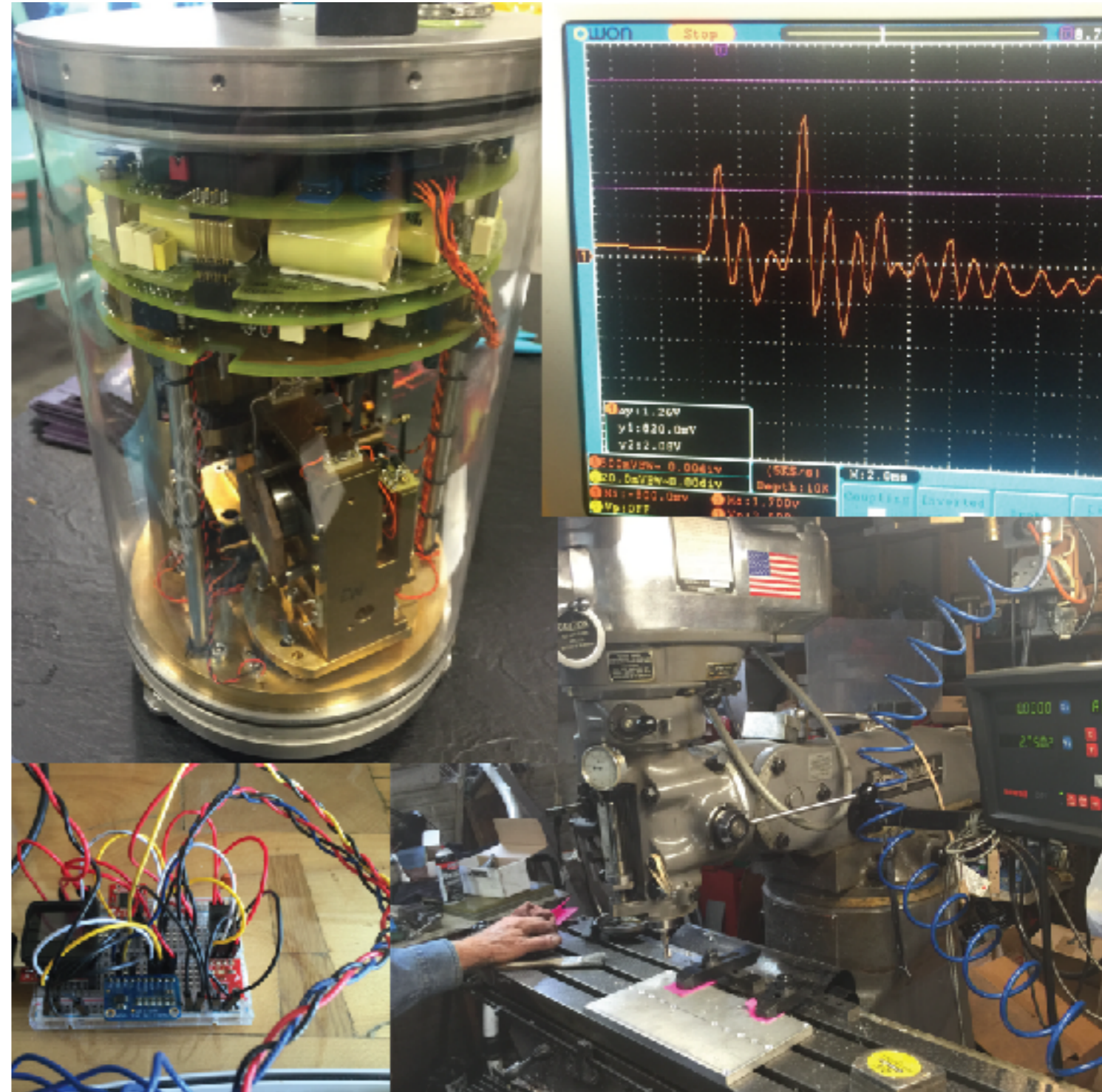


# 3D CAD and Design for Printing

J.R. Leeman and C. Marone

Techniques of Geoscientific  
Experimentation

September 27, 2016



# Today we'll go over how to use OnShape as well as how to effectively design parts for 3D printing

The image shows a screenshot of the OnShape website. At the top right, there are links for "CREATE ACCOUNT" and "SIGN IN". The OnShape logo is on the left. A navigation menu includes "CAD", "LEARN", "CUSTOMERS", "PARTNERS", "COMMUNITY", "ABOUT", and "BLOG". The main heading reads "THE LEADING CAD PLATFORM FOR AGILE PRODUCT DESIGN". Below this, a paragraph states: "Onshape is a full-cloud CAD system that's perfect for agile product design. Unlike installed CAD and PDM, Onshape gives everyone on the team instant access to the same CAD system and same CAD data." A button labeled "LEARN MORE ABOUT FULL CLOUD CAD" is positioned below the text. To the right, a sign-up form includes fields for "FIRST NAME", "LAST NAME", and "EMAIL", followed by a yellow "CREATE ACCOUNT" button and a link: "Are you an Engineering Executive? Click Here >>".

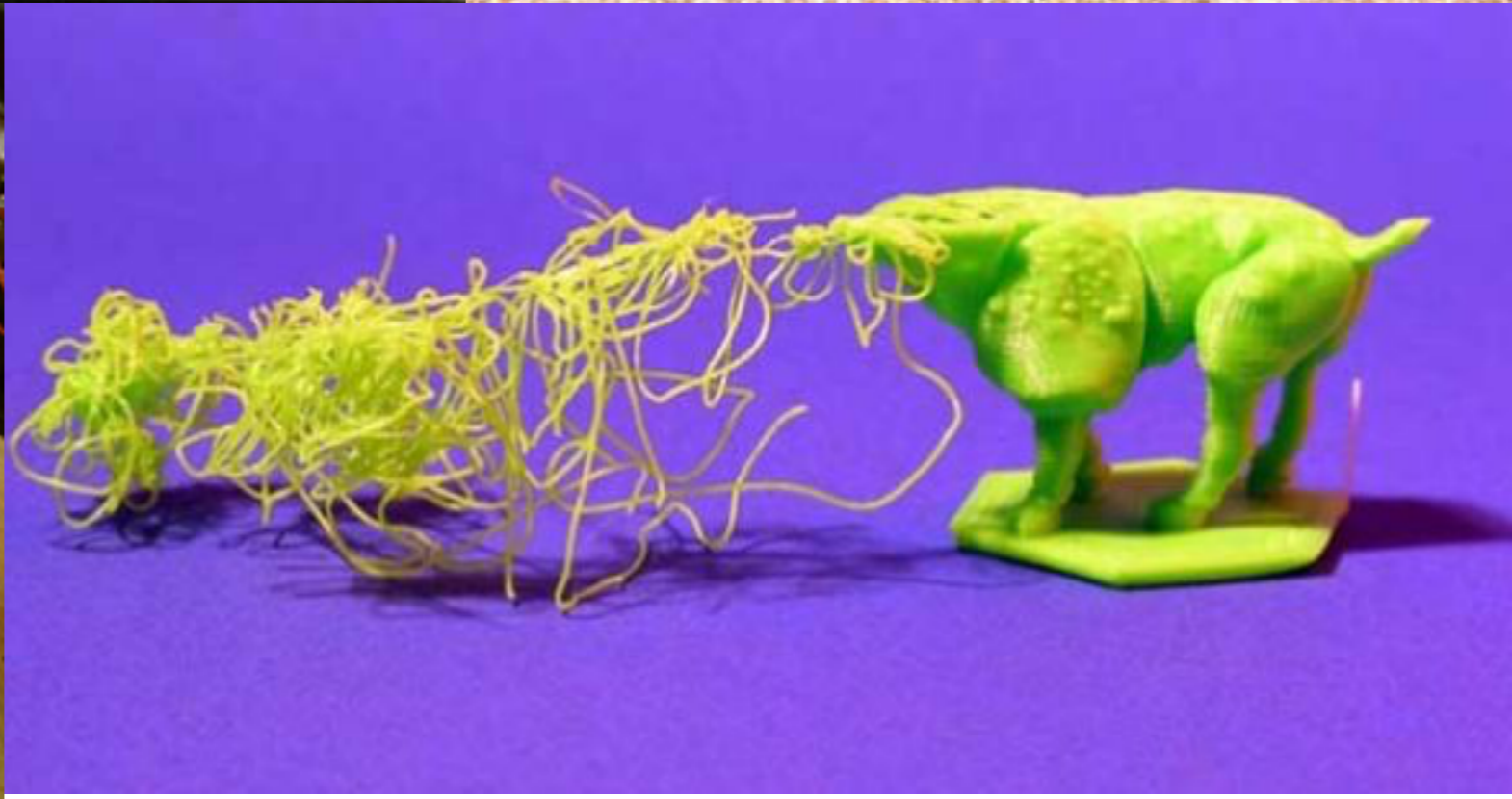
The bottom portion of the image shows a tablet displaying the OnShape CAD interface. The window title is "Cylinder Shell - Main". The interface includes a "Features (202)" list on the left with items like "Ext Profile S...", "Ext Profile", "Sketch 2", "Sketch 3", "Revolve 3", "Hole Sketch 1", "Sketch 5", and "Revolve 4". Below this is a "Parts (1)" list with "Cylinder Shell". A central 3D model of a yellow cylindrical part is shown with a dimension of 6.5 in. A numeric keypad is overlaid on the model, and a "Delete Dimension" dialog box is visible. A smartphone in the foreground displays a 3D assembly model titled "Bevel Gear Assembly" with a time of 3:17.

# 3D printing is available in many locations

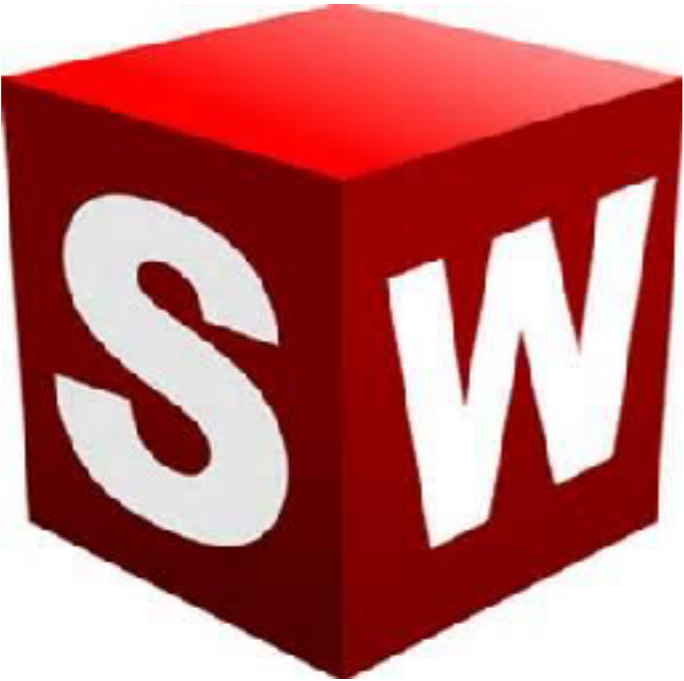
- Hackerspaces
- Libraries
- Campus
- Online Services



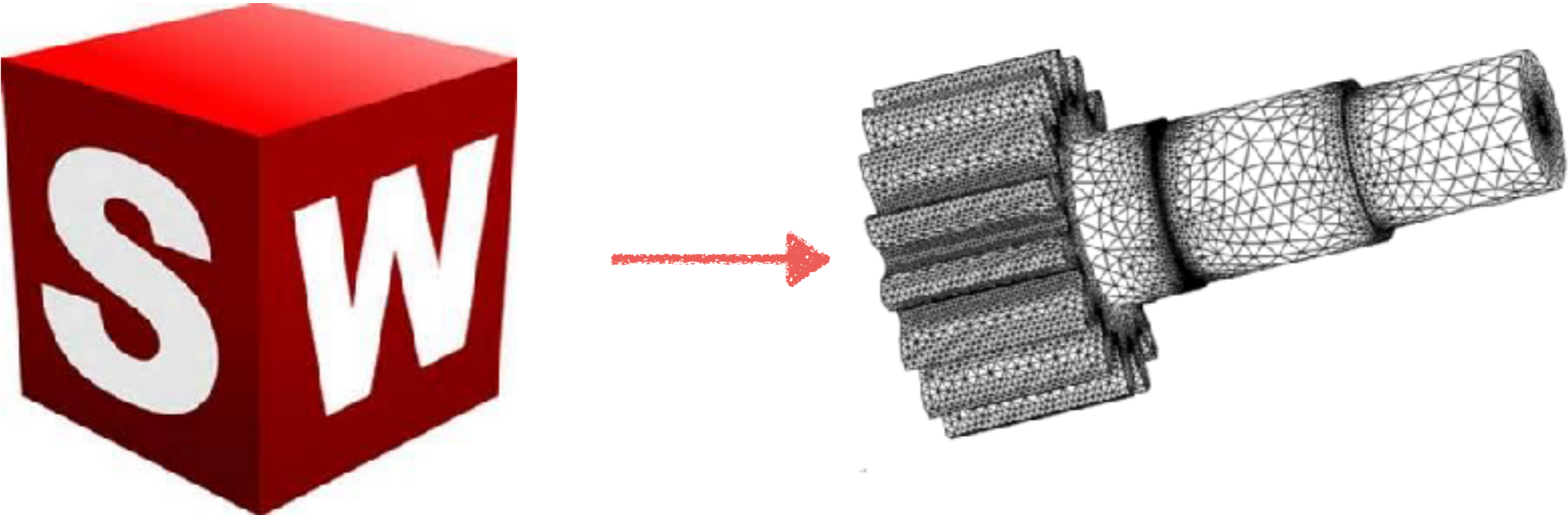
# Prints can go horribly wrong if you just send any design



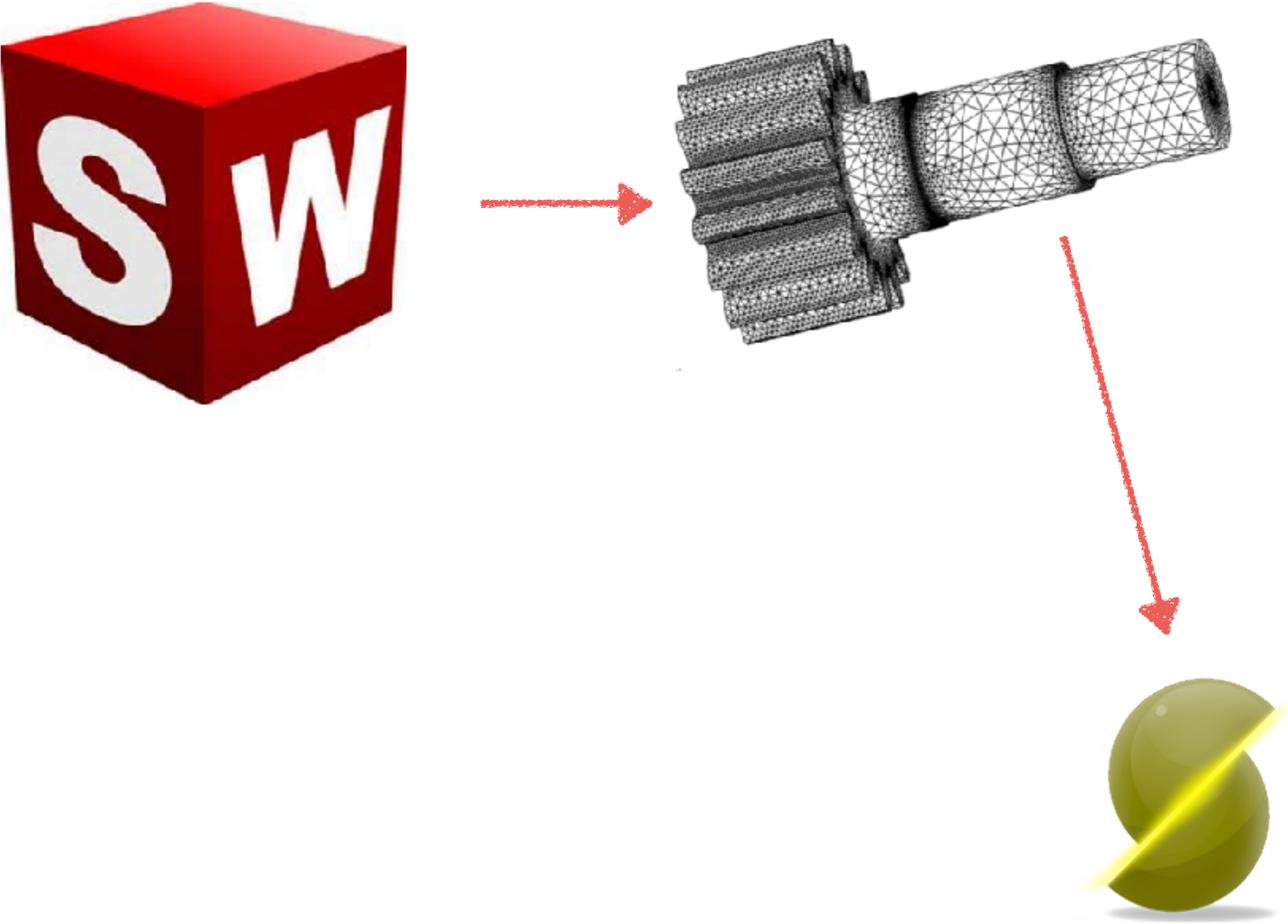
# Understanding the 3D printing toolchain will help you understand its strengths and limitations



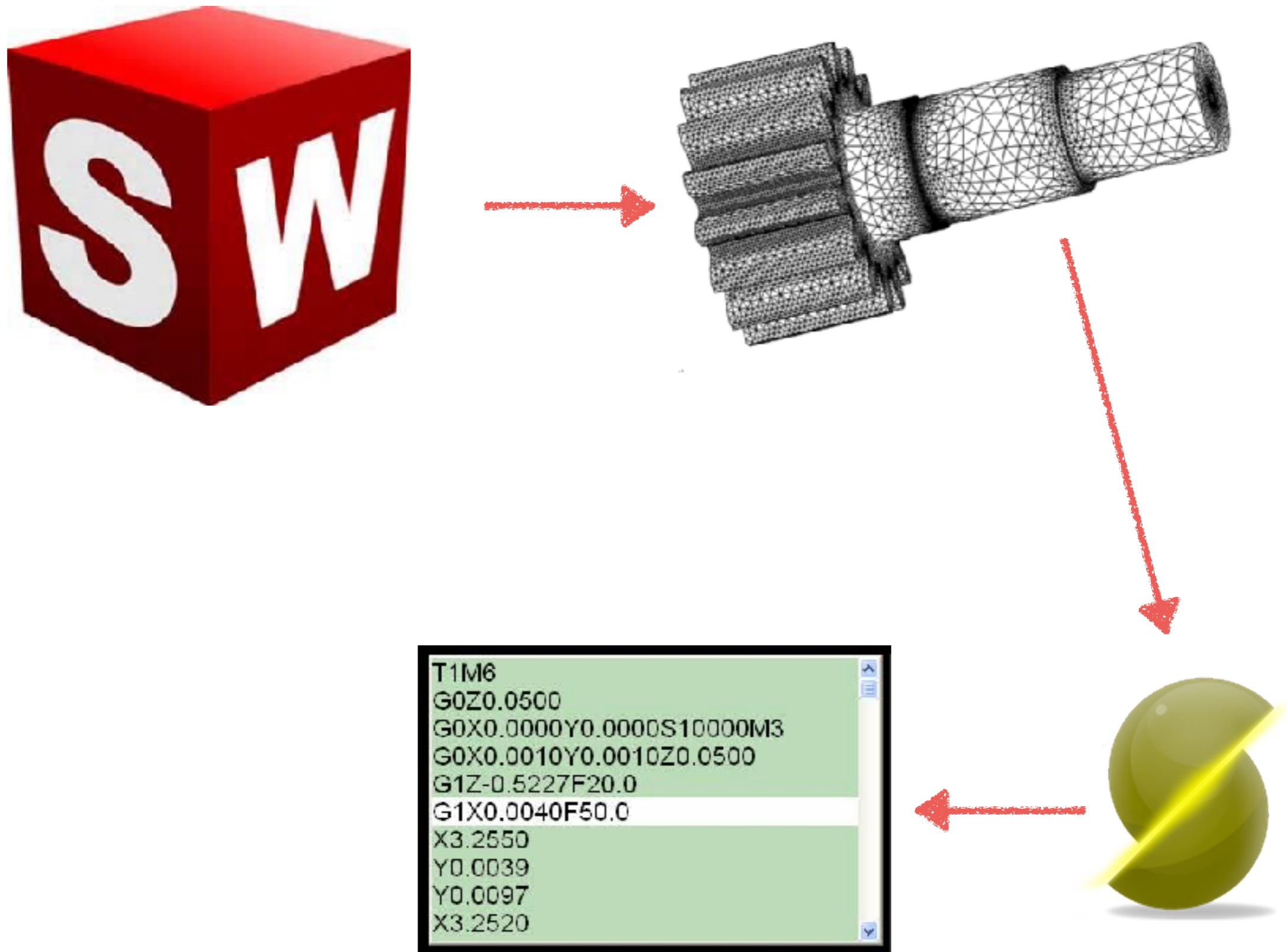
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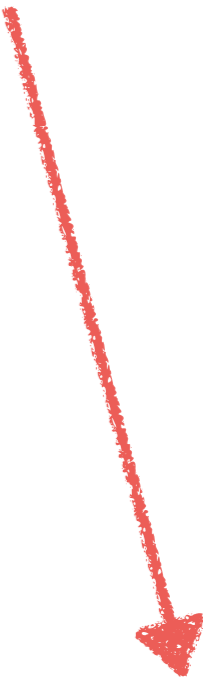
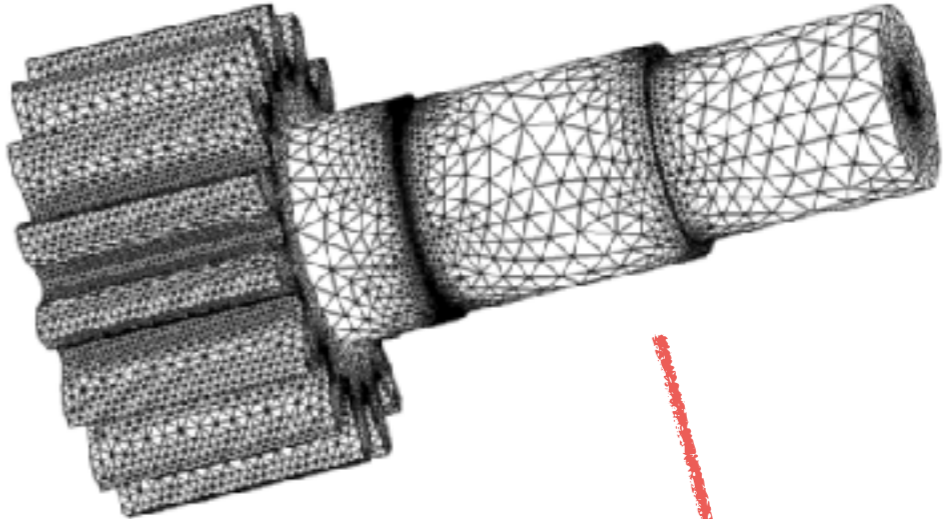
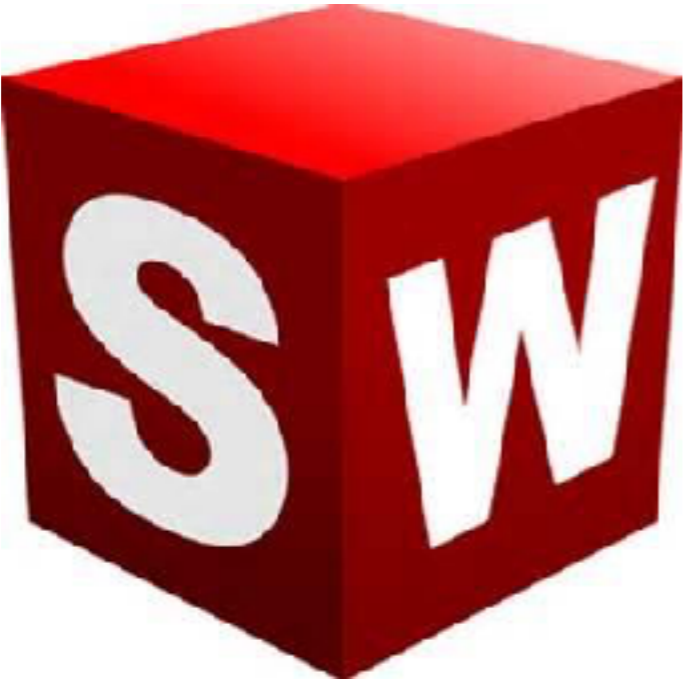
# Understanding the 3D printing toolchain will help you understand its strengths and limitations



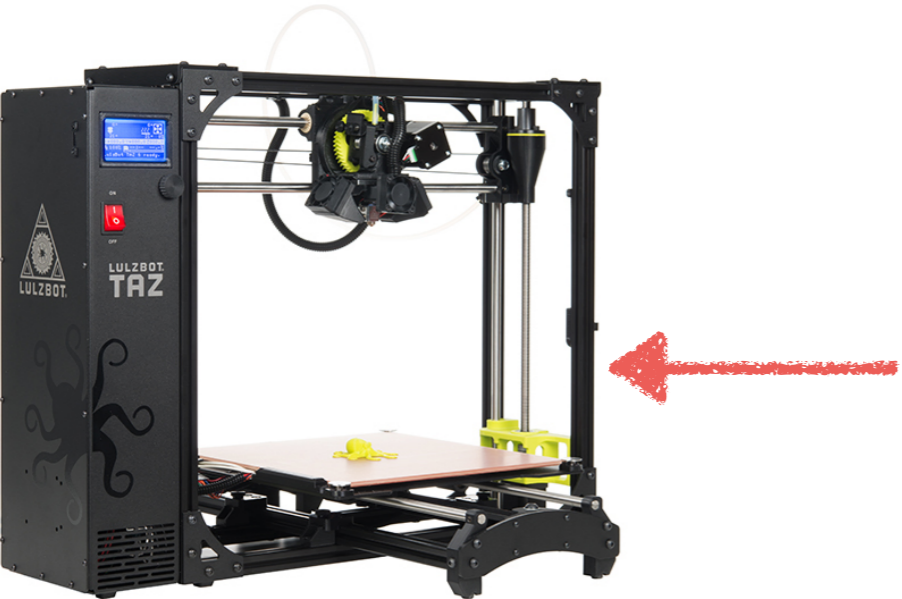
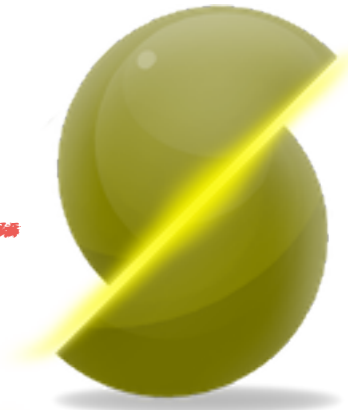
```
T1M6
G0Z0.0500
G0X0.0000Y0.0000S10000M3
G0X0.0010Y0.0010Z0.0500
G1Z-0.5227F20.0
G1X0.0040F50.0
X3.2550
Y0.0039
Y0.0097
X3.2520
```



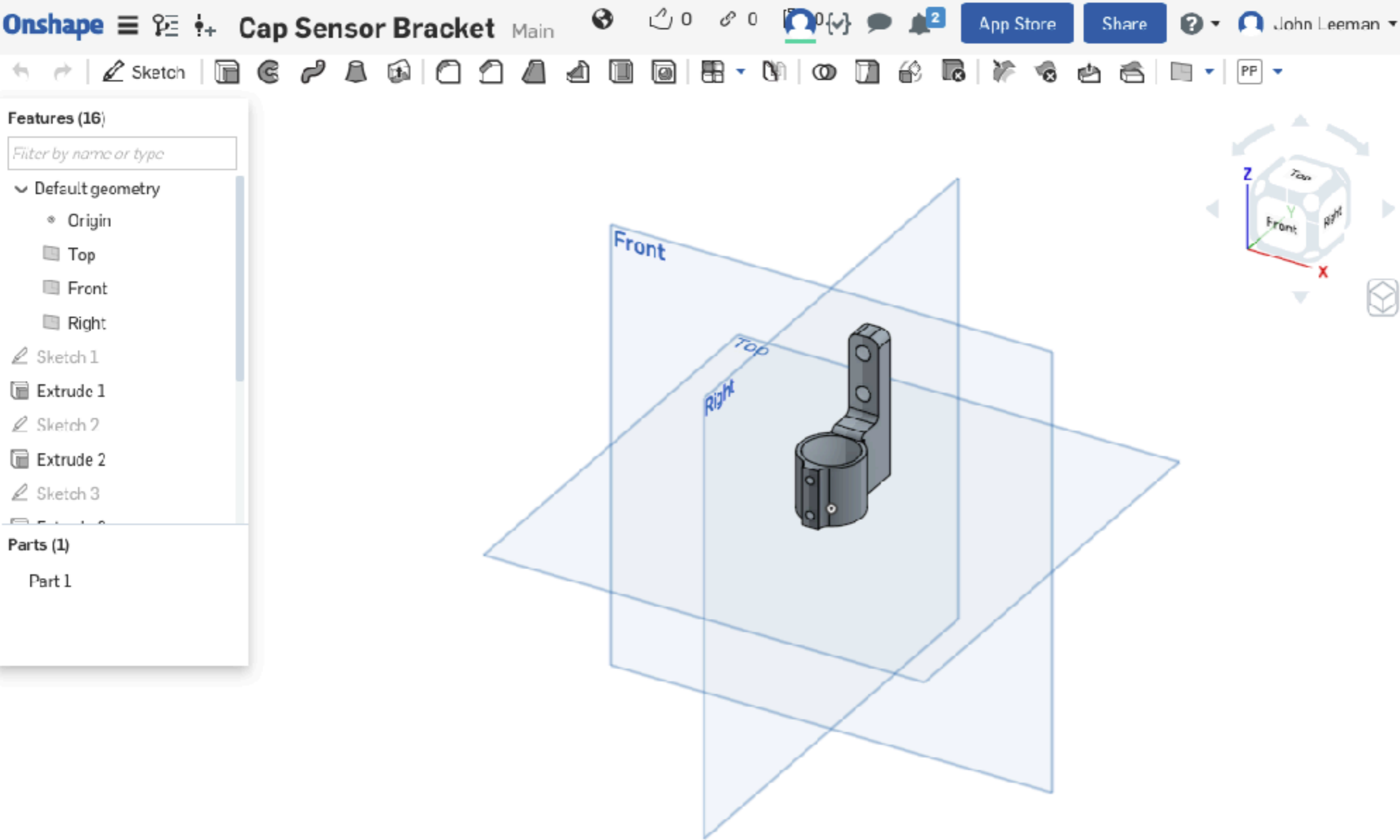
# Understanding the 3D printing toolchain will help you understand its strengths and limitations



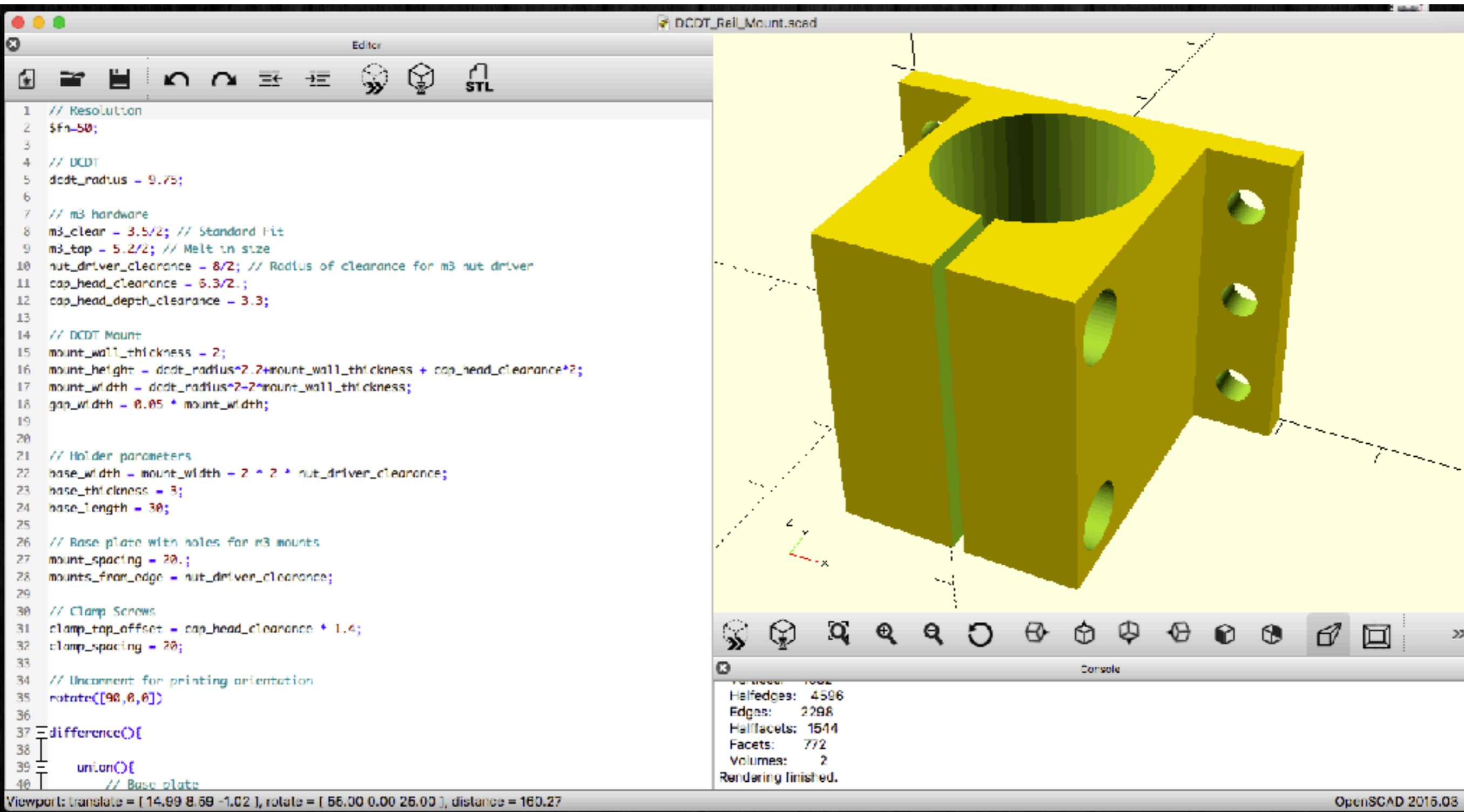
```
T1M6  
G0Z0.0500  
G0X0.0000Y0.0000S10000M3  
G0X0.0010Y0.0010Z0.0500  
G1Z-0.5227F20.0  
G1X0.0040F50.0  
X3.2550  
Y0.0039  
Y0.0097  
X3.2520
```



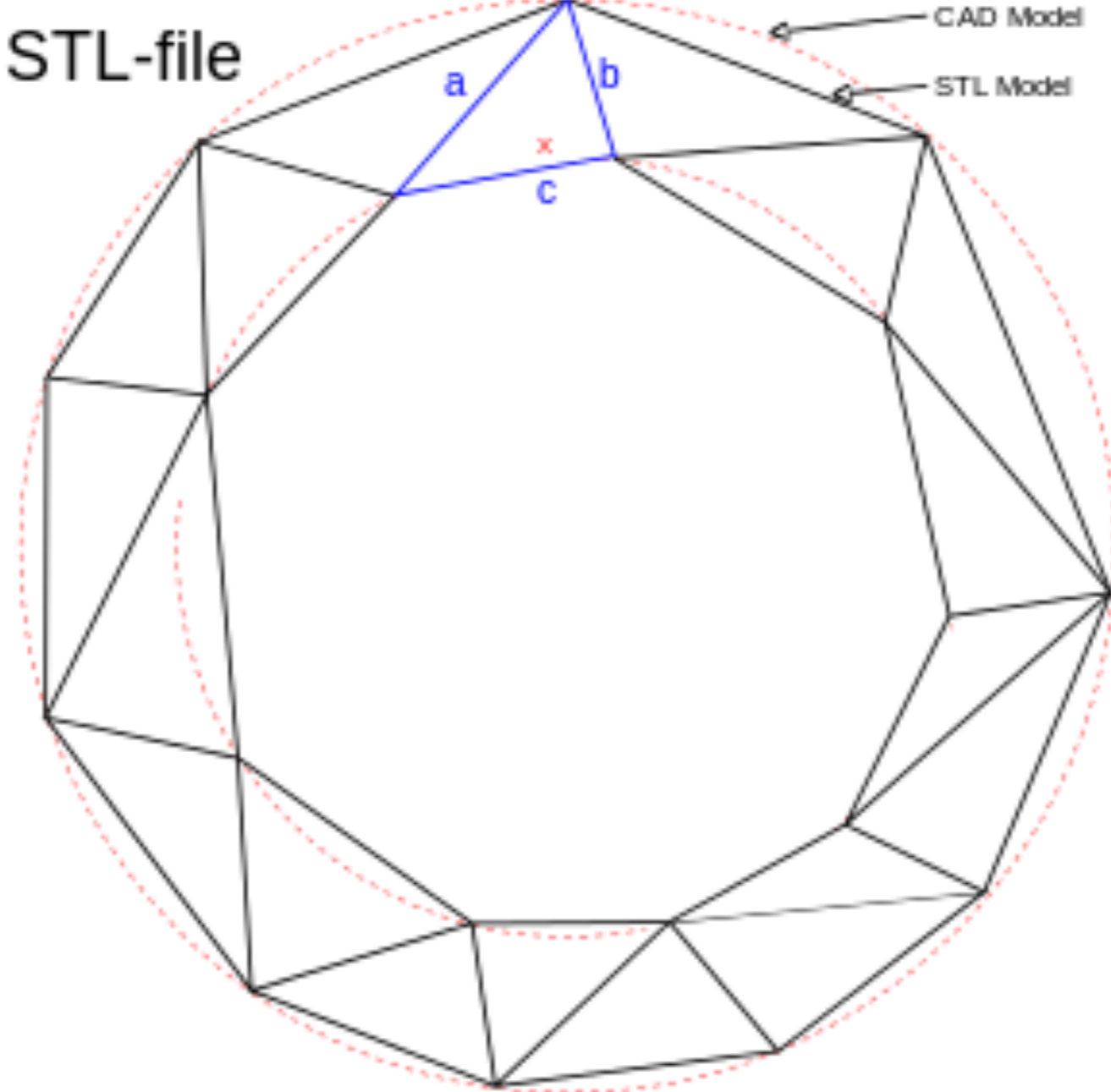
# The design starts in a CAD tool



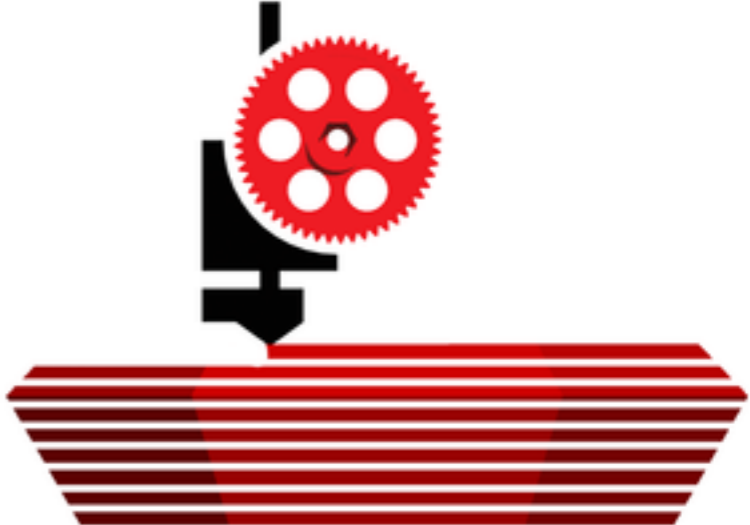
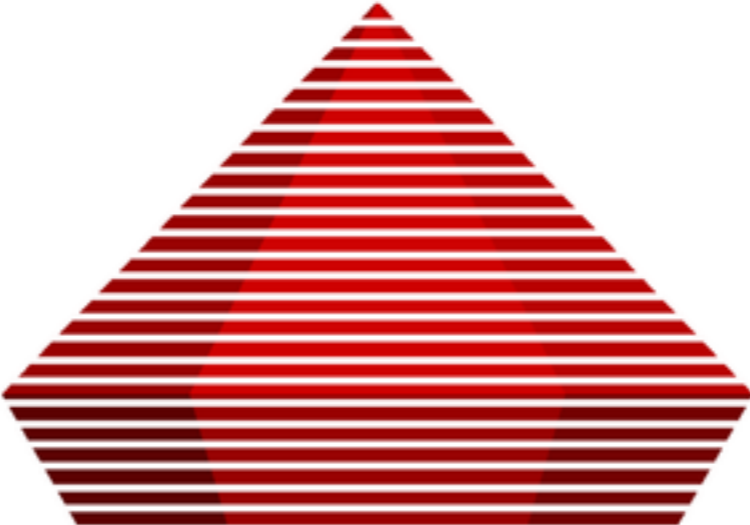
# The design starts in a CAD tool



# The design is then exported, generally to a STL file



**We then slice the file to generate fills, rafts, etc.**



# GCODE generated by the slicer is then sent to the printer

```
1 | generated by Slic3r 1.0.1 on 2014-08-25 at 19:03:28
2
3 | ; layer_height = 0.22
4 | ; perimeters = 2
5 | ; top_solid_layers = 3
6 | ; bottom_solid_layers = 3
7 | ; fill_density = 0.5
8 | ; perimeter_speed = 100
9 | ; infill_speed = 115
10 | ; travel_speed = 180
11 | ; nozzle_diameter = 0.35
12 | ; filament_diameter = 2.89
13 | ; extrusion_multiplier = 1
14 | ; perimeters extrusion width = 0.35mm
15 | ; infill extrusion width = 0.46mm
16 | ; solid infill extrusion width = 0.46mm
17 | ; top infill extrusion width = 0.46mm
18 | ; first layer extrusion width = 0.70mm
19
20 G21 ; set units to millimeters
21 M107
22 G28 ; home all axes
23 M203 X192 Y208 Z3 ; Speed limits to minimize skipped steps when moving really fast courtesy of forum.lulzbot.com user 1013
24 G90 ; use absolute coordinates
25 G92 E0
26 M82 ; use absolute distances for extrusion
27 G1 F1800.000 E-2.00000
28 G92 E0
29 G1 Z0.350 F10800.000
30 G1 X110.380 Y86.290 F10800.000
31 G1 E2.00000 F1800.000
32 G1 X111.300 Y85.380 E2.04314 F1800.000
33 G1 X112.370 Y84.660 E2.08615
34 G1 X113.570 Y84.160 E2.12949
35 G1 X114.840 Y83.910 E2.17265
36 G1 X144.840 Y80.910 E3.17788
37 G1 X145.500 Y80.880 E3.19991
38 G1 X152.500 Y80.880 E3.43330
39 G1 X153.160 Y80.910 E3.45533
40 G1 X183.160 Y83.910 E4.46056
41 G1 X184.430 Y84.160 E4.50372
42 G1 X185.630 Y84.660 E4.54706
43 G1 X186.700 Y85.380 E4.59006
44 G1 X187.620 Y86.290 E4.63321
45 G1 X189.240 Y87.290 E4.67640
```

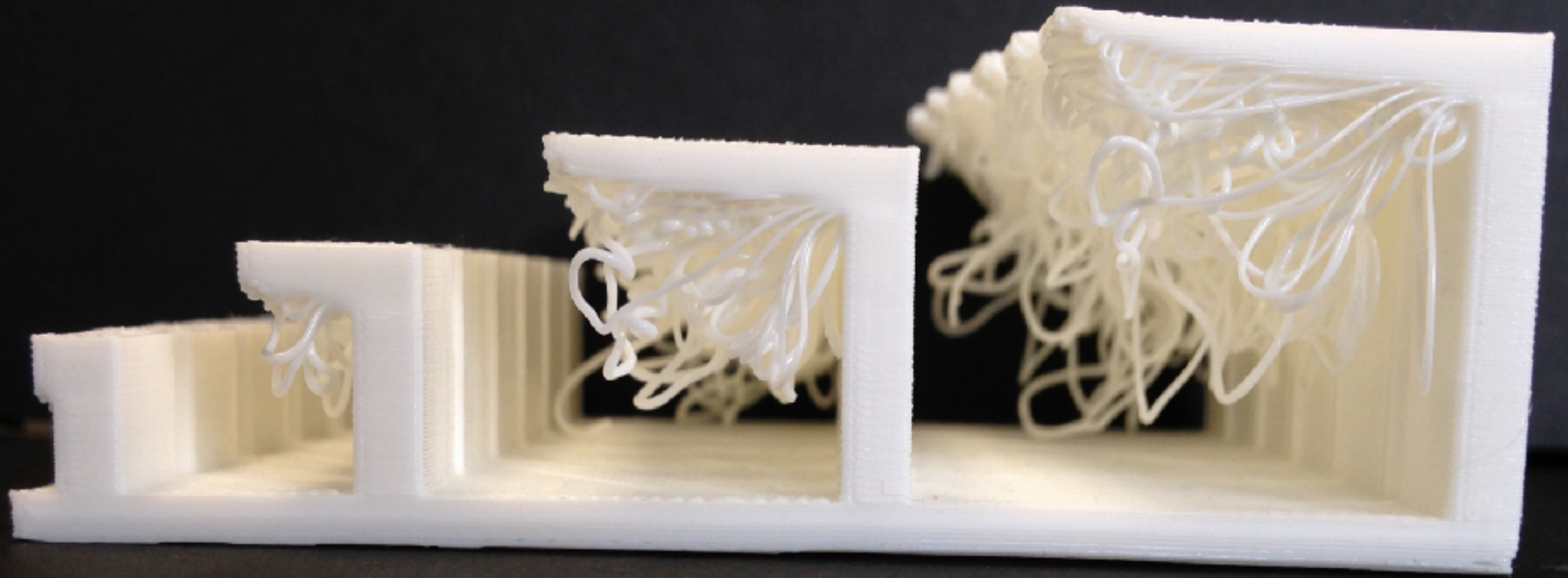
# There is a limit to the bridging distance



Clockwise from top left

$\leq 36\text{mm}$  – 0-0.5mm drooping, 36-60mm – 0.5-2mm drooping,  $\geq 60\text{mm}$  – 2-5mm drooping

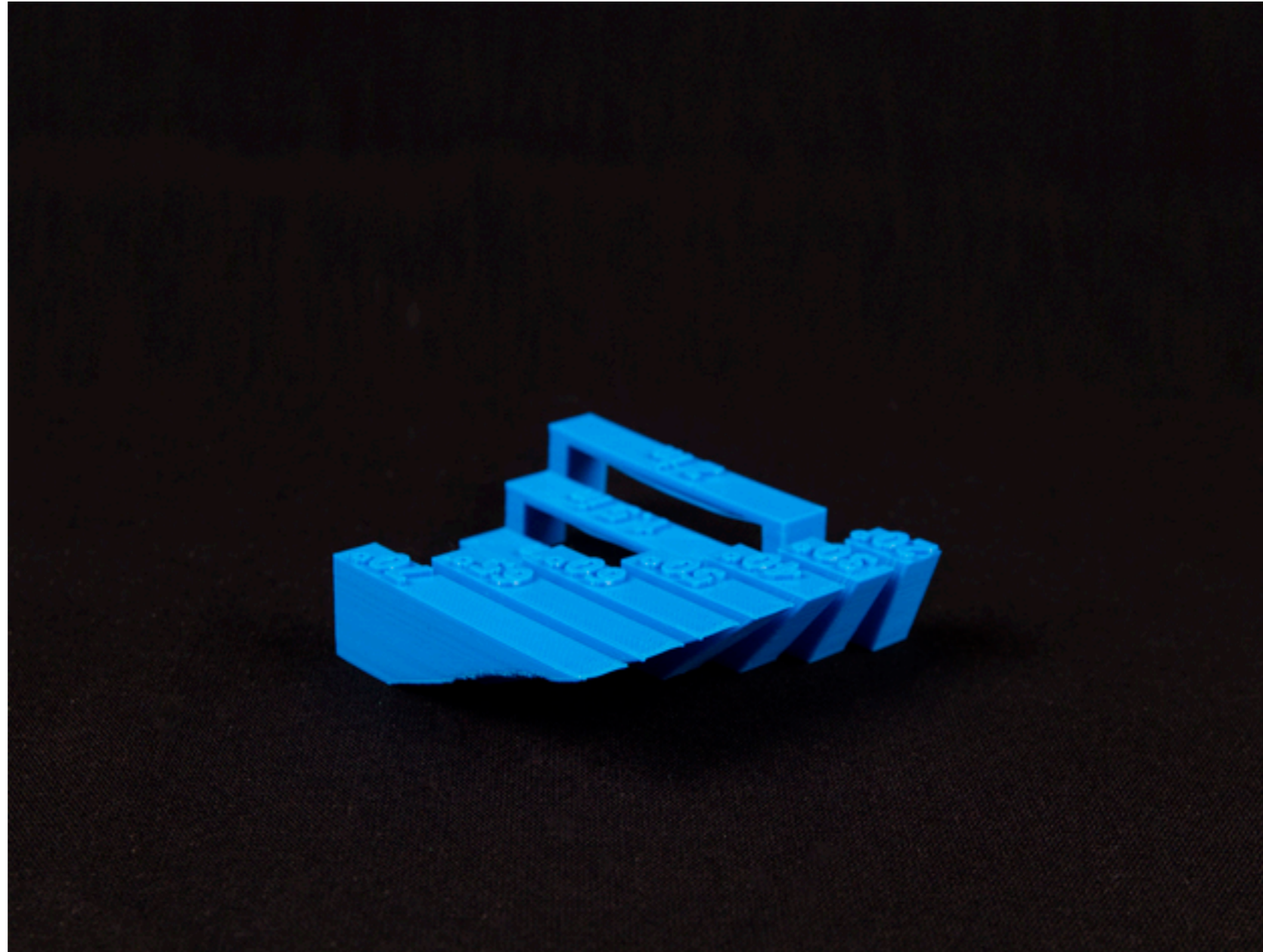
**Overhangs should be limited to less than 45 degrees**



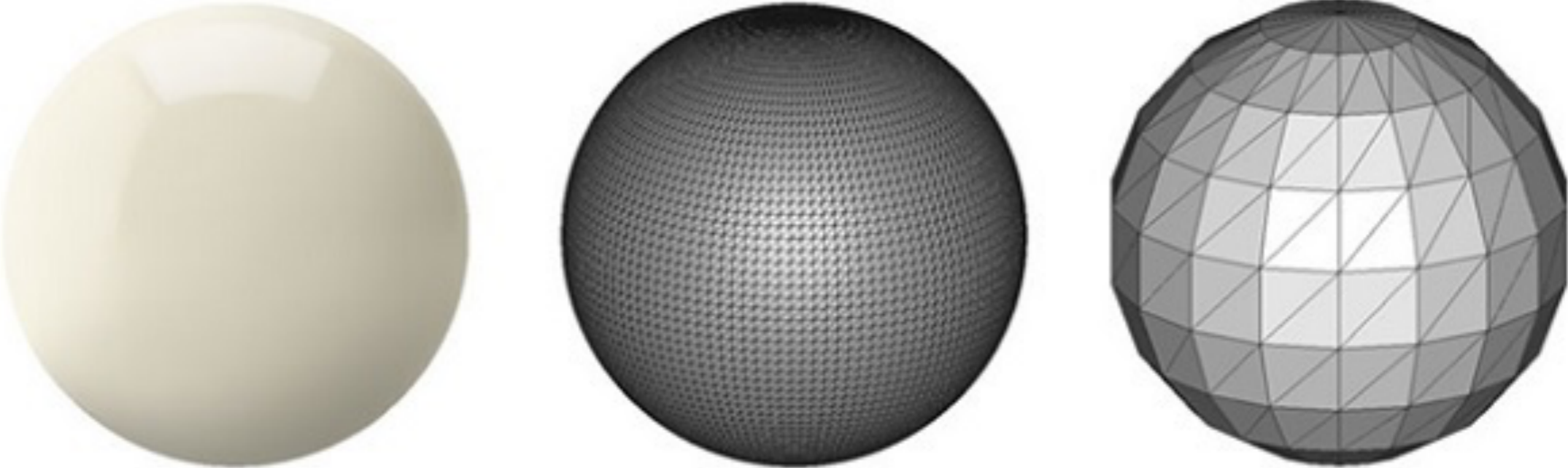
**Failed Horizontal Overhangs**



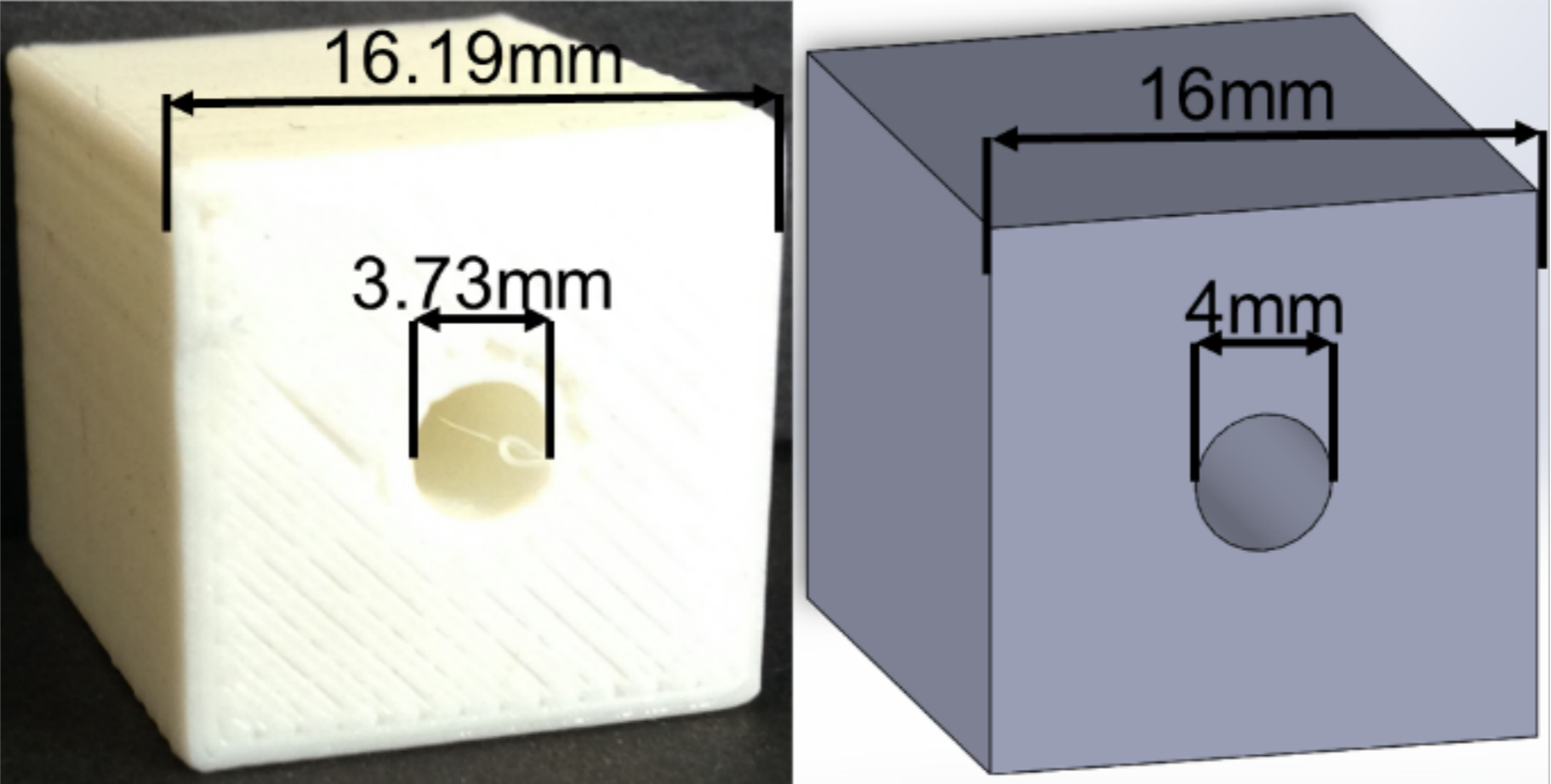
**Do a variety of test prints to help you understand a printer's capabilities or ask the service provider**



# Make sure you export the file at a high enough resolution



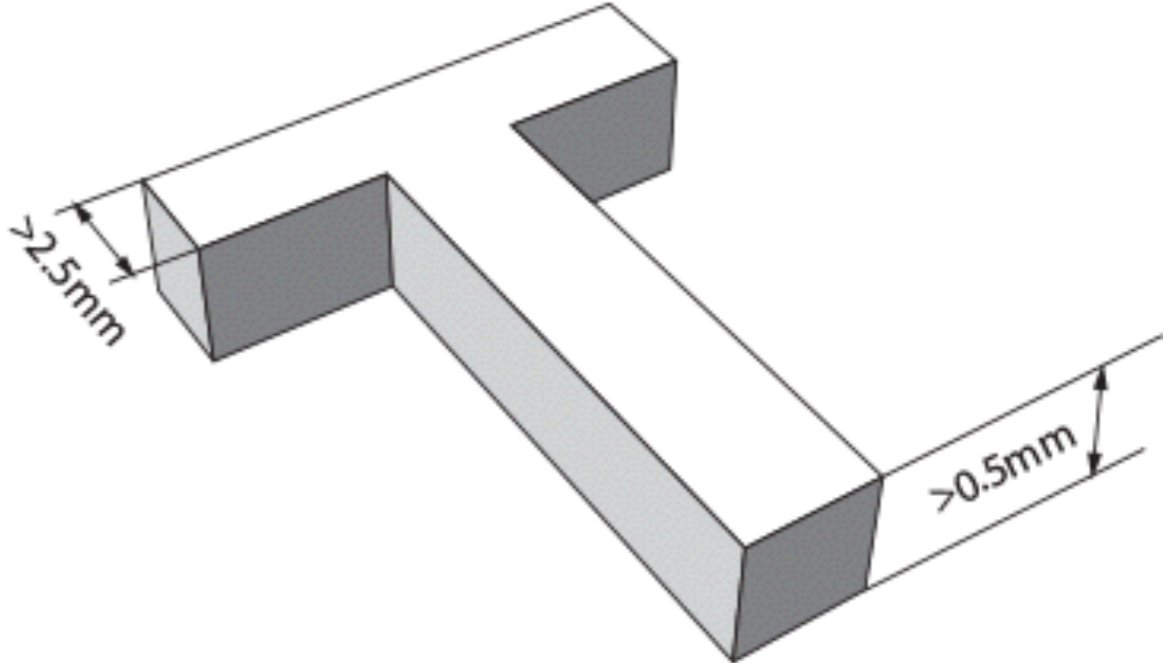
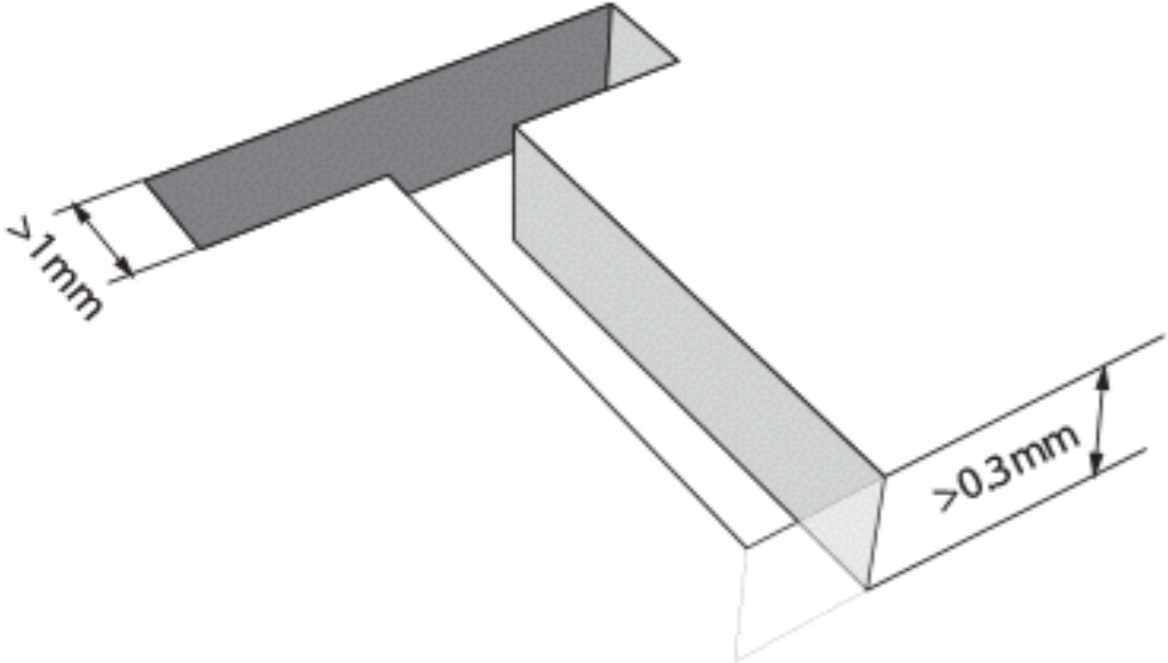
# You will likely need to account for machine and thermal accuracy



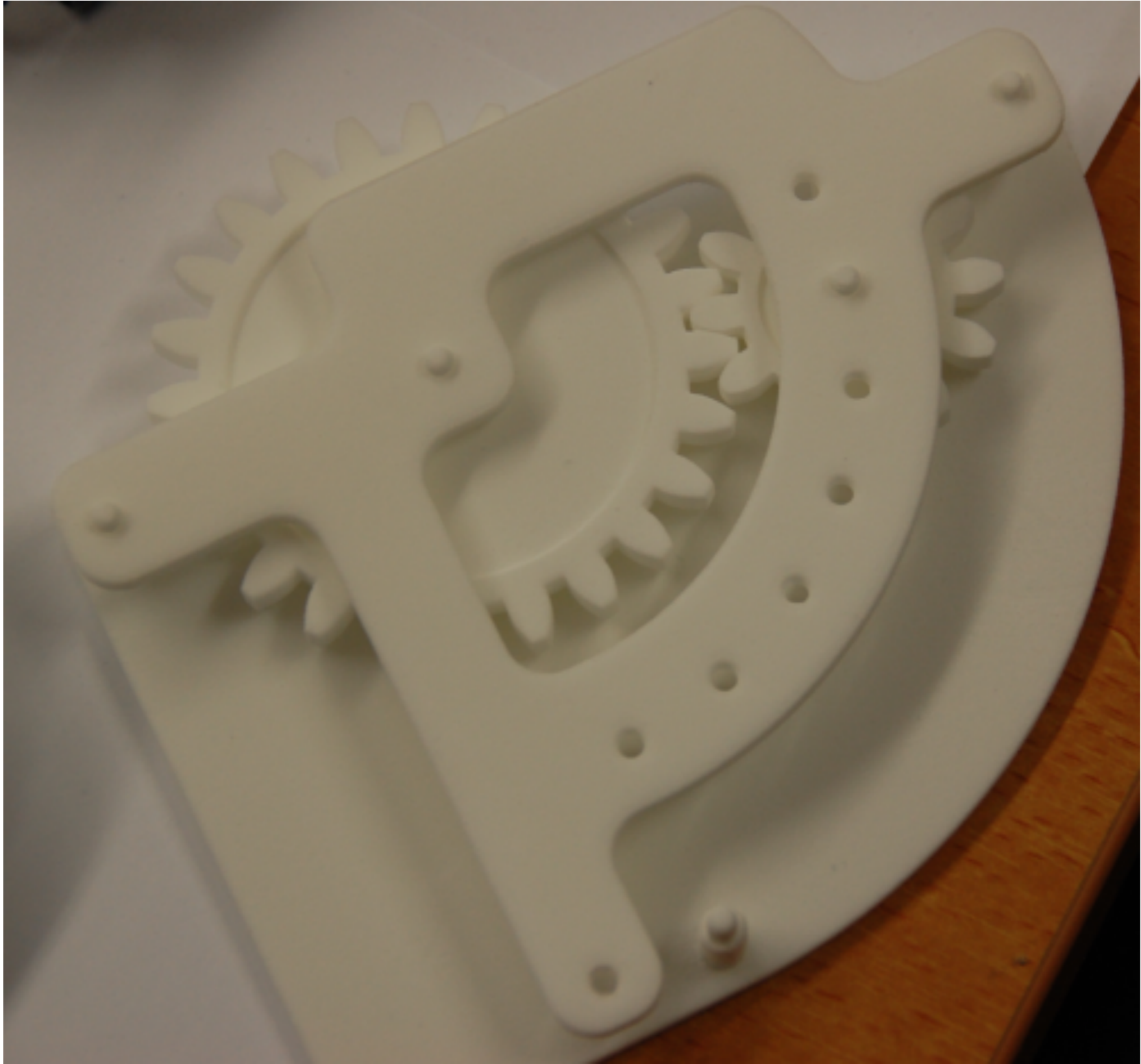
# It is easy to make something impossible to machine



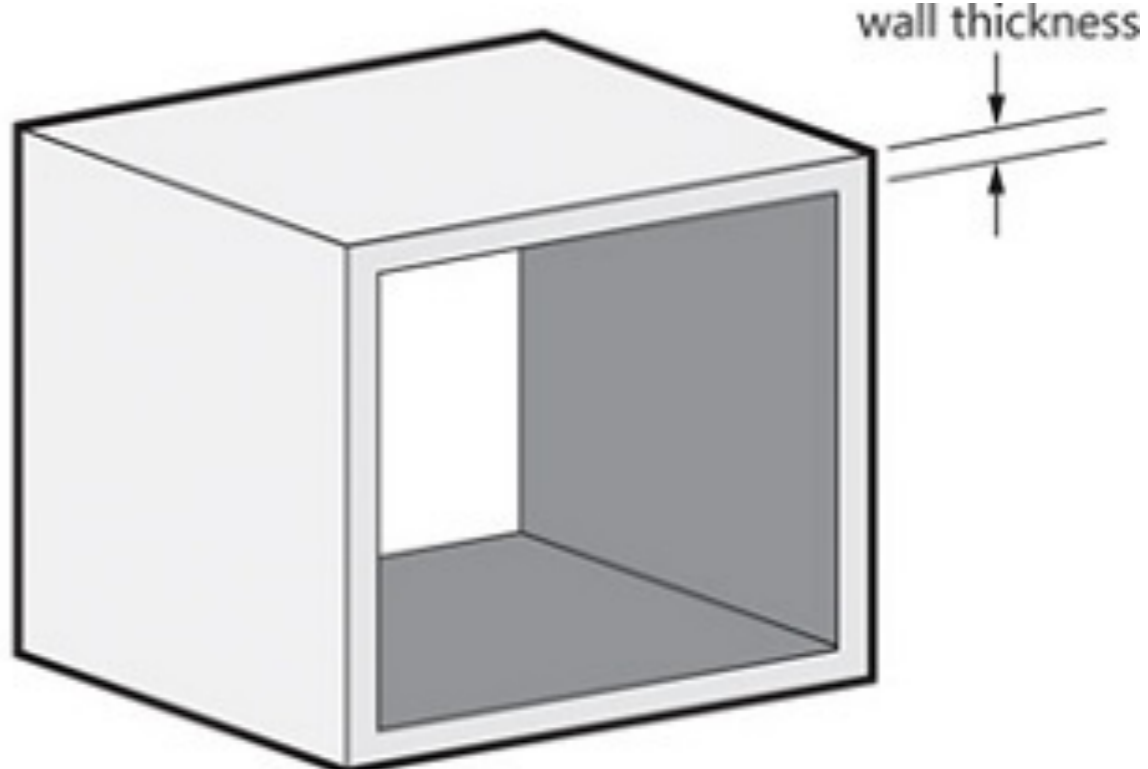
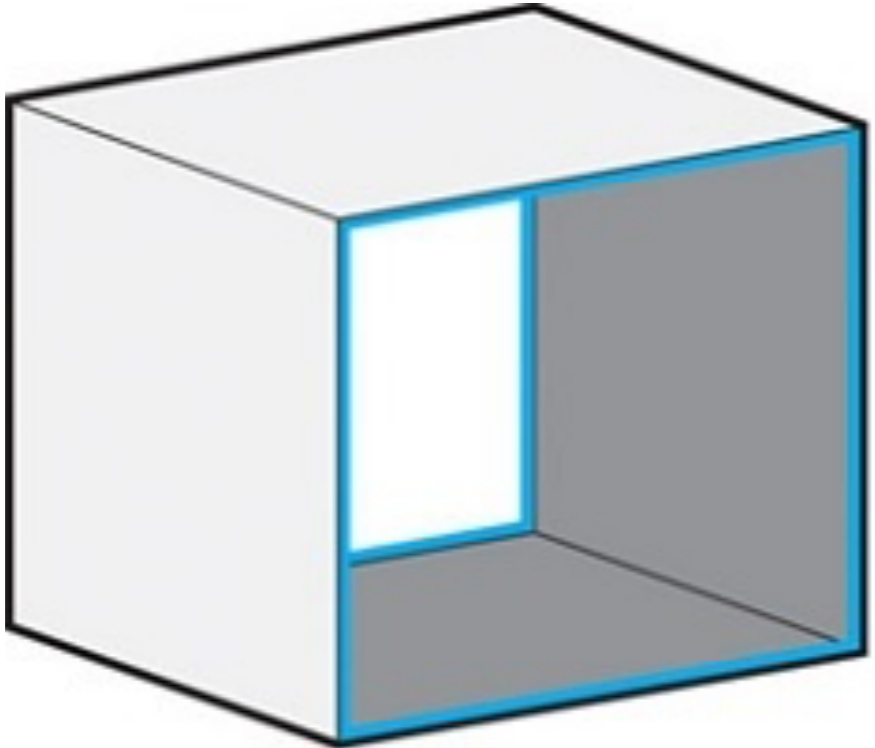
# Use recessed text (engraved) when possible



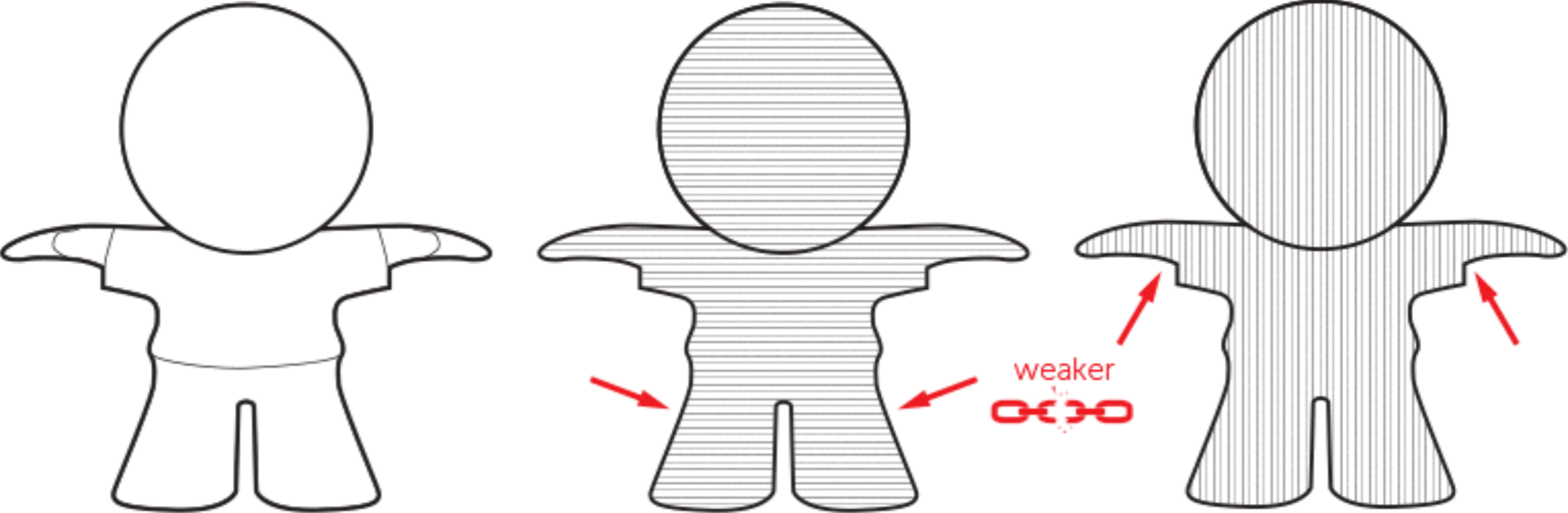
# Add design clearance for interlocking parts



# Make sure that you use appropriate wall thickness



# The strength of 3D prints is anisotropic





# There are a number of places to get 3D models online

- <http://www.mcmaster.com>
- <https://grabcad.com>
- <http://www.thingiverse.com>
- <https://nasa3d.arc.nasa.gov>
- And many more!

# Commercial 3D Design Software

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## 3D Studio Max

An extensive suite of 3D design tools, with a unique and intuitive interface.

Windows



## AutoCAD

An advanced design and documentation tool. Ideal for architects and design engineers.

Windows, Mac



## Cinema 4D

A well known design Suite in the VFX community, it has great tools for 3D modeling for printing as well.

Windows, Mac



## Lightwave 3D

A classic 3D graphic software, which includes powerful rendering, animation and modeling tools.

Windows, Mac



## Autodesk Maya

A massive, complete suite of tools for professional all aspects of 3D design including modeling, rigging, dynamics and animation.

Windows, Mac



## Photoshop CC

The Industry standard software for 2D content editing and creation applied to 3D design. Offers integration directly with Shapeways.

[Learn how Photoshop and Shapeways work together](#)

Windows, Mac



## RhinoCeros

Very popular curve based modelling software.

Windows, Mac



## ZBrush

A popular, advanced 3D sculpting tool with a powerful voxel-based system.

Windows, Mac



## Solidworks

An advanced modeling tool that is great for mechanical, precise product design.

[Learn how Solidworks and Shapeways work together](#)

Windows, Mac

# Free 3D Design Software



## AUTODESK 123D

### Autodesk 123D Design

Easy-to-use yet powerful modeling tool with library of existing components or the ability to create from scratch. Also available for the iPad. Integrated and prints directly to Shapeways.

[Learn how 123D Design and Shapeways work together](#)

Windows, Mac, Online Service



### Tinkercad

A fantastic beginner program, that leads you to learn complex things through simple quests. Runs right in your browser, and the skills you learn are easily transferable to more advanced programs. Integrated and prints directly to Shapeways!

[Learn how Tinkercad and Shapeways work together](#)

Online Service



### 3D Tin

Another browser based program using WebGL, this is free as long as you share your designs under Creative Commons.

Online Service



### Blender

A powerful application with full-fledged professional tools, Blender has a wide community and resources to help you learn.

[Learn how Blender and Shapeways work together](#)

Windows, Mac, Linux



### FreeCAD

An open source parametric 3D modeler, great for both the home user, hobbyist and experienced designer. Parametric modeling allows for easy editing of your design.

Windows, Mac, Linux



### Open SCAD

OpenSCAD is not an interactive 3D design tool. It is something like a programmatic 3D-compiler that reads a script file containing 3D geometry definitions, and in turn generates a solid 3D model as output.

Windows, Mac, Linux, BSD



### Sculptris

A free, introductory digital sculpting tool, a great stepping stone for digital sculptors, created by the makers of Zbrush.

Windows, Mac



### Sketchup

Drawing-based tool for architects, designers, builders, makers and engineers who design for the physical world. SketchUp Make is a free version and SketchUp Pro is a paid version with additional functionality.

Windows, Mac



### 3D Model To Print

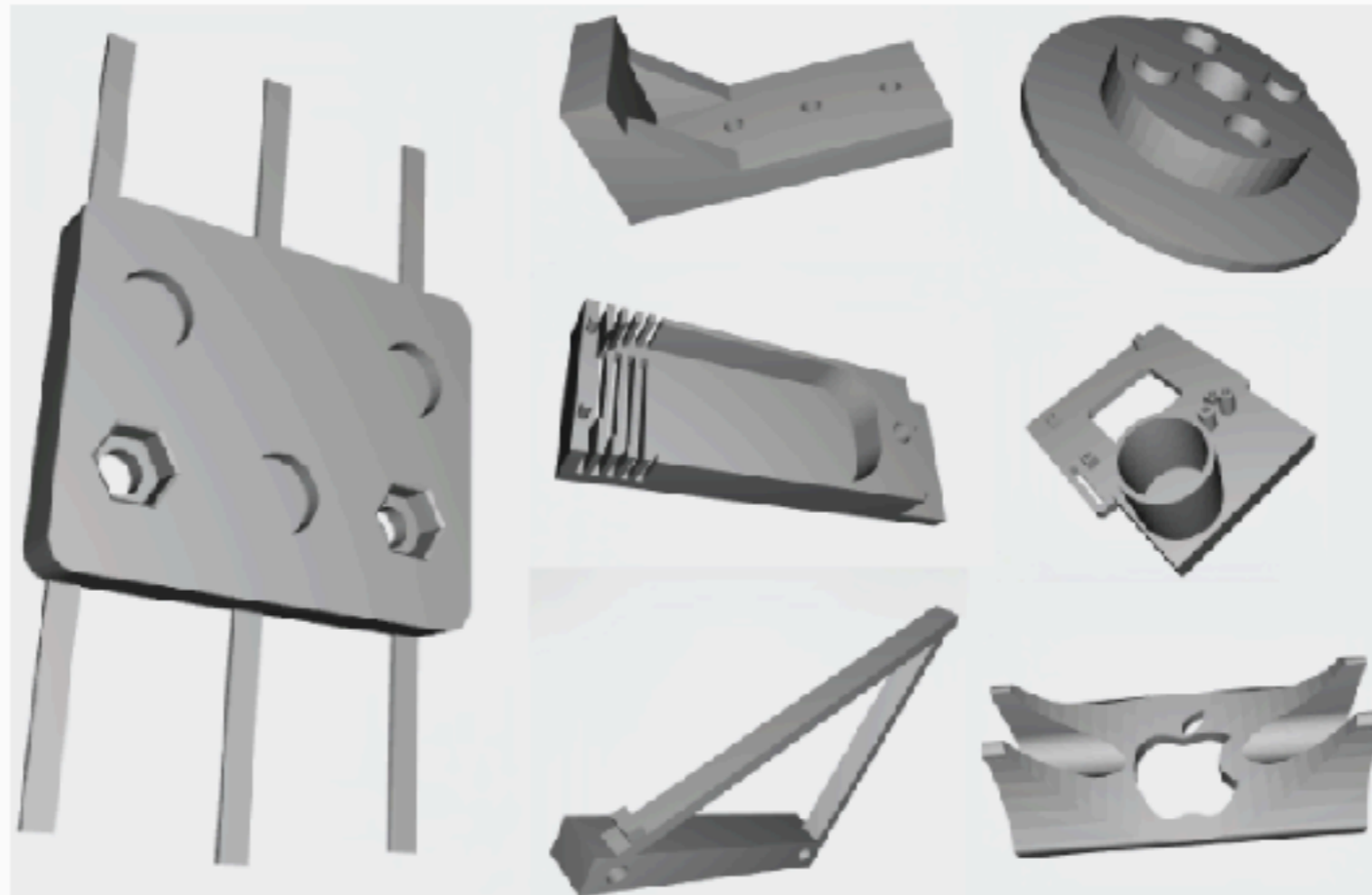
A cloud-based software service, focused on 3D architectural models. 3DMTP automatically and efficiently transforms 3D designs into scalable and 3D printable model files.

Online Service

# Assignment: 3D Printing Activity

In this activity you will design and print a 3D part. You may take an existing CAD file from a repository such as [Thingiverse](#), [GrabCAD](#), etc. and modify it to suit your purpose (must be a non-trivial change) or create your own design. You can make your design in your preferred CAD tool, a few great choices are [OnShape](#), [OpenSCAD](#), [FreeCAD](#), [AutoDeskInventor](#), and [SketchUp](#). These can be simple brackets and parts or very complex structures. Be sure to make something that actually can be 3D printed though - remember the design concerns we discussed in class. A few examples of CAD files designed for 3D printing are shown below.

Many universities, public libraries, and maker spaces have 3D printers that you can use for little or no cost. Penn State operates the [Maker Commons](#) as a part of the library that allows students to print. There are also commercial service bureaus that will make your print on professional grade machines and ship it to your door. Of these, [Shapeways](#) seems to have the largest variety of materials and services. Often service bureaus and library services can get very busy, so make sure you allow enough time for manufacturing and shipping!



**DUE: 10/13/16**

# Activity: Designing Parts in OnShape

The image shows the OnShape website's sign-up page. At the top right, there are links for 'CREATE ACCOUNT' and 'SIGN IN'. The OnShape logo is on the left. The main heading reads 'THE LEADING CAD PLATFORM FOR AGILE PRODUCT DESIGN'. Below this, a paragraph describes OnShape as a full-cloud CAD system. A yellow 'CREATE ACCOUNT' button is prominent. A link for 'Engineering Executives' is also present. The bottom half of the image features a tablet and a smartphone displaying the OnShape CAD interface. The tablet screen shows a 'Cylinder Shell' part with a feature tree on the left and a numeric keypad overlay. The smartphone screen shows a 'Bevel Gear Assembly' with a 3D model of the assembly.

**Onshape**

CREATE ACCOUNT or SIGN IN

CAD LEARN CUSTOMERS PARTNERS COMMUNITY ABOUT BLOG

## THE LEADING CAD PLATFORM FOR AGILE PRODUCT DESIGN

Onshape is a full-cloud CAD system that's perfect for agile product design. Unlike installed CAD and PDM, Onshape gives everyone on the team instant access to the same CAD system and same CAD data.

[LEARN MORE ABOUT FULL CLOUD CAD](#)

CREATE ACCOUNT

[Are you an Engineering Executive? Click Here >>](#)

Cylinder Shell - Main

Features (202)

- Ext Profile S...
- Ext Profile
- Sketch 2
- Sketch 3
- Revolve 3
- Hole Sketch 1
- Sketch 5
- Revolve 4

Parts (1)

- Cylinder Shell

6.5 in

7 8 9

4 6

1 2 3

0 +/-

Delete Dimension

Bevel Gear Assembly

3:17

Front