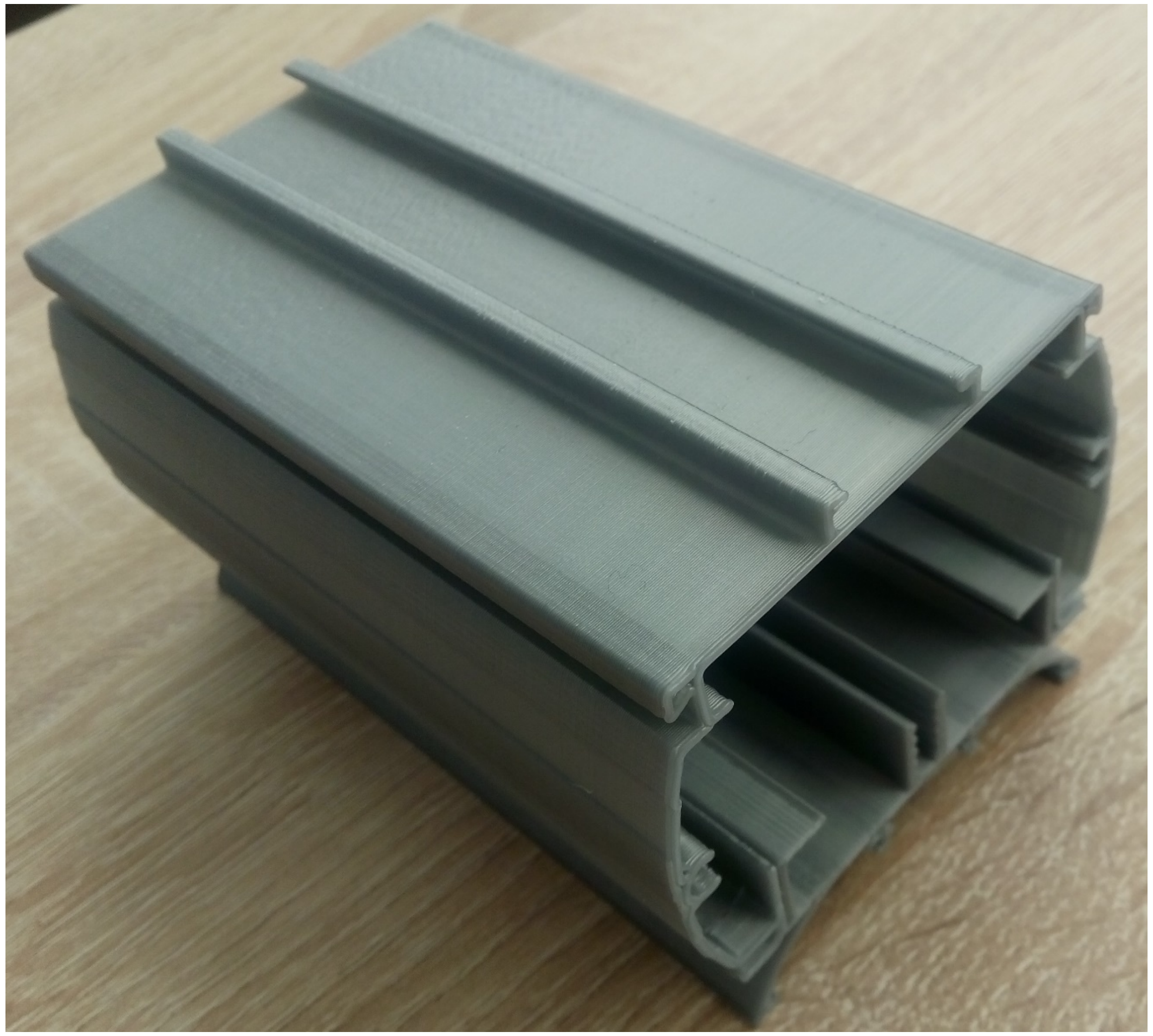


Figure 1.3.7. Production ready prototype. Source: Ludor Engineering

3DP ADVANTAGES

- ***Less risky route to market***

The final product can be produced in small batches by 3DP for testing the market before making the large investments required for mass production.

Figure 1.3.8. 3D printed final product. Source: Ludor Engineering

3DP LIMITATIONS

- 3DP has also some disadvantages and, definitely, it is not always the right tool for the job. The limitations range from a restricted availability of materials to questions over whether the technology is feasible for short-run and long-run manufacturing.

Figure 1.3.9. 3DP has limitations. Source: Ludor Engineering

3DP LIMITATIONS

- ***Higher cost for large production runs***

3DP has the advantage of virtually no upfront cost to making a new part. For a small batch, 3DP can be more economical but, as the production run increases, the traditional manufacturing methods become more price competitive than 3DP.

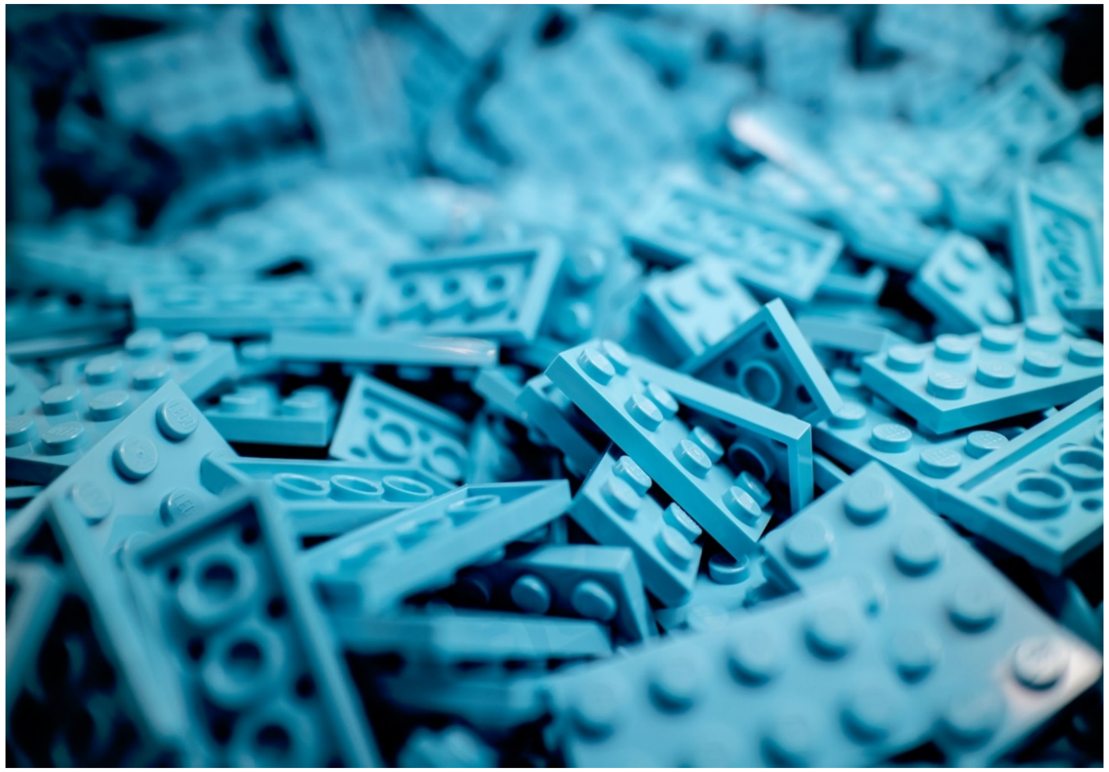


Figure 1.3.10. Large production run. Source: Pixabay

3DP LIMITATIONS

- ***Higher cost for large production runs***

Using 3DP, the unit cost of production remains constant regardless of the number of parts produced. Using injection moulding, the mould must be made prior to making the first unit. From there, each unit can be made for an additional small cost. In the picture can be seen that for large production runs, 3DP is more expensive.

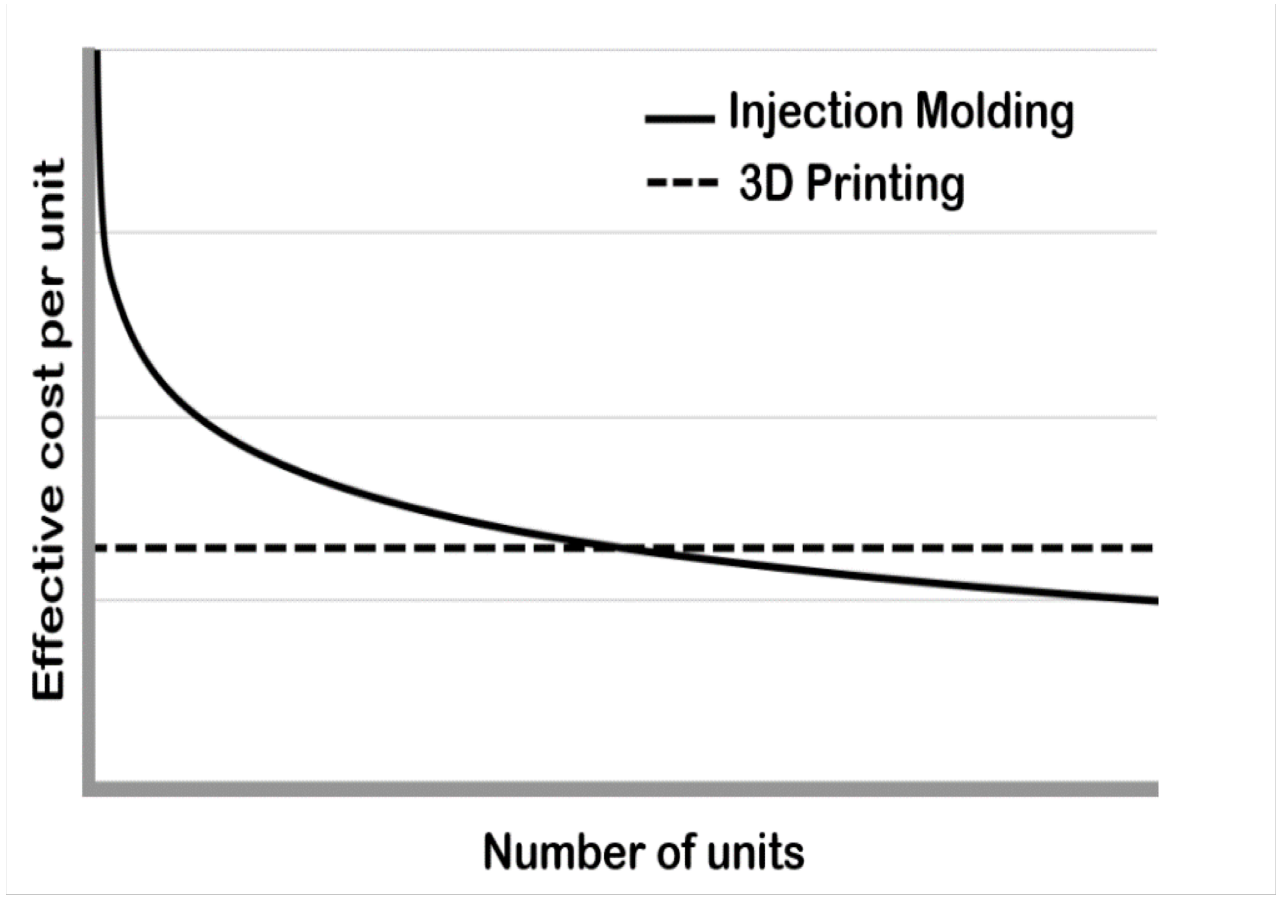


Figure 1.3.11. 3DP vs. injection moulding. Source: Ludor Engineering

3DP LIMITATIONS

- ***Less material choices, colours, finishes***

The range of materials that can be 3D printed is quite limited nowadays. Although metal 3DP is quickly evolving, the plastic is the most used material. Plastic may vary in strength capacity and may not be suitable for some components.

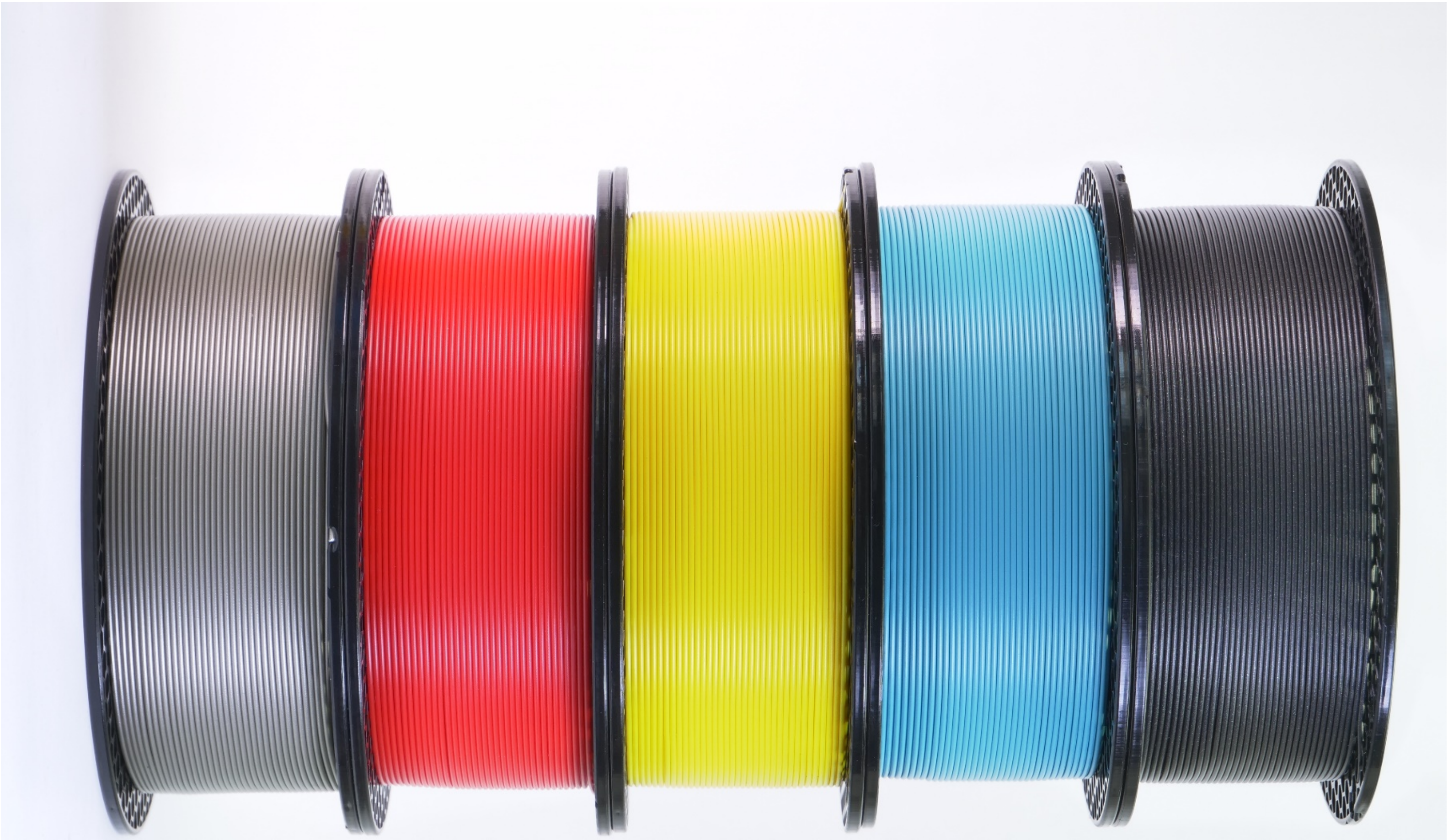


Figure 1.3.12. 3DP materials. Source: Prusa Research

3DP LIMITATIONS

- ***Limited strength and endurance***

The layer-by-layer fabrication process typical for 3DP adversely affects the part strength uniformity making 3D printed parts weaker than their traditionally manufactured counterparts.

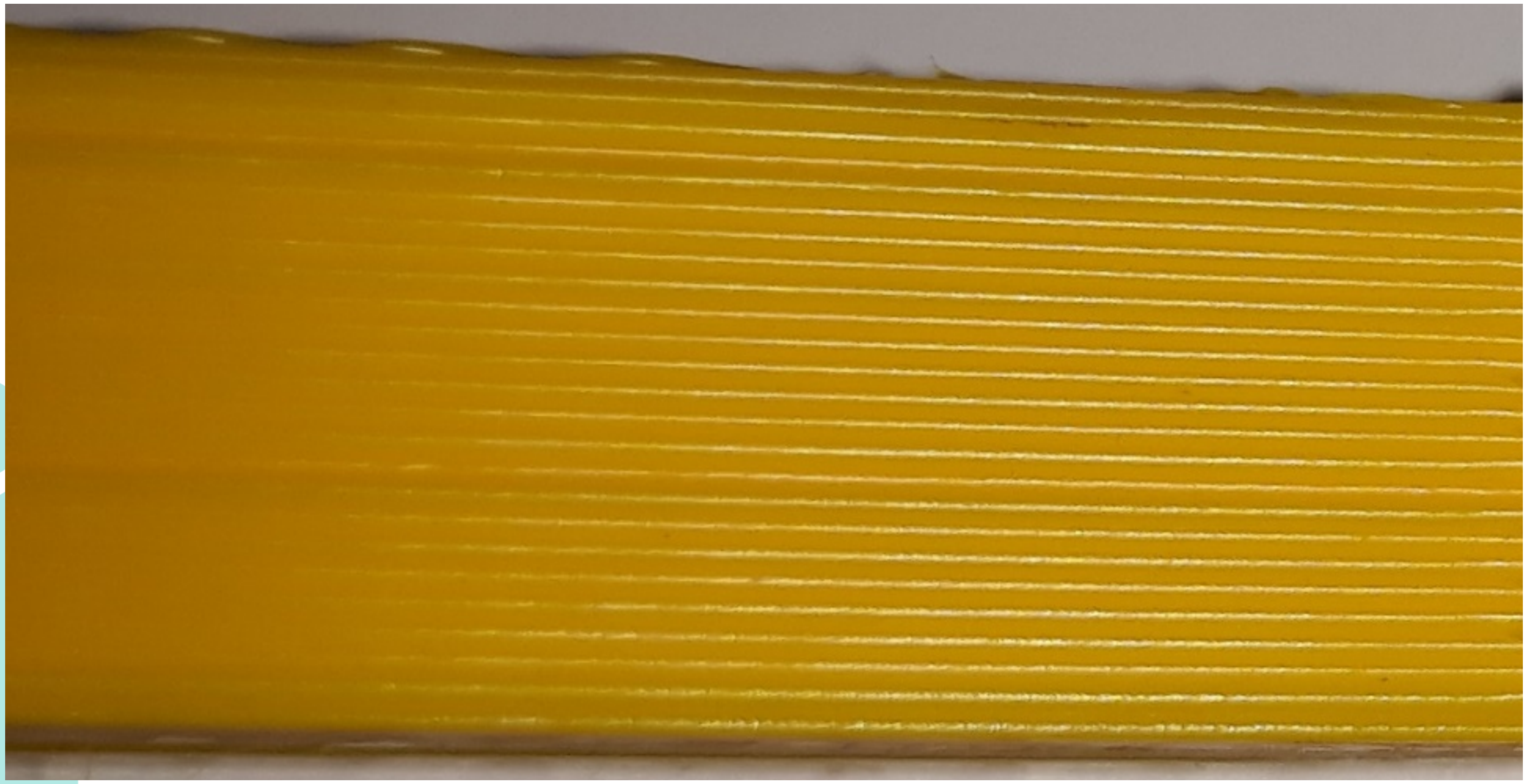


Figure 1.3.13. 3DP layers. Source: Ludor Engineering

3DP LIMITATIONS

- ***Low accuracy, low quality of small details***

The accuracy of 3D printed parts is lower than what can be achieved with CNC machining, for example. Also, the surface quality is not very good.

Figure 1.3.14. 3D printed part. Source: Ludor Engineering

3DP LIMITATIONS

- ***High energy consumption***

3D printers consume much more energy than traditional manufacturing.

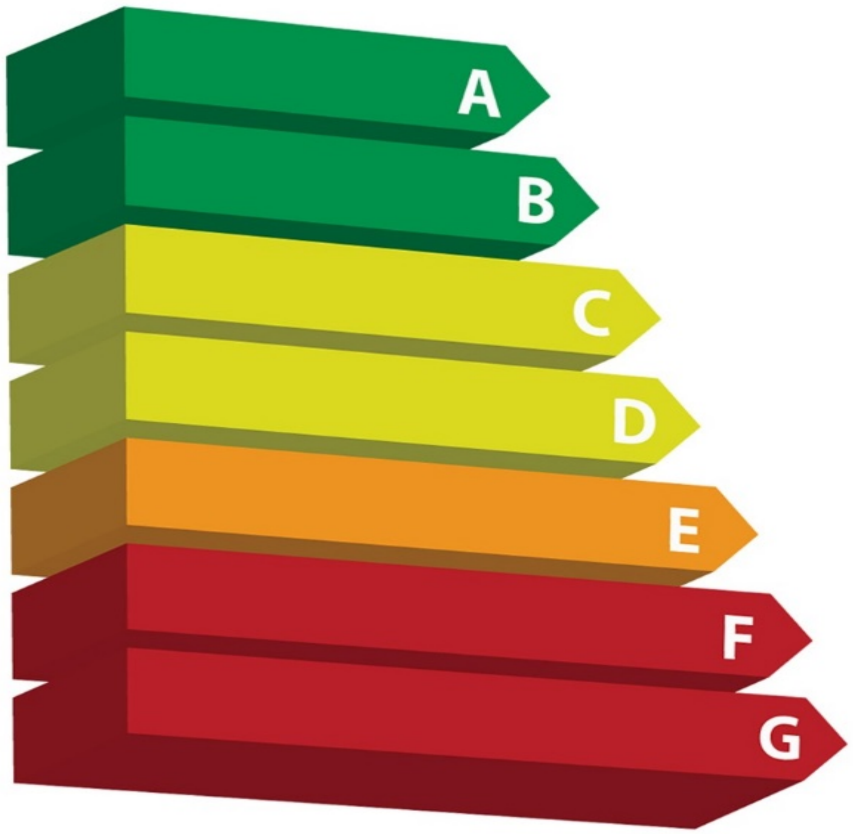


Figure 1.3.15. 3DP is not energy efficient. Source: Pixabay

3DP LIMITATIONS

- ***3D printers are slow***

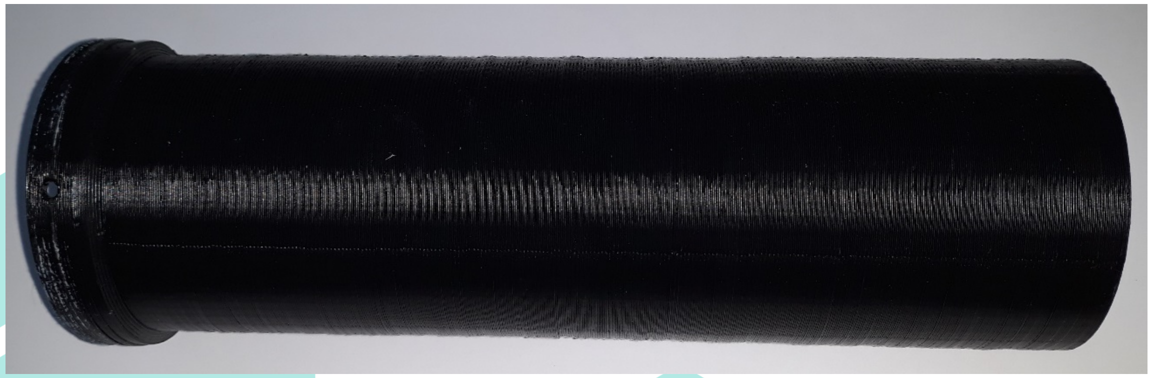
With the current technology, manufacturing by 3DP is very slow. The printing speed depends on many factors: object size, desired resolution, material, type of process, printer quality, etc.

Figure 1.3.16. 3DP is slow. Source: Pixabay

CASE STUDY

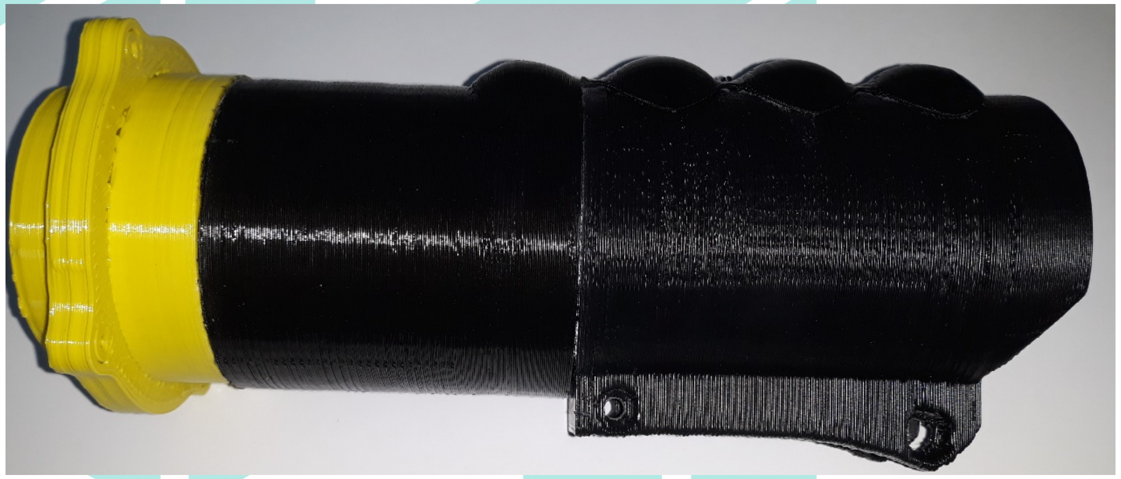
- Using 3D printing for rapid design iterations and faster product development

- In order to develop an ergonomic hand held device for a given application, 3 different prototypes have been successively printed – (a) for the evaluation of functional dimensions, (b) for assessing the ergonomics and the coupling solution and (c) for final testing on functionality, ergonomics and integration in the application. 3D printing allowed for quick, easy and cost effective prototyping and helped speeding the product development process.



(a)

(c)



(b)

Figure 1.3.17. Using 3DP for rapid design iterations. Source: Ludor Engineering

FURTHER LEARNING

3DP advantages
https://www.3dhubs.com/knowledge-base/advantages-3d-printing

3DP disadvantages
https://3dinsider.com/3d-printing-disadvantages/

3DP in product development
https://ultimaker.com/en/explore/where-is-3d-printing-used/product-design

https://3dprint.com/227268/why-use-rapid-prototyping-in-product-development/

An online platform for 3DP training
https://3d-p.eu/lms/

1.4. 3DP MATERIALS

- In this lesson you will learn about the various materials used in 3DP.
- Expected learning outcomes: basic knowledge needed to select the right material for making different parts of your prototype.

Duration	1 academic hrs
Author / Lecturer	Doru Cantemir, Ludor Engineering
Delivery methods	Individual / Teamwork / P2P
Evaluation methods	Test / Report / Feedback / Exam etc.

3DP MATERIALS

- There are various types of raw materials that can be used by the different 3DP technologies. They can be in different states: liquid, filament, pellets, powder, paste, solid sheet.

- Plastics are the most common but the options are constantly growing, 3DP using now materials like metals, ceramics, composites, glass, paper, concrete, food and even organic materials.

Figure 1.4.1. 3DP materials. Source: Ludor Engineering

3DP MATERIALS - THERMOPLASTICS

- A thermoplastic is a plastic material that becomes soft above a specific temperature and hardens upon cooling. The most used in 3DP are:

Polylactic Acid (PLA)	Acrylonitrile Butadiene Styrene (ABS)
Polycarbonate (PC)	High-Impact Polystyrene (HIPS)
Polyamides (Nylon)	Polyethylene terephthalate (PET)
Polyvinyl Alcohol (PVA)	Thermoplastic Elastomers (TPE)

- Thermoplastics for 3DP are coming in the shapes of filament, powder and pellets.

Figure 1.4.2. Thermoplastics used in 3DP. Source: Ludor Engineering

3DP MATERIALS - PLA

- Polylactic Acid (PLA) is derived from renewable resources, it has a moderate price and has properties and technical specifications which makes it the filament of choice for hobby 3DP.

Figure 1.4.3. PLA. Source: Ludor Engineering

3DP MATERIALS - ABS

- Acrylonitrile Butadiene Styrene (ABS) is an petroleum based polymer, a pretty cheap material. The parts made in ABS can be employed for end use applications. Along with PLA, it is the most common FDM desktop printing material.

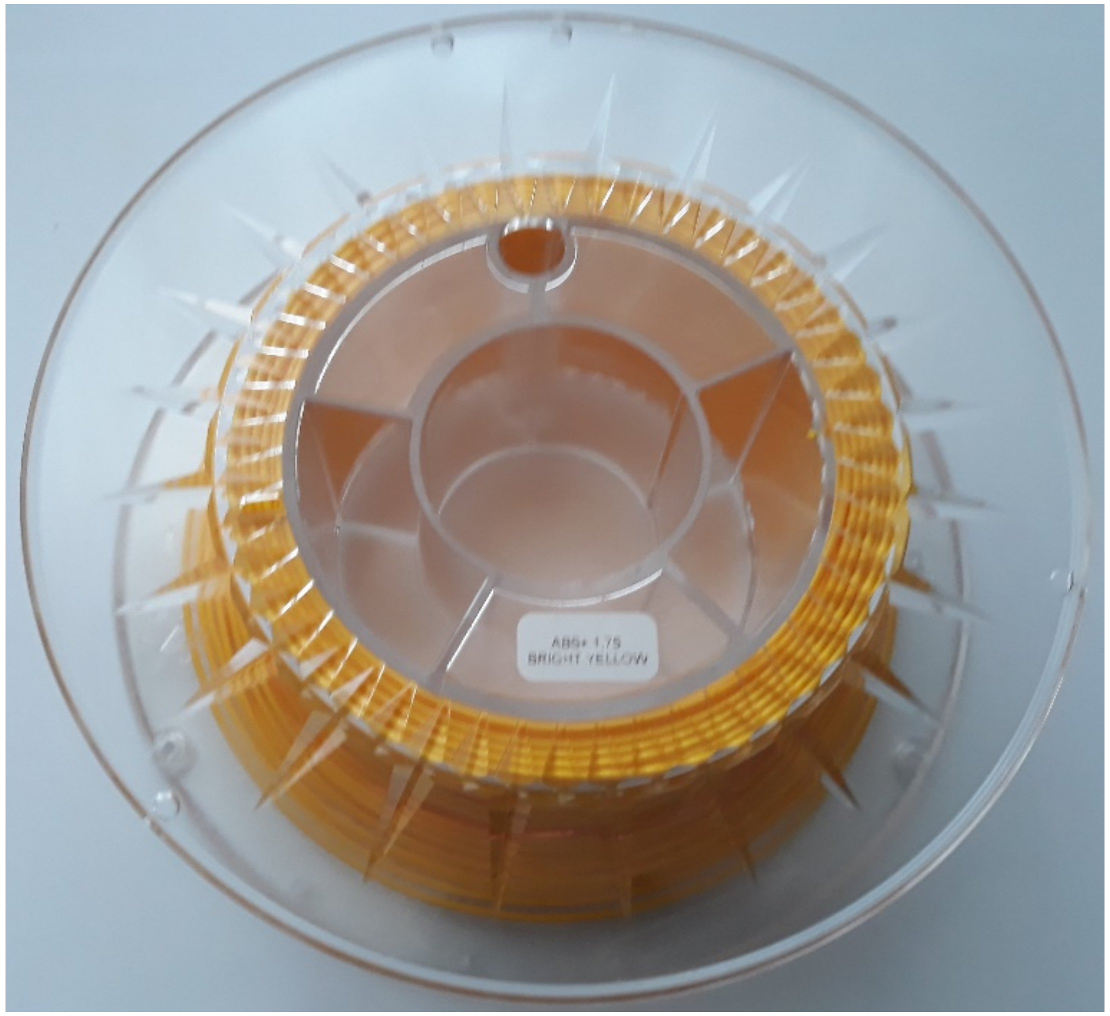


Figure 1.4.4. ABS. Source: Ludor Engineering

3DP MATERIALS - PC

- Polycarbonate (PC) is useful for high temperature applications, it can be transparent, it is stronger than both PLA and ABS but yet flexible.

Figure 1.4.5. PC filament. Source: Polymaker

3DP MATERIALS - *POLYAMIDES*

- Nylon offers high flexibility and great strength while being extremely light weight. Printed Nylon parts are not as brittle as those printed with either ABS or PLA, which means printed parts can be ten times stronger without cracking or breaking.

- Nylon is applicable to FDM and SLS printing being employed as filament and powder.

Figure 1.4.6. Nylon powder. Source: Shapeways

3DP MATERIALS - PVA

- Polyvinyl Alcohol (PVA) is a water-soluble material that is often used as a support material. A 3D printer with 2 extruders is normally used, one printing the part with normal filament and the second printing the supports. The part is then placed in water until all PVA supports are dissolved. Generally works well with PLA and Nylon filaments but it can also be used to print independently.

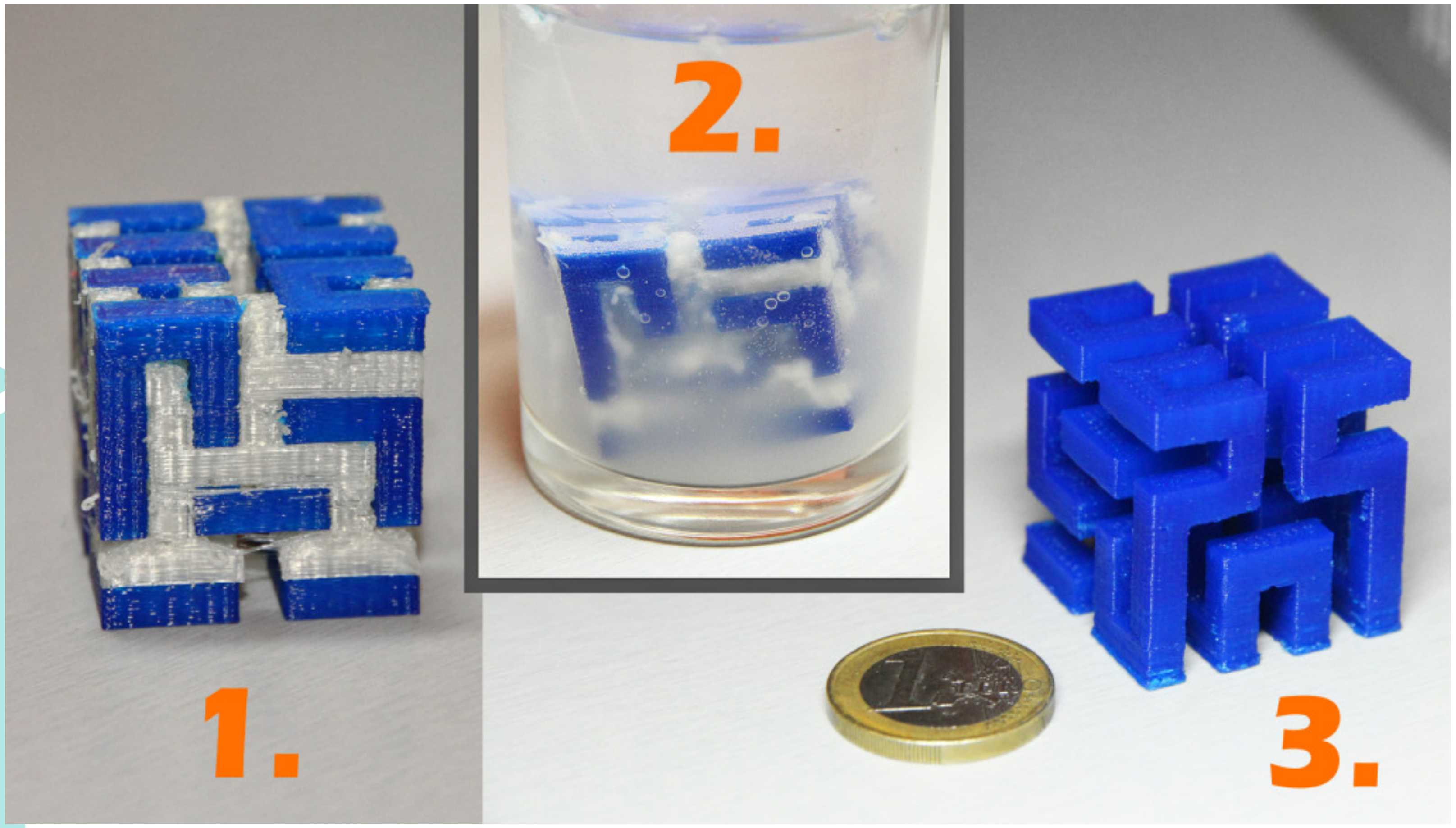


Figure 1.4.7. PVA used as support. Source: filamentguide.net

3DP MATERIALS - HIPS

- High-Impact Polystyrene (HIPS) is a material that dissolves in limonene solution and, like PVA, it's often used for support material. It works only with ABS because the other filaments are damaged by the limonene.

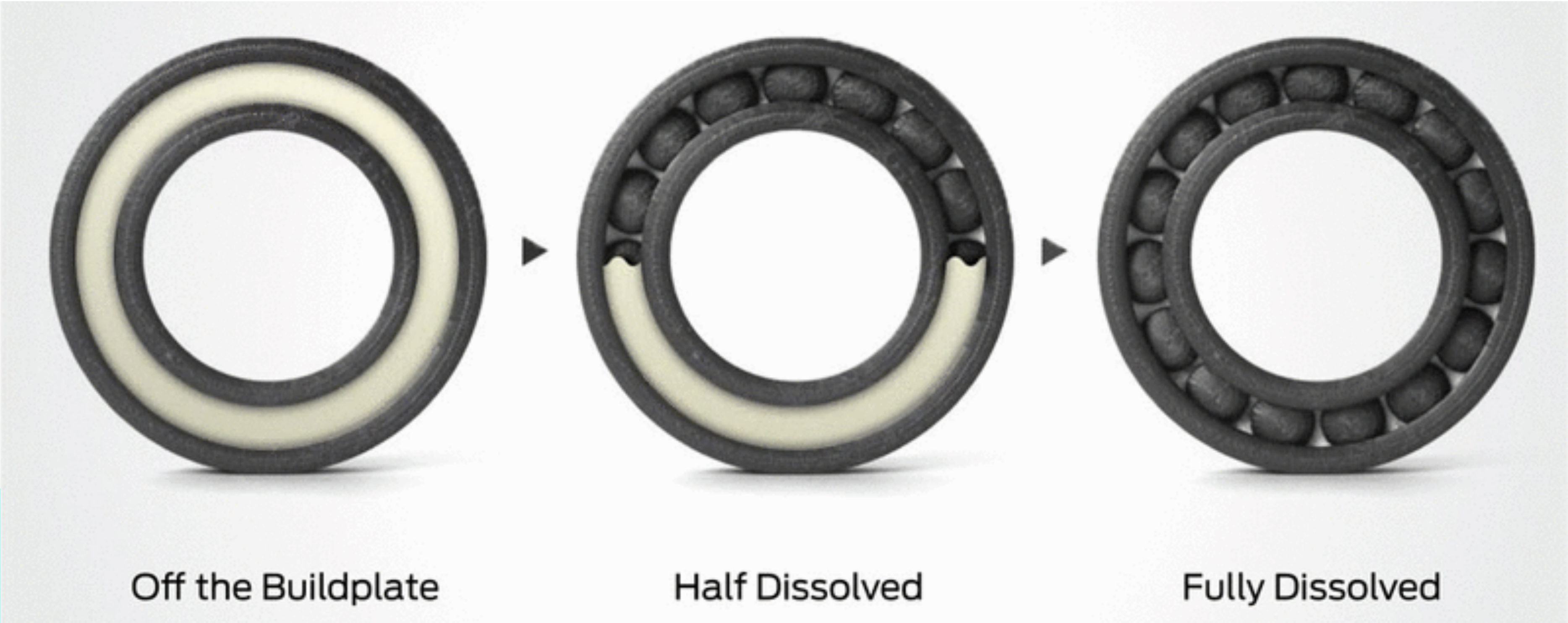


Figure 1.4.8. HIPS used as support. Source: MatterHackers

3DP MATERIALS - PET

- Polyethylene terephthalate (PET) is the most commonly used plastic in the world. The most used variants of PET in 3DP are PETG and PETT.

- PETG combines the strength, temperature resistance and durability of ABS with the ease of use of PLA .

- PETT is strong, food-safe, and transparent.

Figure 1.4.9. PETT filament. Source: Ludor Engineering

3DP MATERIALS - TPE

- Thermoplastic Elastomers (TPE) can be used to 3D print flexible, rubber-like, objects. One of the most used types of TPE is TPU (Thermoplastic Polyurethane) and has applications like automotive instrument panels, sporting goods, medical devices, footwear, drive belts, etc.

Figure 1.4.10. Object 3D printed in TPE. Source: Adidas

3DP MATERIALS - RESINS

- There is a large variety of resins used in 3DP, resulting in different material properties and suitable for different applications and technologies. They are made of liquid polymer and reach their end state with exposure to UV light.

- The main advantages of 3D printed resins are smooth surfaces, high-quality, detailed prints and a huge variety of finishing and post-processing possibilities.

Figure 1.4.11. Object 3D printed in resin. Source: Ludor Engineering

3DP MATERIALS - METALS

- Various 3DP technologies are able to print different metals and alloys, like steel, bronze, aluminium, titanium, platinum, gold, silver, nickel, Inconel, etc.

- The feedstock can have various shapes: metal powder, polymer filament or rod infused with metal powders, metal wire, metal slurry.

Figure 1.4.12. Object 3D printed in metal. Source: Ludor Engineering

3DP MATERIALS - COMPOSITES

- Composites are materials made from two or more basic materials mixed together. Polymers are often selected as matrix while for reinforcement can be employed metals, glass, carbon, ceramics, etc.

- There are many polymer-based composites in the shape of filaments, that can be used with FDM technology. Also, composite slurries, powders or sheets can be used with other 3DP technologies.

Figure 1.4.13. Bronze-polymer composite filament. Source: Ludor Engineering

3DP MATERIALS - CERAMICS

- Various ceramic materials can be 3D printed with FDM, SLA and other techniques. They came in different shapes: ceramic suspension, powder, ceramic-polymer composite filament, pasta.

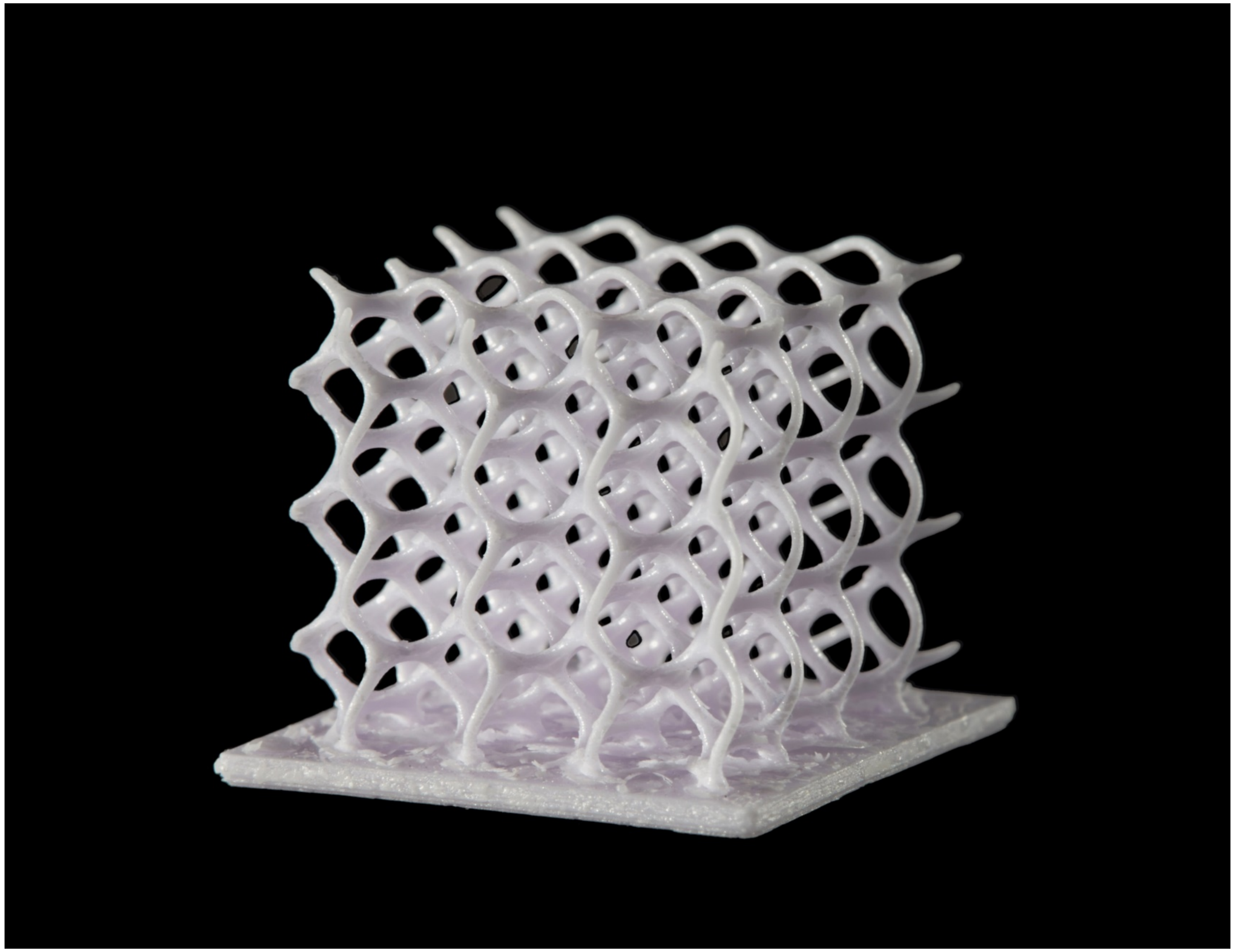


Figure 1.4.14. Object 3D printed in ceramics. Source: LITHOZ

3DP MATERIALS - FOOD

- Typically, food 3D printers rely on technology similar to FDM but use a paste instead of a plastic filament. This paste can consist of different ingredients including chocolate, sugar, chewing gum, tomatoes sauce, etc. However, some other 3DP technologies are also used in the food field. Among these, SLS uses powder raw materials.

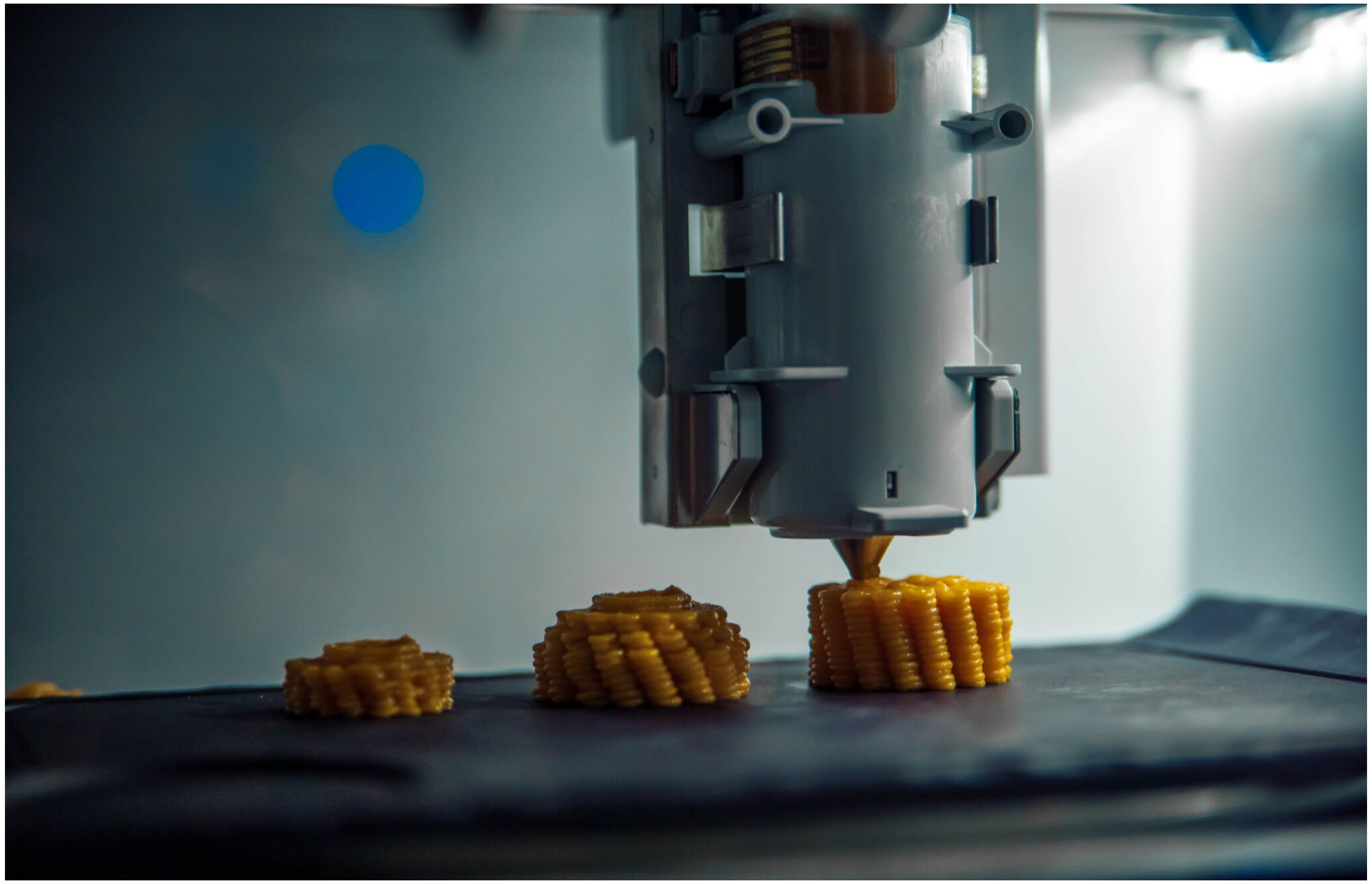


Figure 1.4.15. Food 3D printing. Source: Natural Machines

3DP MATERIALS - BIOMATERIALS

- A 3D printer can also dispense biological materials making possible the bio-printing. 3D bio-printing involves depositing layers of living cells onto biomaterials to build up biological tissue and organs.

Figure 1.4.16.Bio-printing. Source: Wake Forest Institute for Regenerative Medicine

CASE STUDY

- Selecting the right material for 3D printed part

- A very stiff part destined to work at around 70C was needed. Among the available materials, a special filament reinforced with 20% carbon fibers (XT-CF20 from colorFabb) was find to be the best choice because can work up to 80C and grants high stiffness to the 3D printed parts. The part behavior in the real working conditions confirmed the suitability of material selection.

Figure 1.4.17. Part 3D printed in carbon fibre reinforced filament. Source: Ludor Engineering

FURTHER LEARNING

3DP filament guide
https://all3dp.com/1/3d-printer-filament-types-3d-printing-3d-filament/

Using PVA for support structures
https://www.youtube.com/watch?v=0ENgGkPP94w

Using HIPS for support structures
https://www.youtube.com/watch?v=Ow__9LWpCJA

Ceramic 3D printing
https://www.youtube.com/watch?v=r0TQKm5ciY0
https://all3dp.com/1/3d-printing-ceramic-3d-printer/

Metal 3D printing
https://www.youtube.com/watch?v=te9OaSZ0kf8

Food 3D printing
https://www.youtube.com/watch?v=XQni3wb0tyM

TECHNICAL CREATIVITY IN 3D PRINTING MODULE

1.5. 3DP WORKFLOW

- In this lesson you will learn about the different steps in the 3DP workflow.

- Expected learning outcomes: basic knowledge about the operations to be done in order to obtain the 3D printed parts needed for your prototype.

Duration	1 academic hrs
Author / Lecturer	Doru Cantemir, Ludor Engineering
Delivery methods	Individual / Teamwork / P2P
Evaluation methods	Test / Report / Feedback / Exam etc.

3DP WORKFLOW

- 3D printing workflow is the process of how one starts with a 3D model and then gets a finished part from a 3D printer.

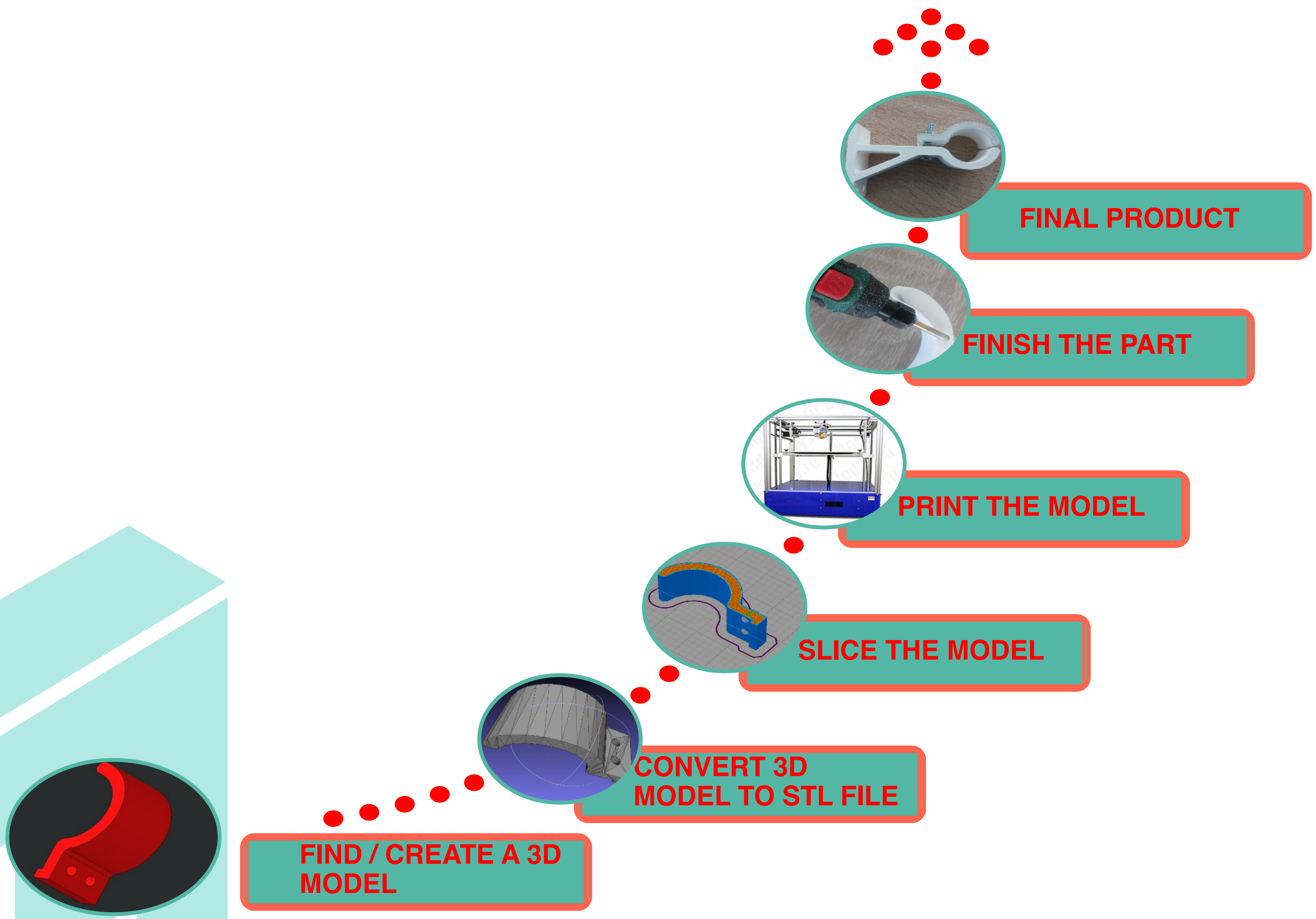


Figure 1.5.1. 3DP workflow. Source: Ludor Engineering

3D MODEL

- You can obtain a 3D model in the following ways:
  - Create it with computer graphics software
  - Create it by 3D scanning
  - Download it from an online marketplace
  - Hire a designer

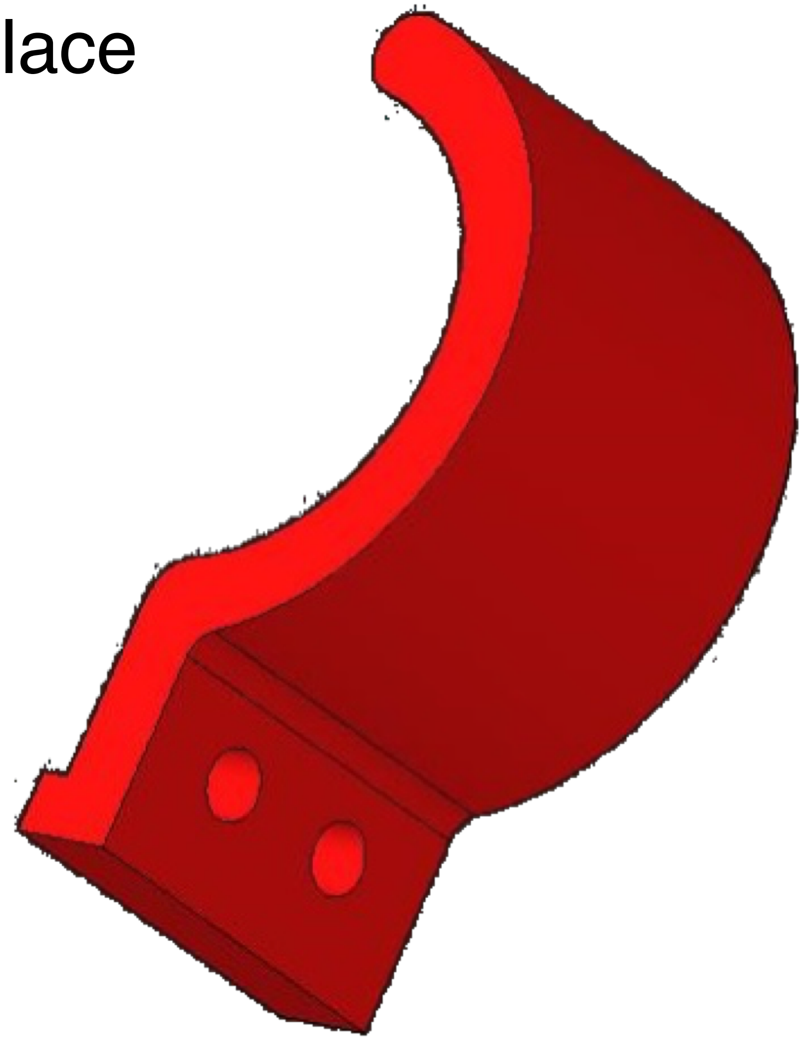


Figure 1.5.2. 3D model. Source: Ludor Engineering

STL FILE

- The conversion of a 3D model to a STL file is normally possible with most of the software used to create it.

- There are many converters supporting the translation of virtually any type of 3D geometry into STL files.

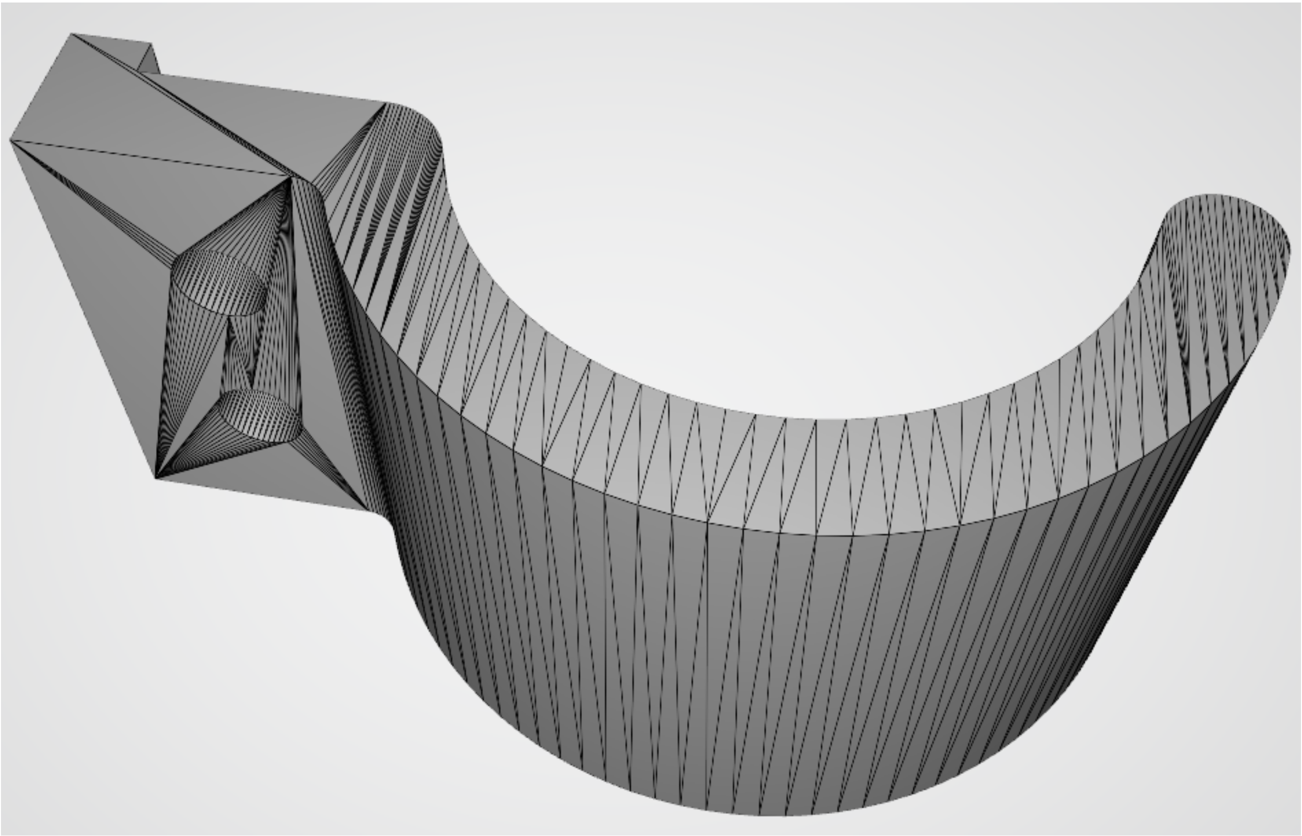


Figure 1.5.3. STL file. Source: Ludor Engineering

SLICING

- The STL file is sliced into a set of 2D sections with the help of a slicer software. Some slicer software can also repair the STL file, visualise it in various ways, generate statistics, calculate volumes, edit mesh, etc.

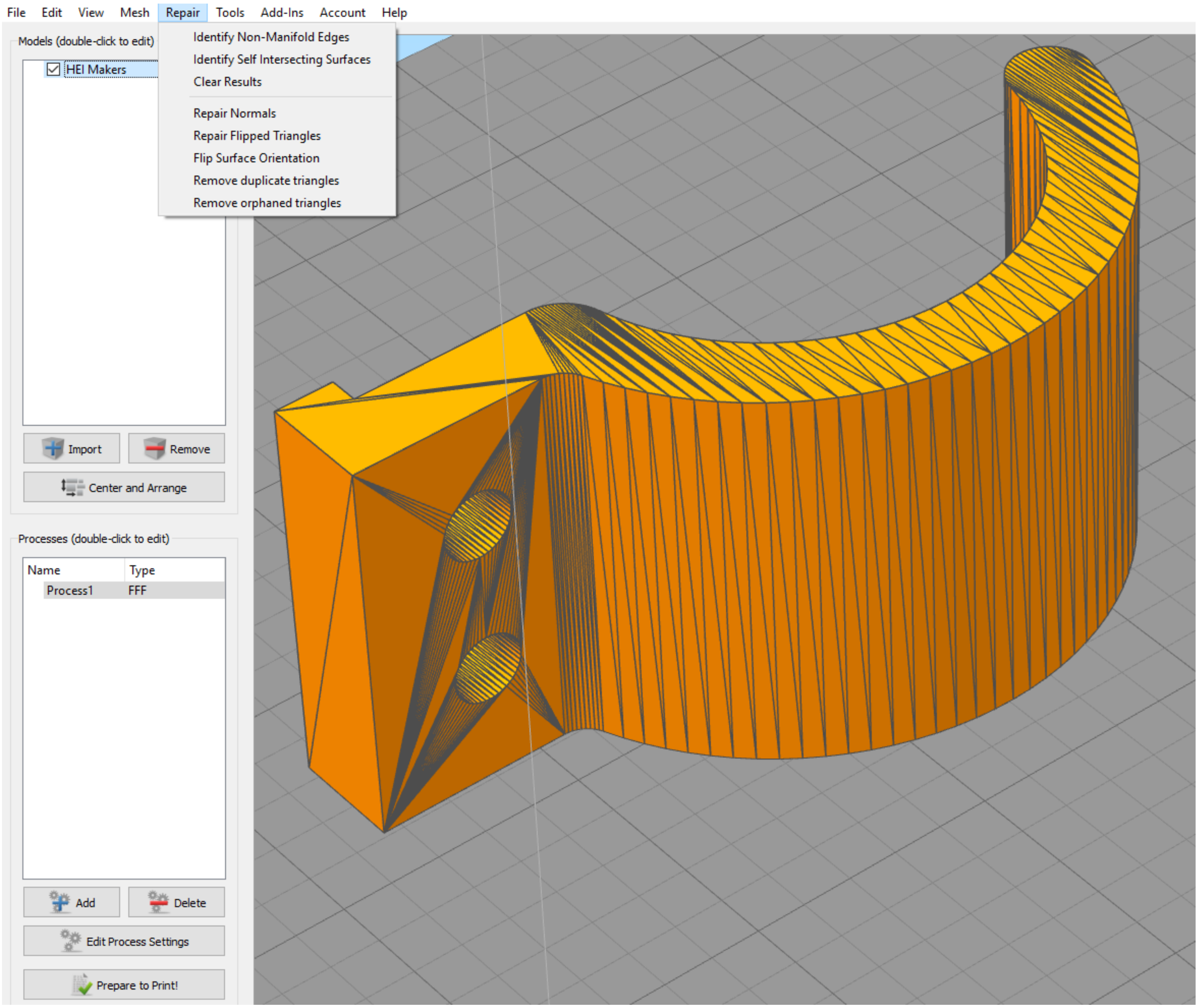


Figure 1.5.4. Slicer. Source: Ludor Engineering

SLICING - G-CODE FILE

- The slicer is also used to position the part, generate the support structures, set the printing parameters (temperatures, speed, cooling, infill, etc.), scale the part, etc. The final result is a g-code file including all information needed by the 3D printer to fabricate the part.

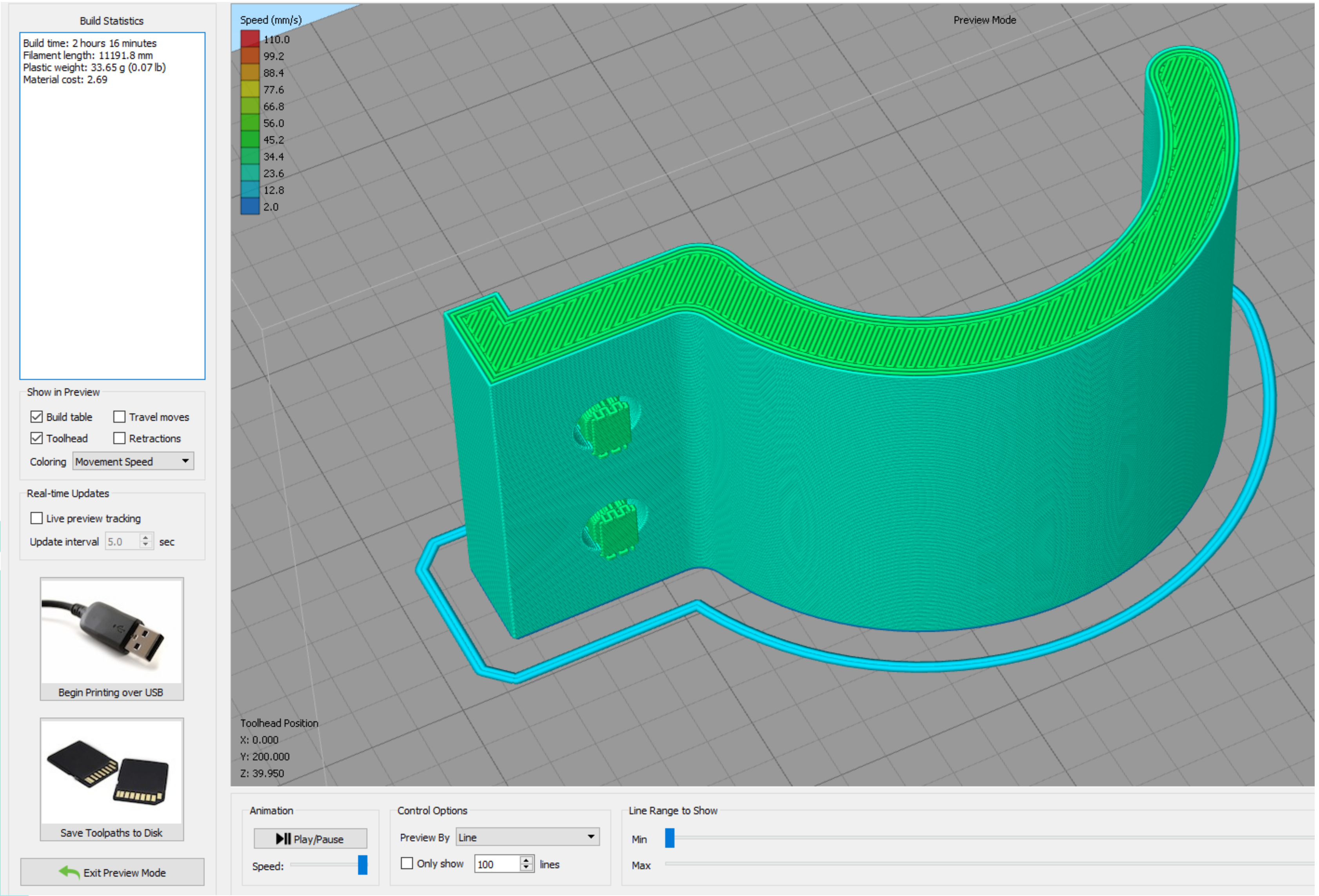


Figure 1.5.5. Part prepared for 3DP. Source: Ludor Engineering

3D PRINTING & FINISHING

- The g-code file is sent to 3D printer and printed.
- Usually, the 3D printed parts need to be finished – removing support structures, cleaning some imperfections, calibrating the holes, etc.

Figure 1.5.6. Part finishing. Source: Ludor Engineering

CASE STUDY

- Design and 3D printing of a PLA object

- Below are the steps done in order to fabricate a PLA object.

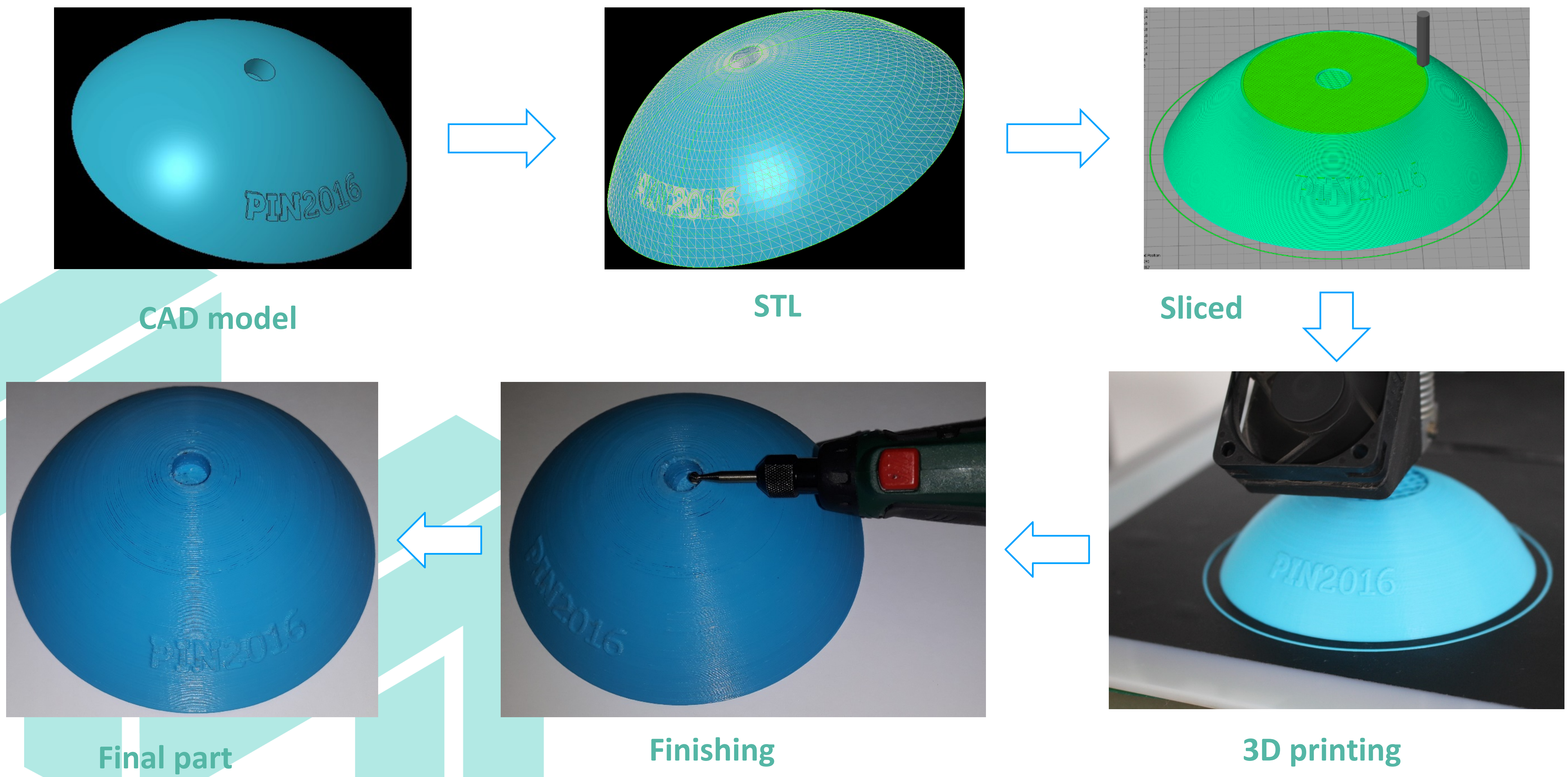


Figure 1.5.7. 3DP workflow. Source: Ludor Engineering

FURTHER LEARNING

3DP workflow video
https://www.materialise.com/en/academy/software/general/3d-printing-workflow

3DP workflow - explanations
https://blog.grabcad.com/blog/2016/06/06/todays-3d-printing-workflow/
https://all3dp.com/1/best-free-3d-printing-software-3d-printer-program/#workflow

3DP software tools
https://all3dp.com/1/best-free-3d-printing-software-3d-printer-program/

Top 20: Most Popular 3D Modeling & Design Software for 3D Printing
https://i.materialise.com/blog/en/top-25-most-popular-3d-modeling-design-software-for-3d-printing/

Best 3D Scanners of Winter 2018-19
https://all3dp.com/1/best-3d-scanner-diy-handheld-app-software/

Finishing 3D Prints 101: How to Sand 3D Printed Parts
https://www.youtube.com/watch?v=NLoB52nPuao

TASKS FOR REFLECTIONS

- What benefits do you think 3D Printing can bring to a startup?
- How can a startup use 3D printing to gain competitiveness?
- What do you think are the biggest problems in implementing 3D printing in a business?
- Find a startup idea that can use the 3DP advantages presented in this lesson to gain competitiveness.
- Think to one or more existing products that might be produced by 3D printing. Find pros and cons for making them by 3DP.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