EXP 12: 3D Printing and Rapid Prototyping

Abstract

In this experiment, you will learn the principles of 3D printing. You will learn how to use SketchUp 3D modeling software to make 3D models. You will learn the different steps in the process in 3D printing.

Introduction and Theory

What is 3D printing?

3D printing or additive manufacturing is a process of making a three-dimensional solid object of virtually any shape from a digital model. 3D printing is achieved using an *additive process*, where successive layers of material are laid down in different shapes. 3D printing is also considered distinct from traditional machining techniques, which mostly rely on the removal of material by methods such as cutting or drilling (*subtractive* processes).

A 3D printer is a limited type of industrial robot that is capable of carrying out an additive process under computer control.

The 3D printing technology is used for both prototyping and distributed manufacturing with applications in architecture, construction (AEC), industrial design, automotive, aerospace, military, engineering, dental and medical industries, biotech (human tissue replacement), fashion, footwear, jewelry, eyewear, education, geographic information systems, food, and many other fields. One study has found that open source 3D printing could become a mass-market item because domestic 3D printers can offset their capital costs by enabling consumers to avoid costs associated with purchasing common household objects.

Technologies used in 3D printing

1. Fused Deposition Modeling (FDM):

   The model or part is produced by extruding small beads of thermoplastic material to form layers as the material hardens immediately after extrusion from the nozzle. A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off. There is typically a worm-drive that pushes the filament into the nozzle at a controlled rate.

   The nozzle is heated to melt the material. The thermoplastics are heated past their glass transition temperature and are then deposited by an extrusion head.

The nozzle can be moved in both horizontal and vertical directions by a numerically controlled mechanism. The nozzle follows a tool-path controlled by a computer-aided manufacturing (CAM) software package, and the part is built from the bottom up, one layer at a time. Stepper motors or servomotors are typically employed to move the extrusion head. The mechanism used is often an X-Y-Z rectilinear design.

Although as a printing technology FDM is very flexible, and it is capable of dealing with small overhangs by the support from lower layers, FDM generally has some restrictions on the slope of the overhang, and cannot produce unsupported stalactites.

Myriad materials are available, such as ABS, PLA, polycarbonate, polyamides, polystyrene, lignin, among many others, with different trade-offs between strength and temperature properties.

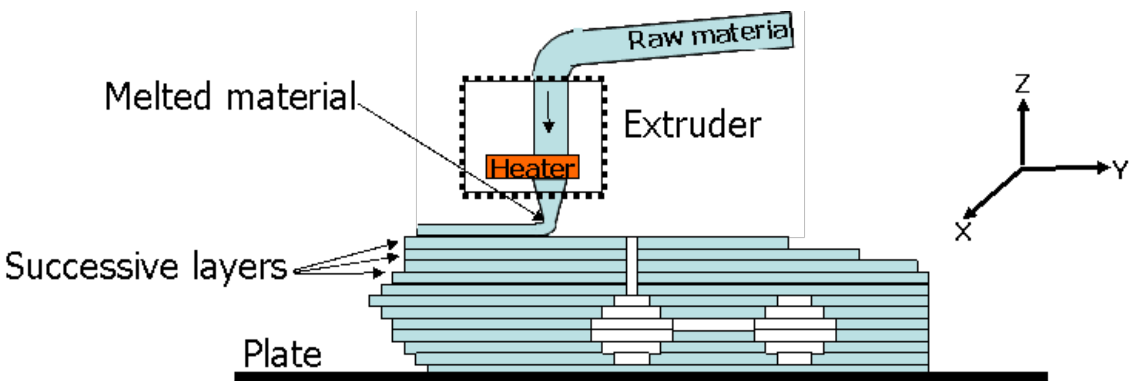


Figure 1: FMD Process

2. Stereolithography:

    Stereolithography is an additive manufacturing process which employs a vat of liquid ultraviolet curable photopolymer "resin" and an ultraviolet laser to build parts' layers one at a time. For each layer, the laser beam traces a cross-section of the part pattern on the surface of the liquid resin. Exposure to the ultraviolet laser light cures and solidifies the pattern traced on the resin and joins it to the layer below.

    After the pattern has been traced, the SLA's elevator platform descends by a distance equal to the thickness of a single layer, typically 0.05 mm to 0.15 mm (0.002" to 0.006"). Then, a resin-filled blade sweeps across the cross section of the part, re-coating it with fresh material. On this new liquid surface, the subsequent layer pattern is traced, joining the previous layer. A complete 3-D part is formed by this process. After being built, parts are immersed in a chemical bath in order to be cleaned of excess resin and are subsequently cured in an ultraviolet oven.

Stereolithography requires the use of supporting structures which serve to attach the part to the elevator platform, prevent deflection due to gravity and hold the cross sections in place so that they resist lateral pressure from the re-coater blade. Supports are generated automatically during the preparation of 3D Computer Aided Design models for use on the stereolithography machine, although they may be manipulated manually. Supports must be removed from the finished product manually, unlike in other, less costly, rapid prototyping technologies.

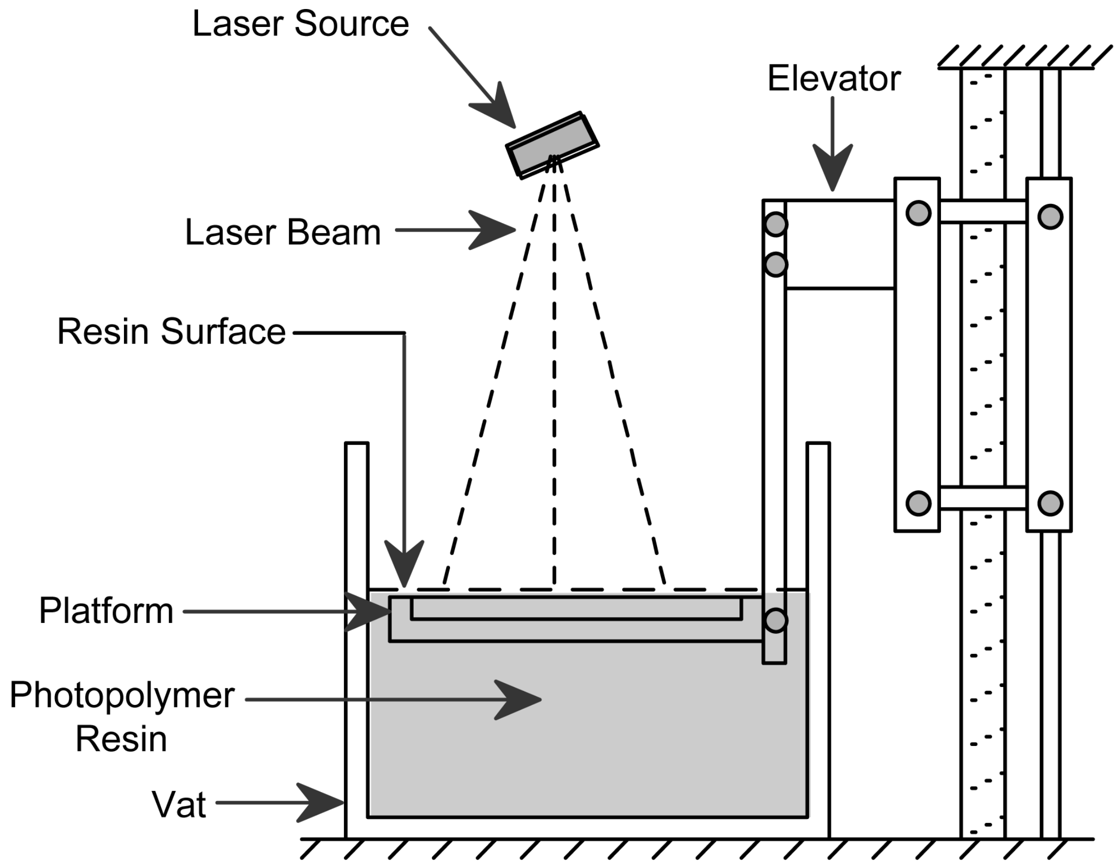


Figure 2

3. Selective laser sintering:

An additive manufacturing layer technology, SLS involves the use of a high power laser (for example, a carbon dioxide laser) to fuse small particles of plastic, metal(direct metal laser sintering), ceramic, or glass powders into a mass that has a desired three-dimensional shape. The laser selectively fuses powdered material by scanning cross-sections generated from a 3-D digital description of the part (for example from a CAD file or scan data) on the surface of a powder bed. After each cross-section is scanned, the powder bed is lowered by one layer thickness, a new layer of material is applied on top, and the process is repeated until the part is completed.

Because finished part density depends on peak laser power, rather than laser duration, a SLS machine typically uses a pulsed laser. The SLS machine preheats the bulk powder material in the powder bed somewhat below its melting point, to make it easier for the laser to raise the temperature of the selected regions the rest of the way to the melting point.[6]

Unlike some other additive manufacturing processes, such as stereolithography (SLA) and fused deposition modeling (FDM), SLS does not require support structures due to the fact that the part being constructed is surrounded by unsintered powder at all times, this allows for the construction of previously impossible geometries.

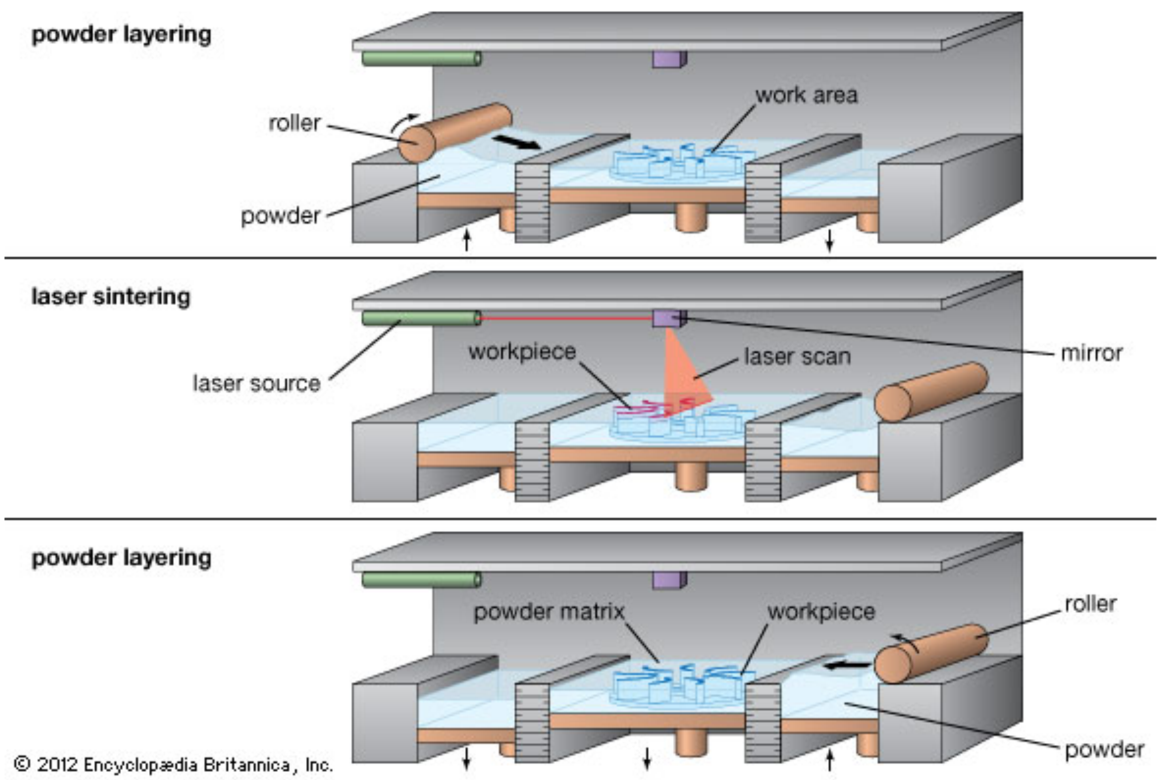
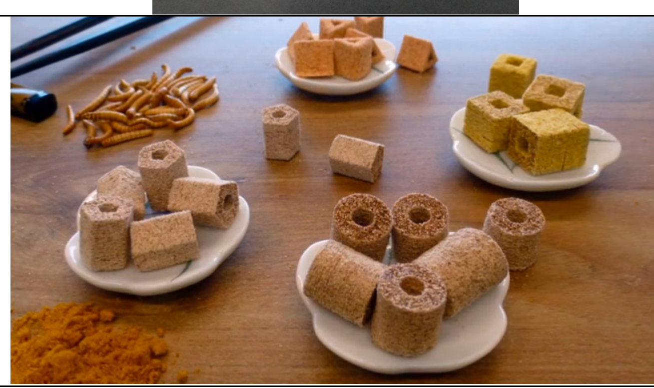
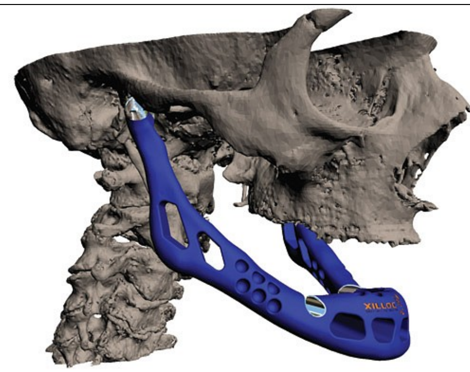


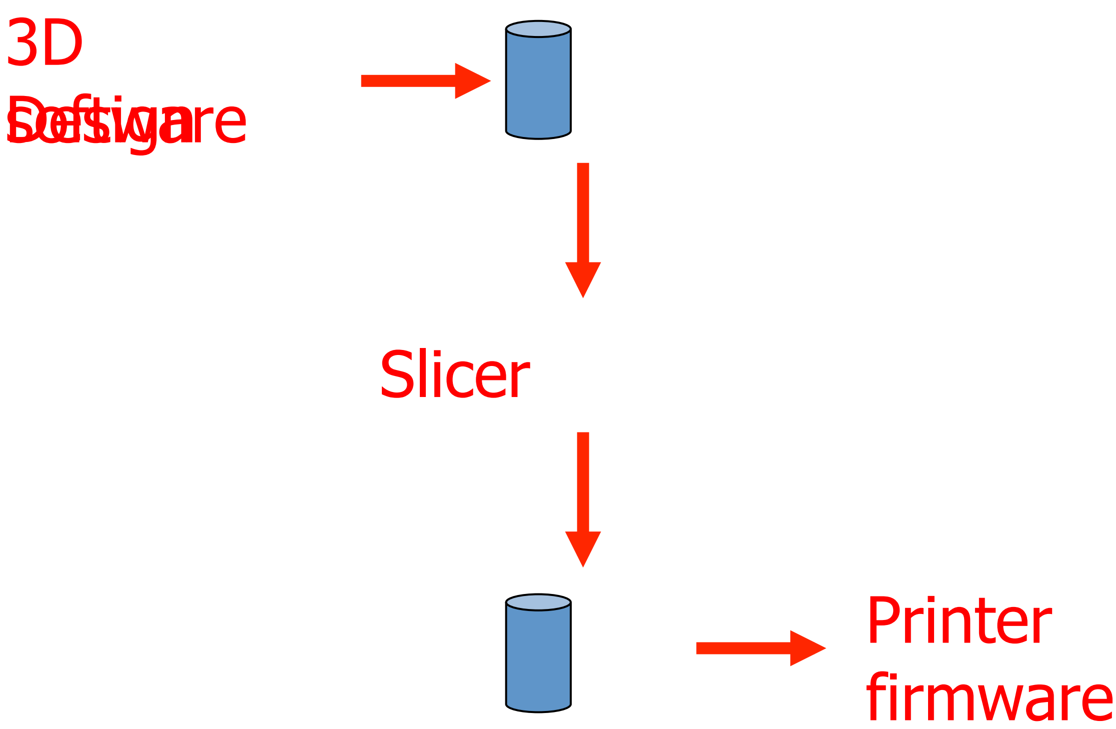
Figure 3

3D printing in industry

Rapid prototyping	
Fashion	
Architectural model production	
Food	

Medicine	

3D Modeling and Software used in 3D printing



The 3D Design software generates a mathematical 3D model. This model is converted by the Slicer software into instructions that will be executed by the Firmware of the 3D printer to drive its actuators (X, Y, Z and extruder motors, extruder and bed heaters).

1. 3D Modeling

You will use SketchUp software to generate 3D models for later printing, you can download sketchup from: http://www.sketchup.com/download

Any 3D form (polyhedral or curved) can be approximated by a triangulated surface. For example: Polygons of 4 or more sides can be divided into triangles.

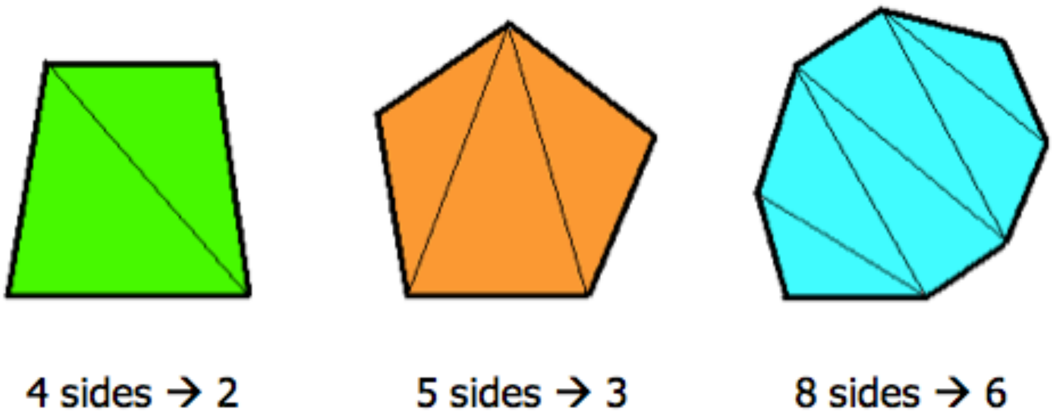
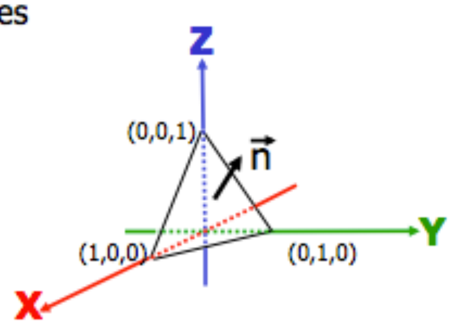


Figure 4

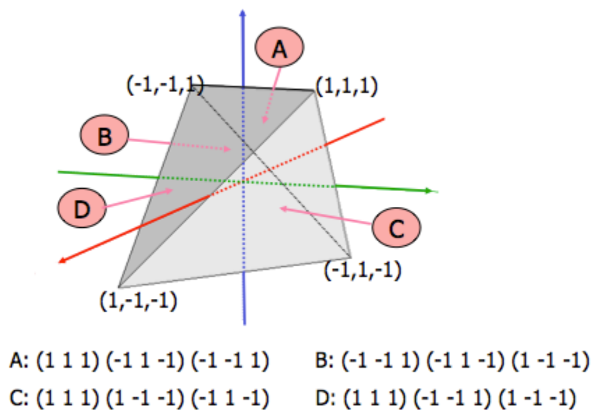
An *n*-gon is represented as *n*-2 triangles. On a computer they are represented by listing the three corners for each triangle.

- Each corner (a vertex) has (X, Y, Z) coordinates
- List vertices starting with any of the three
- List counter-clockwise as seen from outside
- "Normal vector" points out from object
- Use "Right-handed" XYZ axes



Triangle: (1,0,0) (0,1,0) (0,0,1)
Or: (0,1,0) (0,0,1) (1,0,0)
Or: (0,0,1) (1,0,0) (0,1,0)

Example:

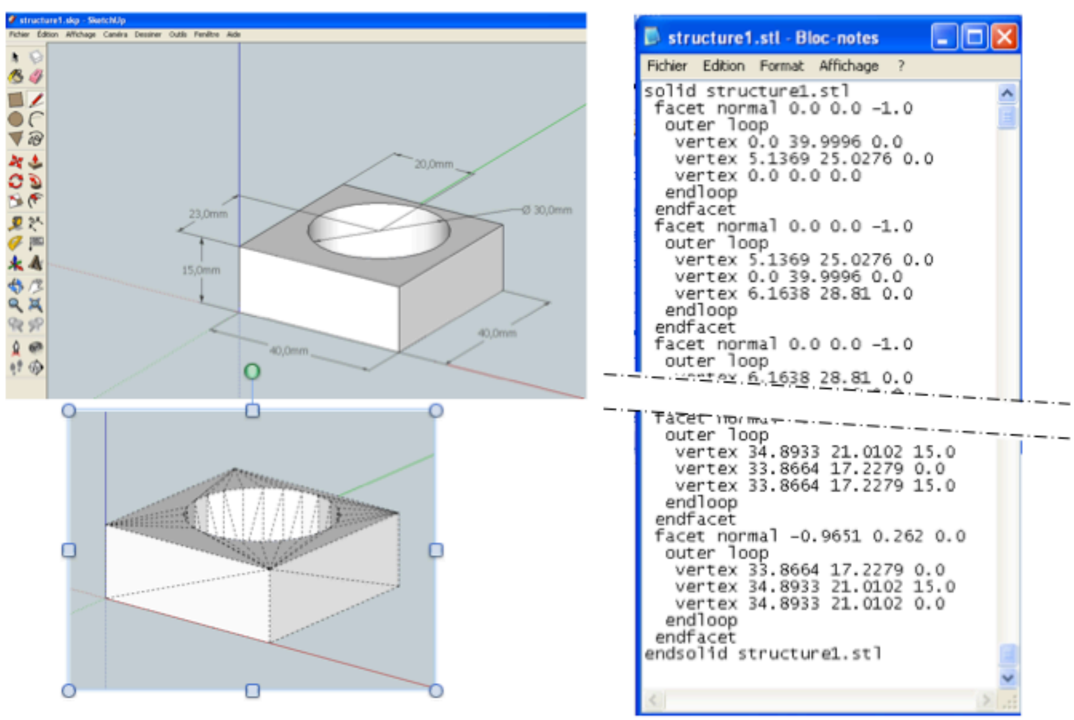


3D Model: File Format:
Different 3D formats describing

- Triangles, polygons, curves,
- Colors, textures, images, lights, animation….

STL (STereoLithography)

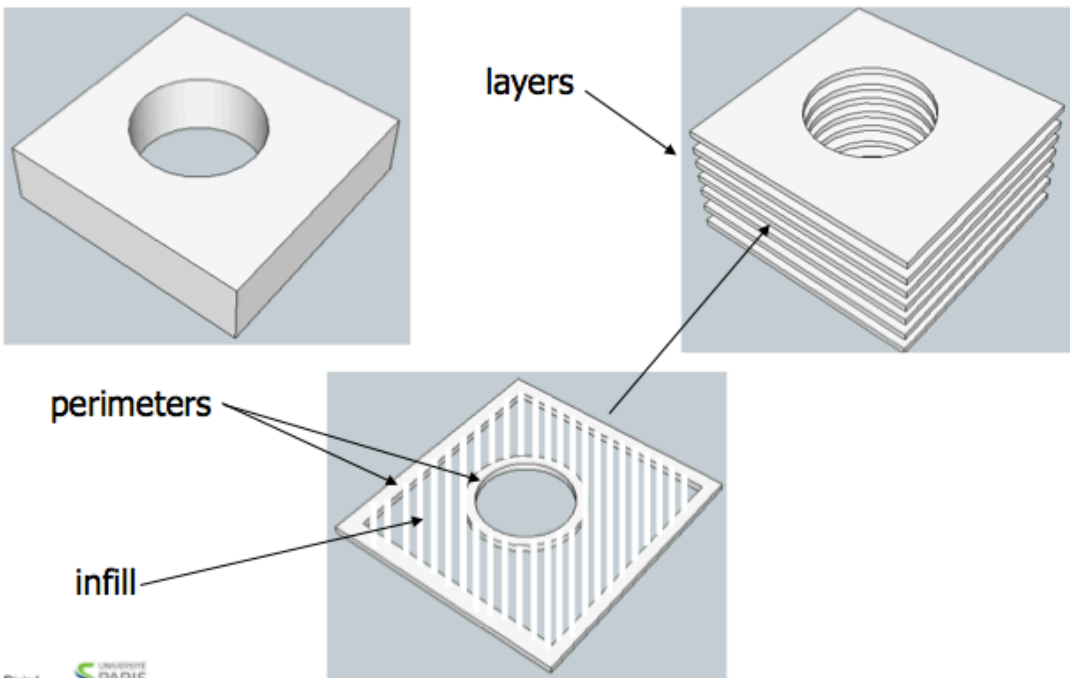
- Created by 3D Systems.
- Based on triangles modeling
- Supported by many software packages
- Widely used for **rapid prototyping** and computer-aided manufacturing.
- Describes only the surface geometry of a three dimensional object without any representation of color, texture or other common CAD model attributes.
- ASCII and binary representations



2. Slicer:

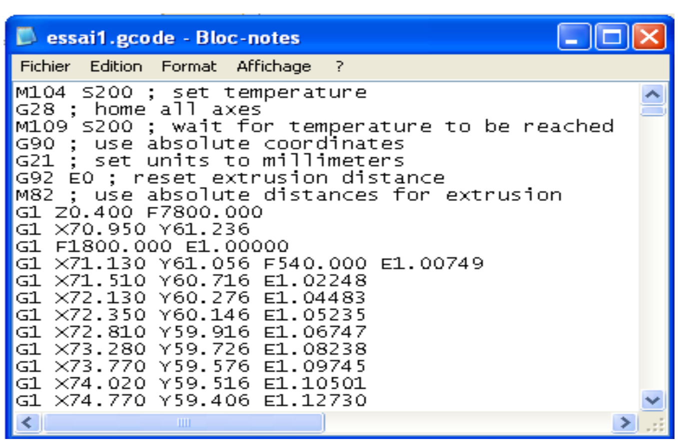
The slicer is a software that convert the 3D model to instructions to be used by the firmware of the 3D printer. Slicer generate files with .gcode extension.

The slicer cuts the model into horizontal slices (layers), generates toolpaths to fill them and calculates the amount of material to be extruded.



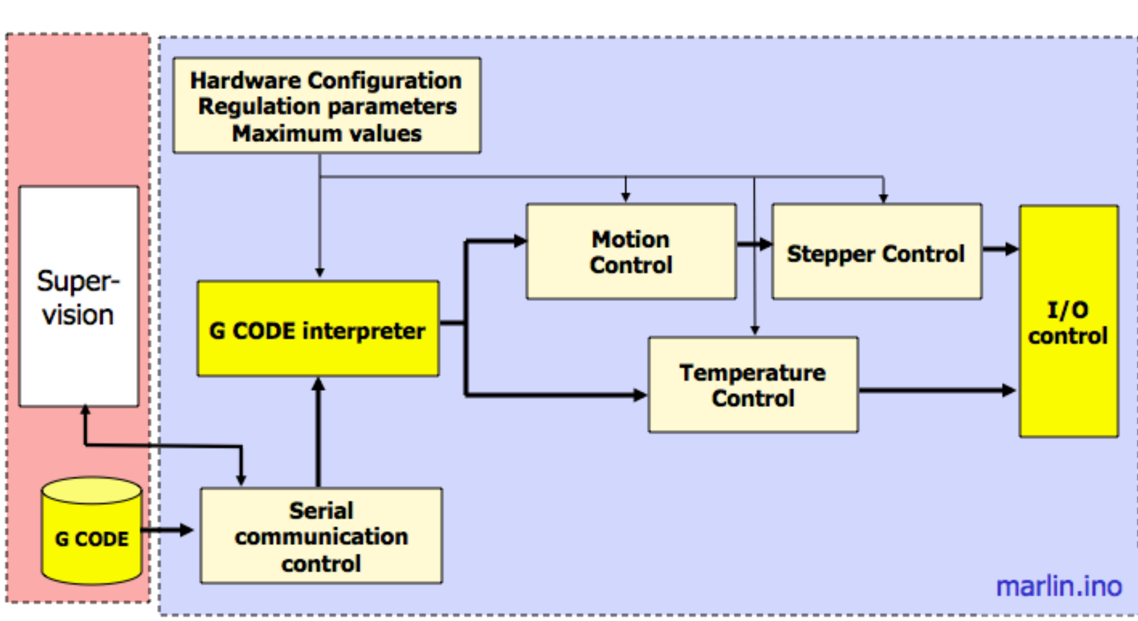
Gcode files:

- G Codes are directives.
- G Codes tell computer numerical control devices how to move and behave.
- The codes that do start with G tell the machine where to “Go”.
- The codes that start with M tell the machine how to behave.



3. Marlin Firmware

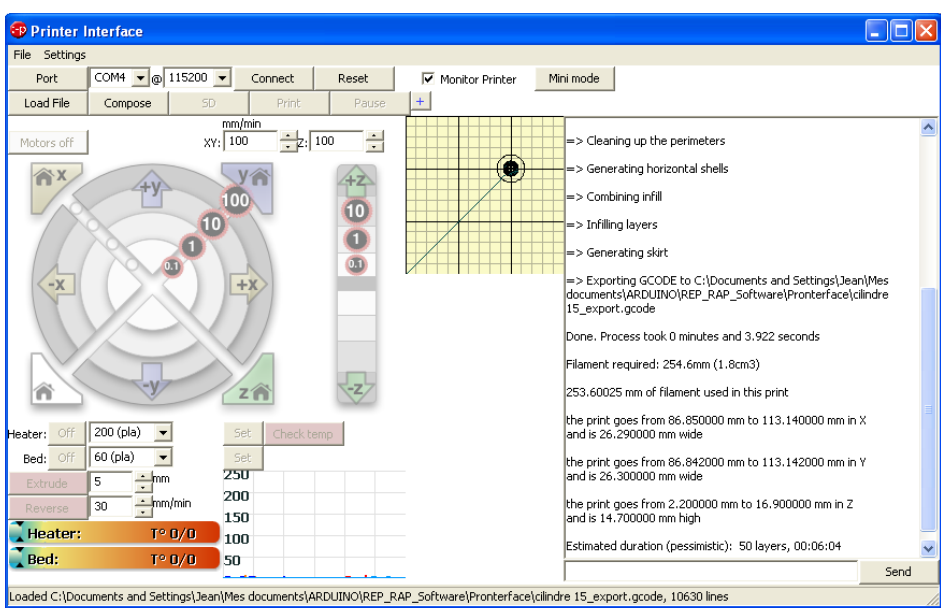
This program is executed by the microcontroller embedded in the printer



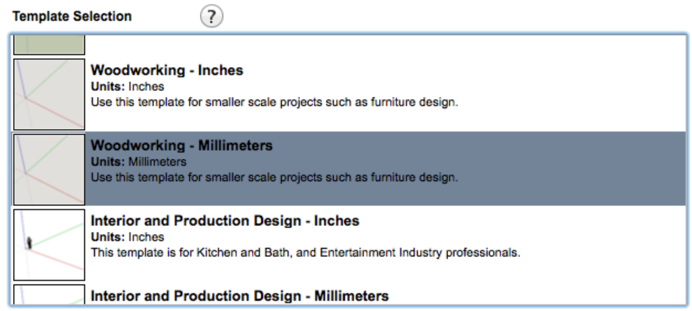
4. **Pronterface: supervision and control interface**

This program allows

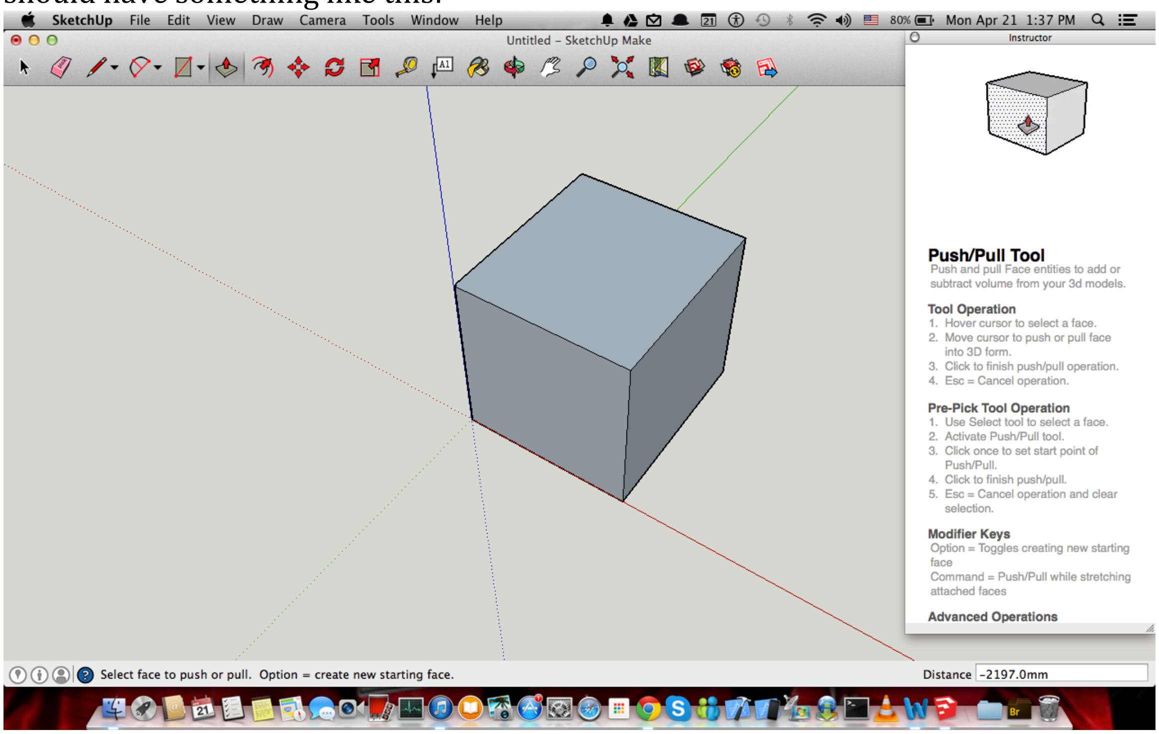
- Downloading the G-Code to the microcontroller.
- Monitoring the printing.
- Executing step by step initializations of the printer.
- Changing parameters in real time.



Procedure

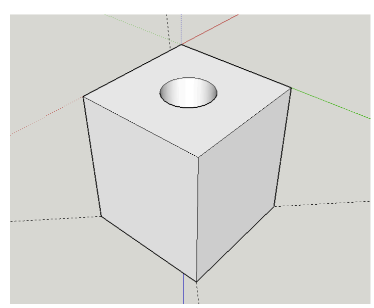


1- Open SketchUp Software.
2- Choose "choose template".
3- Choose "WoodWorking - Millimeters"
4- Press "Start Using SketchUp".
5- Explore the different icons and their functionalities.
6- Select the rectangle tool, starting from the center draw a rectangle with 80x80 Mm Square.
7- Using the push/push tool, pull the square you draw to make a cube. You should have something like this:

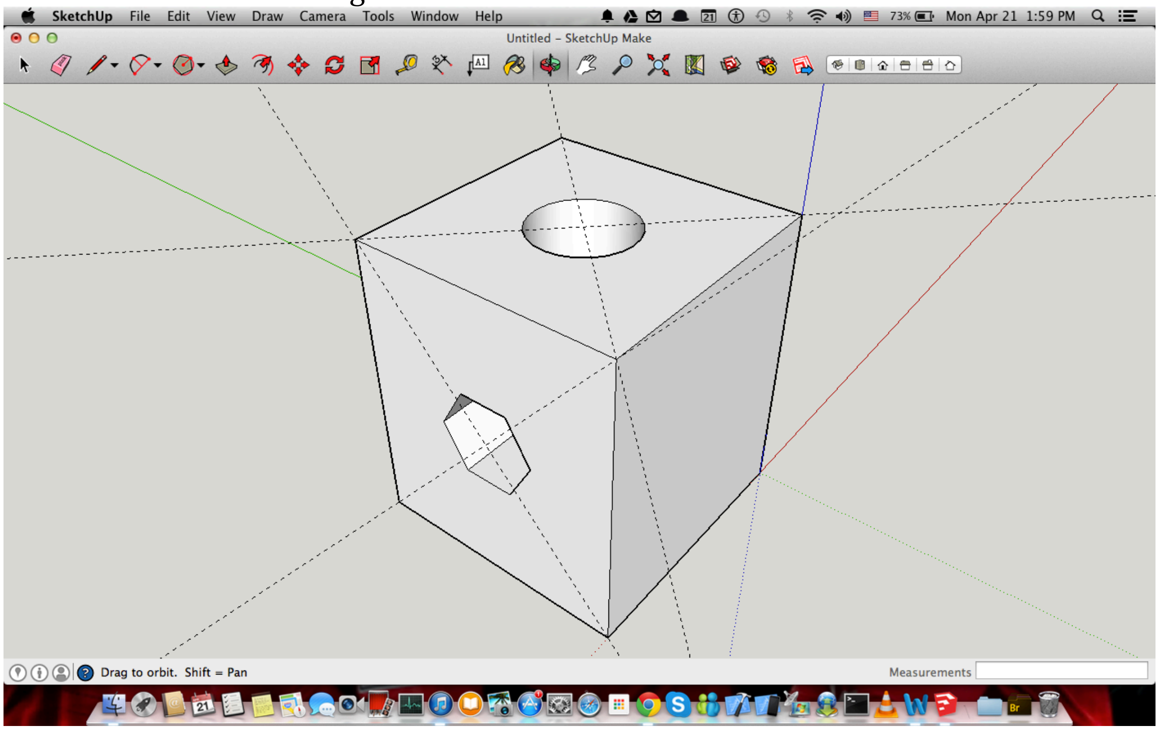


8- Draw a circle of radius 25mm at the top surface of the cube. Centered in the center of the top square of the cube. Using the Tape Measure tool.

9- Use the push/pull tool to push the circle to the bottom edge of the cube to make a hole in the cube, you must see this:

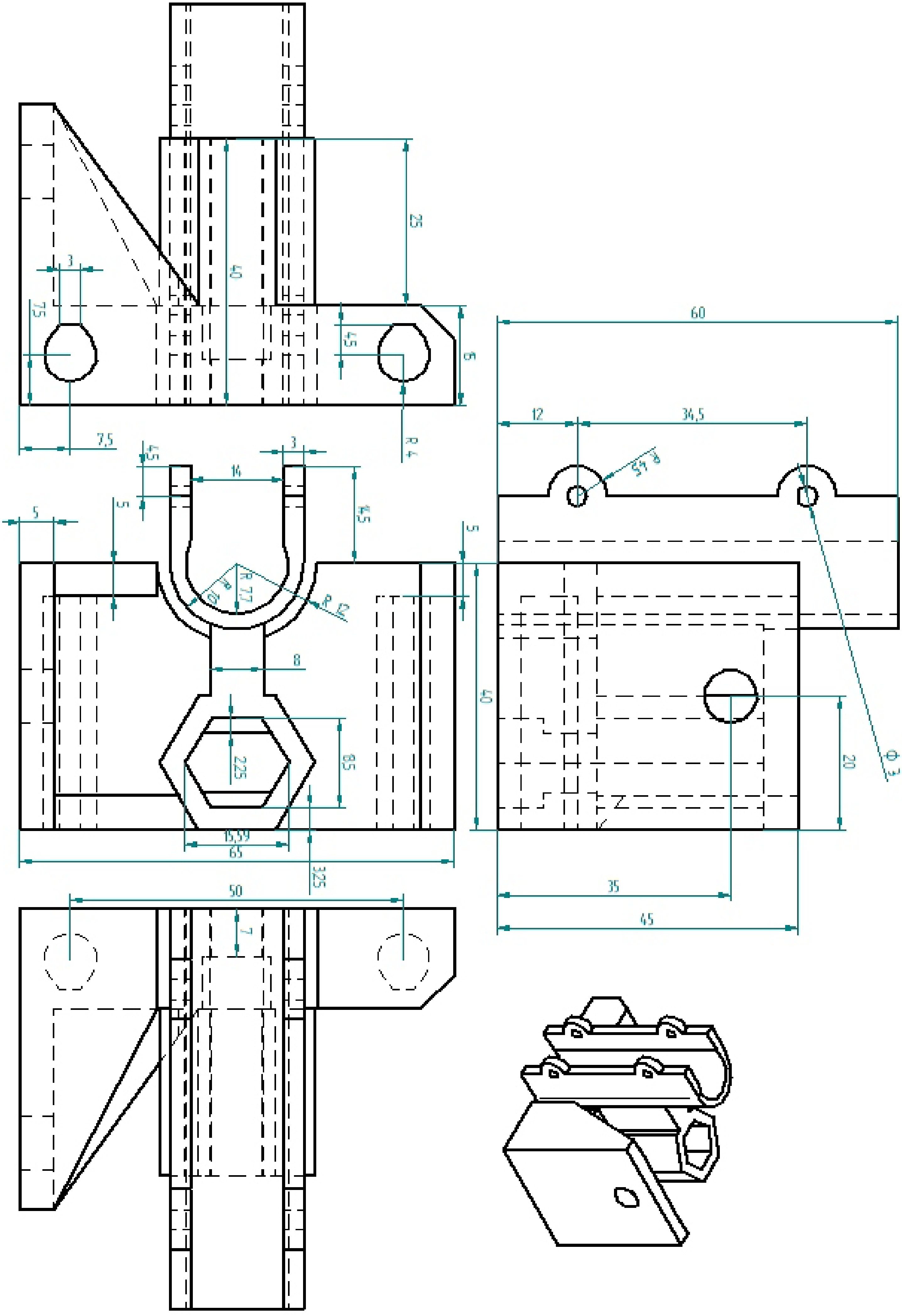


10- In the same way, draw a polygon on the front end and push it to the other end of the cube to get this:



Get yourself familiar with SketchUp. Now we want to design a model for a component of the 3D printer following the following tutorial.

Sketch-up Introduction



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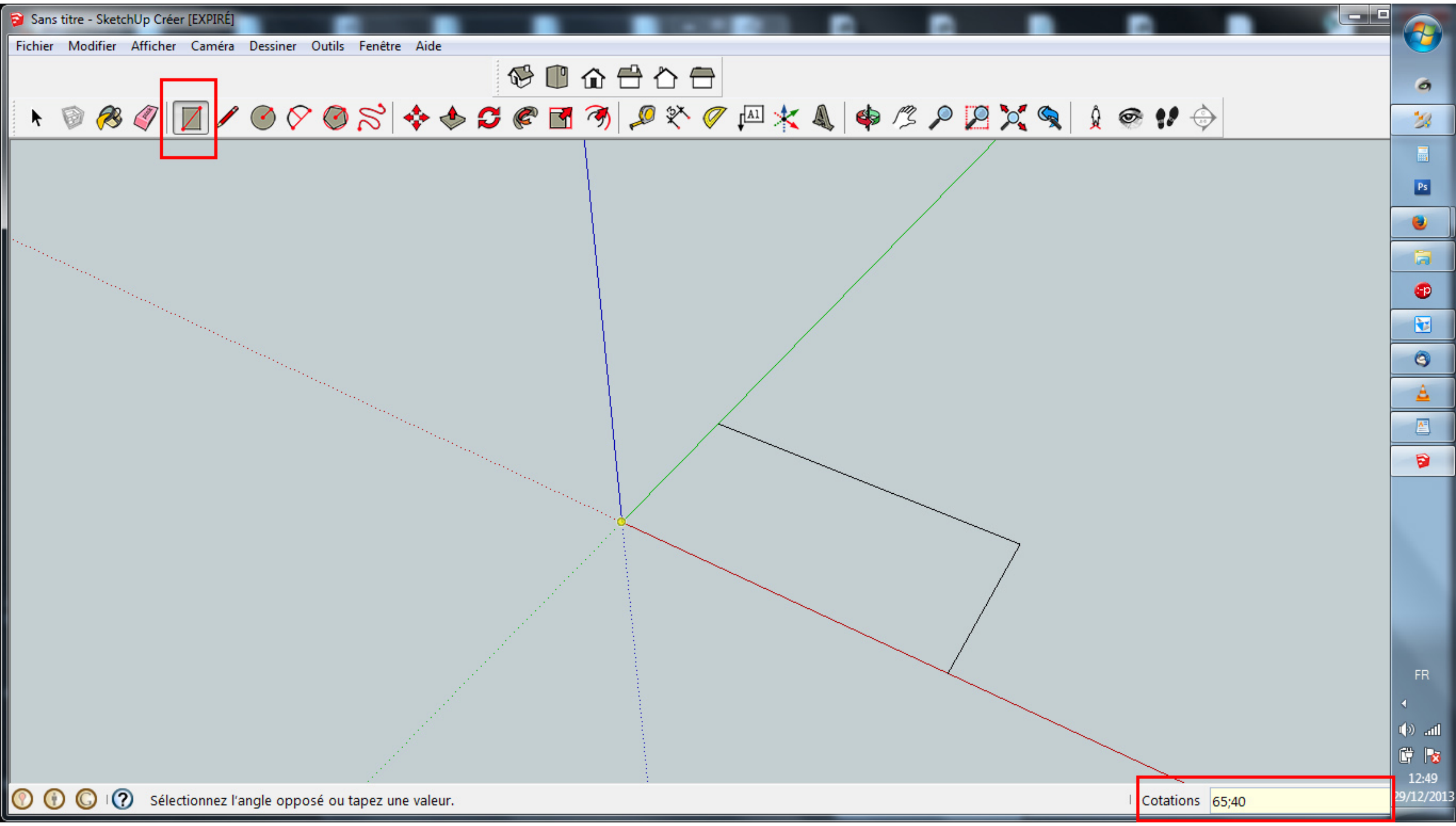
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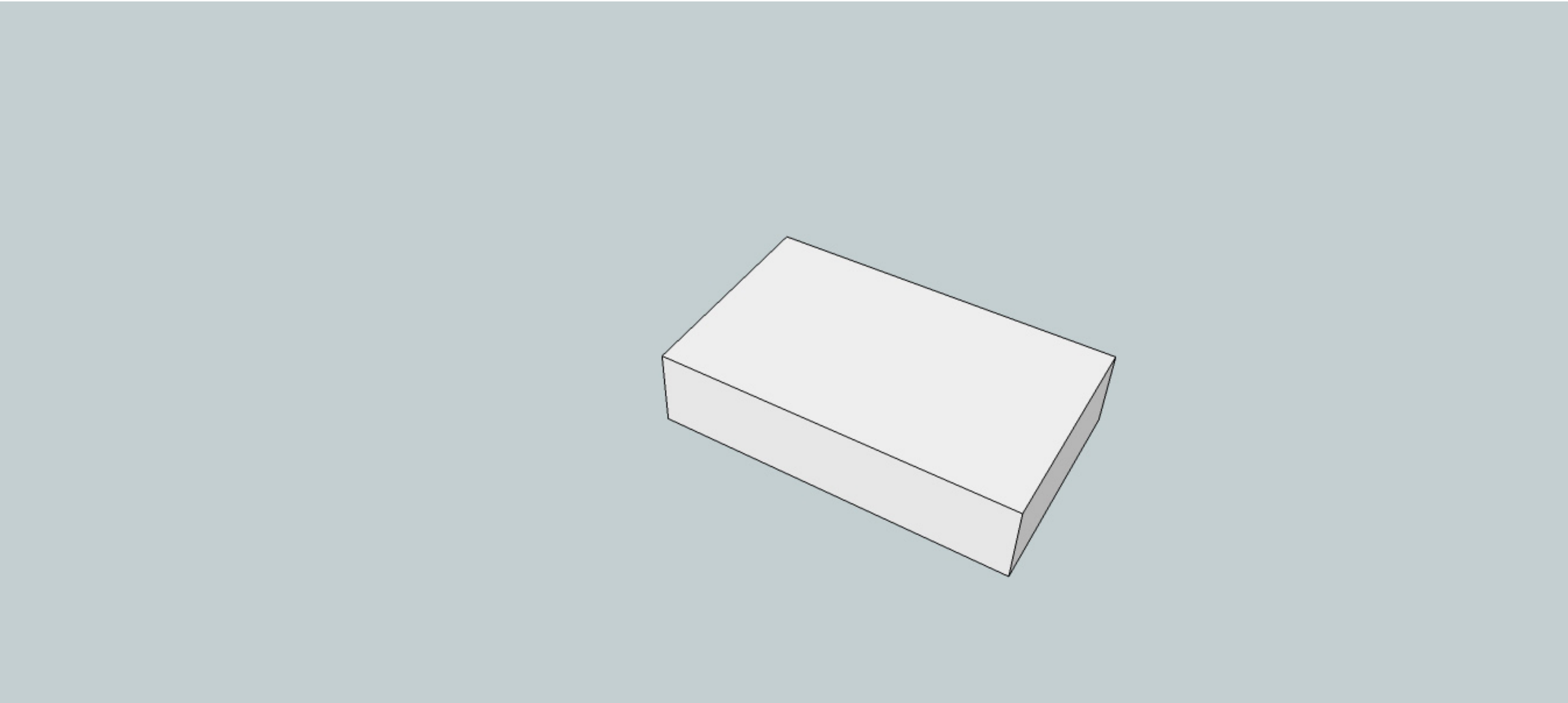
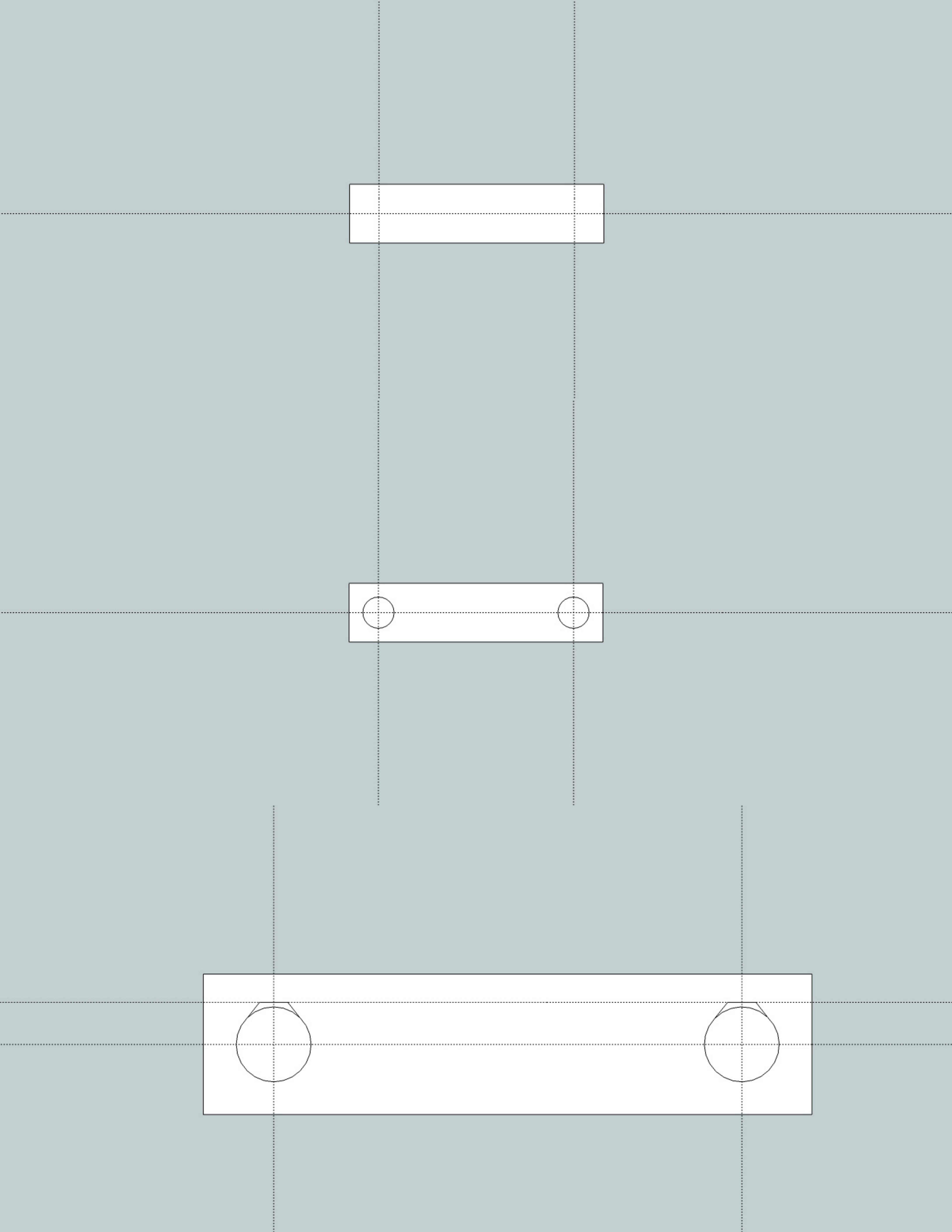
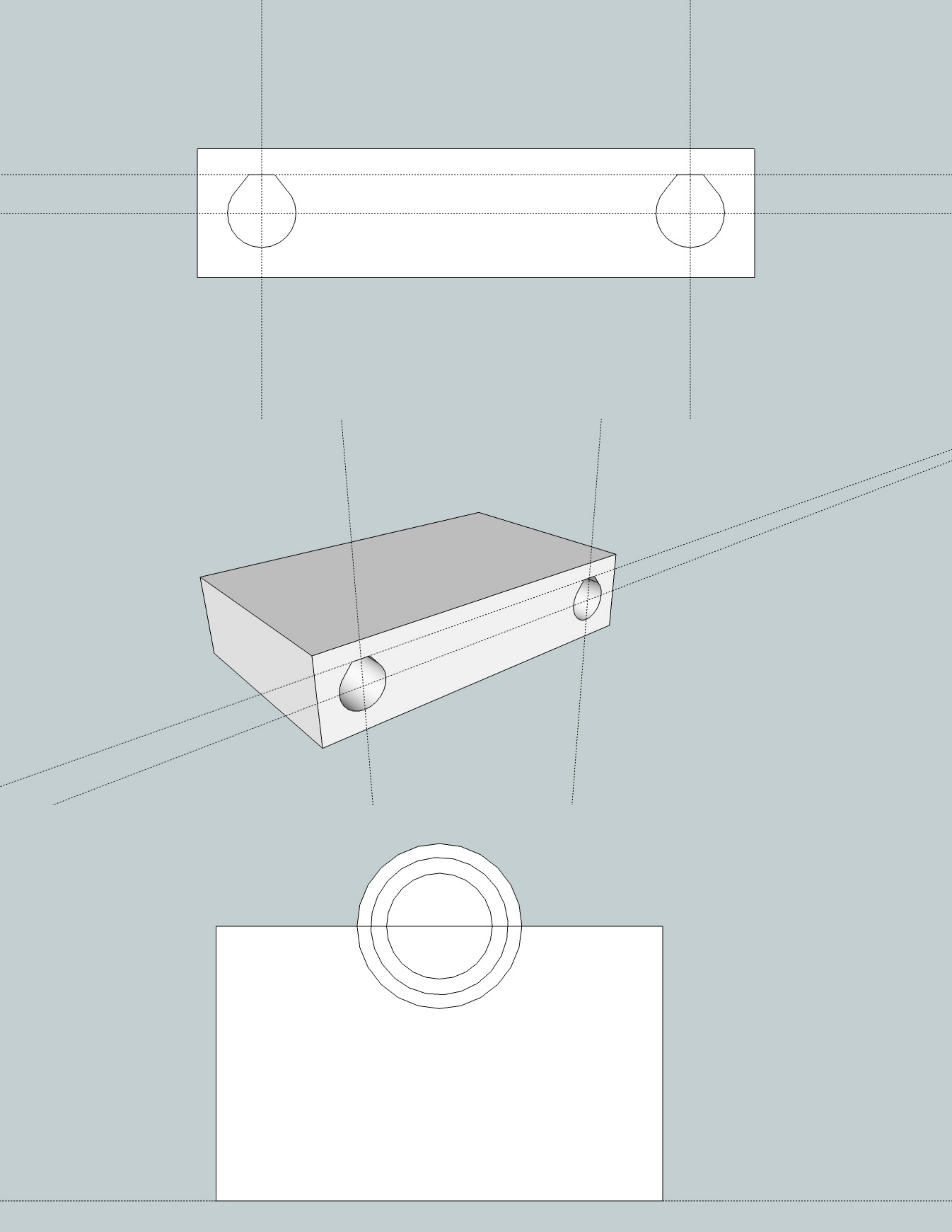
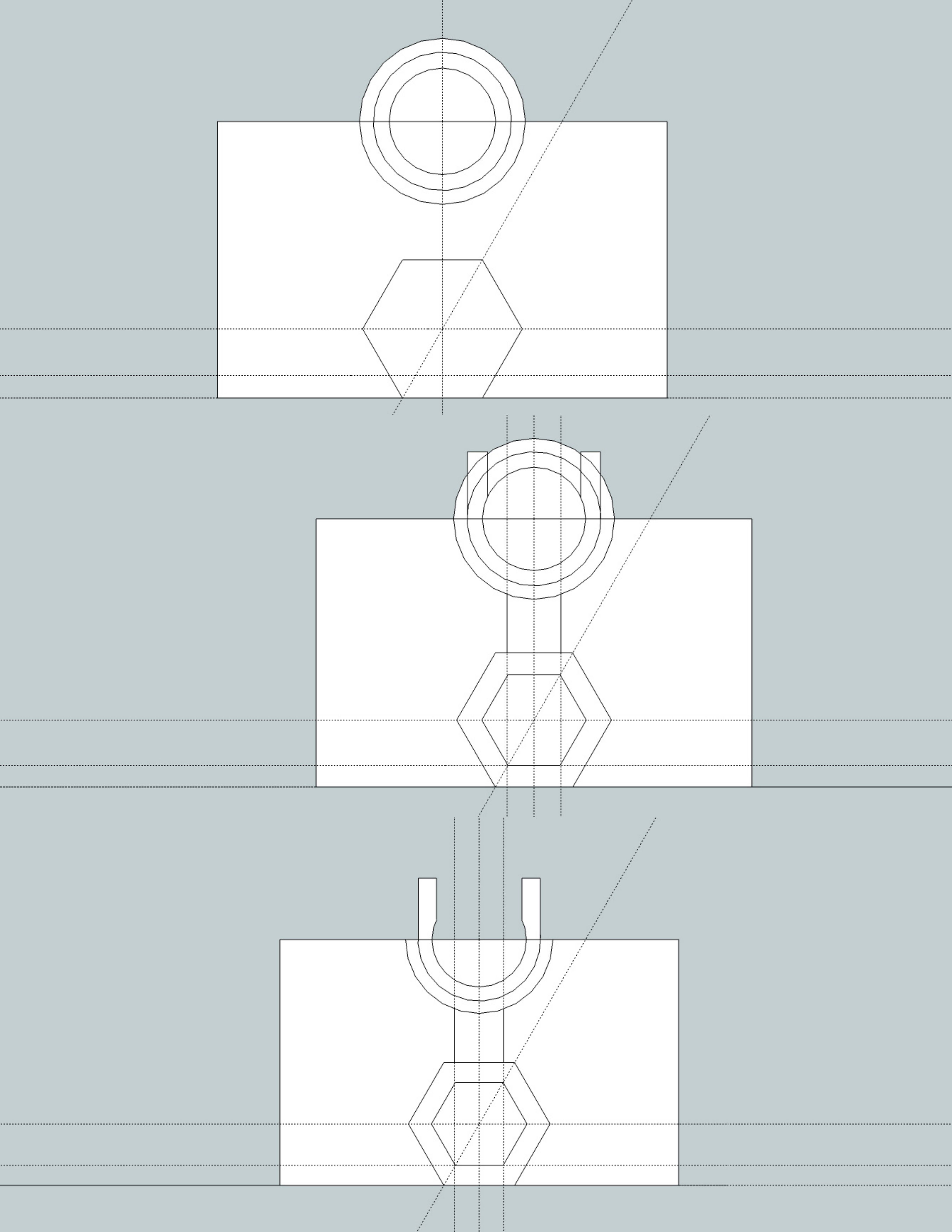
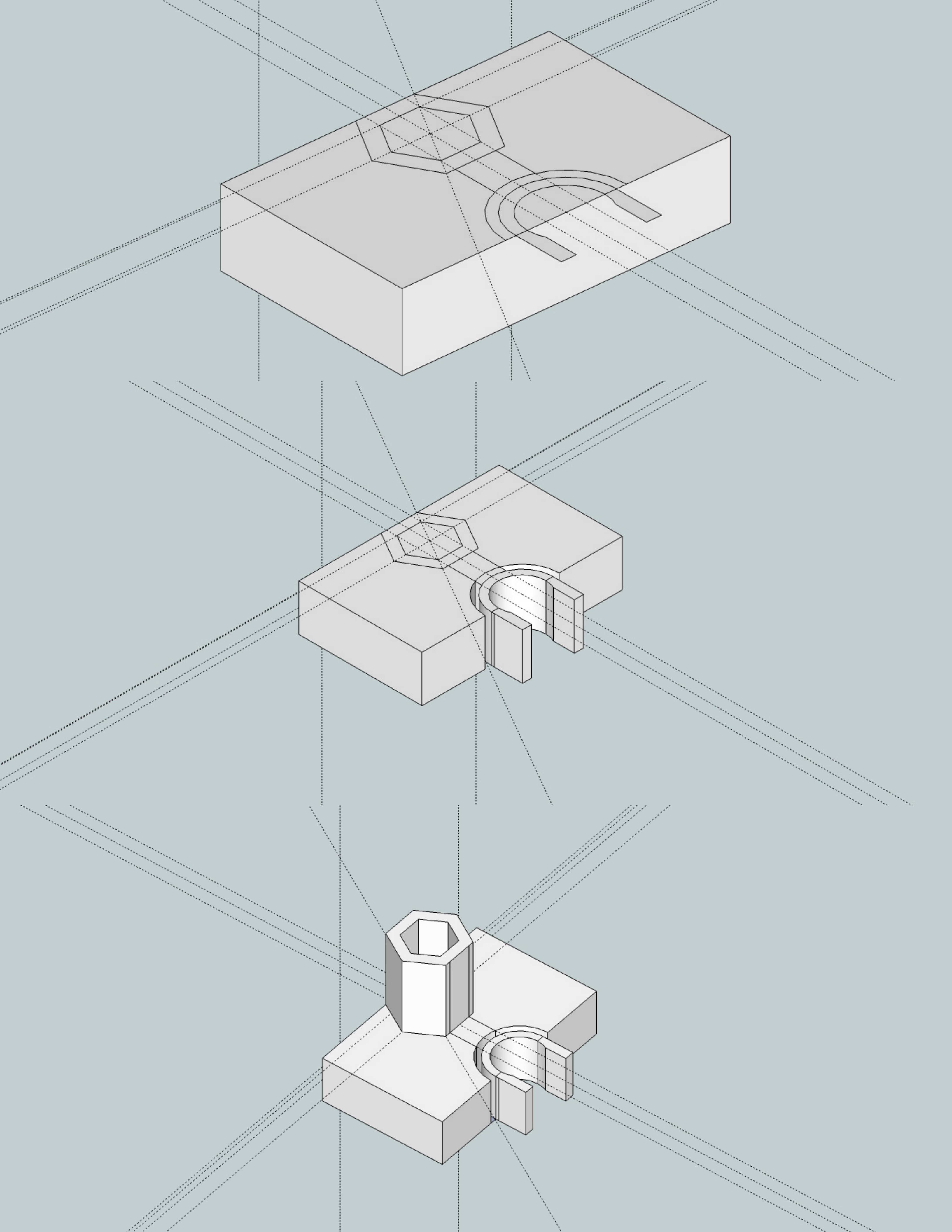
Cotations 65;40

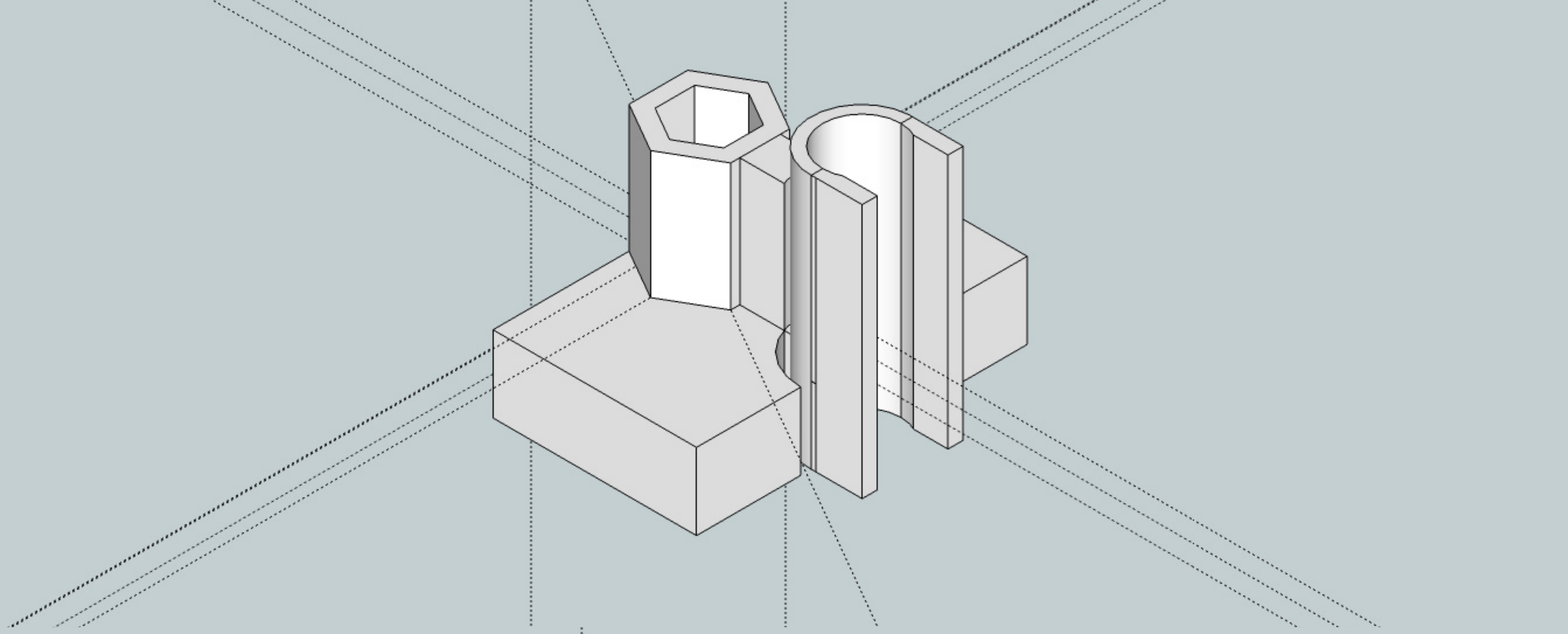


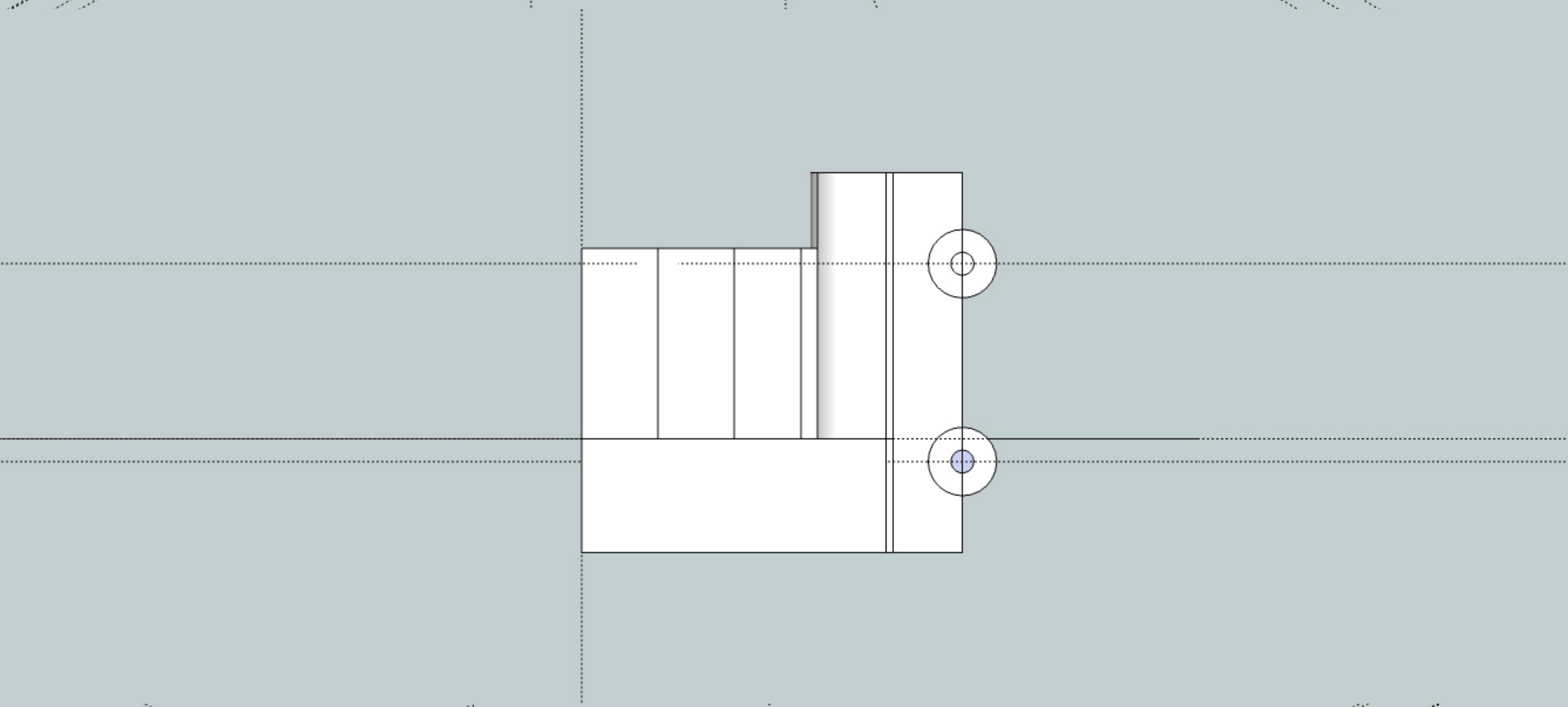


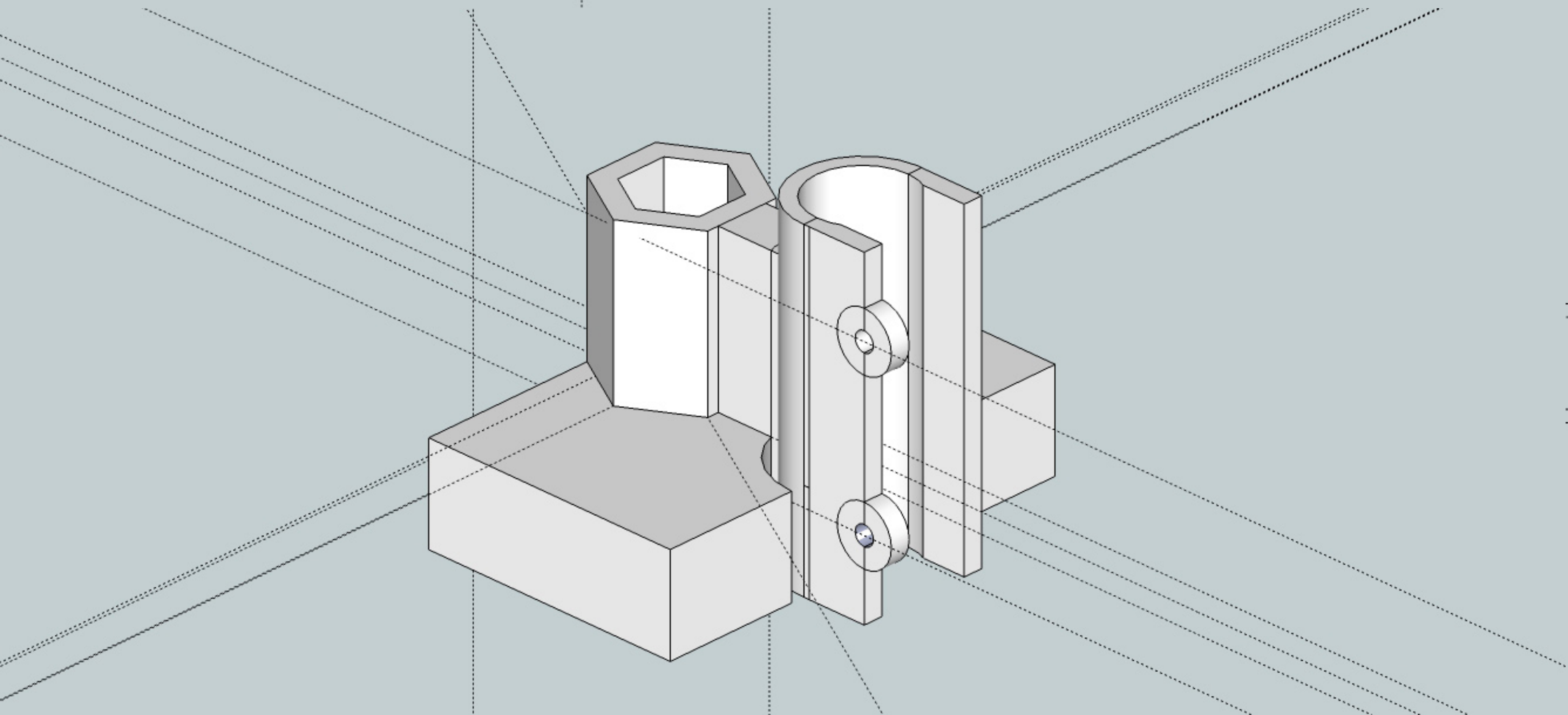


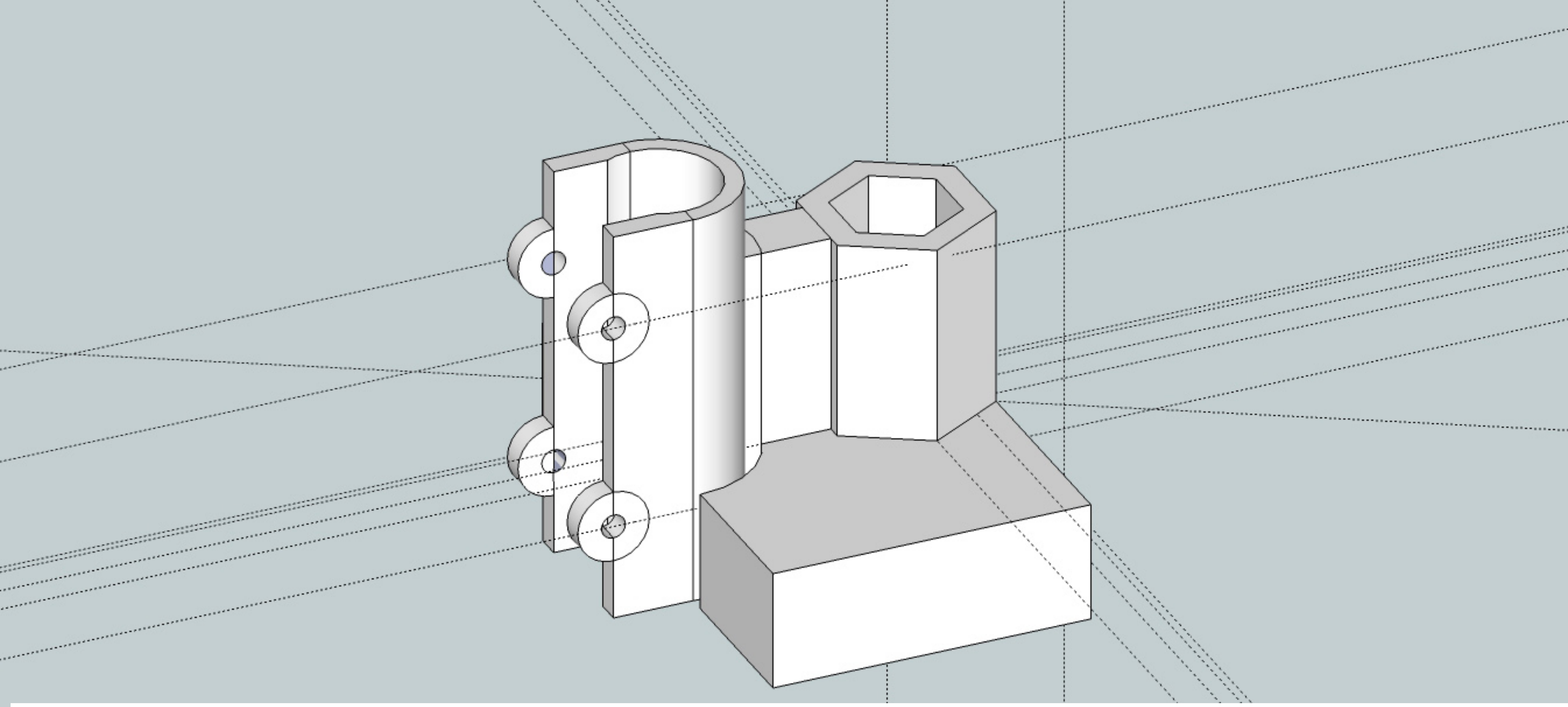


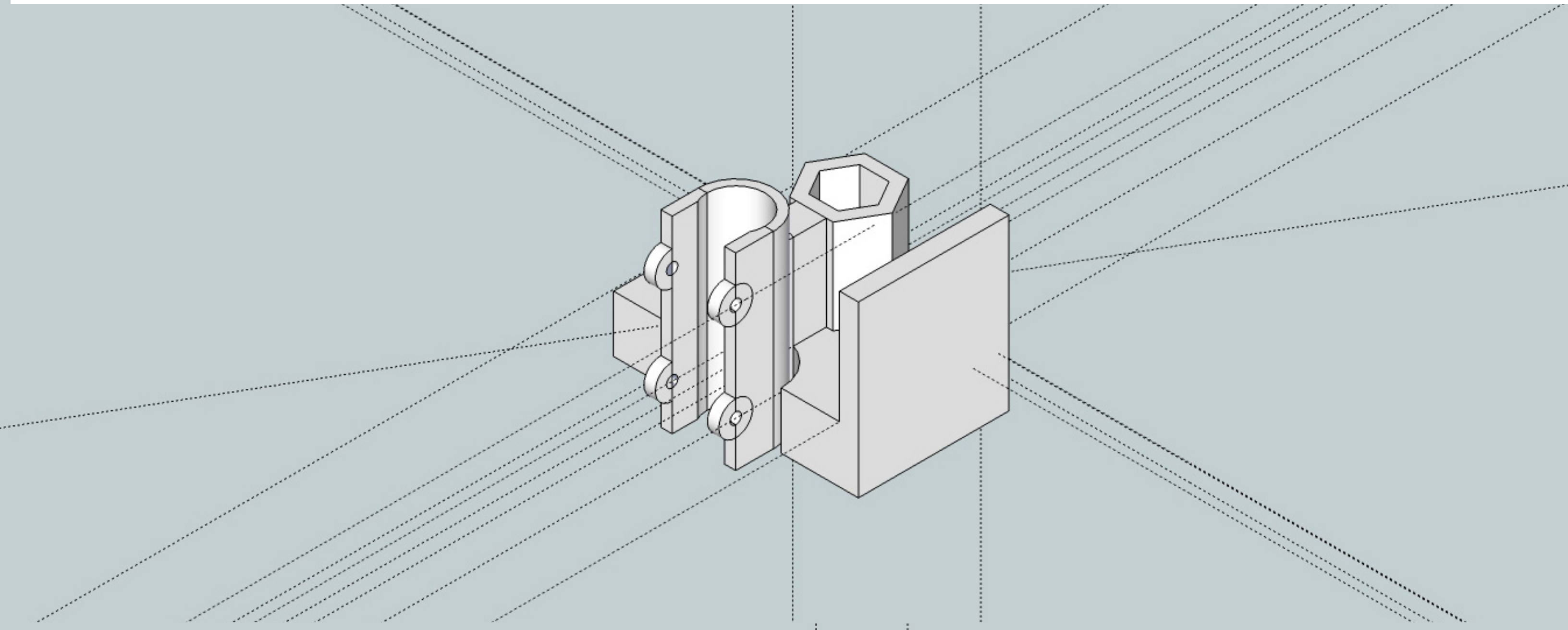


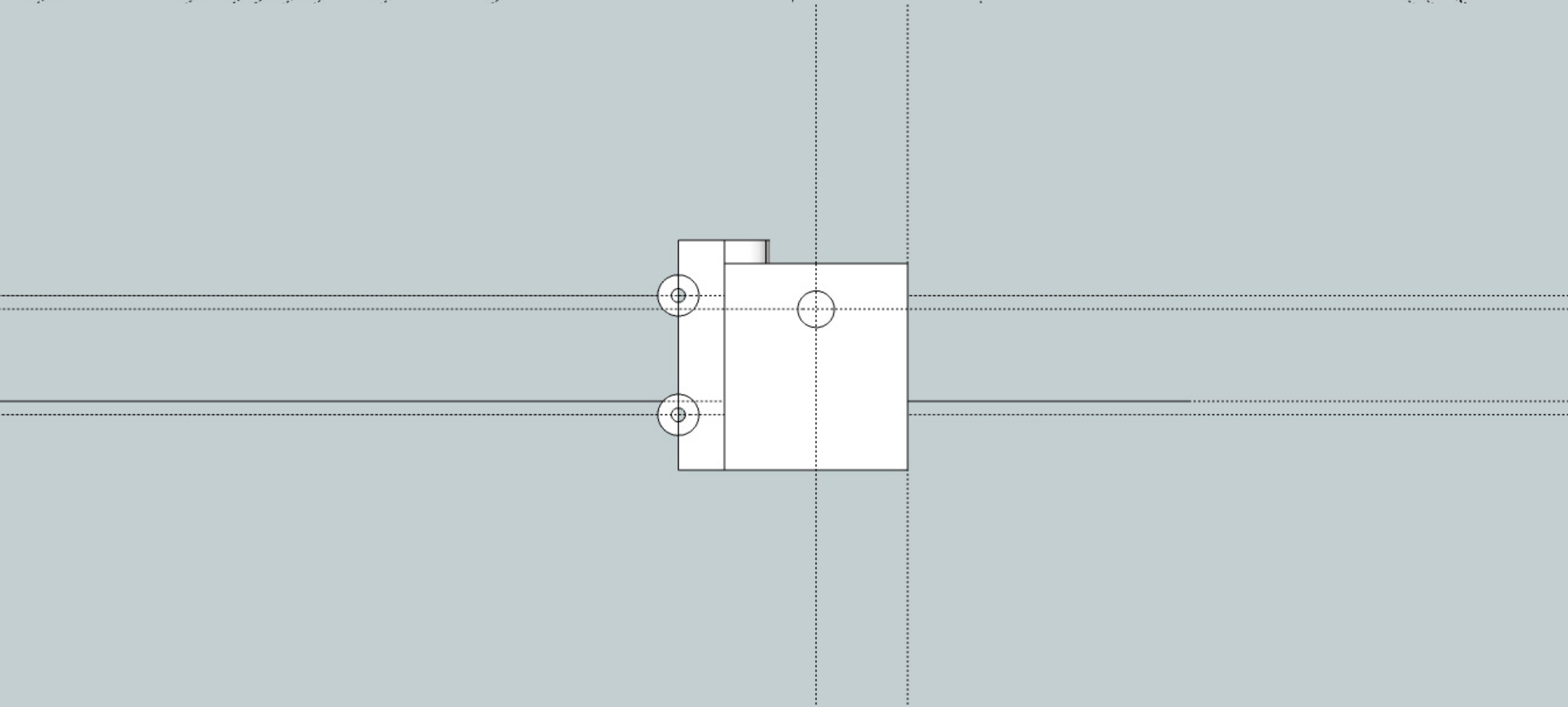


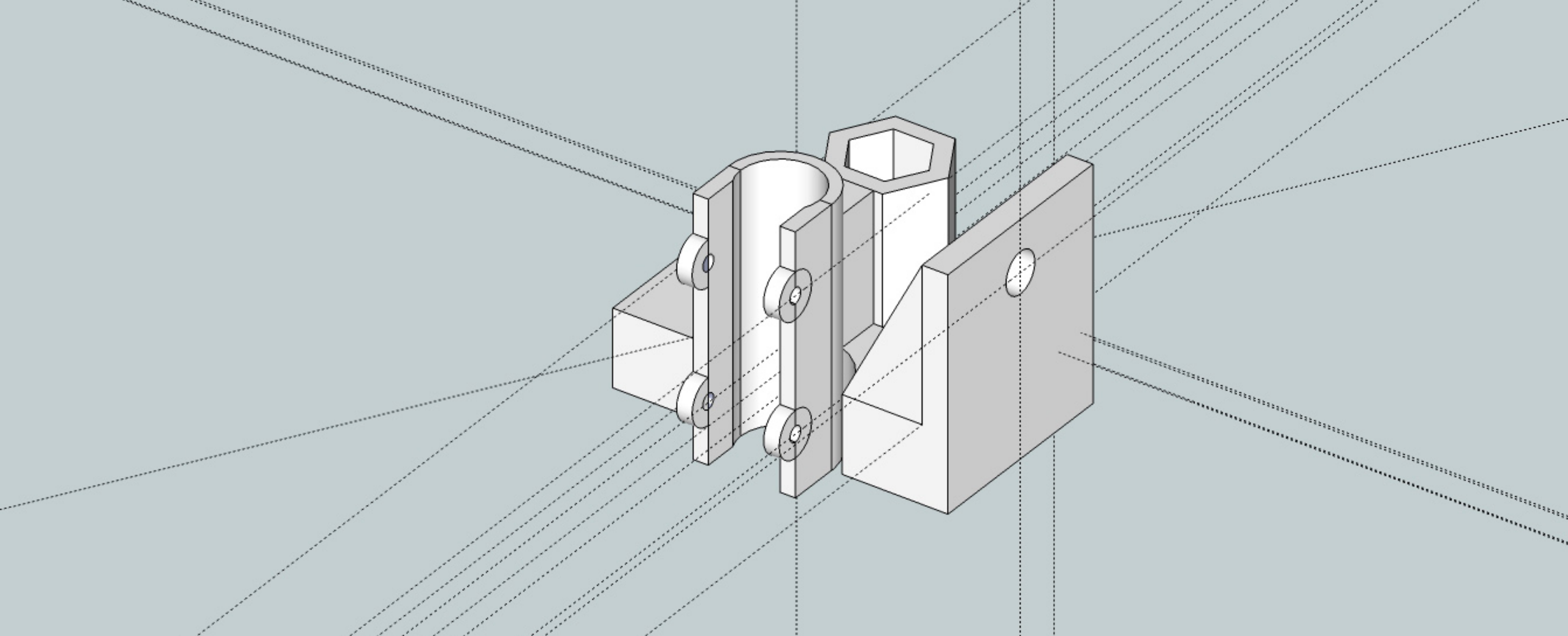
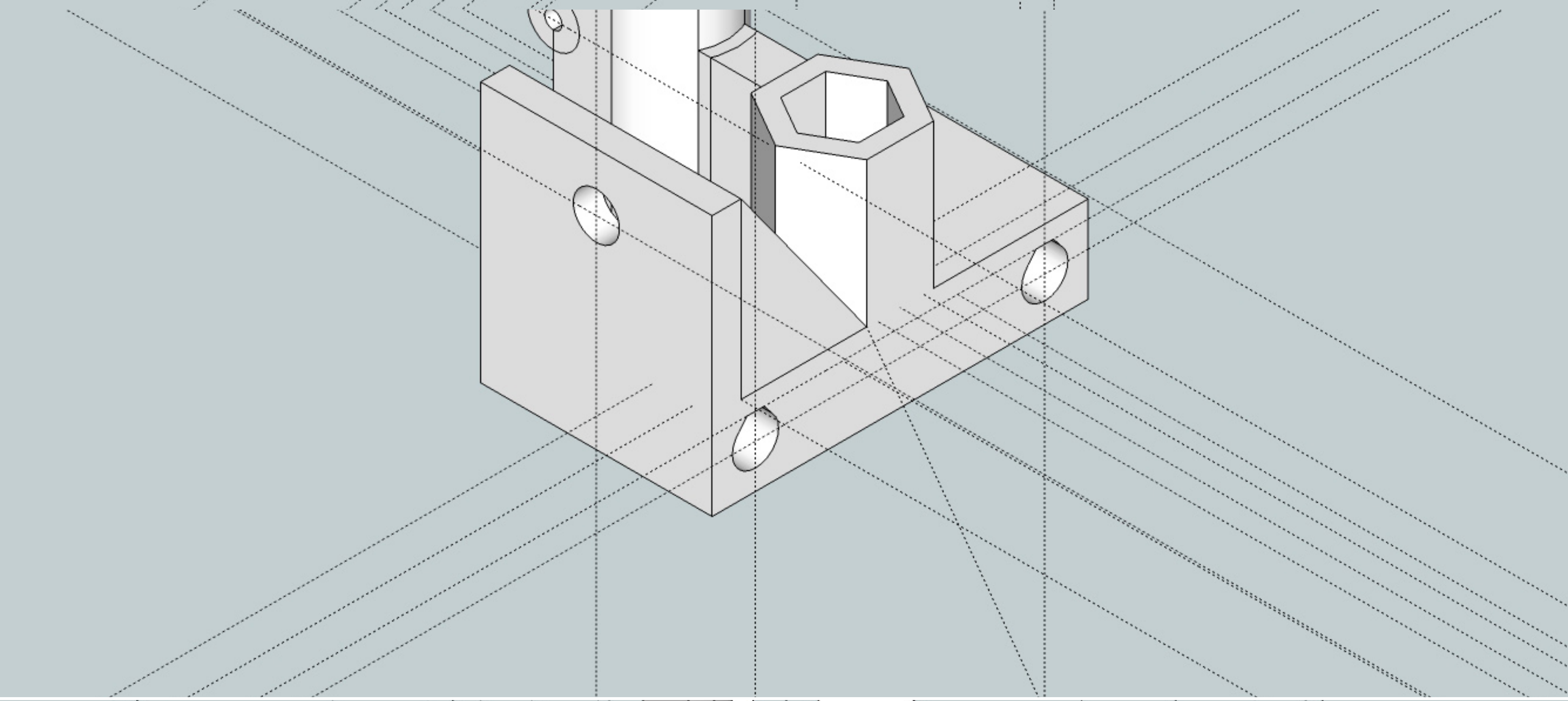
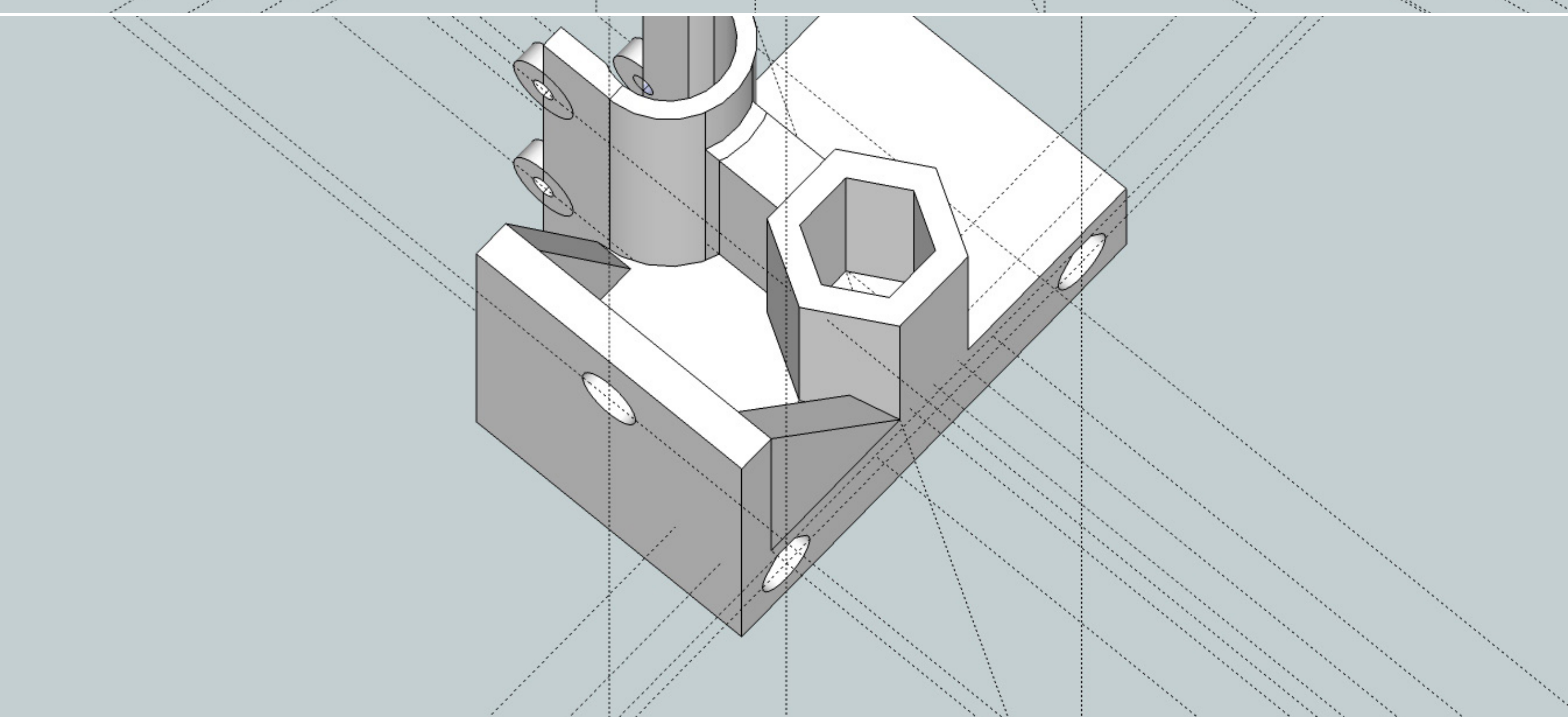


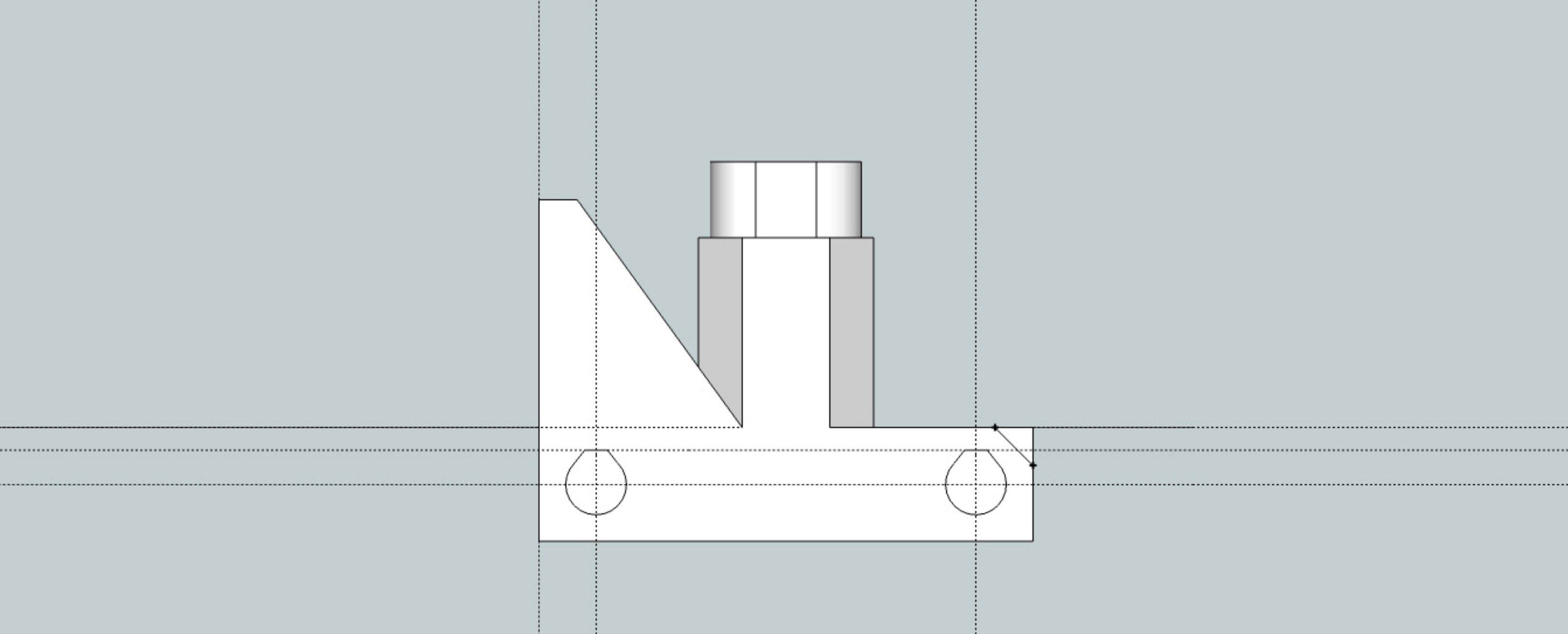
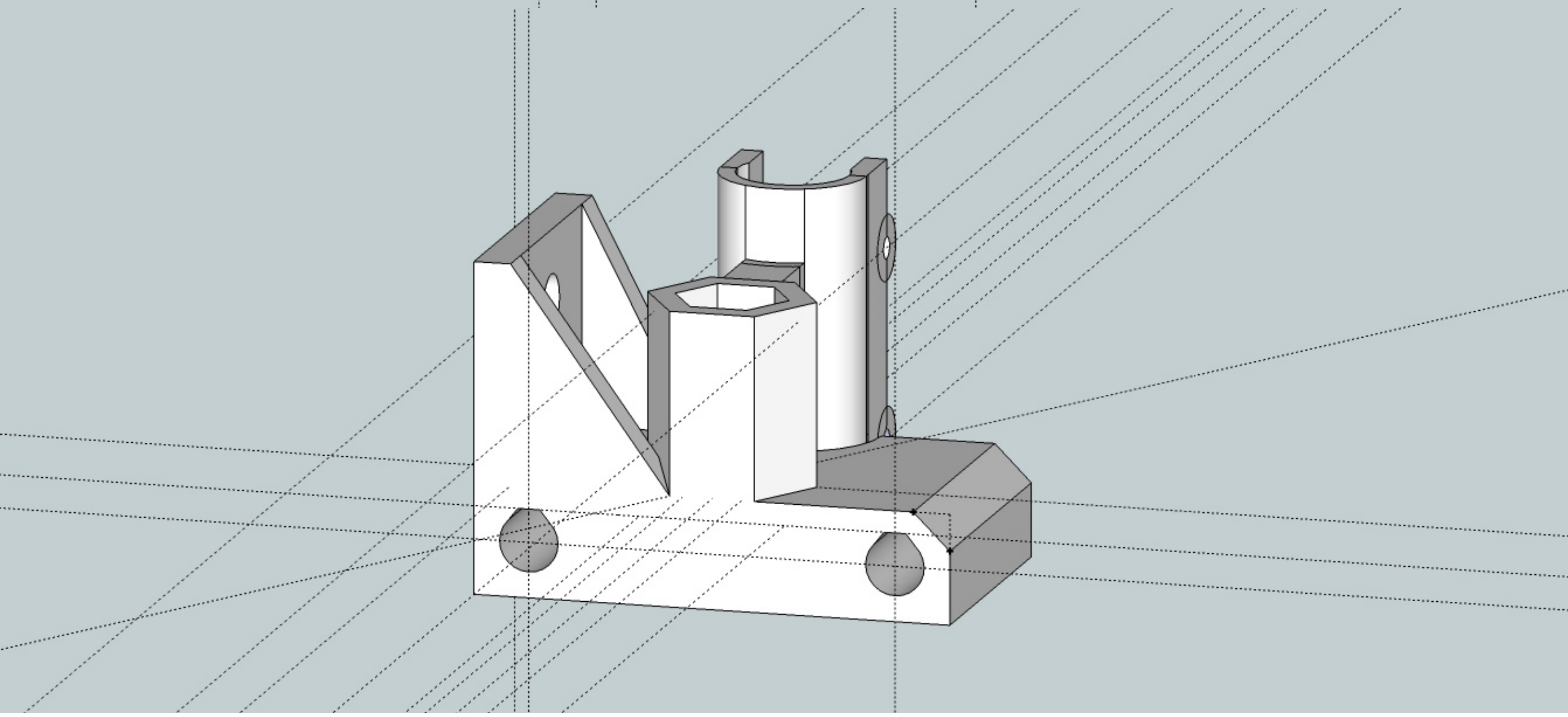
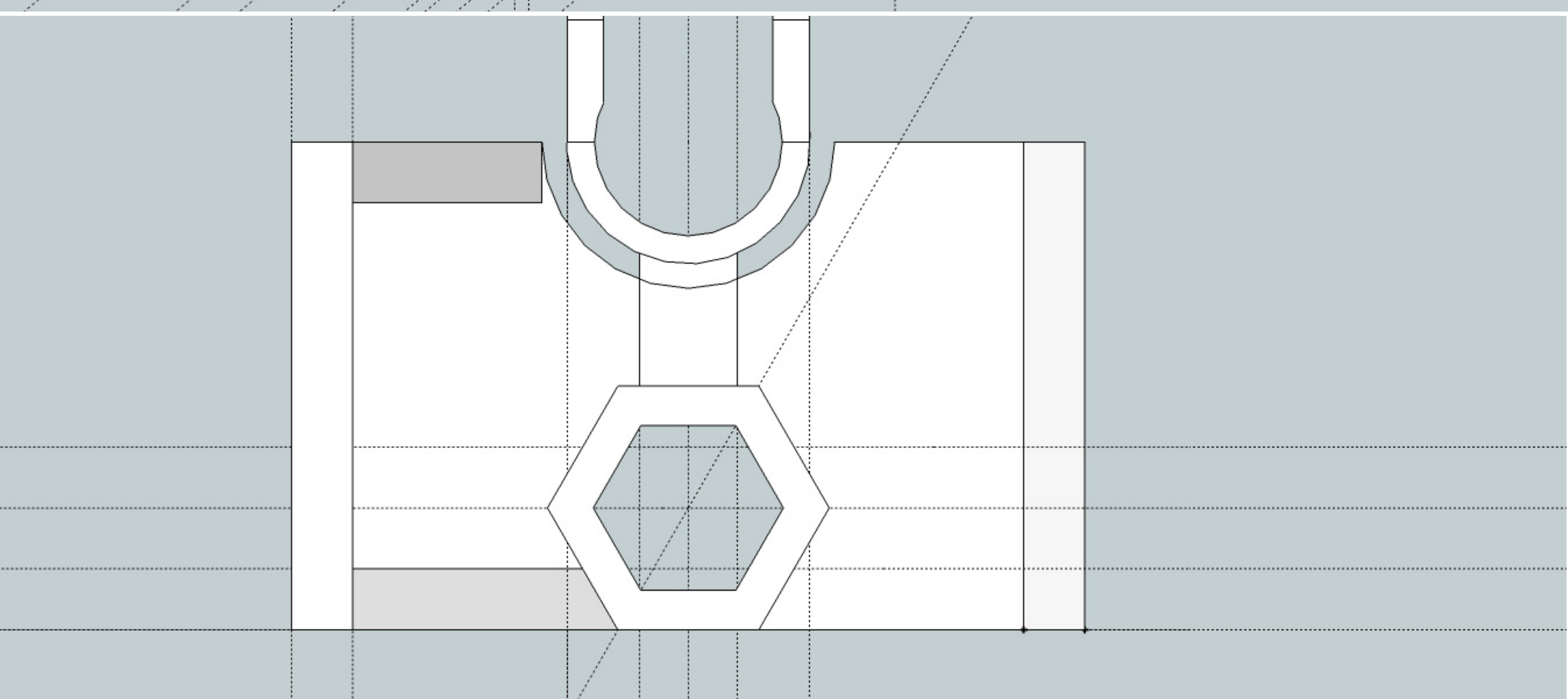


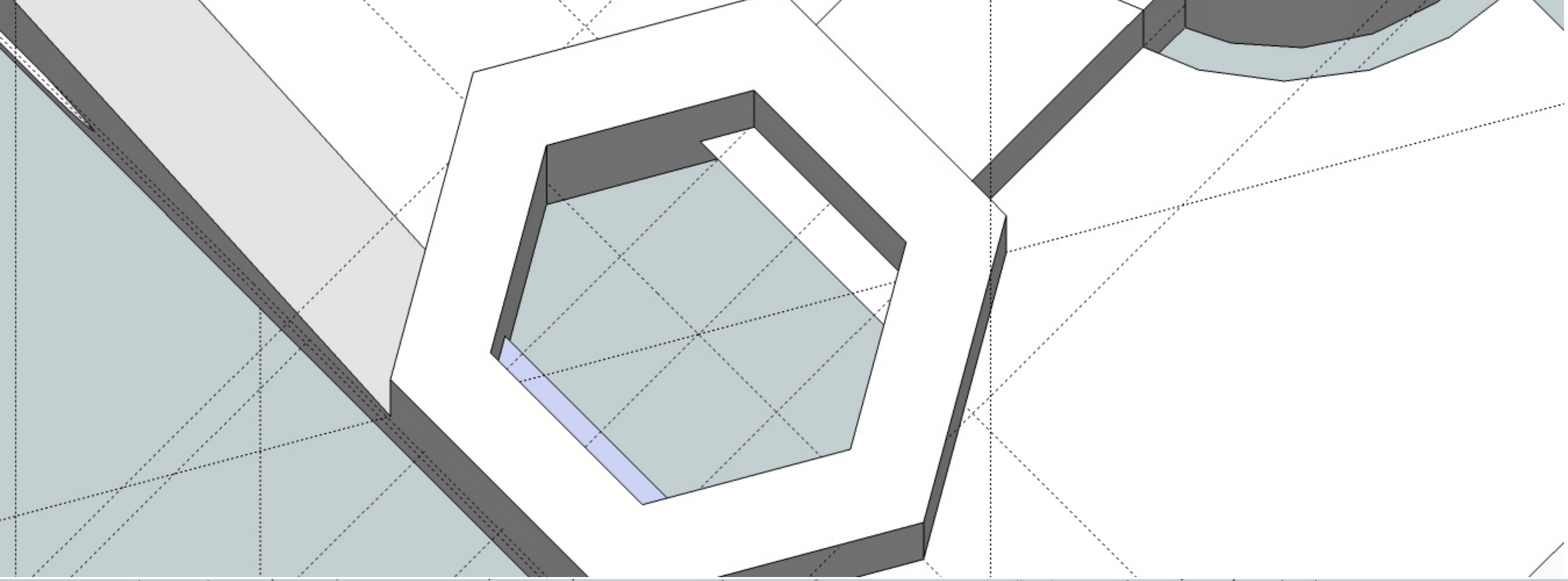


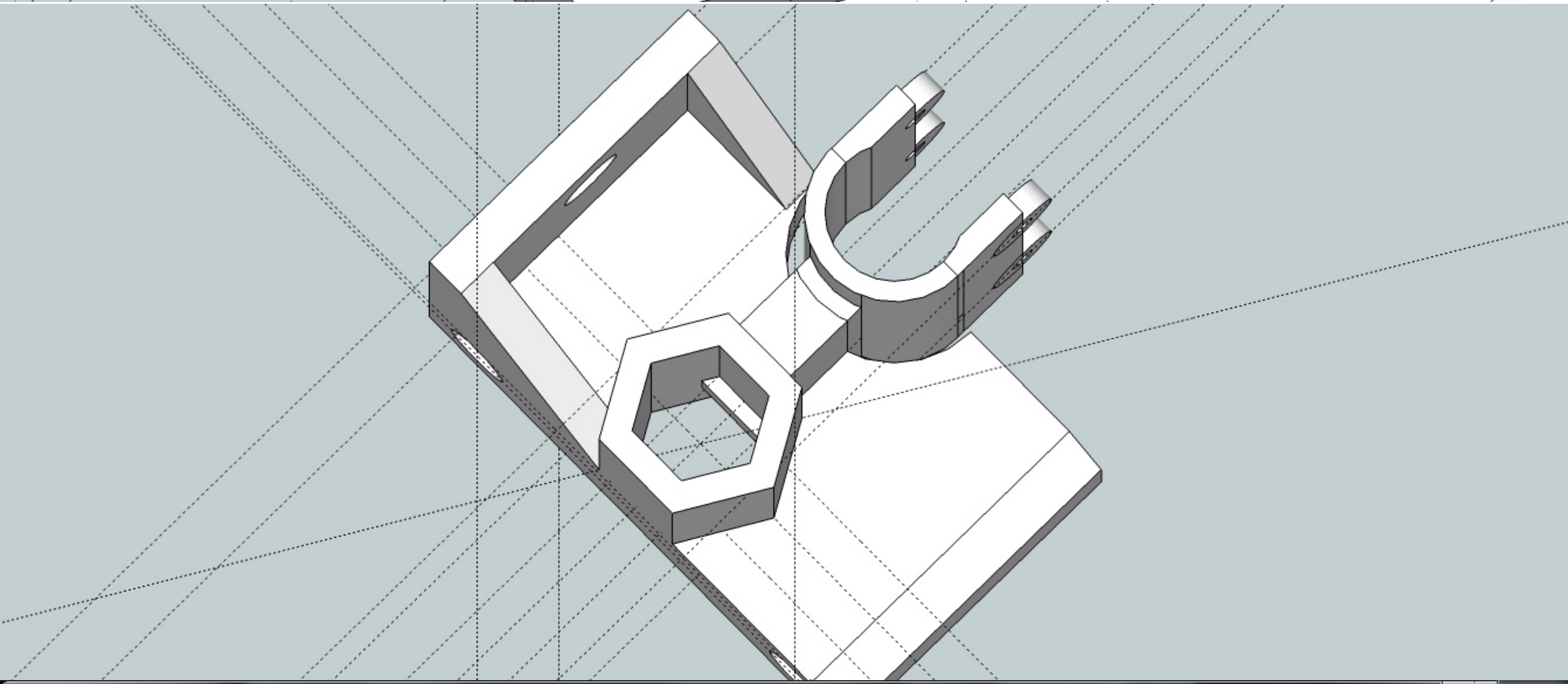


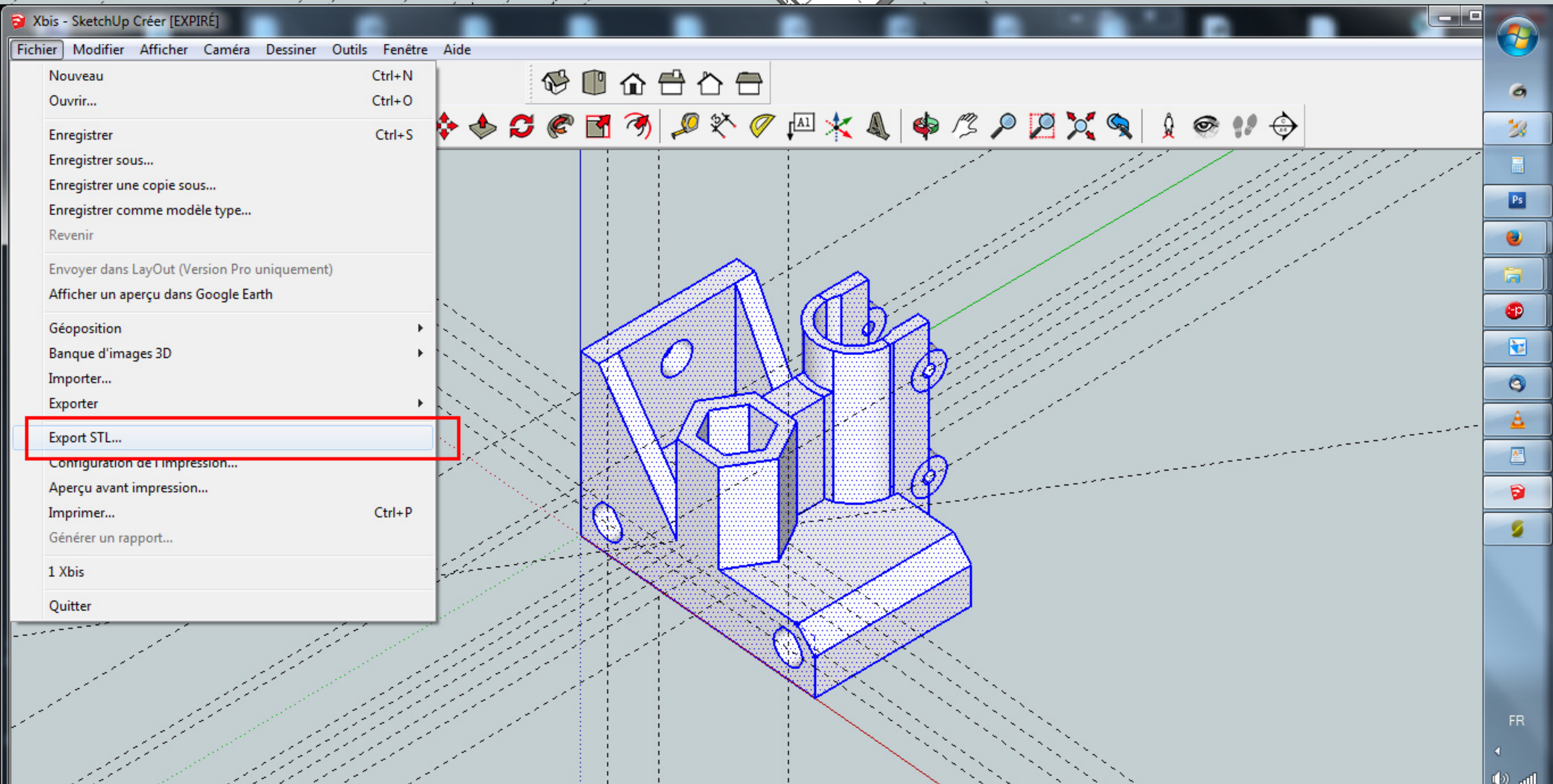




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Envoyer dans LayOut (Version Pro uniquement)
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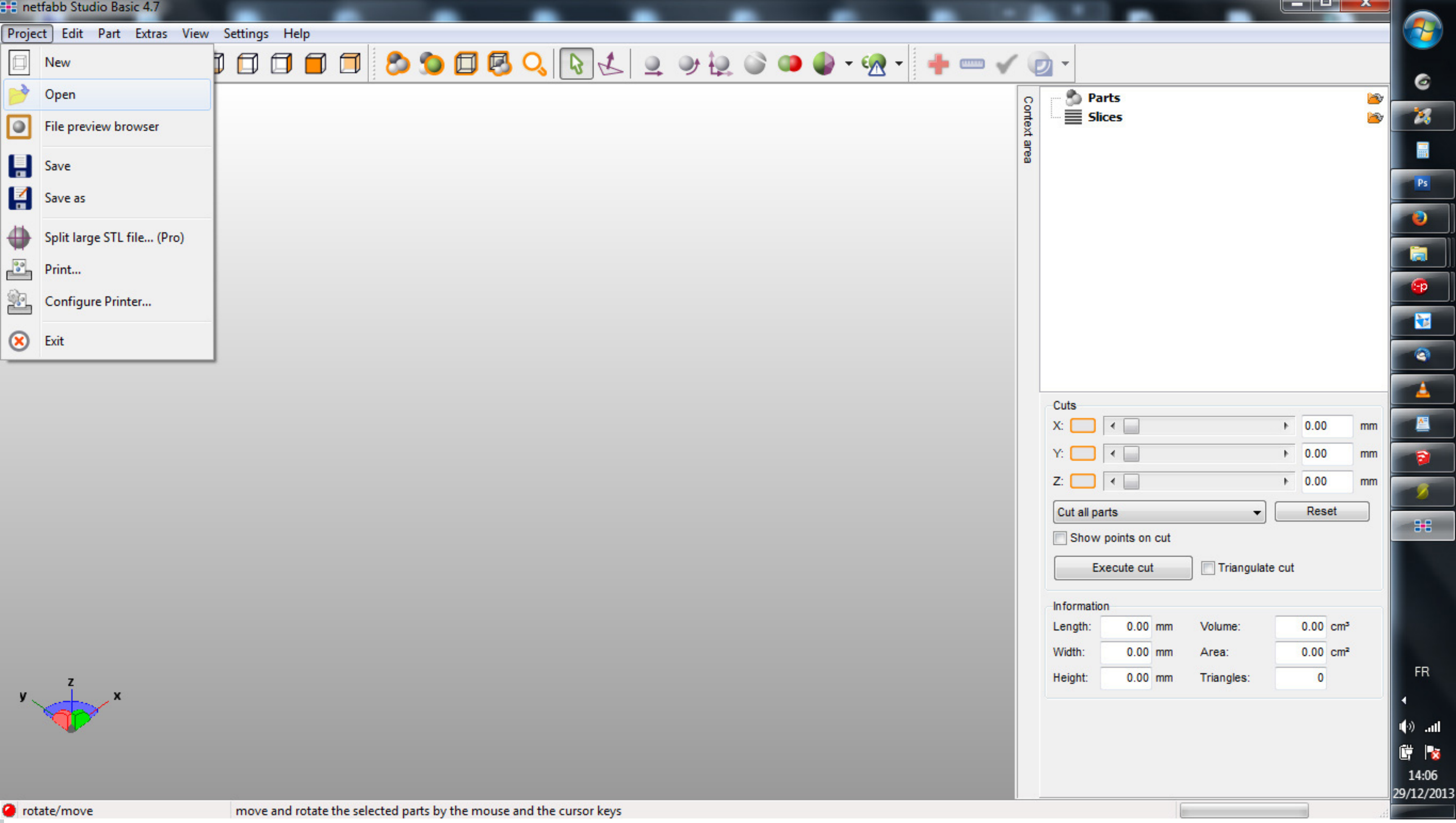
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Project
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Split large STL file... (Pro)
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Context area
Parts
Slices
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Cut all parts
Reset
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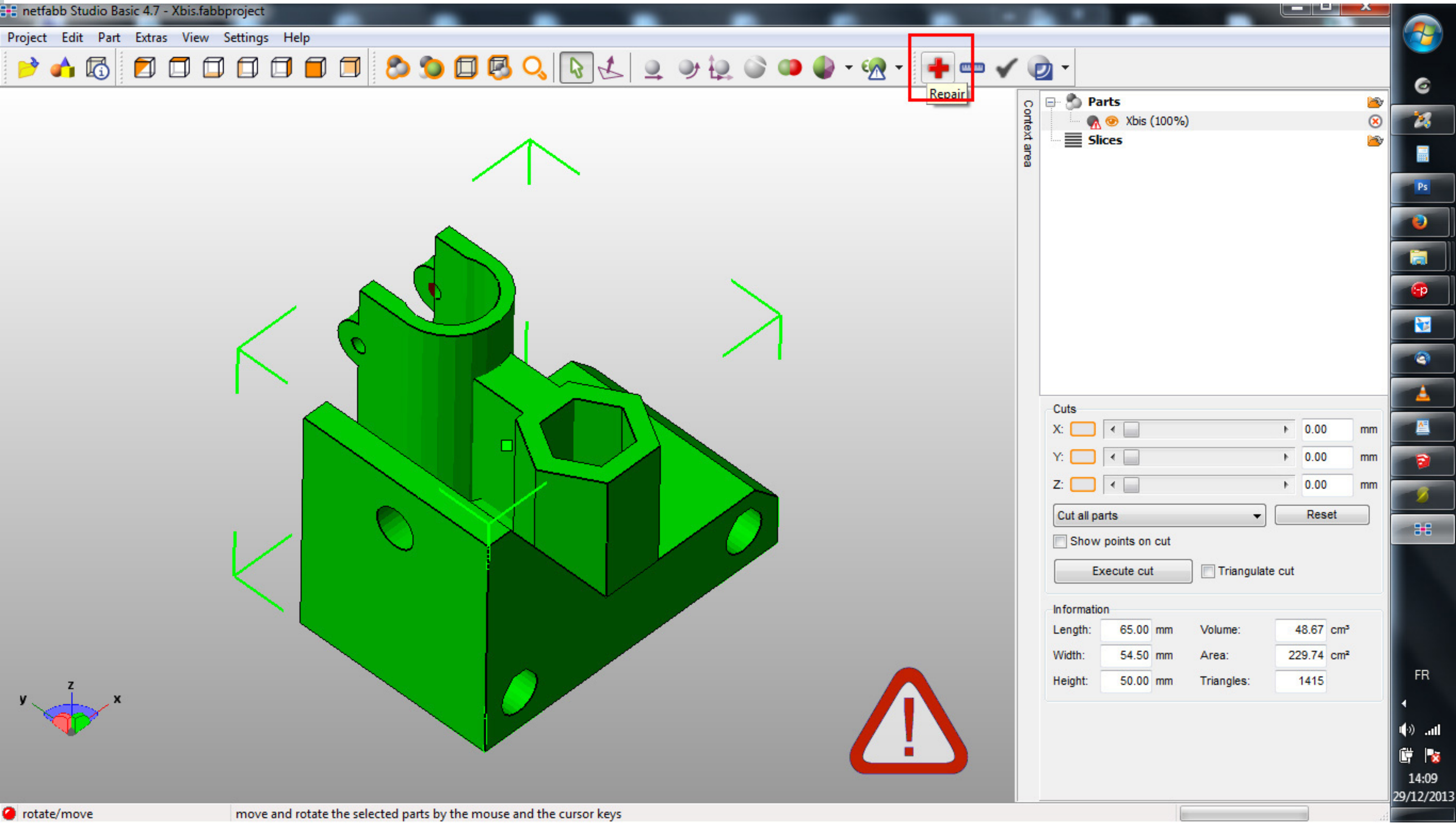
rotate/move
move and rotate the selected parts by the mouse and the cursor keys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Slices
Cuts
Cut all parts
Reset
Show points on cut
Execute cut
Triangulate cut
Information
Length: 65.00 mm
Width: 54.50 mm
Height: 50.00 mm
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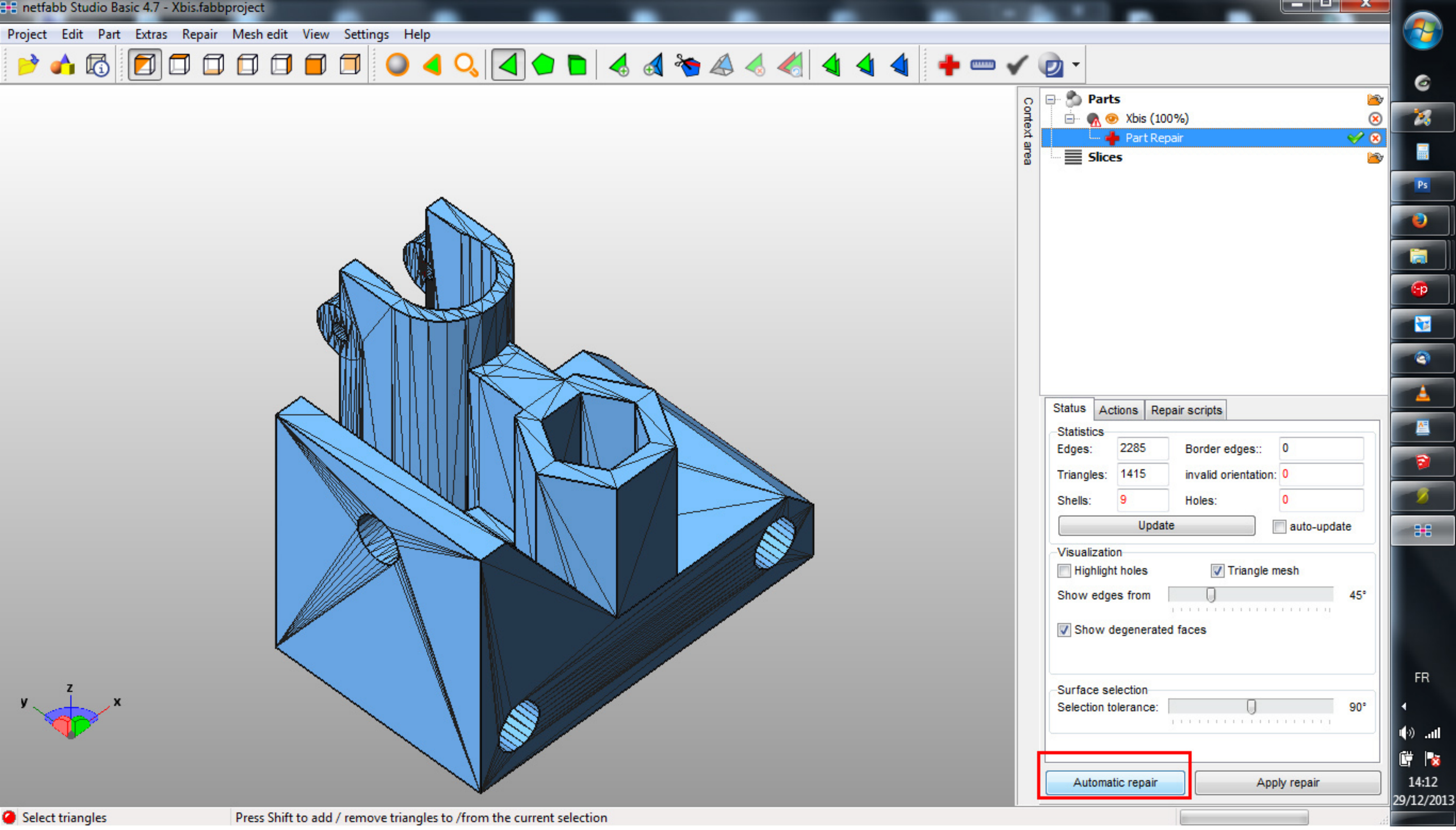
Area: 229.74 cm²
Triangles: 1415
rotate/move
move and rotate the selected parts by the mouse and the cursor keys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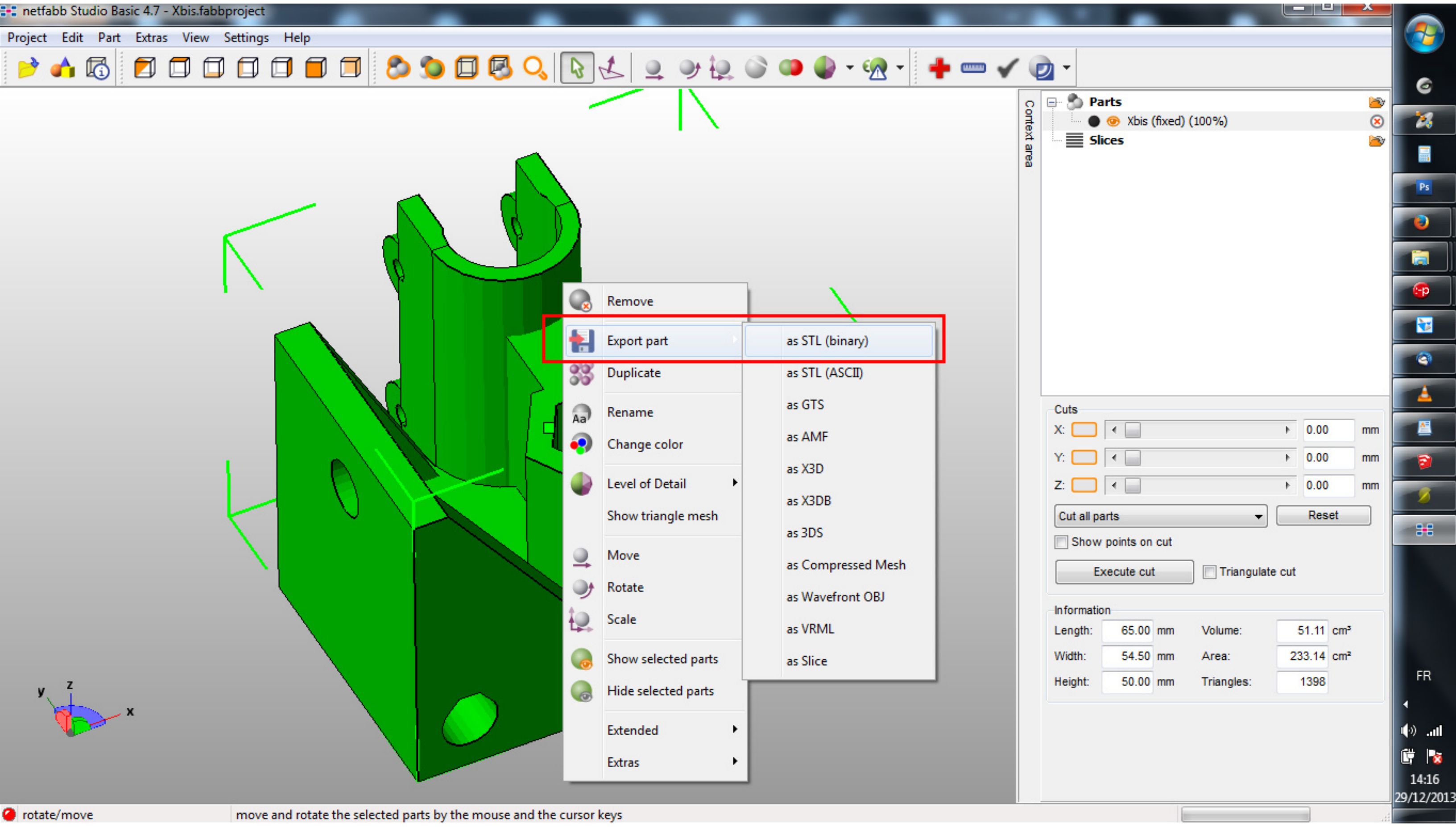
Border edges:: 0
Triangles: 1415
invalid orientation: 0
Shells: 9
Holes: 0
Update
auto-update
Visualization
Highlight holes
Triangle mesh
Show edges from 45°
Show degenerated faces
Surface selection
Selection tolerance: 90°
Automatic repair
Apply repair
Select triangles
Press Shift to add / remove triangles to /from the current selection
14:12
29/12/2013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Project Edit Part Extras View Settings Help
Parts
Xbis (fixed) (100%)
Slices
Remove
Export part
Duplicate
Rename
Change color
Level of Detail
Show triangle mesh
Move
Rotate
Scale
Show selected parts
Hide selected parts
Extended
Extras
as STL (binary)
as STL (ASCII)
as GTS
as AMF
as X3D
as X3DB
as 3DS
as Compressed Mesh
as Wavefront OBJ
as VRML
as Slice
Cuts
X: 0.00 mm
Y: 0.00 mm
Z: 0.00 mm
Cut all parts
Reset
Show points on cut
Execute cut
Triangulate cut
Information
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Width: 54.50 mm
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Triangles: 1398
rotate/move
move and rotate the selected parts by the mouse and the cursor keys
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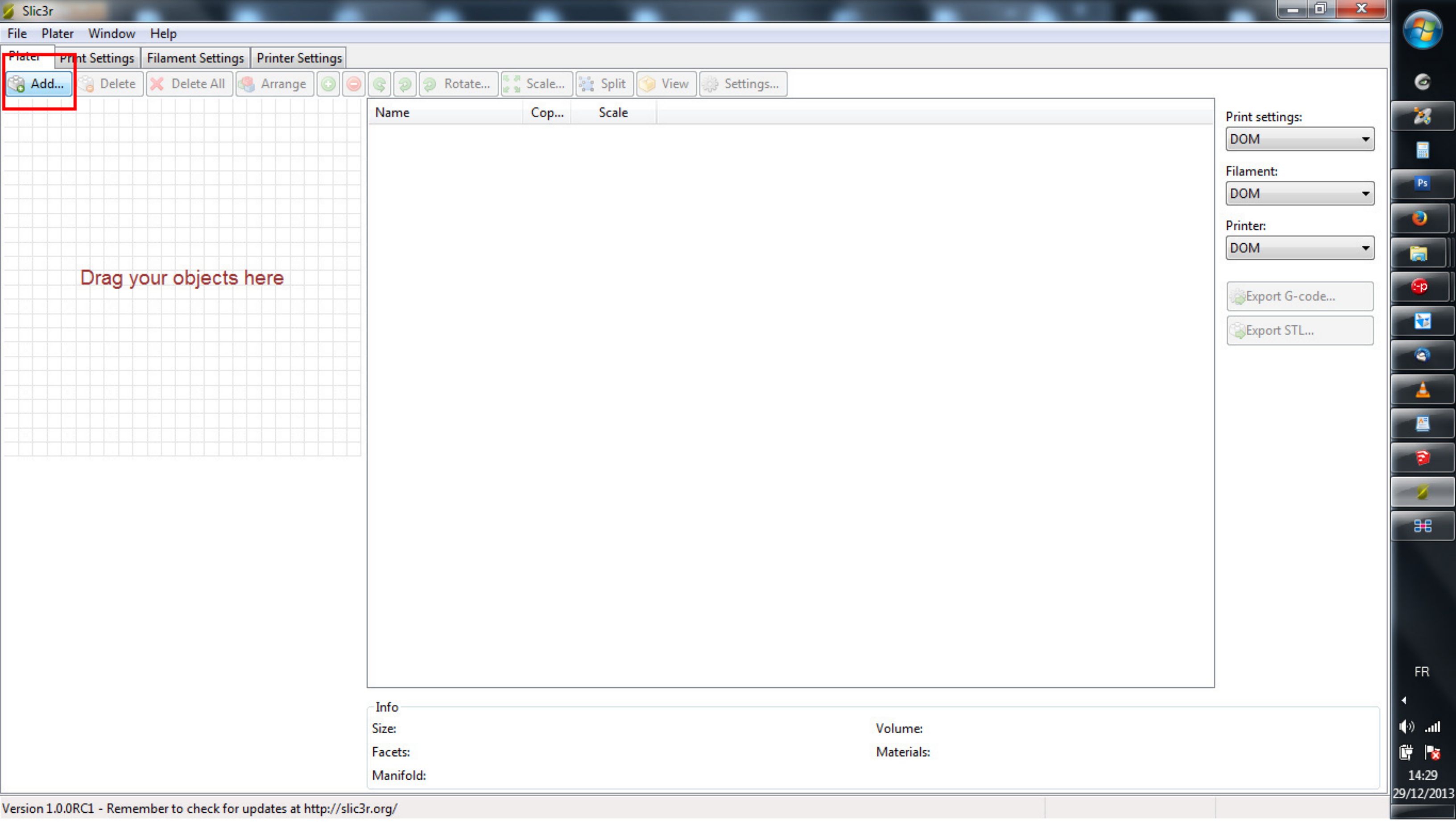
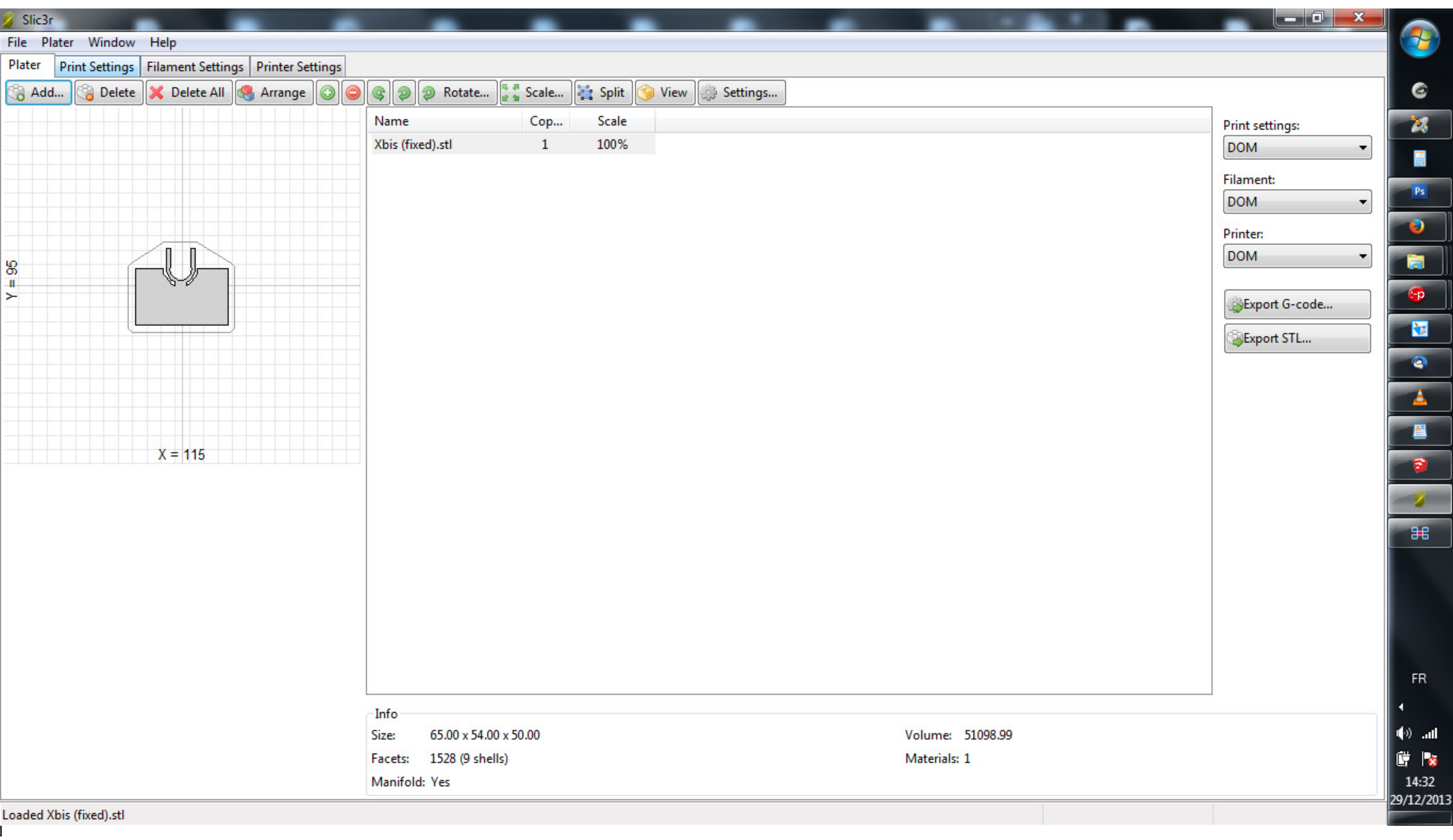

Slic3r
File Plater Window Help
Plater Print Settings Filament Settings Printer Settings
Add... Delete Delete All Arrange Rotate... Scale... Split View Settings...
Name Cop... Scale
Print settings: DOM
Filament: DOM
Printer: DOM
Export G-code...
Export STL...
Drag your objects here
Info
Size:
Facets:
Manifold:
Volume:
Materials:
Version 1.0.0RC1 - Remember to check for updates at http://slic3r.org/
FR
14:29
29/12/2013


Slic3r
File Plater Window Help
Plater Print Settings Filament Settings Printer Settings
Add... Delete Delete All Arrange Rotate... Scale... Split View Settings...
Name Cop... Scale
Xbis (fixed).stl 1 100%
Print settings: DOM
Filament: DOM
Printer: DOM
Export G-code...
Export STL...
Y = 95
X = 115
Info
Size: 65.00 x 54.00 x 50.00
Facets: 1528 (9 shells)
Manifold: Yes
Volume: 51098.99
Materials: 1
Loaded Xbis (fixed).stl
FR
14:32
29/12/2013