



# 3D PRINTING TRAINING

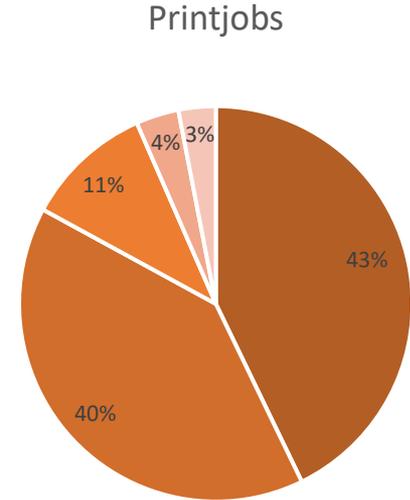
- General information
- What is 3D printing?
- SPOT 3D printers
- The prototyping cycle
- Expected behavior
- Steps for successful 3D printing
- Demo



[https://make.epfl.ch/wiki/public/spot\\_-\\_3d\\_printing/start](https://make.epfl.ch/wiki/public/spot_-_3d_printing/start)

- For who?
  - **Every** Bachelor and Master students of EPFL
  - Who followed the **specific training**

- For what?
  - MAKE interdisciplinary projects
  - Courses
  - Semester/Master projects
  - Other accredited projects and associations

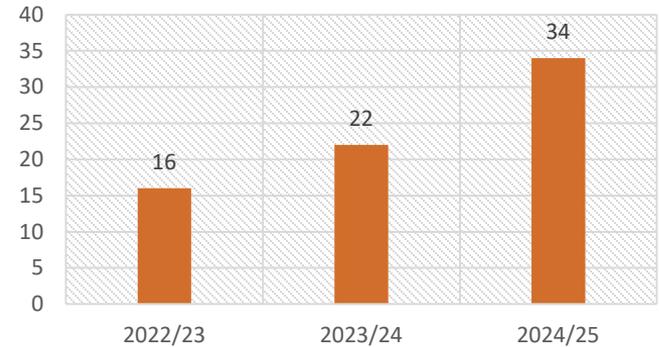


■ MAKE projects ■ Courses ■ Semester Projects ■ Other ■ Perso

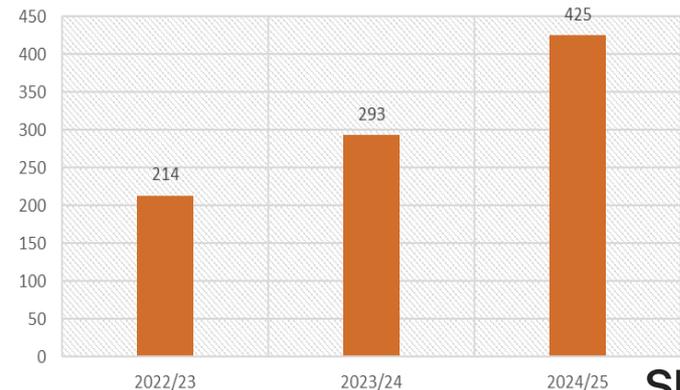
- Otherwise:
  - **Personal projects** are accepted under specific conditions ([wiki](#)). Please **ask first**.
  - For any non-credited professional projects (internship, research, private company, etc.), please go to [AFA](#) (additive manufacturing professional workshop).

- A modern and evolutive space
- A high volume workshop  
Per year:
  - 8'000** print jobs (30~40'000 parts)
  - 400+ kg** of printed filament (130 km)
  - 1'200 days** of printing
- A community of users
  - 1'000+** trained users

Number of printers



Printed filament (kg)



# WHAT IS 3D PRINTING?

3D printing, also known as **additive manufacturing**, is a family of manufacturing methods to create 3D objects, directly from a CAD model,

## Layer by Layer

### Main advantages:

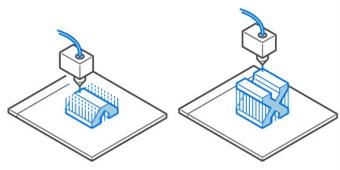
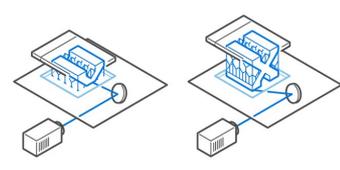
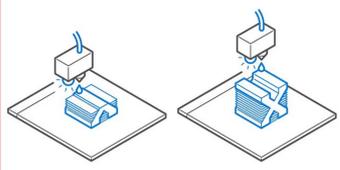
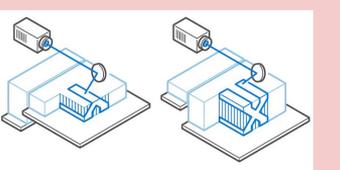
- Complex geometries capability
- No “minimal volume”
- Fast “design to production”
- Efficiency (energy, wastes...)

### Biggest limitations:

- Materials and properties
- Dimensions, accuracy
- **NO 100% SUCCESS RATE!**

# WHAT IS 3D PRINTING?

The most common 3D printing types:

Type Name	Material extrusion Fused deposition modeling (FDM)	VAT Polymerization Stereolithography (SLA) Digital light processing (DLP)	Material jetting	Powder bed fusion Selective laser sintering (SLS) or melting (SLM)
Principle				
Materials	Polymer filaments	Photopolymer resins	Photopolymer resin	Thermoplastic, metal or ceramic powder
Strengths	Lowest cost, wide range of functional materials, simple	Smooth surface finish, fine details, complex geometries, special properties	Surface finish, multicolor and multi-material	Functional parts, mechanical properties, complex geometries
Availability	SPOT SKIL AFA	SPOT AFA	AFA	AFA (polymers) External partners (metals)

## ▪ PRUSA MK3S+ AND MK4S

- Open access printers ([level 2](#))
- Technology: FDM (filament)
- Build volume (x,y,z) : 250 x 210 x 210 mm
- Materials:
  - **PETG** (0,05 CHF/g)
  - Technical PETG (HT, PTFE, CF)
  - TPU (0,1 CHF/g)
- Easy to use, precise, reliable, sustainable
- For 95% of your needs



See available materials  
[HERE](#)

## ▪ PRUSA XL

- Only under supervision (level 3)
- Technology: FDM (filament) – 2 extruders
- Build volume (x,y,z) : 360 x 360 x 360 mm
- Materials:
  - PETG
  - Technical PETG (HT, PTFE, CF)
  - TPU
  - Soluble supports
- For bigger and multi-material parts



## ▪ PRUSA PRO HT90

- Only under supervision (level 3)
- Technology: FDM (filament) – 1 extruder
- Build volume (x,y,z) : Ø300 x 400 mm
- Materials:
  - PETG and technical PETG
  - Other technical materials (ASA, PC, PA, etc.)
  - PEEK Family!
- For bigger parts and/or more technical materials



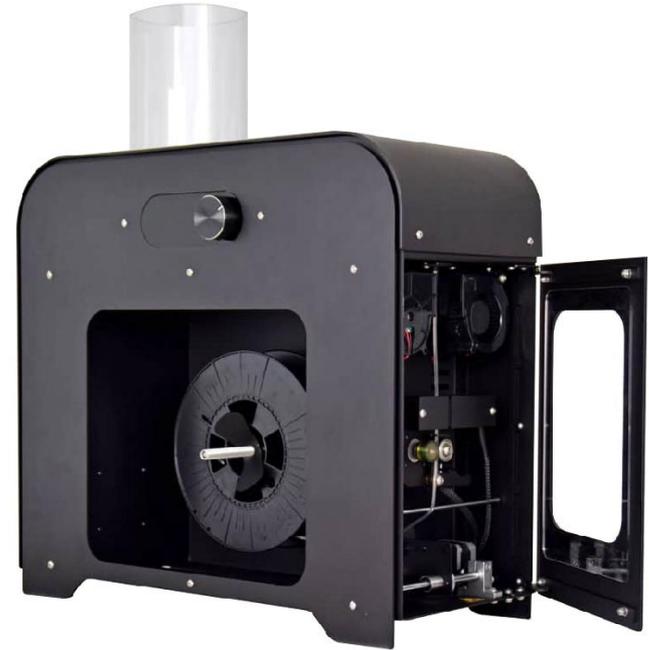
## ▪ FORMLABS FORM3+

- Only under supervision (level 3)
- Technology: SLA (resin)
- Build volume (x,y,z) : 145 x 145 x 185 mm
- Materials:
  - Standard
  - Clear, high rigidity, elastic, high temp, etc.
- For high quality surfaces, precision, details, specific properties

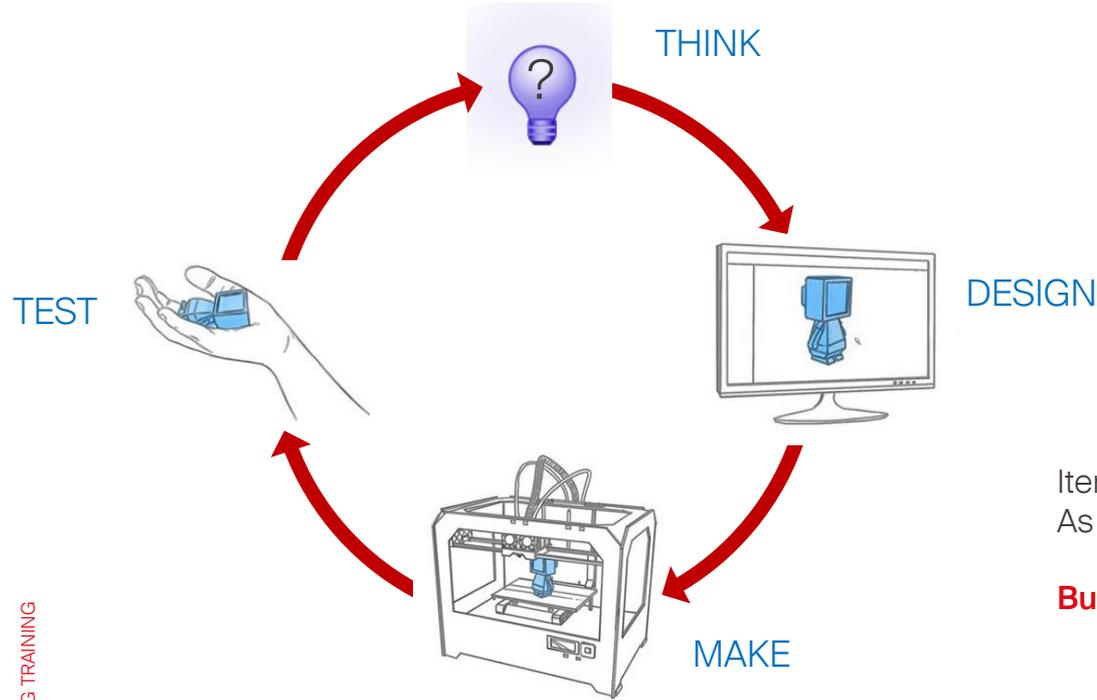


## ▪ 3DEVO extrusion line

- Only under supervision (**level 3**)
- Ongoing project to recycle PET-G waste to make our own filament [> wiki](#)
- Sorting > shredding > drying > extruding
- Around 20 kg of SPOT-G per year



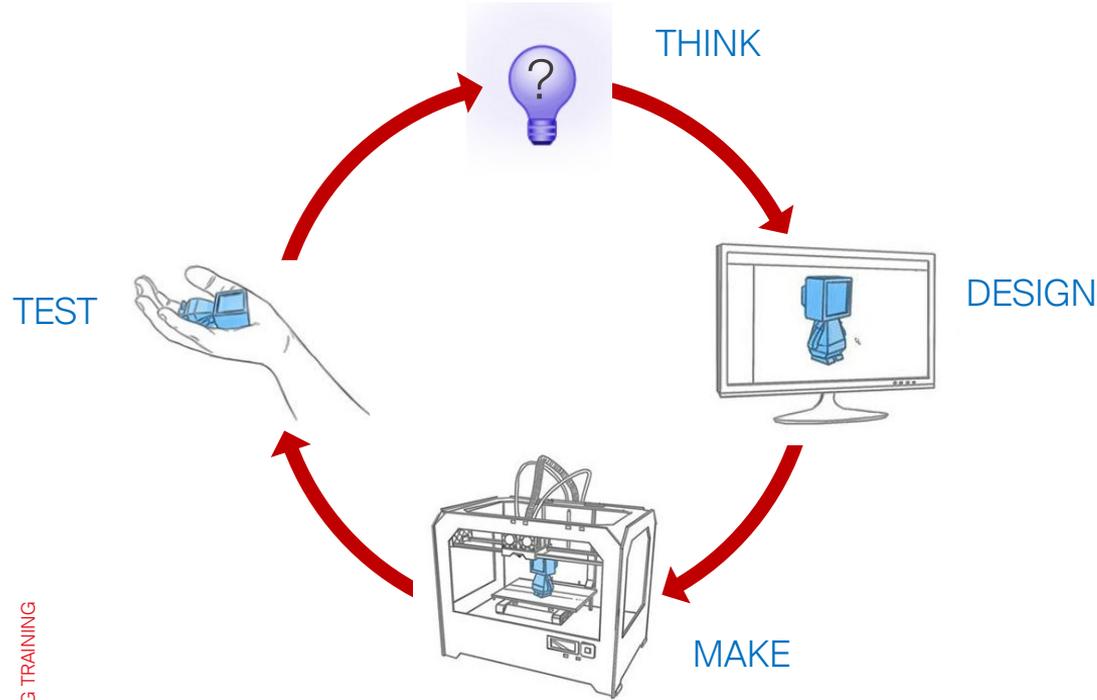
# THE PROTOTYPING CYCLE



Iterating is part of the process.  
As well as learning from failures.

**But don't forget to learn in the process!**

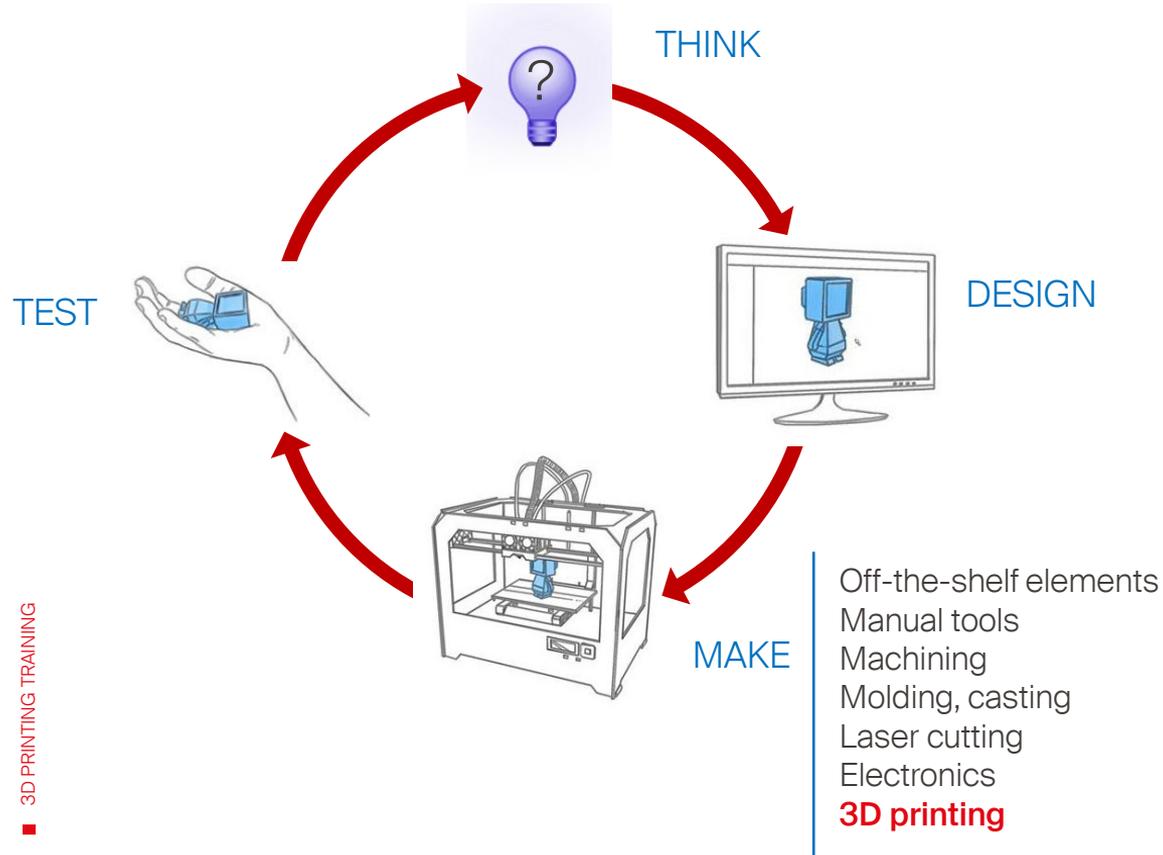
# THE PROTOTYPING CYCLE



**YOUR COACHES CAN HELP YOU!**

**PLEASE SHOW US YOUR PROJECT  
AS EARLY AS POSSIBLE**

# THE PROTOTYPING CYCLE



**Use the right tools for your needs!**

# EXPECTED BEHAVIOR

**You're part of a community: respect the others!**

The rules are the same for everyone and are made so that this space works and serves everyone equally and continuously.

**RESPECT**

**SHARE**

**STAY SAFE**

**BE PROFESSIONAL AND RESPONSIBLE**

## TOWARDS TOOLS AND EQUIPMENT

## RESPECT

## SHARE

- No dust, no food, no drink
- Keep the place and the printers clean
- Please clean your printbed before leaving
  
- Use only the materials and tools available in the space (you can not bring your own filament)
- Don't take anything out of the room
  
- Print responsibly
- Print only your own G-Codes

- Share the printers
- Short printjobs during the day, long printjobs during the night
  
- Store filament properly in the dry cabinet
  
- Communicate if something is missing or if you have any suggestions
- Communicate if something's wrong with a printer (put in maintenance)

## TOWARDS OTHER PEOPLE

## RESPECT EVERYBODY

- Handle other people's parts **with care**
- **Don't remove parts** from printbed if they're not yours
- Don't lie on your project budget

## SHARE THE KNOWLEDE

- Never hesitate to **ask for help**
- Share your experience and **help each other**
- **Be nice**, don't judge
- Share your ideas, success and lessons learned

## YOUR COACH

- Not a cop, not a cleaner > Experienced engineer, specialized in 3D Printing for 20+ years.
- Many tips and experience to share with you, at each step of your project.
- Here to help you and everybody at the same time, not to judge you. **Don't be shy ;)**

## STAY SAFE

### Access restrictions

- Don't enter the "under supervision" area without the coach's permission
- Don't let unauthorized people enter the room or let the door open
- Don't work alone in the space after 8pm and during weekends
- Don't work if you're "tired"



### Potential risks

- **Flammable chemicals**
  - No open flame and no smoking
- **Hot surfaces and moving parts**
  - Don't touch the printers while running or before proper cooling
  - Tie your hair and be careful with loose accessories and computers



### Personal protection equipment

- Use the appropriate PPE when indicated
- **IMPORTANT:** Safety glasses are mandatory for post processing (support removal)



## IN CASE OF PROBLEM

### Phone

For all emergencies, 24h/24

- From an EPFL landline: **115**
- From a personal mobile phone: **021 693 30 00**
- From the EPFL Campus app: **SOS**

### Available treatment devices

#### First aid kit

- To treat minor injuries.
- For major injuries: call **115**

#### Eye/face wash kit

In case of splashing in the eyes:

1. Act quickly
2. A colleague calls **115**
3. Flush your eyes thoroughly until help arrives

Notify the COSEC (coach) if you use any of these devices

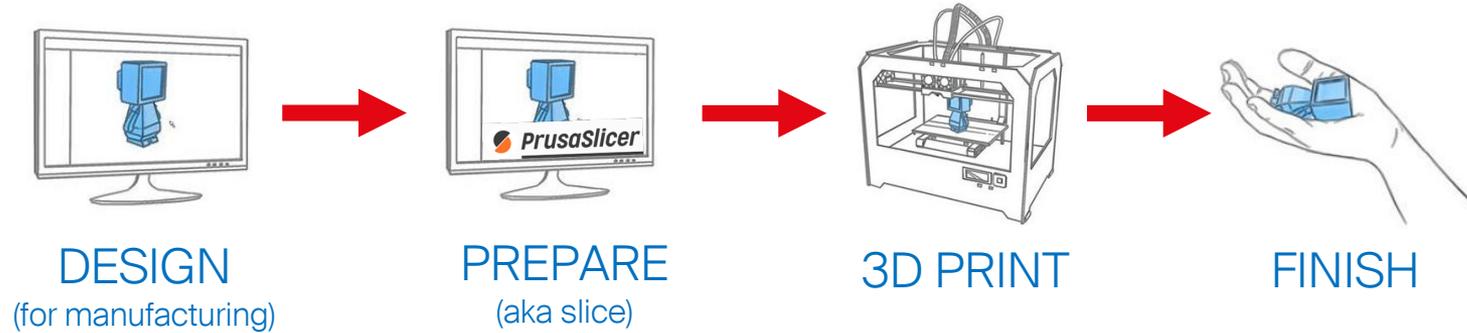
### In case of fire

If you know how to use it

- **Fire blanket** in the room
- **Fire alarm** and fire **extinguisher** in the corridor

**Most important: give the alarm and help people out**

# STEPS FOR SUCCESSFUL 3D PRINTING



- Each step is important, takes time and determines the others.
- Don't waste time and materials. A good design and a good slice reduce the number of iterations, failures and breakdowns.
- Schedule your prints in advance and take some margin.
- Some manual finishing work is part of the job.
- Asking for help is always OK.

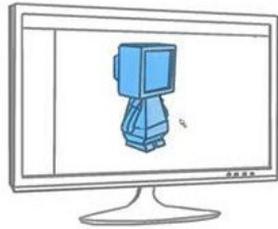
# STEPS FOR SUCCESSFUL 3D PRINTING



- Consider functions, working conditions, constraints, assemblies...
- Anticipate the following steps:
  - How will you print the parts, in which orientation, which material?
  - On which type of printer will you print? What is it capable of?
  - Can you reduce the amount of material, printing time and manual finishing?

> Export each part in a STEP or STL file

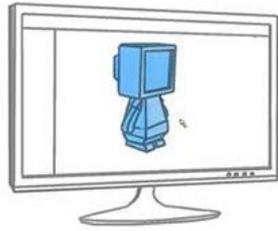
# STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN  
(for manufacturing)

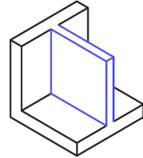
- Using your favorite **CAD software**
- Determine how your prototype **will work**
  - Functions
  - Assemblies
  - Working conditions, constraints...
- **Anticipate** what's coming next:
  - How will you manufacture/print the parts, in which orientation, in which material?
  - On which type of printer will you print? What is it capable of (size, precision, etc.) ?
  - Can you improve strength and reduce the amount of material, printing time and manual finishing?
- **Think Additive**, not machining nor injection molding.
- Export each part in **.STEP (or .STL) format**

# STEPS FOR SUCCESSFUL 3D PRINTING

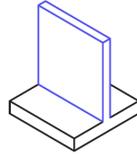


**DESIGN**  
(for manufacturing)

Wall thickness

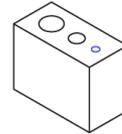


Min. 0.8 mm

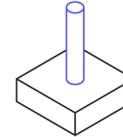


Min. 1.2 mm

Hole and pin diameter

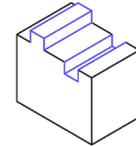


Min. 2 mm



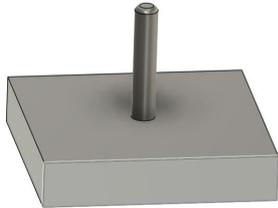
Min. 4 mm

Embossed and engraved details



Min. 0.8 mm wide and high

Avoid fragile elements

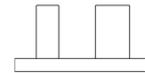
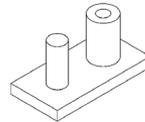


X

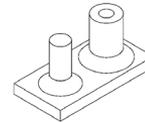


V

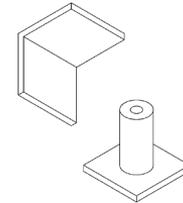
Add fillets and ribs



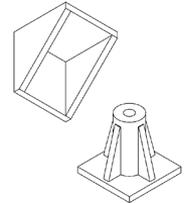
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V

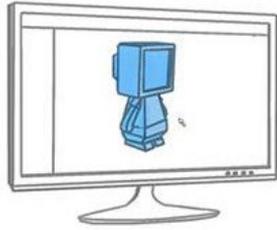


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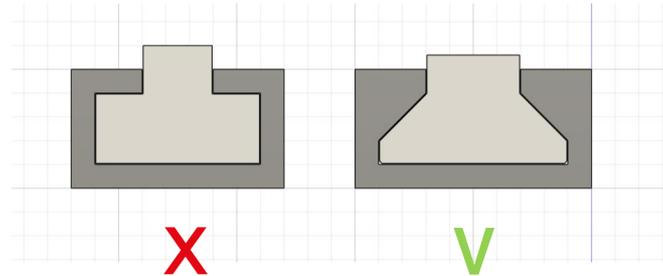
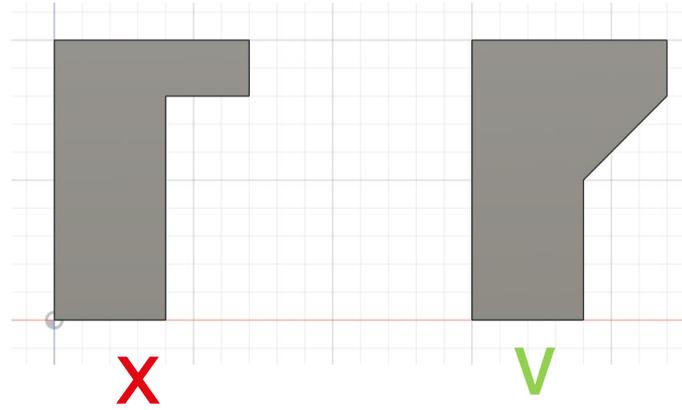
V

# STEPS FOR SUCCESSFUL 3D PRINTING

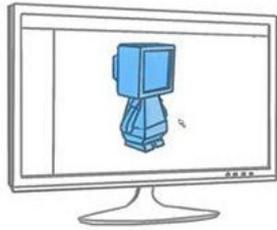


DESIGN  
(for manufacturing)

Avoid useless overhangs and supports

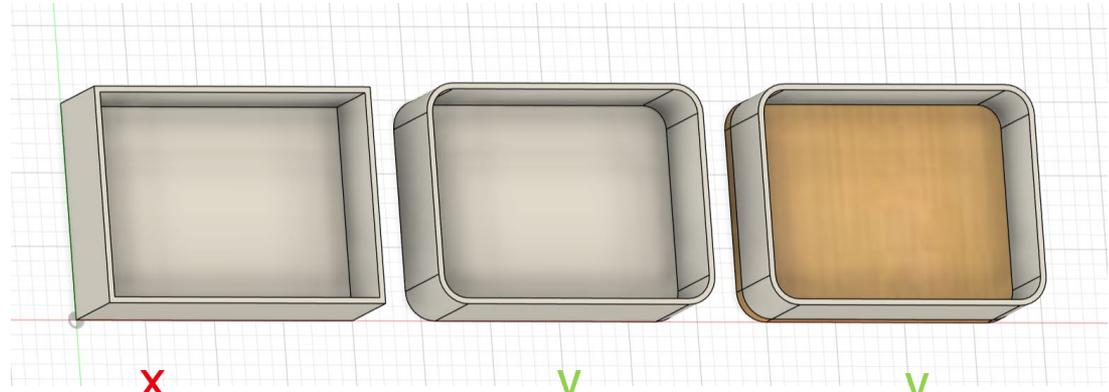


# STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN  
(for manufacturing)

Avoid large rectangular bases



X

V

V

Avoid downward facing fillet

Rounded corners

Laser cut base

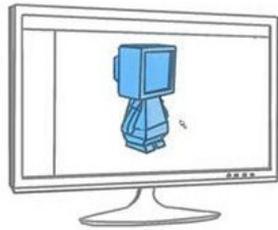


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V

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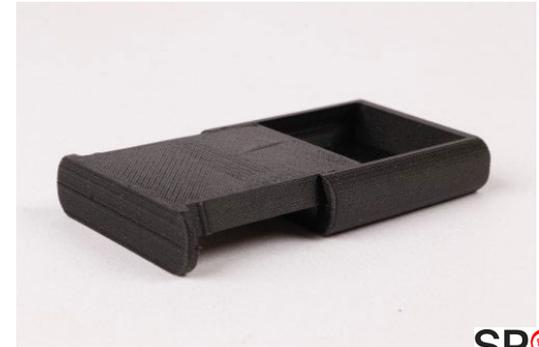
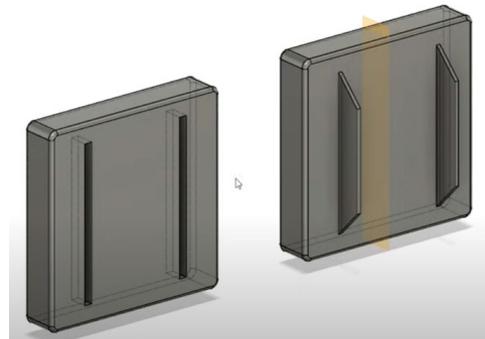
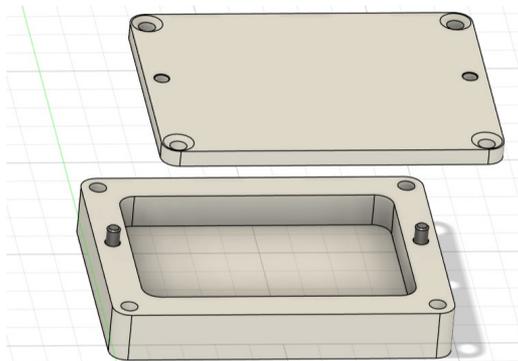


## DESIGN

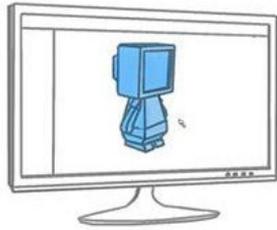
(for manufacturing)

### ■ Designing assemblies > Positioning elements

- If you need to assemble parts together, you should not forget to ensure a good positioning by designing positioning elements such as:
- Pins and holes of any shape (prefer standard pins when possible)
- Any other positioning element.
- Don't forget the tolerance consideration of next slide.



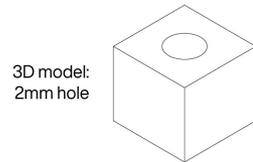
# STEPS FOR SUCCESSFUL 3D PRINTING



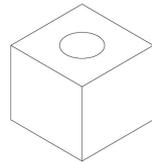
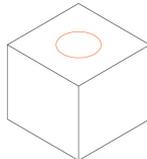
DESIGN  
(for manufacturing)

## ■ Designing assemblies > Tolerances

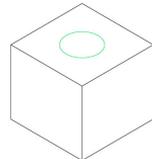
- The printed dimensions are generally **larger** than the 3D model (about 0.1 mm everywhere).
- Leave a distance between parts for easy assembly. Typical value for FDM 3D printing: **0.1 – 0.2 mm**
- Use **chamfers** for easy insertion.
- See the tolerance test parts in the room, or print your own to determine precise tolerances



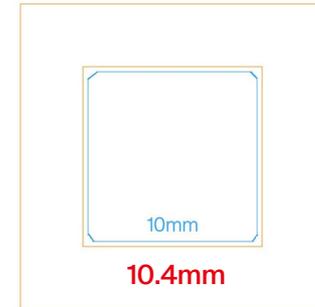
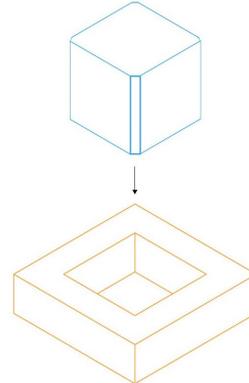
3D print:  
1.8mm hole



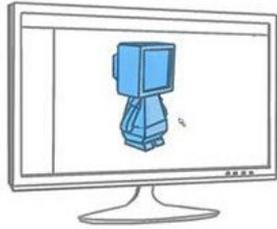
3D model:  
2.2mm hole



3D print:  
2mm hole



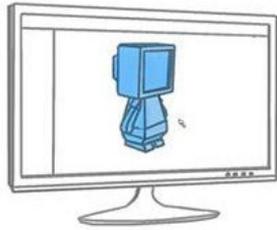
# STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN  
(for manufacturing)

- **Designing assemblies > Fixing parts together**
  - There are many options to secure parts together.
  - You can use:
    - Glue (strong but not reversible)
    - Magnets (reversible but not strong)
    - Screws (strong and reversible) > **See next slide**
    - Other options like snap fits, zip ties, etc.
    - Tips and samples coming soon > **Ask your coach**

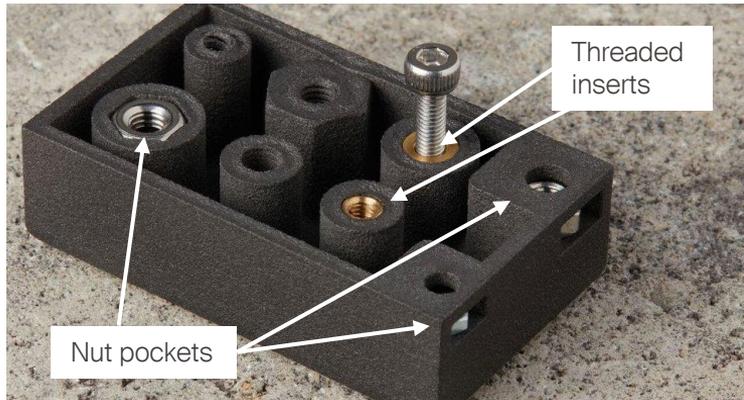
# STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN  
(for manufacturing)

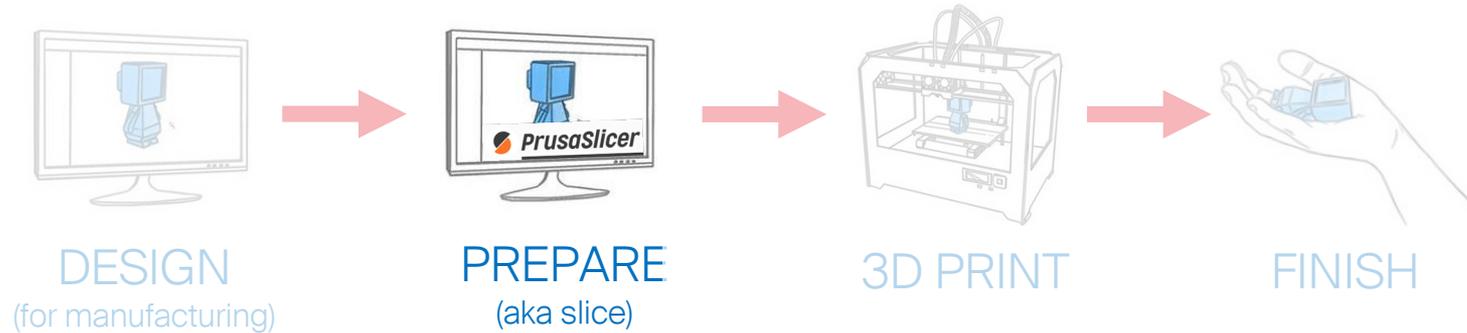
## ■ Designing assemblies > Screwing parts together

- 3D printing threads or threading 3d printed parts is generally **not a good idea** (not precise and strong enough)
- Use standard elements such as:
  - **Nut pockets**
  - **Threaded inserts** > Check the hole dimensions before printing
  - Tips and tutorial > **Wiki**



[https://make.epfl.ch/wiki/public/spot-\\_3d\\_printing/how\\_to\\_use\\_threaded\\_inserts](https://make.epfl.ch/wiki/public/spot-_3d_printing/how_to_use_threaded_inserts)

# STEPS FOR SUCCESSFUL 3D PRINTING



- Transform geometry (STL, STEP) into instructions for the printer (G-code)
  - Printer model, material, advanced settings
  - Part orientation, support structure (if necessary)
  - A bad slicing can ruin your print and even the printer > **Double check before printing!**
- > Export G-code on an SD card (MK3) or USB stick (MK4)

# STEPS FOR SUCCESSFUL 3D PRINTING



PREPARE  
(aka slice)

## ■ Configure PrusaSlicer

- Use only UpToDate **PrusaSlicer**
- Configure the right printers and filament profiles

[https://make.epfl.ch/wiki/public/spot\\_-\\_3d\\_printing/prusaslicer\\_configuration](https://make.epfl.ch/wiki/public/spot_-_3d_printing/prusaslicer_configuration)



- **Prusa i3 MK3S+** with **0.4 mm nozzle**
  - SPOT PETG – MK3S+
- **Prusa MK4 Input Shaper** with **0.4 mm nozzle**
  - SPOT PETG – MK4IS
- **Prusa MK4S** with **0.4 mm High flow nozzle**
  - SPOT PETG – MK4S
- For other printers and materials, ask your coach or refer to documentation

# STEPS FOR SUCCESSFUL 3D PRINTING



PREPARE  
(aka slice)

## Start slicing

- Work in Expert mode
- Import your STEP or STL files
- Choose your printer type and filament
- Choose your print settings
  - 0.15 mm or **0.2 mm** layer height
  - Quality or Structural settings are always better than **Speed!**

Expert mode  Log in

Print settings:

  0.15mm STRUCTURAL  

Filament:

 SPOT PETG - MK4IS  

Printer:

  Original Prusa MK4 Input Shaper 0.4 nozzle  

# STEPS FOR SUCCESSFUL 3D PRINTING



PREPARE  
(aka slice)

## ■ Orient your part:

A good part orientation is decisive for a successful print.  
Keep in mind the following factors

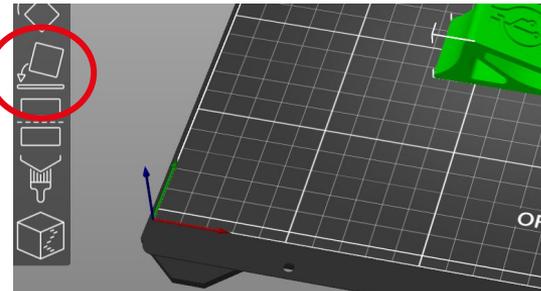
- **Tensile strength** is lower along the Z axis (layers separation)
- The **best precision/resolution** is on XY plan
- **Supports** affect the surface quality once removed

If you don't find the good orientation, try to change your design.

### Place on face tool:

Choose which surface will face the printbed.

**Preferably use this tool!**



# STEPS FOR SUCCESSFUL 3D PRINTING



PREPARE  
(aka slice)

## ■ Generate supports:

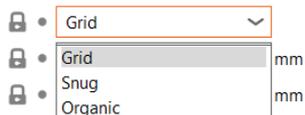
- **You can't print in the air!**
- Surfaces that are not supported enough **can ruin your print.**
- In case of doubt, place supports **everywhere.**
- Remember you will have to **access** the support for removal.
- And that supported surfaces are **altered.**
- You can find different support styles here:
  - Print settings > Support material > Style
  - **Snug** and **Organic** are particularly easy to remove

### Options for support material and raft

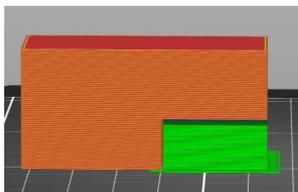
● Style:

● Top contact Z distance:

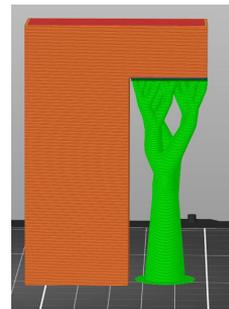
● Bottom contact Z distance:



For large and low supported areas



For small and high supported areas



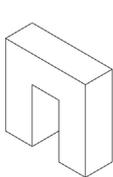
# STEPS FOR SUCCESSFUL 3D PRINTING



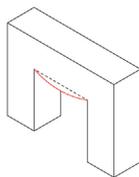
PREPARE  
(aka slice)

## ■ Generate supports:

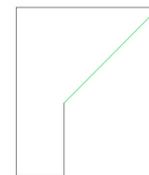
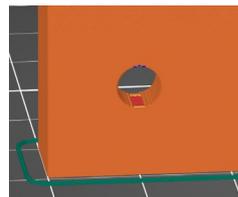
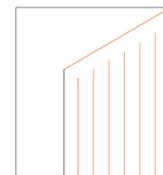
- **Small bridges** are fine. Small horizontal holes don't need to be supported
- Overhangs above  $40^\circ$  are ok



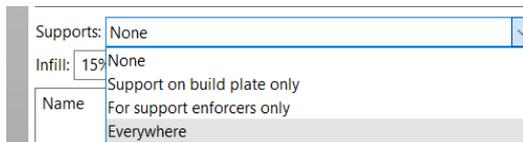
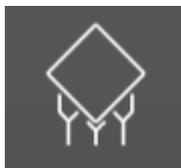
10mm



20mm

 $>40^\circ$  $<40^\circ$ 

- You can also place supports selectively using the **paint-on supports tool** and the **“For support enforcers only”** option.

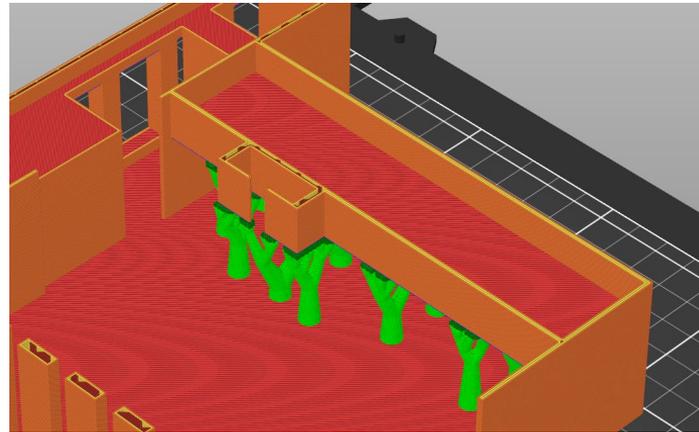


# STEPS FOR SUCCESSFUL 3D PRINTING



PREPARE  
(aka slice)

- **Generate supports:**
- **Warning:** avoid supports printed on top of a flat printed surface.



- The need for supports can be optimized by changing:
  - your **design** (splitting parts, adding chamfers, etc.)
  - and/or your part **orientation**

# STEPS FOR SUCCESSFUL 3D PRINTING

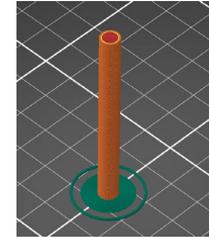


PREPARE  
(aka slice)

- **TIP:** Prevent **warping** or **bad adhesion** to the bed

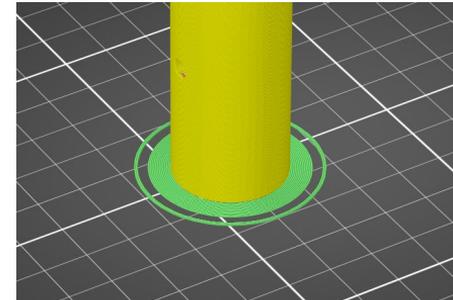
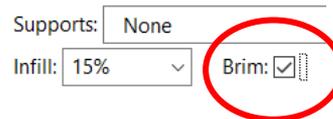


Big parts



Thin and high parts

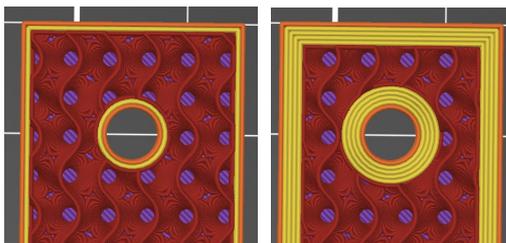
> Add a brim



# STEPS FOR SUCCESSFUL 3D PRINTING

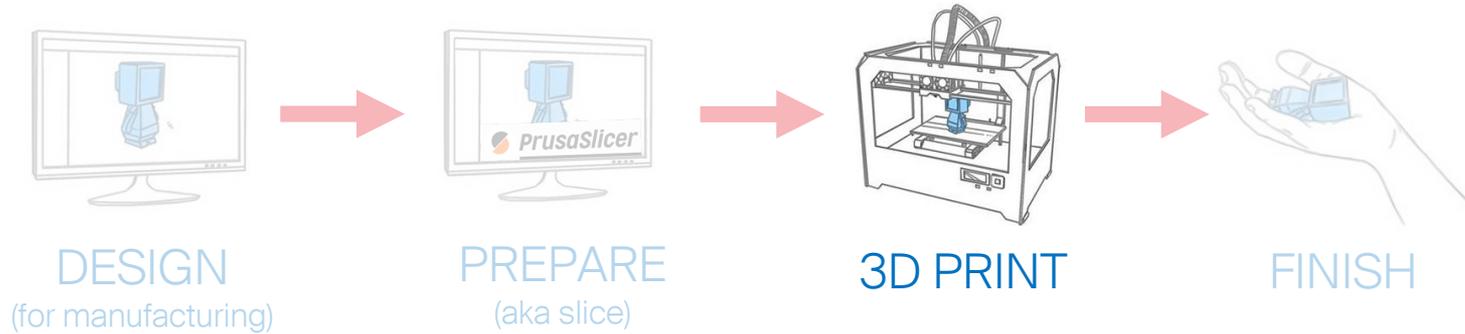


PREPARE  
(aka slice)



- **TIP: Increase strength**
    - **Part orientation**
      - Avoid layers delamination
    - **Infill**
      - Small strength increase
      - Big time and filament usage increase
    - **Perimeters**
      - **Big strength increase**
      - Also increases print time
      - Allows you to mechanically correct the part afterward (increase a hole diameter)
      - Improves sealing as well as compliance capability
- Print settings > Layer and perimeters > perimeters > 2 (default) -> **4 to 6**

# STEPS FOR SUCCESSFUL 3D PRINTING



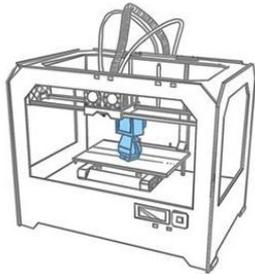
- Unlock the printer on [make.epfl.ch/3dprint](https://make.epfl.ch/3dprint) and choose your budget
- If your project's list is wrong > update it on [make.epfl.ch/training](https://make.epfl.ch/training)
- Do the different checks (printbed, filament, nozzle)
- Insert your SD card or USB stick
- Start printing and **stay for at least one layer**

*wiki*



[https://make.epfl.ch/wiki/public/spot\\_-\\_3d\\_printing/how\\_to\\_unlock\\_a\\_printer\\_using\\_internet](https://make.epfl.ch/wiki/public/spot_-_3d_printing/how_to_unlock_a_printer_using_internet)

# STEPS FOR SUCCESSFUL 3D PRINTING



## 3D PRINT

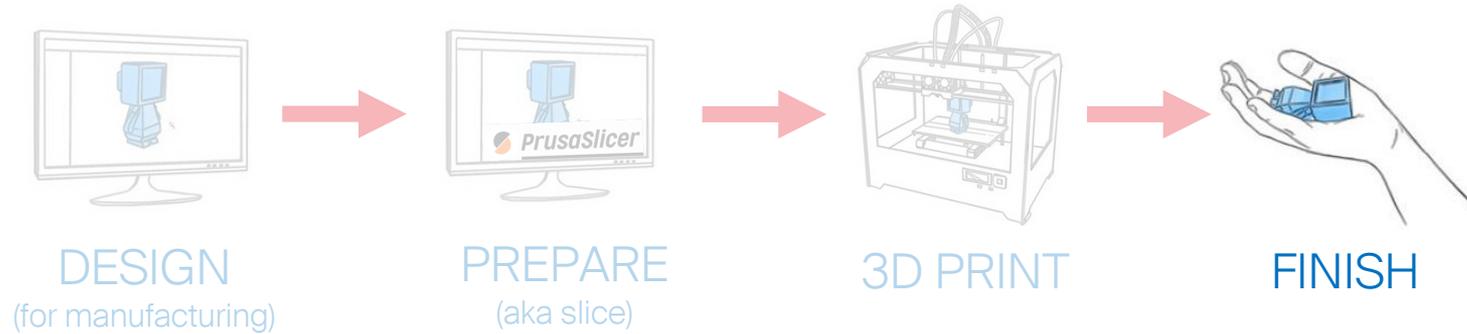


- **Respect** the tools and the rules
- Don't take other user's parts off the printbed.
- > Put the previous printbed on the table and take a **new clean printbed**.
- Place the printbed properly
- Check the filament (type and amount)
  - > [Tutorial for filament change](#)
- Check if the nozzle is clean
  - If not, preheat the printer and remove excess filament with a plier or ask for help
- **Start** your print and **stay** for the first layers to check everything is ok and eventually come back from time to time



[https://make.epfl.ch/wiki/public/spot-\\_3d\\_printing/load\\_filament](https://make.epfl.ch/wiki/public/spot-_3d_printing/load_filament)

# STEPS FOR SUCCESSFUL 3D PRINTING



- Remove the printbed from the printer
- Remove carefully your parts from the printbed and the supports from your part
- Clean your workplace and printbed, manage your wastes
- Sanding, drilling, assembling > **In the atrium**

# STEPS FOR SUCCESSFUL 3D PRINTING



## FINISH / ASSEMBLE

### ▪ After printing

- Remove the printed part from the printer
- **Wear safety glasses!**
- Remove your part from the printbed  
Please, avoid scratching the surface
- Remove the **supports** > use pliers
- **Clean** the workplace
- **Clean** the printbed (soap and water)
- Use the **PETG bin!**
  - Only for dust-free PETG parts and supports
  - **No screws, inserts, glue, dust**
- Sanding, drilling, assembling, etc. > **In the atrium**





- Your 3D printing coach is **Sébastien Martinerie**

	Monday	Tuesday	Wednesday	Thursday	Friday
Morning (9h30-12h)	YES	-	YES	-	YES
Afternoon (13h-17h30)	YES	-	YES	YES	YES

- E-mail: [sebastien.martinerie@epfl.ch](mailto:sebastien.martinerie@epfl.ch)
- Slack

# HAPPY PRINTING @SPOT !!