EPFL

3D PRINTING TRAINING

SPOT

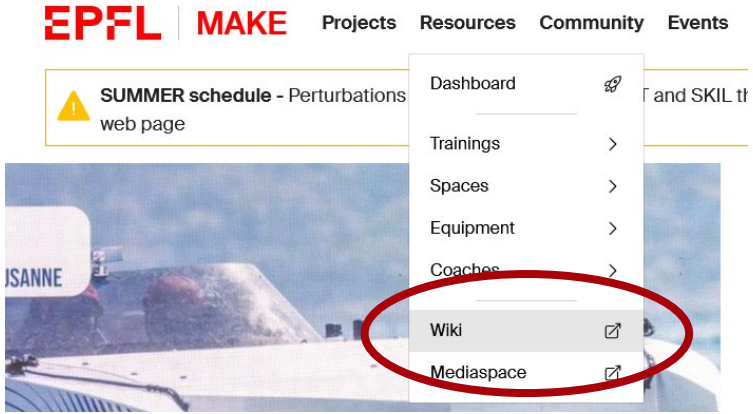
Student Prototyping
and Outreach Tank

Sébastien Martinerie

V6.1

WELCOME

- 3D printing at SPOT
- SPOT 3D printers
- Expected behavior
- FDM 3D printing basic knowledge
- Steps for successful 3D printing
- Troubleshooting

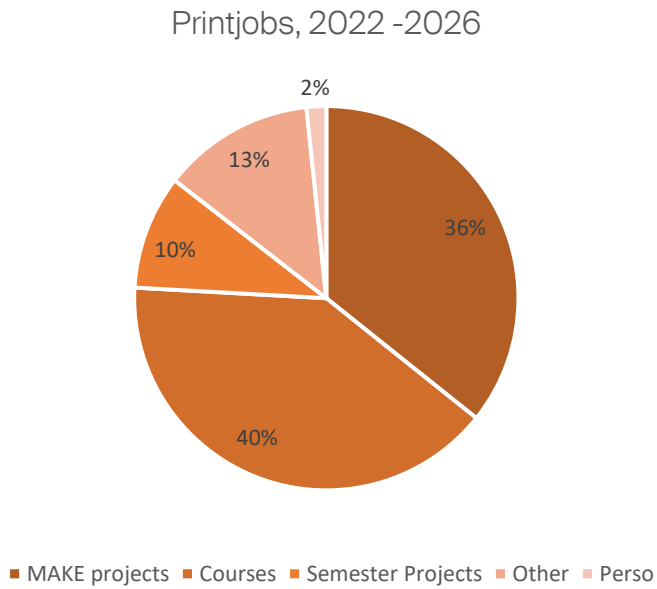


https://make.epfl.ch/wiki/public/spot_-_3d_printing/start

3D PRINTING @SPOT

- 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



- 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).

3D PRINTING @SPOT

- A modern and evolutive space
- A high volume workshop

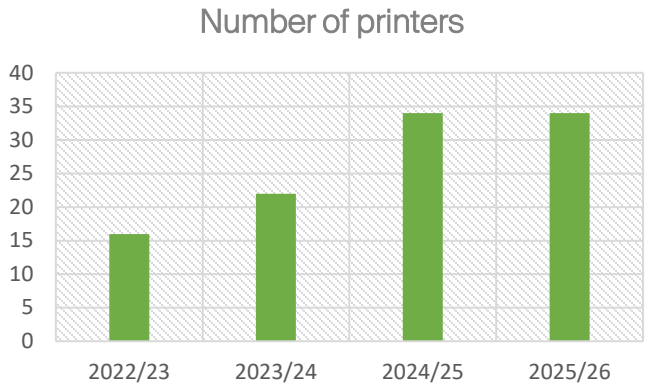
  Per year:

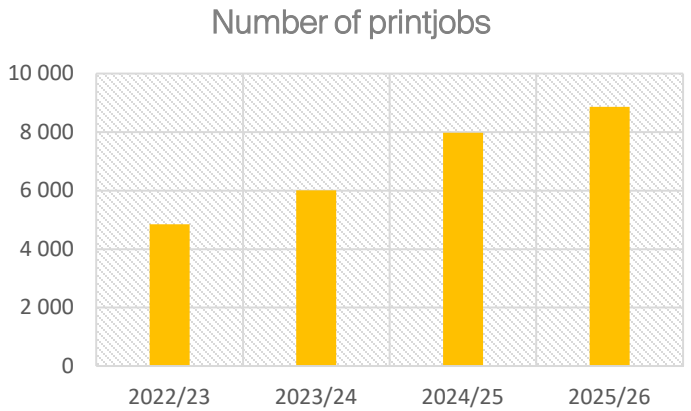
  8'000 print jobs (40'000 parts ?)

  400 kg of printed filament (130 km)

  1'200 days of printing
- A community of users

  1'000+ registered users
- 2 areas:
  - Open-access
  - Under-supervision

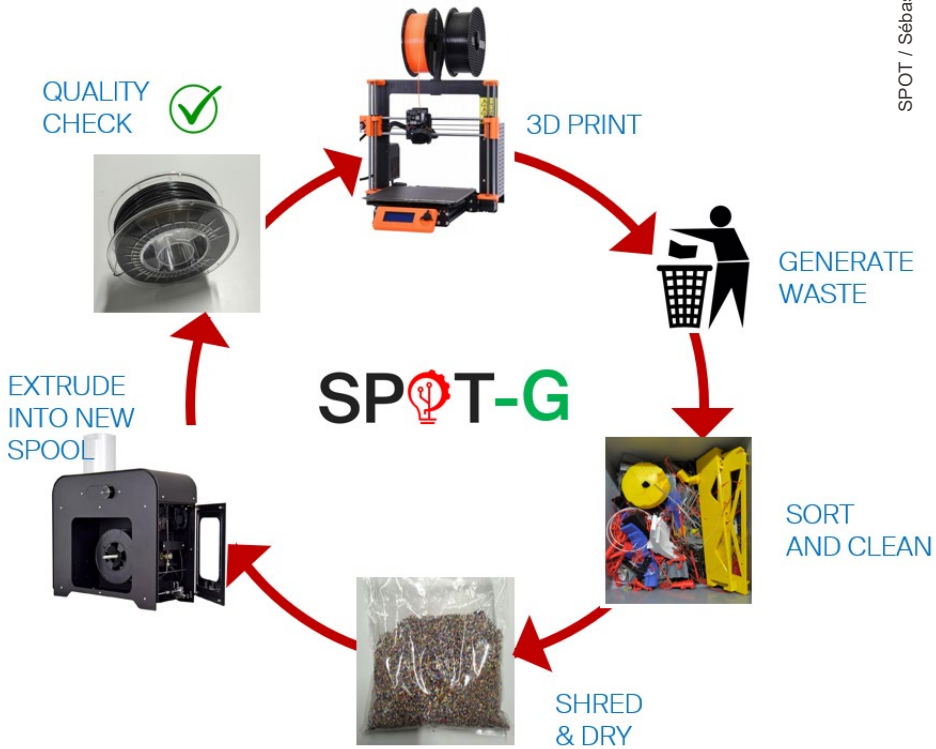




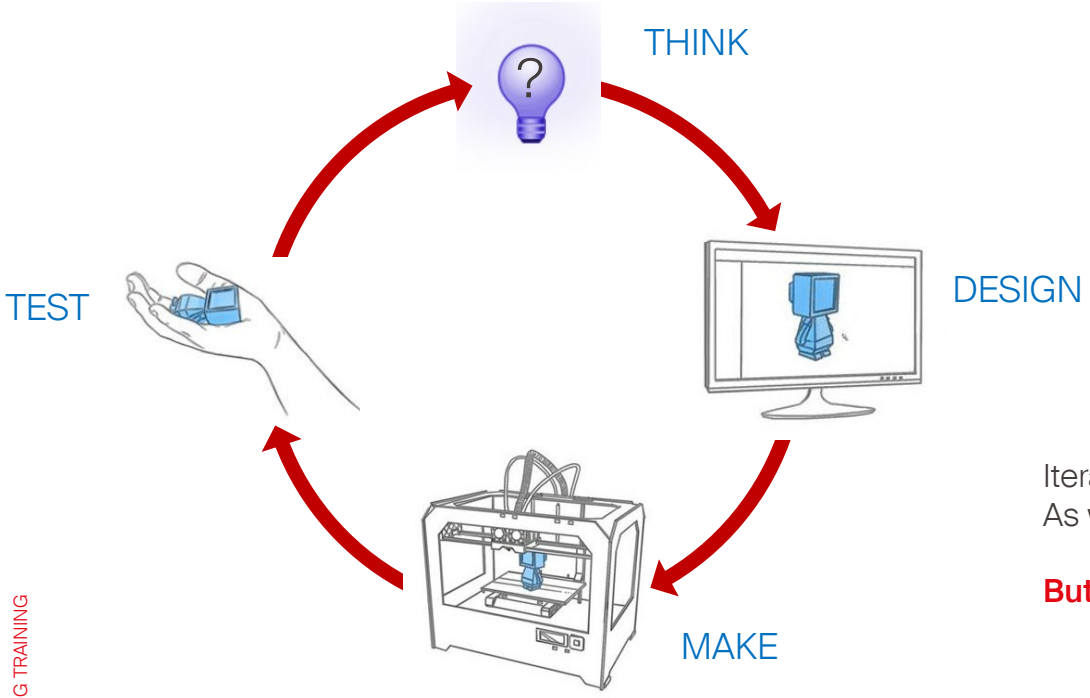
3D PRINTING @SPOT

- **Sustainability program**
  - 3D printers
  - Consumables
  - Training
  - Recycling

New MAKE project:
ReSpool



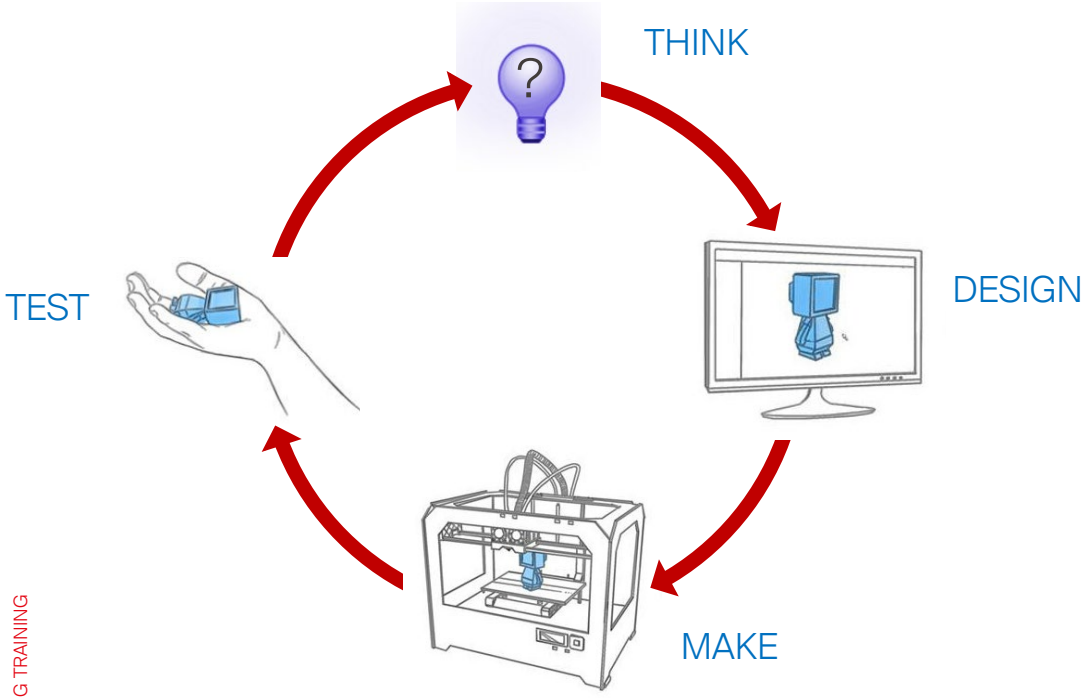
THE PROTOTYPING CYCLE



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

But don't forget to learn in the process!

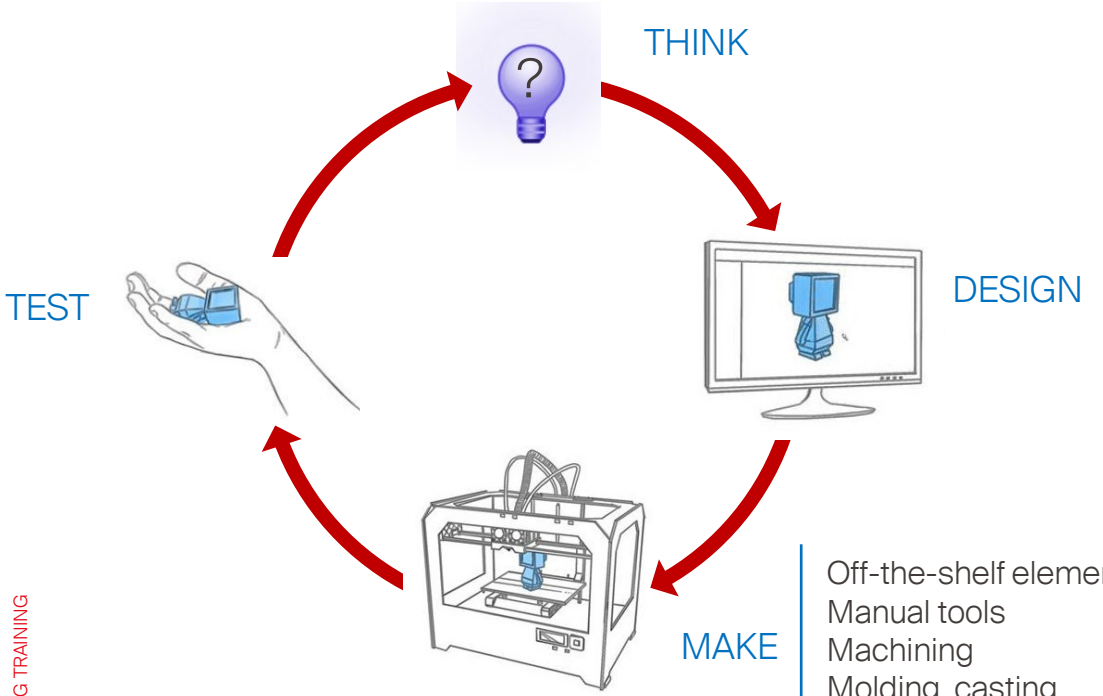
THE PROTOTYPING CYCLE



YOUR COACHES CAN HELP YOU!

PLEASE SHOW US YOUR PROJECT AS EARLY AS POSSIBLE

THE PROTOTYPING CYCLE



Off-the-shelf elements
Manual tools
Machining
Molding, casting
Laser cutting
Electronics
3D printing

Use the right tools for your needs!

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 part”

- Efficiency (energy, wastes...)

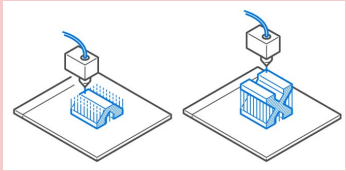
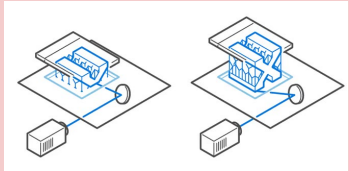
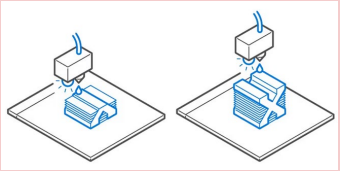
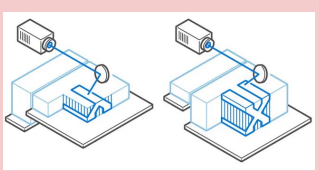
Biggest limitations:

- Materials and properties
- Dimensions, accuracy
- Not isotropic (FDM)

- **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 UV printing	Powder bed fusion Selective laser sintering (SLS) or melting (SLM)
Principle				
Materials	Polymer filaments	Photopolymer resins	Photopolymer resins	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)

SPOT 3D PRINTERS

PRUSA MK4S AND CORE ONE+

- Open access printers (level 2)

- Technology: FDM (filament)
- Build volume (x,y,z) : 250 x 210 x 210 mm
- Materials:
  - **PETG**
  - Technical PETG (HT, PTFE, CF)
  - TPU

- Easy to use, precise, reliable, sustainable
- For 95% of your needs

See available materials on the WIKI

SPOT 3D PRINTERS

- **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

SPOT 3D PRINTERS

▪ 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

SPOT 3D PRINTERS

▪ 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

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

EXPECTED BEHAVIOR

TOWARDS TOOLS AND EQUIPMENT

RESPECT

- 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

- 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)

EXPECTED BEHAVIOR

TOWARDS OTHER PEOPLE

RESPECT EVERYBODY !

- Other users, teaching assistants
- 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
- Transparency is the Key!

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 or punish you. Don't be shy ;)

EXPECTED BEHAVIOR

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)

EXPECTED BEHAVIOR

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

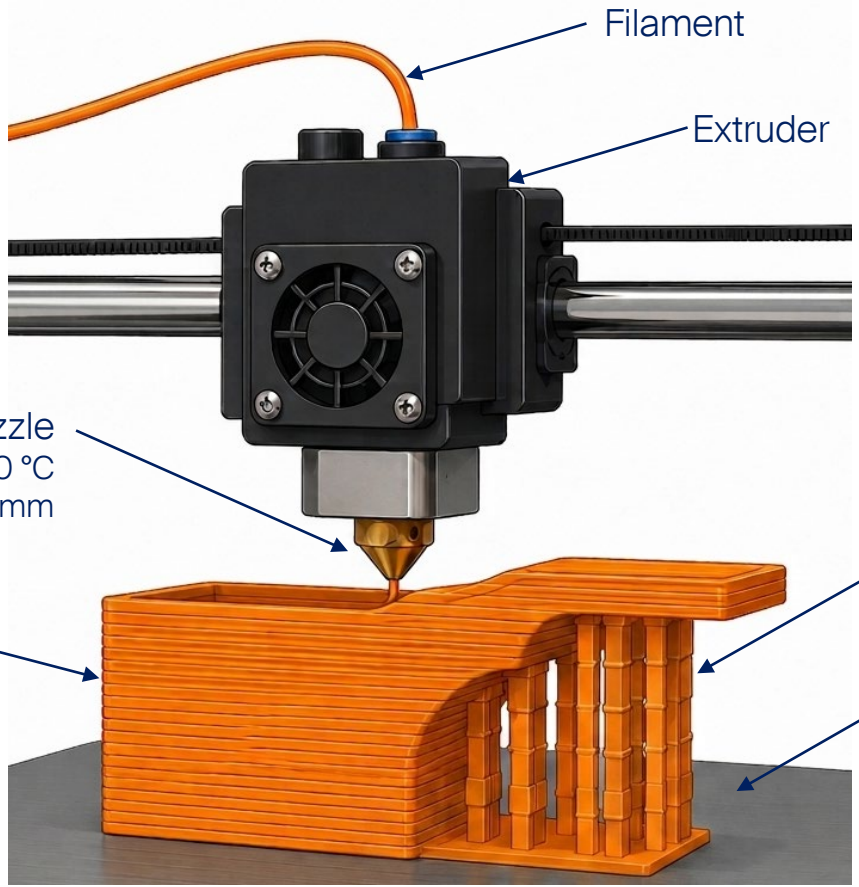
Notify the COSEC (coach) if you use any of these devices

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

FDM 3D PRINTING



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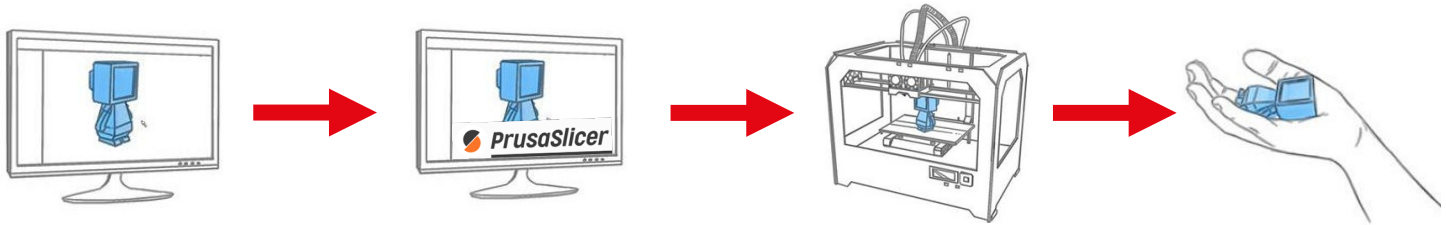
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

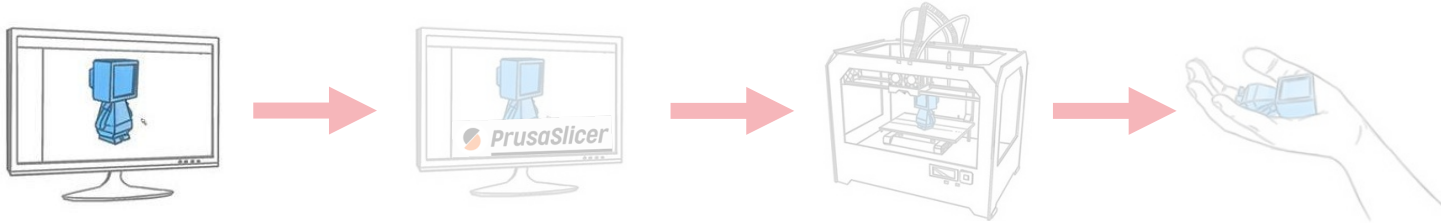
PREPARE
(aka slice)

3D PRINT

FINISH

- 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



DESIGN
(for manufacturing)

PREPARE
(aka slice)

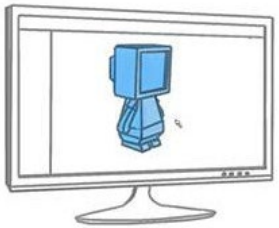
3D PRINT

FINISH

- 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**

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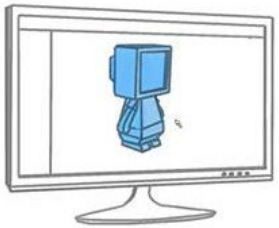
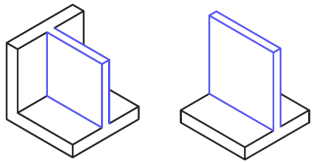
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

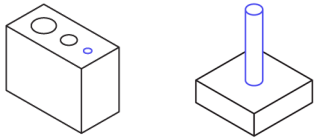
Wall thickness



Min. 0.8 mm

Min. 1.2 mm

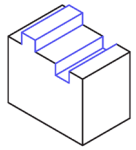
Hole and pin diameter



Min. 2 mm

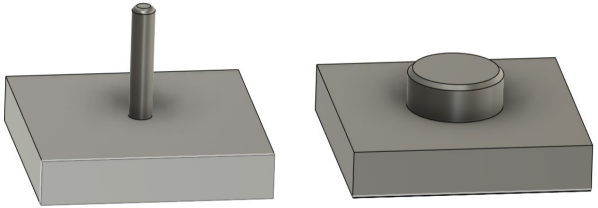
Min. 4 mm

Embossed and engraved details



Min. 0.8 mm wide and high

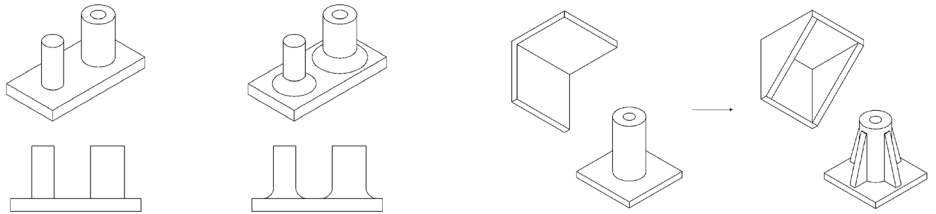
Avoid fragile elements



X

V

Add filets and ribs



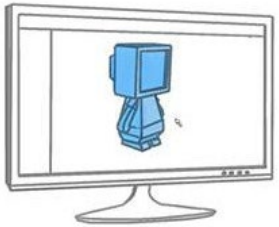
X

V

X

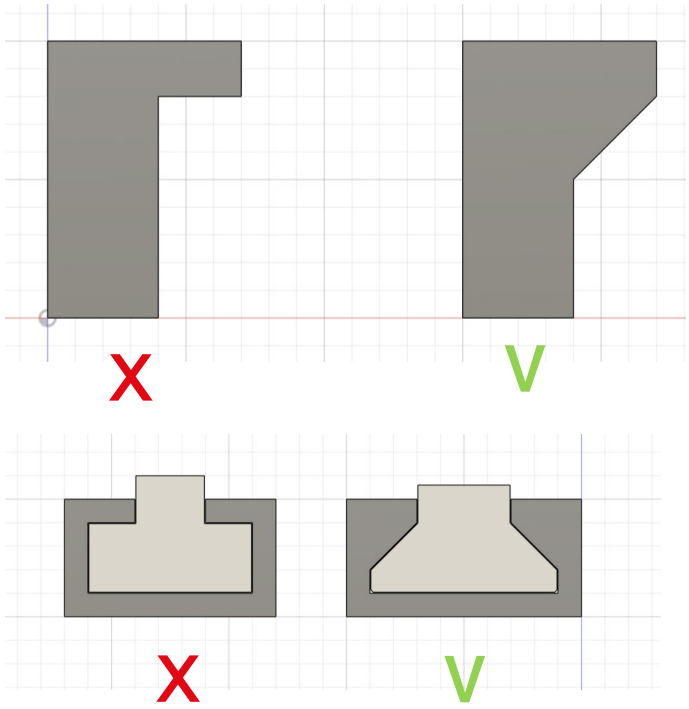
V

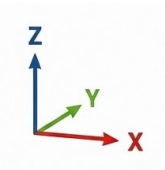
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

Avoid useless overhangs and supports





STEPS FOR SUCCESSFUL 3D PRINTING

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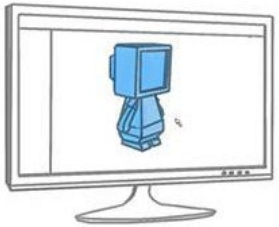
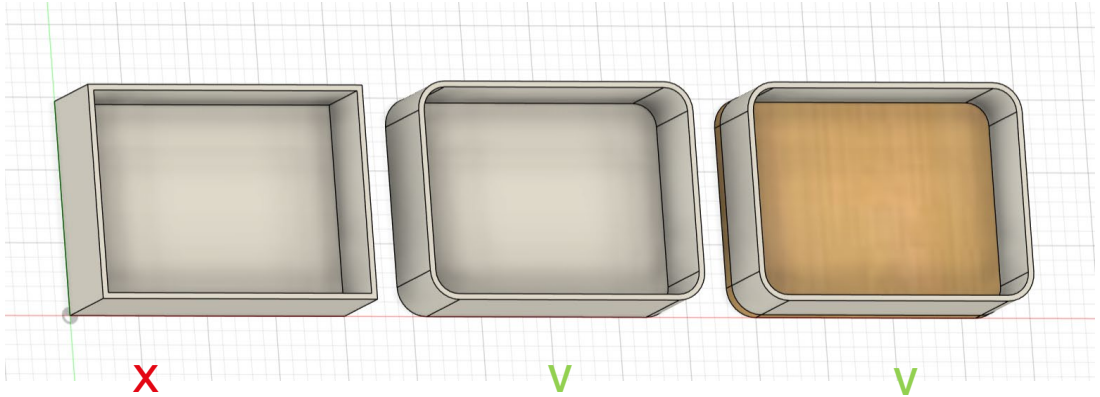


DESIGN
(for manufacturing)

Avoid large rectangular bases



X

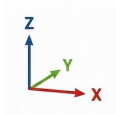
V
Rounded corners

V
Laser cut base

Avoid downward facing filet

X

V



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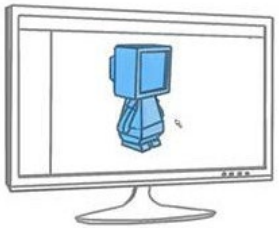
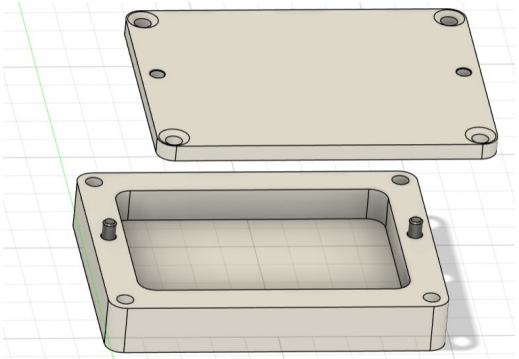
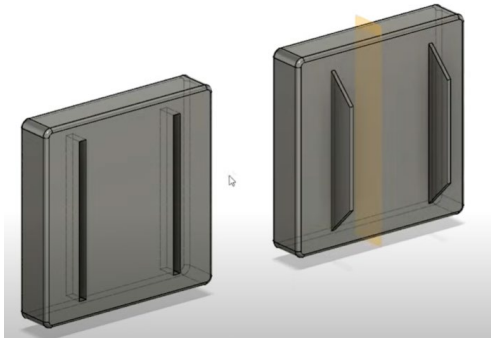


DESIGN
(for manufacturing)

- **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.





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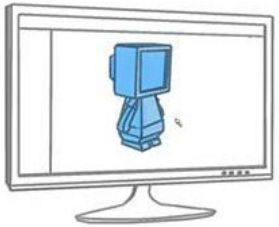
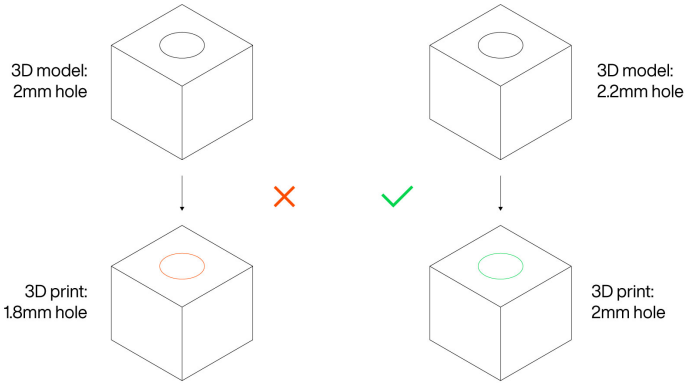
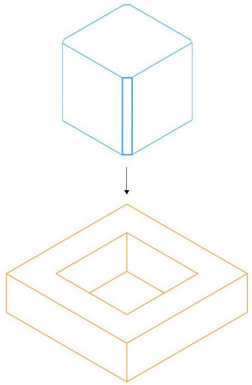
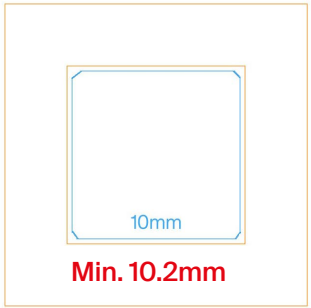


DESIGN
(for manufacturing)

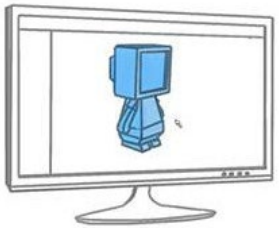
- **Designing assemblies > Tolerances**
  - The printed dimensions are generally larger than the 3D model (about 0.1 mm everywhere).
  - Leave a distance between parts for easy assembly. Typical value for FDM 3D printing: **0.1 – 0.2 mm**
  - Use chamfers for easy insertion.
  - See the tolerance test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







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

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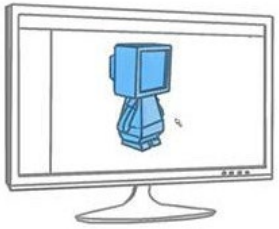
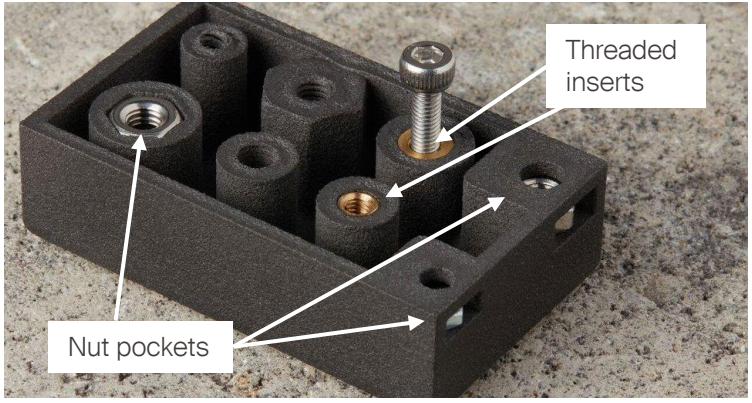
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

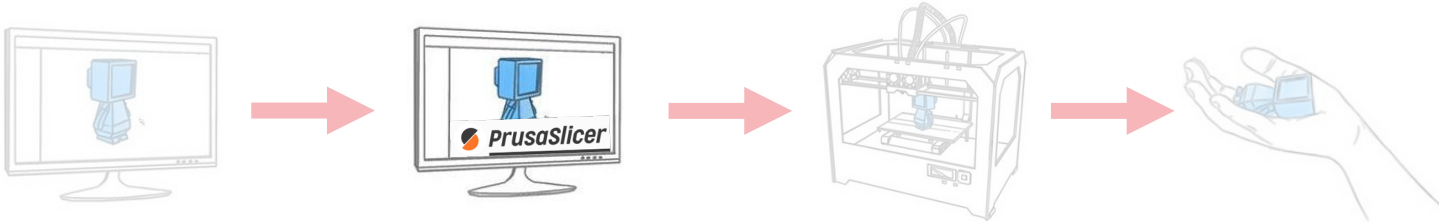
- **Designing assemblies > Screwing parts together**
  - 3D printing threads or threading 3d printed parts is generally not a good idea (not precise and strong enough). Use standard elements such as:
  - **Nut pockets > BEST OPTION !**
  - **Threaded inserts >** Check the hole dimensions before printing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



https://make.epfl.ch/wiki/public/spot_-_3d_printing/how_to_use_threaded_inserts

SPOT / Sébastien Martinerie

STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

PREPARE
(aka slice)

3D PRINT

FINISH

- 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 a USB stick

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

➢ **Prusa MK4S** with **0.4 mm High Flow nozzle**
  ➢ **SPOT PETG_2026**

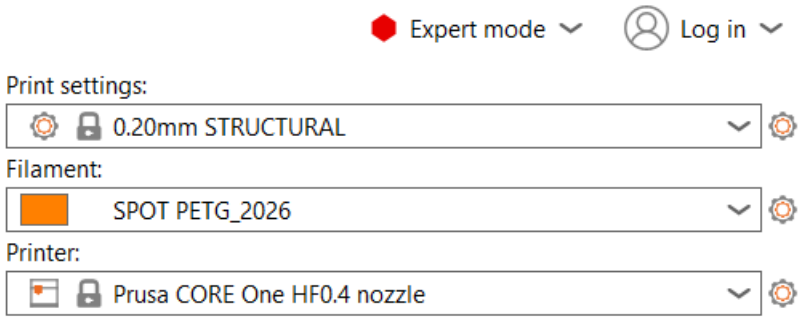
➢ **Prusa Core One+** with **0.4 mm High Flow nozzle**
  ➢ **SPOT PETG_2026**

- 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
    - **0.2 mm** layer height
    - **Structural** settings are always better than Speed!



STEPS FOR SUCCESSFUL 3D PRINTING

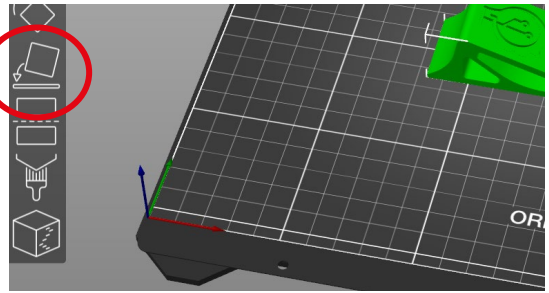
PREPARE
(aka slice)

- **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.

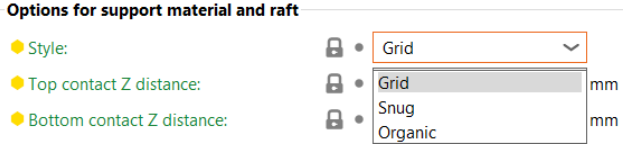


Place on face tool:
Choose which surface will face the printbed.
Preferably use this tool!

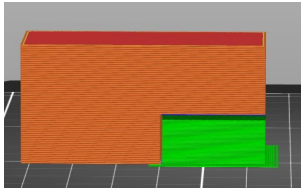
STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)

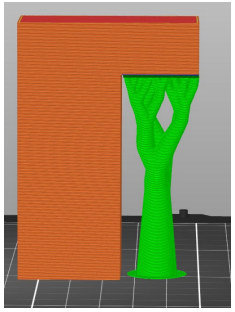
- **Generate supports:**
  - **You can't print in the air!**
  - Surfaces that are not supported enough **can ruin your print.**
  - In case of doubt, place supports **everywhere.**
  - Remember you will have to access the support for removal.
  - And that supported surfaces are altered.
  - You can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



For large and low supported areas



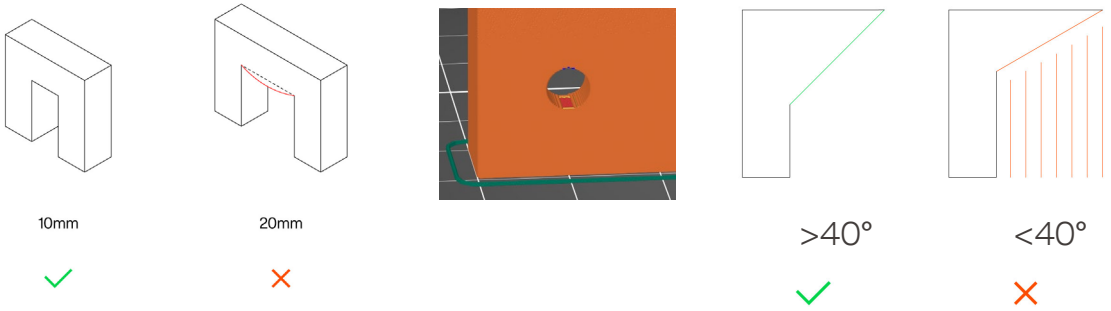
For small and high supported areas



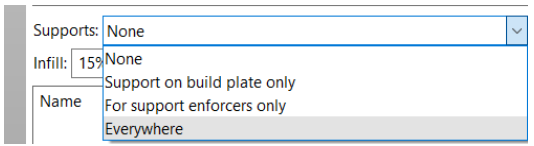
STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)

- **Generate supports:**
  - Small bridges are fine. Short horizontal holes don't need to be supported
  - Overhangs above 40° are ok



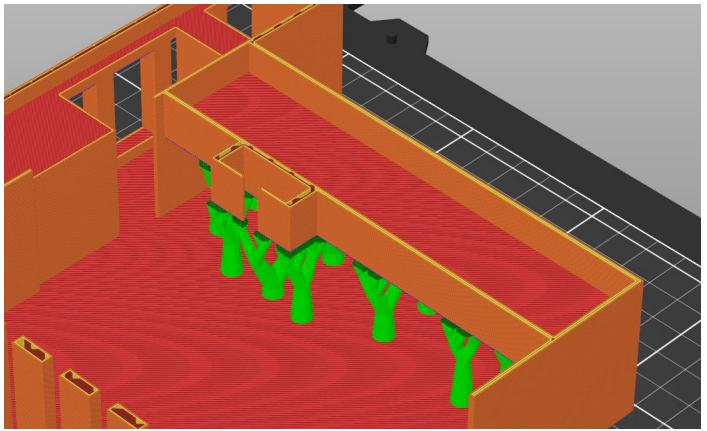
- You can also place supports selectively using the **paint-on supports tool** and the **"For support enforcers only"** option.



STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)

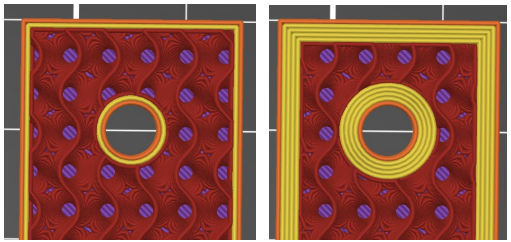
- **Generate supports:**
- **Warning**: avoid supports printed on top of a flat printed surface.



- 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: Increase strength**
  - **Part design**
    - Avoid stress concentrations
  - **Part orientation**
    - Avoid layers delamination
  - **Infill**
    - Big time and filament usage increase > Slight strength 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

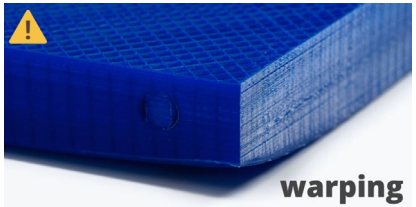
➢ Print settings > Layer and perimeters > perimeters

> 2 (default) -> **4 to 6**

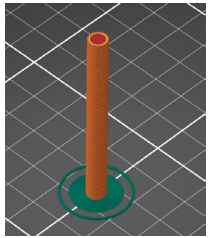
STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)

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

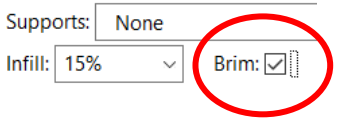


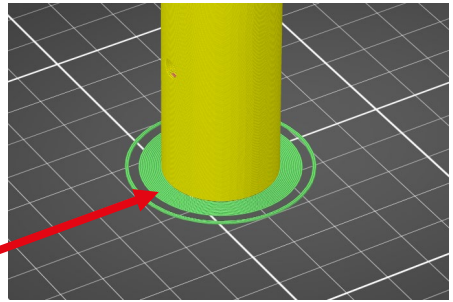
Large rectangular base



Thin and high parts

1) **Avoid that kind of parts**
2) **Take a smooth printbed**
3) **Add a brim**





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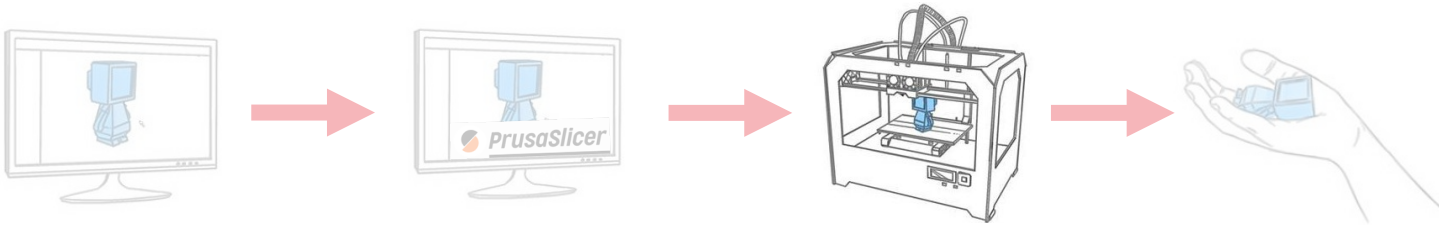
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

PREPARE
(aka slice)

3D PRINT

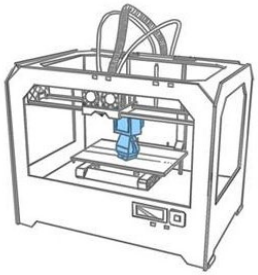
FINISH

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

Wiki

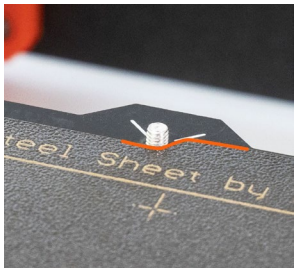
https://make.epfl.ch/wiki/public/spot_-_3d_printing/how_to_unlock_a_printer_using_internet

STEPS FOR SUCCESSFUL 3D PRINTING



3D PRINT

- **Respect** the tools and the rules
- Put the previous user's printbed on the table
- Take any **new clean printbed** and place it properly.
  - Textured printbed for easy part removal
  - Smooth printbed for stronger adhesion



- Check the filament (type and amount)
  > Tutorial for filament change →

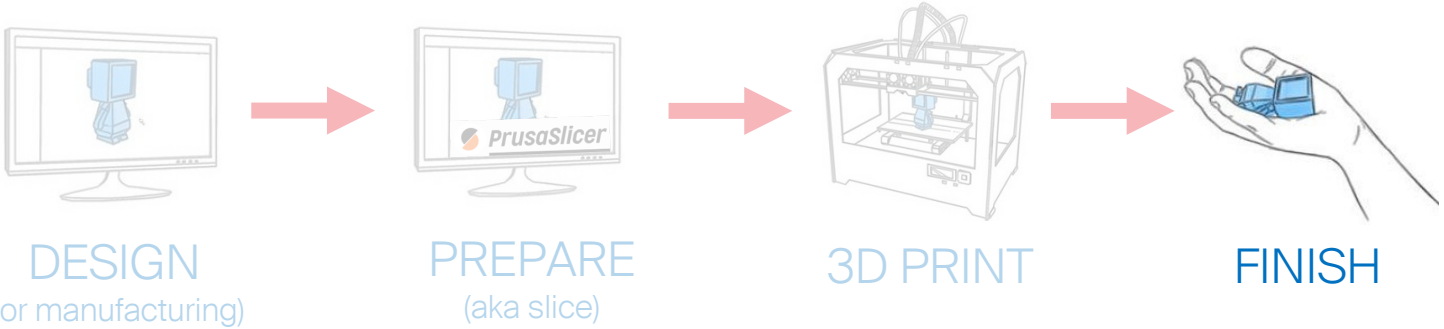
- Check if the nozzle is clean

  If not, preheat the printer and remove excess filament with a plier or ask for help

https://make.epfl.ch/wiki/public/spot_-_3d_printing/load_filament

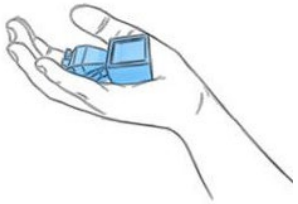
- **Start** your print and **stay for the first layers** and eventually come back from time to time

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**

- Unload filament and store it properly
- Remove the printbed 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**

TROUBLESHOOTING

- If a print fails, do not simply reprint without investigating the issue.
- Please check the condition of the printer, your parts, and your G-code to determine the cause of the problem.

- Bad or no extrusion :
  - Is filament properly loaded ?
    - Try to pull it out of the extruder. If it comes, that means that it was not loaded.
  - Did you load enough filament for you print ?
    - The printer should detect if it's out of filament and pause until someone loads a new spool. But shit happens...
  - Is filament tangled, blocked, broken ?
    - If the problem is too tricky to solve, put the printer in maintenance

TROUBLESHOOTING

- Bad adhesion on the printbed :
  - Did you check your first layer ???????
  - Is the first layer of your part oriented correctly on the Slicer ?
    - Orient your part using “place on face” tool
  - Is the first layer large enough for good adhesion ?
    - Change your design or part orientation.
    - Or sink your part into the bed (negative vertical translation)
  - Is the first layer too large and part detaches in the corners or warps?
    - Change your design (round the corners) and/or your process (laser cutting ?)
    - Add a brim
    - Be sure to slice with SPOT PETG_2006 material setting
    - Use a clean smooth printbed

TROUBLESHOOTING

- Spaghettis everywhere :
  - Did you slice with SPOT PETG_2006 material setting ?
  - Did you generate enough supports ?
  - Did you check your first layer ???????
- Also, if you see any print that is failing (printing spaghettis or making weird noise for example), please pause the print and communicate with a note.
- If you're not sure, please ask for help !
- Putting a printer in maintenance:
  - Cooldown the nozzle and wait until Temp. is under 50°C
  - Turn off
  - Put a maintenance card with explanation on a post-it

CONTACT

- Your 3D printing coach is Sébastien Martinerie

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

- E-mail: sebastien.martinerie@epfl.ch
- Slack

HAPPY PRINTING @SPOT !!