EPFL

3D PRINTING TRAINING

SPOT

Student Prototyping
and Outreach Tank

Sébastien Martinerie

V5.2

WELCOME

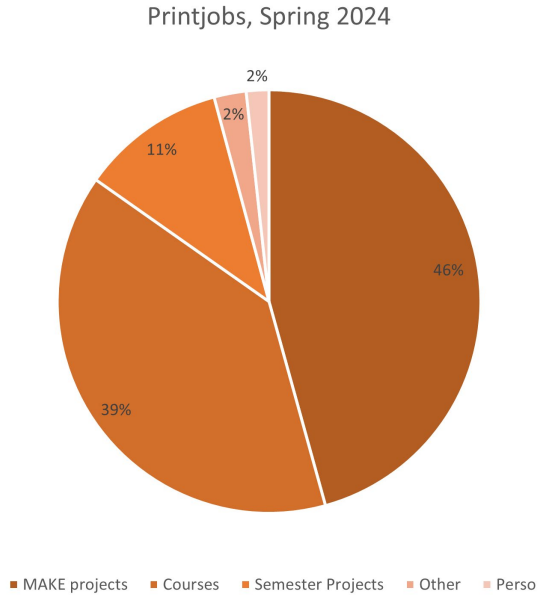
- General information
- What is 3D printing?
- SPOT 3D printers
- The prototyping cycle
- Expected behavior
- Steps for successful 3D printing
- Demo

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

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. 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 evolutionary space

- A high volume workshop

  Per year:

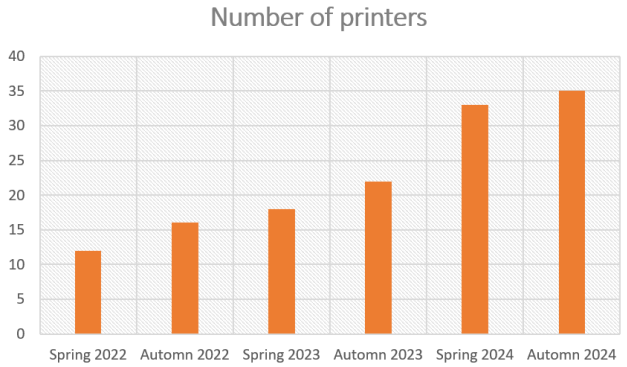
  7'500 print jobs

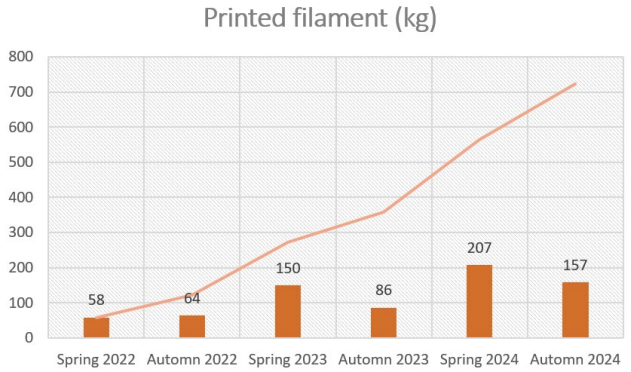
  120 km of printed filament (350 kg)

  1'200 days of printing

- A community of users

  1'000+ trained users





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
- Fast “design to production”
- Efficiency (energy, wastes...)

Biggest limitations:

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

WHAT IS 3D PRINTING?

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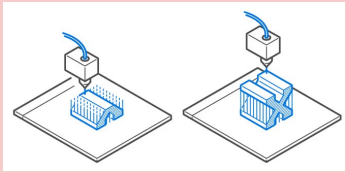
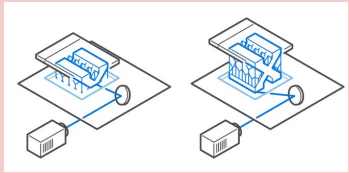
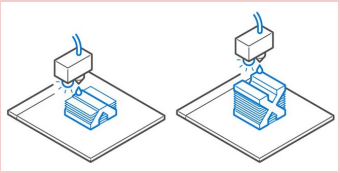
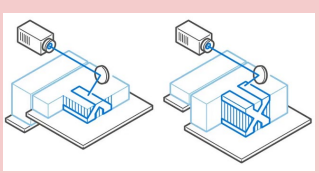
The most common 3D printing types:

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)

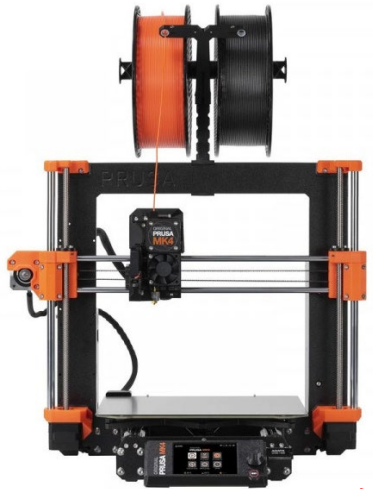
SPOT 3D PRINTERS

▪ PRUSA MK3S+ AND MK4

- 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



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)
  - Soluble supports
  - TPU

- 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
  - Technical materials (ASA, PC, PA, etc.)
  - PEEK Family!

- For bigger and/or more technical parts

SPOT 3D PRINTERS

FORMLABS FORM3+

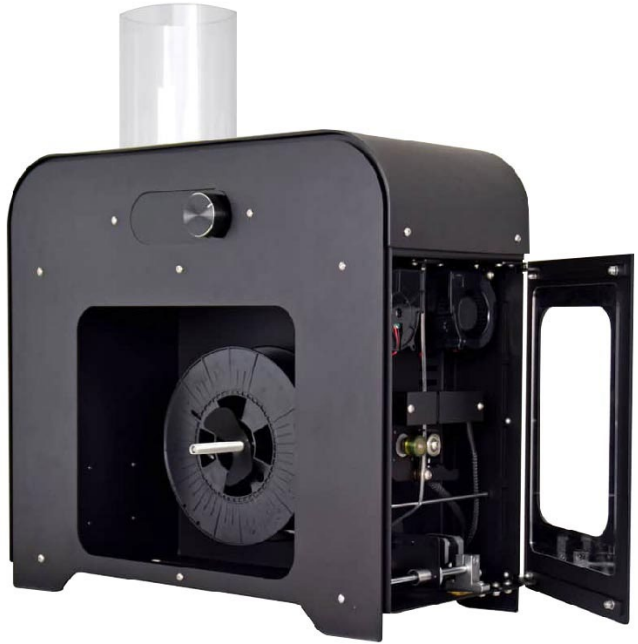
- Only under supervision (level 3)

- Technology: SLA (resin)
- Build volume (x,y,z) : 145 x 145 x 185 mm
- Materials:
  - Standard
  - Clear, high rigidity, elastic, high temp, etc.

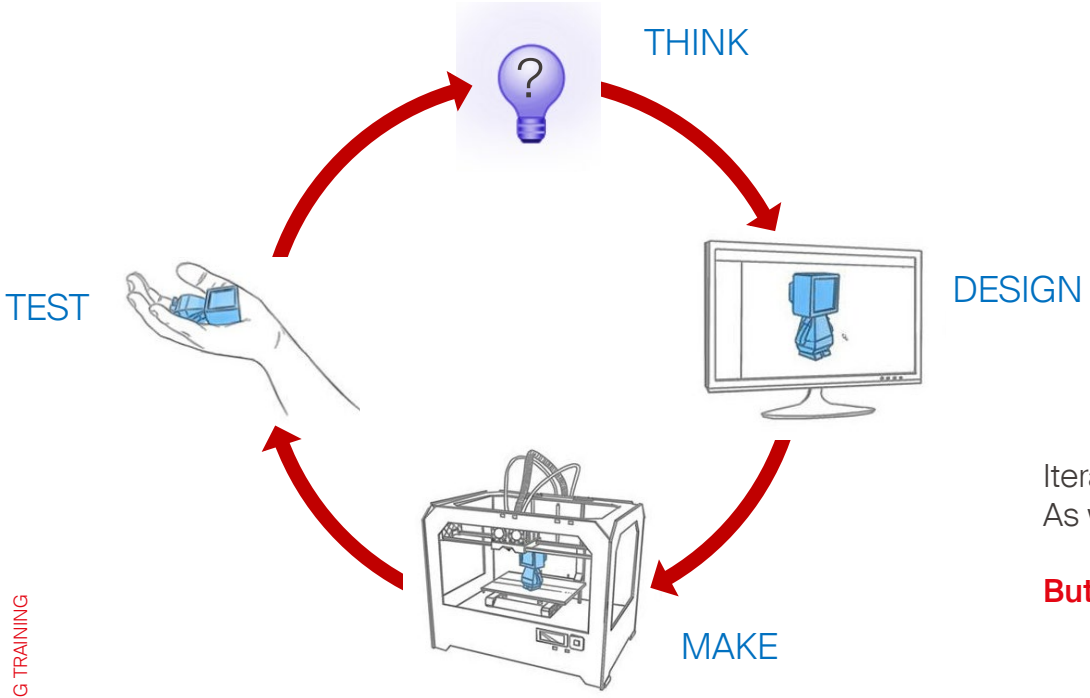
- For high quality surfaces, precision, details, specific properties

SPOT RECYCLING PROJECT

- **3DEVO extrusion line**
  - Only under supervision (level 3)
  - Ongoing project to recycle PET-G waste to make our own filament
  - Shredding, drying, extruding
  - Around 20 kg of PET-G per year



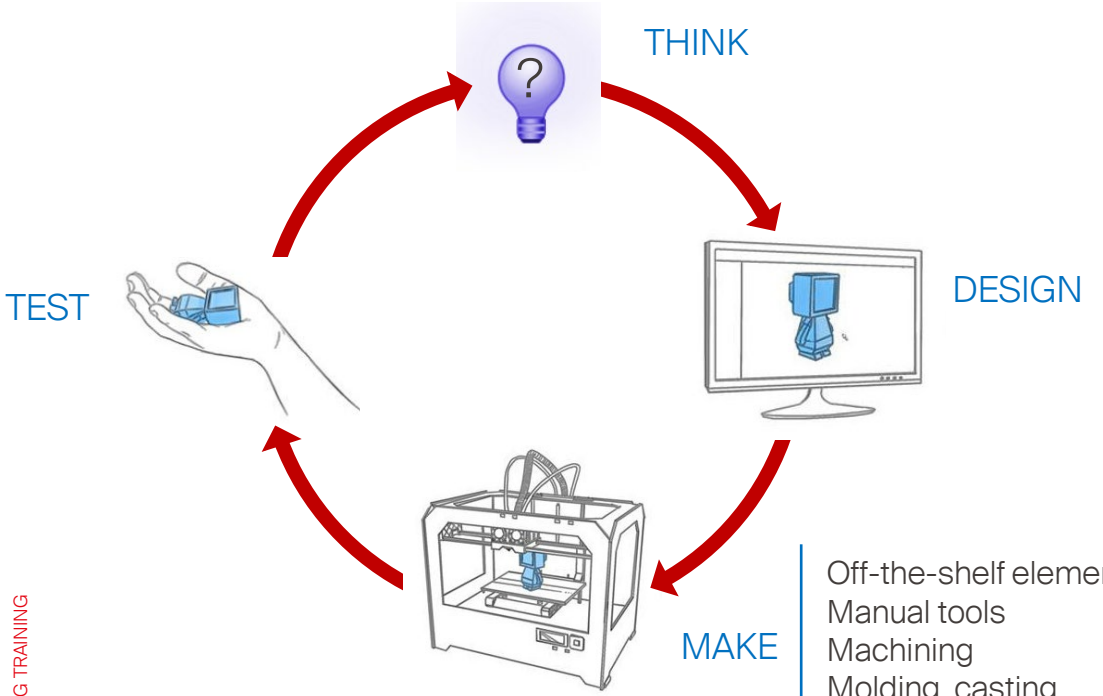
THE PROTOTYPING CYCLE



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

But don't forget to learn in the process!

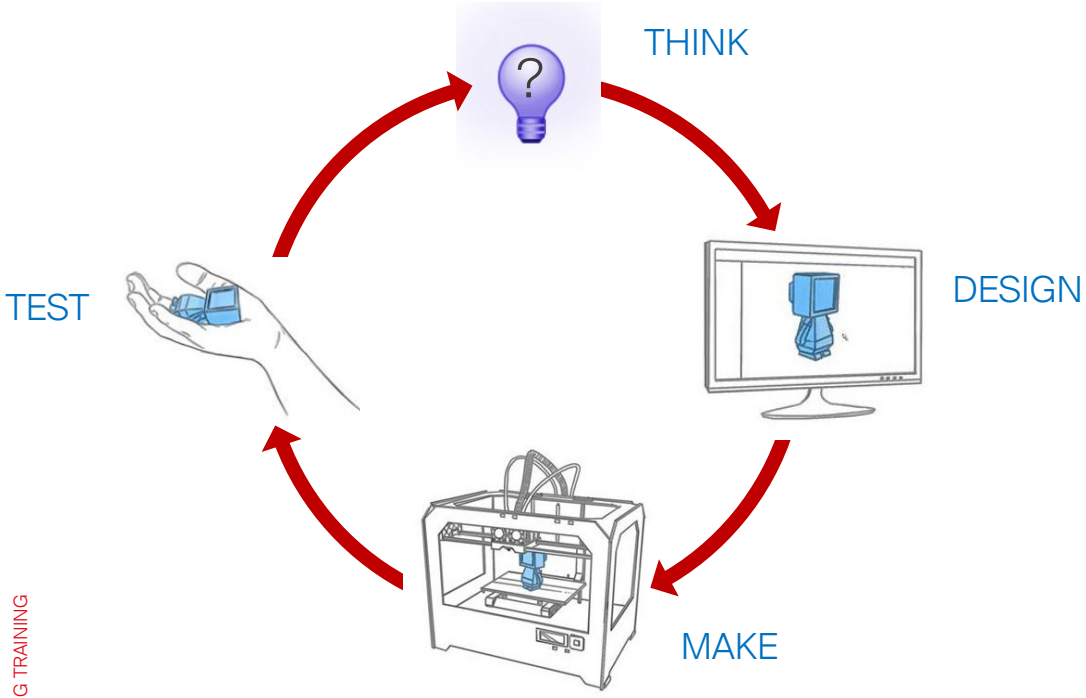
THE PROTOTYPING CYCLE



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

Use the right tools for your needs!

THE PROTOTYPING CYCLE



YOUR COACHES CAN HELP YOU!

PLEASE SHOW US YOUR PROJECT AS EARLY AS POSSIBLE

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

PLEASE RESPECT

The tools and equipment

- No dust, no food, no drink
- Keep the place and the printers clean
- Use only the materials and tools available in the space (you can not bring your own filament) and don't take them out of the room
- Communicate if something is missing or broken or if you have any suggestions
- Print only your own G-Codes

Other people and their work

- Handle other people's parts with care
- Share the printers
- You cannot reserve the machines. First come, first served.
- Share your experience and help each other
- Be nice, don't judge

The 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.
- Ask for help

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
- 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

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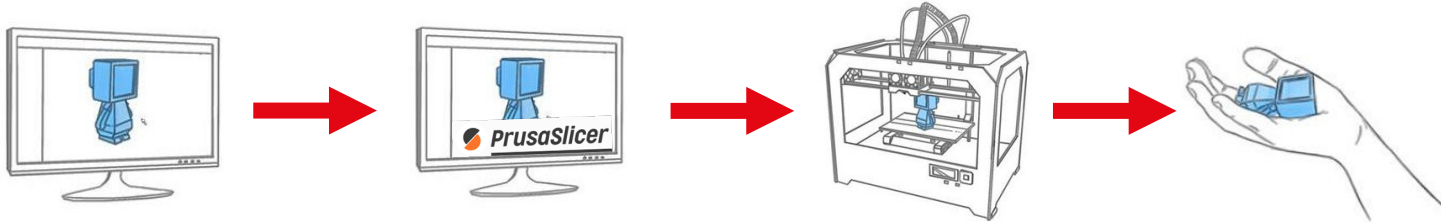
STEPS FOR SUCCESSFUL 3D PRINTING



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.

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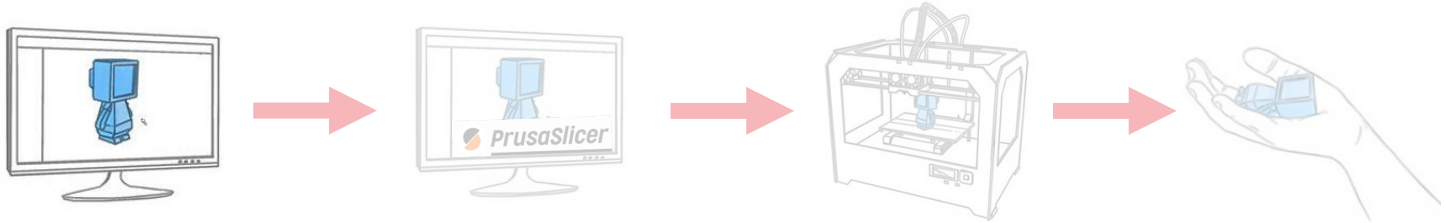
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

PREPARE
(aka slice)

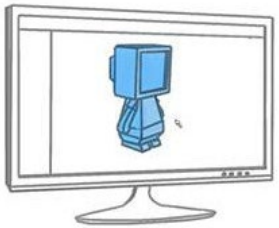
3D PRINT

FINISH

- Functions, working conditions, constraints, assemblies…
- Anticipate the three 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

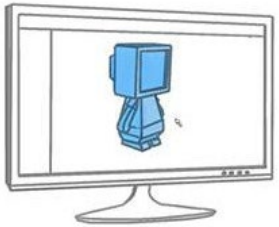
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

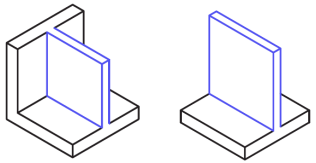
- Using your favorite **CAD software**
- Determine how your prototype **will work**
  - Functions
  - Assemblies
  - Working conditions, constraints…
- **Anticipate** what's coming next:
  - How will you manufacture/print the parts, in which orientation, in which material?
  - On which type of printer 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)

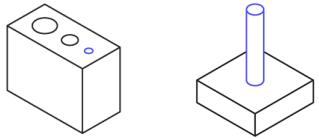
Wall thickness



Min. 0.8 mm

Min. 1.2 mm

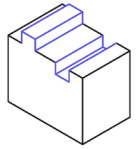
Hole and pin diameter



Min. 2 mm

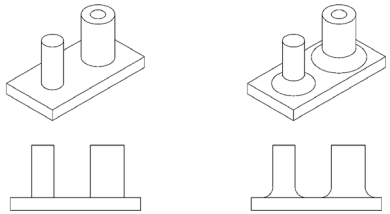
Min. 4 mm

Embossed and engraved details



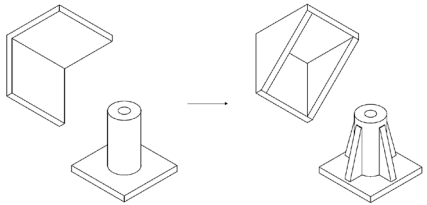
Min. 0.8 mm wide and high

Add filets and ribs



X

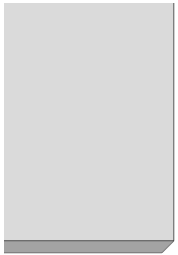
V



X

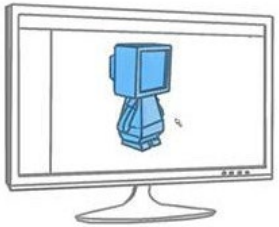
V

X



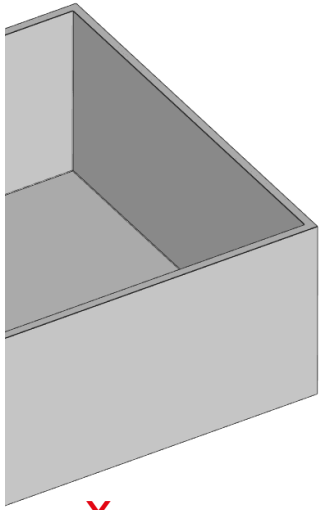
V

STEPS FOR SUCCESSFUL 3D PRINTING

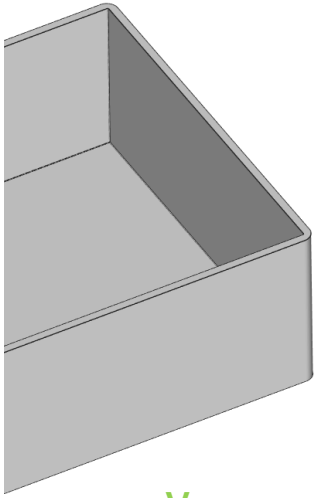


DESIGN
(for manufacturing)

Avoid large rectangular bases

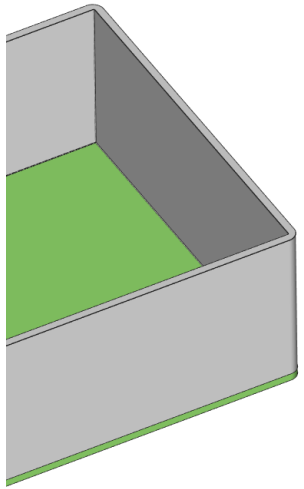


X



V

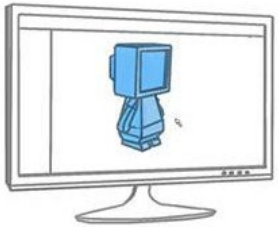
Rounded corners



V

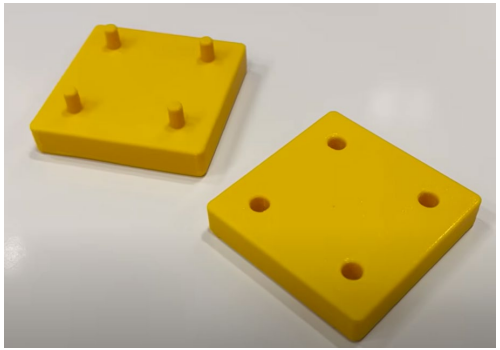
Laser cut base

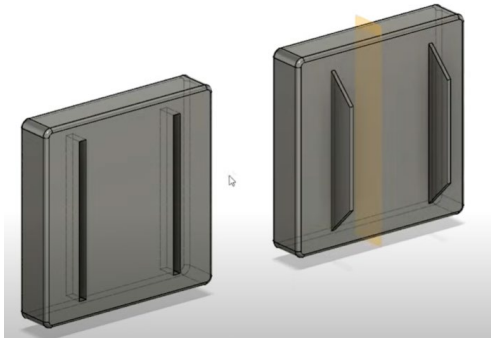
STEPS FOR SUCCESSFUL 3D PRINTING



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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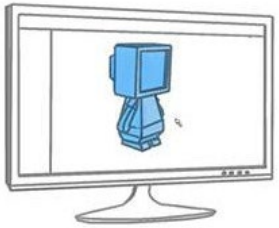
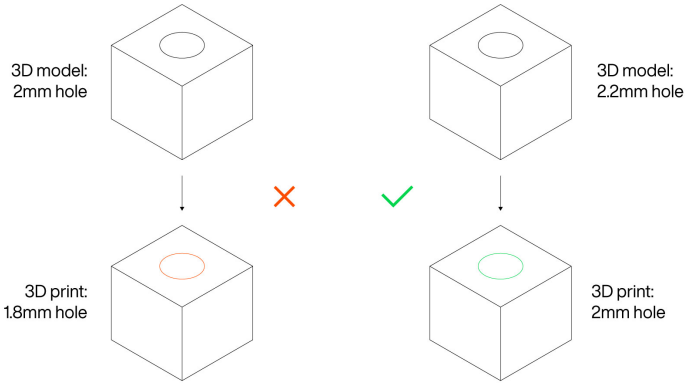
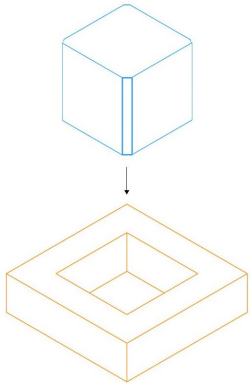
STEPS FOR SUCCESSFUL 3D PRINTING

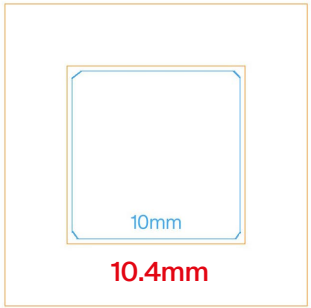


DESIGN
(for manufacturing)

- **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: **0.15 – 0.3 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

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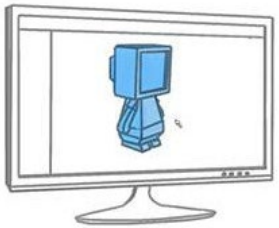
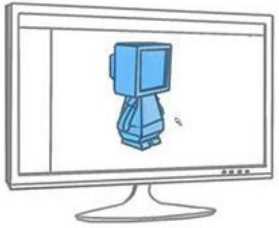


DESIGN
(for manufacturing)

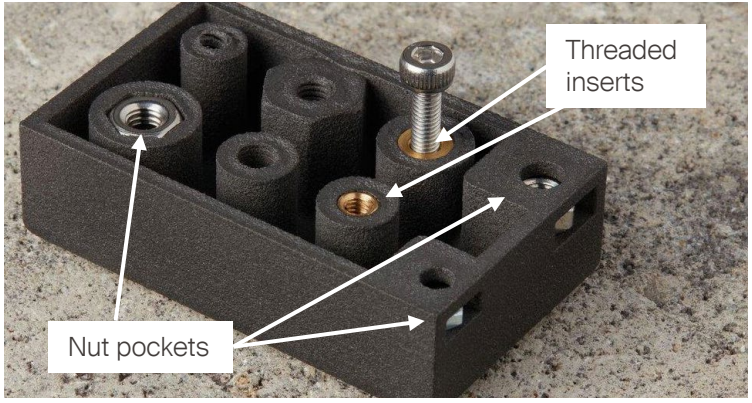
- **Designing assemblies > Fixing parts together**
  - There are many options to secure parts together.
  - You can use:
    - Glue (strong but not reversible)
    - Magnets (reversible but not strong)
    - Screws (strong and reversible) > See next slide
    - Other options like snap fits, zip ties,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



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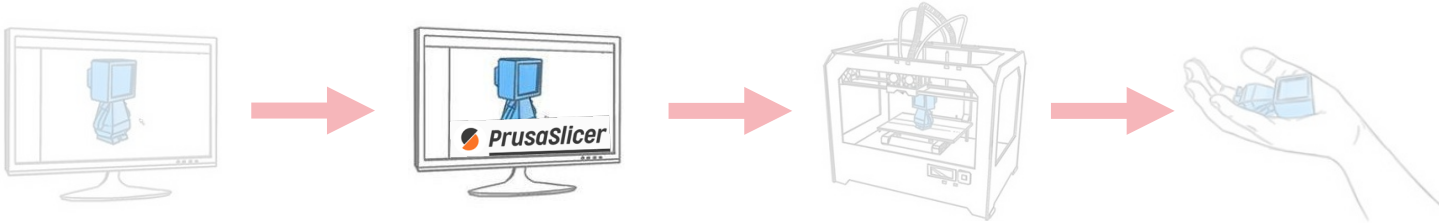
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

PREPARE
(aka slice)

3D PRINT

FINISH

- Transform geometry (STL, STEP) into instructions for the printer (G-code)
- Part orientation, support structure (if necessary)
- Printer model, material, advanced settings
- 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

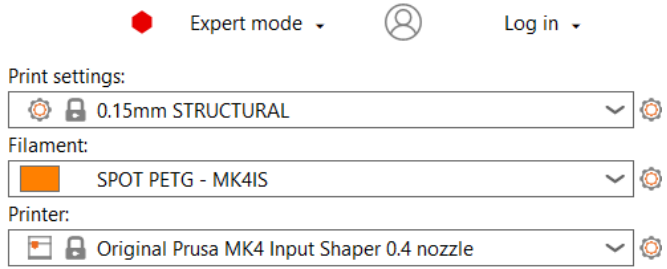
➢ **Prusa i3 MK3S+** with **0.4 mm nozzle**
  ➢ **SPOT PETG – MK3S+**
➢ **Prusa MK4 Input Shaper** with **0.4 mm nozzle**
  ➢ **SPOT PETG – MK4IS**

- 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 – Not Speed!



STEPS FOR SUCCESSFUL 3D PRINTING

SPOT / Sébastien Martinerie

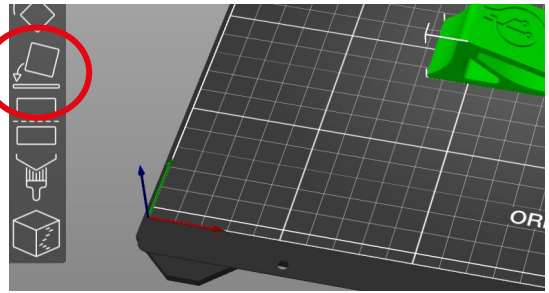
PREPARE
(aka slice)

- **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
  - The **best precision** is on XY plan
  - **Supports** affect the surface quality once removed

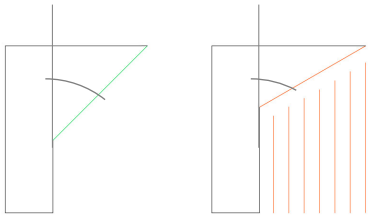
  If you don't find the good orientation, try to change your design.



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

STEPS FOR SUCCESSFUL 3D PRINTING

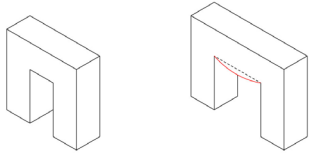
PREPARE
(aka slice)

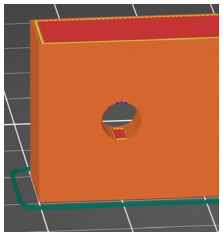


45° - 60° ✓

> 60° ✗

- **Generate supports:**
  - **You can't print in the air!**
  - Surfaces that are not supported enough **can ruin your print** (and the printer).
  - Remember you will have to access the support for removal.
  - Small bridges are fine. Small horizontal holes don't need to be supported





Overhangs up to 60° are ok (45° are perfect)

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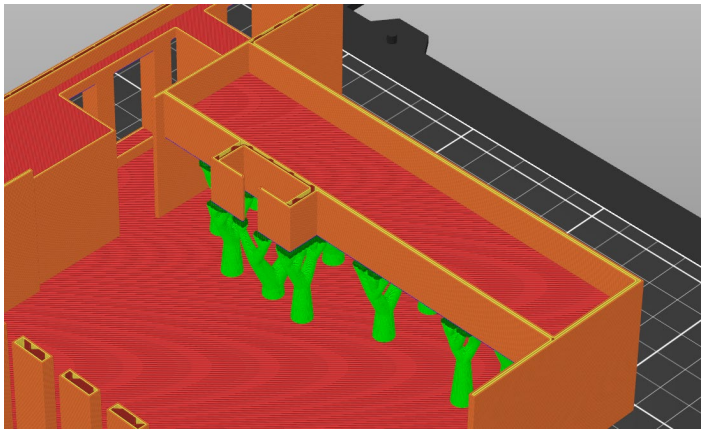
STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)

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

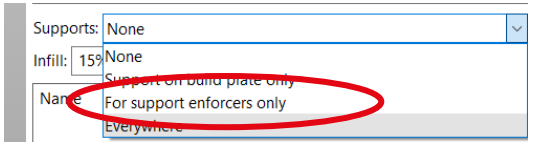


- The need for supports can be optimized by changing:
  - your **design** (splitting parts, adding chamfers, etc.)
  - and/or your part **orientation**

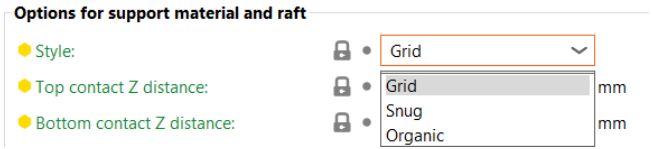
STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)

- **Generate supports:**
  - In case of doubt, place supports **everywhere.**
  - You can also place supports selectively using the **paint-on supports tool** and the **"For support enforcers only"** option.

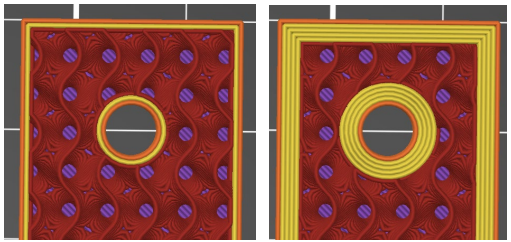


  - You can find different support styles here:
    - Print settings > Support material > Style
    - Snug and Organic are particularly easy to remove



STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)



- 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**

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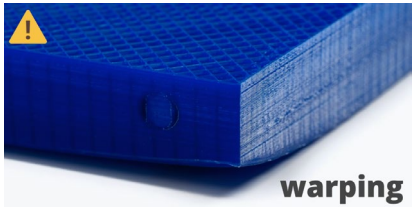
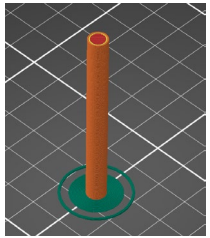
STEPS FOR SUCCESSFUL 3D PRINTING

PREPARE
(aka slice)

- Prevent warping or bad adhesion to the bed

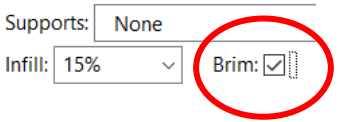


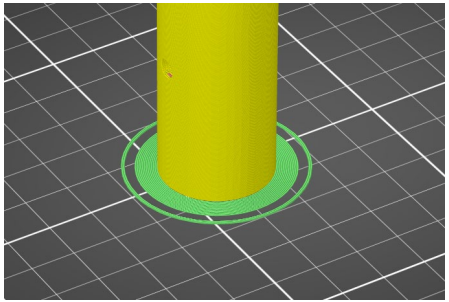
Big parts



Thin and high parts

> Add a brim





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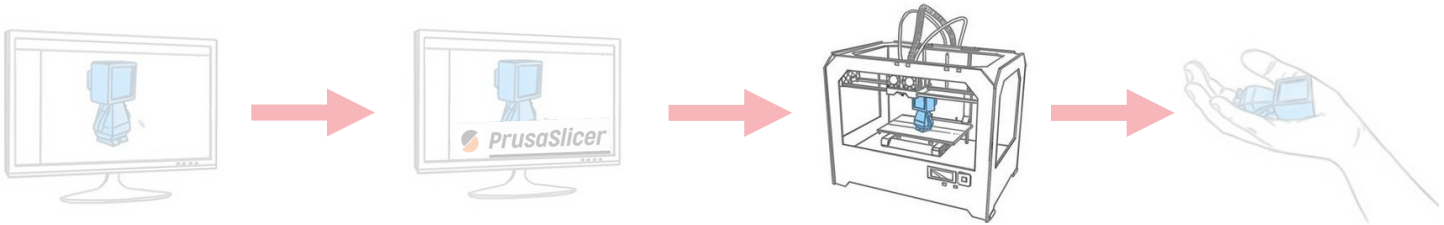
STEPS FOR SUCCESSFUL 3D PRINTING



DESIGN
(for manufacturing)

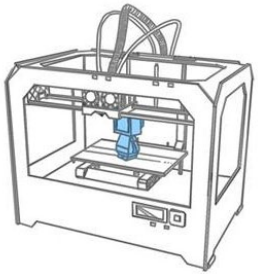
PREPARE
(aka slice)

3D PRINT

FINISH

- Unlock the printer on make.epfl.ch/3dprint and choose your budget
- If your project's list is not right > update it on 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

STEPS FOR SUCCESSFUL 3D PRINTING

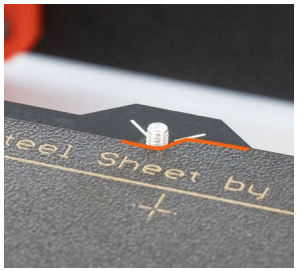


3D PRINT

- **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

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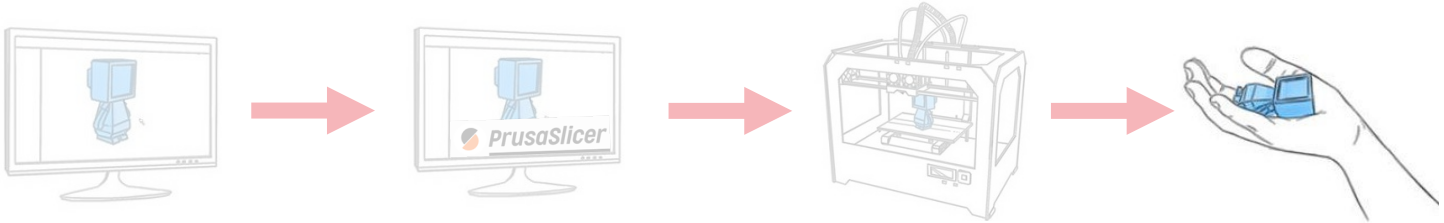
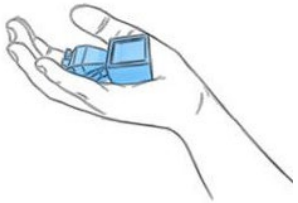
STEPS FOR SUCCESSFUL 3D PRINTING



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

STEPS FOR SUCCESSFUL 3D PRINTING



FINISH / ASSEMBLE

- **After printing**

- 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**

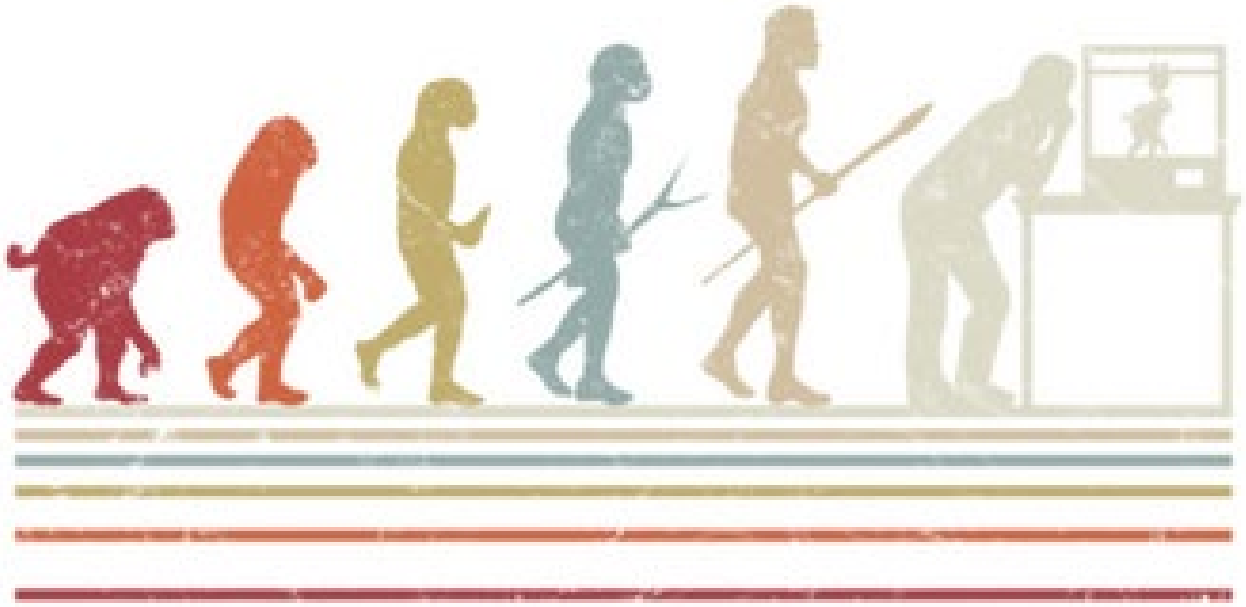
RESSOURCES

- Your 3D printing coach is Sébastien Martinerie

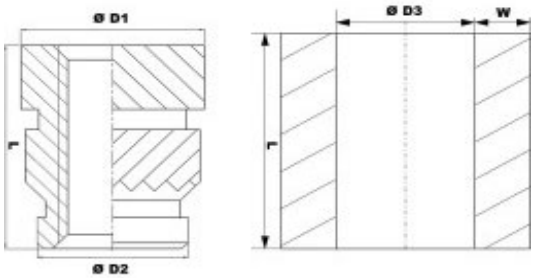
	Monday	Tuesday	Wednesday	Thursday	Friday
Morning (9h30-12h)	YES	-	YES	-	YES
Afternoon (13h-17h30)	YES	-	YES	YES	YES

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

HAPPY PRINTING @ SPOT!



BONUS:
Threaded inserts



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

Taille de filetage	Ø D1	Ø D2	Ø D3	L (+1 mm)	W (minimum)
M2	3,6 mm	3,1 mm	3,2 mm	5 mm	1,3 mm
M2,5	4,6 mm	3,9 mm	4,0 mm	5,7 mm	1,6 mm
M3	4,6 mm	3,9 mm	4,0 mm	5,7 mm	1,6 mm
M4S	6,3 mm	5,5 mm	5,6 mm	6,35 mm	2,1 mm
M4	6,3 mm	5,5 mm	5,6 mm	8,1 mm	2,1 mm
M5	7,1 mm	6,3 mm	6,4 mm	9,5 mm	2,6 mm
M6	8,7 mm	7,9 mm	8,0 mm	12,7 mm	3,3 mm
M8	10,24 mm	9,5 mm	9,6 mm	12,7 mm	4,5 mm

BONUS:
Available filaments (level 2 printers)

Name	PrusaSlicer Profile	Price	Characteristics / Applications
PET-G	**SPOT PETG**	**0,05 CHF/g**	**Standard filament. Easy to print with good properties. Perfect for most applications.**
TPU	NinjaTek Ninjaflex TPU	0,1 CHF/g	Flexible filament with a 85 shore A hardness. Ideal for flexible geometries, tyres, bumpers, etc. Print with glue on the printbed.
SPOT-G	SPOT PETG	0,01 CHF/g	Made at the SPOT from 100% recycled PETG waste! For low quality prototyping. Success of your print is not guaranteed!
PETG-HT	Colorfabb HT	0,05 CHF/g	A translucent PETG material with higher temperature resistance (up to 100°C). For hot airflow, lighting designs, etc.
PETG-PTFE	Generic PETG	0,05 CHF/g	PETG with 10% PTFE, commonly known as Teflon, with self-lubricating properties. For low friction applications, such as sliding elements and gears.
PET-CF15	Prusament PETG Carbon Fiber	0,1 CHF/g	The easiest carbon fiber material to print. With excellent mechanical and thermal properties. 80 MPa of tensile strength, 9 GPa of modulus of elasticity and 125°C of service temperature! For high demanding applications only.