

Introduction to 3D Printing



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Aim and Learning Outcomes

Module Aim:	To equip students with basic understanding of 3D Printing
Number of Hours:	4 hours
Learning outcomes:	<ul style="list-style-type: none">• Knowledge on 3D Printing approach and basic terminology• Understanding the advantages and limitations of 3D Printing for different applications• Knowledge on the process steps for obtaining an object using 3D Printing technology

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Lecture Outline

- Additive Manufacturing approach
- 3D Printing advantages and limitations
- History of 3D Printing
- 3D Printing technology steps
- 3D Printing applications fields

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Additive Manufacturing approach

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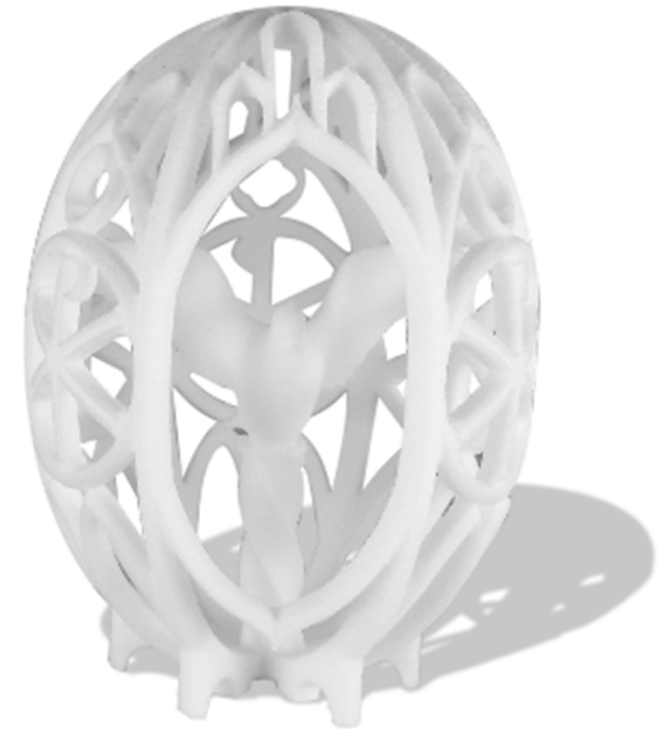
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Additive Manufacturing approach

3D Printing or additive manufacturing is a process of making three dimensional solid objects adding material layer by layer. Physical objects are produced by using digital model data from 3D model or other data source, like AMF* file.

By using 3D Printing it is possible to produce objects of almost any shape and form.

Curently many different 3D printing technologies and materials are used. Recently 3D printing tools are available for industrial manufacturing and for home users as well.



Source: www.smartfactory.it

**AMF – Additive Manufacturing File*

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Additive Manufacturing approach

**What is 3D
Printing and
How Does It
Work?**



<https://www.youtube.com/watch?v=Vx0Z6LplaMU>

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3D Printing advantages and limitations

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3DP advantages

Complexity and freedom of design

- 3D printing lets create complex shapes and parts – many of which cannot be produced by conventional manufacturing methods.
- Complex geometries can be created easily and it allows a large amount of design freedom.
- By using 3D Printing complex models can be produced as a single piece on the spot, therefore there is no need to produce smaller parts and assemble them.



3D printed lamp

Source: <http://mymodernmet.com/bathsheba-grossman-3d-printed-lamps/>

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3DP advantages

Customization and personalization

- 3D printing allows for easy customization. Each and every item can be customized without additional manufacturing costs.
- If there is a need to change a design of particular item, the digital design has to be changed only with no expensive manufacturing process or additional tooling.



OwnPhones – customized earphones

Source: <https://www.kickstarter.com/projects/ownphones/ownphones-the-worlds-first-custom-fit-3d-printed-e>

3DP advantages

No need for tools

- One of the advantages of 3D printing compared to traditional manufacturing is that the 3D printing process generally doesn't require any special new tooling to produce model or it's parts.
- No additional costs or lead times are required between making an object complex or simple.



3DP advantages

Speed and costs savings

- One of the main advantages of 3D Printing is the speed of production comparing to traditional manufacturing methods. Complex models can be printed in a relatively short time.
- Lowering costs is also achieved by saving time. For example objects or their parts could be produced much quicker and as they are needed, therefore the costs of inventory storage and labor time could be reduced.



3DP advantages

Faster and less risky route to market

- As models or their parts can be produced in a short time, 3D Printing is used for rapid verification and development of design ideas. It is cheaper to produce a 3D prototype, then to redesign an existing, if there is a need.
- Therefore, 3D printing is good choice for those, who are looking into manufacturing a product idea, because there is much less risky route to the market.
- 3D Printing can also reduce risk of danger associated with some manual prototyping processes.



3DP advantages

Less waste, sustainable, environmentally friendly

- 3D printing is an additive process - an object is created from the raw material layer by layer. Additive manufacturing methods generally only use the amount of material needed to create that particular object.
- Most processes use materials that can be recycled or can be reused for more than one build resulting in additive manufacturing process producing very little waste.

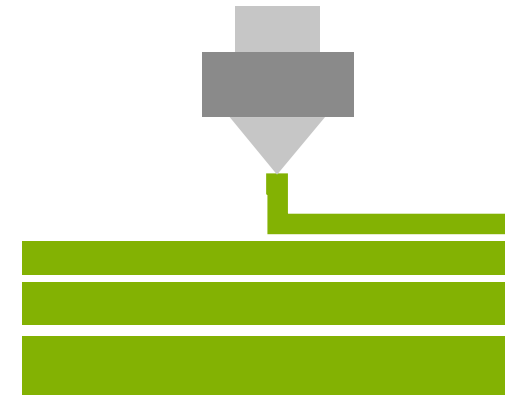
3DP limitations

- **Higher cost for large production runs**
 - The price of printers and raw materials are still expensive but in near future these expenses tend to decrease
- **Less material choices, colours, finishes**
 - There are still some limitations compared to conventional product materials, colors and finishes
- **Limited strength and endurance**
 - Not all printing technologies can ensure strength of produced objects, and the strength is not uniform due the layer-by-layer fabrication process
- **Accuracy of printed objects**
 - If there is a need to print precise parts or finer details – it is still difficult to ensure the high precision capabilities of certain manufacturing processes
- **Majority of 3D printers are limited by scale and size**



3D Printing challenges

Despite limitations that we have today, 3D Printing technologies are developing very fast and expenses of 3D Printing tend to reduce, therefore use of this technology becomes more and more widespread.



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Short history of 3D Printing

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Short history of 3D Printing

In **1983** Chuck Hull, co-founder of 3D systems, invented the first 3D printing process and called it '**stereolithography**' (SLA).

In a patent, he defined stereolithography as 'a method and apparatus for making solid objects by successively "printing" thin layers of the ultraviolet curable material one on top of the other'.

With this, he built the foundation of what we today know as additive manufacturing (AM) – or 3D printing.



The SLA-1, the first commercially available 3D printer

Source: <https://www.3dsystems.com>

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Short history of 3D Printing

The first Selective Laser Sintering (SLS) printer was developed and patented by Dr. Carl Deckard and Dr. Joe Beaman at the University of Texas in 1986.



American Newspaper, 1987

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The first 3D printed part



Source: <https://www.3dsystems.com/>

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Short history of 3DP

In **1989**, S. Scott Crump with his wife and Stratasys co-founder Lisa Crump invented and filed a patented '**Fused Deposition Modeling**' technology (FDM).

FDM is trademarked by Stratasys - as such, many industry professionals choose to use FFF (Fused Filament Fabrication) instead.

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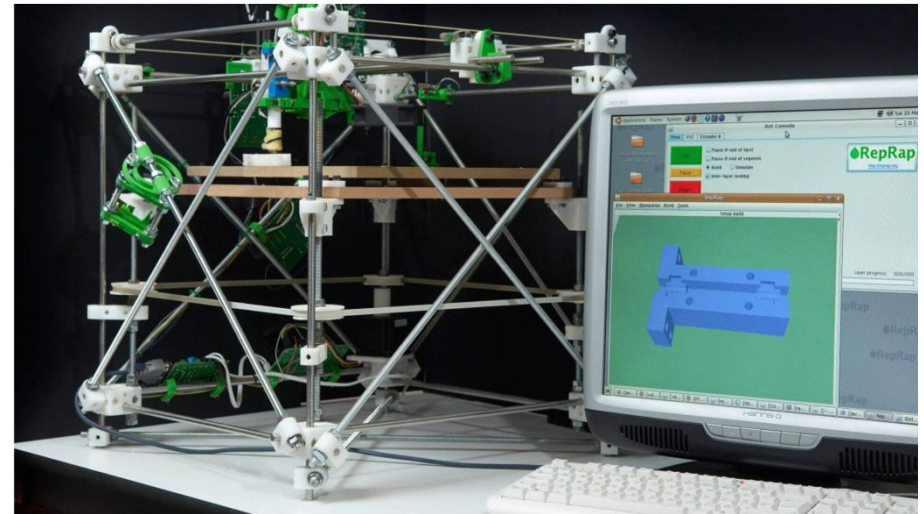
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Short history of 3DP

By 2005, additive technology patents were starting to expire.

In 2004 **RepRap** project was launched at the University of Bath (England) by a senior lecturer in mechanical engineering dr. Adrian Bowyer. The project aim was to create a low-cost 3D printer capable of replicating itself.

On 9 February 2008, RepRap 1.0 "Darwin" successfully 3D printed over 18% of its own components.



Source: <https://all3dp.com/history-of-the-reprap-project/>

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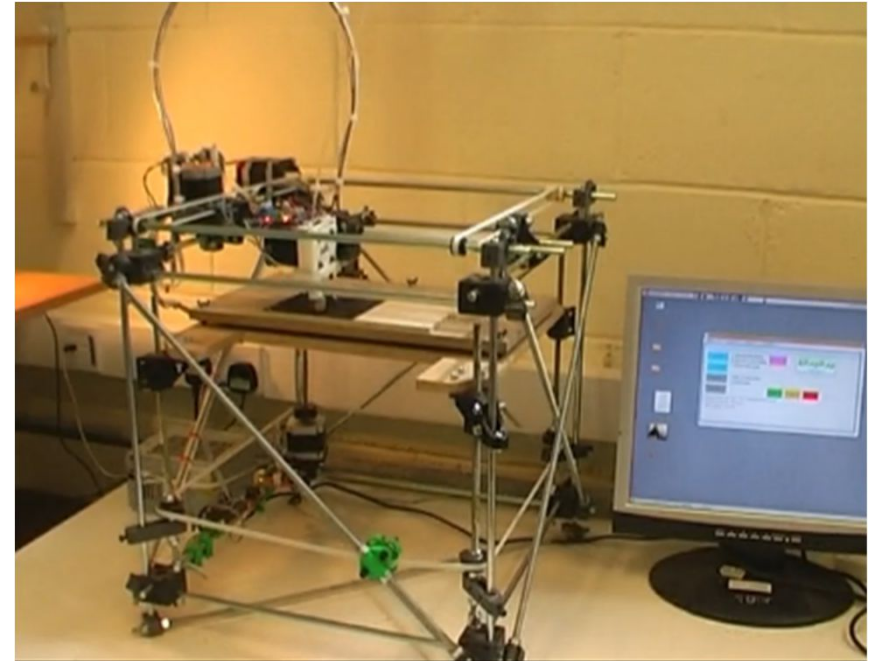


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Short history of 3DP

Advent of compact, open source, free-software printers like the **RepRap** helped to bring the technology to a wide group of users and allowed for small-scale commercial, educational, and domestic use, and low-cost 3D printing companies started to emerge.

The first desktop 3D printer was born through the RepRap project.



Source: www.reprap.org

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Short history of 3DP

3D printing was mostly limited to industrial uses until 2009.

3D printer sales have been growing ever since.

It is expected many more innovations in the years to come.

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Short history of 3DP

Carbon3D,
one of the
fastest 3D
printing
technologies
currently
under
development



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

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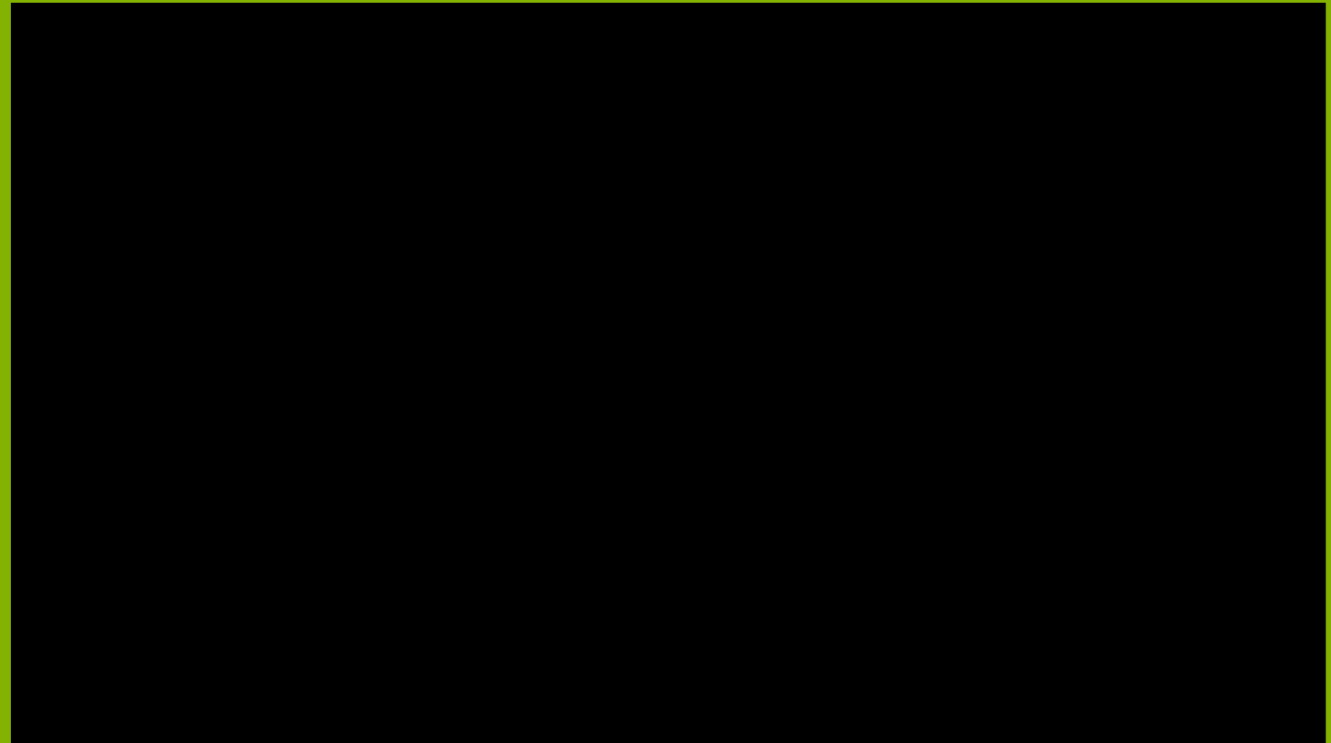
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Short history of 3DP

**Chuck Hull / 3D
Printing
Inventor**



https://www.youtube.com/watch?v=OjaW6C61_dc

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3D Printing technology steps

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3DP technology steps

1. CAD

The first step in the additive manufacturing process is producing a digital model. For this purpose Computer Aided Design (CAD) modeling is used.

There are many CAD programs that use different modeling principles, capabilities and pricing policy. For example Solidworks, Autodesk Fusion 360, SketchUp could be used.

Reverse engineering can also be used to generate a digital model via 3D scanning.

3DP technology steps

2. Model in STL format

In this step of additive manufacturing (AM) process a CAD model is converted into a STL (stereolithography) file that is acceptable by AM Machines.

It is also possible to select a STL model from online repositories like Pinshape, GrabCAD etc. Some of these repositories offer models for free, some are charged.

3DP technology steps

3. STL model analysis and repair

In this step it is required to repair any errors within the STL file. Typical errors could be like missing triangles, non connected edges or inverted normals where the “wrong side” of a triangle facet is identified as the interior of the part.

There are software for STL model manipulations, for example Meshlab, 3DPrintCloud, Netfabb etc.

If there are no errors, then some object corrections like sizing, density, geometry changes could be made.

A proper orientation of the 3D model also could be set up.

Once a STL file has been generated it is imported into a slicer program which converts it into G-code. G-code is a numerical control (NC) programming language, used in computer-aided manufacturing (CAM) to control automated machine tools like 3D printers.

3DP technology steps

4. Setting up device

In this step device should be prepared for printing. This process requires proper printer setup and control, cleaning from previous build and loading print material. A routine check of all critical build settings and process controls is also necessary.

When hardware is ready, build file could be uploaded to the machine.



3DP technology steps

5. Printing

The whole printing procedure is mainly automatic. Depending on the size of a thing, machine and materials employed, the procedure might take several hours or even days. There is a need to check occasionally if there are no errors.

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3DP technology steps

6. Removal of prints

In most cases of non industrial 3D Printing removal of the finished print is a simple task: separating the printed part from the print bed.

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3DP technology steps

7. Post processing

Post processing may vary greatly depending on printing technology and materials used. For example a print made with SLA must be cured under UV, while print made with FDM can be handled right away.

Post processing the final product may include high pressure air cleaning, polishing, colouring and other actions to prepare for final use.

3D Printing application fields

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Automotive industry

3D printing in the automotive industry is used to both prototypes and finished parts.

Many Formula 1 racing teams have been using 3D printing for prototyping, testing and ultimately, creating custom car parts that are used in competitive races.



Racing car seat

Source: www.voxeljet.com

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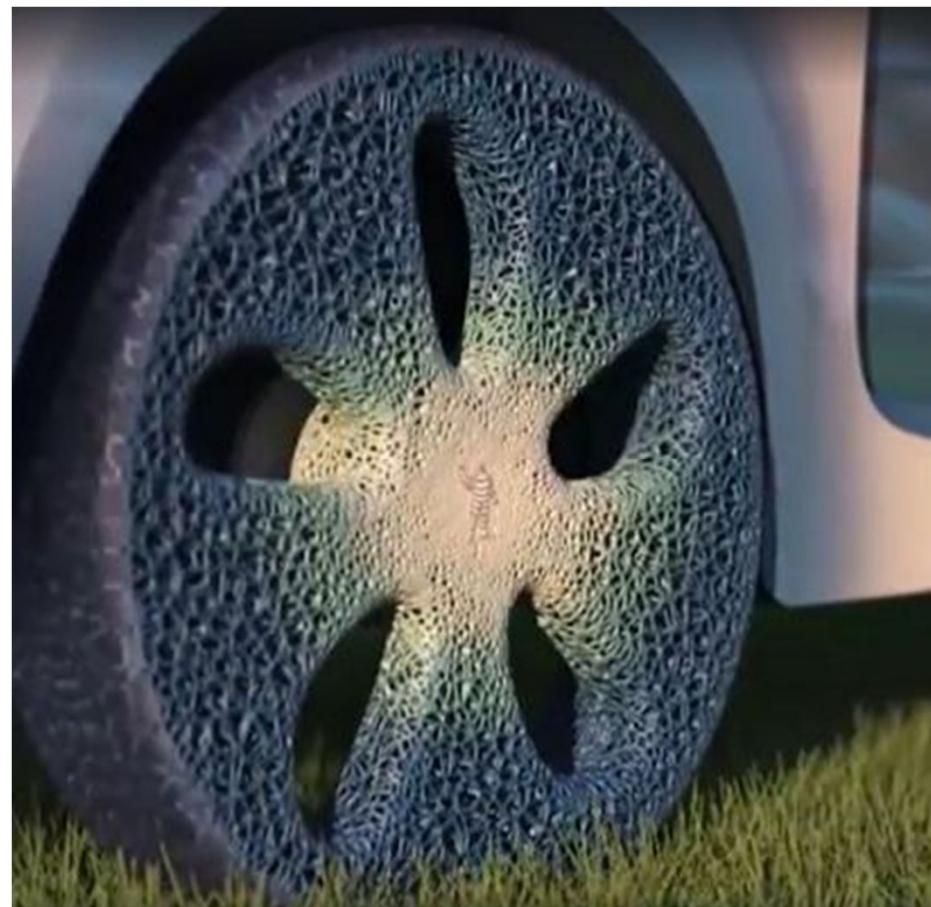
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Automotive industry

This Michelin concept tire doesn't need air because it is 3D printed and would never need replacing.



Rebuildable car tire

Source: <https://futurism.com/videos/meet-the-tire-that-never-needs-air-or-be-replaced/>

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Medical industry

One of the most important applications of 3D printing is in the medical industry.

With 3D printing, surgeons can produce patient-specific 3D printed models of patients' body parts or organs. They can use these models to plan and practice surgeries, potentially saving lives.



The first 3D printed polymer implant to receive FDA approval

Source: <http://3dprintingindustry.com/news/the-first-3d-printed-polymer-implant-to-receive-fda-approval-5821/>

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Prosthesis



3d printed body part

Source: <http://weburbanist.com/2015/01/08/exo-prosthetics-light-cheap-custom-3d-printed-body-parts/>

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Prosthesis



3D-Printed Prosthesis

Source: <http://weburbanist.com/2013/07/18/handicapable-3d-printed-flexible-casts-artificial-limbs/>

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Prosthesis

Designing Confidence

The innovative work of Scott Summit demonstrates how 3D Printing and digital scanning can be used to greatly improve Prosthetic design.



<https://www.youtube.com/watch?v=6wnnNk91EMs>

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Dental industry



3D printing for dental industry

Source: x3dprinting

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Aircraft

GE Aviation and Safran have developed a method to 3D print fuel nozzles for jet engines. The technology allows engineers to replace complex assemblies with a single part that is lighter than previous designs, saves weight and boosts a jet engine's fuel efficiency by up to 15%.



Jet Engines with 3D-Printed Parts Power Next-Gen Airbus Passenger Jet

Source: <http://www.gereports.com/post/119370423770/jet-engines-with-3d-printed-parts-power-next-gen/>

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Aerospace

Elon Musk's commercial space company SpaceX used 3D printing to manufacture the engine chambers for their SuperDraco engine that will be installed on the company's Dragon spacecraft.

[Read more](#)



A 3-D printed SuperDraco combustion chamber.

Photo Credit: SpaceX

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Entertainment

Instead of blowing up a priceless classic car *SkyFall* movie makers 3d printed one-third scale replica of Aston Martin DB5s from scratch and then in a destructive special effects scene blew it up.

[Read more.](#)



Plastic parts of the Aston Martins ©Propshop Modelmakers Ltd



Finished model of the Aston Martins ©Propshop Modelmakers Ltd

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Art/Design/Sculpture

Artists and designers use 3D Printing technology by creating various art works. It opens up entirely new dimensions in creative design that go beyond the limits of conventional technologies.



Designer lamps from 3D printers

Source: <https://www.voxeljet.com/industries/foundries/printed-designer-lamps/>

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Art/Design/Sculpture



Designer chair

Source: <https://www.voxeljet.com/industries/foundries/designer-furniture/>

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Art/Design/Sculpture



Ivan the Gorilla sculptor utilizes new 3-D printing technology

Source: <https://www.voxeljet.com/industries/foundries/3d-printing-helps-to-return-a-silverback-gorilla-back-to-life/>

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Architecture

3D printing is widely used in architecture field. Architects can quickly and easily create 3D printed scale model from their CAD data that is used for developing blueprints. 3D printed models can be printed in multiple materials and realistic colors.



Source: <https://www.frendel.com/gallery-image/project-absolute-world/>

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Architecture

The beautiful
Absolute
Towers in
Ontario,
Canada are
the creation
of architect
Attila Burka



<https://www.youtube.com/watch?v=il5H-9oKBVo>

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Jewelry

3 D Printing may open up the art of creating jewelry to a wider range of hobbyists as it does not require expensive precision tools, steady hand and many years of experience.



Source: [CustomMade](#)

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Fashion

Although not necessary economical 3D Printing can be used in fashion field – for making high heels, bikinis and handbags can be 3-D printed instead of sewn.



Source: Shapeways

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Fashion

**World's first
3D printed
bikini heads
for the beach**



<https://www.youtube.com/watch?v=d2iT8S0m3m4>

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Food

**World's first
chocolate 3D
printer**



<https://www.youtube.com/watch?v=BFi8but3Vw>

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Education

3D printing provides an excellent method for geometry visualizations and design initiatives at art schools. It is also used in numerous disciplines of study for research purposes.



3D Printer Frog Dissection Kit.

Source: [MakerBot Thingiverse](#)

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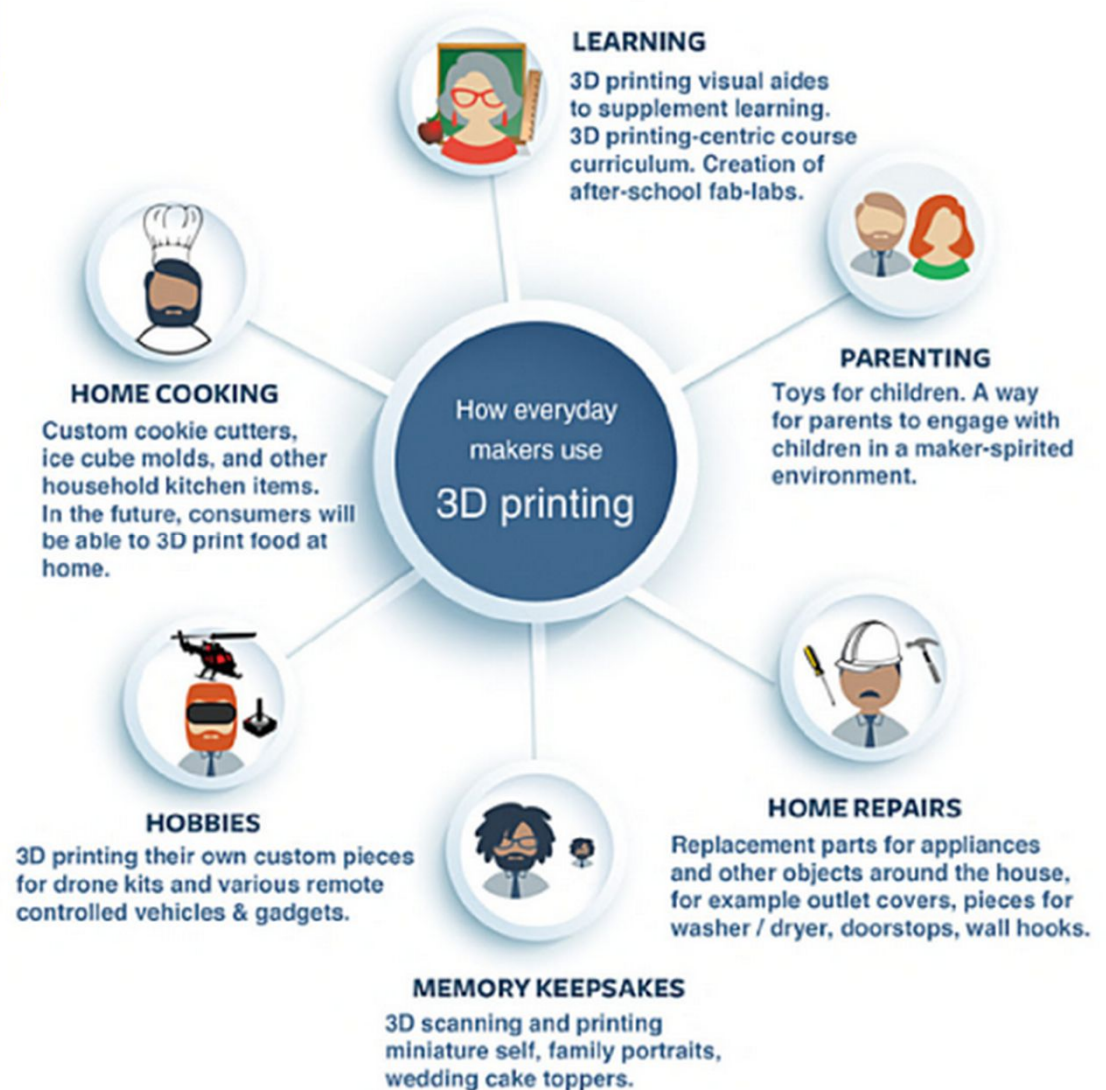
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Other fields

Examples how 3D Printing could be used for everyone



Infographics by Jeff Hansen, HoneyPoint3D™

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Useful Topic Related Links



https://en.wikipedia.org/wiki/3D_printing

https://www.youtube.com/watch?v=Vx0Z6Lpl_aMU

<https://youtu.be/Tyc4Apyk2Rc>

https://www.ted.com/talks/avi_reichental_what_s_next_in_3d_printing

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Available 3D Printing Technologies



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Aim and Learning Outcomes

Module Aim:

To equip students with basic knowledge on the main 3D Printing processes, their advantages and limitations, basic understanding on materials issues in 3D Printing and with basic knowledge on STL file format

Number of Hours:

3hrs

Learning outcomes:

- Acquiring knowledge on the main 3D Printing processes together with their advantages and limitations
- Understanding the basics of materials issues in 3D Printing
- Acquiring knowledge on the STL file format

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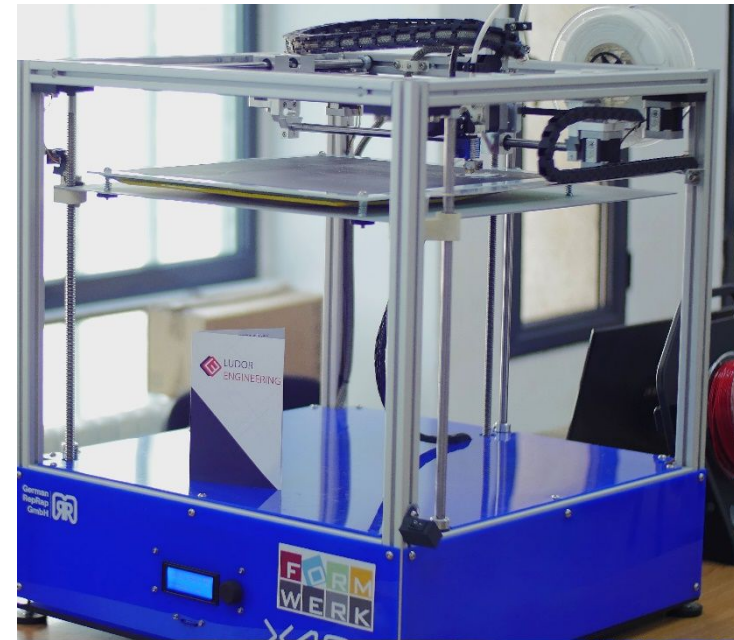
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Lecture Outline

- Types of 3D Printing processes:
 - basic principle
 - main characteristics
 - materials
 - advantages and limitations
 - examples
- STL file format



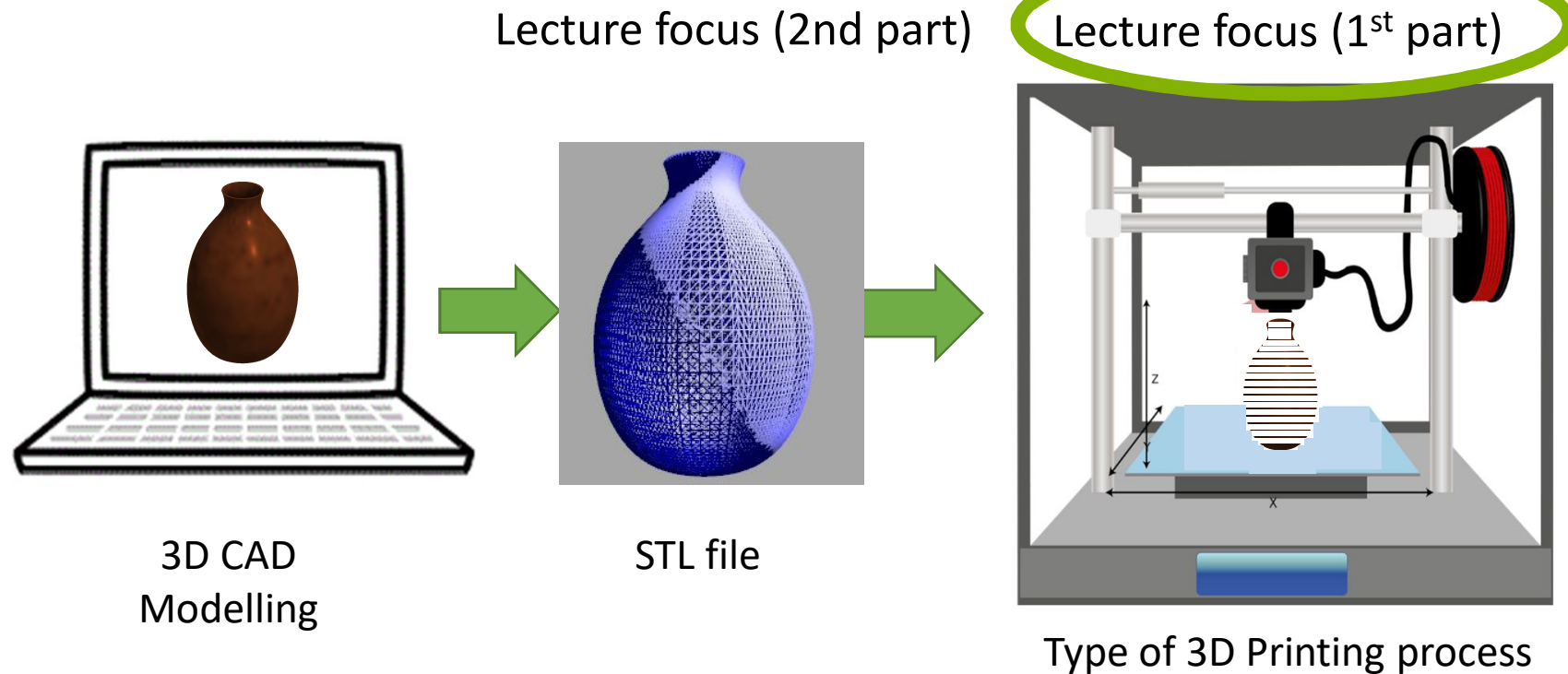
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Lecture Focus



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Types of 3D Printing Processes

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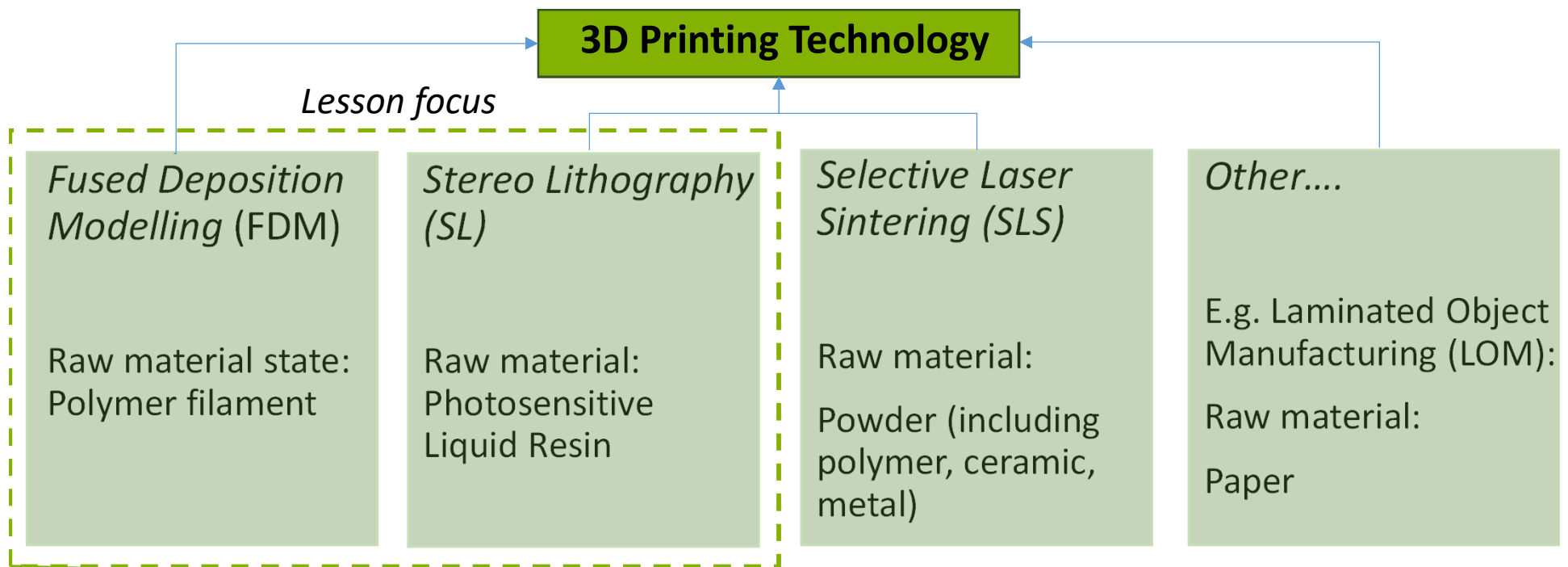


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Types of 3D Printing processes

Can be classified according to the state of the raw material which is utilised

Two types of processes are considered, as these are the most commonly used:



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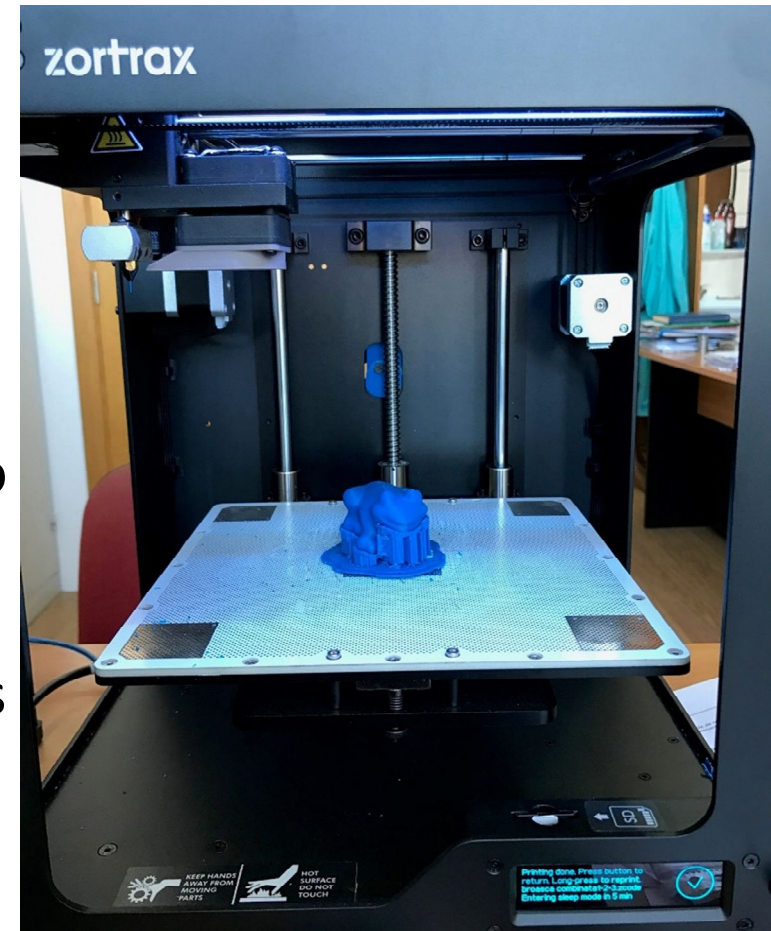


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Fused Deposition Modelling (FDM)

Basic Principle:

1. A filament of polymer is extruded from a nozzle where it is heated above its melting point and deposited on the table surface
2. When this layer solidifies, the nozzle is coordinated according to the part geometry at that level
3. The polymer is again extruded and when it contacts the previous surface, it solidifies to form the second layer
4. The procedure is repeated until the part is finished



Zortrax FDM Printer

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FDM Principle

Click on the video on the right to understand how FDM works



<https://www.youtube.com/watch?v=WHO6G67GJbM>

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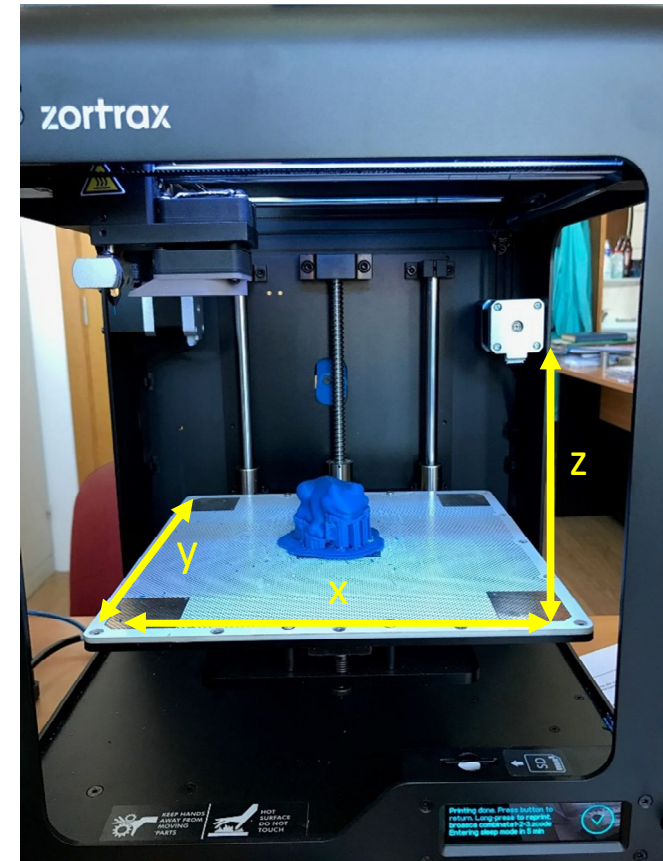


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FDM – Main Characteristics

1. Layer thickness range (mm): 0.127 to 0.33 (depending on material)
2. Part build envelope (mm): 600 x 500 x 600 max.
3. Tolerance: $\pm 0.254\text{mm}$
4. Built part: fully functional, however, weak in the z-direction

N.B.: The above are only *indicative* characteristics as these vary from one FDM 3D Printer make and model. This applies for other 3DP technologies.



Building envelope of the
Zortrax FDM Printer

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FDM – Materials

- Typically FDM requires two types of material:
 1. **Build material** which constitute the desired 3D form geometry
 2. **Support material** which is required for overhangs/undercuts. The support structures are automatically generated by the software program supporting the FDM 3D printer.

Build material constituting the desired geometry



Support material required for the internal thread

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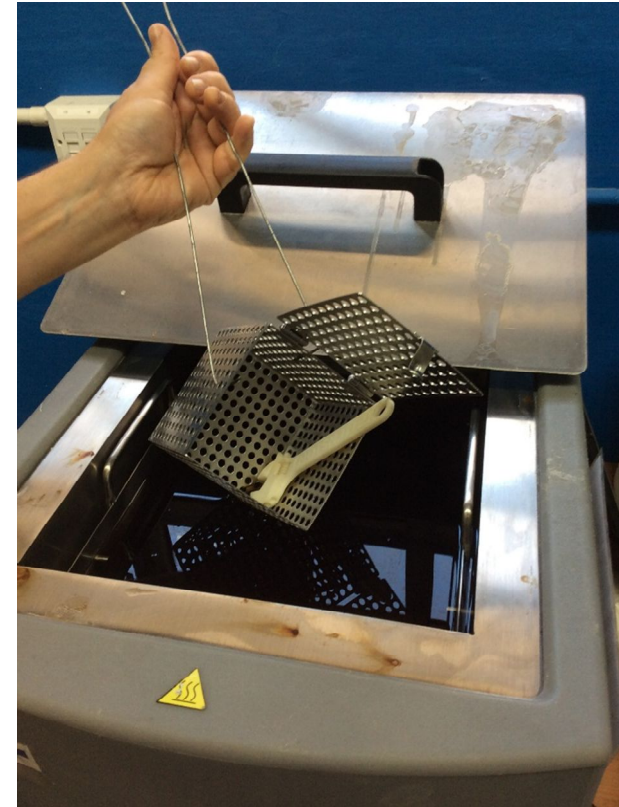
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FDM – Materials

Support material can either be manually broken away or removed automatically by inserting the 3D physical model into a water-based solution



Example of an FDM part inserted into a water-based solution to remove support material

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FDM – Materials

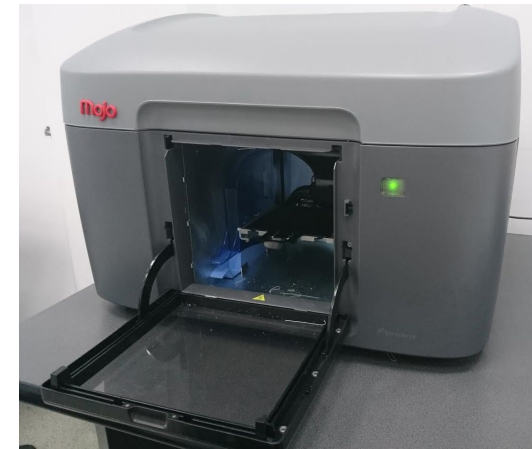
- Examples of commonly used build material in FDM:
 1. **ABS** - used for functional prototypes with good mechanical strength & chemical resistance. Available in different colours
 2. **PC** - used for functional prototypes with a very high impact resistance and a thermal deflection at 125°C



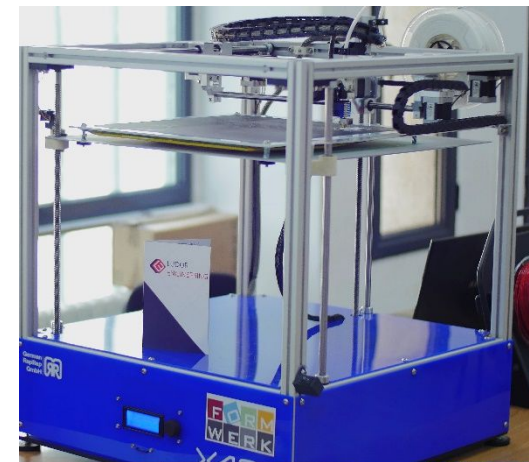
Example of an ABS cartridge used to build parts in an FDM printer

FDM – Advantages & Limitations

- Advantages
 1. no use any toxic material, can be used in an office
 2. simple post-processing is required
 3. some FDM 3D printers are very cheap and hence very accessible
- Limitations
 1. part accuracy is dictated by the filament thickness
 2. parts are weak in the vertical direction



Stratasys desktop FDM Printer



Reprap FDM Printer

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FDM – Examples of 3D Printed Parts

- Exemplar physical replicas of medical models



(Source: University Politehnica of Bucharest)

- Model of the regions in Lithuania



(Source: Northern Lithuania College)

- Prototype of a shipyard crane



(Source: Centro Formación Somorrostro)

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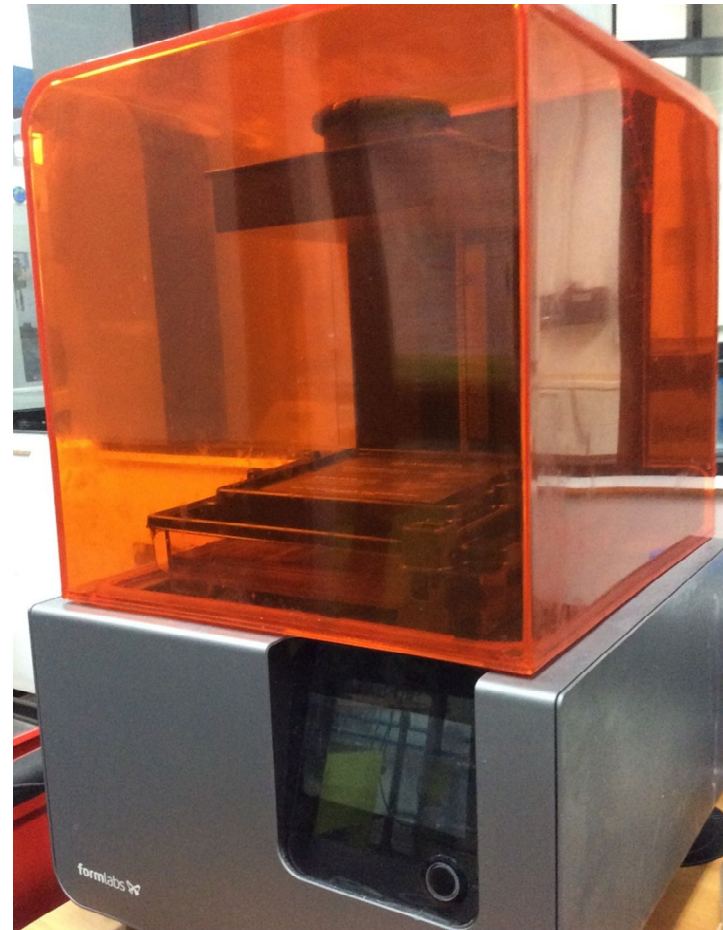


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Stereolithography(SL)

Basic Principle:

1. The platform is initially positioned near the surface of a photosensitive liquid polymer
2. A directed laser beam solidifies the polymer
3. When the initial layer is completed, the platform is lowered and a second layer is formed
4. The procedure is repeated until the part is finished



Formlab2 SL Printer

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SL Principle

Click on the video on the right to understand how SL works



<https://www.youtube.com/watch?v=NM55ct5Kwil>

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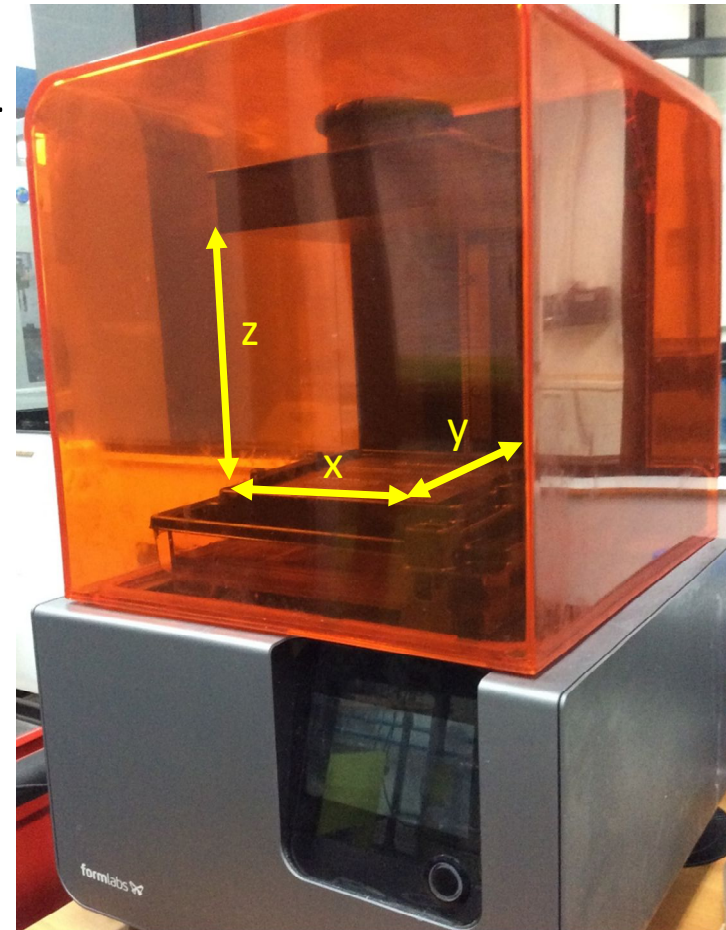
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SL – Main Characteristics

1. Layer thickness range (mm): 0.016 – 0.127
2. Part build envelope (mm): 2100 x 700 x 800 max.
3. Tolerance: $\pm 0.15\text{mm}$
4. Built part: fine details, very good accuracy and surface finishes



Build envelope of the
Formlab2 SL Printer

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SL – Materials

- In the case of SL, the support structures required for overhangs/undercuts is made up from the same material used for building the prototype.
- Support structures are removed manually
- SL parts are typically post cured in an UV oven

Build material constituting the desired geometry



Support structure

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SL – Materials

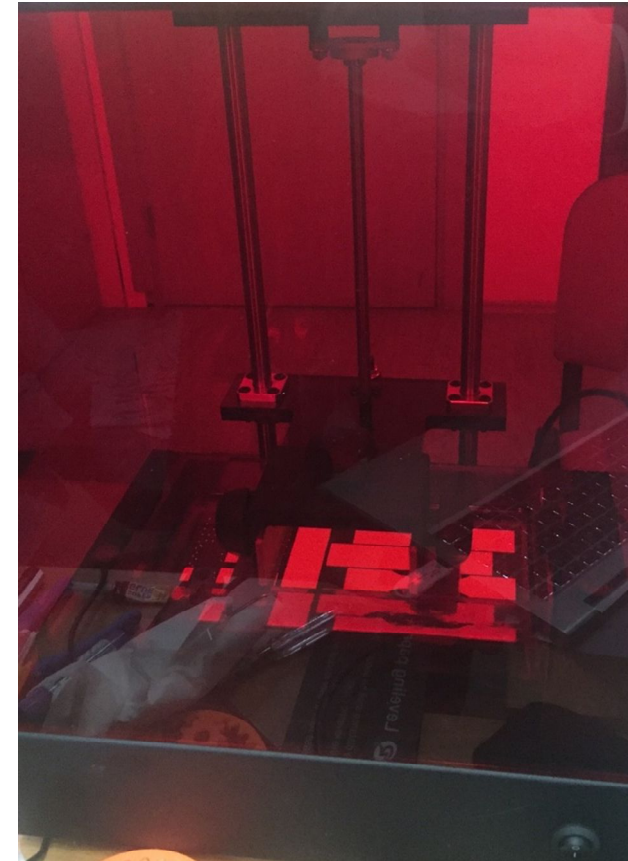
- Build material used in SL is mostly a **photosensitive resin**, meaning that it cures when exposed to UV radiation
- Mechanical properties of part depends mainly on material type and post-curing time
- There are different trade names of resins used by specific SL printers (e.g. *Accura 25* utilised by *3D Systems* SL printers)



Example of tough photopolymer resin cartridge from *Formlabs*

SL – Advantages & Limitations

- Advantages
 1. SL produces accurate parts with high surface finish
 2. wide spectrum of photopolymer materials is available with different characteristics
- Limitations
 1. material must be photosensitive and is more expensive compared to that used in FDM
 2. build process can be slow



Parts produced by the
Photocentric SL Printer

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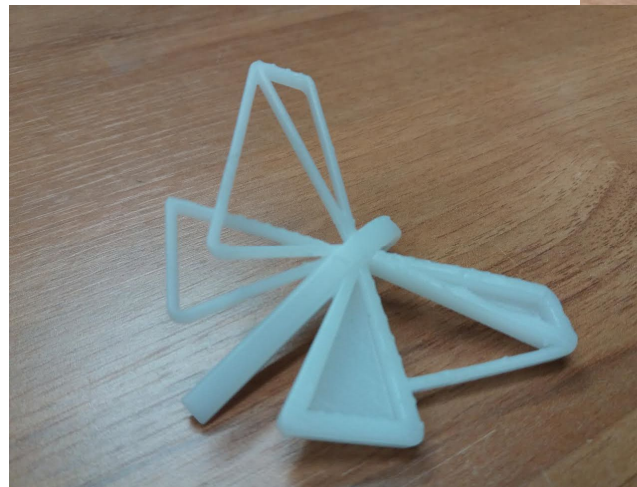
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SL – Examples of 3D Printed Parts

Prosthesis hand and company logo
produced by *Formlab2* SL printer



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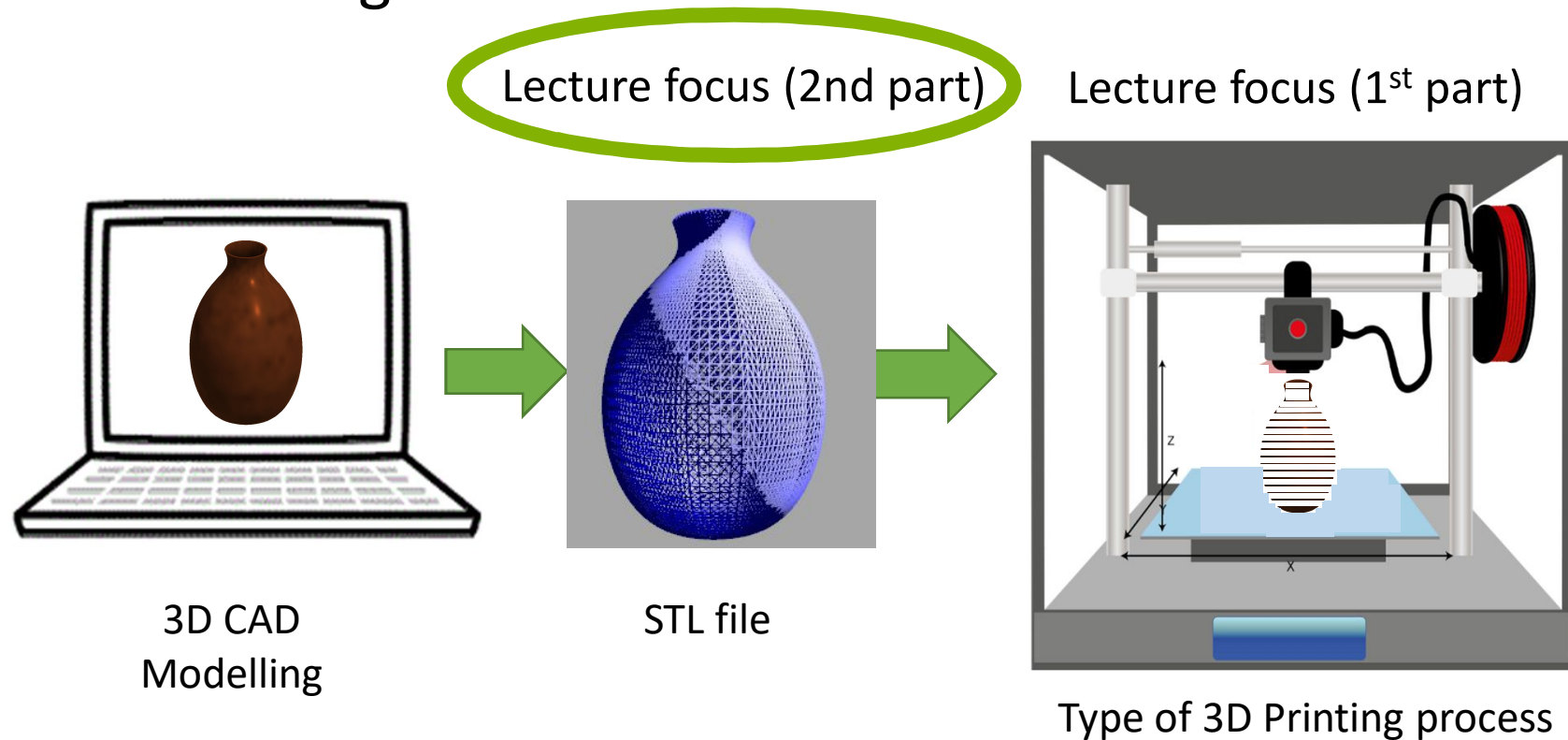
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Lecture Outline

- Lecture organisation



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STL File Format

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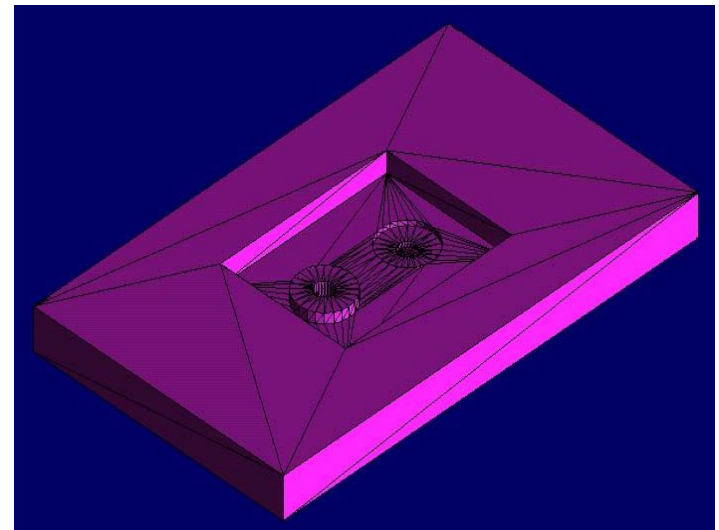
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STL File Format

- STL is the de facto neutral format for interfacing CAD and 3DP systems
- Stands for Standard Tessellation Language
- STL files are generated through tessellation of accurate CAD models
- Surfaces of 3D solid models are approximated with **triangular facets**
- There are two types of STL file formats – ASCII and binary. With the latter format, STL files are smaller in size



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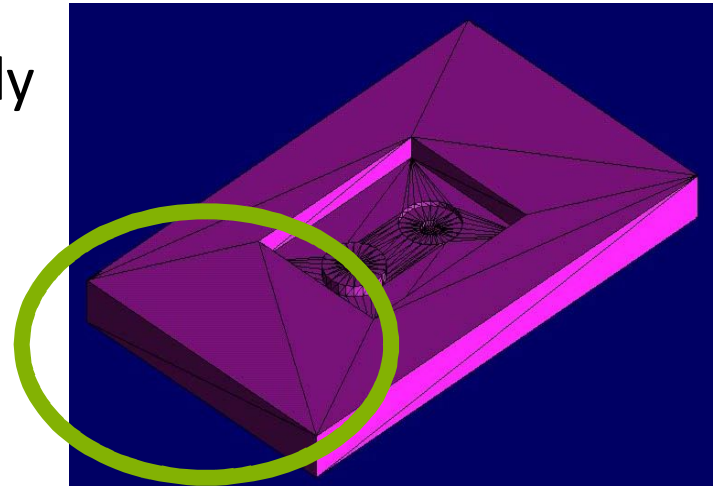
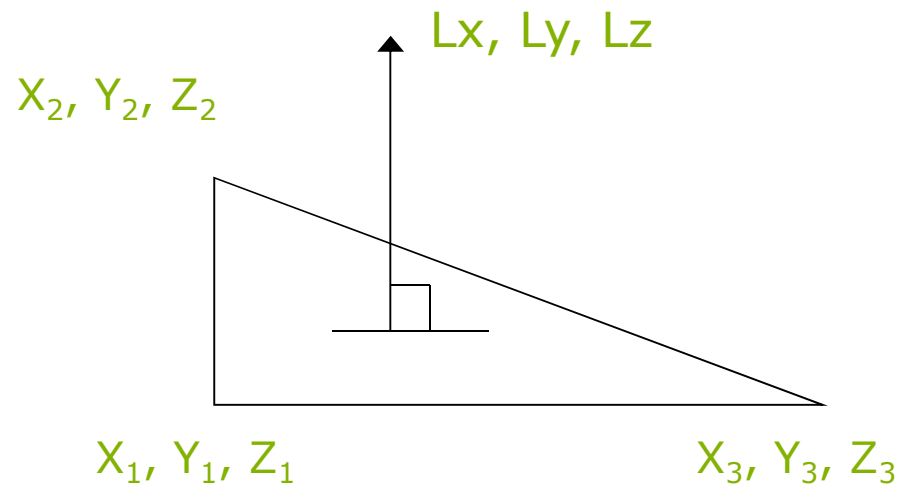
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STL File Format

- Each triangle is defined independently by its 3 vertices and a unit normal



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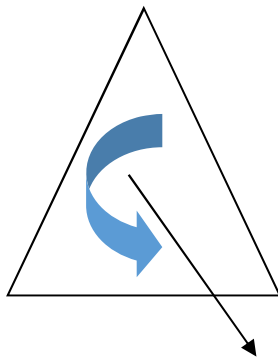
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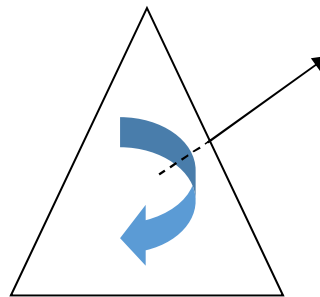
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STL File Format

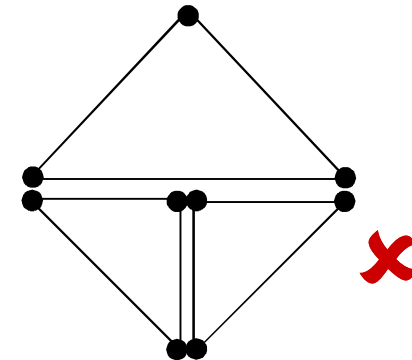
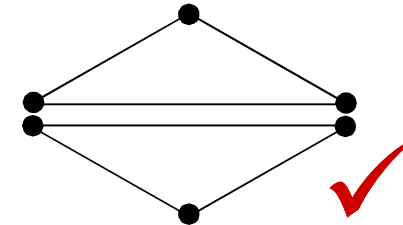
- Two important requirements during STL file generation:
 - ordering of vertex labelling
 - observance of vertex-to-vertex rule



Ext. surface

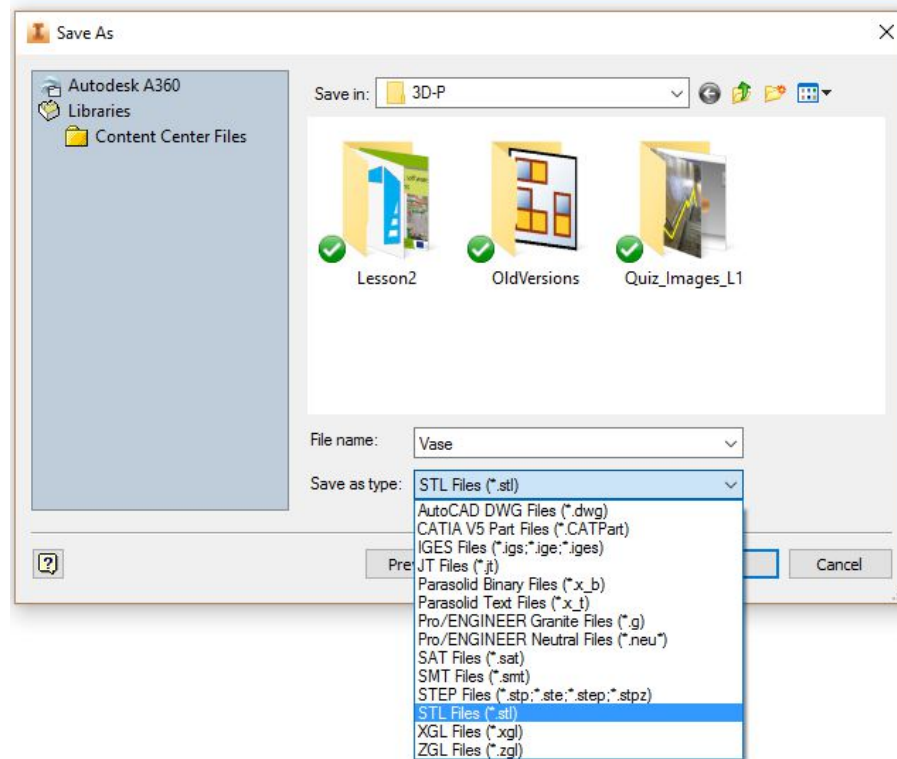


Int. surface



STL File Format

- A virtual 3D model can be converted to STL file format in a CAD system



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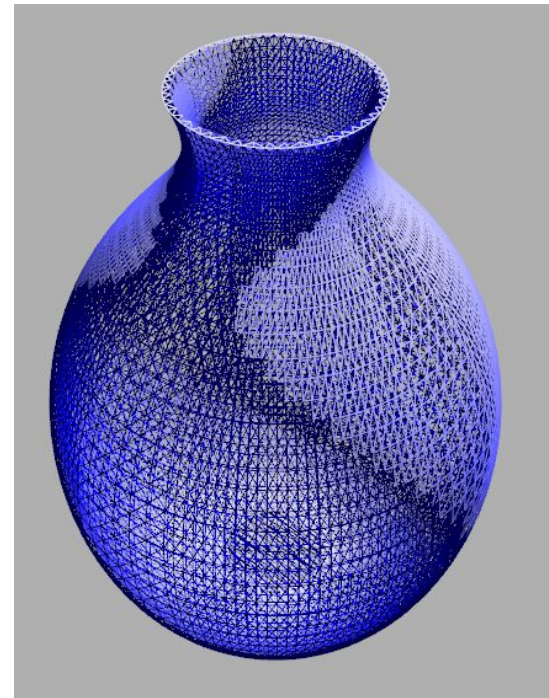
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STL File Format

- The tessellated 3D model in STL can be viewed in a free **STL file viewer** software package (e.g. *Open3D Model Viewer*)



Original 3D CAD model



Tessellated 3D model in *Open3D Model Viewer*

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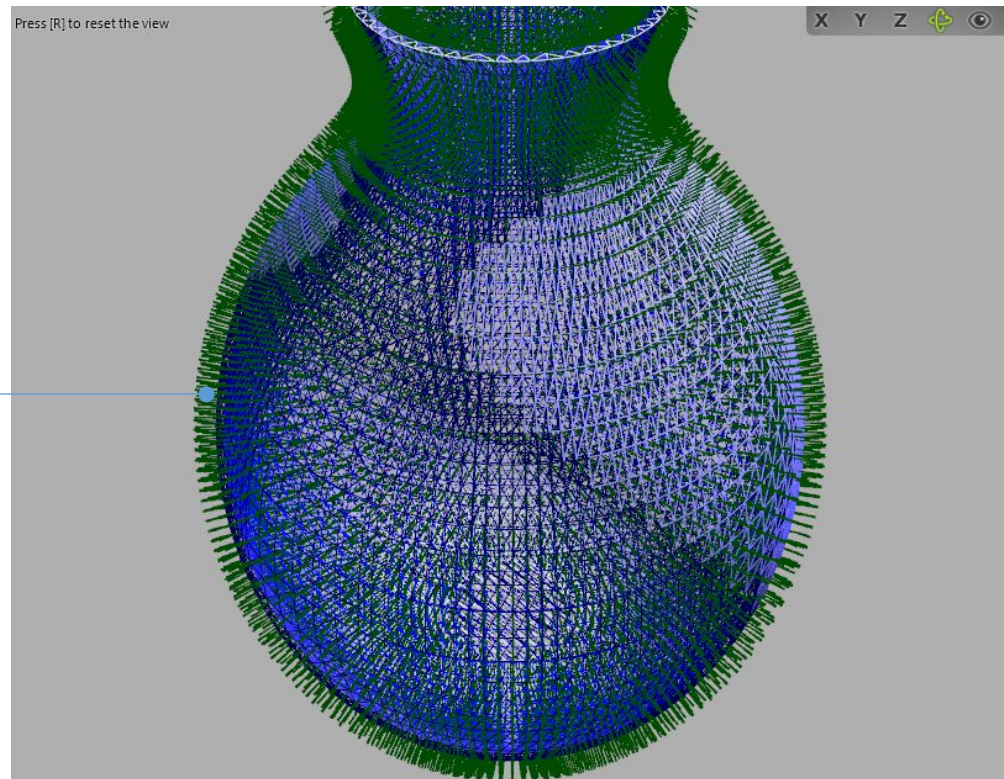


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STL File Format

- Such a software allows user to zoom in/out of the tessellated 3D model, view normal at each face etc.

Normal at each
triangulated face
displayed in *Open3D*
Model Viewer



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Useful Topic Related Links



[What is tessellation?](#)



[Fused Deposition Modelling](#)



[Stereolithography](#)



[Preparing STL files for 3D Printing](#)



[Exporting STL files in Fusion 360](#)

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3D Printing equipment



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Aim and Learning Outcomes

Module Aim:

To equip students with basic understanding of difference between industrial 3D printer, desktop 3D printer and home/hobbyist 3D printers, basic understanding of the main components of a FDM 3D printer

Number of Hours:

2hrs

Learning outcomes:

- Understanding difference between industrial 3D printer, desktop 3D printer and home/hobbyist 3D printers
- Understanding the main components of a FDM 3D printer

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Lecture Outline

- RepRap project
- Fused Deposition Modelling/Fused Filament Fabrication process
- FDM/FFF equipment

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RepRap Project

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RepRap project

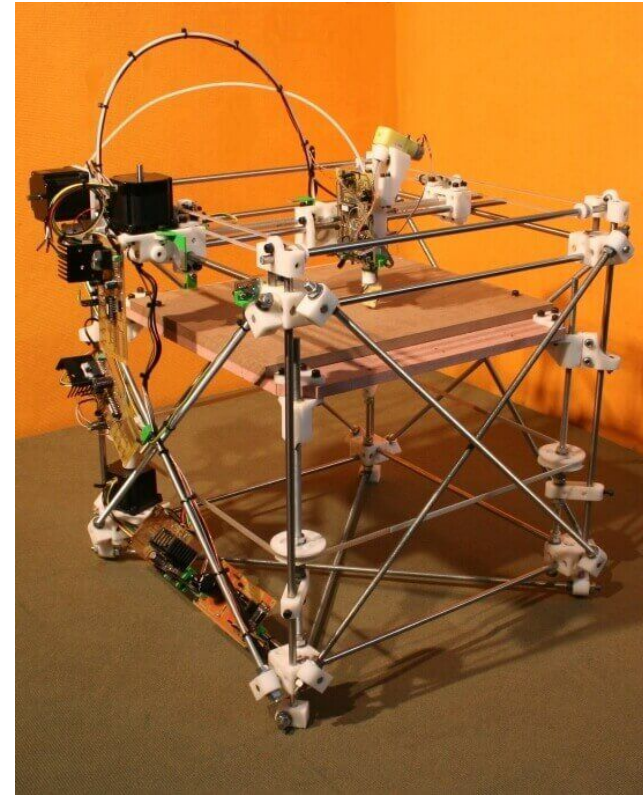
RepRap (**Re**plicating **Ra**pid-prototype) is the self-replicating 3D printer.

At the University of Bath (England) the **RepRap project** was started with the aim to develop a low-cost 3D printer with capability to replicate itself.

RepRap uses an additive manufacturing technique called *Fused Filament Fabrication* (FFF) to lay down material in layers: a plastic filament is unwound from a coil, melted and fused to manufacture a part.

Through the RepRap project's mission to build a self-replicating machine, the first desktop 3D printer was born.

Read more at www.reprap.org



RepRap version 1.0 (Darwin)

Source: <https://all3dp.com/history-of-the-reprap-project/>

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RepRap project

Currently hundreds of collaborators from entire world contribute to RepRap project. As RepRap is an open design, all of the intellectual property produced by the project is released under a free software license, the GNU General Public License.

- [How to build a reRap 3D printer - RepRapOneDarwin](#) (1st generation)
- [How to build a reRap 3D printer - Huxley](#) (mini-reRap, portable)
- [How to build a reRap 3D printer - Mendel](#) (RepRap Version II)
- [How to build a reRap 3D printer - Prusa](#) (easy to assemble)



RepRap project

**RepRap Open
Source 3D Printer**



<https://www.youtube.com/watch?v=FUB1WgiAFHg>

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RepRap project

**Timelapse of
Adrian
assembling
the first
RepRap
“Darwin”**



https://www.youtube.com/watch?v=Mo5Hp_6uD-E

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FDM / FFF process

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FDM/FFF process

FDM (Fused Deposition Modelling) is most widely used and affordable technology in 3D Printing.

FDM is also sometimes referred to FFF (Fused Filament Fabrication) since FDM is a proprietary term that can only be used by Stratasys Inc. The RepRap project coined FFF so that the technique could be used without trademark infringement.



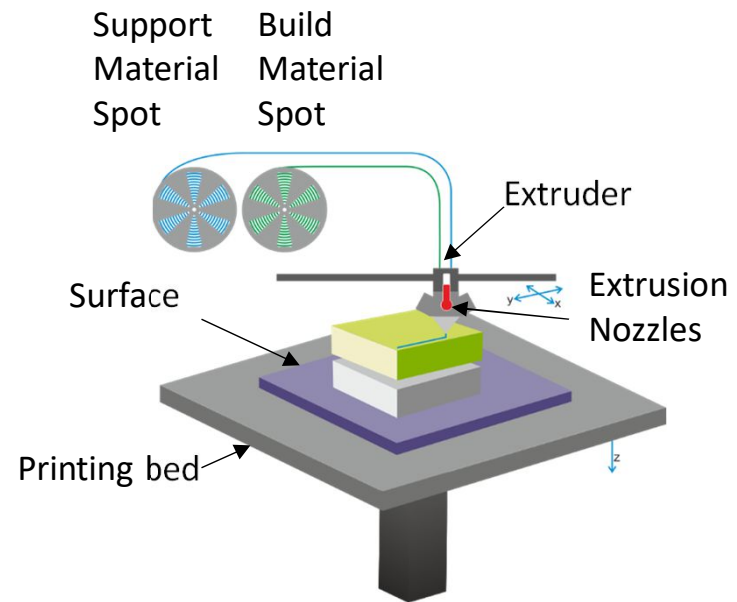
FDM/FFF process

Basic Principle

Using Fused Deposition Modeling (FDM) filament of plastic material is heated and extruded through an extrusion head. Then molten plastic is deposited in X and Y coordinates layer by layer, while the build table lowers the object in the Z direction.

This way building of the object is done from the bottom up.

For elaborate objects some support structures acting as scaffolding are printed which are removed after the printing is finished.



Schematic of FDM technology

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FDM/FFF process

**Fused Deposition
Modeling (FDM)
Technology**



<https://www.youtube.com/watch?v=WHO6G67GJbM>

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FDM equipment

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Home/hobbyists FDM 3D Printers

Home/hobbyist 3D Printers

– low cost, but there is a need of ‘do-it yourself’ skills and some technical knowledge.

They are mainly used for creating customized items, toys, decorative objects and such.



Source: <http://www.independent.co.uk/life-style/gadgets-and-tech/features/q-how-hard-can-3d-printing-really-be-a-quite-hard-8761809.html>

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Desktop FDM 3D Printers

For 3D printing right from user's desk desktop FDM machines are used. These machines are easy to use, have software with user-friendly and intuitive interface and can produce parts quickly and in a cost-effective way. Users can create objects' designs by themselves or find them on the online repositories and customize them according to their need.

A special group of desktop 3D printers are professional printers. They are used for concept modelling, producing functional prototypes or even end-use parts. These printers are more powerful and more expensive than consumer grade desktop printers.

Desktop 3D printers can be used in small business, education sectors and other.



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Industrial FDM 3D Printers

Industrial 3D Printers are used to produce fully functioning high quality products, achieve large build volume and requires some special conditions like large working space, appropriate power supply and others.

Industrial printers are large, sometimes even need to be installed right in the building, have high printing resolution and use quality materials, mainly engineering plastics which can have special properties like high impact strength, chemical resistance, thermal stability.

The major differences of desktop and industrial printers are associated costs and production capabilities – industrial printers can produce larger parts in one print and complete order of the same size faster.



Source: [Stratasys](https://www.stratasys.com)



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Industrial FDM vs. Desktop FDM

Property	Industrial FDM	Desktop FDM
Standard accuracy	$\pm 0.15\%$ (lower limit ± 0.2 mm)	$\pm 1\%$ (lower limit: ± 1.0 mm)
Typical layer thickness	0.18 - 0.5 mm	0.10 - 0.25 mm
Minimum wall thickness	1 mm	0.8 - 1 mm
Maximum build envelope	Large (e.g. 900 x 600 x 900 mm)	Medium (e.g. 200 x 200 x 200 mm)
Common materials	ABS, PC, ULTEM	PLA, ABS, PETG
Support material	Water-soluble	Same as part (typically)
Production capabilities (per machine)	Low/Medium	Low
Cost	\$50000+	\$500 - \$5000

Source: <https://www.3dhubs.com/>

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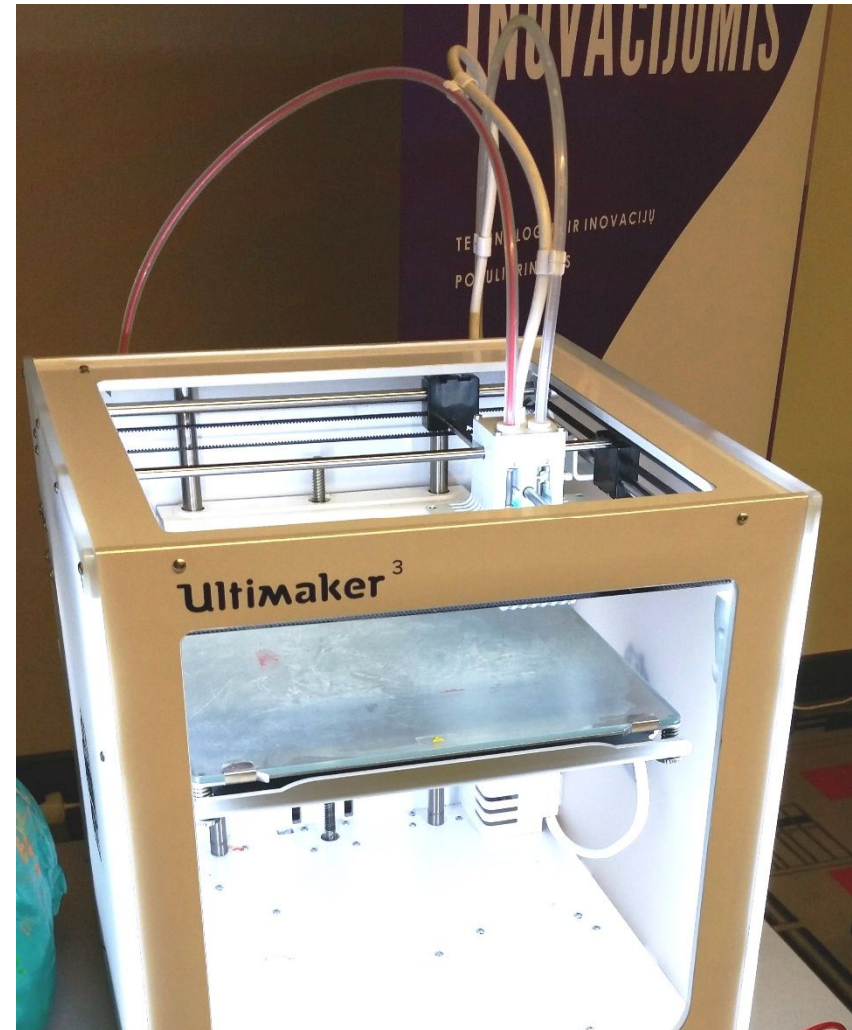
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Main components of FDM 3D printer

Print bed

Typical print bed (the surface that objects are printed on to) is a sheet of glass with some kind of surface on top for helping the plastic stick.

Most printers have heating element for heating the bed. This is needed to prevent the object from warping and peeling off the bed during printing process.



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Main components of FDM 3D printer

Bed surfaces

The bed surface helps the plastic stick to the bed during printing but also allows it to be removed easily when printing is done. There are many different kinds of bed surfaces. Most printers will come with some kind of all purpose surface, however, for best results it is better to use different surfaces depending on the printing material.



Main components of FDM 3D printer

Filament

In FDM printers a thin filament of thermoplastics (plastics that melt when heated and solidify at room temperature) is used.



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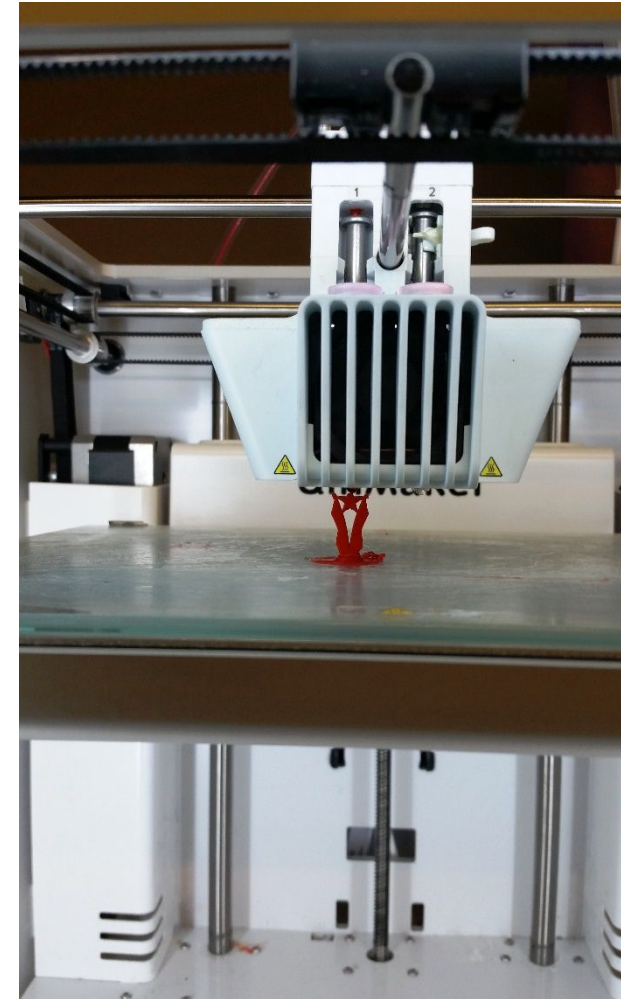


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Main components of FDM 3D printer

Extruder

The essential part of 3D printer is the extruder. It has two parts: cold end with motor, which draws the filament in and pushes it through, and hot end where the filament is melted and squirted out.



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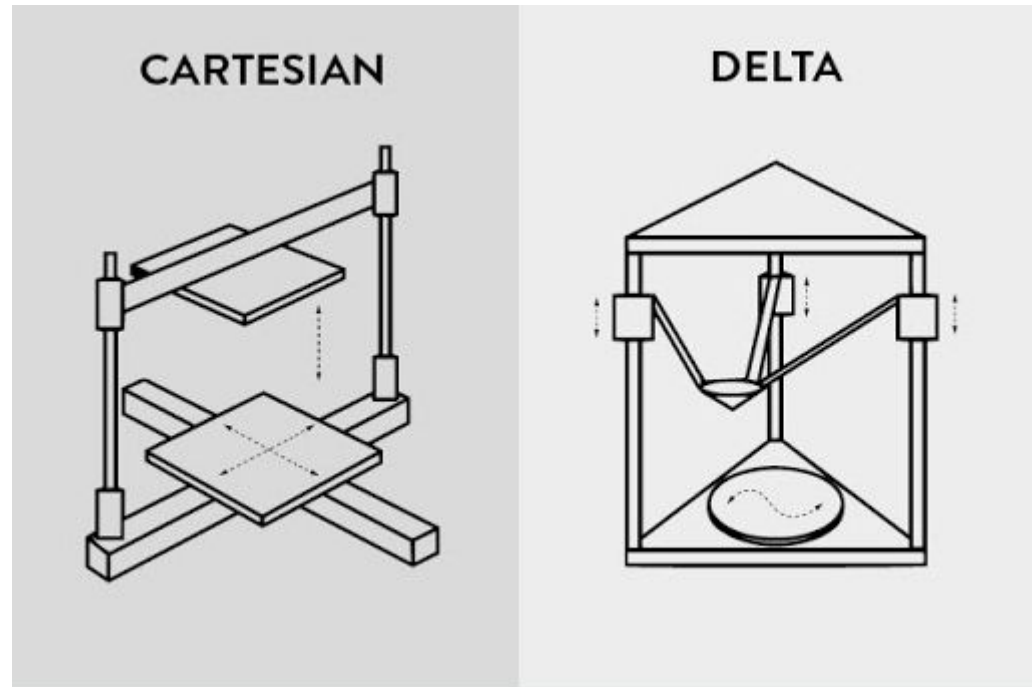
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Main components of FDM 3D printer

Head movement mechanics

The most common 3D printers on the market are **Cartesian printers**, named after cartesian coordinate system. Such printers have rectangular frame wherein any movement can happen along one of three perpendicular axes: X, Y or Z. Typically print bed moves in the Z-axis, while the extruder can move in four directions along X and Y-axis.

In **Delta 3D printers**, the extruder is held by three arms in a triangular configuration (thus the name “Delta”). The print bed is usually circular and does not move. Print-head position is estimated using trigonometry. Delta printers are faster than Cartesian and because of their design can print relatively tall objects, but may be less accurate than Cartesian printers.



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Main components of FDM 3D printer

Head movement mechanics

Polar 3D printers use polar coordinate system, where positioning is determined by an angle and a length, rather than coordinates X, Y and Z. This means, that the bed rotates in a circle, while the print-head moves up, down, left and right. Polar printers can function with only two stepper motors and can make larger objects while using less space.

The fourth category, which is beginning to see an increase in use, is 3D printing using **Robotic Arm** with advantages like mobility, flexibility in printer head positioning and printing process which is not fixed to a printing plate. However, the print quality is not as good as conventional Cartesian printers.

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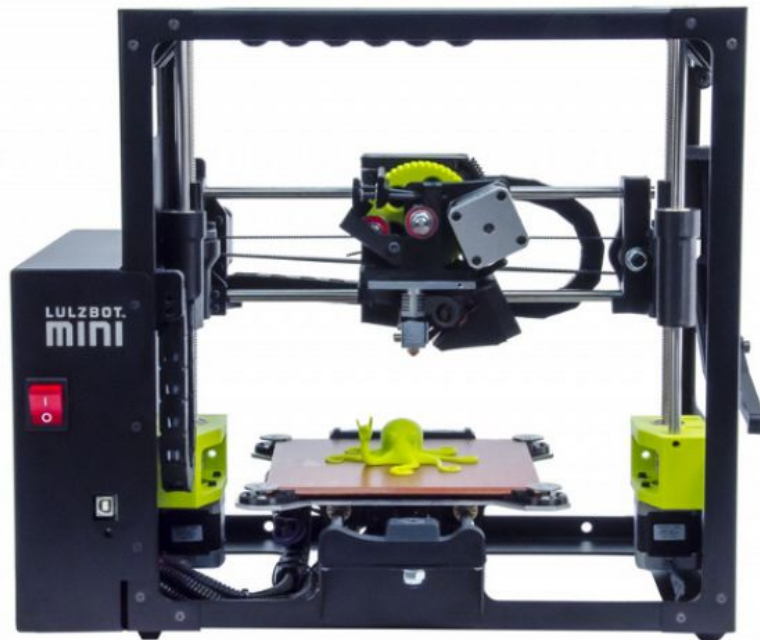
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Main components of FDM 3D printer

Example of Cartesian 3D printer –
LulzBot Mini 3D Printer



Example of Delta 3D Printer –
SeeMeCNC Rostock MAX v3 3D Printer

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Main components of FDM 3D printer

Stepper Motors

In 3D printers for precise position control stepper motors are used, which, when given power, rotate in increments rather than continuously.

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Main components of FDM 3D printer

The Frame

Frame holds all other parts of 3D printer together. It can be made of sheet metal, aluminium or plastic. Often many frame parts can be 3D printed themselves.

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Main components of FDM 3D printer

Electrical components

- **Power Supply** – converts the 120V AC electricity from the wall to low voltage DC power for the printer.
- **Motherboard** - orchestrates execution of commands in the form of G-Code given to it by the computer.
- **Stepper Drivers** - run the stepper motors by firing the coils of the motors in sequence, causing it to move in increments.
- **User interface** – some printers may have a LCD screen which allows to control them directly without the need of computer.
- **SD Card Slot** – some printers also have an SD card slot from which they can load G-Code files.



Useful Topic Related Links



https://en.wikipedia.org/wiki/Fused_filament_fabrication



<https://www.youtube.com/watch?v=f4RGU2jXQiE>



<https://vimeo.com/5202148>

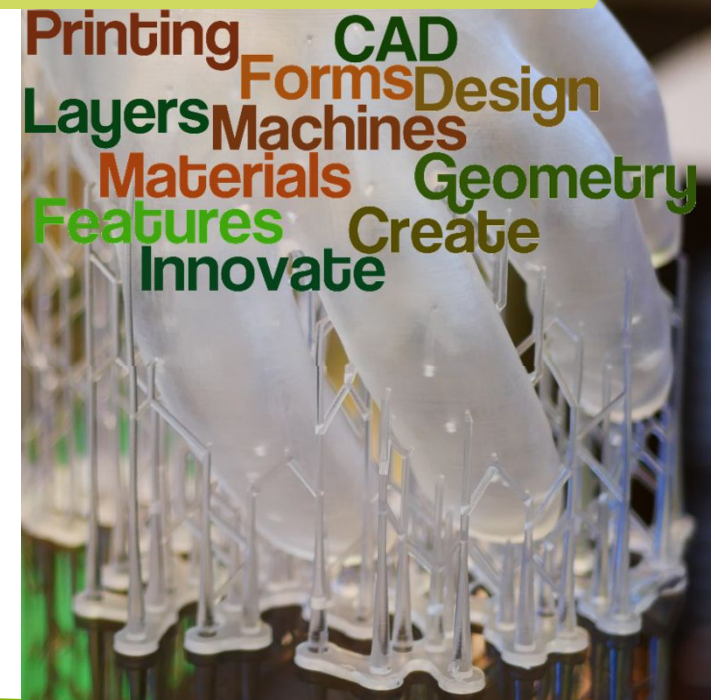
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3D CAD modelling software applications



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Aim and Learning Outcomes

Module Aim:	To equip students with basic understanding of 3D CAD modelling principles and with basic knowledge on CAD freeware
Number of Hours:	2hrs
Learning outcomes:	<ul style="list-style-type: none">• Understanding the basics of 3D CAD modelling• Acquiring knowledge on different free 3D CAD applications

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Lecture Outline

- What is CAD Technology?
- 2D Modelling
- 3D Modelling
- Benefits of CAD
- Free 3D CAD applications
- A360 Fusion – A general overview

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What is CAD Technology?

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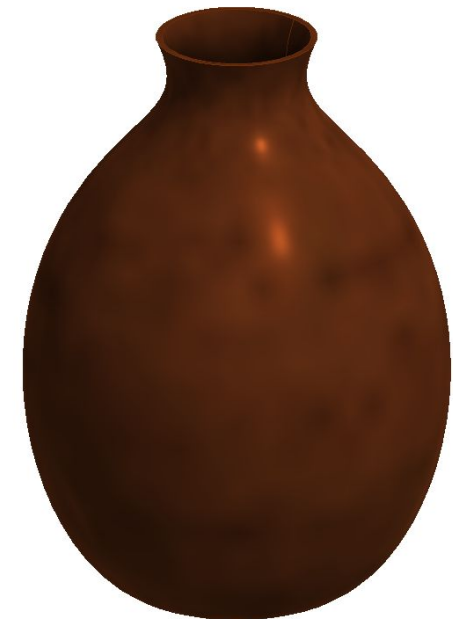
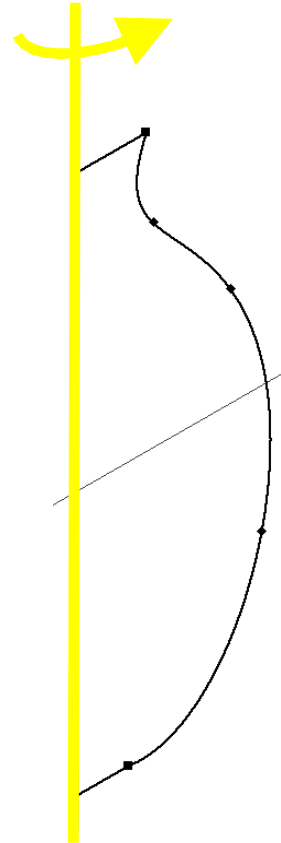


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What is CAD Technology?

Computer-aided design (CAD) is the use of computer technology to aid in the design and in the generation of two-dimensional (2D) drawings and three-dimensional (3D) models of a component or product

E.g. a 2D cross-section which is revolved about an axis to produce a 3D model



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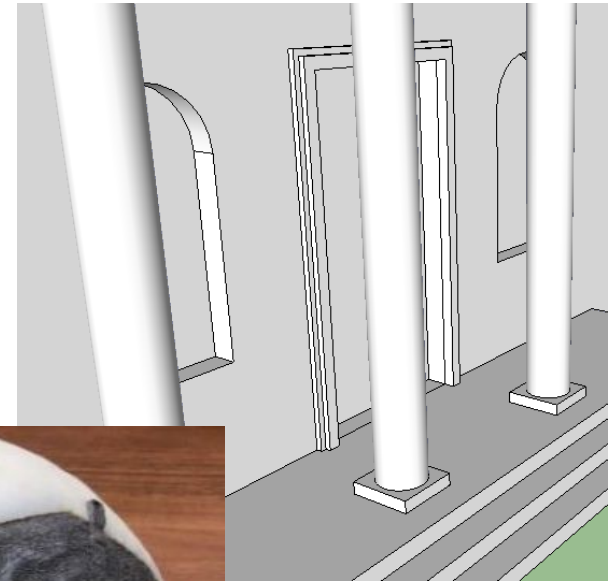


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What is CAD Technology?

CAD technology has nowadays become part and parcel of a design activity in a range of sectors including:

- architecture
- product design
- jewellery design
- interior design
- medical etc.



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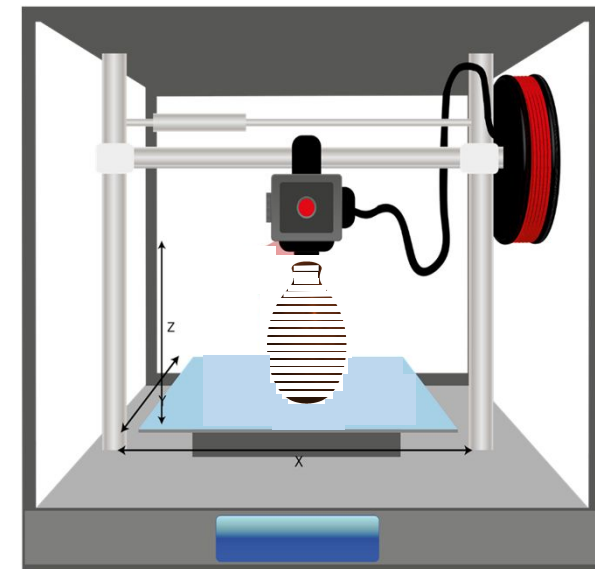
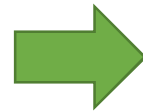
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Link of 3D CAD to 3D-Printing

A 3D CAD model is first created using a free/commercial CAD package

The CAD model is then prepared for 3D printing (e.g. converting it to STL, removing any errors, setting up layer thickness etc.)

The 3D printing process follows



3D Printing

Lecture focus:

3D CAD
Modelling

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2D Modelling

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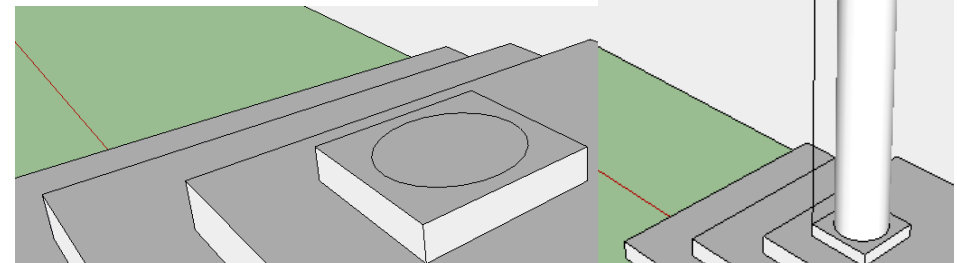
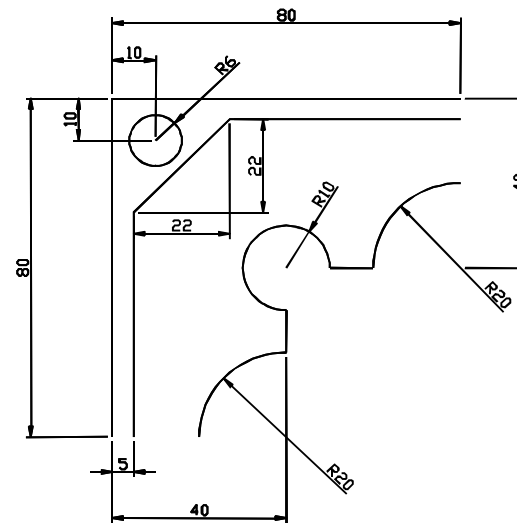
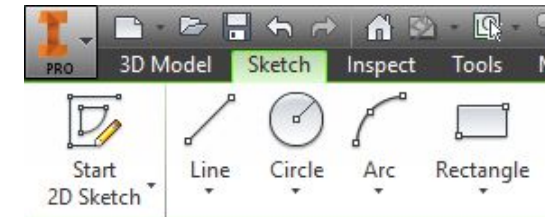
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2D Modelling

CAD can be used to create 2D shapes in, say, the XY plane using simple drawing entities (e.g. lines, arcs and circles)

2D shapes can be modified by applying basic modify commands such as mirror, etc.

Such 2D shapes can be used as a basis to generate 3D models => 2D modelling is required for 3D modelling



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3D Modelling

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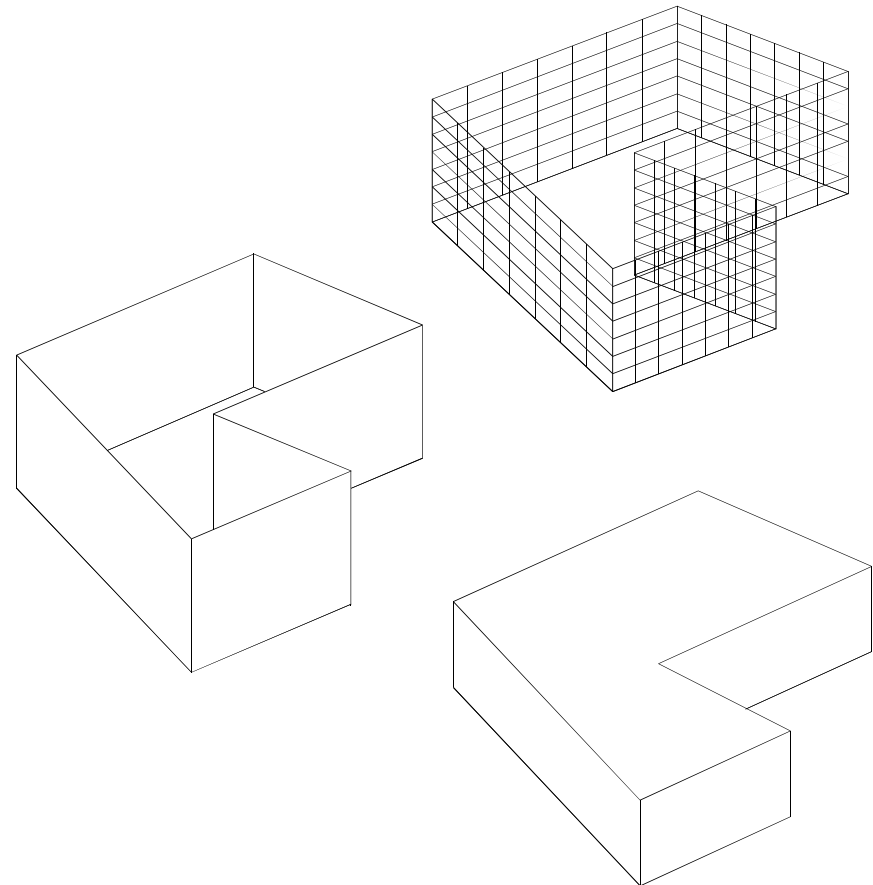


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3D Modelling

There are three main types of 3D models:

- Wireframe (made up of vertices and edges)
- Surface (represent the boundary of the object, not its volume – analogy: thin eggshell).
- Solid (represent the volume of the object)



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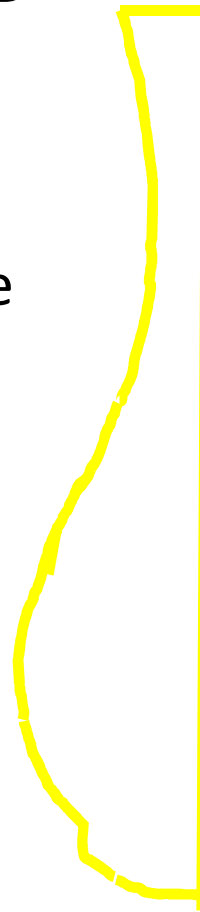
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3D Modelling

Many 3D geometries have a common 2D cross-section on which a 3D operation has been applied

How we can convert 2D shapes into 3D entities? We have already seen how we can transform a simple 2D polyline to a 3D entity

Basic 3D modelling commands (e.g. extrude, sweep, loft), which are commonly found in commercial CAD packages, allow use to create a wide range of 3D models



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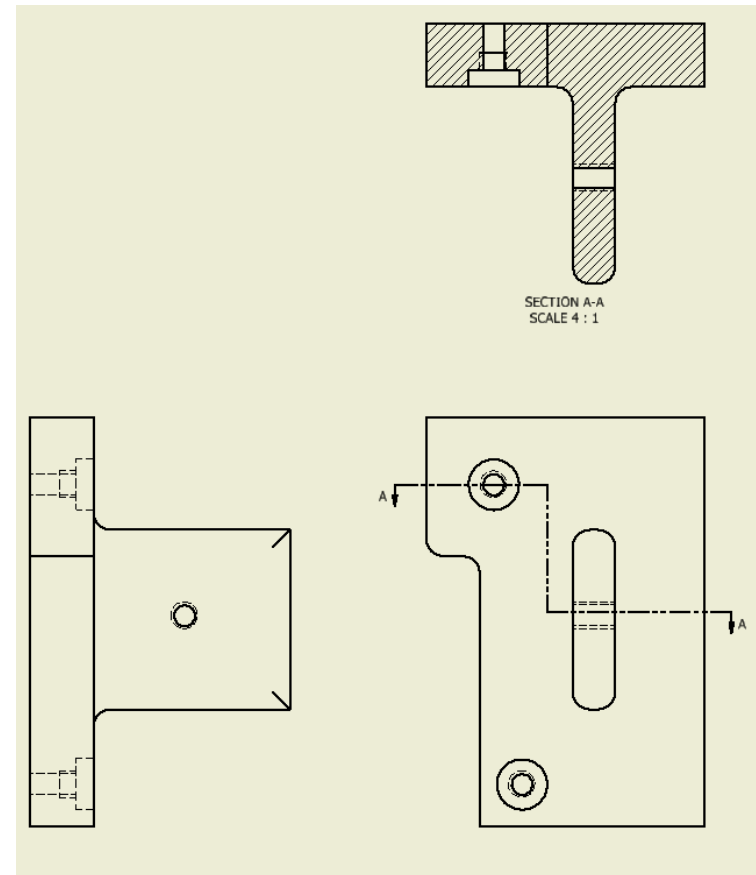
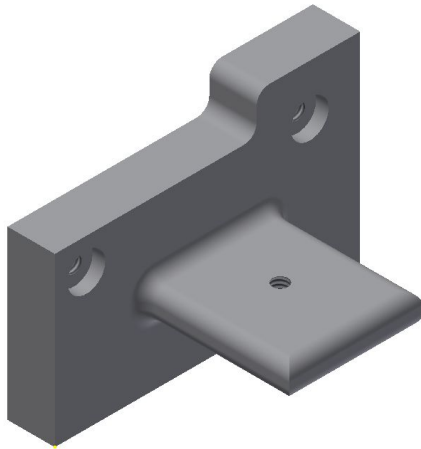
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3D Modelling

We can also create cross-sections through a 3D CAD model in order to illustrate/visualize hidden features



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Benefits of CAD

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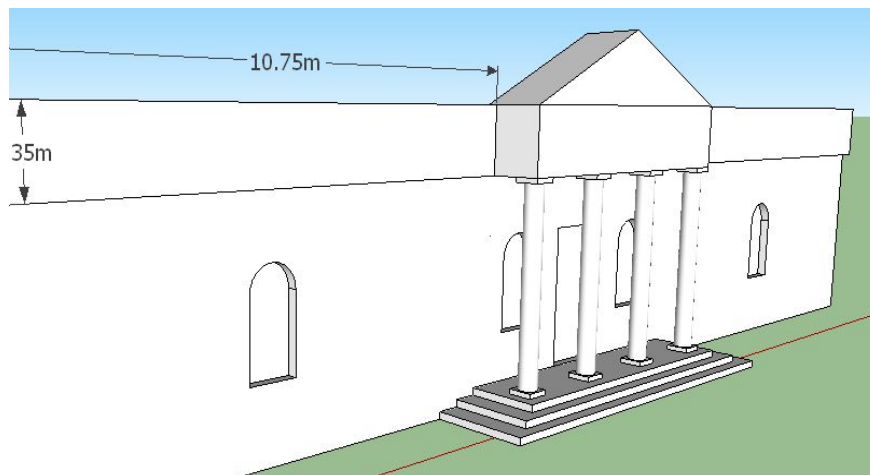
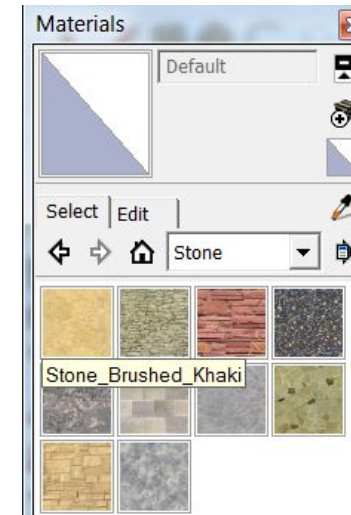
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Benefits of CAD

A CAD virtual model can be rendered statically to reflect how an artefact (e.g. product, building etc.) will realistically look like...



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Benefits of CAD

...this will help clients to visualise better different colour schemes, room configurations etc.



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Benefits of CAD

CAD virtual models can be rendered dynamically to mimic, for instance, the function physical artefacts



<https://youtu.be/a2pJfuDeZdo>

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Free 3D CAD applications

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Free CAD applications

A number of free CAD modelling software packages are available, such as:

- *Trimble SketchUp*
- *TinkerCAD*
- *A360 Fusion*



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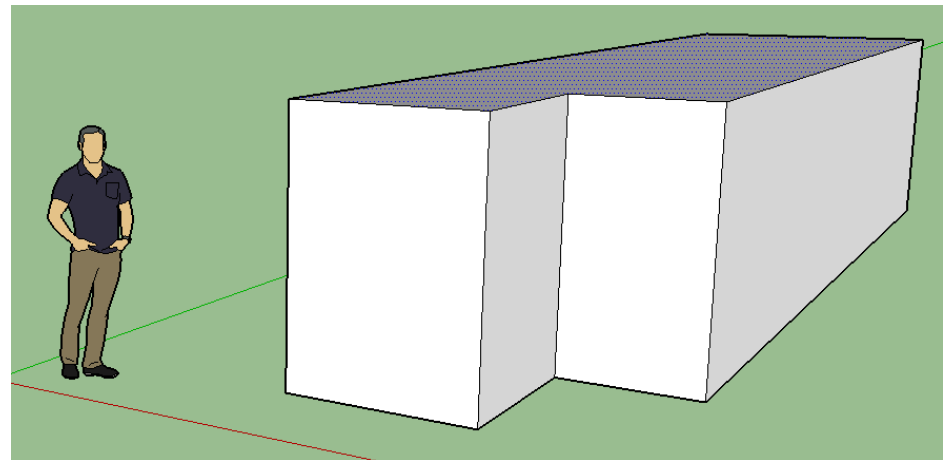
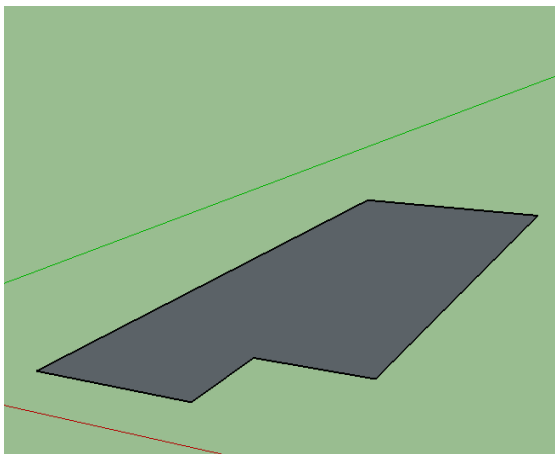
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Free CAD applications – SketchUp

Allows users to easily create 3D virtual models through a number of straight-forward functions, such as Push/Pull and much more...



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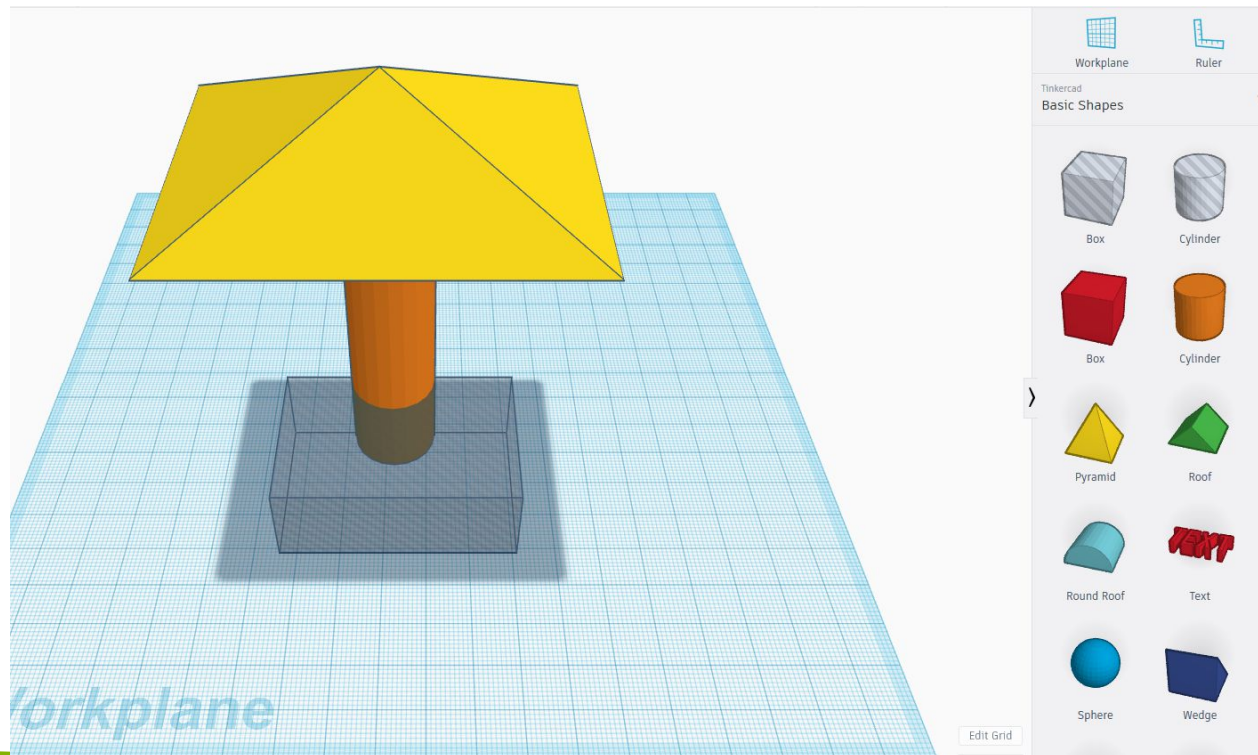
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Free CAD applications – TinkerCAD

Allows users to easily create 3D virtual models on-line, via a simple web-browser



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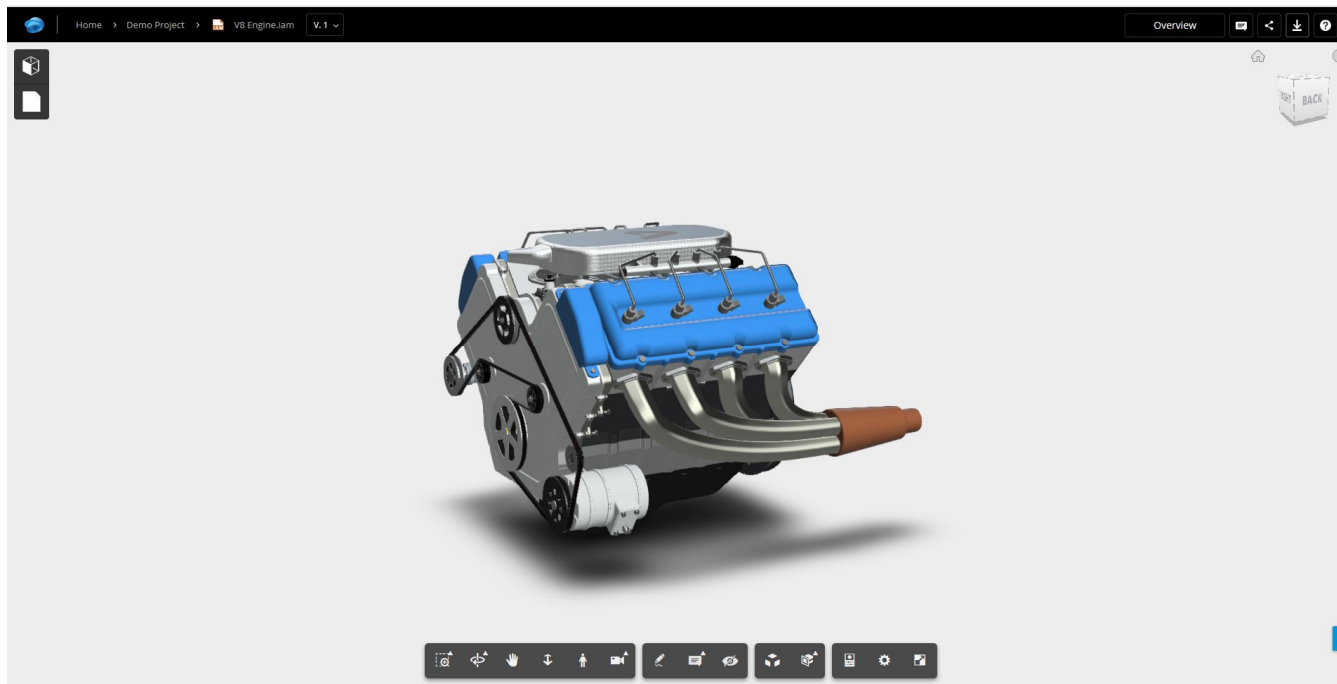
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Free CAD applications – A360 Fusion

Allows users to easily upload and share 3D virtual models and drawings on-line, through a web-browser



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A360 Fusion – A general overview

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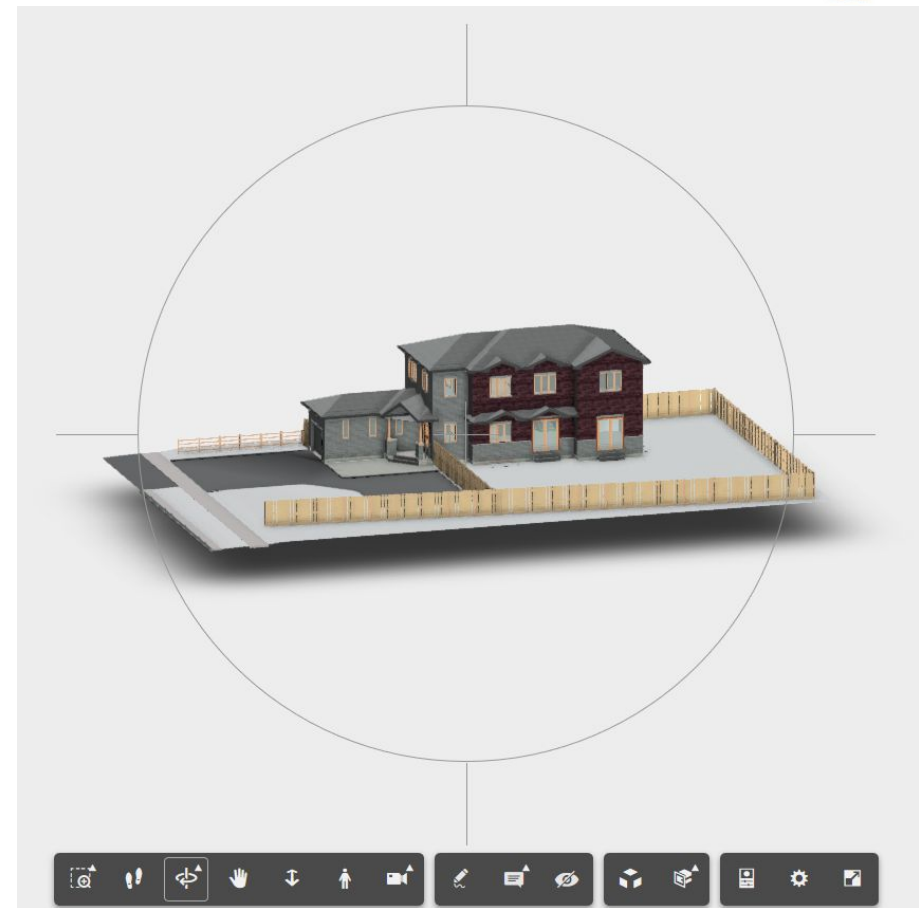


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A360 Fusion – Viewing Features



One can view the CAD model from different angles using the orbit tool



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What is Autodesk Fusion 360?

Click on the
video on the
right to play



<https://www.youtube.com/watch?v=h9wpIYhYvh4>

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Useful Topic Related Links



[Computer-Aided Design](#)



[What is Autodesk FUSION 360?](#)



[Fusion 360 for Beginners Webinar](#)

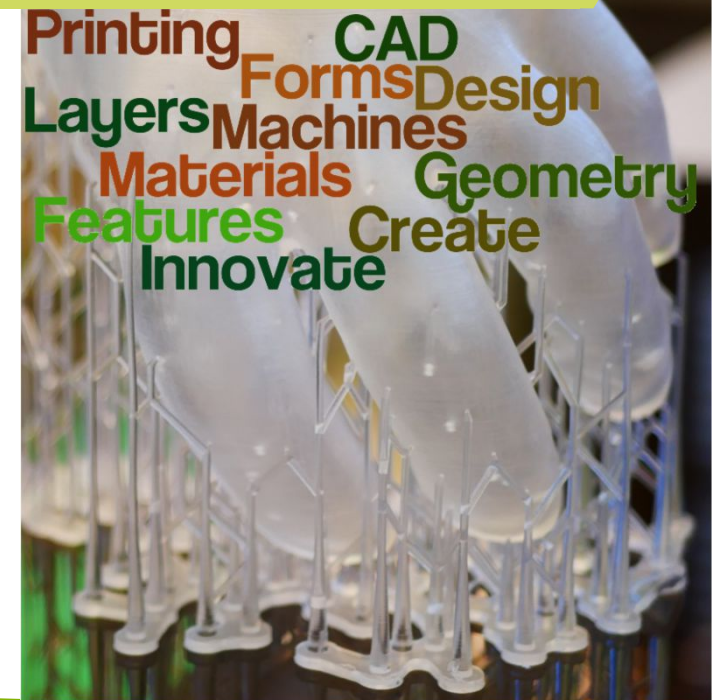
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3D CAD modelling using Autodesk Fusion 360



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Aim and Learning Outcomes

Module Aim:

To equip students with the basic knowledge needed to produce their own 3D printing models with Autodesk Fusion 360 software

Number of Hours:

11 hrs

Learning outcomes:

- Knowledge on modelling a 3D object from scratch using Fusion 360 software
- Knowledge on how to generate STL files from Fusion 360 software

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Lecture Outline

- Prologue
- Getting started
- Create 2D sketches
- 3D modelling
- Use materials to control the appearance
- Save model as STL file

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Prologue

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Chapter Outline

Prologue

- Introduction
- Learning Objectives
- Course program
- What is Fusion 360?
- About this study material

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Introduction

The aim of this Fusion 360 study material is to provide participants a brief overview of the software opportunities and to equip them with basic knowledge about using this program.

Fusion 360 software is a very comprehensive product development system and it's impossible to consider all its features here in detail. Also, we are considering only the **creation of models for 3D printing**. Thus, this material focuses on some fundamental skills and preparation concepts, after the acquisition of which the students can independently develop their skills further.

This material should be taken as a simplified Fusion 360 tutorial but not as a substitute of the software documentation.

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Learning objectives

This material consists of six chapters. Themes are logically connected and it is recommended to acquire them in the presented order. To improve acquisition of this material, some key issues are related to the practical exercises.

All subsequent material is prepared on the basis of a real product (a desk organizer) designed to be 3D printed.

In the course you will learn about tools and techniques of Fusion 360 useful for 3D printing models preparation, going step-by-step through the details of desk organizer modeling.

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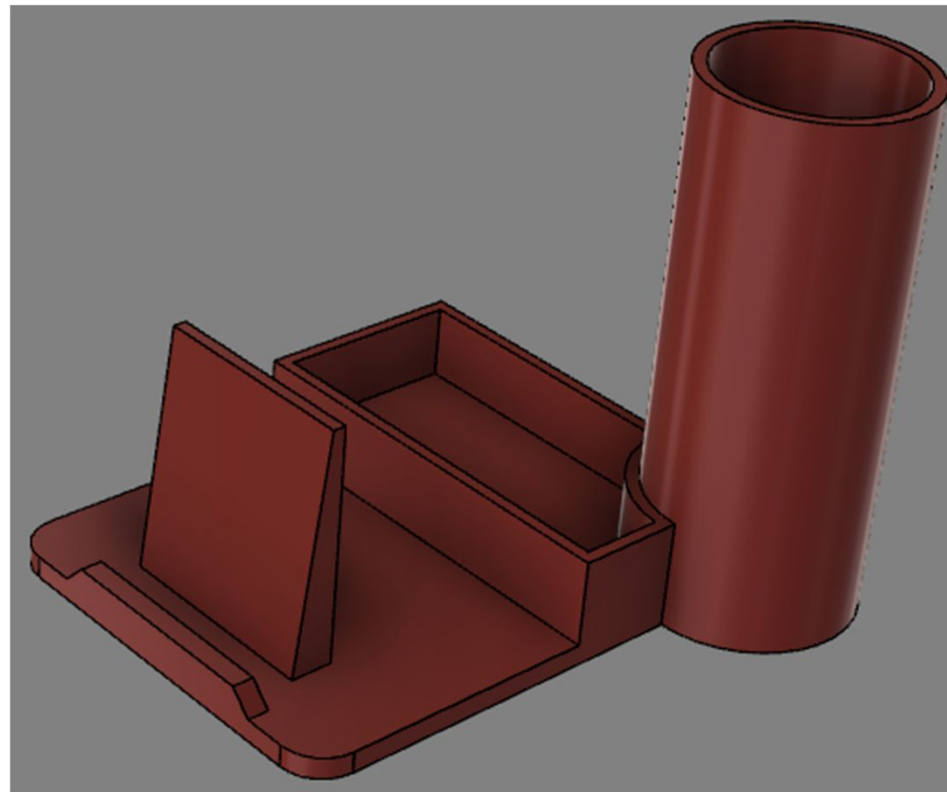
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The product to be designed

- 3D printable desk organizer



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Course program

Getting started

- Download and opening the program
- Fusion 360 Interface
- Basic settings
- Import and open files
- Entering the command
- Navigation and selection tools

Create 2D sketches

- Planning a sketch
- Create a 2D sketch
- Constrain and dimension a sketch

3D Modelling

- 3D modelling tools
- Create 3D models
- Edit existing features

Use materials to control the appearance

- Apply and edit materials
- Modify appearance

Export models as STL file

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What is Fusion 360?

Fusion 360 is a cloud-based tool for product development that integrates CAD, CAM and CAE software, created by Autodesk Corporation.

Fusion 360 has many features:

- freeform sculpting and modelling
- solid/parametric/mesh modelling
- simulation and testing
- data translation
- assembly modelling
- machining
- 3d printing and many more.

It is an excellent choice for creating models for 3D printing.

About this study material

Since this course material's screenshots and menu steps are taken from a computer with June 2017 version of Fusion 360, the future versions of Fusion 360 may cause differences from this material (both – in screenshots and menu steps).

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Getting started

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Chapter Outline

Getting started

- Download and opening the program
- Fusion 360 Interface
- Basic settings
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Learning objectives of this chapter

In this chapter you will learn how to get started with Fusion 360.

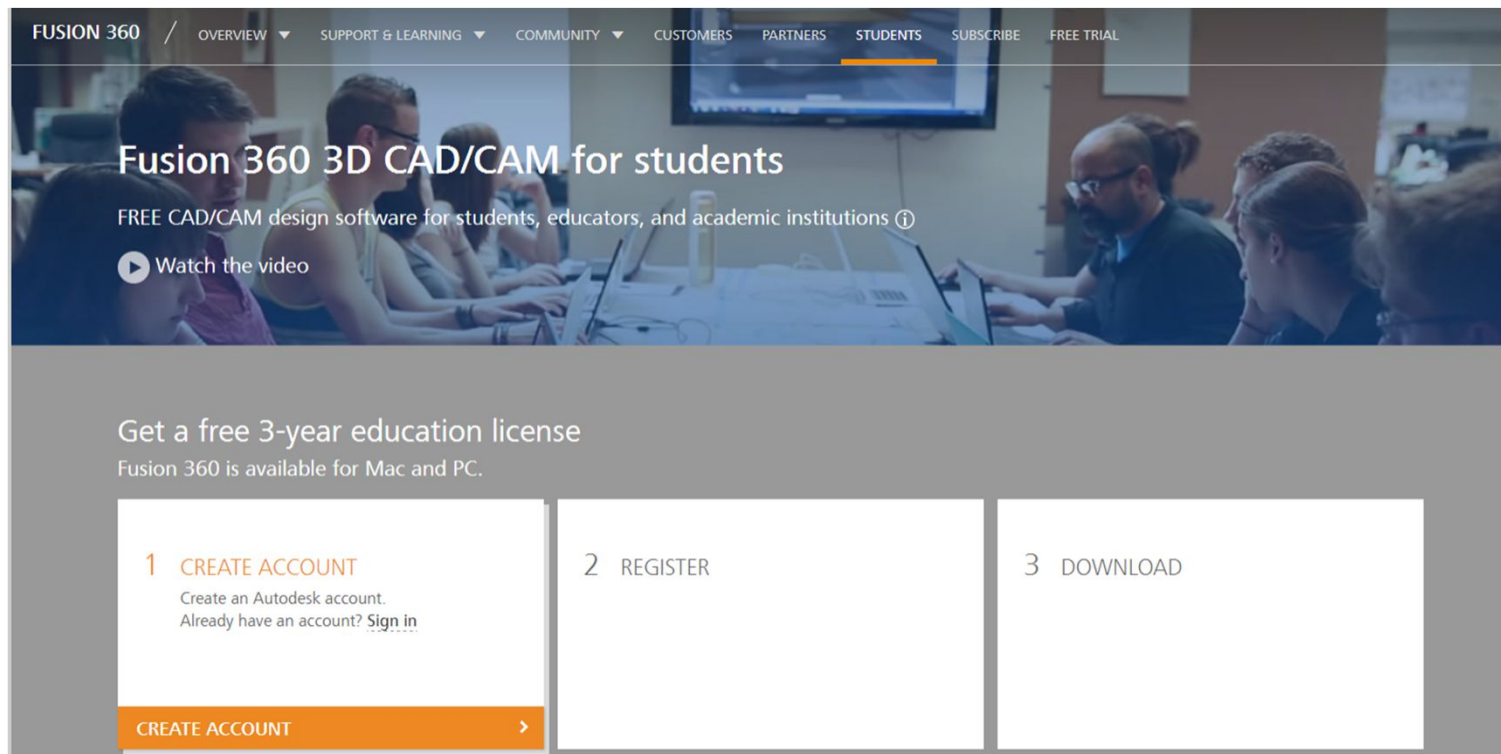
After completing this chapter, you'll know how to:

- download and open Fusion 360
- use Fusion 360 user interface
- set basic settings
- open and import Fusion 360 files
- do command entering
- use model navigation and selection tools



Download Fusion 360

To download and use Fusion 360, you will need an Autodesk ID. As a student or educator you can obtain an Autodesk ID and Fusion 360 at www.autodesk.com/education/free-software/fusion-360



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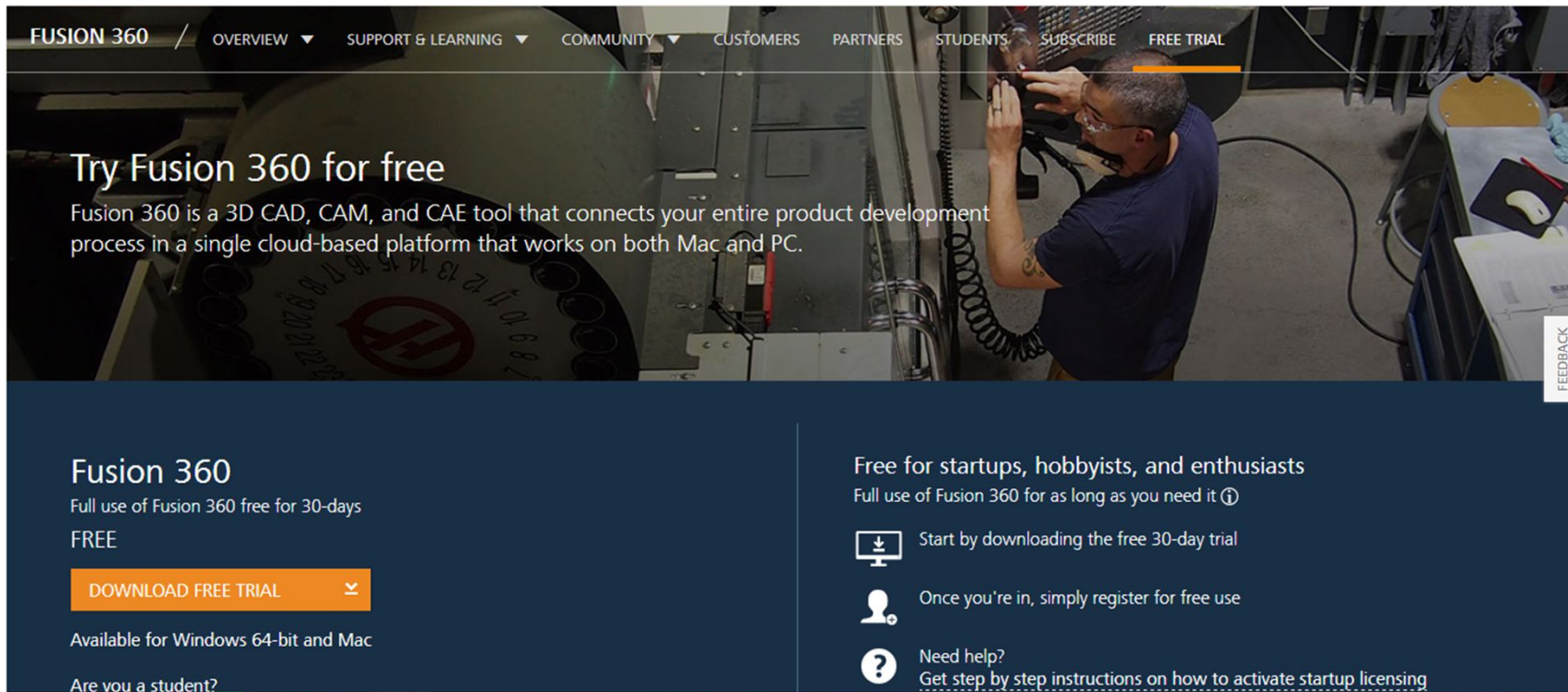
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Download Fusion 360

To download and use Fusion 360, you will need an Autodesk ID. As a student, hobbyists or enthusiasts you can obtain an Autodesk ID and Fusion 360 at www.autodesk.com/products/fusion-360/free-trial



The screenshot shows the Autodesk Fusion 360 website. At the top is a navigation bar with links: FUSION 360, OVERVIEW, SUPPORT & LEARNING, COMMUNITY, CUSTOMERS, PARTNERS, STUDENTS, SUBSCRIBE, and FREE TRIAL. The main banner features a background image of a person working on a machine. The text on the banner reads: "Try Fusion 360 for free" and "Fusion 360 is a 3D CAD, CAM, and CAE tool that connects your entire product development process in a single cloud-based platform that works on both Mac and PC." Below the banner, there are two columns of information. The left column is titled "Fusion 360" and states "Full use of Fusion 360 free for 30-days FREE". It includes a "DOWNLOAD FREE TRIAL" button and mentions "Available for Windows 64-bit and Mac". At the bottom of this column is a link "Are you a student?". The right column is titled "Free for startups, hobbyists, and enthusiasts" and states "Full use of Fusion 360 for as long as you need it". It includes three steps: 1. "Start by downloading the free 30-day trial" with a download icon, 2. "Once you're in, simply register for free use" with a user icon, and 3. "Need help? Get step by step instructions on how to activate startup licensing" with a question mark icon. A "FEEDBACK" button is visible on the right side of the banner image.

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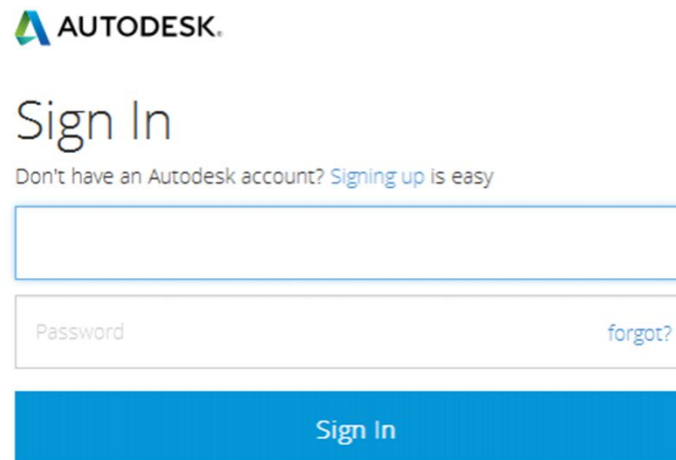


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Start Fusion 360

The design files that you create in Fusion 360 are saved to the cloud-based Autodesk 360 (A360) platform in a Project folder. Thus, you can access your design files from any web browser or computer with Fusion 360 installed by logging in with your Autodesk ID.

- Start Fusion 360.
- If required, sign in using your Autodesk ID.



The image shows the Autodesk Sign In interface. At the top is the Autodesk logo. Below it is the text "Sign In". Underneath that is a link: "Don't have an Autodesk account? [Signing up](#) is easy". There are two input fields: the first is for the email/username, and the second is for the password. To the right of the password field is a link that says "forgot?". At the bottom is a large blue button labeled "Sign In".

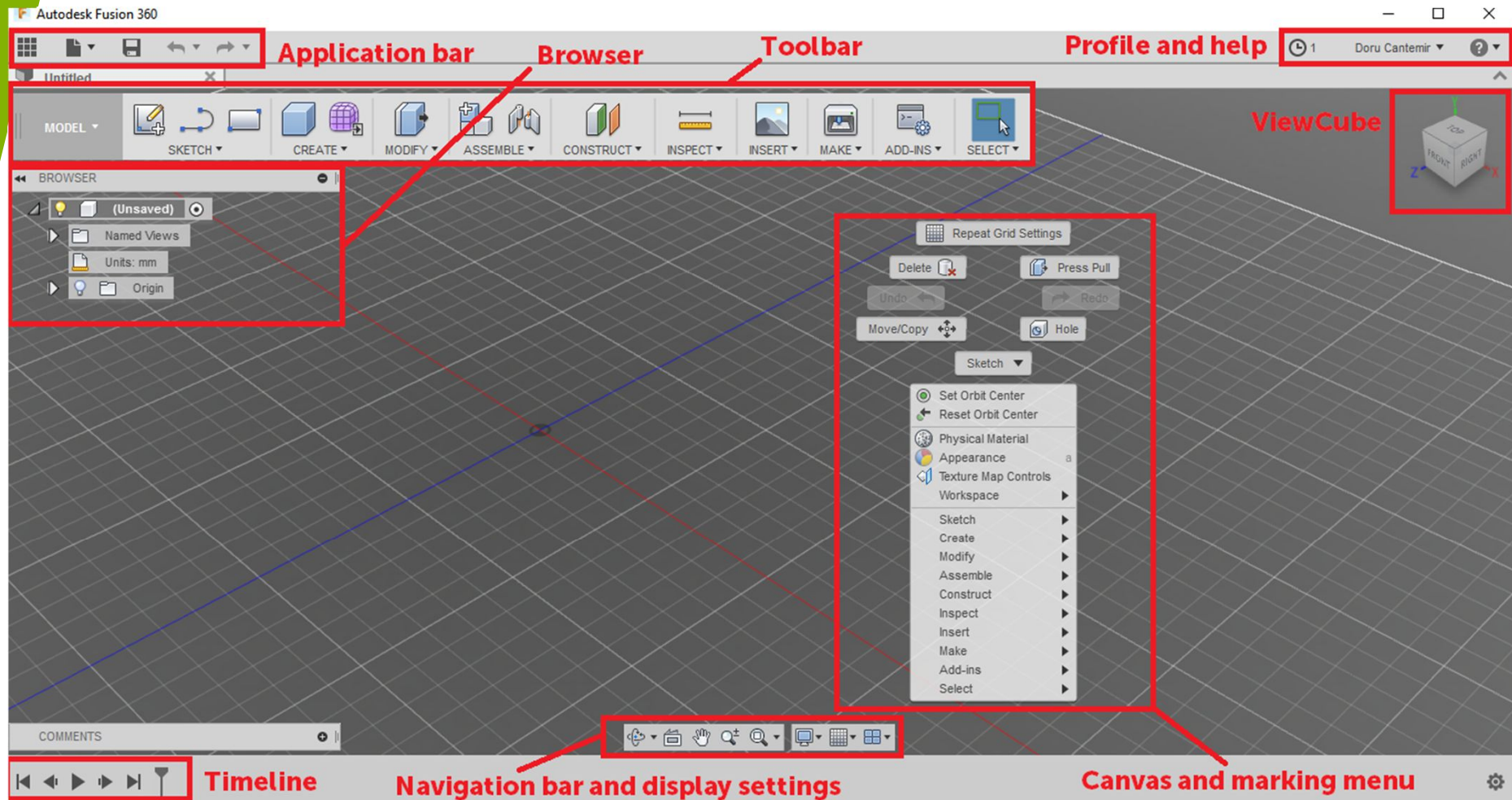
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Fusion 360 Interface



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Fusion 360 Interface

- **Application bar** - Access the Data Panel, file operations, save, undo and redo
- **Profile and help** - control profile and account settings; help and learning
- **Toolbar** - select the workspace and the tool
- **ViewCube** - orbit the design or view it from standard view positions
- **Browser** - lists objects in your design. Can be used to make changes to objects and control their visibility.

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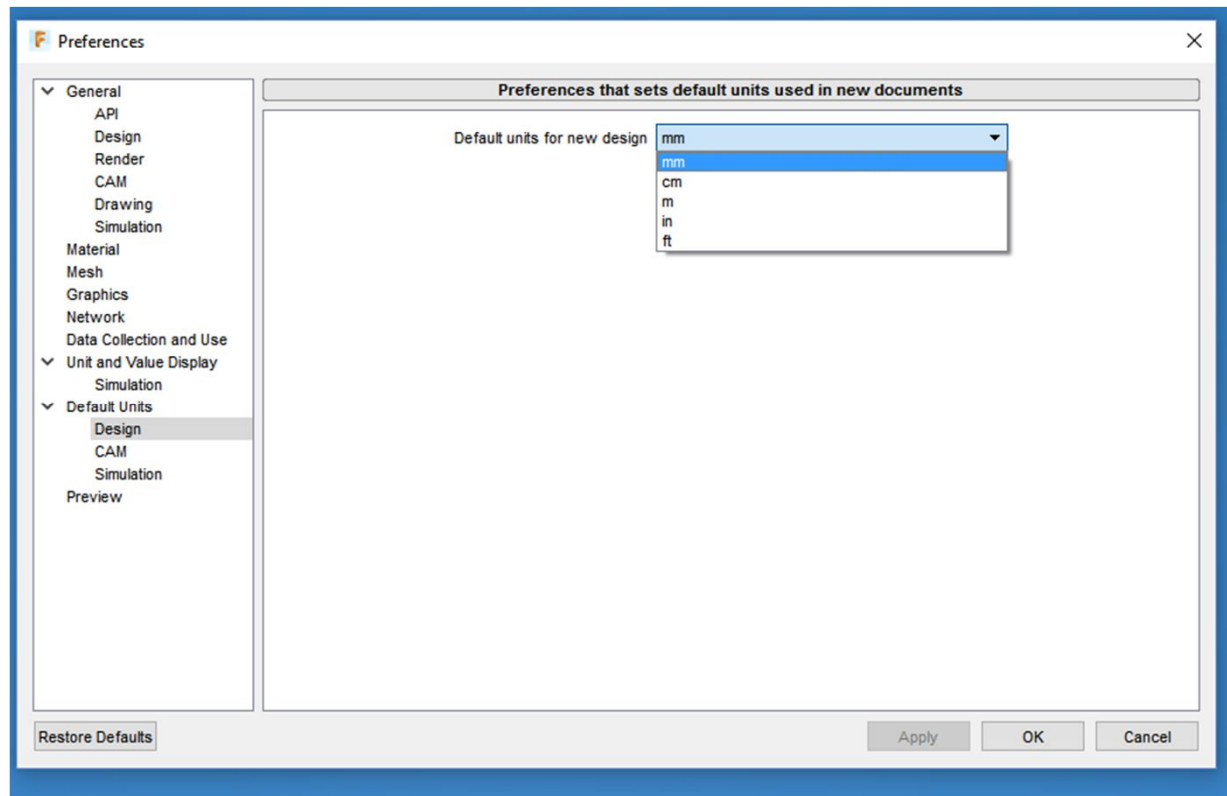
Fusion 360 Interface

- **Canvas and marking menu** - Left click to select objects in the canvas. Right-click to access the marking menu (it contains frequently used commands in the wheel and all commands in the overflow menu).
- **Timeline** - lists operations performed on your design. Right-click operations in the timeline to make changes. Drag operations to change the order they are calculated.
- **Navigation bar and display settings** - The navigation bar contains commands used to zoom, pan, and orbit your design. The display settings control the appearance of the interface and how designs are displayed in canvas.



Basic settings

In the *User Profile* drop-down menu located in the top right corner, click “Preferences”. Here you can set your preferences regarding UI behavior, Units, Visibility, Material, Graphics, etc.



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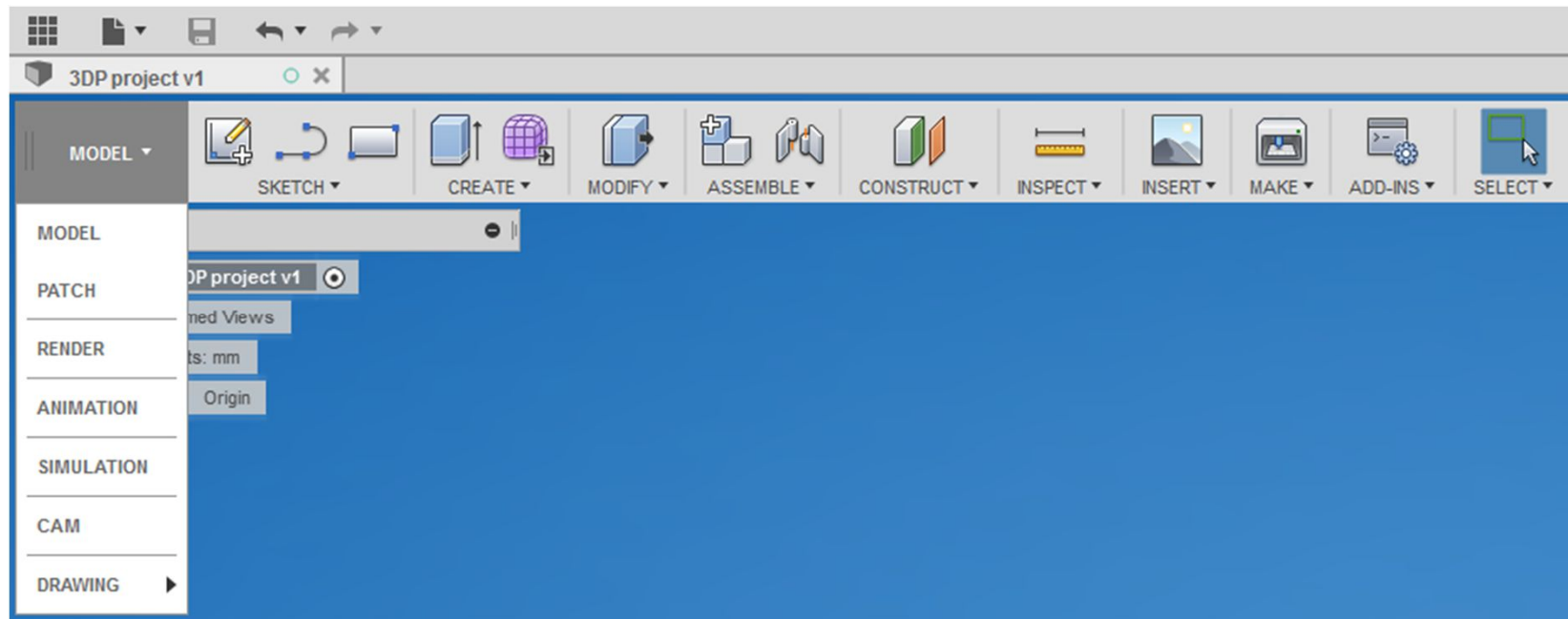
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Select workspace

Fusion 360 has 7 different workspaces, each of them displaying a toolbar with tools relevant to that specific workspace. To select a workspace, click *Model*.



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Available workspaces

Model: create and edit solid geometry

Patch: create and edit surface geometry

Render: generate realistic renderings of the design

Animation: create animations of how the design should work

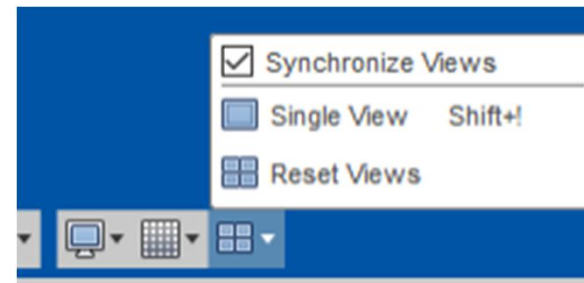
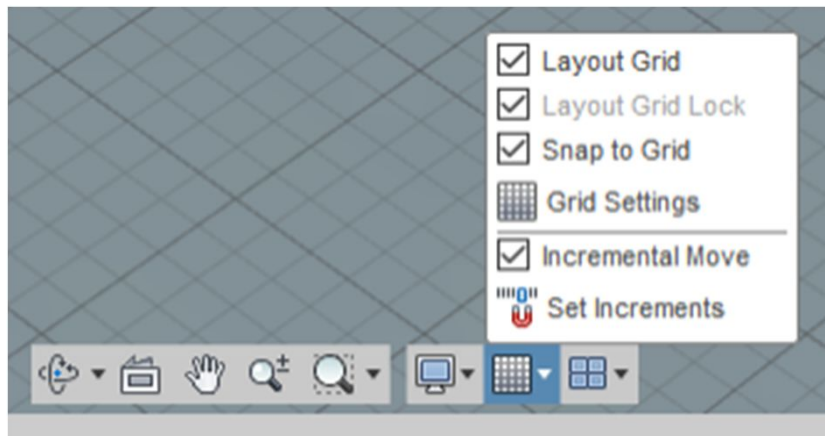
Simulation: perform stress analysis

CAM: generate tool-path strategies for the design to get fabricated

Drawing: create 2D drawings of a model

Display settings

The display settings bar is located at the bottom of the screen and control the appearance of the interface and how designs are displayed in canvas.



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Import and open a file

In this section you'll learn how to import and open files.

After completing this section, you'll be able to:

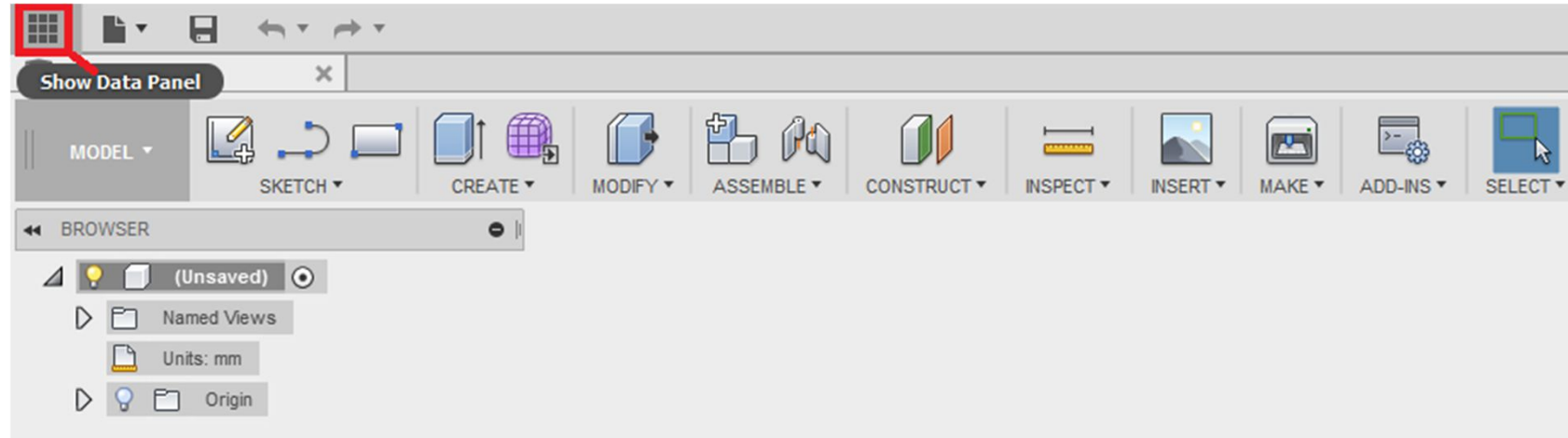
- Import files using Cloud Translators
- Import files using Local Translators
- Insert files and components



Import and open a file

There are several ways to open, import or translate a file in Fusion 360. To import a file is to upload it to the cloud. Once it's imported, the file may be opened in Fusion 360 through the Data Panel.

If the Data Panel is not shown in the Fusion 360 window, click the icon within the red square below.



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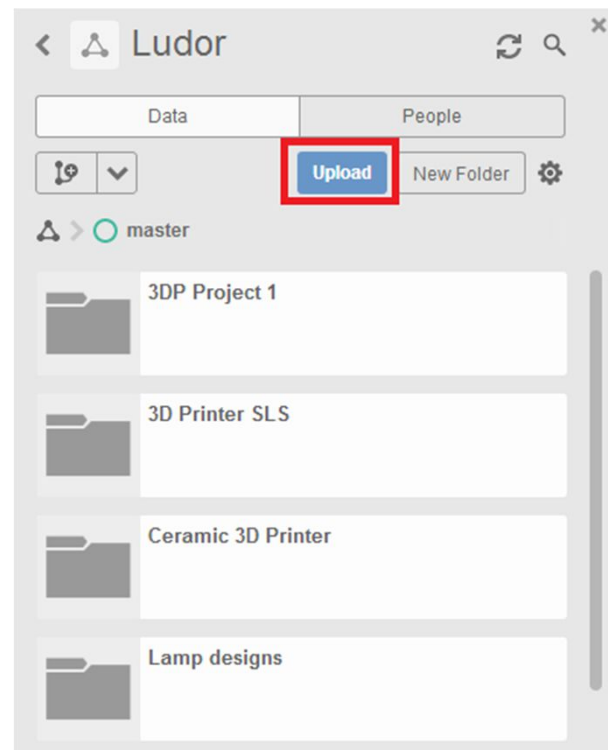
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Import files using Cloud Translators

Use the Upload command (you have to be inside of a project) to import a file into Fusion 360. Several file types can be imported into Fusion 360, including IGES, OBJ, STEP, STL.



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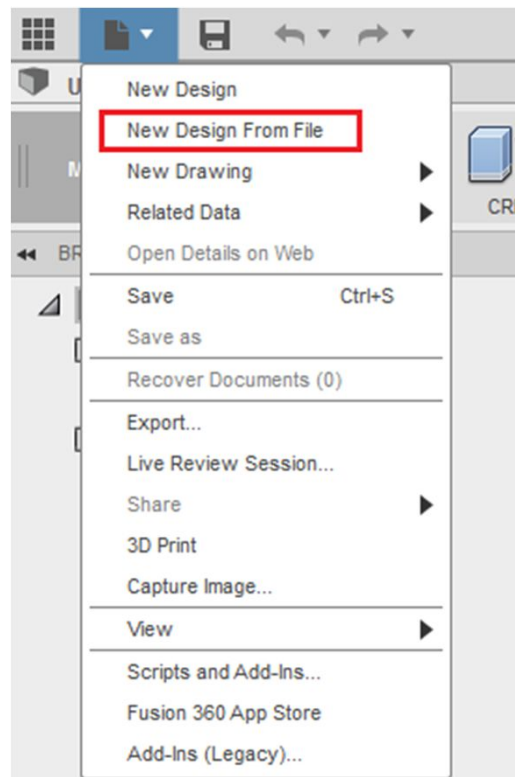
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Import files using Local Translators

Use the "New Design from File" command to import Autodesk Fusion 360 Archive Files, IGES, SAT/SMT Files and STEP Files



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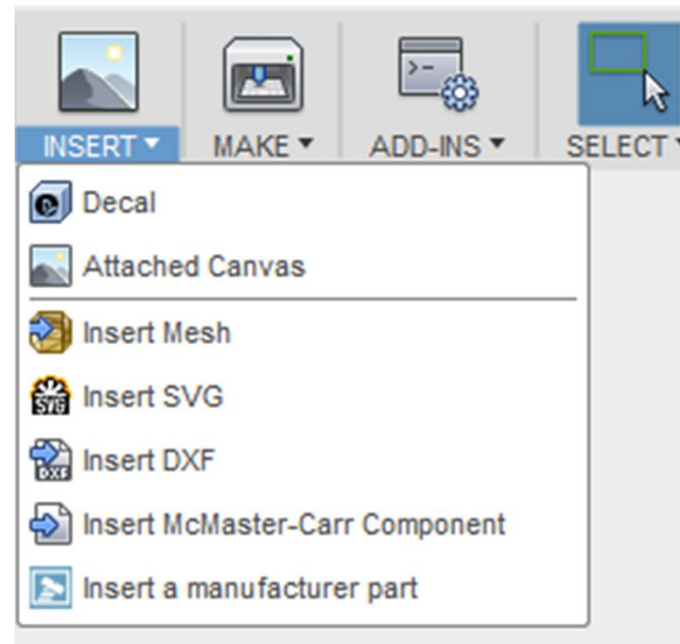
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Insert files and components

Use the various Insert command to import components and files (OBJ, STL, DXF and SVG).



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Entering the command

Workflow in Fusion 360 is intended to be flexible for user preferences. The commands can be entered by using:

- command icons from Toolbar
- right-click on objects listed on Browser
- right-click on canvas
- keyboard shortcuts



Navigation tools

There are multiple ways to manipulate the view of your design:

- Navigation Bar
- ViewCube
- Mouse navigation
- Touch gestures for touchpad and touch screen devices



Navigation commands

The navigation commands are started by clicking on an icon from Navigation Bar.

Orbit - commands that rotate the current view.

Look At - views faces of a model from a selected plane.

Pan - moves the view parallel to the screen.

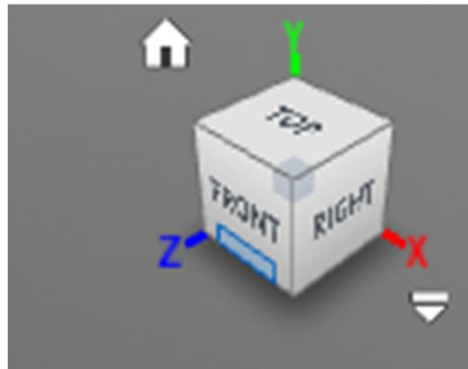
Zoom - increases or decreases the magnification of the current view.

Fit - positions the entire model on the screen.



ViewCube

- Use the ViewCube to rotate the camera
- Drag the ViewCube to perform a free orbit
- Click faces and corners of the cube to access standard orthographic and isometric views.



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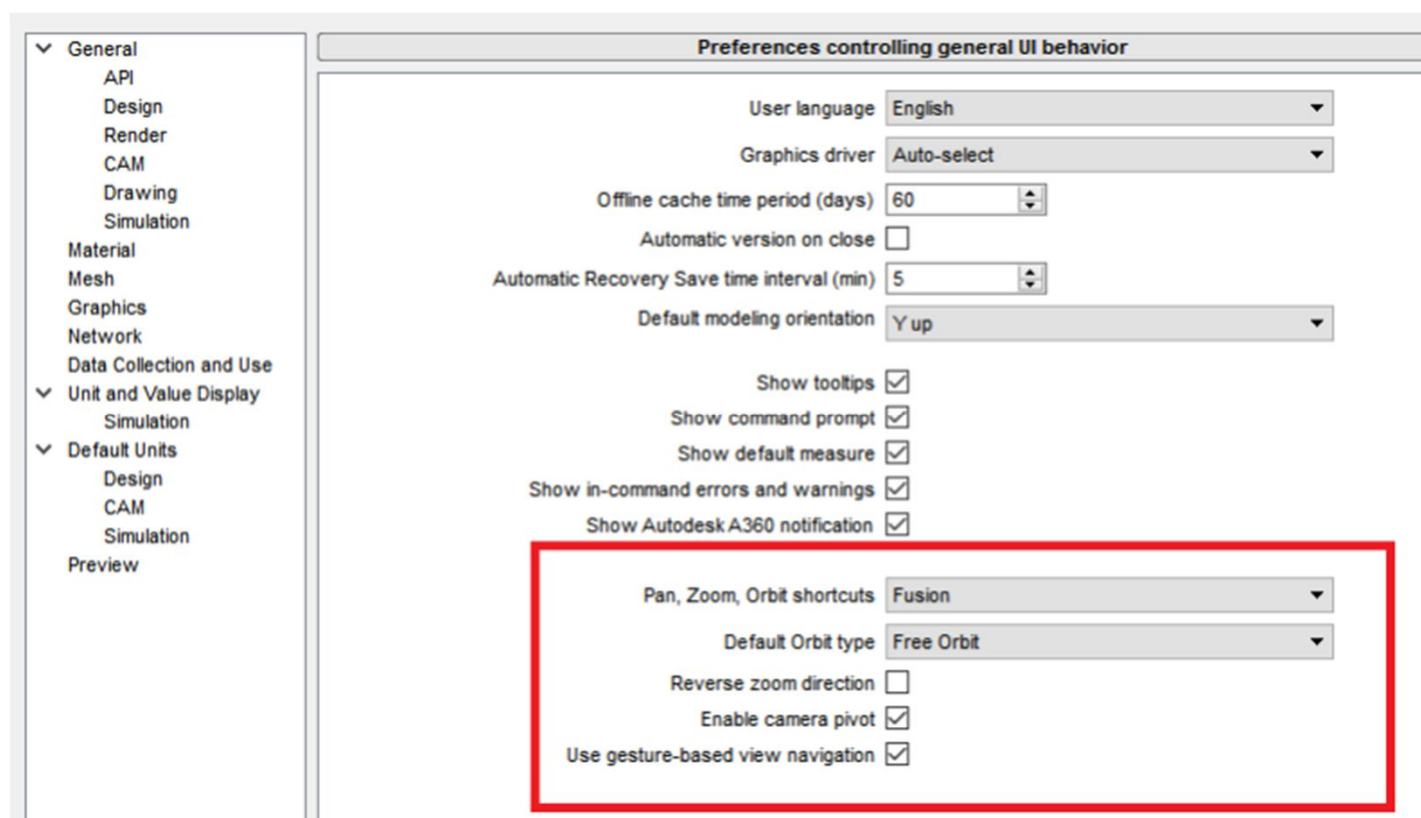
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Mouse

Use mouse shortcuts to zoom in/out, pan the view and orbit the view. Set the Default Mouse Control in Preferences to change how you pan, zoom, and orbit with the mouse.



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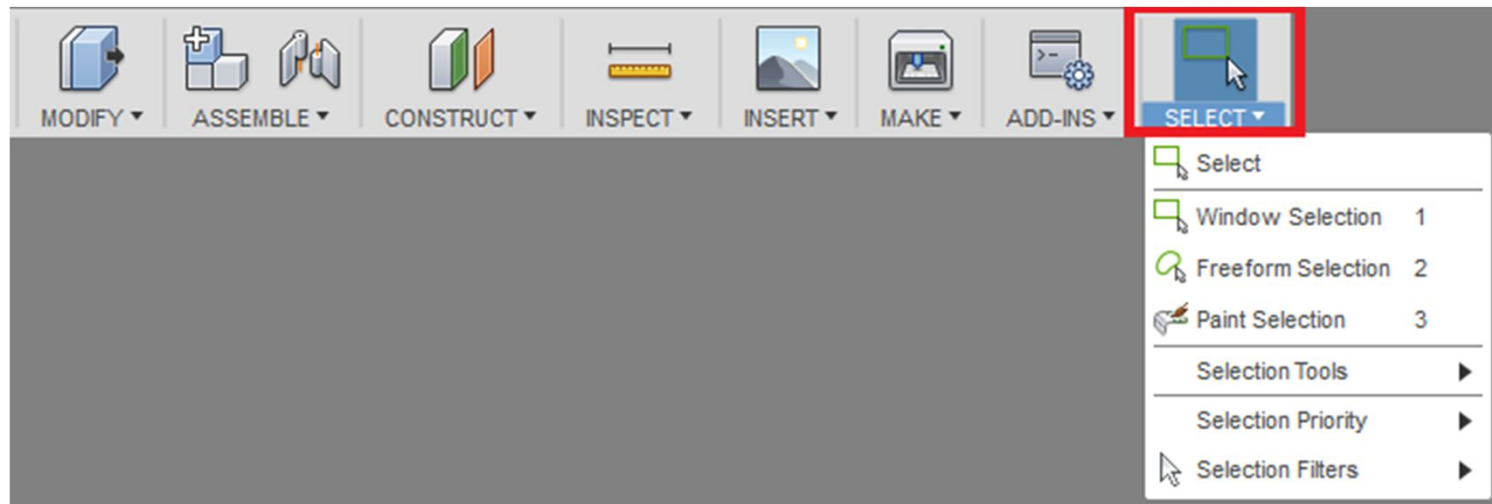
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Selection tools

There are many ways to select objects in Fusion 360.



The icon at the top of the pull down indicates which selection mode is active.

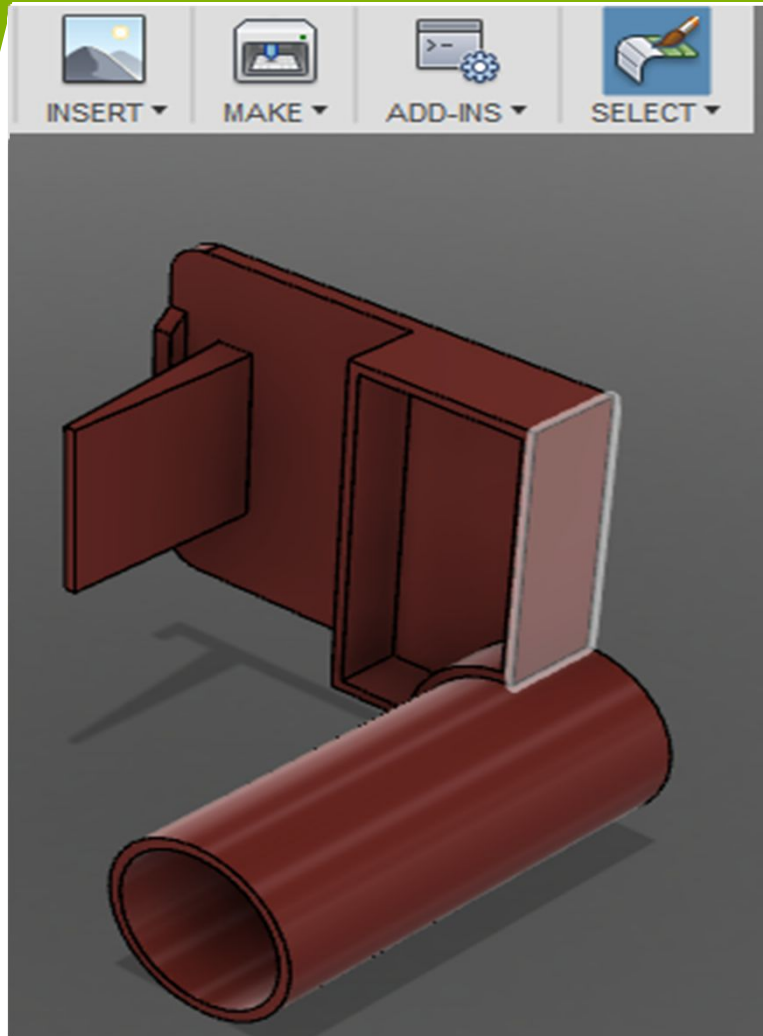
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Selection mode



- **Window Selection** Drag to draw a rectangle to select objects.
- **Freeform Form Selection** Drag to draw a lasso to select objects.
- **Paint Selection** Drag to select objects the cursor touches.

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Selection tools and filters

There are many ways tools and filters that can be used:

- **Select by Name** - to select objects by name.
- **Select by Boundary** - to select objects within a boundary shape you define.
- **Select by Size** - to select objects based on size.
- **Invert Selection** - to invert the active selection.
- **Selection Priority** - to specify the priority of selected objects in the canvas.
- **Selection Filters** – to control which objects types are available for selection.



Create 2D sketches

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Chapter Outline

Create 2D sketches

- Create a 2D sketch
- Create geometry in a sketch
- Use constraints to position geometry
- Use dimensions to set the size of geometry

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Learning objectives of this chapter

In this section you will learn how to create sketches and how to apply dimensions and geometric constraints.

After completing this section, you will:

- know the basic workflow for creating a sketch
- be able to create, constrain and dimension a sketch

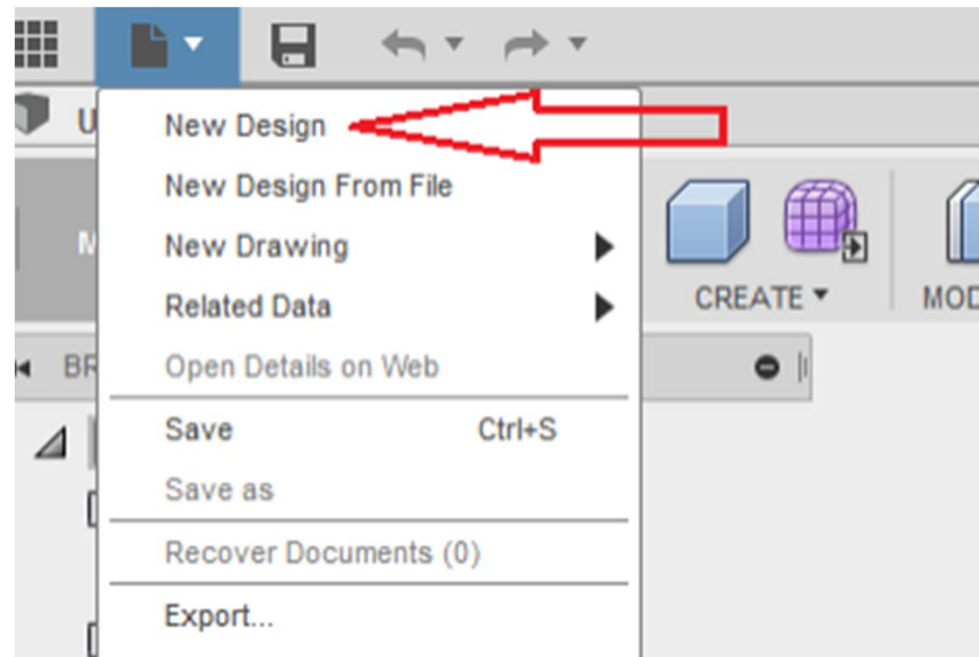


Create a 2D sketch

A sketch is an object containing the geometry needed to define profiles. Sketches must be created on origin planes, construction planes, or a flat model face.

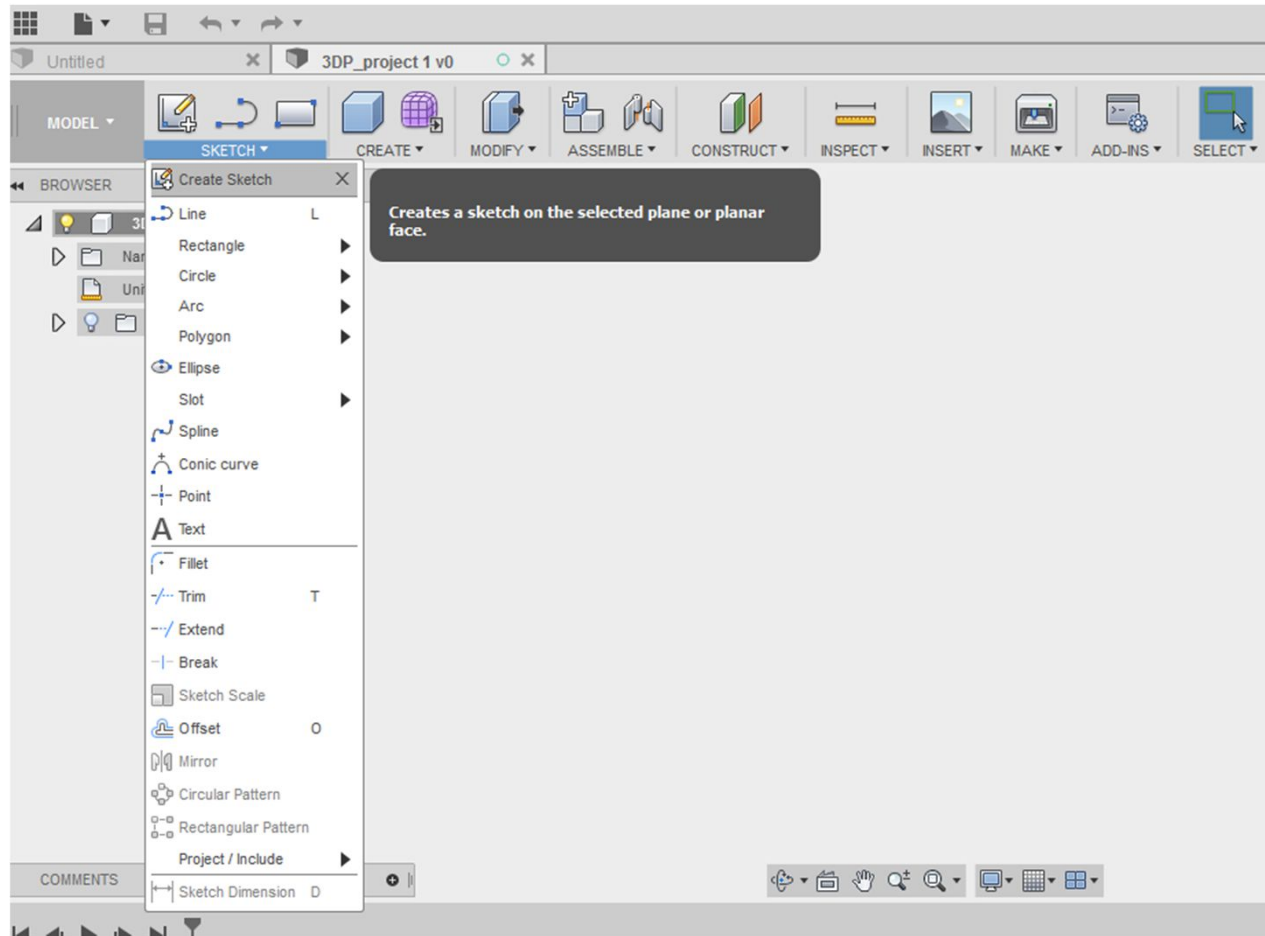
First step is to start a new design where you will create geometry:

- Launch Fusion 360
- Start a new design



Create a new sketch

Select **Sketch** > **Create Sketch**



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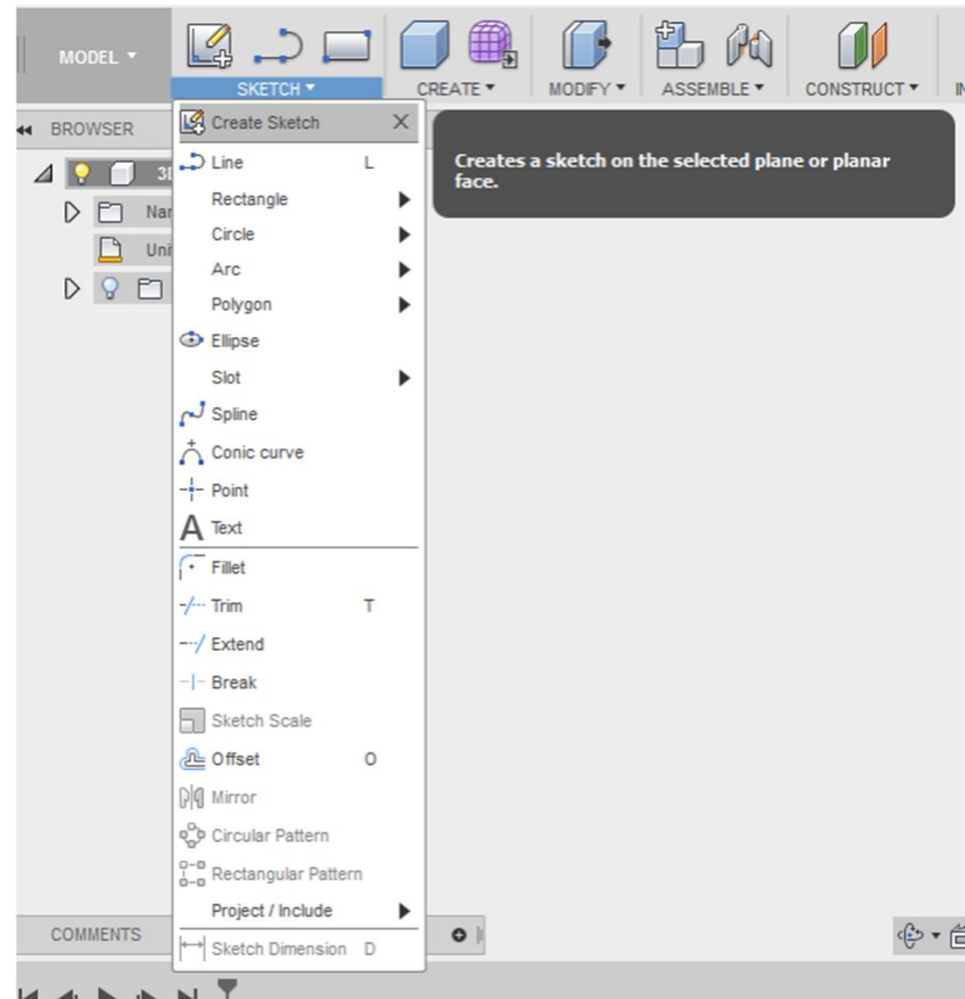
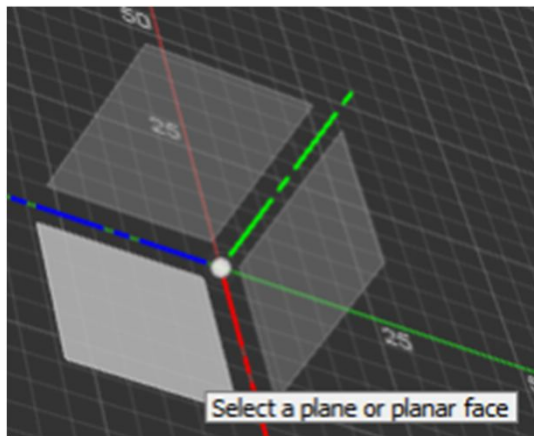


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Create a new sketch

Select **Sketch > Create Sketch**

Select the “Top” (XZ) plane



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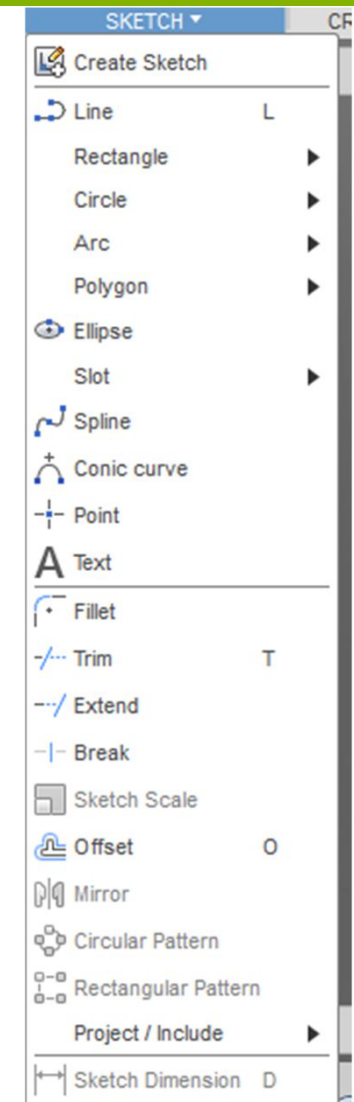
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Create geometry in a sketch

Sketch geometry can be created and edited using many available commands. Next, we will create a profile using Line command.



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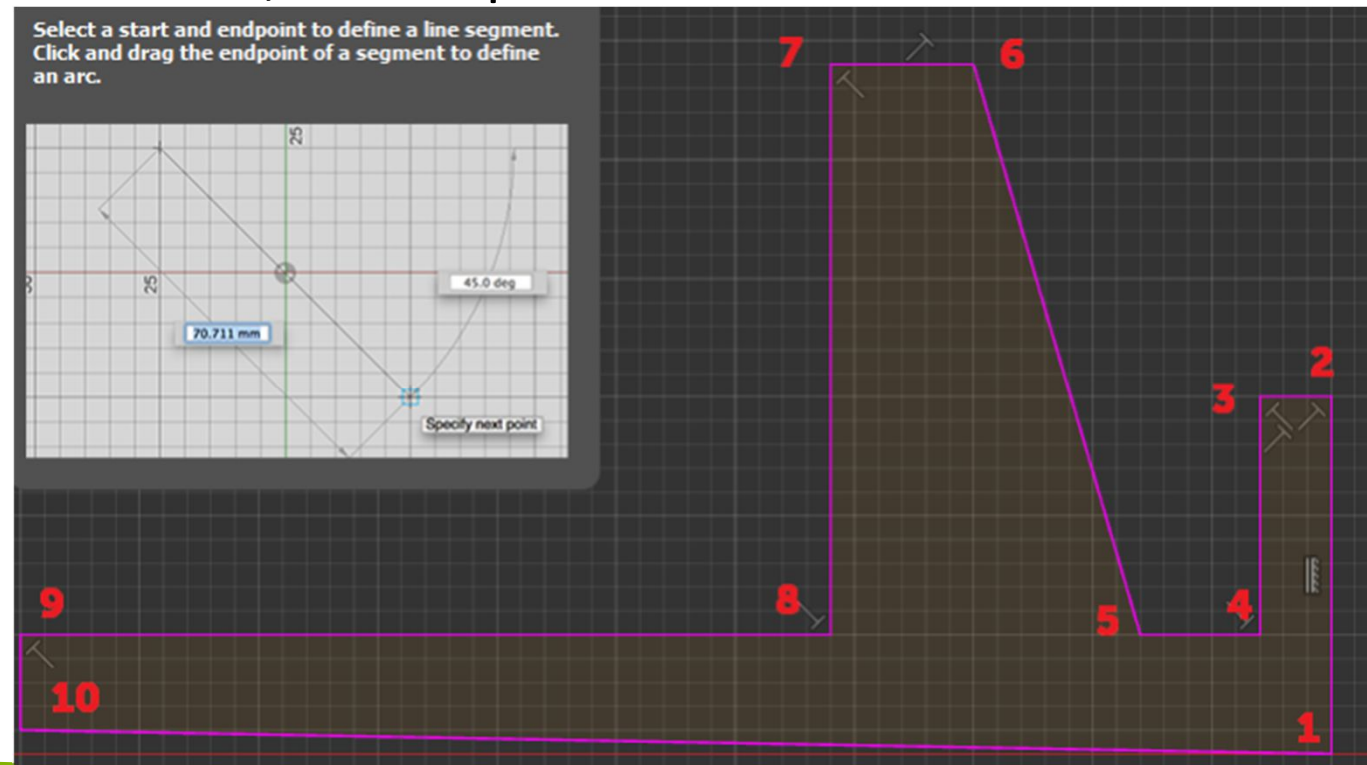
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Sketch a profile

- Select **Sketch > Line**
- Draw the shape from the picture by clicking in the indicated order
- Make sure you connect the last line to the start point, creating a closed shape. If correct, the shape is shaded in.



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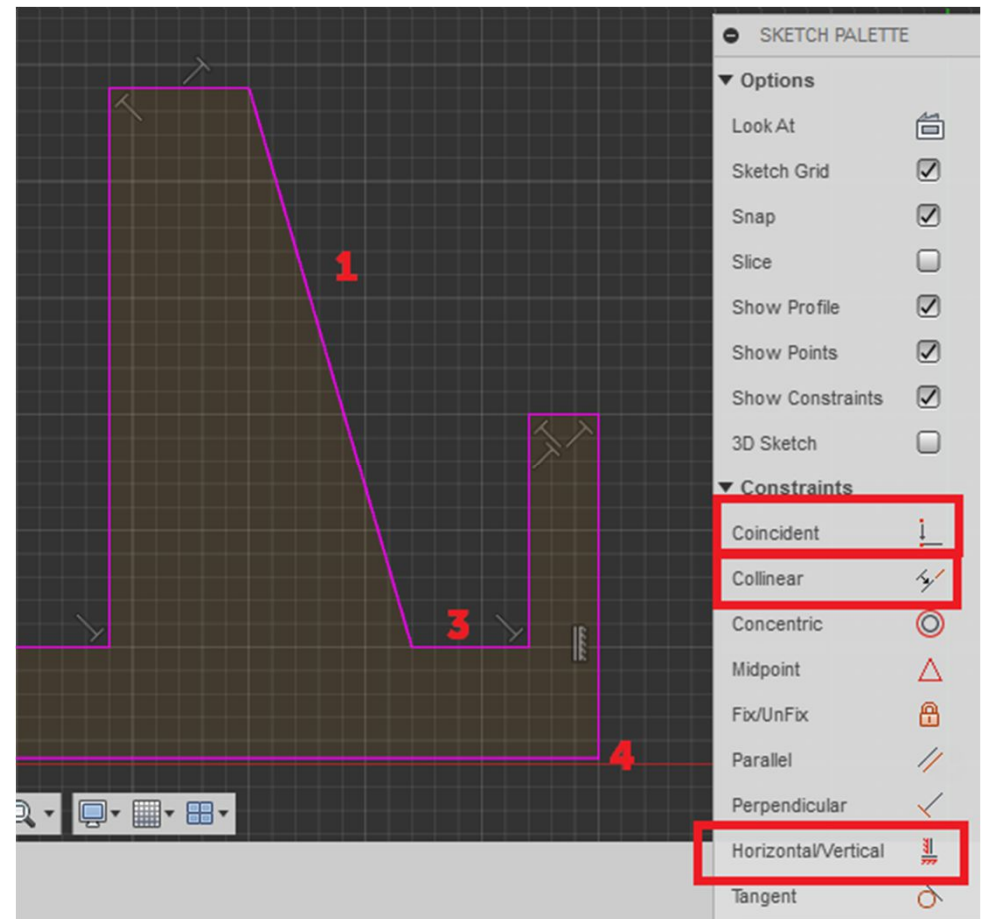
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Constrain the profile

- From the **Sketch Palette**> **Constraints** select **Horizontal/Vertical**
- Apply **Horizontal/Vertical** on all the lines, except line 1



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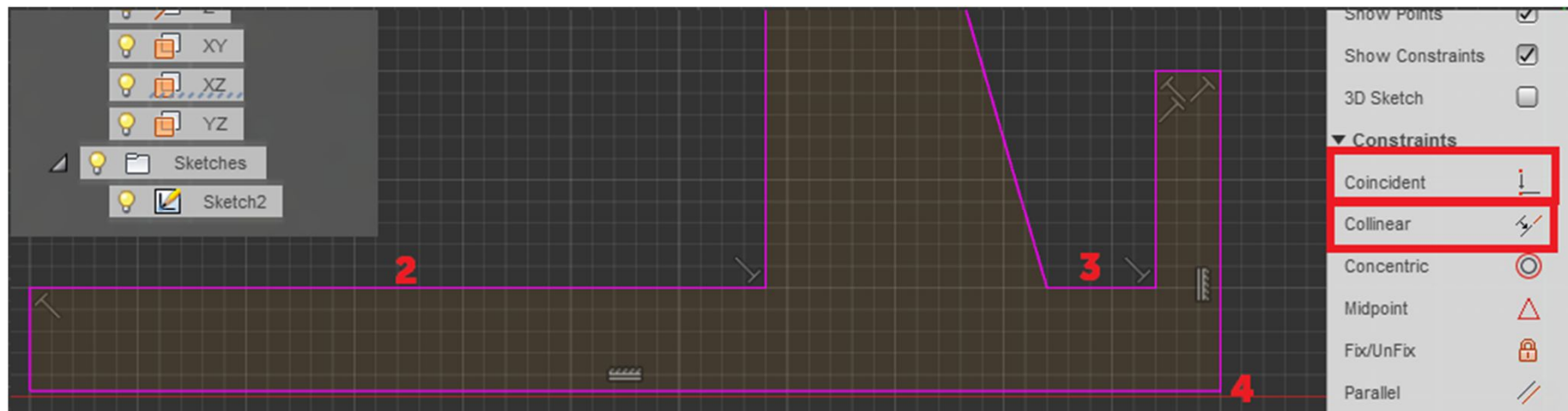
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Constrain the profile

- From the **Sketch Palette**> **Constraints** select **Collinear**
- Select line 2 and 3



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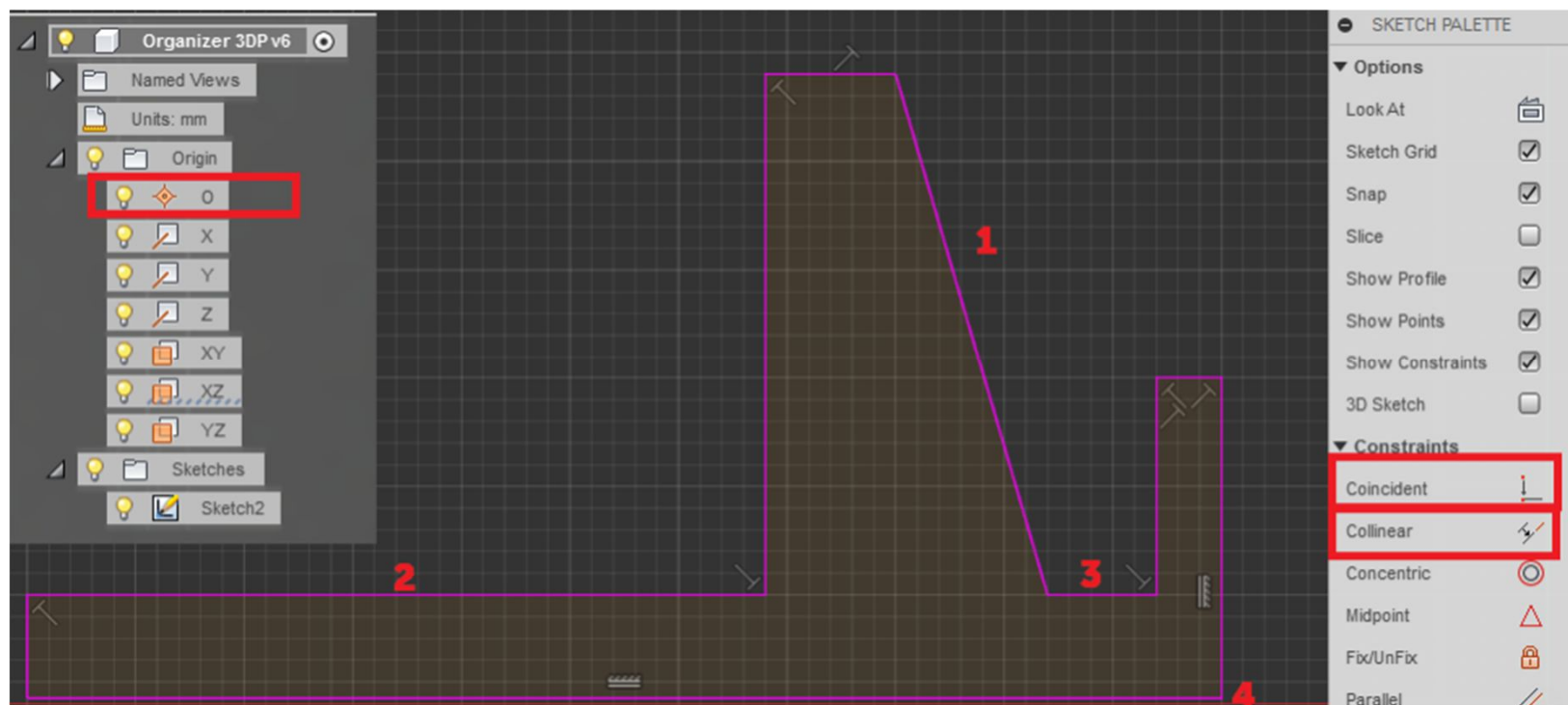
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Constrain the profile

- From the **Sketch Palette**> **Constraints** select **Coincident**
- Select point 4 then, from Browser, the origin of the coordinate system



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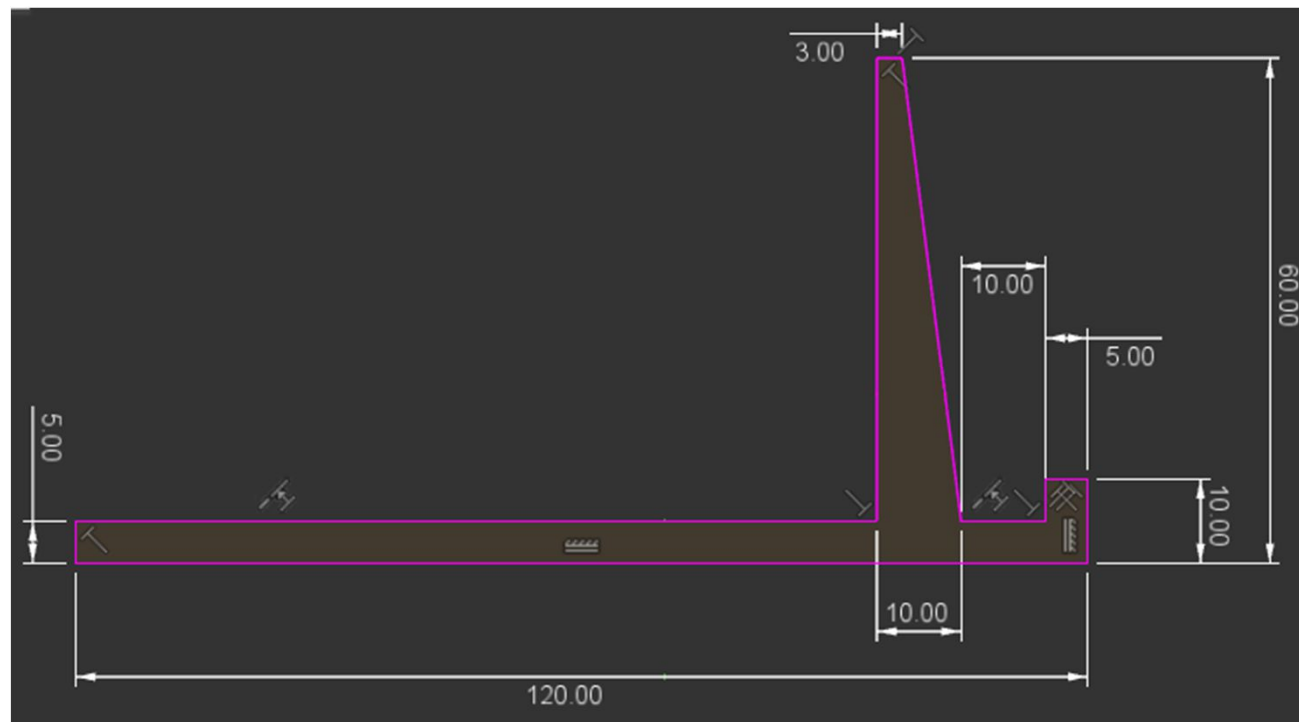
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Dimension the profile

- Select **Sketch > Sketch Dimension**
- Place dimension on the lines according to the picture
- Select **Stop Sketch**



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3D modelling

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Chapter Outline

3D modelling

- 3D modelling tools
- Create 3D models
- Edit existing features

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Learning objectives of this chapter

In this section you will learn how to turn a sketch into a parametric 3D model and to create solid bodies using primitive shapes.

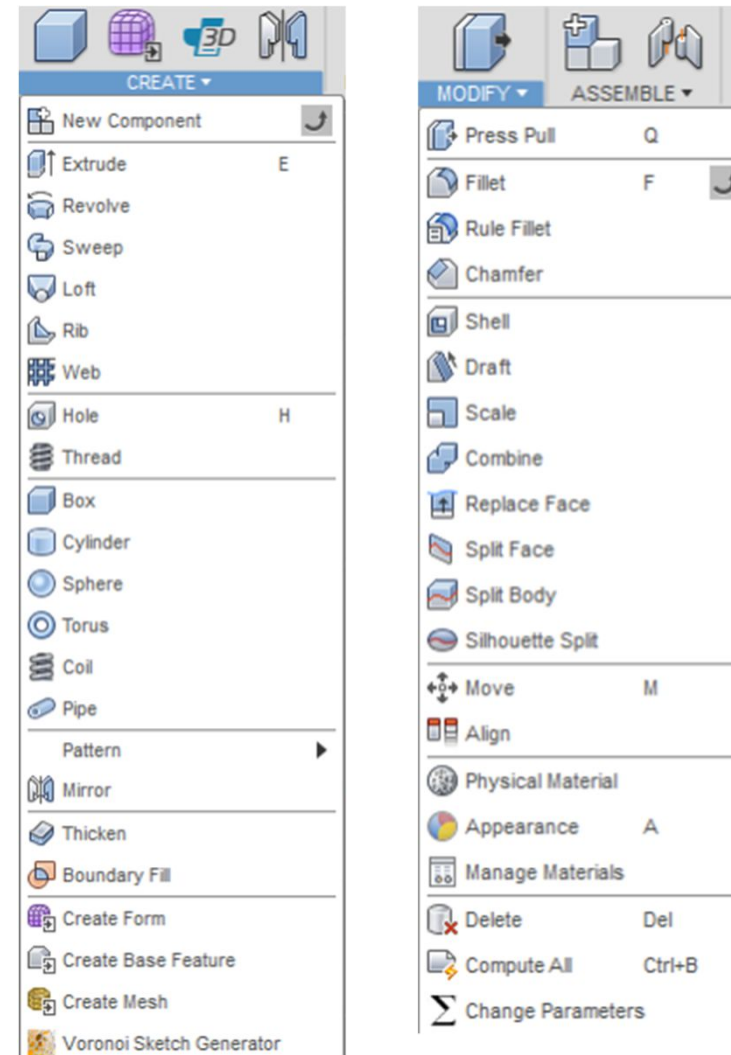
After completing this chapter, you will :

- be able to use main tools to create 3D models
- know how to modify existing features



3D modelling tools

There are multiple modelling tools inside Fusion 360. In this course we will study only the solid parametric modelling and the creation of solid models from primitive shapes.



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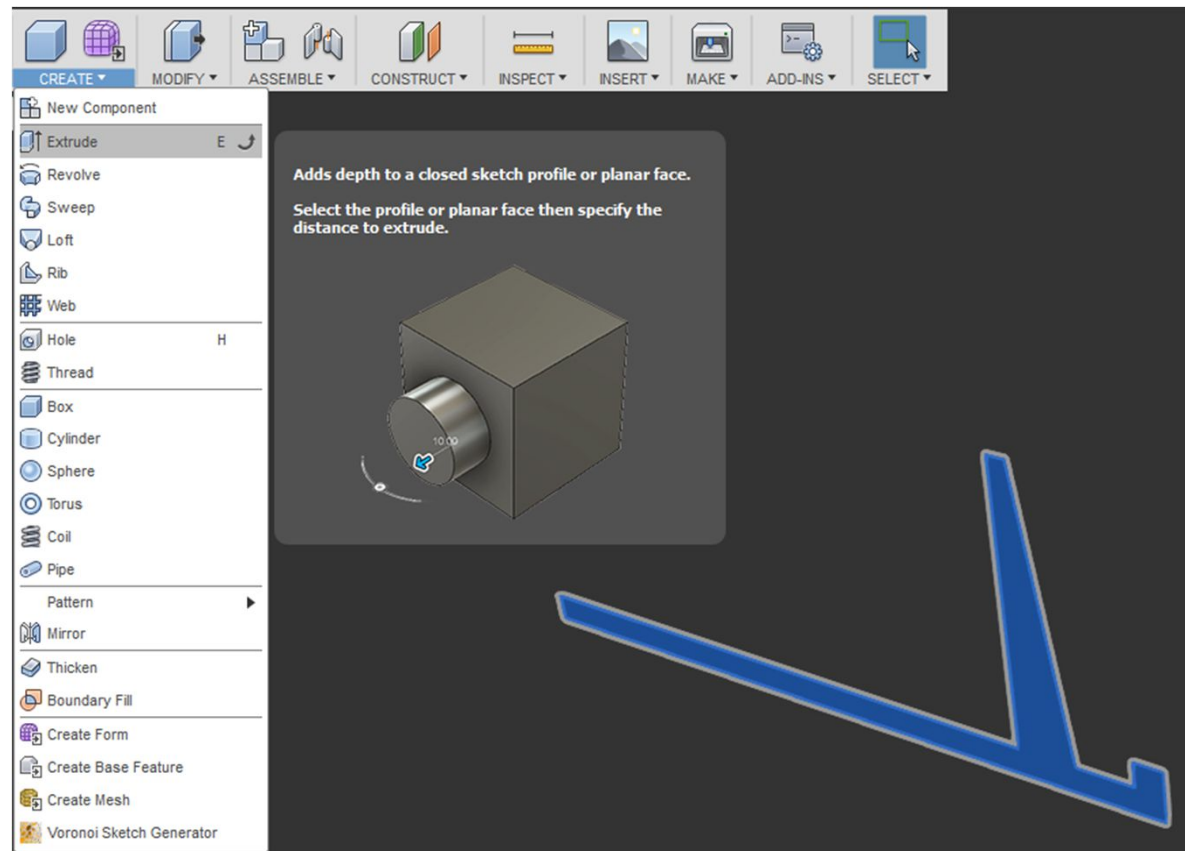


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Create a body using Extrude

Extrude command creates a 3D solid by extending the shape of a 2D object in a perpendicular direction into 3D space.

- Select profile – click inside the profile
- Click **Create> Extrude**



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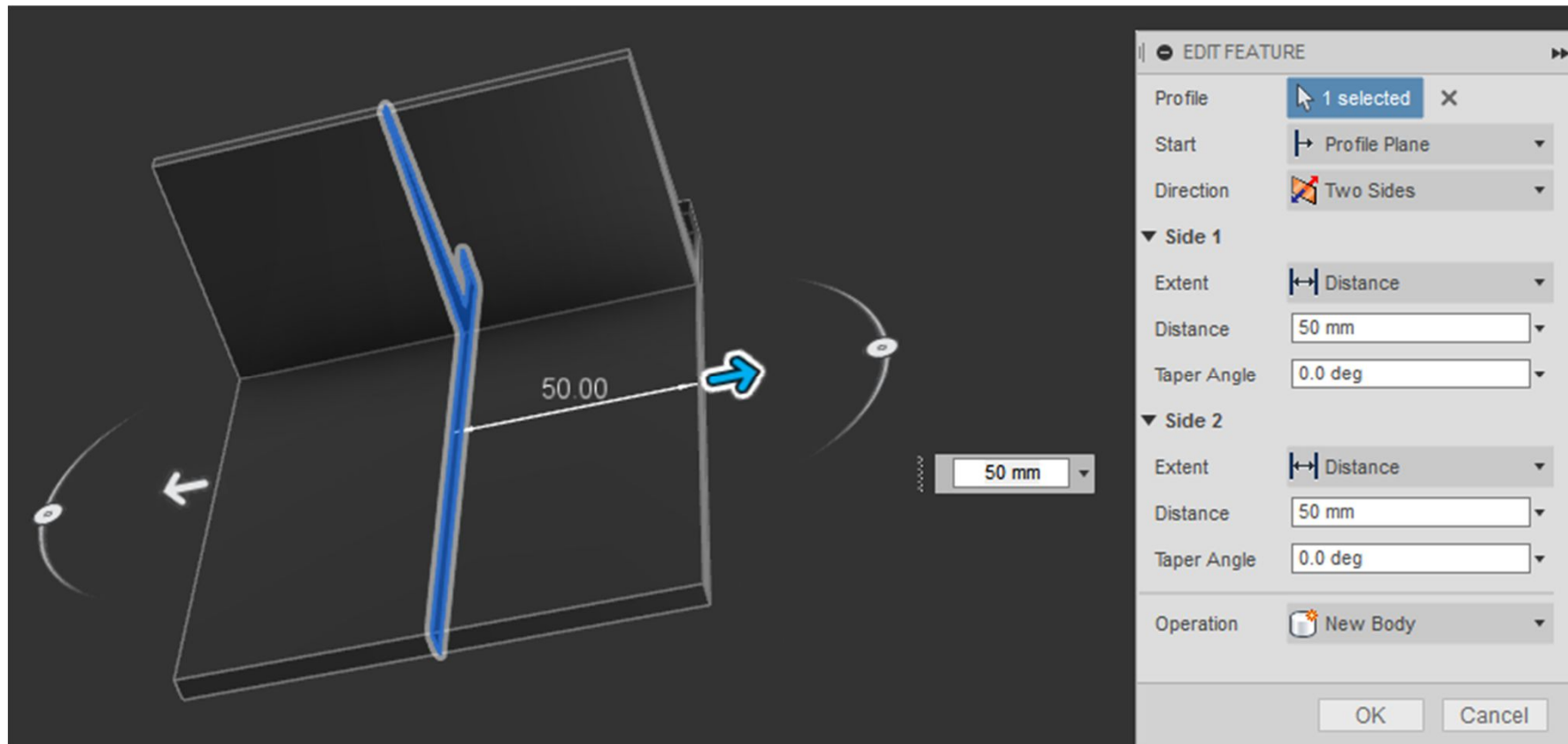
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Create a body using Extrude

Set the extrude options, according to the picture.



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Cut body using Press Pull

Press Pull command is a selection command that allows quick access to either the "Extrude," "Fillet," or "Offset Face" command depending on the type of geometry initially selected.

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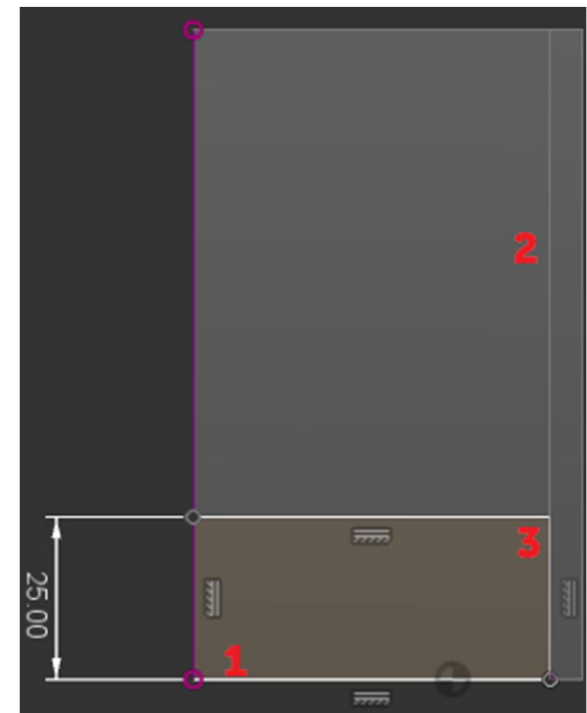


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Cut body using Press Pull

Sketch cutting profile

- Select **Sketch > Create Sketch**
- Select the **LEFT** view.
- Select **Sketch > Rectangle> 2-Point Rectangle**
- Click on point 1 to start the rectangle
- Move the mouse to the line 2 and place of the rectangle's opposite corner
- Click to complete the command
- Select **Sketch > Sketch Dimension**
- Place the 25 mm dimension
- Select **Stop Sketch**



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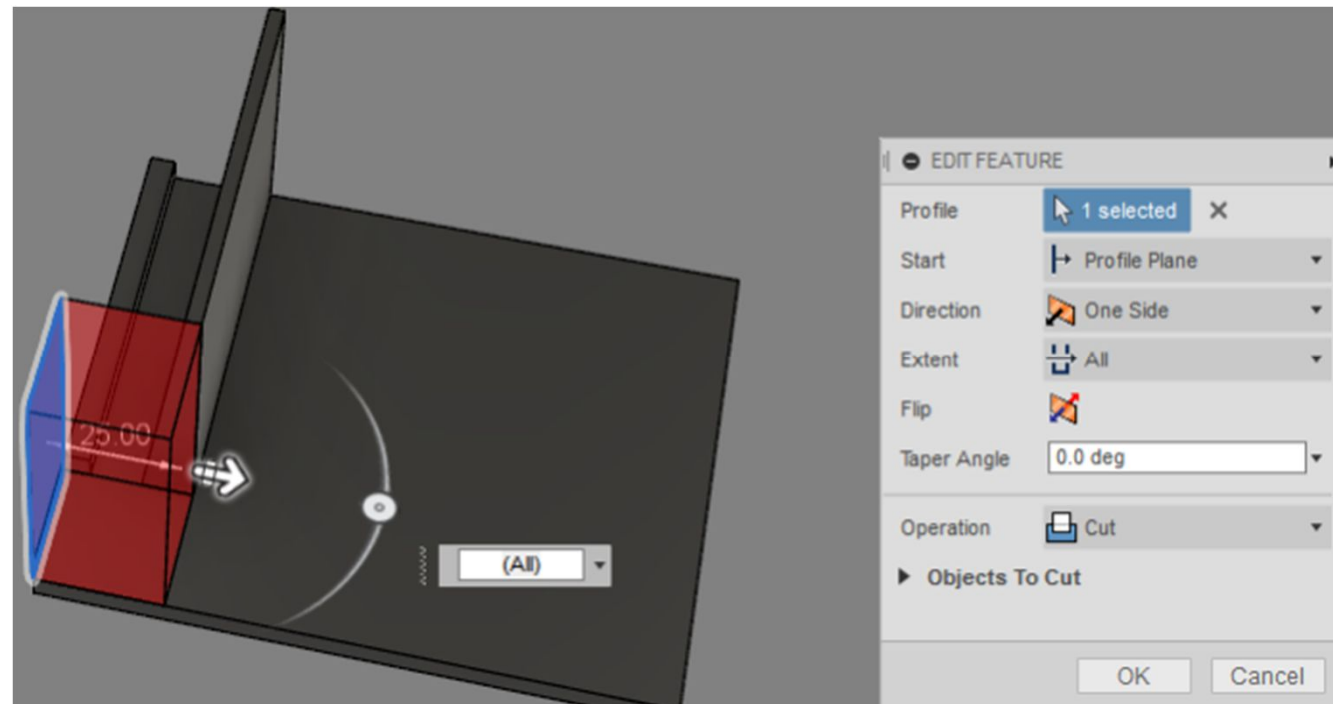


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Cut body using Press Pull

Place cut

- Select profile – click inside the rectangular sketch
- Right-click and select **Press Pull**
- Set the extrude options according to the picture.
- Click OK.



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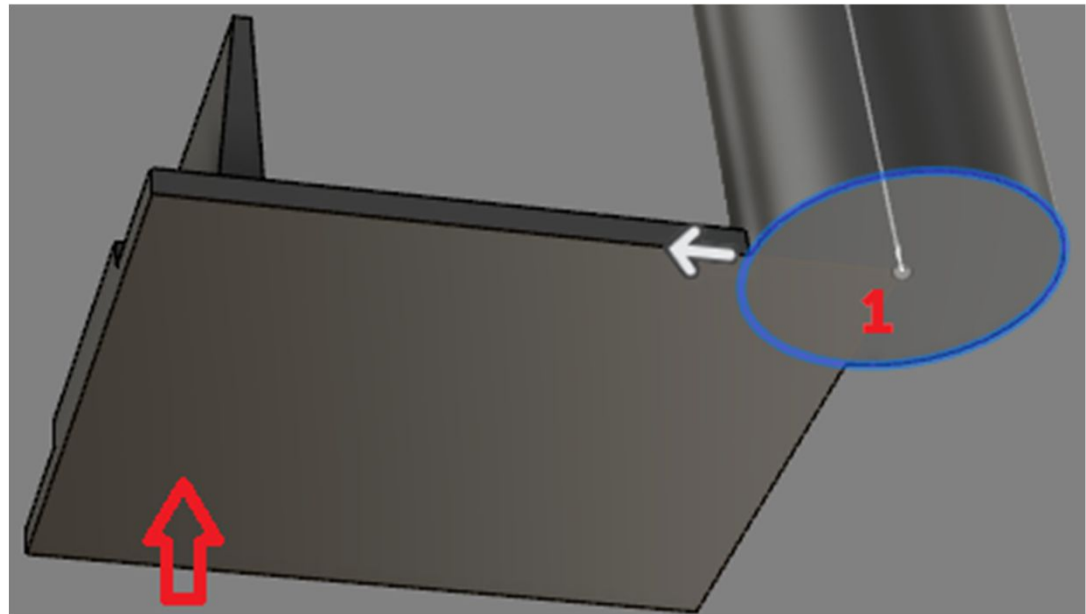


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Create body with Cylinder primitive

Cylinder command creates a body by adding depth to a circular region.

- Click **Create > Cylinder**
- Select the bottom surface of the object
- Select the corner 1 to place the cylinder's center point



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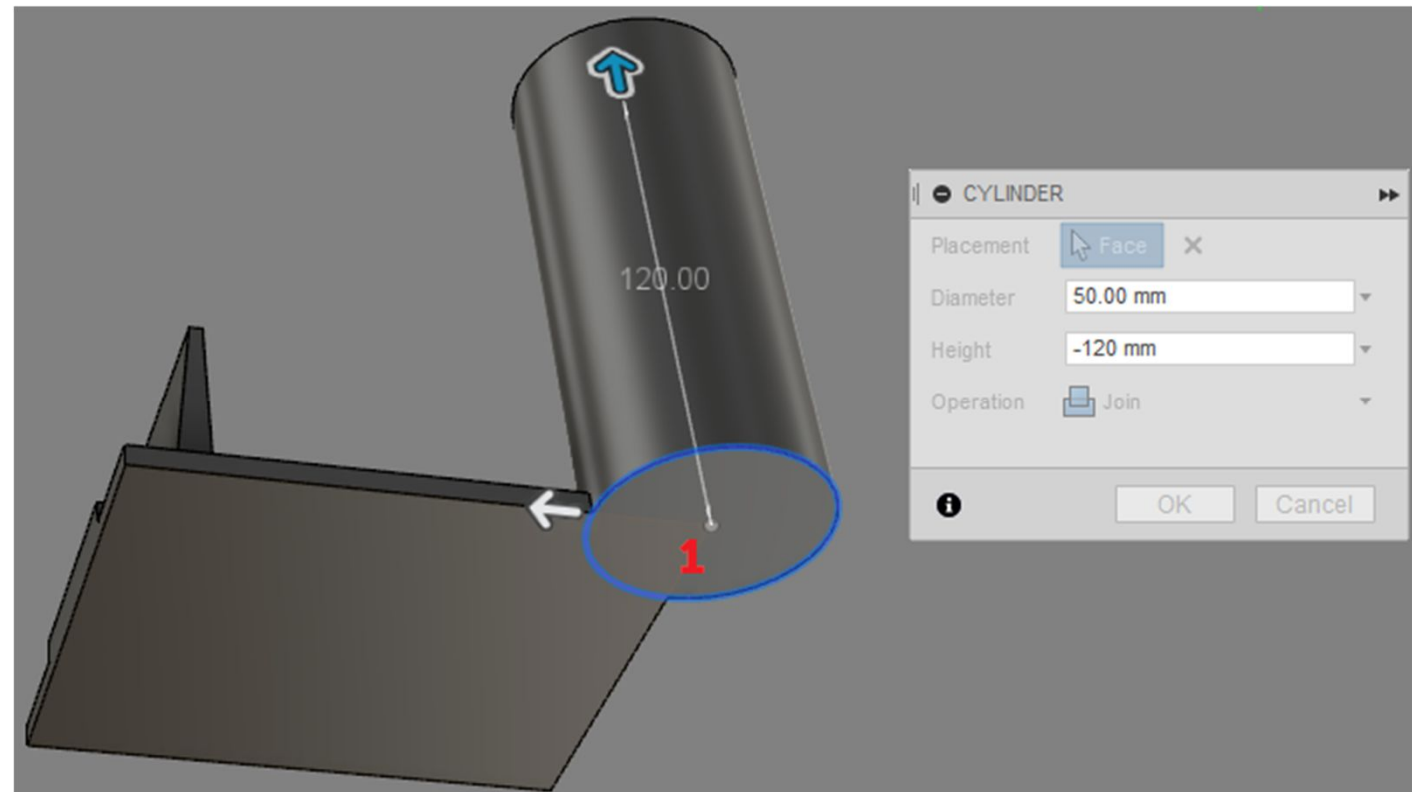
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Create body using Cylinder

- Move the cursor until you reach 50 mm. Click to confirm the size.
- Drag the arrow manipulator to set the cylinder height to 120 mm
- Set Operation to **Join**
- Click OK



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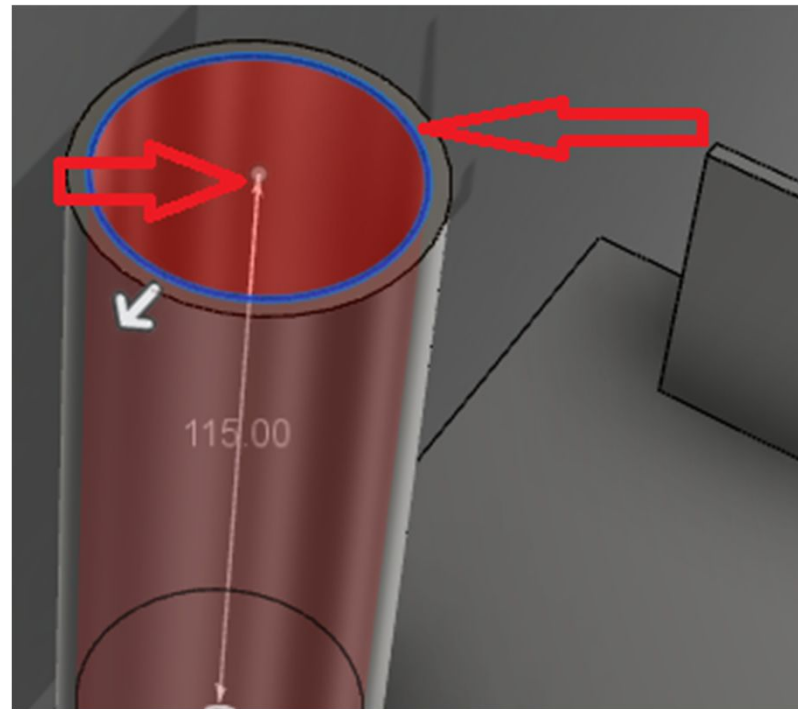
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Cut body using Cylinder

- Click **Create > Cylinder**
- Select the top surface of the cylinder created previously
- Select the center of top surface to place the cylinder's center point



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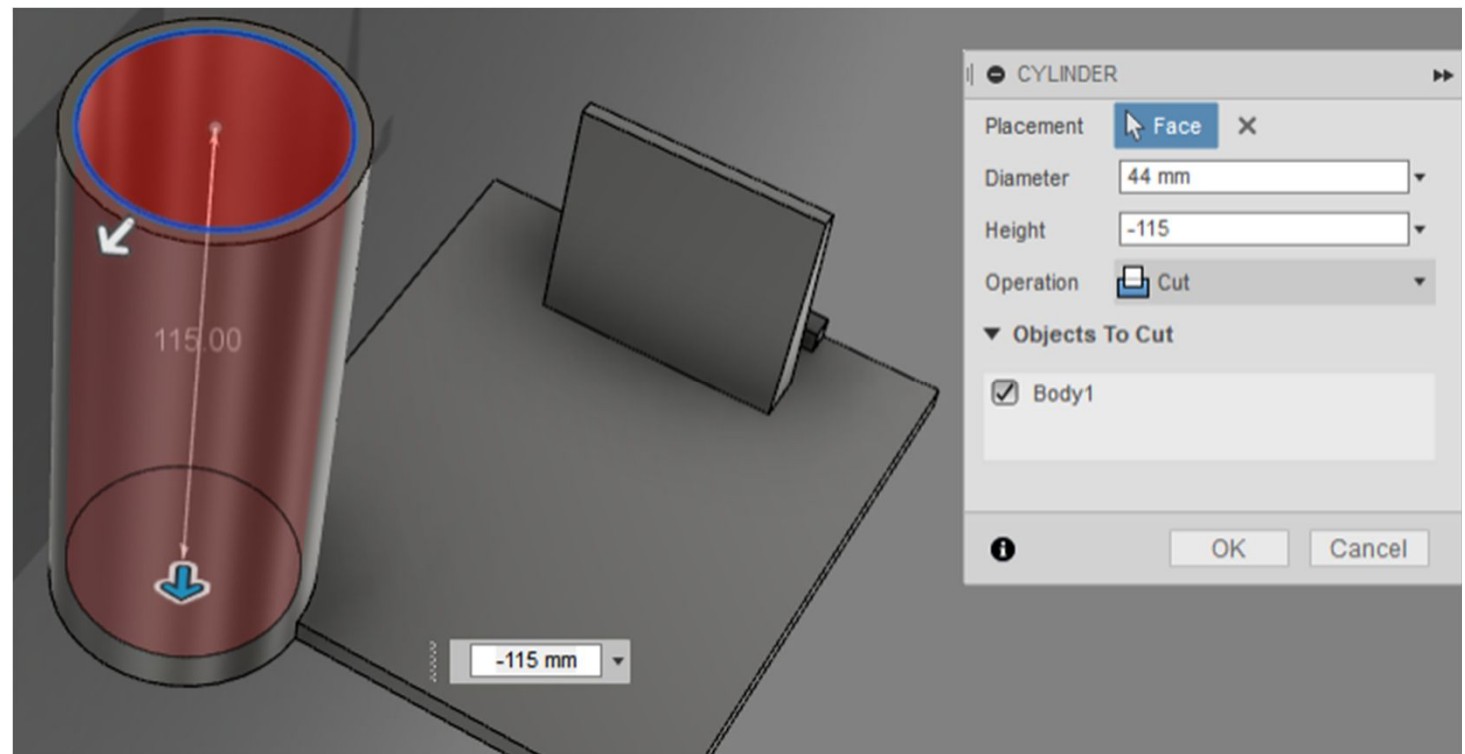
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Cut body using Cylinder

- Move the cursor until you reach 44 mm. Click to confirm the size.
- Drag the arrow manipulator to set the cylinder depth to 115 mm
- Set Operation to **Cut**
- Click OK



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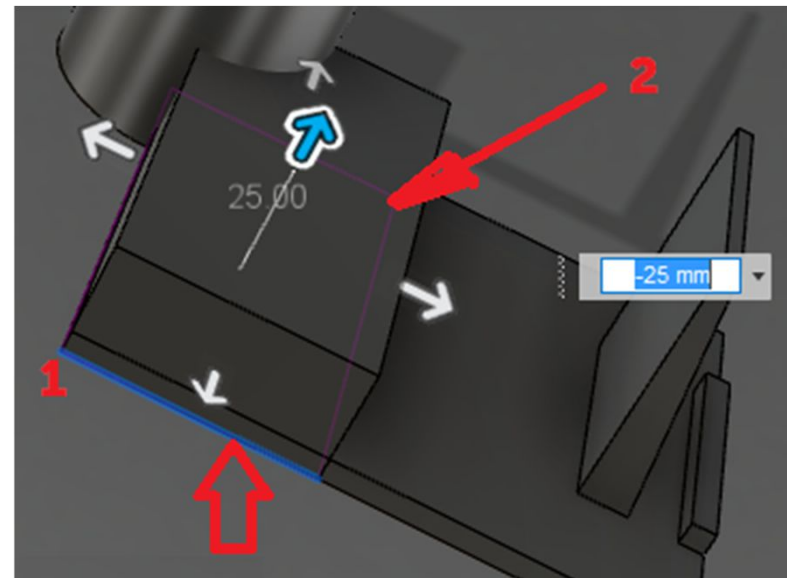


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Create body using Box primitive

Box command creates a rectangular body.

- Click **Create > Box**
- Select the bottom surface of the object
- Select the corner 1 to place the cylinder's center point
- Move the mouse to place the box's opposite corner (point 2)



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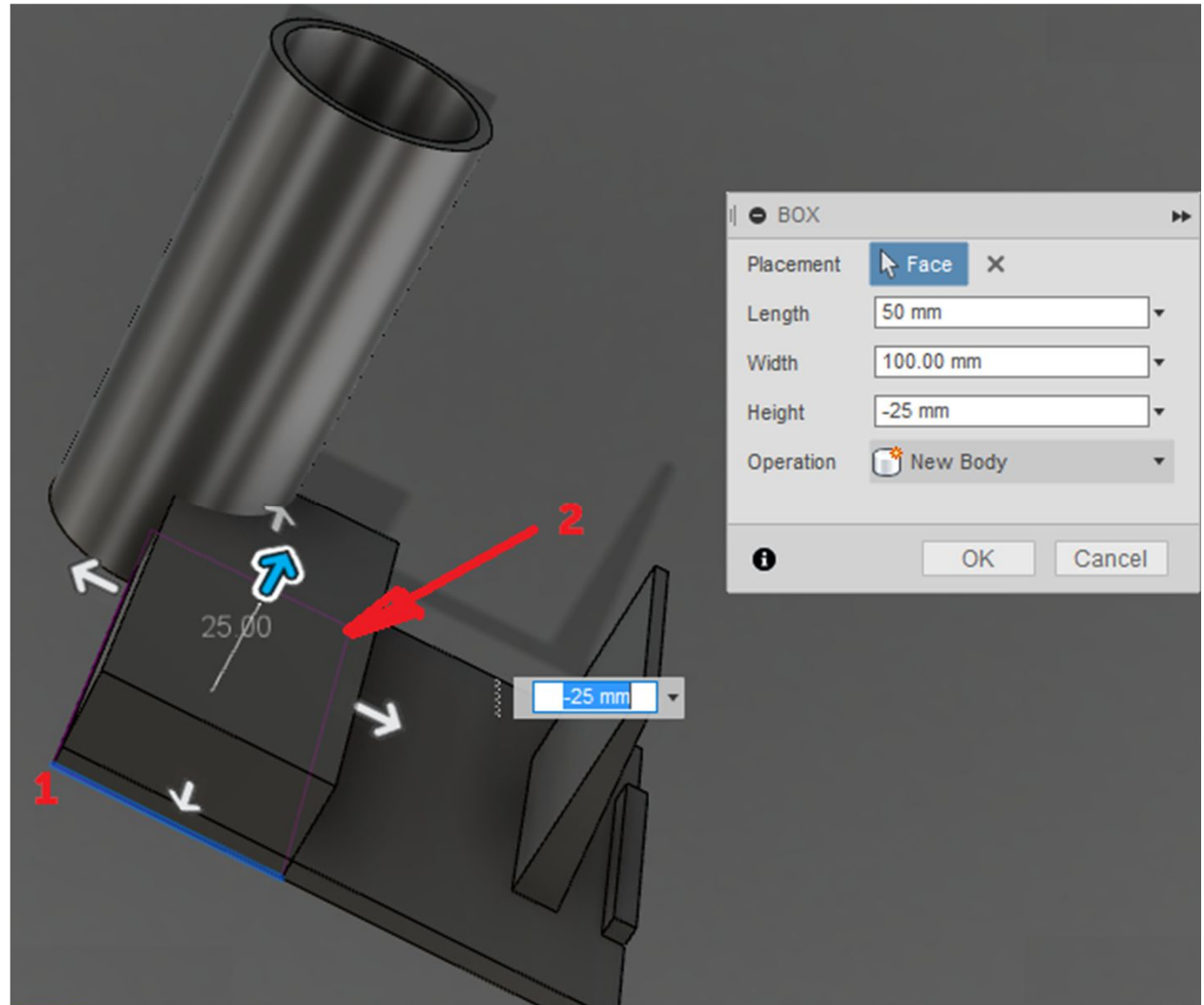
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Create body using Box

- Set the Box options according to the picture
- Click OK



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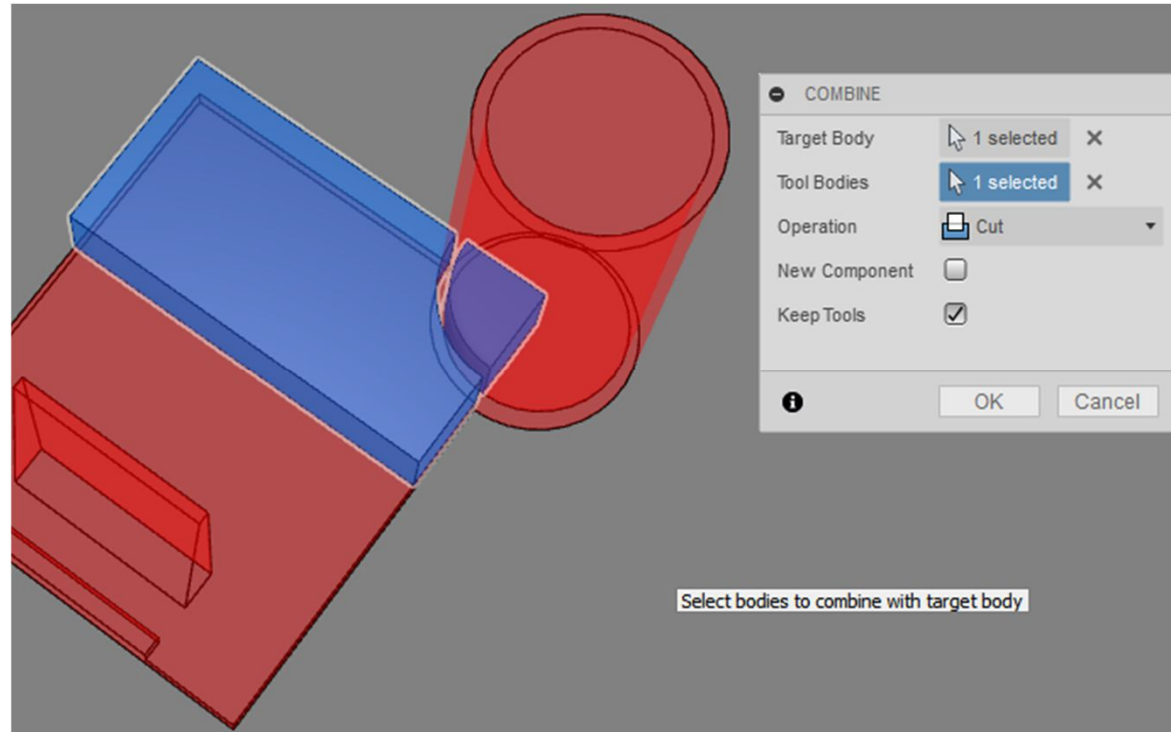
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Combine bodies

- Click **Modify > Combine**
- Select Box as Target Body
- Select Body 1 as Tool Body
- Set Operation to **Cut**
- Check **Keep Tools**
- Click OK to finish



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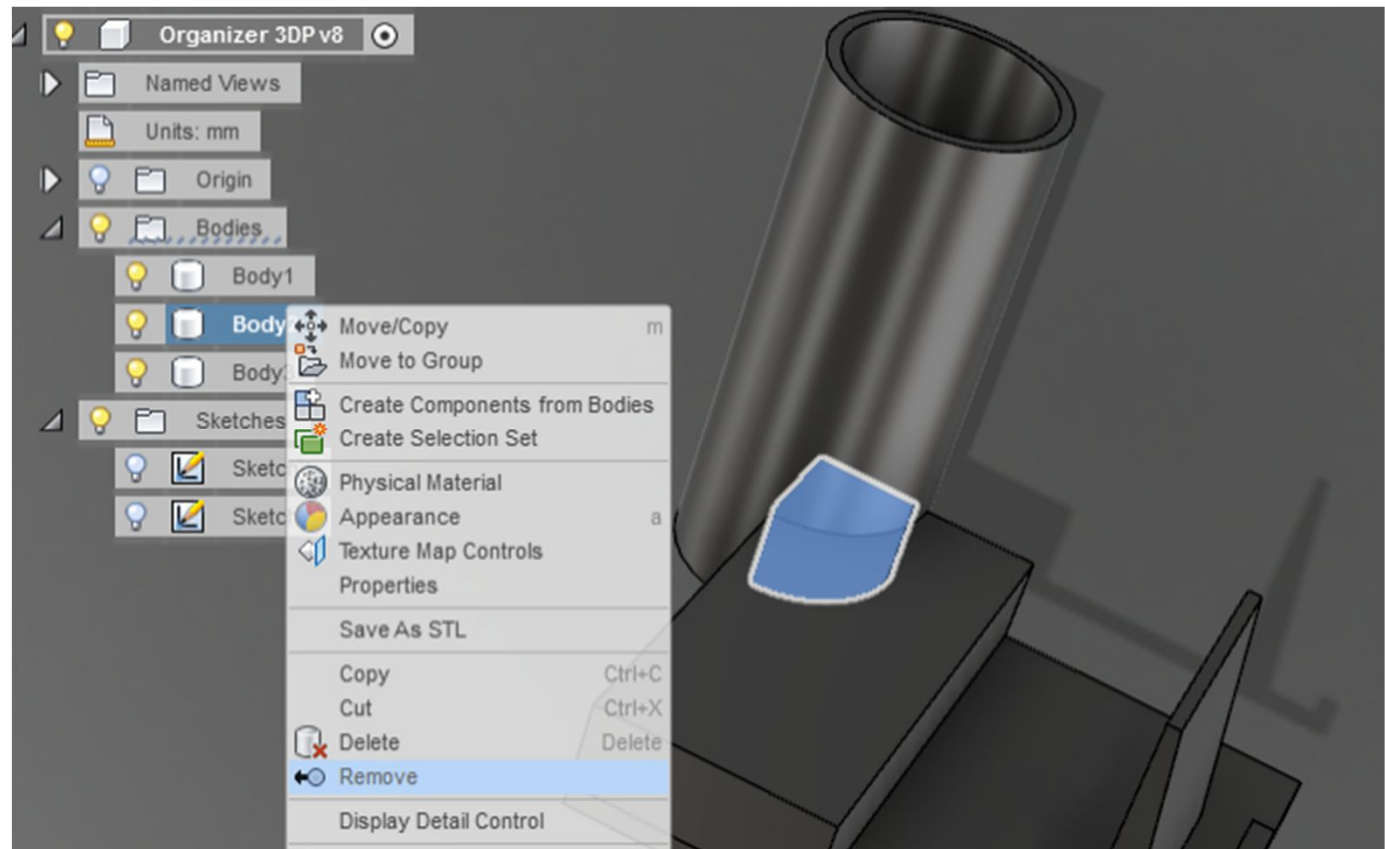
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Remove extra body

A new body has been created and must be removed – right click on the un-needed body, in Browser.



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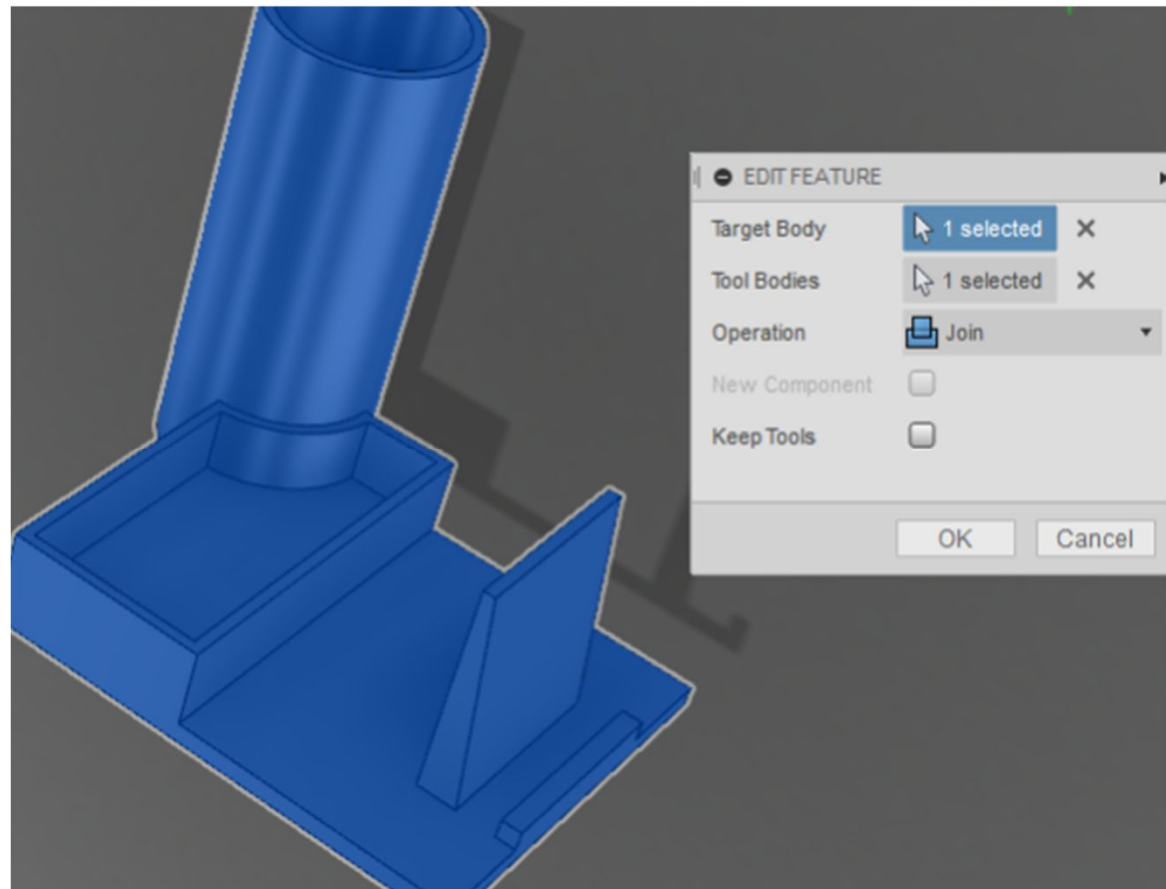


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Join bodies

There are 2 bodies now and will join them to have only one.

- Click **Modify > Combine**
- Select first body as Target Body
- Select second body as Tool Body
- Establece la operación **Join**
- Deselectionar **Keep Tools**
- Clic en OK para finalizar



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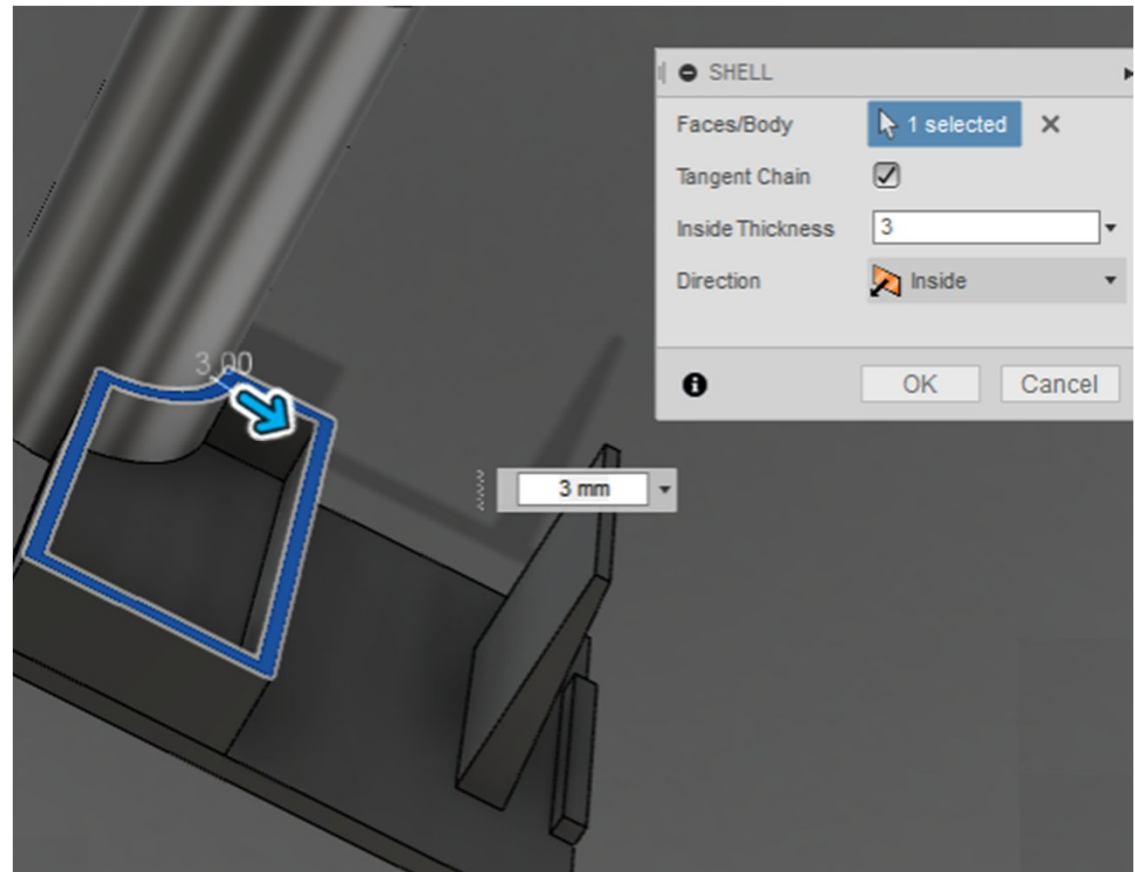
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Modificar la caja usando Shell

- Clic en **Modify > Shell**
- Seleccionar la superficie del superior Box
- Establecer **Inside Thickness** en 3 mm
- Establecer la Dirección en **Inside**
- Clic en OK para finalizar



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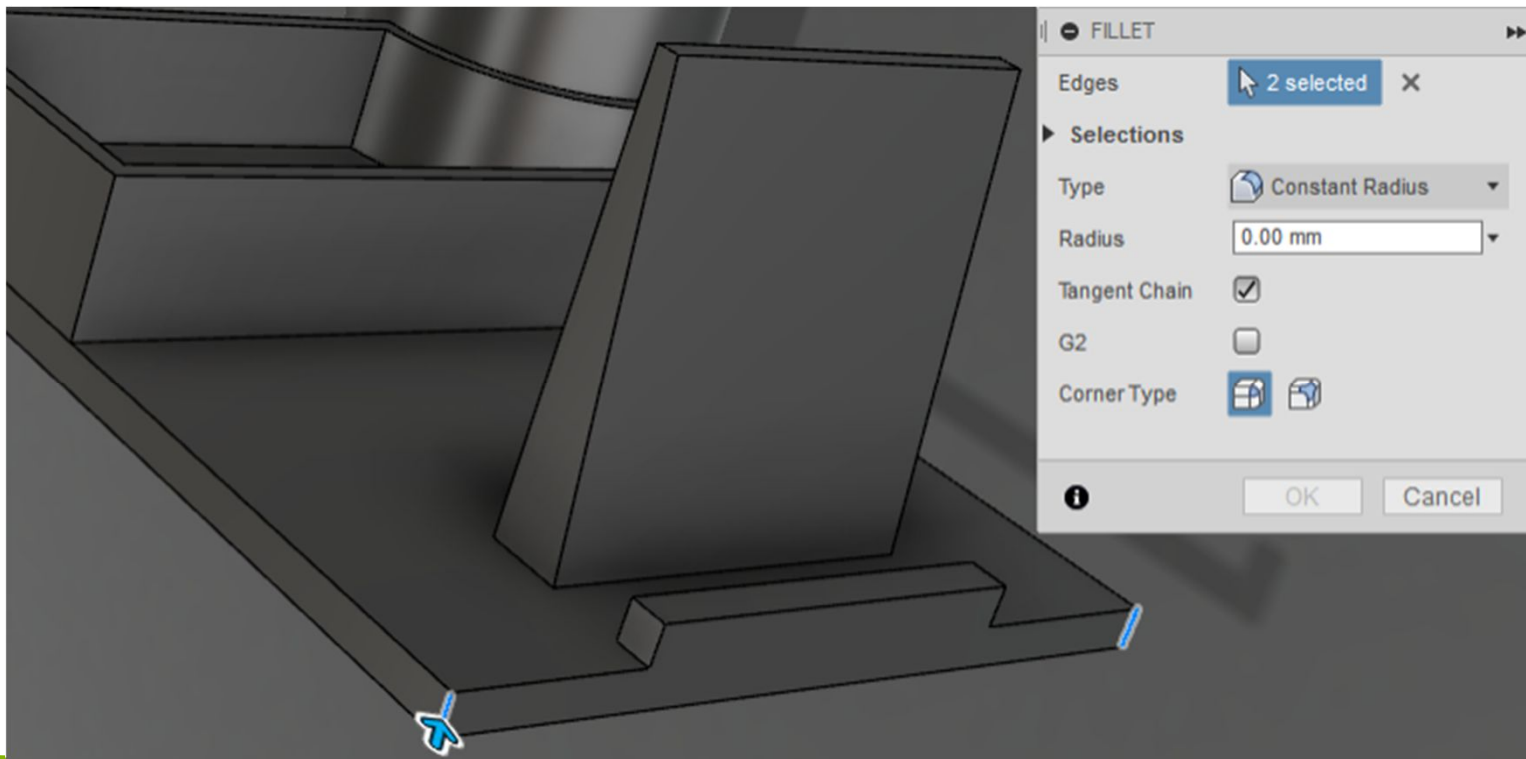
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Fillet edges

- Hold the Shift key and select the two edges shown in the image
- Right-click and select Fillet
- Set the Radius to 10 mm



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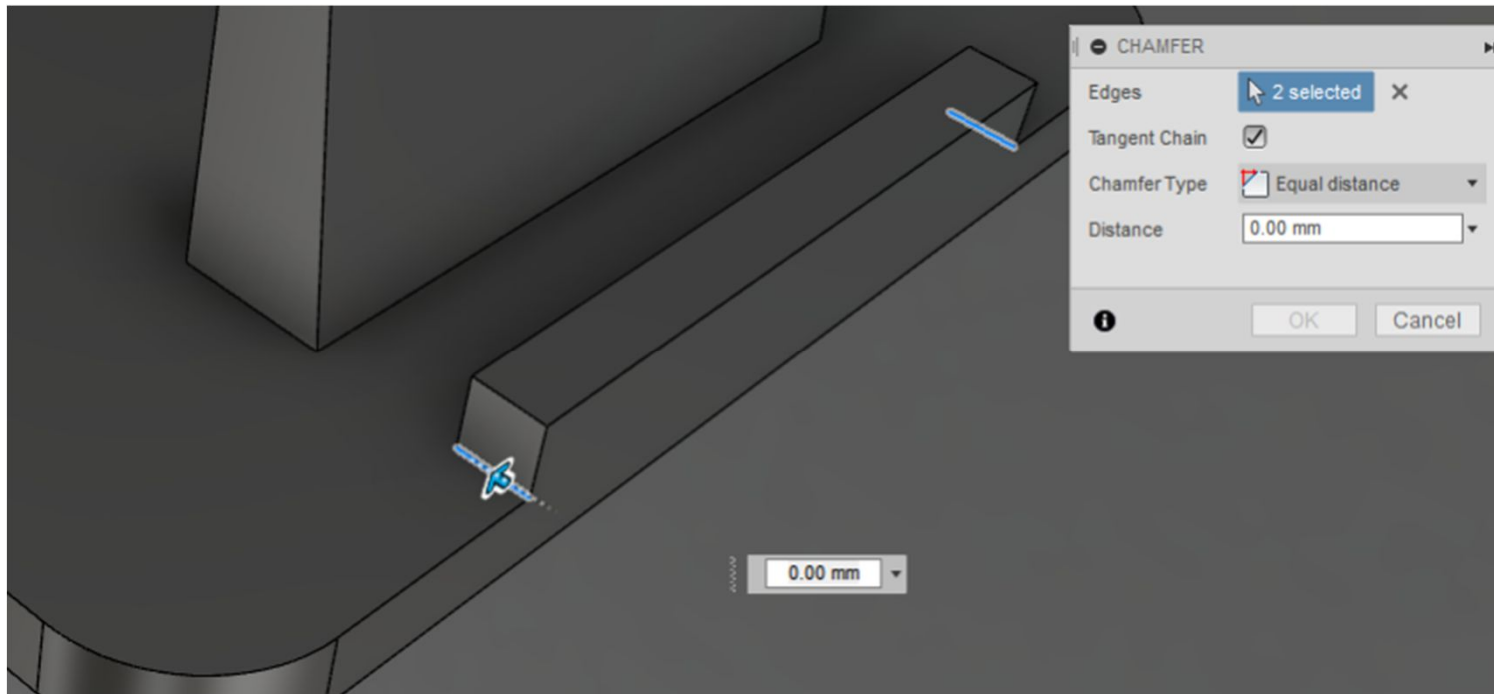
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Chamfer edges

- Hold the Shift key and select the two edges shown in the image
- Right-click and select Chamfer
- Set the Distance to 5 mm



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Use materials to control the appearance

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Chapter Outline

Use materials to control the appearance

- Apply and edit materials
- Modify appearance

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Learning objectives of this chapter

In this section you will learn how to use physical materials and visual materials.

After completing this chapter, you will be able to:

- apply and edit materials
- modify the design appearance

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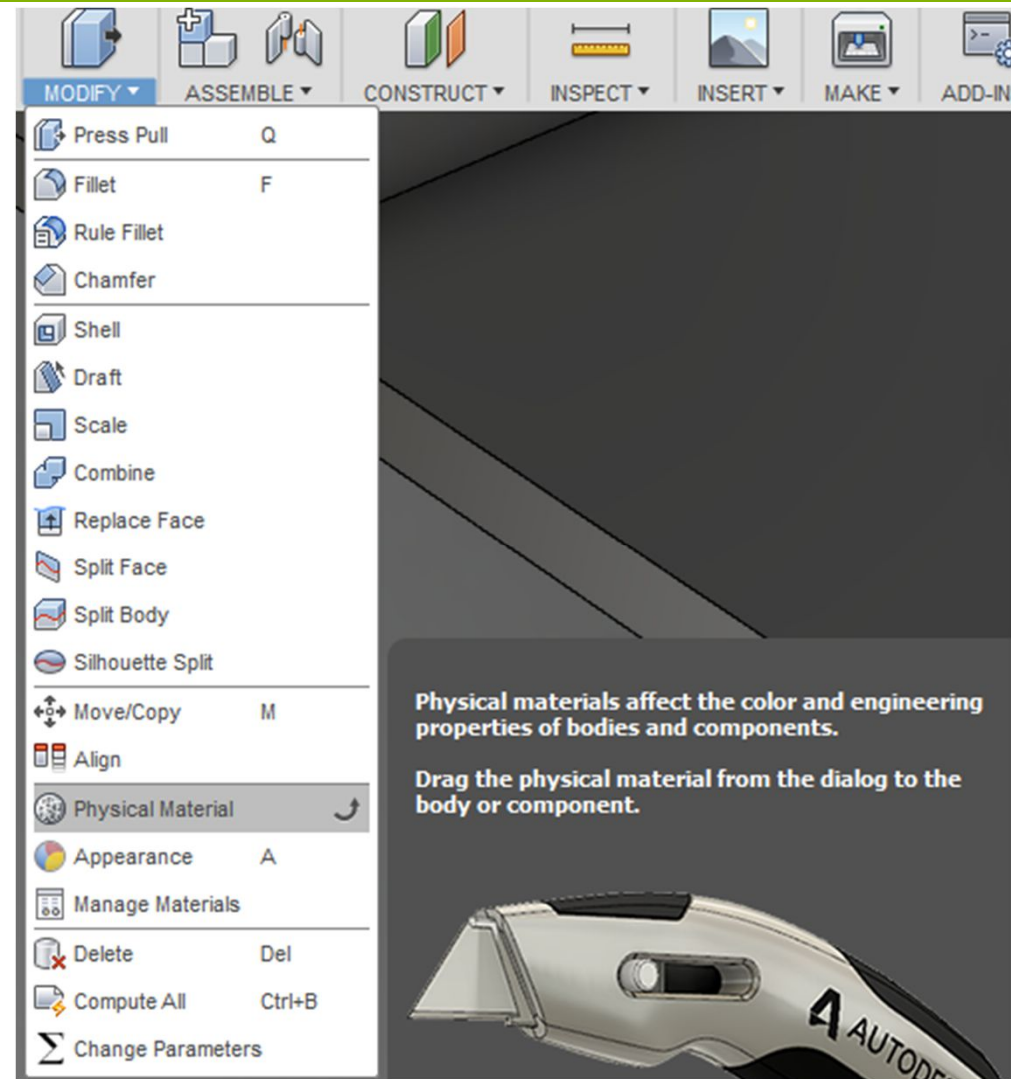


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Apply and Edit materials

There are two types of materials in Fusion360:

- **physical materials** - control the appearance and engineering properties of a component.
- **appearance materials** - override the appearance only.



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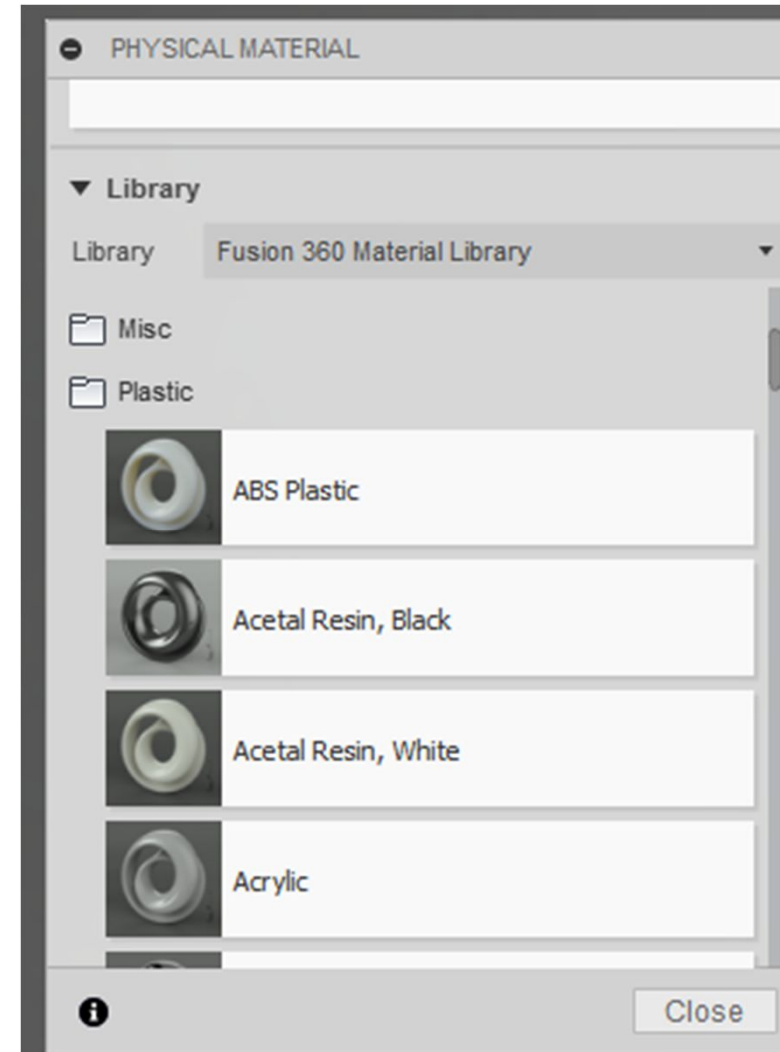
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Add Physical Material

- Click **Modify > Physical Material**
- In the Physical Material dialog box, expand the **Plastic** folder
- Drag **ABS Plastic** onto the model. The material and color of the model are modified
- In the Physical Material dialog box, click Close



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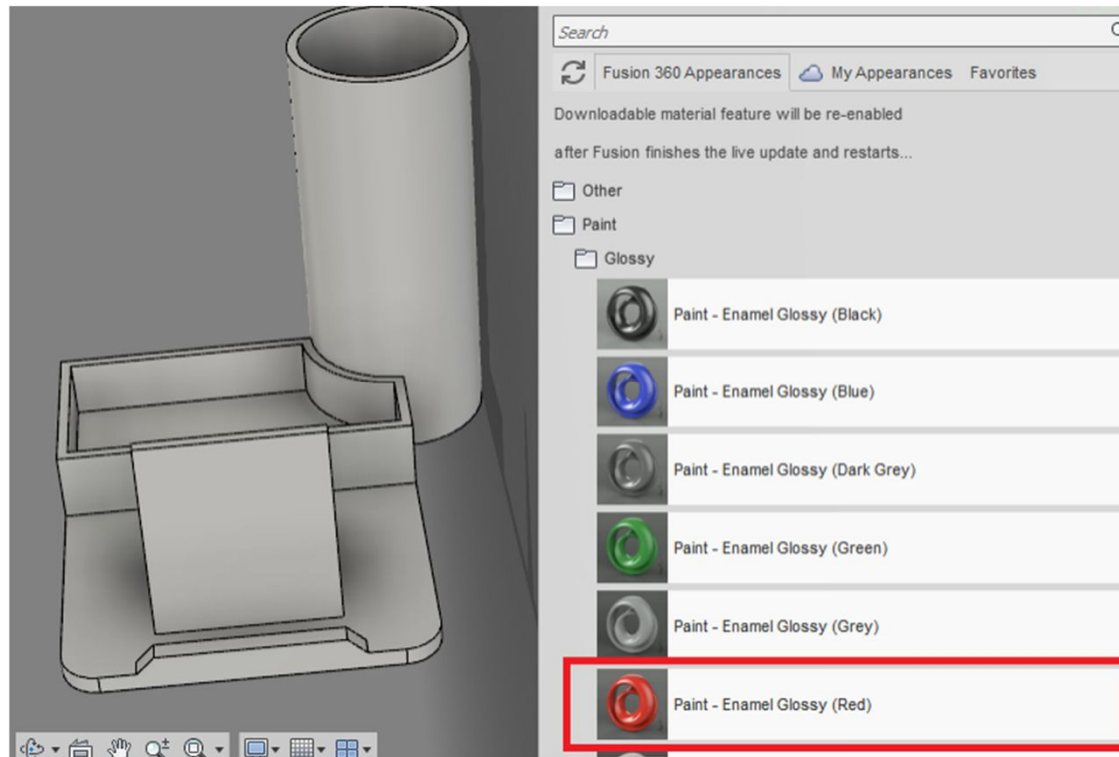
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Modify the Appearance

- Right-click the model. Click **Appearance**
- In the **Appearance** dialog box, expand the **Paint > Glossy** folder
- Scroll down the list to **Paint – Enamel Glossy (Red)**



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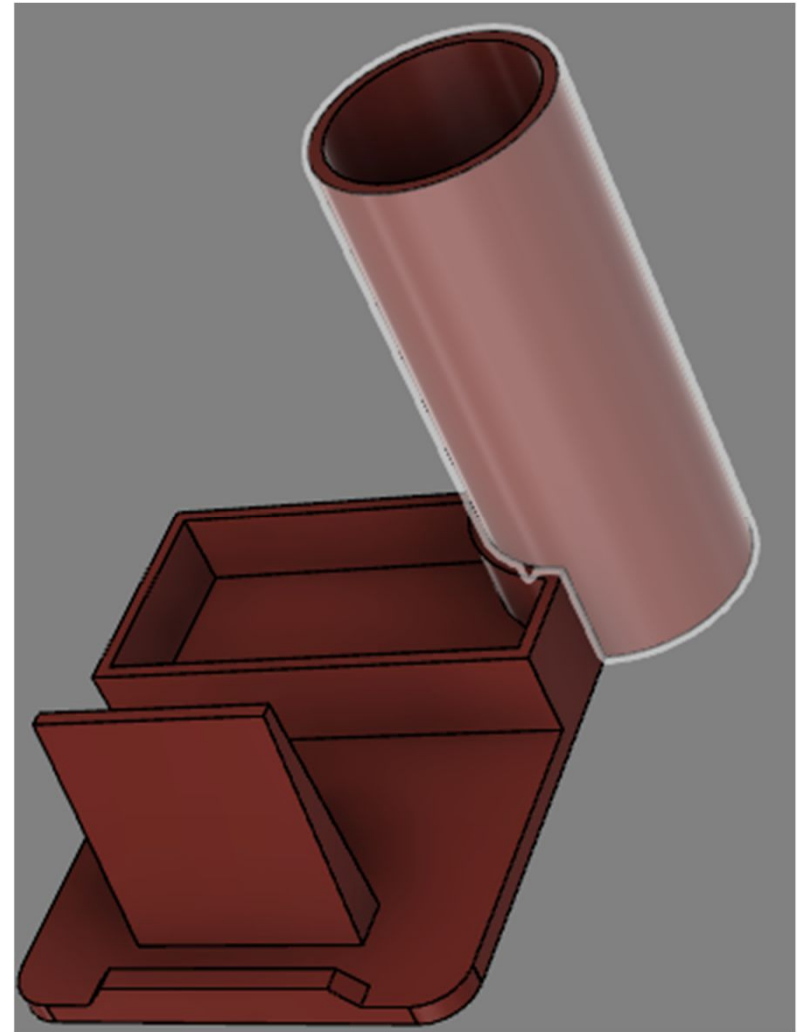
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Modify the Appearance

- Drag **Paint – Enamel Glossy (Red)** onto the model. The material color is modified. Note that the physical material is still ABS.
- In the Physical Material dialog box, click **Close**



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Export models as STL file

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Learning objectives of this chapter

In this section you will learn how to export the 3D models as STL file.

After completing this chapter, you'll be able to export the 3D models as STL file.

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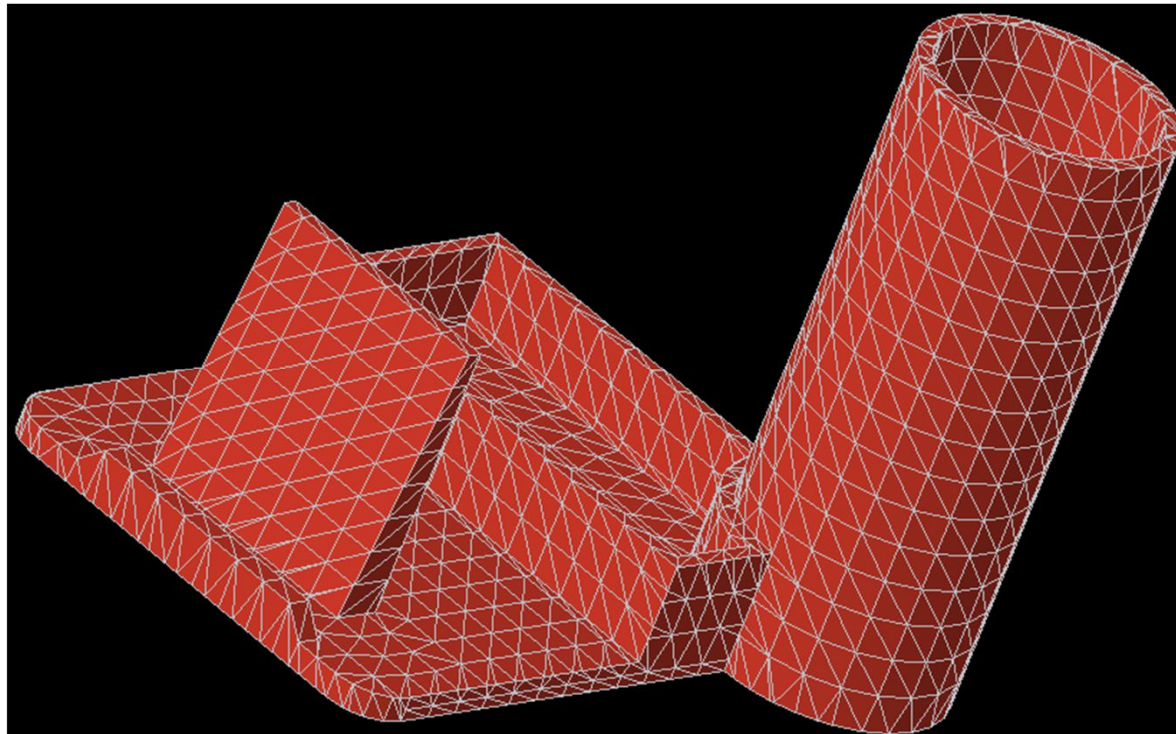
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STL files

STL (STereoLithography) is a common file format used in 3D printing and contains the 3D model which will be printed. STL is a triangulated representation of a 3D CAD model.



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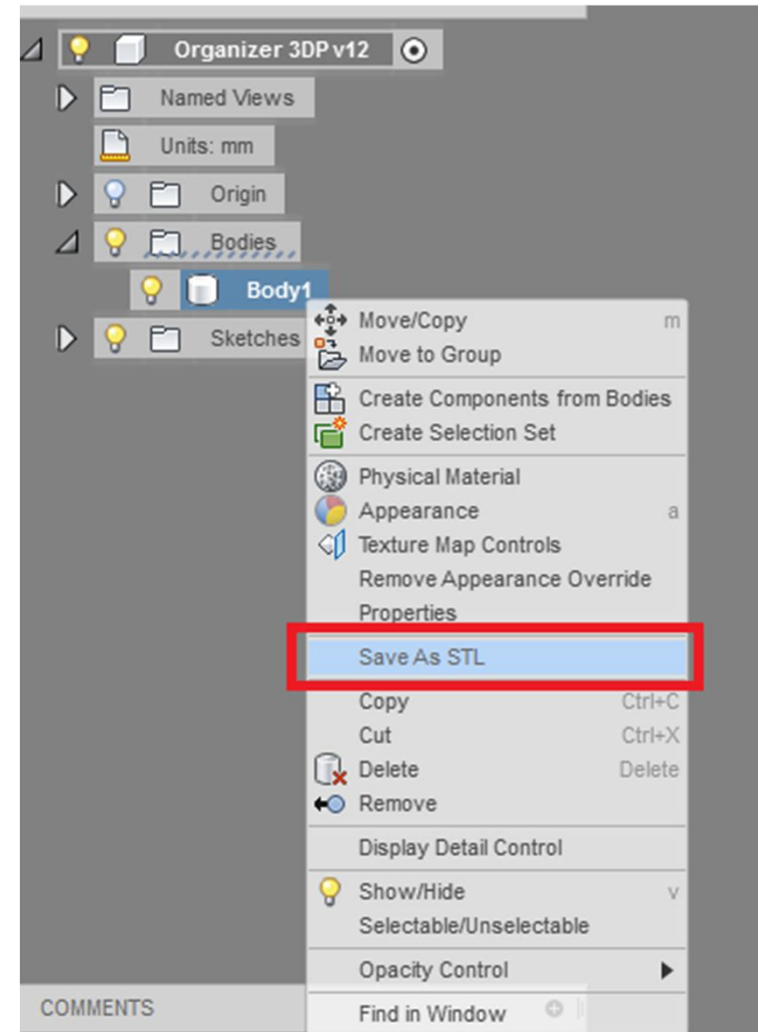
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Export models as STL file

- In the Browser, right click on Body1 > select **Save as STL**
- In the „Save as STL" dialog box select Refinement as **Medium**
- Click OK
- Browse to the folder where you want to save the STL file
- Click Save



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Useful Topic Related Links



<https://www.autodesk.com/products/fusion-360/overview>

<http://help.autodesk.com/view/fusion360/ENU/>

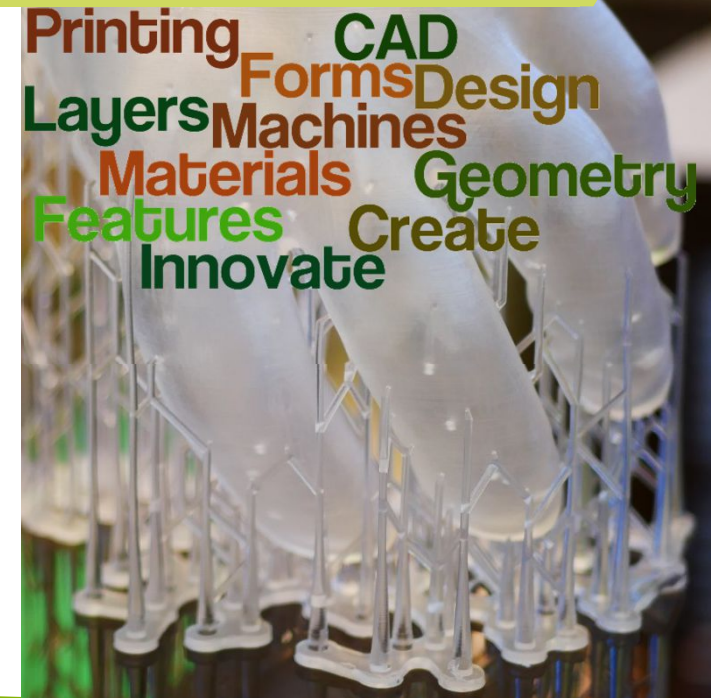
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Select a STL model from online resources



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Aim and Learning Outcomes

Module Aim:

To equip students with basic understanding of using STL files resources for searching and downloading models for 3D printing technology

Number of Hours:

3hrs

Learning outcomes:

- Theoretical knowledge and practical skills on how to access STL files from online repositories/marketplaces/search engines, to search and to download the desired model

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Lecture Outline

- Access STL models online resources (repositories/marketplaces/search engines) such as: Thingiverse, GrabCAD, Pinshape, Yeggi, etc.:
 - Browse the repositories and libraries and download STL models
 - Illustrative examples



Access STL models from online resources

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Access STL files repositories

- STL models can be downloaded, free or paid, from several repositories, marketplaces or search engines such as: Thingiverse, GrabCAD, SketchFab, Pinshape, Yeggi, Autodesk 123d, Pinshape, CGtrader, etc.
- These are offering STL files (in Binary or ASCII formats) usually grouped in categories for making the search and selection easier, but also 3D CAD files in neutral or native formats that can be transformed in STL files and then used for 3D printing.



Access STL files repositories

- STL files can be also uploaded on these repositories for sharing creative and useful ideas/objects
- Some of these repositories are owned by 3D printers manufactures:
 - Examples: Thingiverse by Makerbot, YouMagine by Ultimaker, Zortrax Library by Zortrax or GrabCAD by Stratasys.



Access STL files repositories

- Details on the most important resources for STL files

Name	Link	Type	Free/paid
Thingiverse	www.thingiverse.com	Repository	Free
GrabCAD	www.grabcad.com	Repository	Free
SetkchFab	https://sketchfab.com/tags/repository	Repository	Free
Yeggi	www.yeggi.com	Search engine	Free, paid
Autodesk123d	http://www.123dapp.com/Gallery/content/all	Repository	Free
STL Finder	www.stlfinder.com	Search engine	Free, paid
Pinshape	https://pinshape.com/	Marketplace	Free, paid
CGTrader	https://www.cgtrader.com	Marketplace	Free, paid
Yobi3D	https://www.yobi3d.com/	Search engine	Free
Zortrax Library	http://library.zortrax.com/	Repository	Free
YouMagine	https://www.youmagine.com	Repository	Free

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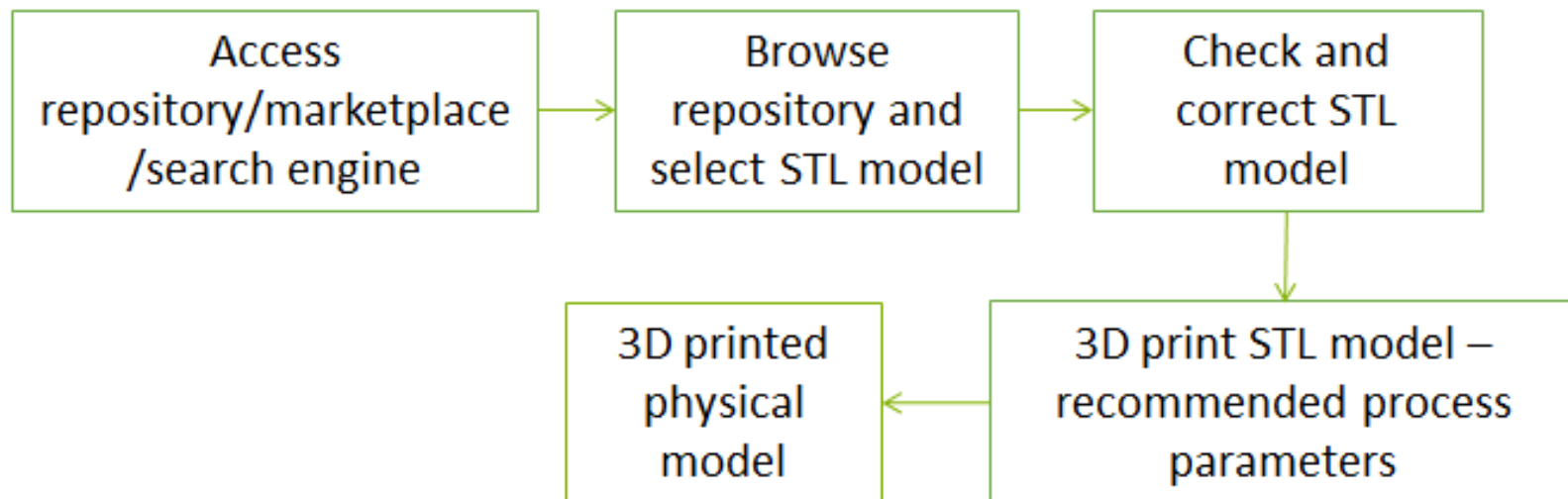
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Access STL files repositories

- Workflow for 3D printing a STL model from an online repository/search engine/marketplace



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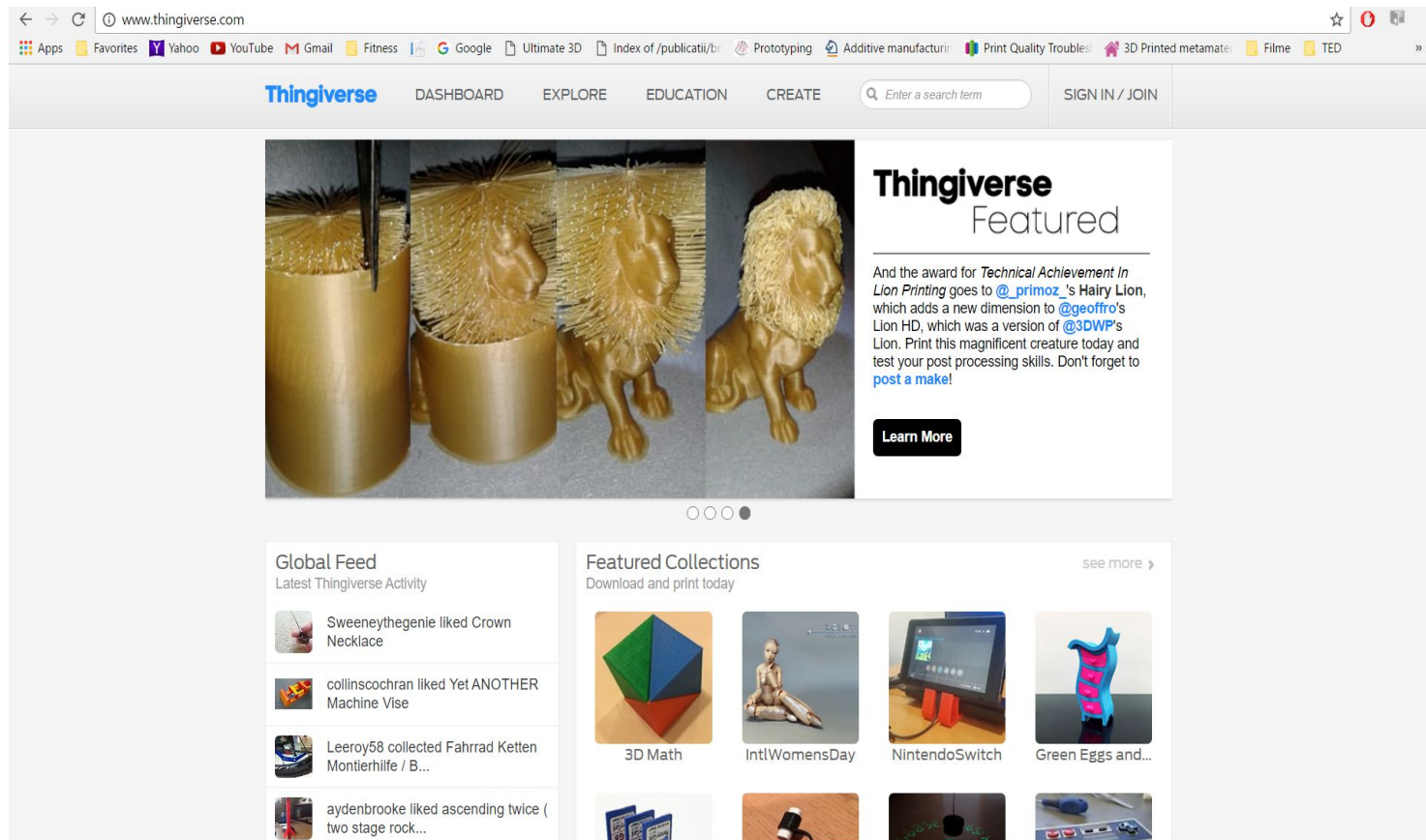
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Examples – Thingiverse

- Thingiverse – repository of millions of STL models



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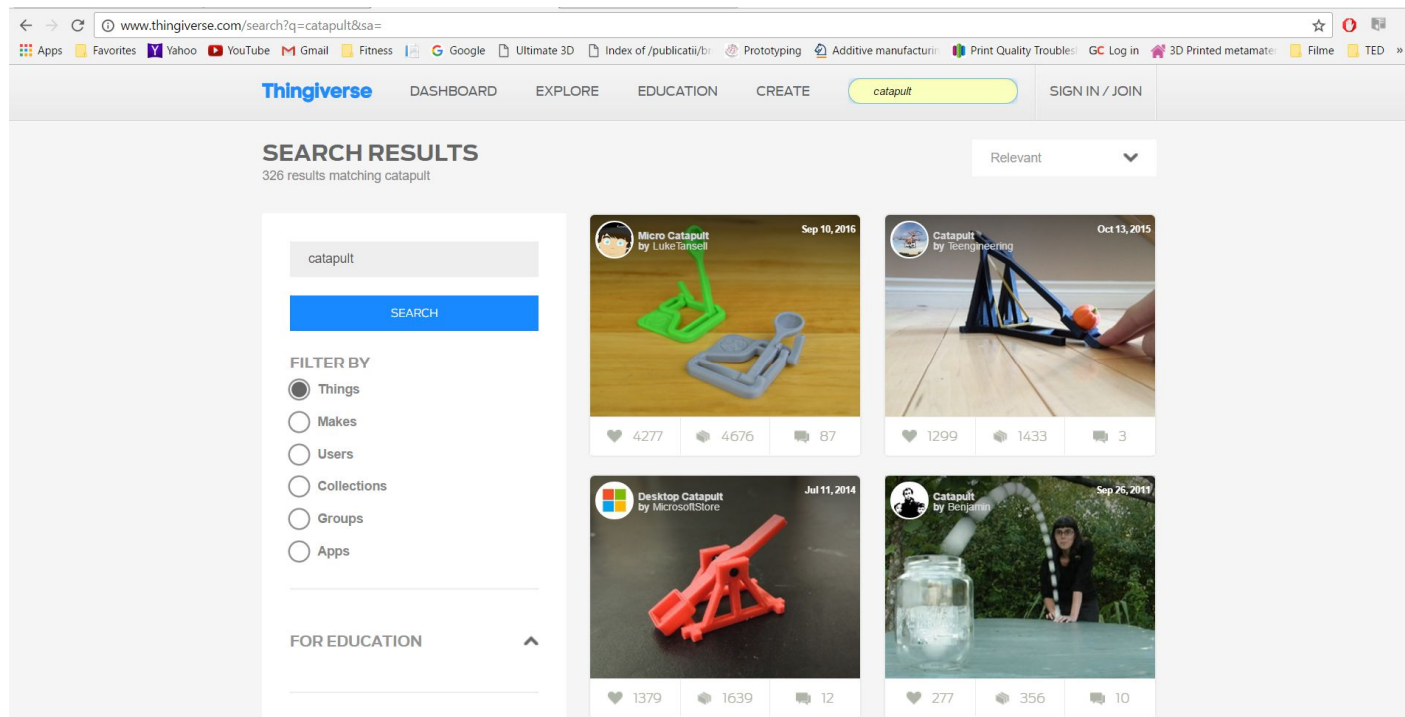
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Examples – Thingiverse

- Step 1: Searching database using the term: “catapult” determines the display of different models associated with this word.



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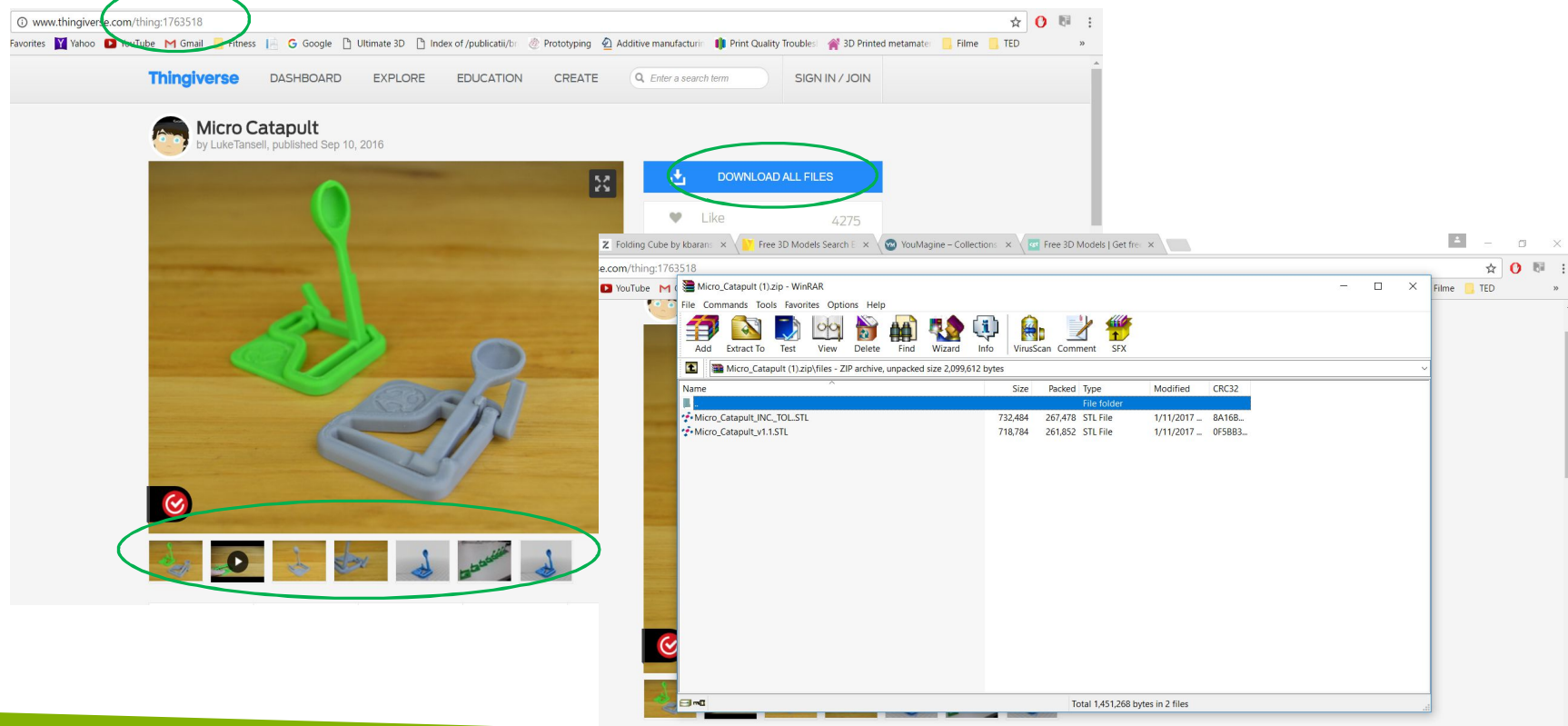
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Examples – Thingiverse

- Step 2: One model catapult is selected (no 1763518) and different images of 3D CAD models, a short movie and pictures of 3D printed catapult are shown.



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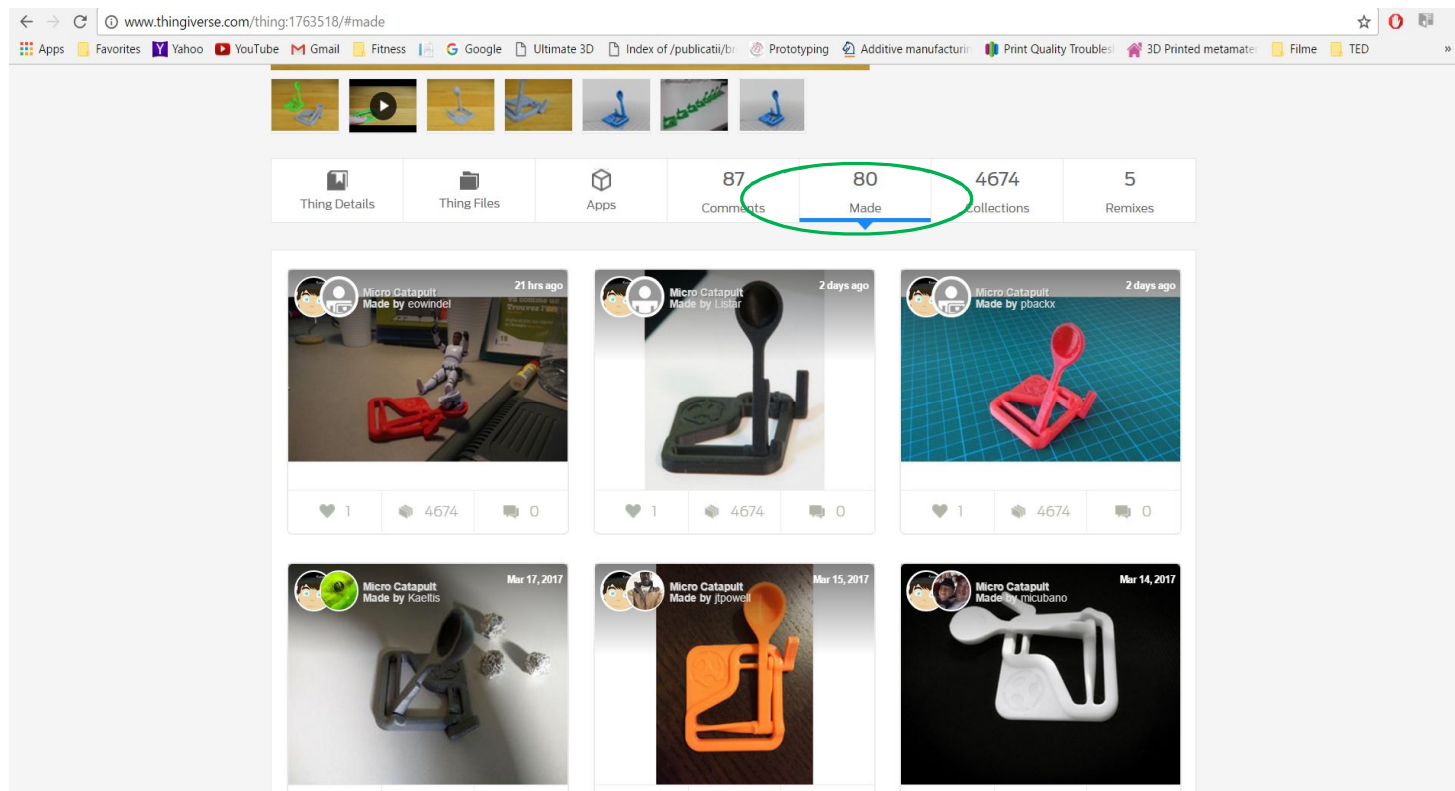
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Examples – Thingiverse

- Step 3: Access information and comments on 3D printed variants of the catapult under Made tab



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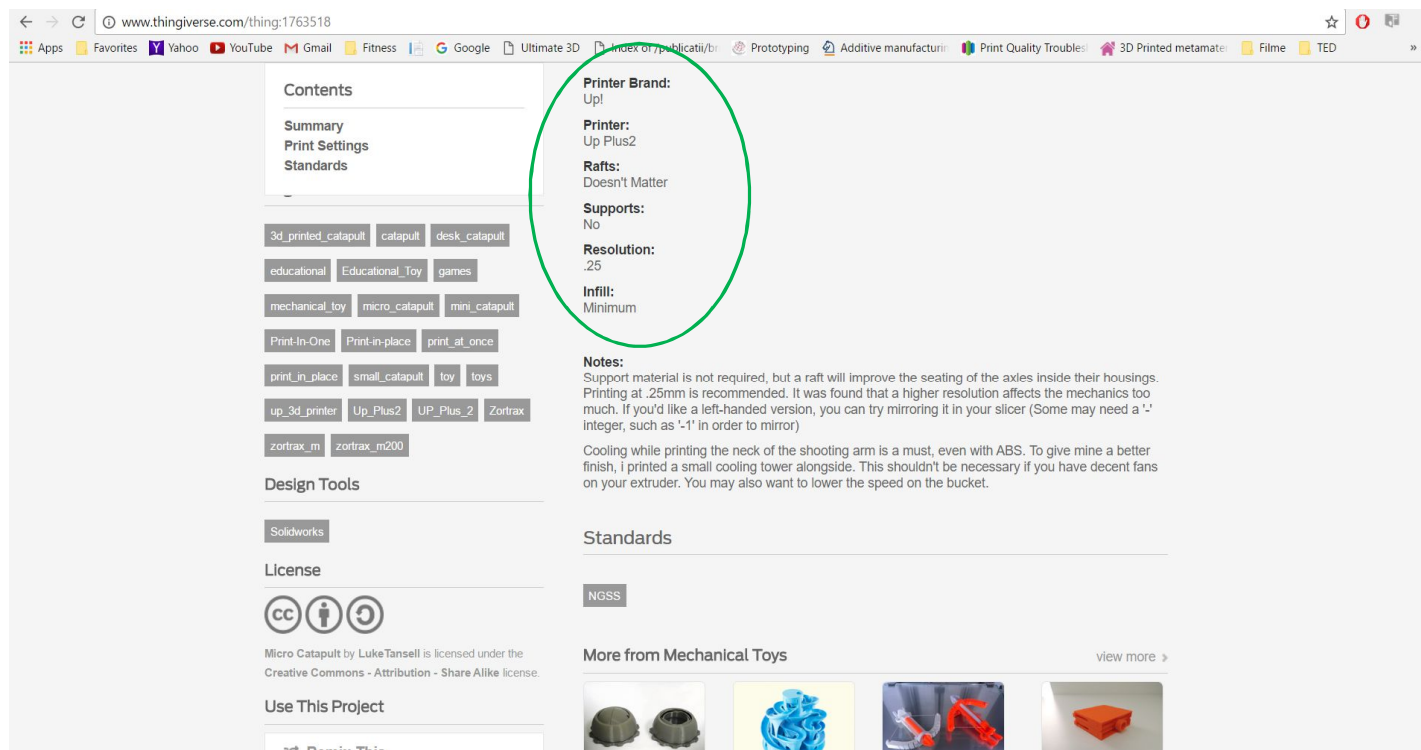
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Examples – Thingiverse

- Step 4: Access information (Summary) on recommended 3D printing settings: material, layer width or resolution, nozzle diameter, orientation supports, etc.



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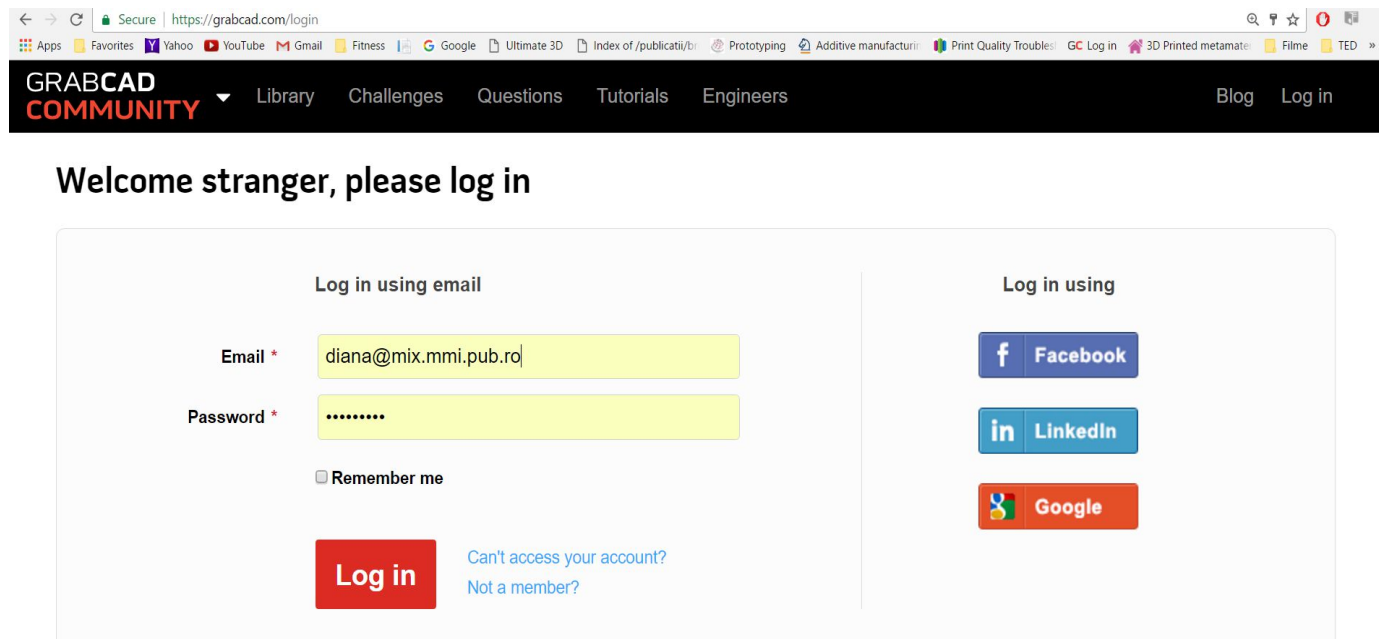
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Examples – GrabCAD

- GrabCAD – repository for 3D CAD models and STL files
 - Requires creating an user account



The screenshot shows the GrabCAD Community login page. The browser address bar displays 'https://grabcad.com/login'. The page header includes the 'GRABCAD COMMUNITY' logo and navigation links: Library, Challenges, Questions, Tutorials, Engineers, Blog, and Log in. The main heading reads 'Welcome stranger, please log in'. The login section is divided into two columns. The left column, titled 'Log in using email', contains fields for 'Email *' (with the text 'diana@mix.mmi.pub.ro') and 'Password *' (masked with dots), a 'Remember me' checkbox, and a red 'Log in' button. Below the button are links for 'Can't access your account?' and 'Not a member?'. The right column, titled 'Log in using', features three social login buttons: Facebook, LinkedIn, and Google.

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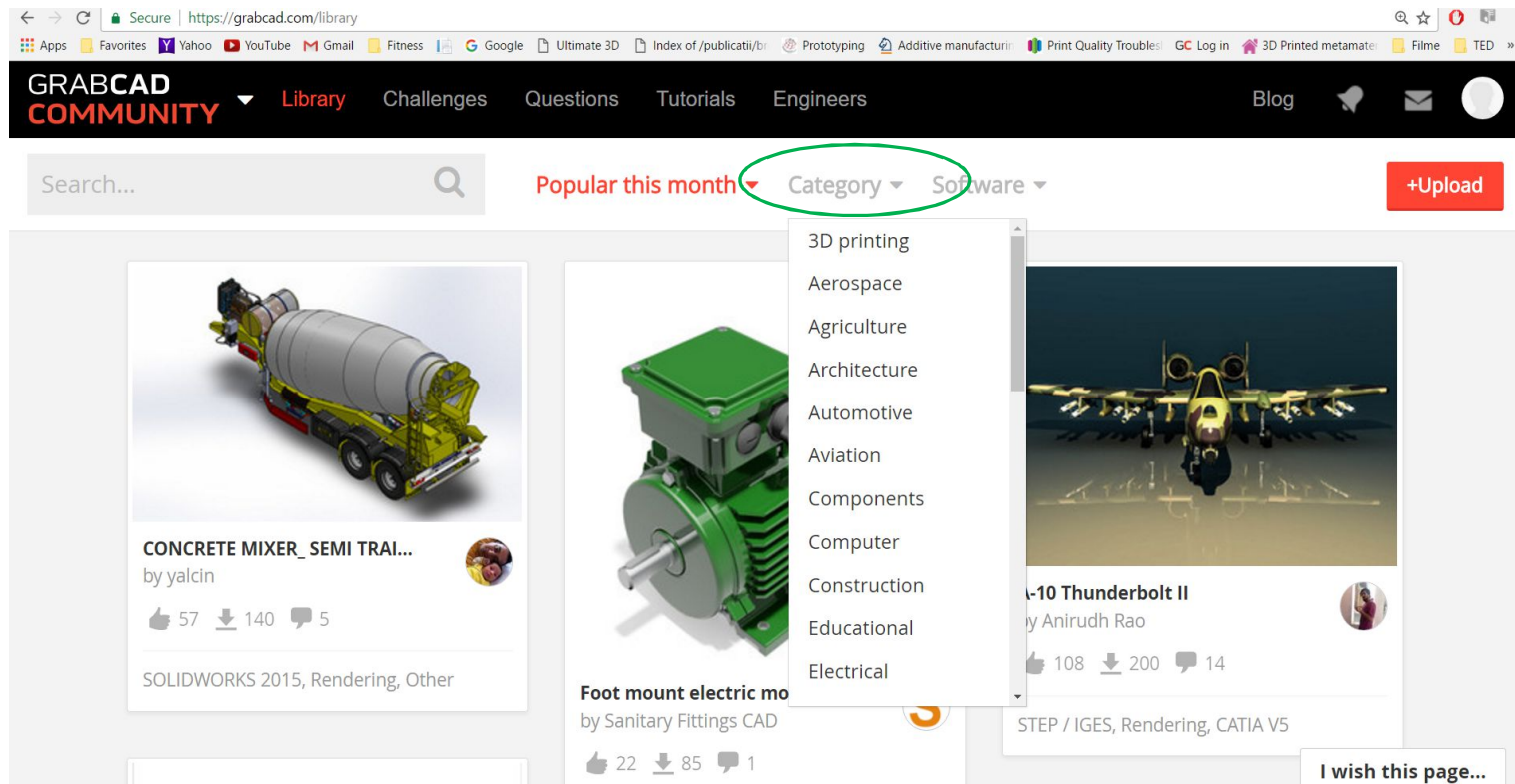
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Examples – GrabCAD

- Browsing GrabCAD by categories



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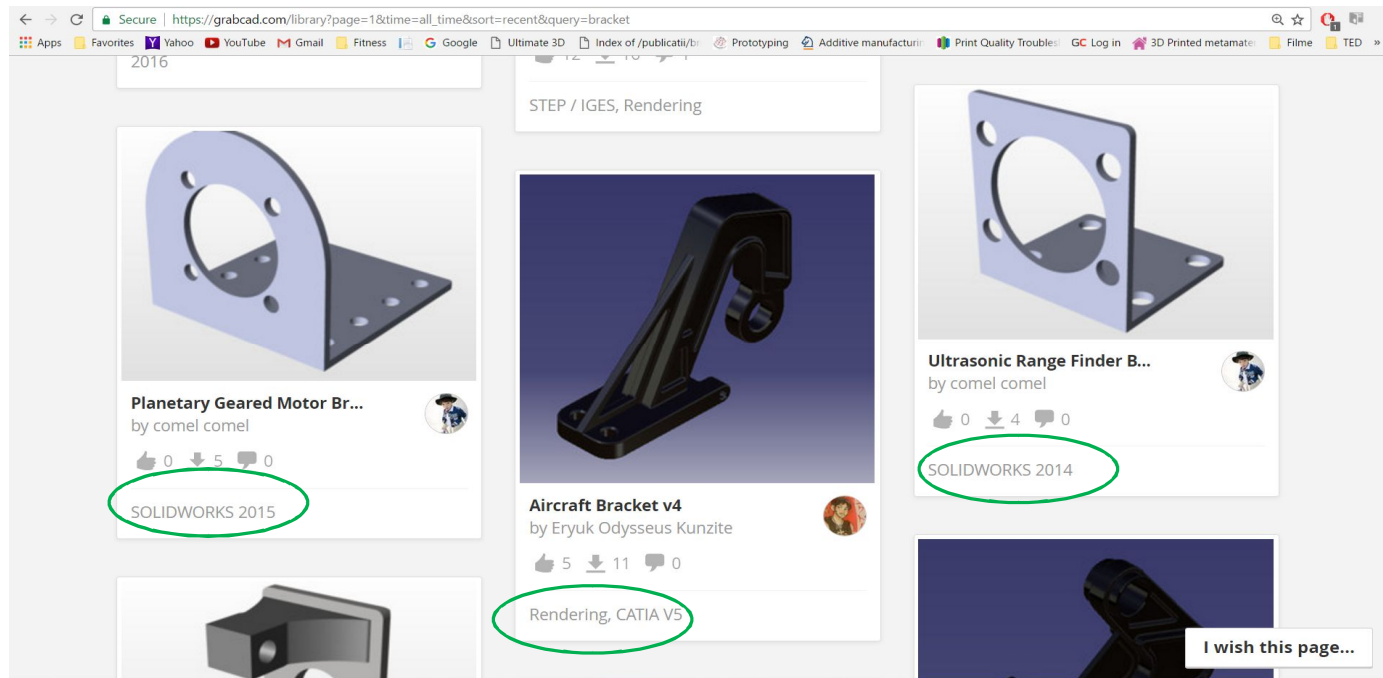
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Examples – GrabCAD

- Step 1: Searching the word “bracket” on GrabCAD produces the results below. For each model, the format in which the object can be found (neutral format or 3D CAD native format) is specified.



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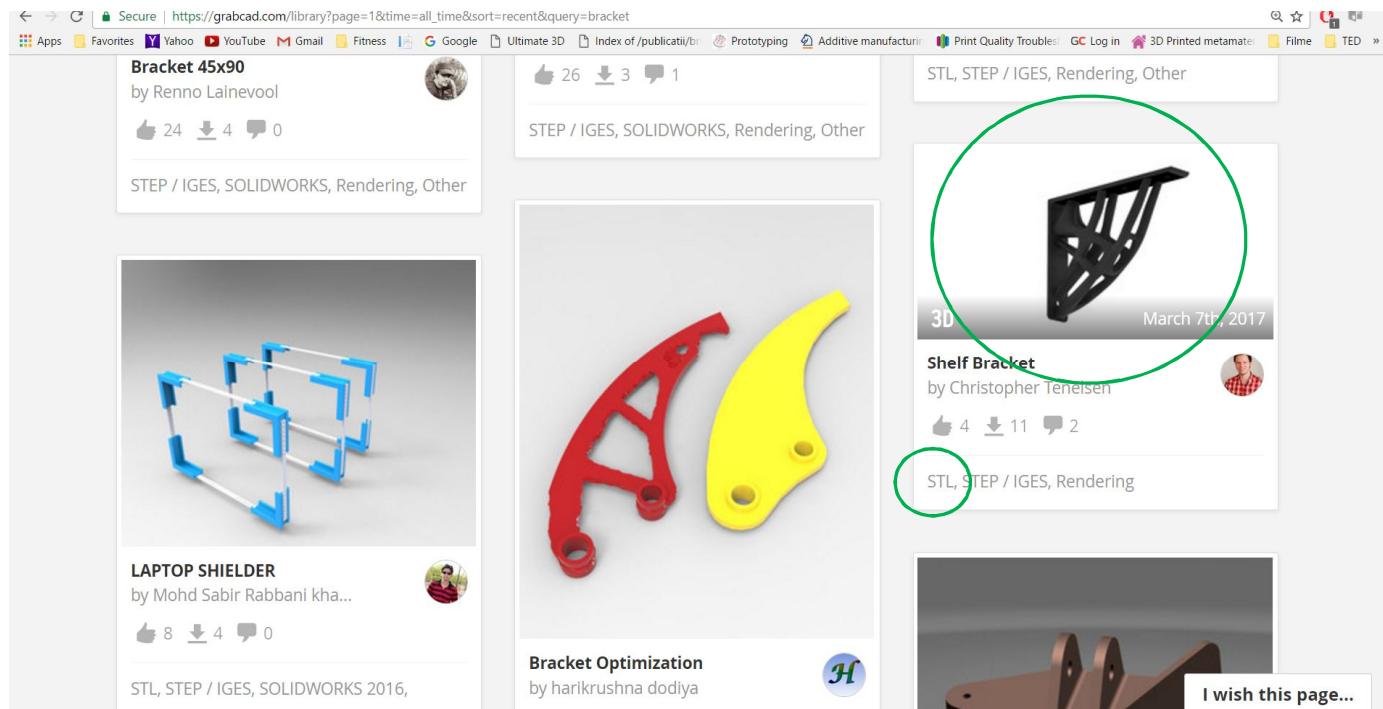
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Examples – GrabCAD

- Step 2: Select and download on model of bracket in STL file format



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Examples – GrabCAD





- Step 3: Access information on model or recommended 3D printing settings

Germany.

And this is my topology-optimized design of a shelf bracket. It is strong enough to carry up to 50 kg (110 lbs) per part while printed with ABS-M30 (according to FEA simulations). It is easy to print as you can see on the picture (built with my home printer, PLA). It can carry shelves with a depth of about 7-10 in (170-250 mm). The idea was to give a futuristic-looking bionical design to a common thing and which can only be produced using additive manufacturing.

[Show less...](#)

Files (5)

Shelf Bracket /			
	Shelf Bracket 2.stl	stl	March 7th, 2017
	DSC_0003.JPG	jpg	March 7th, 2017
	Shelf Bracket.stp	stp	March 7th, 2017
	untitled.17.jpg	jpg	March 7th, 2017


Details

Uploaded: March 7th, 2017
Softwares: STL, STEP / IGES, Rendering
Categories: 3D printing
Tags: extremeredesignengineeringp

11 Downloads **4 Likes** **2 Comments**

4 Likes

More by Christopher Tenelsen [View all](#)



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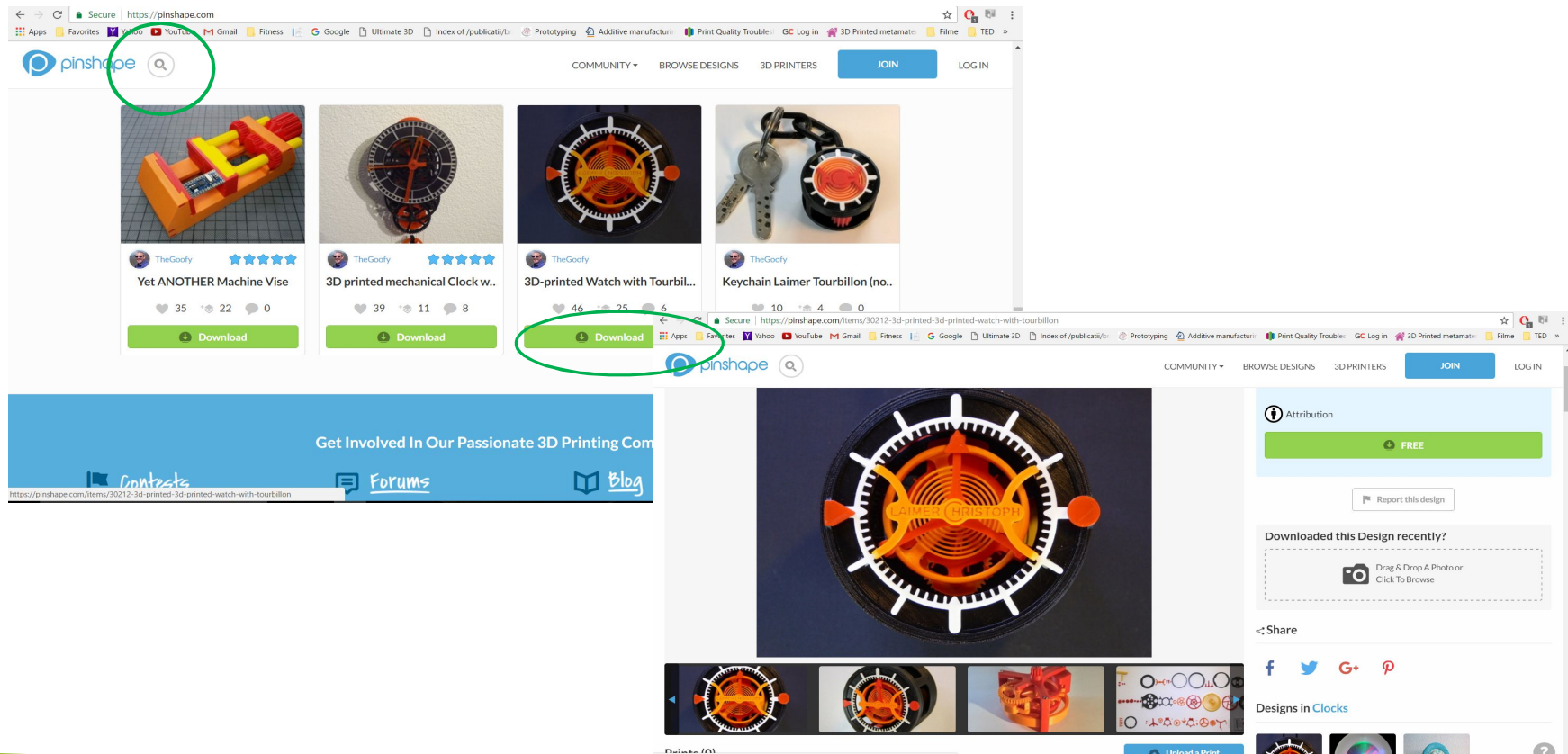
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Examples – Pinshape

- Step 1: Access Pinshape and search a model: “3D watch” – for example



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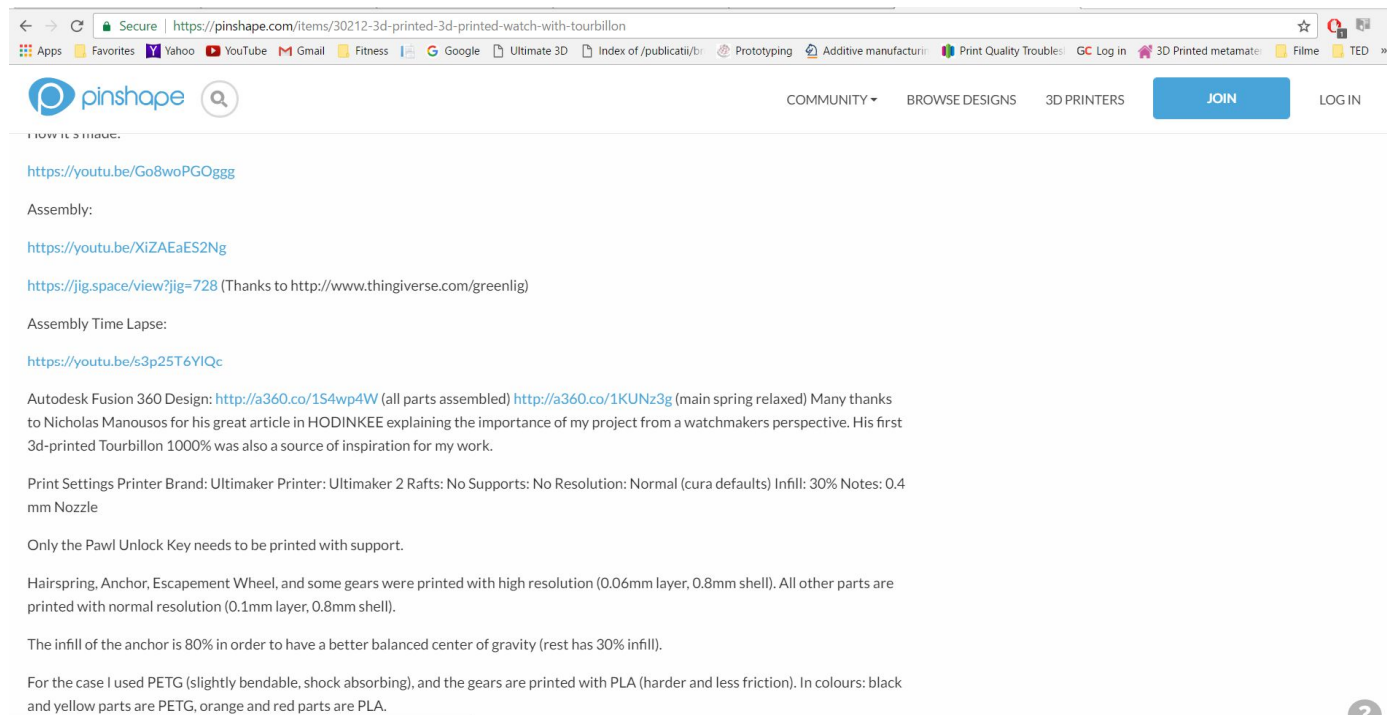
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Examples – Pinshape

- Step 2: Access information on how to 3D print the components and to assembled them. This are presented as text and/or using videos.



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Examples – Pinshape

- Step 3: Download and extract each component of the 3D watch

The screenshot shows a web browser displaying a Pinshape project page for a 3D printed watch with a tourbillon. The page includes a list of parts and a WinRAR file extraction window.

Part List:

- 1 Pin, Diameter 1.5 mm, Length 55.5 mm (tourbillon axis)
- 1 Pin, Diameter 1.5 mm, Length 12 mm (anchor axis)
- 1 Pin, Diameter 1.5 mm, Length 8.5 mm (planet gear axis)
- 3 Pins, Diameter 2 mm, Length 57 mm (axis for pinions for minutes and hours)
- 6 Pins, Diameter 2 mm, Length 22 mm (axis for basic transmission)
- 1 Pin, Diameter 2 mm, Length 15 mm (attachment main spring)
- 1 Pin, Diameter 3 mm, Length 22.5 mm (axis for main spring)
- 1 Pin, Diameter 3 mm, Length 31 mm (axis for main pinion)
- 3 Washers, Diameter 3 mm (main spring, pinion)
- 6 Washers, Diameter 2 mm (transmission)
- 5 Washers, Diameter 1.5 mm (tourbillon, escapement)
- 5 Screws, Diameter 1.8 mm, Length 6.5 mm (ratchet pawls)
- 5 Screws, Diameter 1.5 mm, Length 5 mm (going barrel)
- 4 Screws, Diameter 1.5 mm, Length 10 mm (base plate)
- 4 Screws, Diameter 1.8 mm, Length 12 mm (clock face)
- 3 Screws, Diameter 1.5 mm, Length 10 mm (tourbillon cage)

Small holes are usually not very accurately printed. Use a drill to smooth the inner with very little friction, and very little play. If you don't find pins or screws with the larger pieces - there is some "meet" which can be drilled out.

The WinRAR window shows the following files:

Name	Size	Packed	Type	Modified	CRC32
CaseBasePlate.stl	1,321,784	366,037	STL File	3/6/2017 6...	1949A...
CaseCenterPlate.stl	966,884	315,129	STL File	3/6/2017 6...	CBFA...
CaseFaceTicks.stl	194,884	42,769	STL File	3/6/2017 6...	794E7E...
CaseHook.stl	516,284	209,663	STL File	3/6/2017 6...	97F102...
CaseHoursWheelBearing.stl	200,084	54,437	STL File	3/6/2017 6...	4D9D6...
CaseMinutesWheelBearing.stl	244,684	61,827	STL File	3/6/2017 6...	ED680...
CaseTourbillonBearingFront.stl	326,084	91,431	STL File	3/6/2017 6...	412802...
CaseTourbillonBearingFrontV1.stl	302,484	93,659	STL File	3/6/2017 6...	47EDB...
ChainLinks.stl	263,484	56,650	STL File	3/6/2017 6...	61825E...
ChainRings.stl	256,284	72,445	STL File	3/6/2017 6...	EF0486...
GearsHoursA1.stl	721,284	165,726	STL File	3/6/2017 6...	F599C5...
GearsHoursA2.stl	710,484	145,718	STL File	3/6/2017 6...	626807...
GearsHoursA3_Clamp.stl	314,084	67,907	STL File	3/6/2017 6...	7BF897...
GearsHoursB.stl	646,284	177,680	STL File	3/6/2017 6...	798623...
GearsHoursC.stl	596,384	146,887	STL File	3/6/2017 6...	DC92E...
GearsHoursD.stl	502,884	112,803	STL File	3/6/2017 6...	600E84...
GearsHoursE1.stl	778,884	161,258	STL File	3/6/2017 6...	A09DF...
GearsHoursE2.stl	247,284	40,985	STL File	3/6/2017 6...	701D4...
GearsHoursF.stl	860,384	278,954	STL File	3/6/2017 6...	95ABD...
GearsHoursHand.stl	26,984	6,782	STL File	3/6/2017 6...	F84AC...

Total 30,201,936 bytes in 54 files

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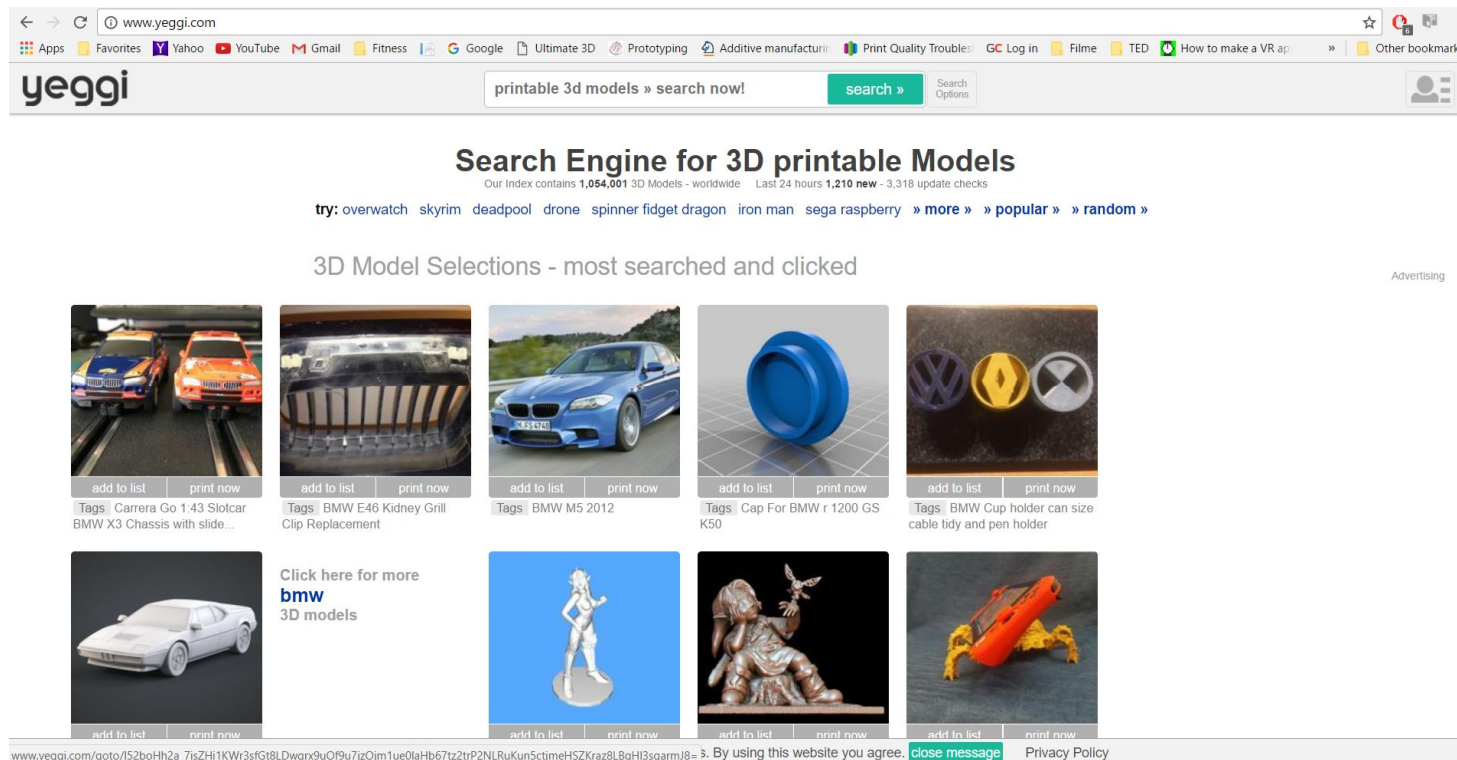
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Examples – Yeggi

- Yeggi repository gathers STL models (over 60000) from different repositories



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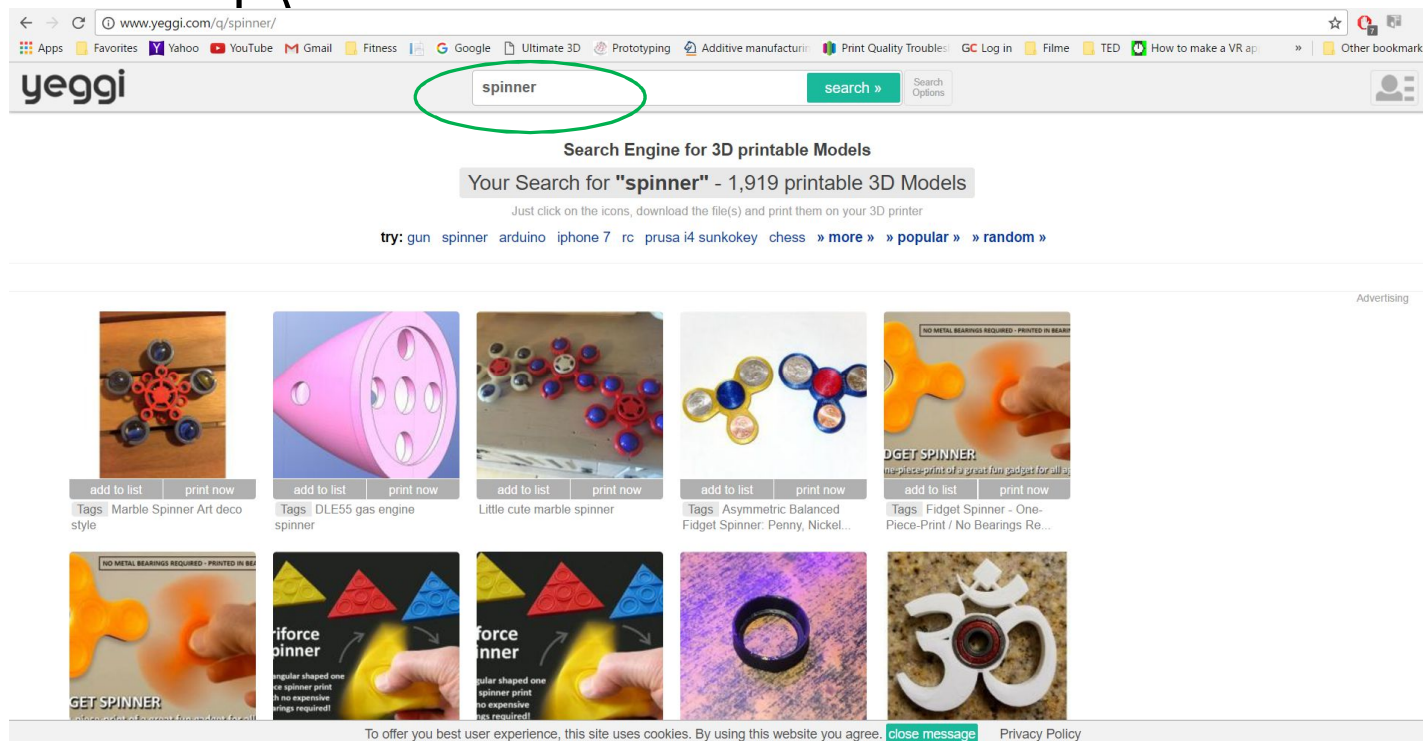
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Examples – Yeggi

- Step 1: Search the database using a key word, example: “spinner”. Depending selected model, the platform is redirecting user to a specific repository (Minifactory, as



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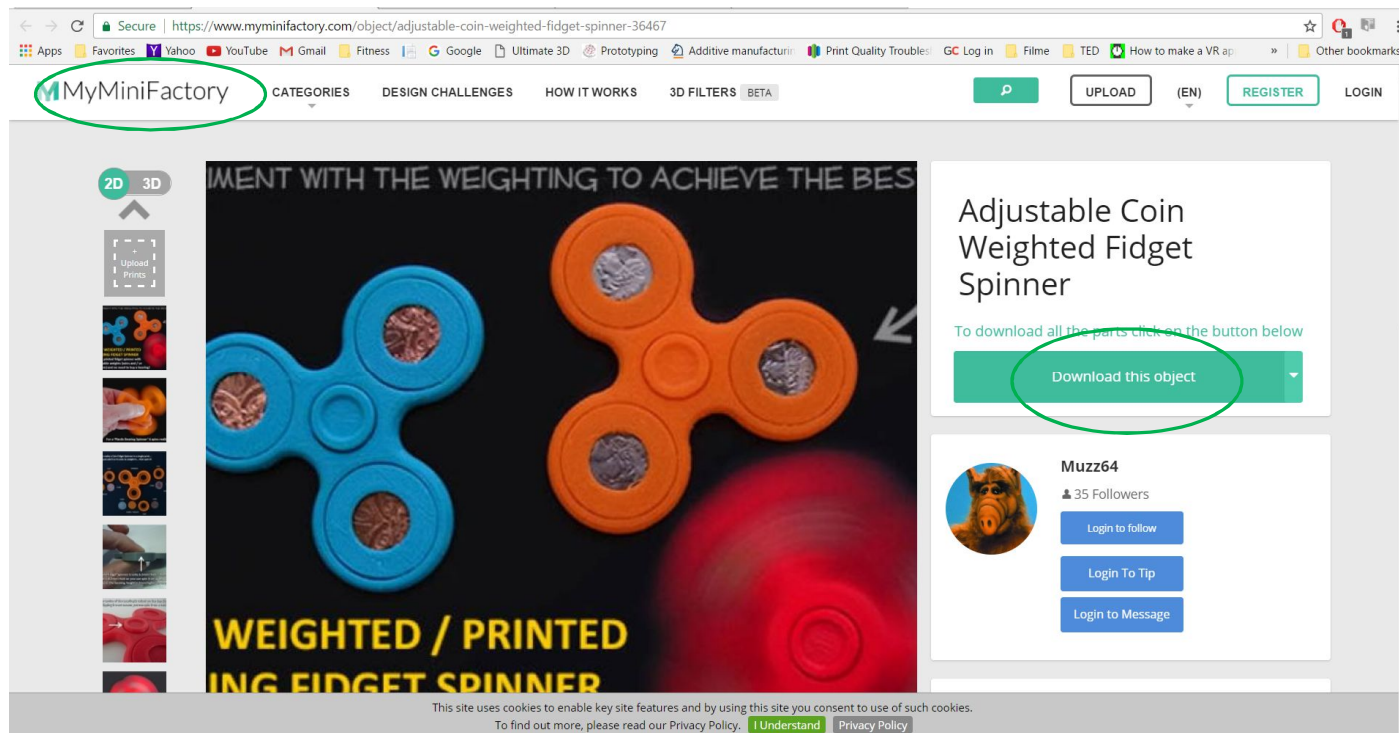
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Examples – Yeggi

- Step 2: Depending selected model, the platform is redirecting user to a specific repository (Minifactory, as example) from where the model can be downloaded.



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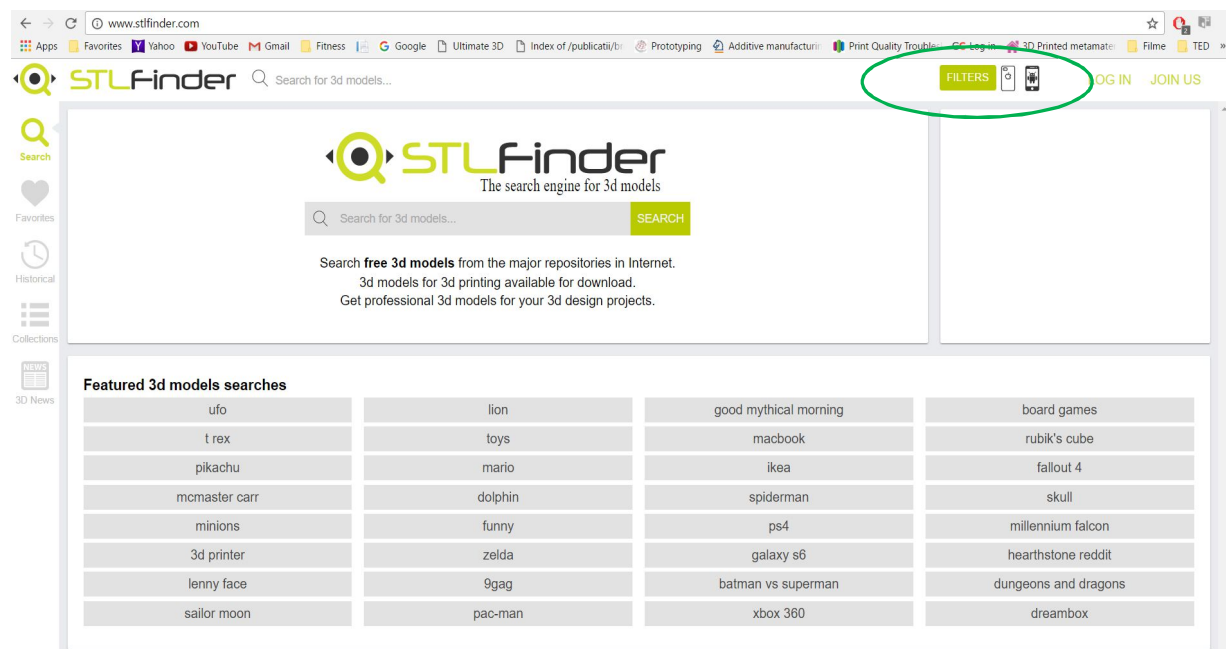
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Examples – STL Finder

- STL Finder is a search engine for STL models.
- The search can be performed using keywords or by categories.
- Use Filters to establish the repository database



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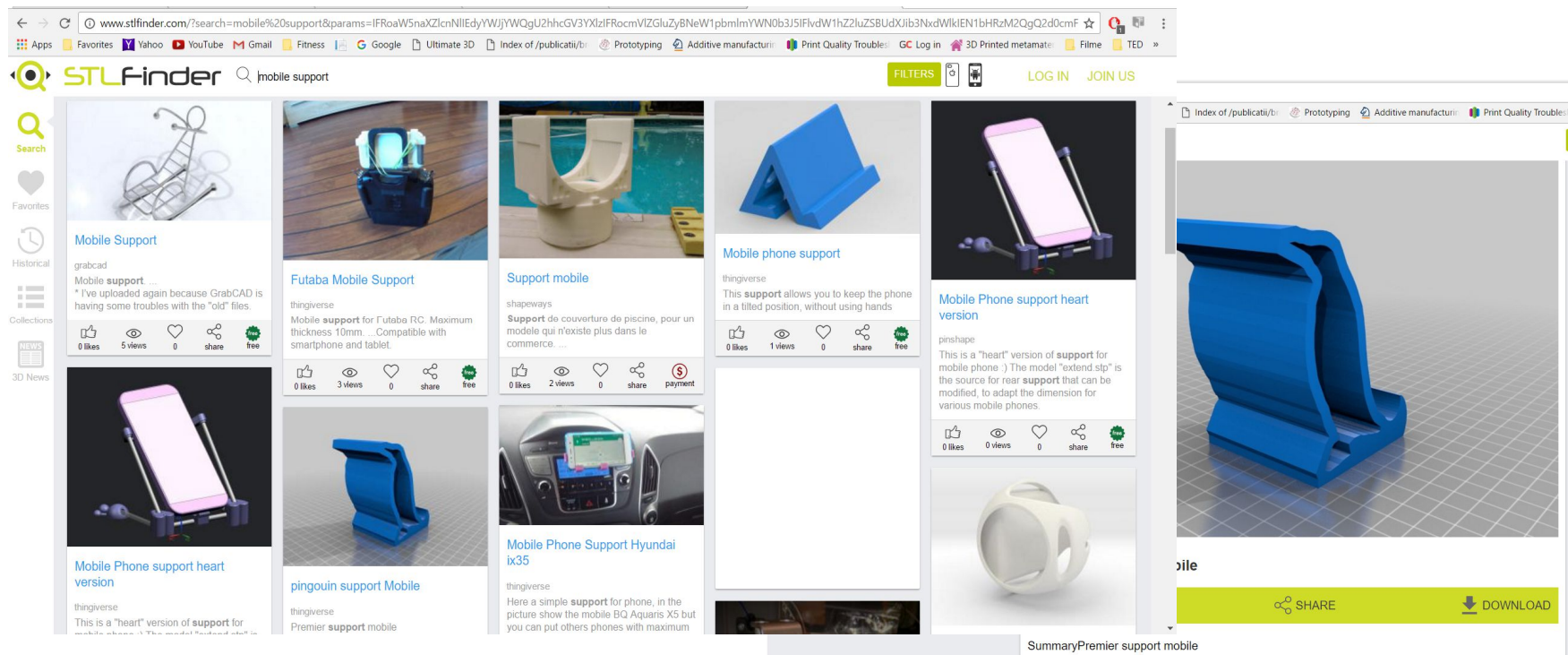
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Examples – STL Finder

- Step 1: Search by keywords: “mobile support”.
- Step 2: Selecting one model redirects the user to Thingiverse repository



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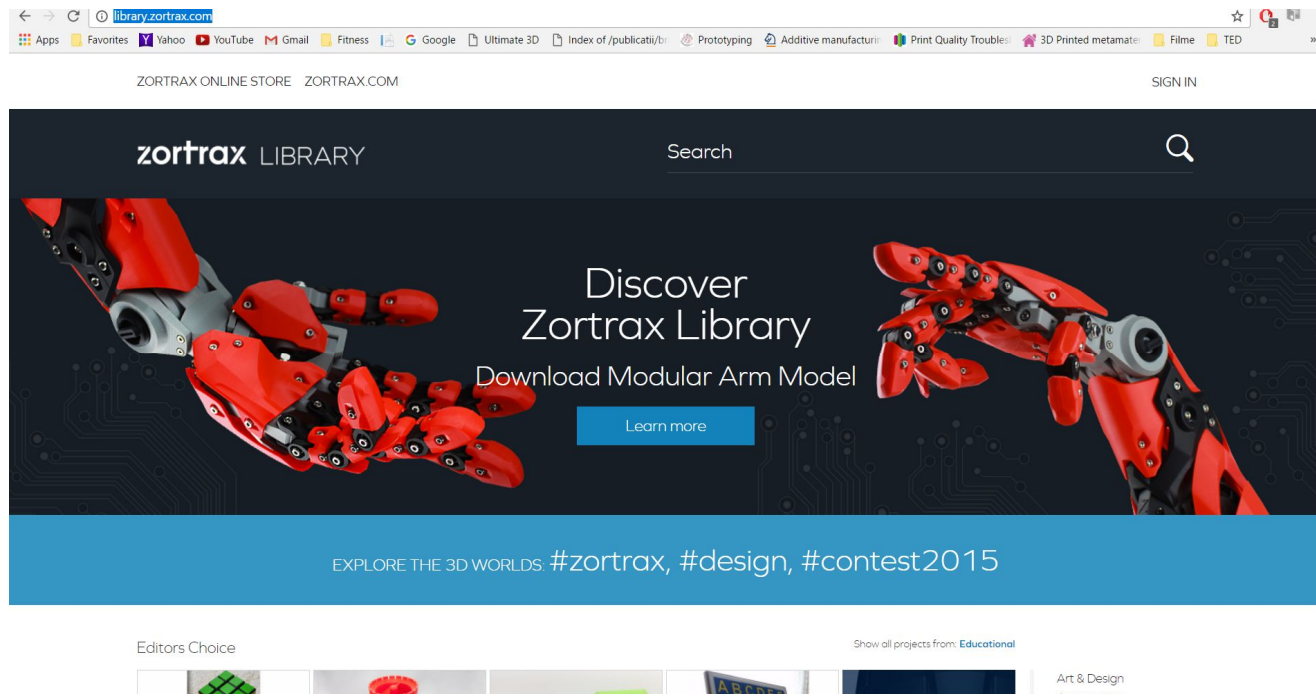
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Examples – Zortrax Library

- Zortrax library requires an user account.
- Models on Zortrax Library are included in categories, editors choices being also available on the front page



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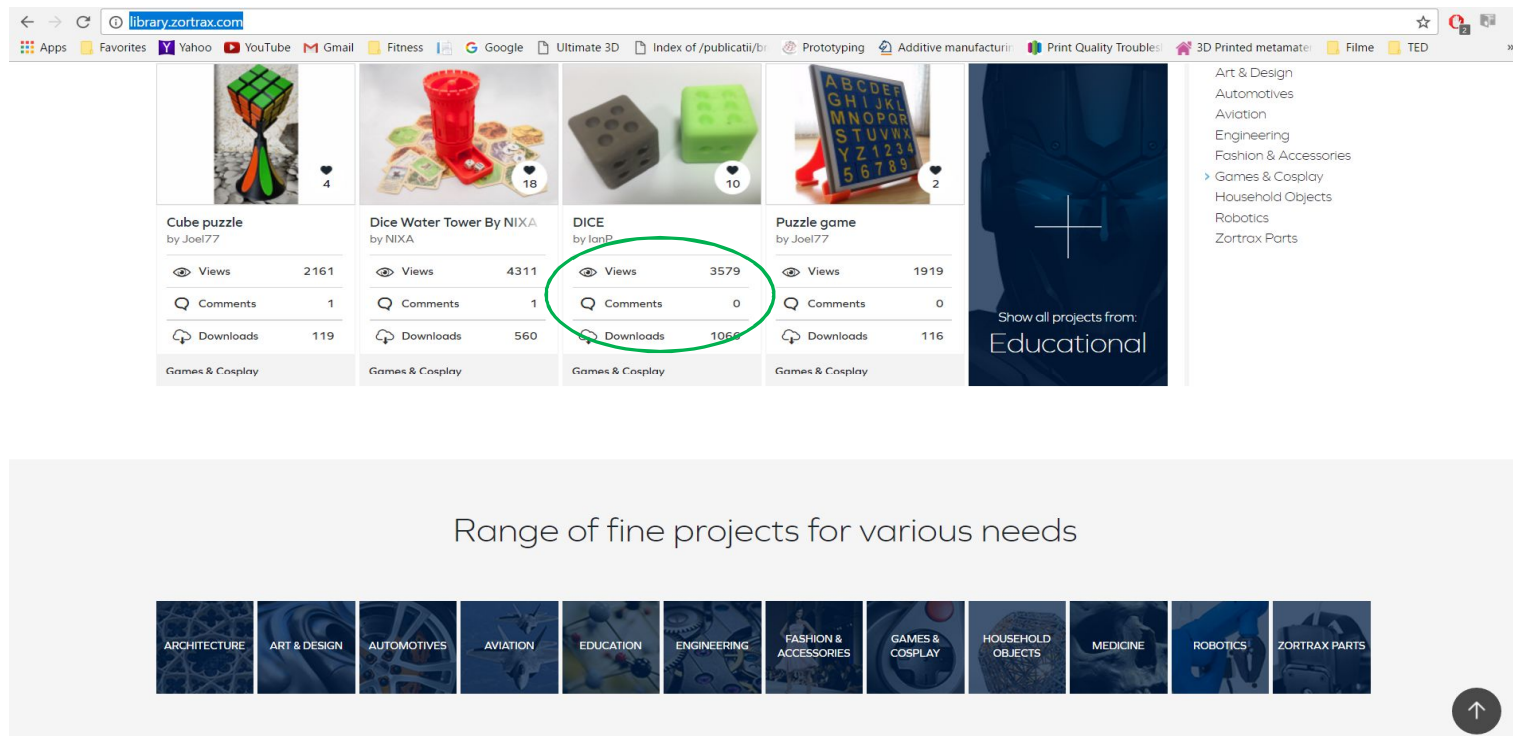
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Examples – Zortrax Library

- Information on the number of visualizations, comments and number of downloads for each model is presented on website.



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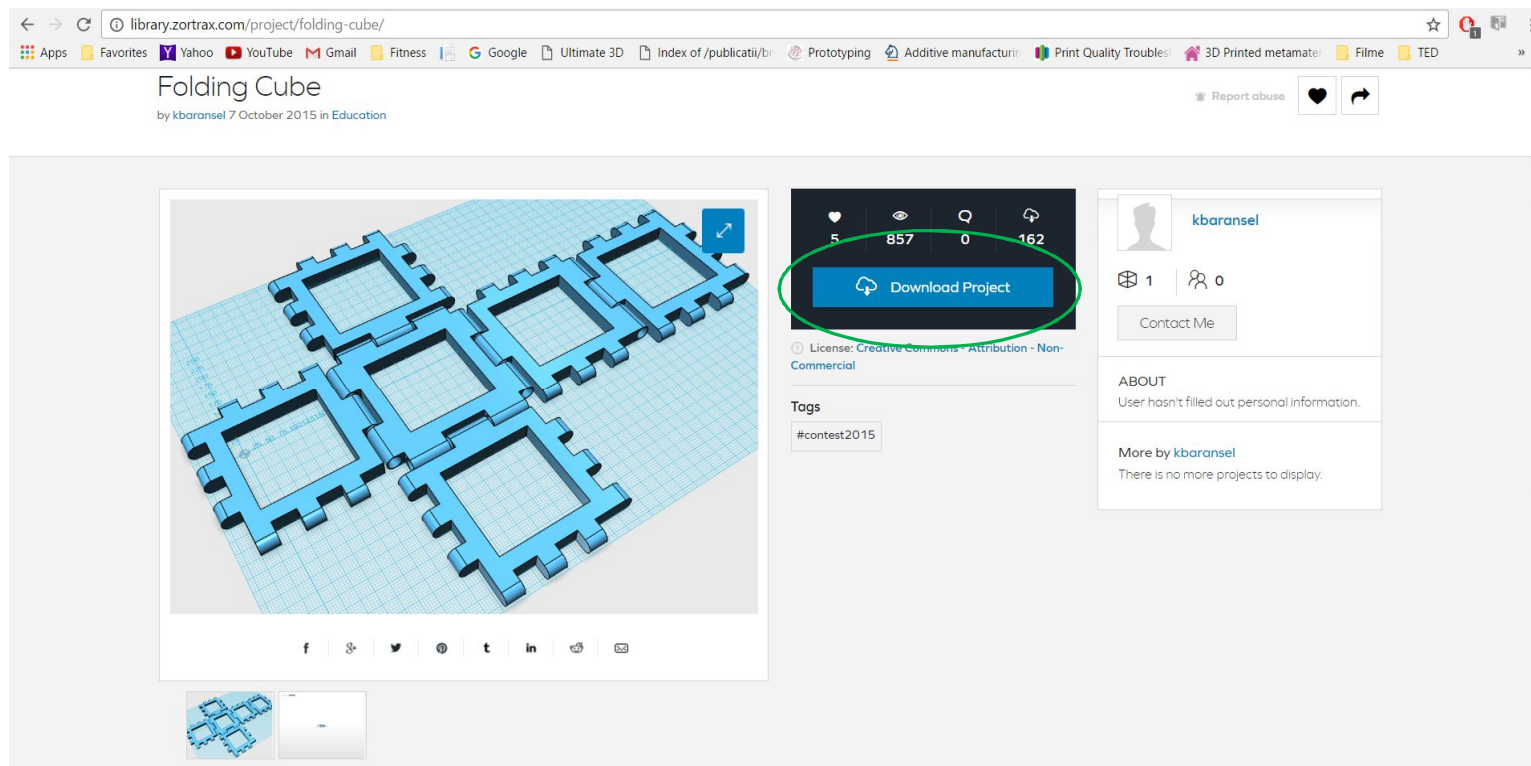
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Examples – Zortrax Library

- Search by word: “cube” → Select “Folding Cube” model → Press Download project



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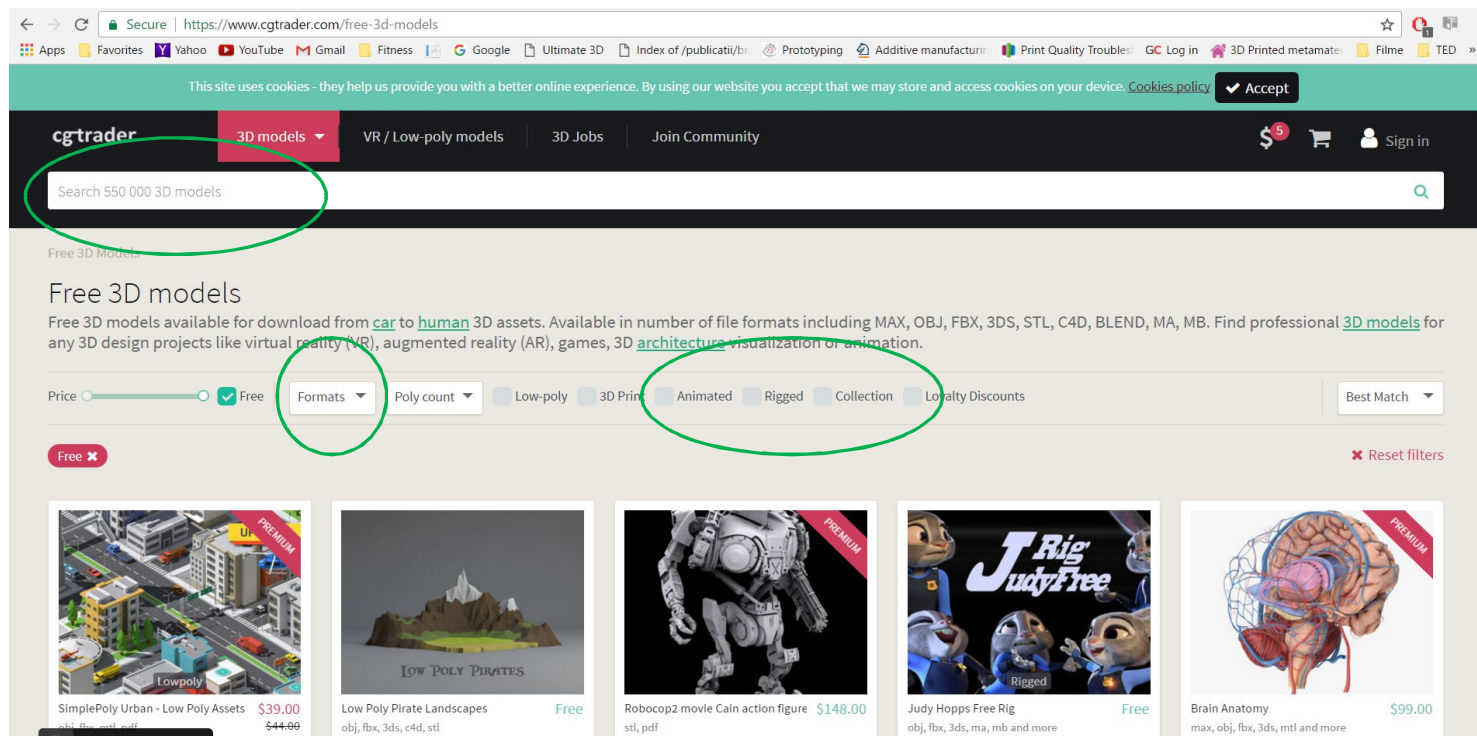
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Examples – CGTrade

- CGTrade platform allows selecting free or paid models, the model format (STL in this case), 3D Print, Collection etc.
- Downloading a model requires creating an user account



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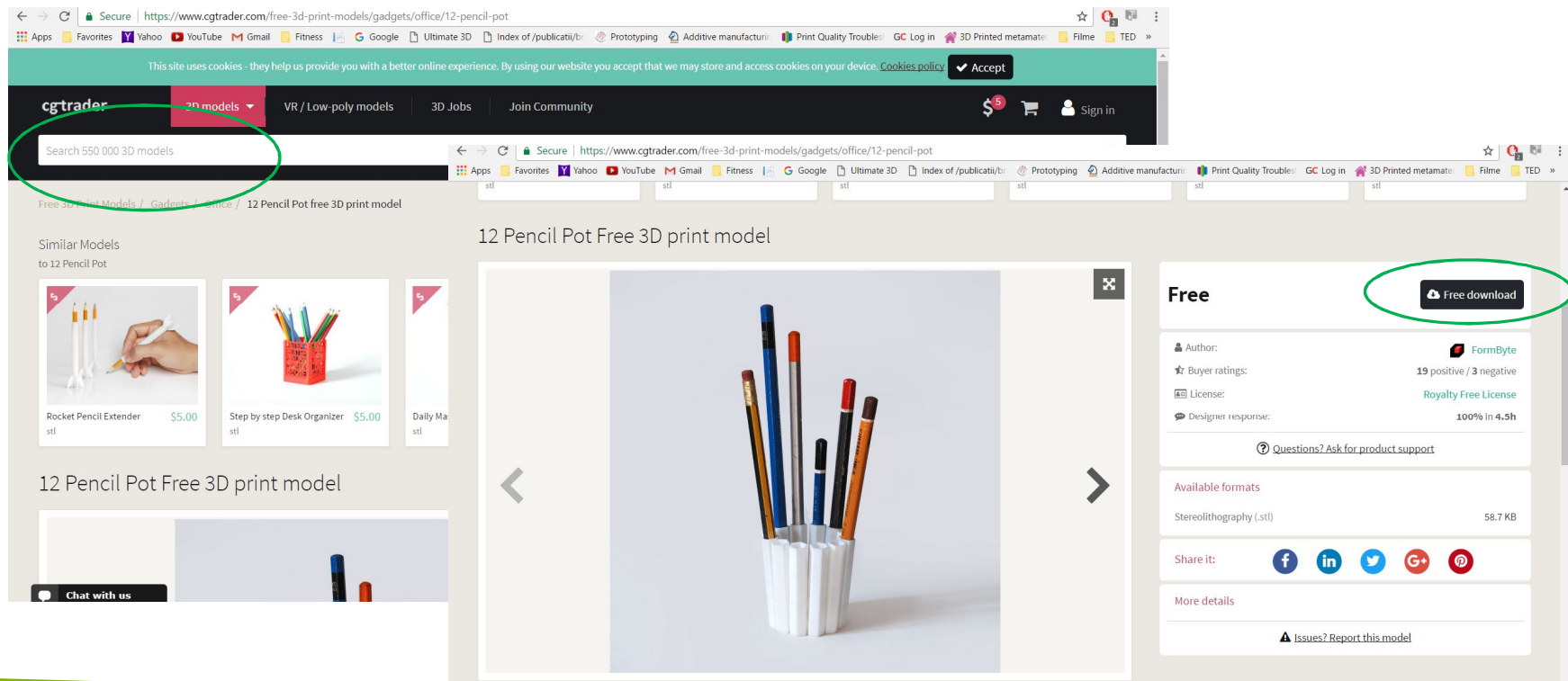
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Examples – CGTrade

- Step1: Create user account
- Step 2: Search and download object: “pencil box” – as an example.



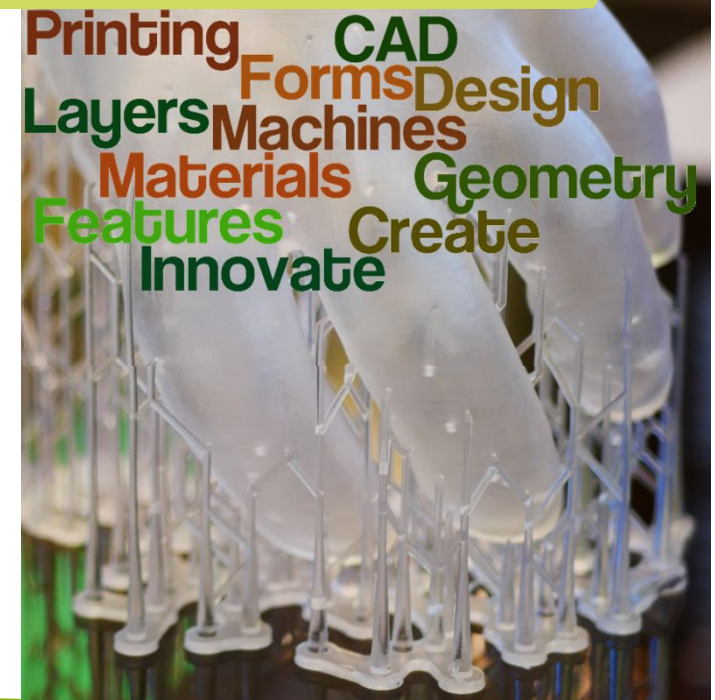
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Check and correct STL files using dedicated software



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Aim and Learning Outcomes

Module Aim:

To equip students with understanding of using dedicated software for checking and correcting STL models

Number of Hours:

3hrs

Learning outcomes:

- Acquiring knowledge about Netfabb, MeshLab, MiniMagics software solutions
- Acquiring knowledge on using automated tools/commands for checking and correcting STL models
- Acquiring knowledge on using manual tools/commands for correcting STL models

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Lecture Outline

- STL models analysis and repair
- Software solutions for STL models analysis and repair:
 - Examples: Netfabb, MeshLab, Materialise 3DPrint Cloud

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STL models analysis and repair

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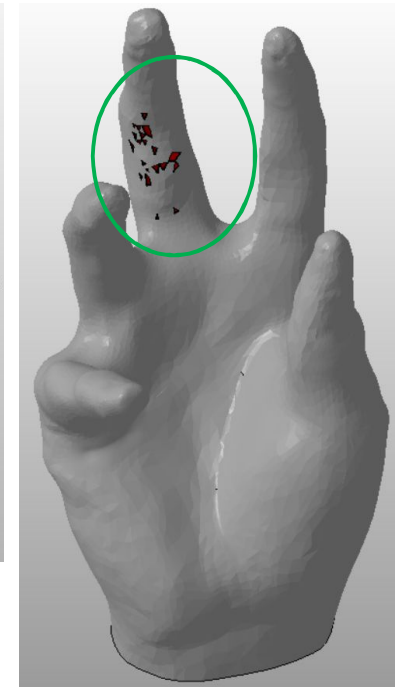
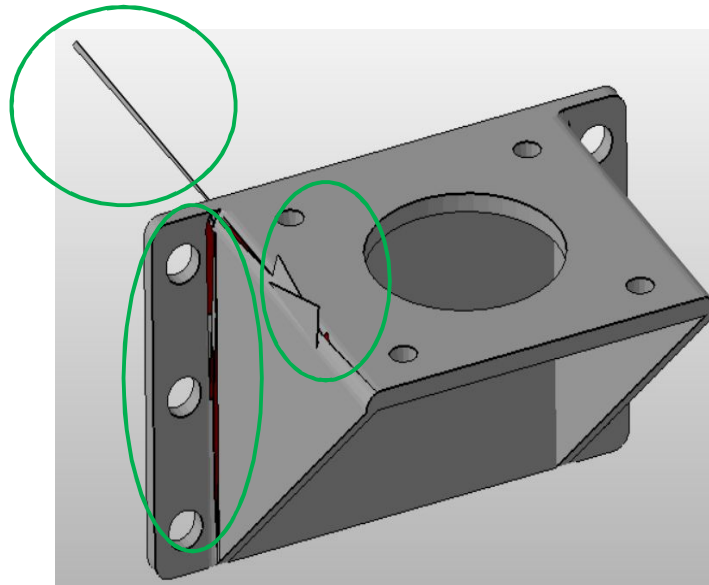


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STL models analysis and repair

Main type of STL models errors:

- Missing triangles
- Inverted normals
- Non connected edges
- Bad edges



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STL models analysis and repair

- Analysis and, if necessary, repair of STL models are steps to be performed before sending the STL file to the 3D printer
- Dedicated software solutions are used for STL checking and repair
- STL model repair can be performed automatically or manually



Software solutions for STL models analysis and repair

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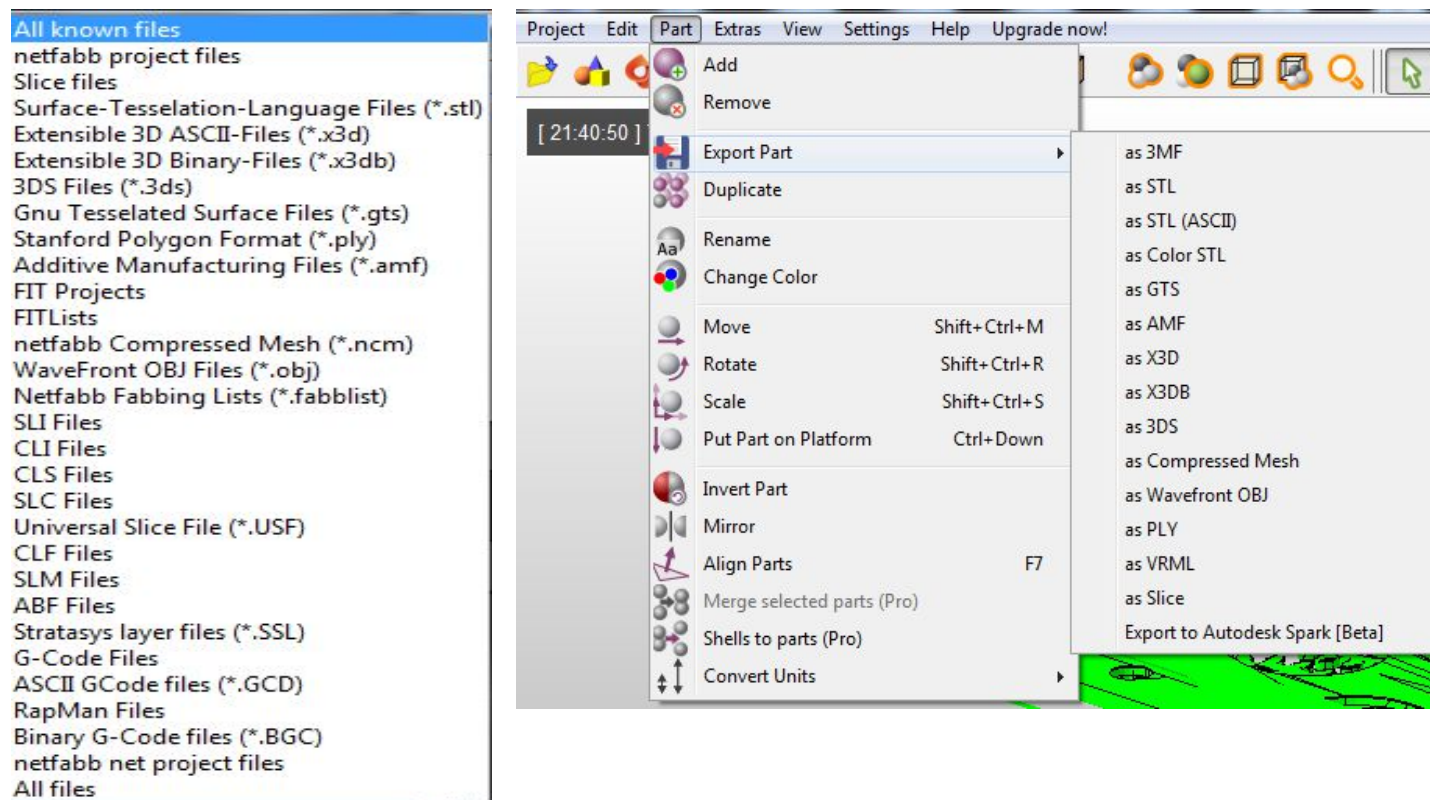
Software for STL models - Netfabb

- **Netfabb software**, www.netfabb.com
- Free version options:
 - Tools for manually or automated STL checking and repair
 - Tools for measuring model walls thickness
 - Tools for cutting the models
- Automated STL repair options solve many of the usual problems of this type of file (holes, inverted normal, bad edges, etc.)



Software for STL models - Netfabb

- Import and export formats in Netfabb



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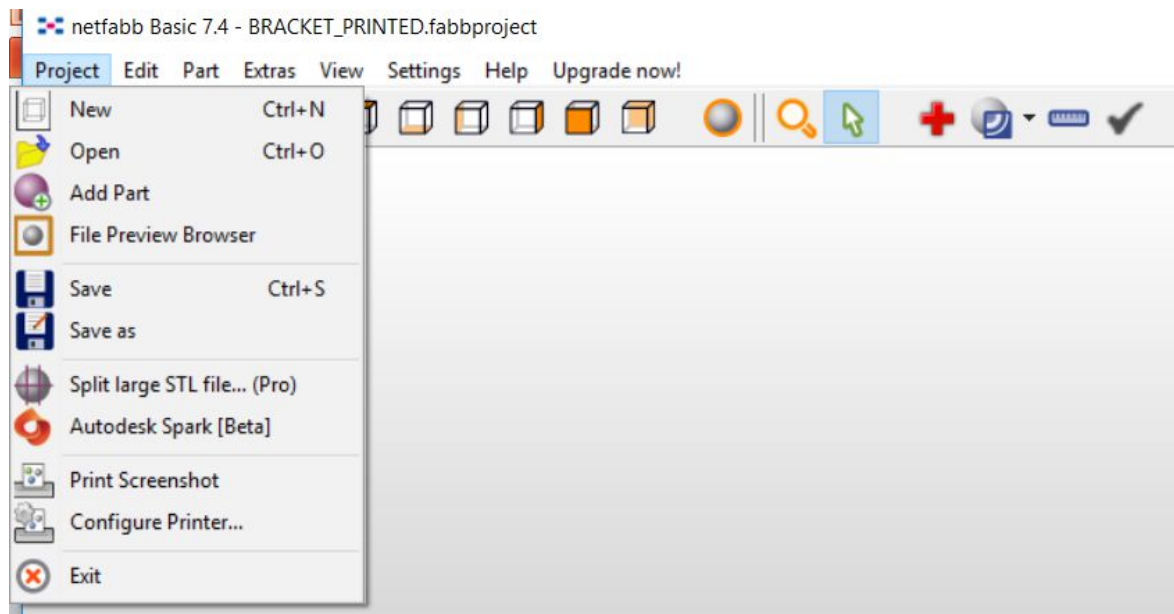
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Software for STL models - Netfabb

- Opening an existing STL model:
 - Project → Open (or Ctrl+O)
 - Project → Add part
 - Drag-and-drop model in application



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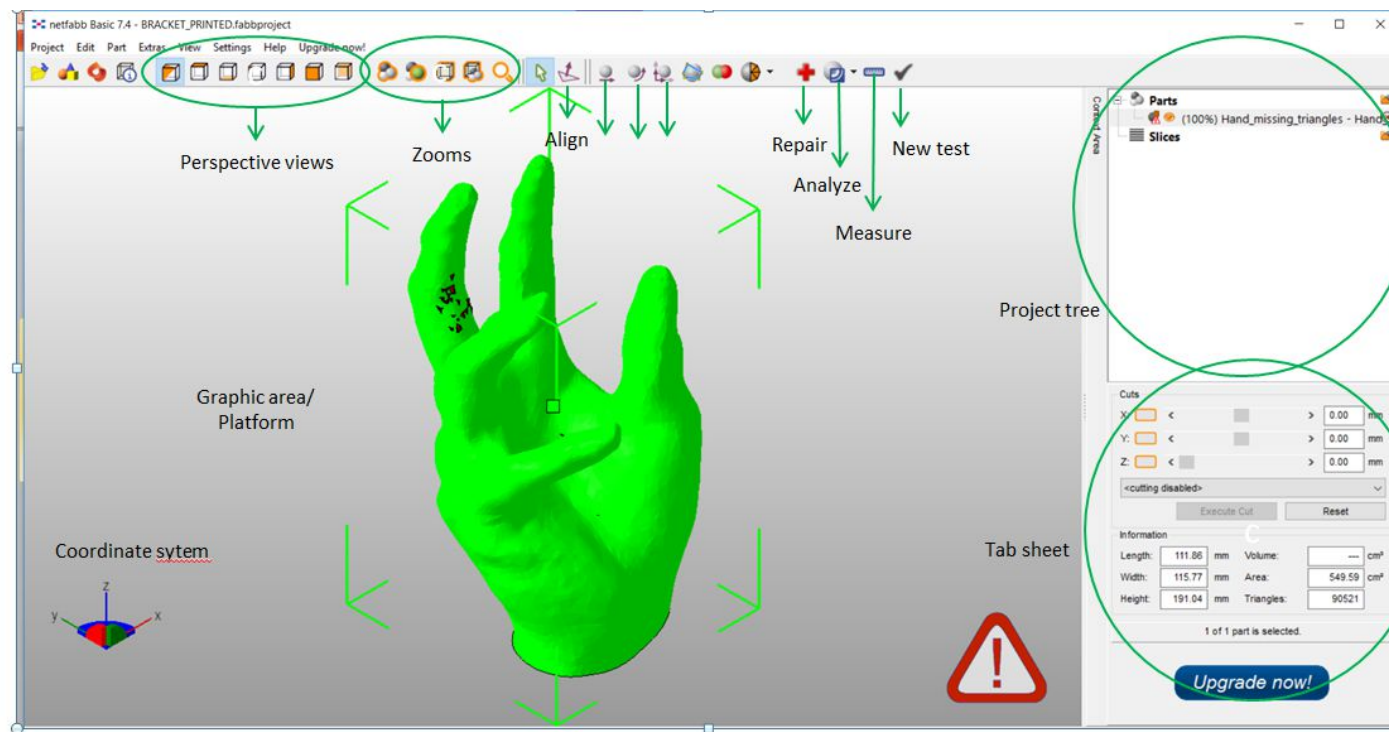
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Software for STL models - Netfabb

- A hand model, which can be used as mobile phone support, is used for explaining analysis and automatic repair options in Netfabb



Model volume is not calculated because of the holes in the model. Model dimensions on x, y, z axis are shown

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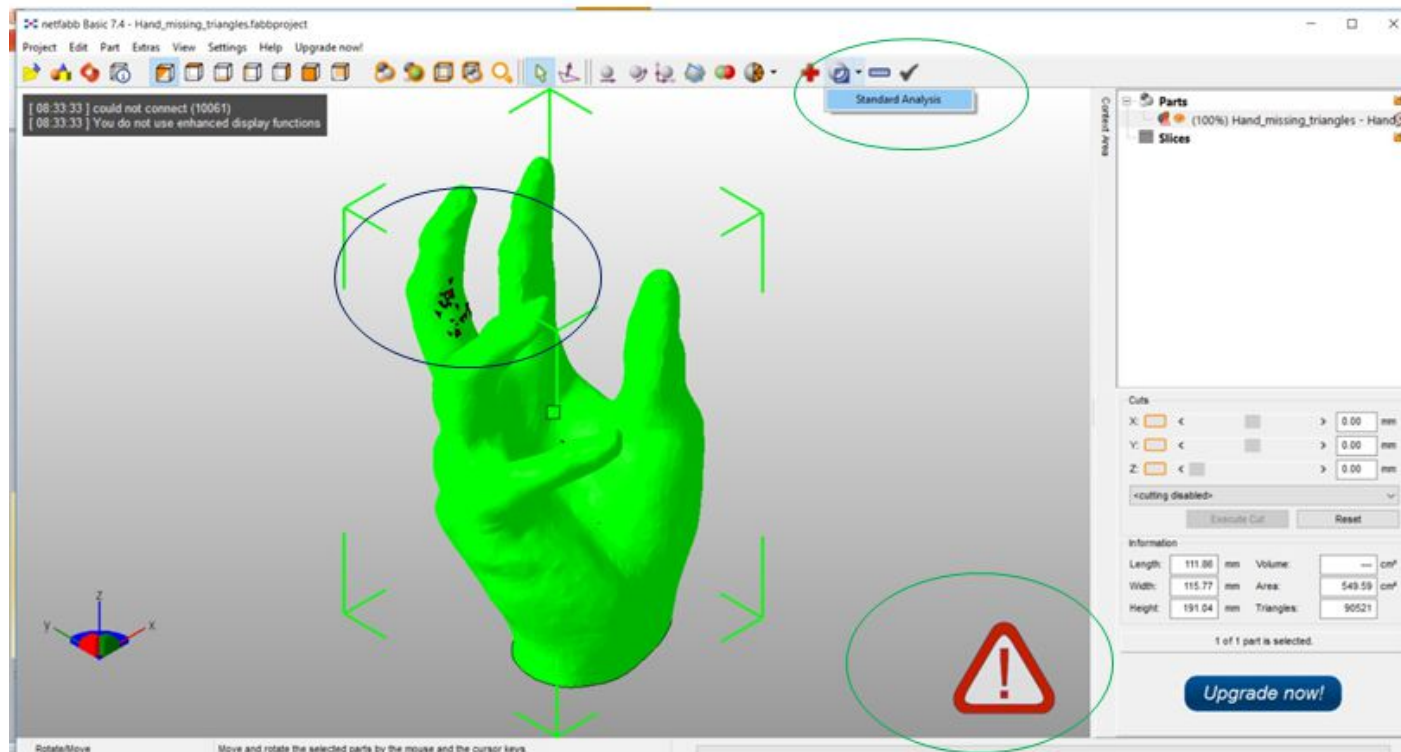
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Software for STL models - Netfabb

- The exclamation mark means the model contains errors.
- A standard analysis is performed.



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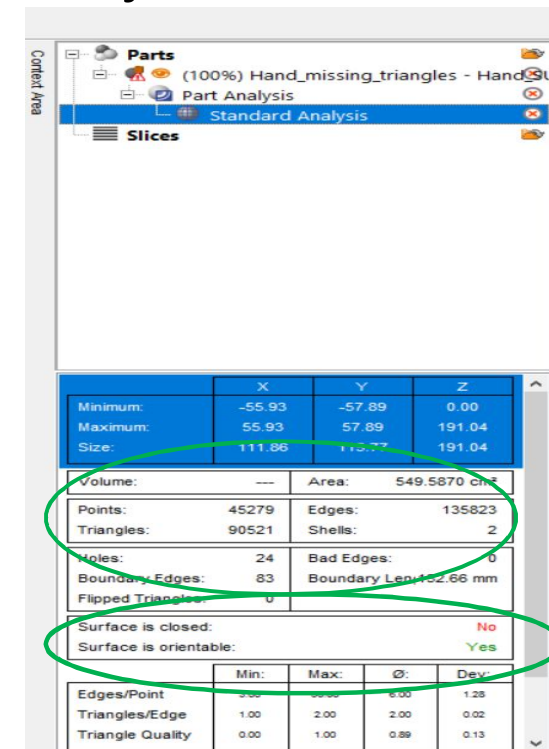
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Software for STL models - Netfabb

- Analysis results shows that the surface is orientable, but it is not closed.
- Standard analysis operation is shown also in Project Tree.
- Other available information:
 - Number of holes
 - Flipped Triangles
 - Bad Edges
 - Number of points
 - Number of triangles
 - Number of edges, etc.



	X	Y	Z
Minimum:	-55.93	-57.89	0.00
Maximum:	55.93	57.89	191.04
Size:	111.88	115.77	191.04

Volume:	---	Area:	549.5870 cm²
Points:	45279	Edges:	135823
Triangles:	90521	Shells:	2
Holes:	24	Bad Edges:	0
Boundary Edges:	83	Boundary Length:	152.66 mm
Flipped Triangles:	0		
Surface is closed:	No		
Surface is orientable:	Yes		

	Min:	Max:	Q:	Dev:
Edges/Point	2.00	9.00	6.00	1.28
Triangles/Edge	1.00	2.00	2.00	0.02
Triangle Quality	0.00	1.00	0.89	0.13

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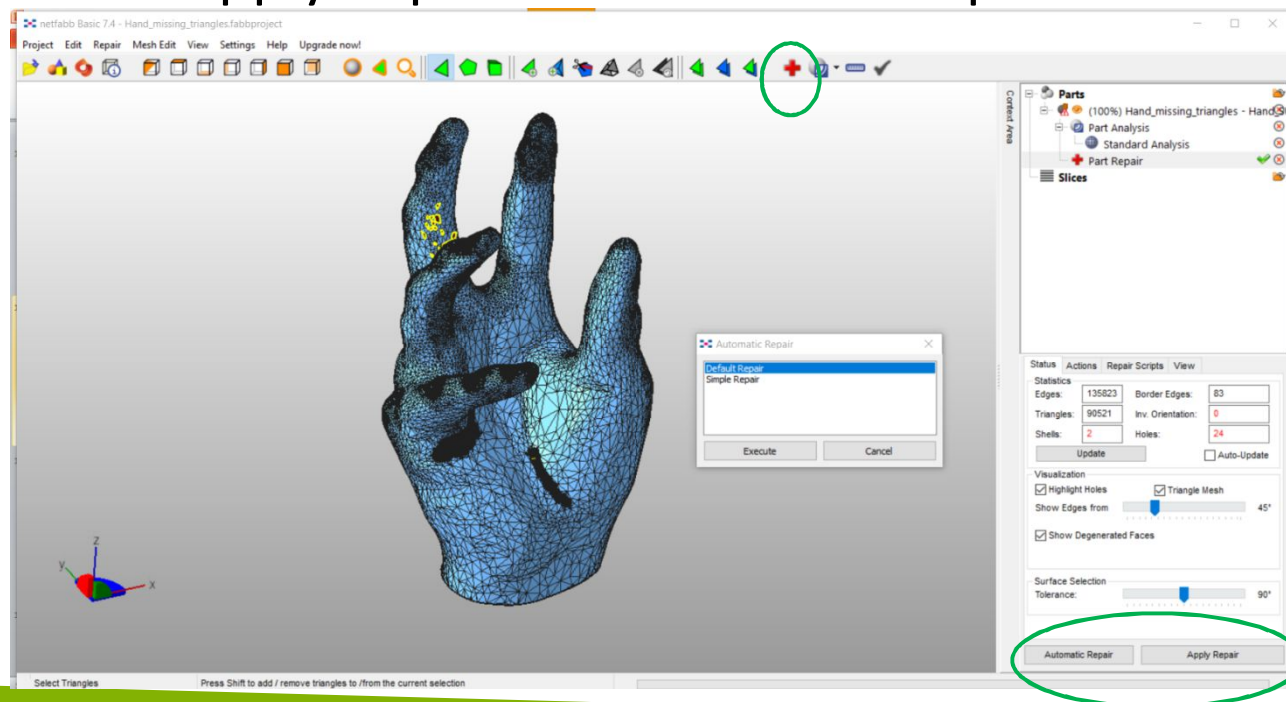
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Software for STL models - Netfabb

- The zone with missing triangles is shown in yellow when activating Repair option (red cross sign).
- Automatic Repair is applied with sub-option Default Repair. Then Apply Repair and Remove Old parts.



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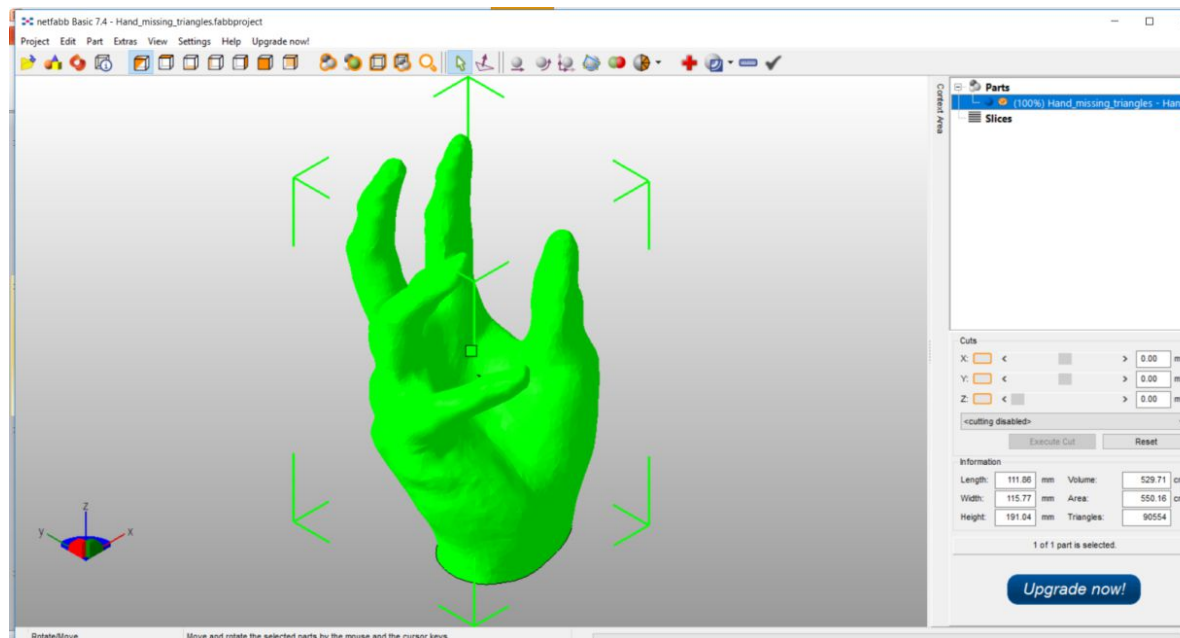
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Software for STL models - Netfabb

- The results of Repair option is shown. A new test analysis should be performed for checking if the STL model is closed.
- Then the model can be saved and used for 3D printing: Project → Save, Project → Save As or Export Part → STL.



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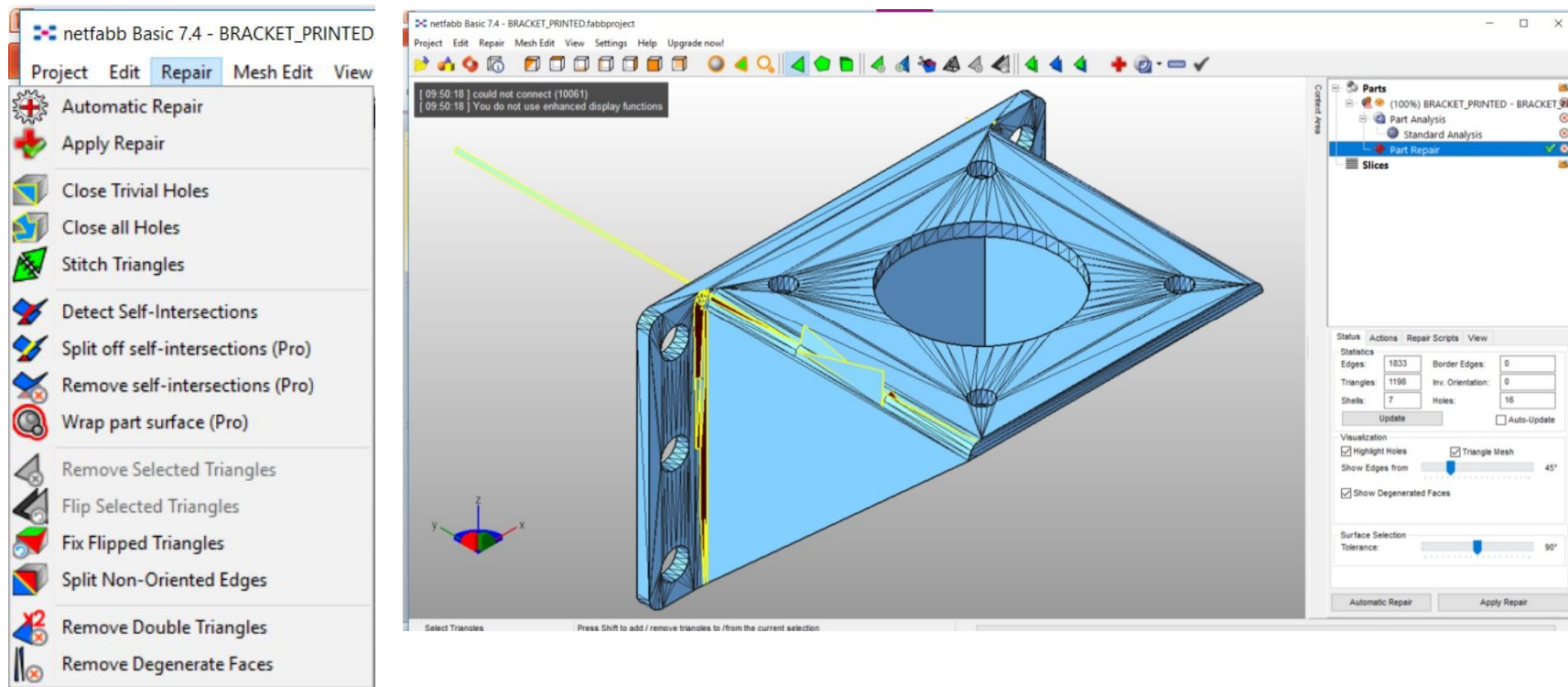
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Software for STL models - Netfabb

- A bracket model is used for illustrating the manual repair options in Netfabb



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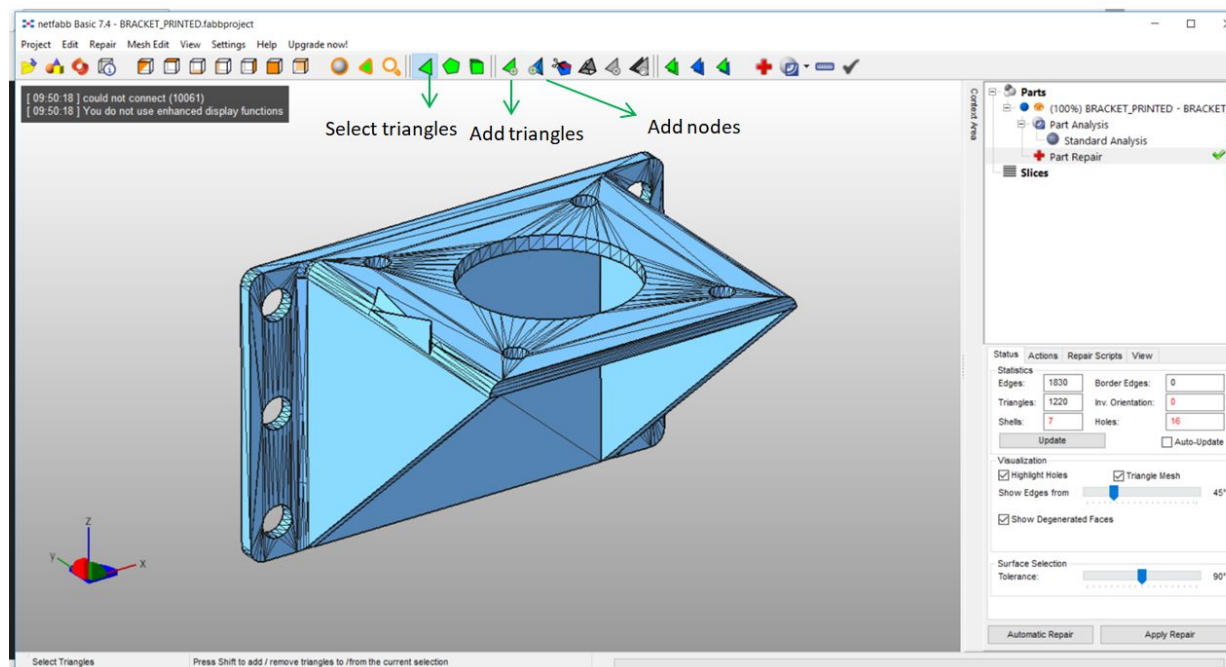
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Software for STL models - Netfabb

- STL model after Automatic Repair is shown.
- Manual operations are used for deleting triangles. Triangle are selected (Select triangle option) and then erased (Delete key).



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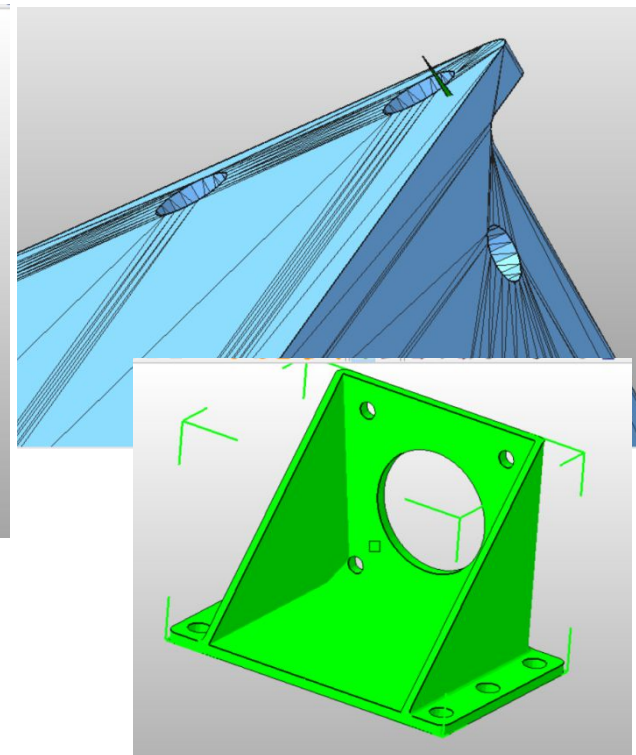
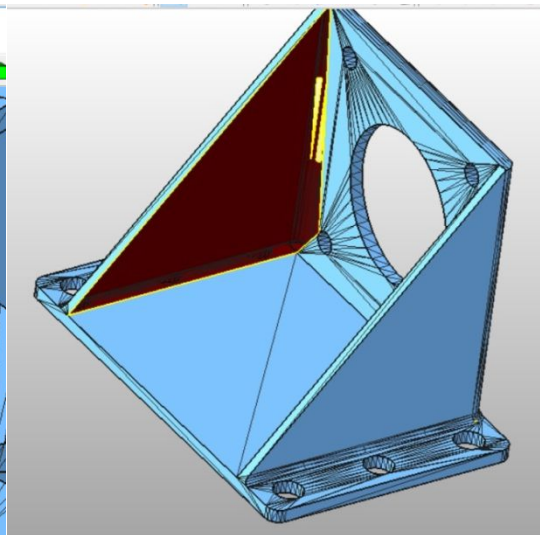
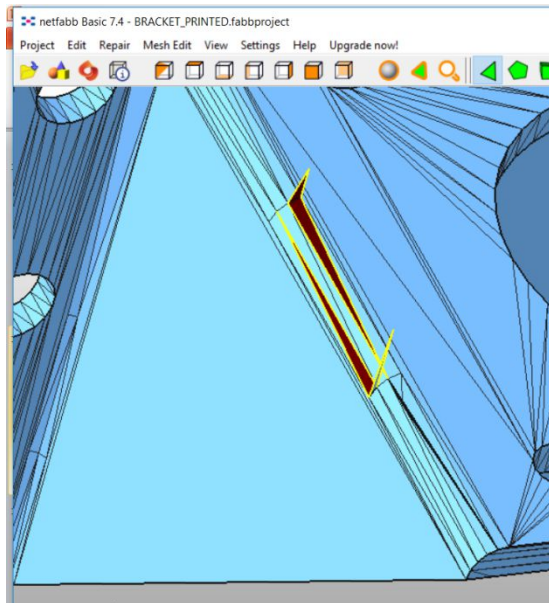
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Software for STL models - Netfabb

- Images of different steps of Manual repair: selecting triangles, deleting triangles
- Automatic Repair option is then applied



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Software for STL models - Netfabb

- **Hands-on session (45 minutes)**
 - Download a STL model from a repository
 - Check the STL model using Netfabb
 - If the STL model is correct, exported as STL ASCII
 - Open STL ASCII file using Notepad and erase several triangles, modify vertex coordinates and/or normals orientation
 - Save the STL file thus modified
 - Open the new STL file in Netfabb and repair it.

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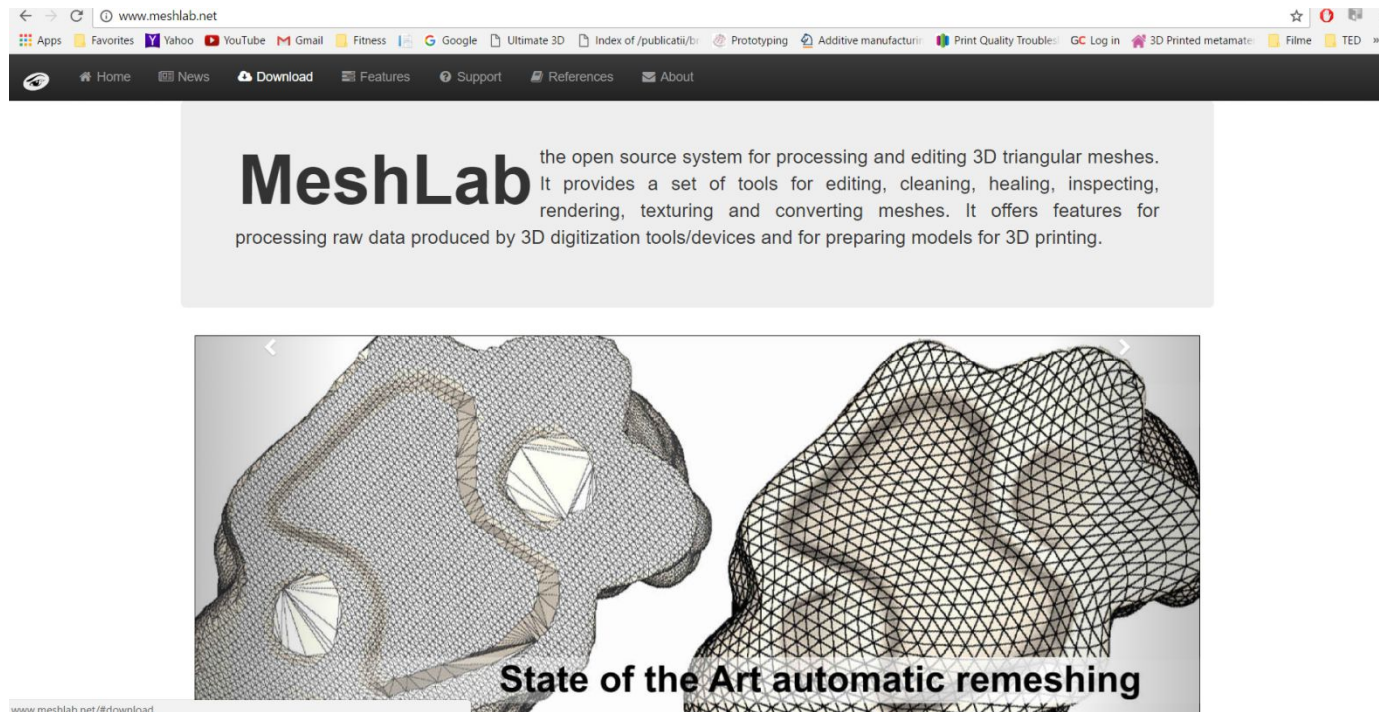
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Software for STL models - Meshlab

- **MeshLab**, www.meshlab.net – solution for inspecting, editing, cleaning, healing, inspecting, rendering, texturing and converting meshes, including STL models.



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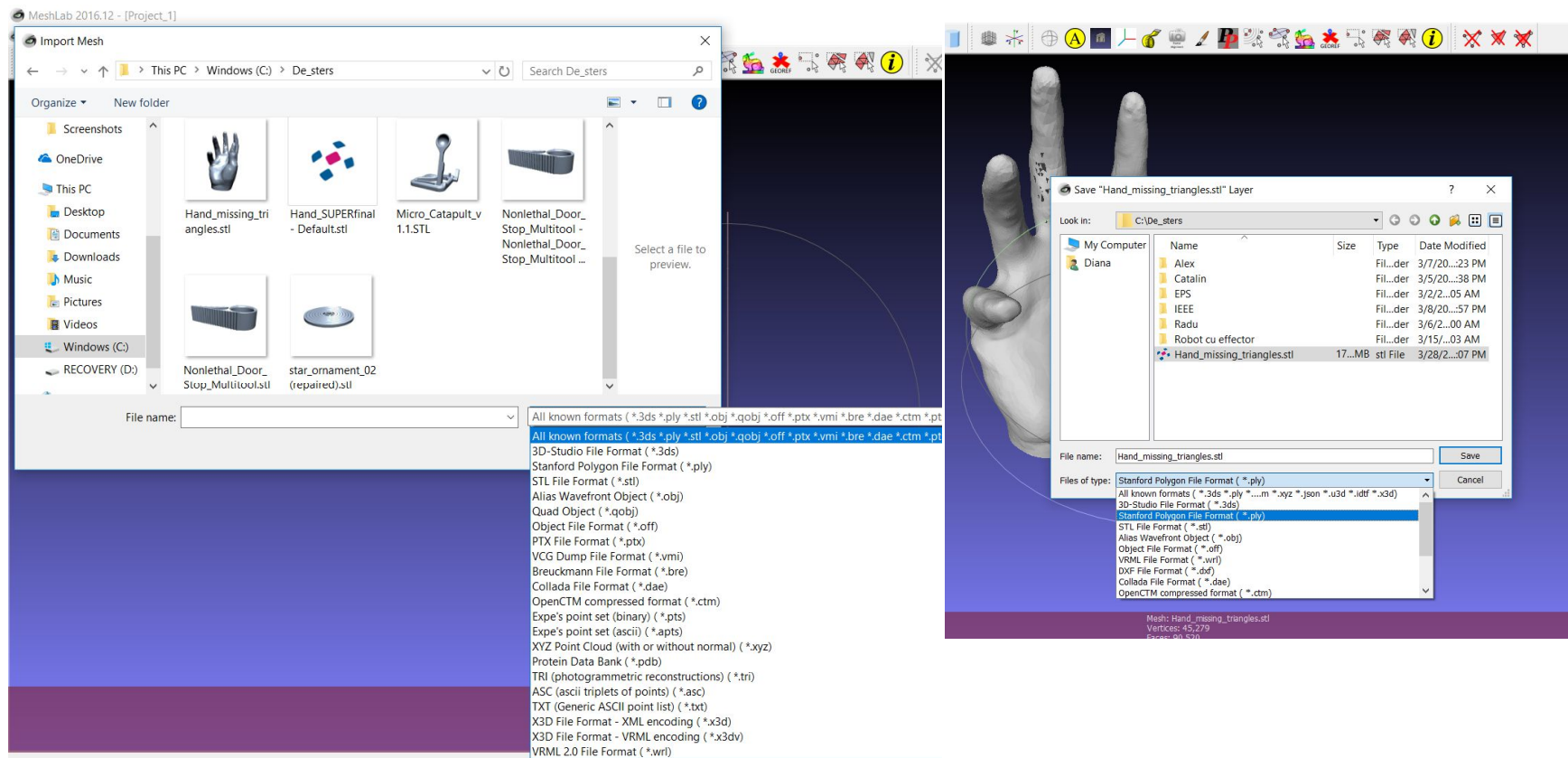
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Software for STL models - Meshlab

- MeshLab import and export file formats



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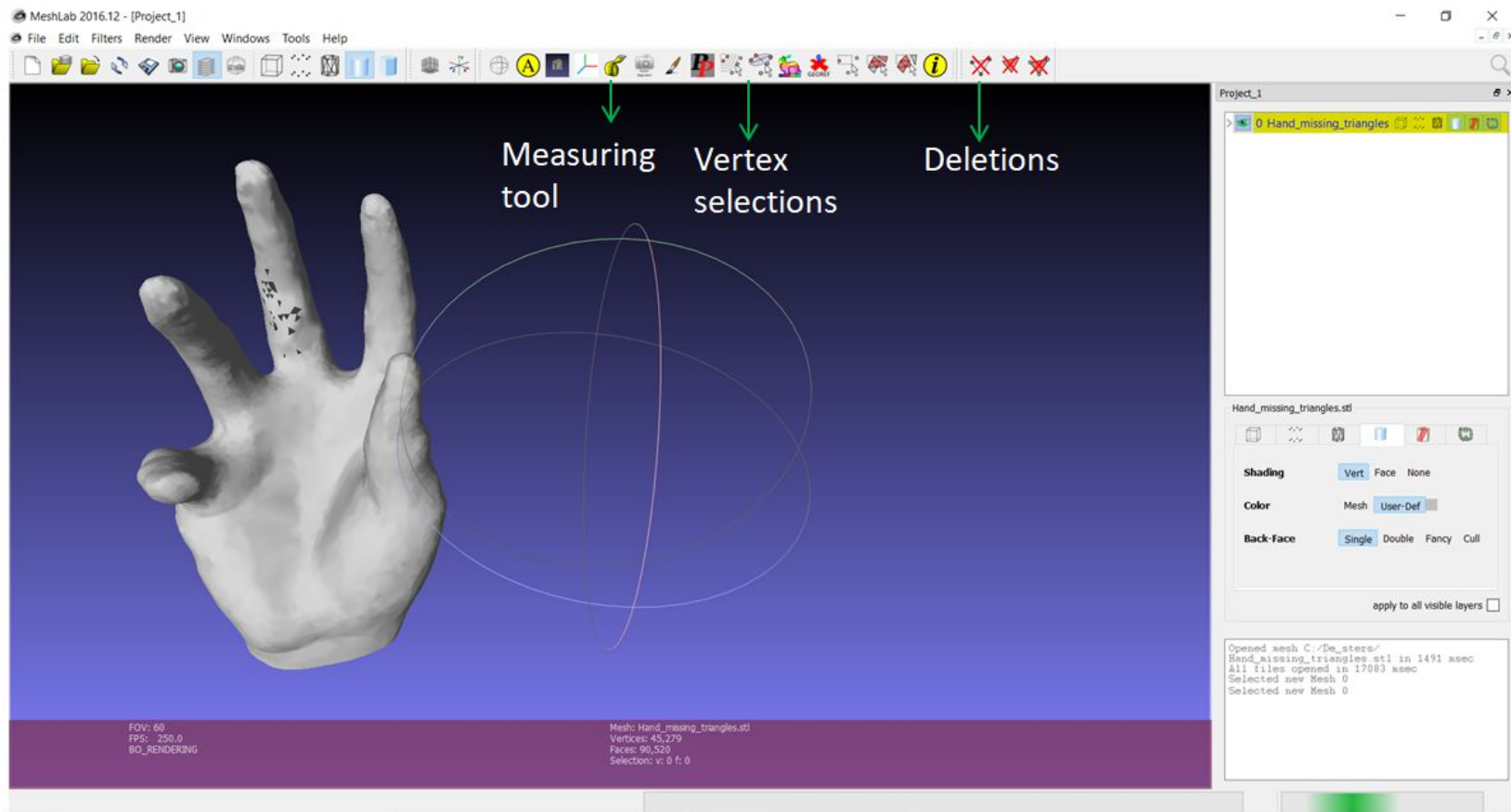
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Software for STL models - Meshlab

- MeshLab, interface explained



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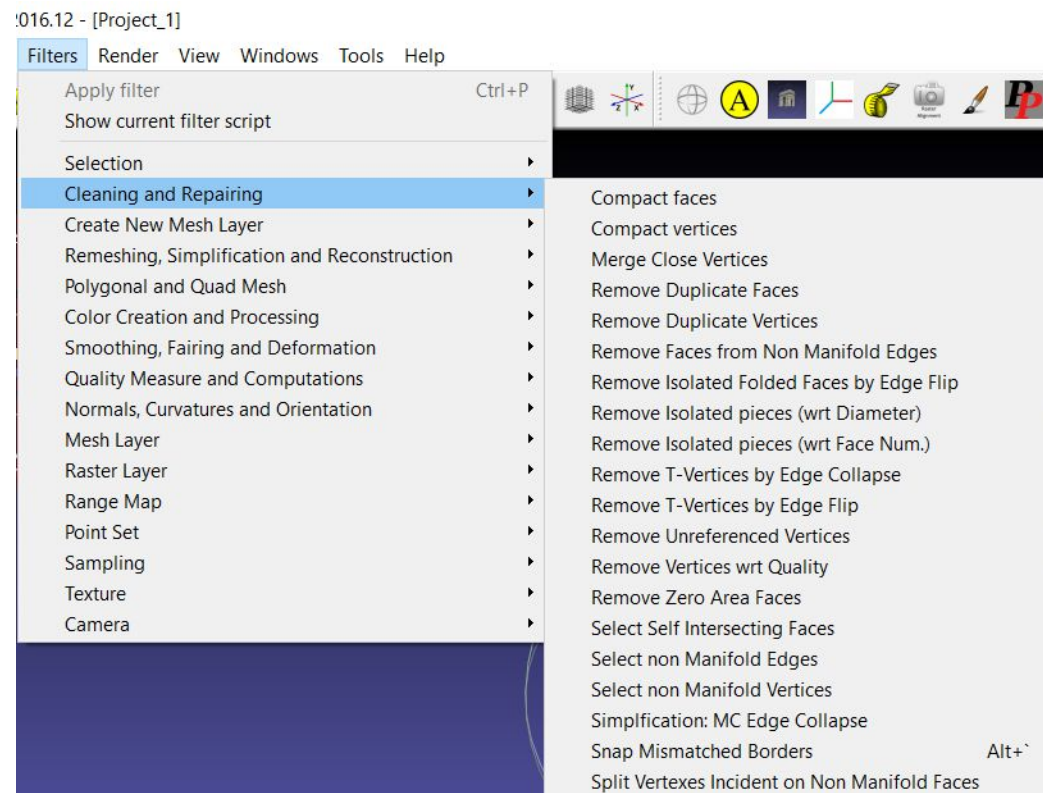
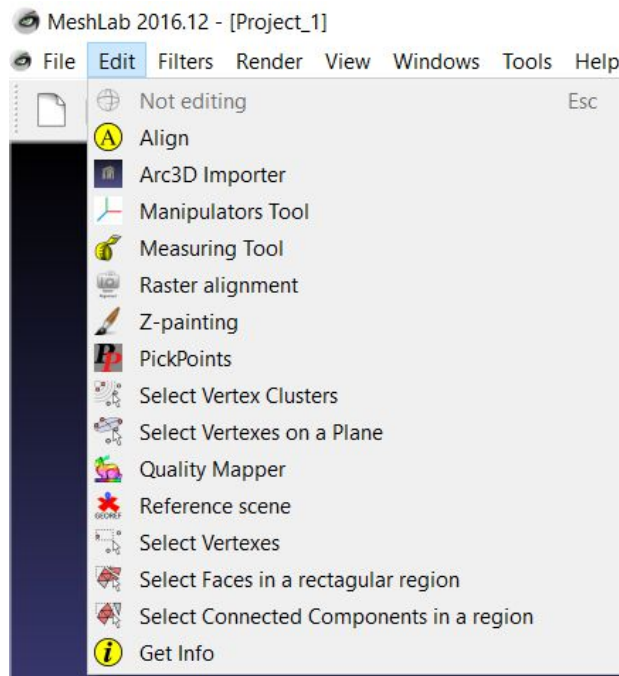
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Software for STL models - Meshlab

- MeshLab editing options
- MeshLab cleaning options



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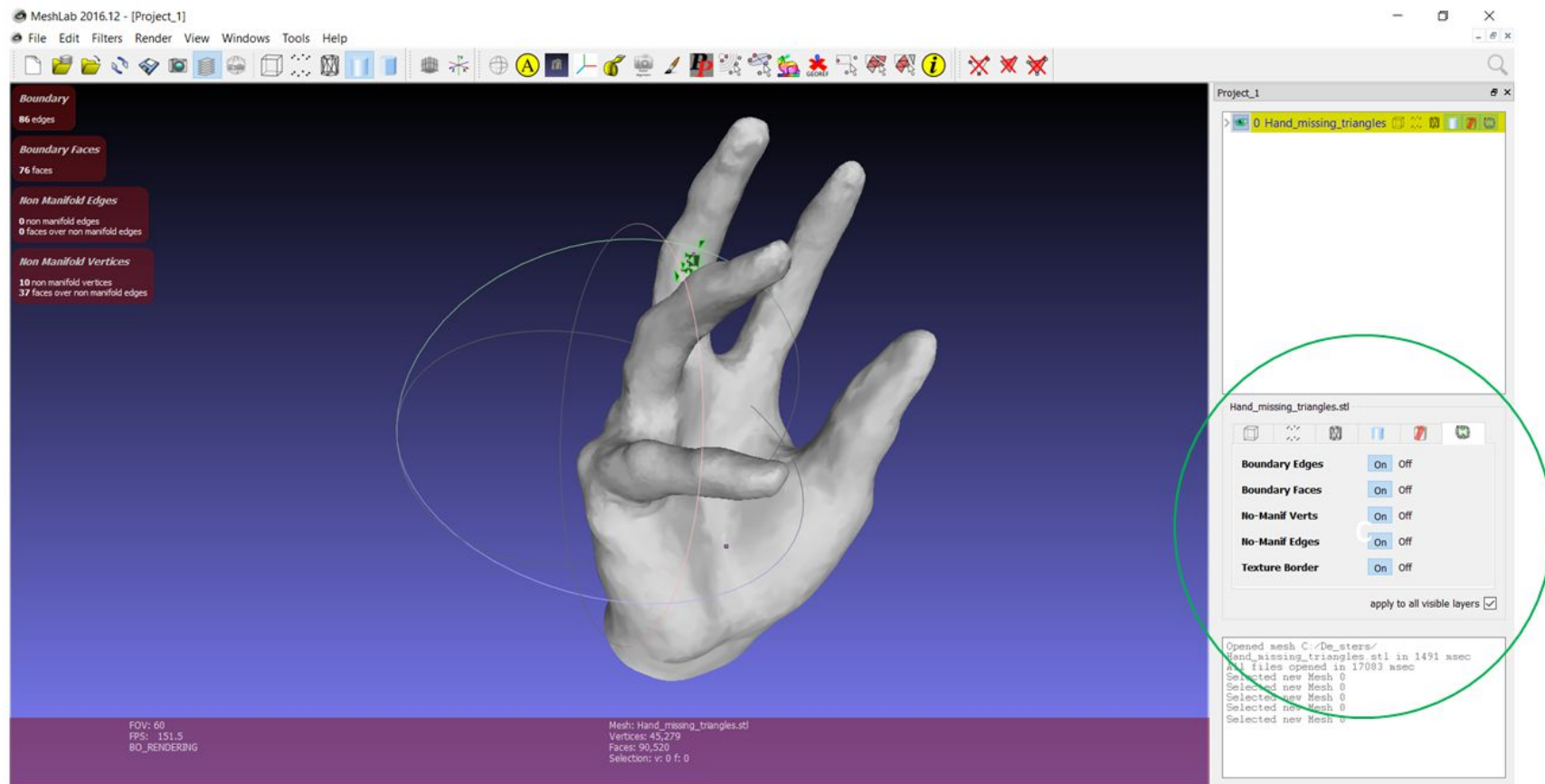
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Software for STL models - Meshlab

- Making errors visible in the hand support model example



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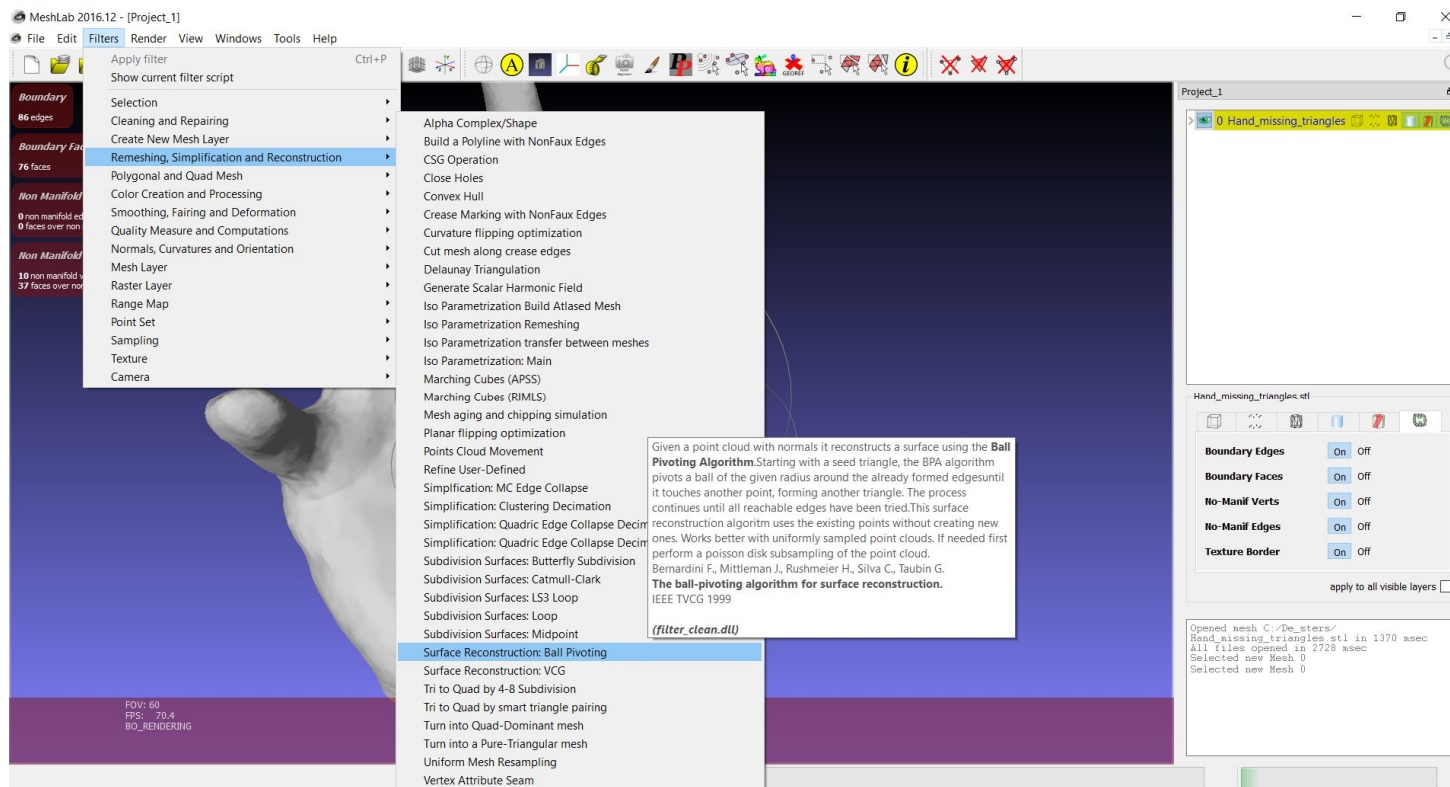
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Software for STL models - Meshlab

- Accessing: Remeshing, Simplification and Reconstruction for repairing the defects in the hand support model



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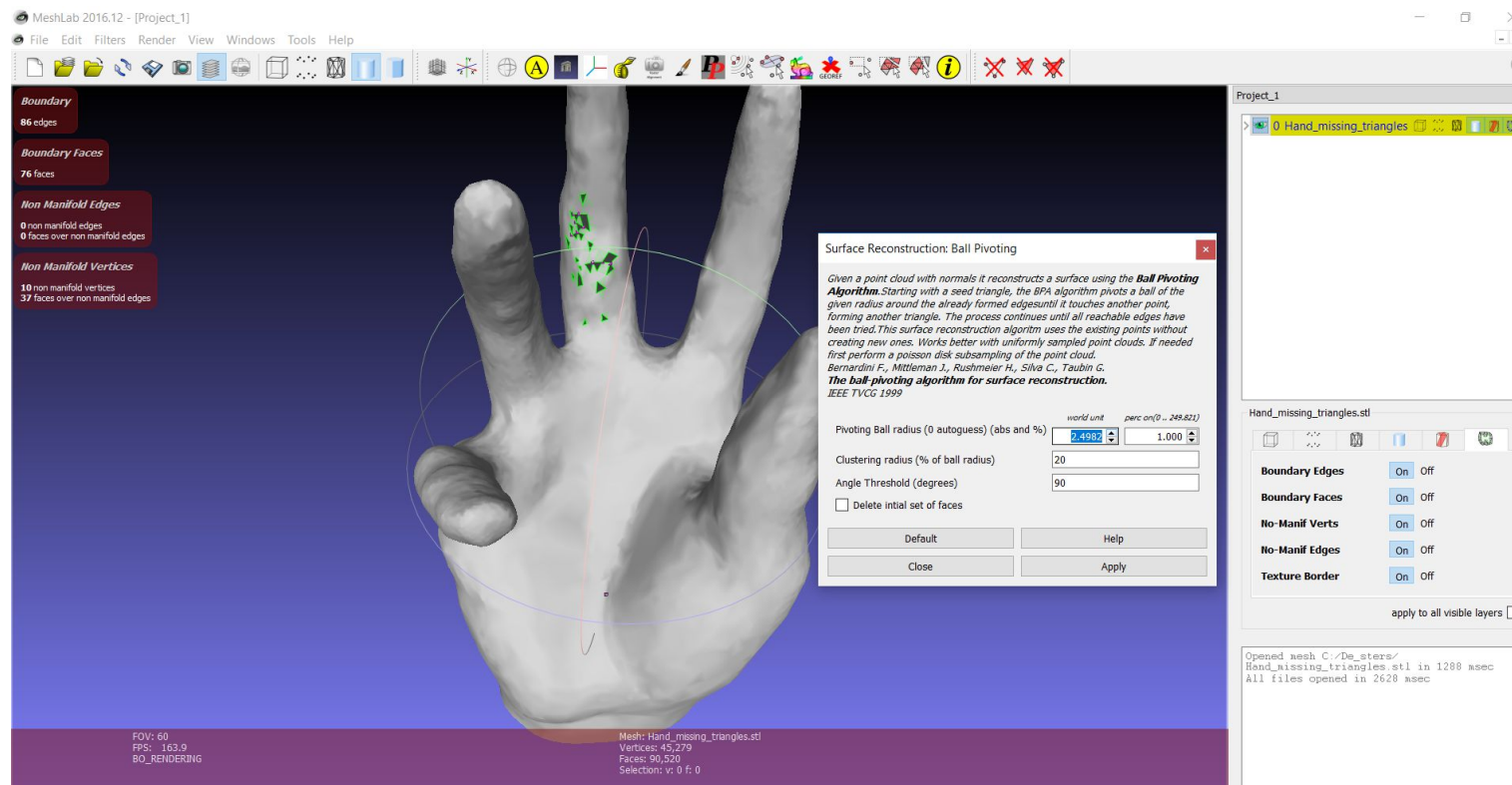
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Software for STL models - Meshlab

- Applying Surface Reconstruction Ball Pivoting option for filling the gaps in the model



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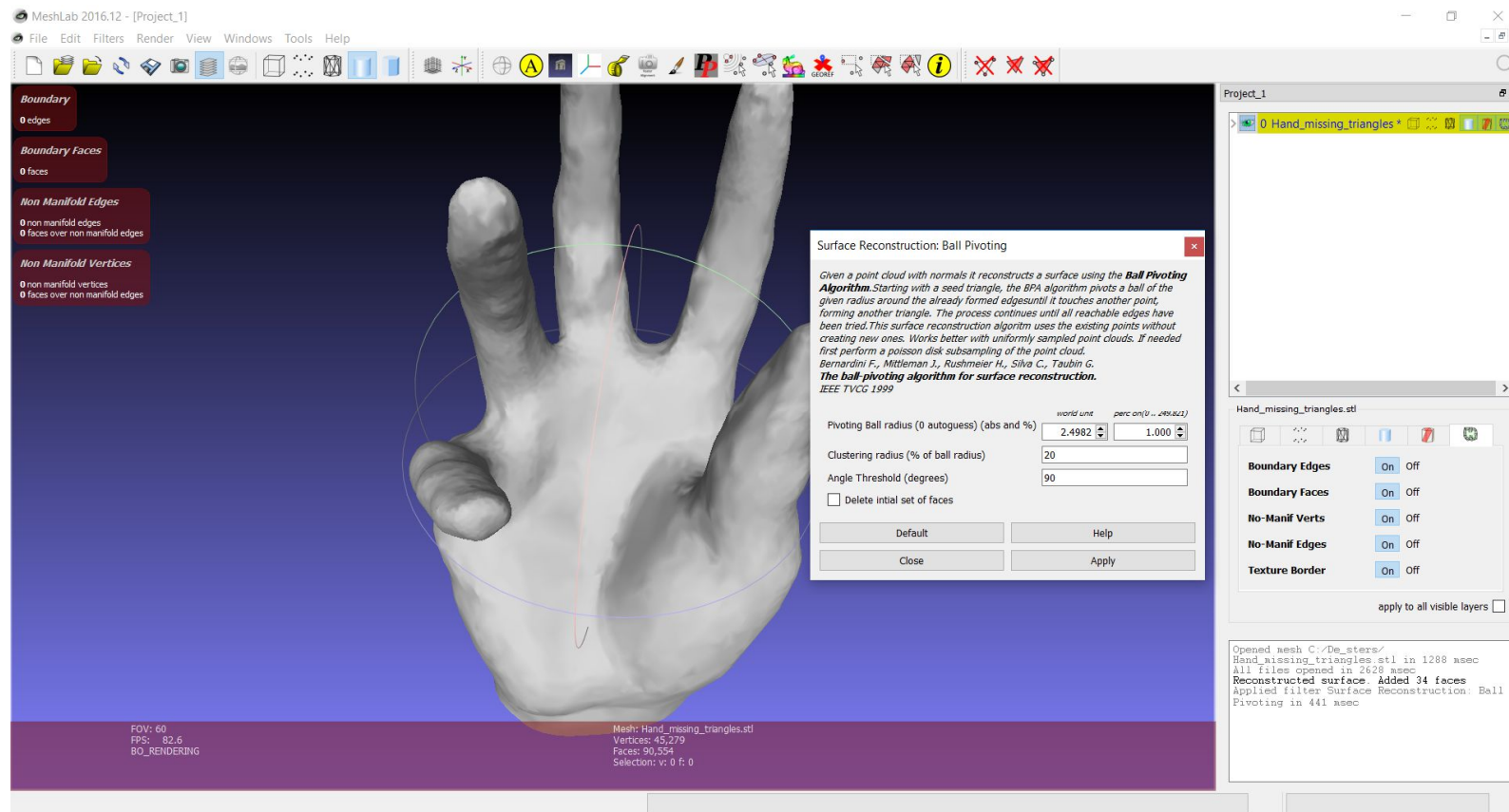
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Software for STL models - Meshlab

- The result of applying Ball Pivoting surface reconstruction



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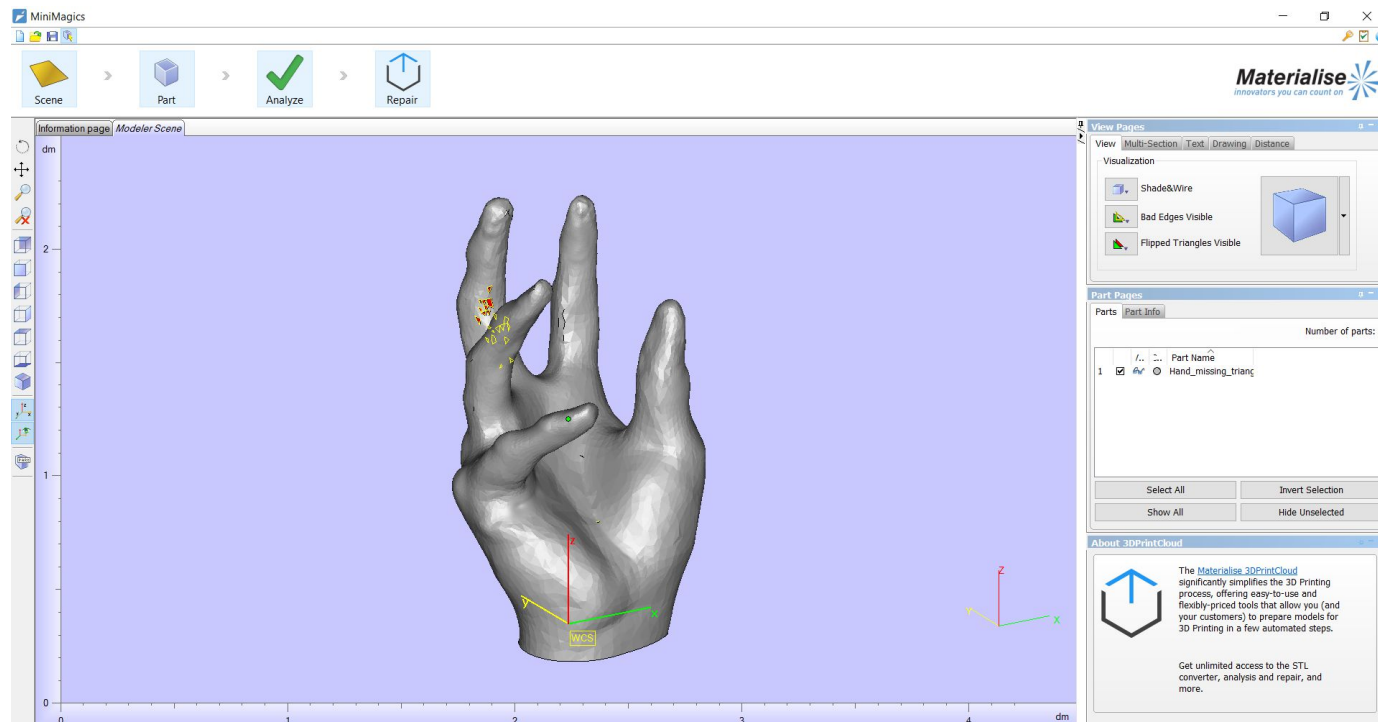
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Software for STL models - 3DPrintCloud

- MiniMagics, www.materialise.com/en/software/minimagics
- Loading the hand support model in MiniMagics software or in 3DPrint Cloud, <https://cloud.materialise.com/>



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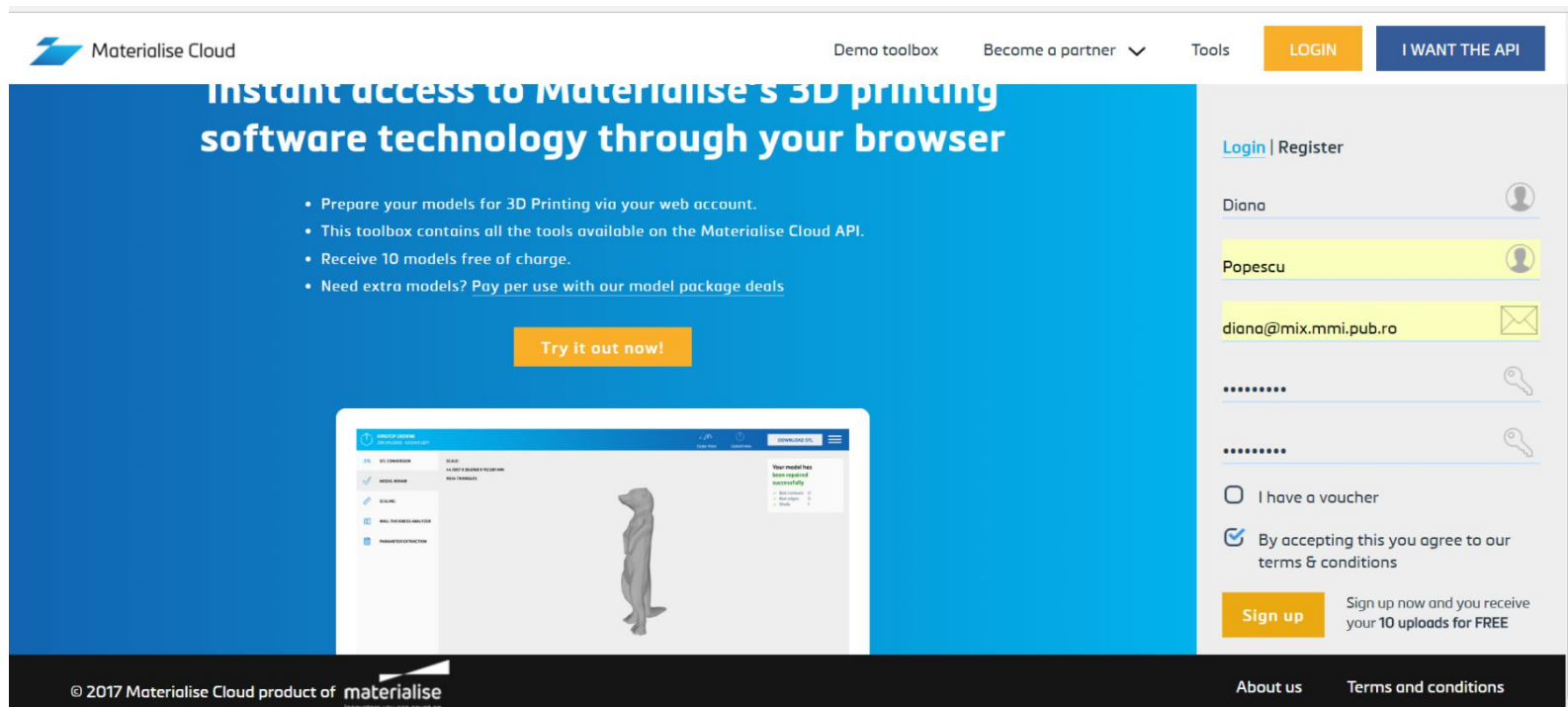
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Software for STL models - 3DPrintCloud

- In case of MiniMagics application, repair options are automatic and they are available in 3DPrintCloud
- User account is needed



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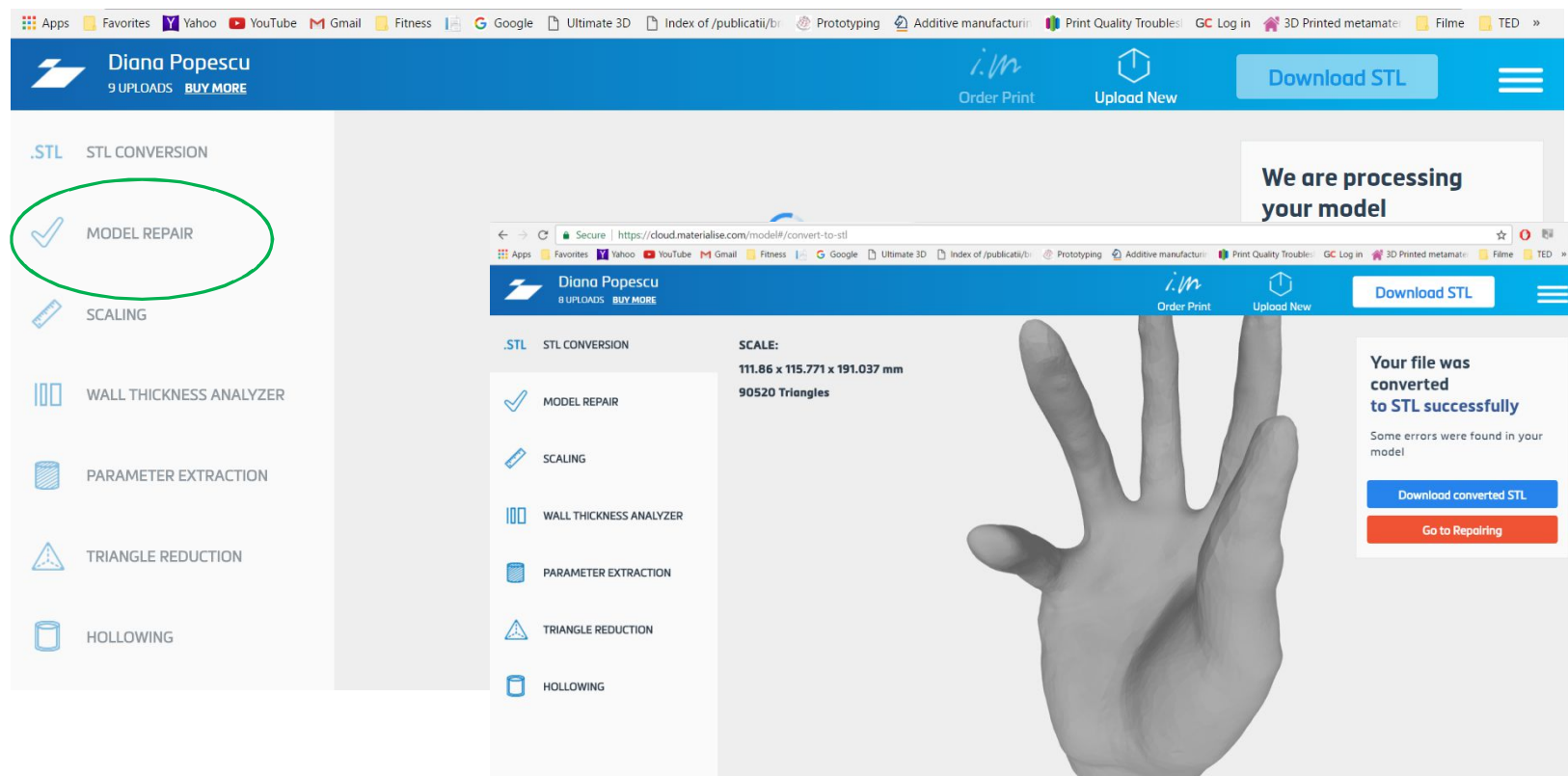
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Software for STL models - 3DPrintCloud

- Hand STL model is uploaded and mm is set as measure unit.
- Model Repair option is then applied



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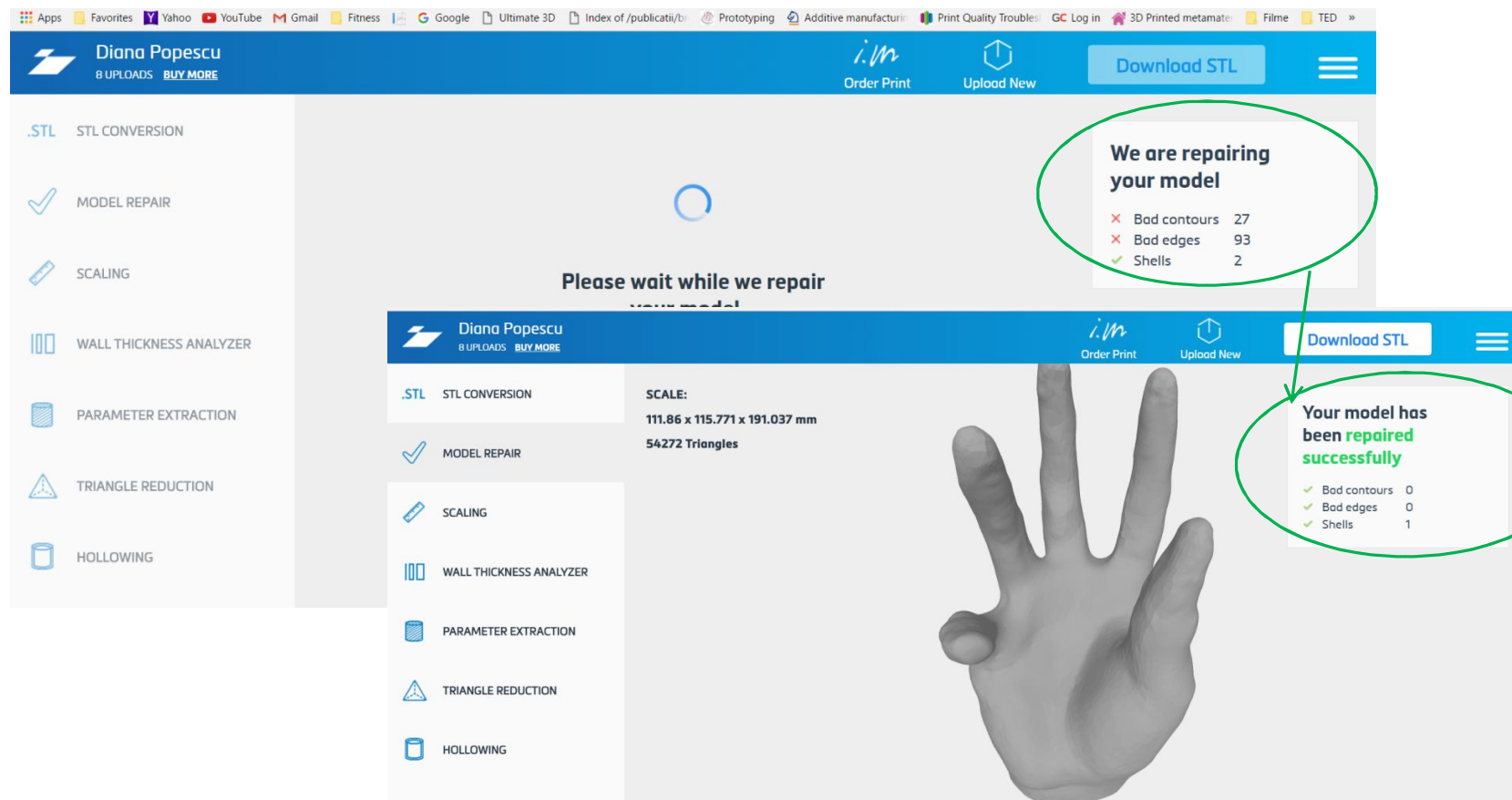
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Software for STL models - 3DPrintCloud

- The results of automatically repairing the model



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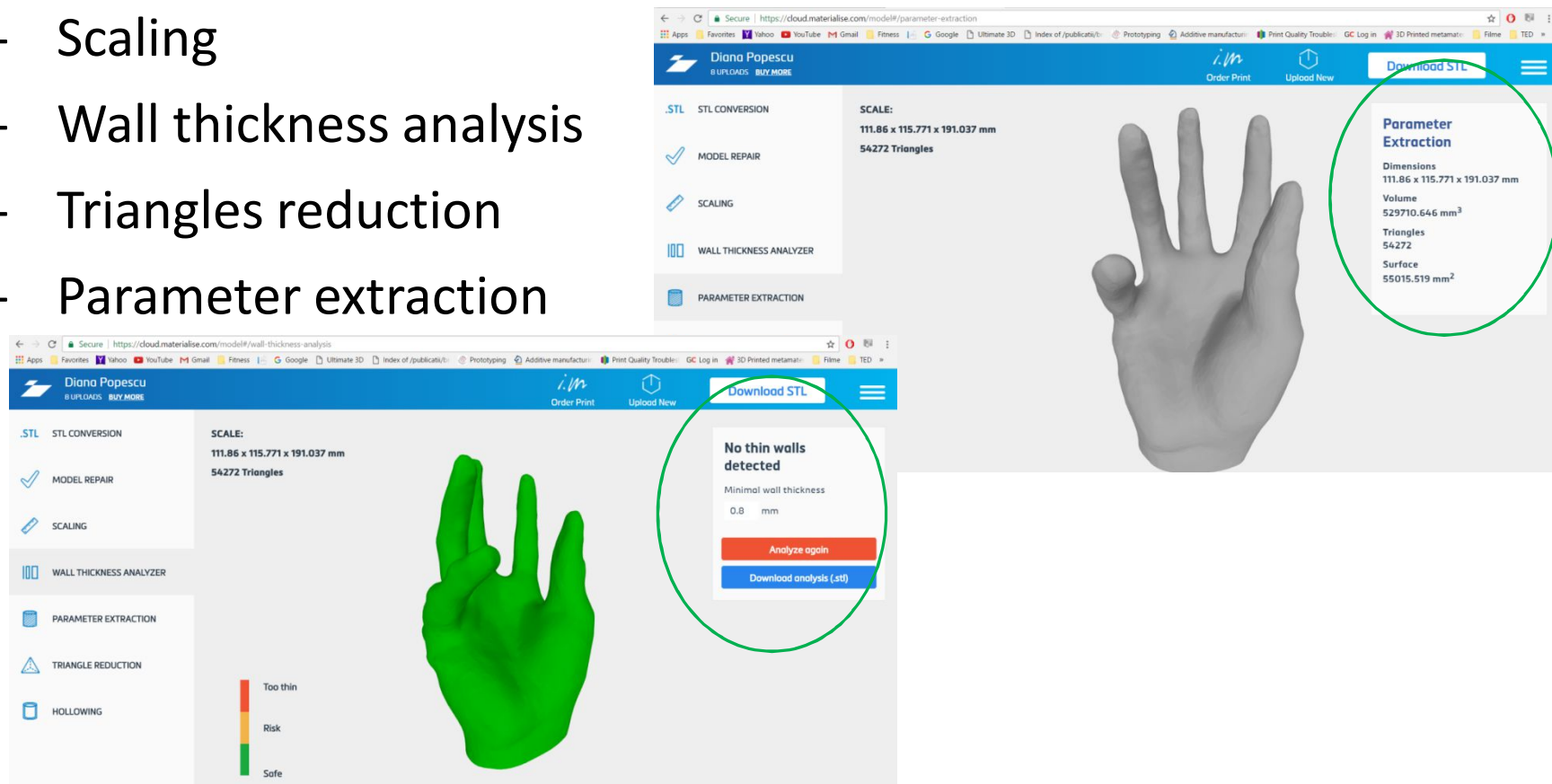
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Software for STL models - 3DPrintCloud

- Other options available in MinigMagics 3DPrintCloud:
 - Scaling
 - Wall thickness analysis
 - Triangles reduction
 - Parameter extraction



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Software for STL models - 3DPrintCloud

- **Hands-on session (15 minutes)**
 - Using the same model as in first hands-on session, repair the model with MiniMagics/3DPrint Cloud

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3D print models using online services



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Aim and Learning Outcomes

Module Aim:

To equip students with understanding of on how to access online service bureaus or platforms for loading model, estimating 3D printing costs and placing orders for manufacturing the desired object

Number of Hours:

3hrs

Learning outcomes:

- Knowledge on how to access 3D Printing online services providers
- Knowledge on how to upload STL model, select material, 3D Printing process, machine
- Knowledge on how to evaluate cost, delivery time and access other information provided by producers/platforms

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Lecture Outline

- 3D printing online services:
 - File formats accepted by 3D printing service providers
 - Workflow for using 3D printing online services
- 3D printing using platforms such as: 3DHubs, Sculpteo, Shapeways, i.Materialise, Ponoko

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3D printing online services

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3D printing online service providers

- Some 3D printing online services providers with instant quotes:

Provider	Website	Type of business	3D Printing process	Materials
3D Hubs	www.3dhubs.com	B2C, B2B	FDM, SLS, Sla, Polyjet,	Thermoplastics, Resins, Metals, Paper
Shapeways	www.shapeways.com	B2C, B2B	SLS, FDM	Thermoplastics, Metals,
Sculpteo	www.sculpteo.com	B2C, B2B	FDM, SL, SLS, SLM, CLIP, Polyjet, DMLS	Plastics, Resins, Metals,
i.materialise	https://i.materialise.com/	B2C, B2B	Thermoplastics, Metals, Ceramics, Resins	FDM, SLS, SL, Ceramic Jet, DMLS, Polyjet
Ponoko	www.ponoko.com	B2C, B2B	FDM, SLS, Polyjet	Thermoplastics, Metals
Protolabs	www.protolabs.com	B2B	FDM, SL, SLS, DMLS	Thermoplastics, Nylon, Metals
StrataSys Direct	www.stratasysdirect.com	B2B	FDM, SLS, Polyjet, DMLS, LS	Thermoplastics, Metals, Acrylic
QuickParts	http://www.quickparts.3dsystems.com/solutions	B2B	FDM, SL, SLS, Polyjet, DMLS	Thermoplastics, Resins, Metals, Nylon
BuildParts	www.buildparts.com	B2C, B2B	FDM, Polyjet, SLA, SLS, CLIP	Thermoplastics, Metals, Resins
Make XYZ	www.makexyz.com/	B2C, B2B	FDM, SL	Thermoplastics, Nylon, Resins

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3D printing online service providers

- File formats accepted by 3D printing service providers (examples):
 - 3DHubs: STL, OBJ
 - Shapeways: STL, OBJ, X3D, DAE, VRML
 - Sculpteo: STL, OBJ, SKP, OFF, PLY, KMZ, 3DS, AC3D, IPT, DAE, MD2/MD3, Q3O, COB, DXF, LWO, IGES, STP, VRML, SCAD, ZIP, RAR, TGZ, CARPART, CATPRODUCT, CGR, SLDPRT, SLDASM, IGES, IGS, SAT, 3DM, 3MF, PRC, U3D, X_T
 - i.materialise: STL, OBJ, WRL, SKP, DAE, 3MF, 3DS, IGS, MODEL, 3DM, FBX, PLY, MAGICS, MGX, X3D, STP, STEP, PRT, MATPART
 - Ponoko: STL, DAE, VRML
 - Make XYZ: STL, OBJ, ZIP, STEP, STP, IGES, IGS, 3DS, WRL

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3D printing online service providers

- The **workflow** for all 3D printing online providers consists in the following steps:
 1. Access 3D printing service provider webpage
 2. Upload model (using one of the file formats accepted, usually STL)
 3. Choose 3D printing process and/or material
 4. Decide if you want to 3D print the model based on the received quote and delivery time/conditions



3D printing online providers

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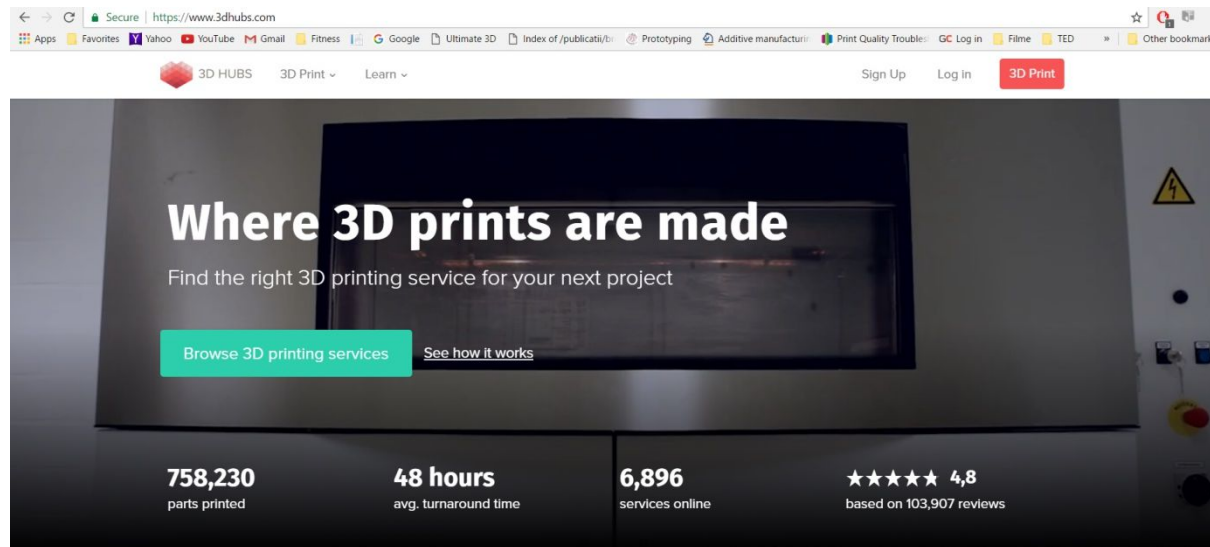
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3DHubs

- **3D Hubs**
- Gathers thousands of 3D printers owners from all over the world
- Offers suggestions regarding building material depending on price, surface quality, functional



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3DHubs

- 3D Hubs working flow

The screenshot displays the 3DHubs website interface. At the top, there's a navigation bar with '3D HUBS', '3D Print', and 'Learn' links, along with 'Sign Up', 'Log in', and a '3D Print' button. Below this, three main steps are highlighted: 'Upload your 3D Design' (In .STL or .OBJ format), 'Choose a Material' (That is best suited for your application), and 'Choose a 3D Printing Service' (Compare on price, speed and quality). The main content area shows a '1 Upload your parts' section with a 'File uploader' and a '2 Select a material' section. The 'Select a material' section is divided into three columns: 'Prototyping Plastic' (FDM), 'High Detail Resin' (SLA), and 'SLS Nylon' (SLS). Each column lists technical specifications and pros/cons.

Material	Technology	Dimensional accuracy	Minimum feature detail	Supports required	Pros/Cons
Prototyping Plastic	FDM	±1% (lower limit: ~0.5mm)	1mm	Yes	<ul style="list-style-type: none">+ Most affordable 3D printing solution- Limited dimensional accuracy for small parts- Print layers likely visible on surface
High Detail Resin	SLA	±0.5% (lower limit: ~0.15mm)	~0.5mm	Yes	<ul style="list-style-type: none">+ Smooth surface finish+ Fine feature details- Brittle, not suitable for mechanical parts
SLS Nylon	SLS	±0.3% (lower limit: ~0.3mm)	~0.8mm	No	<ul style="list-style-type: none">+ Functional, good mechanical properties+ Large build volume- Longer lead times

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3DHubs

- A STL model was uploaded as example and SLS process and Nylon material were chosen for 3D printing the part.

The screenshot displays the 3DHubs interface. At the top, there's a navigation bar with '3D HUBS', '3D Print', and 'Learn' links, along with 'Sign Up', 'Log in', and a '3D Print 1' button. The main area shows an uploaded STL file named 'nonlethal_door_stop_multitool.stl' with dimensions '121.5 X 52.0 X 30.0 mm' and a quantity of '1'. Below this, a modal window titled '2 Select a material' is open. It features an 'Advanced search' bar with the text 'e.g. SLS, Accura 25 or PolyJet'. Three material options are presented:

- Prototyping Plastic (FDM)**: Fast and affordable parts. Dimensional accuracy: $\pm 1\%$ (lower limit: $\sim 0.5\text{mm}$). Minimum feature detail: 1mm . Supports required: Yes. Pros: Most affordable 3D printing solution. Cons: Limited dimensional accuracy for small parts, Print layers likely visible on surface.
- High Detail Resin (SLA)**: Smooth surface finish and fine detail. Dimensional accuracy: $\pm 0.5\%$ (lower limit: $\sim 0.15\text{mm}$). Minimum feature detail: $\sim 0.5\text{mm}$. Supports required: Yes. Pros: Smooth surface finish, Fine feature details. Cons: Brittle, not suitable for mechanical parts.
- SLS Nylon (SLS)**: Strong and functional parts. Dimensional accuracy: $\pm 0.3\%$ (lower limit: $\sim 0.3\text{mm}$). Minimum feature detail: $\sim 0.8\text{mm}$. Supports required: No. Pros: Functional, good mechanical properties, Large build volume. Cons: Longer lead times.

The 'SLS Nylon' option is marked as 'Selected' with a green checkmark. Each option has a 'Select' button at the bottom.

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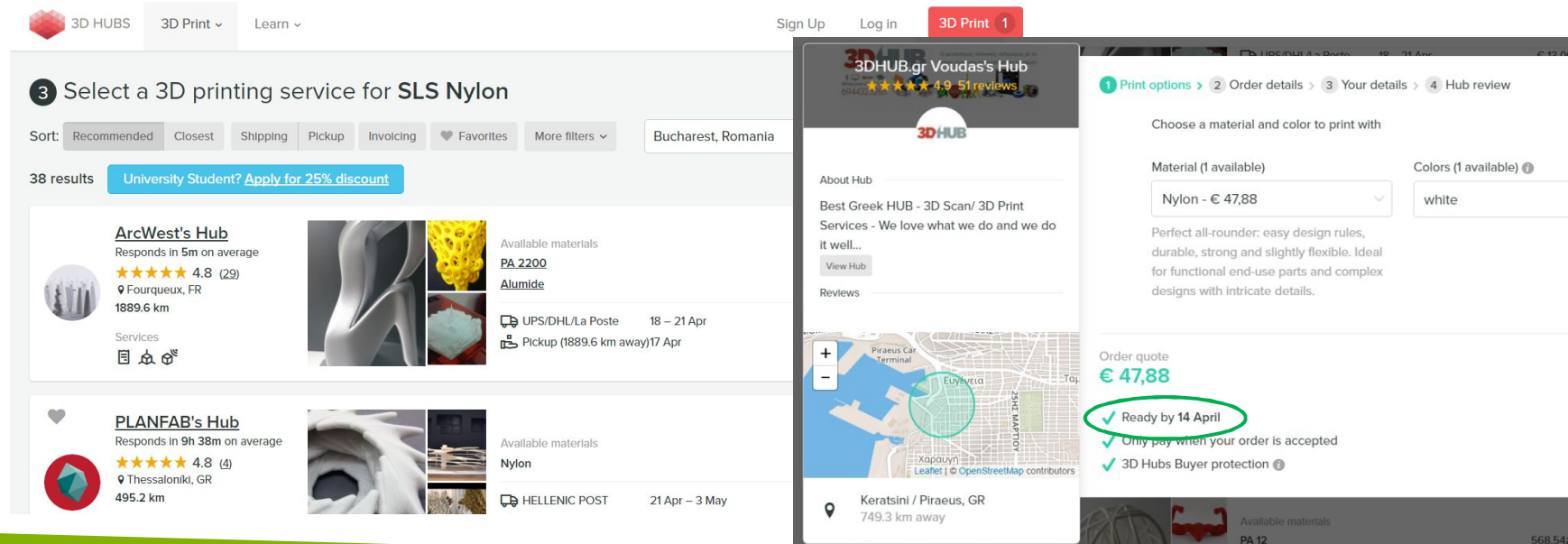
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3DHubs

- The list of suggested 3D printing service providers (enrolled on 3DHubs). They can be sorted depending on how close are to the users' location, price, etc.
- Delivery date is also mentioned (the order was placed on 10 April)



3D HUBS 3D Print Learn Sign Up Log in 3D Print 1

3 Select a 3D printing service for SLS Nylon

Sort: Recommended Closest Shipping Pickup Invoicing Favorites More filters Bucharest, Romania

38 results University Student? Apply for 25% discount

ArcWest's Hub
Responds in 5m on average
★★★★★ 4.8 (29)
Fourqueux, FR
1889.6 km
Services: [Icons]

PLANFAB's Hub
Responds in 9h 38m on average
★★★★★ 4.8 (4)
Thessaloniki, GR
495.2 km

3DHUB.gr Voudas's Hub
★★★★★ 4.9 51 reviews
About Hub
Best Greek HUB - 3D Scan/ 3D Print Services - We love what we do and we do it well...
View Hub
Reviews

Available materials: PA 2200, Alumide, Nylon

Services: UPS/DHL/La Poste (18 - 21 Apr), Pickup (1889.6 km away) 17 Apr, HELLENIC POST (21 Apr - 3 May)

Order quote: €47,88
Ready by 14 April
Only pay when your order is accepted
3D Hubs Buyer protection

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3DHubs

- Material recommendation – the user should answer some questions regarding material (metal or plastic), material properties and accuracy. Several steps are presented:

The screenshot displays the 3DHubs material recommendation wizard. It begins with an 'Upload your parts' section featuring a file uploader and a 'Material' pop-up asking for a recommendation. The main flow consists of several steps: 1. 'What material do you need? (beta)' with a 'Start' button. 2. 'I'm looking to print in:' with 'Metal' and 'Plastic' options. 3. 'What are the accuracy requirements of your design?' with 'Low', 'Medium' (selected), and 'High' options. 4. A recommendation for 'SLS Nylon (SLS)' accompanied by an image of a printed part and a description of its properties. The wizard concludes with a 'Select' button.

Upload your parts

File uploader File units mm

Material

Would you like to get a material recommendation for your parts?

No, thanks Yes, please

Browse for a file or drop parts here

We accept .stl and .obj files

1 → I'm looking to print in: *

A Metal

B Plastic

What material do you need? (beta)

Use this wizard to find the right **3D print material** for your application.
On average the wizard takes **57s** to complete.

Start press ENTER

4 → What are the **accuracy** requirements of your design? *

Low: Basic fit check. No (relevant) feature details below 1mm (\$)

Medium: Good accuracy. Tolerances of ± 0.3 mm or ± 0.05 mm/mm, whichever is greater (\$\$)

High: Tolerance <0.3 mm. Like the real part. Extreme fine details. Exhibition quality. (\$\$\$)

A Low

B Medium ✓

C High

We recommend **SLS Nylon (SLS)**

It's the perfect all-rounder: easy design rules, strong and slightly flexible. Nylon allows for functional end products and complex designs. Can be polished for a completely smooth finish.

Select press ENTER

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Shapeways

- **Shapeways**
- Requires creating an user account
- Offers 3D printing services, as well as a library for STL models

The screenshot displays the Shapeways website interface. The main header includes the Shapeways logo, 'Marketplace', 'My Workshop', and a search bar. The central banner features the text 'Bring your ideas to life' and 'From prototyping to finished product, the best tools to 3D print your ideas'. Below this, a 'Get started here' section contains buttons for 'JEWELRY', 'HOME DECOR', 'SCALE MODELS', 'RC CARS', and 'TABLETOP GAMING'. At the bottom of the banner, it says 'Ready to print your 3D model?' with a button 'UPLOAD A 3D MODEL'.

On the right side, there is a sidebar titled 'Upload Your 3D Design' with a close button (X). It includes a 'SELECT FILE' button, a status 'No file selected.', and 'Model Units' set to 'millimeters'. A large blue 'UPLOAD' button is present. Below the button, a disclaimer states: 'By clicking "Upload," you are representing that this 3D model does not violate Shapeways' Terms & Conditions and that you own all copyrights for this 3D model or have authorization to upload and use it.'

The sidebar also lists 'Supported 3D files' with the following details:

- Maximum file size: 64 MB or 1 million polygons
- Filetypes: DAE, OBJ, STL, X3D, X3DB, X3DV, WRL
- For color 3D prints: DAE, WRL, X3D, X3DB, X3DV
- Textures files: GIF, JPG, PNG
- Upload as ZIP containing model file and textures
- Privacy: Private by default

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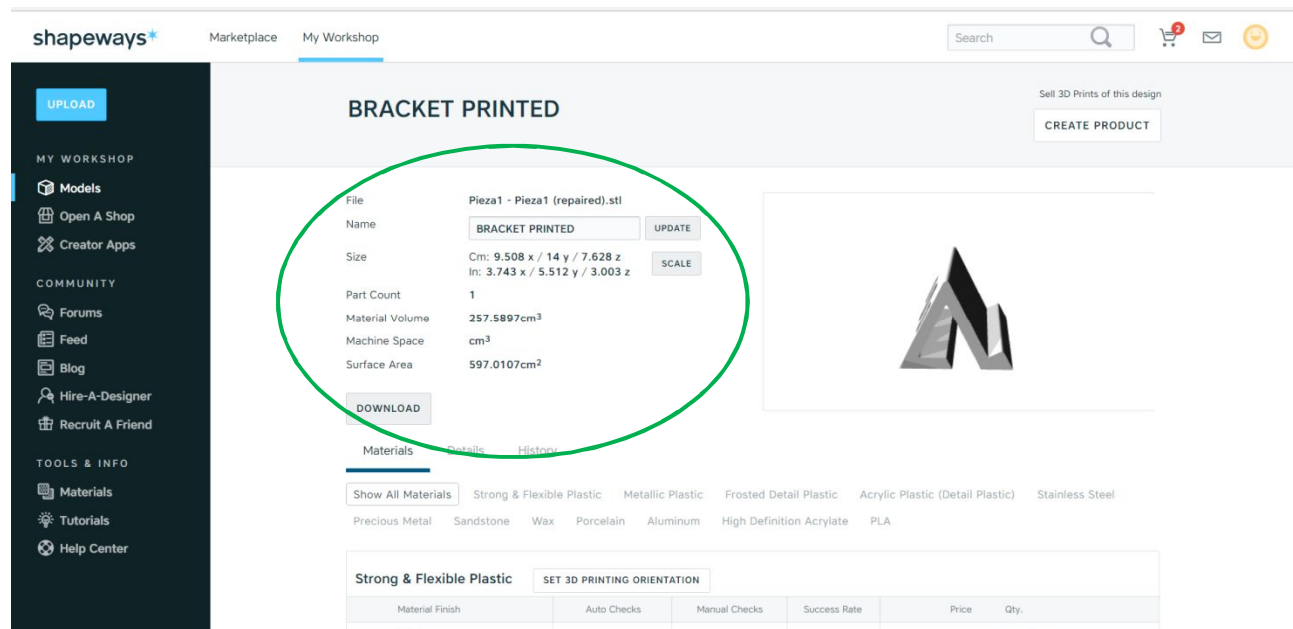
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Shapeways

- The model should be checked for errors before upload.
- After model upload, information on size, volume and surface area is available. Also a 3D model viewer allows visualizing the model (zoom and rotate options are available).



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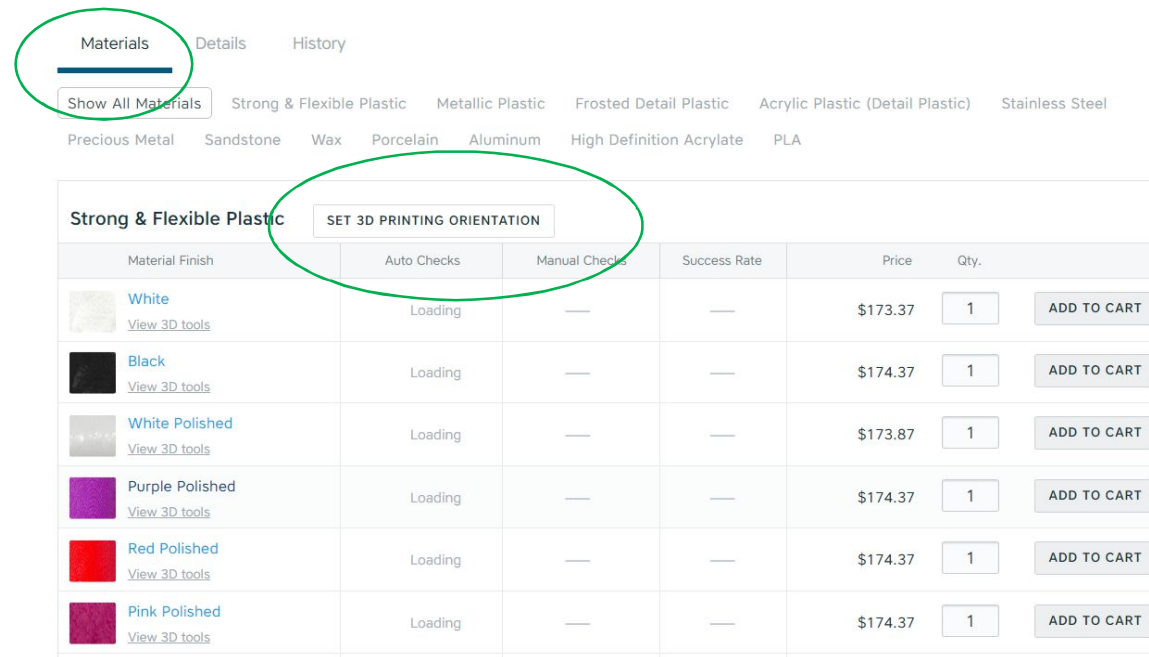
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Shapeways

- The next steps are: choosing a material for the object and setting a building orientation.
- Materials: strong & flexible plastics, metals, was, steel, etc.



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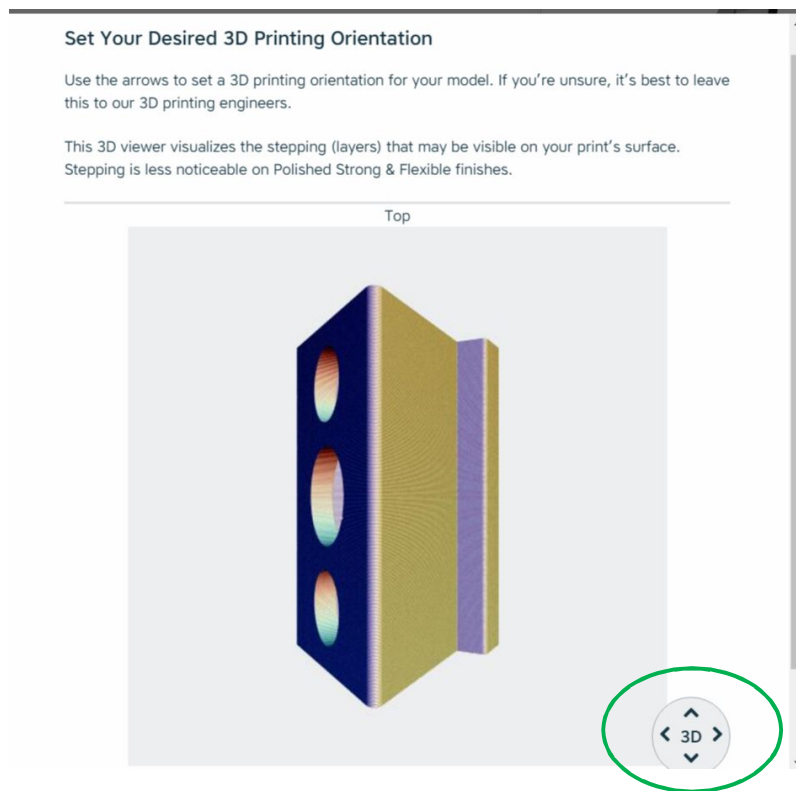
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Shapeways

- Setting building orientation in Shapeways using the arrows from the down-right. Zoom option is available.



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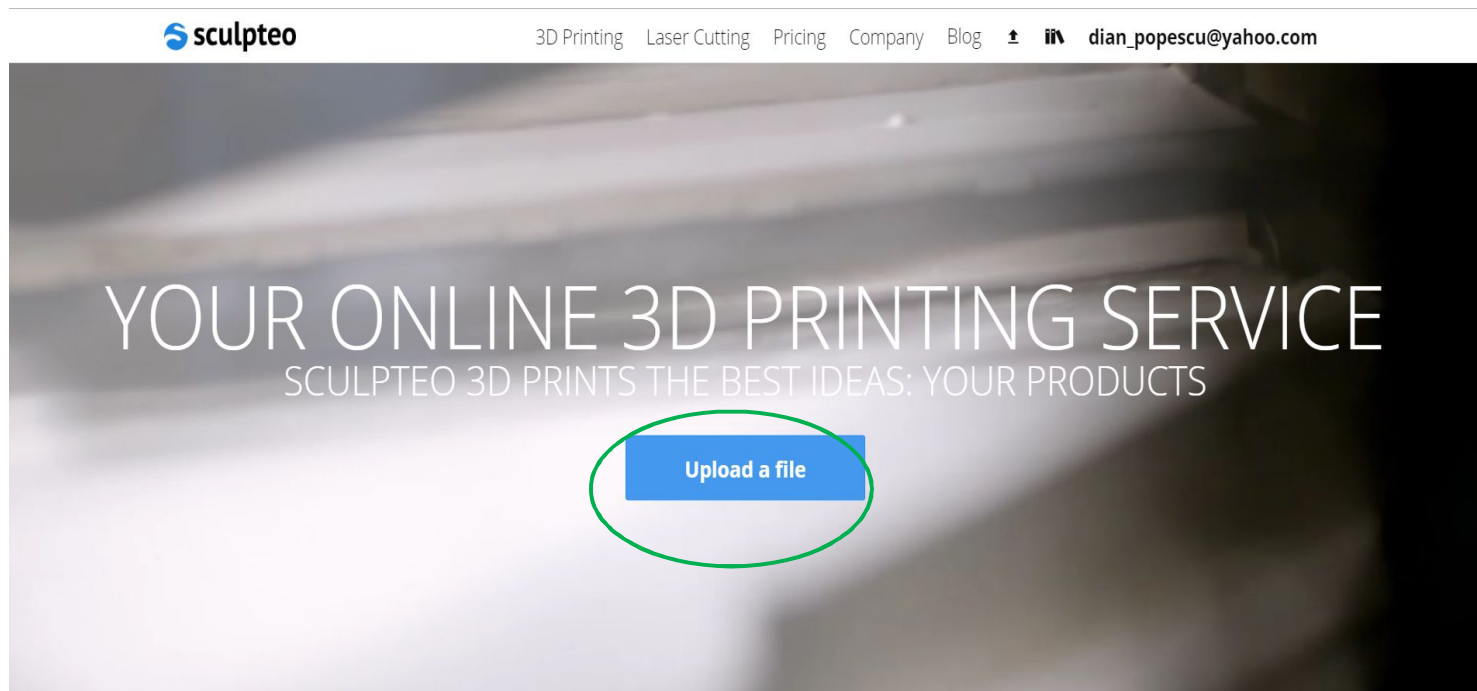
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Sculpteo

- **Sculpteo**
- User account is required



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Sculpteo

- Uploading and visualizing a STL model

The screenshot displays the Sculpteo website interface. At the top, the navigation bar includes the Sculpteo logo, links for 3D Printing, Laser Cutting, Pricing, Company, and Blog, and a user profile for dian_popescu@yahoo.com. Below the navigation bar, the 'Upload a file' section is active, showing a progress bar for a 0.3 MiB file upload. The main content area is divided into three sections: a left sidebar for form completion, a central 3D model viewer, and a right sidebar for pricing and settings.

Form Completion (Left Sidebar):

- Design name ***: luni_binary
- Description**: (Empty text area)
- Visibility**: Private (dropdown menu)
- Let people w**: (Checkboxes for 'Order a co' and 'Customize')
- Category**: --- (dropdown menu)
- *Required**: (Label for the category field)

3D Model Viewer (Center):

- Design name**: luni_binary by dian_popescu@yahoo.com
- Model**: A 3D visualization of a white, L-shaped object.
- Loading 3D model**: (Text and loading icon)

Pricing and Settings (Right Sidebar):

- Unit Price**: \$8.72
- Ships on April 14, 2017**
- Other available production services**:
 - Express: \$19.43
 - Economy: \$6.98
- Ships by April 13, 2017, guaranteed**
- Ships from April 21, 2017, save up to 30%!** (Includes sales taxes)
- Review & Checkout**: (Blue button)
- 3D Print Settings**:
 - Material: Plastic
 - Color: White
 - Finish: Raw
 - Layer Thickness: Standard (100 - 150µm)

Bottom Bar:

- Materials**: Plastic (\$8.72 per item. Ships in 3 working days.)
- Optimize**: (Button)
- Review**: (Button)
- Scale**: 1x (dropdown menu)
- Leave a message**: (Email icon and button)

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Sculpteo

- Information on price and shipping date is provided instantly after choosing material and 3D printing process.

The screenshot displays the Sculpteo website interface. At the top, the navigation bar includes the Sculpteo logo, links for 3D Printing, Laser Cutting, Pricing, Company, and Blog, and a user profile for dian_popescu@yahoo.com. The main content area features a large 3D model of a curved, metallic part. To the right of the model is a 'Review & Checkout' button. Below the model, there are three tabs: 'Materials', 'Optimize', and 'Review'. The 'Materials' tab is active, showing a list of material options: Plastic, Resin (Polyjet), Resin (CLIP), Alumide, Multicolor, and Metal (Laser melting). The 'Metal (Laser melting)' option is selected and highlighted with a green circle. To the right of the material list, the 'Optimize' tab is also highlighted with a green circle, displaying the price '\$89.98 per item. Ships in 6 working days.' and a detailed description of the Aluminum (AlSi7Mg0.6) material and its properties. The 'Review' tab is currently inactive. On the right side of the interface, the '3D Print Settings' section shows dropdown menus for Material (Metal (Laser melting)), Type (Aluminium), and Finish (Rough). The Scale is set to 45.5 x 30.7 x 36.5 mm, and the Weight is 16.9 g.

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Sculpteo

- The possibility to review the model for checking solidity or wall thickness.

sculpteo 3D Printing Laser Cutting Pricing Company Blog [dian_popescu@yahoo.com](#)

Could ship by April 13, 2017, if you choose Standard White Raw Plastic

Includes sales taxes
1 x \$89.98 = \$89.98

Review & Checkout

3D Print Settings
Material: Metal (Laser melting)
Type: Aluminium
Finish: Rough
Scale: 45.5 x 30.7 x 36.5 mm
Weight: 16.9 g

Materials **Optimize** **Review**

Solidity Check
The material you chose has a solidity threshold of around 1mm.

Thickening ☐ OFF

3D Print Dossier - FinalProof
3D Print Dossier provides a full breakdown of every aspect of your 3D Print by email, including FinalProof, Solidity Check, scale blueprints and a full quote if available.

[Receive your 3D Print Dossier](#)

Cookies help us deliver our services. By using our services, you agree to our use of cookies. [Learn more](#)

[Leave a message](#)

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Sculpteo

- Sculpteo can also generate a 3D printing dossier containing all the information and checks presented

2 / 6

3 / 6

Here's your full, free analysis of "luni_binary", as of April 11, 2018, created using Sculpteo's in-house technologies. You can review all the details of your 3D print offline and in your own time.

luni_binary

1 unit, \$91.98 (Includes sales taxes)

Material metal_slm_aluminium_rough

Finish raw

Scale 45.5 x 30.7 x 36.5 mm

Solidity Check (Page 3)

Different materials have different physical characteristics, notably fragility. Very thin part of your design may be fragile or even unprintable. This can cause frustration, delays and damaged items.

To help avoid this, our **Solidity Check** illustrates the areas of your design that, at this scale and in this material, would likely break or be too thin to safely print.

See your design from multiple angles and verify its solidity at a glance.

Blueprints (Page 4)

Some 3D file formats don't include information on the units or absolute scale. While you set the units and scale at any time on the 3D print page, it's always helpful to see a 1:1 scale illustration of your design.

Just print this document at actual size and you'll have 1:1 scale blueprints of your design for confirmation and validation.

Quote

By [creating an account on Sculpteo](#) and filling in your delivery details, we could attach a

Front Back Right Left Top Bottom

Too Thin Looks Good

0 27.3 mm 1.08 in

Solidity Check provides a heatmap of fragile areas (marked red) in your design. Despite these automatic checks, all designs go through a supplementary manual check, just to be sure.

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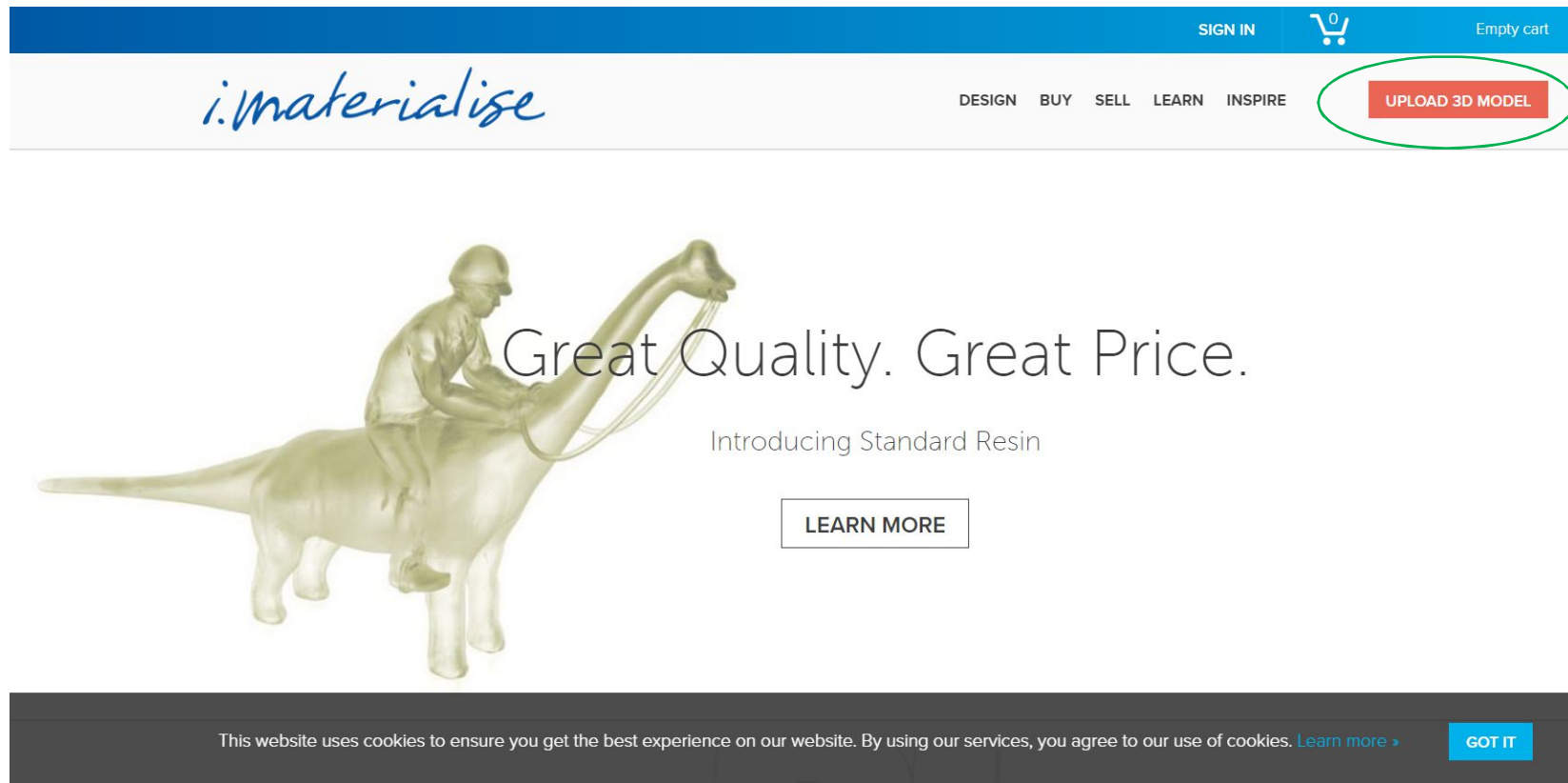
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i.Materialise


- i.Materialise



The screenshot shows the i.Materialise website interface. At the top, a blue navigation bar contains 'SIGN IN' and a shopping cart icon with 'Empty cart' text. Below this is a white header with the 'i.materialise' logo in blue script. To the right of the logo are links for 'DESIGN', 'BUY', 'SELL', 'LEARN', and 'INSPIRE'. A red button labeled 'UPLOAD 3D MODEL' is circled in green. The main content area features a large image of a 3D model of a person riding a dinosaur. To the right of the image, the text 'Great Quality. Great Price.' is displayed, followed by 'Introducing Standard Resin' and a 'LEARN MORE' button. At the bottom, a dark grey footer contains a cookie consent message and a 'GOT IT' button.

SIGN IN  Empty cart

i.materialise DESIGN BUY SELL LEARN INSPIRE **UPLOAD 3D MODEL**

 Great Quality. Great Price.
Introducing Standard Resin
LEARN MORE

This website uses cookies to ensure you get the best experience on our website. By using our services, you agree to our use of cookies. [Learn more >](#) **GOT IT**

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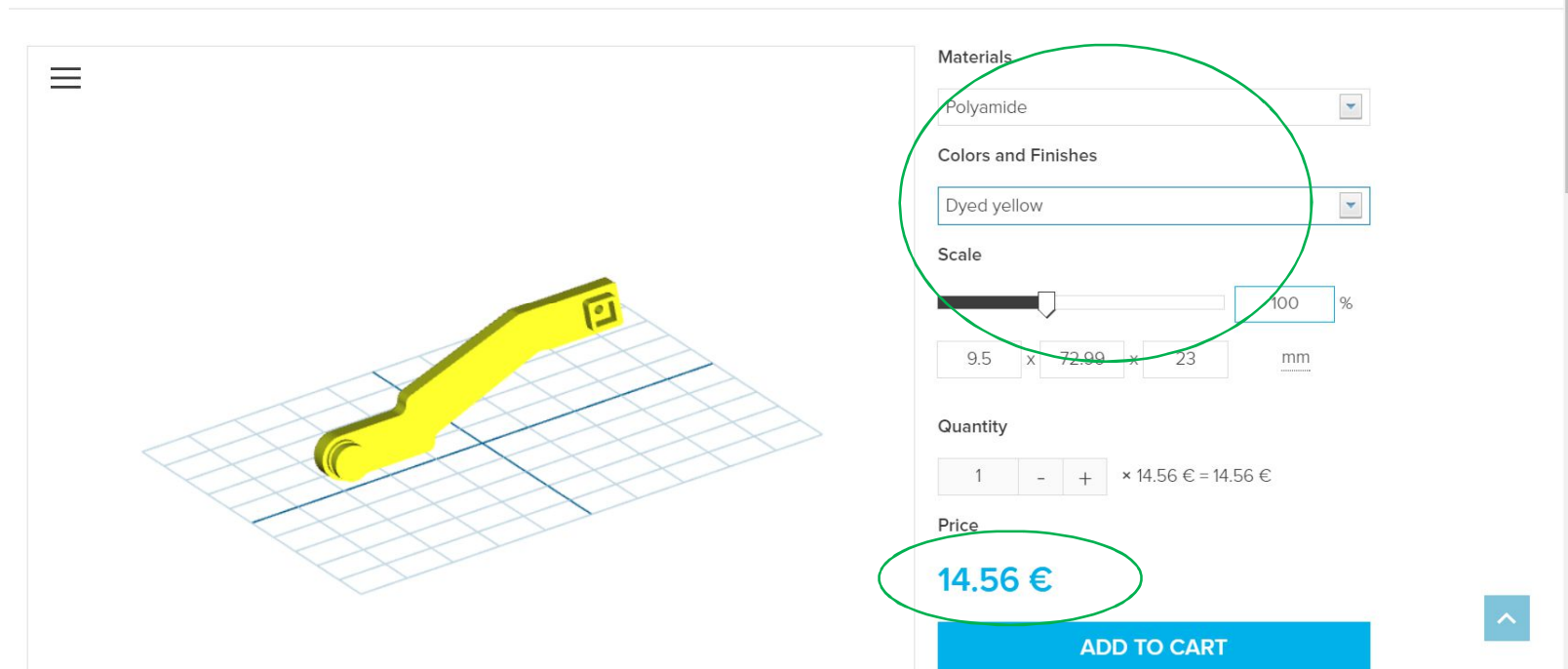


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i.Materialise

- Upload model, choose material, color, finishes and quantity
- The price is displayed instantly

Upload 3D Model



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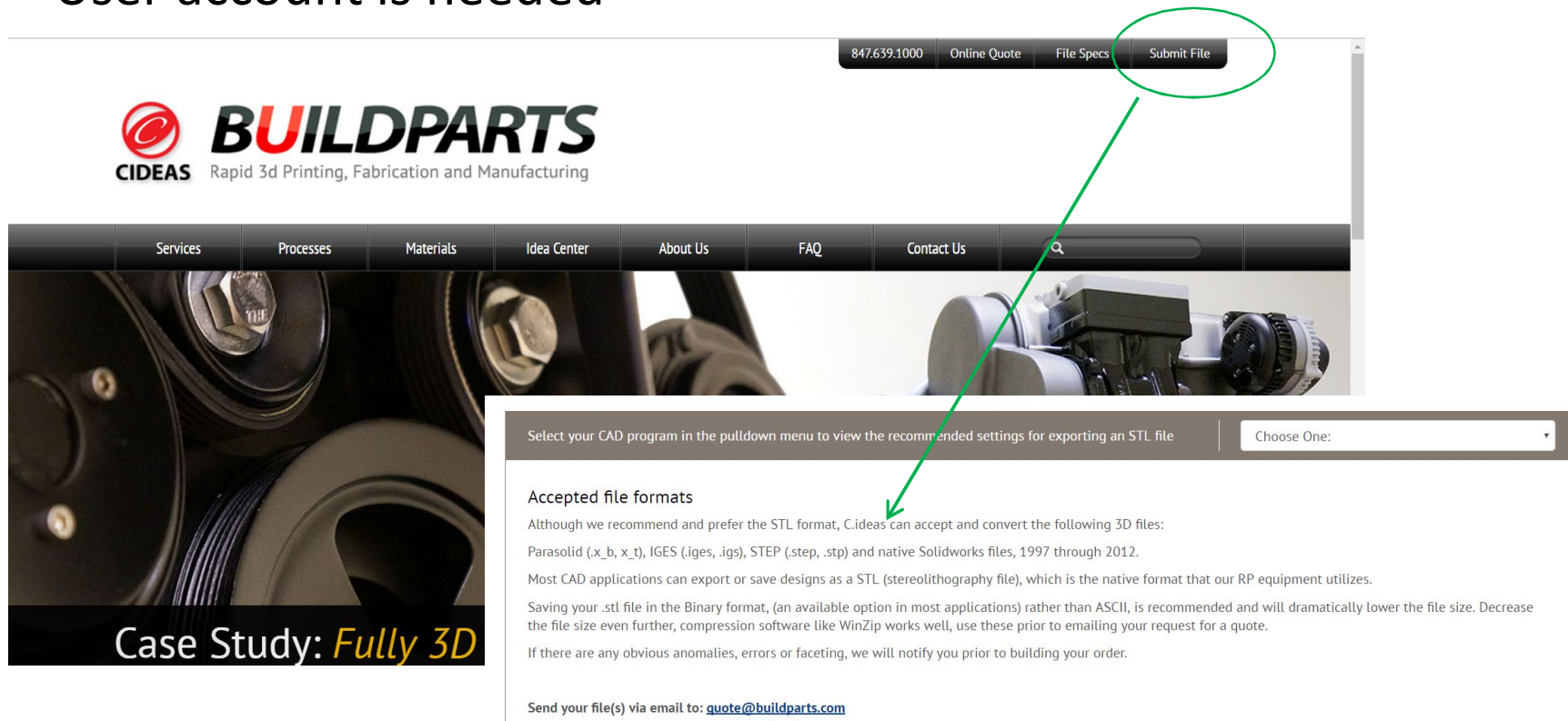
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BuildParts

- BuildParts
- User account is needed



847.639.1000 Online Quote File Specs **Submit File**

CIDEAS BUILDPARTS
Rapid 3d Printing, Fabrication and Manufacturing

Services Processes Materials Idea Center About Us FAQ Contact Us

Select your CAD program in the pulldown menu to view the recommended settings for exporting an STL file Choose One: ▼

Accepted file formats

Although we recommend and prefer the STL format, C.ideas can accept and convert the following 3D files:
Parasolid (.x_b, x_t), IGES (.iges, .igs), STEP (.step, .stp) and native Solidworks files, 1997 through 2012.

Most CAD applications can export or save designs as a STL (stereolithography file), which is the native format that our RP equipment utilizes.

Saving your .stl file in the Binary format, (an available option in most applications) rather than ASCII, is recommended and will dramatically lower the file size. Decrease the file size even further, compression software like WinZip works well, use these prior to emailing your request for a quote.

If there are any obvious anomalies, errors or faceting, we will notify you prior to building your order.

Send your file(s) via email to: quote@buildparts.com

Case Study: Fully 3D

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BuildParts

- **True-Quote** option in **BuildParts**
- Steps: upload model; choose material and process; choose building orientation, resolution, finishing and quantity.

The screenshot displays the CIDEAS True-Quote web interface. The main navigation bar includes the logo, a header with the text "VIEW YOUR STL DRAWINGS - VIRTUAL BUILD QUOTE YOUR PARTS - PLACE YOUR 3D BUILD ORDERS HERE", and a sub-header "With our Patent-Pending Virtual-Build True-Quote™ Technology you'll have the True-Quote™ in minutes." The interface is divided into several sections:

- Left Sidebar:** Contains a vertical list of steps numbered 1 through 8. Step 1 is "Begin", and step 8 is "Quote". A green circle highlights steps 2 through 6, which are: "Build Process and Material", "Units of Measure", "Resolution", "Build Orientation", and "Finish Level".
- Main Content Area:** Titled "Please choose one of the following:", it offers two options: "AUTO QUOTE STL FILES" and "MANUAL QUOTE". The "AUTO QUOTE" section explains that True-Quote accepts STL files under 25mb and provides a link to the manual quote request option. The "MANUAL QUOTE" section explains that CIDEAS accepts most major file formats (STL, IGES, Step, SAT or Parasolid) and provides a link to the manual upload tool. A 3D model of a mechanical part is shown on the right.
- Right Sidebar:** Contains a "Build Process and Material" section with a table of options. The table has two columns: "Process" and "Material". The "Process" column includes options like FDM, SLA, SLS, PolyJet, and others. The "Material" column includes options like ABS M100, ABS M30, ABS M30i, ABS P400, ABS P500, NYLON 12, PC, PC-ABS, PC-ISO, and ULTEM 1010. Below the table, there are sections for "UNITS OF MEASURE" (Millimeters, Bounding Box: X=2.9), "PROCESS / MATERIAL / RESOLUTION / FINISHING" (FDM, ABS M100 Natural, Standard .010 slice, STD Support Removal), and a "Zero XYZ" section with buttons for X, Y, and Z.

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BuildParts

- Model is uploaded and manually oriented



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BuildParts

- Generating quote for the model

1 Add another File Help Account

PROPERTIES OF FILE IN VIEWER

Varianta_dintr-o_bucata.stl
Size: 1.173 kb.
Raw Extents: X=53.00 Y=72.99 Z=23.00

2 Build Process and Material

3 Units of Measure 4 Resolution

5 Build Orientation 6 Finish Level

UNITS OF MEASURE OF FILE IN VIEWER

Millimeters
Bounding Box: X=2.91in. Y=2.14in. Z=0.91in.

PROCESS / MATERIAL / RESOLUTION / FINISHING

FDM
ABS M100 Natural (color shown is approximate)
Standard .010 slice
STD Support Removed

7 Qty: 1 8 Quote
Quote Part in Viewer
View Recent Quotes

varianta_dintr-o_bucata
ready to quote this part.

of our project managers.

QUOTATION

NUMBER 166234
Created: Apr 11 2017 4:32am CST

ATTENTION:


Diana Popescu
dian_popescu@yahoo.com
0040744649727

University Politehnica din Bucuresti
-
Bucharest, Romania 060032

FROM:

CIDEAS Inc.
125 Erick Street
Unit 115
Crystal Lake, IL 60014

www.buildparts.com
847 639-1000
847 639-1983 FAX

Item	QTY	Part	File Name & Part Extents	Process & Resolution	Material & Finish	UNIT PRICE	EXT. PRICE
1	1		Varianta_dintr-o_bucata.stl 2.91in. x 2.14in. x 0.91in.	FDM Standard .010 slice	ABS M100 Natural STD Support Removed	\$71.28	\$71.28

Comments:

QUOTE TOTAL \$71.28
*Excludes Tax
**Excludes Shipping

Print Download PDF Email PDF Save Quote Create Order

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BuildParts

- **Hands-on session:**
 - Download a STL file from an online repository
 - Choose at least two 3D printing service providers and upload your model
 - Choose material and/or process and compare manufacturing prices

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3D printing on low-cost filament deposition 3D printer



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Aim and Learning Outcomes

Module Aim:

- To equip students with knowledge on setting building orientation, process parameters and build an object on a low-cost 3D printer, as well as with knowledge on 3D printer software

Number of Hours:

4hrs

Learning outcomes:

- Knowledge on importing STL file in 3D printer software, scale and position object within building envelope, set process parameters, slice the model
- Knowledge on applying post-processing operations for 3D printed objects

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Lecture Outline

- 3D print an object using Z-suite for Zortrax 3D printer
- 3D print an object using Cura for Ultimaker printers
- 3D print an object using Slic3r software for RepRap 3D printers
- 3D print an object using ReplicatorG for RepRap 3D printers, Makerbot Replicator, Thing-O-Matic

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3D print an object using Z-suite for Zortrax 3D printer

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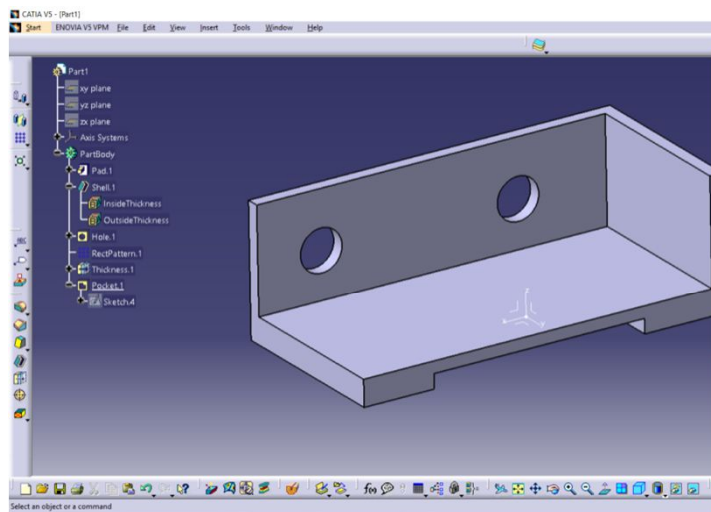
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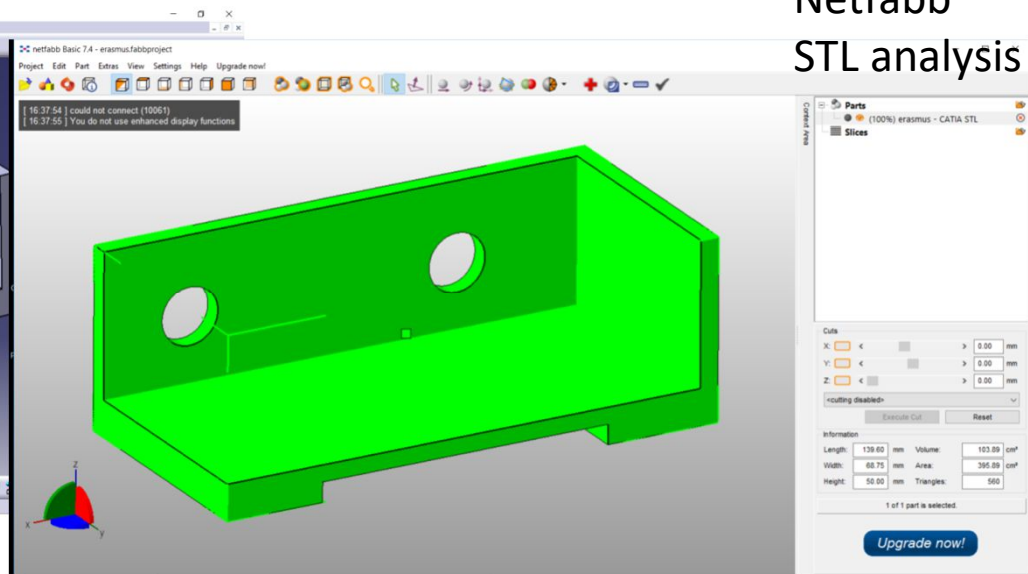
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3D print using Z-suite software

- **Z-Suite software for Zortrax 3D printers**
- A virtual 3D model is designed or downloaded from repositories as STL file.
- If object is modelled in a 3D CAD application, save it as STL file.
- Verify and, if necessary, correct the STL file in Netfabb



3D CAD modeling



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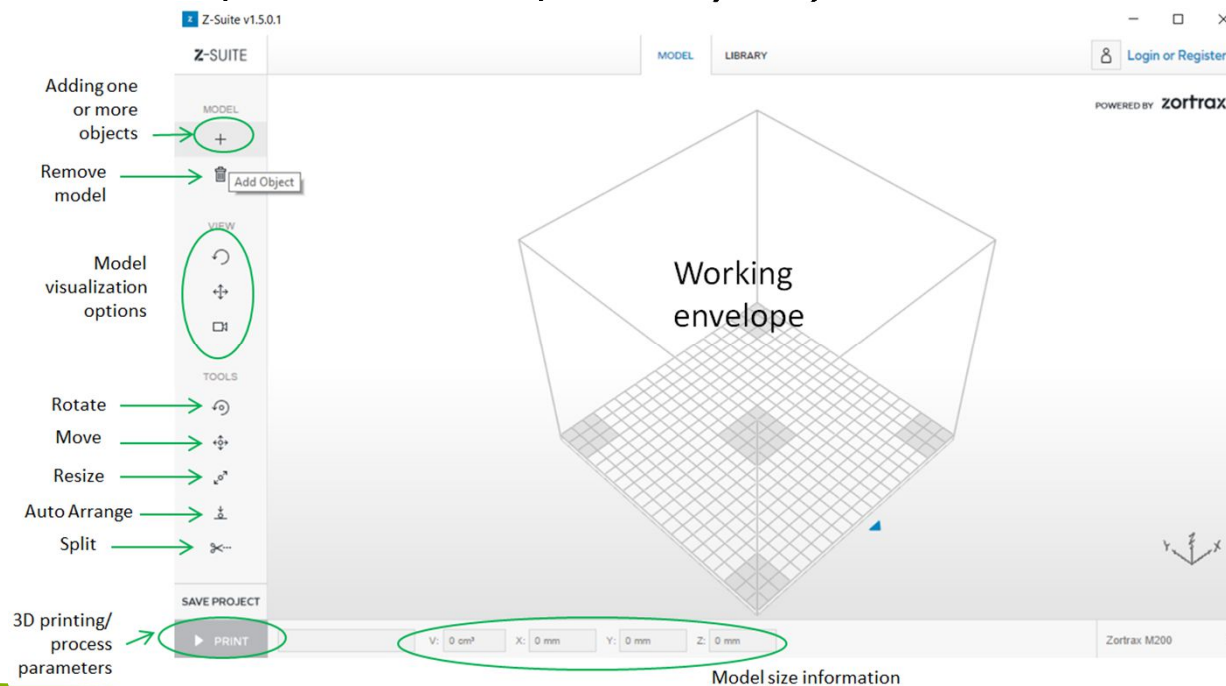
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3D print using Z-suite software

- Open STL file in Z-Suite software using drag-and-drop or with Add Object (+ icon)
- Mouse buttons can be used for manipulating views (MB1-rotate, MB2-zoom, MB3-pan).



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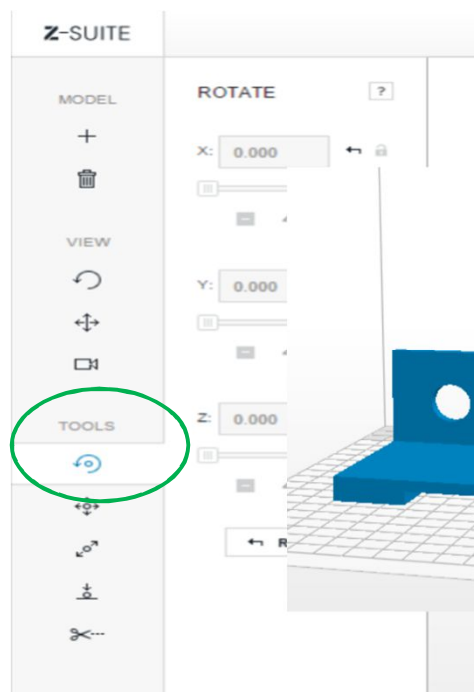
3D print using Z-suite software

- Orient model within the working space so that to fulfill user criteria such as: minimize support structure volume, place holes with axis along building direction, place important surfaces in vertical or horizontal positions, etc.
- Rotation can be performed around x, y and z axes.
- Object is selected by placing the mouse on one of its surfaces and clicking MB3.

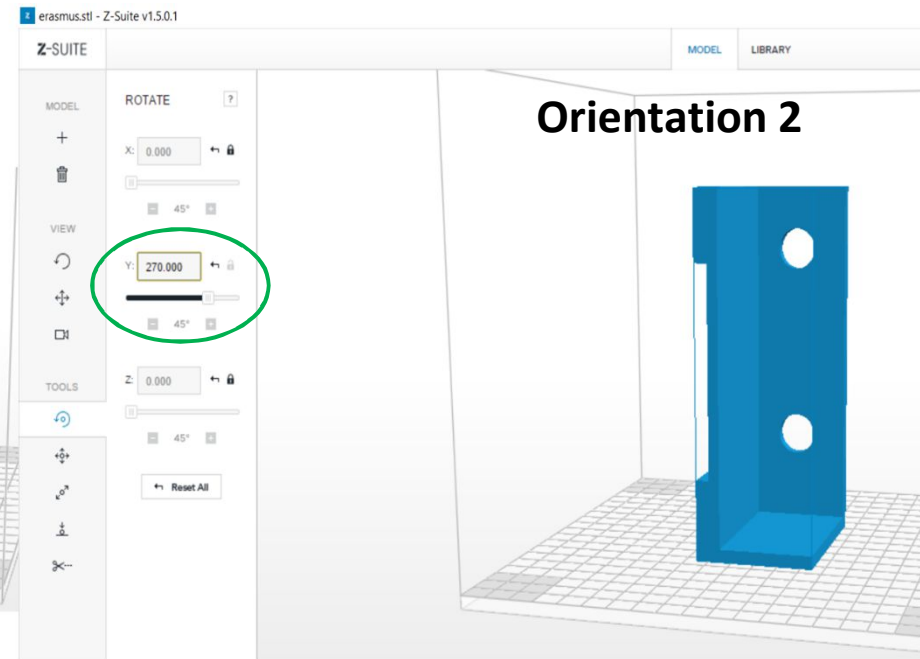


3D print using Z-suite software

- Model orientation within working space



Orientation 1



Object rotated with 270deg around y axis

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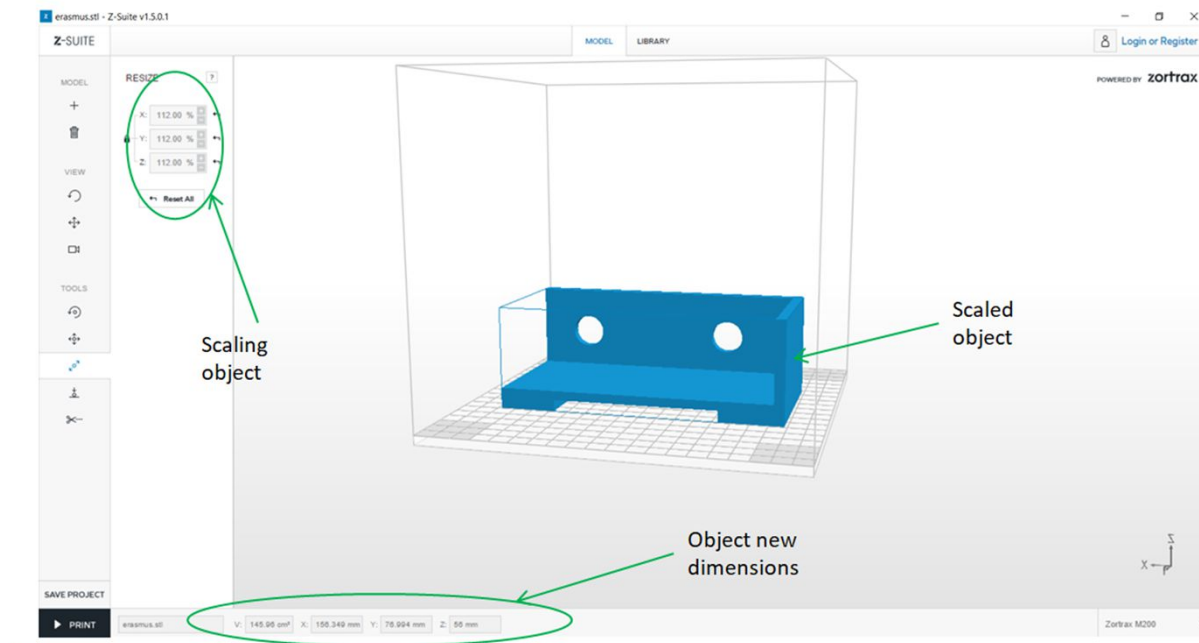
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3D print using Z-suite software

- Also object can be move on the platform using Move button.
- Object can be resized (scaled) with Resize button with the same value in x, y and z directions



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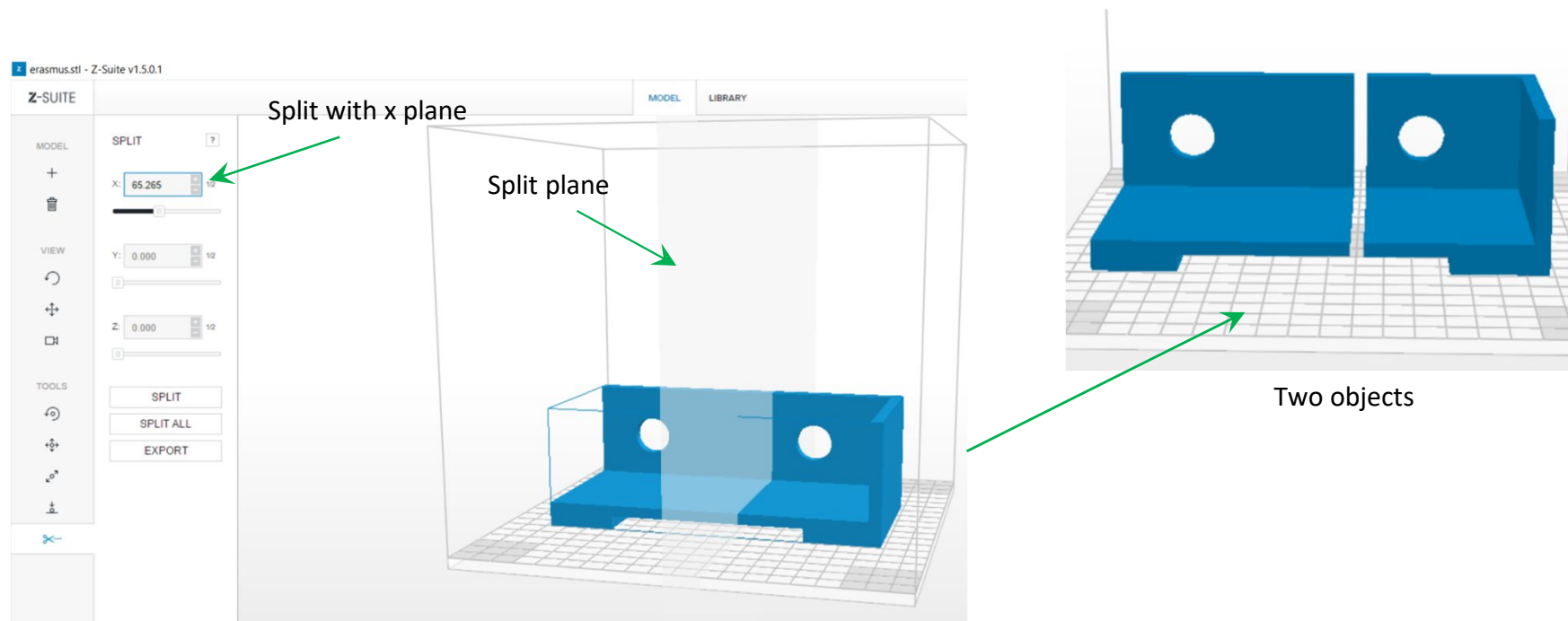
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3D print using Z-suite software

- Object can be split using Split option. As an example, the object is split with plane.



- Each object resulted from Split option can be exported.

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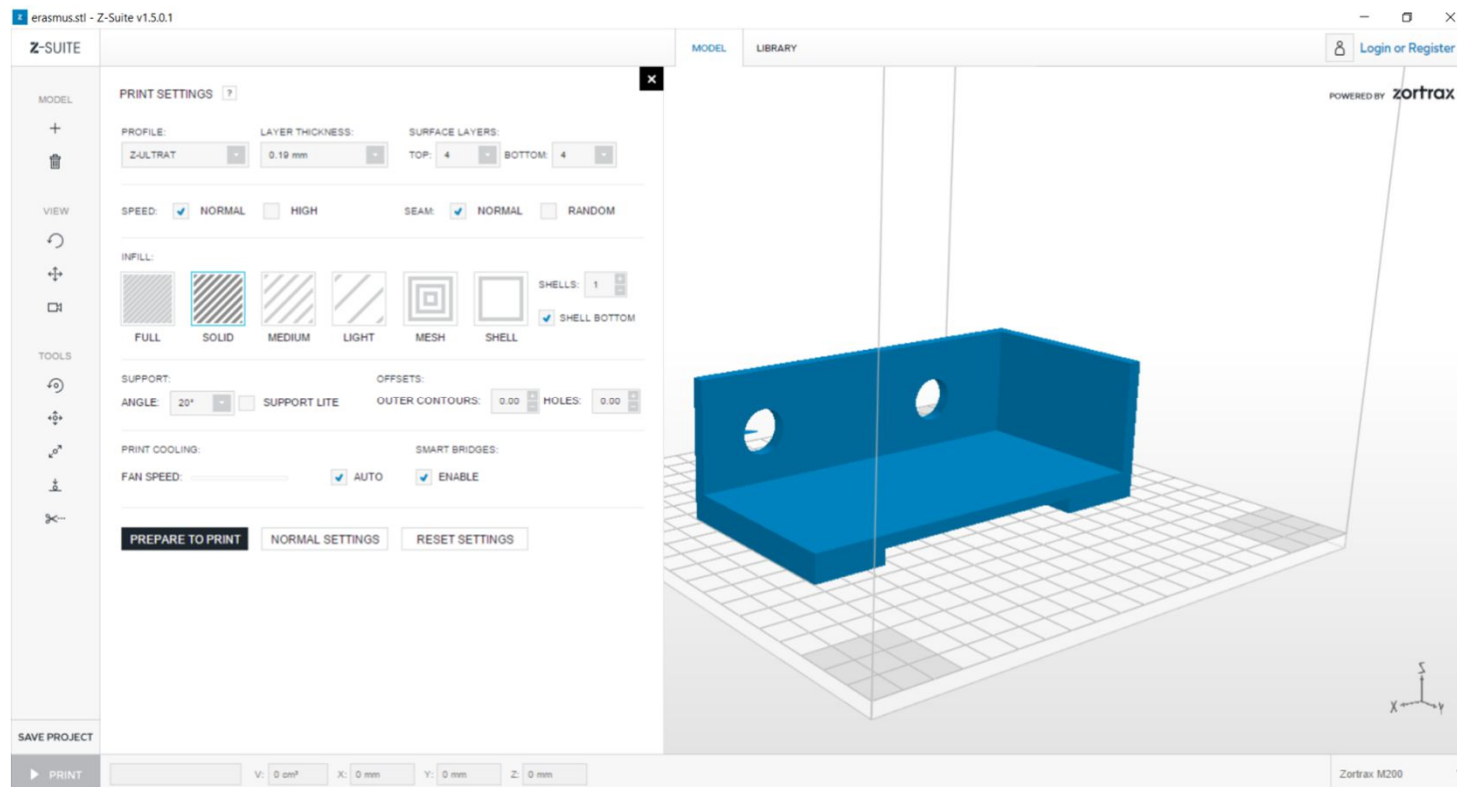
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3D print using Z-suite software

- Set process parameters: material, layer thickness, infill, surface layers, support angle deposition, speed etc.



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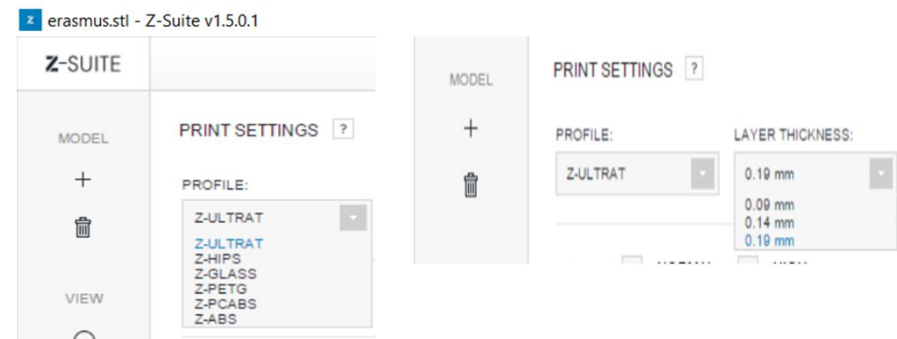
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3D print using Z-suite software

- For each material, a list of layer thicknesses is available.
- Prepare to print option is accessed for starting the slicing process based on the set process parameters. Nozzle paths for deposition model material and support material are generated. In Z-Suite, the model material is displayed in blue, while the supports are displayed in grey. Each layer can be visualized using Pause option from Tools.
- Information about building time (estimated) and filament usage (in meters and grams).



2016-1-RO01-KA202-024578

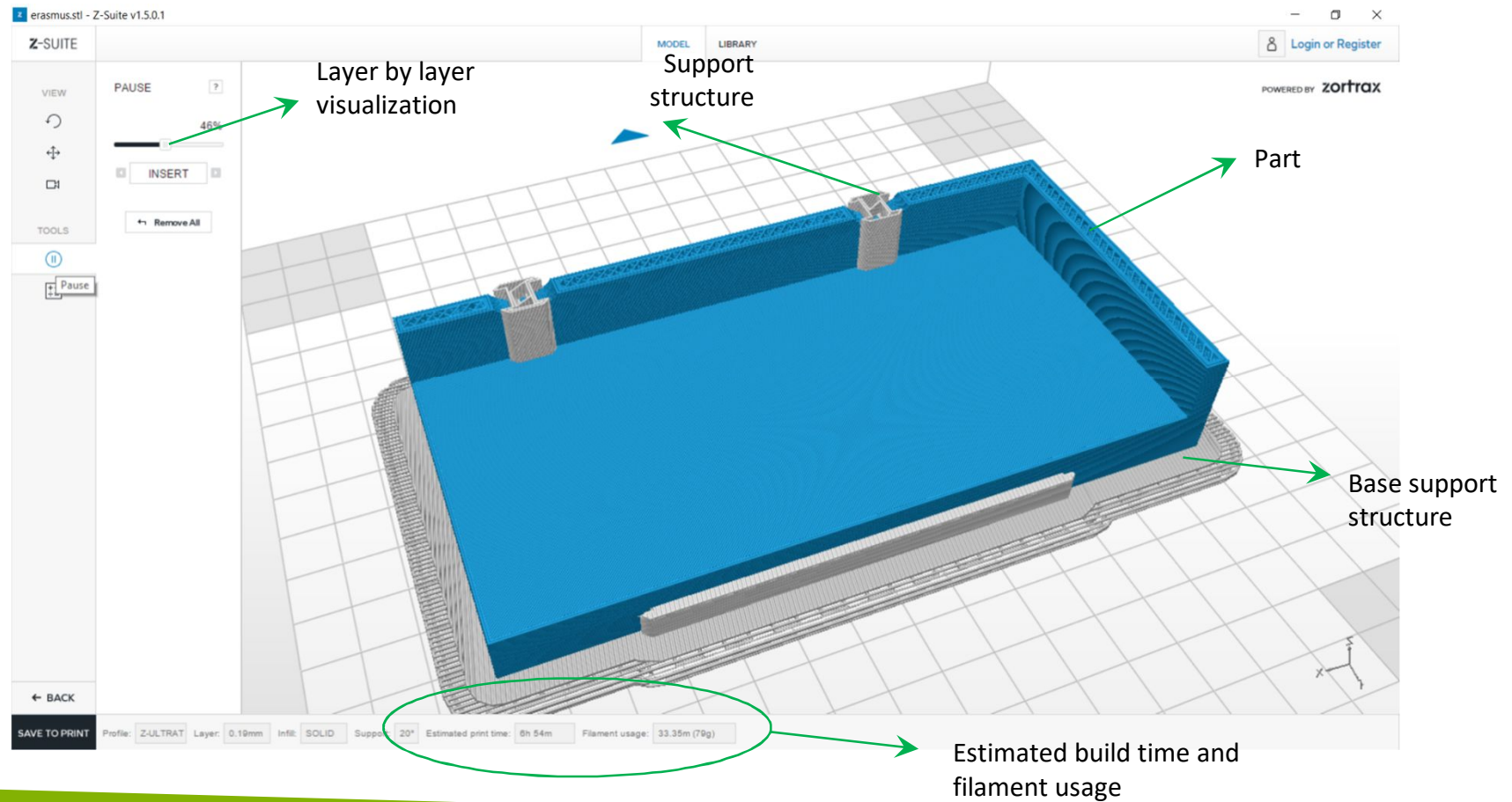
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3D print using Z-suite software

- Layer by layer visualization



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3D print an object using Cura for Ultimaker printers

2016-1-RO01-KA202-024578

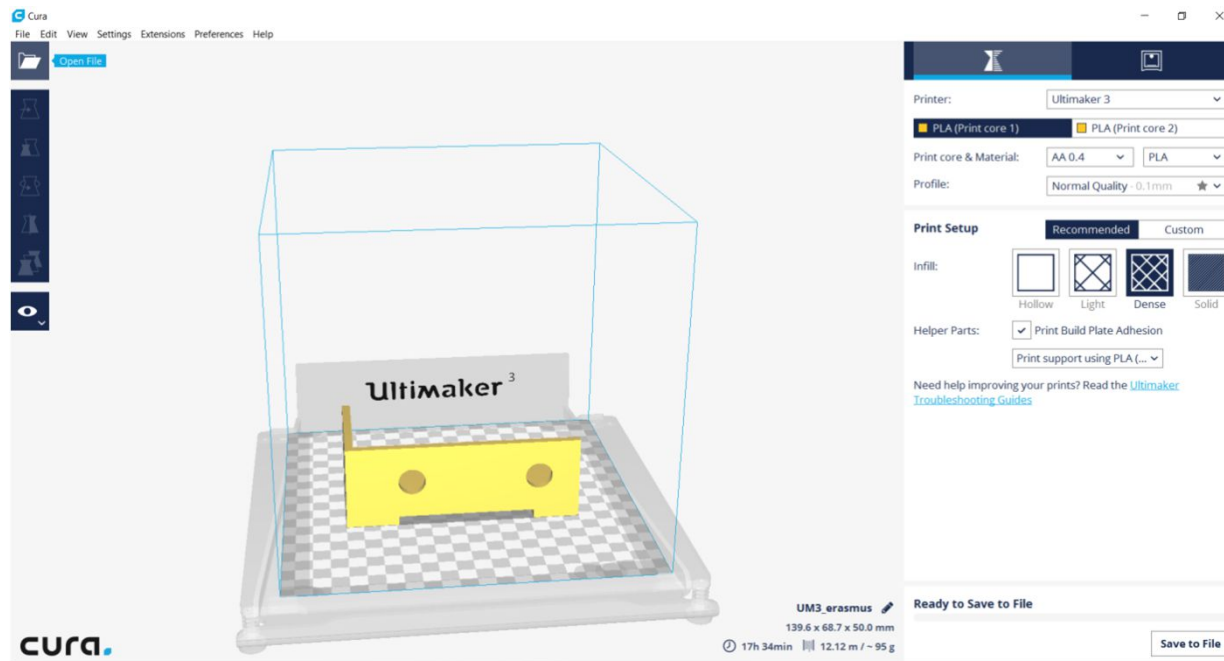
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3D print using Cura software

- Cura software for Ultimaker 3D printers
- Opening an STL file. Model is placed in the middle of the building platform. It is sliced immediately after import and information on build time and filament usage is displayed.



2016-1-RO01-KA202-024578

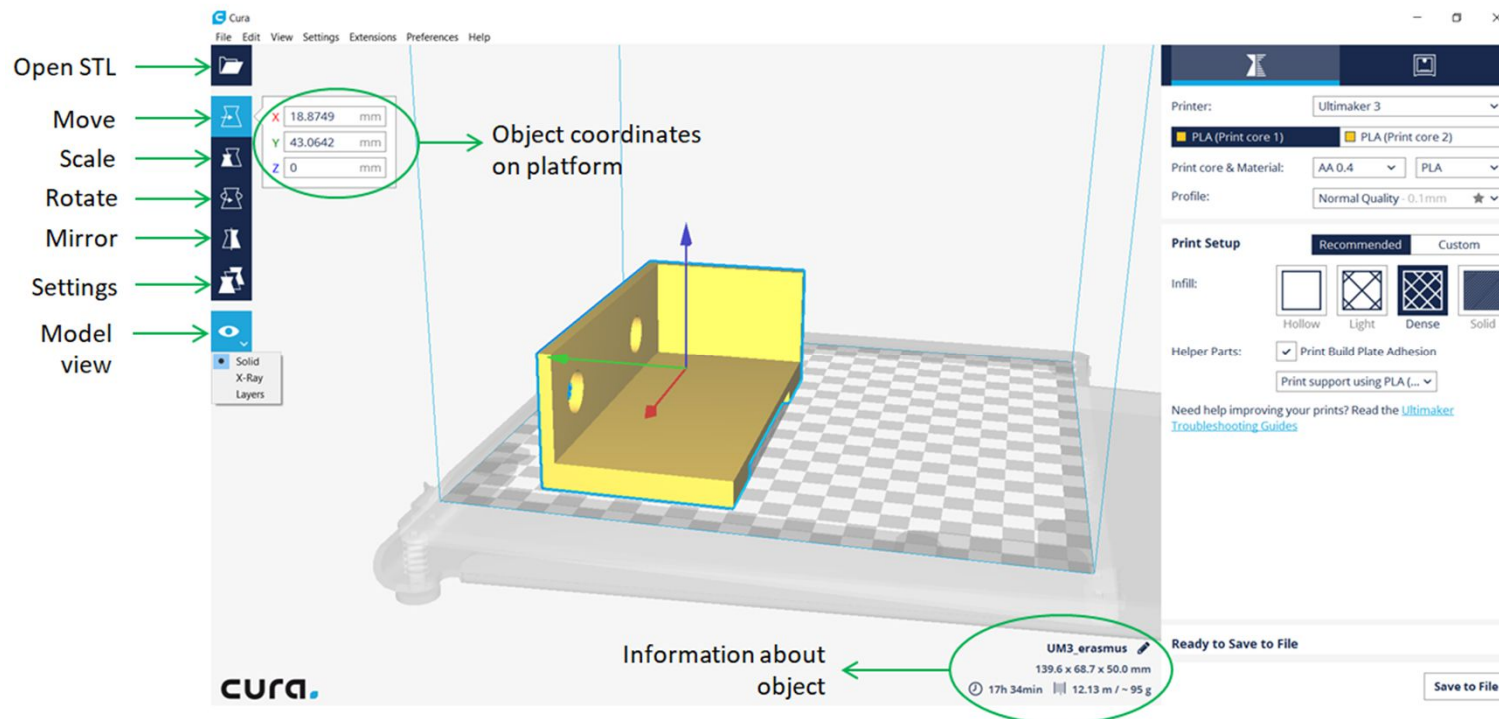
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3D print using Cura software

- Object can be moved on the platform using MB1, can be rotate using MB3 and zoomed using MB2 (also pan). For these actions, buttons can also be used.



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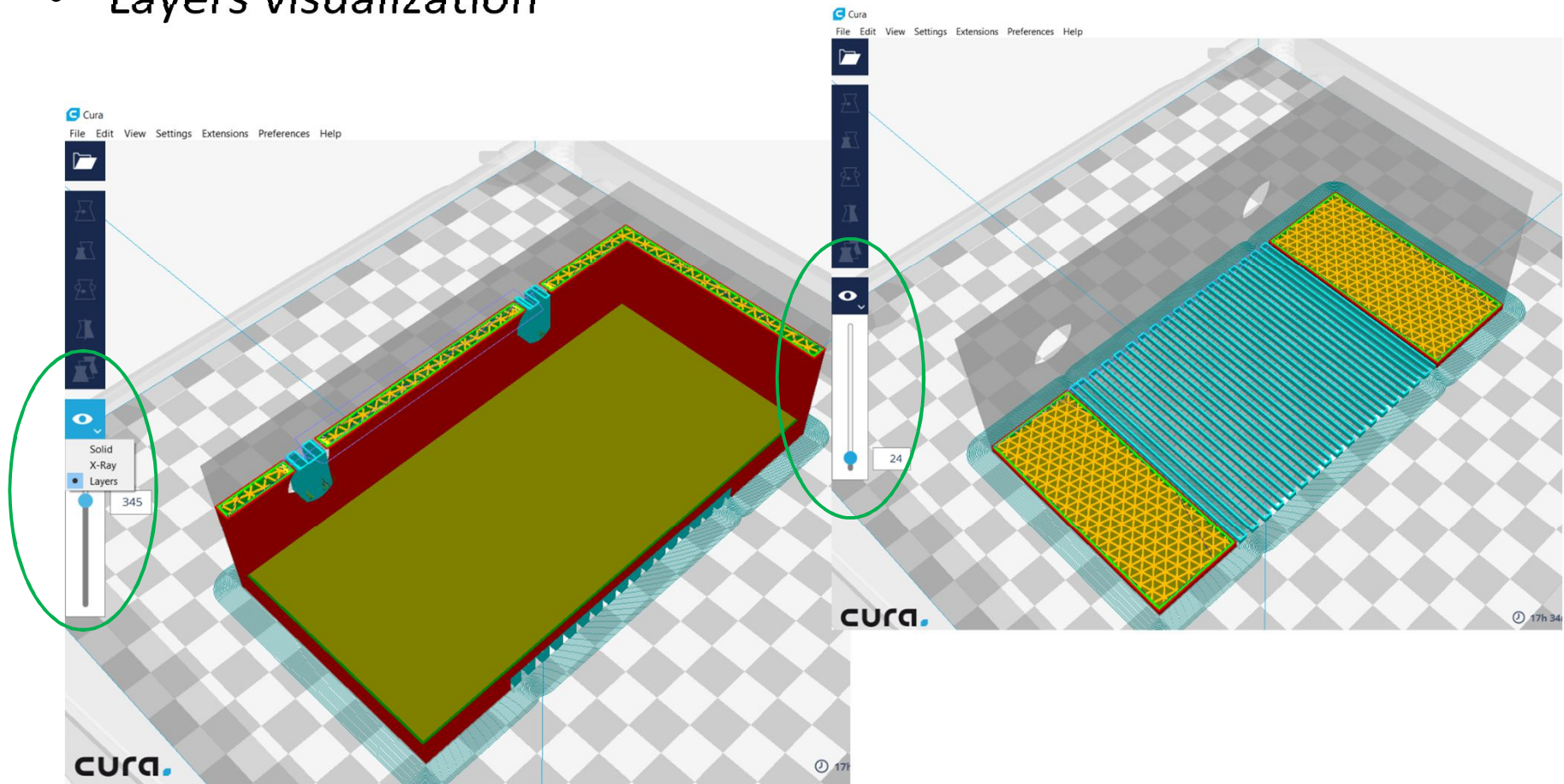
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3D print using Cura software

- Layers visualization



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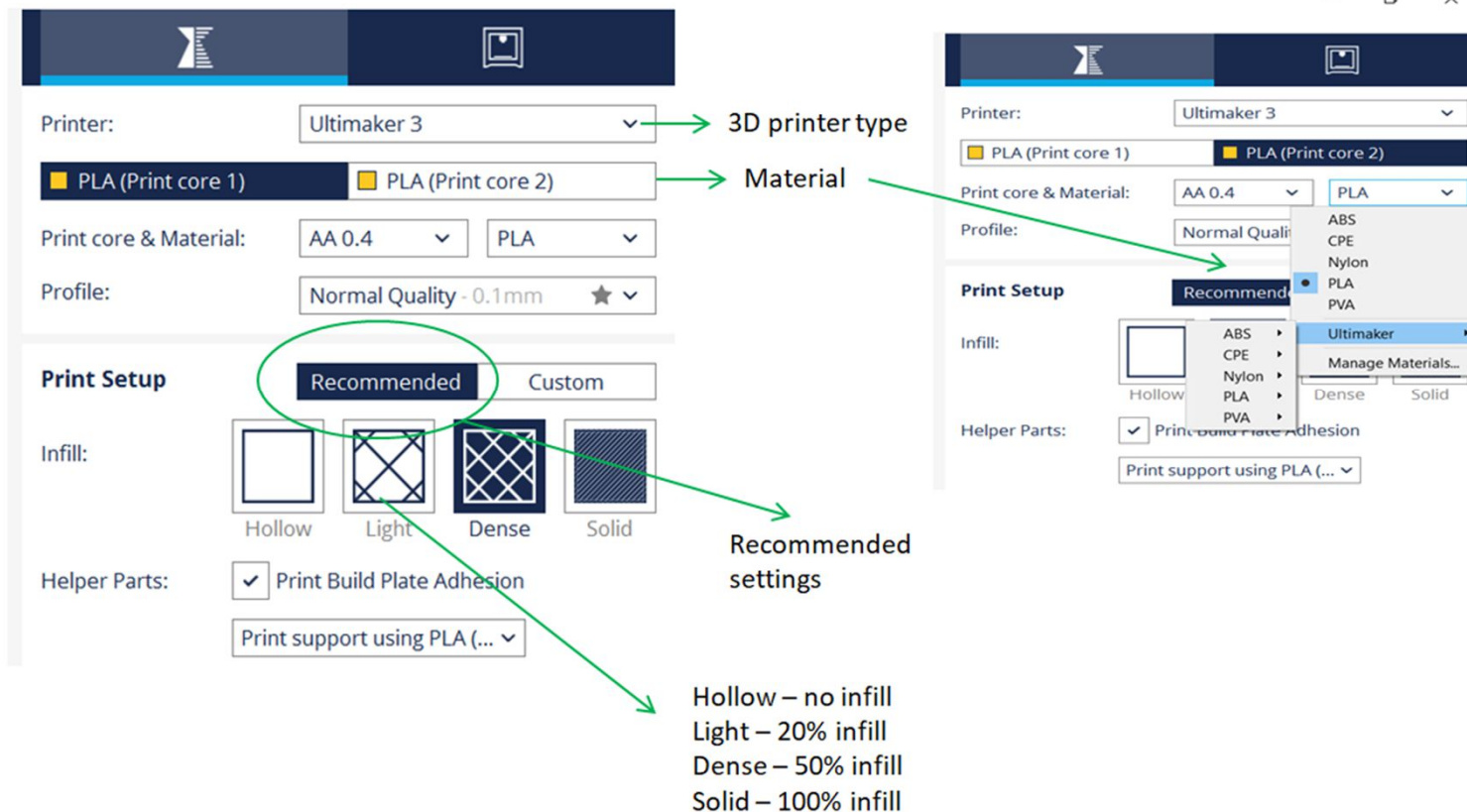
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3D print using Cura software

- Process parameter settings



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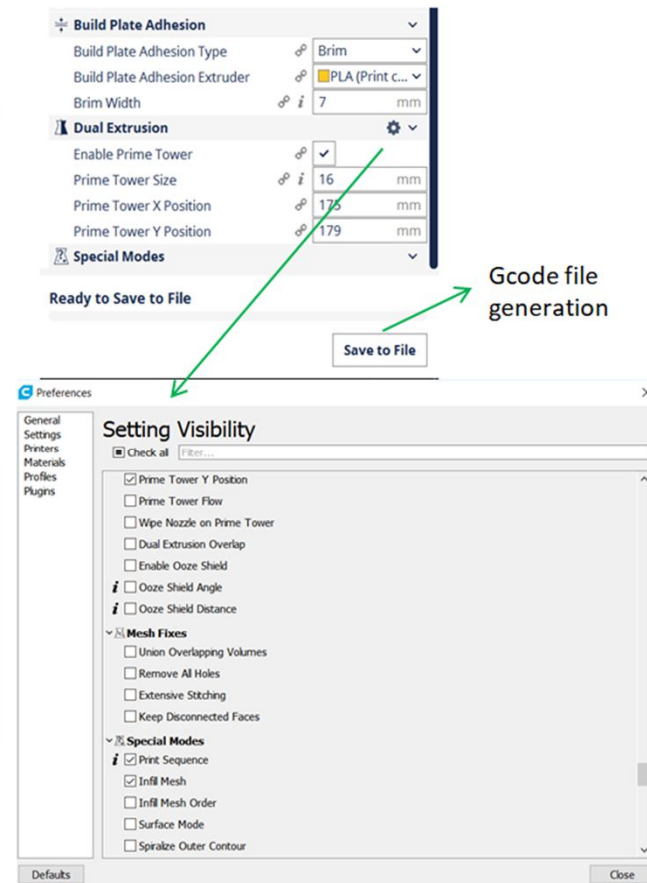
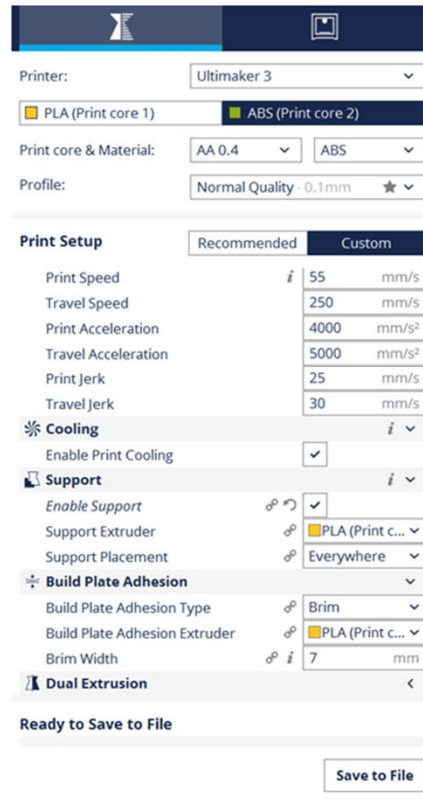
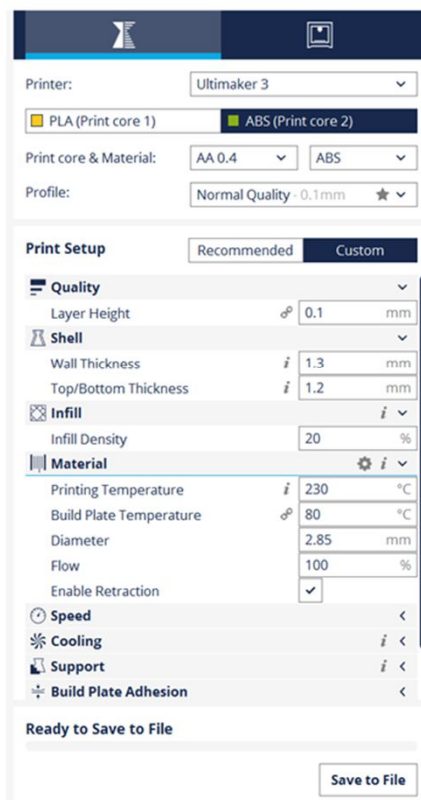
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3D print using Cura software

- Custom 3D printer settings



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3D print using Cura software

- Example of a Gcode file

```
UM3_erasmus.gcode - Notepad
File Edit Format View Help
;START_OF_HEADER
;HEADER_VERSION:0.1
;FLAVOR:Griffin
;GENERATOR.NAME:Cura_SteamEngine
;GENERATOR.VERSION:2.3.1
;GENERATOR.BUILD_DATE:2016-11-04
;TARGET_MACHINE.NAME:Ultimaker 3
;EXTRUDER_TRAIN.0.INITIAL_TEMPERATURE:200
;EXTRUDER_TRAIN.0.MATERIAL.VOLUME_USED:77341
;EXTRUDER_TRAIN.0.MATERIAL.GUID:506c9f0d-e3aa-4bd4-b2d2-23e2
;EXTRUDER_TRAIN.0.NOZZLE.DIAMETER:0.4
;BUILD_PLATE.INITIAL_TEMPERATURE:80
;PRINT.TIME:63254
;PRINT.SIZE.MIN.X:0
;PRINT.SIZE.MIN.Y:0
;PRINT.SIZE.MIN.Z:0
;PRINT.SIZE.MAX.X:215
;PRINT.SIZE.MAX.Y:215
;PRINT.SIZE.MAX.Z:200
;END_OF_HEADER
;Generated with Cura_SteamEngine 2.3.1

T0
G92 E0

M109 S200
G0 F15000 X181 Y2.1 Z2
G280
G1 F1500 E-6.5
;LAYER_COUNT:498
;LAYER:0
M107
M204 S625
M205 X6
G1 Z4
G0 F4285.7 X45.502 Y63.2 Z2.27
M204 S500
```

```
Secure | https://www.youtube.com/watch?v=Uk591e1Sm/U
UM3_erasmus.gcode - Notepad
File Edit Format View Help
G1 X43.202 Y65.811 E13.57466
G1 X43.615 Y65.222 E13.58532
G1 X44.091 Y64.683 E13.59597
G1 X44.623 Y64.199 E13.60662
G1 X45.206 Y63.778 E13.61728
G1 X45.833 Y63.424 E13.62794
M204 S625
M205 X6
G0 F4285.7 X46.161 Y63.655
M204 S500
M205 X5
G1 F1200 X46.813 Y63.401 E13.63831
G1 X47.49 Y63.224 E13.64867
G1 X48.183 Y63.125 E13.65904
G1 X48.702 Y63.103 E13.66674
G1 X79.911 Y63.103 E14.12905
G1 X80.61 Y63.143 E14.13942
G1 X81.299 Y63.262 E14.14978
G1 X81.97 Y63.46 E14.16014
G1 X82.615 Y63.732 E14.17051
G1 X83.143 Y64.03 E14.17949
G1 X83.173 Y64.004 E14.18008
G1 X83.751 Y63.609 E14.19045
G1 X84.37 Y63.283 E14.20081
G1 X85.022 Y63.03 E14.21117
G1 X85.699 Y62.852 E14.22154
G1 X86.392 Y62.753 E14.23191
G1 X86.911 Y62.731 E14.23961
G1 X91.956 Y62.731 E14.31434
G1 X92.655 Y62.771 E14.32471
G1 X93.344 Y62.89 E14.33507
G1 X93.388 Y62.903 E14.33575
G1 X154.194 Y62.903 E15.23649
G1 X154.893 Y62.943 E15.24686
G1 X155.582 Y63.062 E15.25721
G1 X156.253 Y63.26 E15.26758
G1 X156.898 Y63.532 E15.27795
```

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3D print an object using Slic3r for RepRap printers

2016-1-RO01-KA202-024578

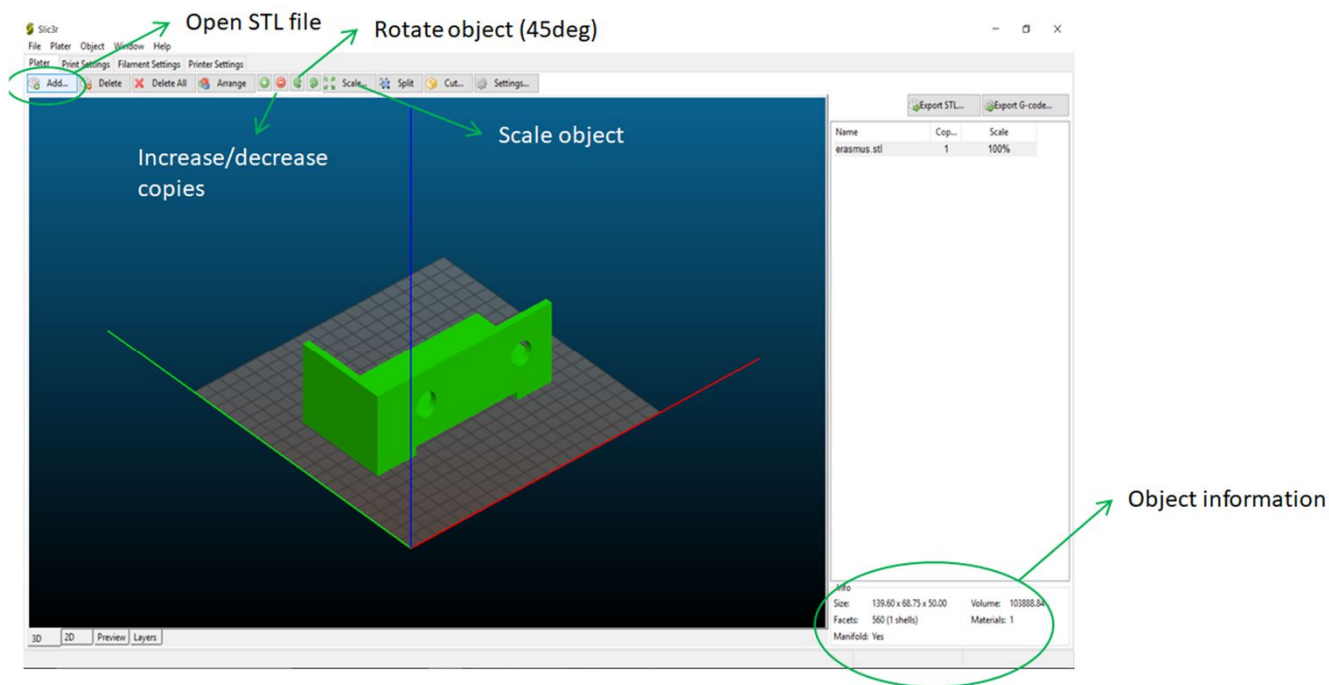
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3D print using Slic3r software

- **Slic3r software for RepRap 3D printers**
- Open STL file using Add option
- View manipulation: MB1-rotate, MB2-zoom and pan, MB3-pan



2016-1-RO01-KA202-024578

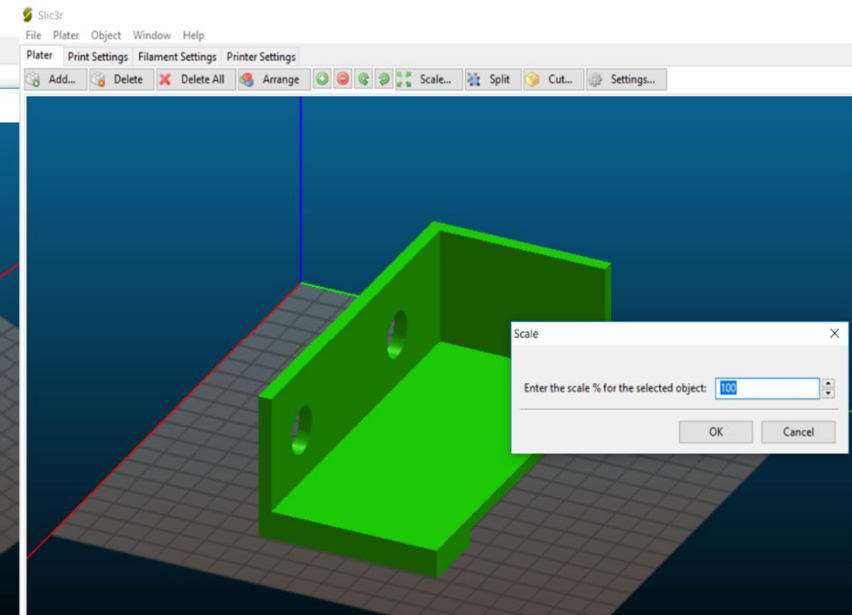
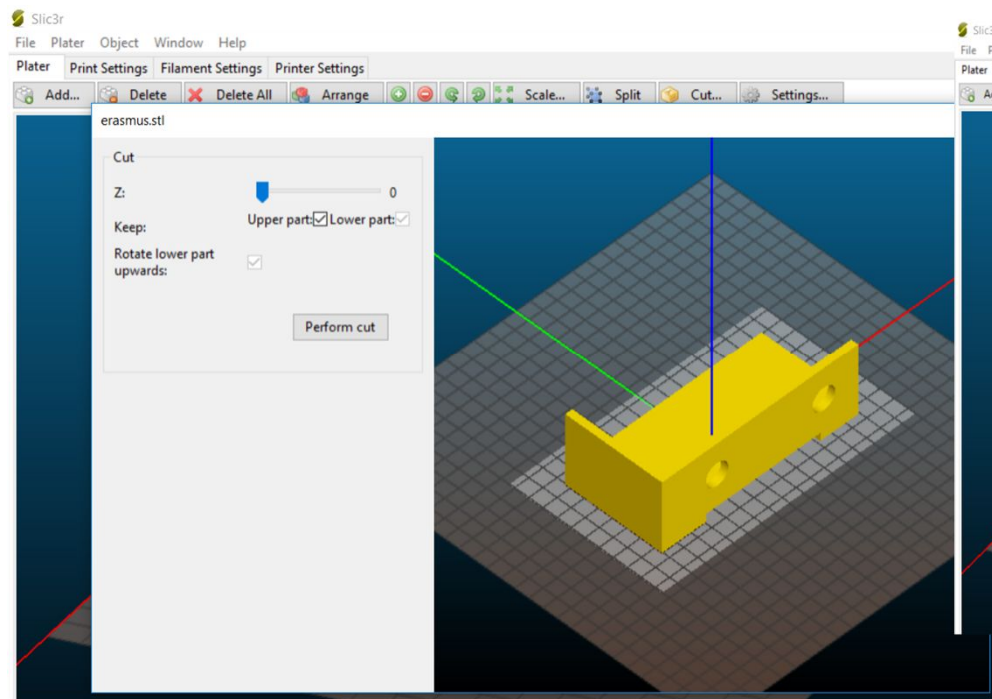
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3D print using Slic3r software

- Cut object in Slic3r
- Scale (uniform) object in Slic3r



2016-1-RO01-KA202-024578

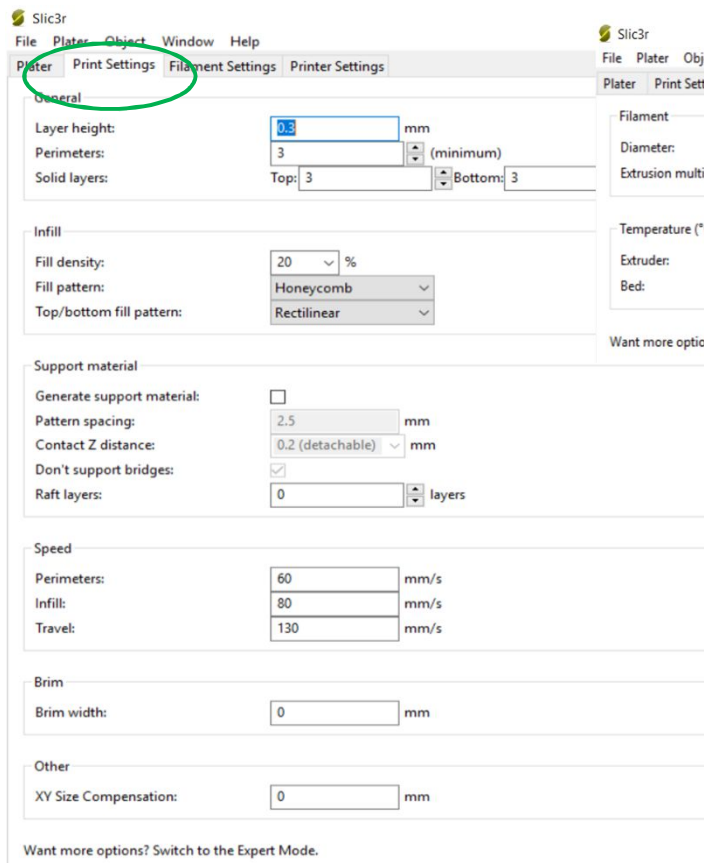
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3D print using Slic3r software

- Print settings
- Filament settings
- Printer settings



Slic3r

File Plater Object Window Help

Plater **Print Settings** Filament Settings Printer Settings

General

Layer height: 0.3 mm

Perimeters: 3 (minimum)

Solid layers: Top: 3 Bottom: 3

Infill

Fill density: 20 %

Fill pattern: Honeycomb

Top/bottom fill pattern: Rectilinear

Support material

Generate support material: ☐

Pattern spacing: 2.5 mm

Contact Z distance: 0.2 (detachable) mm

Don't support bridges: ☒

Raft layers: 0 layers

Speed

Perimeters: 60 mm/s

Infill: 80 mm/s

Travel: 130 mm/s

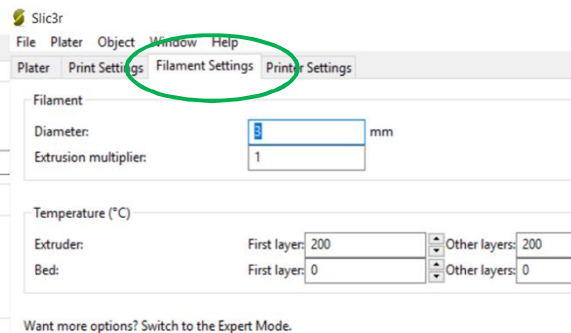
Brim

Brim width: 0 mm

Other

XY Size Compensation: 0 mm

Want more options? Switch to the Expert Mode.



Slic3r

File Plater Object Window Help

Plater **Print Settings** **Filament Settings** Printer Settings

Filament

Diameter: 1.75 mm

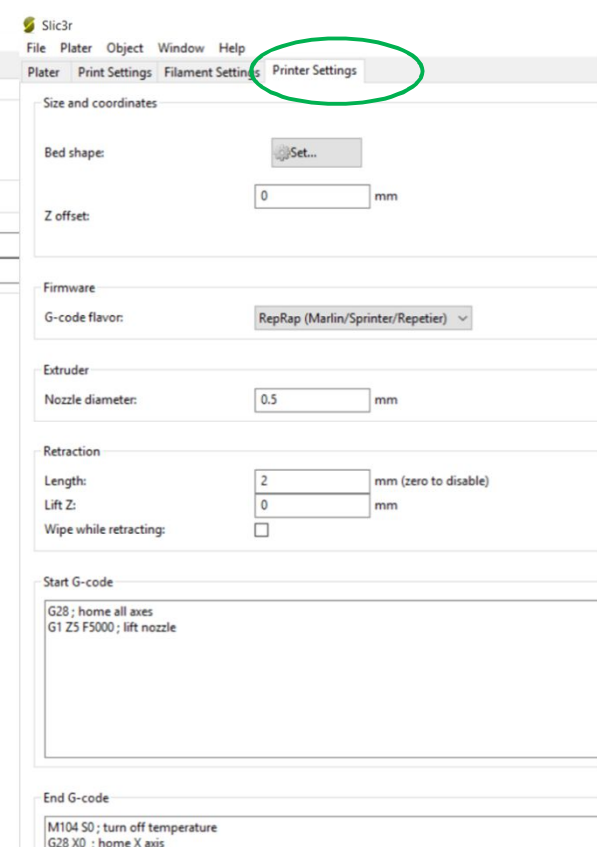
Extrusion multiplier: 1

Temperature (°C)

Extruder: First layer: 200 Other layers: 200

Bed: First layer: 0 Other layers: 0

Want more options? Switch to the Expert Mode.



Slic3r

File Plater Object Window Help

Plater **Print Settings** Filament Settings **Printer Settings**

Size and coordinates

Bed shape: Set...

Z offset: 0 mm

Firmware

G-code flavor: RepRap (Marlin/Sprinter/Repetier)

Extruder

Nozzle diameter: 0.5 mm

Retraction

Length: 2 mm (zero to disable)

Lift Z: 0 mm

Wipe while retracting: ☐

Start G-code

G28 ; home all axes
G1 Z5 F5000 ; lift nozzle

End G-code

M104 S0 ; turn off temperature
G28 X0 ; home X axis

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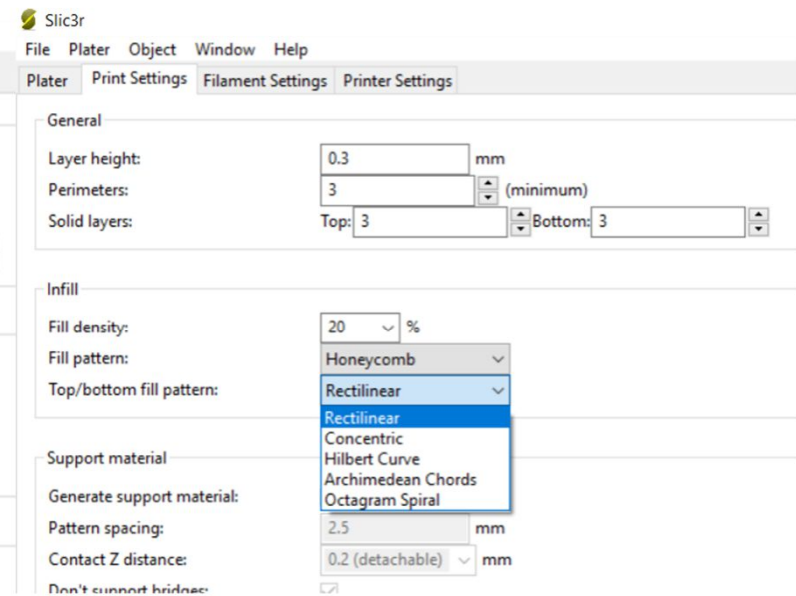
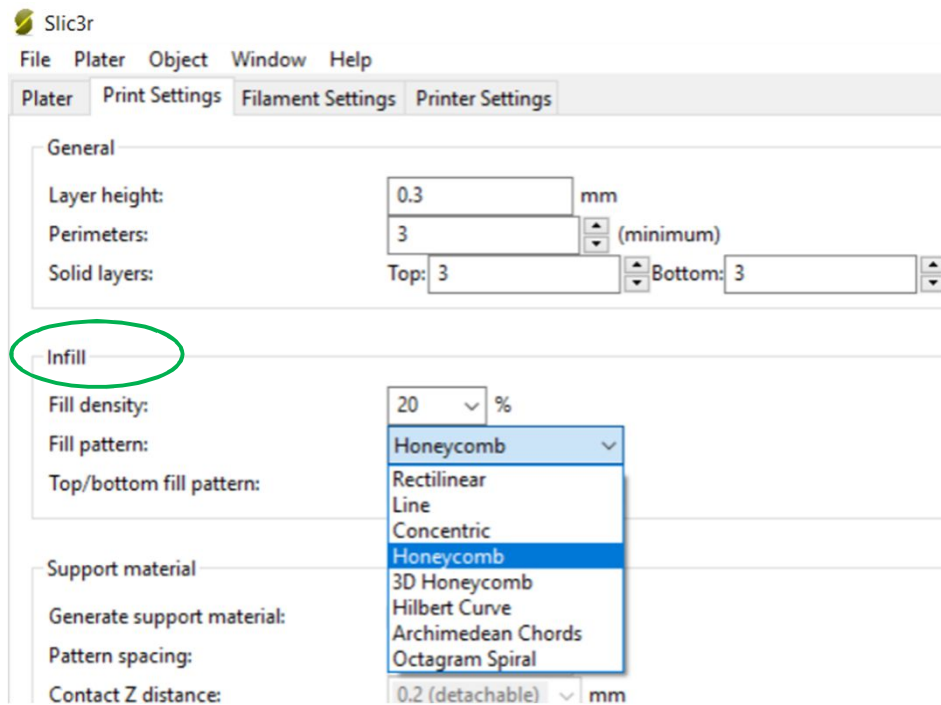
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3D print using Slic3r software

- Infill settings: layer fill density, fill pattern, top/bottom fill pattern



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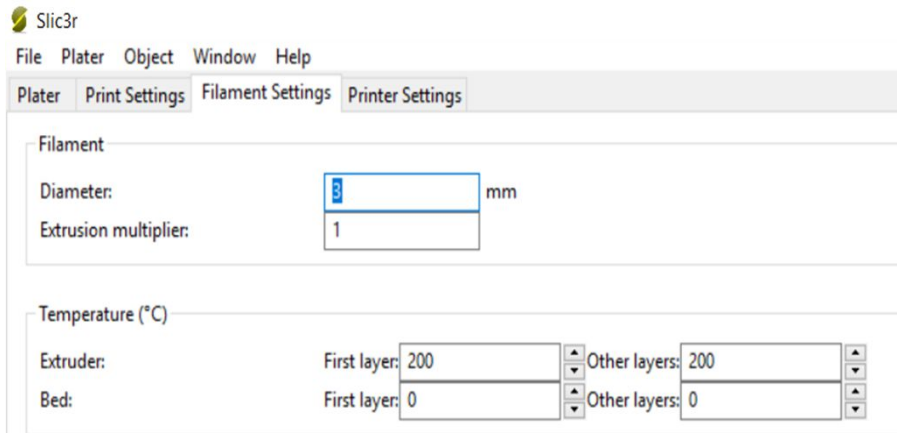
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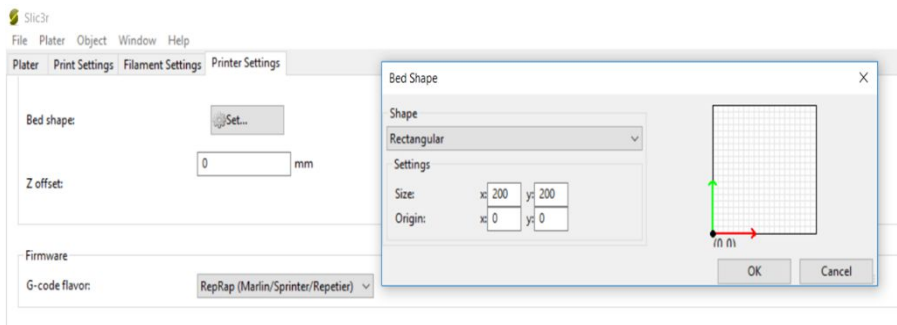
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3D print using Slic3r software

- Filament diameter settings, usually 1.75 mm or 3 mm.



- Bed shape and size settings.



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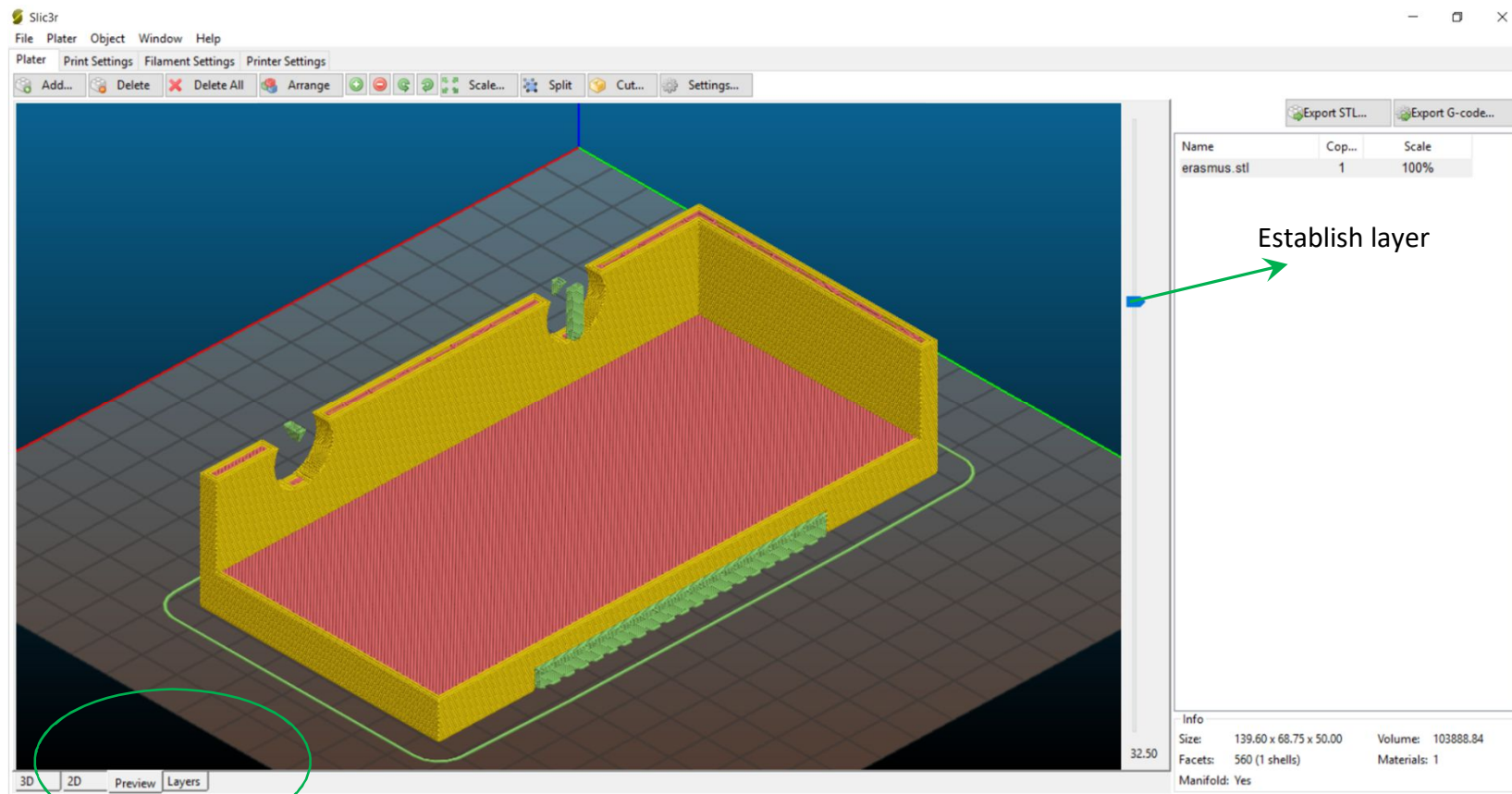
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3D print using Slic3r software

- Layers visualization



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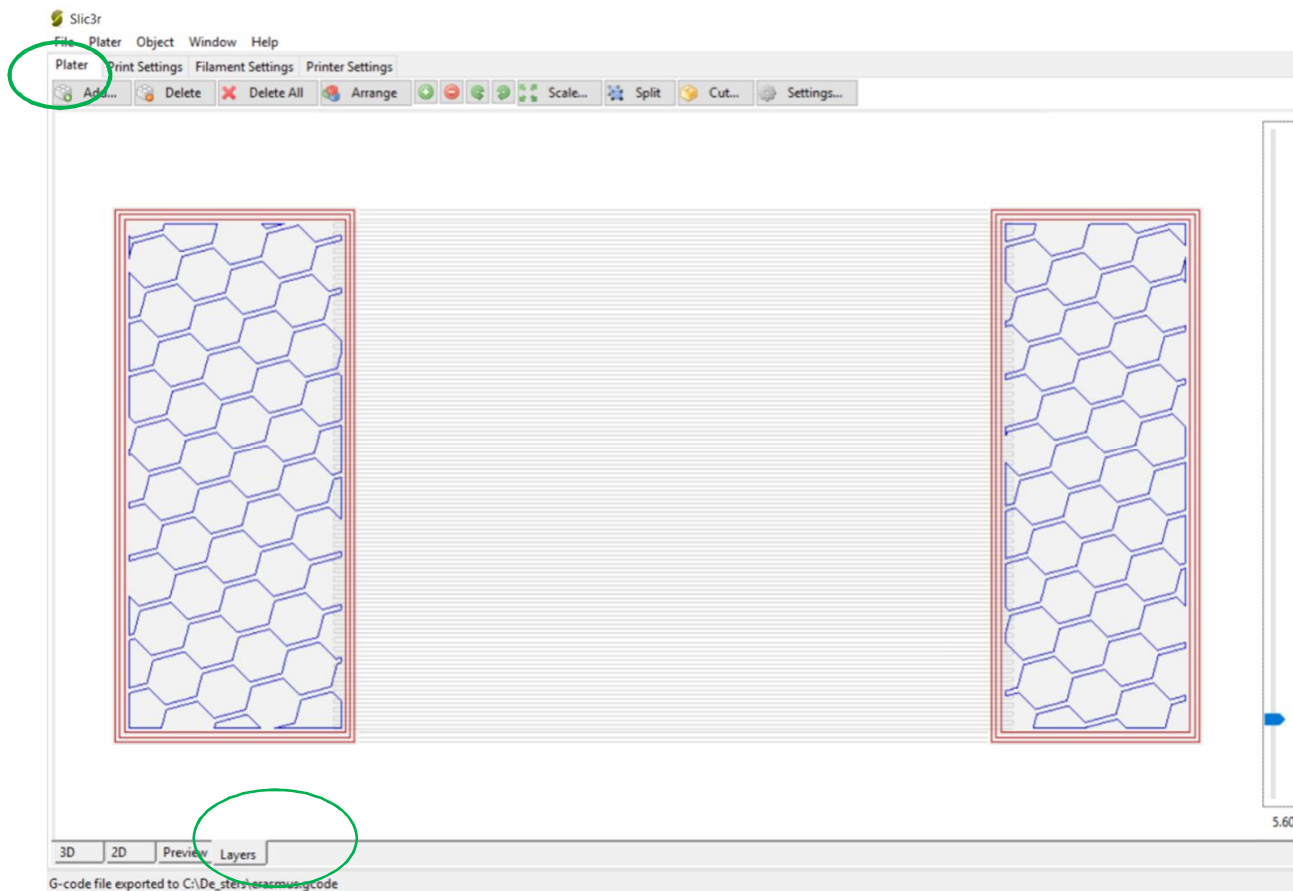
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3D print using Slic3r software

- Layers visualization



2016-1-RO01-KA202-024578

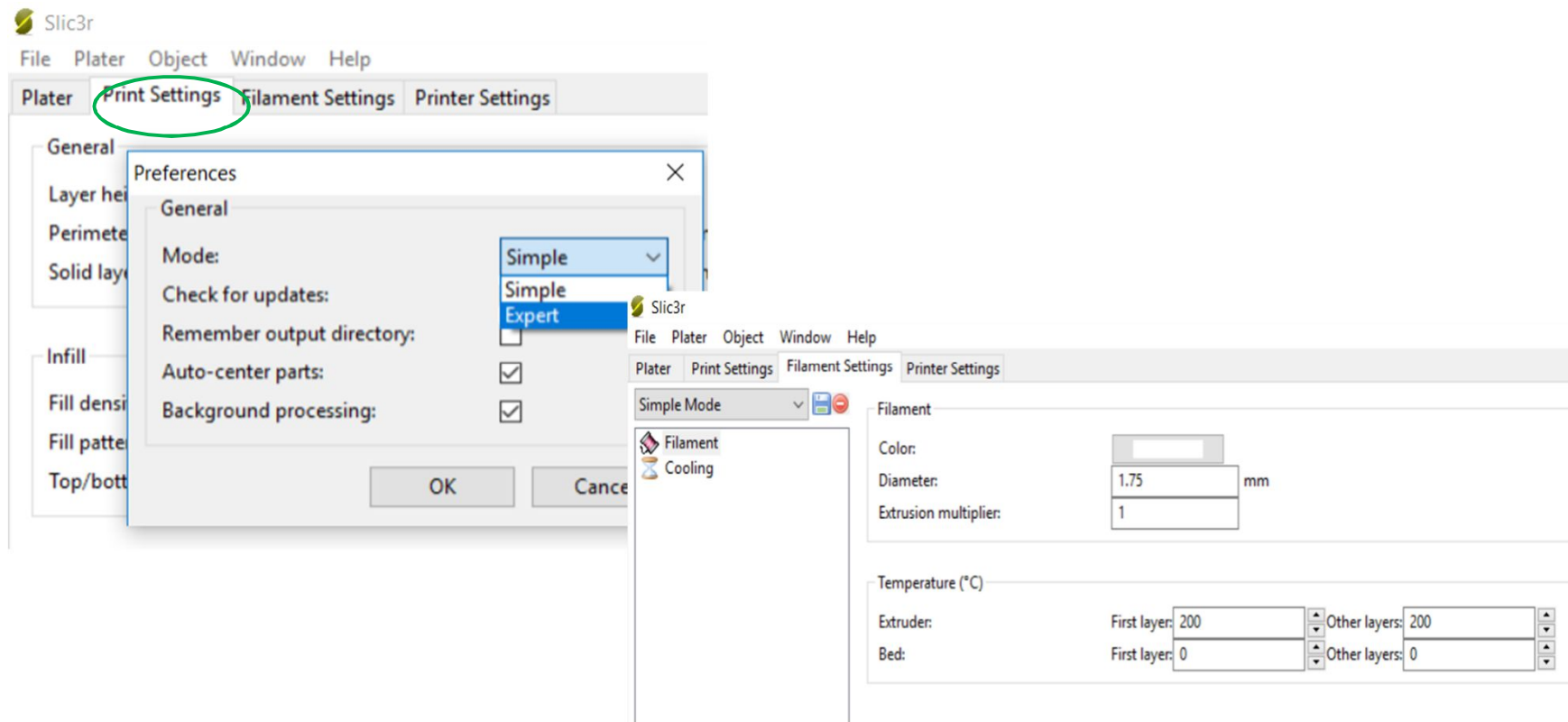
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3D print using Slic3r software

- More options are available in Expert mode which can be accessed from File menu.



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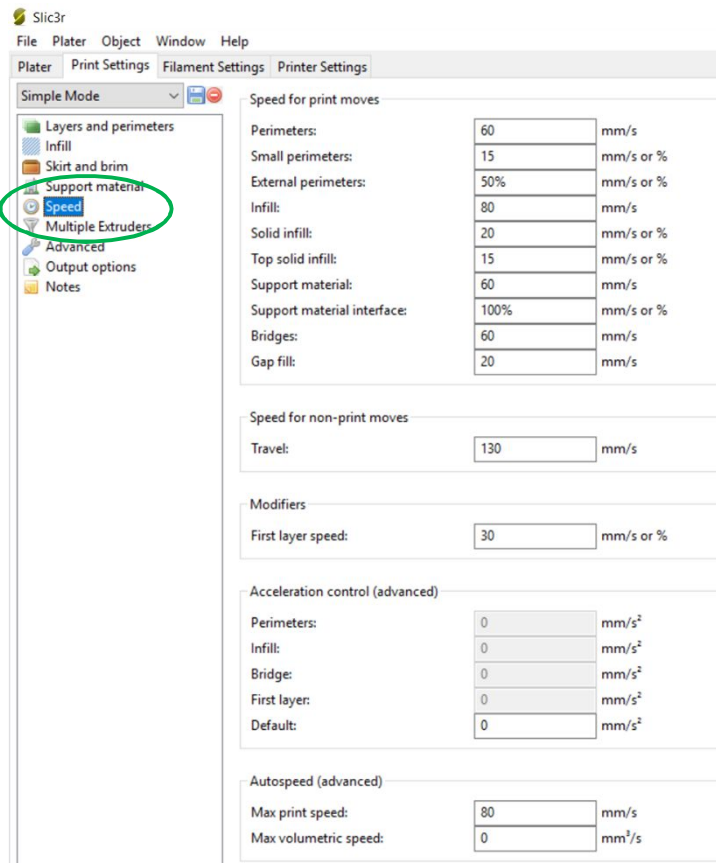
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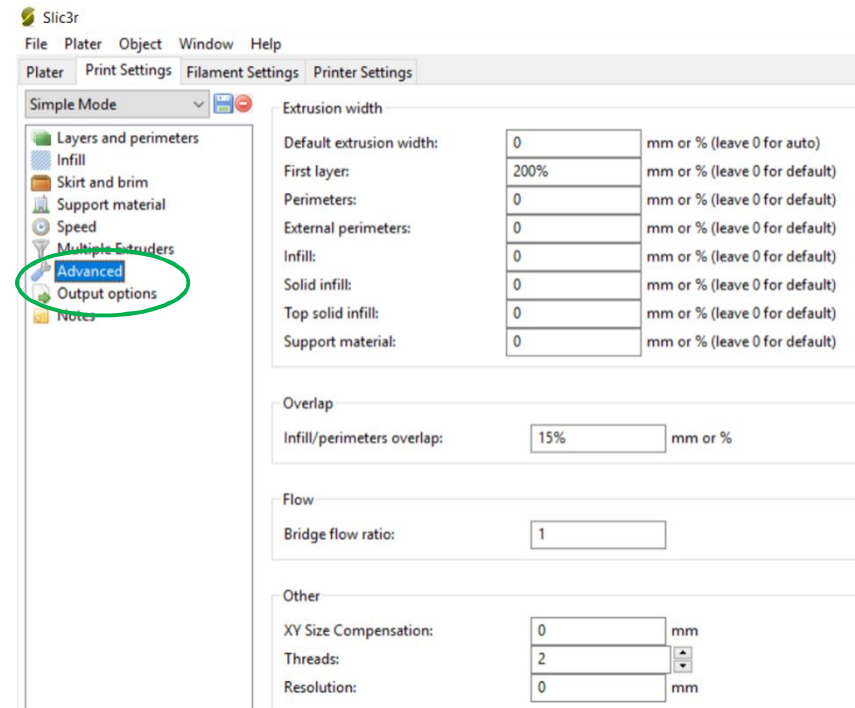
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3D print using Slic3r software

- Speed settings



Advanced settings



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3D print an object using ReplicatorG

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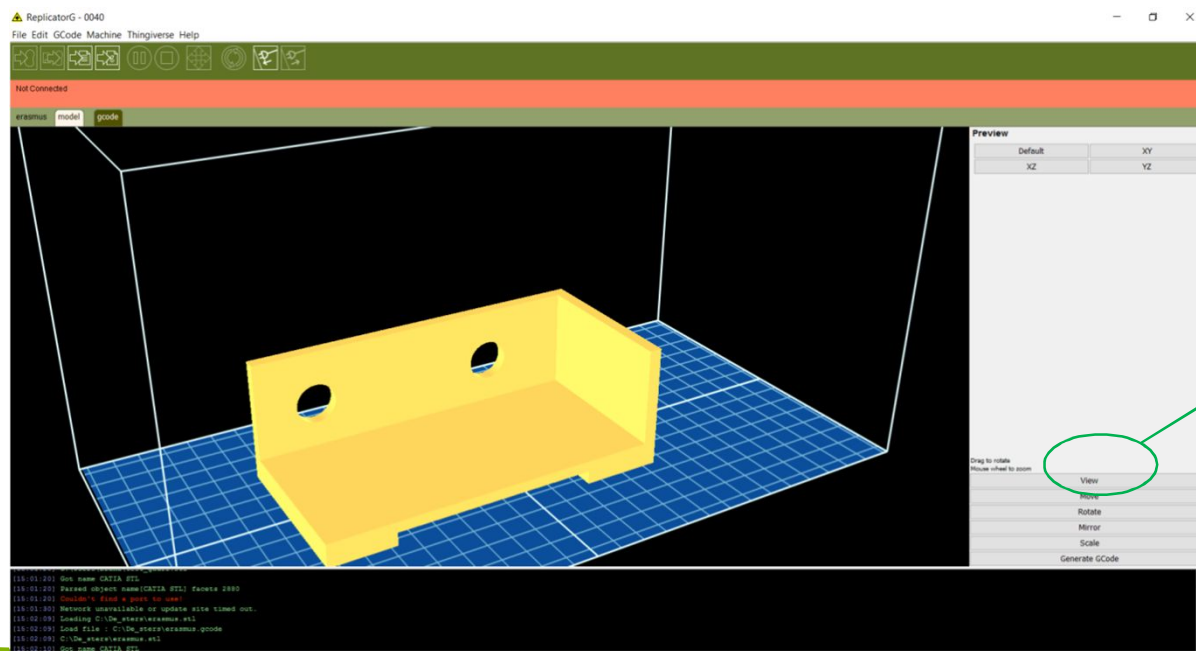
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3D print using ReplicatorG software

- ReplicatorG for RepRap 3D printers, Makerbot Replicator, Thing-O-Matic
- Should be run as Administrator and requires Python
- Open STL file using Open option from File menu



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3D print using ReplicatorG software

- Object can be moved, rotated, mirrored (part is oriented in mirror reflected in x, y or z) or scaled.

Move object on platform

Rotate

Scale

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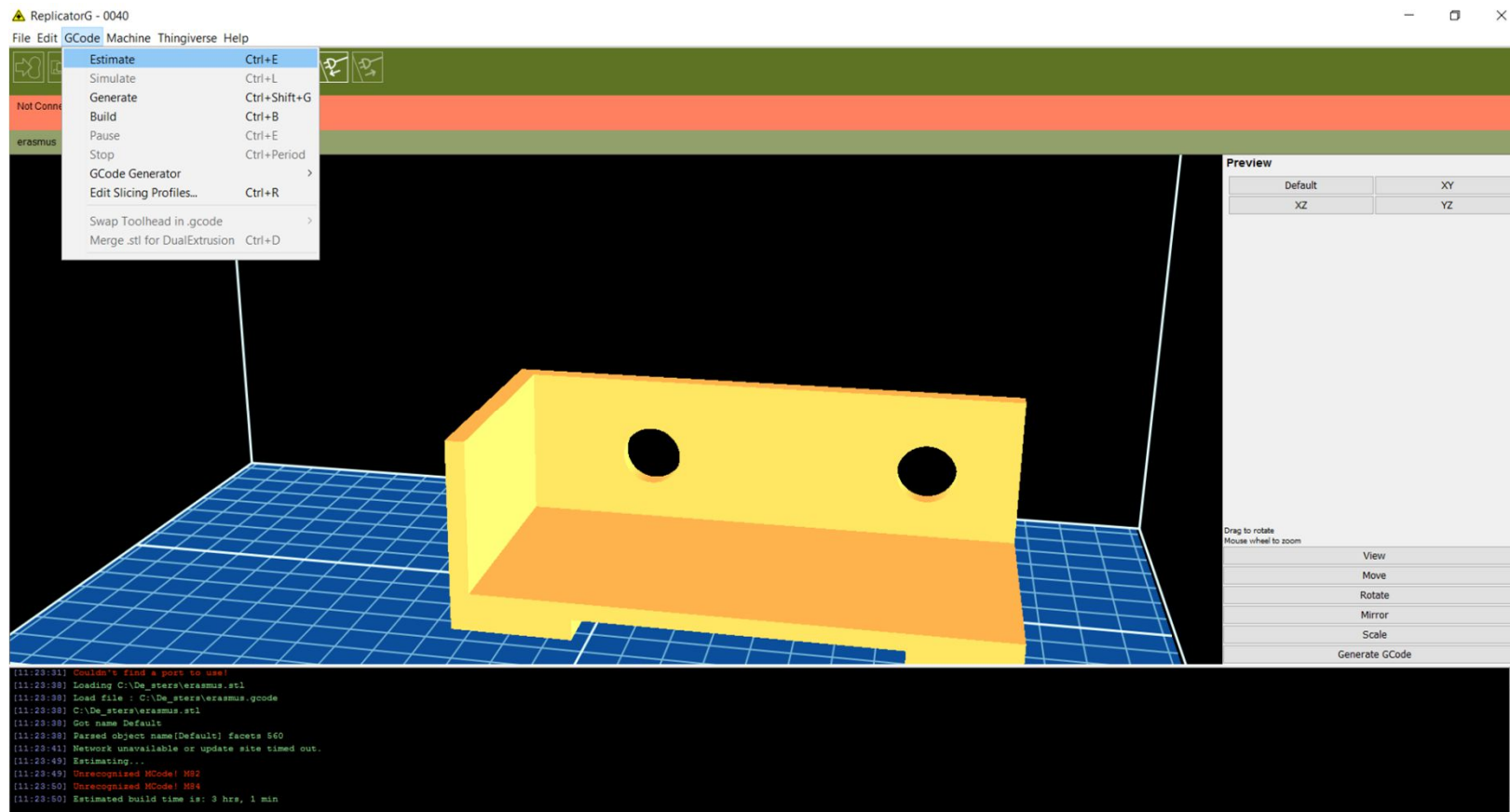
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3D print using ReplicatorG software

- Accessing estimate print time option: 3h 1min



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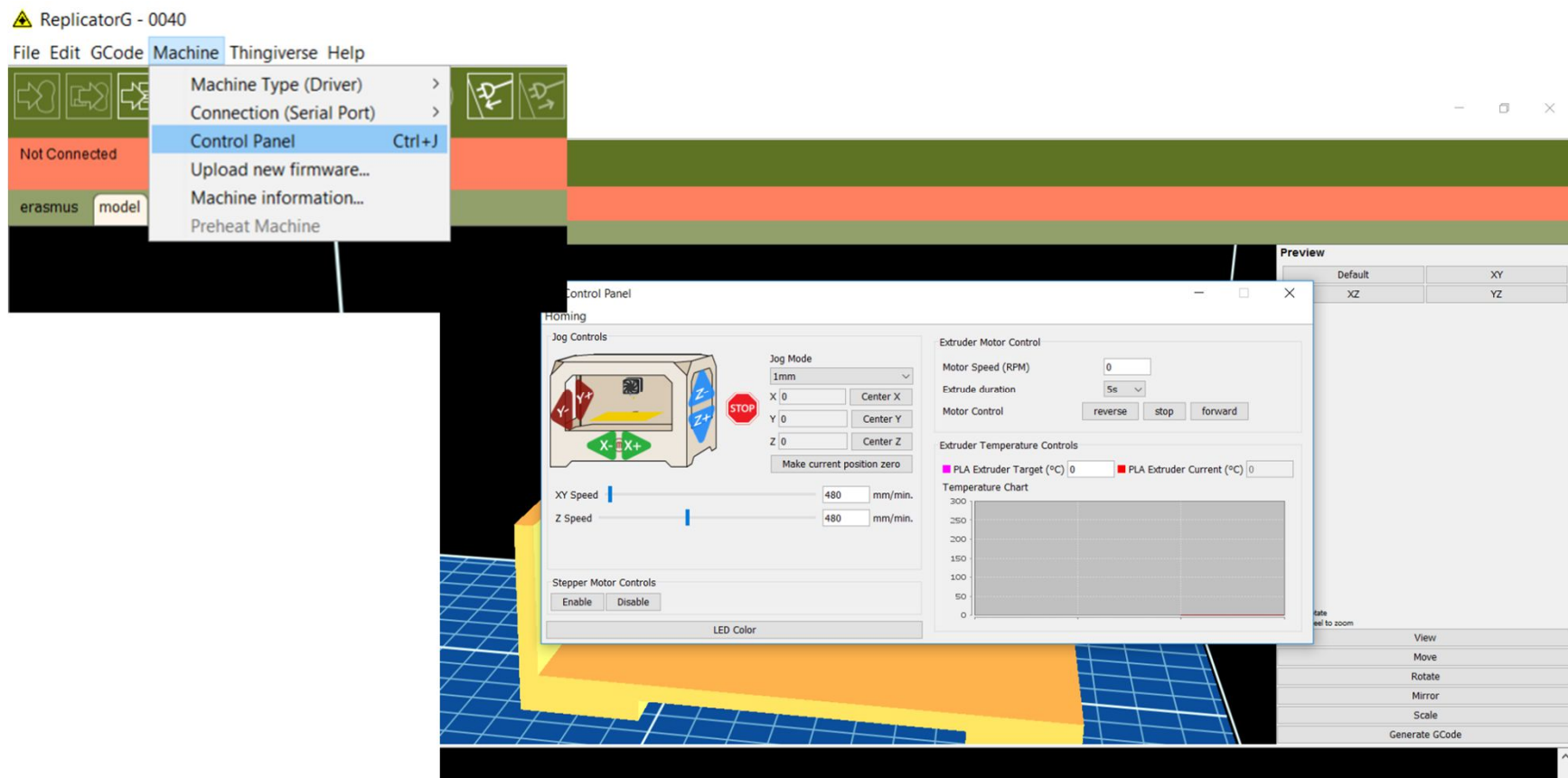
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3D print using ReplicatorG software

- 3D printer control panel



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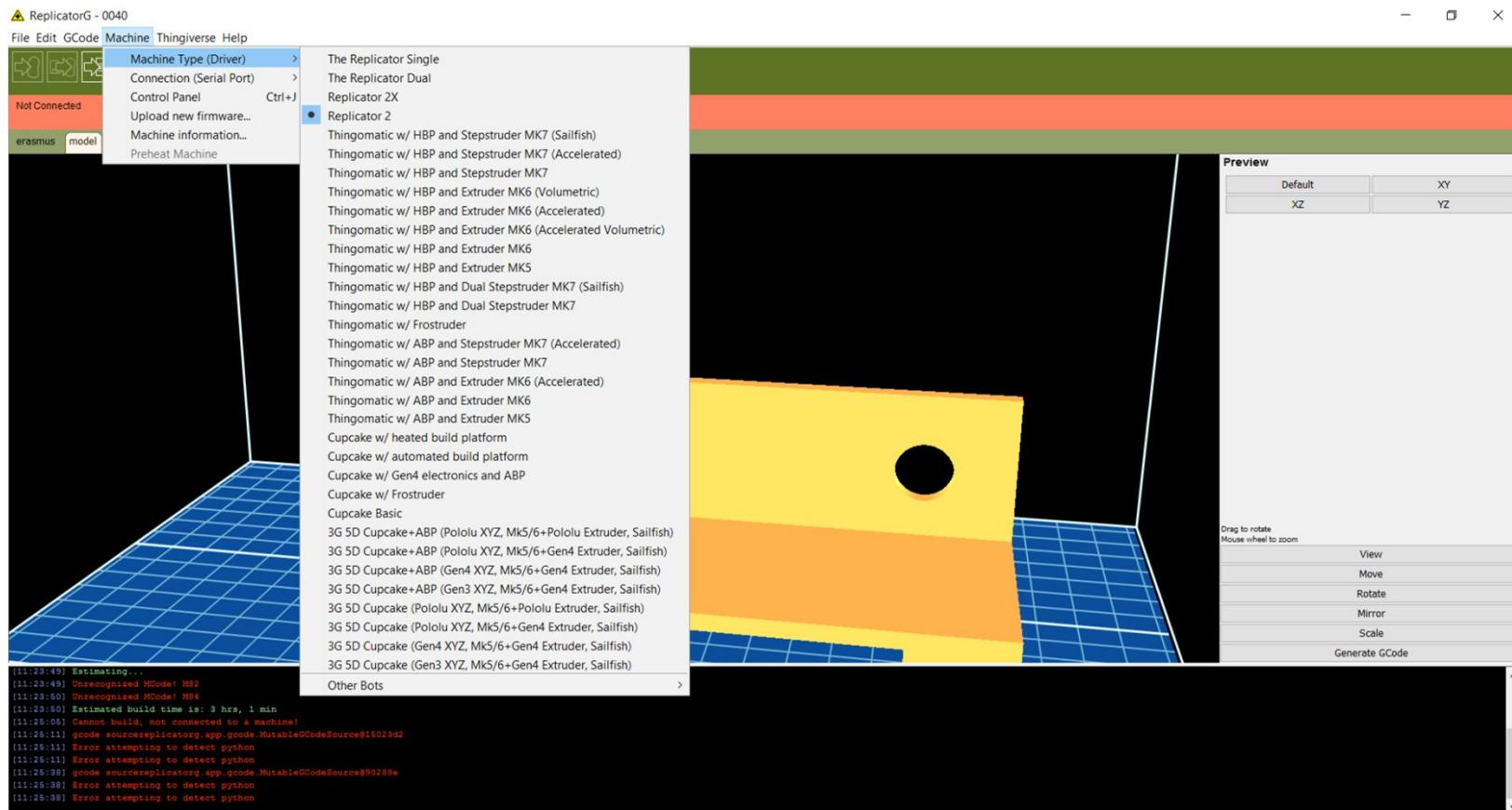
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3D print using ReplicatorG software

- List of 3D printer drivers in ReplicatorG



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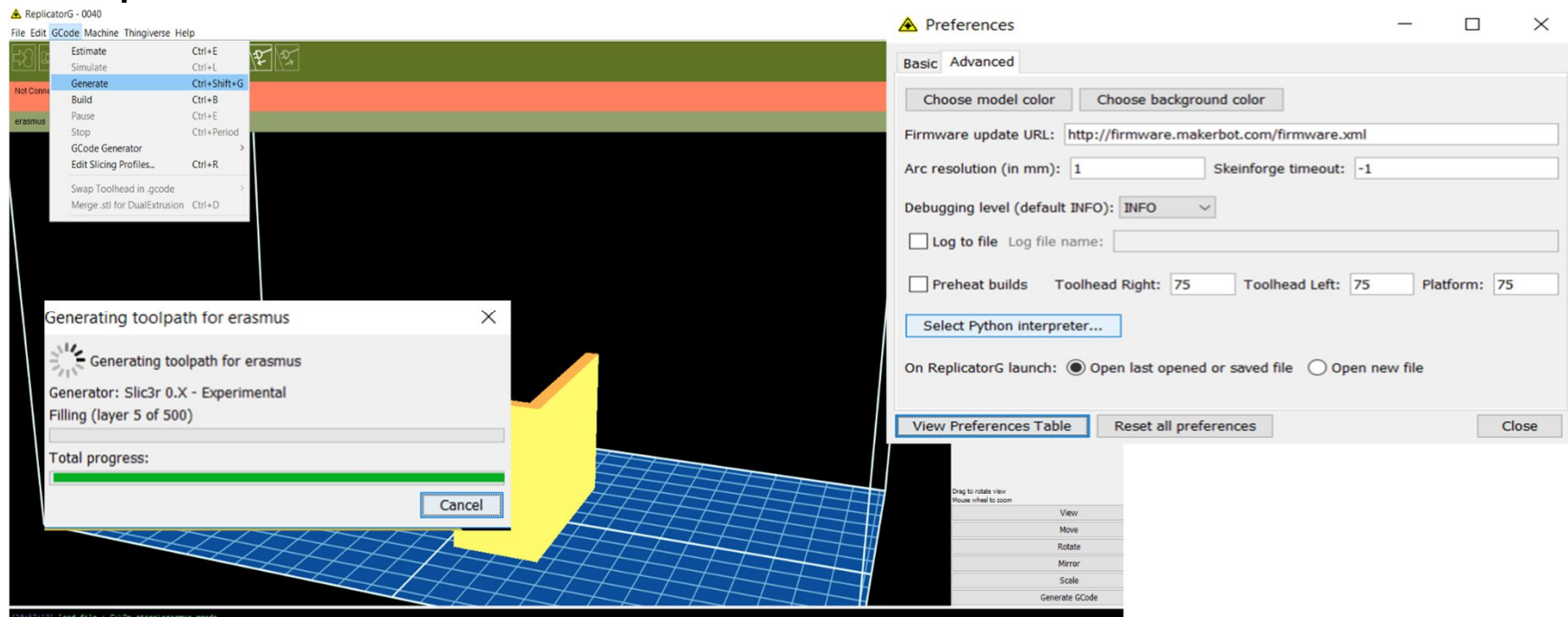
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3D print using ReplicatorG software

- Toolpath generation Gcode->Generate; In Preferences set the path to Python interpreter
- **Skeinforge** or another slicing software such as Slic3r is required.



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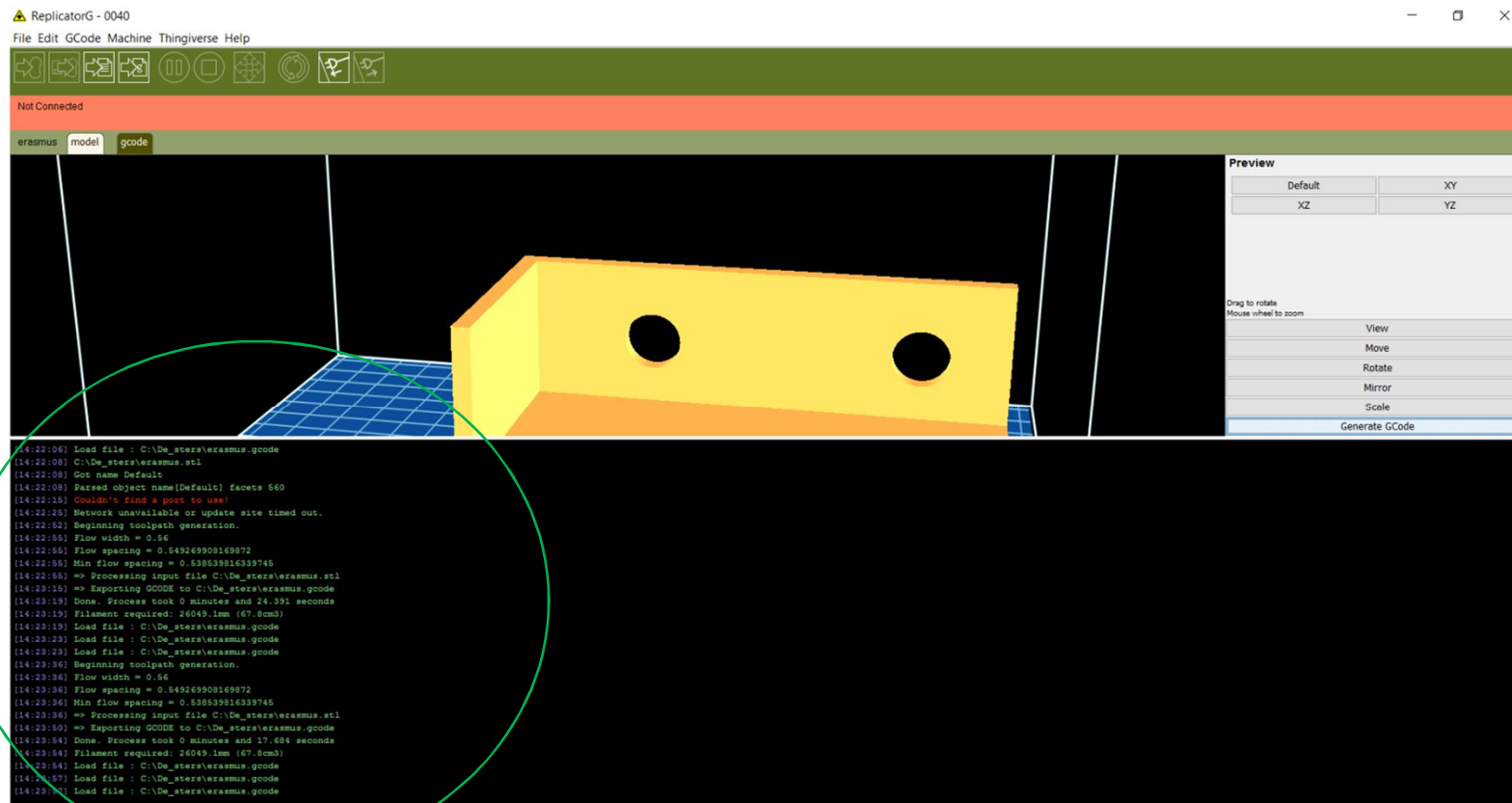
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3D print using ReplicatorG software

- Slicing results



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3D print using ReplicatorG software

- Example of generate Gcode



The screenshot shows the ReplicatorG software interface. At the top, a status bar indicates "Not Connected - ReplicatorG - 0040". Below this is a menu bar with "File", "Edit", "GCode", "Machine", "Thingiverse", and "Help". A toolbar with various icons is visible. The main window displays the G-code for a model named "erasmus". The G-code includes parameters for layer height, perimeters, solid layers, fill density, nozzle diameter, filament diameter, extrusion multiplier, perimeter speed, infill speed, travel speed, extrusion width ratio, scale, and single wall width. It also includes homing commands (M100, M104, M103, M73, G21, G90, G162, G161, G162, G1, G161, M132, G1) and a final command (G1) to move to a waiting position. The bottom status bar shows the process took 0 minutes and 17.694 seconds, and the filament required is 26045.1mm (47.8cm3).

```
Not Connected - ReplicatorG - 0040
File Edit GCode Machine Thingiverse Help

Not Connected
Cupcake Basic Not Connected

erasmus model gcode
generated by Slic3r 0.7.1 on 2017-04-15 at 14:23:50

; layer_height = 0.1
; perimeters = 3
; solid_layers = 3
; fill_density = 0.4
; nozzle_diameter = 0.4
; filament_diameter = 1.02
; extrusion_multiplier = 1
; perimeter_speed = 30
; infill_speed = 80
; travel_speed = 130
; extrusion_width_ratio = 0
; scale = 1
; single wall width = 0.56mm

M100 S100 ; set bed temperature
M104 S230 ; set temperature
(**** start.gcode for The Replicator, single head ****)
M103 (RPM off)
M73 P0 (enable build progress)
G21 (set units to mm)
G90 (set positioning to absolute)
(**** begin homing ****)
G162 X Y F3500 (home XY axes maximum)
G161 Z F1000 (home Z axis minimum)
G62 Z-5 (set Z to -5)
G1 Z0.0 (move Z to "0")
G161 Z F100 (home Z axis minimum)
M132 X Y Z A B (Recall stored home offsets for XYZAB axis)
(**** end homing ****)
G1 X-110.5 Y-74 Z150 F3300.0 (move to waiting position)

[14:23:54] Done. Process took 0 minutes and 17.694 seconds
[14:23:54] Filament required: 26045.1mm (47.8cm3)
[14:23:54] Load file : C:\De_sters\erasmus.gcode
[14:23:57] Load file : C:\De_sters\erasmus.gcode
[14:23:57] Load file : C:\De_sters\erasmus.gcode
[14:23:57] Load file : C:\De_sters\erasmus.gcode
[14:23:57] Cannot build, not connected to a machine!
[14:23:53] Loading simulator.
[14:23:53] Loading driver: replicatorg.drivers.gen3.Sanguino3GDriver
[14:23:53] Couldn't find a port to use!
[14:27:15] gcode source:replicatorg.scp.gcode MutableGCodeSource$20463e
[14:27:28] Load file : C:\De_sters\erasmus.gcode
[14:27:28] Loading C:\De_sters\erasmus.gcode
[14:27:28] Load file : C:\De_sters\erasmus.gcode
[14:27:29] C:\De_sters\erasmus.stl
[14:27:29] Got name Default
[14:27:29] Named object name[Default] facets 560
```

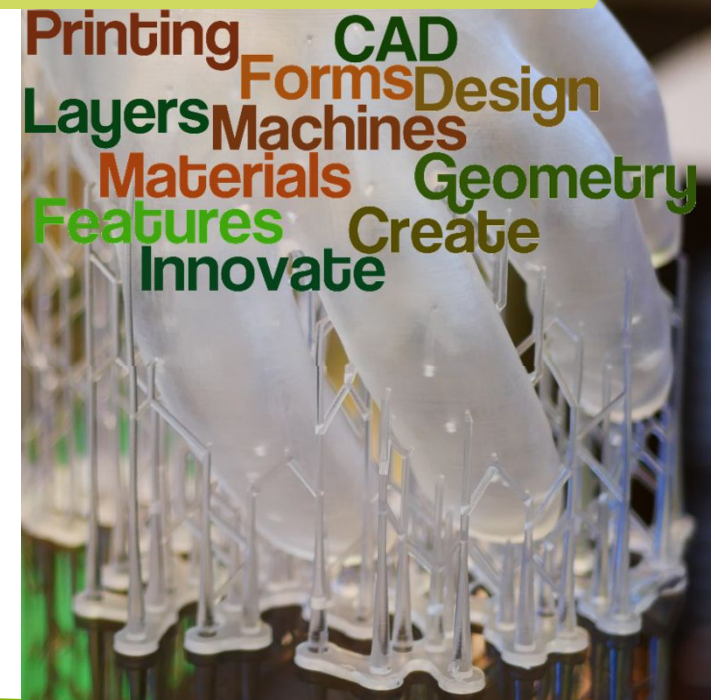
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3DP and entrepreneurship



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Aim and Learning Outcomes

Module Aim:

To inspire and help students to start a 3D Printing based business

Number of Hours:

3hrs

Learning outcomes:

- Knowledge on the opportunities offered by 3D printing in entrepreneurship
- Understanding the requirements of a 3D printing business

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Lecture Outline

- Examples of 3D businesses and start-ups
- Funding sources
- Skills required for a 3DP based business
- Opportunities for freelancers

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Examples of 3DP businesses and start-ups

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3DP businesses and start-ups

3D Printing offers a huge opportunity of investment, with more and more entrepreneurs and potential clients being interested in the possibilities it offers.



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3DP printing services

Companies that print objects on your behalf

Examples:

- Shapeways
- 3D Hubs
- i.materialise
- Sculpteo
- iMakr
- MakeXYZ
- Ponoko



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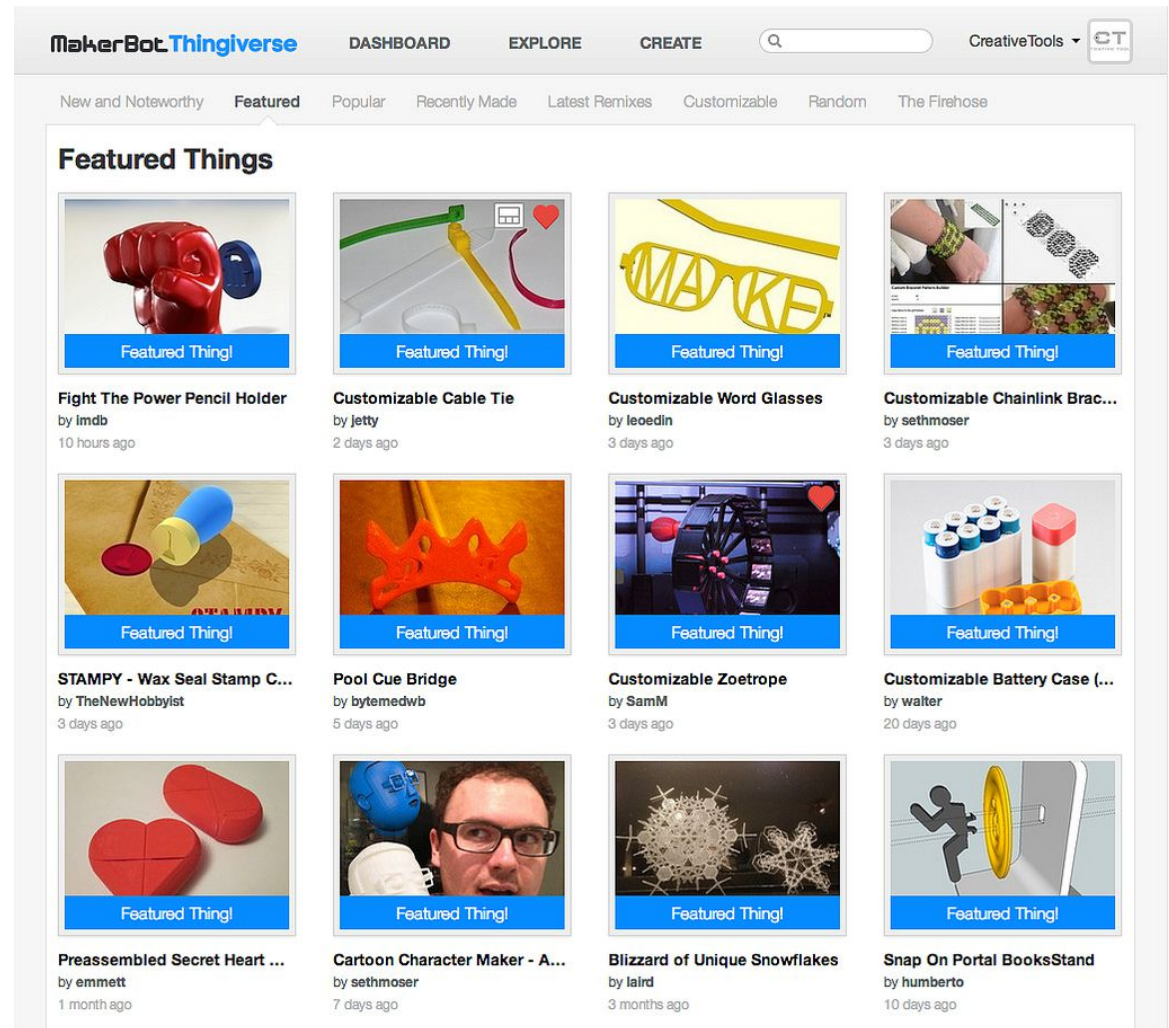
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3DP printing repositories

Platforms that offer
3D printing models

Examples:

- Thingiverse
- GrabCAD
- Sketchfab
- YouMagine
- Cults3D
- Zortrax Library



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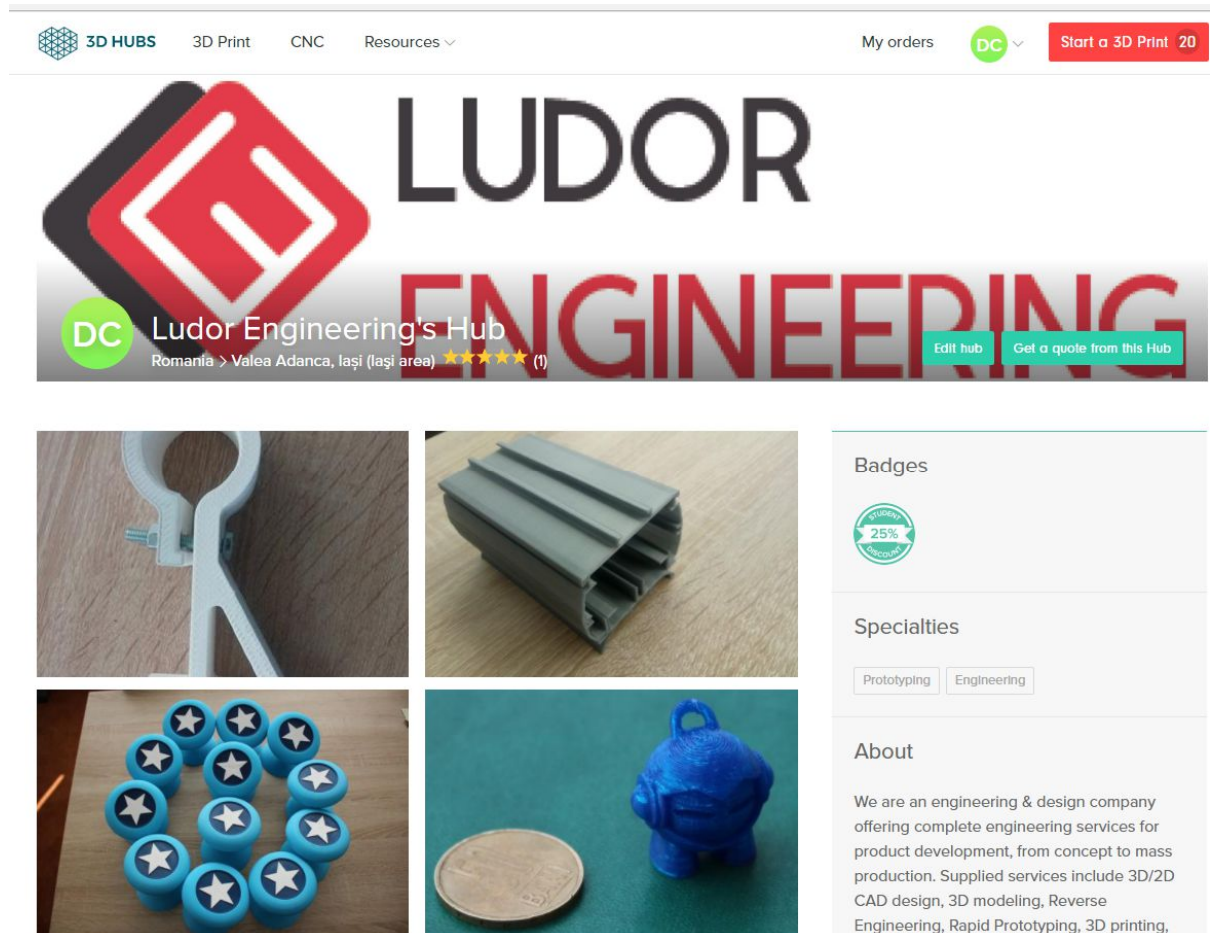
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3DP printing hubs

Networks of 3D printers.

Examples:

- 3DHubs
- MakeXYZ
- Fiverr



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Other 3DP business ideas

- 3DP training providing
- 3D printers manufacturing
- Prototyping as a service
- 3D printed fashion
- 3D printed parts and products
- 3D printed food
- 3DP models creation



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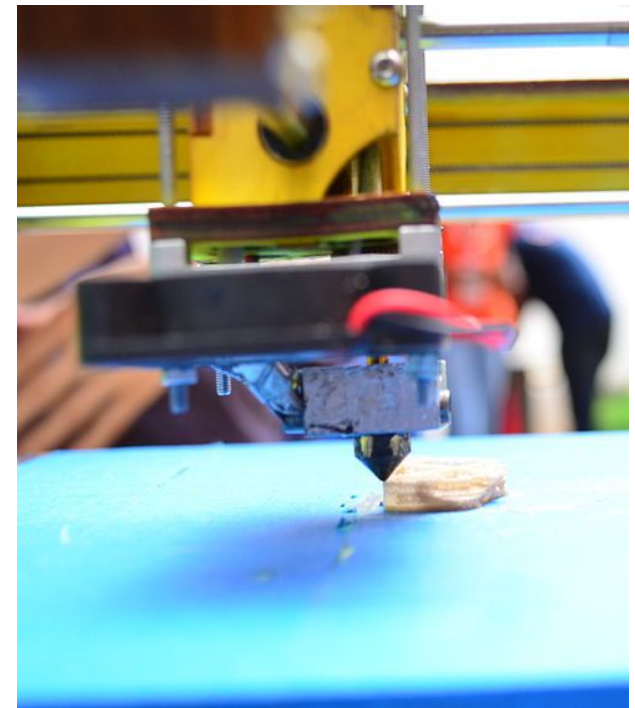
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3D printers manufacturing

- Design and manufacture 3D printers
- Source and 3D print parts, assembly, calibrate and sell 3D printers

Examples:

- Makerbot, Formlabs (USA)
- BQ, BCN3D (Spain)
- WASP, Roboze, Sharebot (Italy)
- Zortrax, Sinterit (Poland)
- Symme3D, Build3DParts (Romania)



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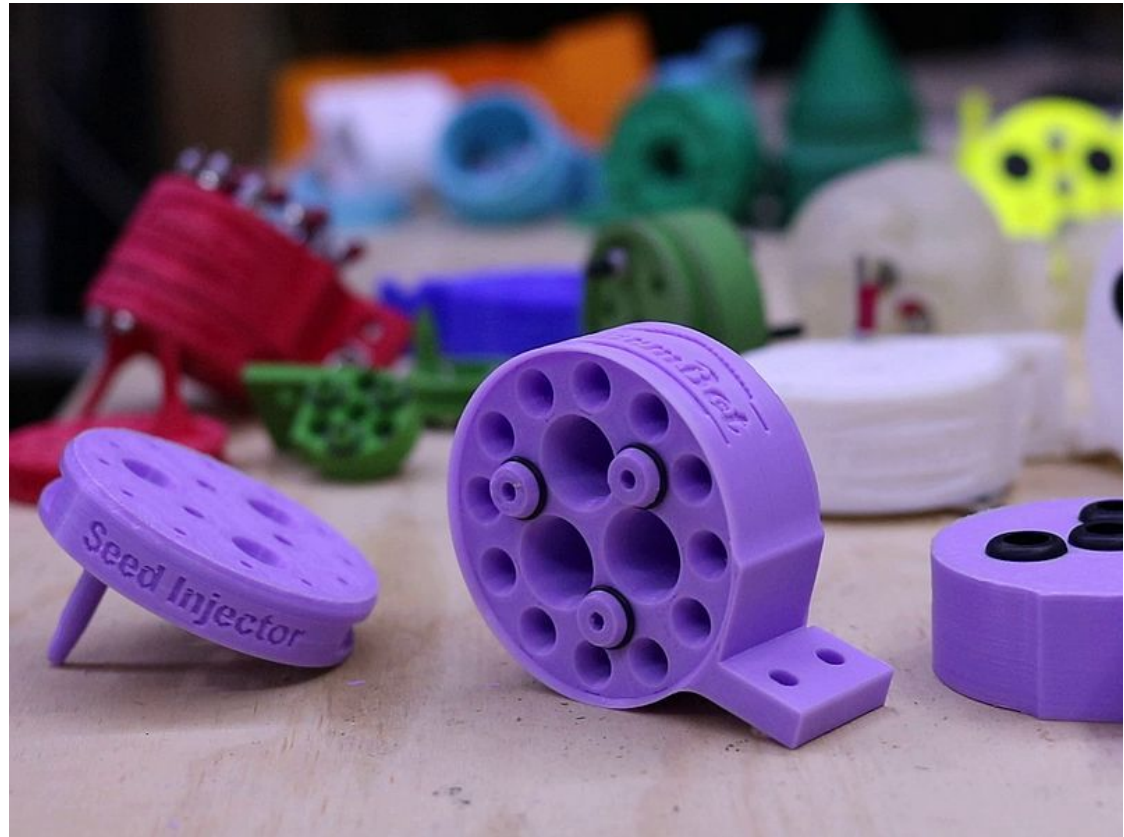
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Customized objects

Huge variation of designs can be created using 3D printing .



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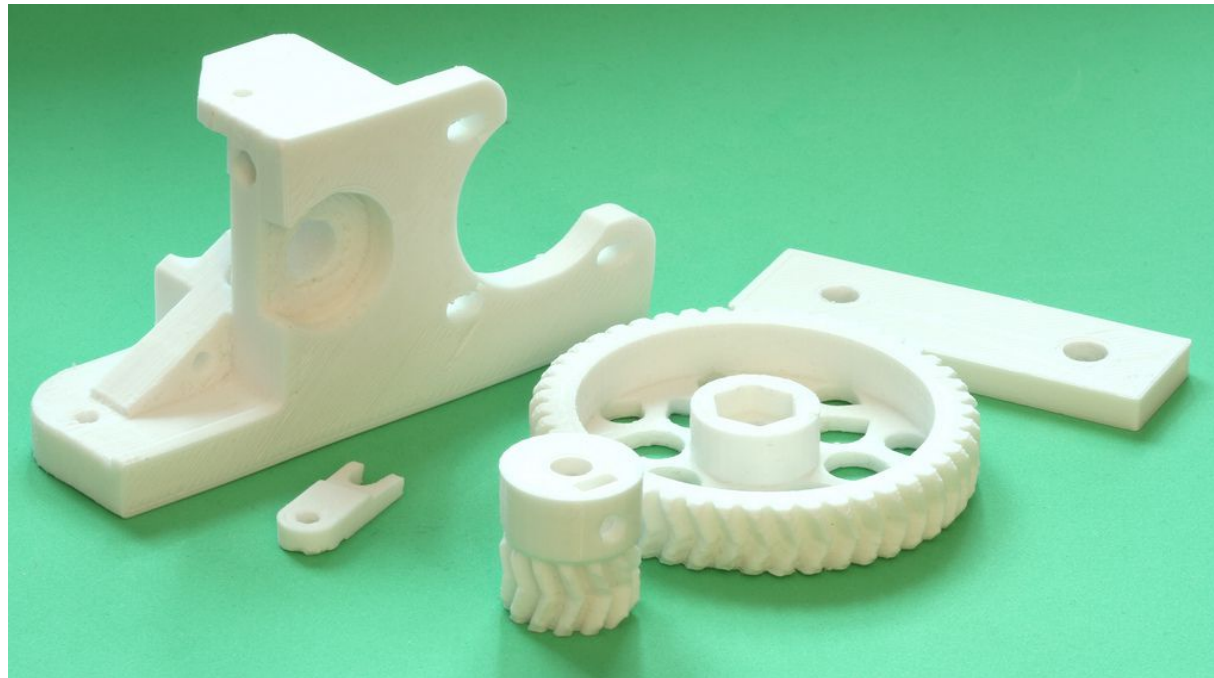
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Prototyping

Prototyping is the most important application of 3D printing.



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3D printed fashion - bags

The Berna Clutch of **Odo Fioravanti**, launched in 2017 in Paris. It has curved layers and is inspired by an unique urban structure of the city of Bern. It is a limited series and having it 3D printed came as an efficient solution from the perspective of costs.



Odo Fioravanti – Clutch Berna

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3D printed fashion - jewels

There are numerous examples regarding jewelry;

Omri Revesz created the collection Penrose which starts from a rigorous geometric architecture that never repeats itself identically because of the asymmetrical model.



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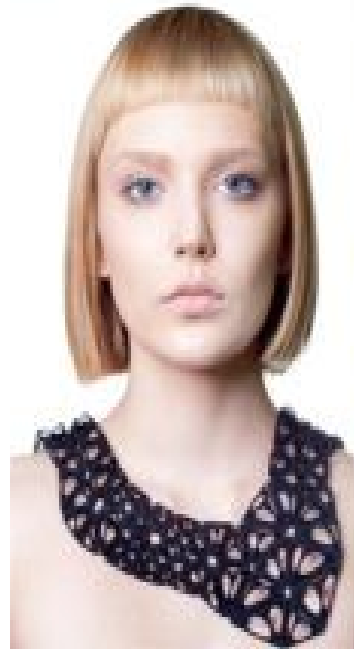


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3D printed fashion - jewels

Nervous System, another successful business, creates jewels inspired by science and technology.

It is based on researching the way in which models and forms appear in nature to create mathematical patterns and simulations that allow them to create more complicated objects, unique and personalized with the help of 3D printing.



Nervous System

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3D printed fashion - clothing

Designer **Danit Peleg**, created an entire collection using her home 3D printers.



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Parts & prototypes for watches

ZGOD. Zegarki, a Polish business, creates watches 3D printing the frames.

Fossil uses 3D printing for watch prototypes. The design can be adjusted any time and reprinted in 3D, producing the prototype is thus less time consuming and a lot less expensive.



Fossil watches



ZGOD Watches. Zegarki

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3D printed toys

A variety of models can be easily produced by 3D printing.



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3D printed medical devices

Medical uses of 3D printing include prosthesis and body parts.



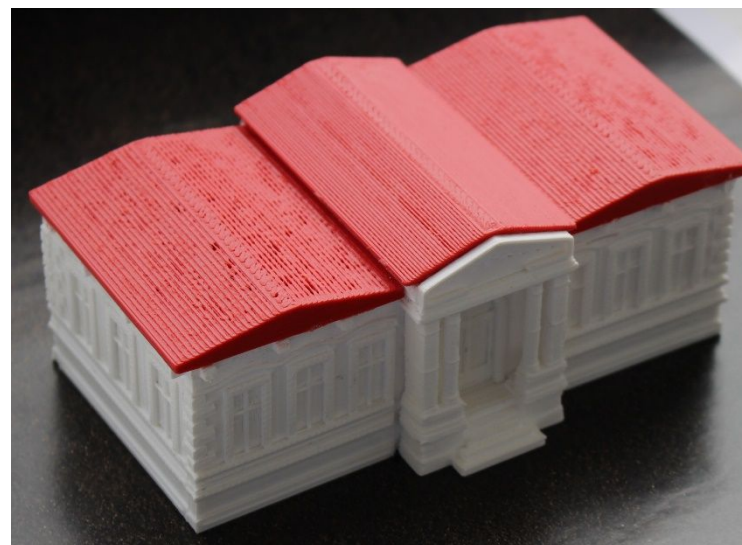
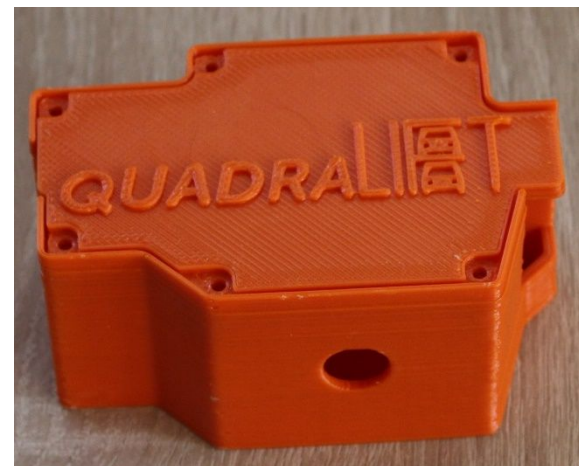
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3D printed customised objects



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3D printed food

Various types of edible designs can be created in 3D printing



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Funding sources

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Funding opportunities

Overview of sources:

1. Personal investment
2. Venture capital and private investors
3. Business incubators and accelerators
4. Bank loans
5. Angel Investors
6. Grants
7. Crowdfunding



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Funding opportunities- Crowdfunding



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Skills required for a 3DP based business

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Required skills

Depending on your business idea, you might need some specific skills to successfully run your business.

These skills may be gained by taking the 3DP course.



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Design skills

Creativity – Generating new concepts

Drawing – envisaging the objects in pen and paper



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Marketing Skills

- insights into the needs of clients
- market analysis



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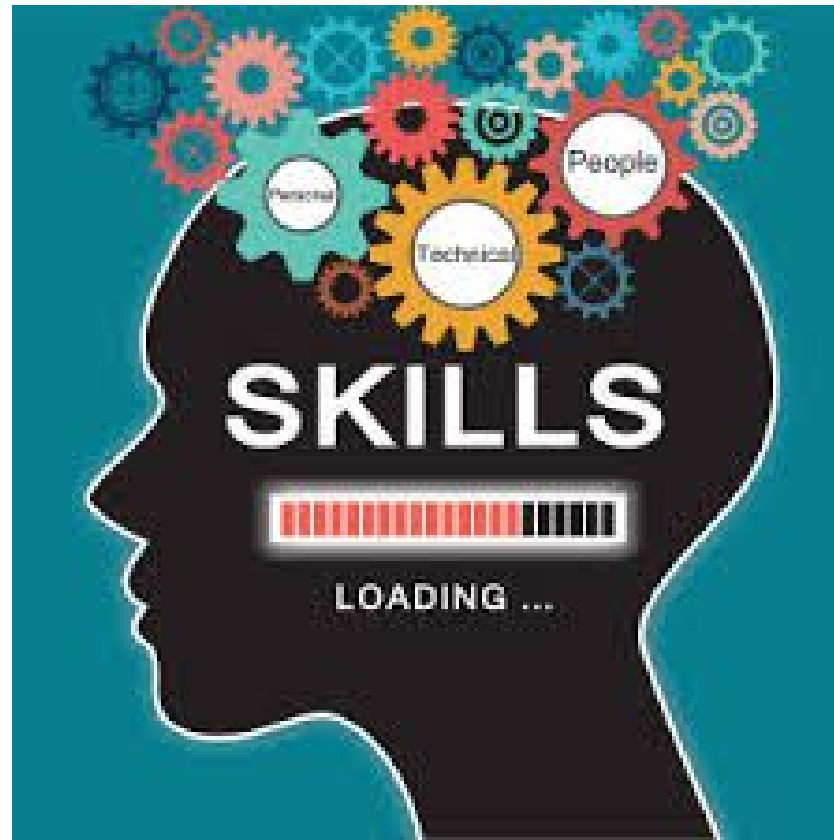
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Engineering and Technical Skills

- Math, Sciences, Physics, Chemistry, Mechanics



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IT skills



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Opportunities for freelancers

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Opportunities for freelancers

- Demand for freelance 3D printing expertise is growing fast
- Most in-demand jobs requiring 3D printing expertise:
 - Industrial and mechanical engineers
 - Software developers, applications
 - Designers
 - Marketing managers

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Freelancing websites

- Upwork
- Guru.com
- CAD crowd
- peopleperhour
- Freelancer
- xplace



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Useful Topic Related Links



- [Upwork.com](https://www.upwork.com/)
- [Guru.com](https://www.guru.com/)
- [CAD Crowd](https://www.cadcrowd.com/)
- [3D Printing Job Board](https://www.3dprintingjobboard.com/)
- [The MediaBistro](https://www.themediabistro.com/)
- <https://www.symme3d.com/>
- <https://www.kickstarter.com/>
- www.indiegogo.com
- <https://3dprinting.com/3d-printing-service/>
- [10 Amazing 3D Printing Startups](https://www.10amazing3dprintingstartups.com/)

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Design with 3D printing in mind



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Aim and Learning Outcomes

Module Aim:

To equip students with basic knowledge on defects typically encountered in 3D printed parts and 3D printing design rules for parts and assemblies in order to minimise the occurrence of such defects.

Number of Hours:

3hrs

Learning outcomes:

- Acquiring knowledge on defects associated with 3D printed parts fabricated by FDM
- Understand the influence of building orientation over parts' quality and mechanical properties
- Acquiring knowledge on 3D Printing design rules for parts and assemblies

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Lecture Outline

- Types of Defects in 3D Printed FDM Parts
- Role of Building Orientation in 3D Printing
- Design Rules for 3D Printing Parts and Assemblies



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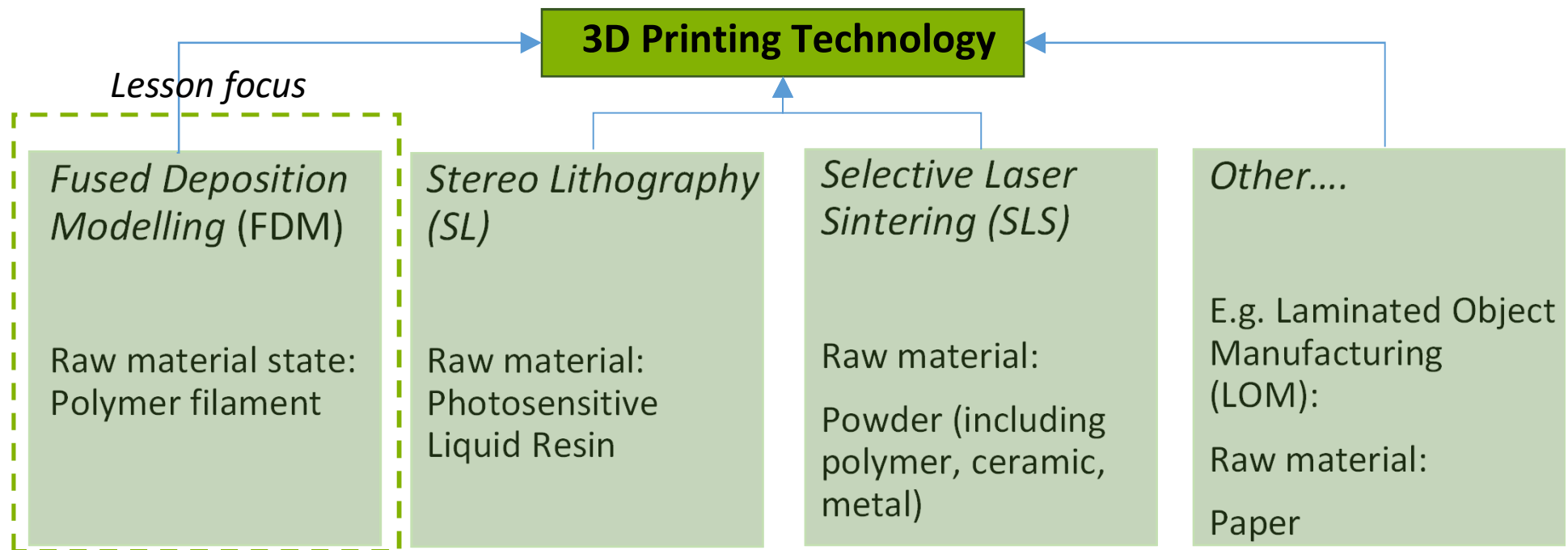
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Lecture Focus

Fused Deposition Modelling (FDM) is going to be taken as the case-study 3DP technology for defects



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Types of Defects in 3D Printed FDM Parts

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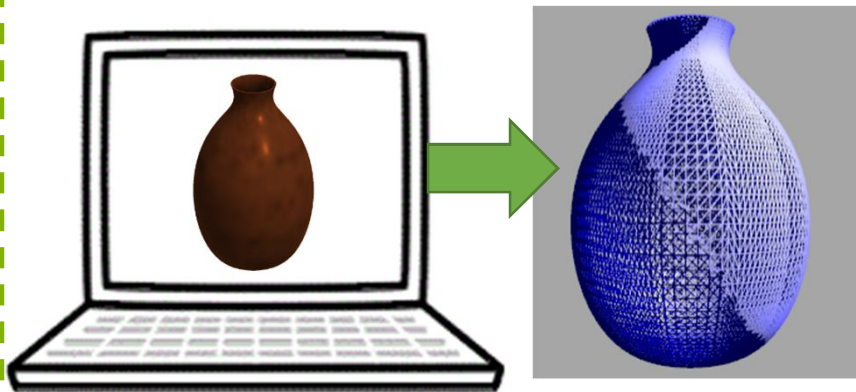


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Defects in 3DP FDM Parts

- Causes of defects are classified according to the stage in which they happen:
- This classification applies to 3D Printing processes in general, not just FDM

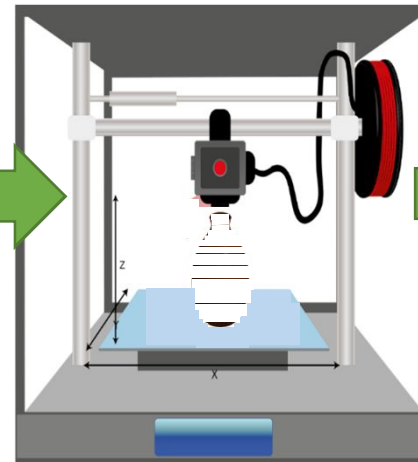
Data preparation defects



3D CAD
Modelling

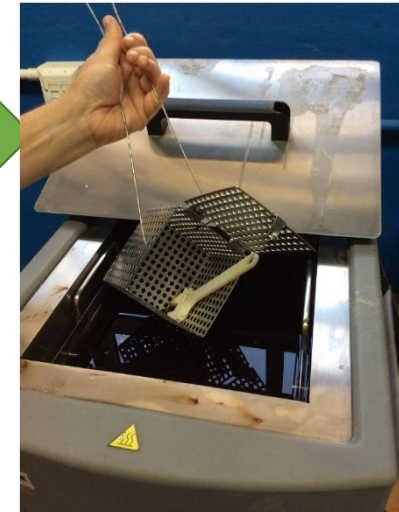
STL file
preparation

Part building defects



3D Printing
process

Post-processing defects



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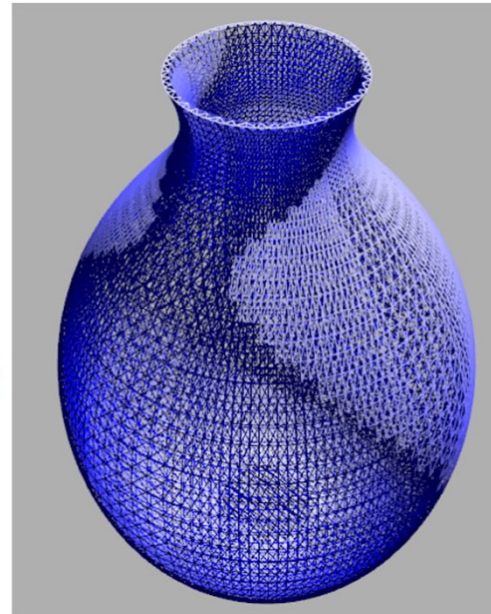
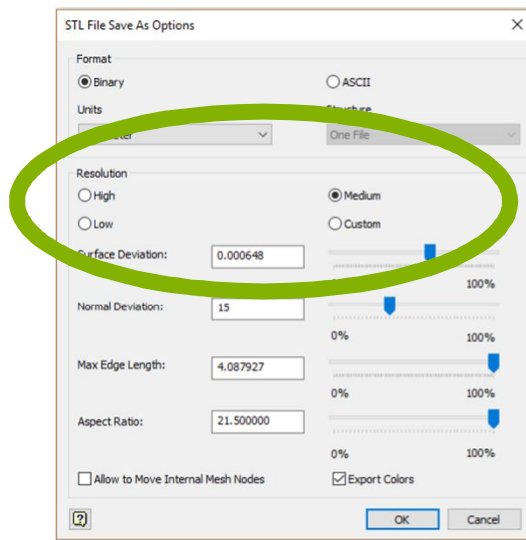
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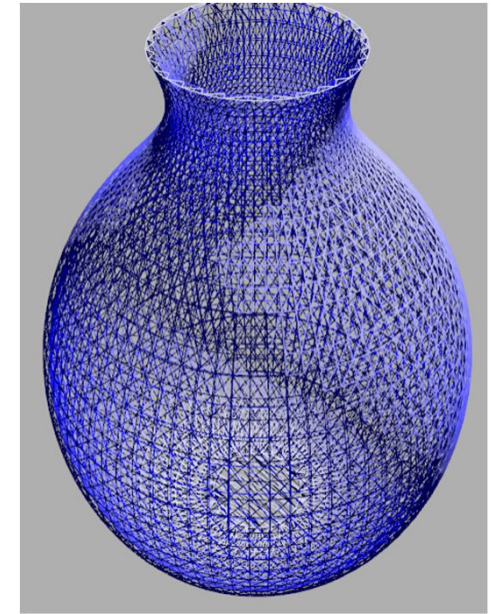
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Defects Related to Data Preparation

- Inaccuracies related to data preparation, such as due:
 1. **STL file generation:** inherent errors due to tessellation of 3D CAD model. The resolution of *STL* files can be controlled during their generation in a 3D CAD system.



Medium STL file
resolution



Low STL file
resolution

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Defects Related to Data Preparation

2. **missing support structures:** software can erroneously omit support structures which result in defects during the fabrication stage

Defective features
on the model due
to missing support
structures



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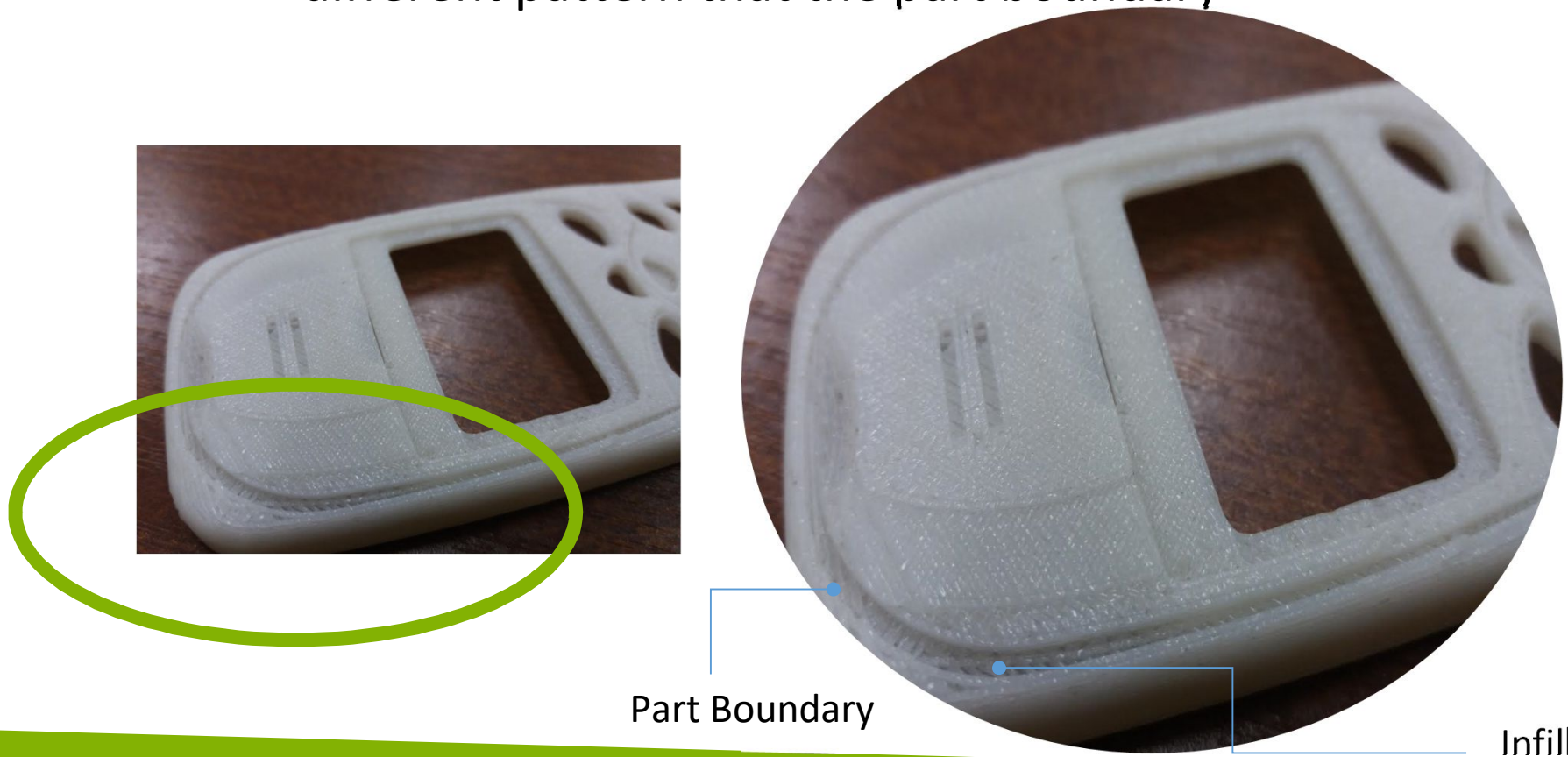
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Defects Related to FDM Process

- Defects related to the FDM process include:
 - Gaps between fill and outline:** the infill uses a different pattern than the part boundary



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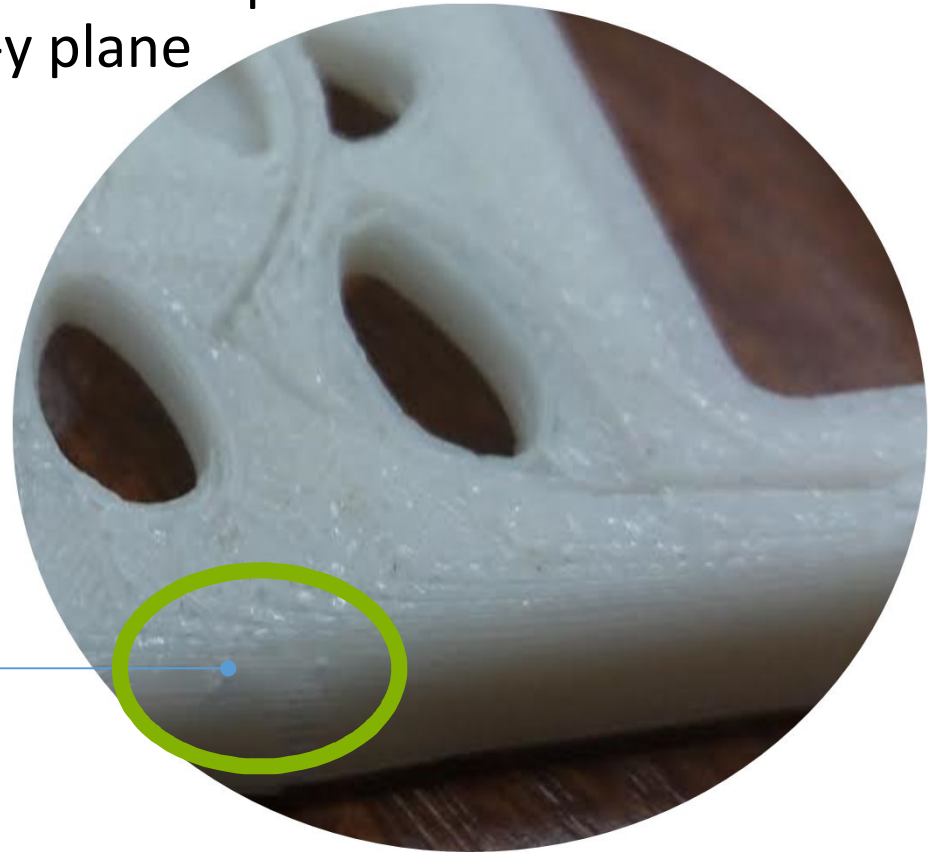
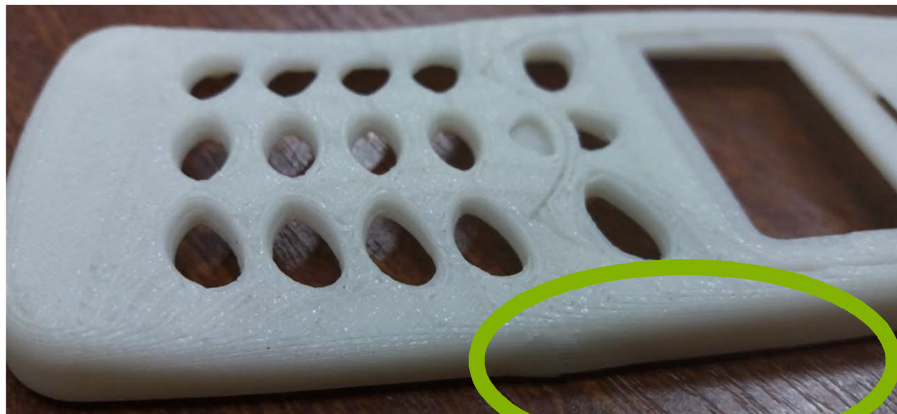
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Defects Related to FDM Process

2. **blobs**: which may appear on the surface of the FDM model, due to the fact that the printer nozzle moves back on forth in the x-y plane



Blobs

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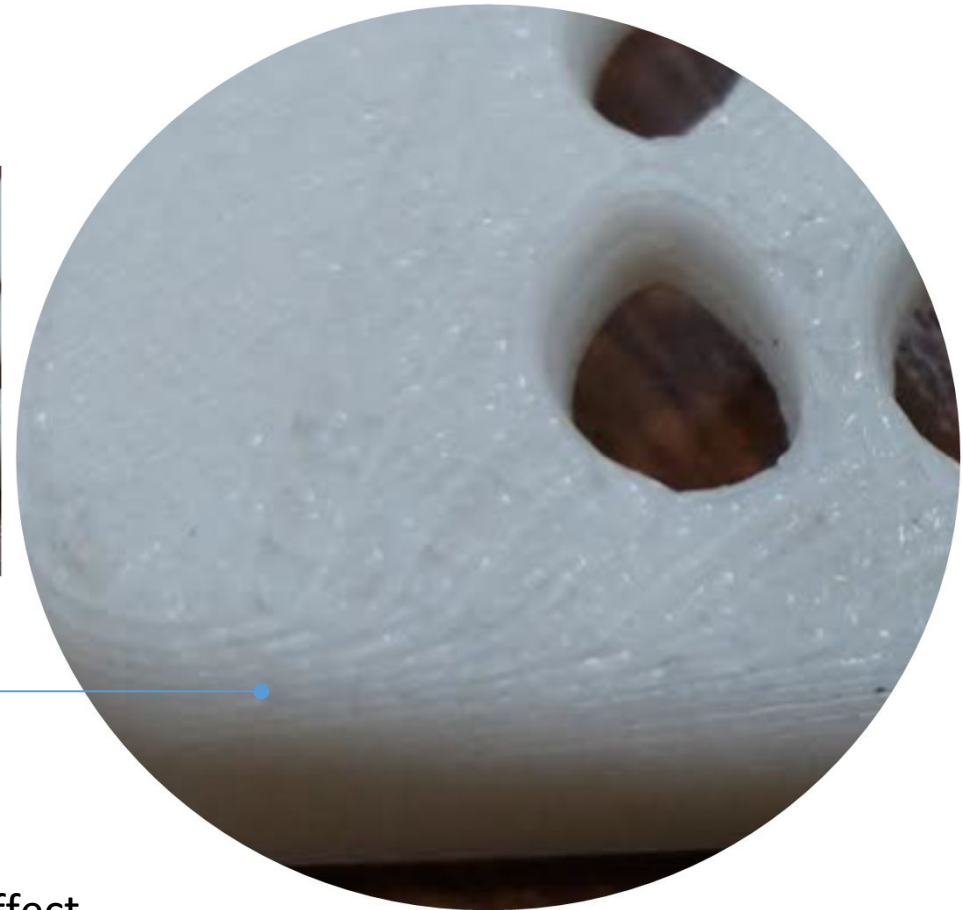
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Defects Related to FDM Process

3. **staircase effect**: due to the slicing of the 3D CAD models in layers



Staircase effect

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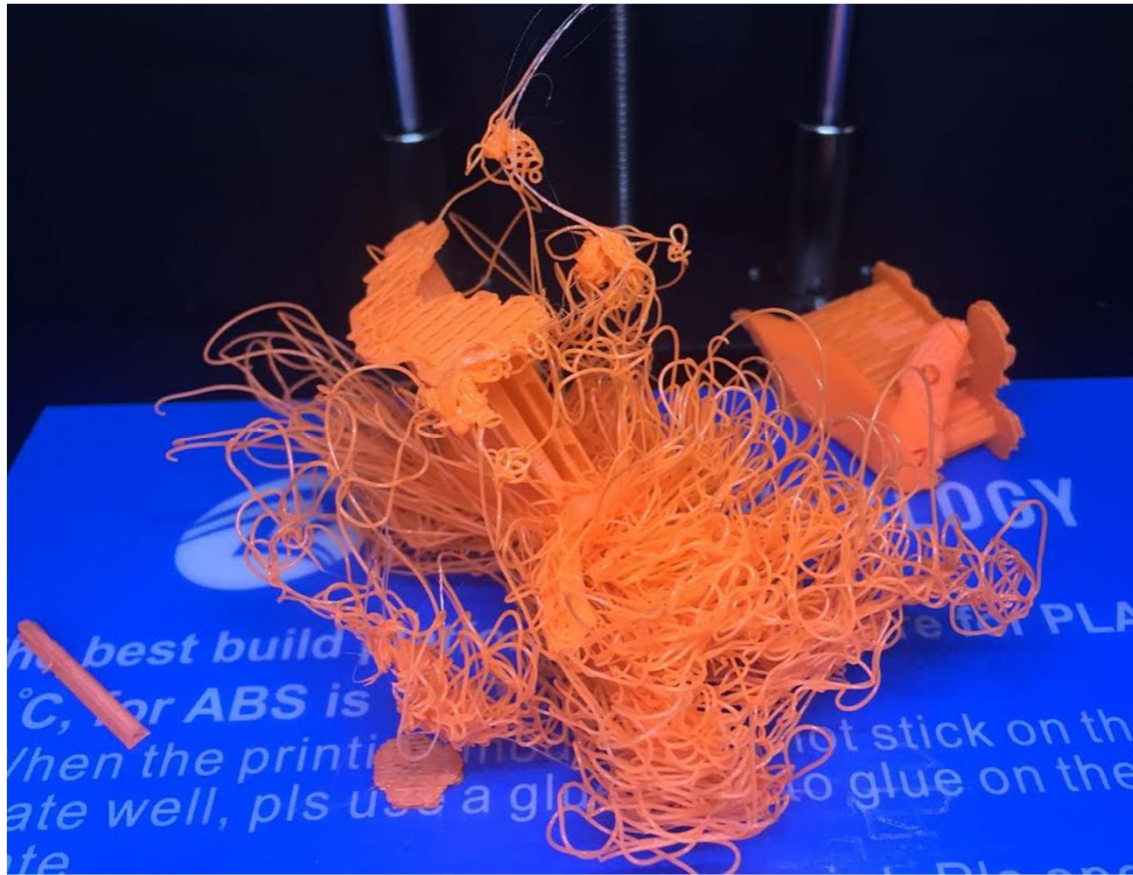
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Defects Related to FDM Process

4. **wrong calibration of the 3D printer:** which can lead to a disastrous built



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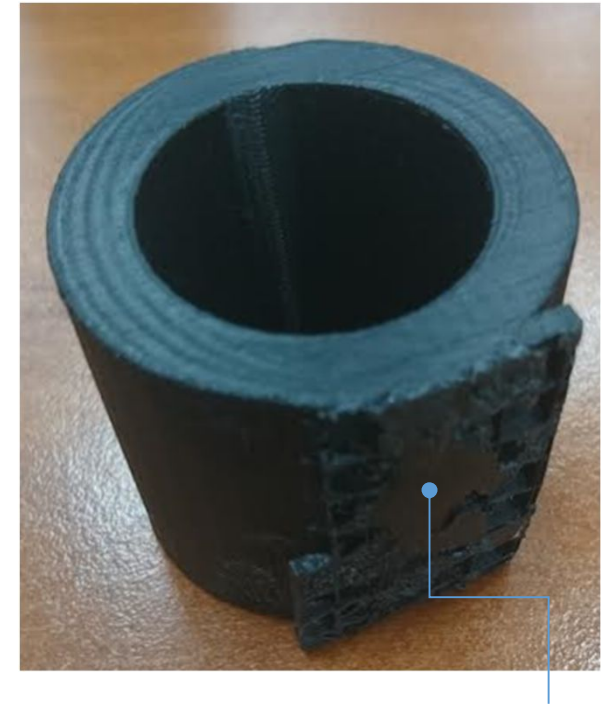
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Defects Related to FDM Process

5. **support structure sticking to part**: sometimes it is difficult to remove support structure, probably do to improper temperature settings.
6. **warp**: part can get warped for various reasons, e.g. incorrect built orientation, over-usage of base plate etc.



Support structure sticking to part

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Defects Related to FDM Post-Process

- Defects related to FDM post-processing include:
 - Unremoved support material:** there can be internal closed features (e.g. roof in the prototype building below) which makes it difficult to remove support material)

Entrapped support material



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Role of Building Orientation in 3D Printing

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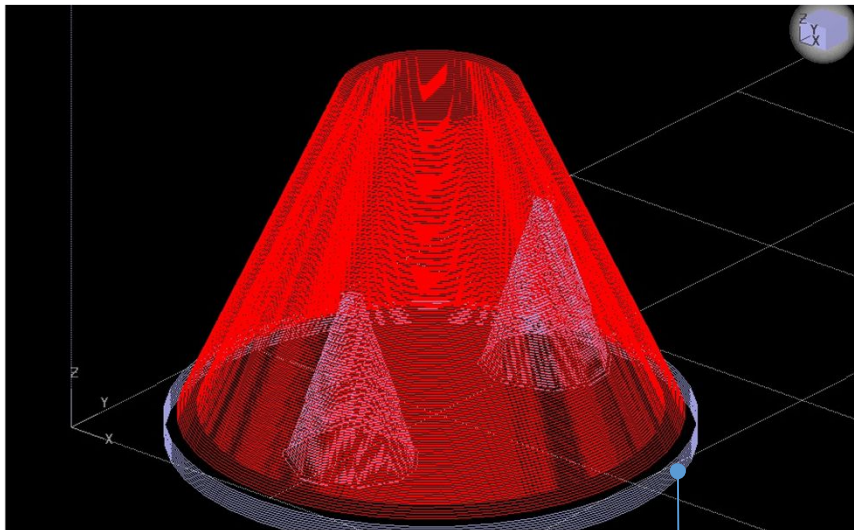
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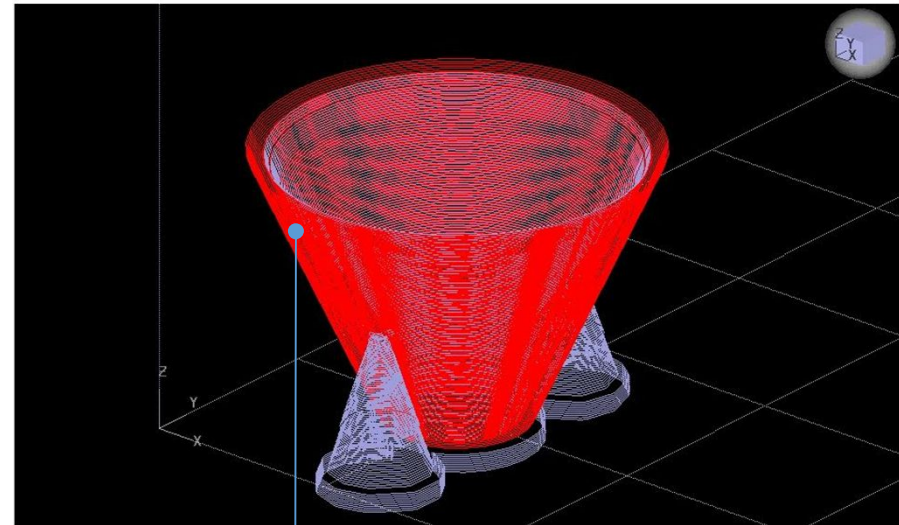
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Role of building orientation

- Part orientation plays a crucial role in FDM, in particular on:
 1. the strength of the part (remember FDM parts are weak in the vertical direction)
 2. the type and amount of support material which is utilised
 3. hence the time required to finish off built



Support material



Build material

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Affect of Orientation on 3DP parts

How Does
FDM Build
Orientation
Affect a 3D
Printed Part?



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

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Design Rules for 3D Printing Parts and Assemblies

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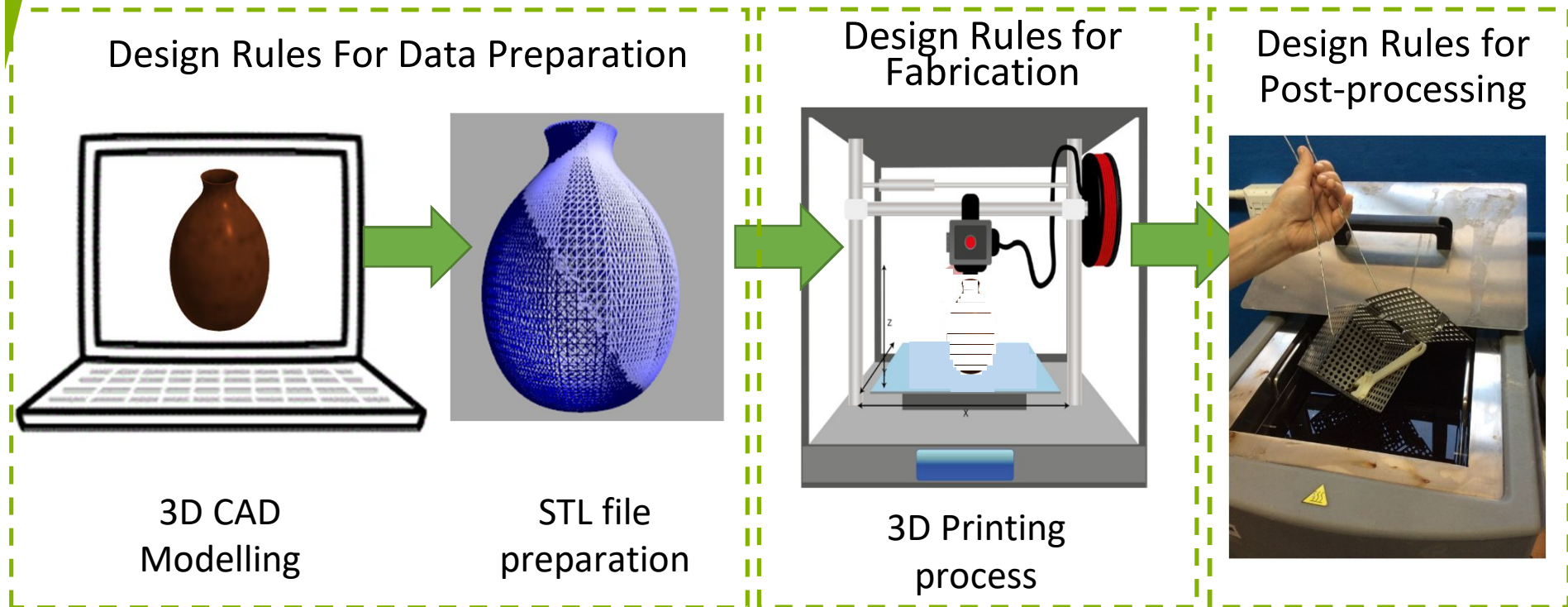
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Design Rules for 3DP FDM Parts

- The design rules have been classified to reflect the three main stages of the 3D printing cycle:



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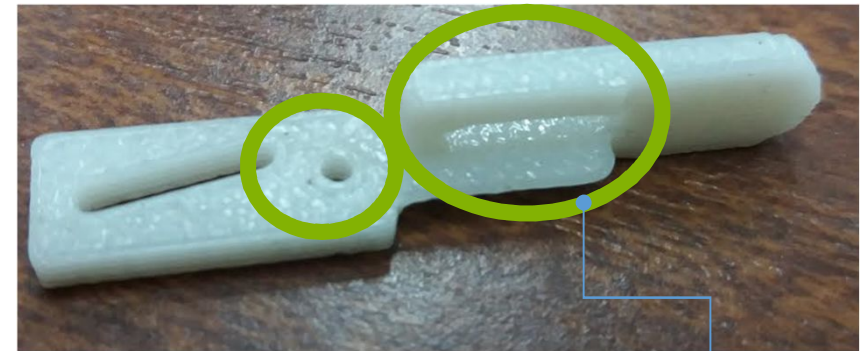
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Design Rules For Data Preparation

1. Add form features (e.g. pockets, ribs, channels and holes) in order to improve the mechanical properties of the part, yet shorten building time and reduce material costs
2. In case of small holes, it is advisable to look at the least diameter of the extruded filament, as this will dictate the size which can be achieved



Adding a pocket to reduce material



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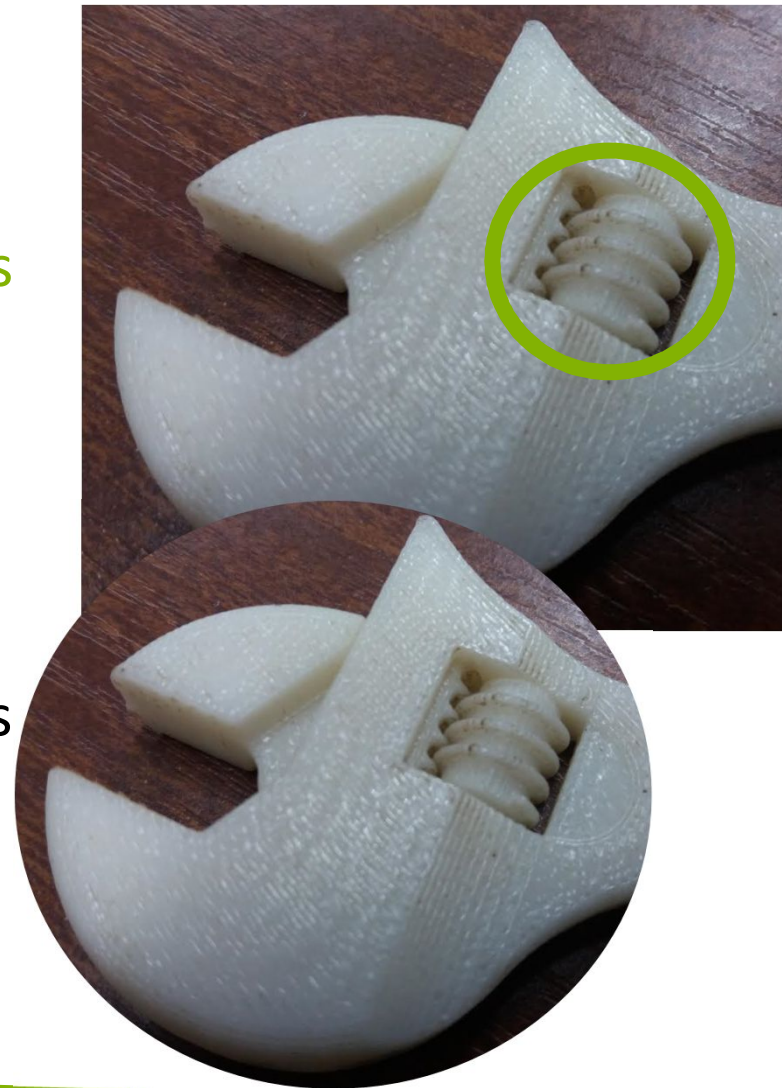


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Design Rules For Data Preparation

3. In case of **assemblies**, **sufficient clearance (e.g. 0.5mm)** between mating parts must be taken into account.

N.B.: This varies from one FDM printer to another – so it is advisable to look at the guidelines issued for specific FDM printer models and makes.



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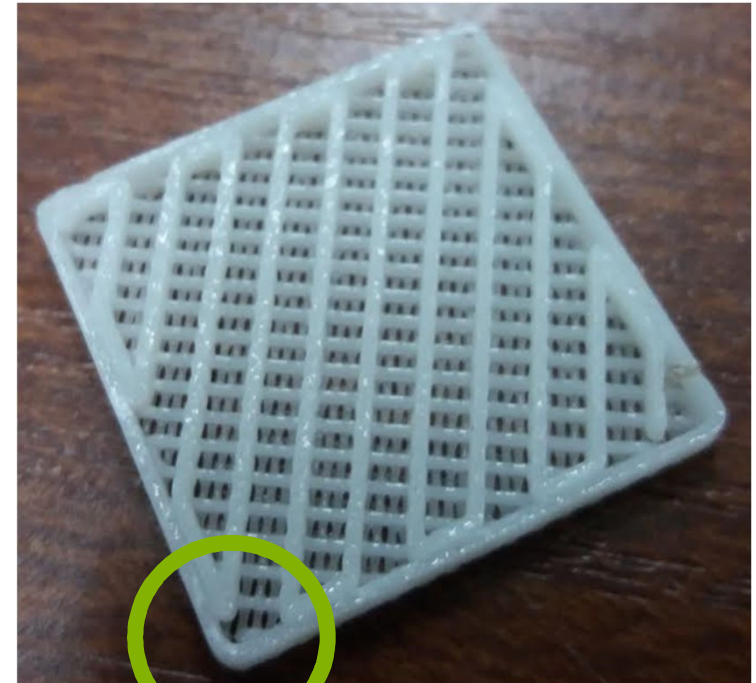
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Design Rules For Data Preparation

4. Add holes, pockets etc. to insert other components, such as RFID tags, electronic circuitry items, metal threaded inserts, during the build process. (In most cases, the build process can be paused.)
5. Try to avoid sharp corners as much as possible as these act as stress concentrators for FDM parts



Round corners to eliminate stress concentration

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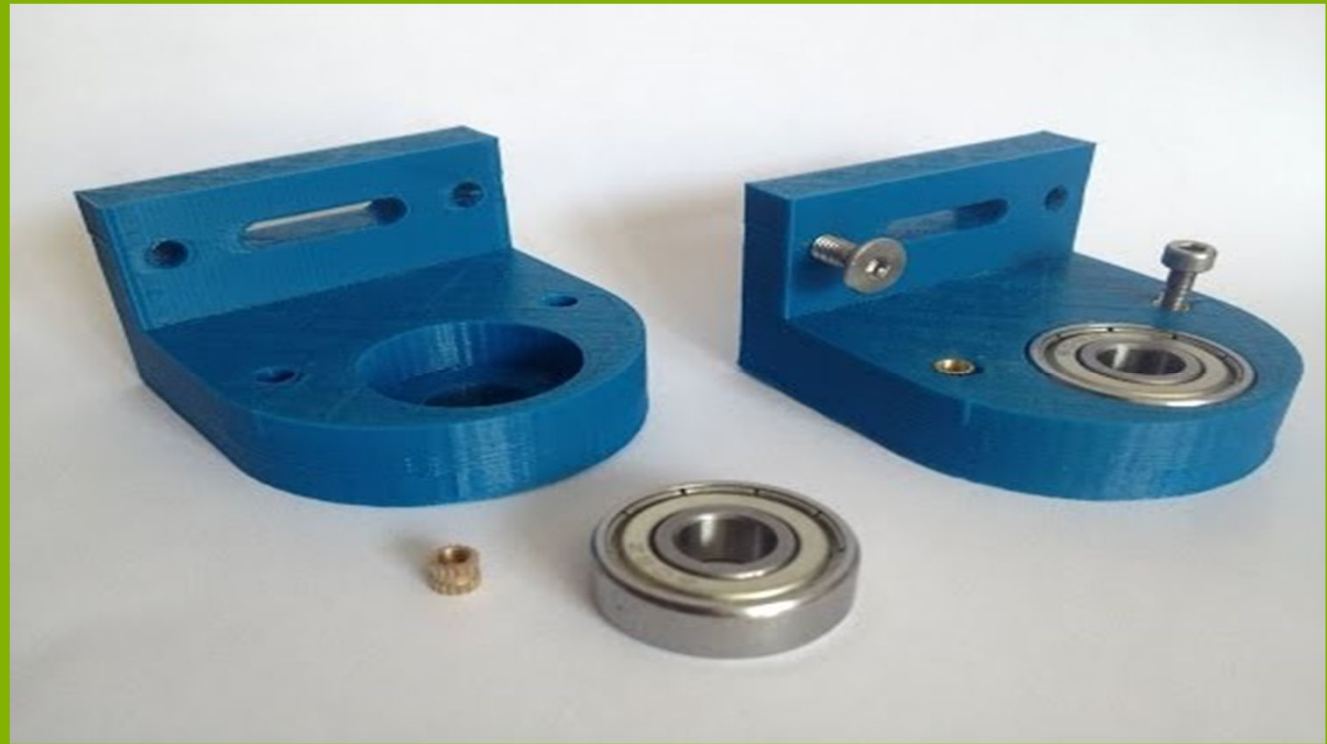
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Inserting Metal Items in FDM parts

Procedure to
insert metal
items in FDM
parts



https://www.youtube.com/watch?v=A_BcU7ipHew

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Design Rules For Data Preparation

5. It is advisable to **design the minimum wall thickness according to the layer thickness.**

E.g. if the wall thickness (T) of the part is 0.3mm, then the layer thickness (t) is 0.1mm; if $T = 0.75\text{mm}$, $t = 0.25\text{mm}$.

In this way, the staircase affect would be minimised



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Design Rules For FDM Fabrication

1. **Material selection** plays a fundamental role in the **properties of the part**, including mechanical, thermal, chemical and electrical properties.
2. **Material has an influence on layer thickness**, hence a direct influence on surface smoothness (e.g. min. thickness for ABS is ca. 0.13mm whereas for PC is ca. 0.18mm)

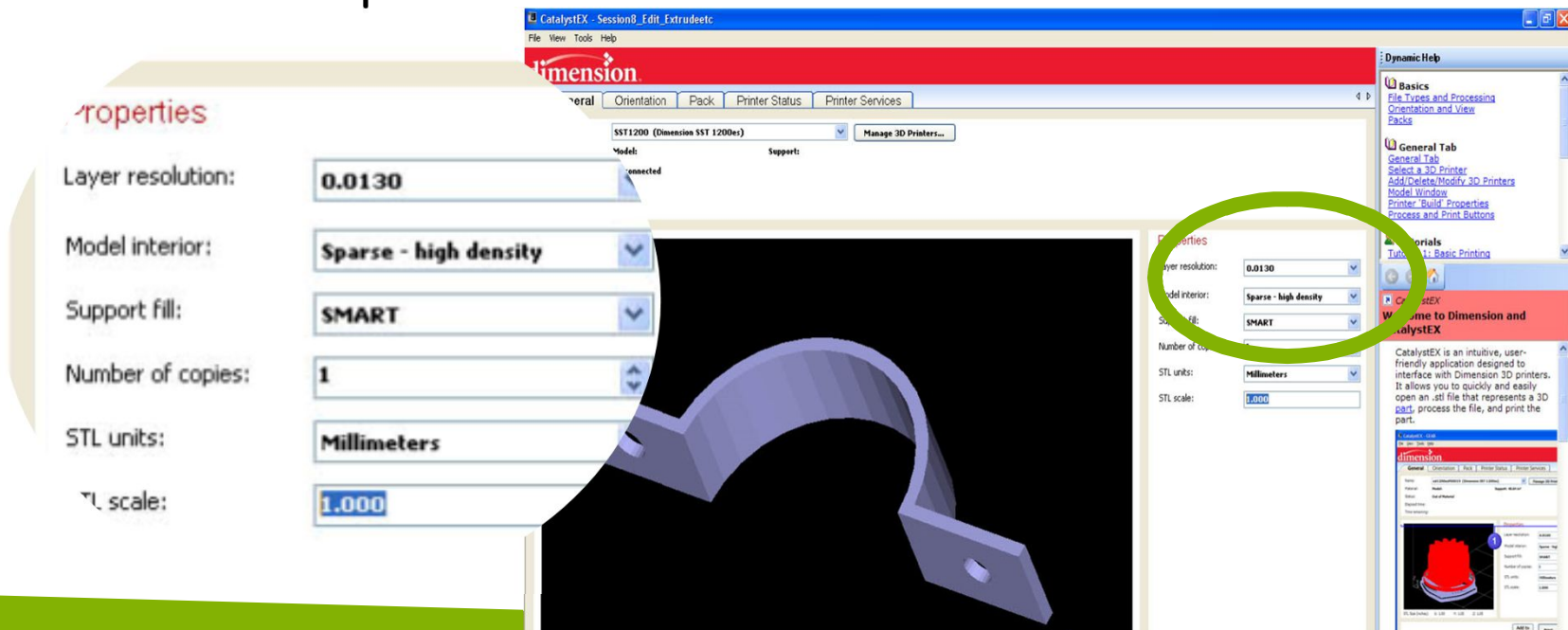


ABS cartridge used in FDM

Design Rules For FDM Fabrication

3. Select **building style** (i.e. density by which filament is deposited – e.g. sparse – high density) depending on the intended function of the printed part.

This parameter has a direct effect on mechanical properties, material consumption and build time



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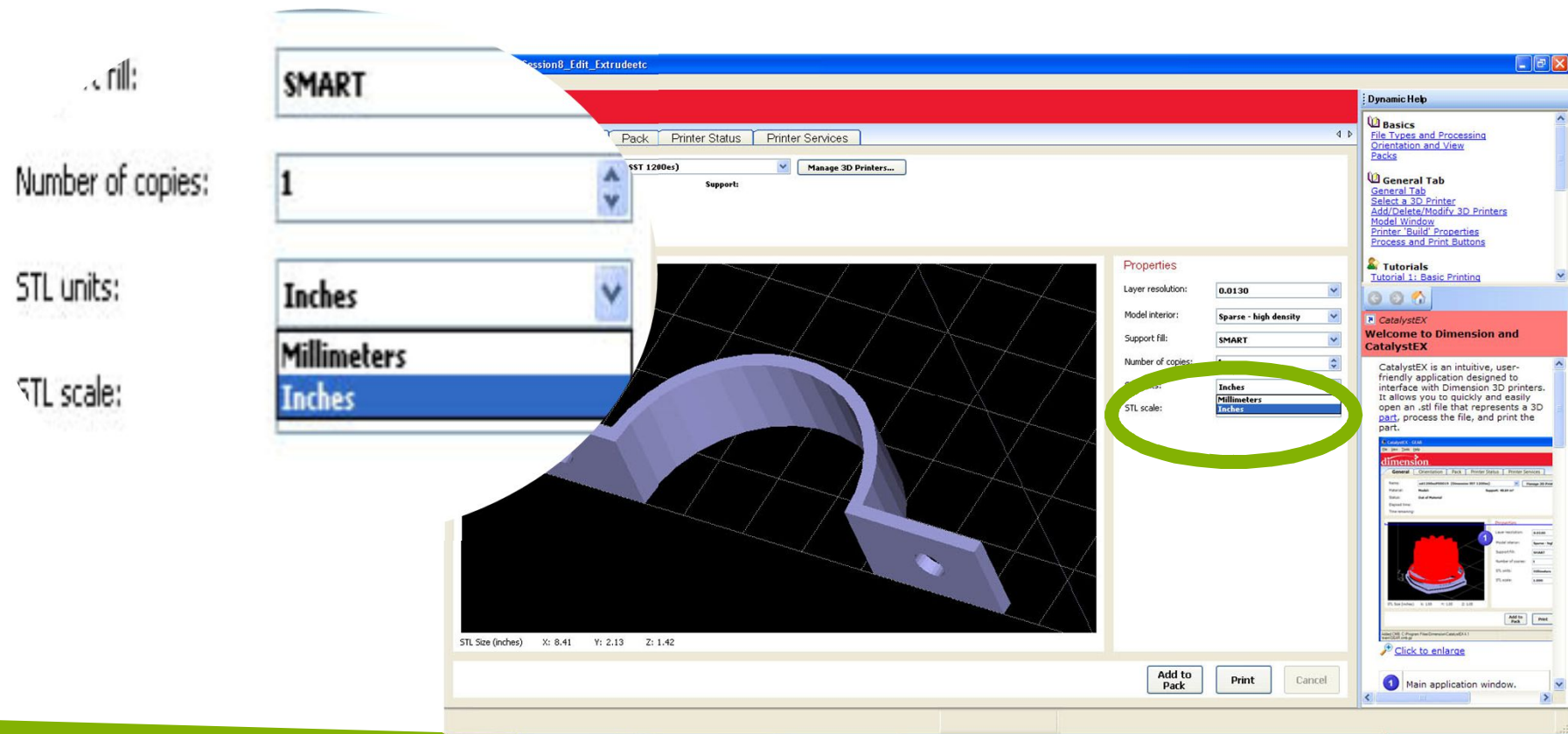
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Design Rules For FDM Fabrication

4. In the 3DP machine software it is advisable that you check that the **STL model units match those of the STL scale.**



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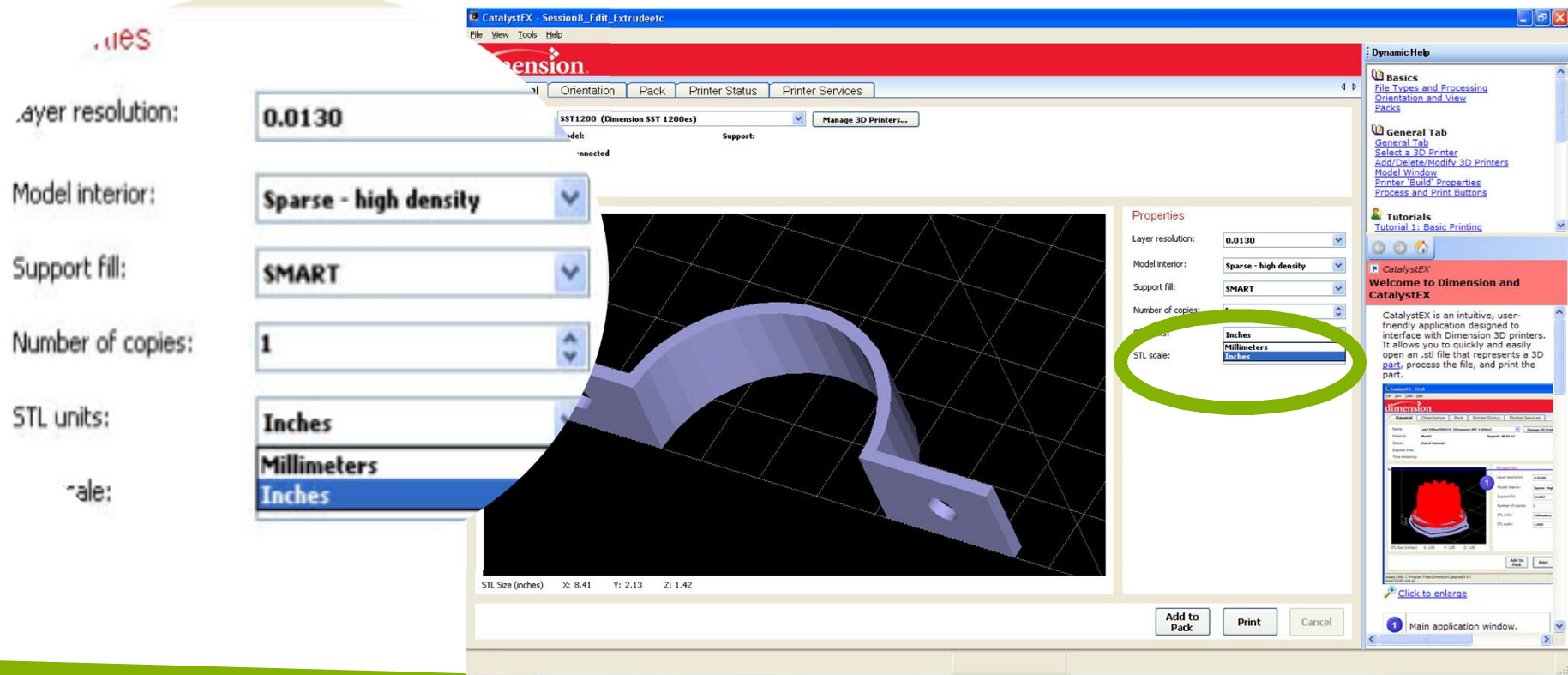
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Design Rules For FDM Fabrication

5. If you want to increase the quality of the surface finish and accuracy, opt for the smallest layer resolution



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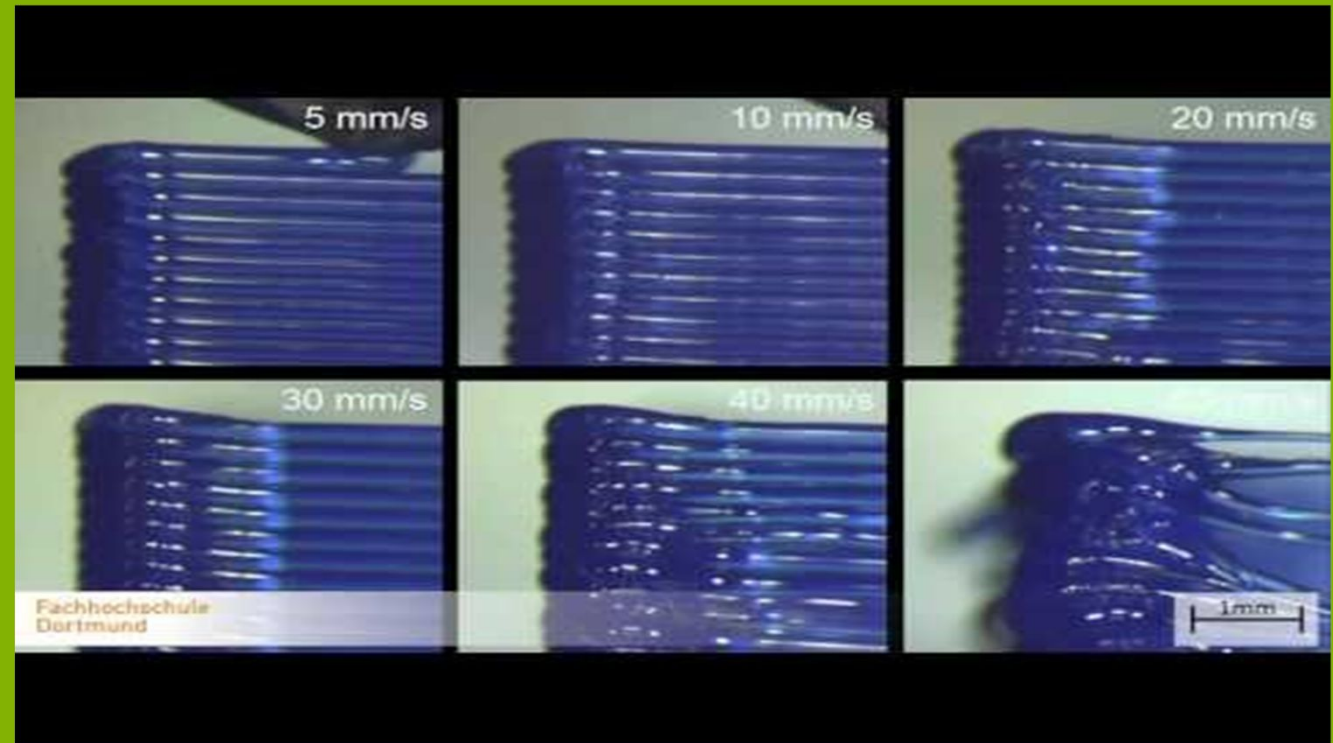
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FDM Defects Due to Different Speeds

Results
obtained
when 3D
Printing using
PLA on FDM
with different
speeds



https://www.youtube.com/watch?v=BBQTD9_34sQ

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Design Rules For FDM Post-Processing

1. Add holes from which soluble support structure material can be drained during post-processing.
2. The more support structures you have, the less fine the surface finish will be. Thus, try to reduce support structures when preparing the file for 3D printing

Scaled down model of an Egyptian mummy head with support material entrapped in chin area



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Useful Topic Related Links



[Dedicated CAD package on Design for 3DP](#)



[FDM for End-Use Parts:
Tips and Techniques for Optimization](#)



[Inserting Metal Inserts Into 3D Printed Parts](#)

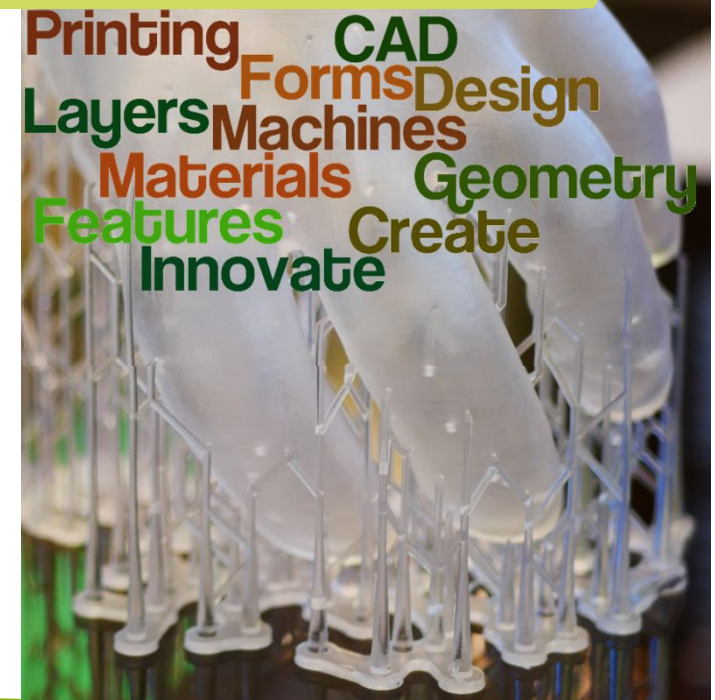
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Boosting entrepreneurial spirit, creativity and innovation-case studies



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Aim and Learning Outcomes

Module Aim:	To equip students with basic understanding of 3D Printing business
Number of Hours:	2hrs
Learning outcomes:	<ul style="list-style-type: none">• Understanding the impact of 3D printing technology in various businesses• Acquiring knowledge of how to build a start-up based on 3D printing

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Lecture Outline

- 3D Printing case studies in architecture and art
- 3D Printing case studies for the medical field
- 3D Printing technology as support for innovation and creativity
- 3D Printing case studies for training and education
- 3D Printing case studies in engineering/industry

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3D Printing case studies in architecture and art

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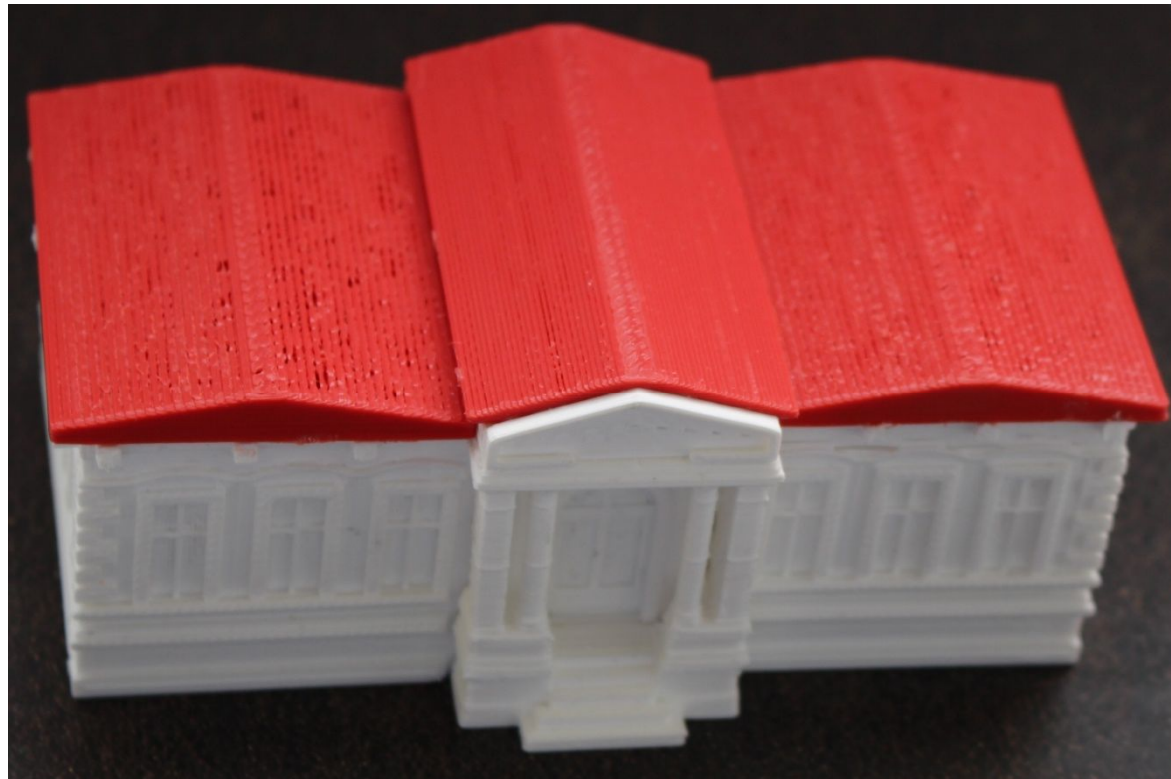
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3D Printing in architecture and art

3D printing - revolutionary and innovative solutions for architectural companies, for museums, national heritage buildings and also for regular customers.



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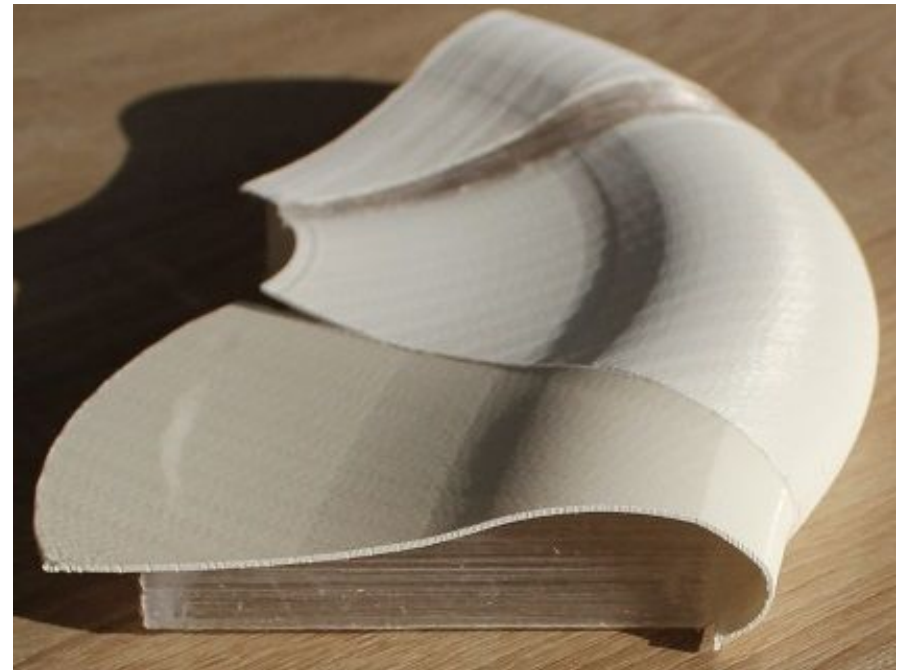


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3D Printing in architecture and art

Benefits:

- enhancing productivity: any complicated design is tangible very fast;
- using many different colours and materials (recycling included);
- flexible to client changes;
- re-edit, re-used, re-print, shared.



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3D Printing case studies for the medical field

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3D Printing in the medical field

3D bio printing – the age when the machines we have built are building bits and pieces of us.

- **Technology:** fusing or depositing materials such as plastic, metal, ceramics, powders, liquids in layers;
- **Visualization:** help preparing and plan a complex surgical operation.



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3D Printing in the medical field

Prosthetics for knee replacements, hands or legs amputation, fracture support casts, eyes, noses for patients with facial disfigurement, ex etc.

- functional, versatile, easily customized;
- realized within a day;
- affordable prices.



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3D Printing in the medical field

Prosthetics – 3D printed robotic arms and legs

- only in USA, close to 200,000 amputations are performed each year;
- easier and quicker printing;
- easier and quicker assembly;
- low price solution 3DP prosthetic with respect to classic technologies.



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3D Printing in the medical field

Prosthetics eyes

- a 3D Printer can produce 150 prosthetic eyes/hour and reducing the cost by 97% of the existing handmade versions.

Prosthetic ears

- hundreds of thousands of people have suffered ear injuries due to gunshot wounds, cancer of the ear or micotia, a malformation of the external ear;
- scientists are creating new ears with 3D-Printing and human stem cells.



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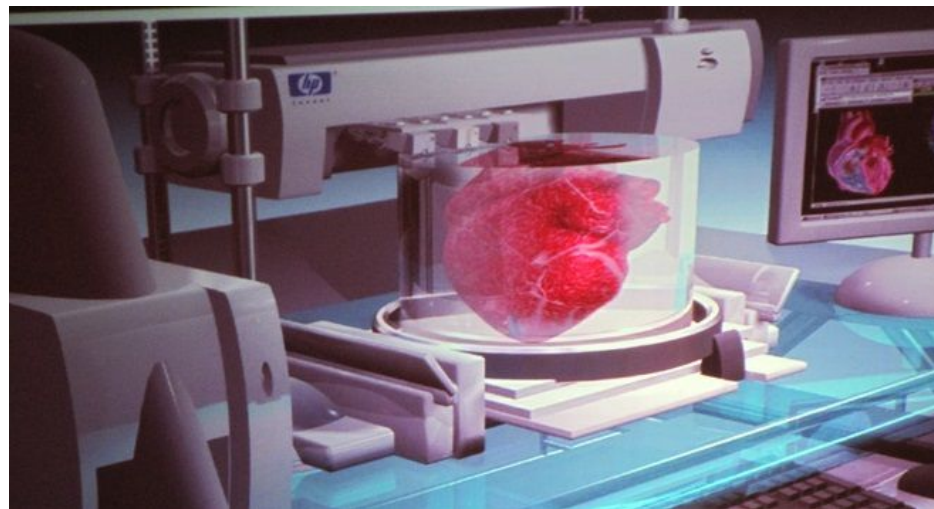


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3D Printing in the medical field

3D bio printing tissues & organs

- a bio printing machine is capable to print human tissues;
- 3D printed skin for burned people;
- Challenge: keeping larger tissues alive, finding materials for 3D bio printing.
- 3D printed heart helps develop lifesaving multi-steerable Sigma Catheter.



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3D Printing in the medical field

Dental 3D Printing - Teeth, Implants, Dentures and Crown;

- personalized, accurate model;
- quick making;
- clean process - a lot less messy than plaster method;
- various materials;
- affordable price;
- easy to store in digital formats.



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3DP in Medicine and Healthcare

3D Printing in Maxillofacial and Oral Surgery – dental implants and crowns;

- helps dentist to diagnose and decide about the treatment;
- create templates and surgical drill guides for birth defects, injury or receding bone surgery;
- duration of the process: approx. one hour.



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3D Printing technology as support for innovation and creativity

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3D Printing-Creativity and Innovation

Print your own bionic limb - *Open Bionics* startup

- allows anyone in the world to download and 3D print their own bionic limbs;
- the business project - **Low-cost bionic hands that look and feel good** - won the finals of Intel's "Make it wearable" Challenge (\$250,000).



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3D Printing-Creativity and Innovation

Integrated Energy System

- clean energy technologies into a 3D-printed building and vehicle;
- connect a natural-gas-powered hybrid electric vehicle with a solar-powered building to create an integrated energy system.



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3D Printing case studies for training and education

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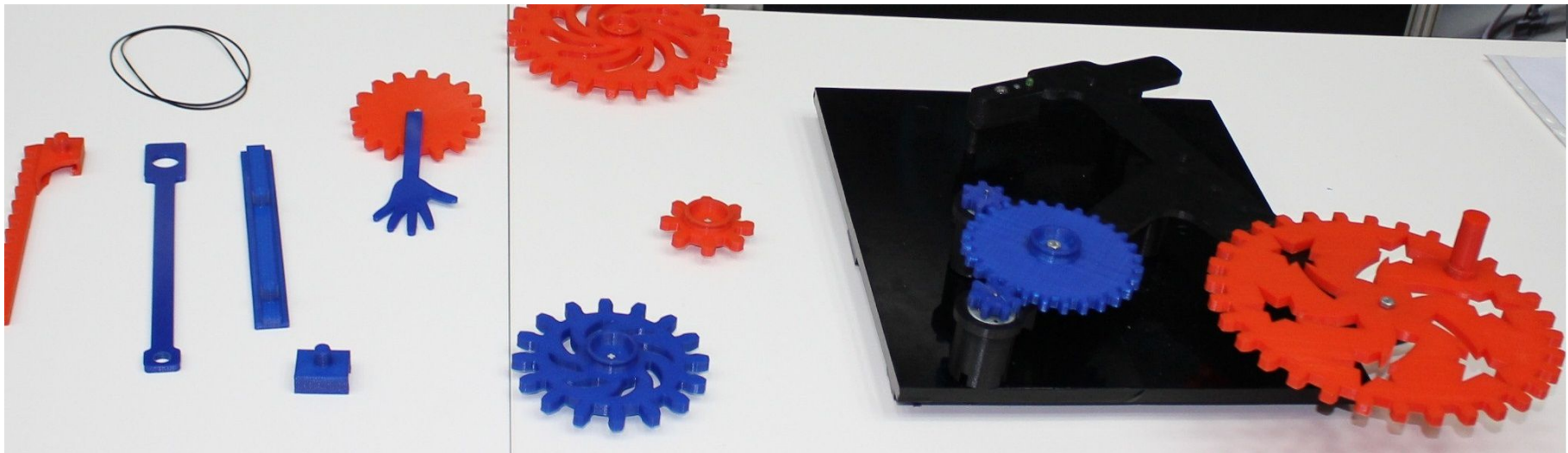


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3D Printing in training and education

Revolutionizing the classroom

- stimulating creativity and innovation;
- encouraging artistic potential;
- promoting team work;
- create responsible digital citizens;
- making everything hands on;
- solving real world problems.



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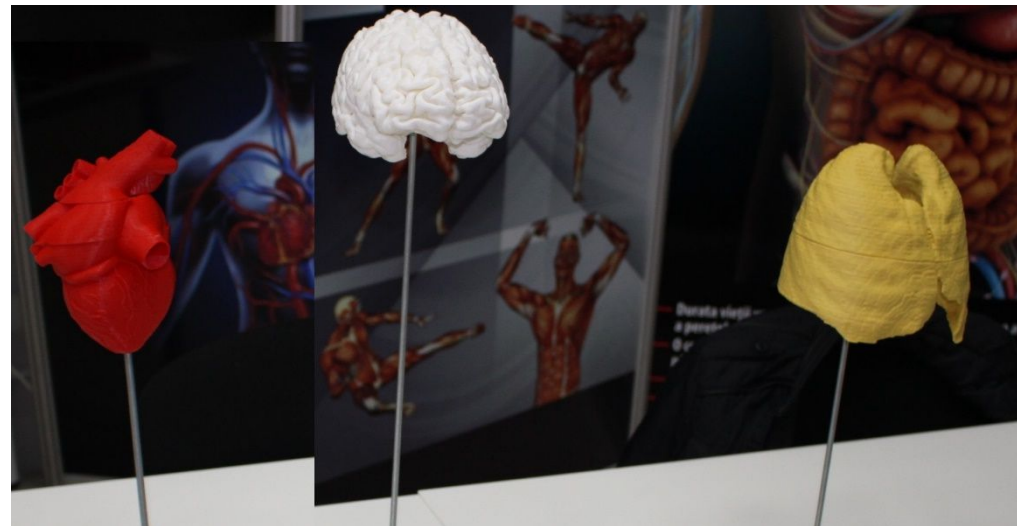


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3D Printing in training and education

Revolutionizing the classroom

- Chemistry – models of complex molecule structures and substances;
- Biology – studying cross section of different organs, bone structures.



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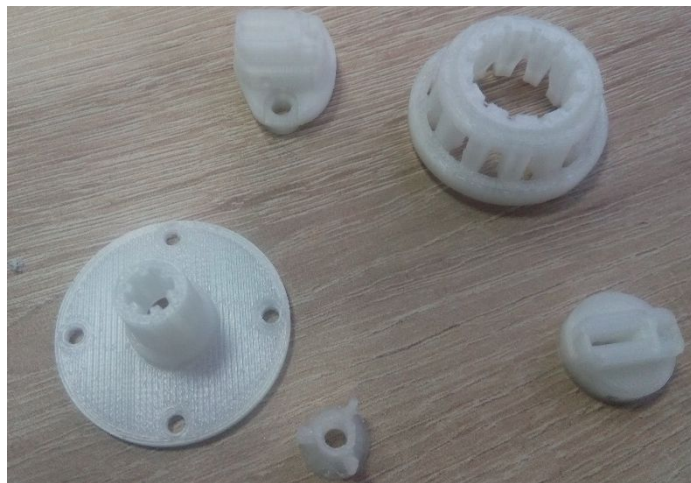


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3D Printing in training and education

Revolutionizing the classroom

- Design and Engineering – students can print their own prototypes: cars, engine parts etc.



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3D Printing in training and education

Revolutionizing the classroom

- History – students can print historical artifacts for examination, historic buildings for examination;



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3D Printing in training and education

Revolutionizing the classroom

- Games – students can print old games elements or can invent new games;
- Musical instruments – new design for regular instruments or creating new ones.



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3D Printing case studies in engineering/industry

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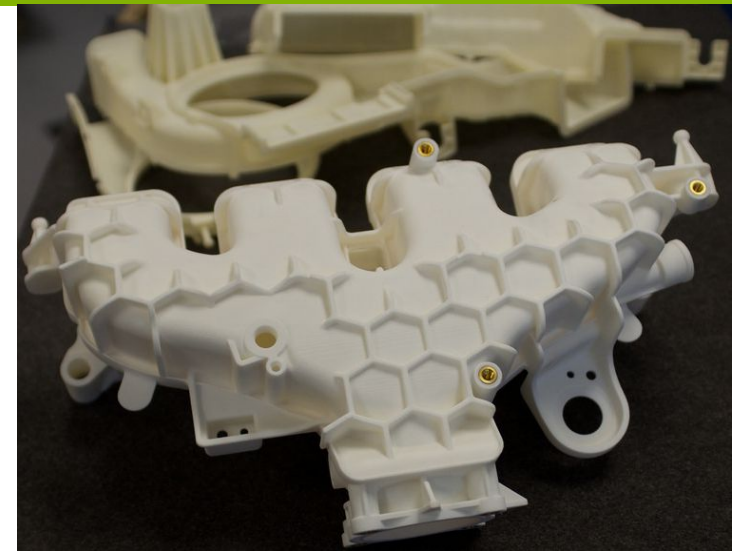


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3D Printing in engineering/industry

Revolutionizing the automotive industry

- Engine design – new models
- 3D Printing - the most cost-effective and time-saving method in the designers tool box to refresh their models



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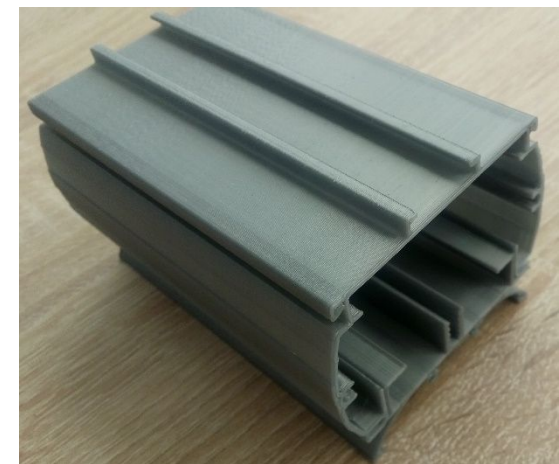
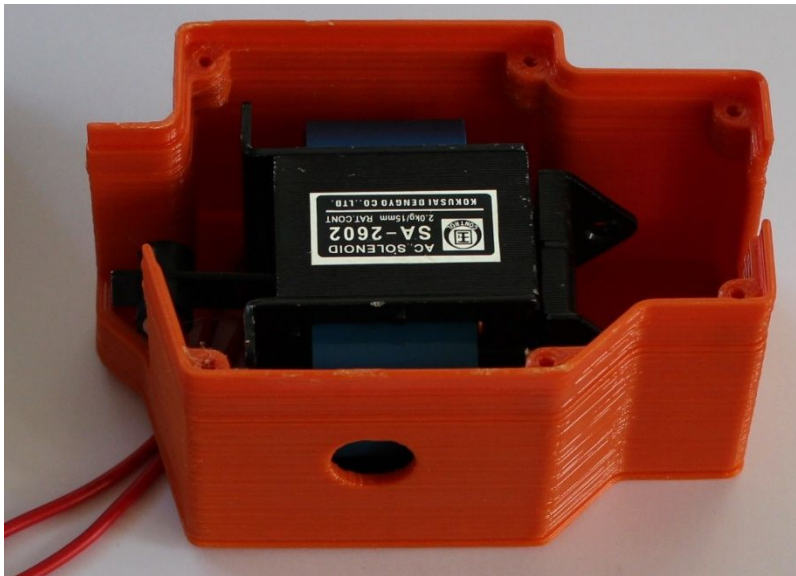
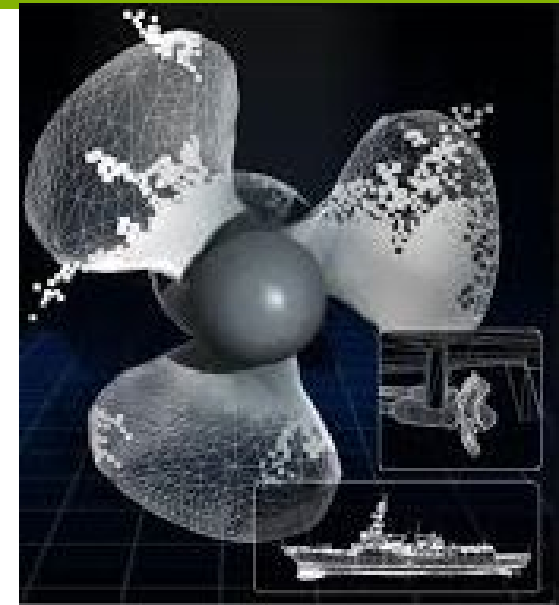


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3D Printing in engineering/industry

Changing the industry

- manufactures use 3D printing for their propeller designs
- revolutionized the way they create prototypes and designs



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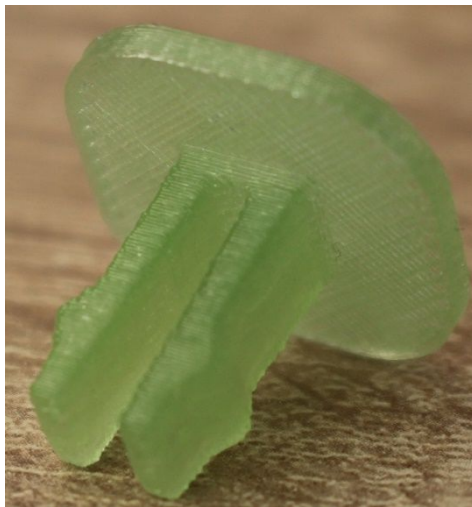
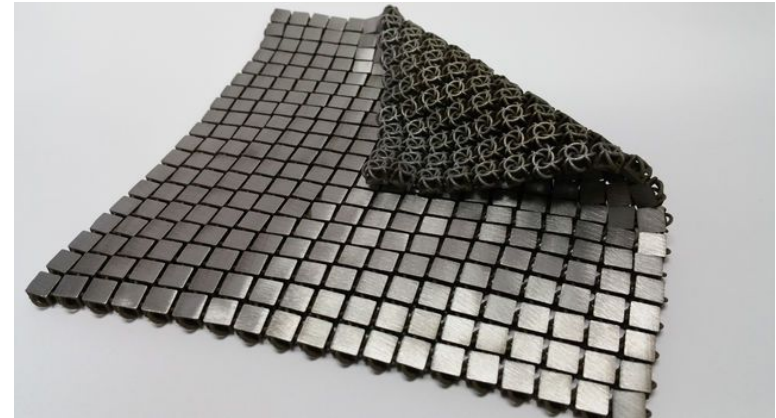


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3D Printing in engineering/industry

Producing factory goods

- Opportunity for smaller companies allowing them to compete with bigger companies and offer consumers choice
- Repair and maintenance market



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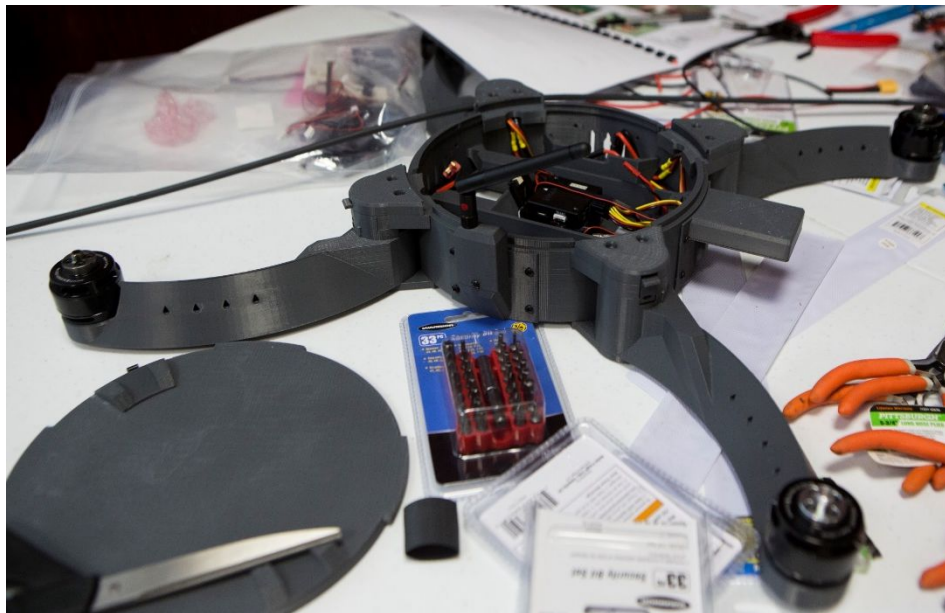


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3D Printing in engineering/industry

Producing factory goods

- Cheaper and more efficient production for auto, medical, and aerospace



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Useful Topic Related Links



- 3D Printer a Game Changer for Architecture Design - <https://www.youtube.com/watch?v=cOaqRkLP4II>
- Sagrada Familia, 3D Printed model
<https://www.youtube.com/watch?v=UJ8NcKNIZzg>
- First 3D printed house build on site
<http://apis-cor.com/en/about/news/first-house>
- 3D Printing for Architects:
<http://my3dconcepts.com/3dp-for-architects-lm/>

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Useful Topic Related Links



- The bioprinting process
https://www.youtube.com/watch?v=s3CiJ26YS_U
- Normal 3D Prints Totally Customized Earphones in 2 days: <https://www.youtube.com/watch?v=5YB8BjOn6B0>
- <https://www.youtube.com/watch?v=XvcpC424HAU>
- Painted Arm Prosthetic for a 5 year old girl:
<https://www.youtube.com/watch?v=JDL16rmwgHw>
- 3D Printing in Education
<https://www.youtube.com/watch?v=X5AZzOw7FwA>

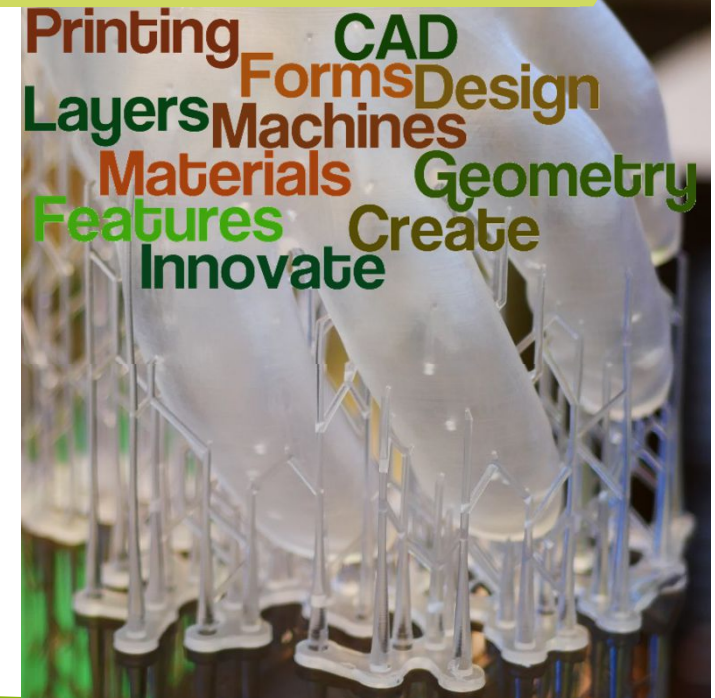
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Future of 3D printing technologies



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Aim and Learning Outcomes

Module Aim:

To present an overview of the 3D printing technologies future

Number of Hours:

2hrs

Learning outcomes:

- Understanding the potential risks and regulations related to 3D printing technologies
- Acquiring knowledge on 3D printing trends and developments

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Lecture Outline

- Myths and reality in 3D Printing
- 3D Printing risks and regulations
- 3D Printing trends and developments
- Examples

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Myths and reality in 3D Printing

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Myths and reality in 3D Printing

The myths are causing a mix of enthusiasm and disappointment with 3D printing technology, potentially slowing its wider adoption and development.

Myth	Reality
3D printers cost too much	The price range is very wide and starts from about \$100
3D printing is only for plastics	Lots of other materials can be 3D printed: metal, wood, resins, carbon fiber, bio-materials, food, concrete, etc.

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Myths and reality in 3D Printing

Myth	Reality
3D printers can print human organs	We cannot 3D print organs today
Things are quicker to make on a 3D printer	3D printing is slower than conventional production processes
Every home will have a 3D printer, soon	There are too few applications for the average person to justify the costs and efforts involved with purchasing and operating a 3D printer.

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Myths and reality in 3D Printing

Myth	Reality
Some things are cheaper to make on a 3D printer	3D printing makes prototyping phase cheaper but end products are still not cheaper to make on a 3D printer
3D printing is for large-scale manufacturing	3D printing is suitable for customized production. It can be convenient to 3D print small batches of highly complex products

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3D Printing risks and regulations

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3D Printing risks – Intellectual property

3D printing technology allows designs and products to be copied and replicated easily.



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3D Printing risks – cyber risks

Blueprints for 3D products are software files so they can be:

- Stolen and used to 3D print products
- Manipulated by hackers



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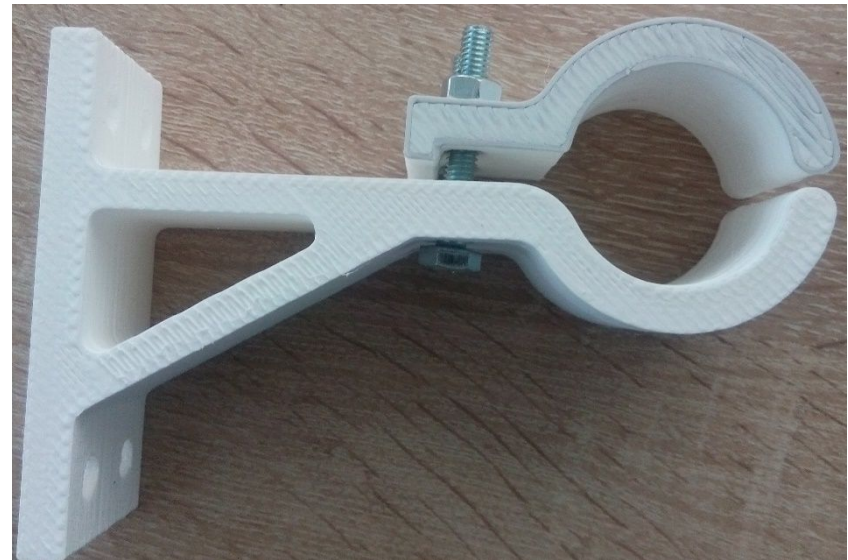


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3D Printing risks – liability

3D printing technology blurs boundaries between the different roles in the production chain.

Who's responsible for damages caused by a 3D printed object? The blueprint creator? The 3D printing provider? The person who printed the object?



A clear legal framework needs to be developed.

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3D Printing risks – counterfeiting

3D printing technology simplifies the manufacture of counterfeit goods.

Big concerns are related to sensitive sectors, like aerospace and medical.



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3D Printing regulation

Regulations is needed especially for controlling 3D printed objects for potential criminal use as for example guns, keys or the manipulation of ATMs.



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3D Printing trends and developments

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3D Printing trends and developments

- Multi-material 3D printing
- Multi-color 3D printing
- Faster, better, larger and easier to use 3D printers
- Easier 3D modelling
- New applications for 3D printing
- Improvements in metal printing
- 3D printed buildings
- New 3D printing materials

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Examples

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Multi-material/multi-color 3D printing

Applications: highly realistic prototypes, models and learning aids; dissolvable supports

Available materials: resins, dissolvable filament



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Metal 3D printing

Applications: prototypes, functional parts, jewelry, medical implants, etc.

Available materials:
aluminum, steel, brass, copper, silver, gold, platinum, titanium



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3D printed buildings

Applications: houses, apartments, office buildings, structures on Moon and Mars

Materials: concrete, plastic, resin, mud, etc.



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Large 3D prints - cars



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