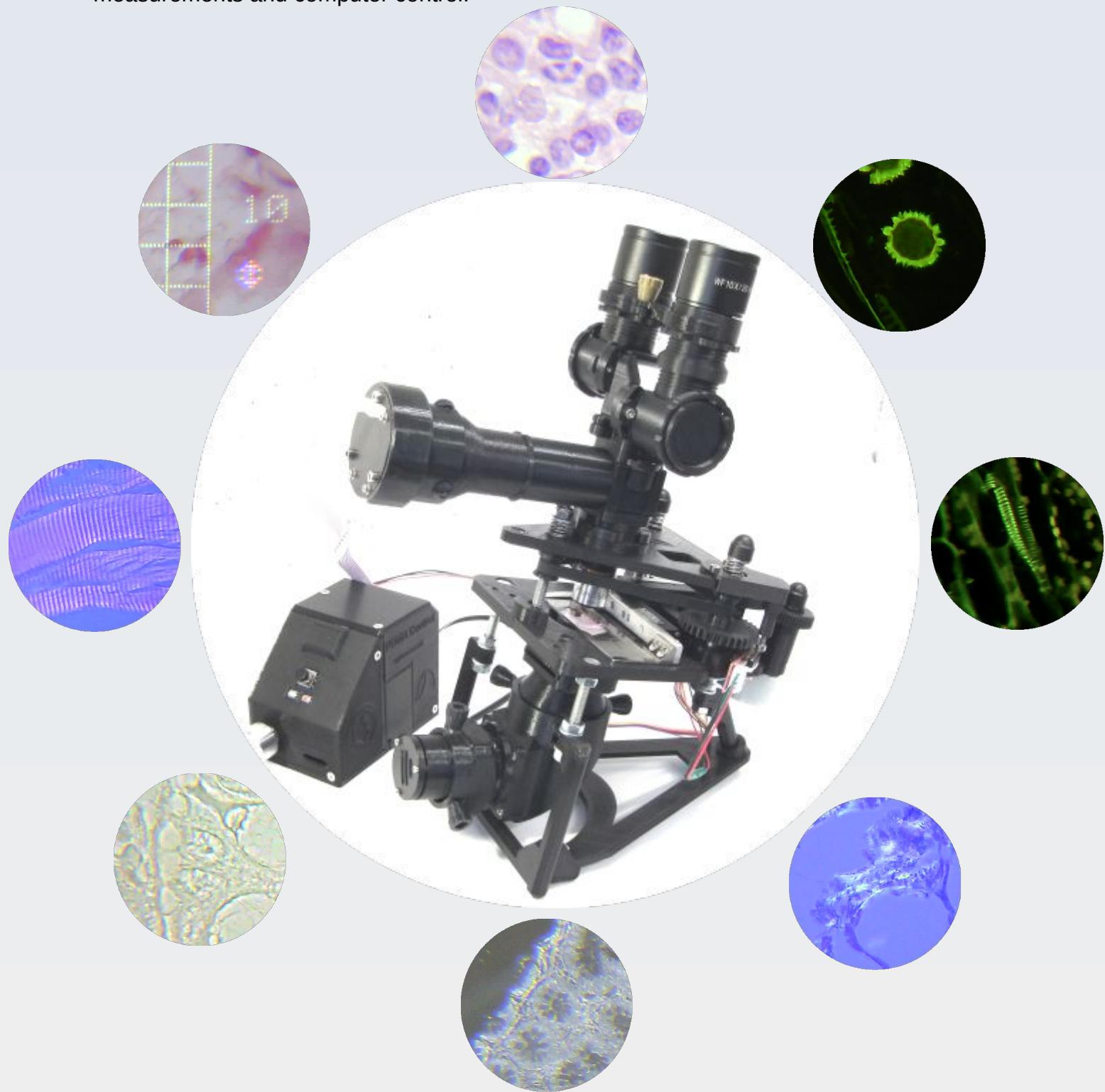




# PUMA 3D Printing Guide

Document created: 26.02.2021, Last edited: 23.03.2022

PUMA: The Open Source (GPL v3.0) 3D printed microscope system designed for direct eye observations and ultra-portability with advanced options for digital imaging, measurements and computer control.



# Contents

Legal Information.....	7
License.....	7
Limitations of Use.....	7
Disclaimer.....	7
Health and Safety Advice.....	9
Burns and Fire.....	9
Toxic Fumes.....	9
Lacerations.....	9
Injury to Eyesight.....	9
Protecting the Vulnerable.....	9
Introduction.....	10
Cover Illustration.....	11
Centre.....	11
From Top Going Clockwise.....	11
Generating the STL Mesh Files.....	12
Printer and Slicer Software and Settings.....	17
Supports.....	17
Mesh Errors.....	18
Post Processing and Aftercare of Prints.....	19
AR Projector.....	20
Resources.....	20
AR_Cc_locknut.stl.....	21
AR_Cc_mount_drawtube.stl.....	22
AR_Cc_Retainer.stl.....	23
AR_Clip_c_adhesin.stl.....	24
AR_Clip_lock.stl.....	25
AR_Cx_Cc_connector.stl.....	26
AR_Cx_Collar.stl.....	27
AR_Cx_Lens_holder.stl.....	28
AR_Stay_thumbwheel.stl.....	29
AR_TFT_DrawTube_F.stl.....	30
AR_TFT_Drawtube_sheath.stl.....	31
AR_TFT_LightShield.stl.....	32

AR_TFT_Mount.stl.....	33
Binocular Head.....	34
Resources.....	34
BN_Cap_spacer_bolt_arm.stl.....	35
BN_Cap_spacer_nut_arm.stl.....	36
BN_CM_BB_Cover.stl.....	37
BN_CM_Tube_short_c_adhesin.stl.....	38
BN_EM_Cover.stl.....	39
BN_MB_Shim.stl.....	40
BN_MBT_Cap.stl.....	41
BN_MBT_Ring.stl.....	42
BN_MB_Tube.stl.....	43
BN_MB_Tube_spacer_0p48mm.stl.....	44
BN_MB_Tube_spacer_2p5mm.stl.....	45
BN_Mirror_mount_bottom.stl.....	46
BN_Mirror_mount_top_ocular.stl.....	47
BN_Ocular_spacer_ring.stl.....	48
BN_Ocular_Base_thread_L.stl.....	49
BN_Ocular_Base_thread_R.stl.....	50
BN_Outlet_lower_spacer.stl.....	51
BN_Outlet_upper.stl.....	52
BN_Splitter_block.stl.....	53
BN_Splitter_support.stl.....	54
Dominus Illuminator.....	55
Resources.....	55
DI_Cnd_Adj_thumbwheel.stl.....	57
DI_Cnd_Crosshair_Cap_c_adhesin.stl.....	58
DI_Cnd_Flange_Spacer_0p48.stl.....	59
DI_Cnd_gripper.stl.....	60
DI_Cnd_Mirror_holder_socket.stl.....	61
DI_Cnd_protector_cap.stl.....	62
DI_Cnd_to_UC.stl.....	63
DI_Collector_mirror_block.stl.....	64
DI_Condenser_23_30.stl.....	65
DI_Condenser_base.stl.....	66

DI_Epi_attachment.stl.....	67
DI_Epi_black_body.stl.....	68
DI_Epi_cap.stl.....	69
DI_Epi_Cnd_Aperture_04.stl.....	70
DI_Epi_Cnd_Aperture_10.stl.....	71
DI_Epi_Cnd_Aperture_13.stl.....	72
DI_Epi_condenser.stl.....	73
DI_Epi_pol.stl.....	74
DI_Ferrule_46_c_adhesin.stl.....	75
DI_Field_Stop_Rectangle.stl.....	76
DI_Field_Stop_Round.stl.....	77
DI_IAD_AP_DF_Stop_10.stl.....	78
DI_IAD_AP_DF_Stop_11.stl.....	79
DI_IAD_AP_DF_Stop_12.stl.....	80
DI_IAD_AP_DF_Stop_2p5.stl.....	81
DI_IAD_AP_DF_Stop_oil_20.stl.....	82
DI_IAD_AP_Phase180_oil.stl.....	83
DI_IAD_AP_Phase180.stl.....	84
DI_IAD_Filter_Tray_oil.stl.....	85
DI_IAD_Filter_Tray.stl.....	86
DI_IAD_SLM_Cover.stl.....	87
DI_IAD_SLM_Filter.stl.....	88
DI_IAD_Tray.stl.....	89
DI_IFD_Adapter.stl.....	90
DI_IFD_Filter_crosshairs.stl.....	91
DI_IFD_Threadjoiner.stl.....	92
DI_IFD_Threadlock.stl.....	93
DI_IFD_Tray.stl.....	94
DI_LC_Adjust_collar.stl.....	95
DI_LC_Cap.stl.....	96
DI_LC_Collar_2.stl.....	97
DI_LC_Collar_7.stl.....	98
DI_LC_Receptacle.stl.....	99
DI_LC_Spacer.stl.....	100
DI_LED_Cover.stl.....	101

DI_LED_Holder.stl.....	102
DI_LED_Washer.stl.....	103
DI_LPC_Lensholder.stl.....	104
DI_LPC_Lens_retainer.stl.....	105
DI_LPC_Lensless_23.stl.....	106
DI_LPC_Single_23.stl.....	107
DI_M3_Adjustment_ring.stl.....	108
DI_M3_Adjustment_ring_Kohler.stl.....	109
DI_M3_Thumbscrew_short_hex.stl.....	110
DI_M3_Thumbscrew_tall.stl.....	111
DI_Mirror_holder_plain.stl.....	112
DI_Mirror_suspend_plain.stl.....	113
DI_Mirror_to_baseplate.stl.....	114
DI_Pol_Adjustment_ring.stl.....	115
DI_Pol_middle.stl.....	116
DI_Pol_Receptacle.stl.....	117
DI_Pol_to_baseplate.stl.....	118
DI_Pol_top_bottom.stl.....	119
DI_Proximal_collector_attachment.stl.....	120
DI_Tool_23.stl.....	121
DI_Tool_44.stl.....	122
DI_UC_Retention_Cap.stl.....	123
DI_UC_Spacer.stl.....	124
Filterblock.....	125
Resources.....	125
FB_Filter_block_simple.stl.....	126
FB_Filter_collar_compression_tool.stl.....	127
FB_Filter_collar.stl.....	128
FB_Filter_F17_slider.stl.....	129
FB_Filter_F_slider.stl.....	130
FB_Filter_slider.stl.....	131
FB_Filter_Slot_bottom.stl.....	132
FB_Filter_slot_stopper.stl.....	133
FB_Filter_slot_top.stl.....	134
FB_Infinity_adapter.stl.....	135

FB_Side_port_separate.stl.....	136
FB_Side_port_separate_EpiStop.stl.....	137
FB_Splitter_case.stl.....	138
FB_Stopper.stl.....	139
FB_Top_connector.stl.....	140
Focus Gears.....	141
Resources.....	141
FG_Fine_gear.stl.....	142
FG.Focus_spacer.stl.....	143
FG_Intermedius.stl.....	144
FG_Pulley_coarse.stl.....	145
FG_Pulley.stl.....	146
FG_Eccentric_Tensioner_Top.stl.....	147
FG_Eccentric_Tensioner_Bottom.stl.....	148
FG_Eccentric_Tensioner_Pulley_c_adhesin.stl.....	149
Legs.....	150
Resources.....	150
LG_Back_leg_angled.stl.....	151
LG_Feet_linker.stl.....	152
LG_Front_legs.stl.....	153
LG_Hind_extension.stl.....	154
LG_Short_leg.stl.....	155
Monocular Head.....	156
Resources.....	156
MN_EM_Block.stl.....	157
MN_EM_Block_cover.stl.....	158
MN_Monocular_tube_c_adhesin.stl.....	159
MN_Monocular_tube_CM_c_adhesin.stl.....	160
MN_Ocular_cap_170.stl.....	161
MN_Ocular_cap.stl.....	162
MN_Ocular_extension_c_adhesin.stl.....	163
MN_Ocular_extension_CM_c_adhesin.stl.....	164
MN_Ocular_lock_nut.stl.....	165
MN_Ocular_protective_cap.stl.....	166
MN_Ocular_tube_protective_cap.stl.....	167

PUMA Control Console.....	168
Resources.....	168
PC_Battery_cover.stl.....	169
PC_Expansion_port_cover.stl.....	170
PC_Front_panel.stl.....	171
PC_Joystick_PCB_clasp.stl.....	172
PC_Lamp_insulator.stl.....	173
PC_Left_panel_Base_Skeleton.stl.....	174
PC_Top_back_panel.stl.....	175
PUMA Lite.....	177
Resources.....	177
PL_Battery_cover.stl.....	178
PL_Knob.stl.....	179
PL_Lamp_insulator.stl.....	179
PL_Left_Base_Back.stl.....	180
PL_Top_Front_Right.stl.....	181
Quick Release Objective Holder.....	183
Resources.....	183
QR_Base_thread.stl.....	184
QR_C-RMS_Thread.stl.....	185
QR_Male_C_extn_1mm.stl.....	186
QR_Male_C_extn_4mm.stl.....	187
QR_Trainer.stl.....	188
QR_Trainer_Male.stl.....	189
Stage.....	190
Resources.....	190
ST_Articulation.stl.....	191
ST_BasePlate.stl.....	192
ST.FocusPlate.stl.....	193
Trinocular Camera Port.....	194
Resources.....	194
TN_Trinoc_CP_tube.stl.....	194
XY Stabiliser.....	195
Resources.....	195
XY_Stabiliser.stl.....	195

Z-Motor.....	196
Resources.....	196
ZM_Motor_attachment.stl.....	197
ZM_Motor_gear.stl.....	198
ZM_Z_Limit_Sw_Mount.stl.....	199
ZM_Z_Probe.stl.....	200
ZM_Z_Yoke.stl.....	201

## Legal Information

### License

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### Limitations of Use

The PUMA microscope and its associated systems do not have any certifications or regulatory approvals in any country for use in clinical diagnostics or treatment (human or veterinary).

The PUMA microscope and its associated systems are released to be used for research and educational purposes only.

### Disclaimer

All PUMA project information, including without limitation any CAD file or STL file and all documentation, advice and instruction (whether provided in video form, audible form, written form or otherwise) is provided 'as is' in good faith and is intended to be helpful but comes with no warranty whatsoever.

Anyone attempting to build or use a PUMA microscope or other PUMA-related material, accessory, module or derivative is hereby advised that there will be risk involved in 3D printing, post-print processing, assembly and usage of the resulting structures. This risk includes, without limitation, the risk of personal damage and loss of resources.

Dr Paul J. Tadrous, TadPath and OptArc cannot accept any liability for any such loss or damages that may occur. All those who attempt to build or use any aspect of the PUMA project or derivatives thereof do so at their own risk.

# **Health and Safety Advice**

## **Burns and Fire**

There is a risk of fire and of burns when working with 3D printers, soldering irons and molten solder. Wear appropriate personal protective equipment such as gloves and eye and face protection. Ensure all electrical components are of the appropriate voltage and current tolerances. Do not leave electrical components powered for longer than they are required for use. Do not leave 3D printers unattended when they are powered up.

## **Toxic Fumes**

Some filaments used in 3D printing can release toxic fumes when heated (such as during the 3D printing process). Working with solder can also release toxic fumes (especially if leaded solder is used). Ensure adequate ventilation at all times during 3D printing and soldering.

## **Lacerations**

Cleaning 3D prints sometimes involves the use of sharp instruments – take appropriate precautions when handling sharp blades. Working with optics – especially thin plates of glass such as beamsplitter mirrors, microscope slides and coverslips and display screen panels can result in flying shards and sharp edges. Wear appropriate personal protective equipment such as gloves and face and eye protection.

## **Injury to Eyesight**

Physical injuries to the eyes may occur from shards and specs of glass and airborne particles of molten or hot solder. Bright lights are used to illuminate the PUMA microscope. These should be used with caution. Do not stare directly into the illumination LED bulb (with or without its collector lenses in place), and only use a brightness setting that is appropriate for comfortable viewing when using the complete microscope. If using a mirror to provide illumination always use a reflection from a diffuse scene such as an open blue or cloudy sky. NEVER allow specular reflections of the sun to enter the field of view of the mirror or permanent eyesight loss may result. If using a bulb that emits UV light, always ensure an appropriate and effective UV blocking filter is used to shield your eyes from the UV light. If a laser is used for illumination then you should never look at the image through the lenses of the scope (you should use a camera for making observations).

## **Protecting the Vulnerable**

The PUMA microscope and its accessories are not toys. Do not allow children, vulnerable adults or pets to come into contact with any PUMA product without appropriate supervision and safeguards.

# Introduction

PUMA is a 3D printed high quality microscope system. The name PUMA stands for **P**ortable, **U**pgradeable, **M**odular and **A**ffordable – key features of this system.

This document provides practical advice for those who want to print their own parts for the building of PUMA-related modules and microscopes.

It also serves as a visual ‘index of parts’ for all the 3D printed parts in the PUMA project and shows which FreeCAD file contains which parts. Within the FreeCAD file those models have the same name as the STL file but without the ‘.stl’ extension and also without the two letter prefix before the first underscore. For example, the file AR\_Cc\_locknut.stl is a mesh generated from the model called ‘Cc\_locknut’ in the FreeCAD file called ‘AR\_Projector.FCStd’.

The information in this file only relates to 3D printed parts. To build a PUMA microscope additional components will be needed such as nuts and bolts and optics elements. None of these additional components are addressed here. See the assembly / usage tutorials and documentation for that information.

Advice is given for each model separately. For most models this advice consists solely in an illustration showing the preferred orientation of the model on the printer build plate. In some cases additional advice and illustrations are given, particularly where they relate to support structures.

This document makes no attempt at explaining what each part does or how to use or assemble them. For that kind of information you would need to see the assembly / usage tutorials and other documentation.

The Cura screenshot illustrations in this document show the models at various zooms and with some angular perspective variations from model to model in order to emphasise different aspects. However the grid and ‘Ender’ logo shown on the build plate should make it clear how the model is to be orientated and indicate the scale.

Each chapter begins with a table of resources showing the print time and length of 1.75 mm diameter PLA filament used to print each STL file as estimated by Cura v.4.8.0 using the recommended print settings described in that chapter for each model.

# Cover Illustration

## Centre

A PUMA microscope in the following configuration: Full Kohler illuminator, motorised Z-stage, mechanical XY Vernier caliper slide holder, advanced filter block, augmented reality projector, binocular head, PUMA control console. a Zeiss Plan 2.5x objective and two high eye point wide field 10x oculars of 20 mm field of view. Many alternative configurations are possible to PUMA's modular design.

## From Top Going Clockwise

These microscope images (all taken with a PUMA microscope in various configurations) are highly cropped and compressed and do not show the full field of view. See the gallery of images on the PUMA websites for full quality and full field images. Magnifications given below are of the objective only:

Bright field Kohler illumination: H&E chronic inflammation, x100 oil immersion.

Fluorescence microscopy: Fluorescein stained *Soncus* bud showing pollen grains and other cellular structures x40.

Fluorescence microscopy: Fluorescein stained showing chloroplasts, vascular structures and other cellular structures x40.

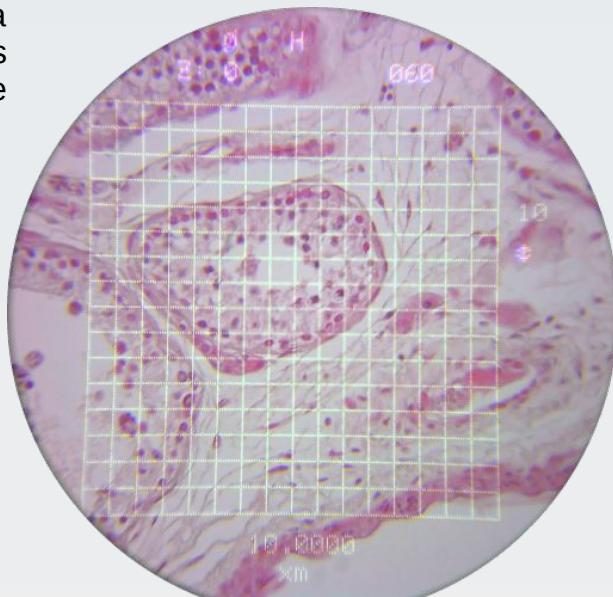
Crossed polarisation microscopy: Amyloid stained with Congo red x40.

Dark field / Dark ground microscopy: Unstained section of colonic tissue x10.

Schlieren phase contrast using a spatial light modulator in the illuminated aperture plane of the condenser: Unstained section of colonic mucosa, x100 oil immersion.

Crossed polarisation microscopy: stained with H&E x40.

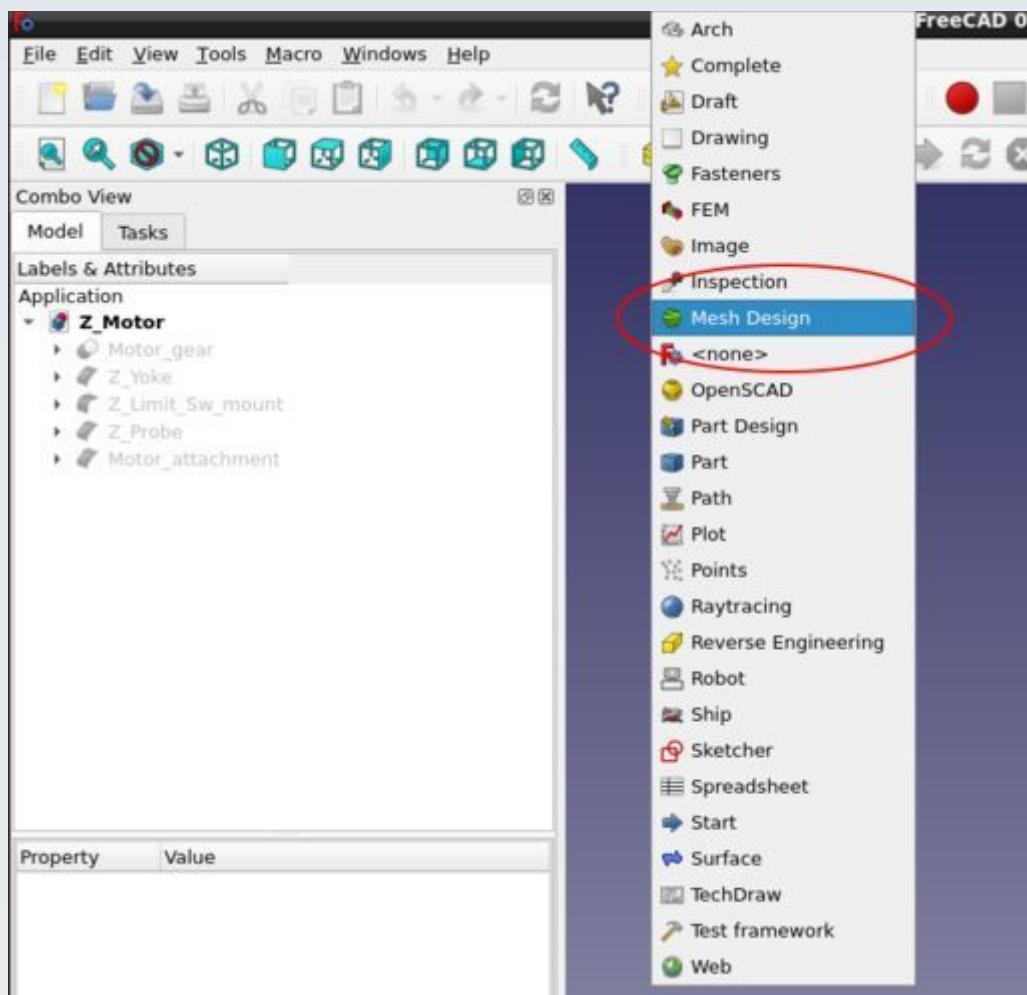
AR HUD Overlay. The figure shows a cropped area from a small part of the field of a x10 view of an H&E section (of testis) with the augmented reality (AR) projector projecting a heads up display (HUD) of a grid and some microscope status information onto the live optical image. The full field image is shown :



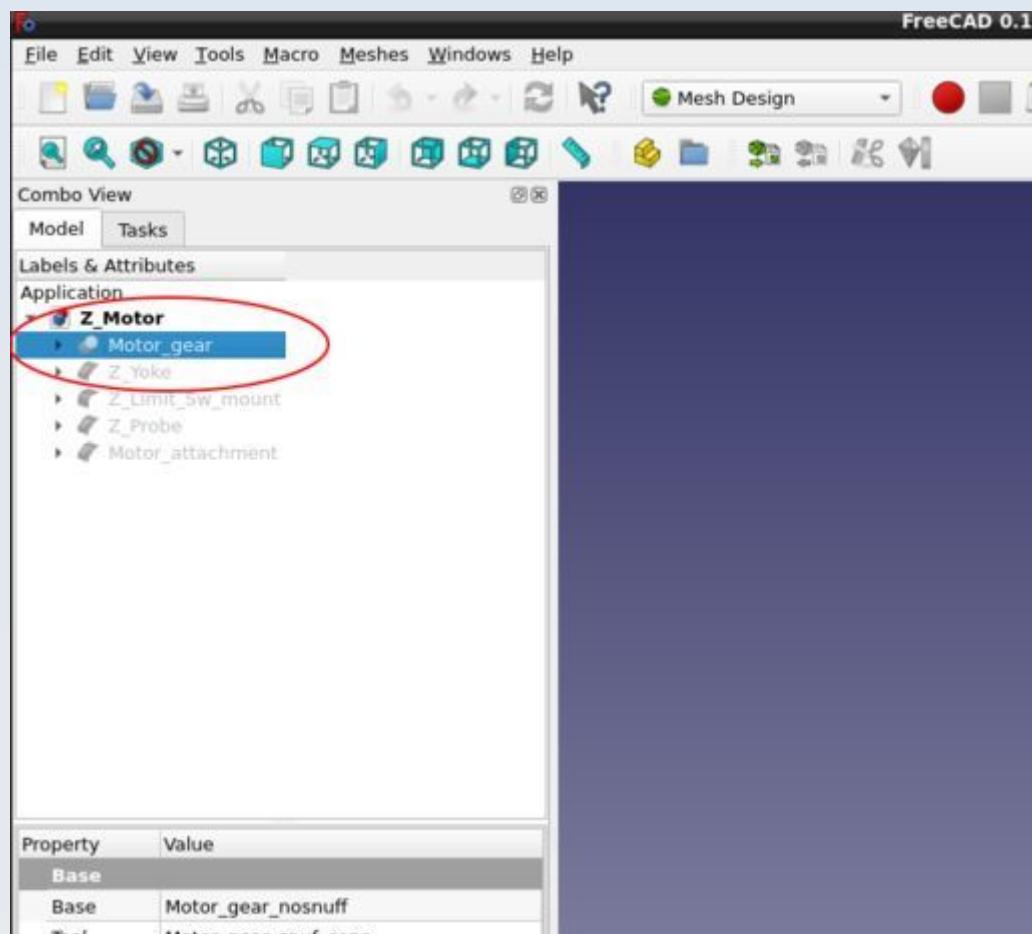
# Generating the STL Mesh Files

The STL mesh files for the PUMA microscope are of variable sizes but many are too large to host on GitHub. However, the CAD files are the source and STL files can be generated from the models in the CAD files using the open source FreeCAD software by means of the following steps.

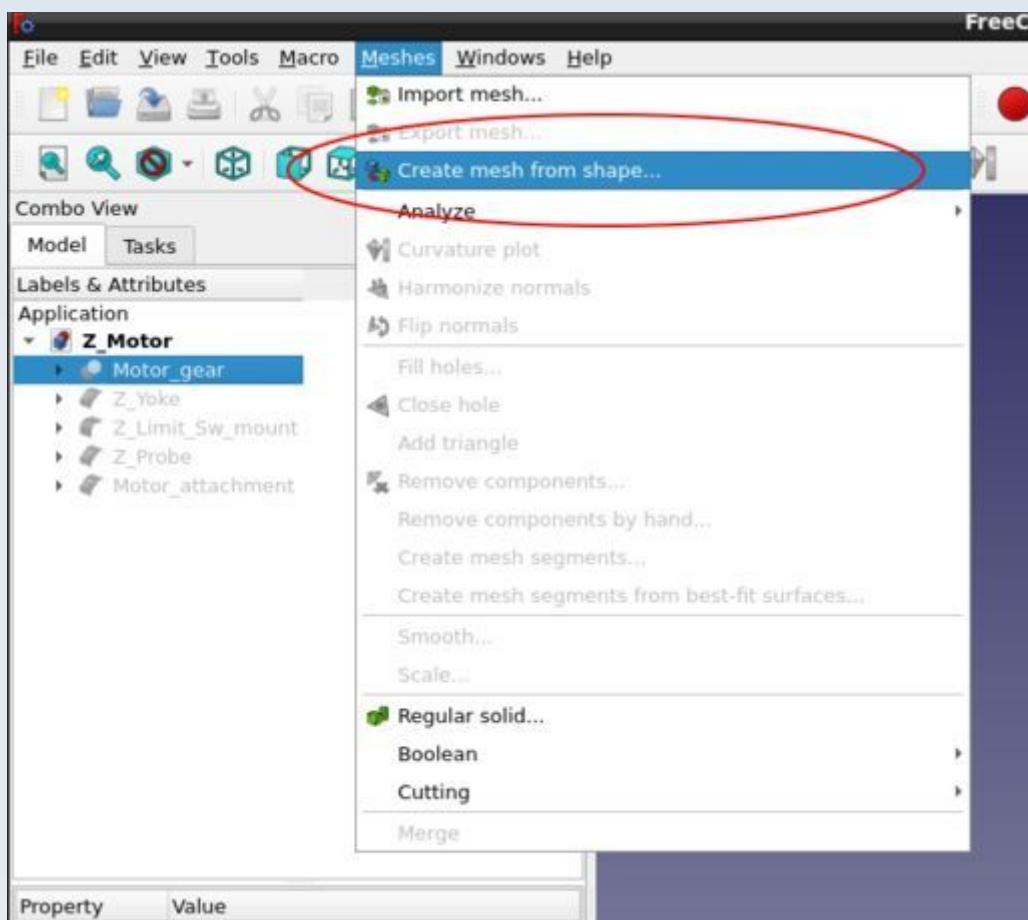
1. Load the CAD file into FreeCAD (I used v. 0.18 to illustrate these steps but a later or the latest version may be required to correctly view and edit the latest models). For the following illustrated examples I have loaded the 'Z\_Motor.FCStd' file from the PUMA project.
2. Select the 'Mesh Design' Workbench from the drop down selection list on the top button bar of FreeCAD.



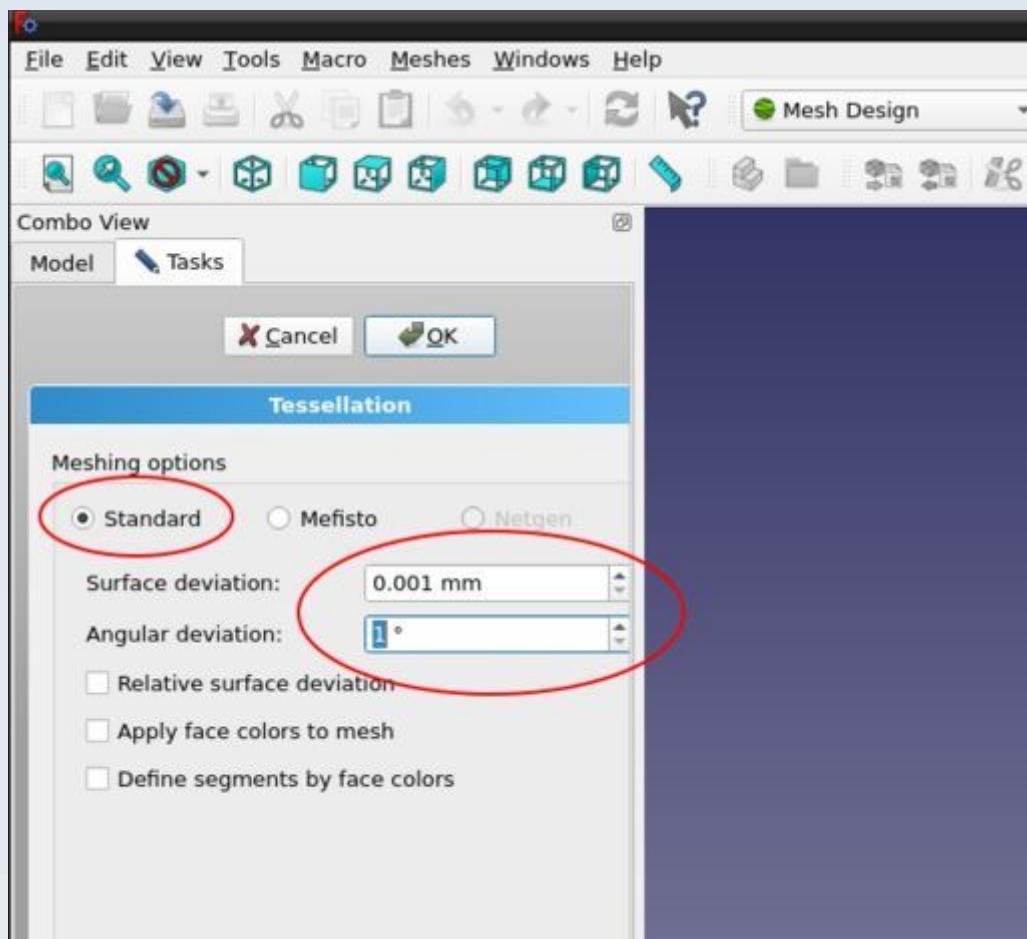
3. Left-click on the model you want to create a mesh for so as to select it.



4. Go to 'Meshes' -> 'Create mesh from shape ...' to bring up the Tessellation dialogue box.



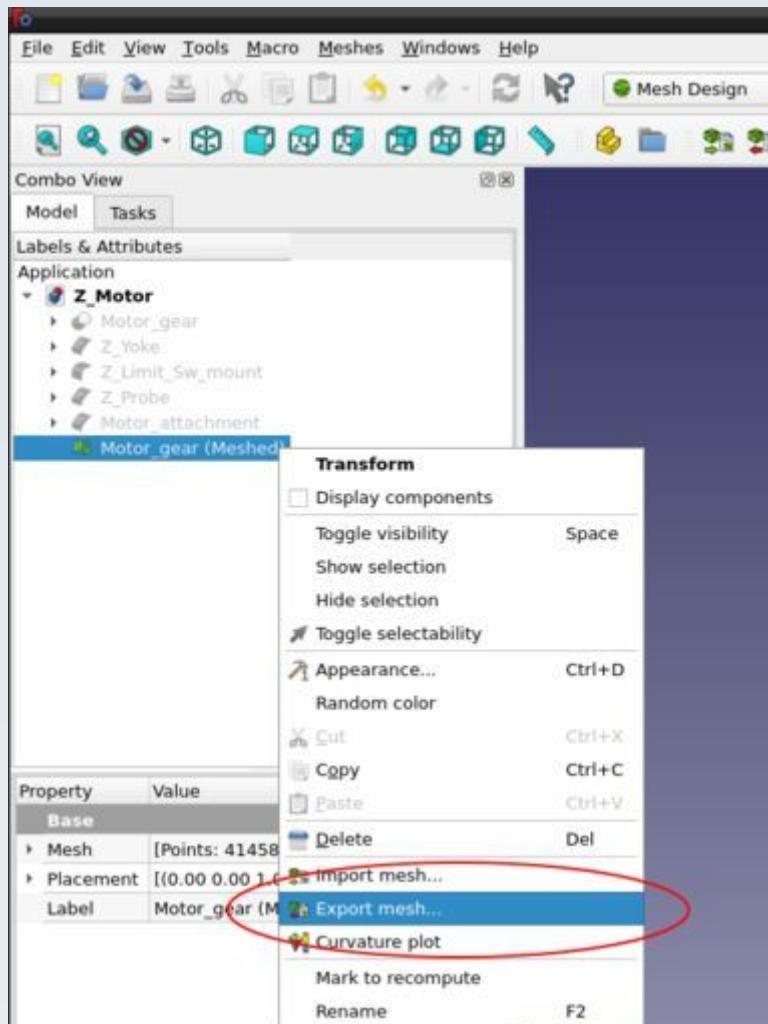
5. Select the 'Standard' meshing option set the 'surface deviation' to 0.001 mm and the 'Angular deviation' to 1 degree.



6. Click OK - it may take a while to complete.

These mesh settings may be overly fine for many of the models in that you could probably get away with coarser settings and lower resolution meshes for some models. However I have not experimented to see how low I can go before the models cease to function or cease to fit properly.

7. When the mesh is generated, right click on the mesh in the 'Model' tab of the combo view and select 'Export Mesh ...' from the drop down menu to save the mesh as an STL file. You might need to rotate the mesh first before export to make it easier to site on the build plate in Cura in the manner required for printing (as will be shown in the illustrations in the rest of this document for each model). Although you can also perform most of those manipulations in Cura itself.



# Printer and Slicer Software and Settings

This advice relates specifically to printing parts using a Creality Ender 3 printer with ordinary PLA 1.75 mm diameter filament and the Ultimaker Cura slicer software (v. 4.8.0 to v. 4.10.0).

If you use a different printer and / or slicer you would need to explore for yourself what are the most appropriate settings and profiles to use and may also need to modify other aspects of the advice given here.

All models are printed with the PUMA custom Cura profile called 'Flats' unless otherwise specified (several other PUMA custom Cura profiles are used on occasion and these are available in the GitHub repository). No supports are used unless specified otherwise. None of the Cura in-built build plate adhesion options are used. Where necessary, custom adhesion structures – called 'adhesins' – are built into the model and these will need to be trimmed off when the model is complete as part of model post print clean up.

I have only ever printed the parts of this project using super high quality print settings and the highest resolution tessellation meshes. No doubt this is 'overkill' for many of the parts but I have not done the practical experimentation required to find out the lowest resolution meshes that will work with the lowest quality / fastest print settings.

I have only ever used standard PLA 1.75 mm filament for printing the parts of this project – although I have used PLA from different suppliers from Creality's own brand to much cheaper generic filament. With the highest quality branded filaments the prints seem a bit smoother but from a functionality point of view all filaments I have tried give acceptable results.

## Supports

You don't need supports for screw thread holes up to M4 diameter that are printed horizontally but Cura will try to insert supports for these which is one of the reasons why support advice in some of the models below specifies to use the 'touching build plate only' option (not 'Everywhere').

When supports are enabled the default overhang angle should be set to 67 degrees.

For 'Tree' supports the default parameters to use are: 'branch distance' is 1 mm, 'branch diameter' is 2 mm, 'branch diameter angle' is 5 degrees and 'collision resolution' is 0.2 mm.

The 'branch angle' for Tree supports may be 40 or 50 degrees depending on the model so this information is provided for each model that required tree supports.

If supports are not stated to be required then ensure supports are off – even if it appears (or Cura suggests) that they might be needed. Sometimes this is emphasised for models where having supports enabled could cause the print to fail or adversely affect the function of the resulting print.

Some models require specific support blockers. These will be illustrated in the figures.

## Mesh Errors

Very occasionally for some models Cura (v.4.8.0) will report model errors in the STL mesh and highlight those areas in bright colours. These 'errors' are very small and the model slices and prints just fine even with them so they can be ignored. During development I have been able to identify and fix some of those mesh errors in FreeCAD but the very few remaining ones were not obvious – and practically they do not matter for printing with an Ender 3 printer.

## Post Processing and Aftercare of Prints

I have noticed that PLA prints will shrink a little if exposed to excessive heat post printing and this may distort closely fitting parts and prevent them from functioning adequately. To avoid this, never keep your 3D printed parts on or very near to a radiator and never use a heater, hair dryer or radiator to dry off any parts that may have gotten wet. Leaving parts in a car in the sun may have a similar detrimental heat shrinkage effect.

Some parts, especially closely fitting parts like threads and push fit components may need scraping or light sanding to remove 'nerds', 'zits' or prominent seams or other imperfections prior to use. It is advised that you allow parts to cool down thoroughly after printing before any such actions (especially sanding) otherwise you may find that you have over-eroded the model and end up with a fit that is too loose. Some 3D printed threads may require 'training' if they seem overly tight. This means you screw and unscrew the thread repeatedly to wear it down a bit – this will usually wear down small prominences / defects in the print that lie in the thread channels. This may need to be done gradually (you may not be able to screw a part all the way in at first). After training the thread should fit snugly without being too tight or too loose.

Some parts require lubrication – such as the polariser wheel and Z-stage bearings. This will be elaborated on in the construction and usage tutorials.

Many thread holes for screws (mostly M2 and M3 sizes but sometimes also up to M6) in many of the parts are printed simply as holes that are slightly too small for the screw and you are expected to cut a thread into the hole by simply screwing the metal screw into the hole. Do this slowly at first concentration on getting the screw perpendicular to the hole and applying downward pressure. For such joints it is important never to overtighten the screws in the finished product because you can easily destroy the plastic thread so produced. Also, you should avoid unscrewing and re-screwing in those holes because the thread will wear out eventually (although they can take quite a few repeats before wearing down to a detrimental degree).

## AR Projector

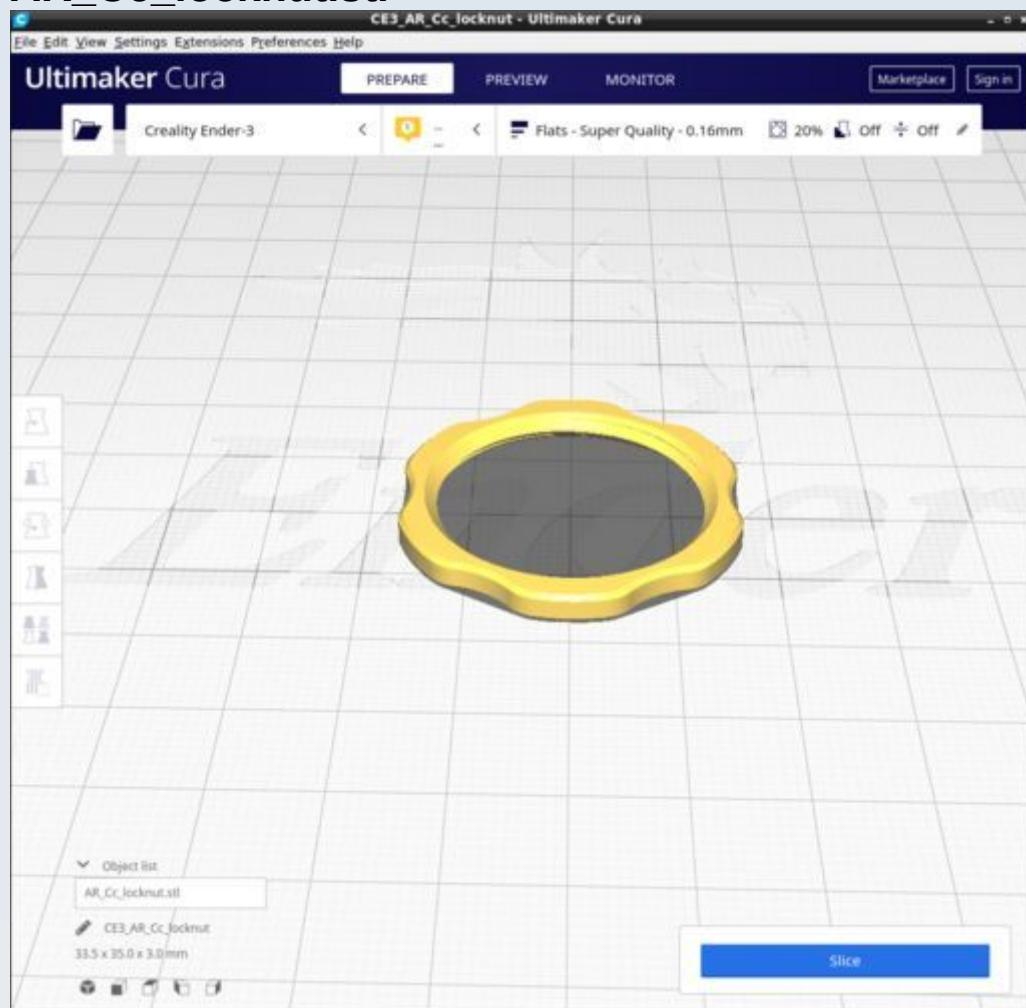
These are the parts for the augmented reality (AR) projector module which provides a heads-up-display (HUD) graphical user interface to the user. The CAD source models for these STL files are found in the file AR\_Projector.FCStd.

## Resources

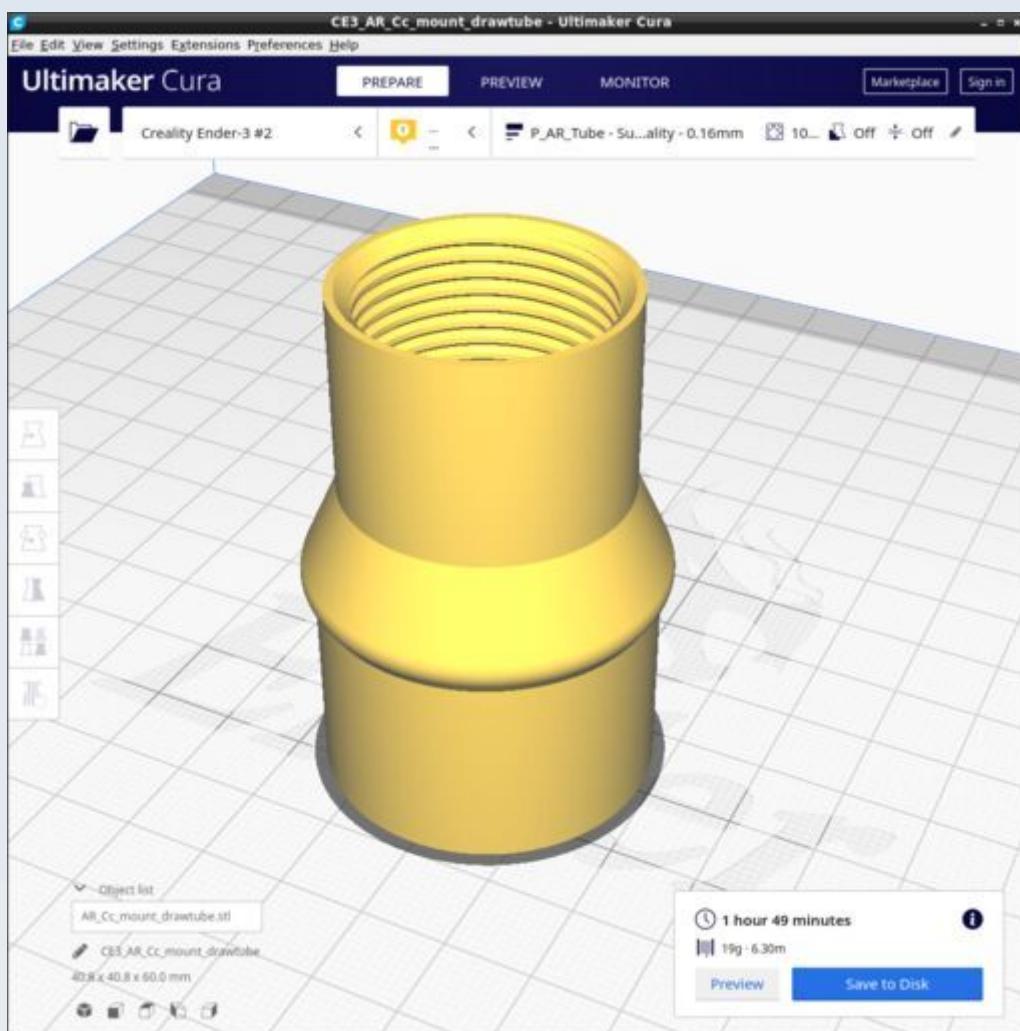
Cura calculates the following resources are required to print each model in this chapter:

AR_Projector	Time_Hr	Time_Min	PLA_Length(m)
AR_Cc_locknut.stl	0	12	0.35
AR_Cc_mount_drawtube.stl	1	49	6.3
AR_Cc_Retainer.stl	0	7	0.28
AR_Cx_Cc_connector.stl	0	28	1.16
AR_Cx_Collar.stl	0	11	0.32
AR_Cx_Lens_holder.stl	0	33	1.72
AR_Clip_c_adhesin.stl	0	57	1.16
AR_Clip_lock	0	37	0.76
AR_Stay_thumbwheel.stl	0	17	0.4
AR_TFT_DrawTube_F.stl	2	27	5.48
AR_TFT_Drawtube_sheath.stl	0	18	0.87
AR_TFT_LightShield.stl	0	43	1.49
AR_TFT_Mount.stl	1	1	2.3

## AR\_Cc\_locknut.stl

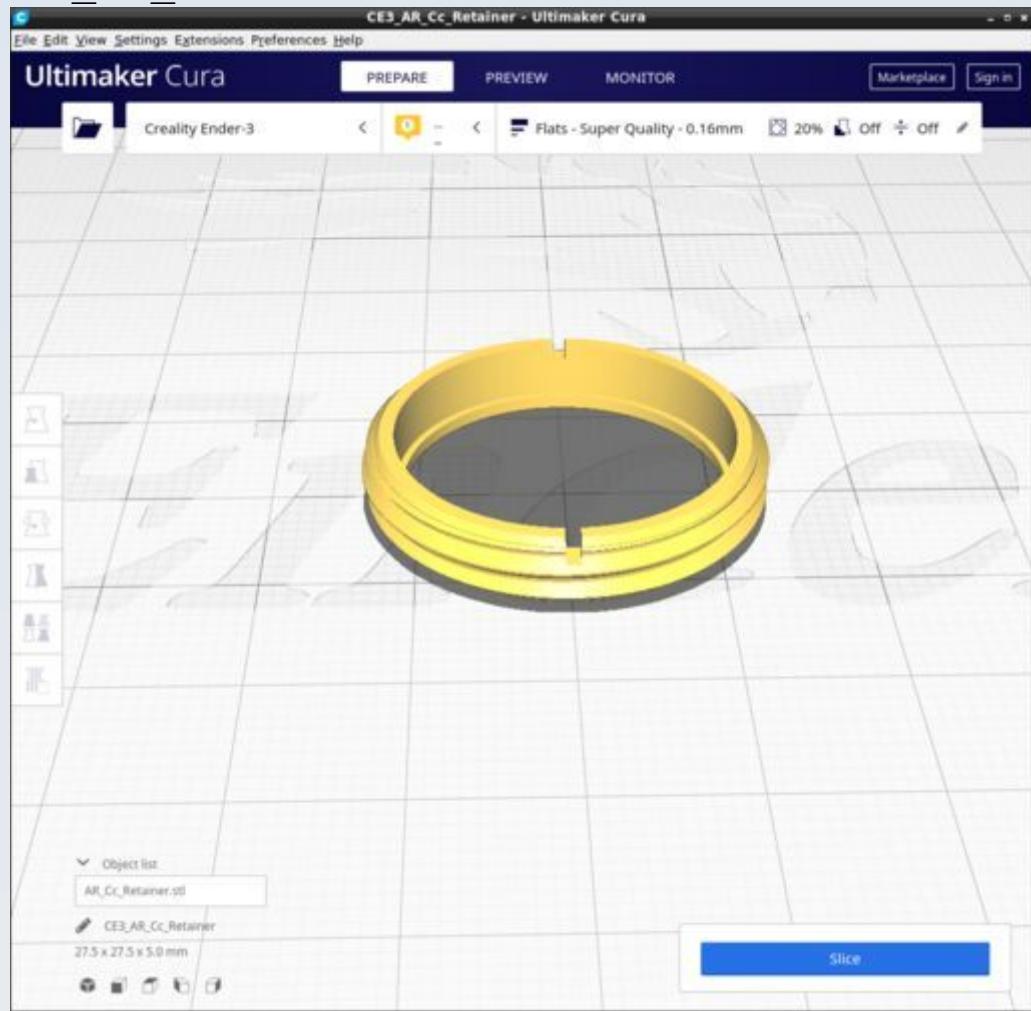


## AR\_Cc\_mount\_drawtube.stl

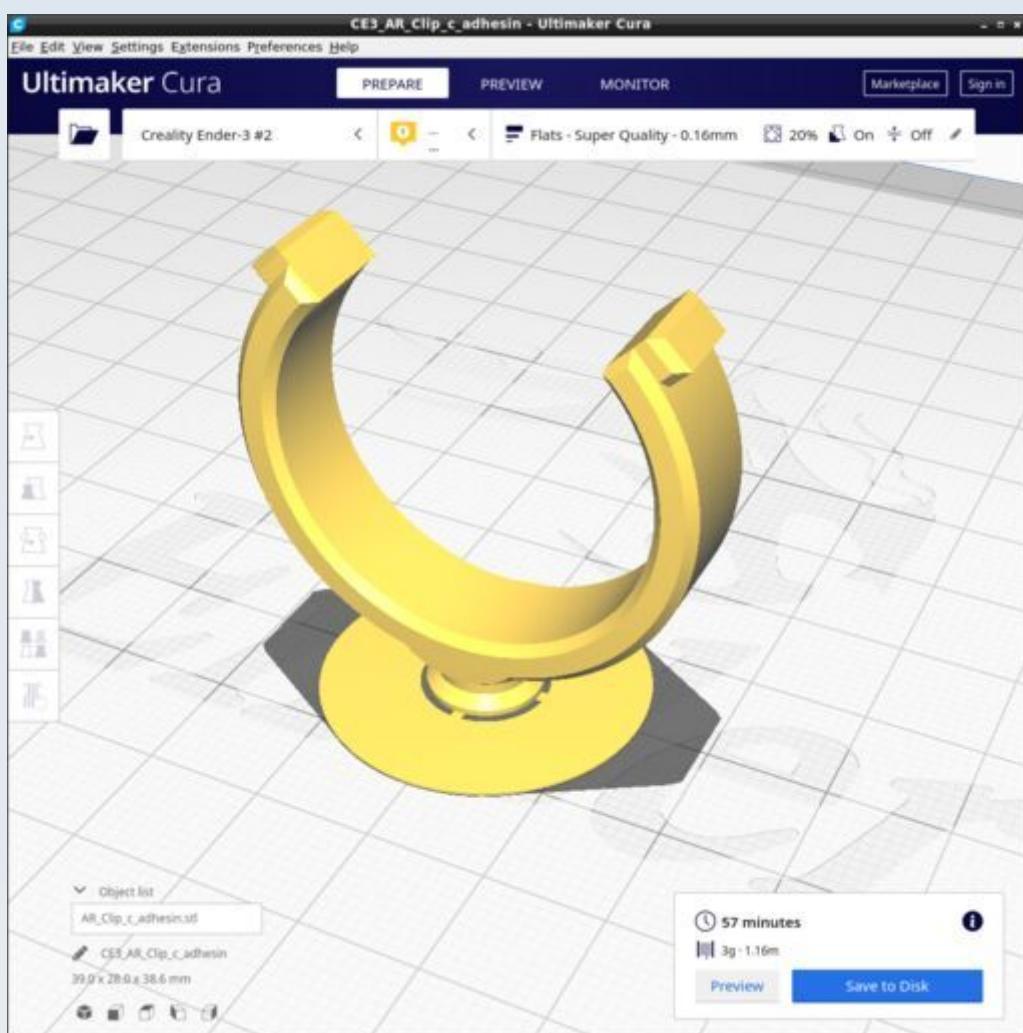


Print with PUMA custom Cura profile 'P\_AR\_Tube'

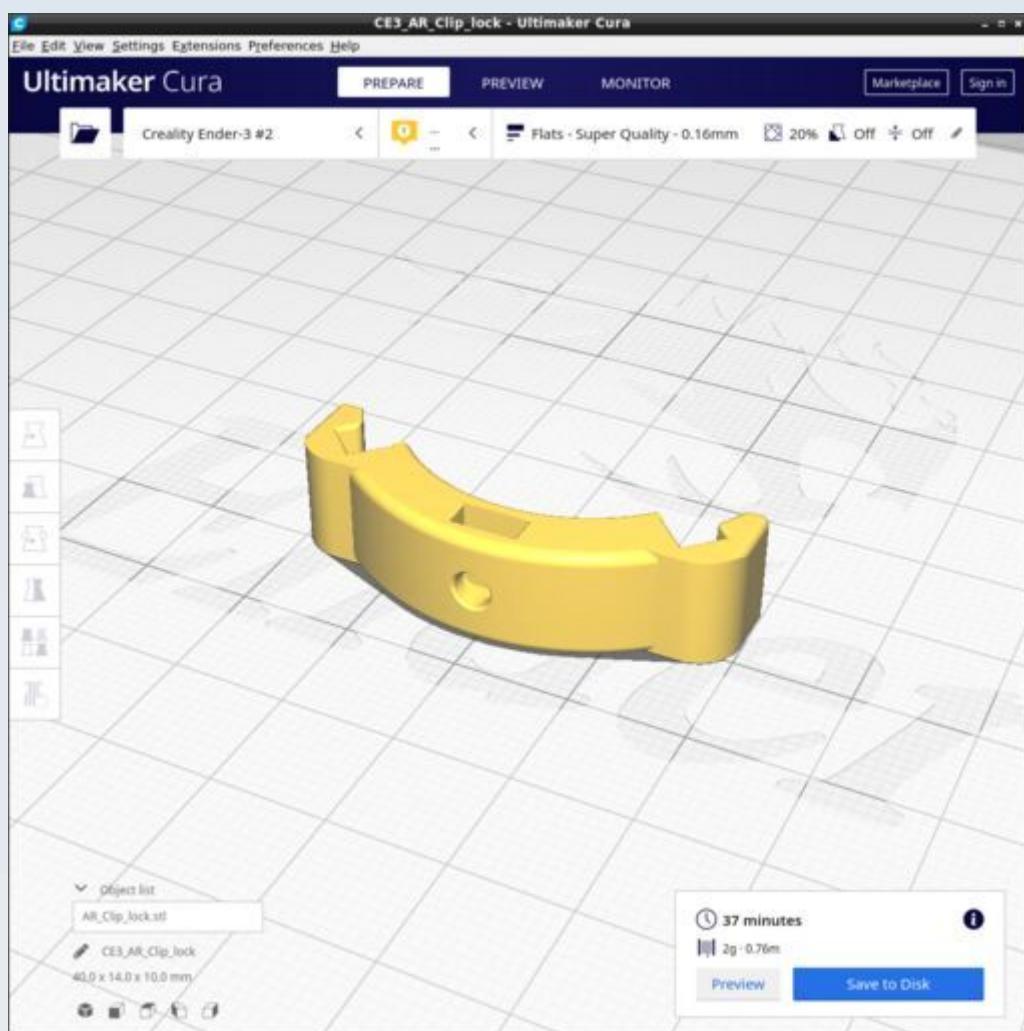
## AR\_Cc\_Retainer.stl



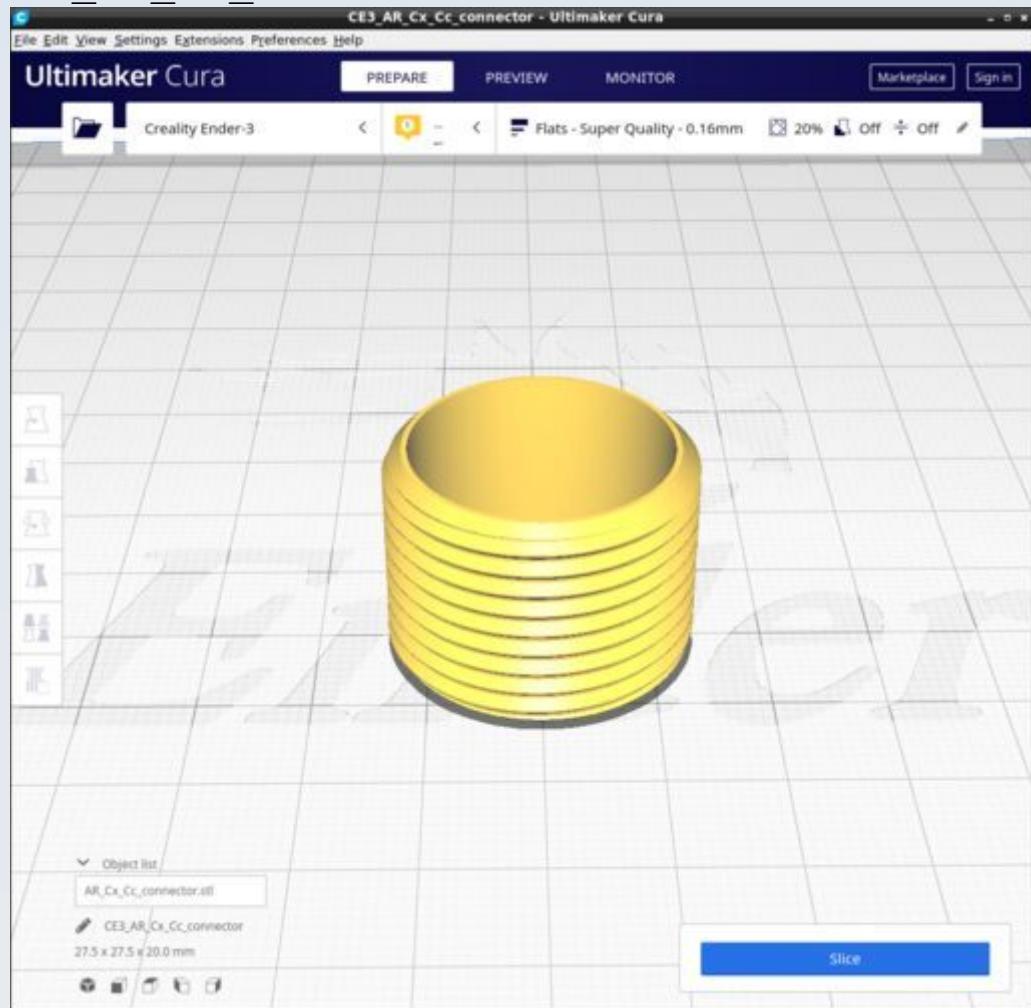
## AR\_Clip\_c\_adhesin.stl



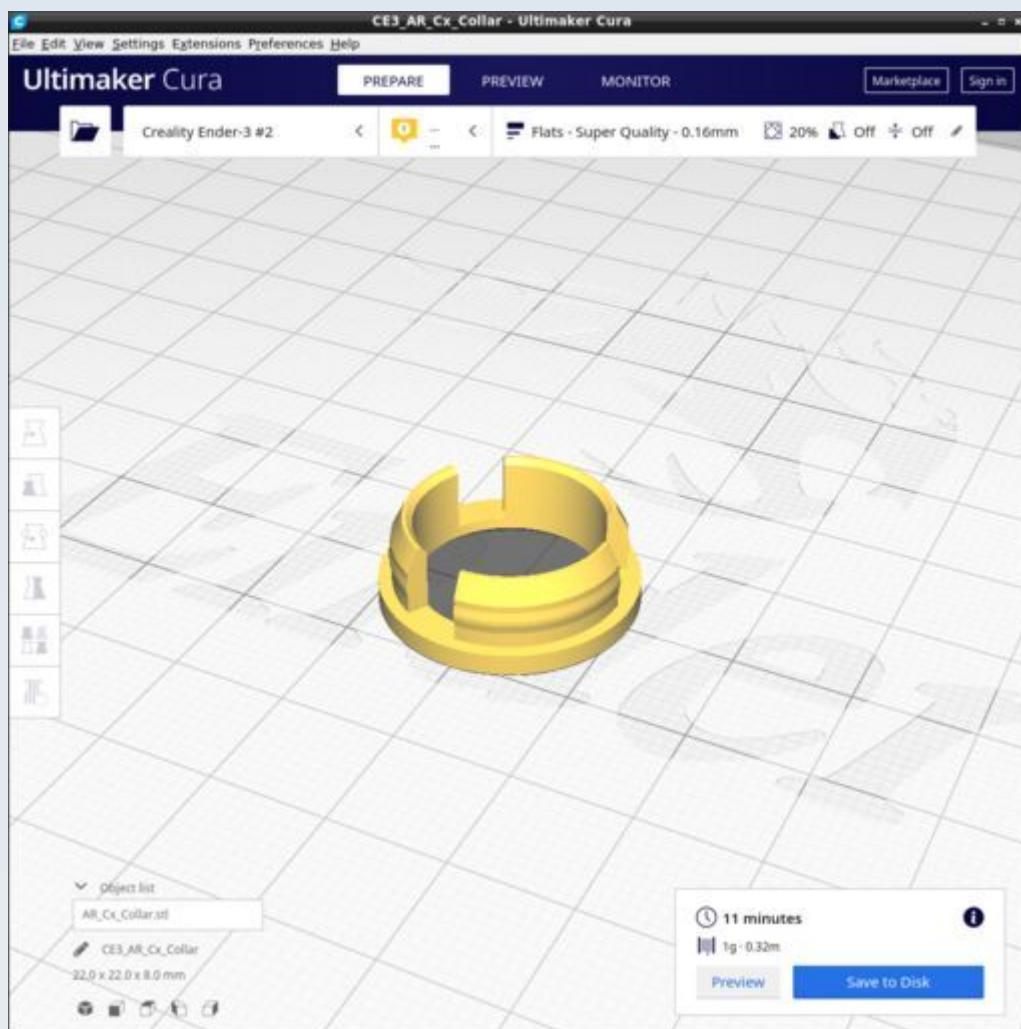
## AR\_Clip\_lock.stl



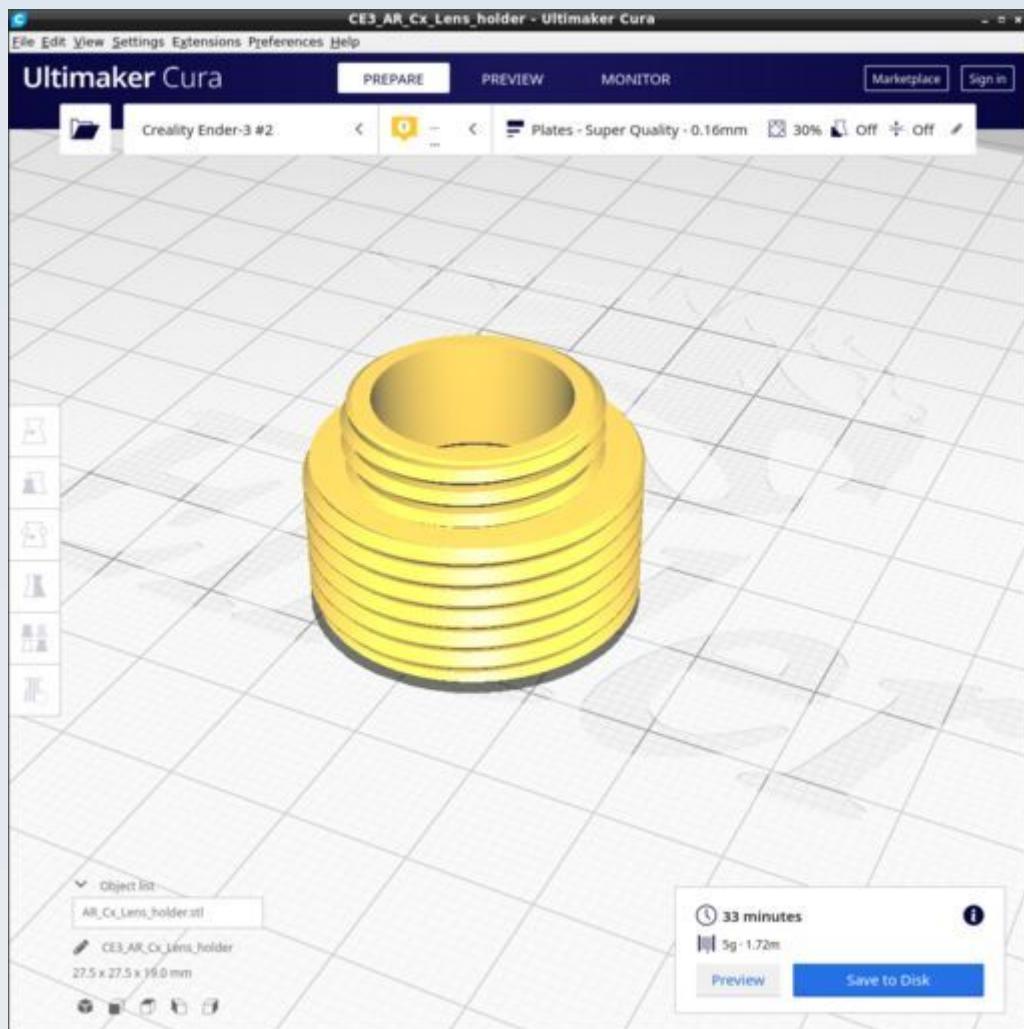
## AR\_Cx\_Cc\_connector.stl



## AR\_Cx\_Collar.stl

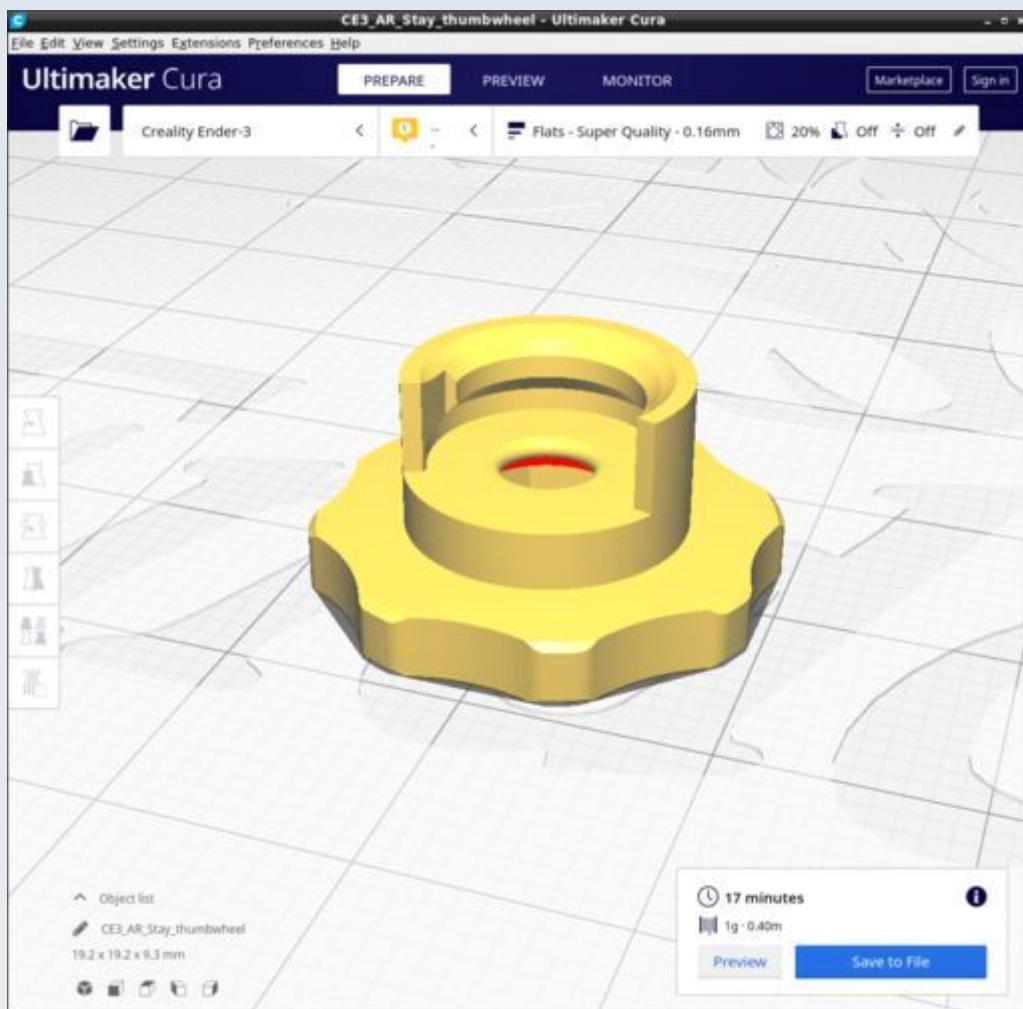


## AR\_Cx\_Lens\_holder.stl

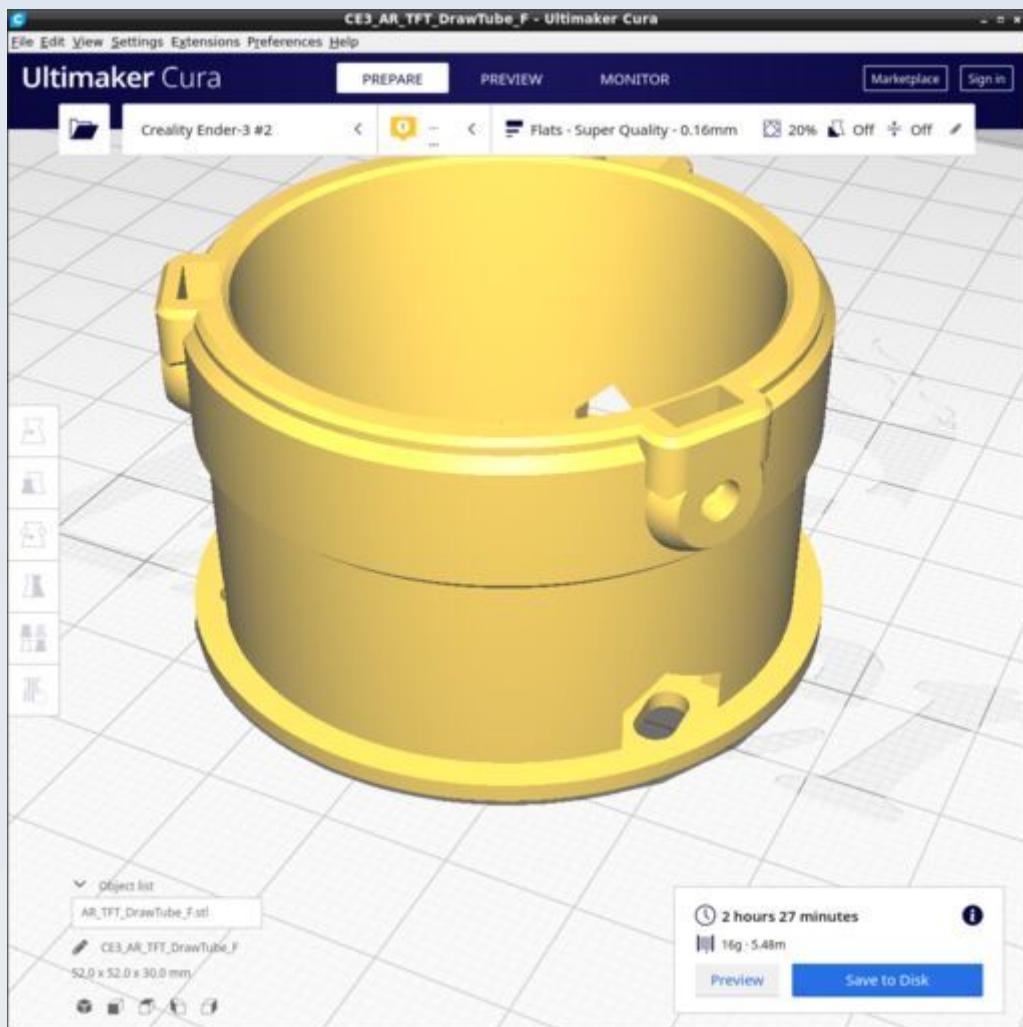


Print with PUMA custom Cura profile 'Strong01'

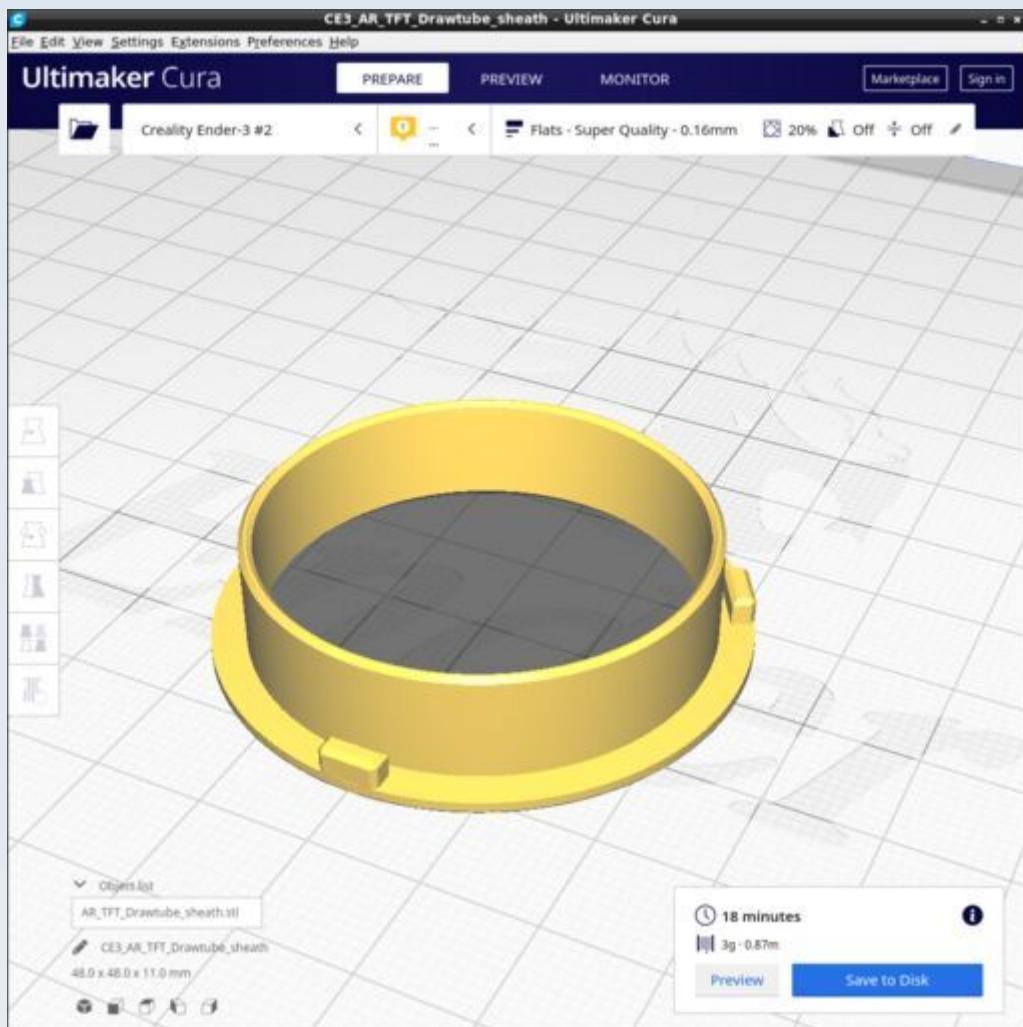
## AR\_Stay\_thumbwheel.stl



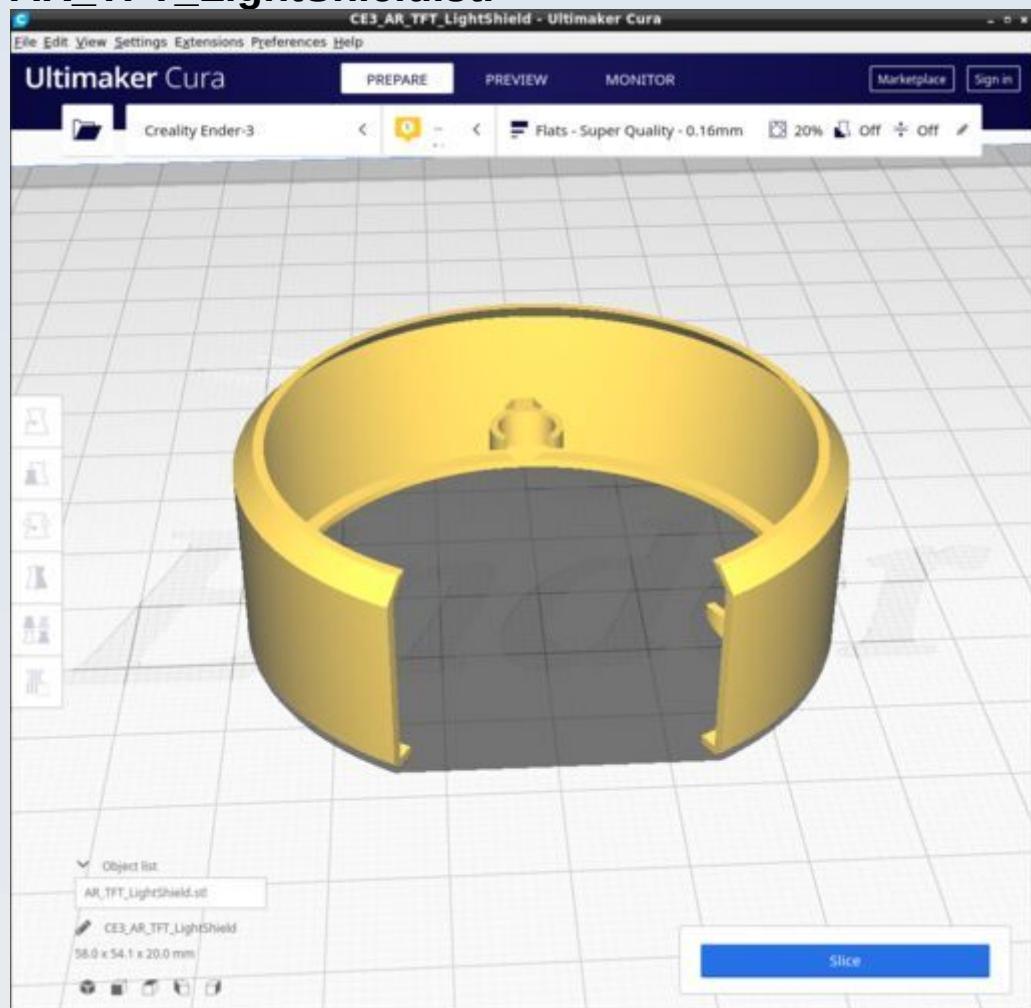
## AR\_TFT\_DrawTube\_F.stl



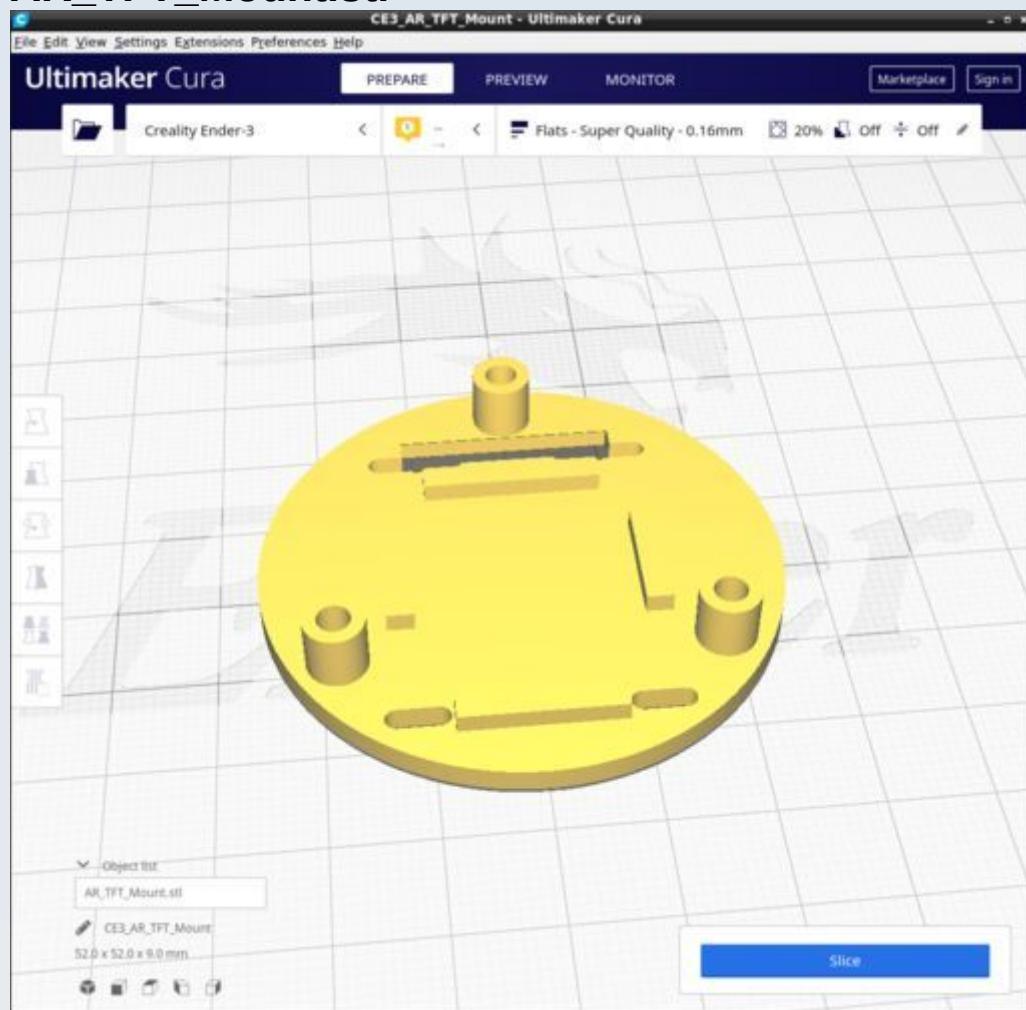
## AR\_TFT\_Drawtube\_sheath.stl



## AR\_TFT\_LightShield.stl



## AR\_TFT\_Mount.stl



## Binocular Head

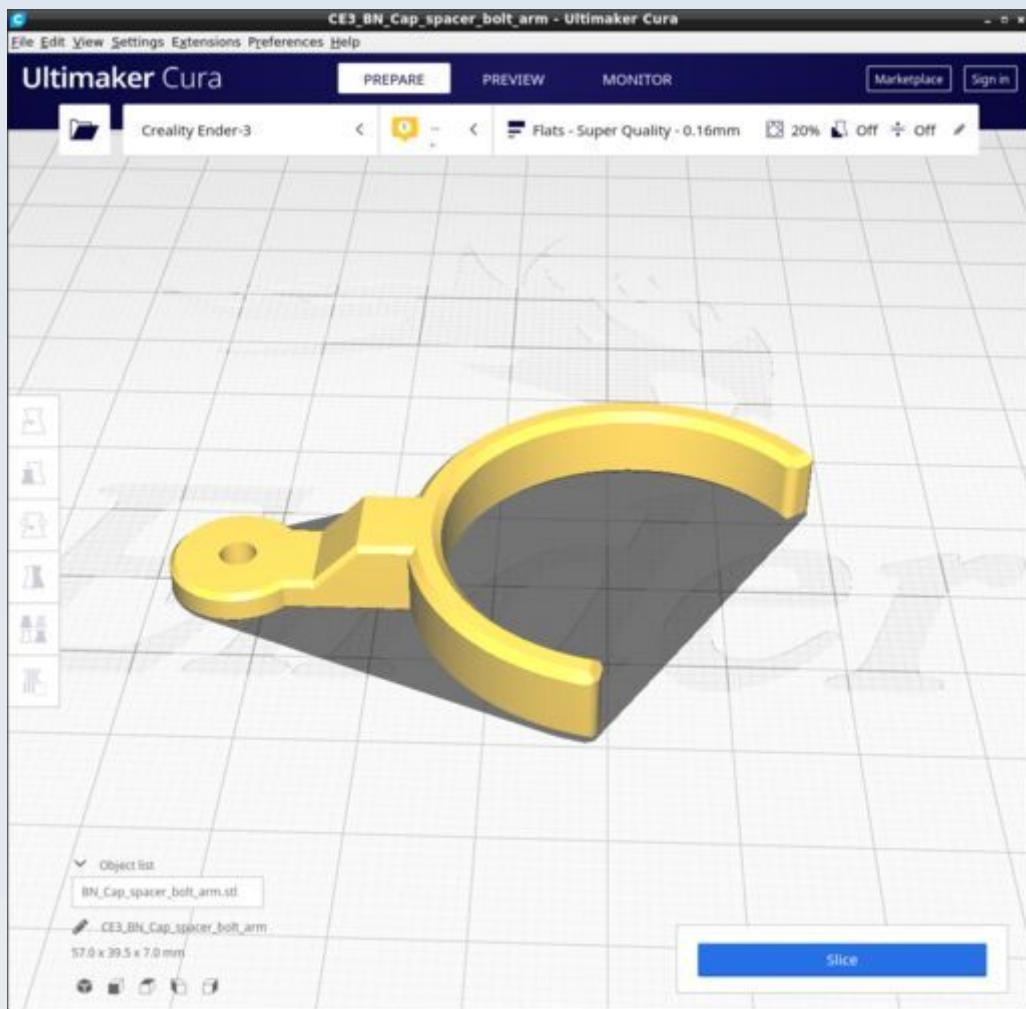
These are the 3D printed parts for the binocular head module. The CAD source models for these STL files are found in the file Binocular.FCStd.

## Resources

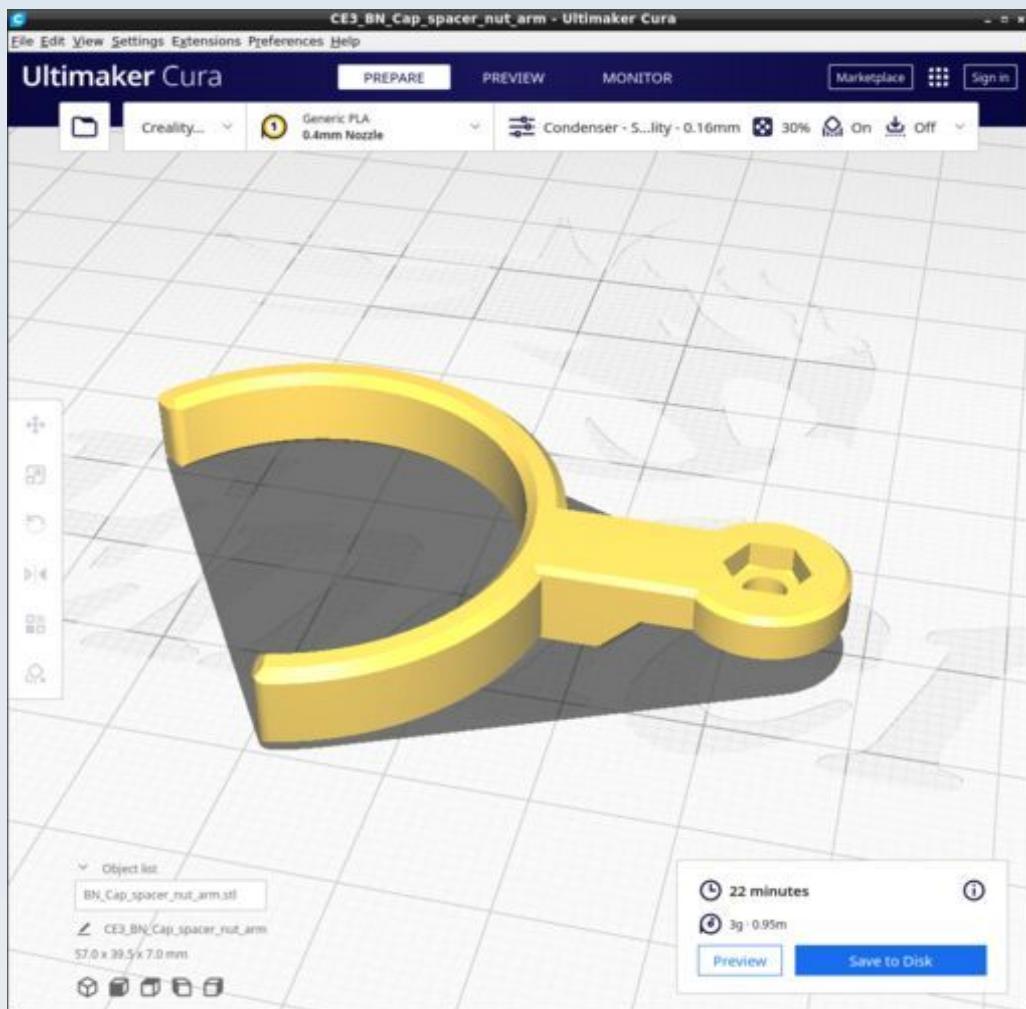
Cura calculates the following resources are required to print each model in this chapter:

Binocular_Head	Time_Hr	Time_Min	PLA_Length(m)
BN_Cap_spacer_bolt_arm.stl	0	21	0.77
BN_Cap_spacer_nut_arm.stl	0	22	0.95
BN_CM_BB_Cover.stl	0	31	1.13
BN_CM_Tube_short_c_adhesin.stl	0	43	1.75
BN_EM_Cover	0	21	0.87
BN_MB_Shim.stl	0	5	0.08
BN_MBT_Cap.stl	0	24	1
BN_MBT_Ring.stl	0	21	0.64
BN_MB_Tube.stl	1	50	3.68
BN_MB_Tube_spacer_2p5mm.stl	0	12	0.28
BN_Mirror_mount_bottom.stl	1	0	1.51
BN_Mirror_mount_top_ocular.stl	1	31	2.84
BN_Ocular_spacer_ring.stl	0	5	0.28
BN_Ocular_Base_thread_L.stl	0	36	0.96
BN_Ocular_Base_thread_R.stl	0	35	0.96
BN_Outlet_lower_spacer.stl	0	0	0.02
BN_Outlet_upper.stl	1	42	2.72
BN_Splitter_block.stl	2	4	3.35
BN_Splitter_support.stl	0	1	0.02

## BN\_Cap\_spacer\_bolt\_arm.stl

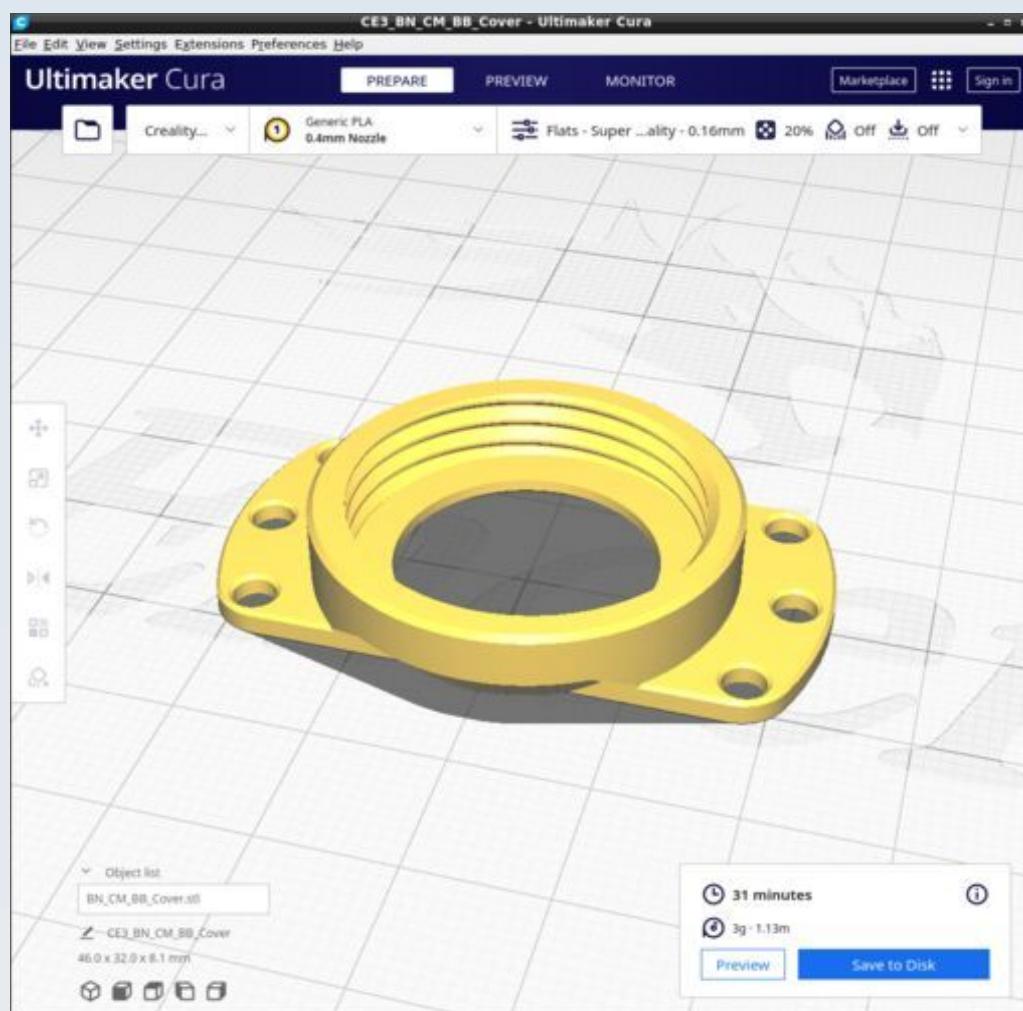


## BN\_Cap\_spacer\_nut\_arm.stl

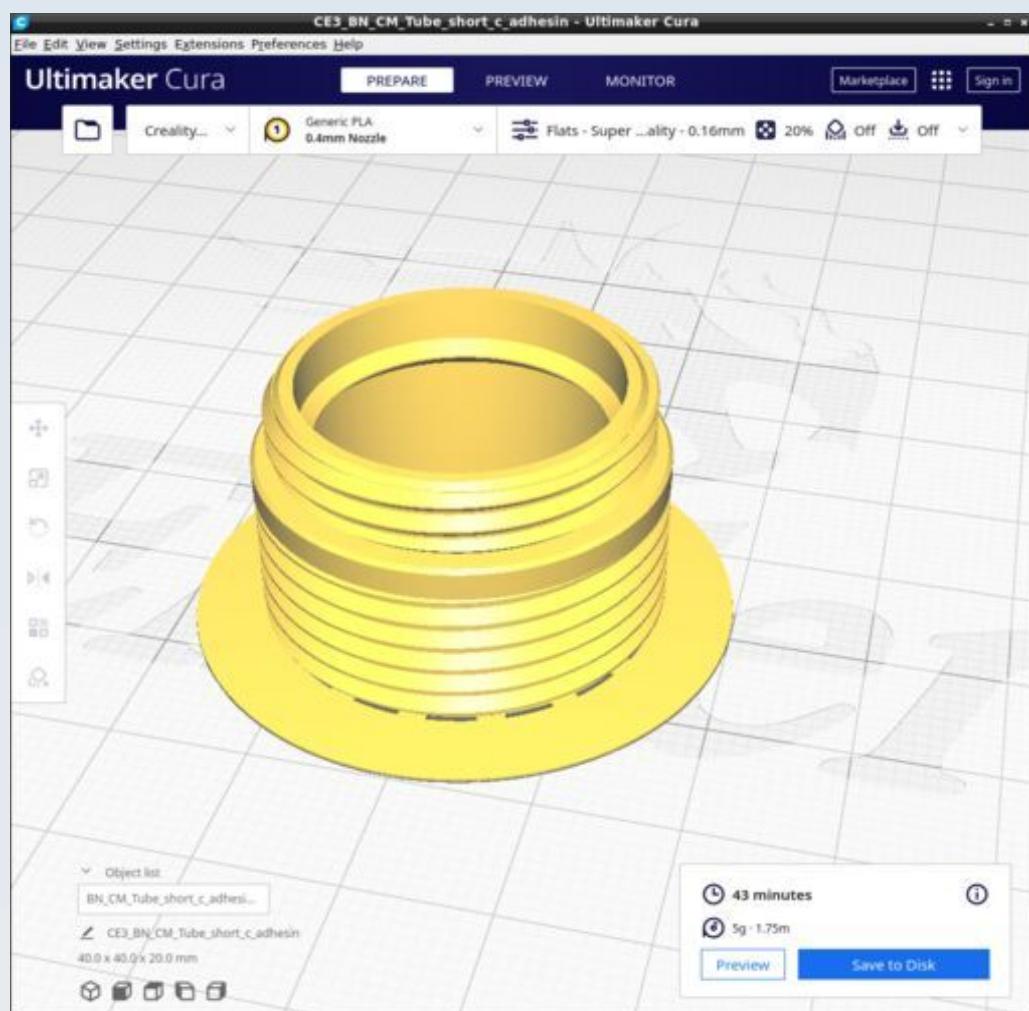


Use the Condenser profile (including its support settings).

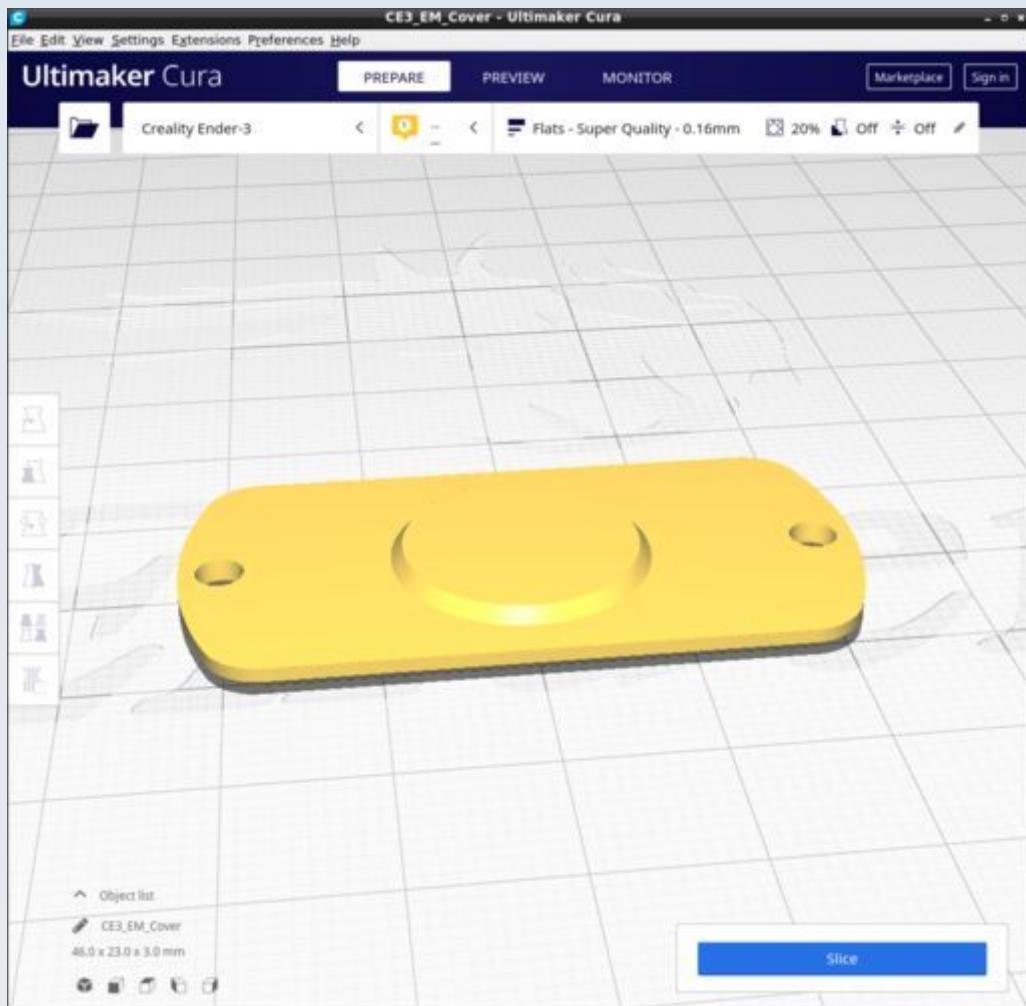
## BN\_CM\_BB\_Cover.stl



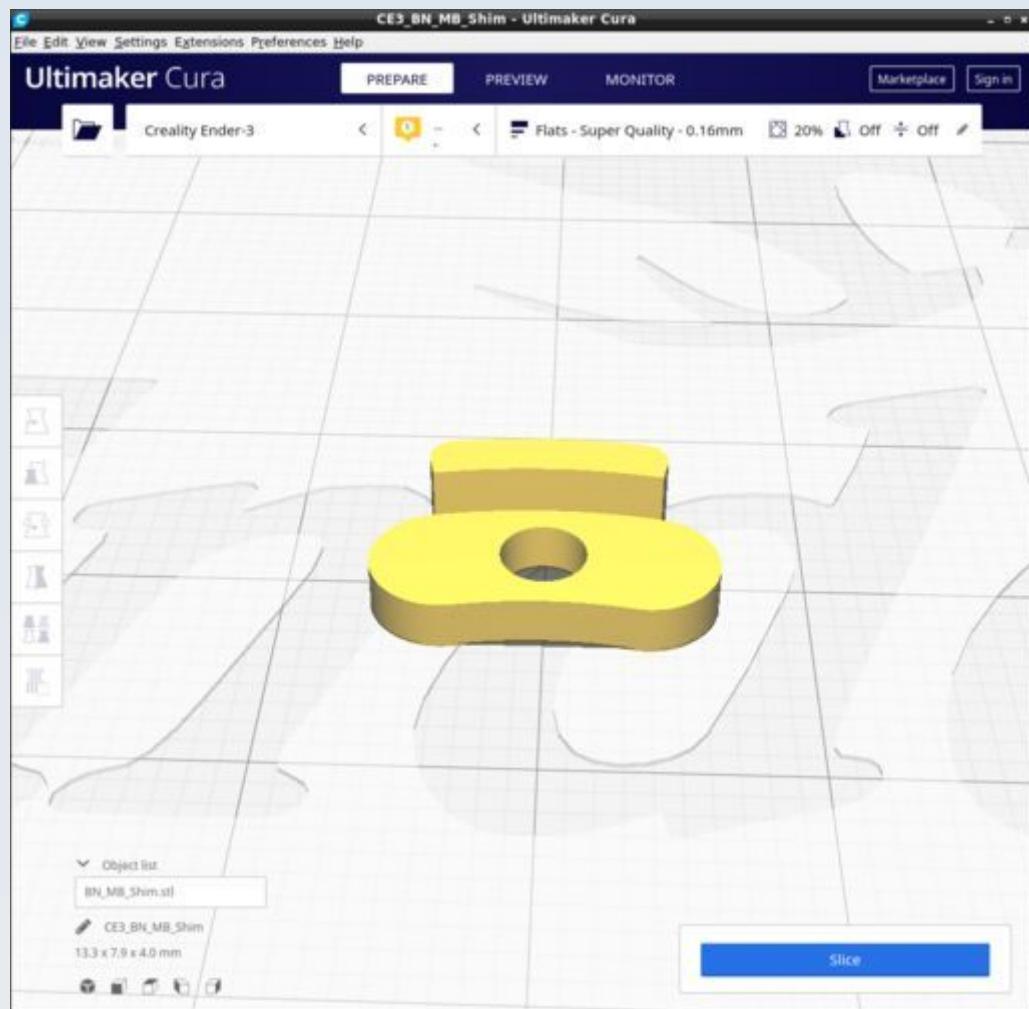
## BN\_CM\_Tube\_short\_c\_adhesin.stl



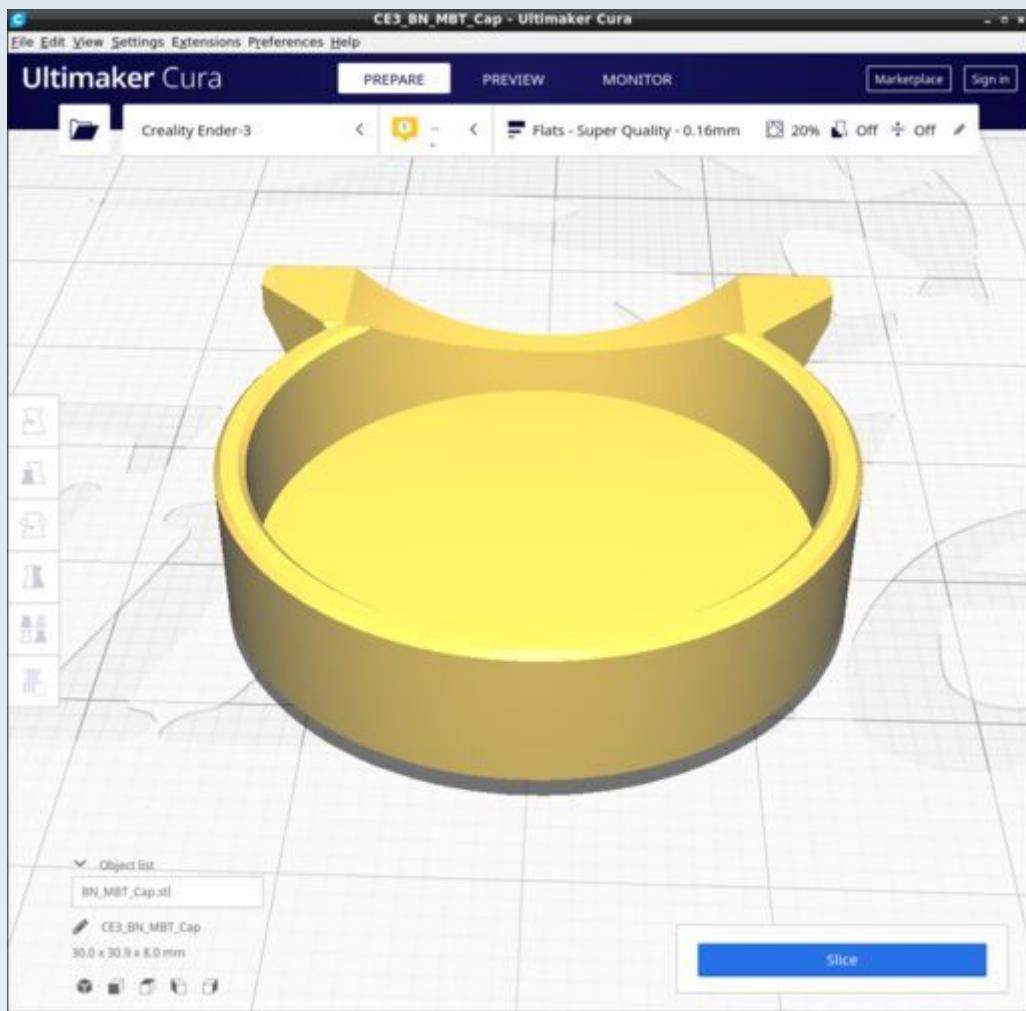
## BN\_EM\_Cover.stl



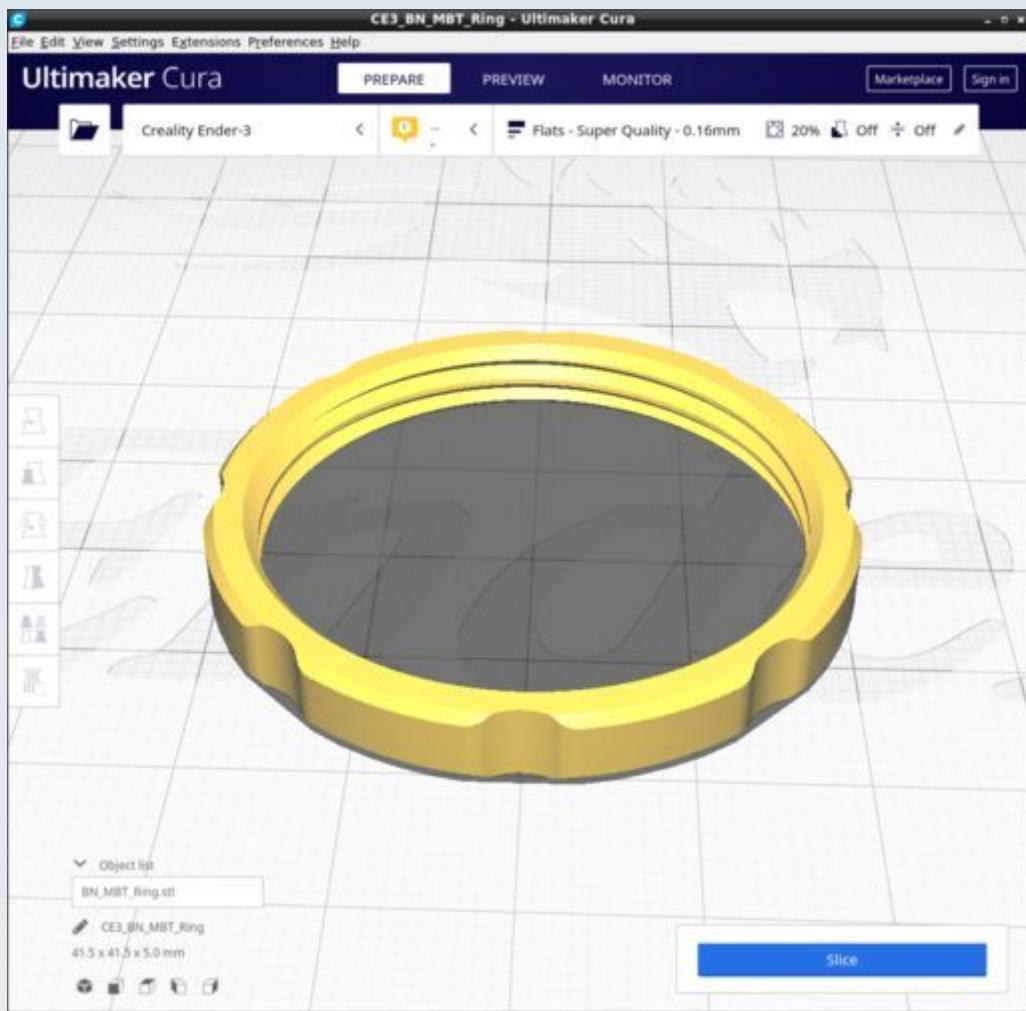
## **BN\_MB\_Shim.stl**



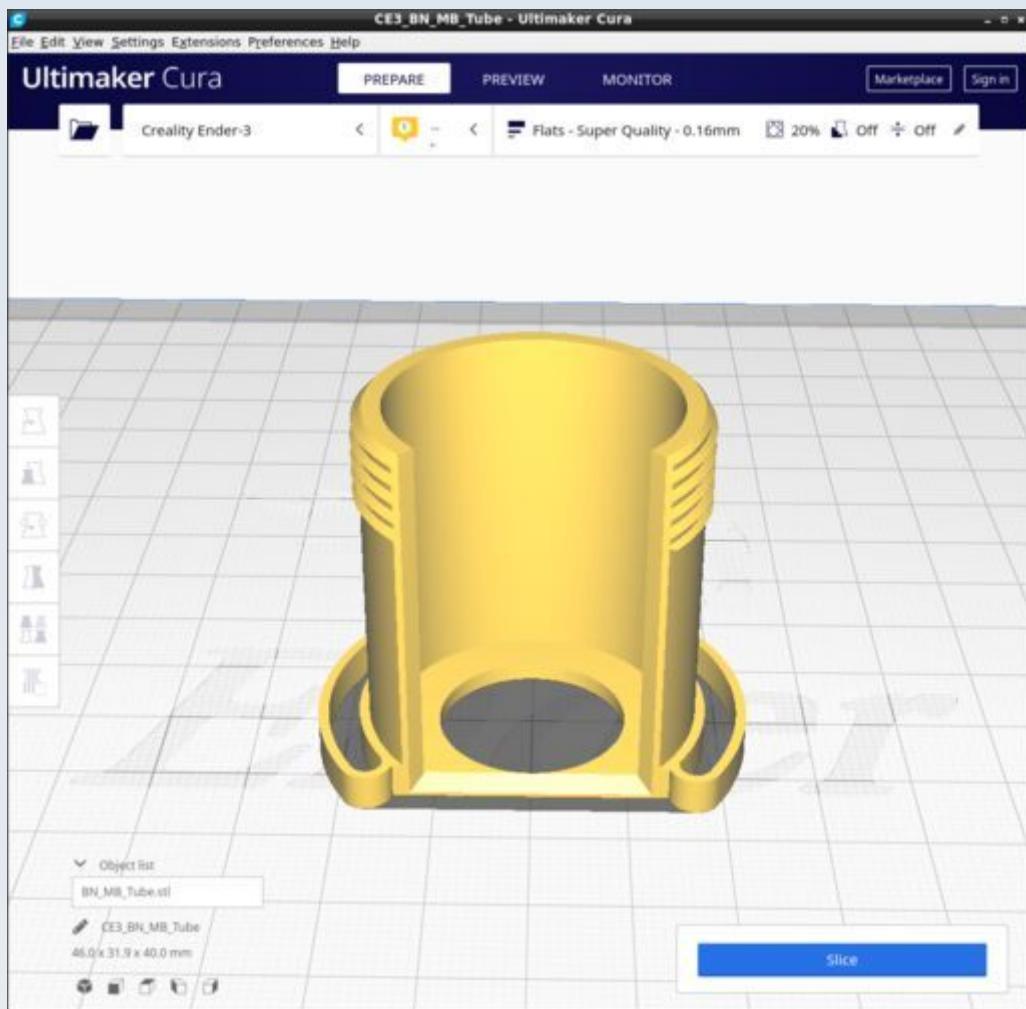
## BN\_MBT\_Cap.stl



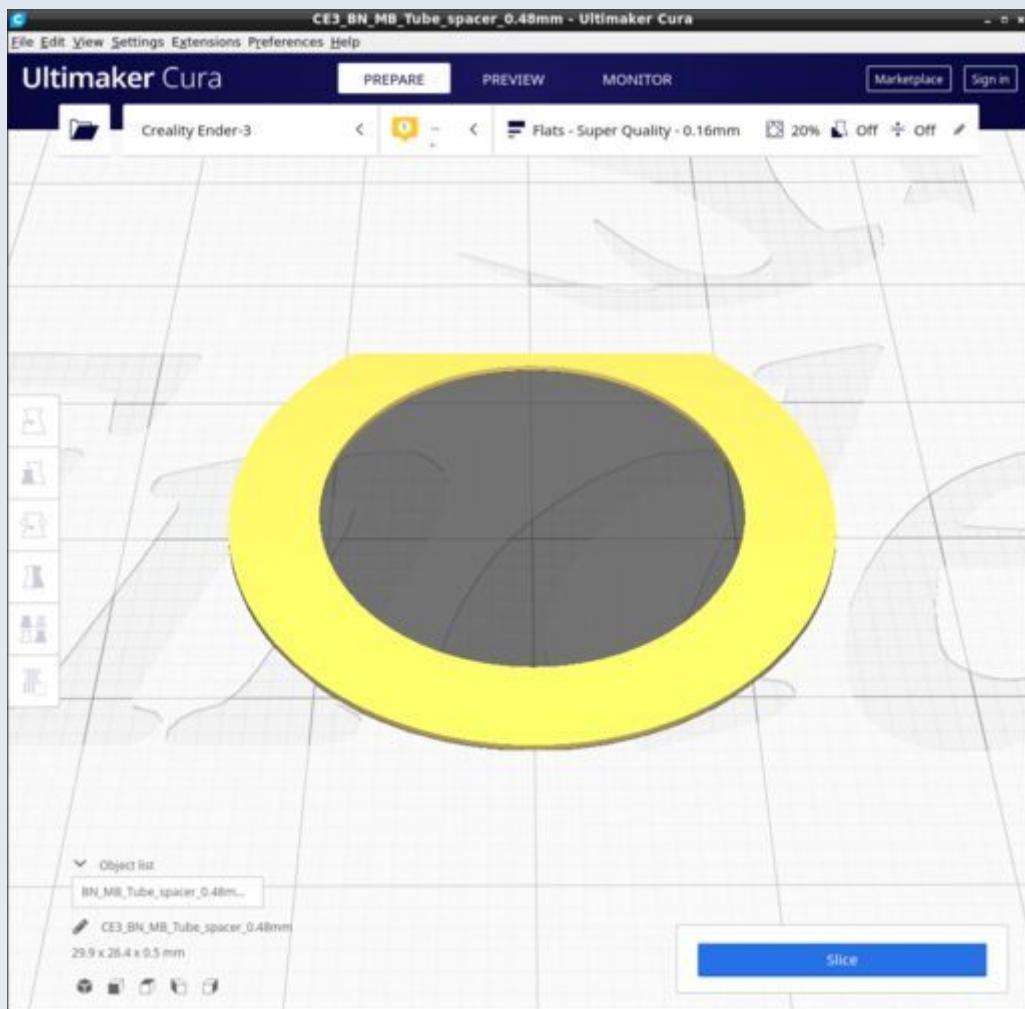
## BN\_MBT\_Ring.stl



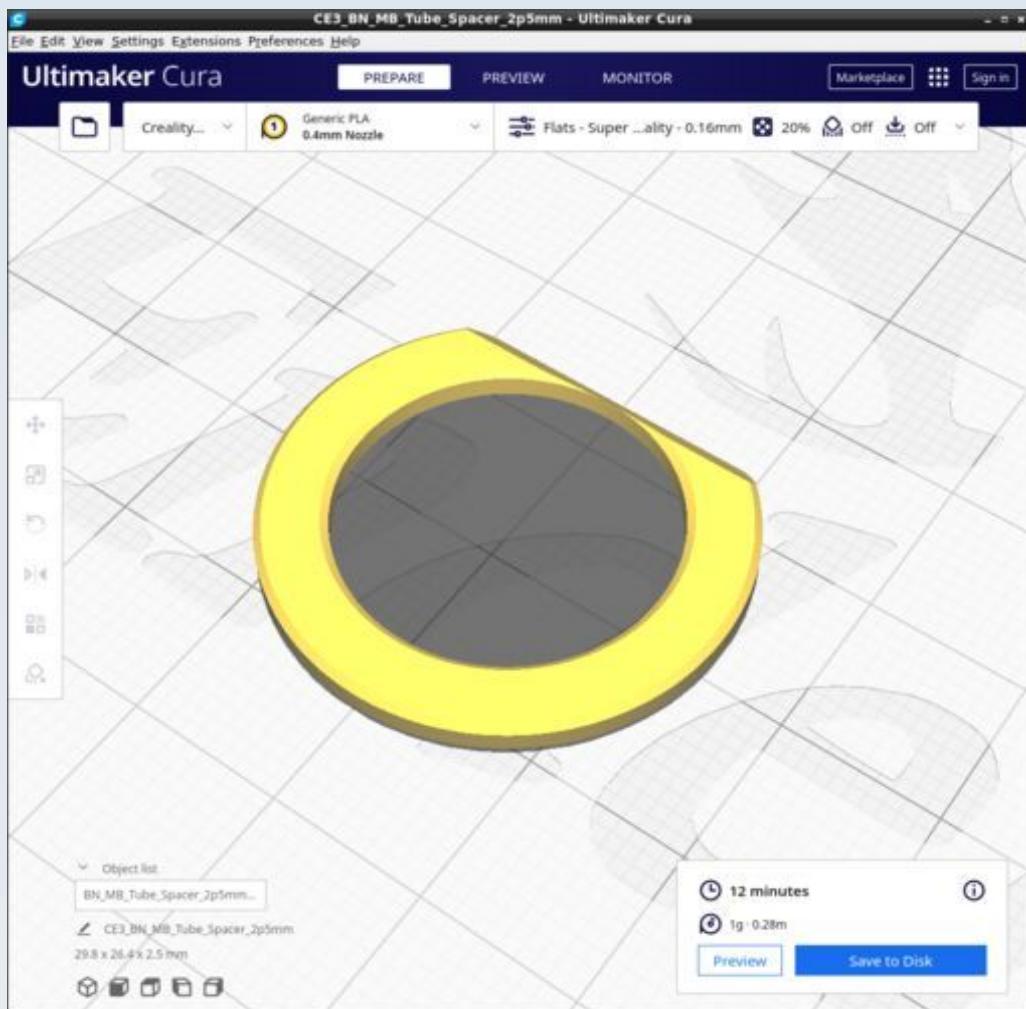
## BN\_MB\_Tube.stl



## BN\_MB\_Tube\_spacer\_0p48mm.stl

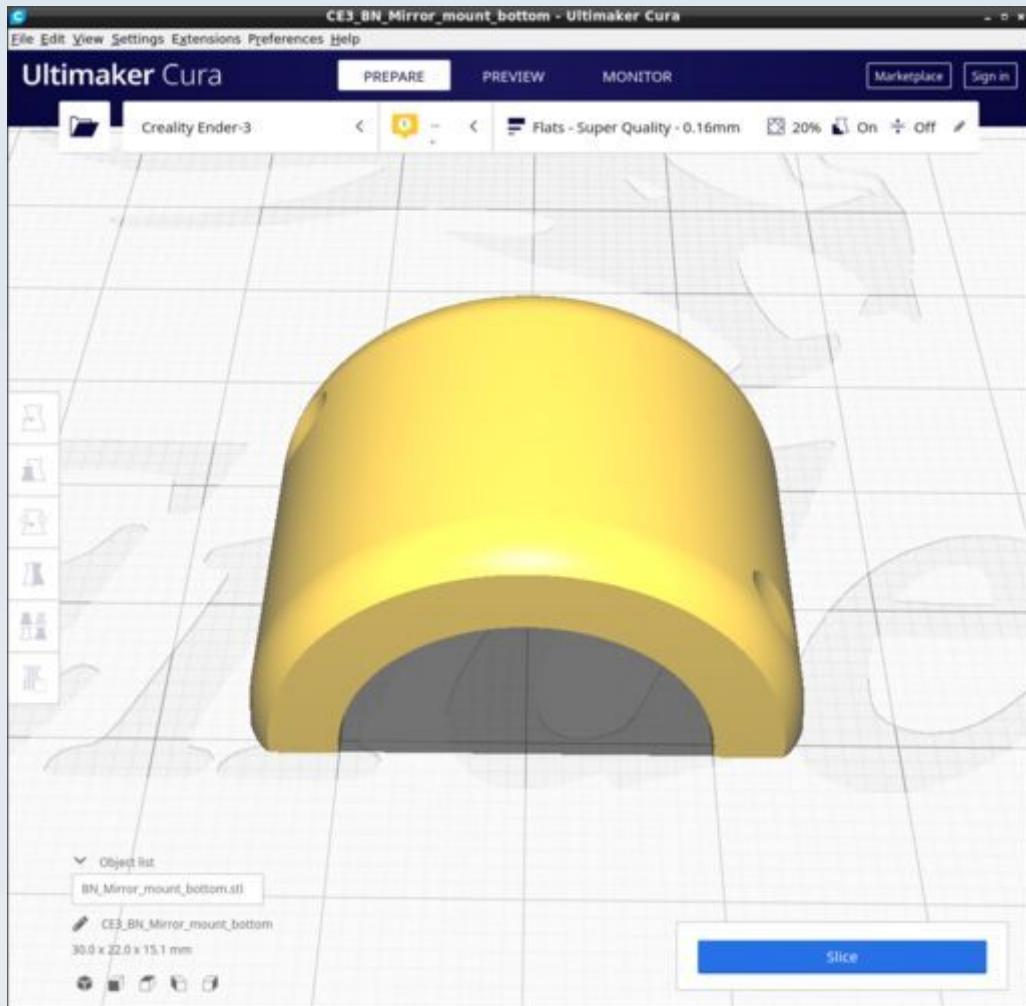


## BN\_MB\_Tube\_spacer\_2p5mm.stl



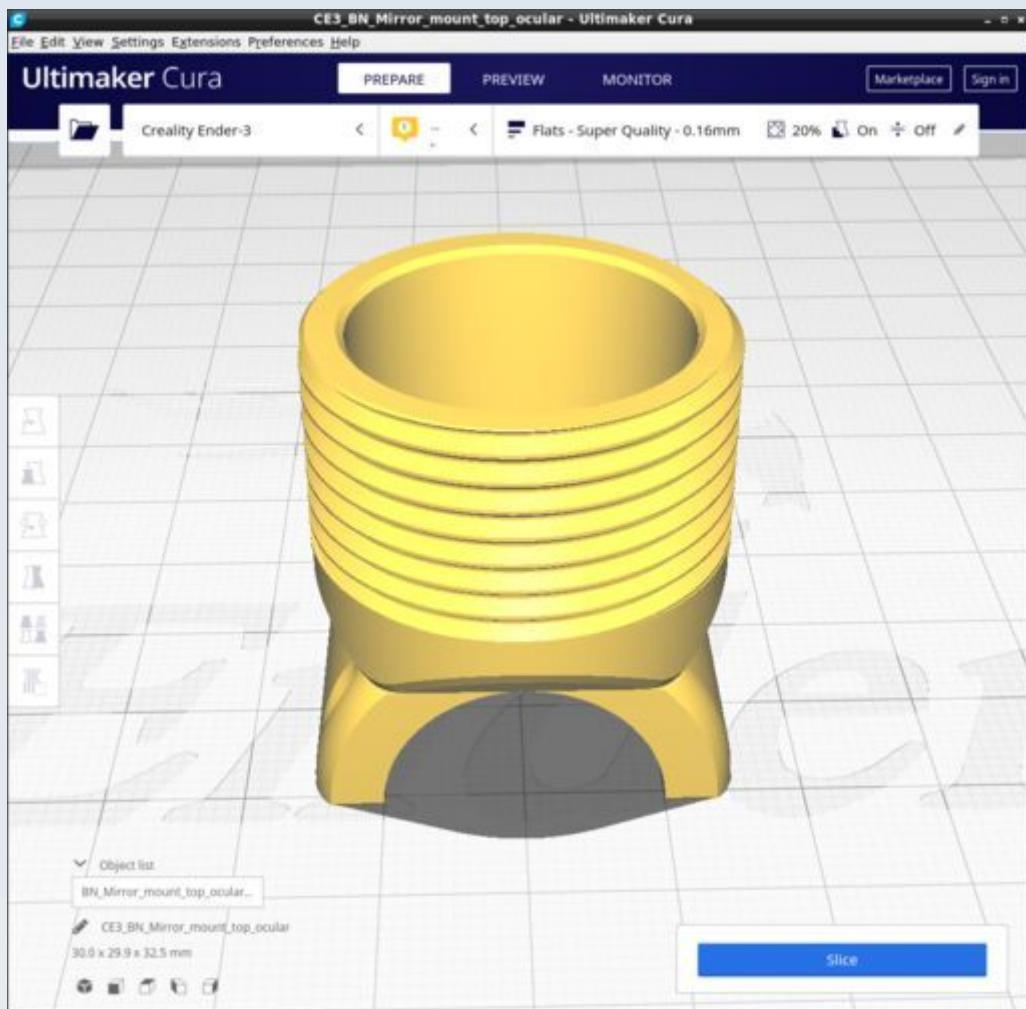
This is just one example from a range of MB\_Tube\_spacers of various thicknesses.

## BN\_Mirror\_mount\_bottom.stl



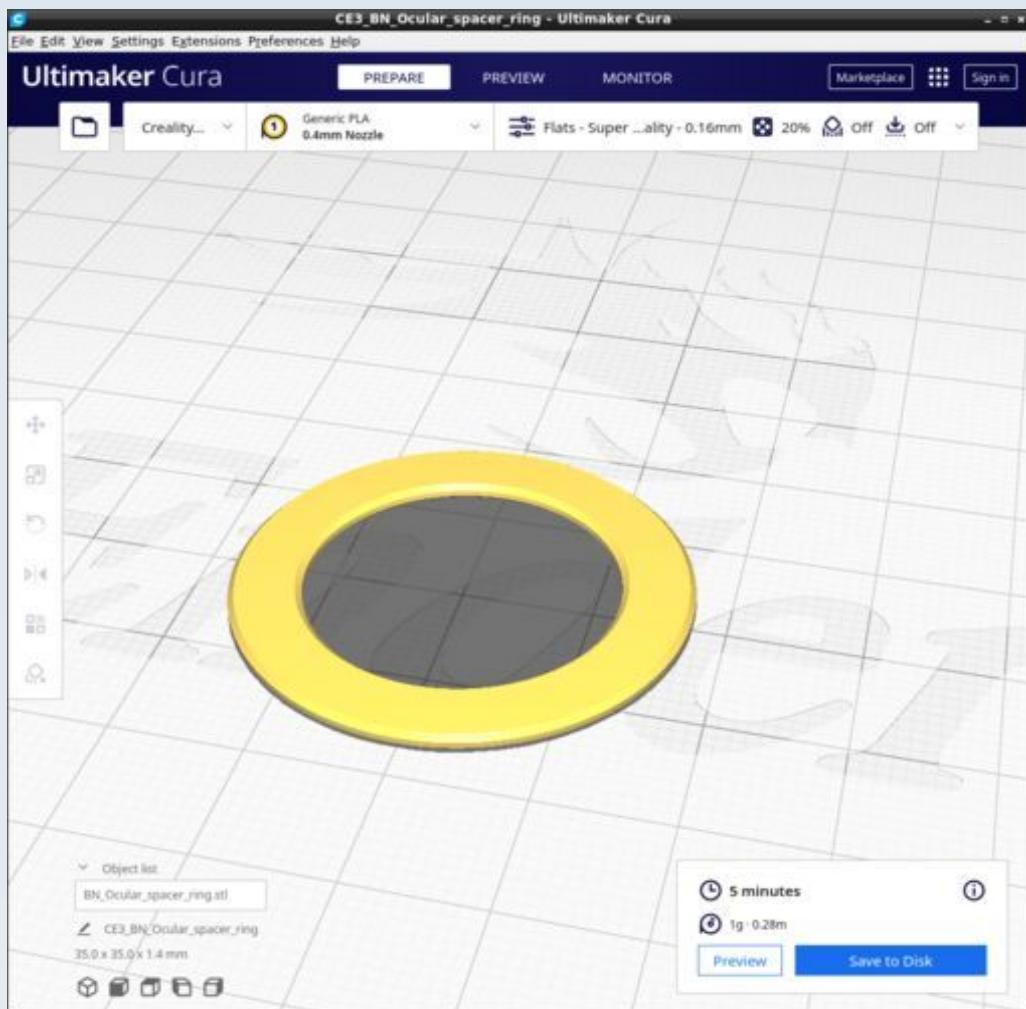
Select supports 'touching build plate only' (not 'Everywhere').

## BN\_Mirror\_mount\_top\_ocular.stl



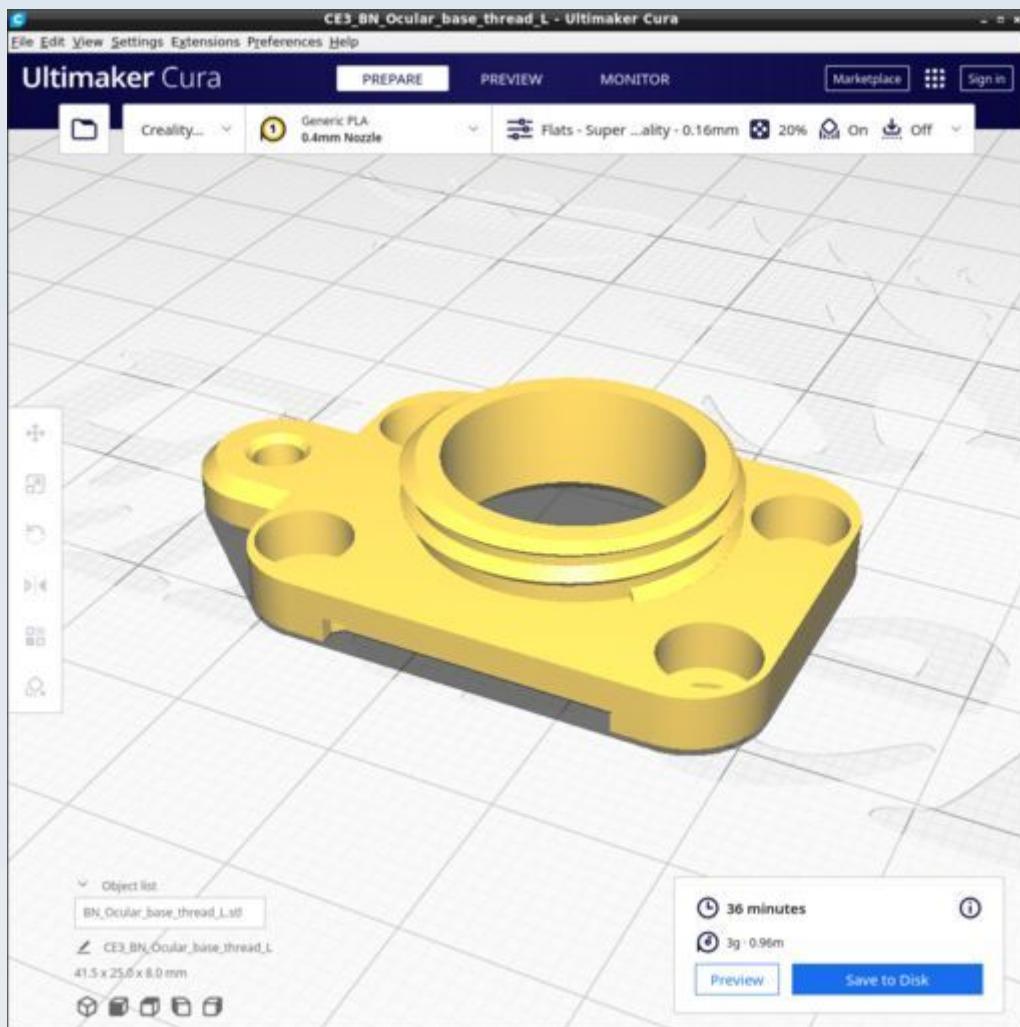
Select supports 'touching build plate only' (not 'Everywhere').

## BN\_Ocular\_spacer\_ring.stl



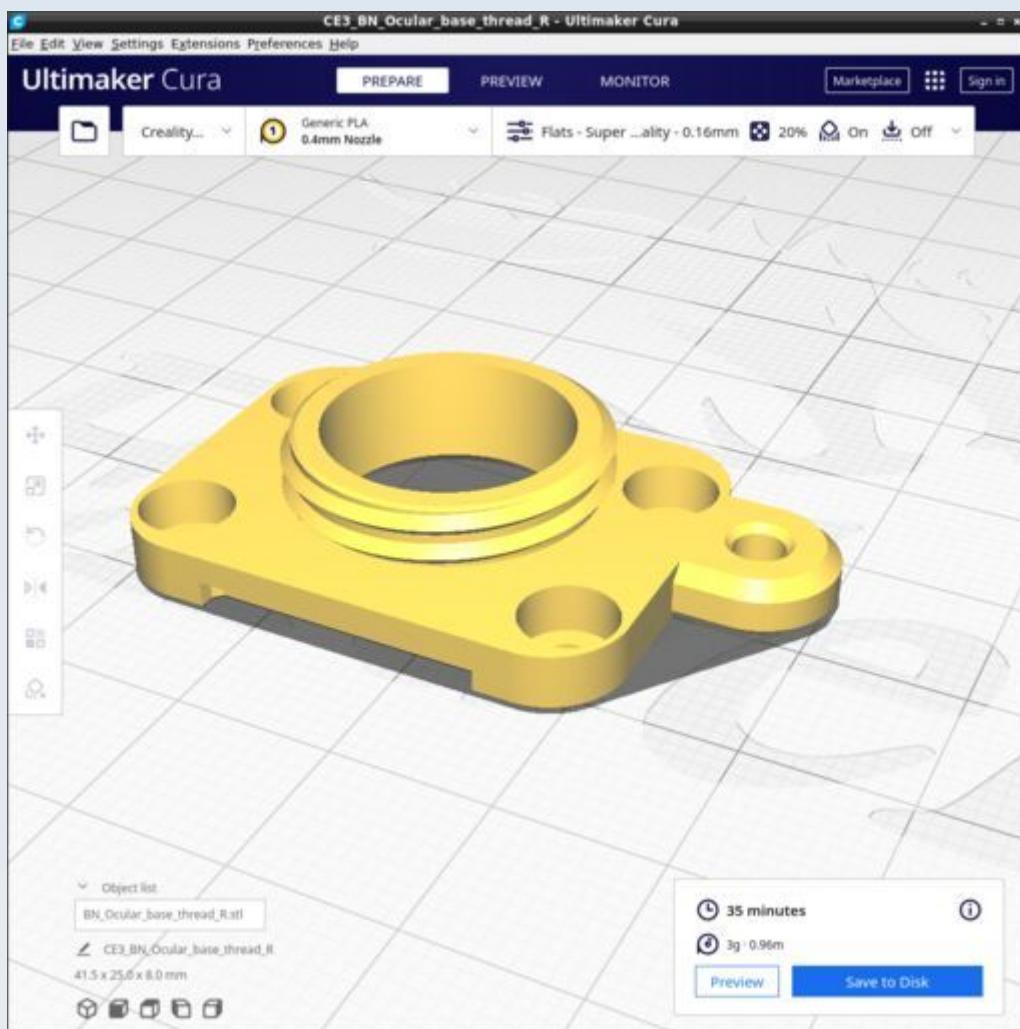
Use 'Top/bottom pattern'='Concentric' in the Top/Bottom' settings

## BN\_Ocular\_Base\_thread\_L.stl



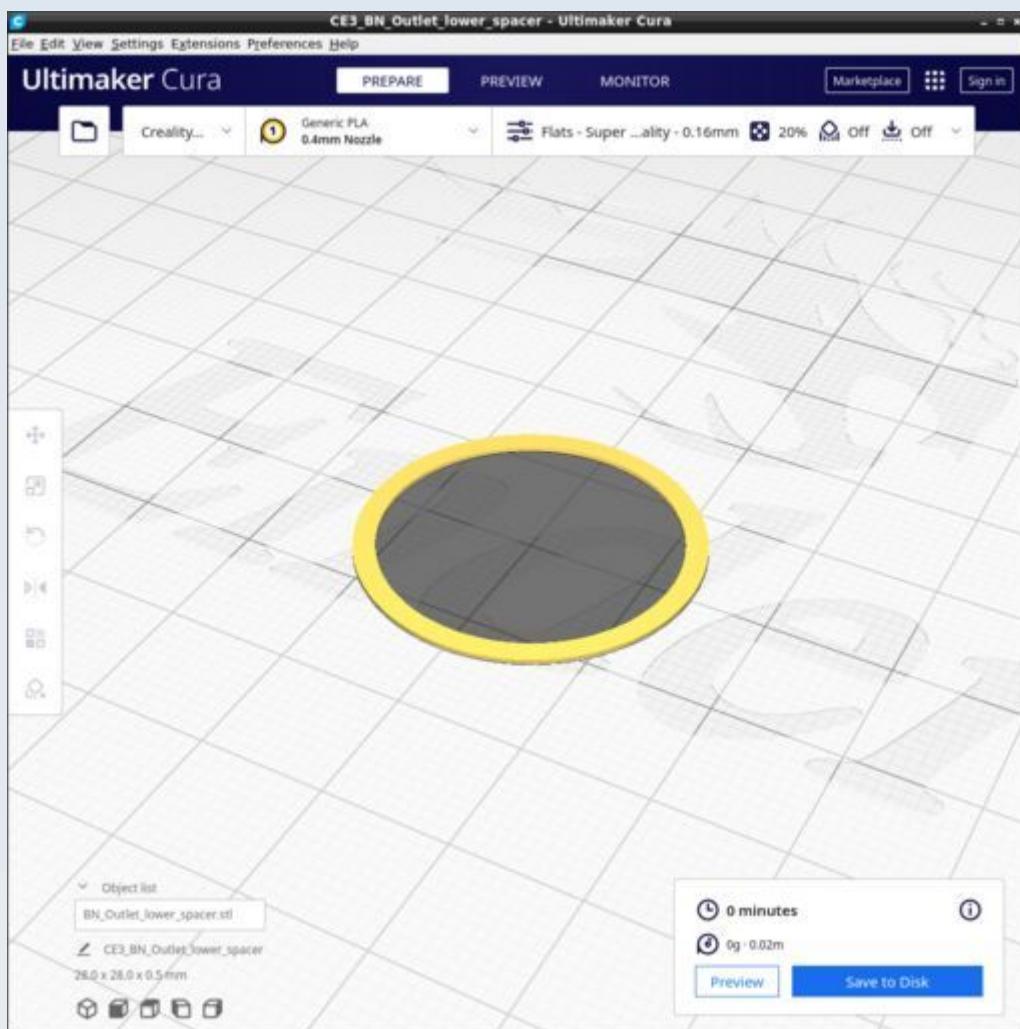
Select supports 'touching build plate only' (not 'Everywhere').

## BN\_Ocular\_Base\_thread\_R.stl

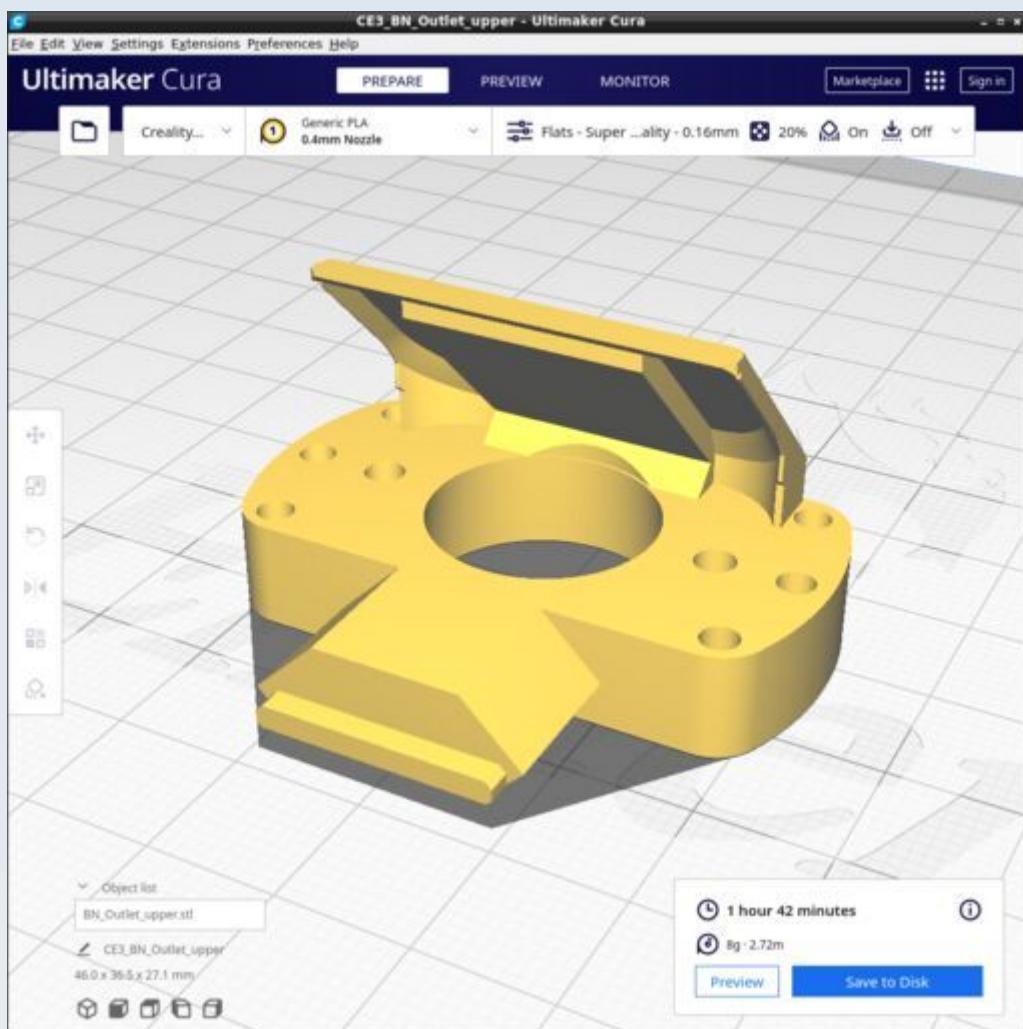


Select supports 'touching build plate only' (not 'Everywhere').

## BN\_Outlet\_lower\_spacer.stl

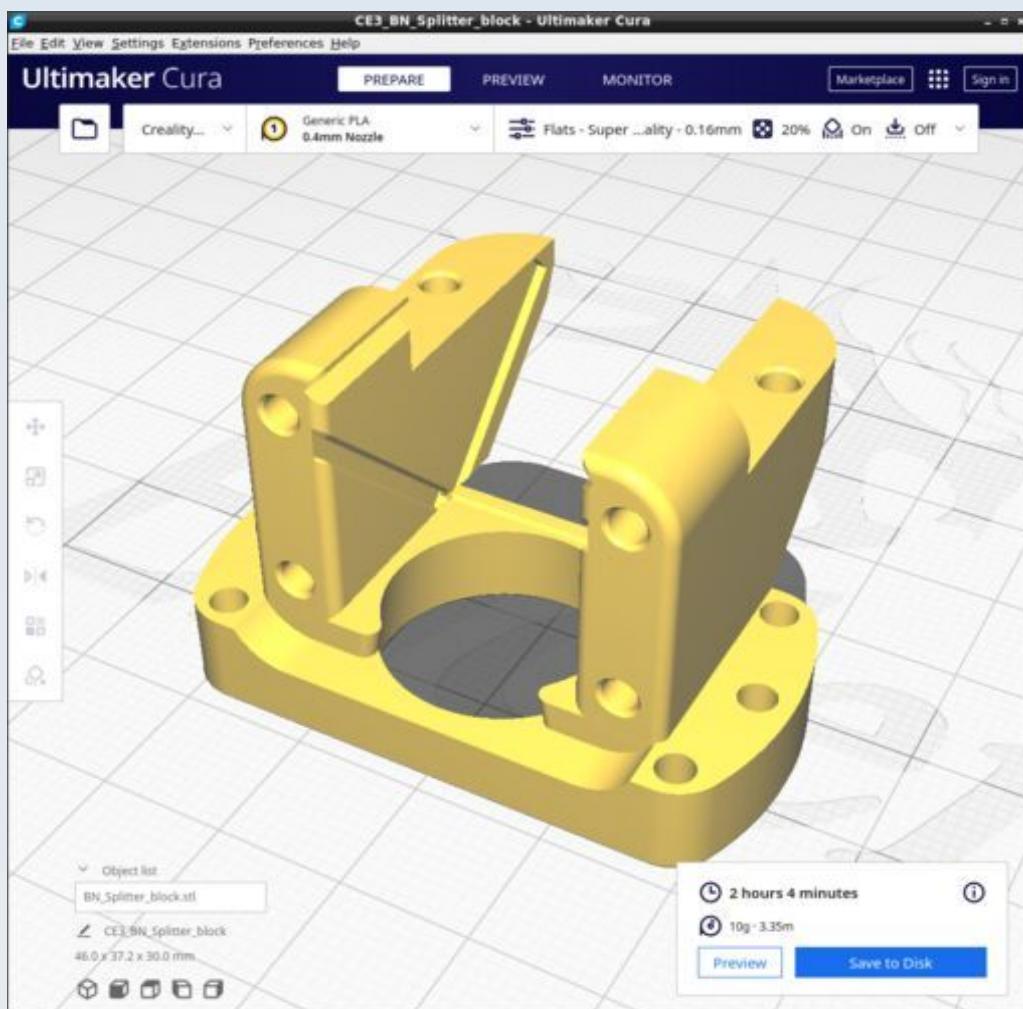


## BN\_Outlet\_upper.stl



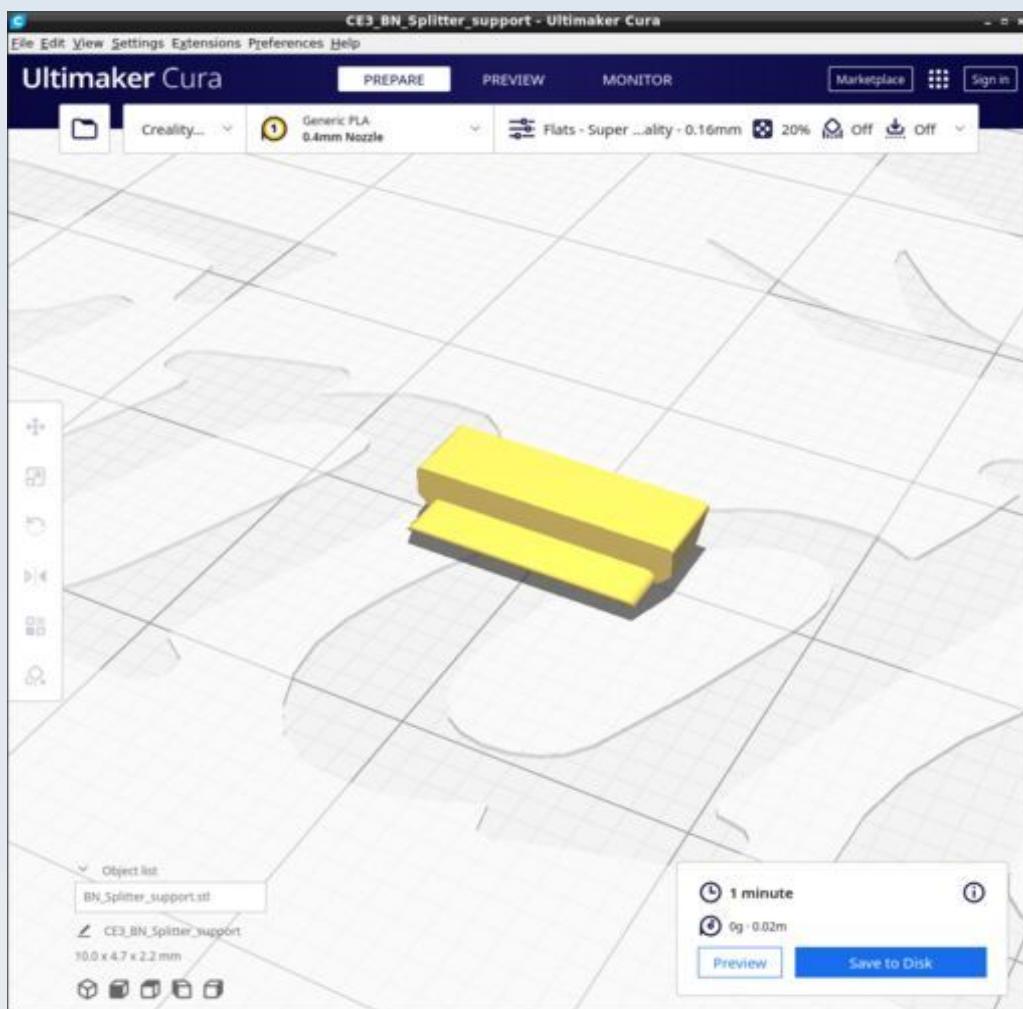
Use supports of 'Tree' type 'touching build plate only' (not 'Everywhere') and change the default for 'tree support branch distance' from 1.0 mm to 0.2 mm.

## BN\_Splitter\_block.stl



Select supports 'touching build plate only' (not 'Everywhere').

## BN\_Splitter\_support.stl



# Dominus Illuminator

These are parts for the modular illumination system of the microscope. The CAD source models for these STL files are found in the file Dominus\_v3.1.FCStd (to keep file sizes below the GitHub 25MB limit, this file has been split into two parts: Dominus\_v3.1\_part1.FCStd and Dominus\_v3.1\_part2.FCStd).

## Resources

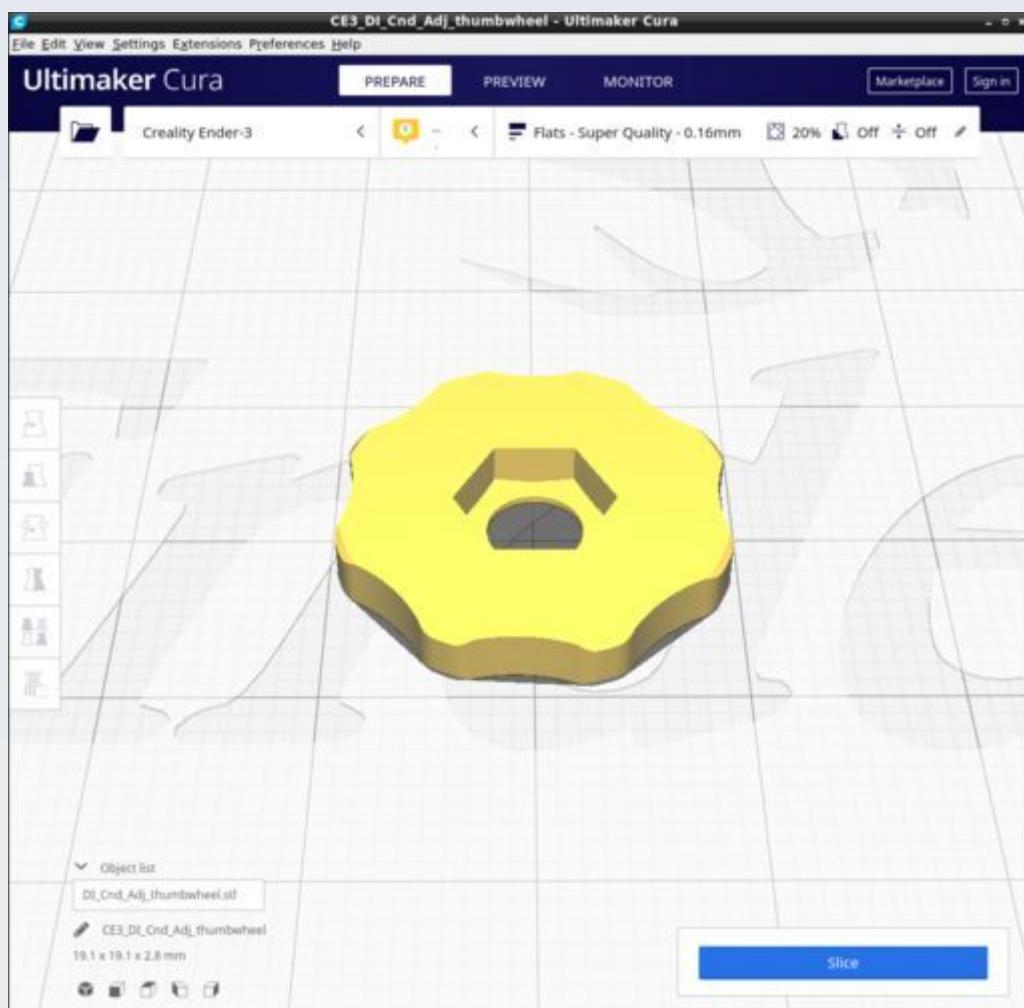
Cura calculates the following resources are required to print each model in this chapter:

Dominus_Illuminator	Time_Hr	Time_Min	PLA_Length(m)
DI_Cnd_Adj_thumbwheel.stl	0	8	0.26
DI_Cnd_Crosshair_Cap_c_adhesin.stl	0	21	0.87
DI_Cnd_Flange_Spacer_0p48.stl	0	5	0.19
DI_Cnd_gripper.stl	1	30	3.69
DI_Cnd_Mirror_holder_socket.stl	1	26	4.01
DI_Cnd_protector_cap.stl	0	22	0.98
DI_Cnd_to_UC.stl	0	58	3.14
DI_Collector_mirror_block.stl	5	34	11.26
DI_Condenser_23_30.stl	2	25	6.02
DI_Condenser_base.stl	0	42	1.33
DI_Epi_attachment.stl	0	47	1.84
DI_Epi_black_body.stl	1	33	4.14
DI_Epi_cap.stl	0	13	0.58
DI_Epi_Cnd_Aperture_04.stl	0	4	0.15
DI_Epi_Cnd_Aperture_10.stl	0	3	0.1
DI_Epi_Cnd_Aperture_13.stl	0	2	0.07
DI_Epi_condenser.stl	2	30	6.23
DI_Epi_pol.stl	1	5	2.14
DI_Ferrule_46_c_adhesin.stl	1	16	4.08
DI_Field_Stop_Rectangle.stl	0	3	0.12
DI_Field_Stop_R	0	3	0.11
DI_IAD_AP_DF_Stop_10.stl	0	1	0.04
DI_IAD_AP_DF_Stop_11.stl	0	1	0.04
DI_IAD_AP_DF_Stop_12.stl	0	1	0.05

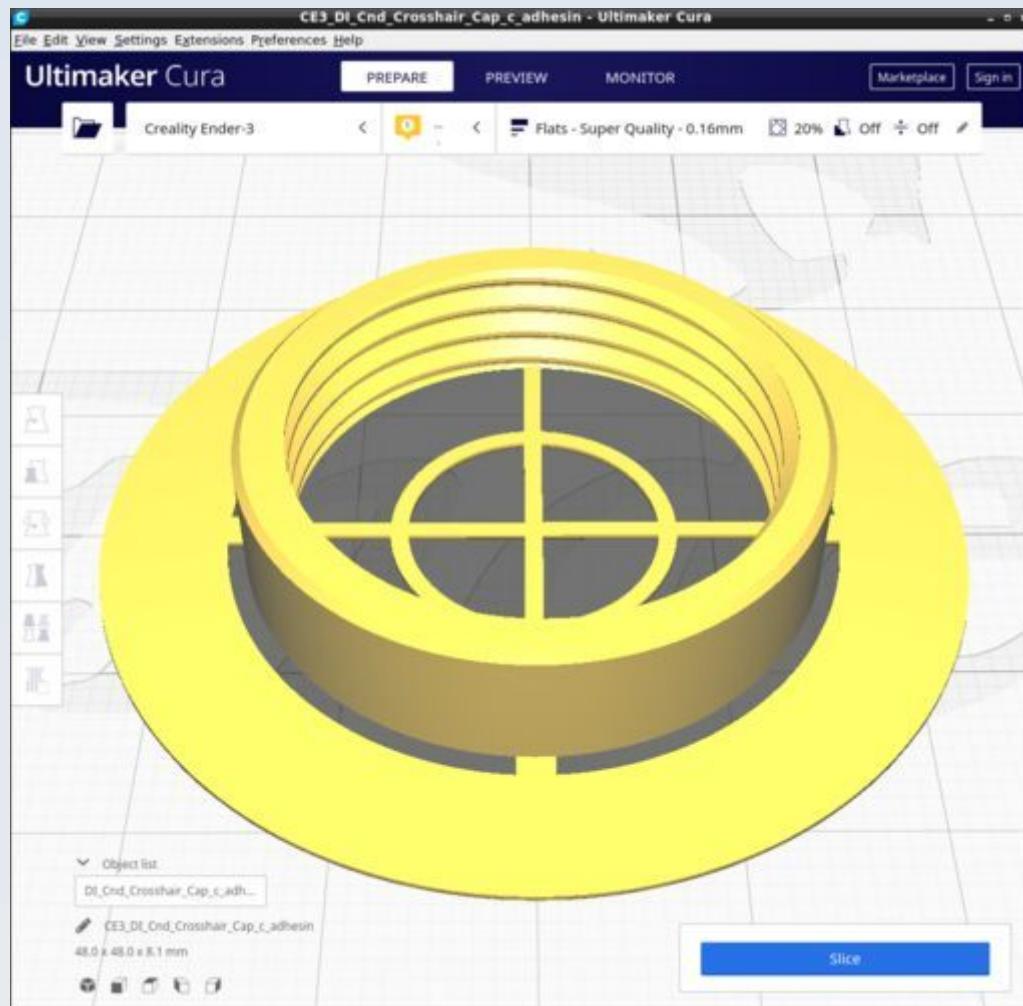
DI_IAD_AP_DF_Stop_2p5.stl	0	1	0.03
DI_IAD_AP_DF_Stop_oil_20.stl	0	2	0.08
DI_IAD_AP_Phase180_oil.stl	0	2	0.08
DI_IAD_AP_Phase180.stl	0	1	0.06
DI_IAD_Filter_Tray_oil.stl	0	33	1.41
DI_IAD_Filter_Tray.stl	0	37	1.64
DI_IAD_SLM_Cover.stl	0	19	0.76
DI_IAD_SLM_Filter.stl	0	29	0.93
DI_IAD_Tray.stl	0	27	0.72
DI_IFD_Adapter.stl	1	5	2.88
DI_IFD_Filter_crosshairs.stl	0	35	1.51
DI_IFD_Threadjoiner.stl	0	50	1.8
DI_IFD_Threadlock.stl	0	24	0.84
DI_IFD_Tray.stl	2	2	4
DI_LC_Adjust_collar.stl	0	20	0.88
DI_LC_Cap.stl	0	21	1.02
DI_LC_Collar_2.stl	0		
DI_LC_Collar_7.stl	0		
DI_LC_Receptacle.stl	0	21	0.77
DI_LC_Spacer.stl	0	16	0.44
DI_LED_Cover.stl	0	34	0.87
DI_LED_Holder.stl	0	57	1.87
DI_LED_Washer.stl	0	2	0.06
DI_LPC_Lensholder.stl	0	16	0.54
DI_LPC_Lens_retainer.stl	0	10	0.3
DI_LPC_Lenseless_23.stl	0	31	1.08
DI_LPC_Single_23.stl	0		0.
DI_M3_Adjustment_ring.stl	1	7	2.35
DI_M3_Adjustment_ring_Kohler.stl	1	40	3.18
DI_M3_Thumbscrew_short_hex.stl	0	8	0.14
DI_M3_Thumbscrew_tall.stl	0	19	0.29
DI_Mirror_holder_plain.stl	1	0	2.45
DI_Mirror_suspend_plain.stl	1	34	3.18

DI_Mirror_to_baseplate.stl	0	49	1.88
DI_Pol_Adjustment_ring.stl	1	22	2.58
DI_Pol_middle.stl	0	5	0.16
DI_Pol_Receptacle.stl	0	46	1.28
DI_Pol_to_baseplate.stl	2	19	4.88
DI_Pol_top_bottom.stl	0	7	0.25
DI_Proximal_collector_attachment.stl	0	39	1.25
DI_Tool_23.stl	0	24	1.14
DI_Tool_44.stl	0	27	0.79
DI_UC_Retention_Cap.stl	0	11	0.63
DI_UC_Spacer.stl	0	1	0.05

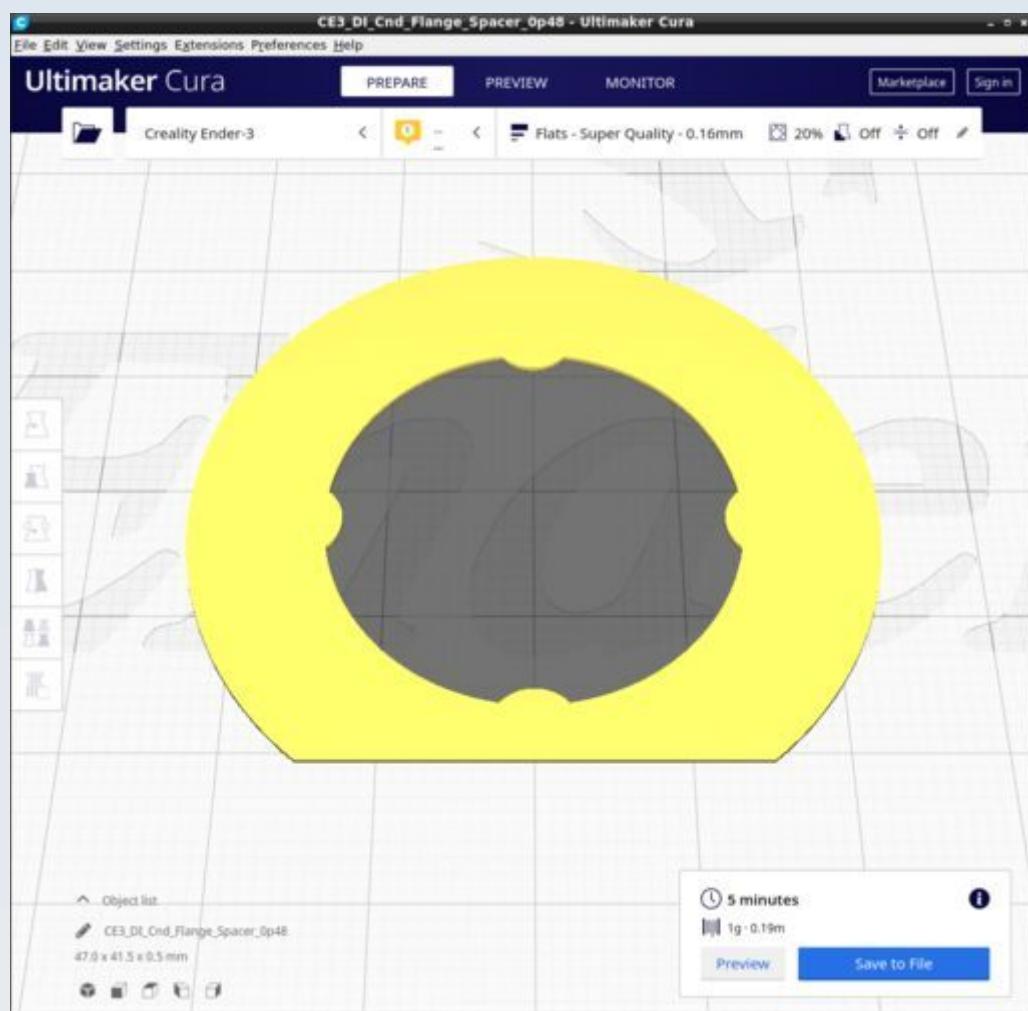
## DI\_Cnd\_Adj\_thumbwheel.stl



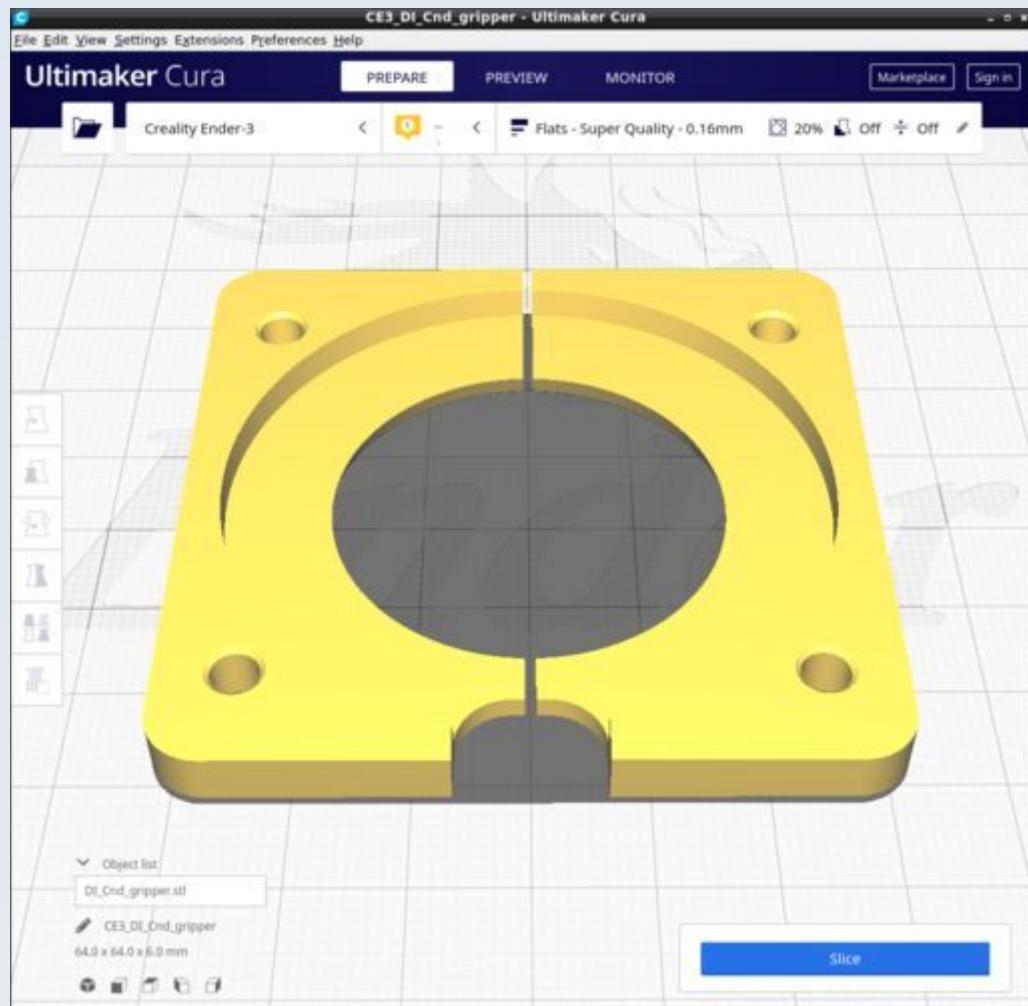
## DI\_Cnd\_Crosshair\_Cap\_c\_adhesin.stl



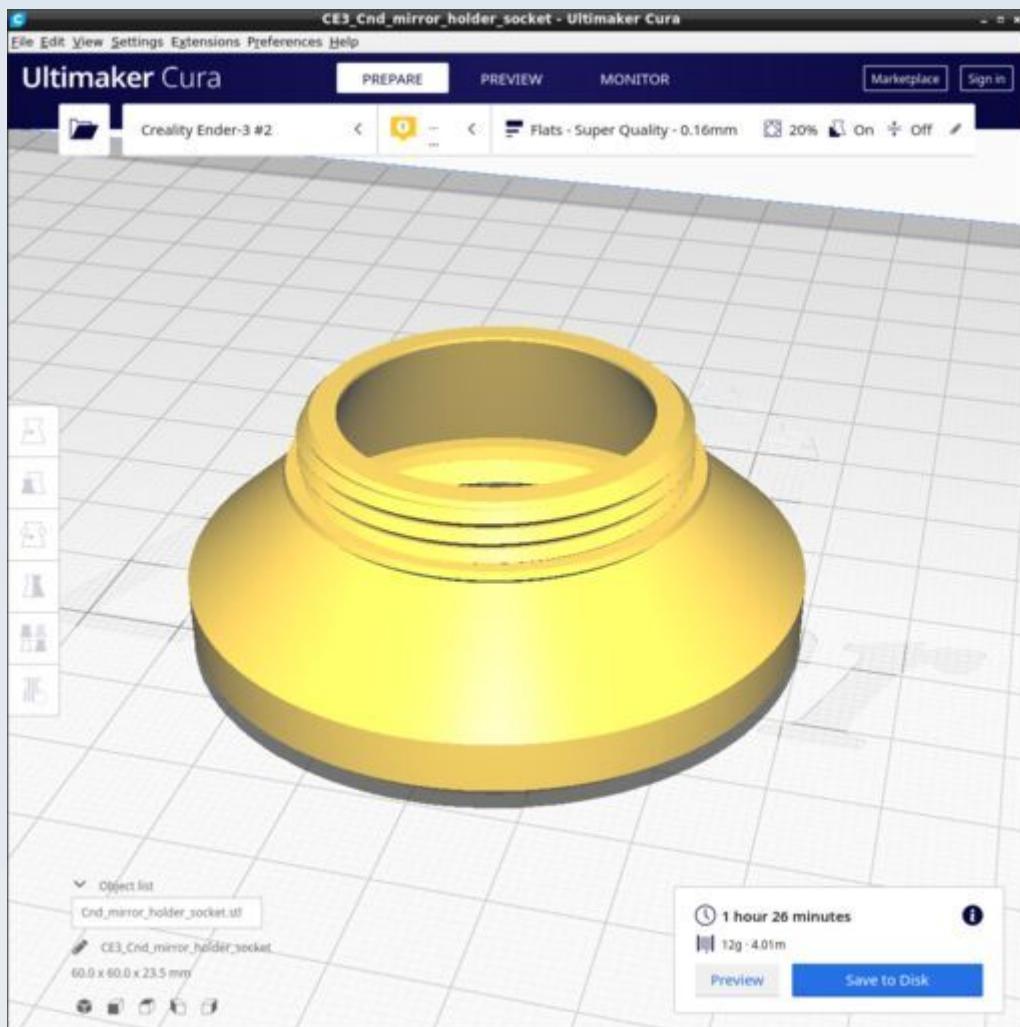
## DI\_Cnd\_Flange\_Spacer\_0p48.stl



## DI\_Cnd\_gripper.stl

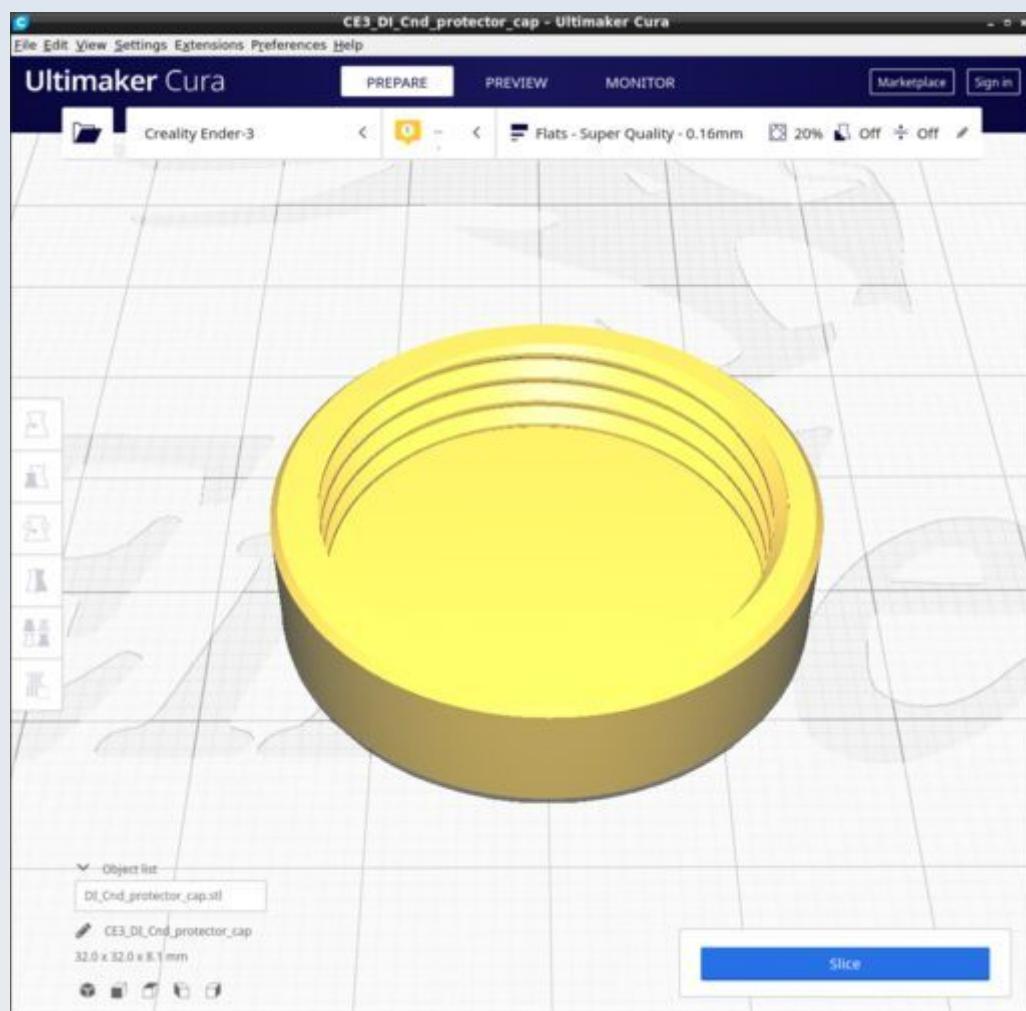


## DI\_Cnd\_Mirror\_holder\_socket.stl

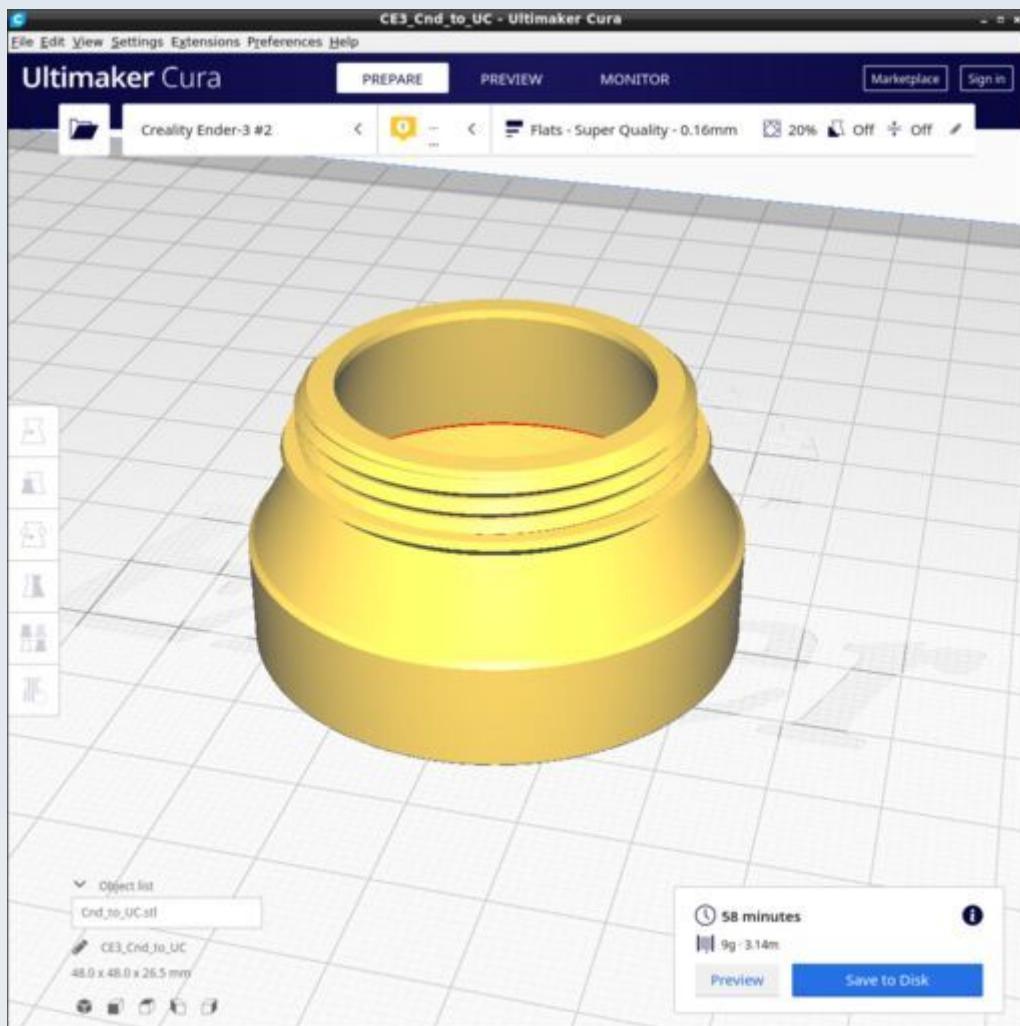


This uses tree support touching baseplate only with tree support branch angle 40 degrees and tree support branch distance 1 mm.

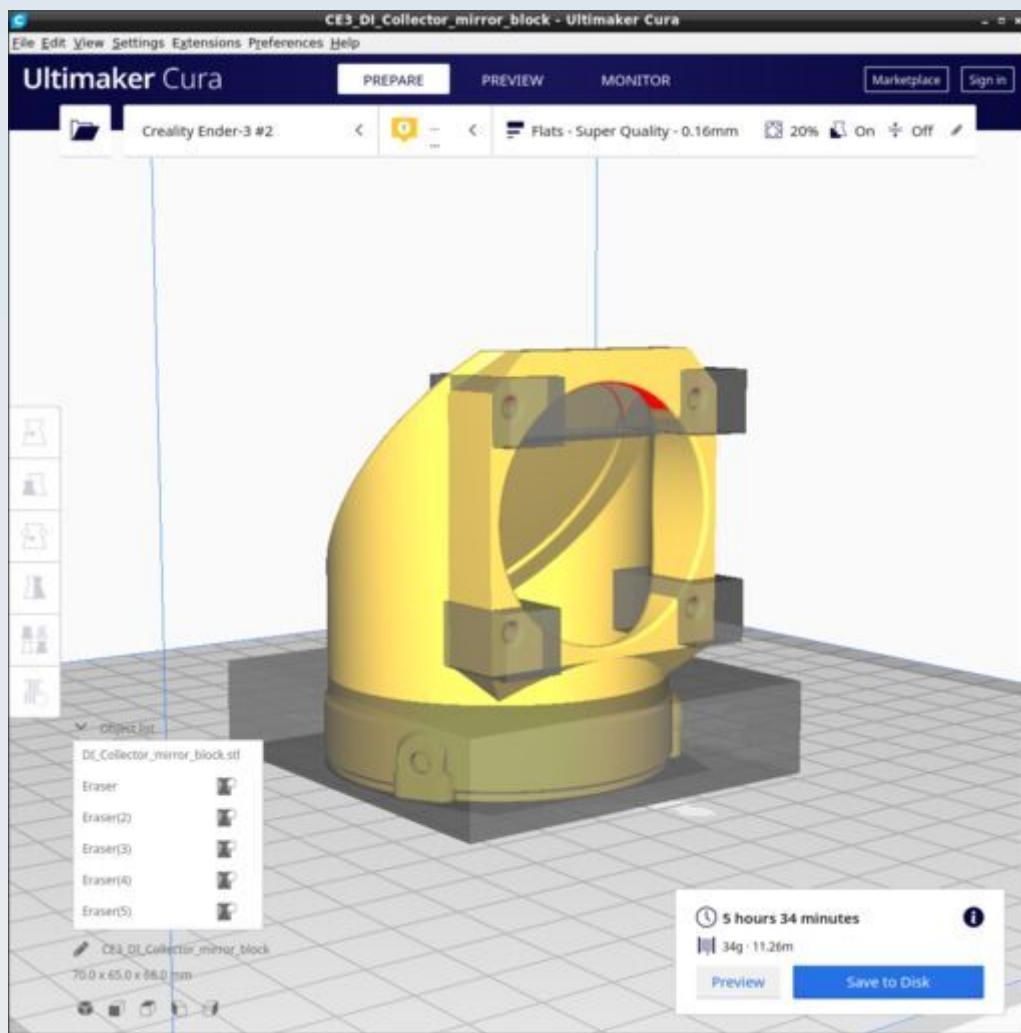
## DI\_Cnd\_protector\_cap.stl



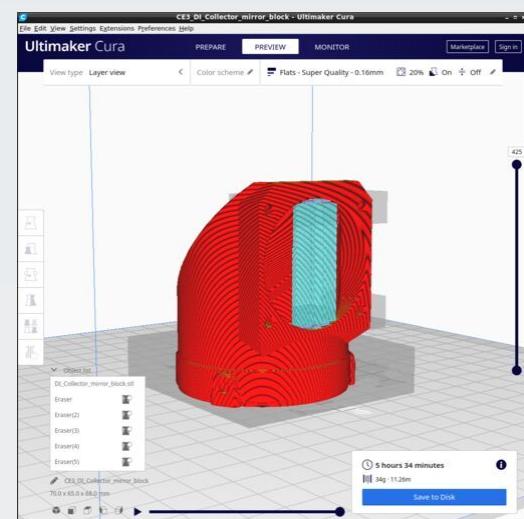
## DI\_Cnd\_to\_UC.stl



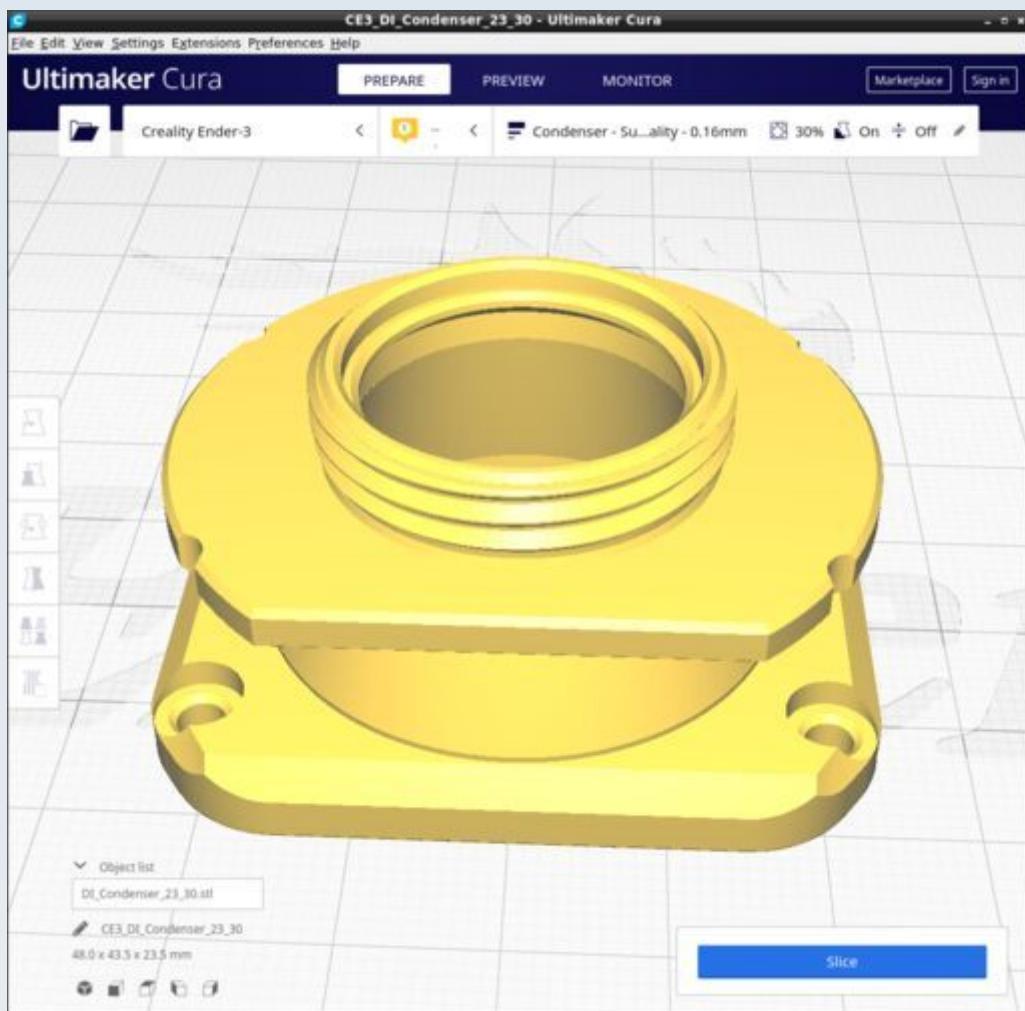
## DI\_Collector\_mirror\_block.stl



Supports on for 'Everywhere' and ensure 'Support overhang angle' is 67. Make support blockers for the M3 holes in the front flat part, the M3 adjustment ring holes and the part of the mirror indentation that overhangs - essentially everywhere except the big vertical aperture - that is what needs support.

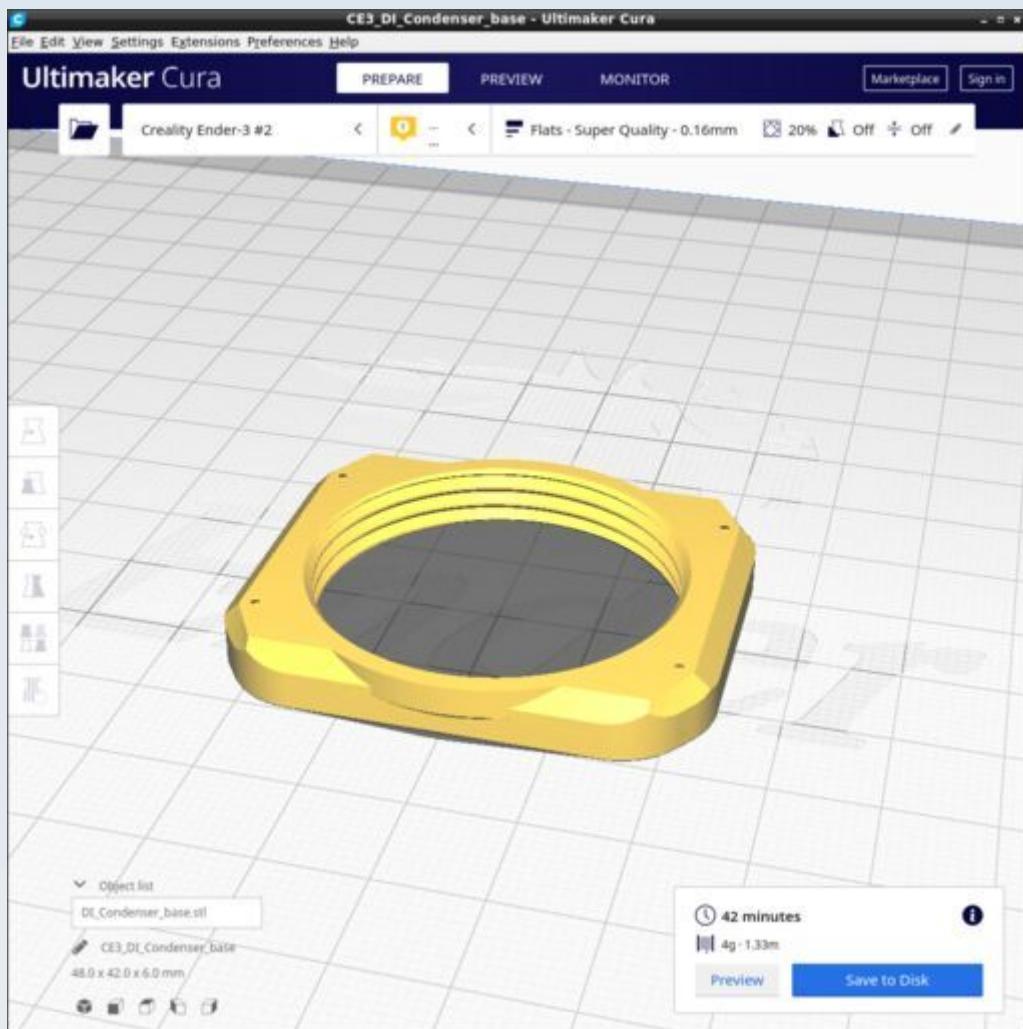


## DI\_Condenser\_23\_30.stl

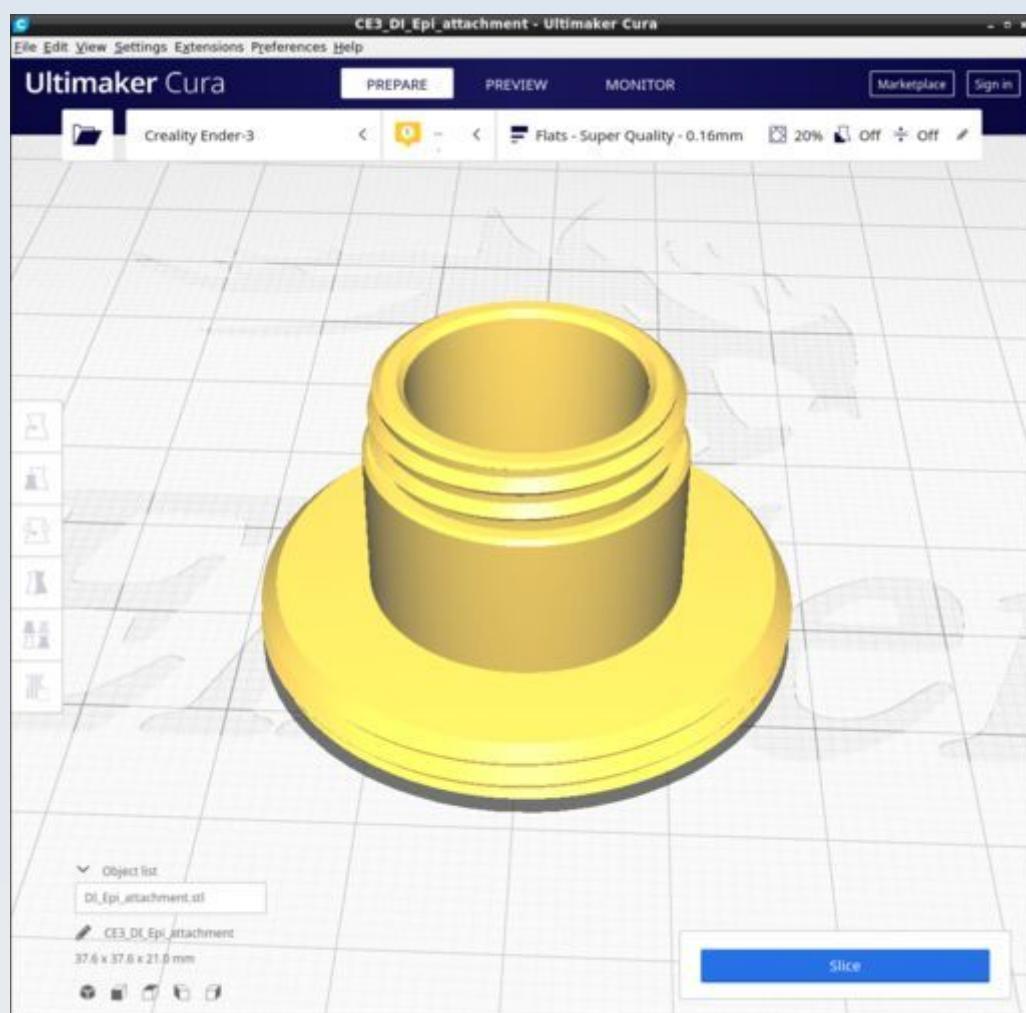


Must be printed with the special custom Cura profile called 'Condenser' which I made to ensure both strength and proper overhang tree supports to the centration flange disc.

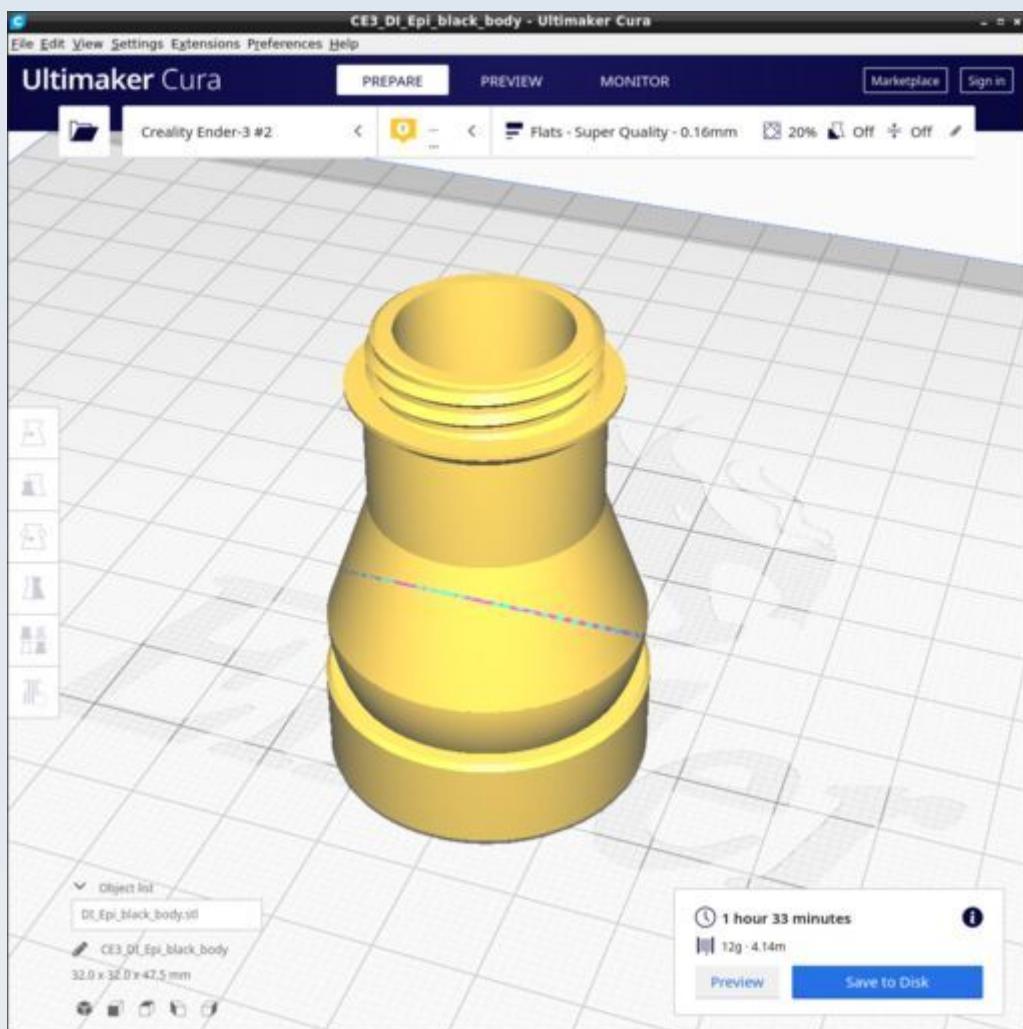
## DI\_Condenser\_base.stl



## DI\_Epi\_attachment.stl

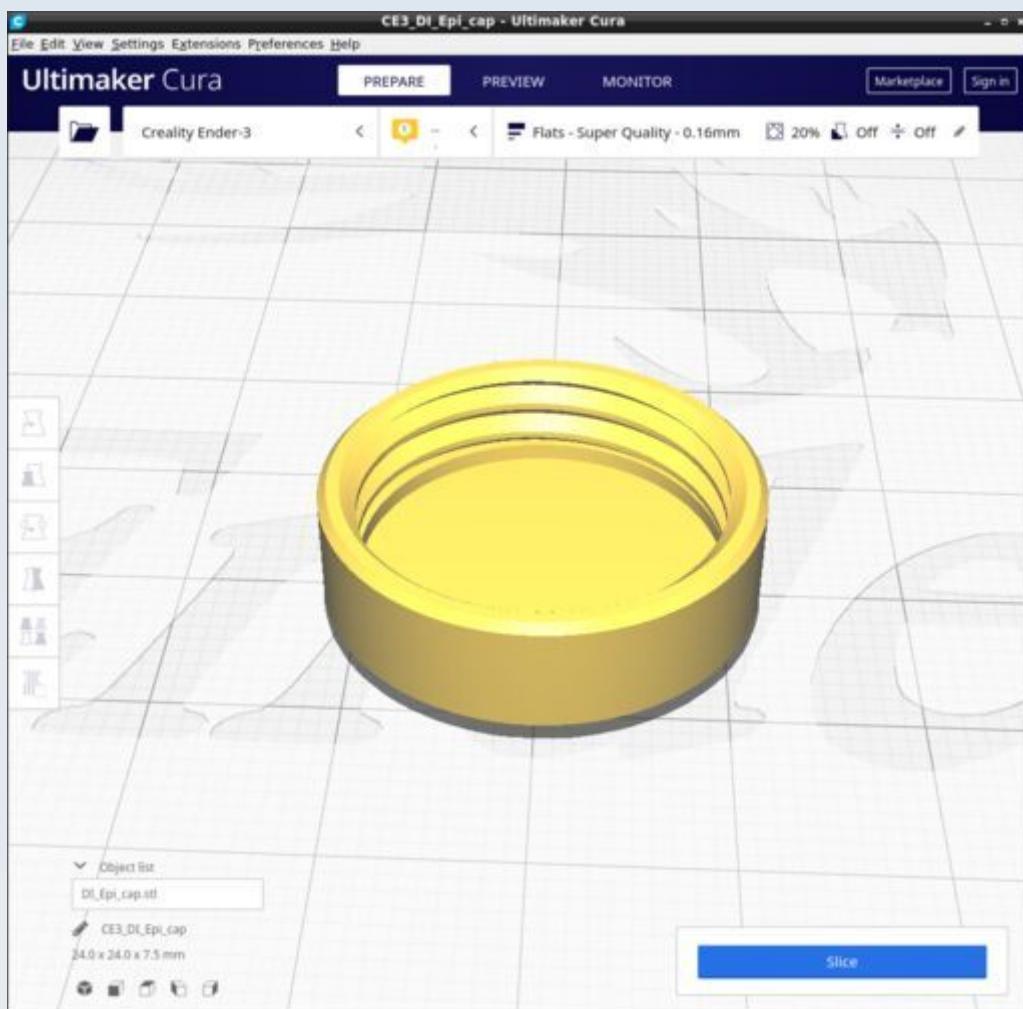


## DI\_Epi\_black\_body.stl

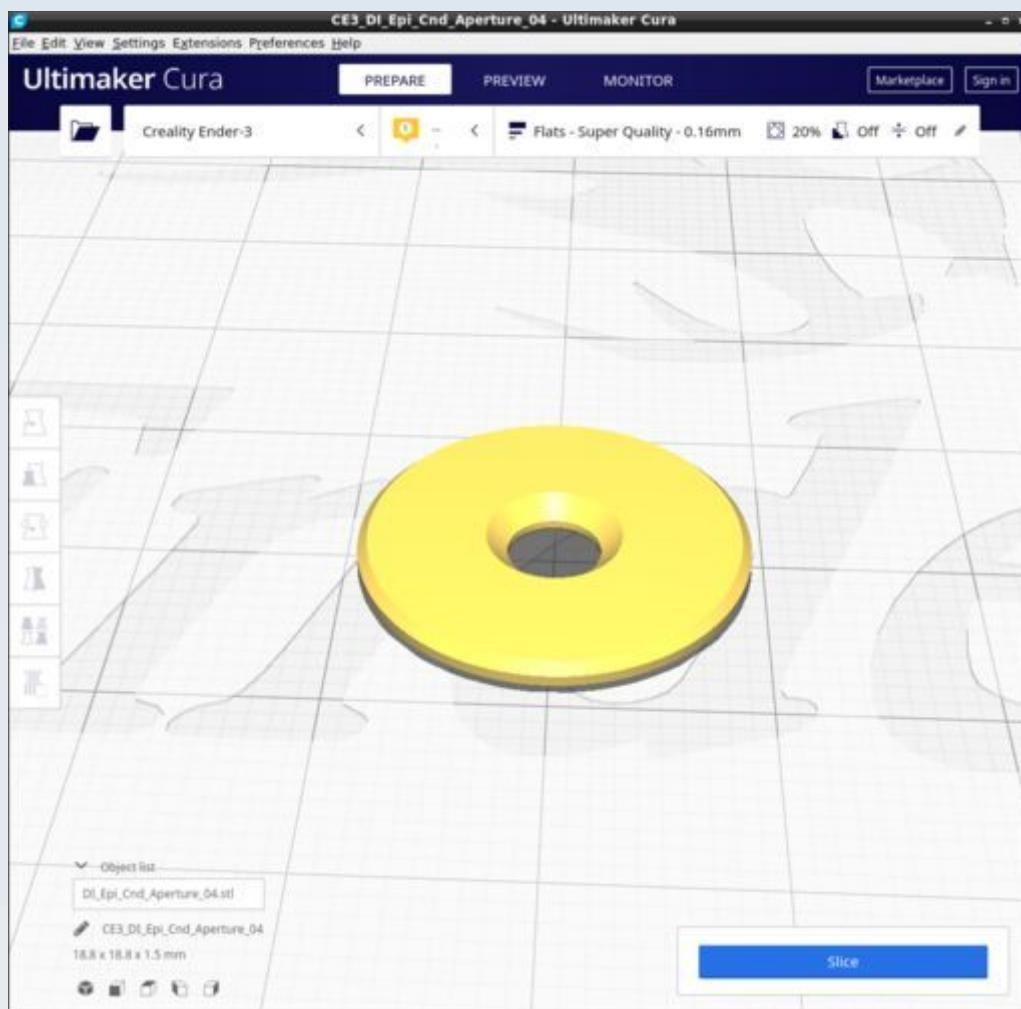


Use the standard 'Flats' profile and do not use supports.

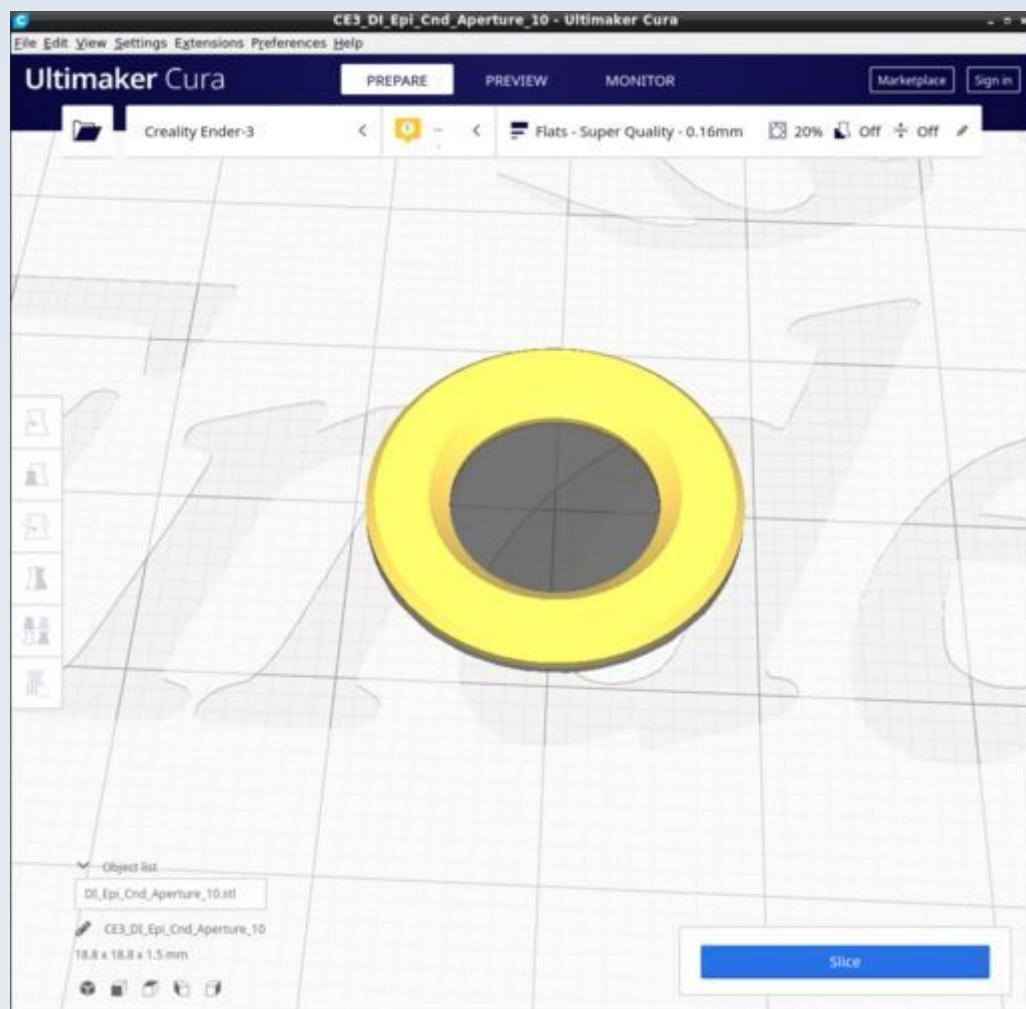
## DI\_Epi\_cap.stl



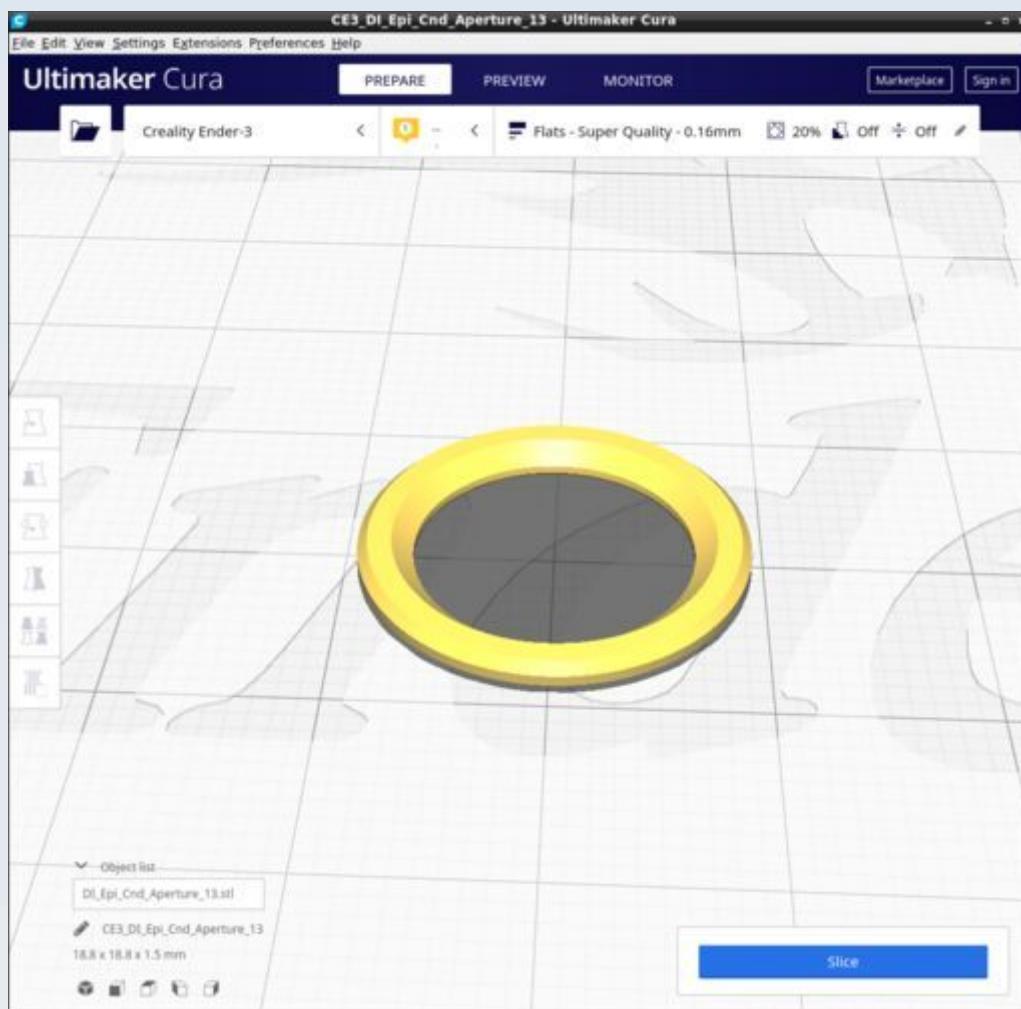
## DI\_Epi\_Cnd\_Aperture\_04.stl



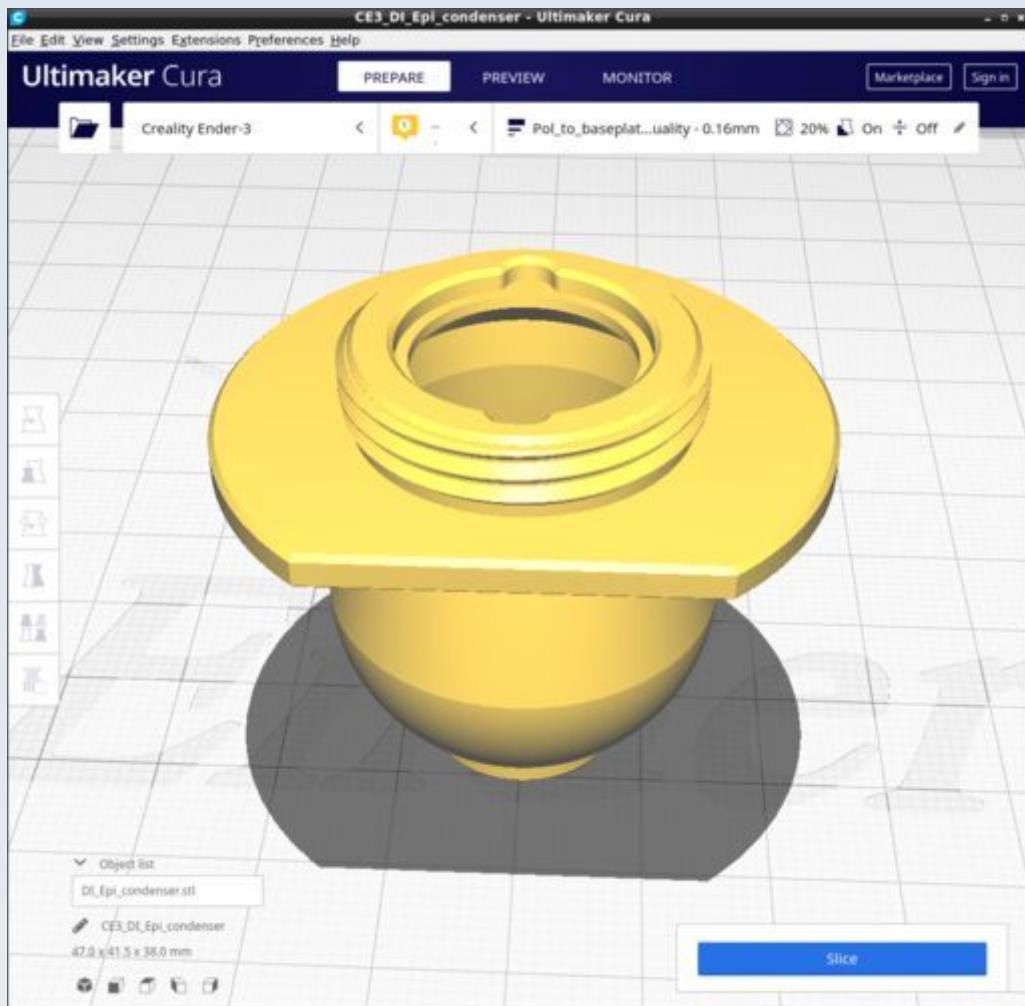
## DI\_Epi\_Cnd\_Aperture\_10.stl



## DI\_Epi\_Cnd\_Aperture\_13.stl

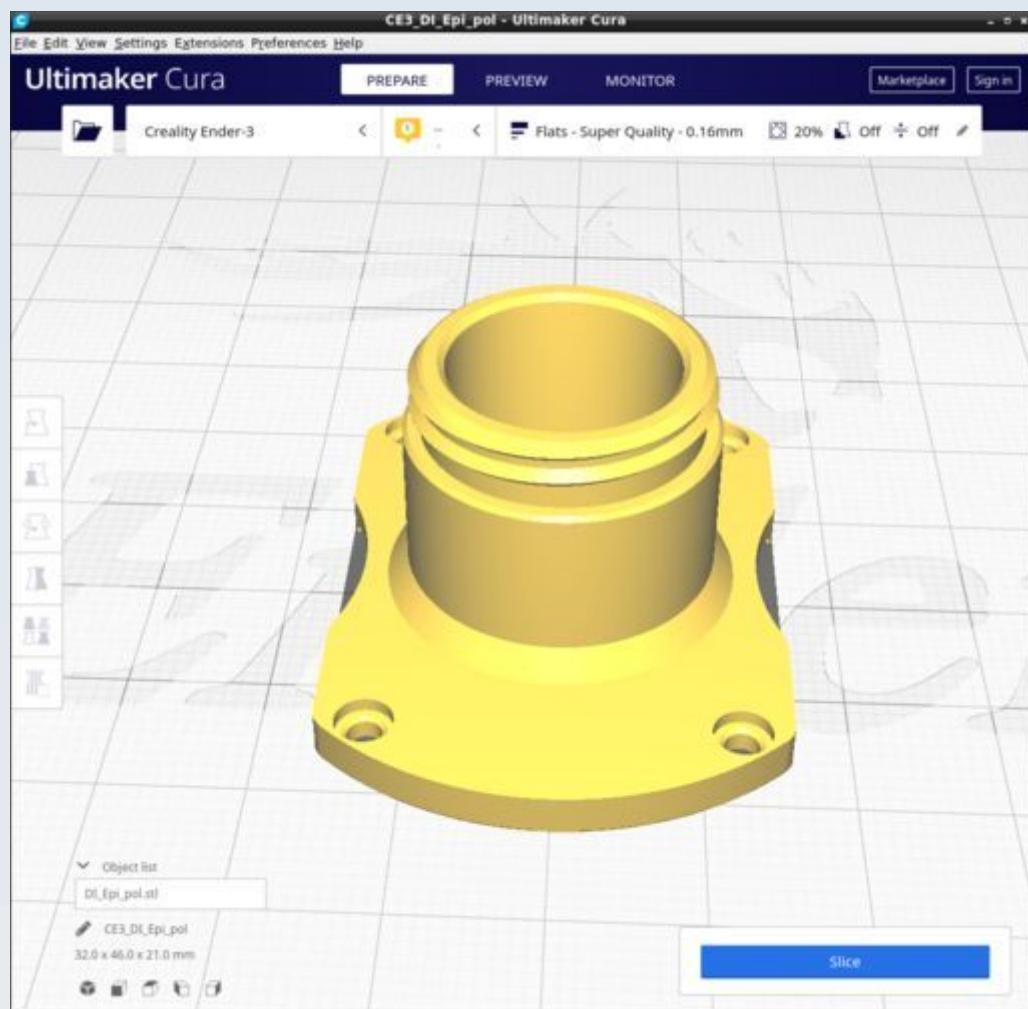


## DI\_Epi\_condenser.stl

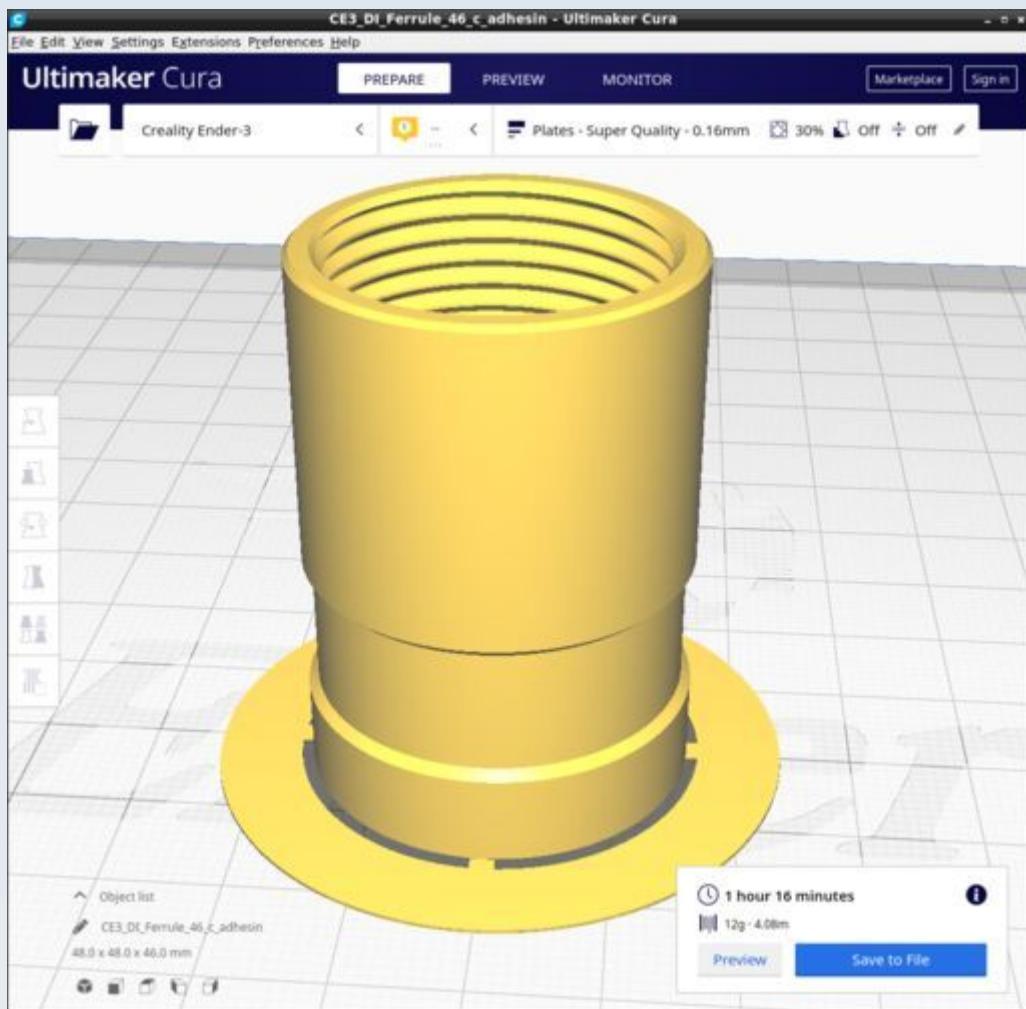


Use the 'Pol\_to\_baseplate' Cura profile.

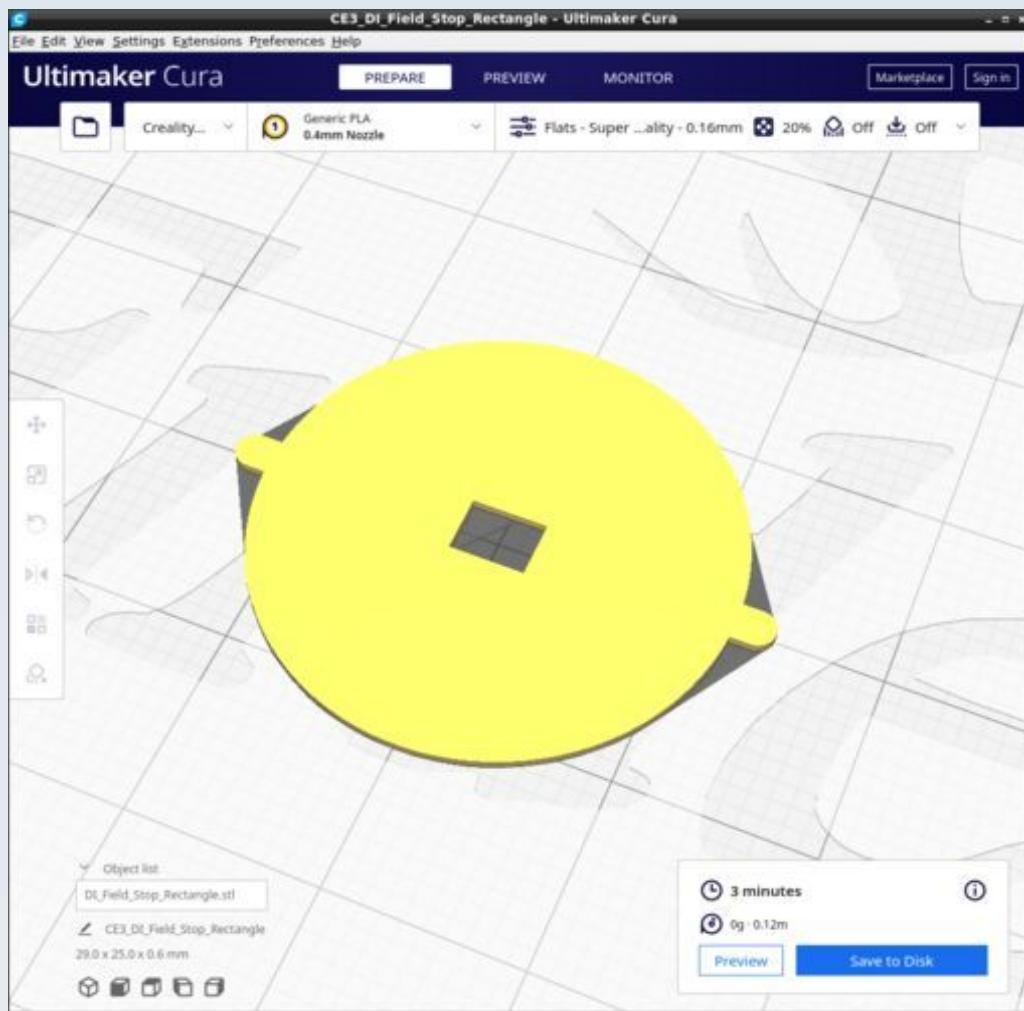
## DI\_Epi\_pol.stl



## DI\_Ferrule\_46\_c\_adhesin.stl



## DI\_Field\_Stop\_Rectangle.stl



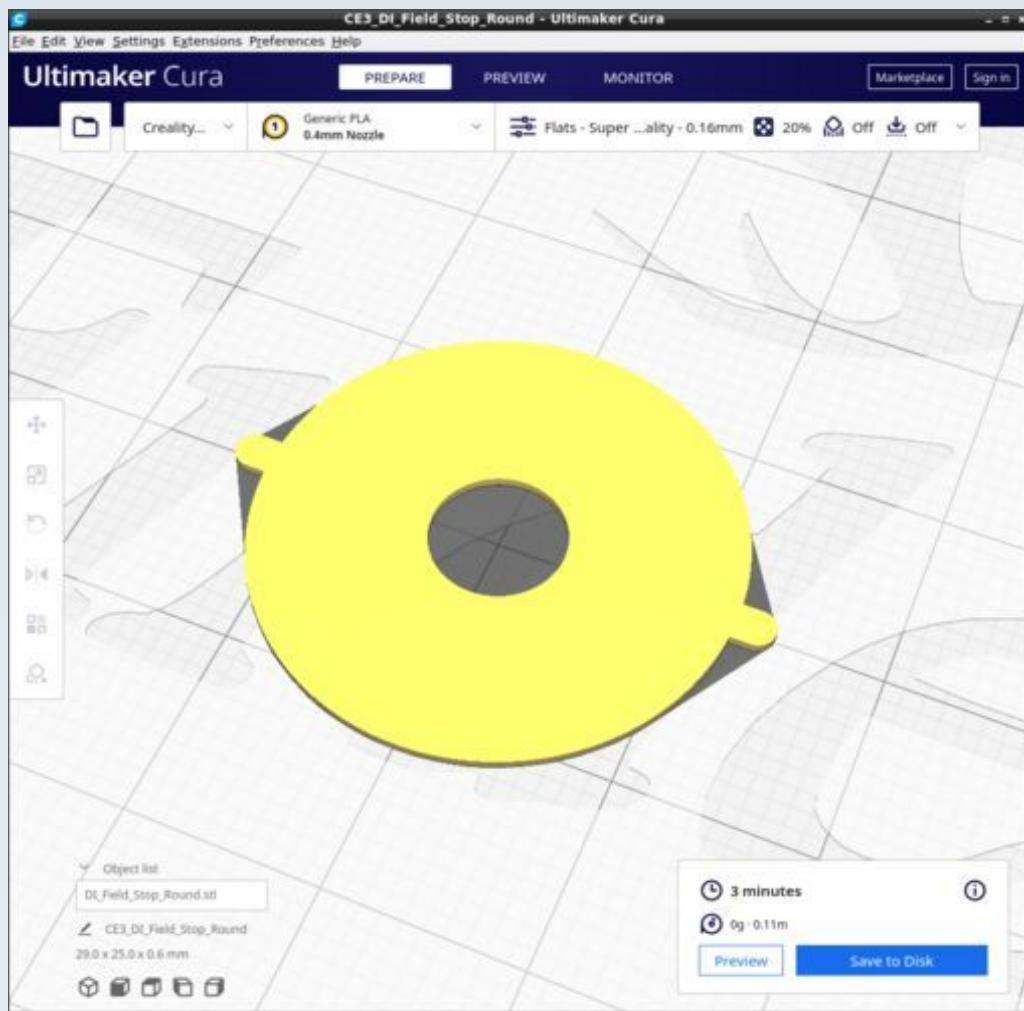
Note that the Field\_Stop models are thicker (have more print layers) than the DI\_IFD\_Filter\_Crosshairs. This is because it is beneficial for the crosshairs to be semitransparent to be able to see the image of the light source behind it for centration purposes but true field stops should be fully opaque.

In FreeCAD:

To change the aperture of the Field\_Stop\_Rectangle alter the dimensions (and XY offset positions accordingly to maintain central position) of the box called 'Aperture\_rectangle' here (the default size is 4 mm by 3 mm):

```
Field_Stop_Rectangle
|_ Sehfeldblende_4x3
    |_ Aperture_rectangle
```

## DI\_Field\_Stop\_Round.stl



Note that the Field\_Stop models are thicker (have more print layers) than the DI\_IFD\_Filter\_Crosshairs. This is because it is beneficial for the crosshairs to be semitransparent to be able to see the image of the light source behind it for centration purposes but true field stops should be fully opaque.

In FreeCAD:

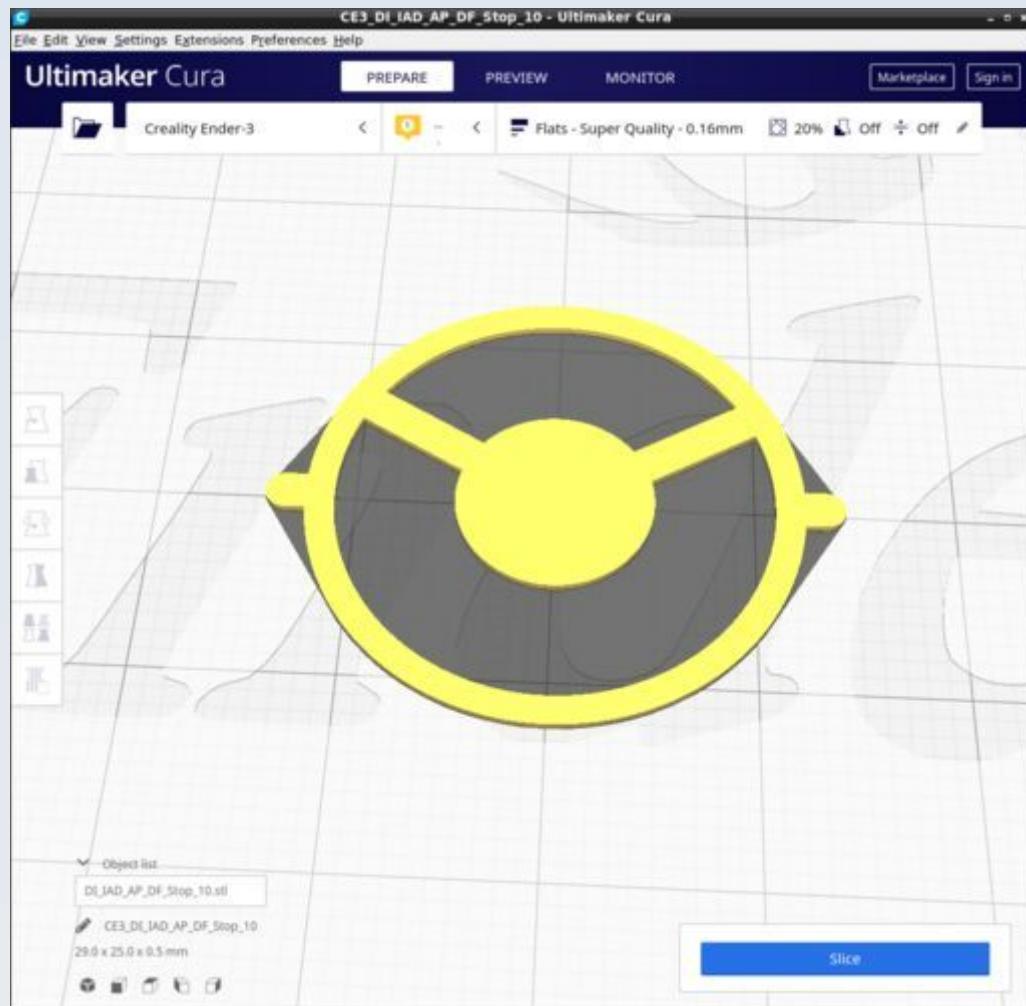
To change the aperture of the Field\_Stop\_Round alter the radius value of the cylinder called 'Aperture\_hole' here (the default is mm):

Field\_Stop\_Round

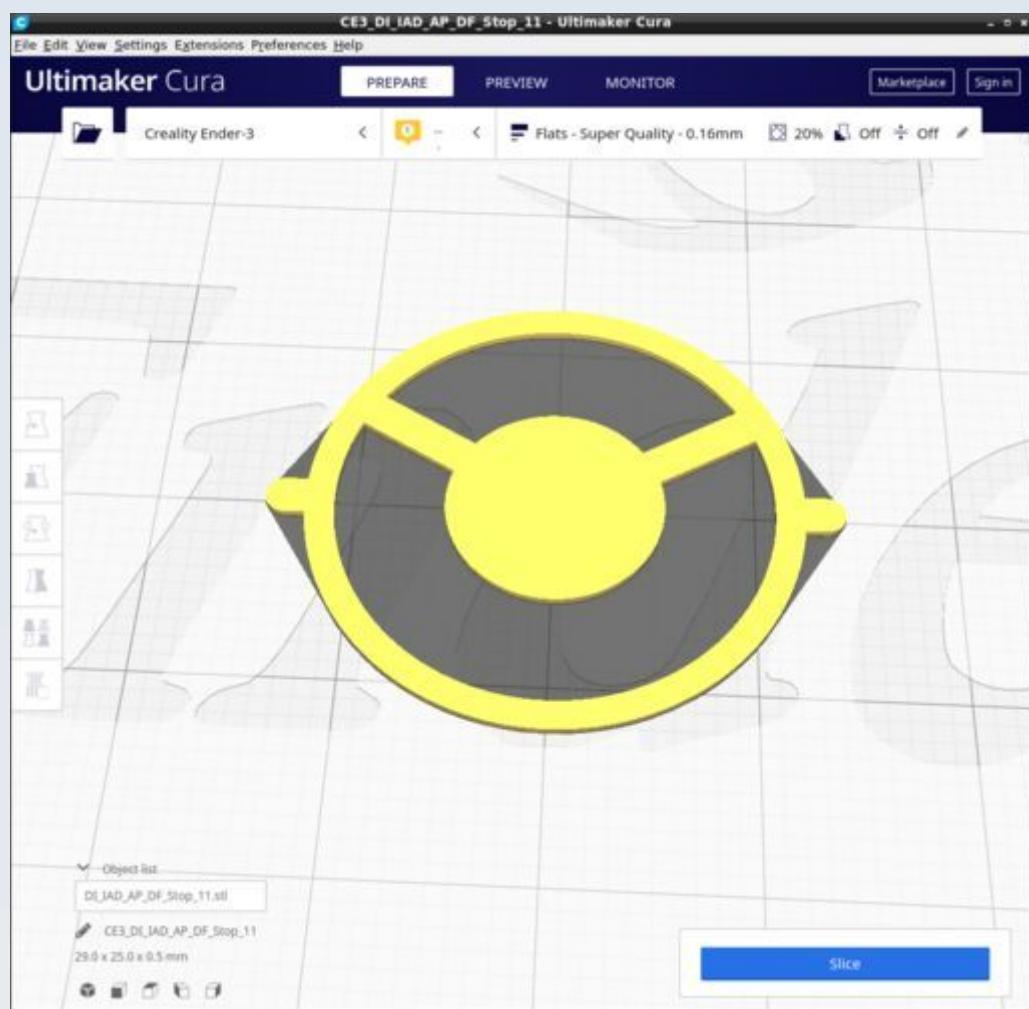
|\_ Sehfeldblende

  |\_ Aperture\_hole

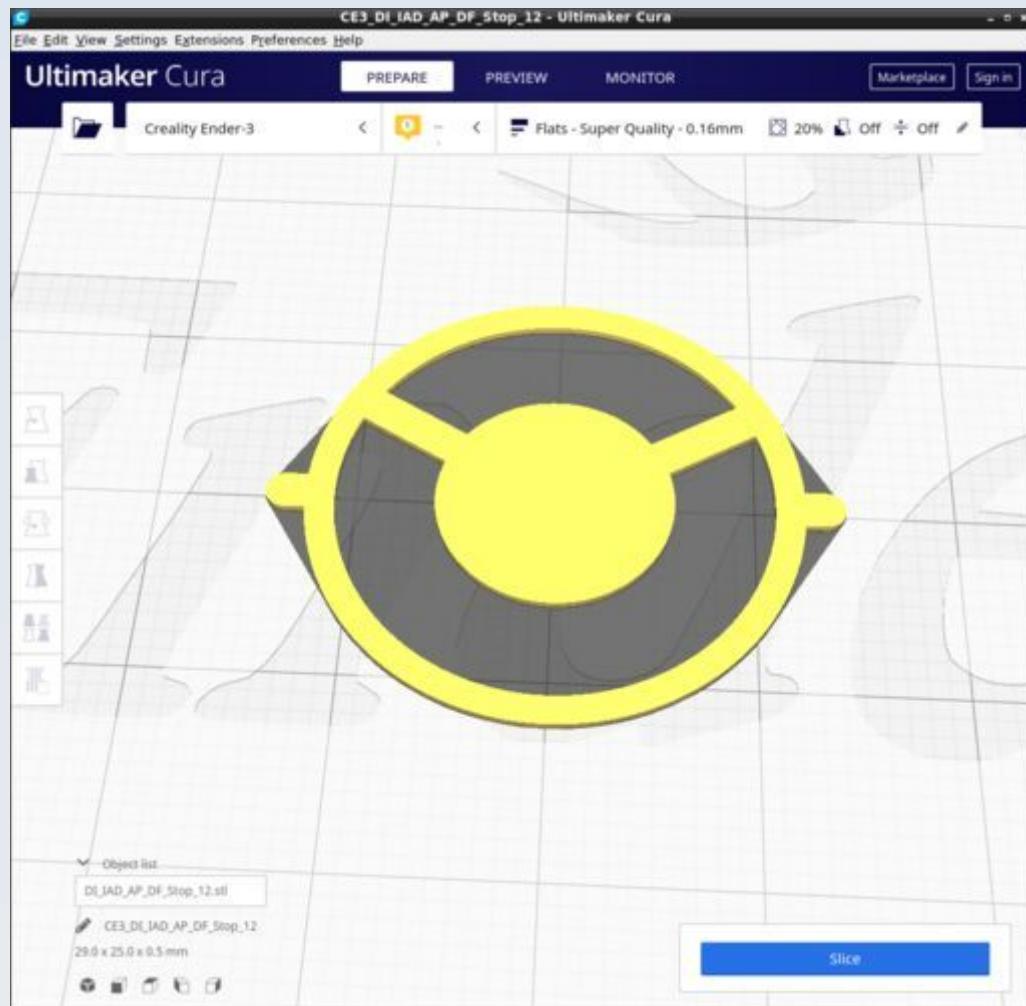
## DI\_IAD\_AP\_DF\_Stop\_10.stl



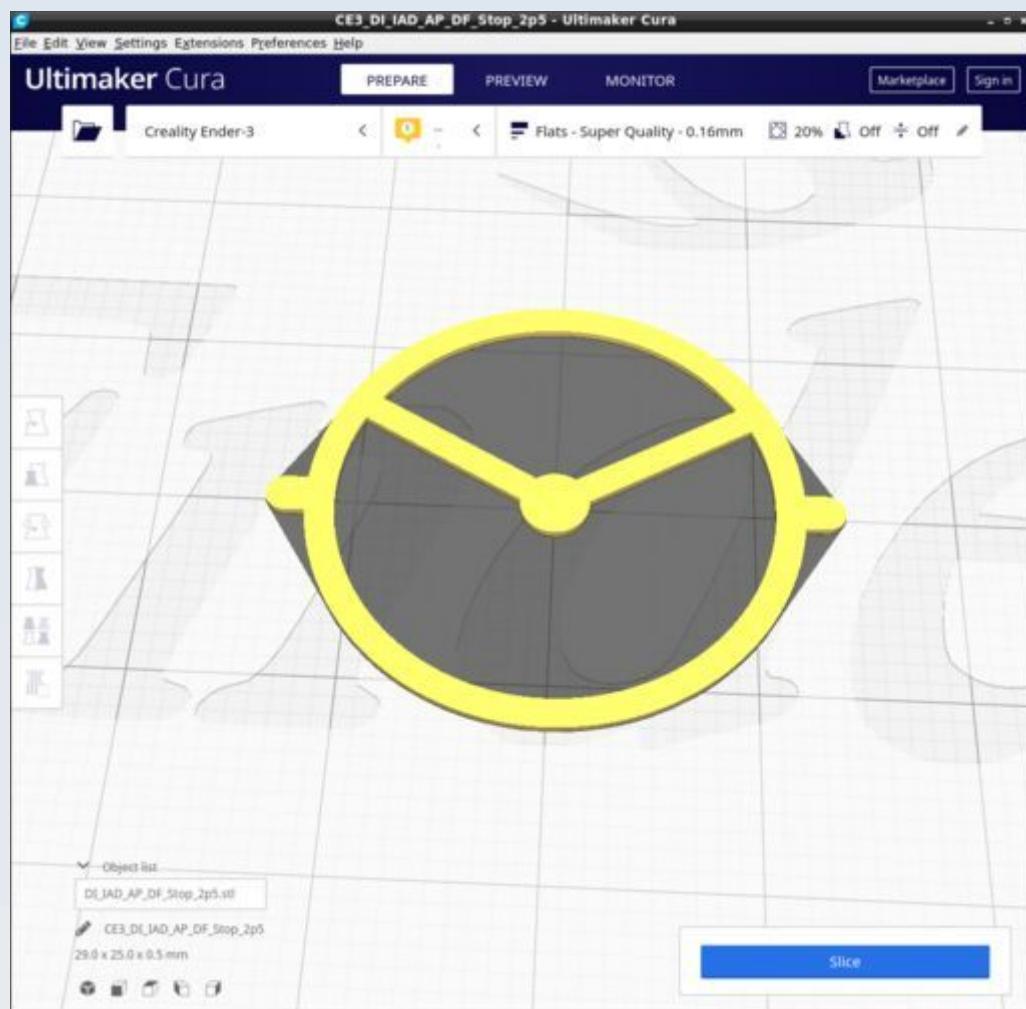
## DI\_IAD\_AP\_DF\_Stop\_11.stl



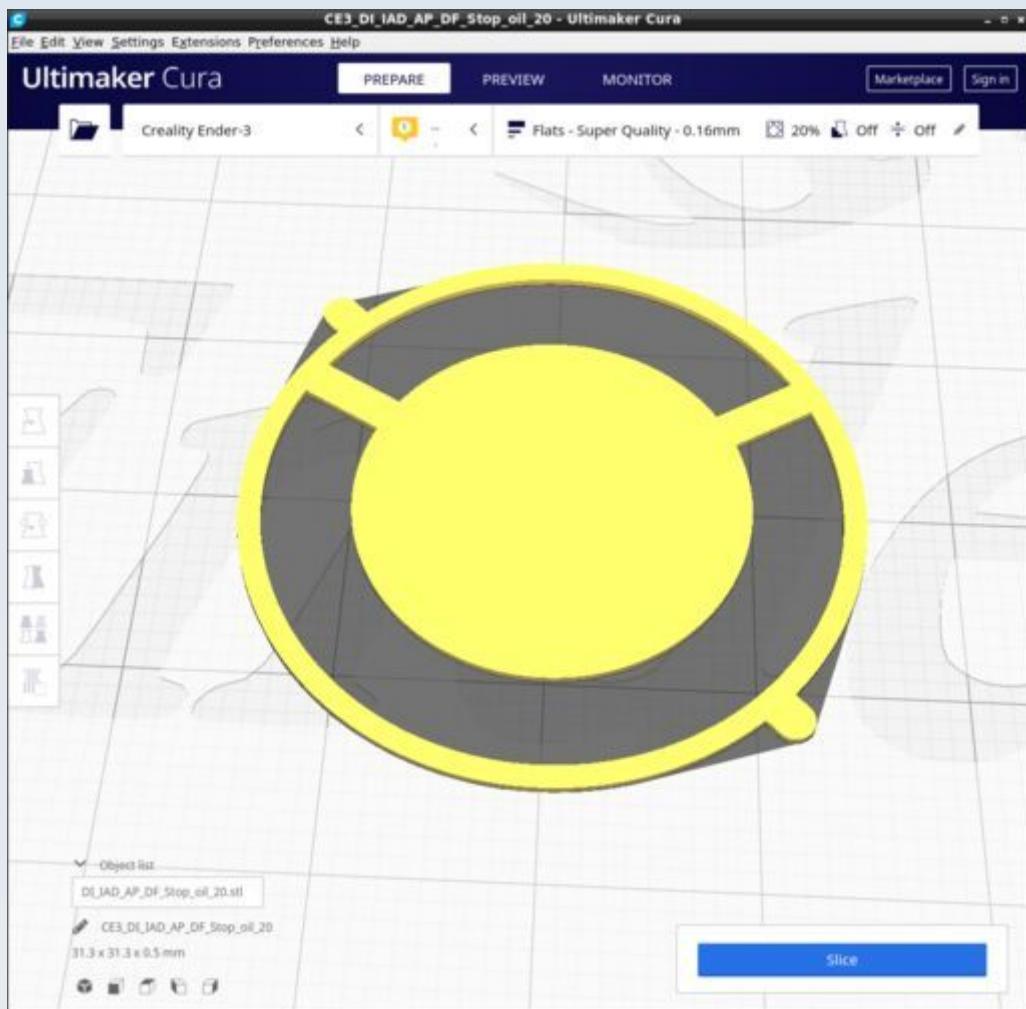
## DI\_IAD\_AP\_DF\_Stop\_12.stl



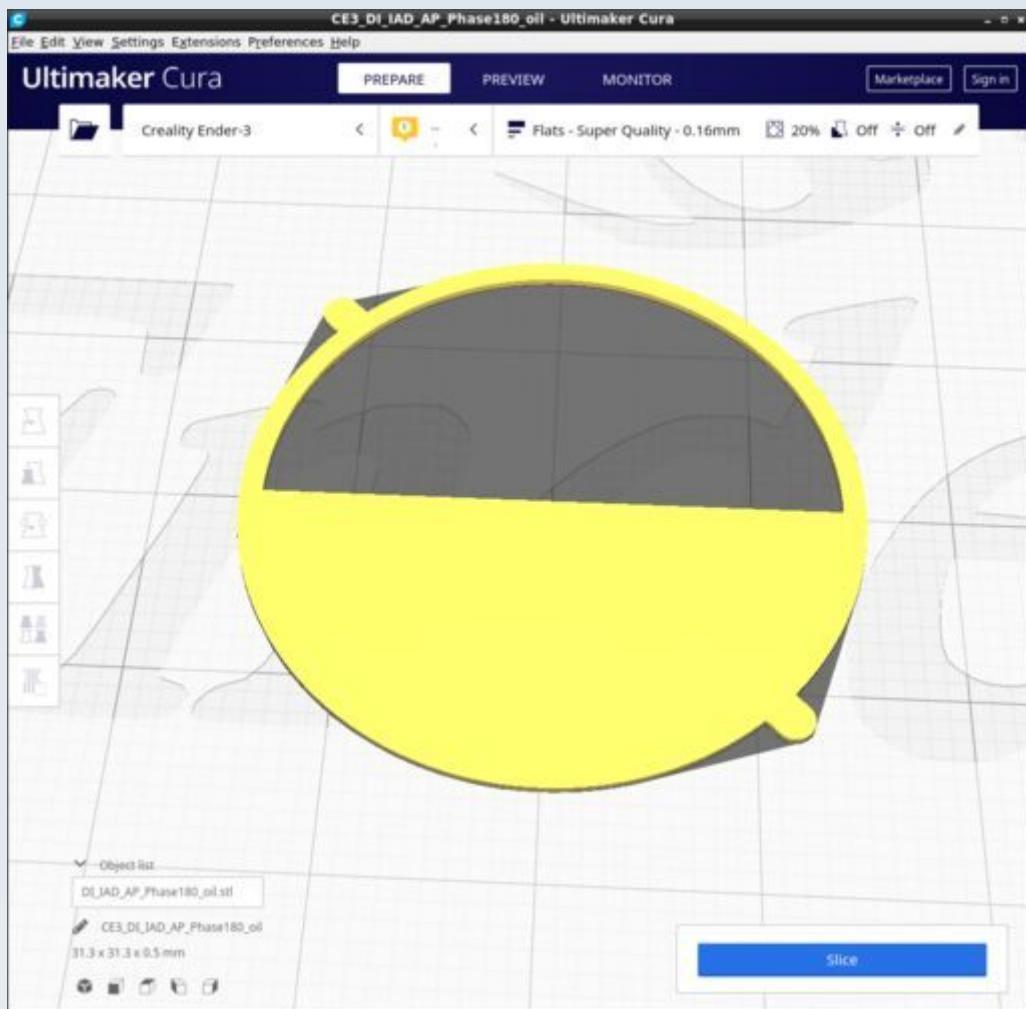
## DI\_IAD\_AP\_DF\_Stop\_2p5.stl



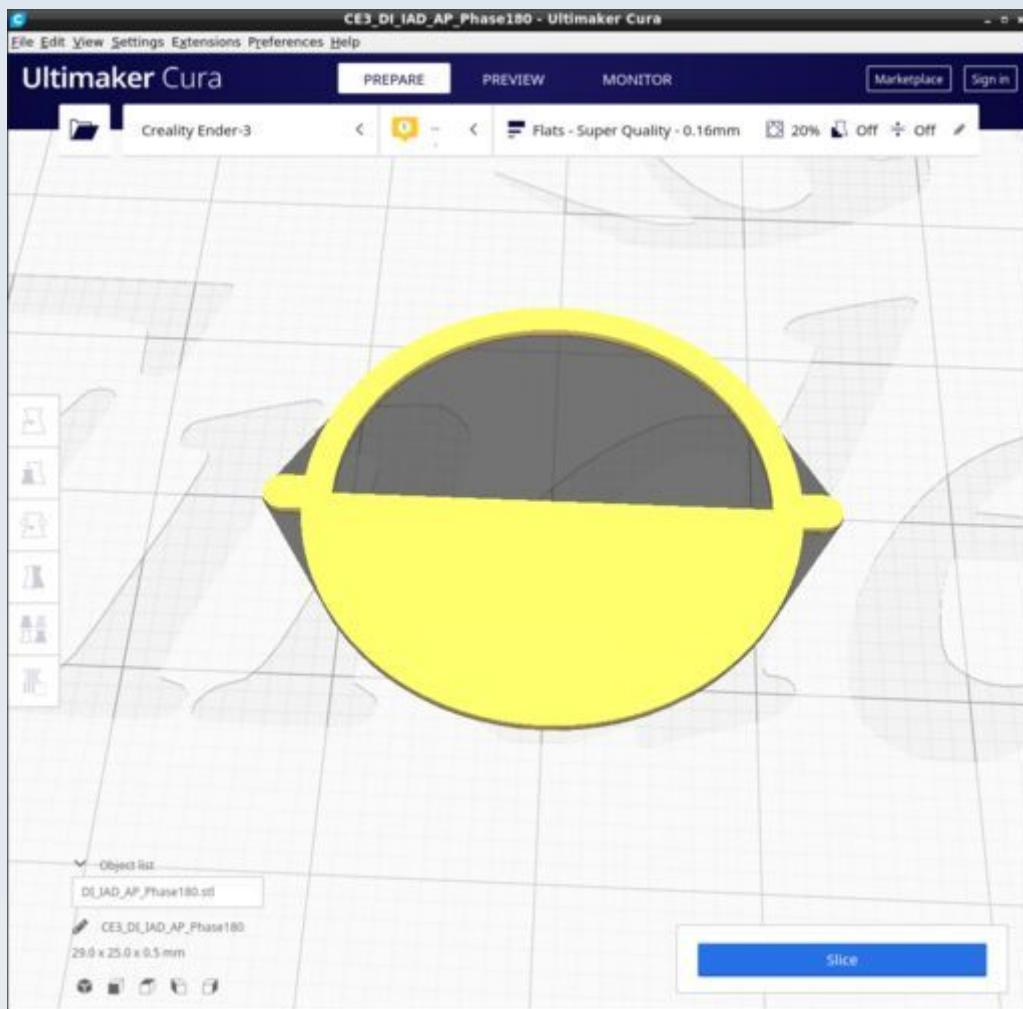
## DI\_IAD\_AP\_DF\_Stop\_oil\_20.stl



## DI\_IAD\_AP\_Phase180\_oil.stl



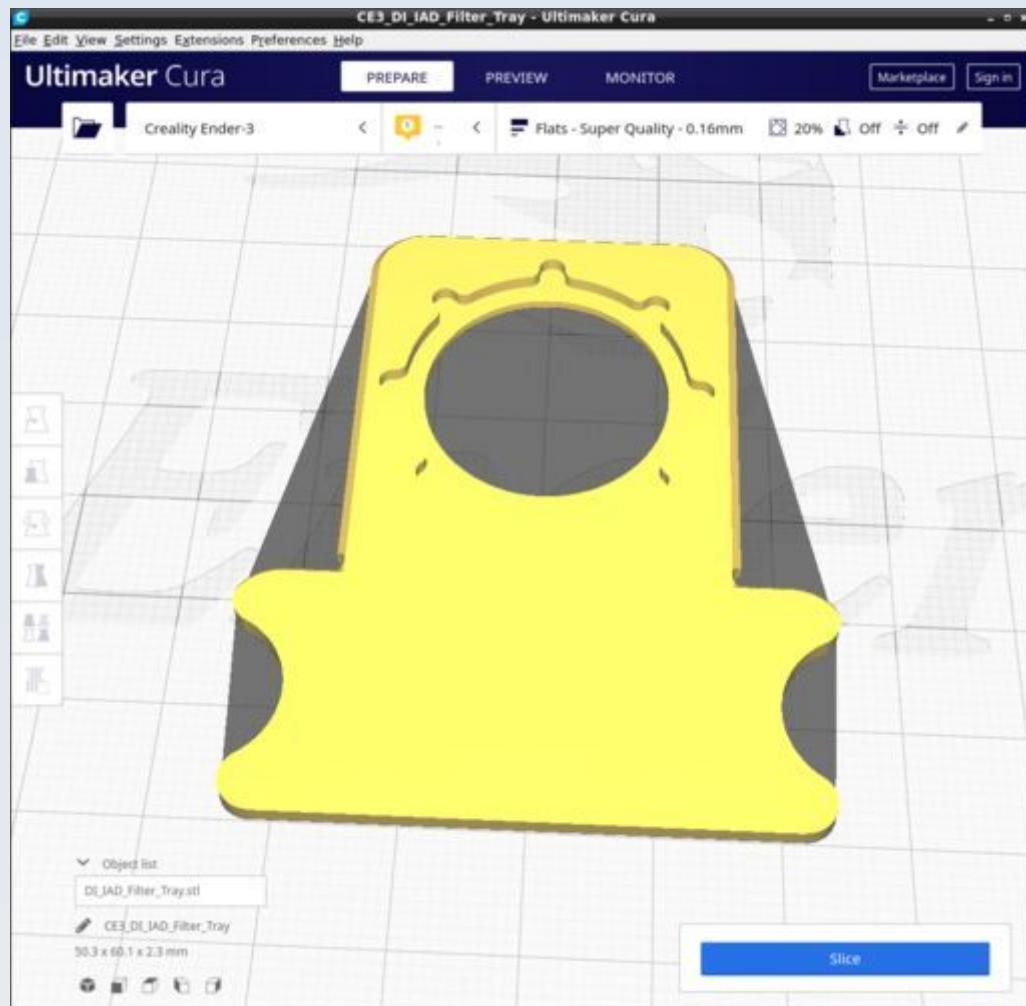
## DI\_IAD\_AP\_Phase180.stl



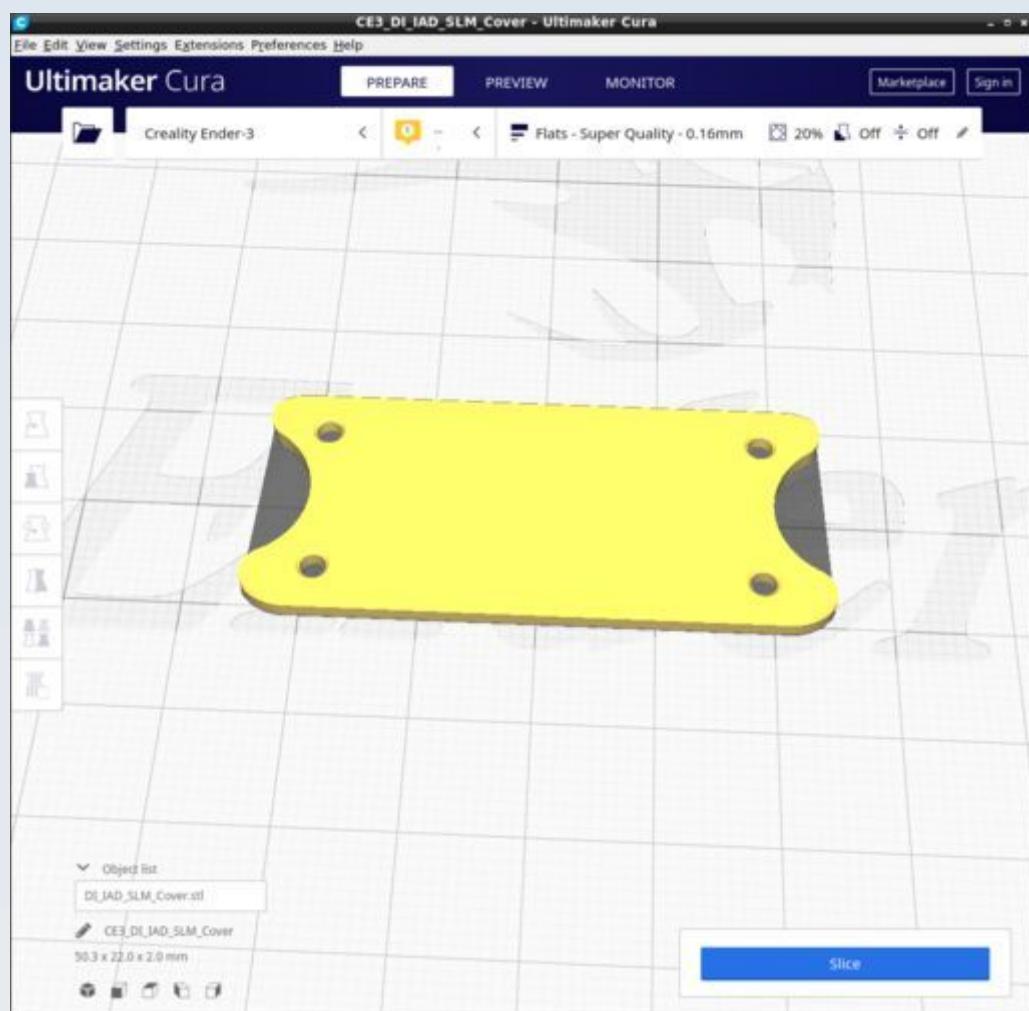
## DI\_IAD\_Filter\_Tray\_oil.stl



## DI\_IAD\_Filter\_Tray.stl



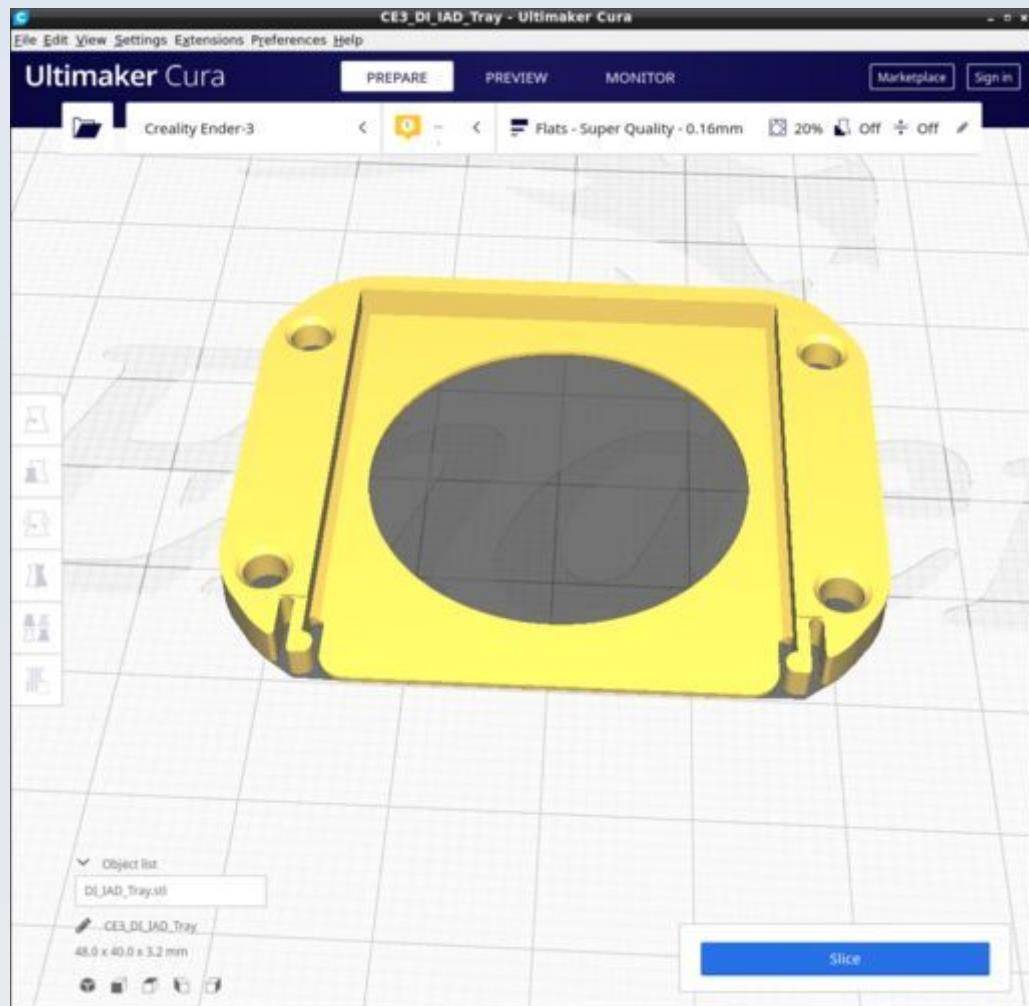
## DI\_IAD\_SLM\_Cover.stl



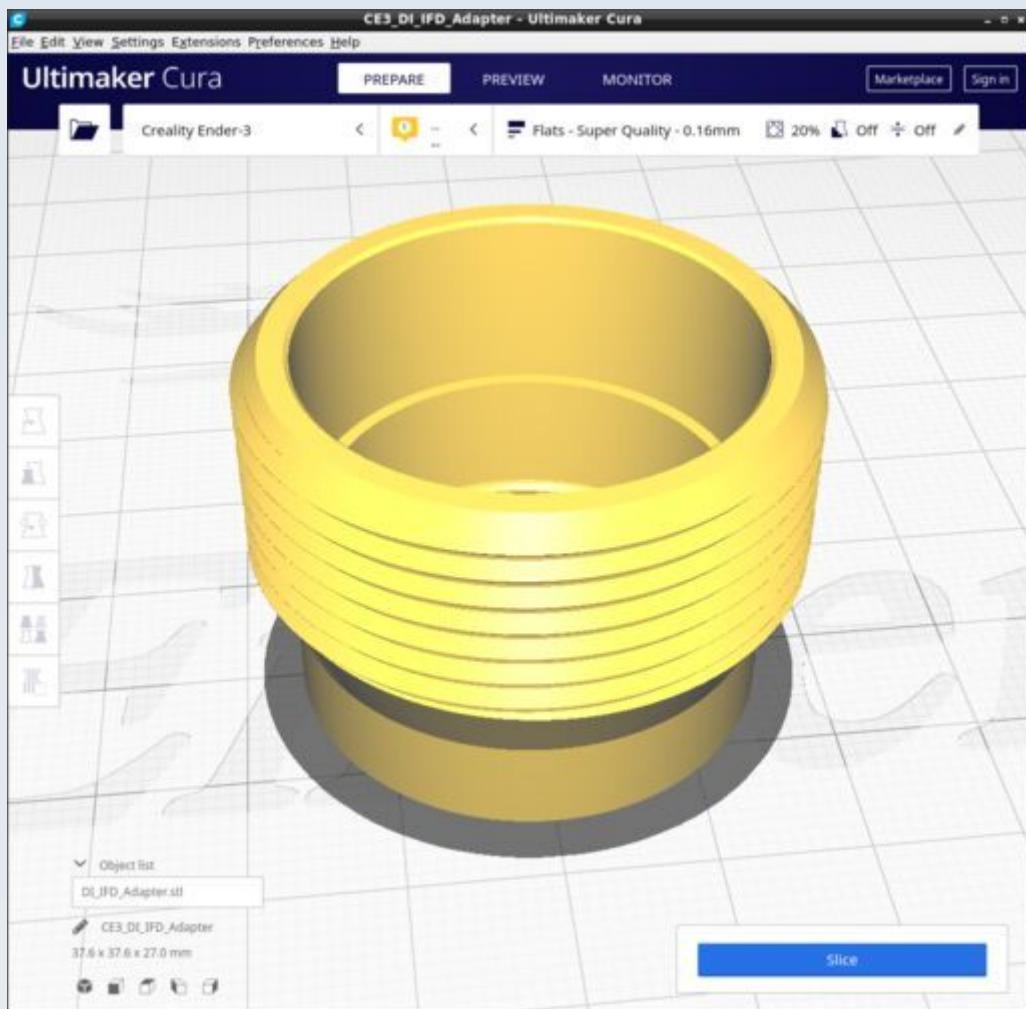
## DI\_IAD\_SLM\_Filter.stl



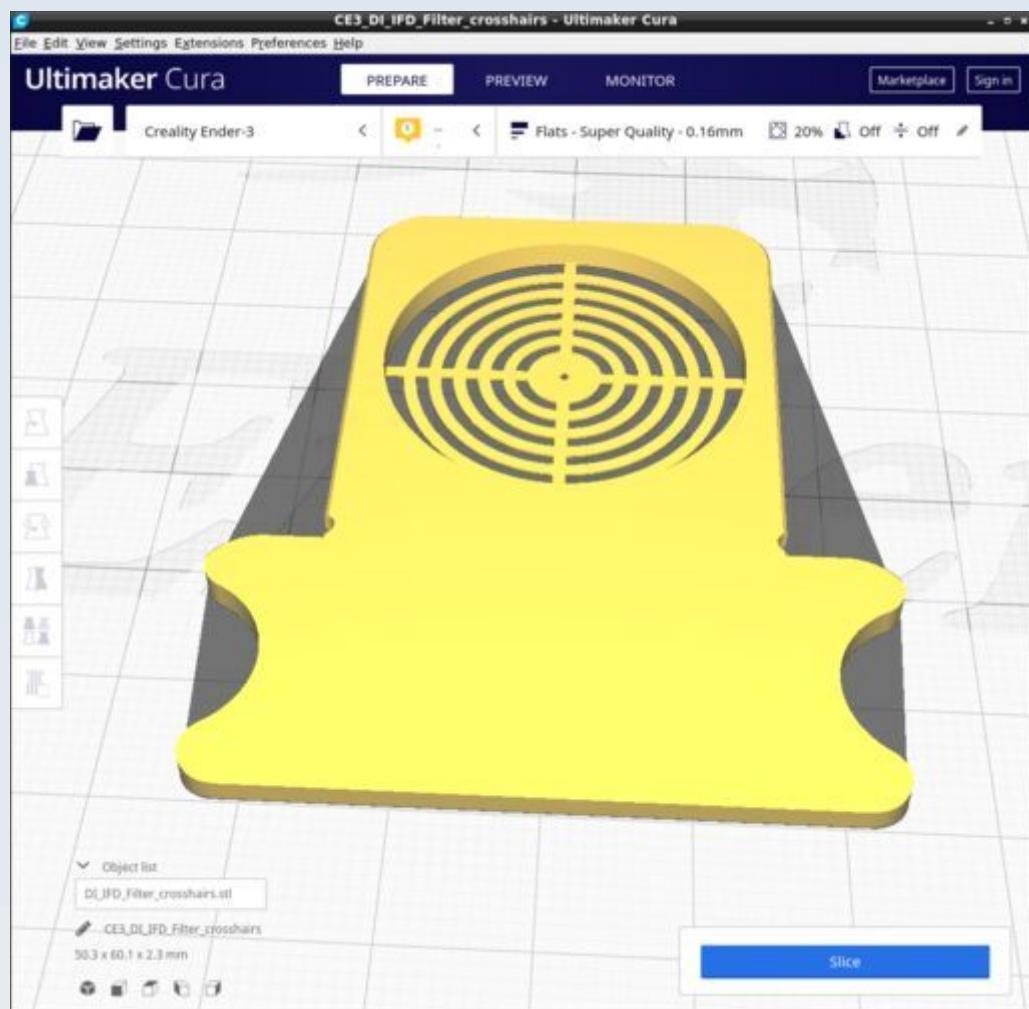
## DI\_IAD\_Tray.stl



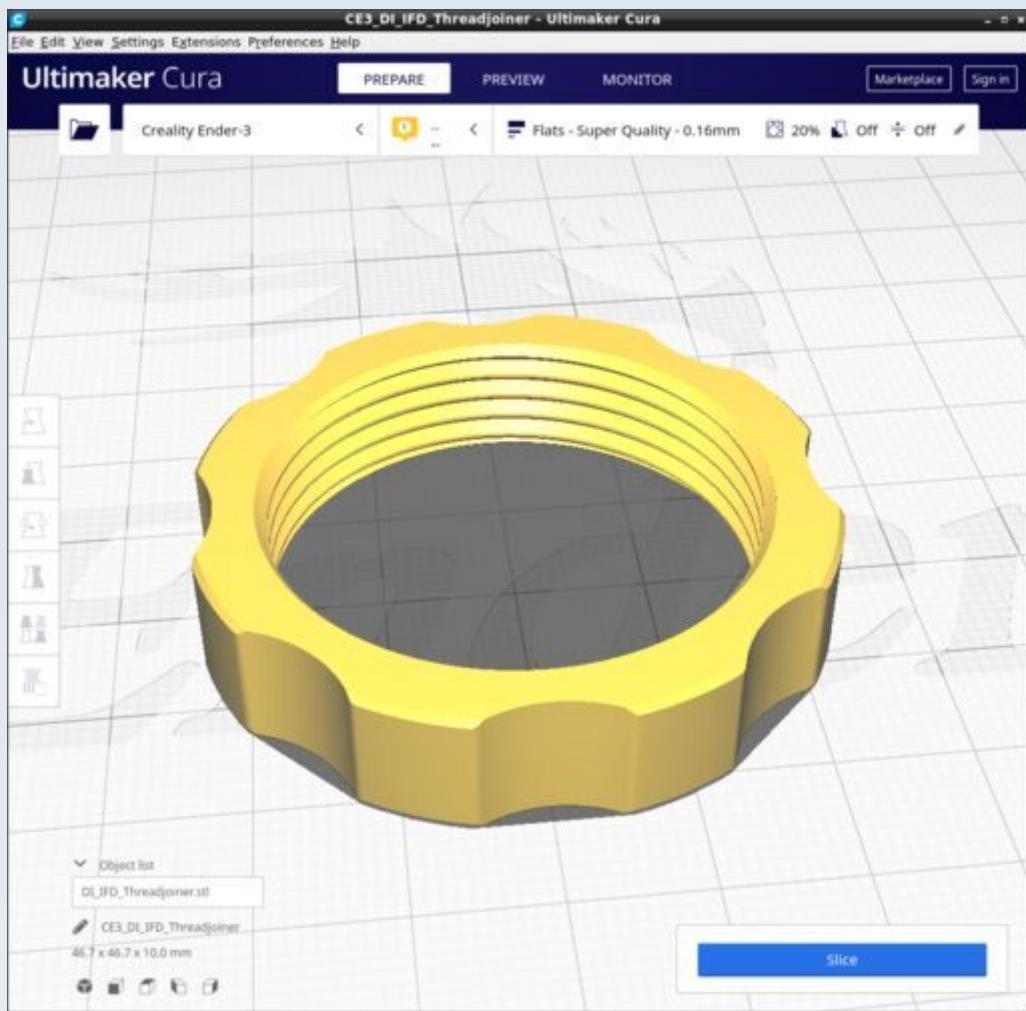
## DI\_IFD\_Adapter.stl



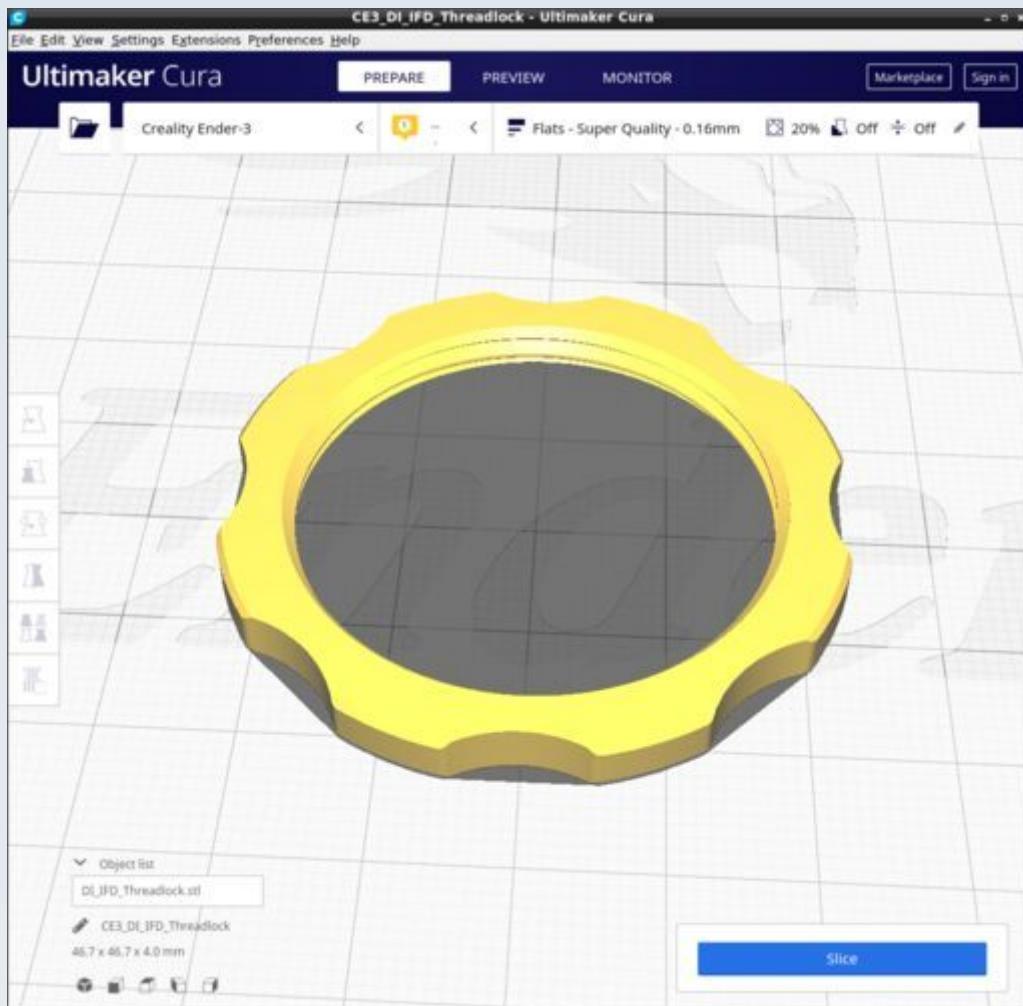
## DI\_IFD\_Filter\_crosshairs.stl



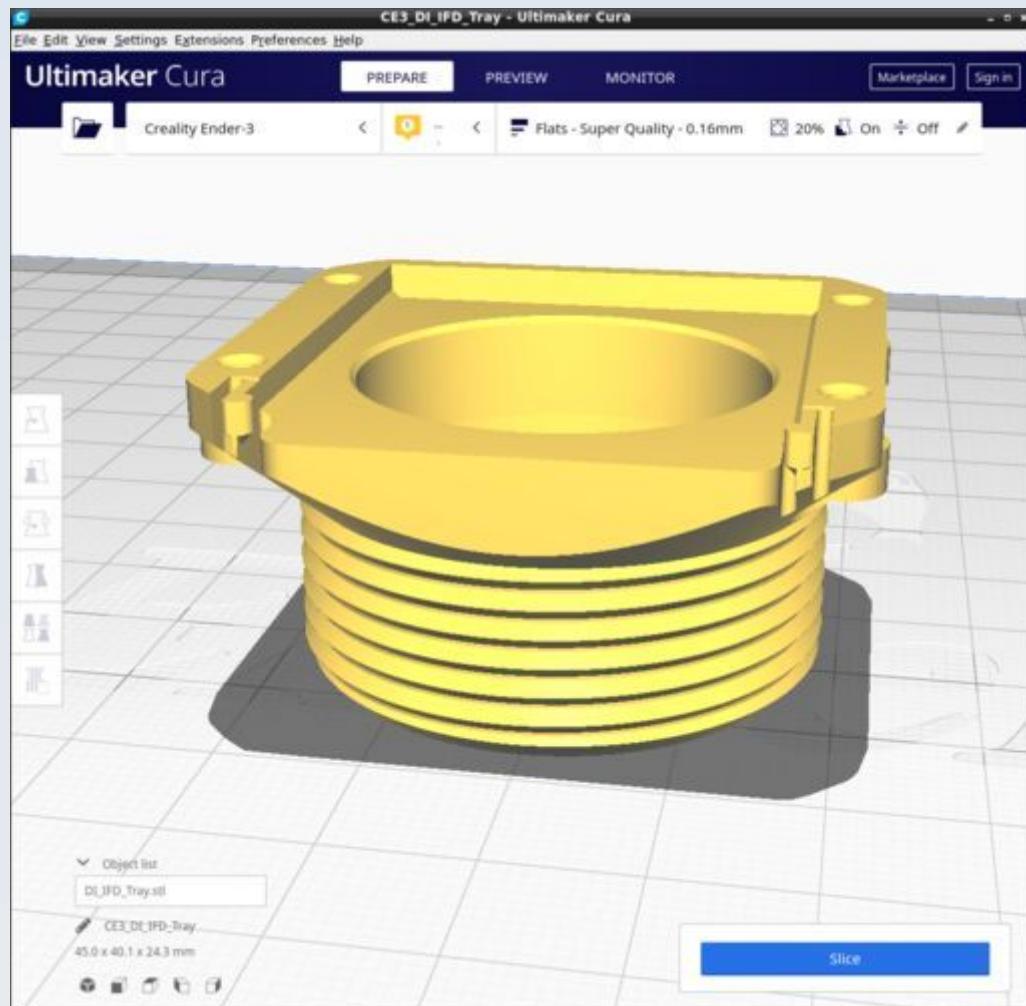
## DI\_IFD\_Threadjoiner.stl



## DI\_IFD\_Threadlock.stl

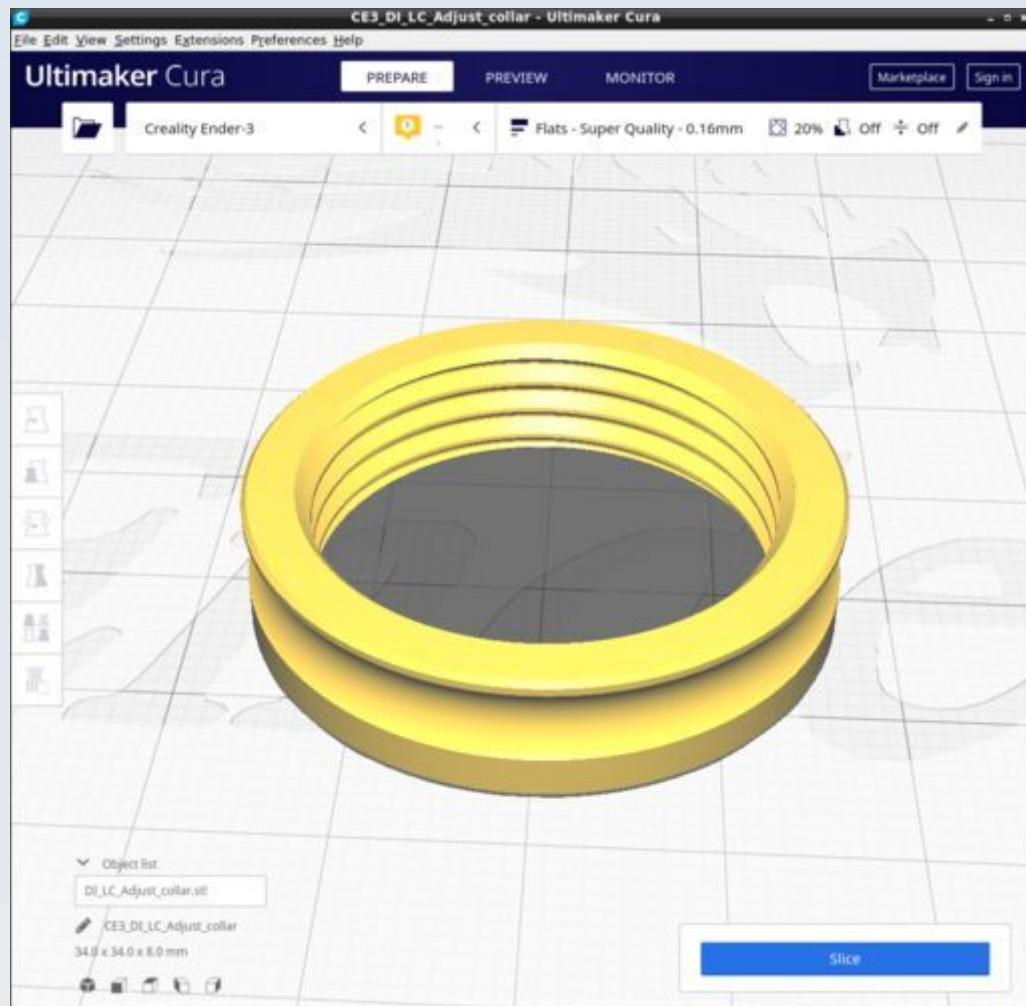


## DI\_IFD\_Tray.stl

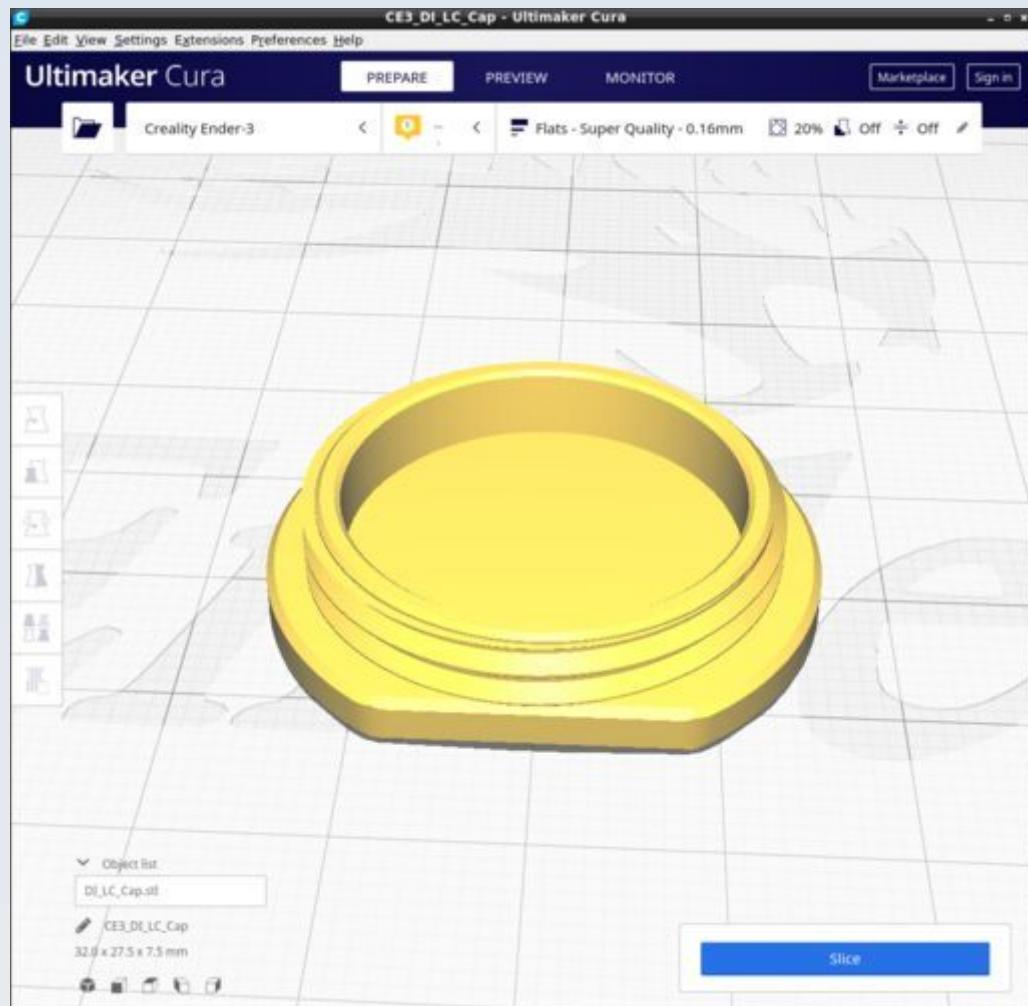


Supports on for 'touching buildplate only'

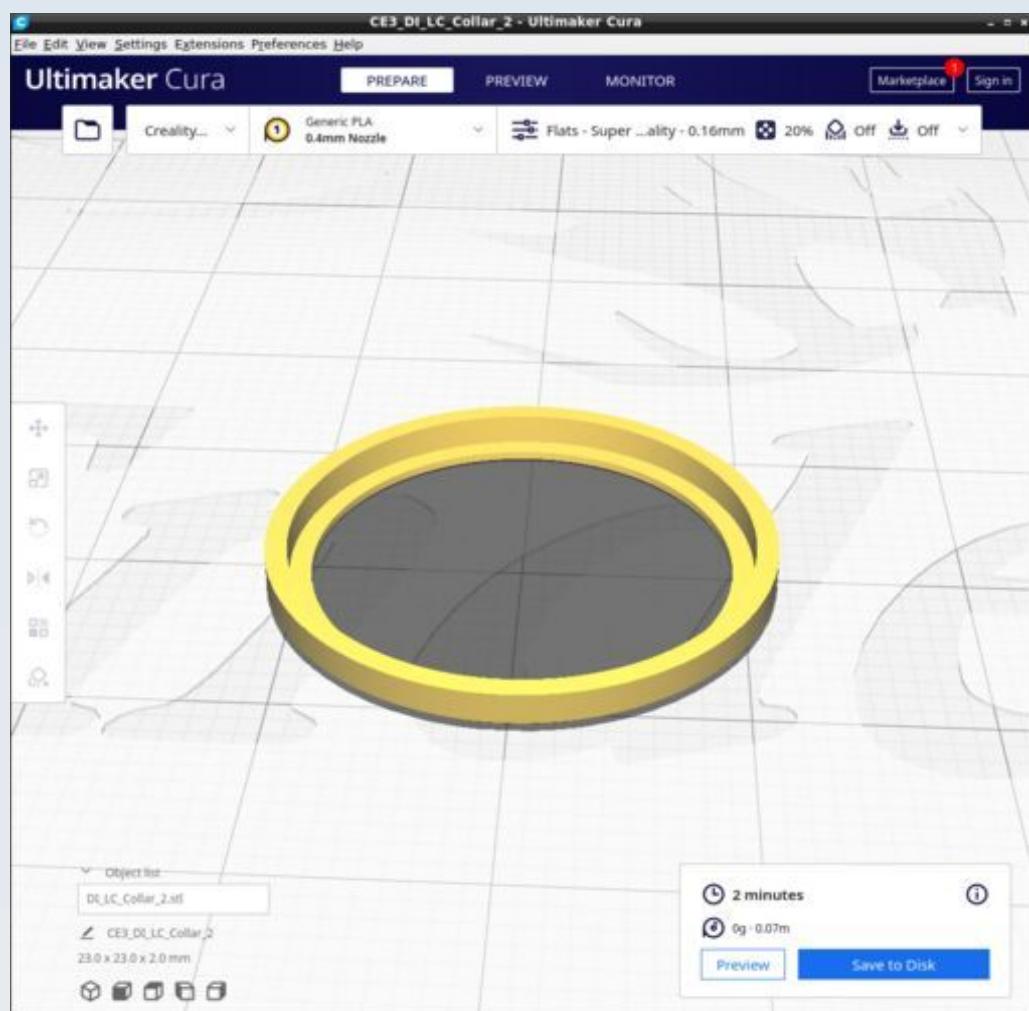
## DI\_LC\_Adjust\_collar.stl



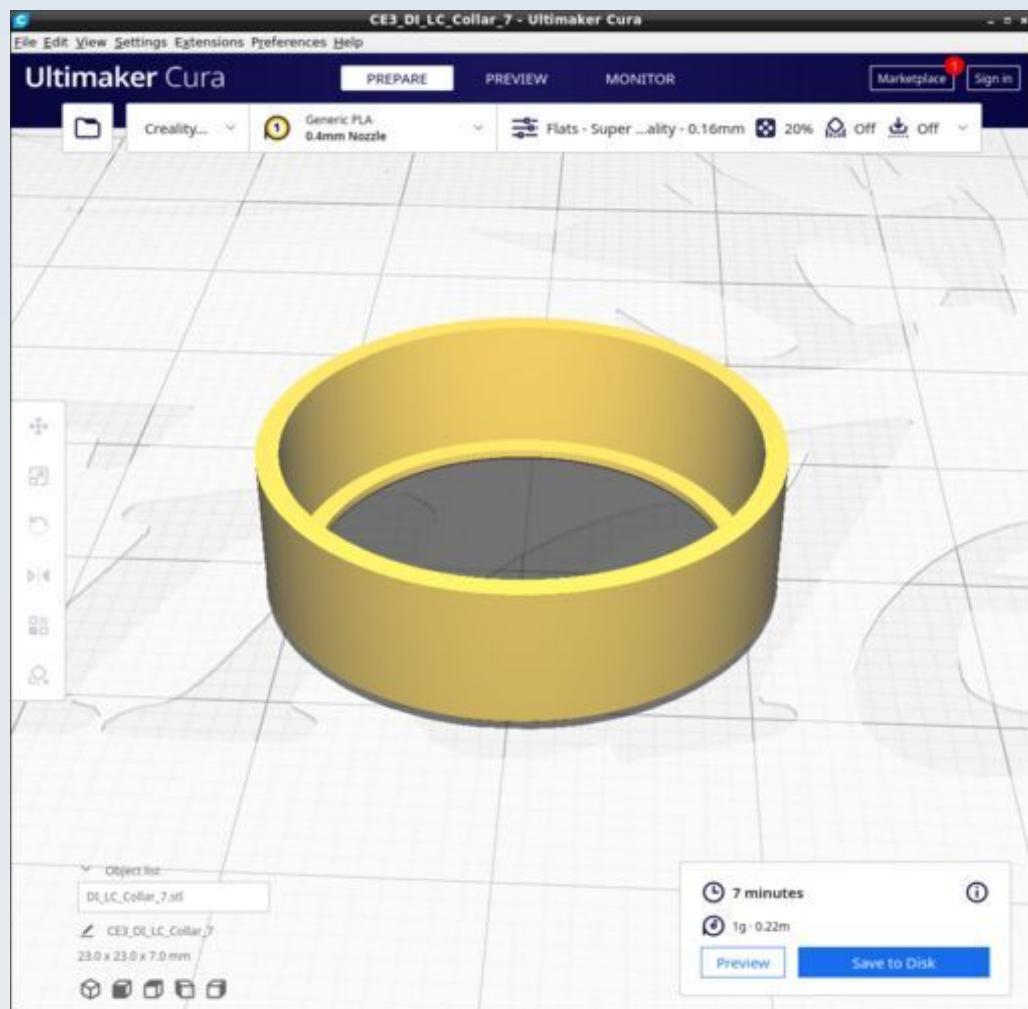
## DI\_LC\_Cap.stl



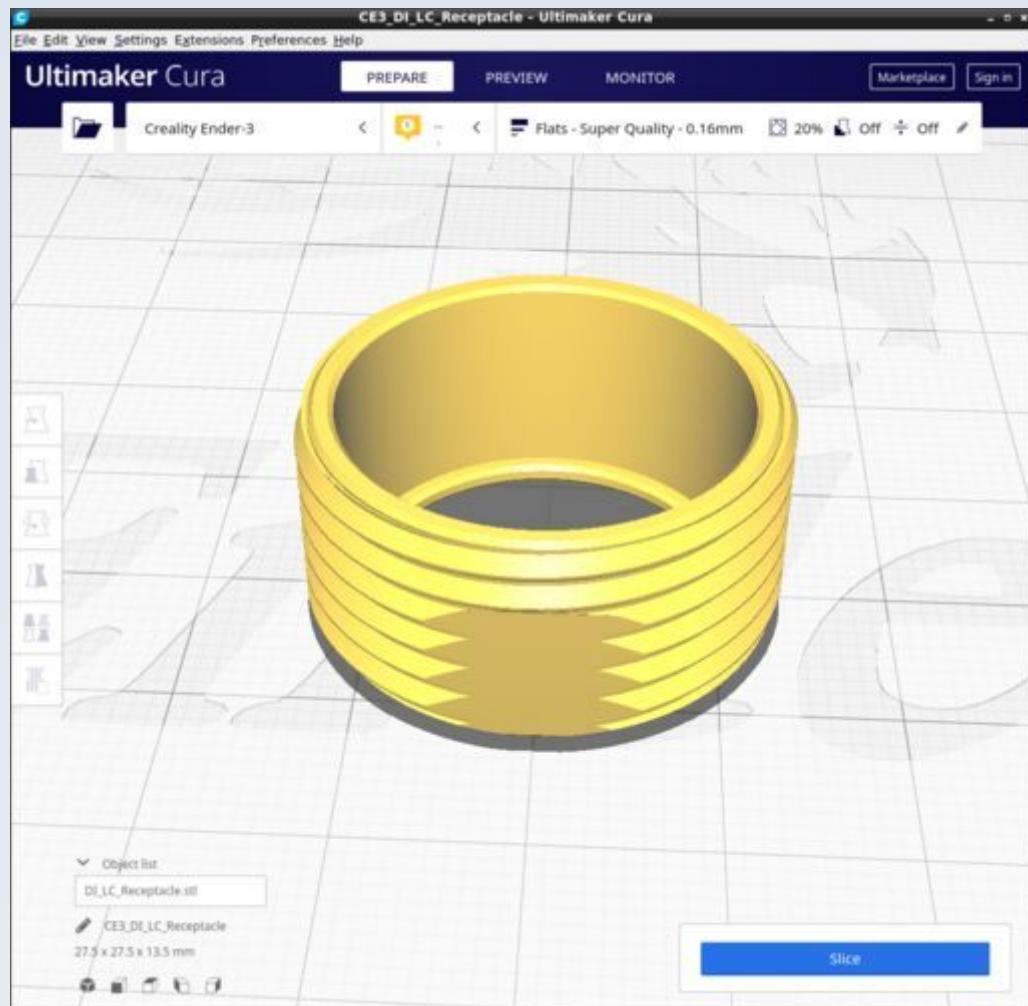
## DI\_LC\_Collar\_2.stl



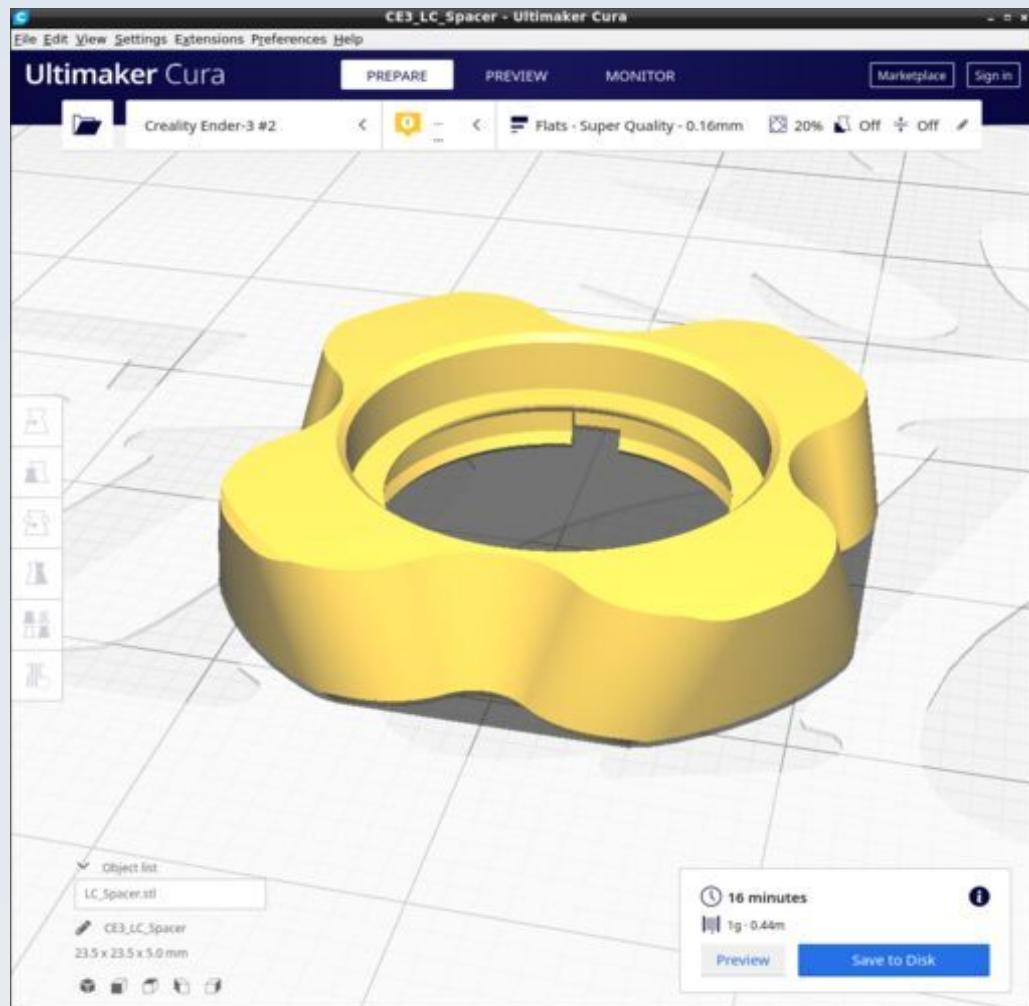
## DI\_LC\_Collar\_7.stl



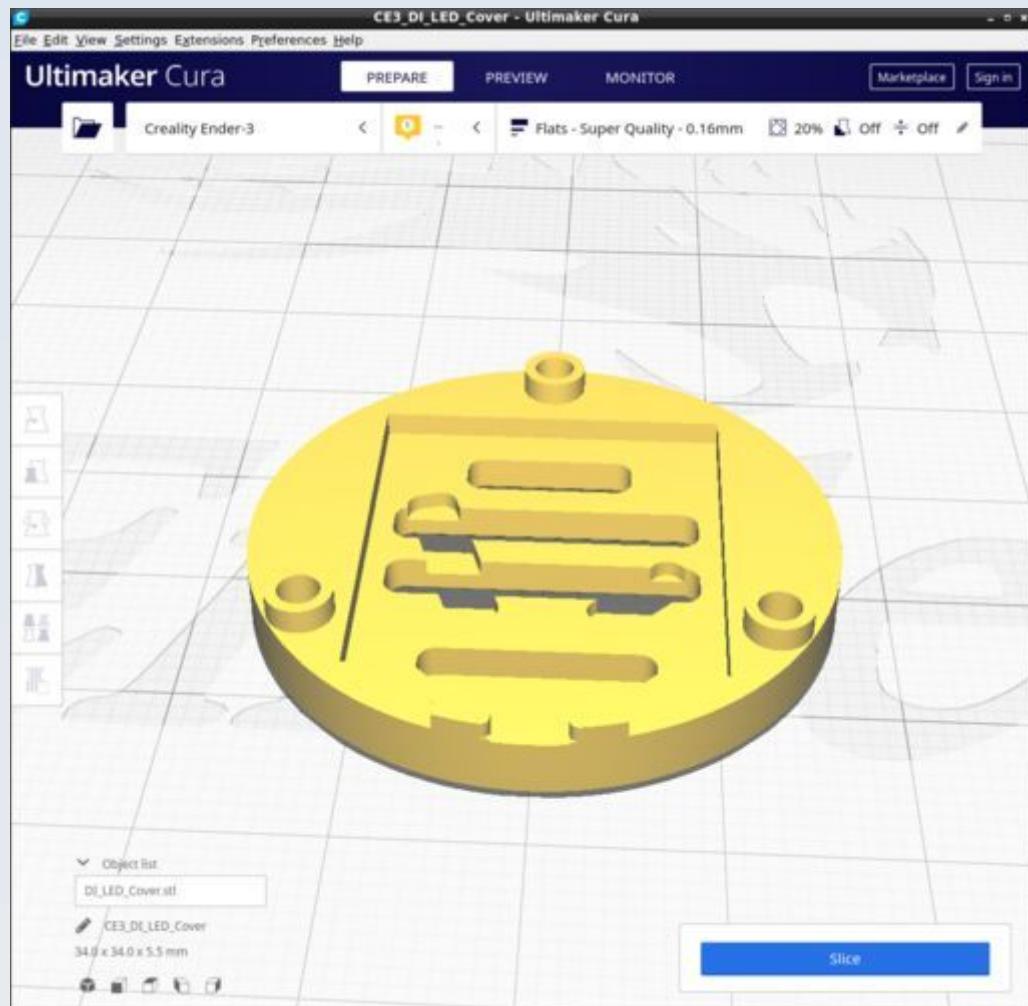
## DI\_LC\_Receptacle.stl



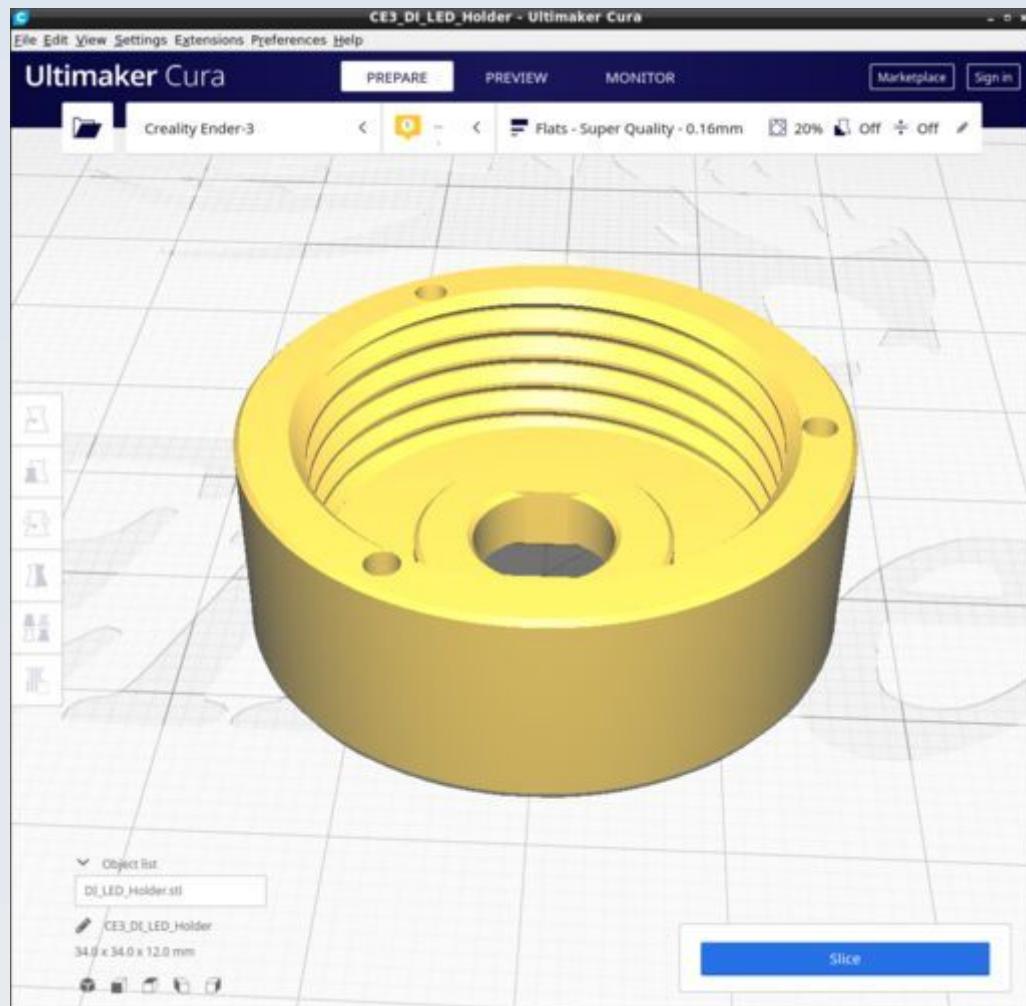
## DI\_LC\_Spacer.stl



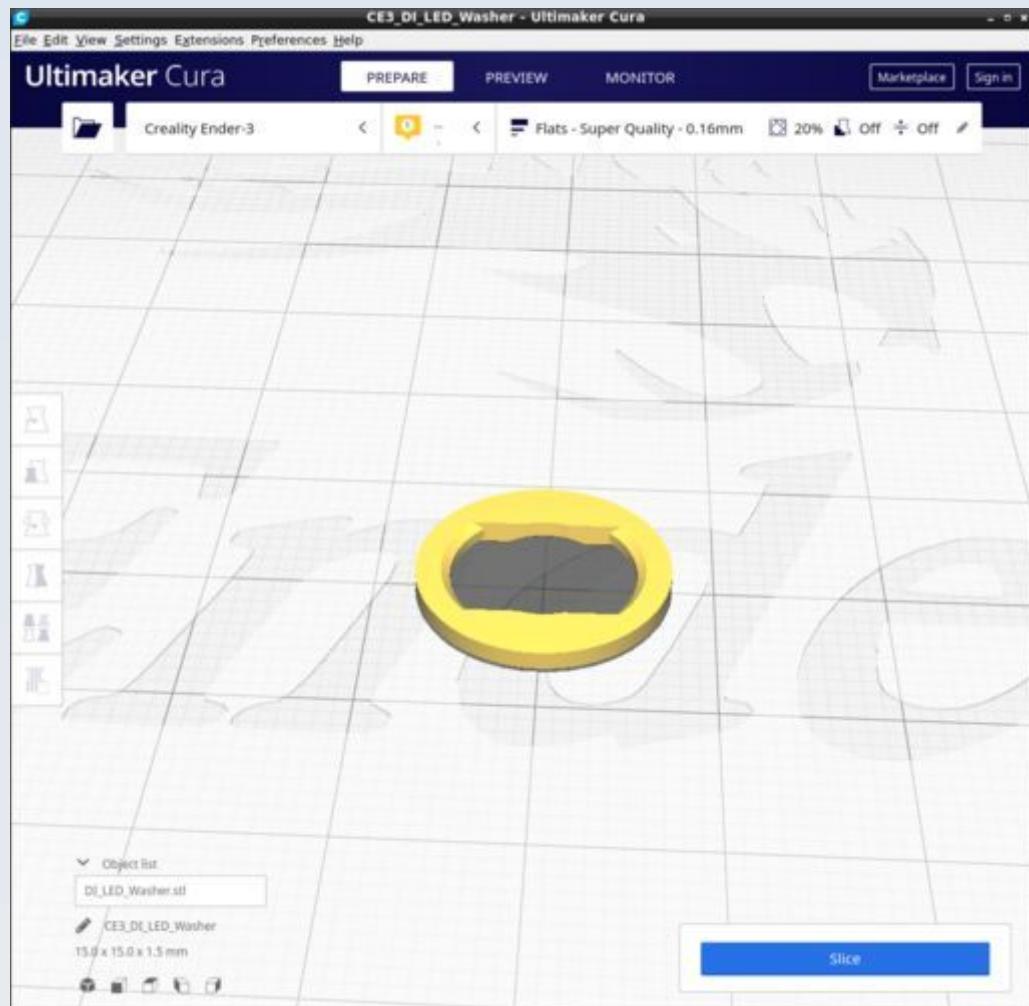
## DI\_LED\_Cover.stl



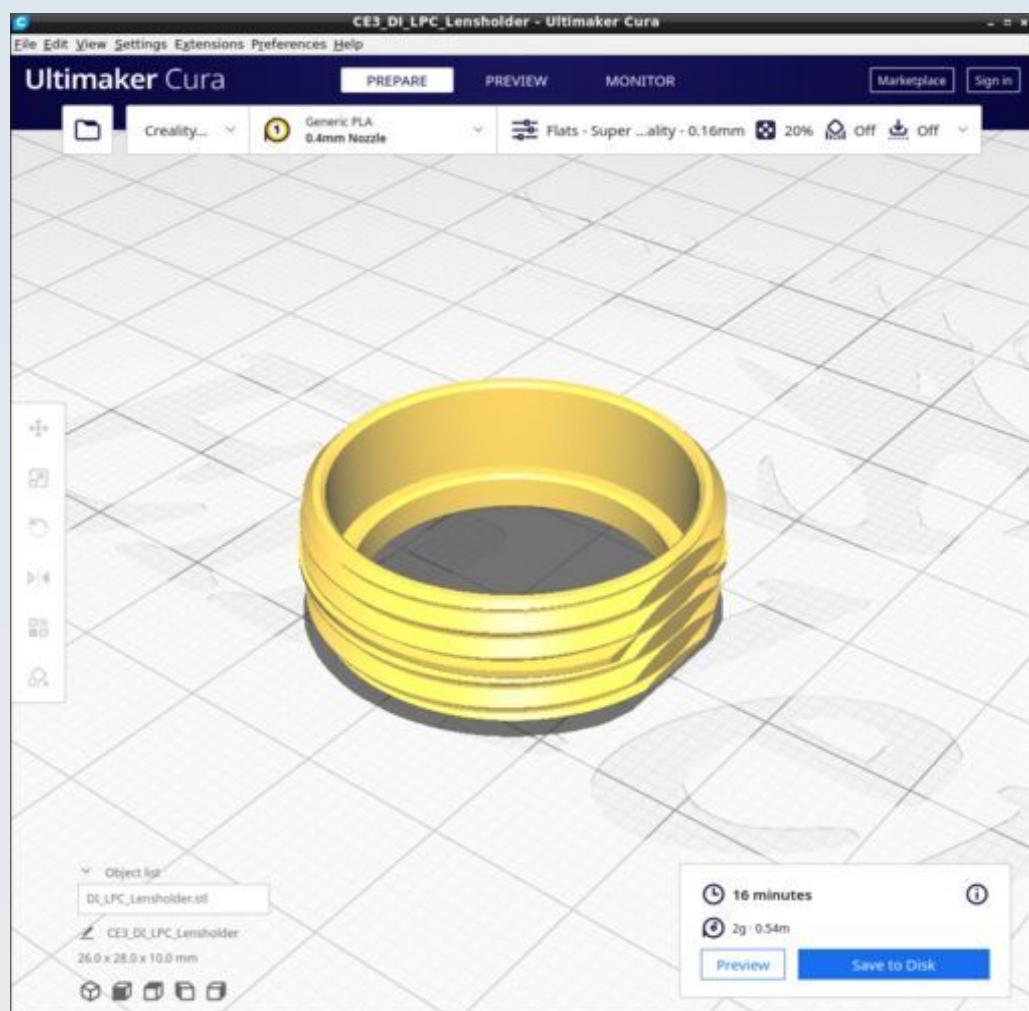
## DI\_LED\_Holder.stl



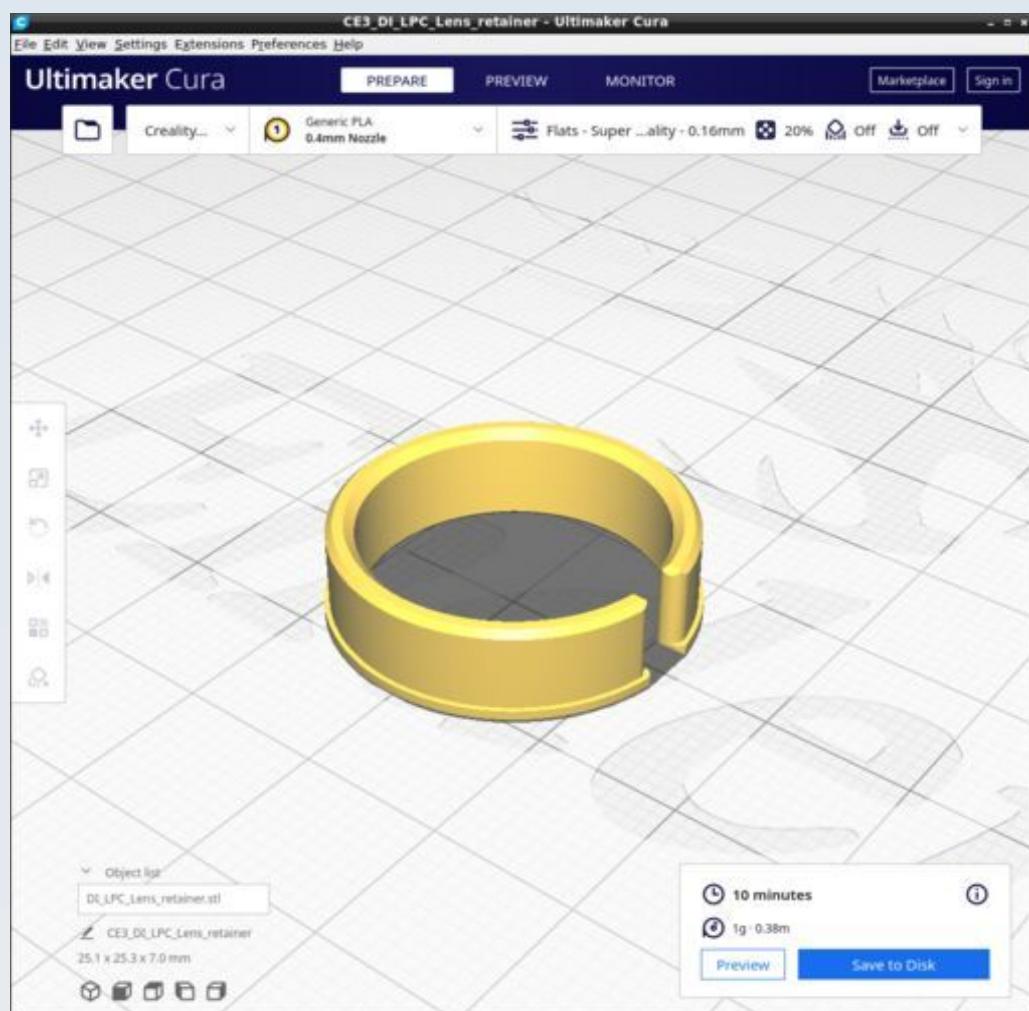
## DI\_LED\_Washer.stl



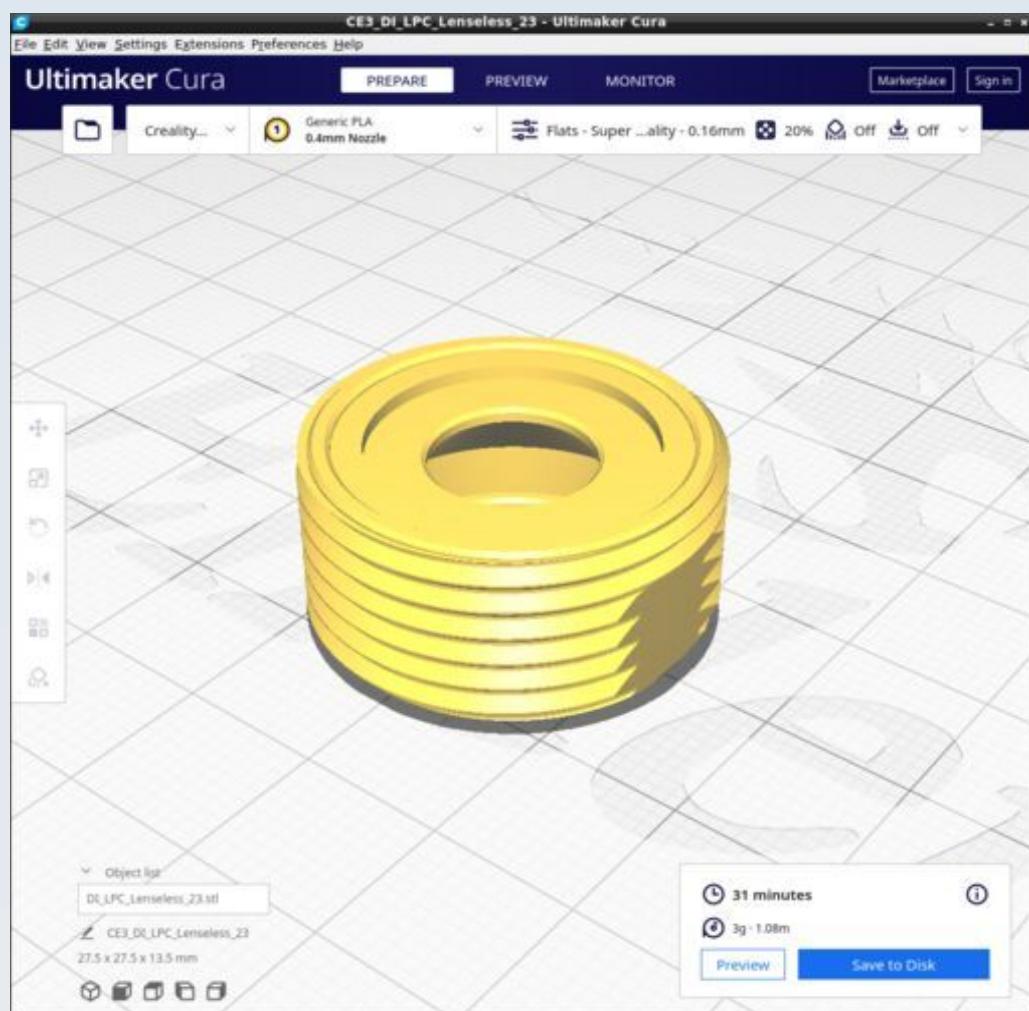
## DI\_LPC\_Lensholder.stl



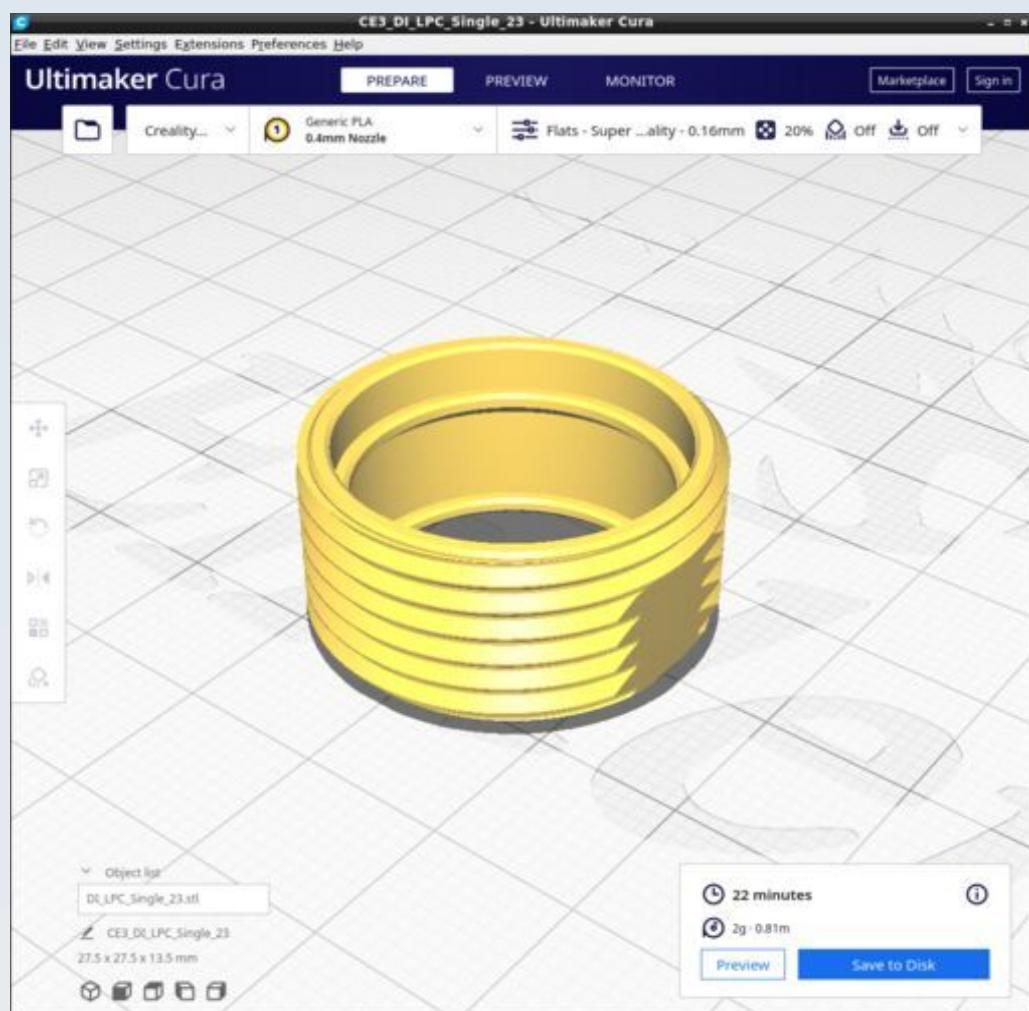
## DI\_LPC\_Lens\_retainer.stl



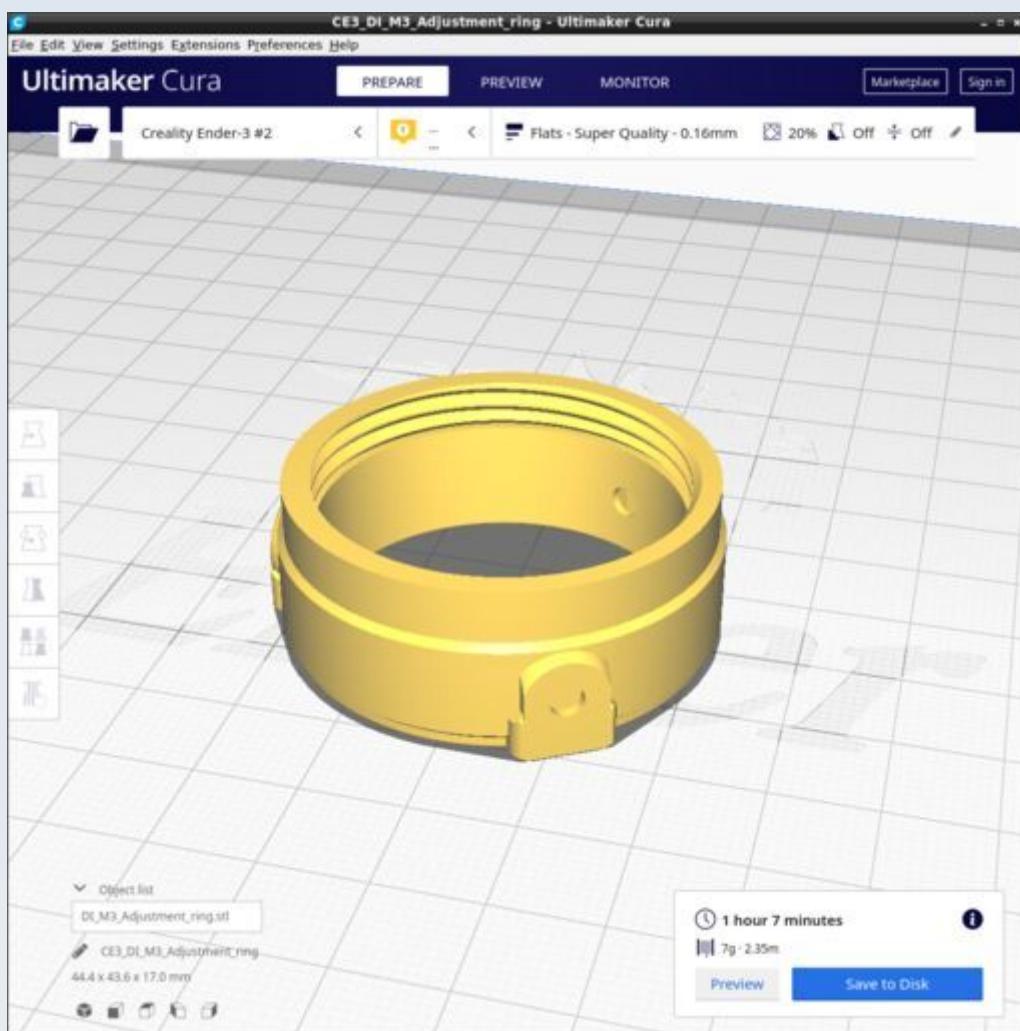
## DI\_LPC\_Lensless\_23.stl



## DI\_LPC\_Single\_23.stl

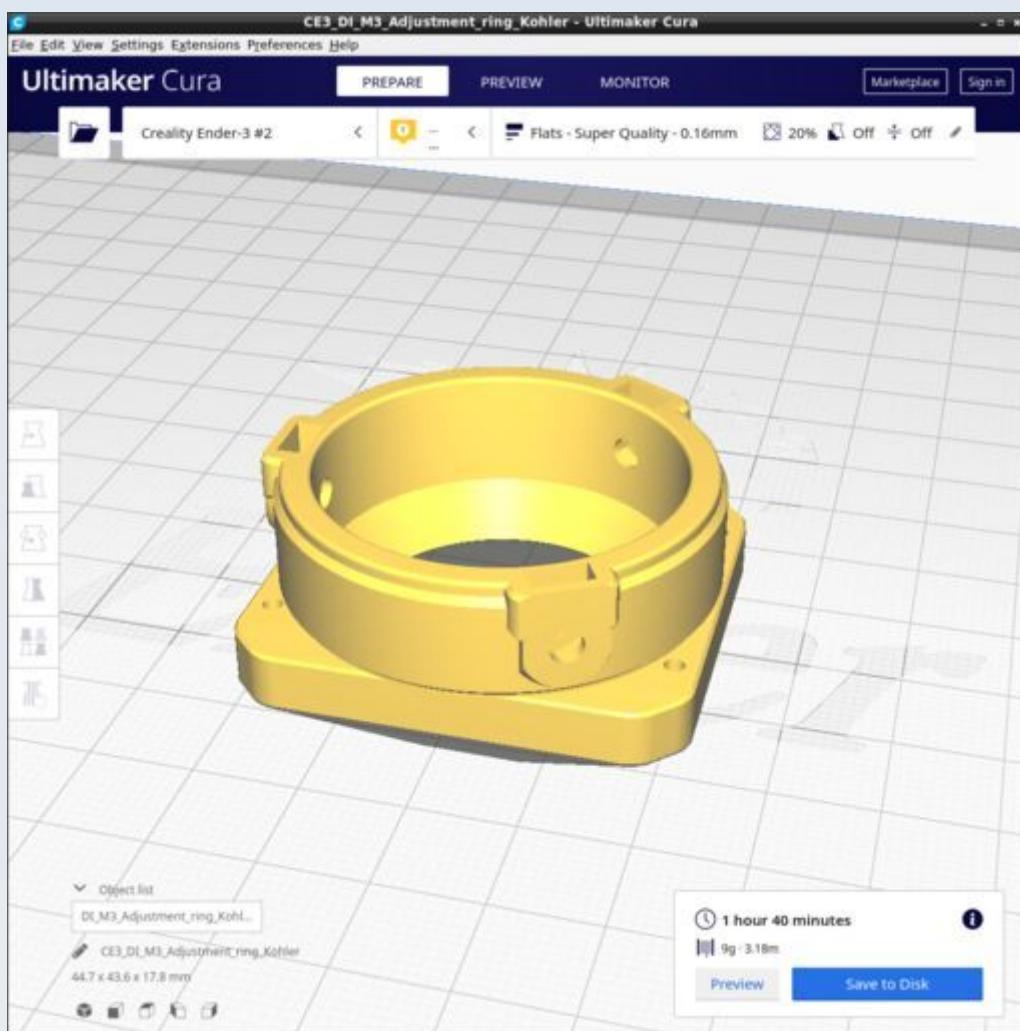


## DI\_M3\_Adjustment\_ring.stl



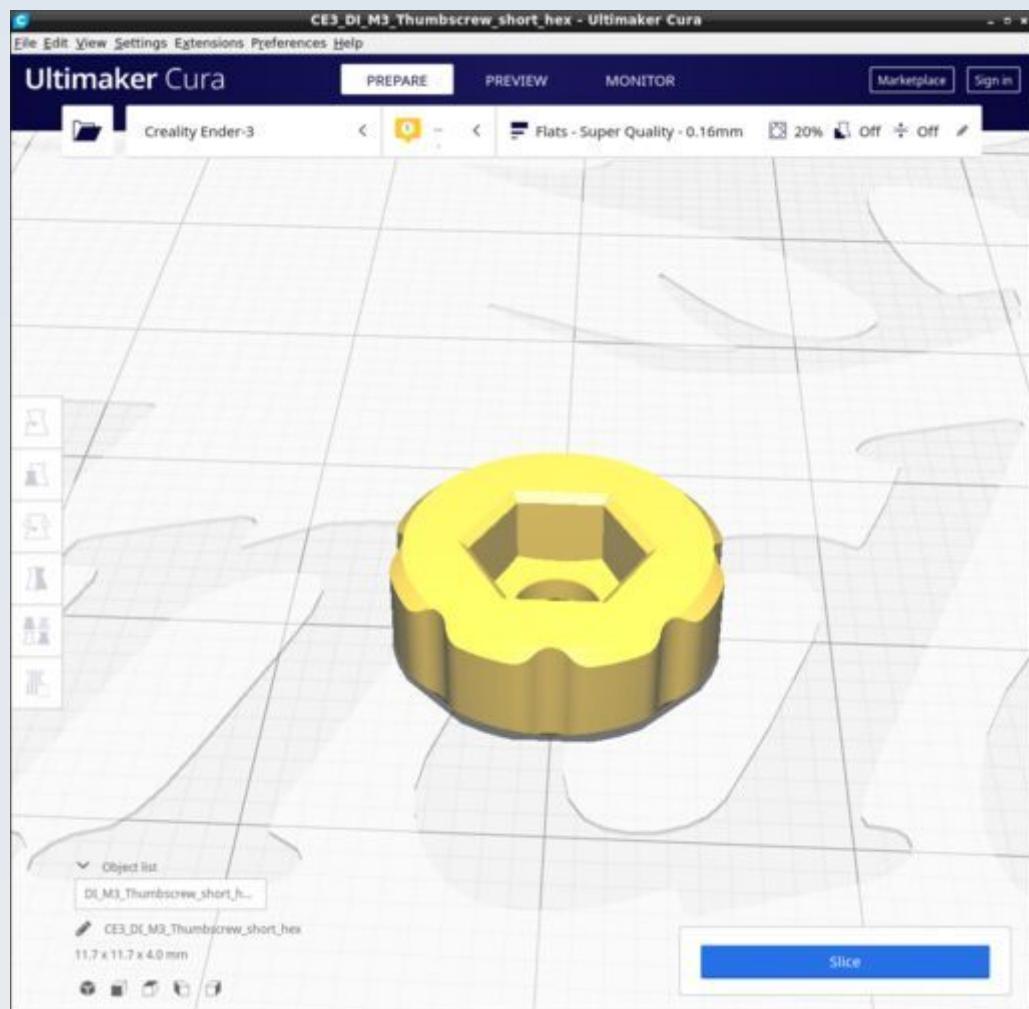
Ensure all supports are OFF

## DI\_M3\_Adjustment\_ring\_Kohler.stl

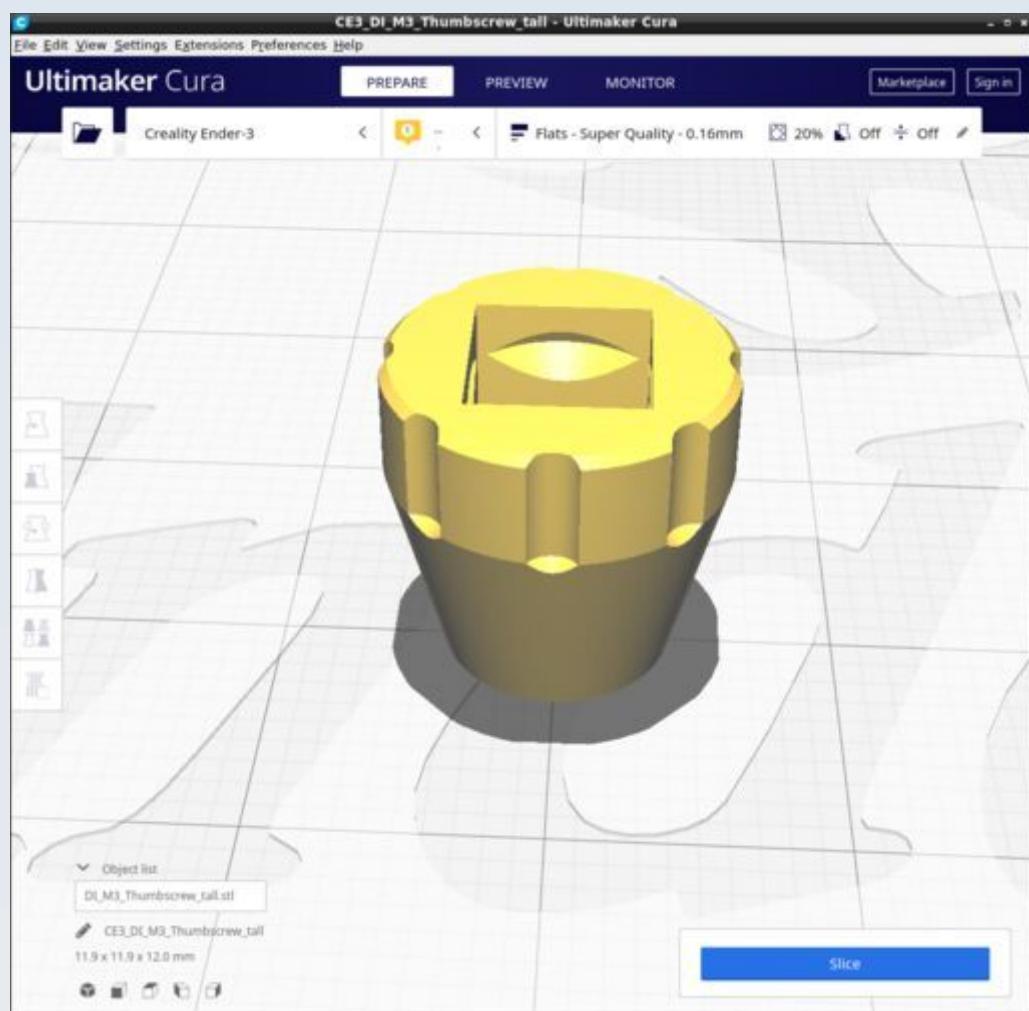


Ensure all supports are OFF

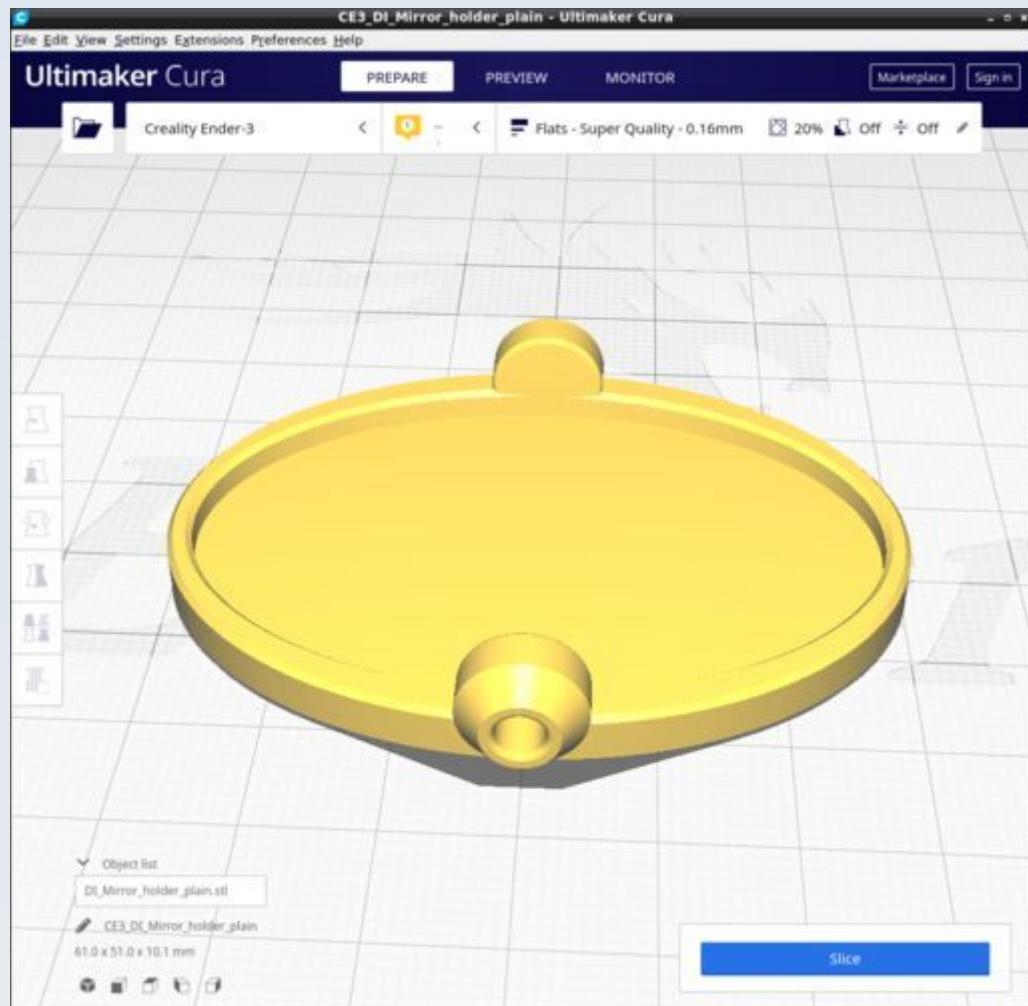
## DI\_M3\_Thumbscrew\_short\_hex.stl



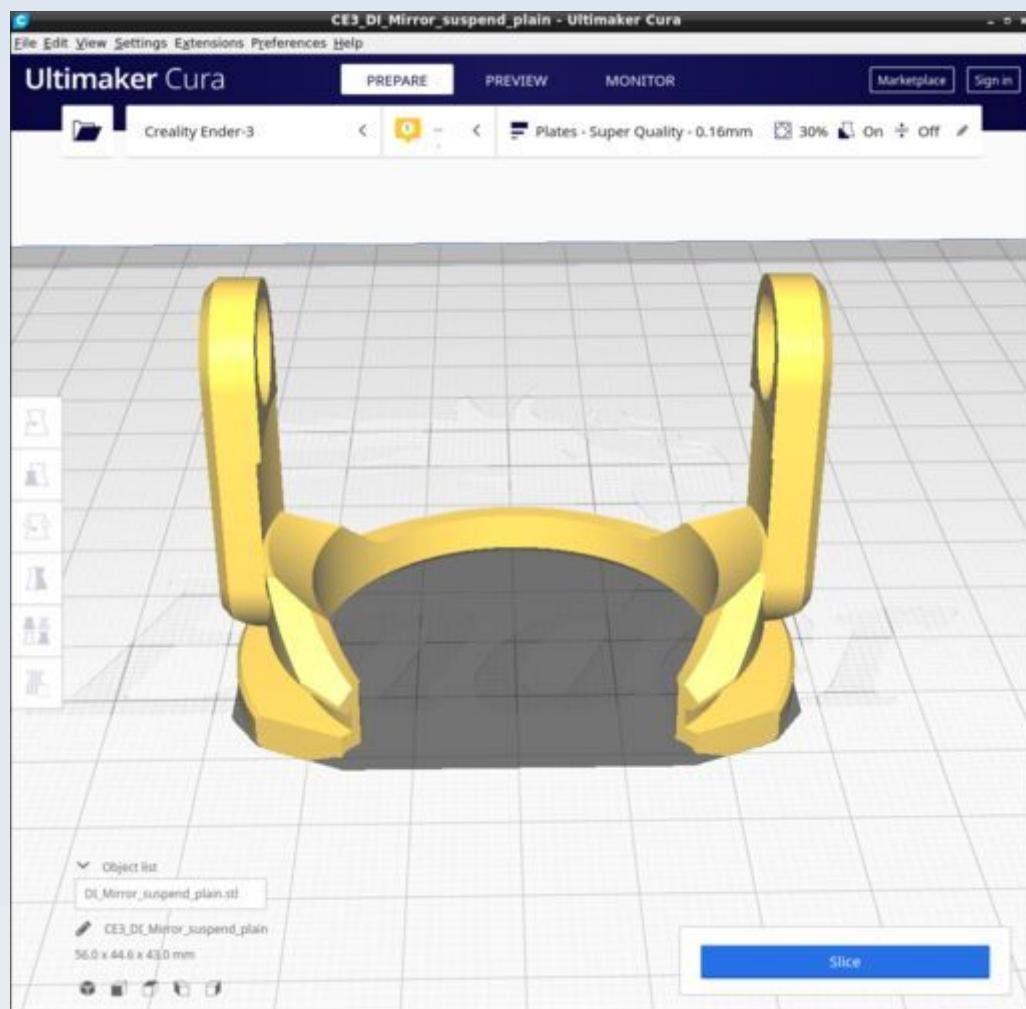
## DI\_M3\_Thumbscrew\_tall.stl



## DI\_Mirror\_holder\_plain.stl

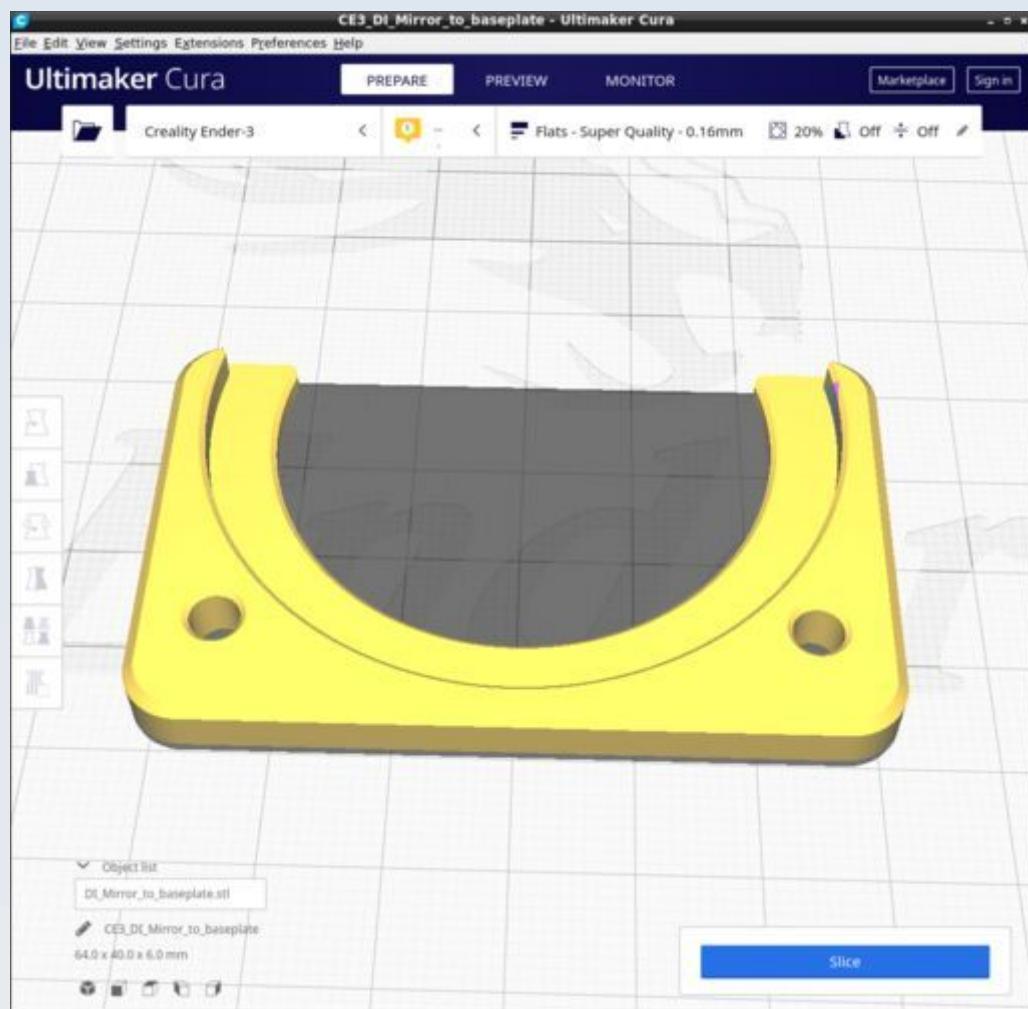


## DI\_Mirror\_suspend\_plain.stl

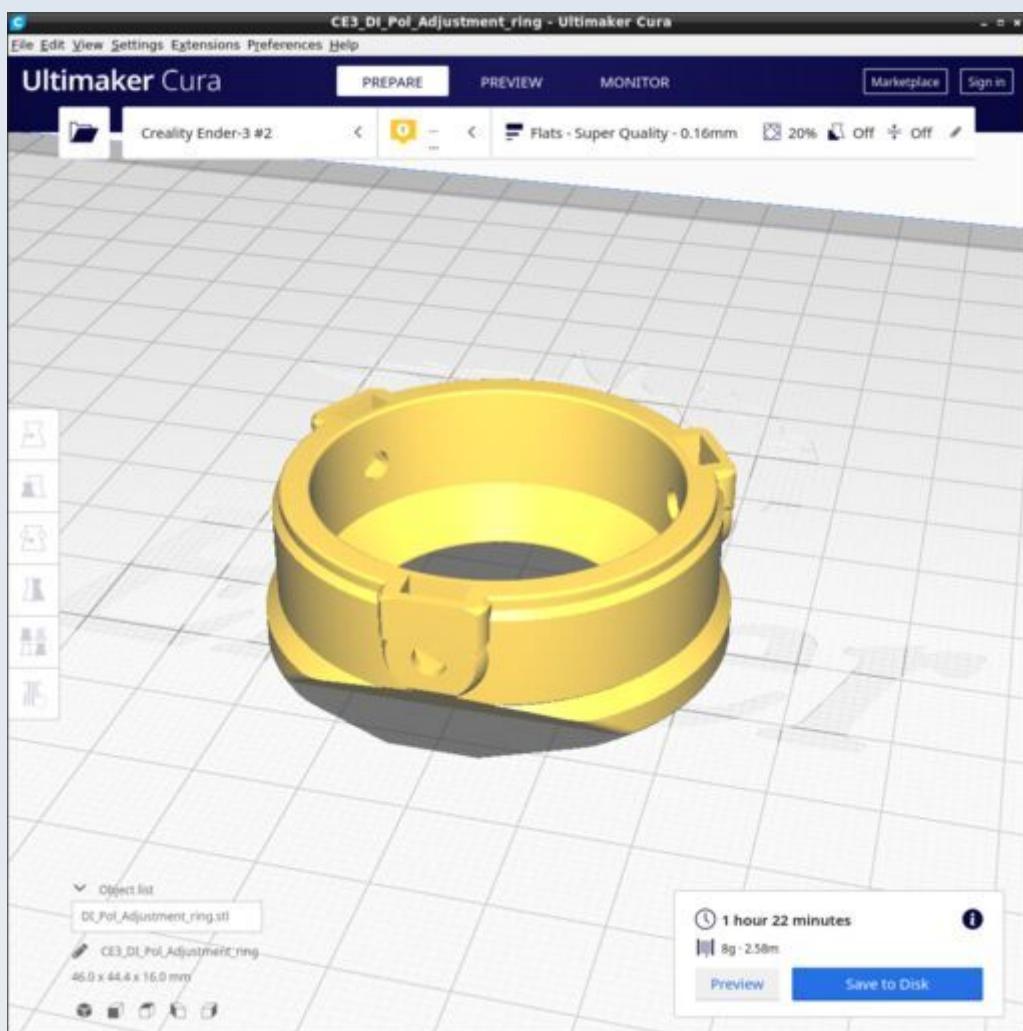


Use the 'Plates' custom Cura profile and enable supports 'touching baseplate only'.

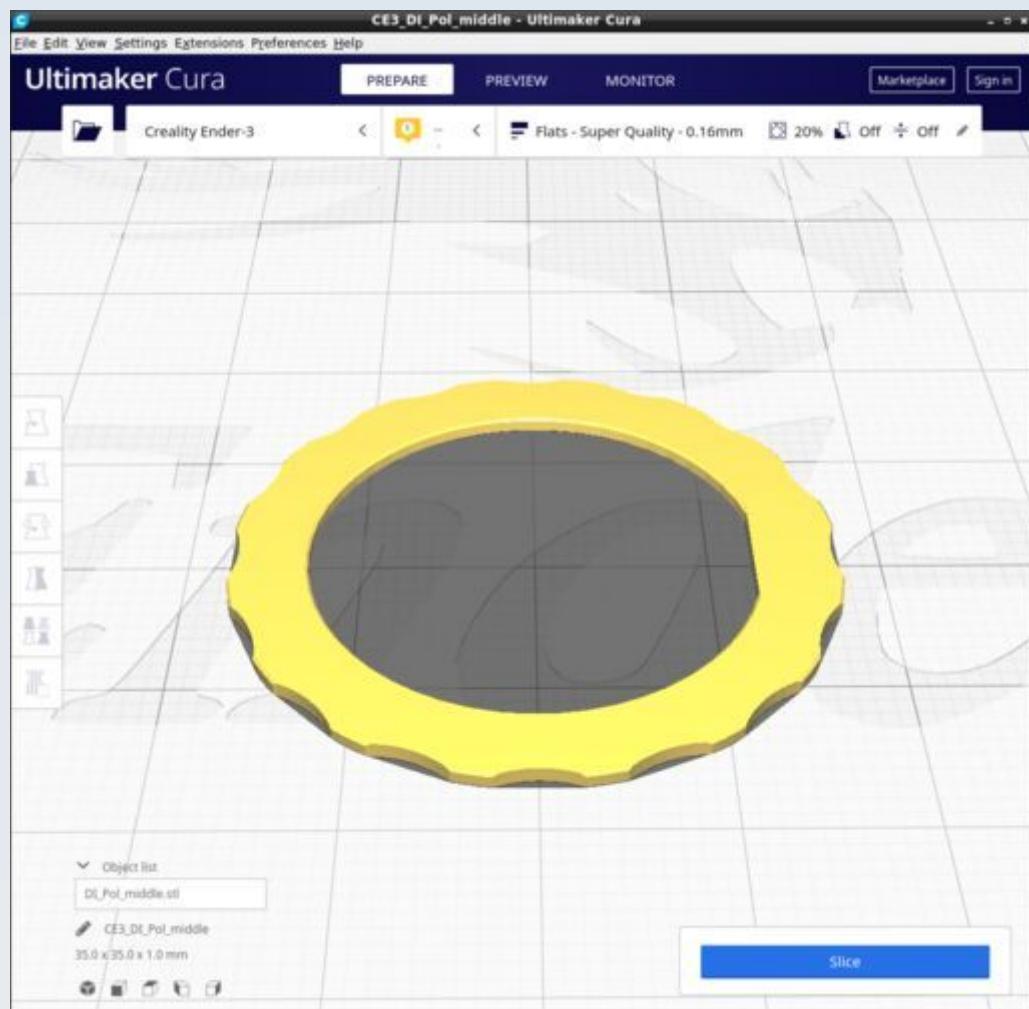
## DI\_Mirror\_to\_baseplate.stl



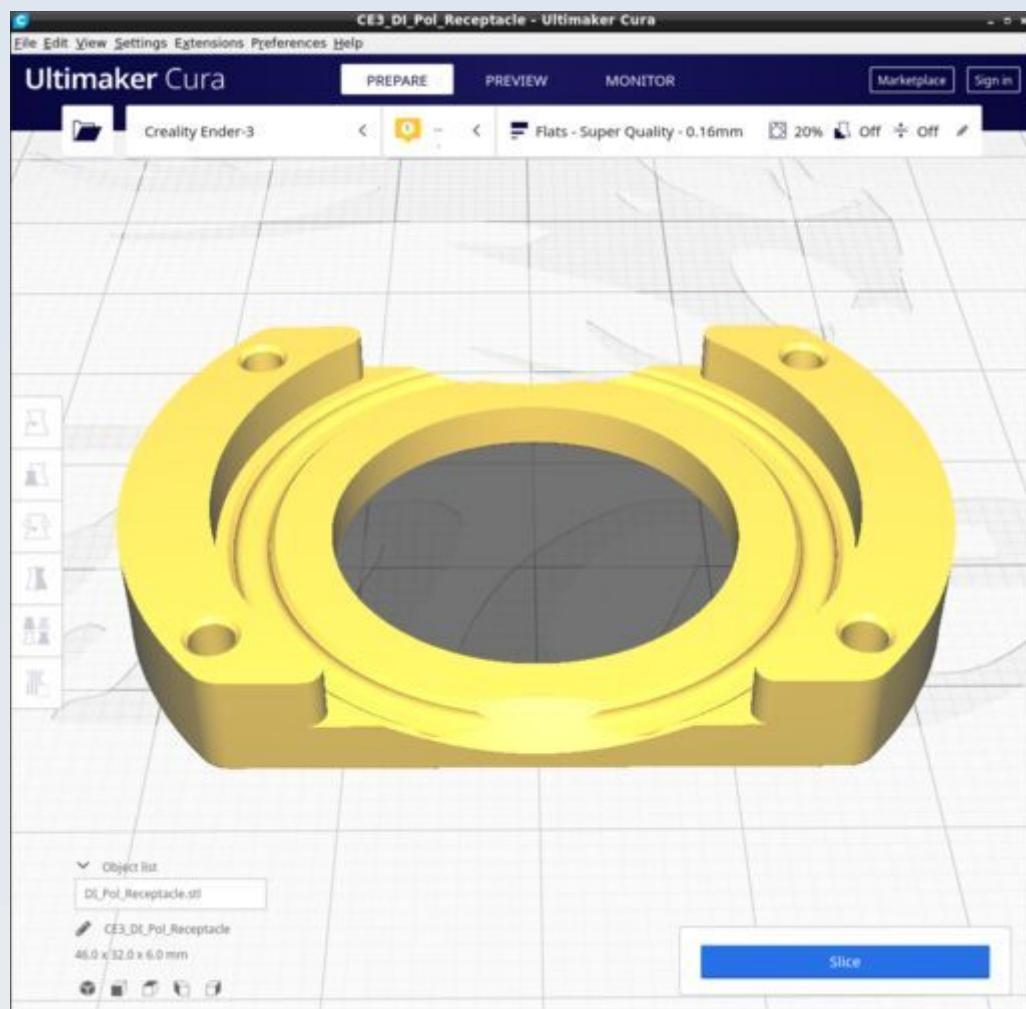
## DI\_Pol\_Adjustment\_ring.stl



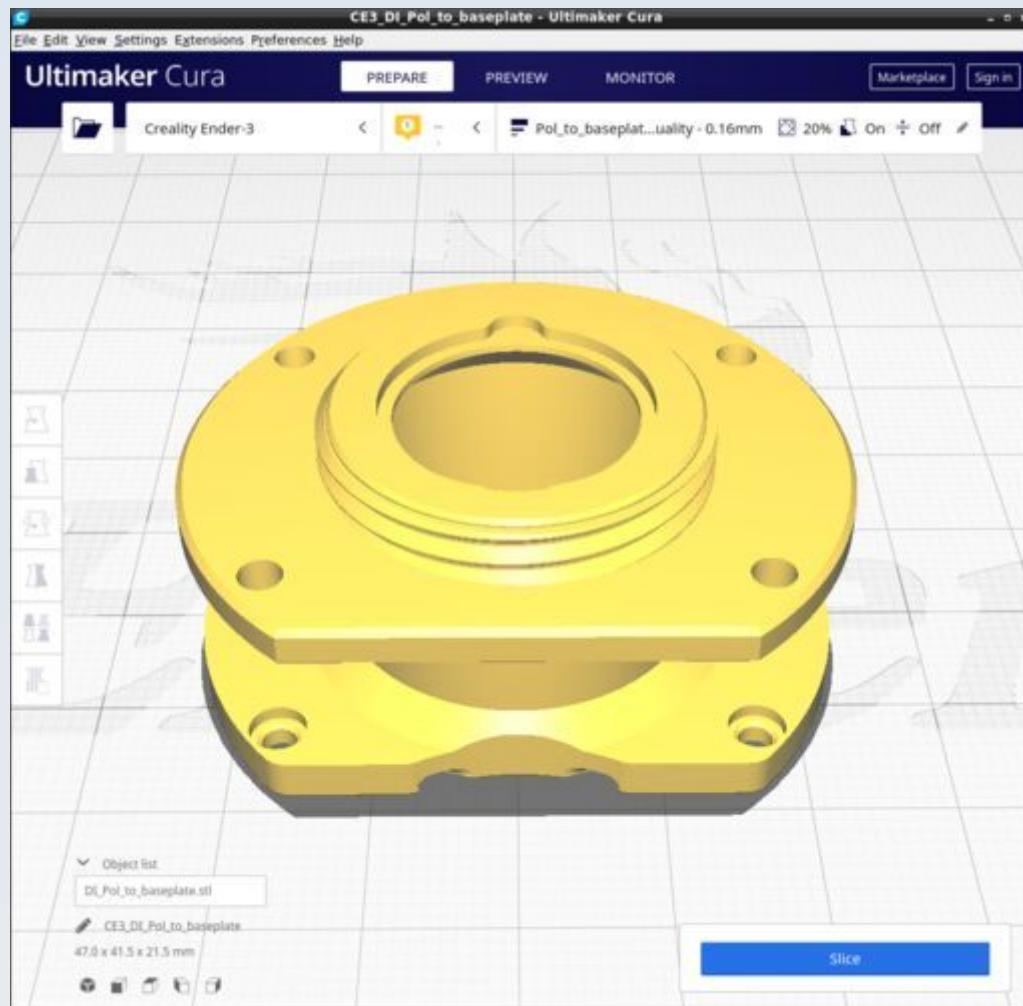
## DL\_Pol\_middle.stl



## DI\_Pol\_Receptacle.stl

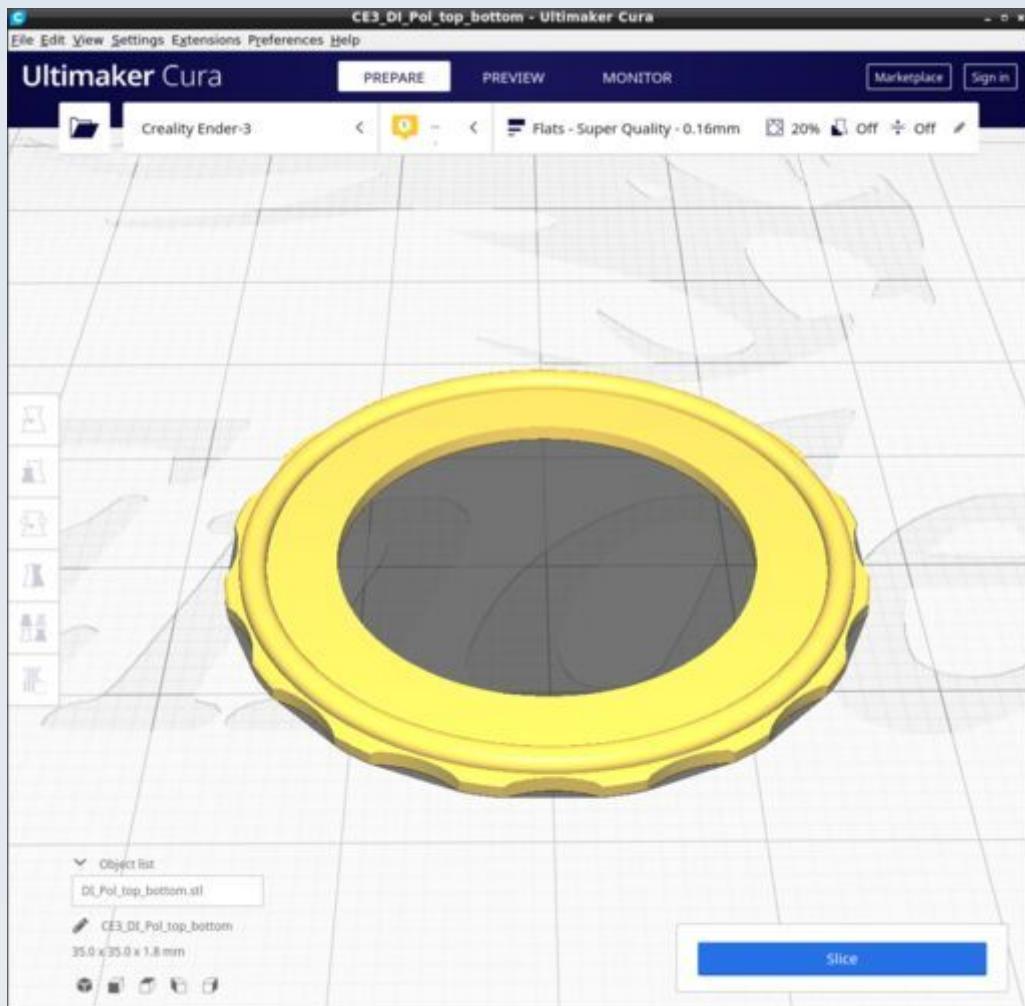


## DI\_Pol\_to\_baseplate.stl

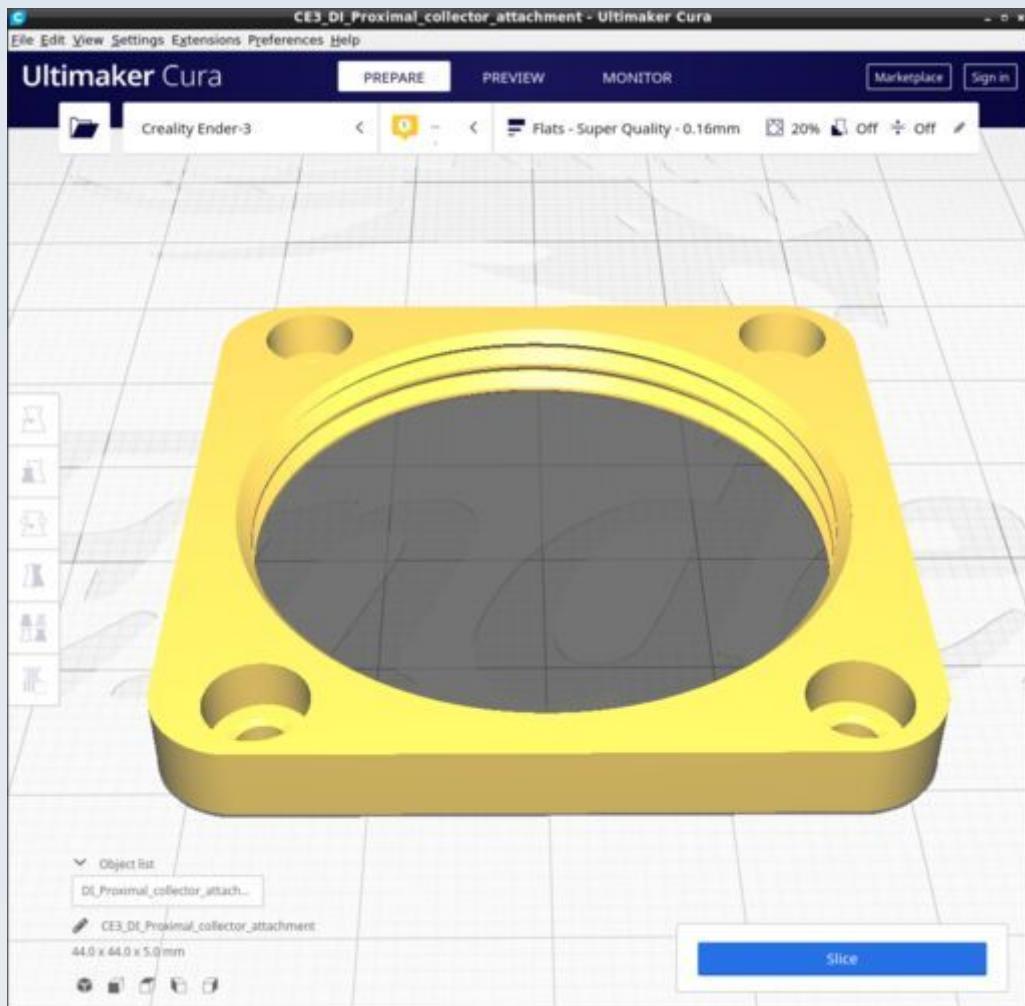


Pol\_to\_baseplate has its own Cura profile with tree supports. This is similar to the 'Condenser' profile but uses an infill density of 20% (not 30%) and has a greater tree angle to avoid making supports on the base of the model.

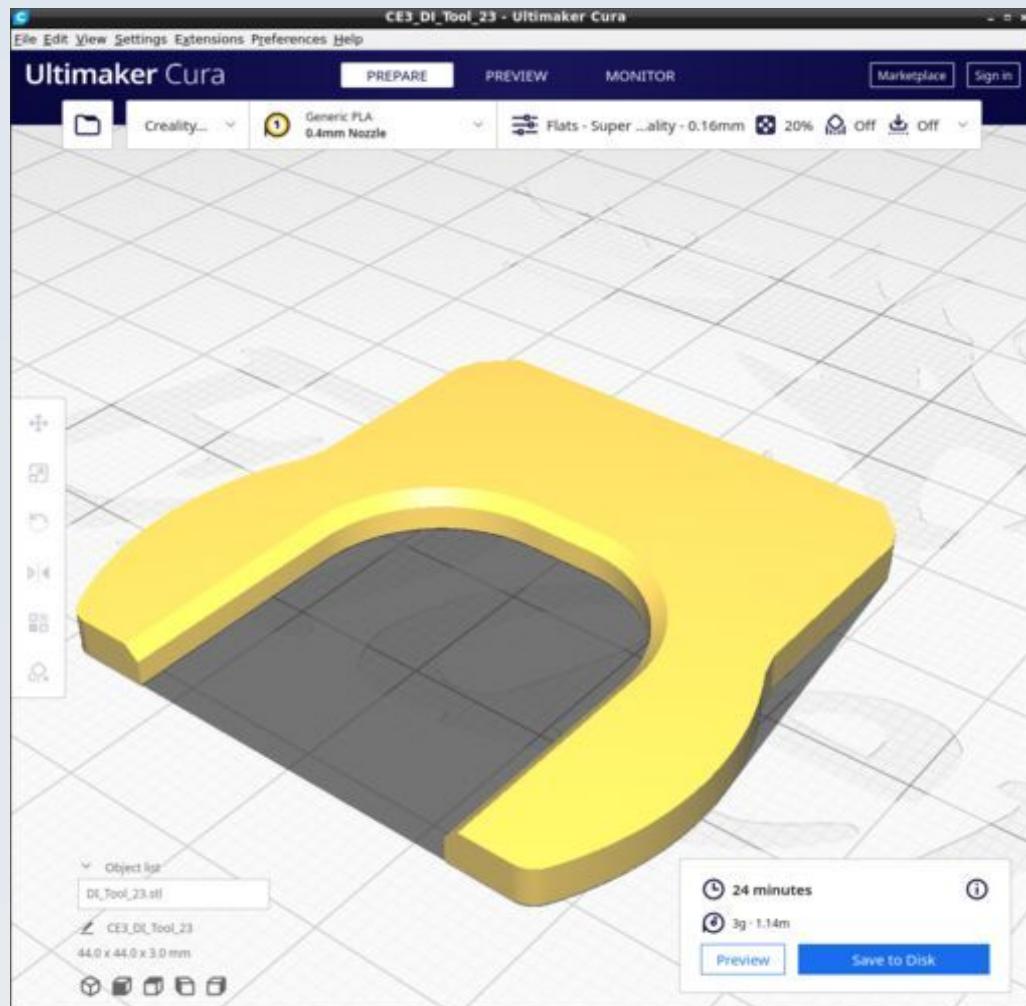
## DI\_Pol\_top\_bottom.stl



## DI\_Proximal\_collector\_attachment.stl

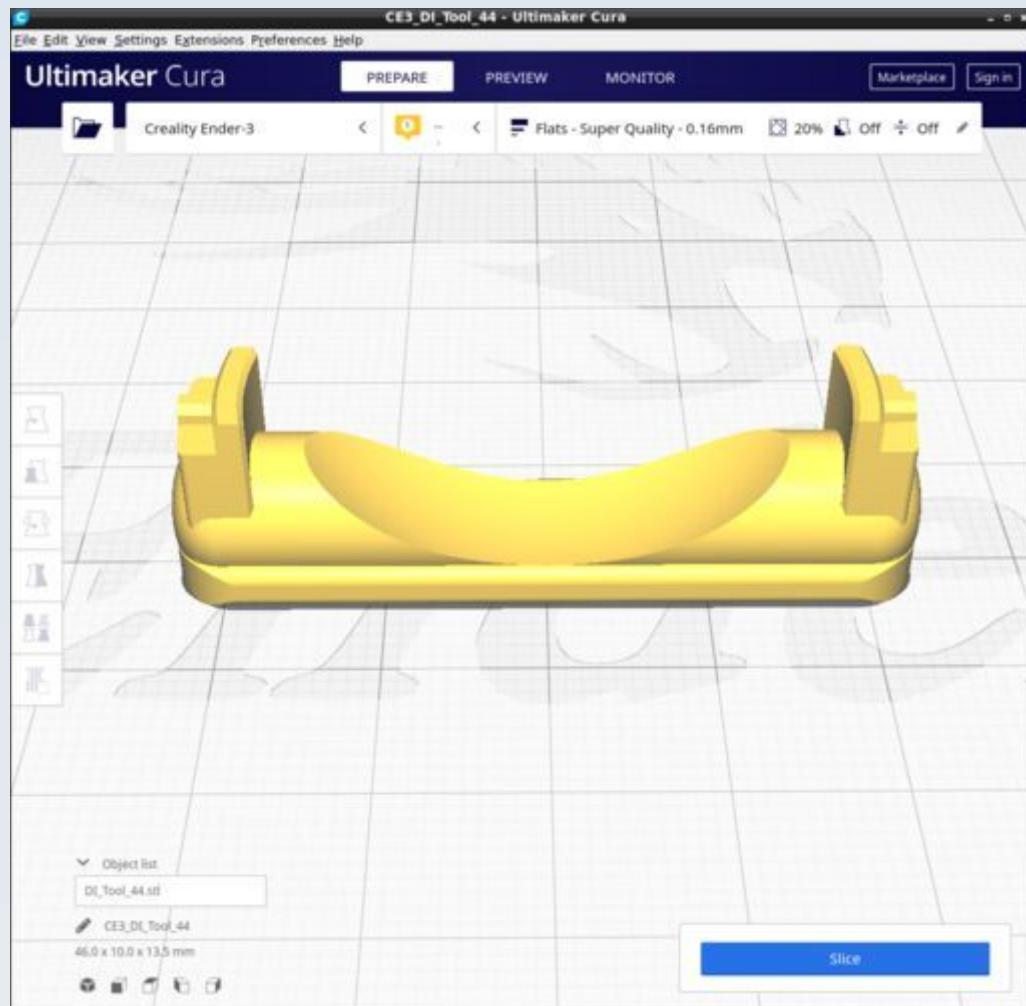


## DI\_Tool\_23.stl

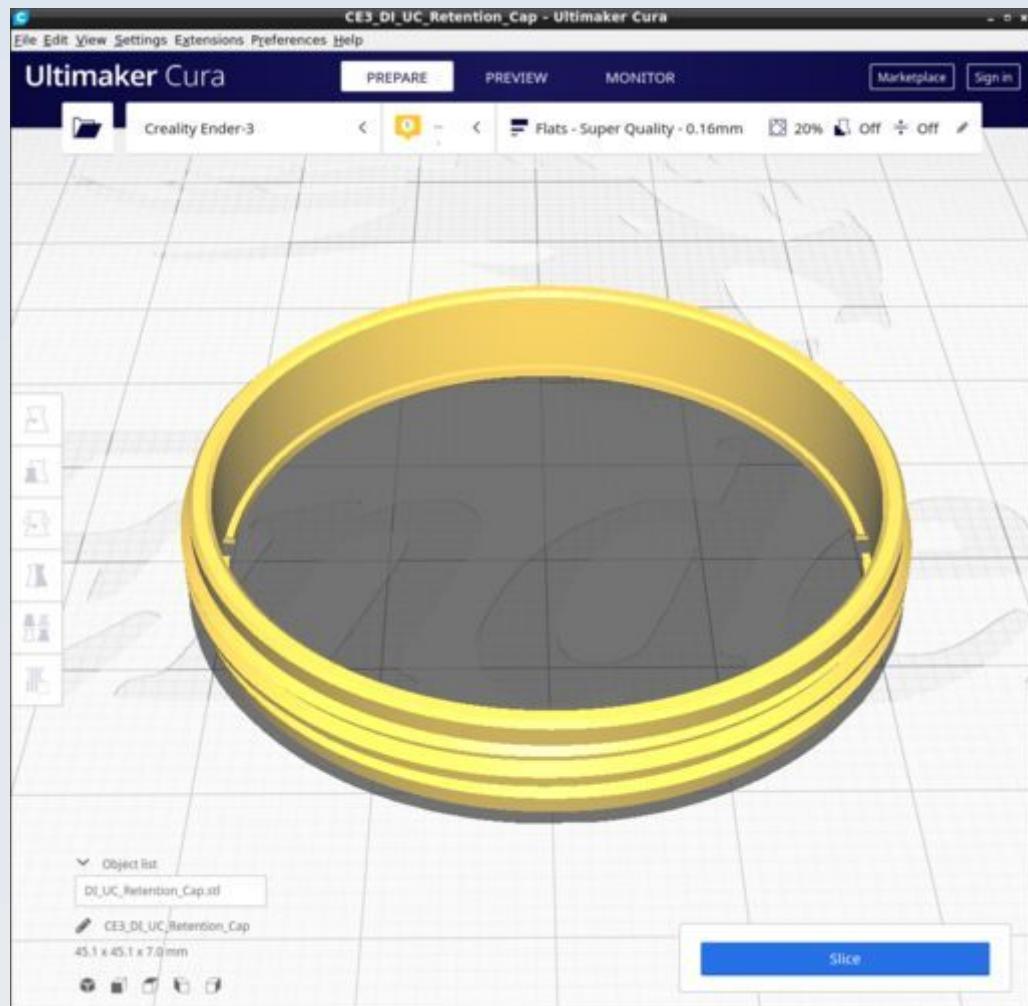


Although shown here with profile 'flats' you may want to print this with a higher density infill for added strength.

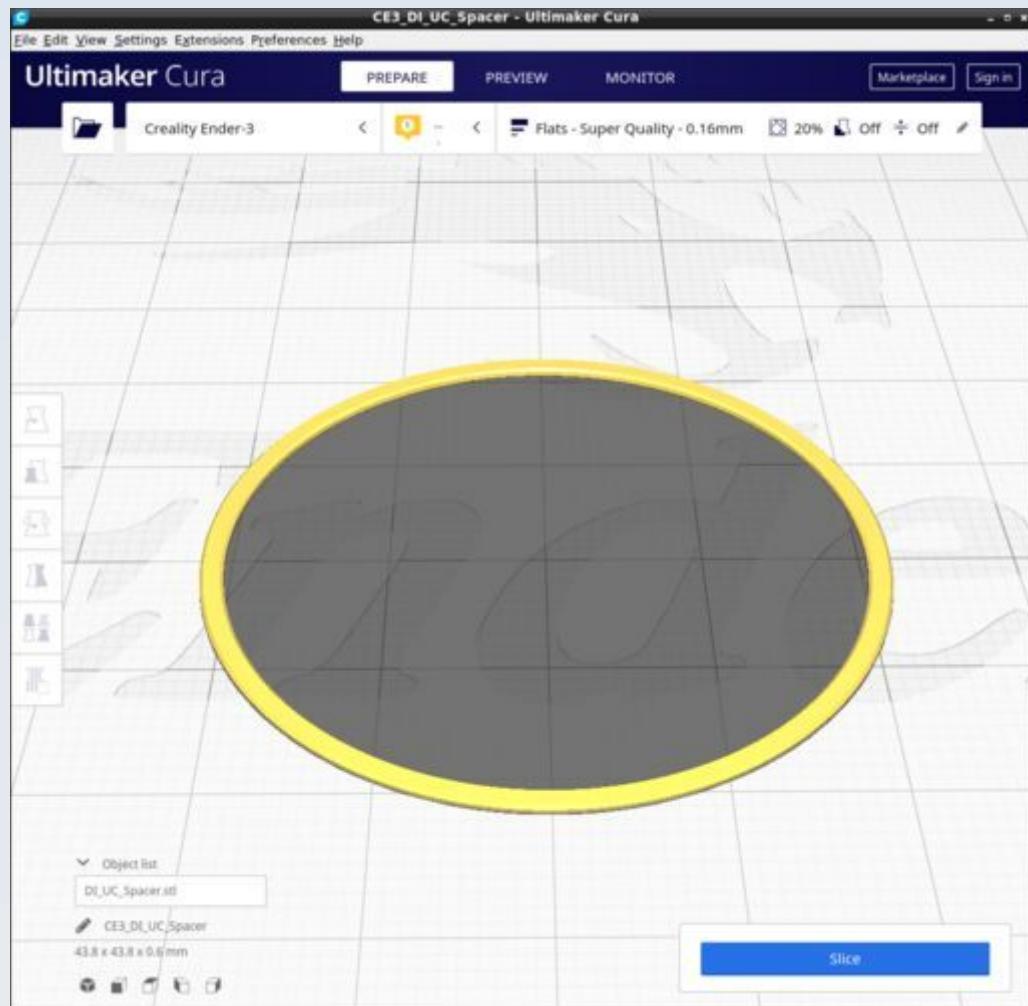
## DI\_Tool\_44.stl



## DI\_UC\_Retention\_Cap.stl



## DI\_UC\_Spacer.stl



# Filterblock

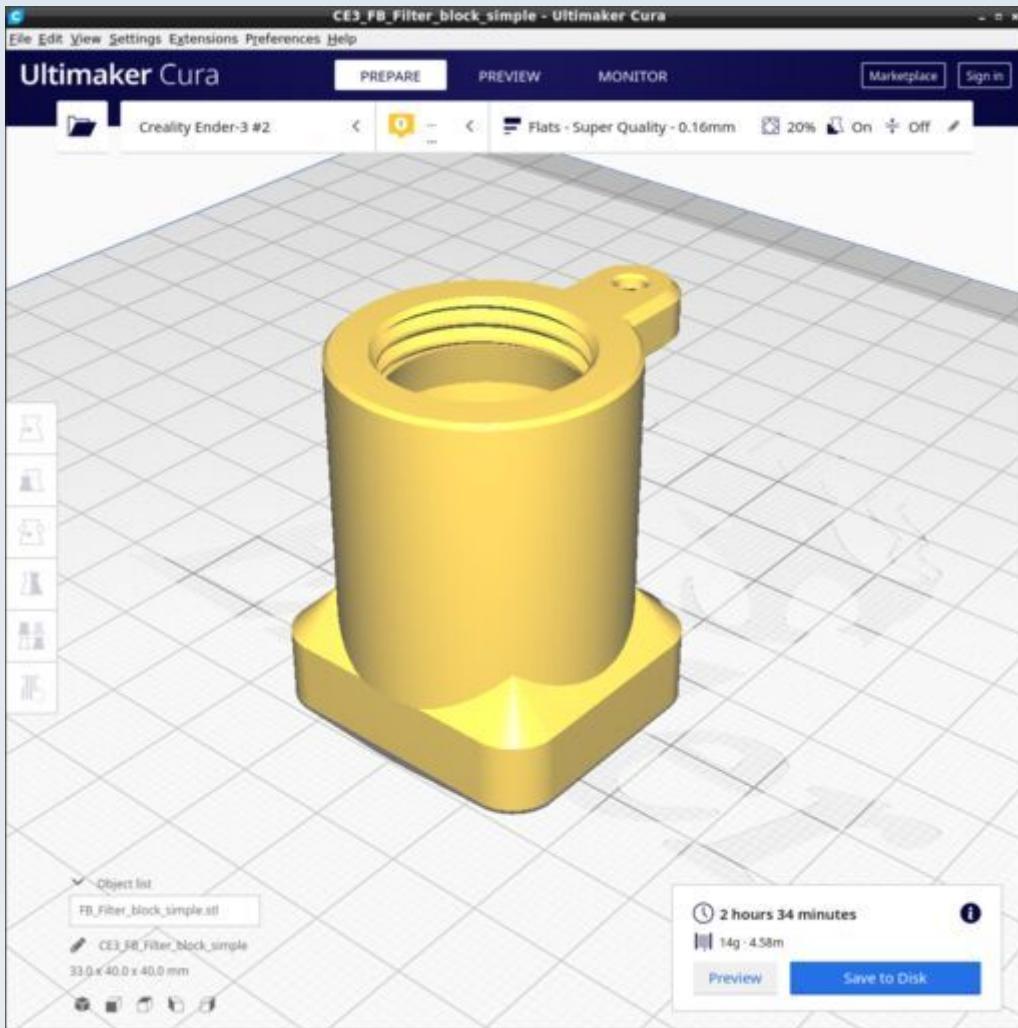
This shows the parts for the filter block segment of the optical tube, the part that goes between the objective holder and the ocular head. The models for these files are found in the FreeCAD file called FilterBlock.FCStd.

## Resources

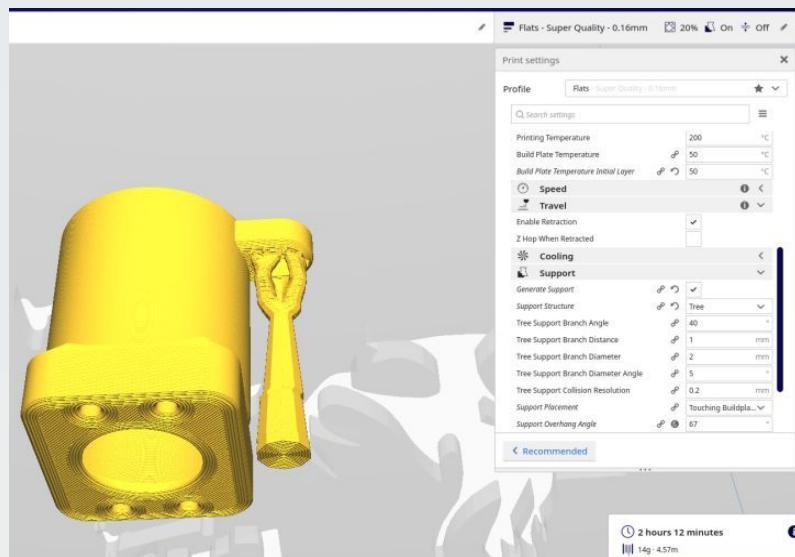
Cura calculates the following resources are required to print each model in this chapter:

Filterblock	Time_Hr	Time_Min	PLA_Length(m)
FB_Filter_block_simple.stl	2	34	4.58
FB_Filter_collar_compression_tool.stl	0	6	0.26
FB_Filter_collar.stl	0	1	0.03
FB_Filter_F17_slider.stl	0	21	0.58
FB_Filter_F_slider.stl	0	12	0.47
FB_Filter_slider.stl	0	19	0.56
FB_Filter_slot_bottom.stl	0	19	0.38
FB_Filter_slot_stopper.stl	0	8	0.35
FB_Filter_slot_top.stl	0	14	0.33
FB_Infinity_adapter.stl	0	41	0.95
FB_Side_port_separate.stl	0	35	0.99
FB_Side_port_separate_EpiStop.stl	0	51	1.25
FB_Splitter_case.stl	1	32	2.58
FB_Stopper.stl	0	24	0.73
FB_Top_connector.stl	0	42	1.13

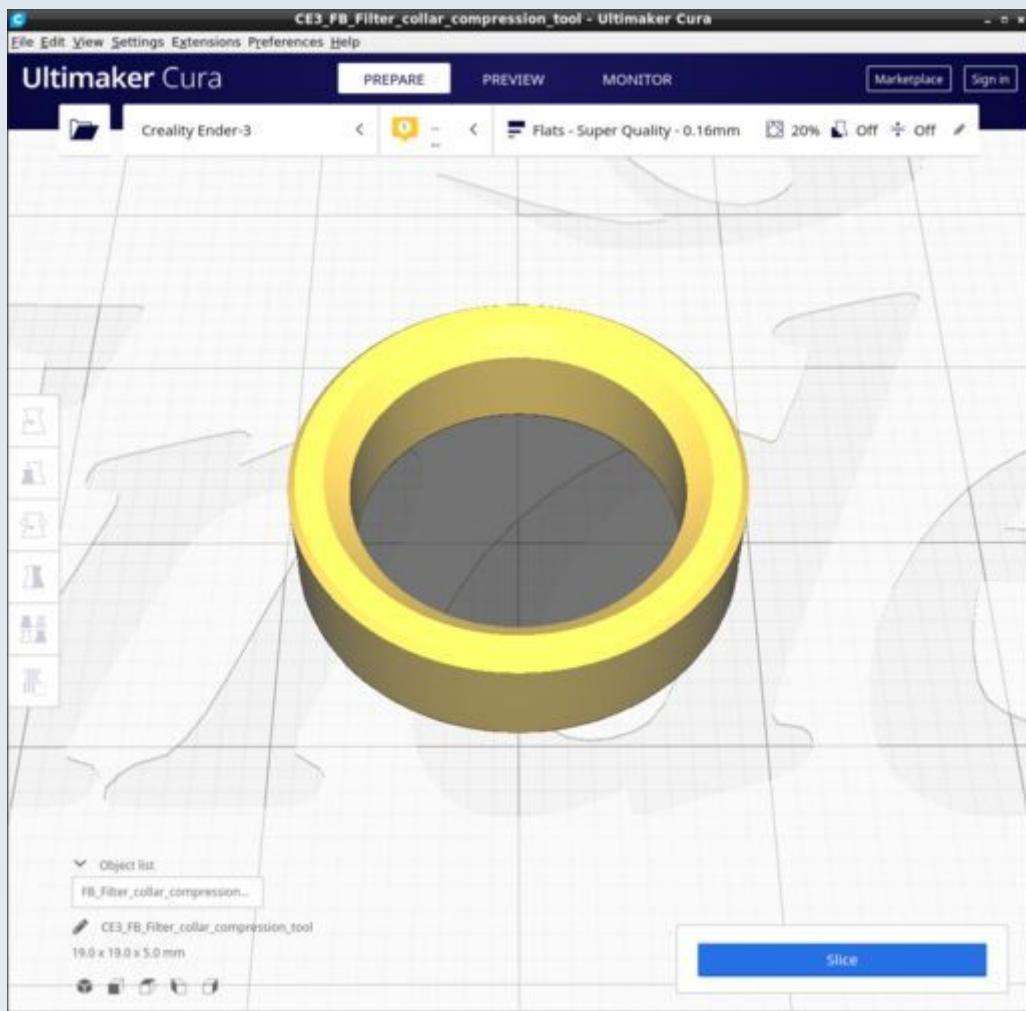
## FB\_Filter\_block\_simple.stl



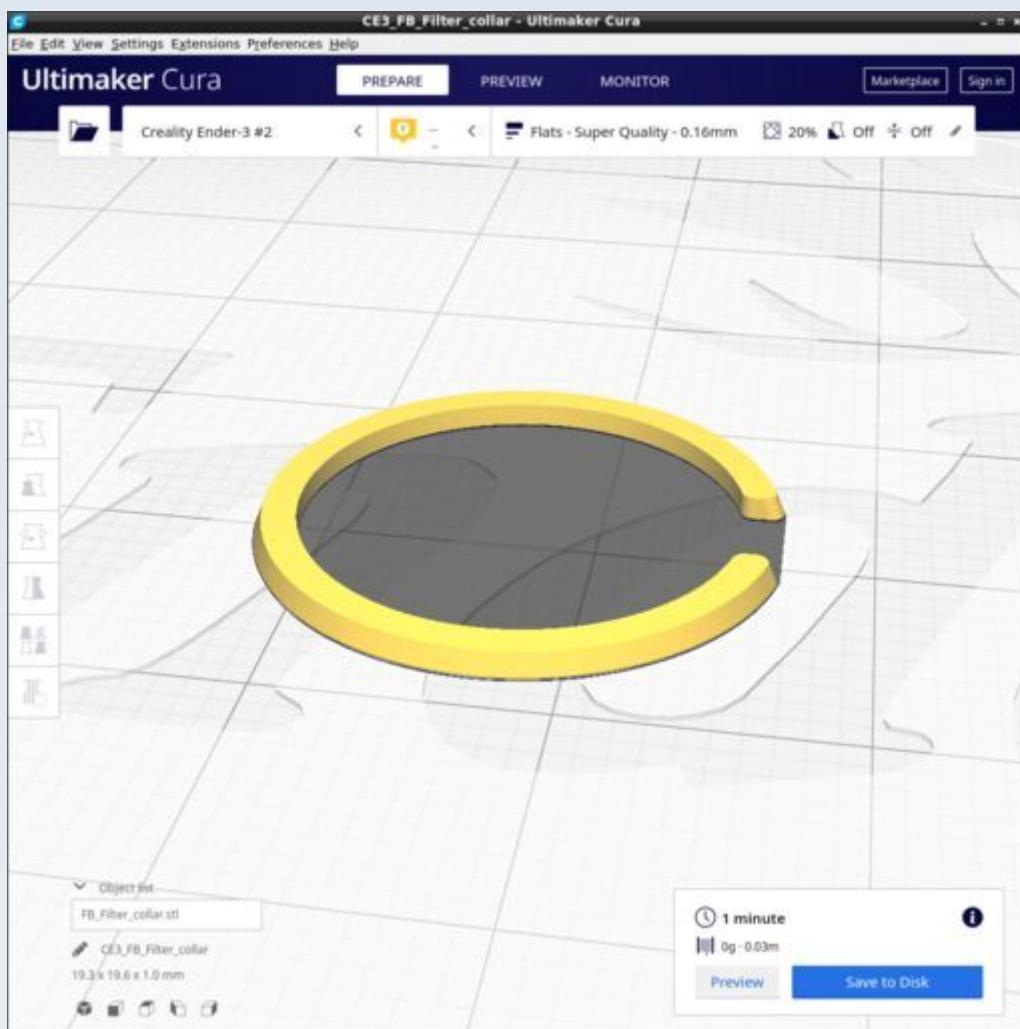
Use tree supports: Branch angle 40. touching baseplate only. Overhang 67 degrees. See picture. The tree gives a solid concentric trunk at the base (better for adhesion). Normal support will result in a hollow square base - less contact area so risk of coming off).



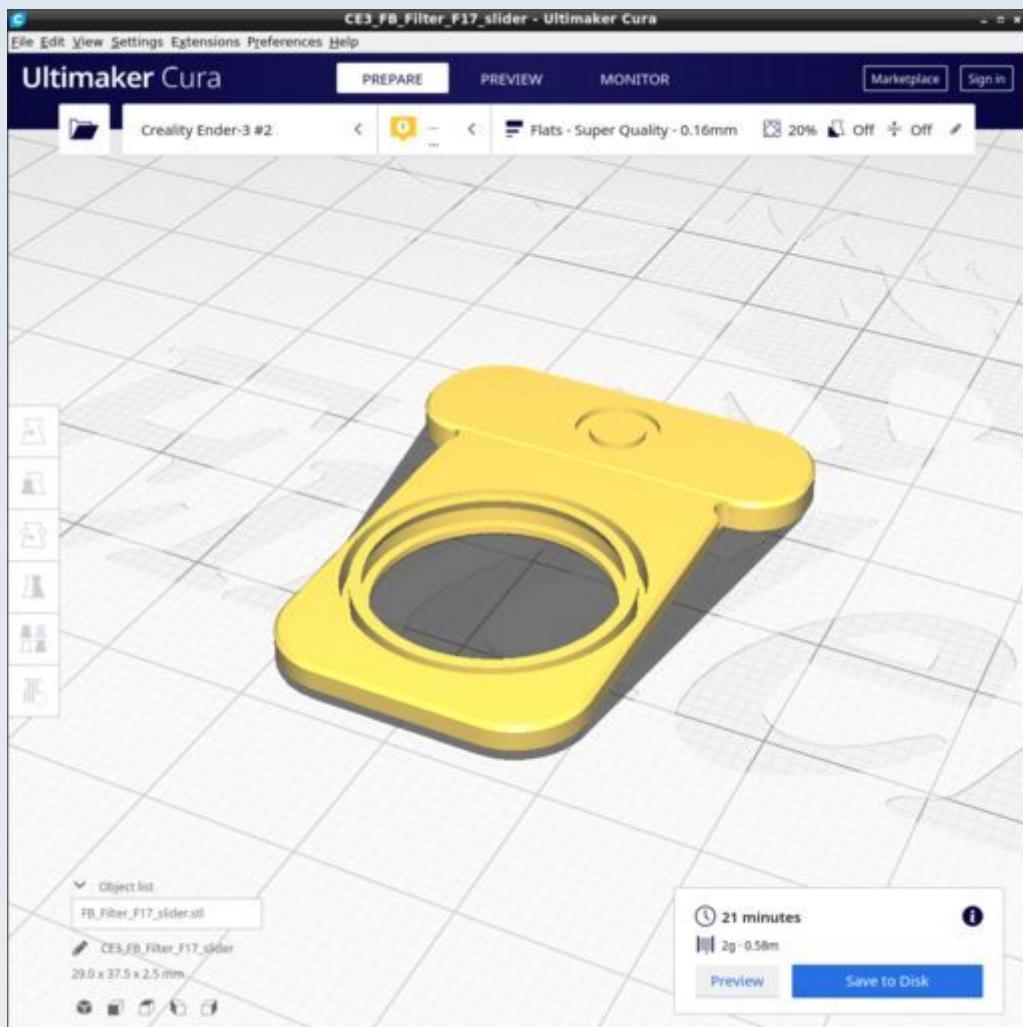
## FB\_Filter\_collar\_compression\_tool.stl



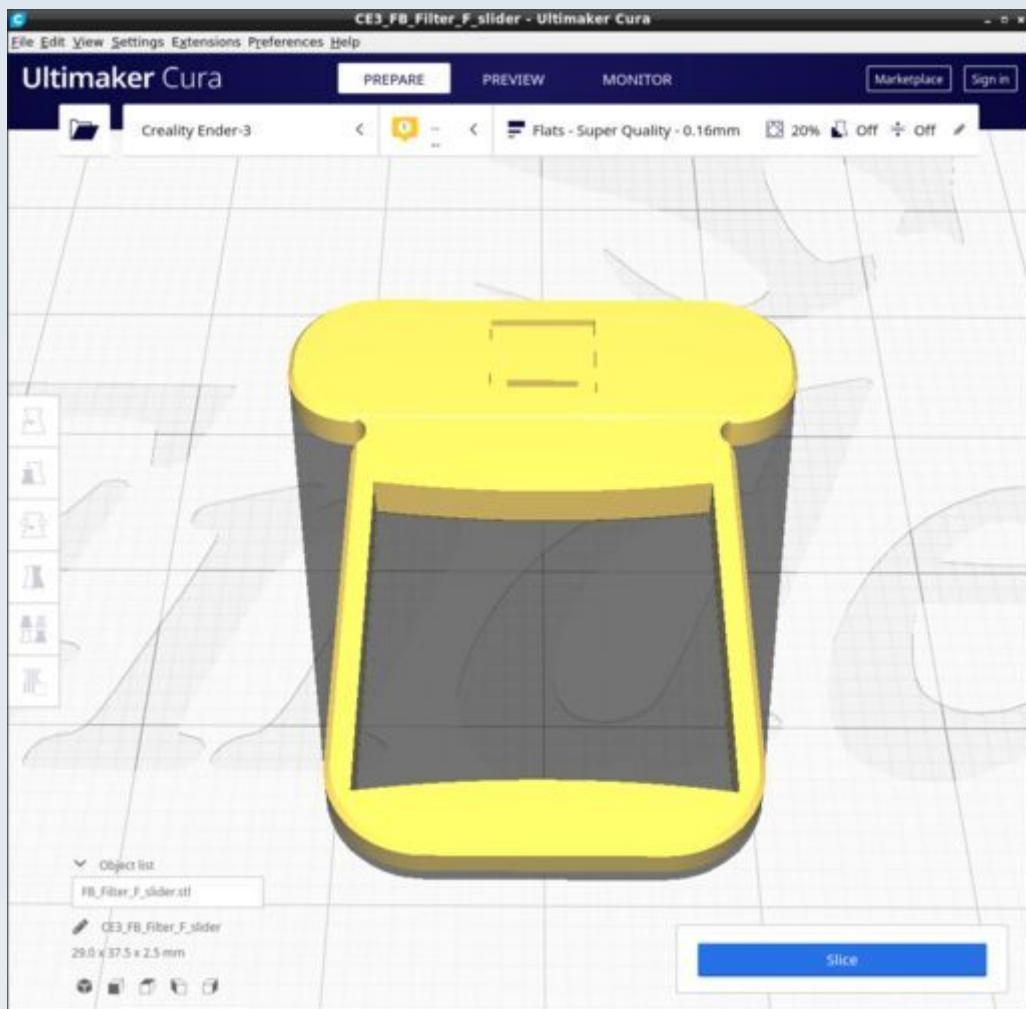
## FB\_Filter\_collar.stl



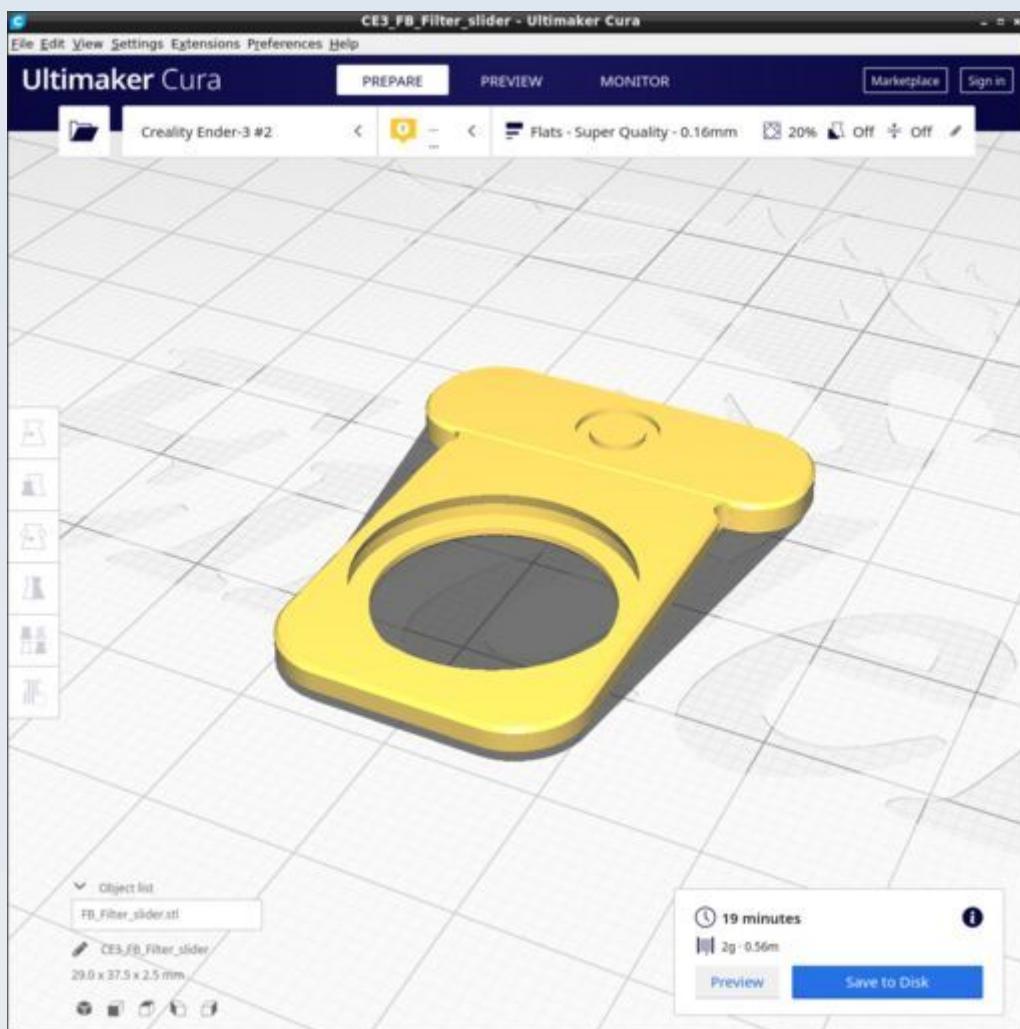
## FB\_Filter\_F17\_slider.stl



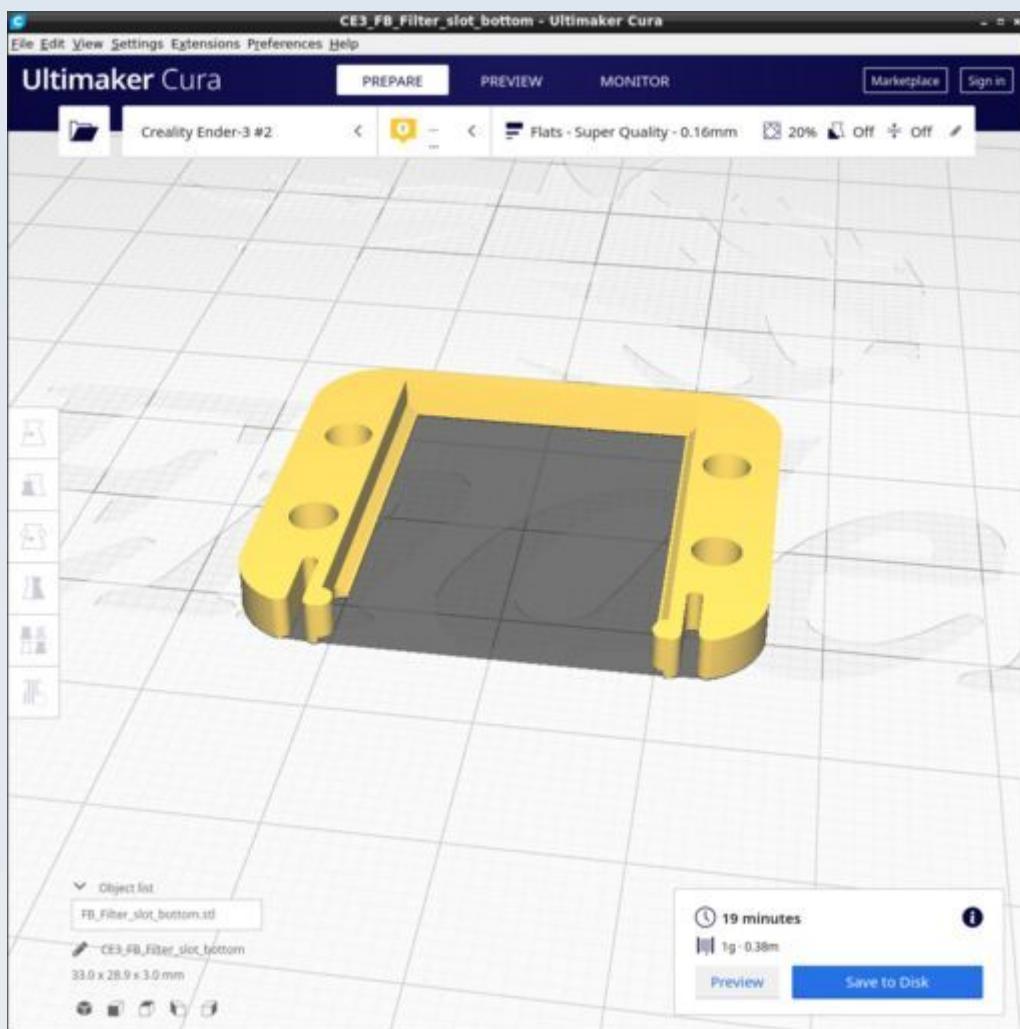
## FB\_Filter\_F\_slider.stl



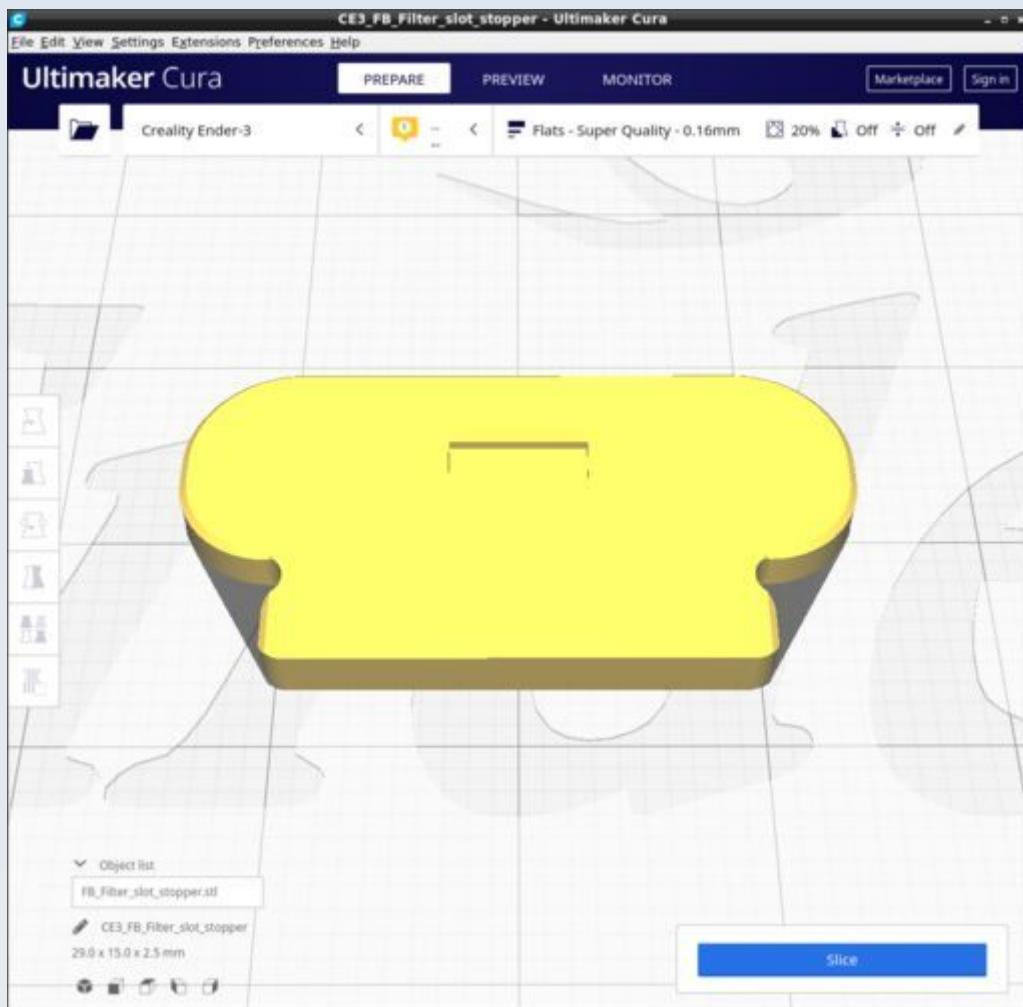
## FB\_Filter\_slider.stl



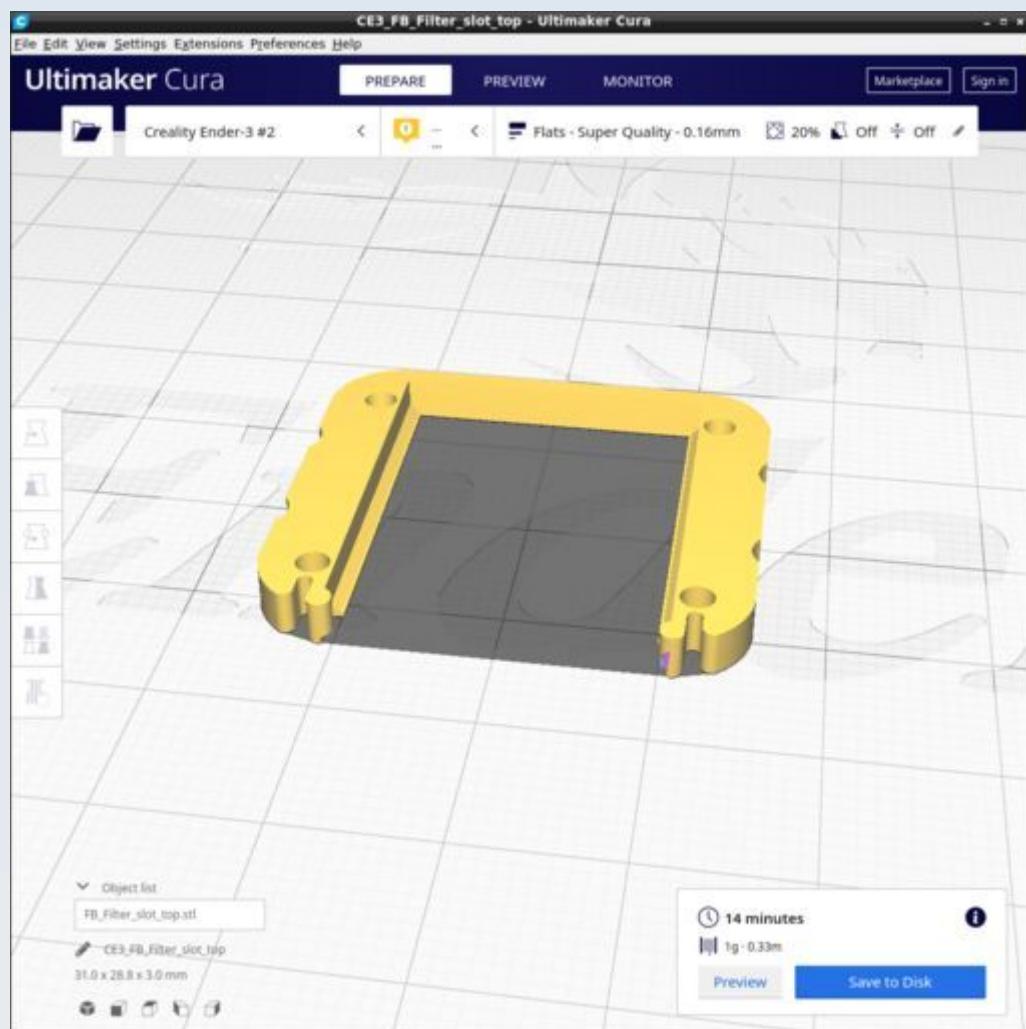
## FB\_Filter\_Slot\_bottom.stl



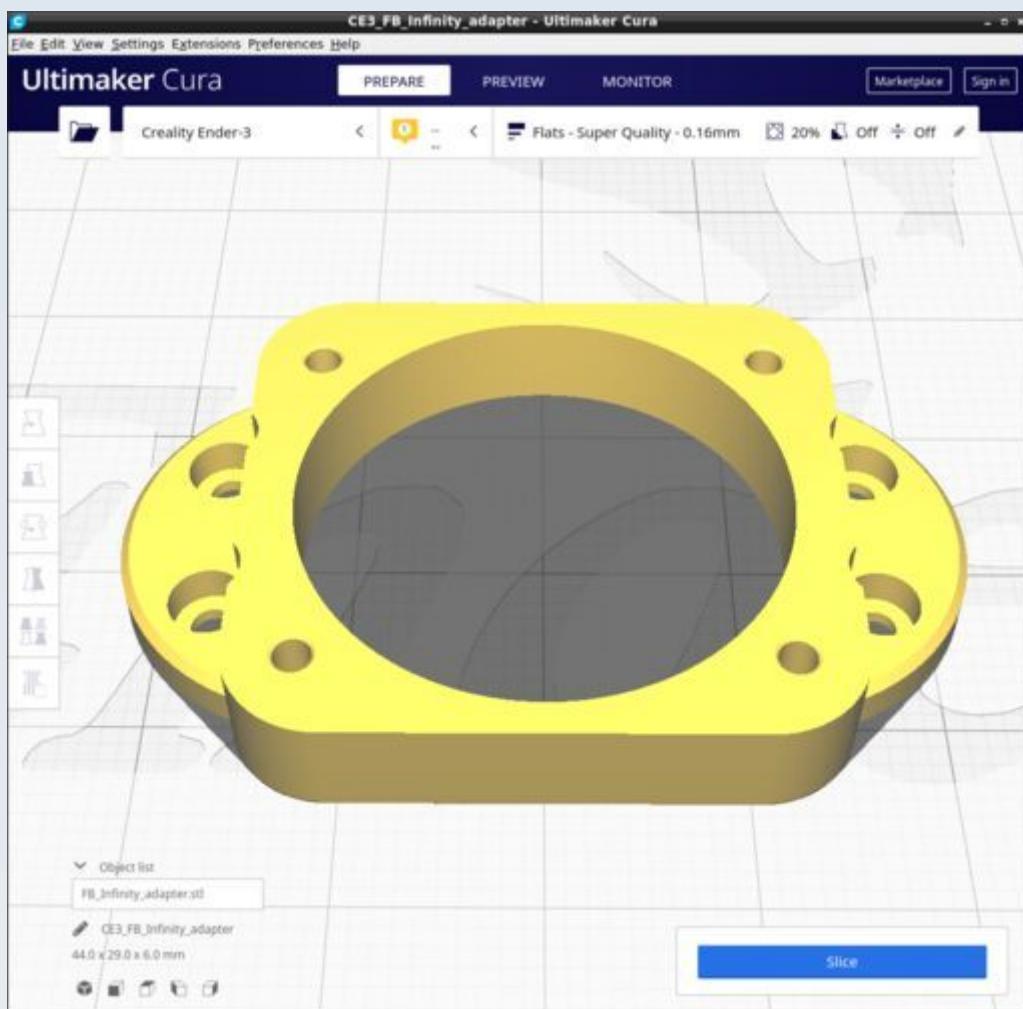
## FB\_Filter\_slot\_stopper.stl



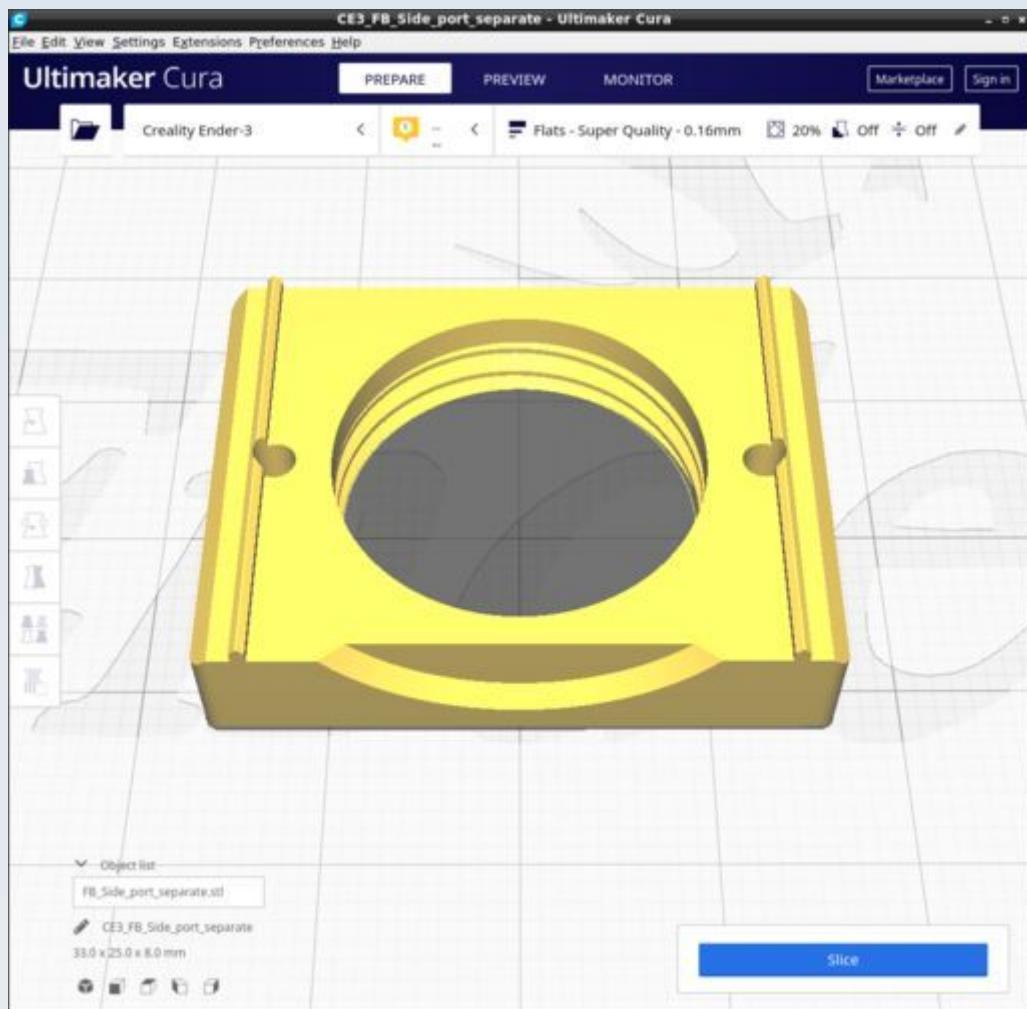
## FB\_Filter\_slot\_top.stl



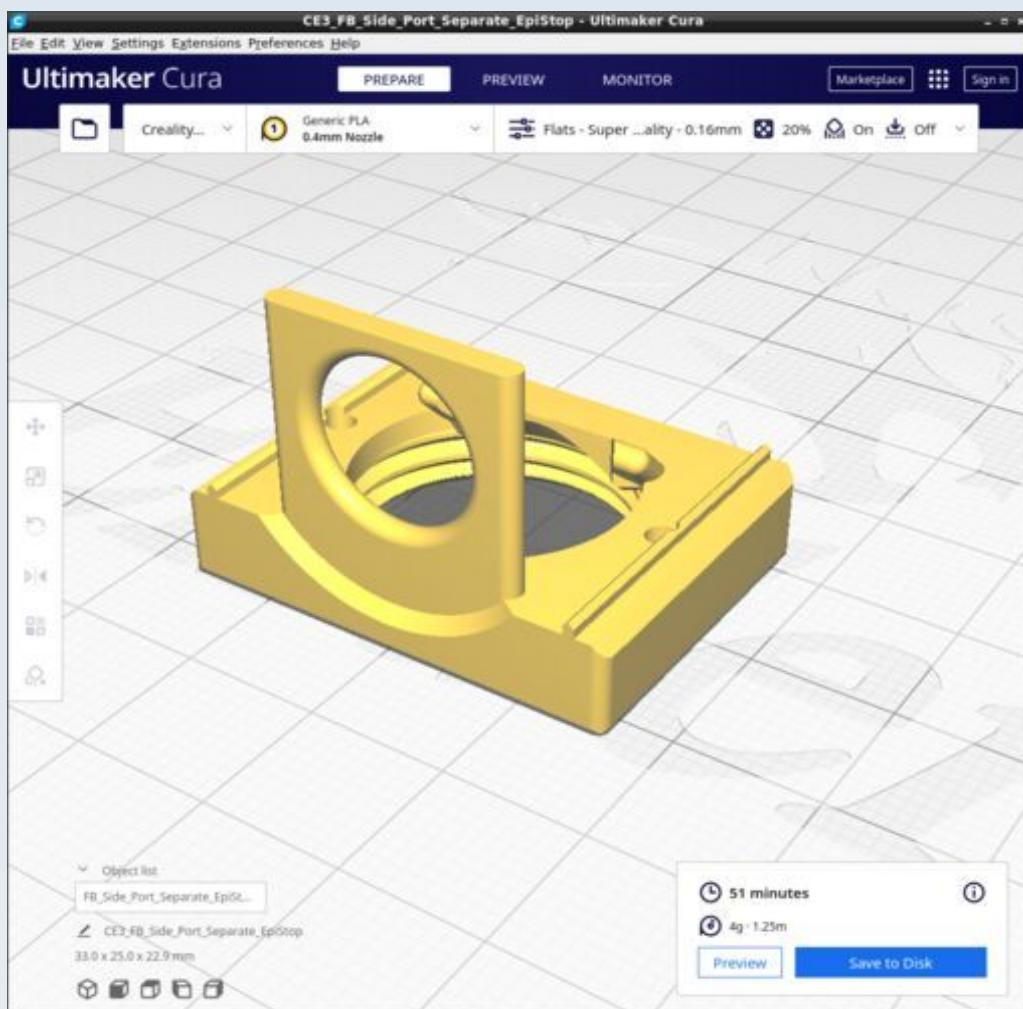
## FB\_Infinity\_adapter.stl



## FB\_Side\_port\_separate.stl

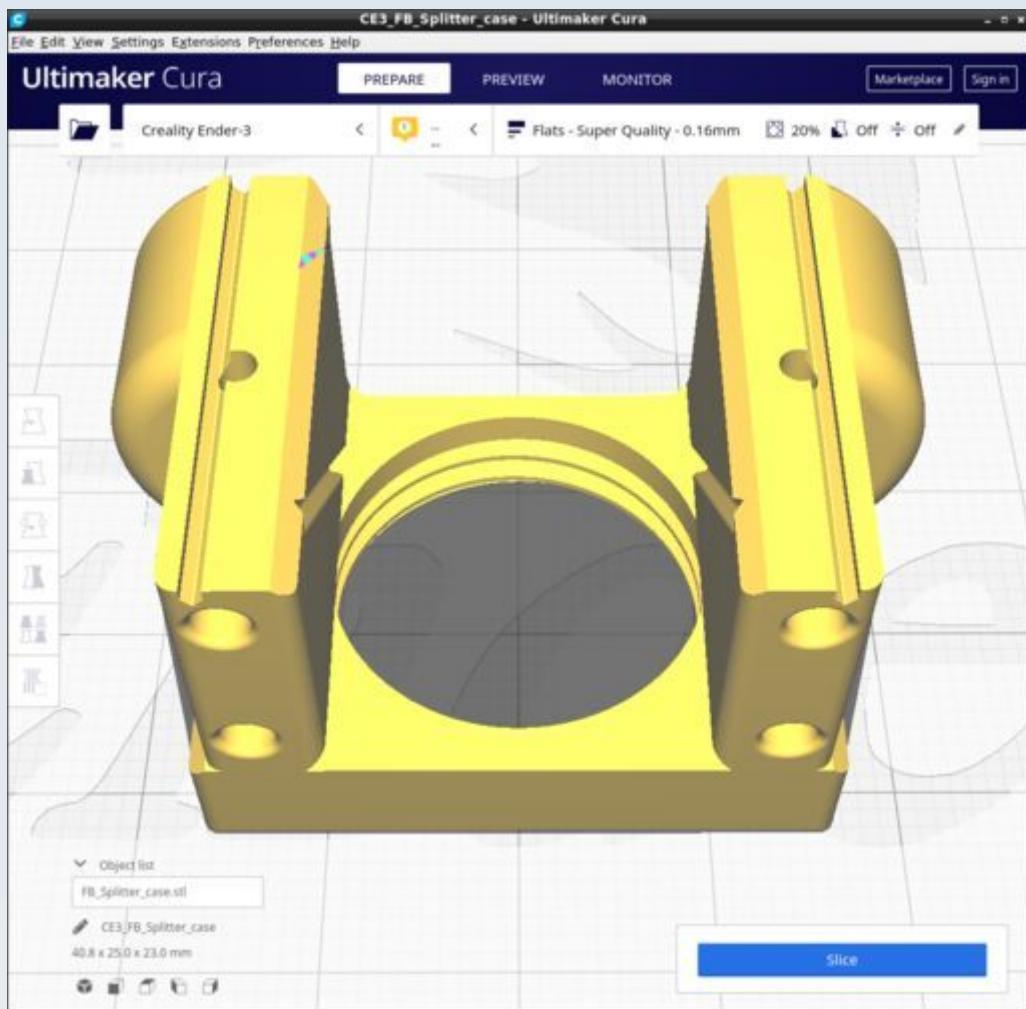


## FB\_Side\_port\_separate\_EpiStop.stl



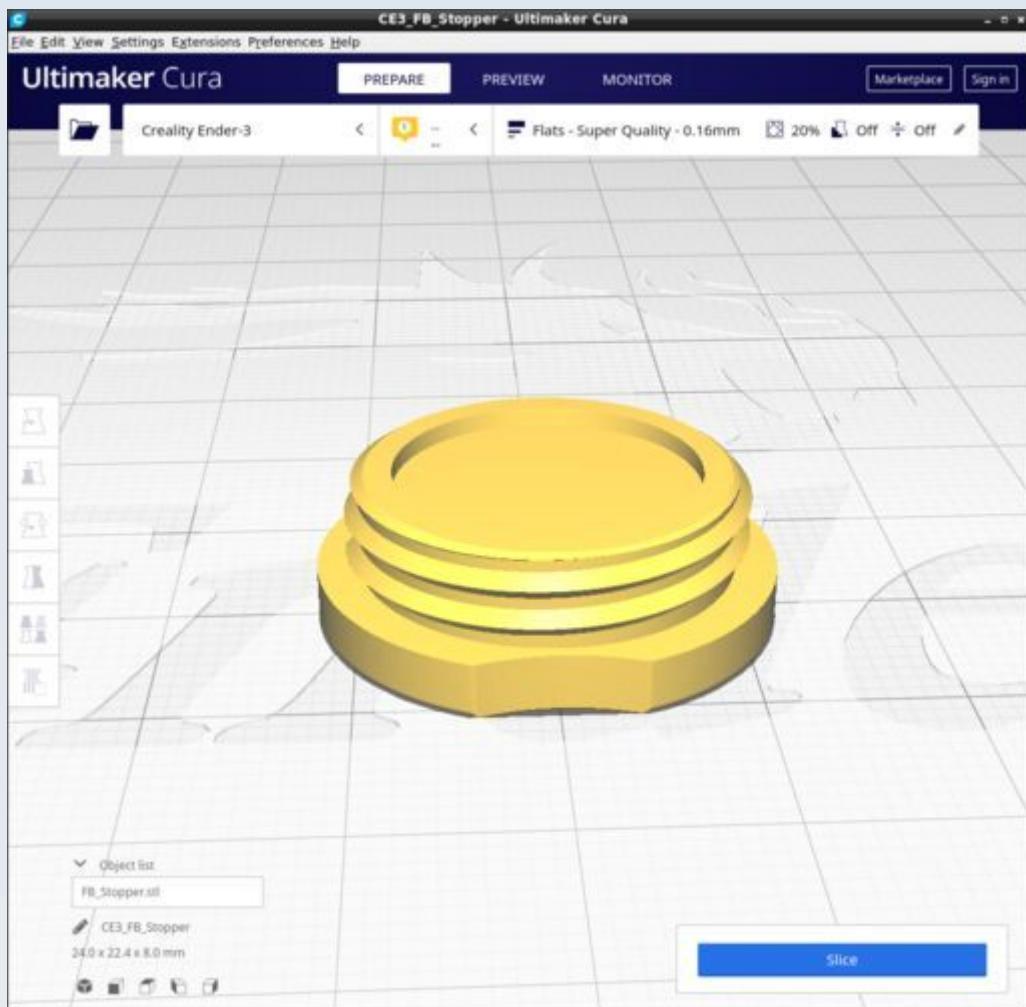
Print with supports on: General (not tree) support, overhang 67 degrees, supports enabled 'everywhere'.

## FB\_Splitter\_case.stl



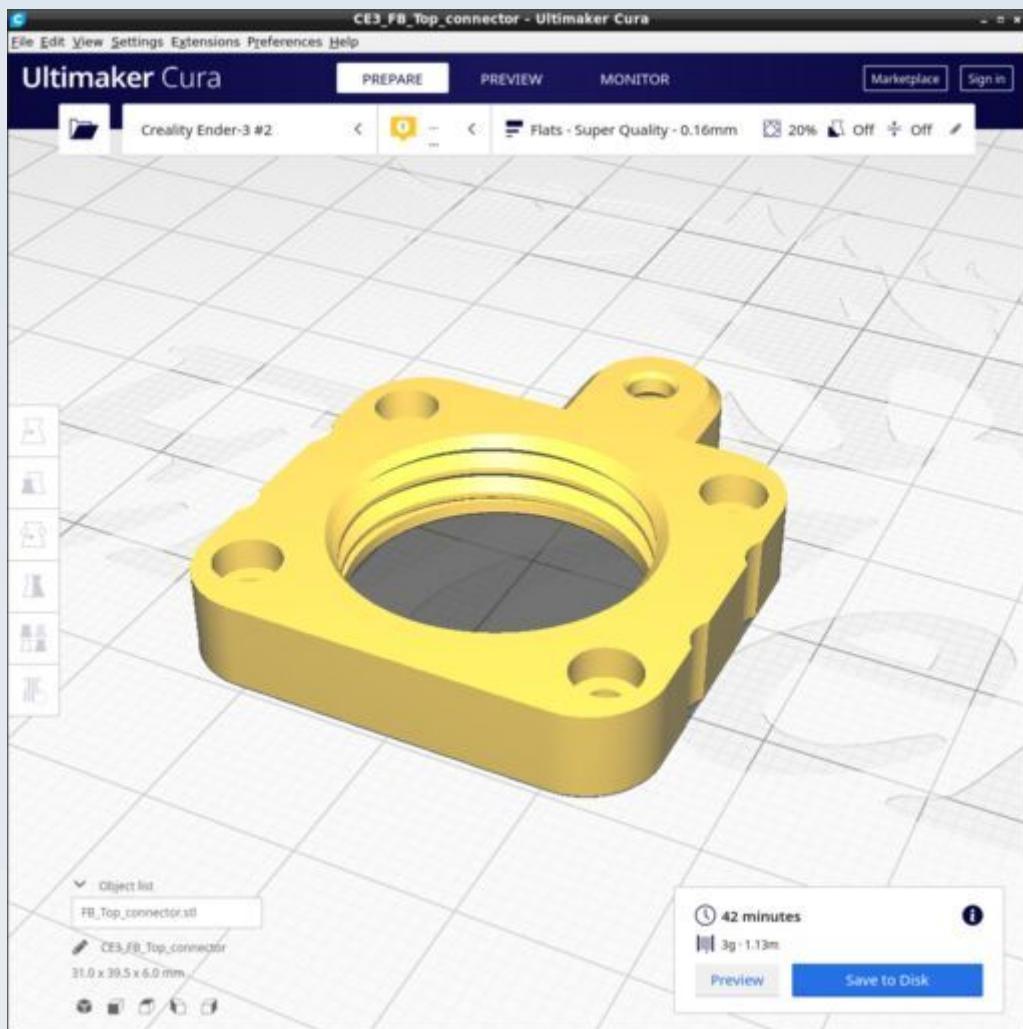
Ensure all supports are off.

## FB\_Stopper.stl



Ensure all supports are off.

## FB\_Top\_connector.stl



## Focus Gears

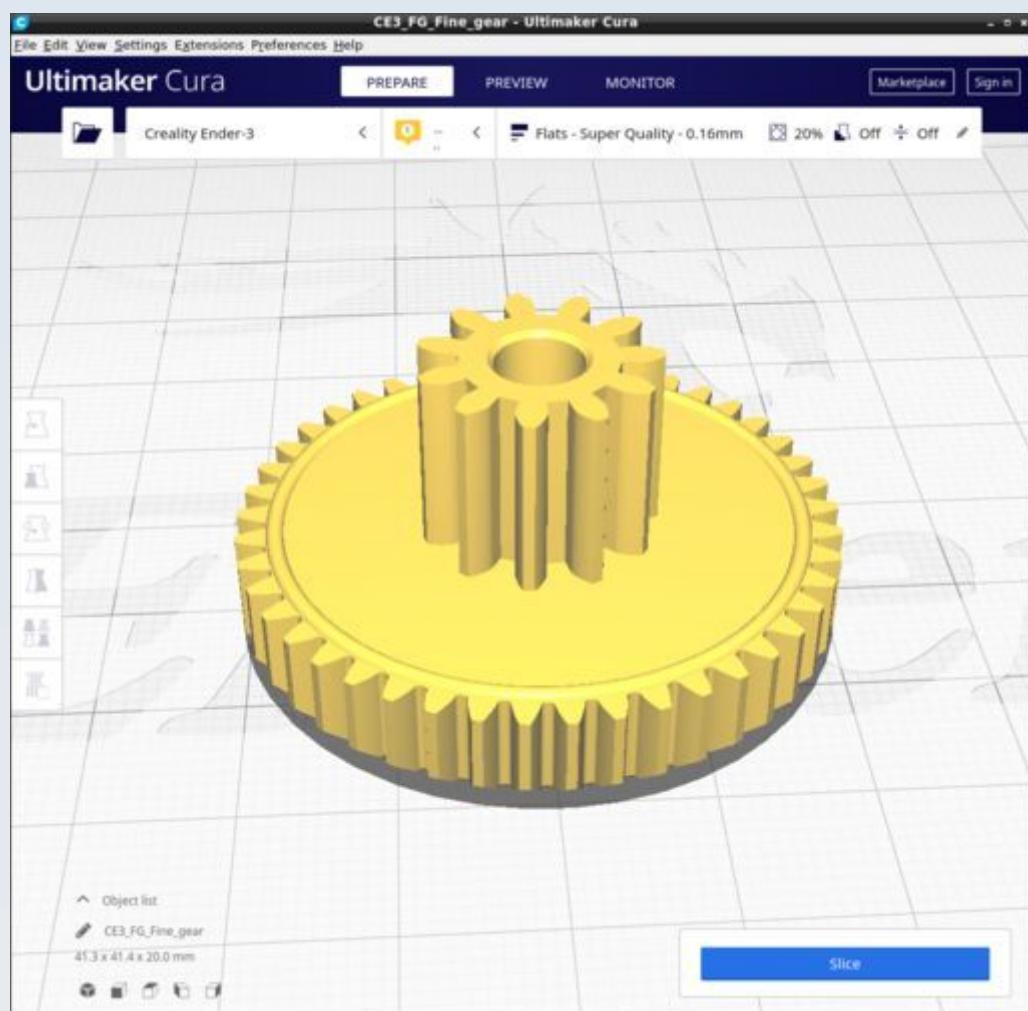
These are the parts for the stage focus mechanism. The CAD source models for these STL files are found in the file Focus\_Gears.FCStd.

## Resources

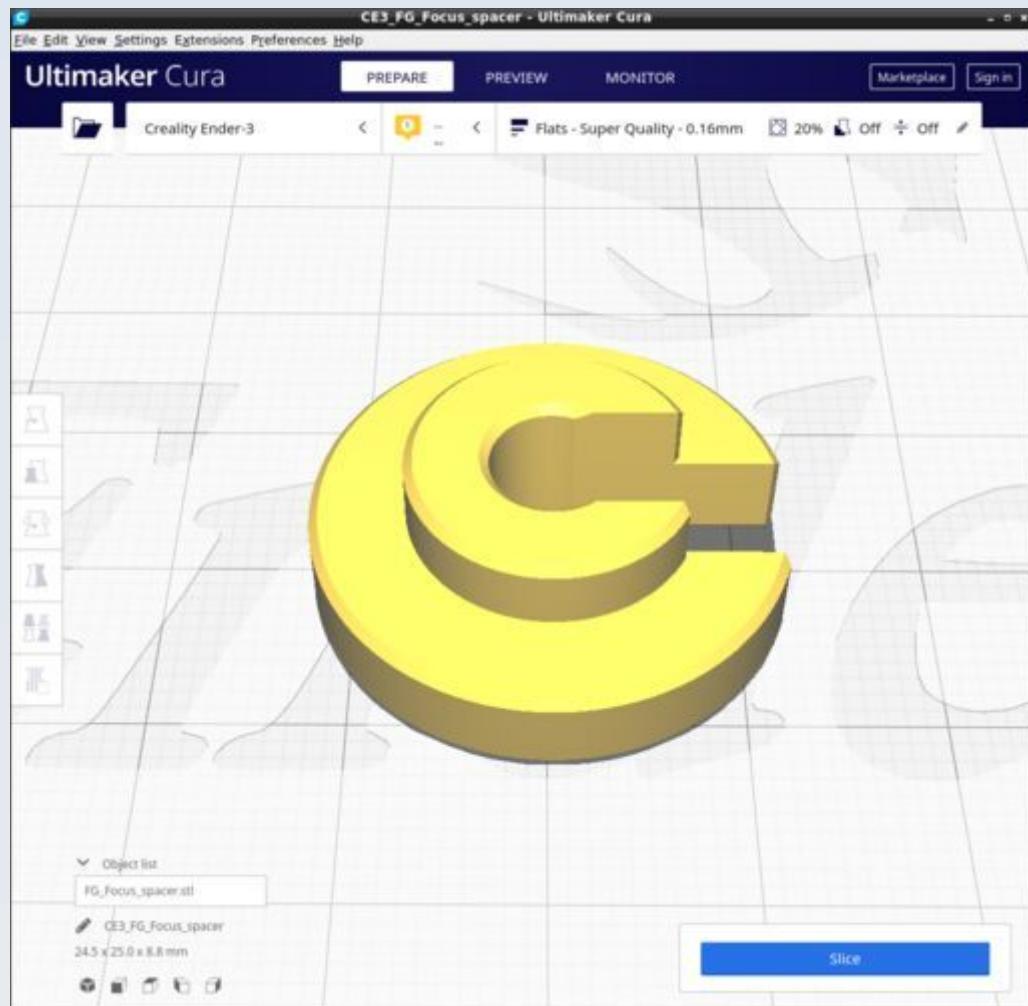
Cura calculates the following resources are required to print each model in this chapter:

Focus Gears	Time_Hr	Time_Min	PLA_Length(m)
FG_Fine_gear.stl	1	38	2.65
FG.Focus_spacer.stl	0	20	0.7
FG_Intermedius.stl	1	7	1.75
FG_Pulley_coarse.stl	1	18	2.03
FG_Pulley.stl	0	21	0.33
FG_Eccentric_Tensioner_Top.stl	0	24	0.69
FG_Eccentric_Tensioner_Bottom.stl	0	19	0.44
FG_Eccentric_Tensioner_Pulley_c_adhesin.stl	0	17	0.22

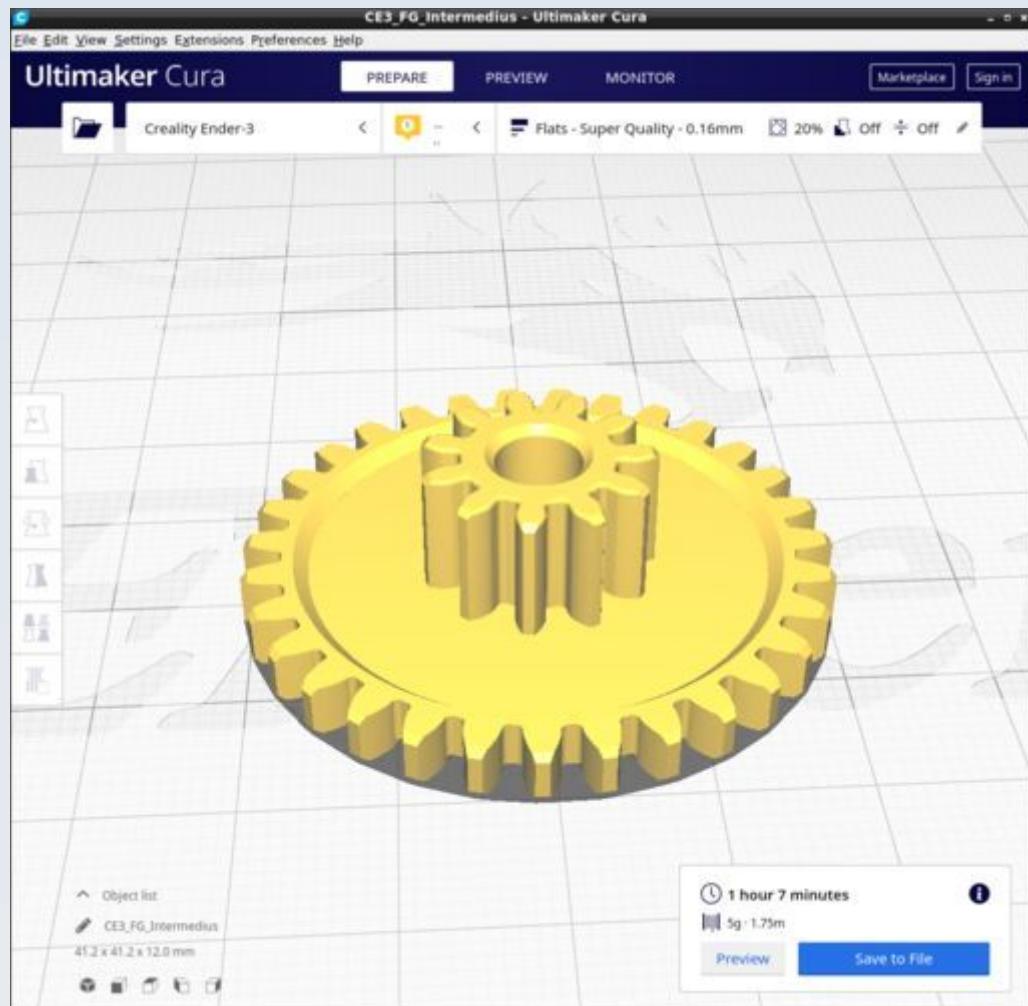
## FG\_Fine\_gear.stl



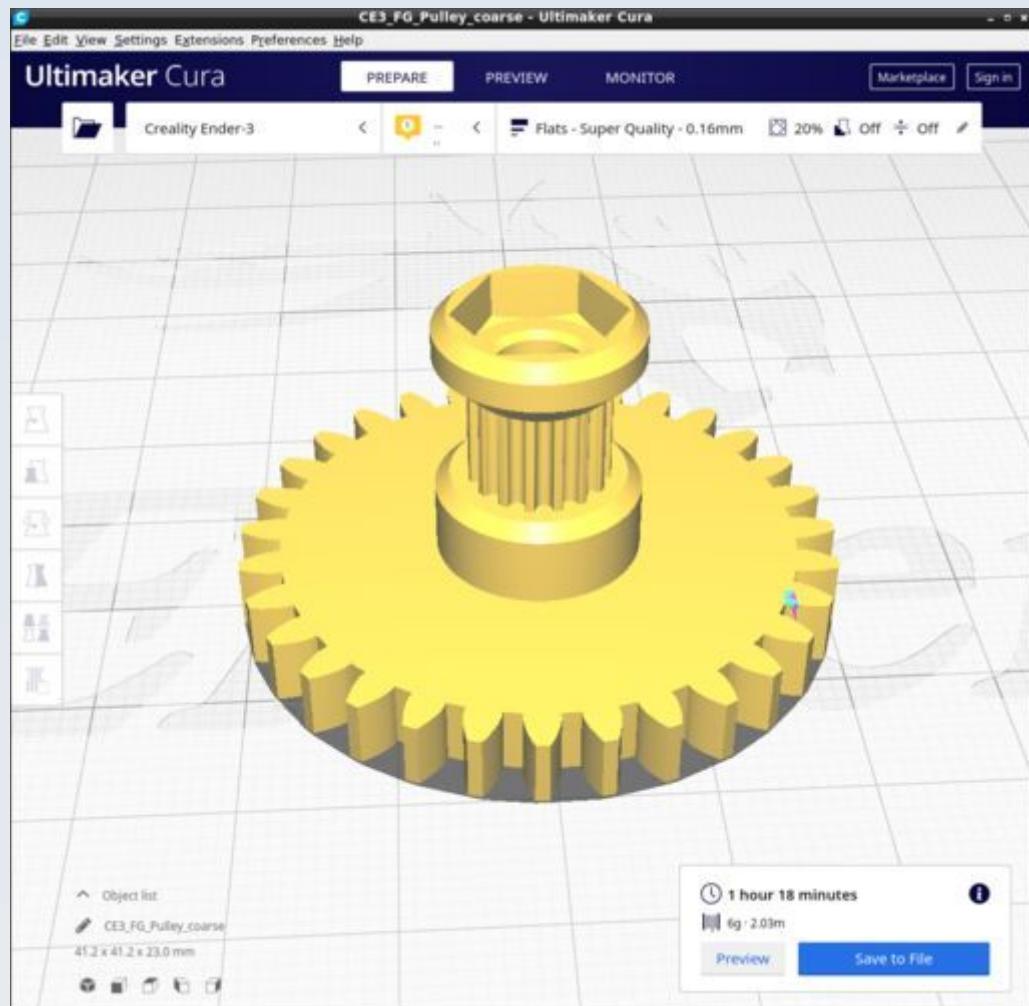
## FG\_Focus\_spacer.stl



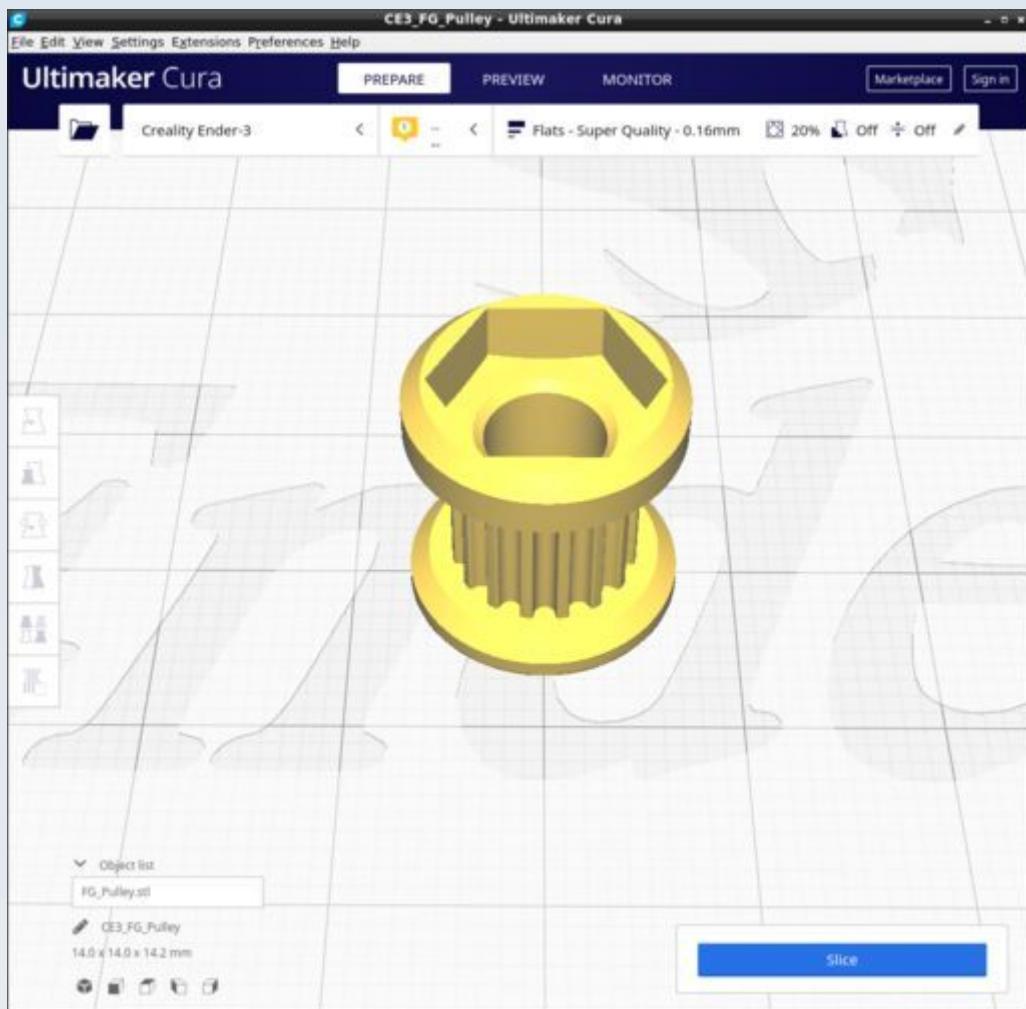
## FG\_Intermedius.stl



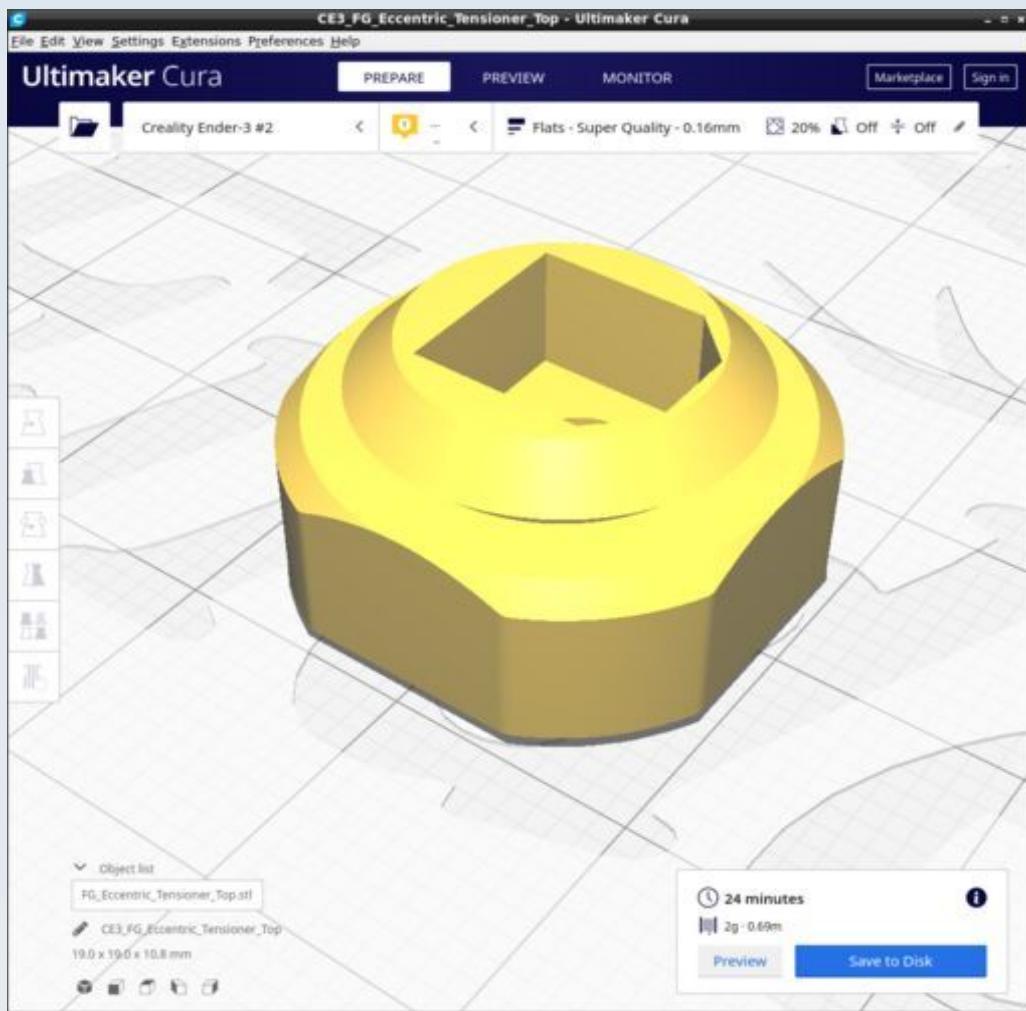
## FG\_Pulley\_coarse.stl



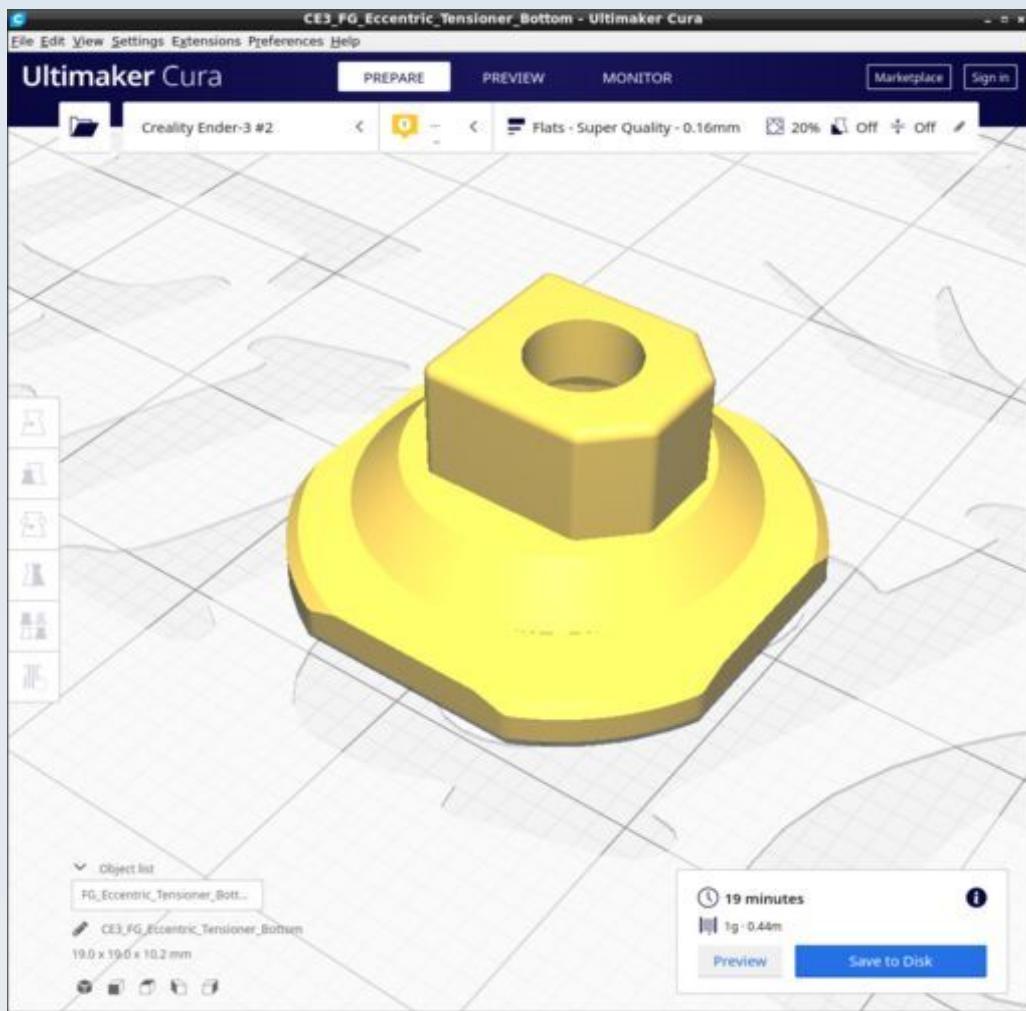
## FG\_Pulley.stl



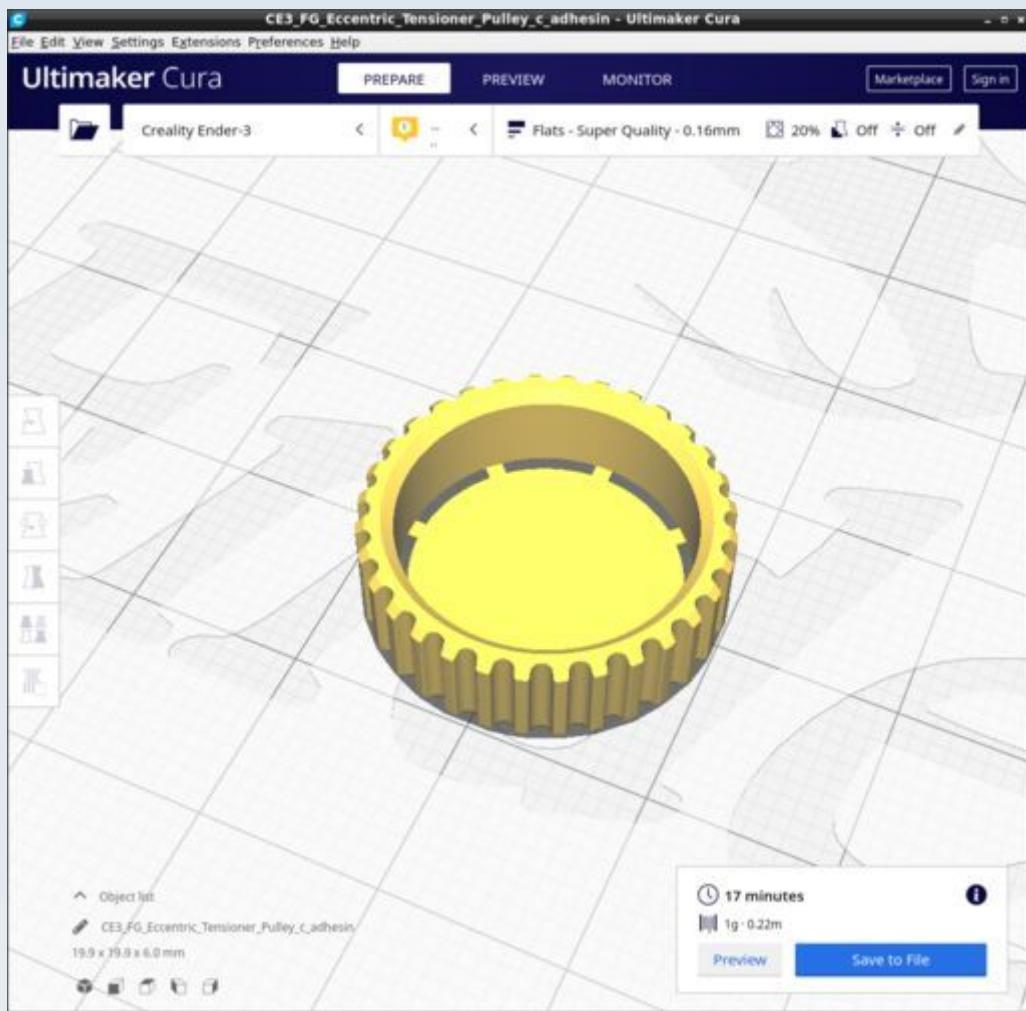
## FG\_Eccentric\_Tensioner\_Top.stl



## FG\_Eccentric\_Tensioner\_Bottom.stl



## FG\_Eccentric\_Tensioner\_Pulley\_c\_adhesin.stl



## Legs

These are the parts for the various legs / stands options for the microscope. The CAD source models for these STL files are found in the file Legs.FCStd.

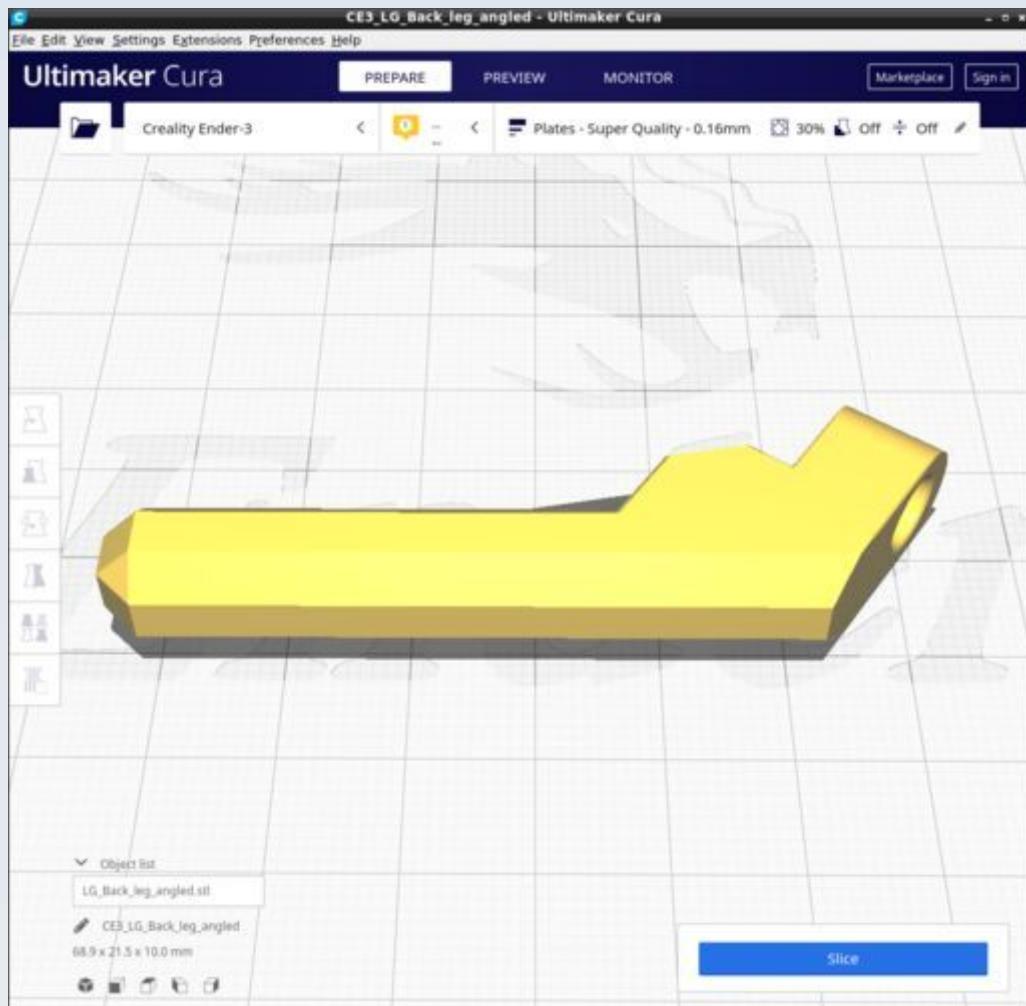
All these should be printed with the 'Plates' custom Cura profile. Only the 'LG\_Feet\_linker.stl' requires supports and special instructions (see below).

## Resources

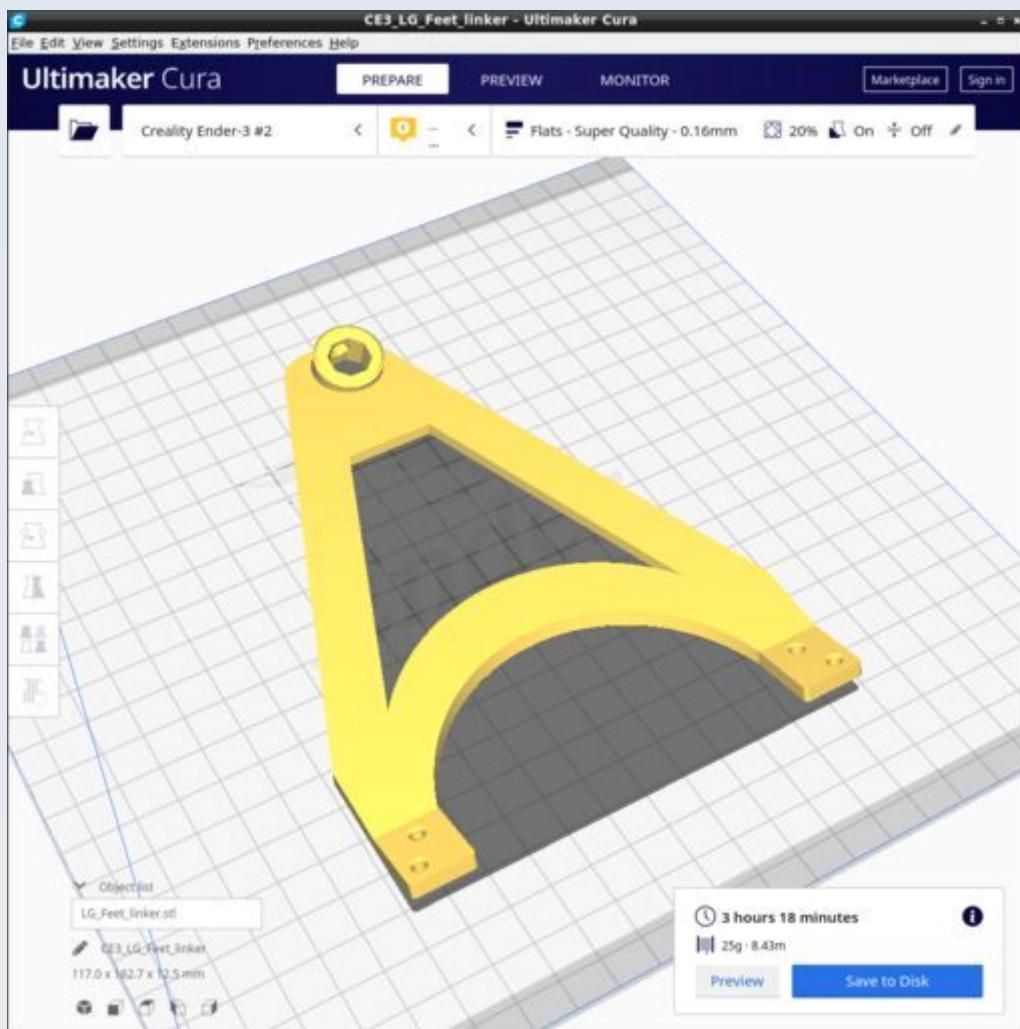
Cura calculates the following resources are required to print each model in this chapter:

Legs	Time_Hr	Time_Min	PLA_Length(m)
LG_Back_leg_angled.stl	0	36	1.68
LG_Feet_linker.stl	3	18	8.43
LG_Front_legs.stl	3	21	9.34
LG_Hind_extension.stl	0	46	1.64
LG_Short_leg.stl	0	16	0.54

## LG\_Back\_leg\_angled.stl



## LG\_Feet\_linker.stl

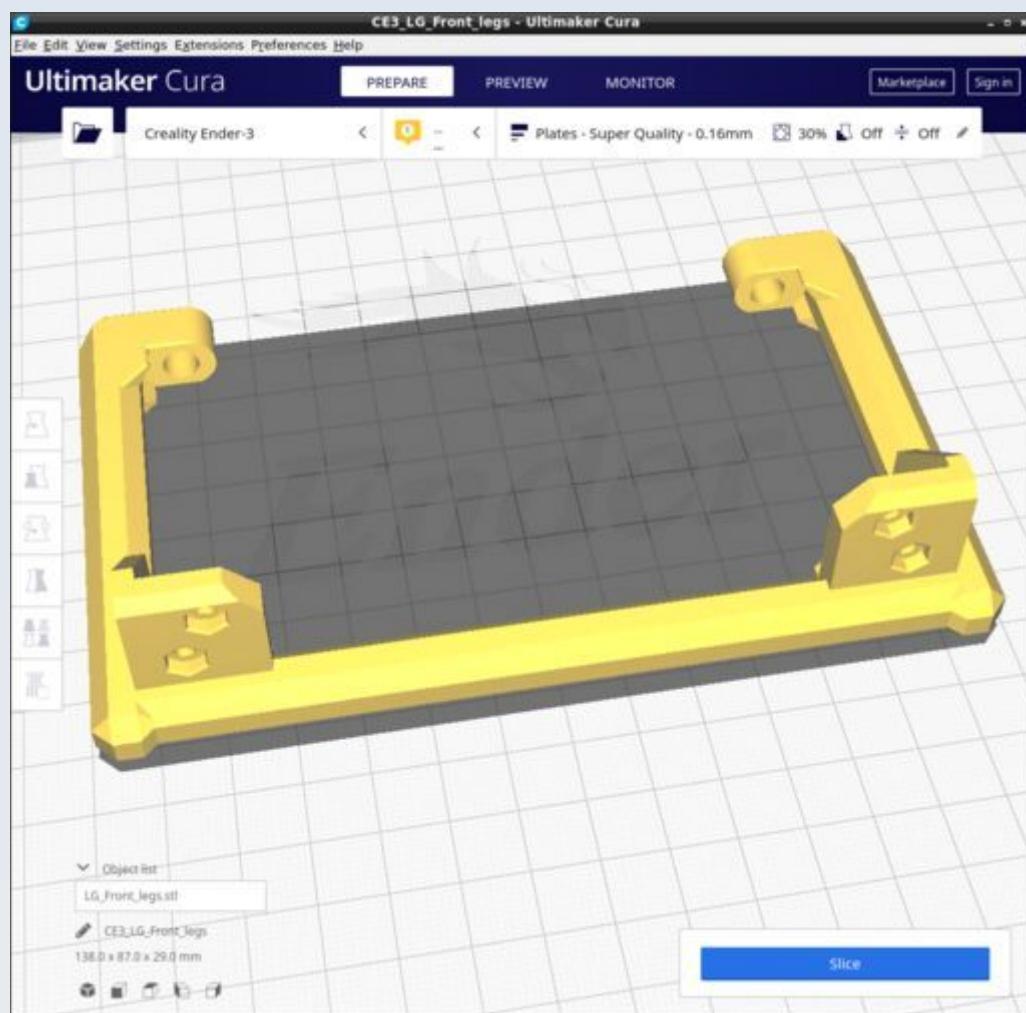


Use supports 'touching baseplate only' with 67 degree overhang angle.

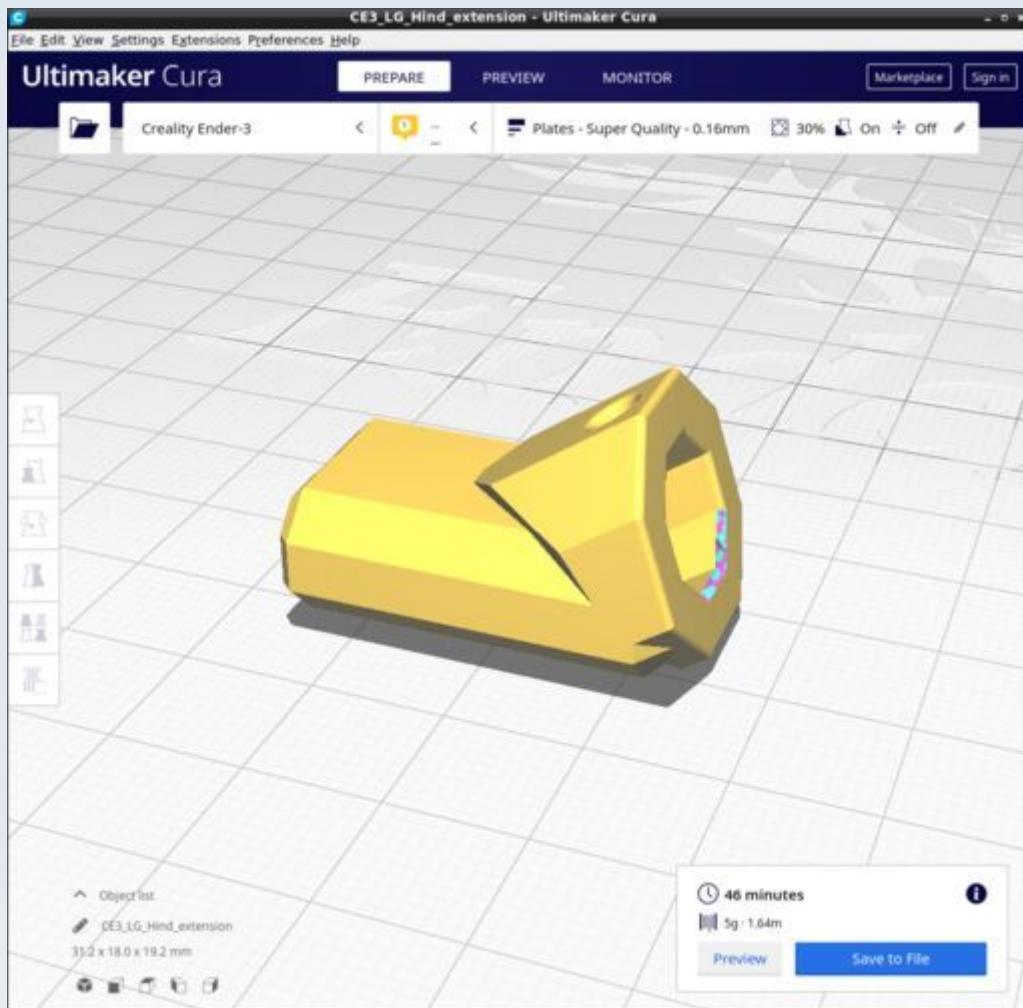
Also, you must rotate it in Cura by 90 degrees to the position shown in the figure and ensure it is lain flat against the build plate because there is a slight angle to it when first loaded (this may be imperceptible by eye but it can cause print failure if not corrected).

This rotation can be achieved in one step by selecting the model, going to the rotations menu and click the 'Lay flat' icon – this will do both things for you automatically (tested and works with Cura 4.8 and Cura 4.10.0).

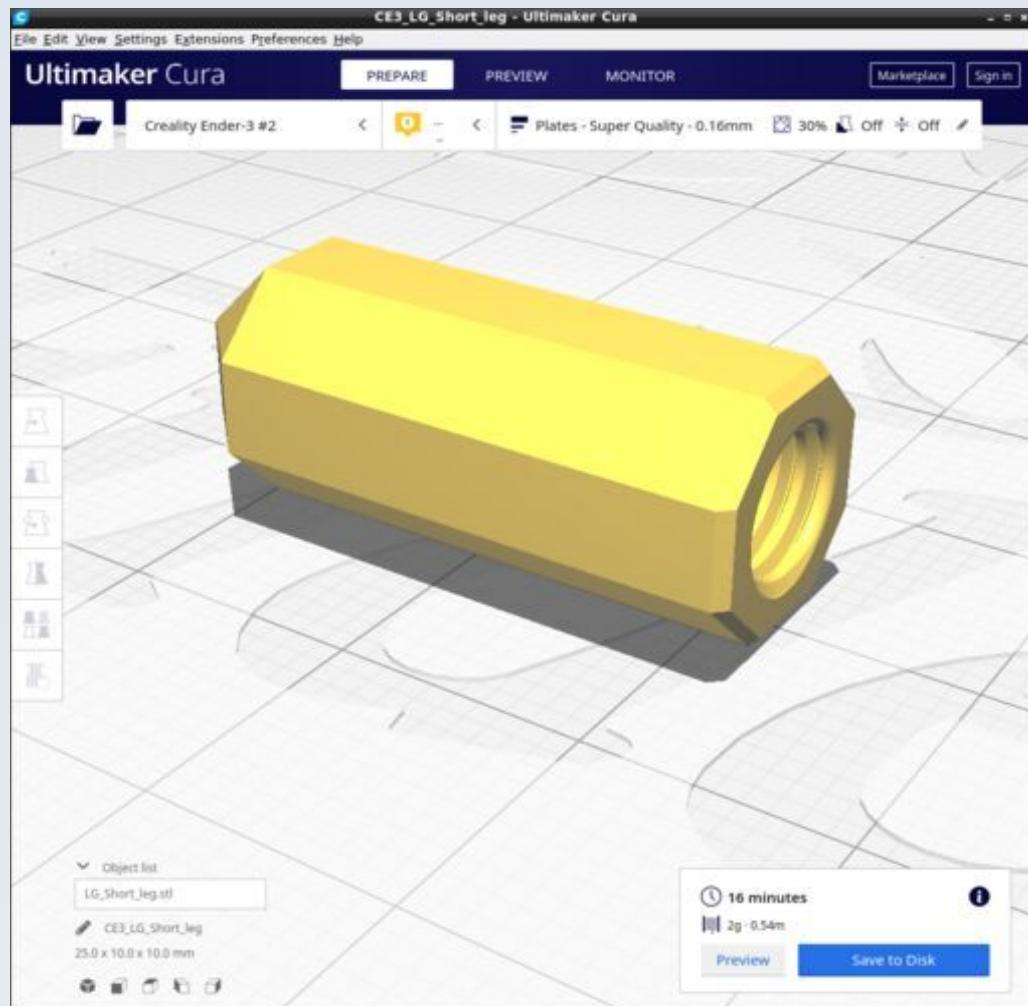
## LG\_Front\_legs.stl



## LG\_Hind\_extension.stl



## LG\_Short\_leg.stl



## Monocular Head

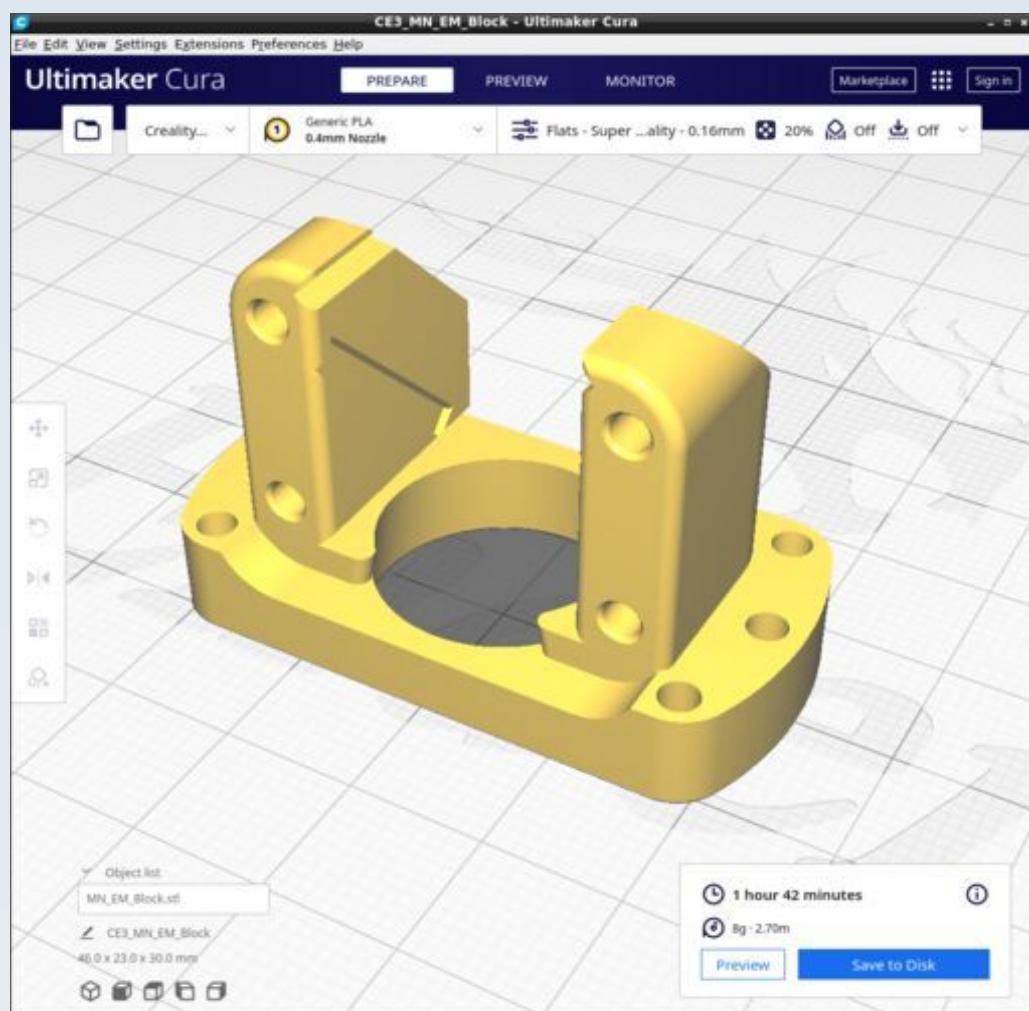
These are the parts for the monocular viewing head of the microscope. Some of the parts here are also used for the binocular and trinocular head modules. The CAD source models for these STL files are found in the file Monocular.FCStd.

## Resources

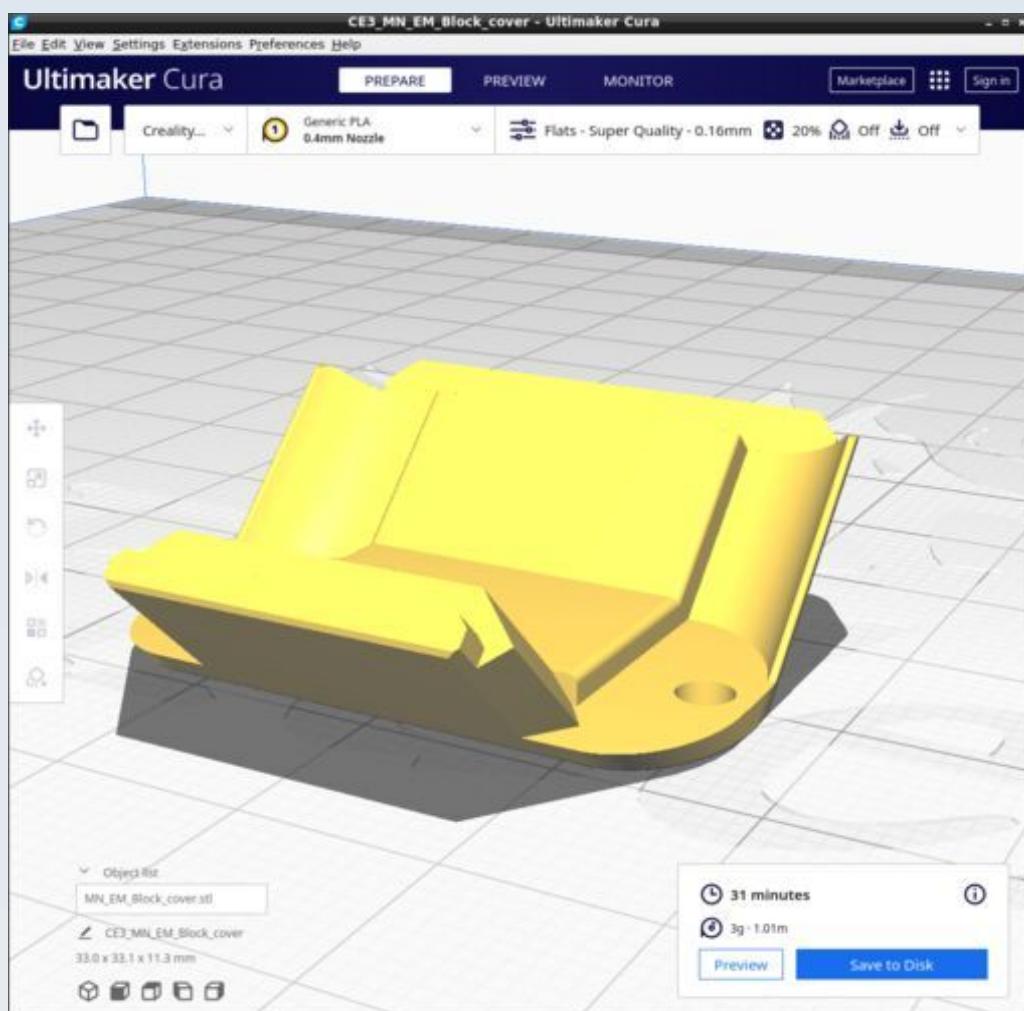
Cura calculates the following resources are required to print each model in this chapter:

Monocular Head	Time_Hr	Time_Min	PLA_Length(m)
MN_EM_Block.stl	1	42	2.7
MN_EM_Block_cover.stl	0	31	1.01
MN_Monocular_tube_c_adhesin.stl	3	10	7.78
MN_Monocular_tube_CM_c_adhesin.stl	2	34	6.39
MN_Ocular_cap_170.stl	1	9	2.83
MN_Ocular_cap.stl	0	42	1.65
MN_Ocular_extension_c_adhesin.stl	0	55	2.19
MN_Ocular_extension_CM_c_adhesin.stl	0	38	1.7
MN_Ocular_lock_nut.stl	0	16	0.47
MN_Ocular_protective_cap.stl	0	19	1.14
MN_Ocular_tube_protective_cap.stl	0	26	1.14

## MN\_EM\_Block.stl



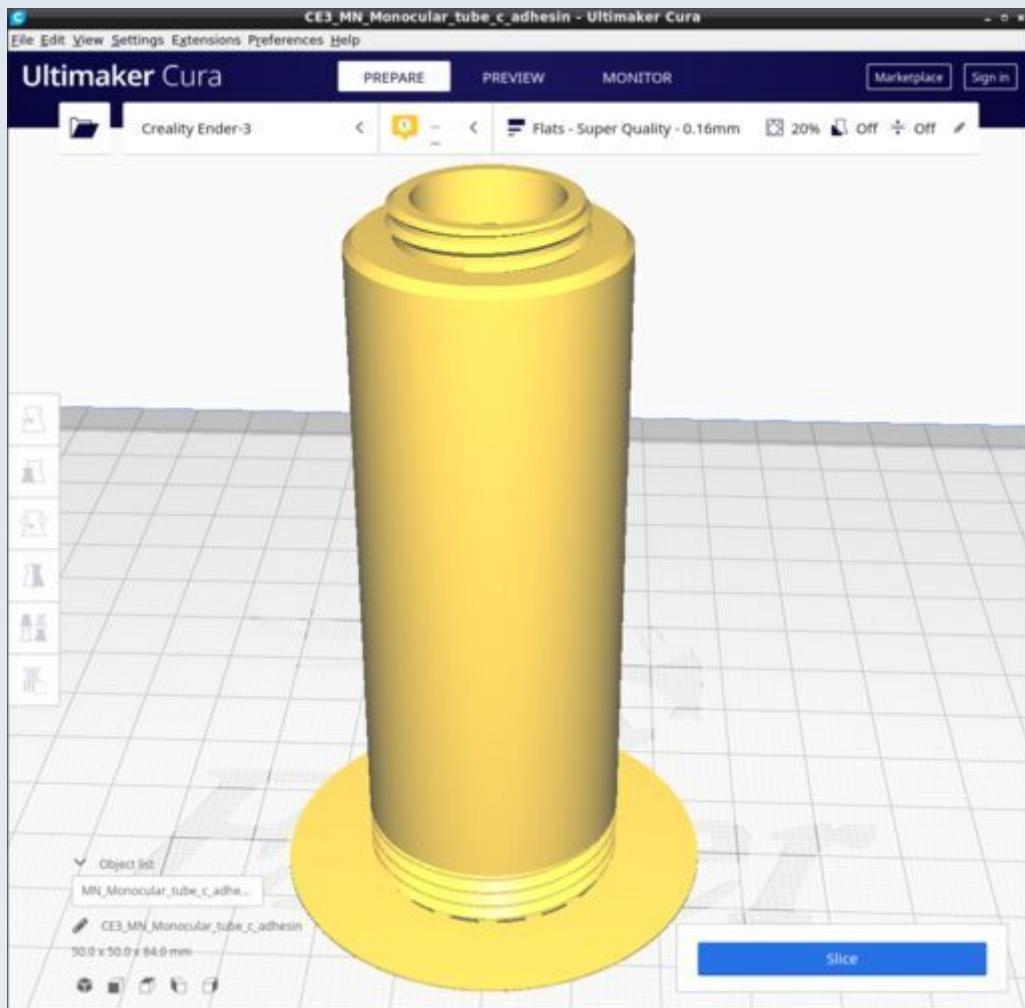
## MN\_EM\_Block\_cover.stl



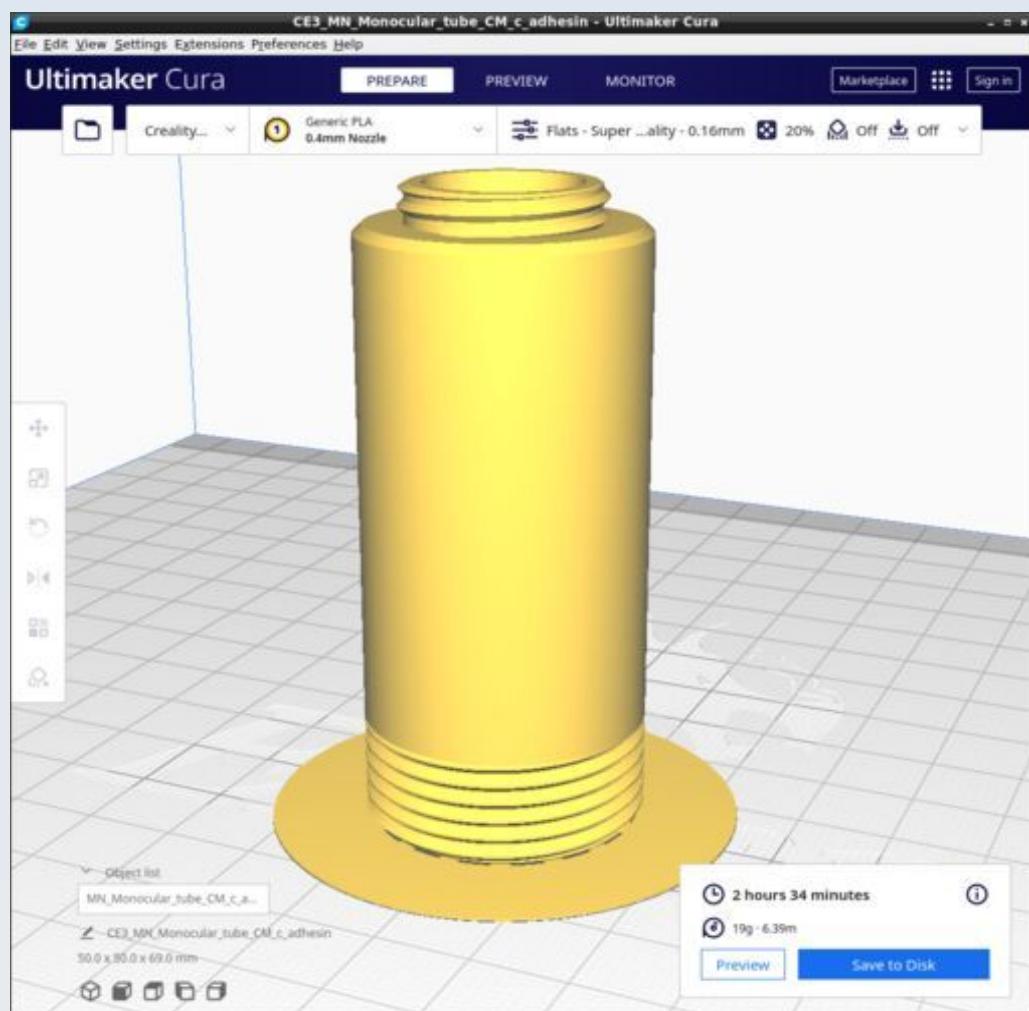
Note the orientation. For some reason, if you try to rotate the mesh by 45 degrees in FreeCAD and export the mesh, the exported mesh needs to be 'laid flat' in Cura because the 45 degree rotation doesn't quite lay it flat.

I have found that it is best to export the mesh from FreeCAD as is, without the 45 degree rotation in FreeCAD, then do that rotation in Cura to position it as shown.

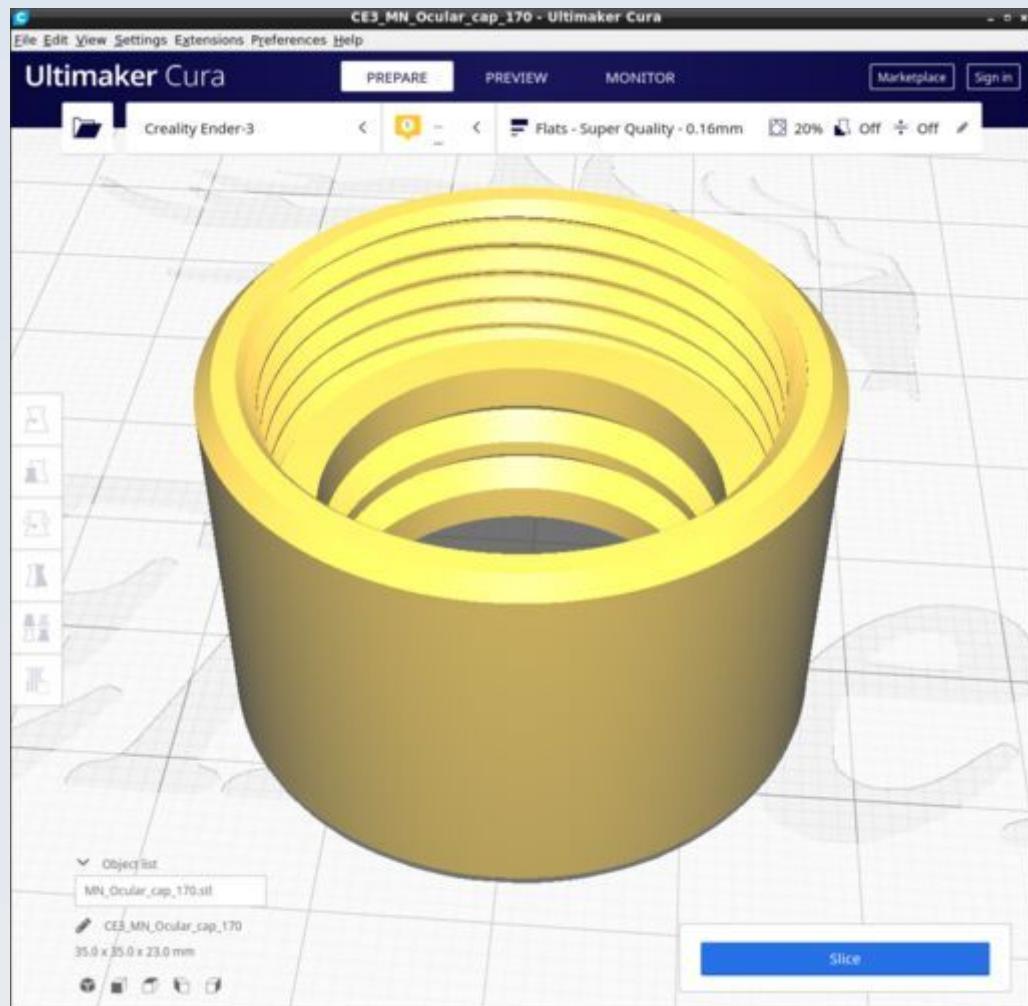
## MN\_Monocular\_tube\_c\_adhesin.stl



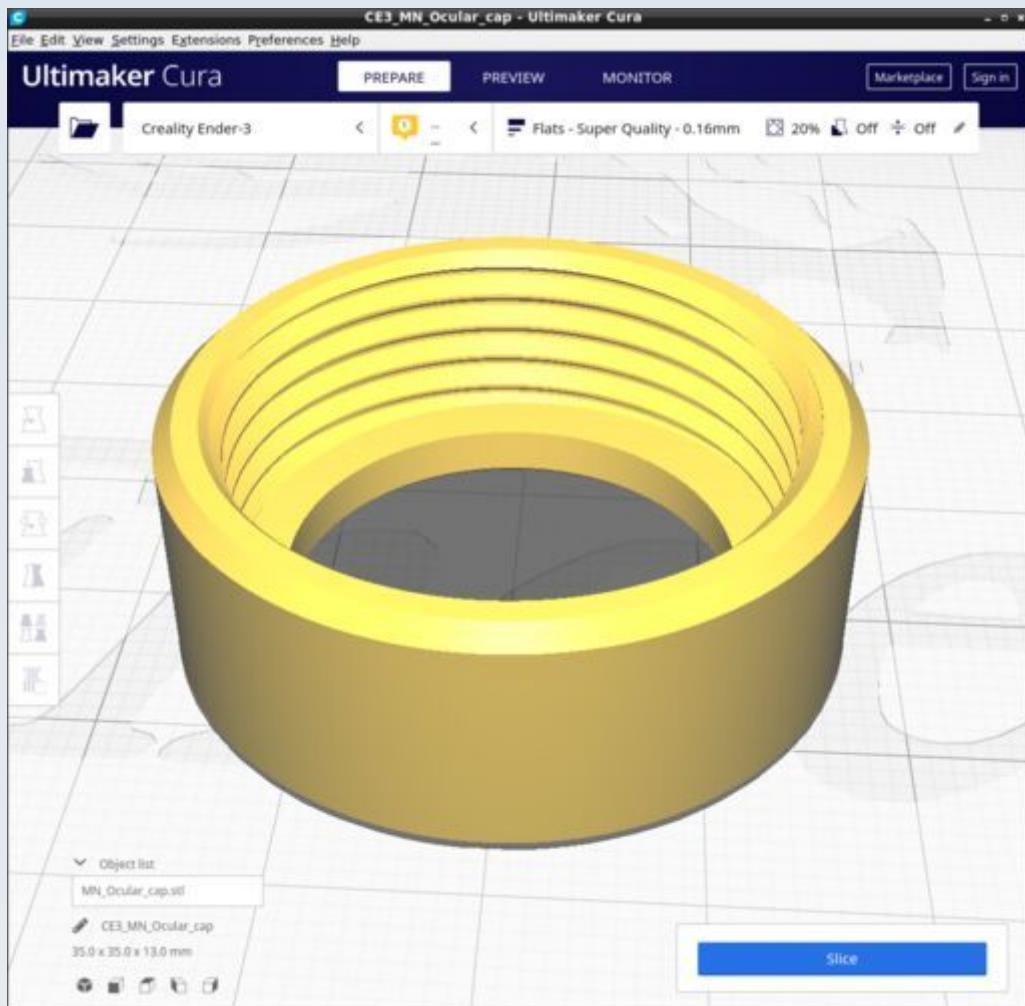
## MN\_Monocular\_tube\_CM\_c\_adhesin.stl



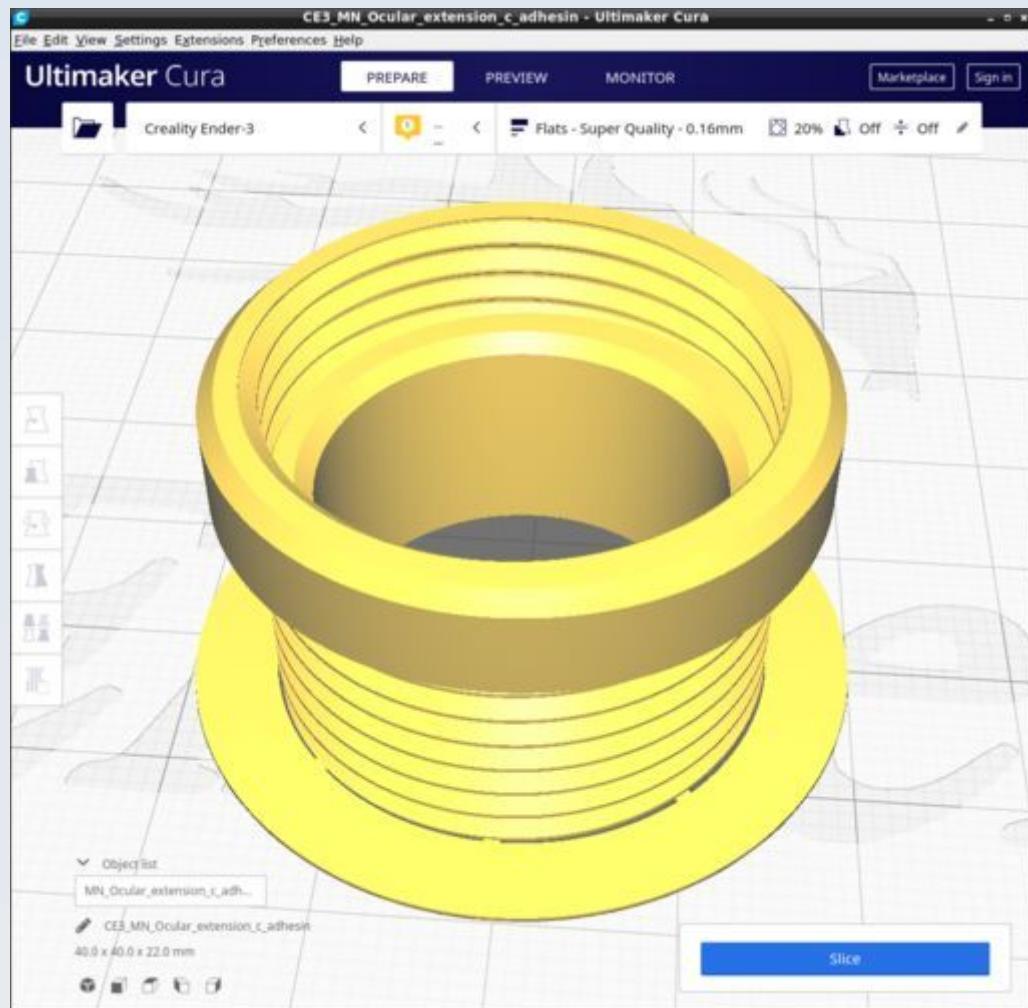
## MN\_Ocular\_cap\_170.stl



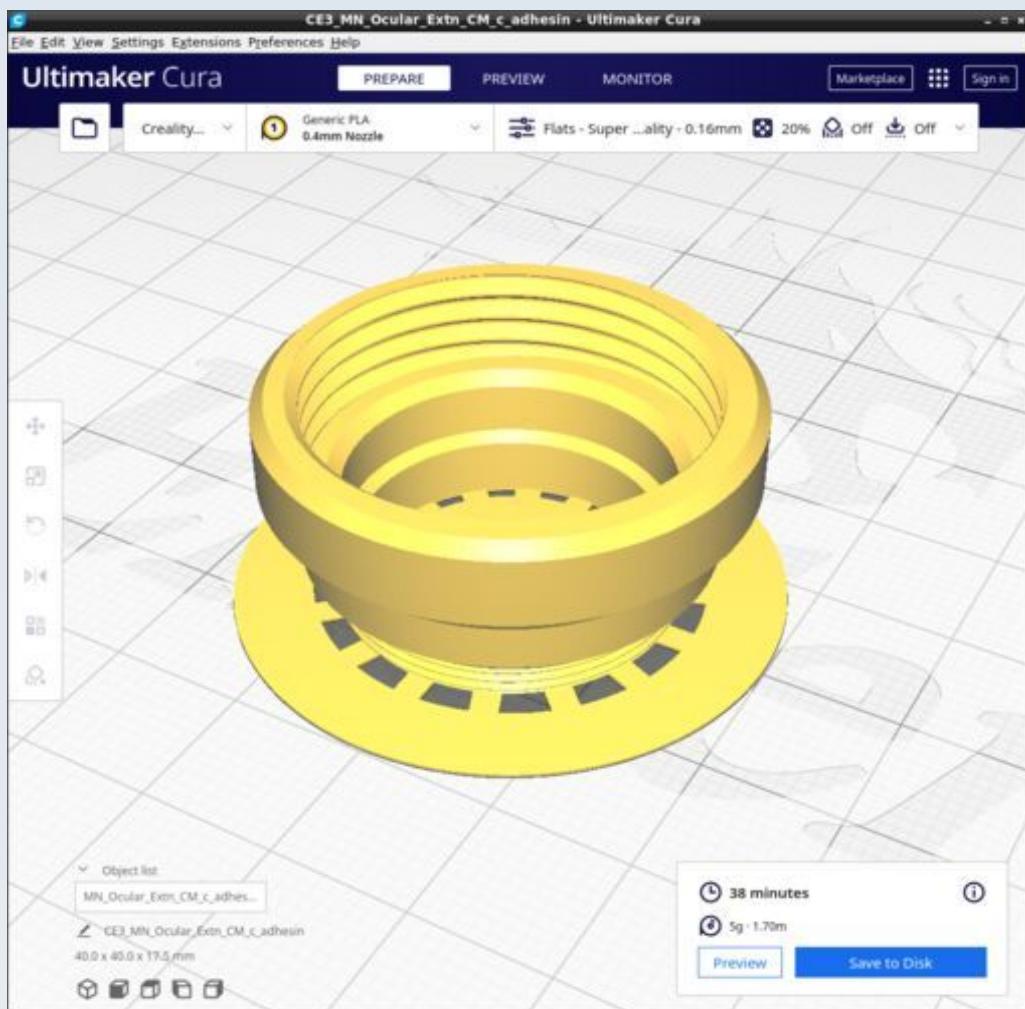
## MN\_Ocular\_cap.stl



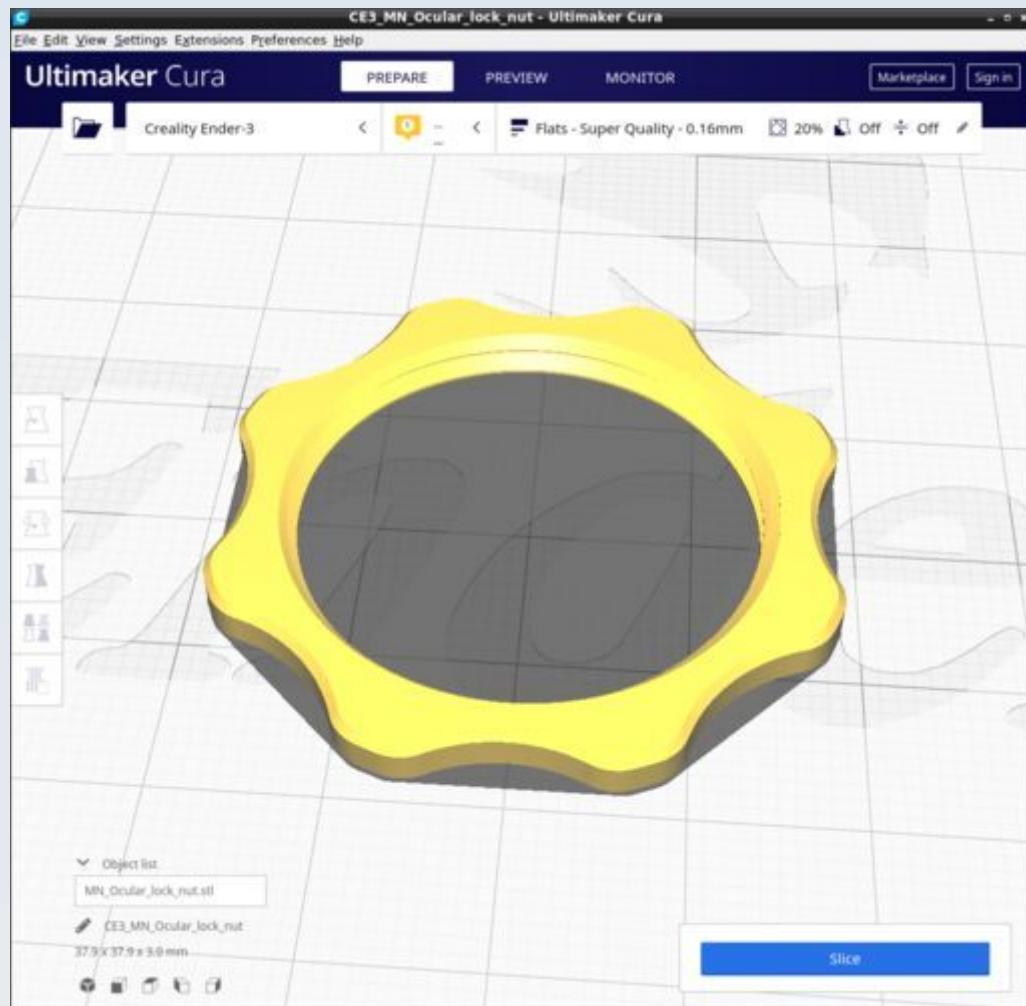
## MN\_Ocular\_extension\_c\_adhesin.stl



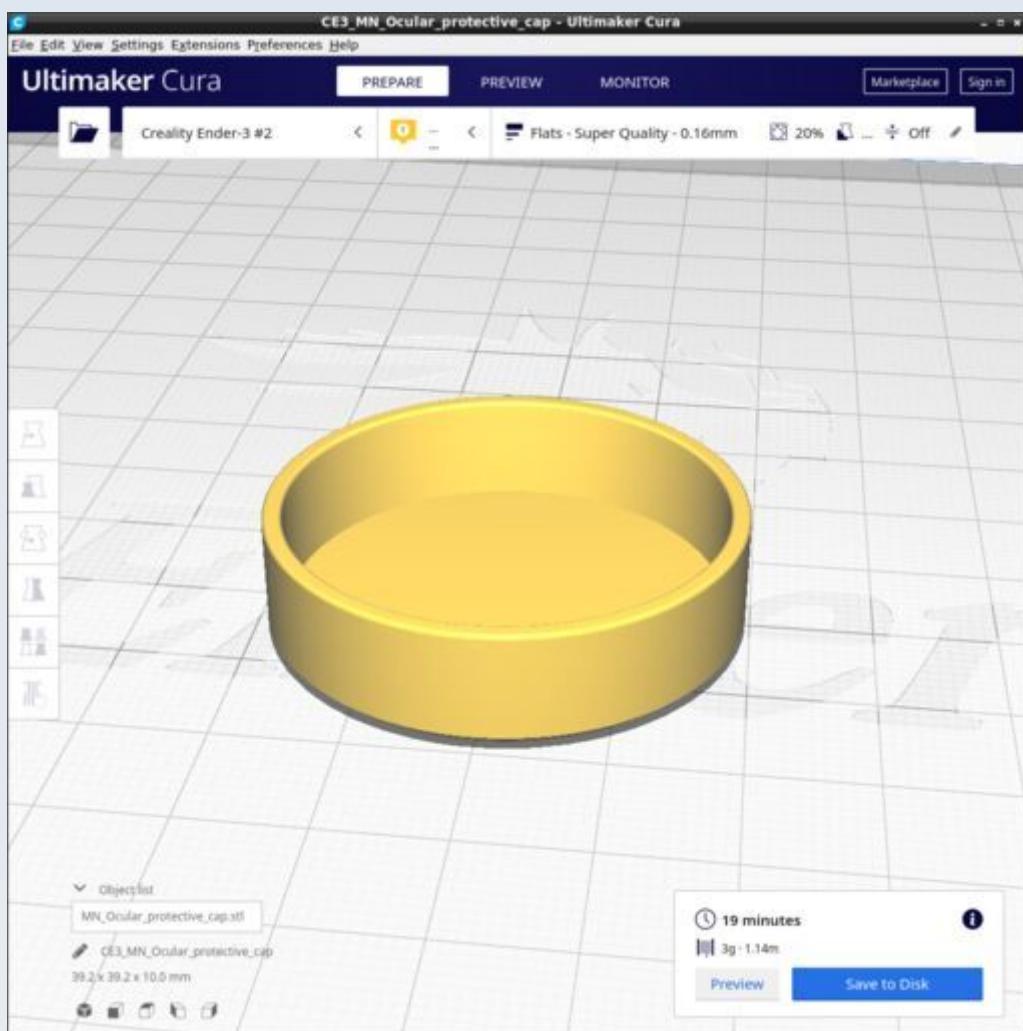
## MN\_Ocular\_extension\_CM\_c\_adhesin.stl



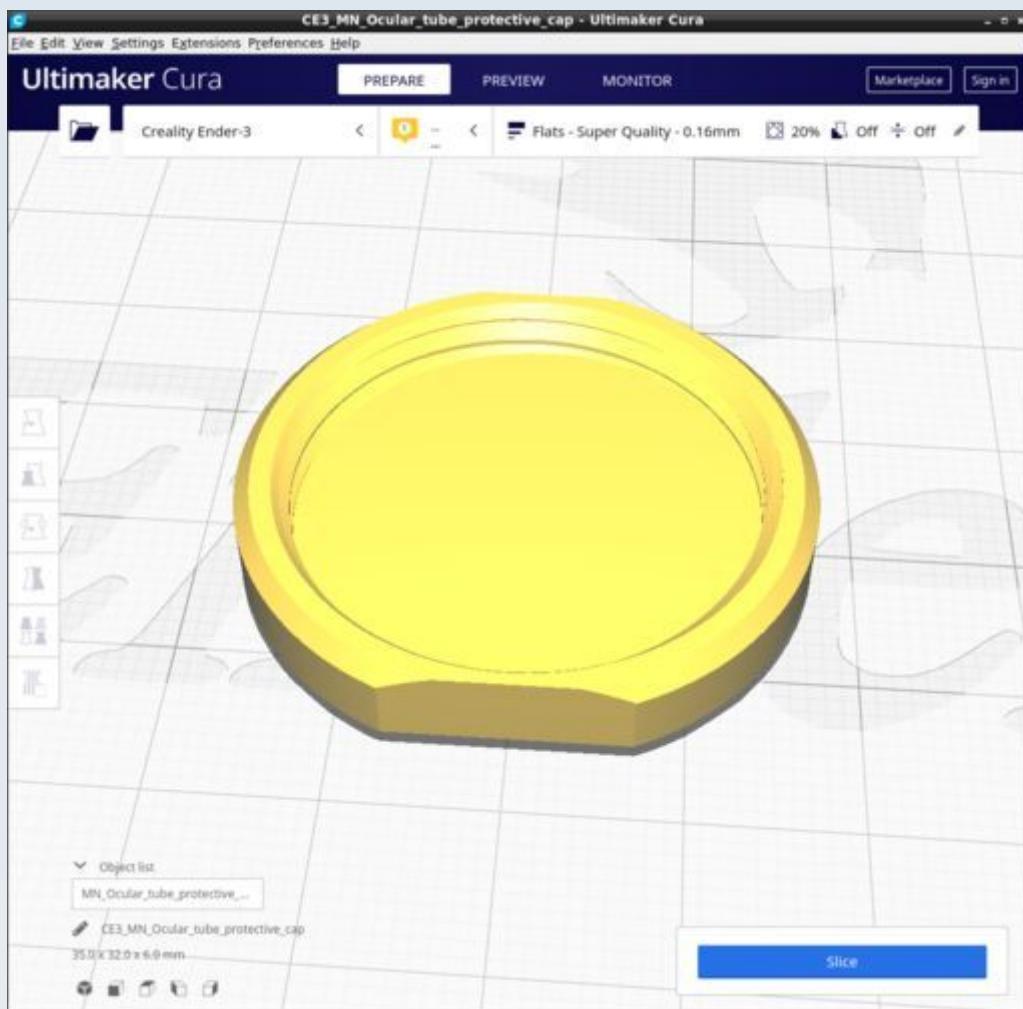
## MN\_Ocular\_lock\_nut.stl



## MN\_Ocular\_protective\_cap.stl



## MN\_Ocular\_tube\_protective\_cap.stl



# PUMA Control Console

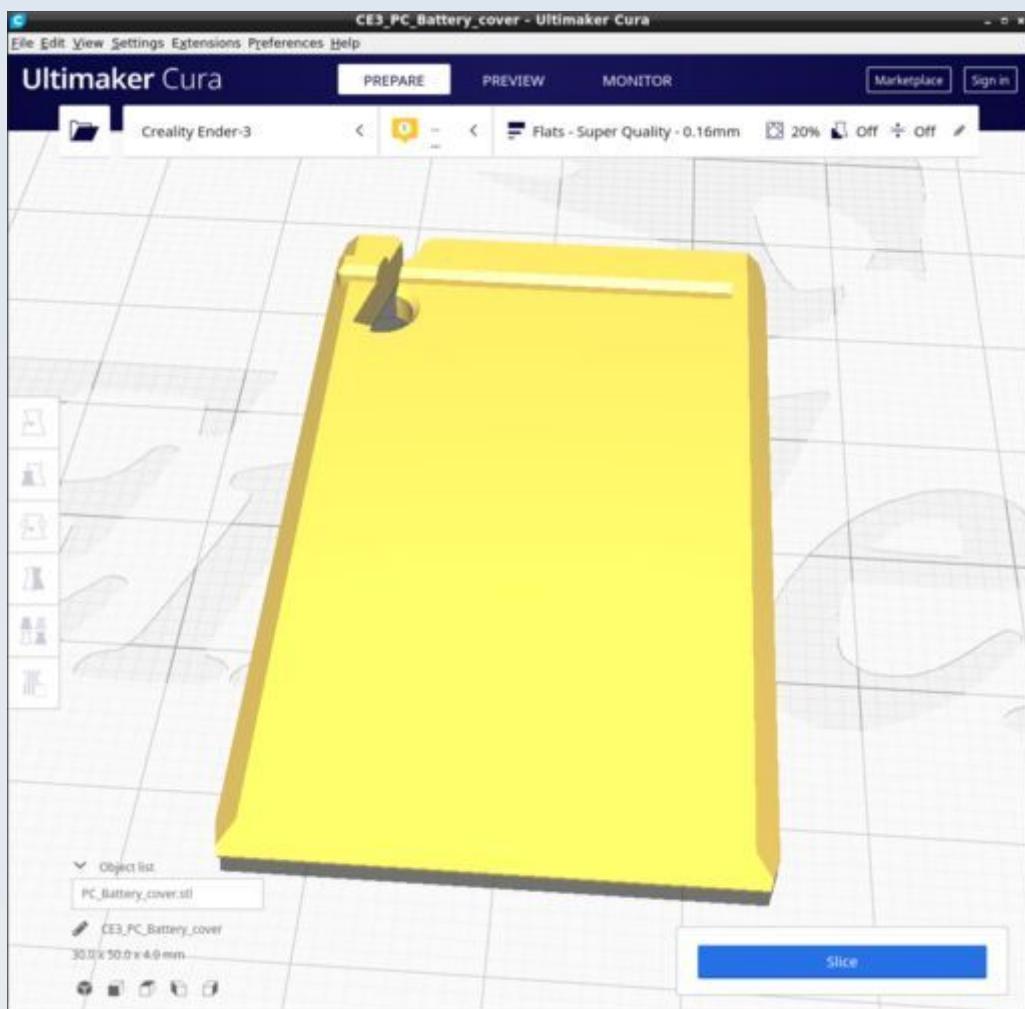
These are the parts for the PUMA Control Console used not only to drive the LED light of the microscope but also allowing control of the Z-stage motor and AR HUD and SLM (either the SLM or the HUD can be driven at any one time – they can't both be driven simultaneously with just one console). The CAD source models for these STL files are found in the file PUMA\_Control.FCStd.

## Resources

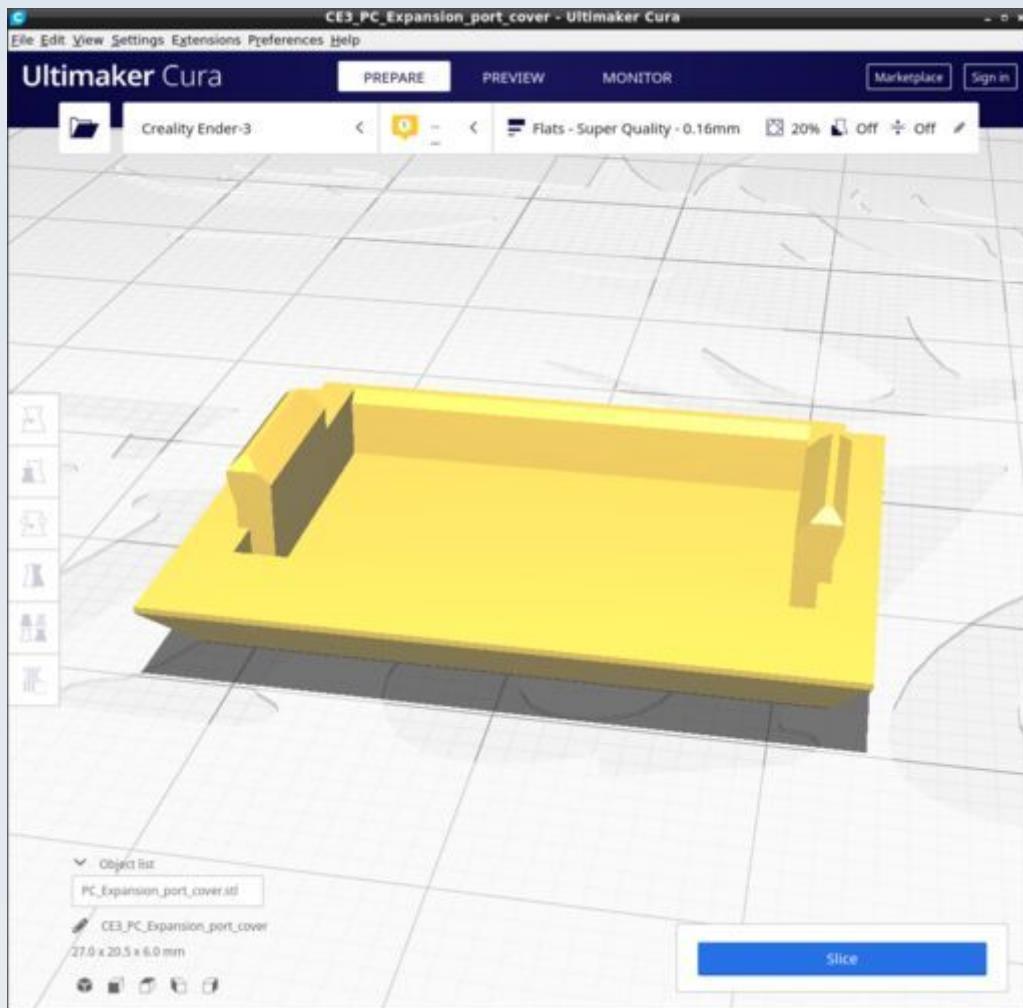
Cura calculates the following resources are required to print each model in this chapter:

PUMA Control Console	Time_Hr	Time_Min	PLA_Length(m)
PC_Battery_cover.stl	0	31	1.44
PC_Expansion_port_cover.stl	0	11	0.37
PC_Front_panel.stl	4	20	7.45
PC_Joystick_PCB_clasp.stl	0	18	0.71
PC_Lamp_insulator.stl	0	1	0.02
PC_Left_panel_Base_Skeleton.stl	12	14	29.02
PC_Top_back_panel.stl	8	51	13.99

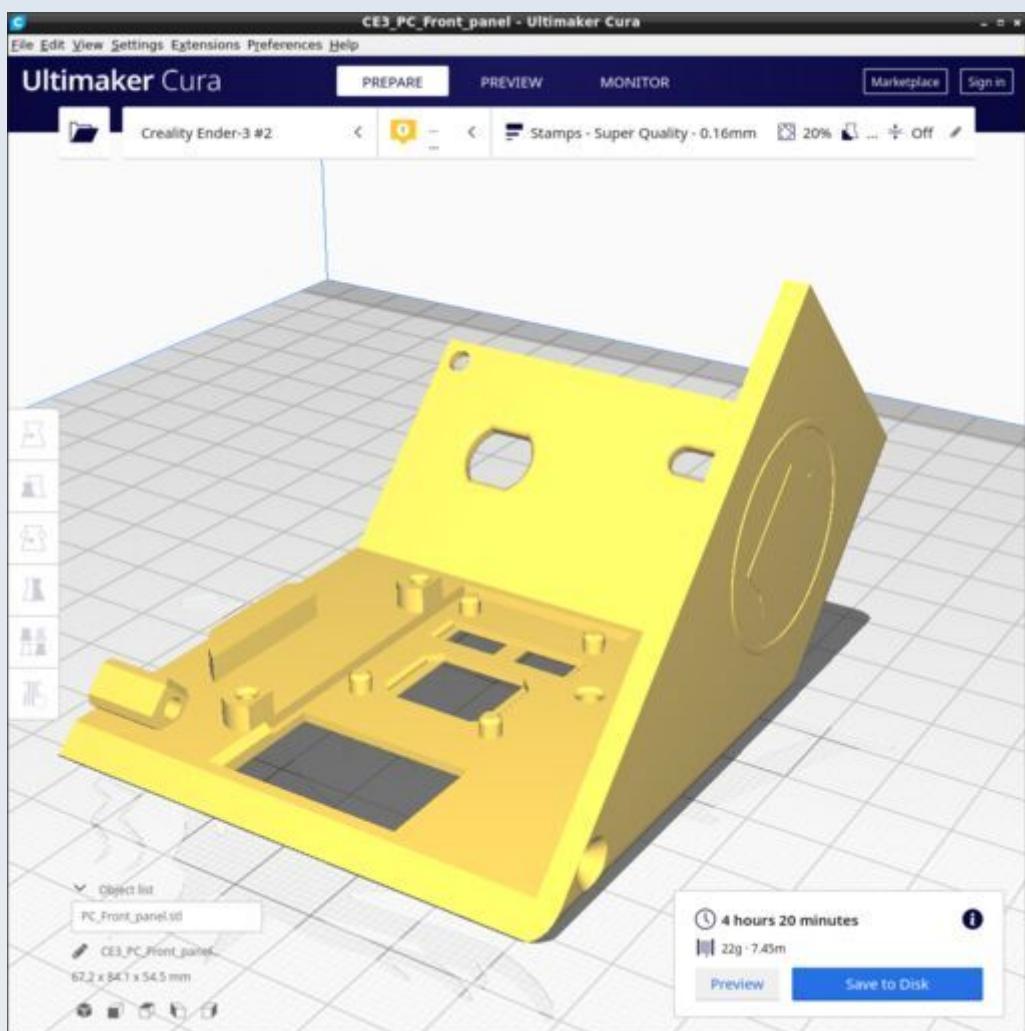
## PC\_Battery\_cover.stl



## PC\_Expansion\_port\_cover.stl

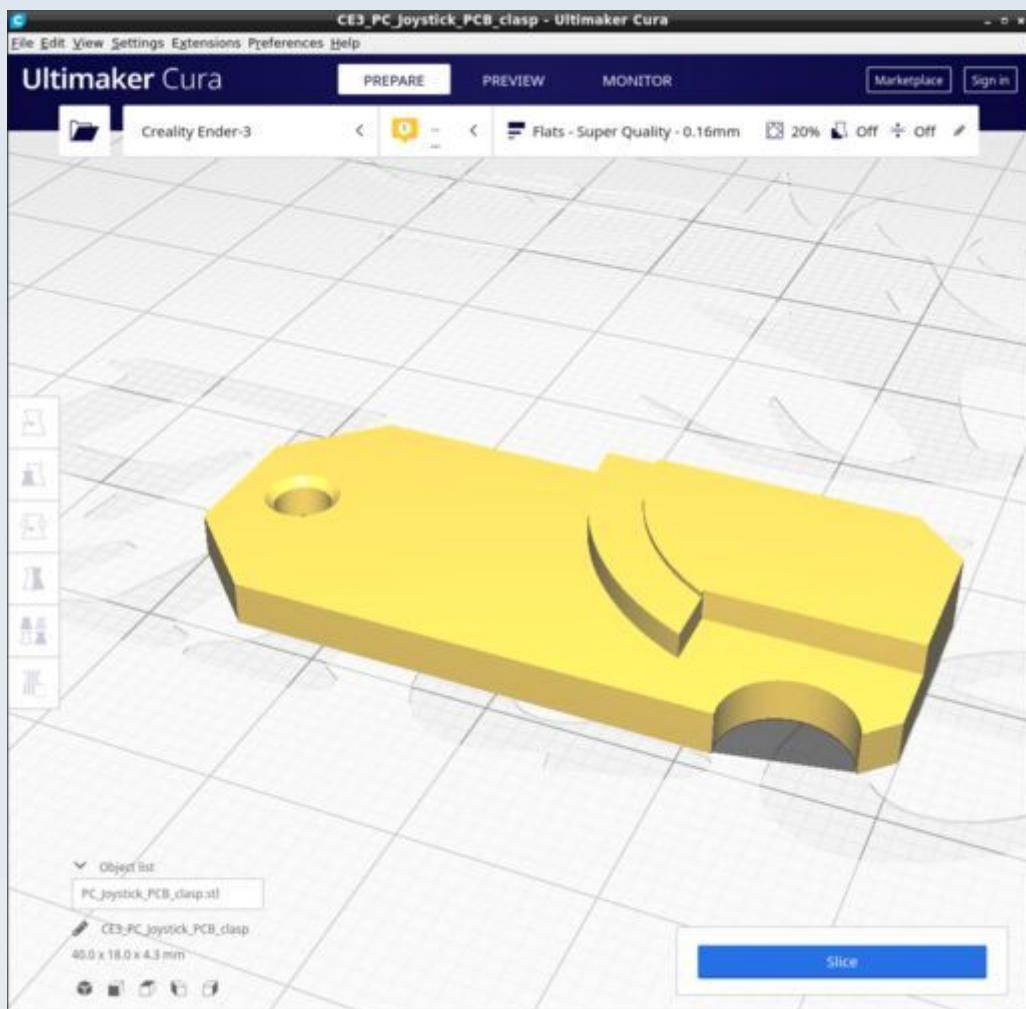


## PC\_Front\_panel.stl

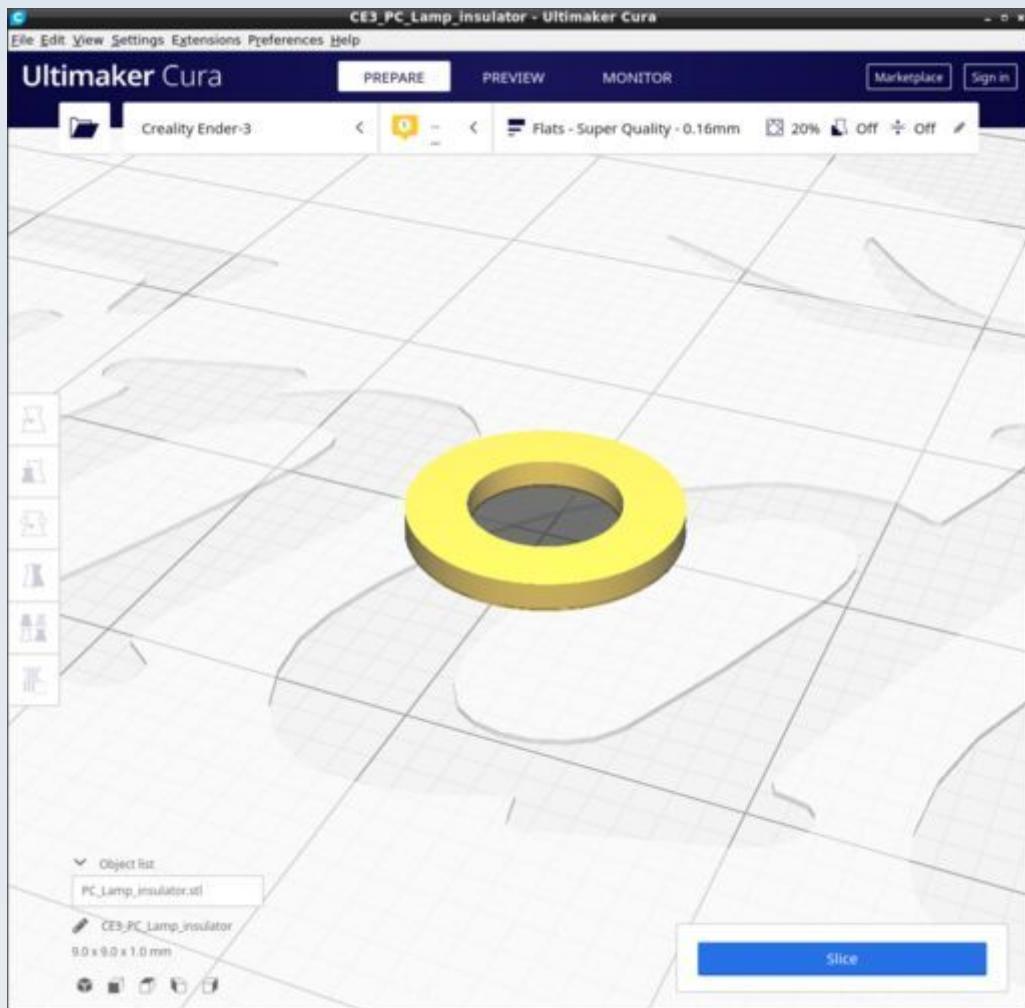


Ensure all supports are disabled.

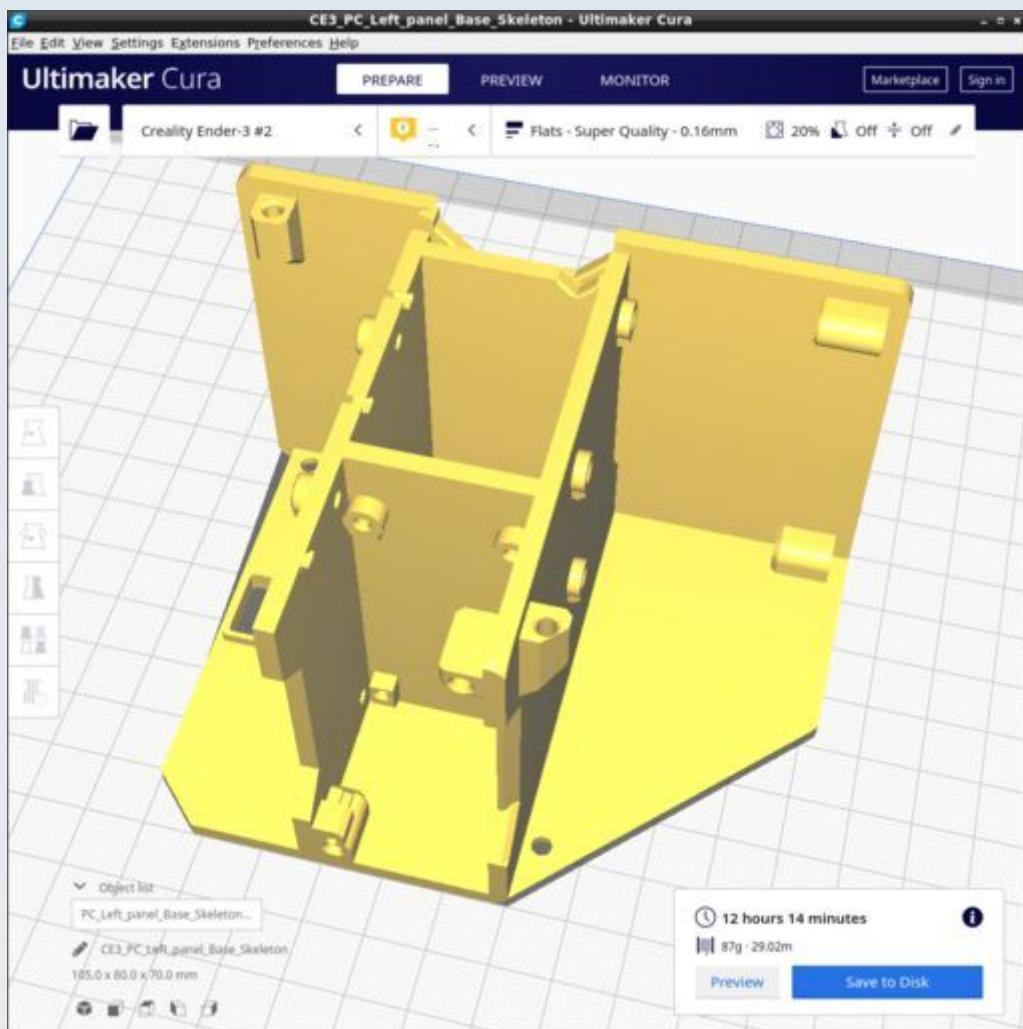
## PC\_Joystick\_PCB\_clasp.stl



## PC\_Lamp\_insulator.stl

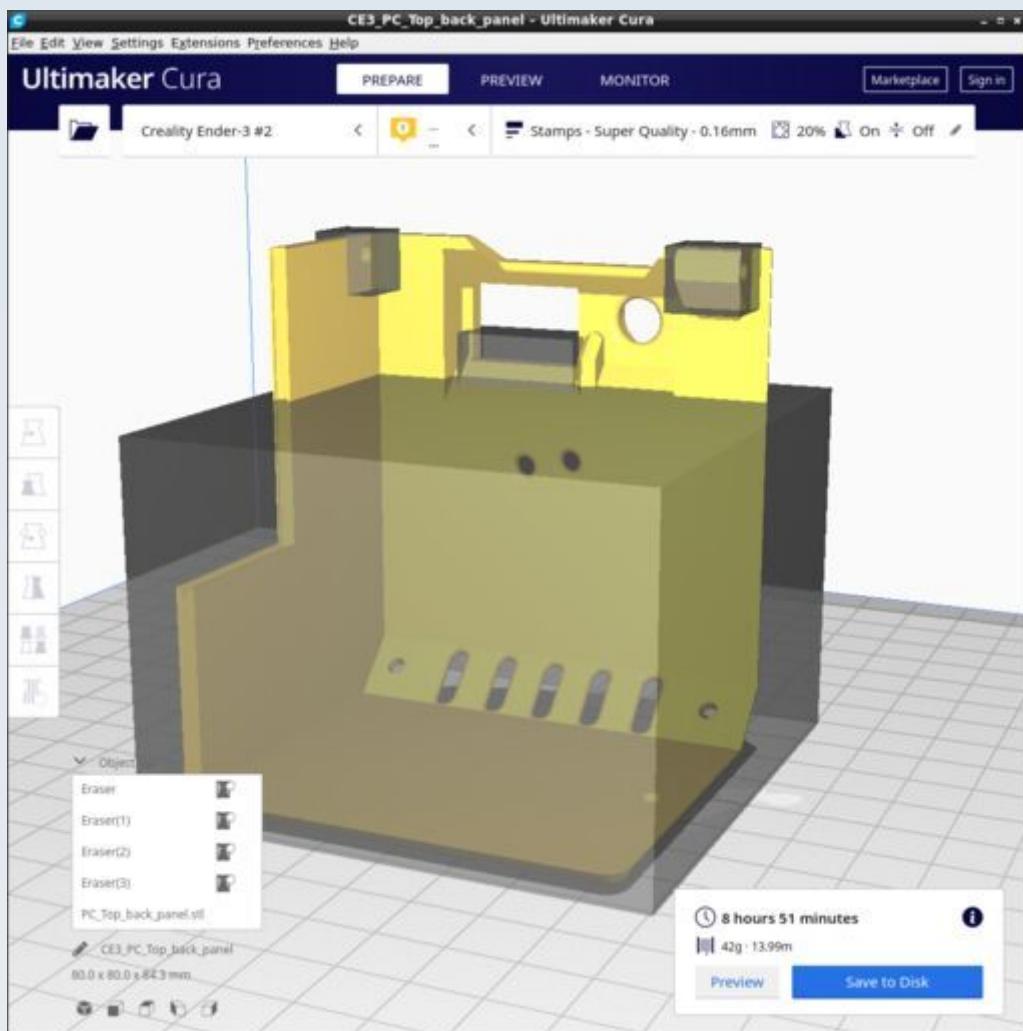


## PC\_Left\_panel\_Base\_Skeleton.stl

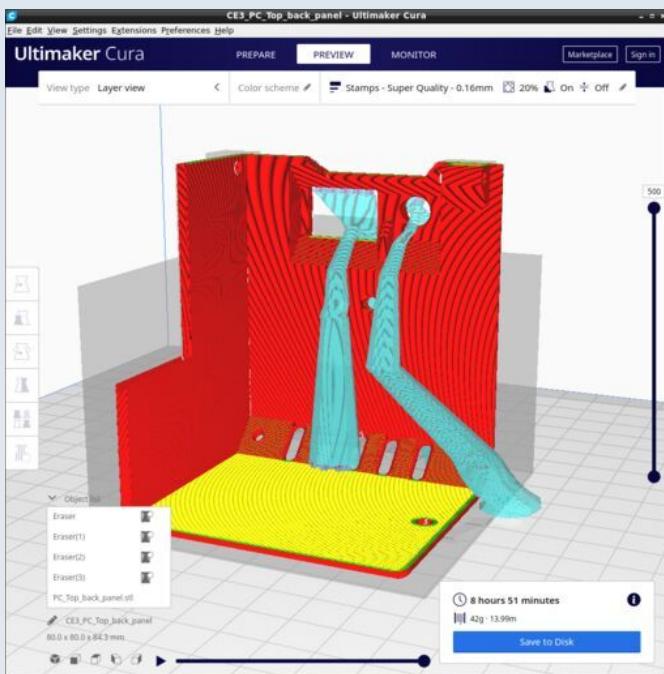


Ensure all supports are disabled.

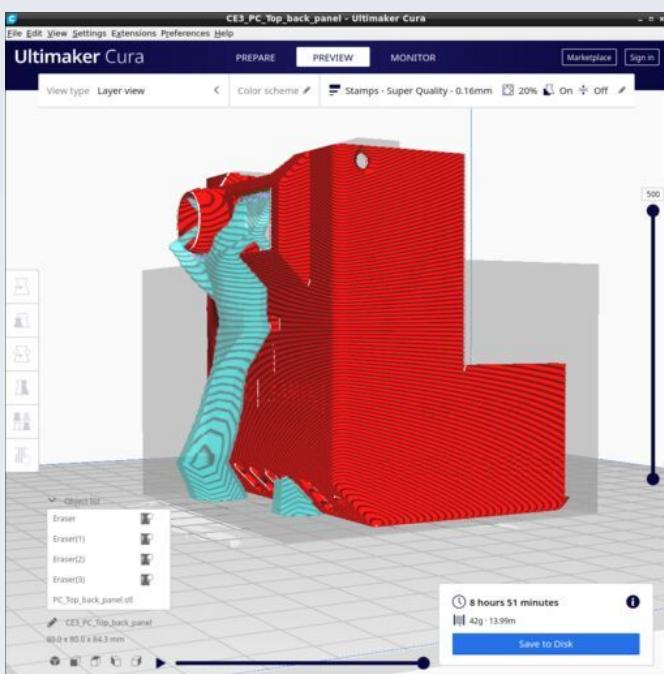
## PC\_Top\_back\_panel.stl



Use a support blocker for everything except the back protrusion, just stopping at the internal beginning of the ON/OFF switch hole as shown.



Then generate tree supports for those areas that are not blocked using 67 degree overhang and tree branch angle of 50 degrees:



Note that the support blocker stops the support tree touching the text on the protruding part of the back panel. This is fine, the text doesn't need support even though Cura's algorithm thinks it does.

## PUMA Lite

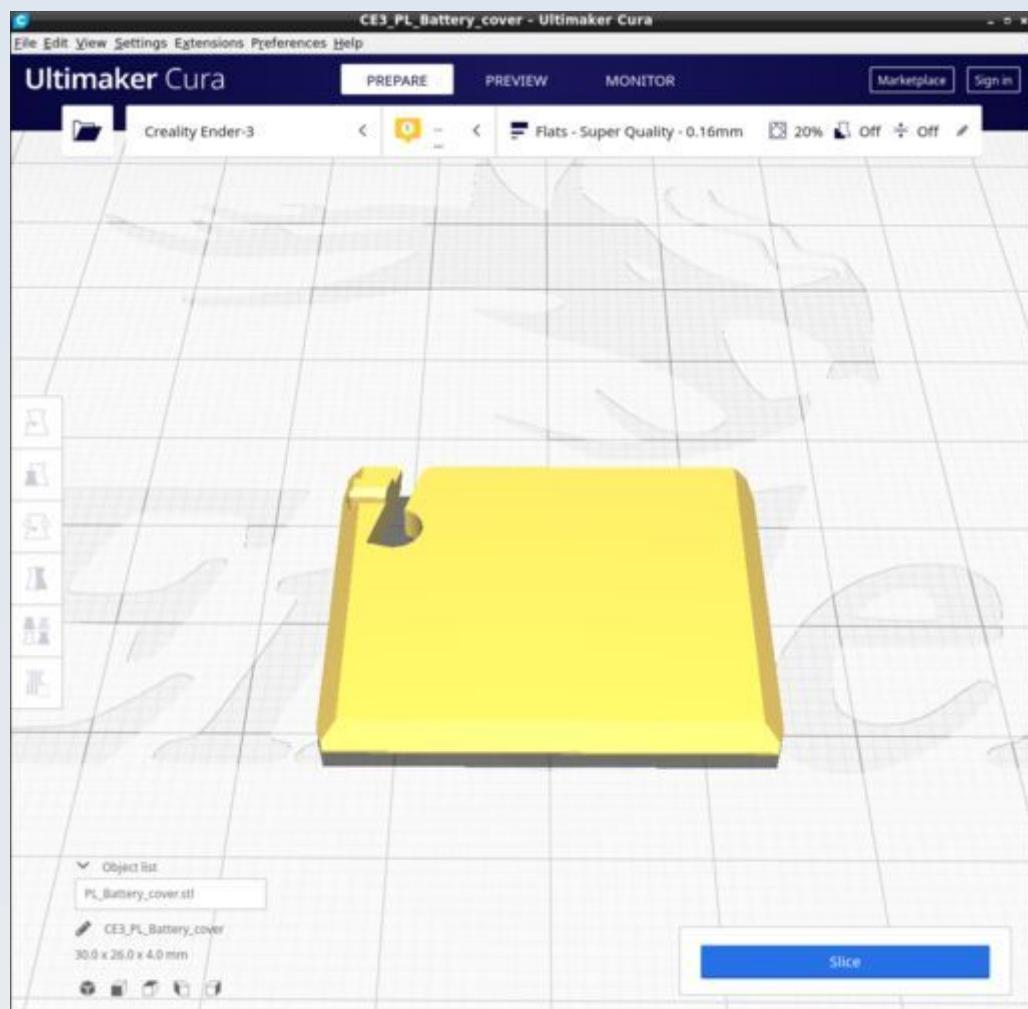
These are the parts for the simple control box use to drive the LED light source of the microscope (but provides no other functions). The CAD source models for these STL files are found in the file PUMALite.FCStd.

## Resources

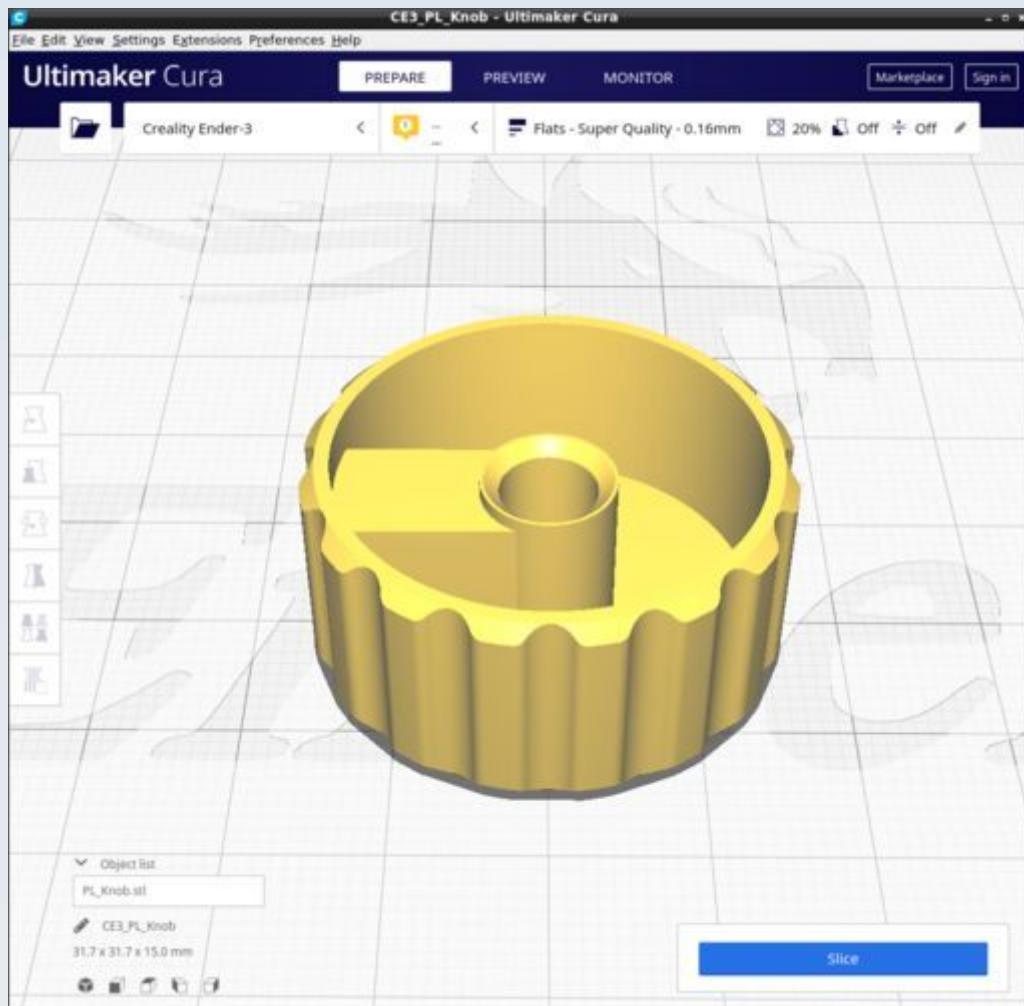
Cura calculates the following resources are required to print each model in this chapter:

PUMA_Lite	Time_Hr	Time_Min	PLA_Length(m)
PL_Battery_cover.stl	0	17	0.72
PL_Knob.stl	1	22	1.77
PL_Lamp_insulator.stl	0	1	0.02
PL_Left_Base_Back.stl	8	35	13.52
PL_Top_Front_Right.stl	3	55	7.11

## PL\_Battery\_cover.stl



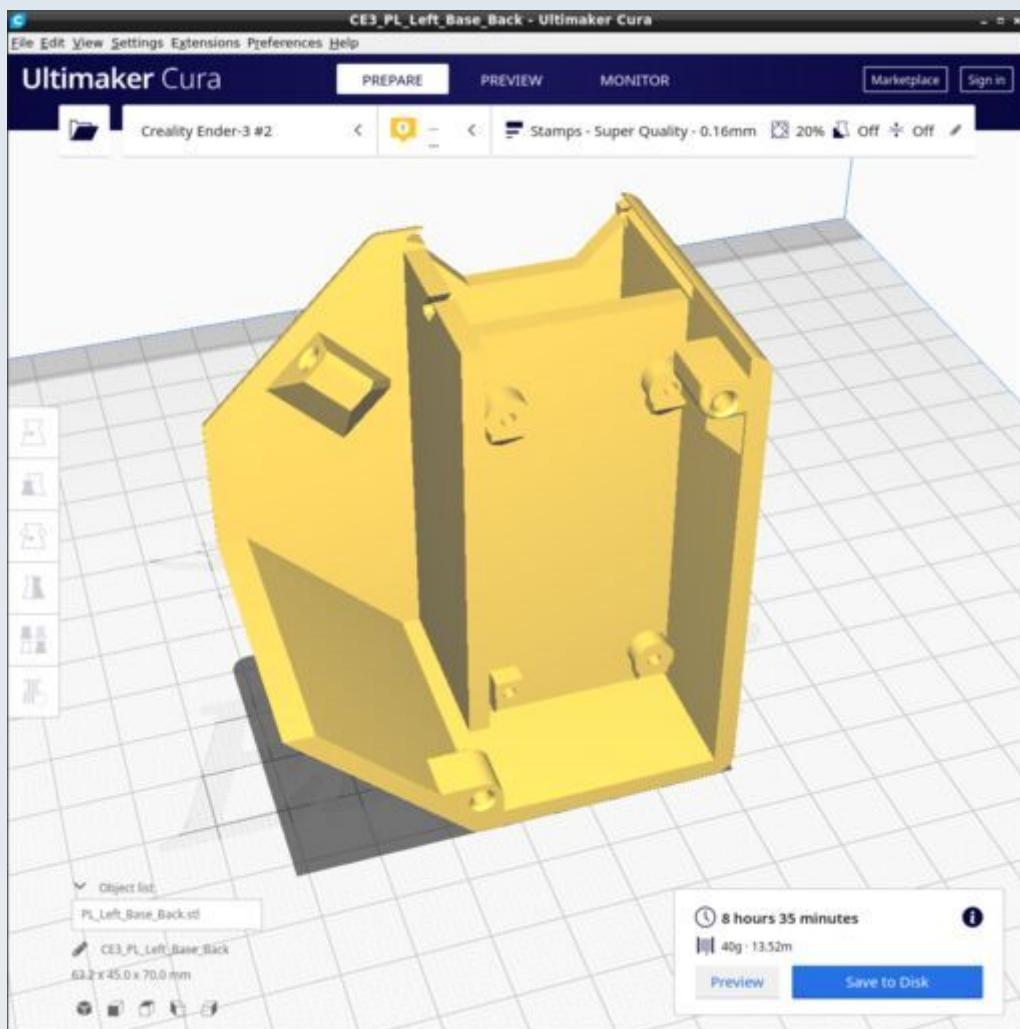
## **PL\_Knob.stl**



## **PL\_Lamp\_insulator.stl**

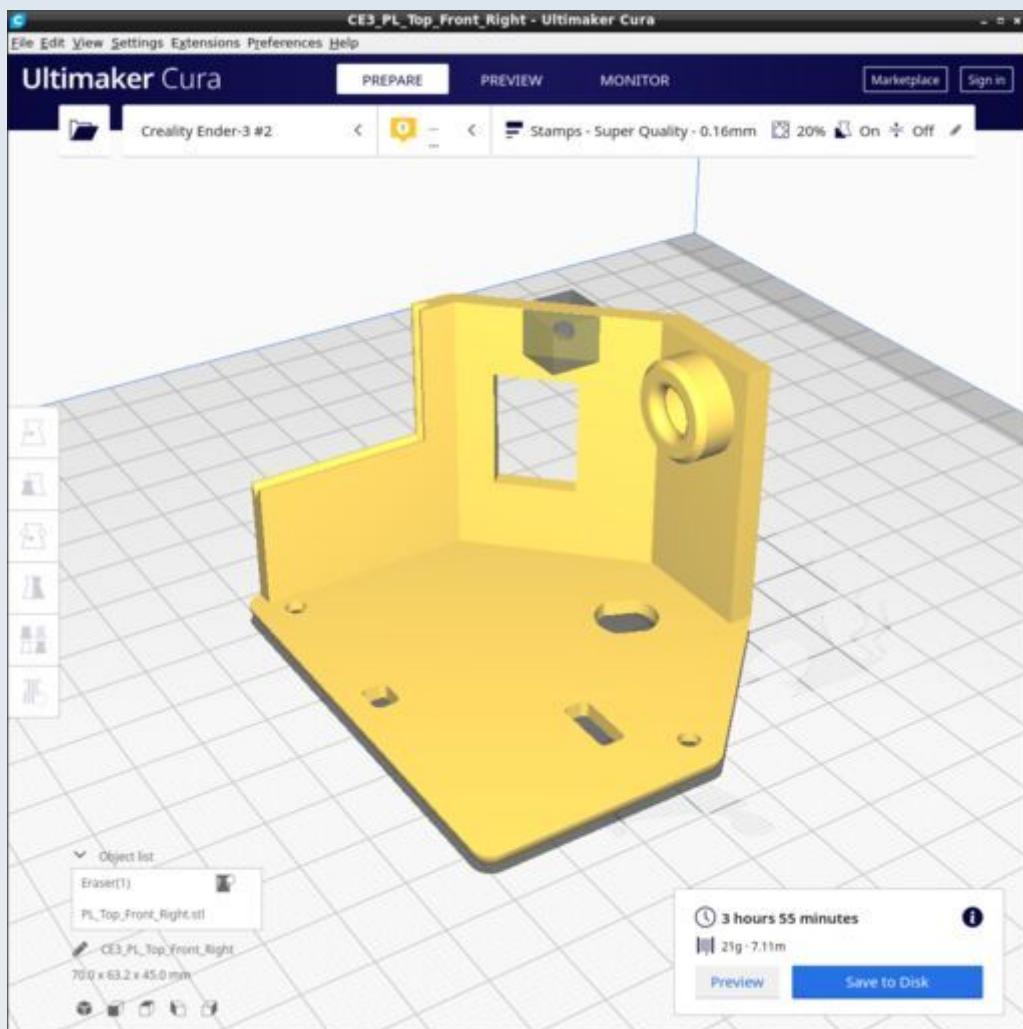
This is identical to the PC\_Lamp\_insulator of the PUMA Control Console (which see).

## PL\_Left\_Base\_Back.stl

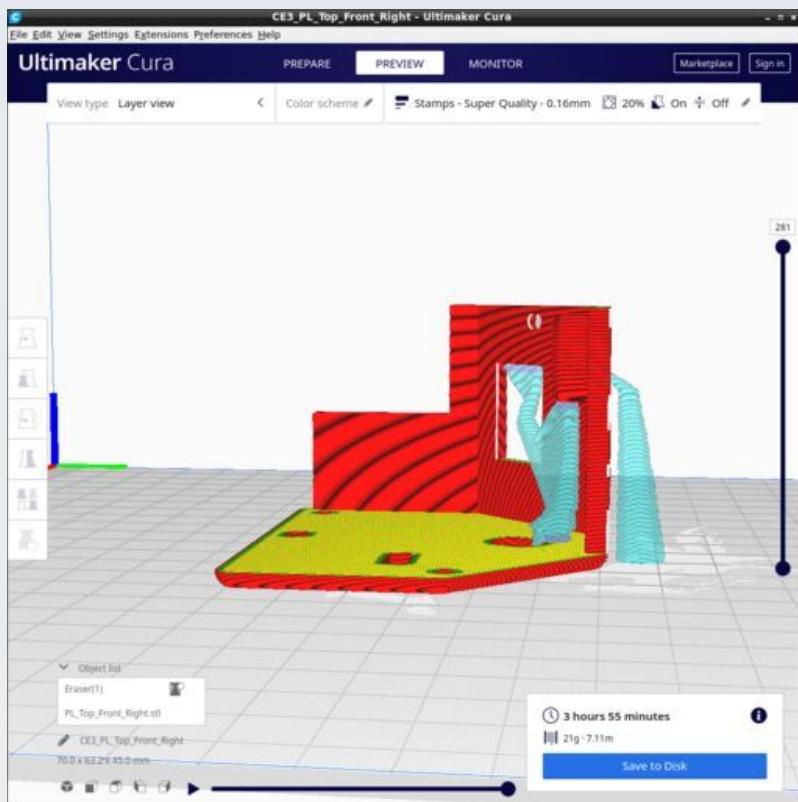
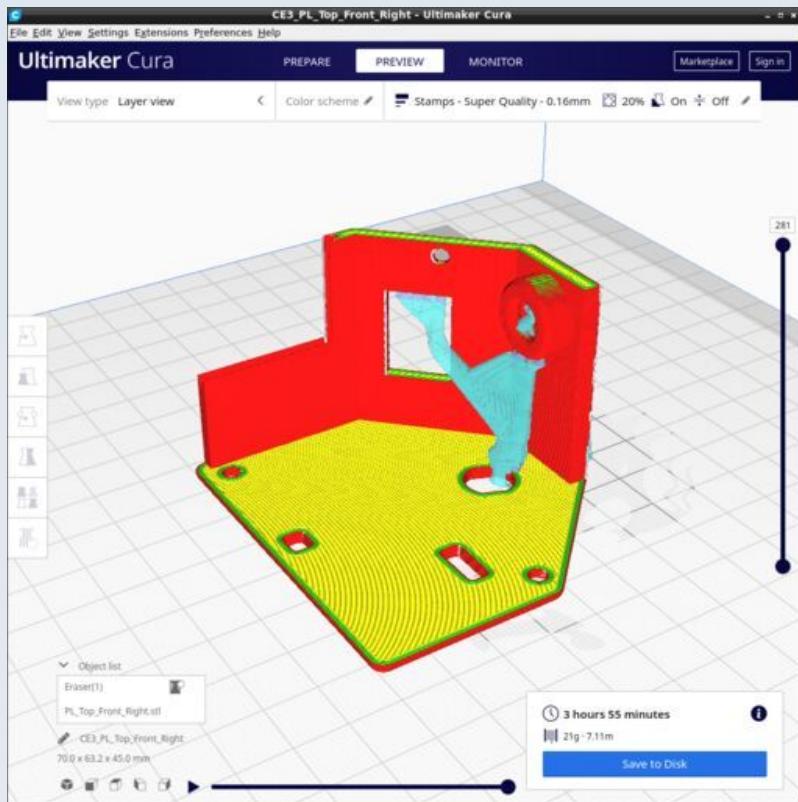


Ensure supports are disabled. Print with the PUMA custom Cura profile 'Stamps'

## PL\_Top\_Front\_Right.stl



Use tree supports with support blocker to prevent the screw hole being supported - as shown in the figure. Support 'everywhere' with overhang 67 degree and tree support branch angle 50 degrees.



# Quick Release Objective Holder

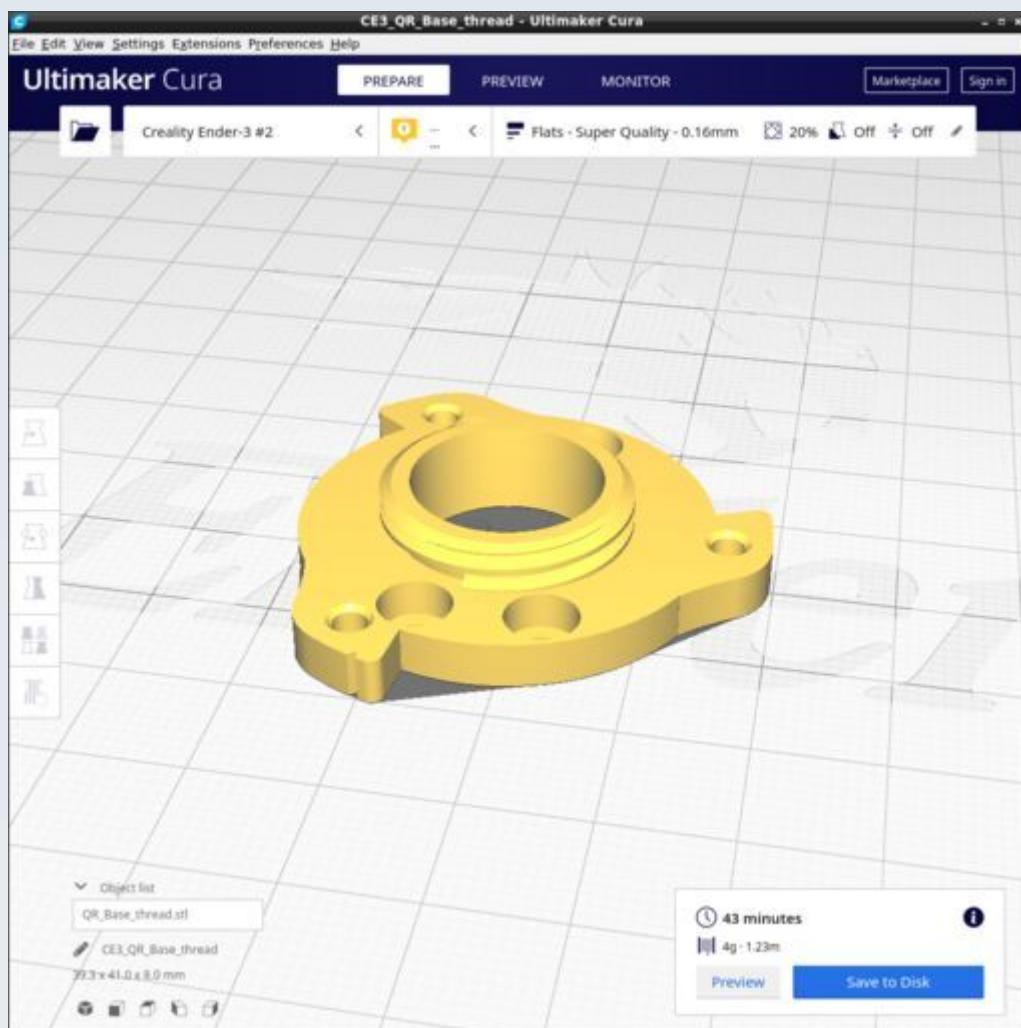
These are the parts for the objective holder that fits onto the focus platform of the microscope stage via a quick-release mechanism. The CAD source models for these STL files are found in the file QuickRelease\_v2.0.FCStd.

## Resources

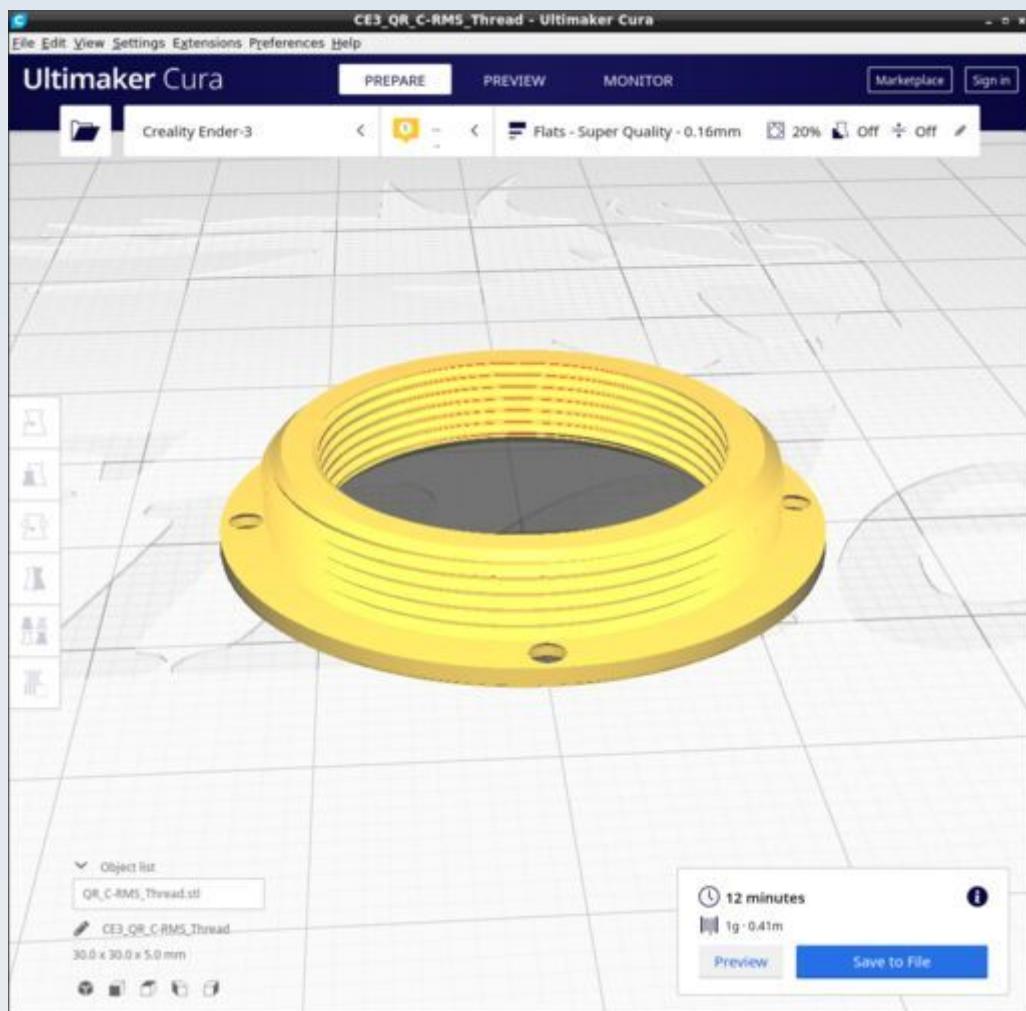
Cura calculates the following resources are required to print each model in this chapter:

Quick Release Objective Holder	Time_Hr	Time_Min	PLA_Length(m)
QR_Base_thread.stl	0	43	1.23
QR_C-RMS_Thread.stl	0	12	0.41
QR_Male_C_extn_1mm.stl	1	30	2.47
QR_Male_C_extn_4mm.stl	1	42	2.82
QR_Trainer.stl	1	8	2.5
QR_Trainer_Male.stl	1	25	2.96

## QR\_Base\_thread.stl



## QR\_C-RMS\_Thread.stl

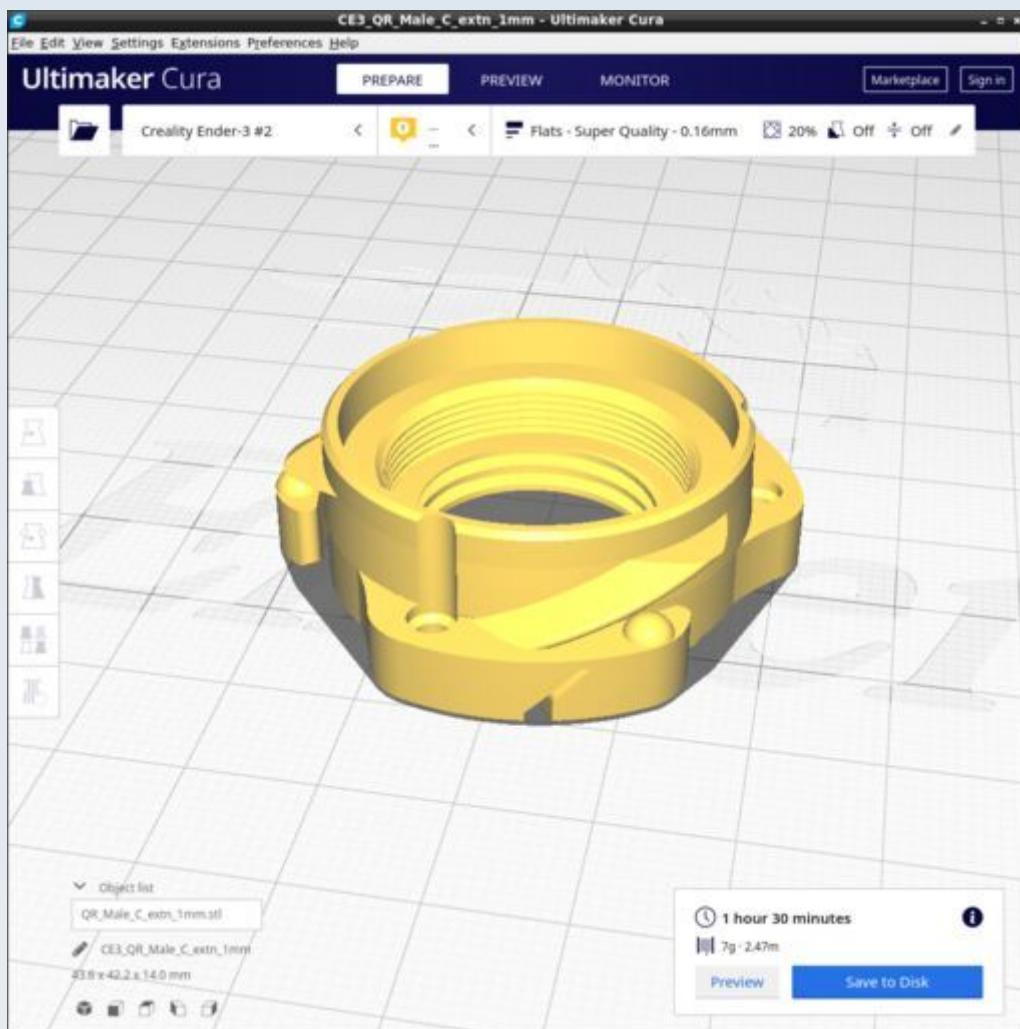


This thread adapter was designed to conform to measurements of similar adapters that are commercially available and made of metal. Thus you can replace the metal adapter if you want all-metal threads (which are easier to align with your objective and harder to cross-thread and destroy and wear out).

If using this 3D printed plastic version, the female RMS thread will require training with a metal RMS male thread (such as on an objective lens). Great care is required not to cross the 3D printed plastic thread and damage it at all times but especially during training.

The male C thread is best trained on a metal C thread such as may be found on a C/CS thread extender ring.

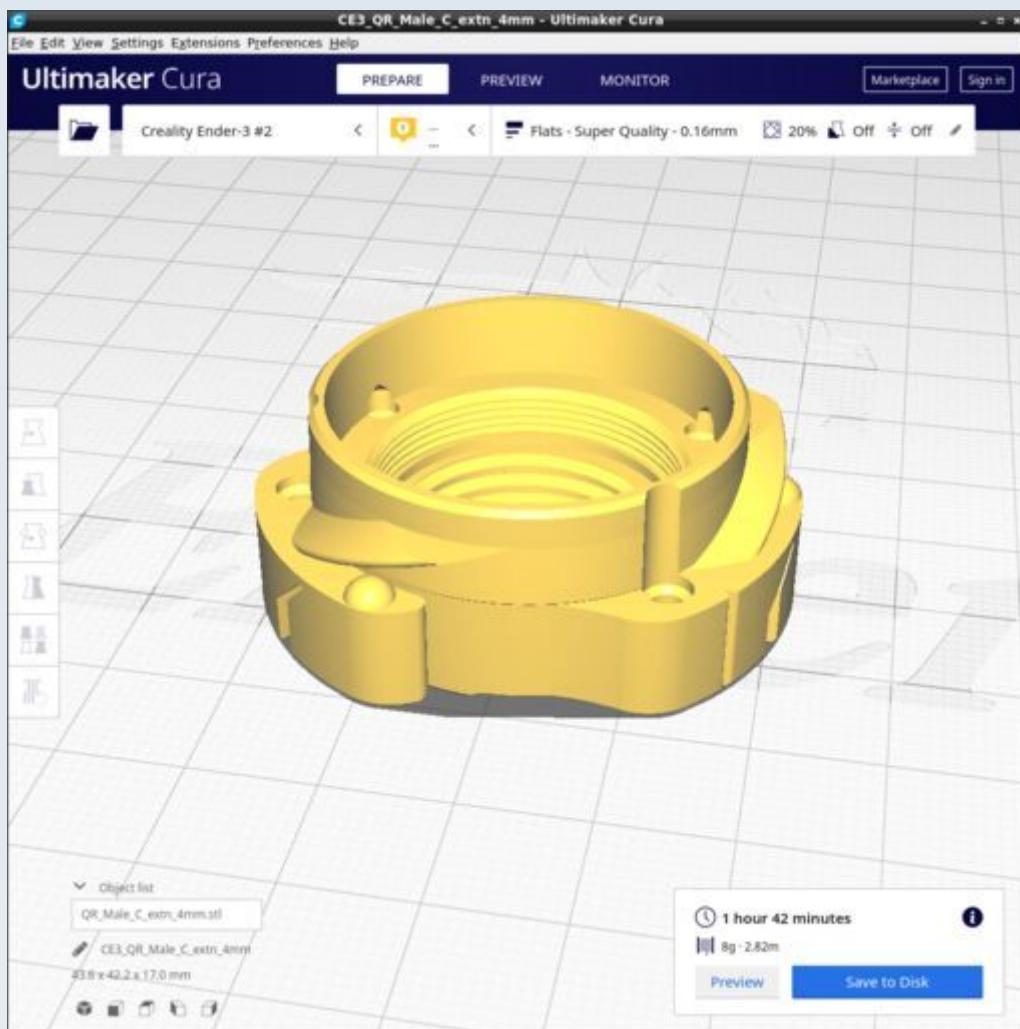
## QR\_Male\_C\_extn\_1mm.stl



The female C thread is best trained on a metal C thread such as may be found on a C-mount lens or C/CS thread extender adapter ring. Great care is required to avoid crossing the 3D printed plastic thread and thereby damaging or destroying it.

The outer quick-release male tri-helix thread should be trained using the QR\_Trainer 3D printed tool (see below).

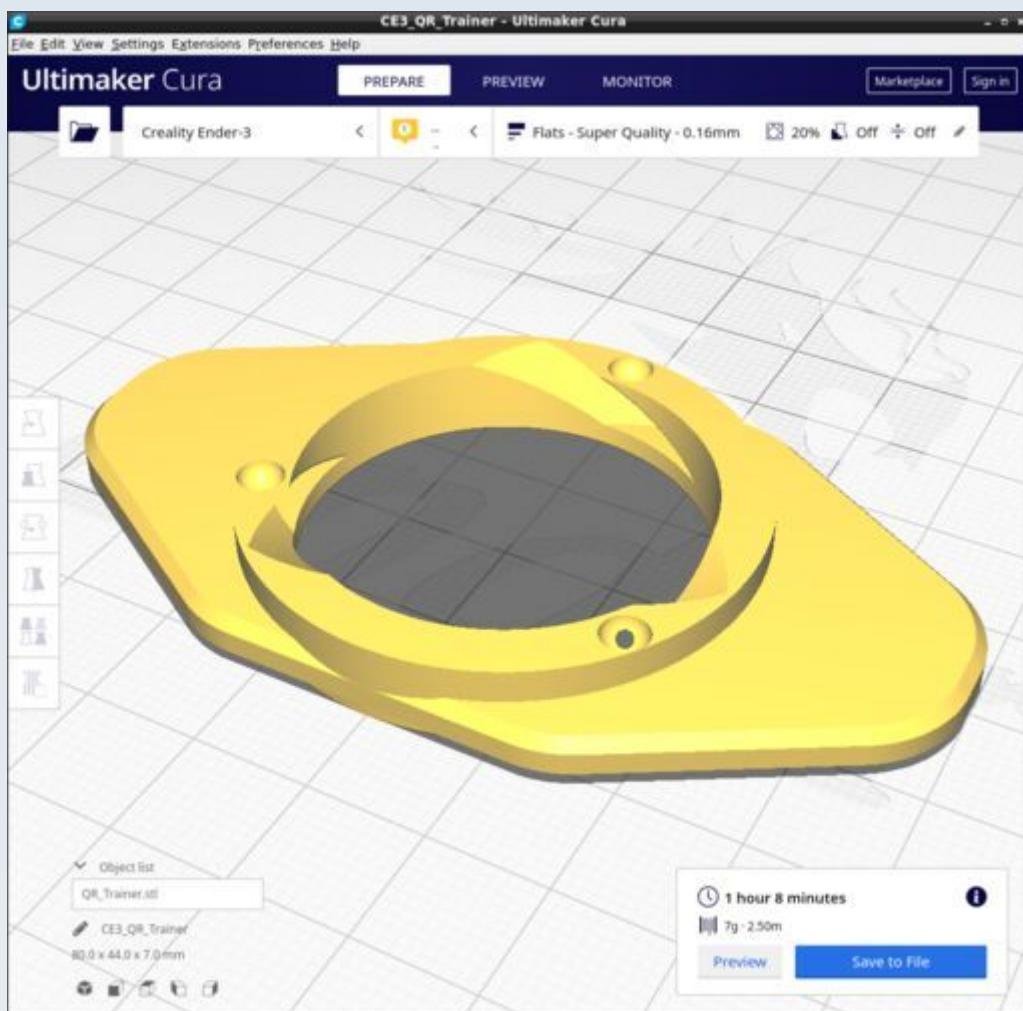
## QR\_Male\_C\_extn\_4mm.stl



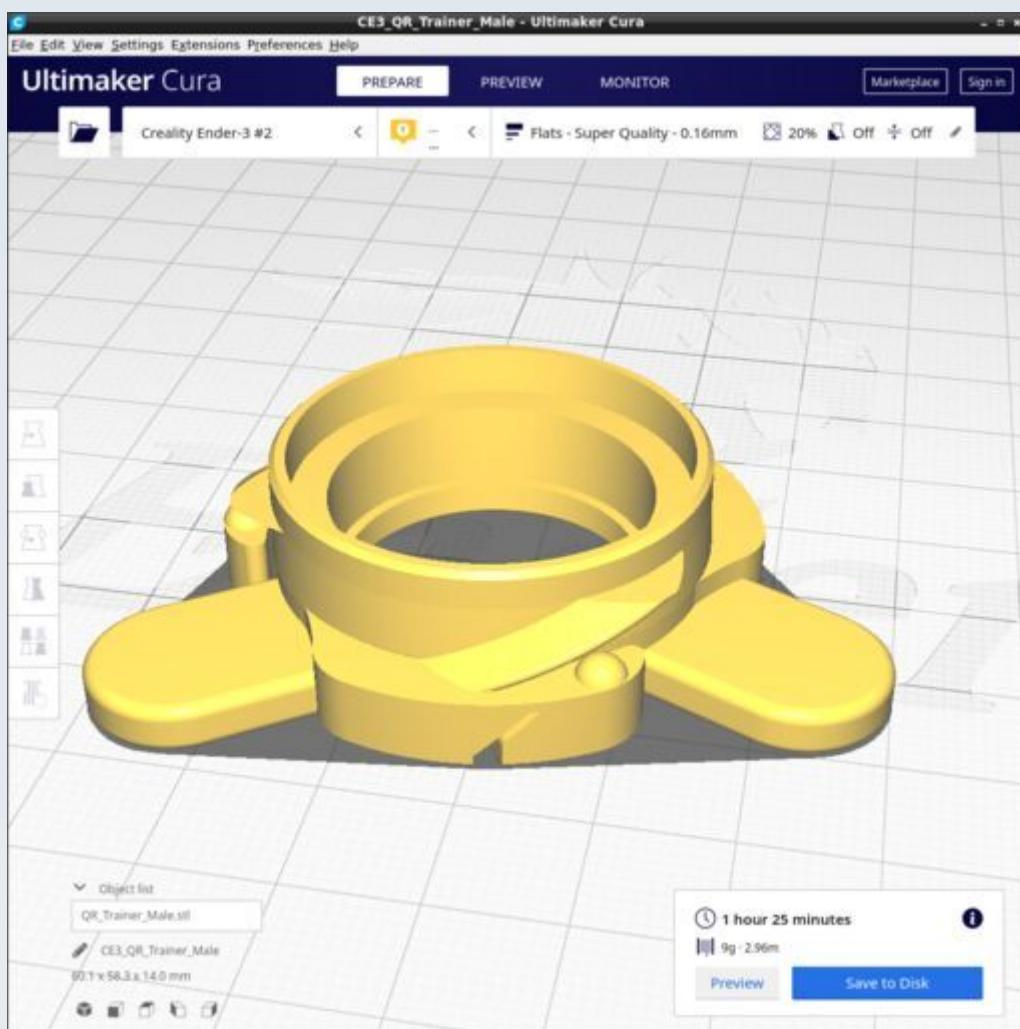
The female C thread is best trained on a metal C thread such as may be found on a C-mount lens or C/CS thread extender adapter ring. Great care is required to avoid crossing the 3D printed plastic thread and thereby damaging or destroying it.

The outer quick-release male tri-helix thread should be trained using the QR\_Trainer 3D printed tool (see below).

## QR\_Trainer.stl



## QR\_Trainer\_Male.stl



## Stage

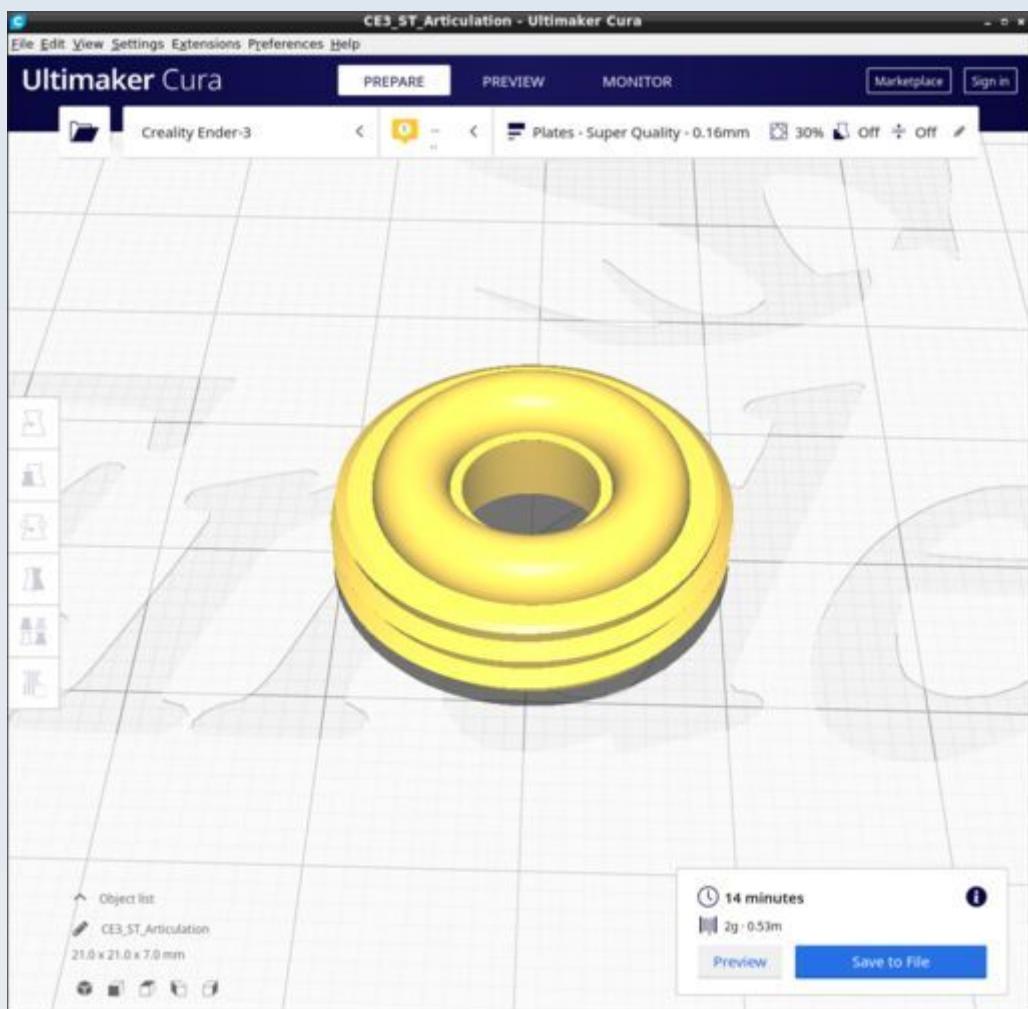
These are the parts for the main stage base plate and focus platform of the microscope. The CAD source models for these STL files are found in the file Stage.FCStd.

## Resources

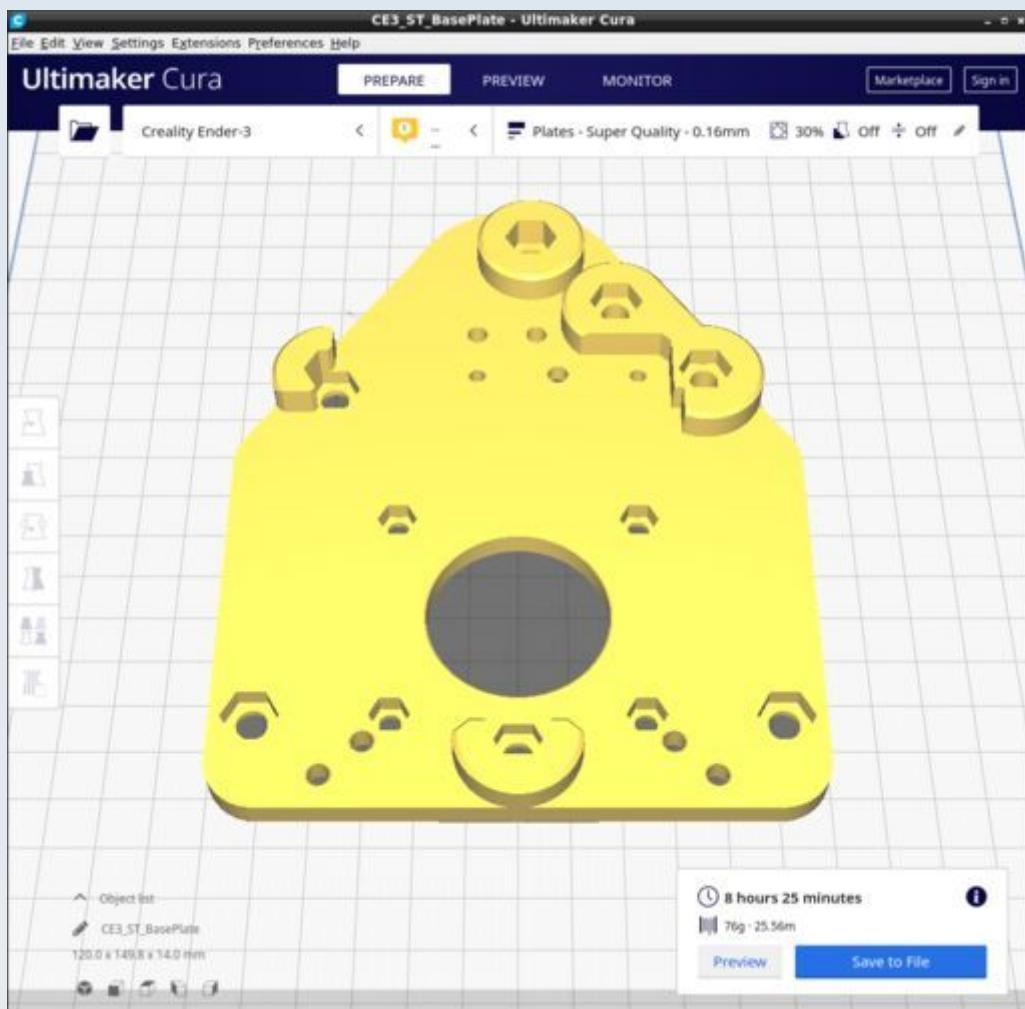
Cura calculates the following resources are required to print each model in this chapter:

Stage	Time_Hr	Time_Min	PLA_Length(m)
ST_Articulation.stl	0	14	0.53
ST_BasePlate.stl	8	25	25.56
ST_FocusPlate.stl	4	8	11.22

## ST\_Articulation.stl

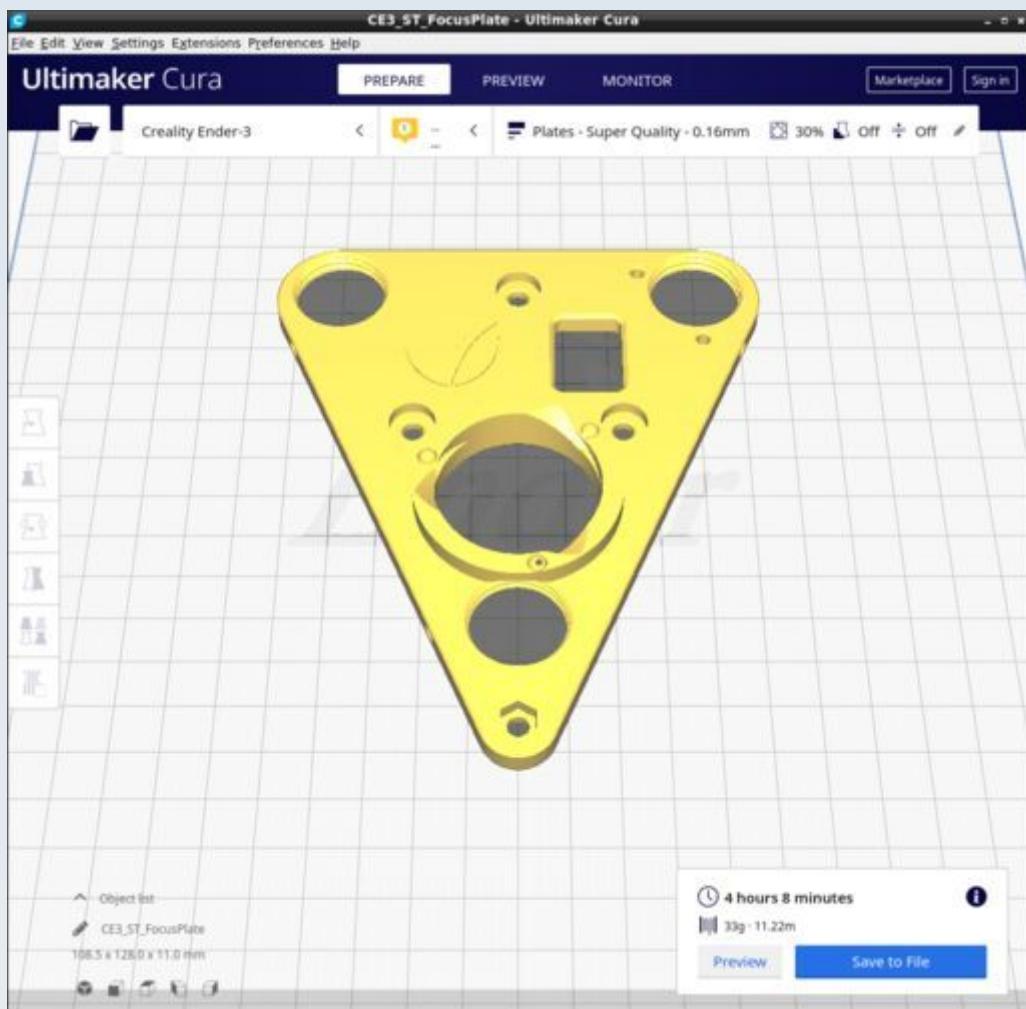


## ST\_BasePlate.stl



Print with the 'Plates' custom Cura profile.

## ST\_FocusPlate.stl



Print with the 'Plates' custom Cura profile.

## Trinocular Camera Port

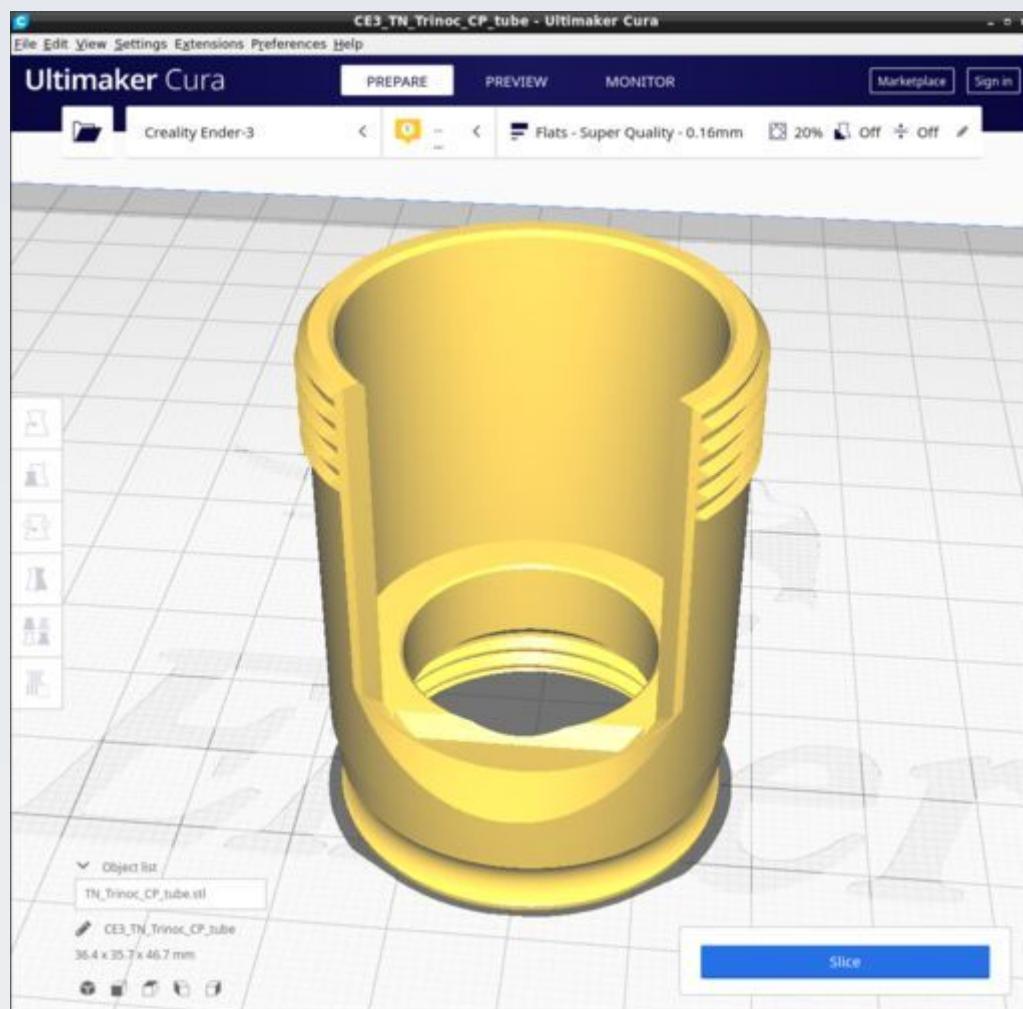
This is the part for the trinocular extension that attaches to the advanced filter block and allows a third eyepiece and / or a camera to be attached (in addition to any cameras or eyepieces that may be attached to the main viewing oculars in the ocular head). The CAD source models for these STL files are found in the file Trinocular\_CP\_v1.FCStd.

## Resources

Cura calculates the following resources are required to print each model in this chapter:

Trinocular_Camera_Port	Time_Hr	Time_Min	PLA_Length(m)
TN_Trinoc_CP_tube.stl	2	5	4.37

## TN\_Trinoc\_CP\_tube.stl



## XY Stabiliser

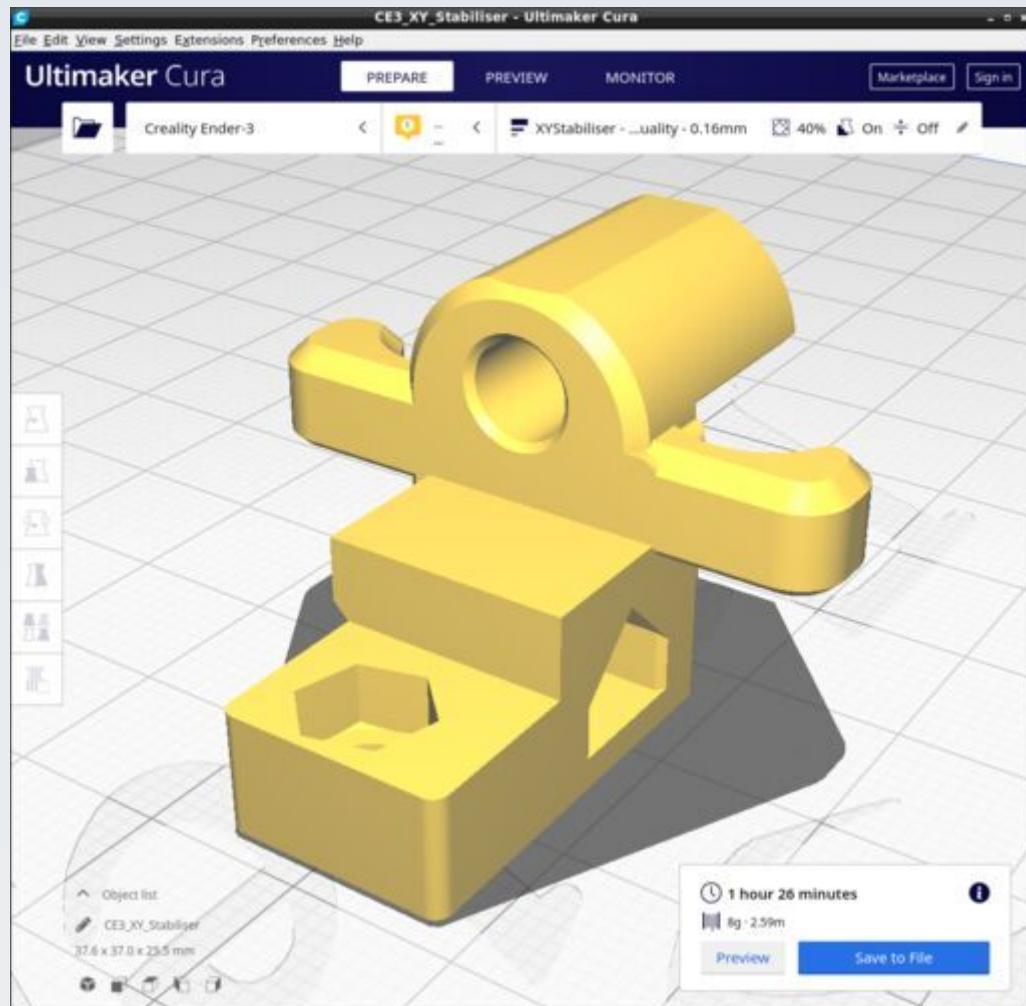
This is the part for an optional mechanism to make the standard XY mechanical stage calipers more stable in their motion. The CAD source models for this STL file is found in the file XY\_Stabiliser.FCStd.

## Resources

Cura calculates the following resources are required to print each model in this chapter:

XY_Stabiliser	Time_Hr	Time_Min	PLA_Length(m)
XY_Stabiliser.stl	1	26	2.59

## XY\_Stabiliser.stl



Print with the 'XYStabiliser' custom Cura profile.

## Z-Motor

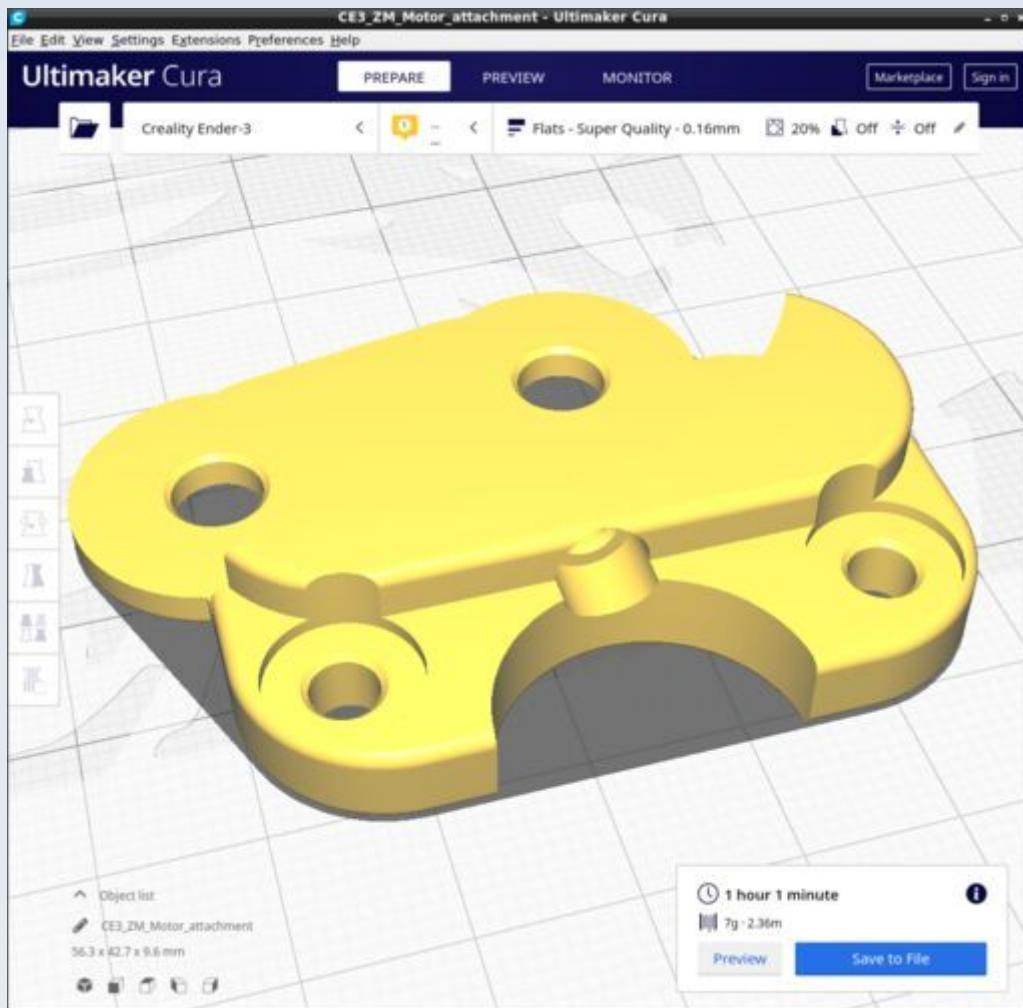
These are the parts for adding a Z-motor to the stage. The CAD source models for these STL files are found in the file Z\_Motor.FCStd.

## Resources

Cura calculates the following resources are required to print each model in this chapter:

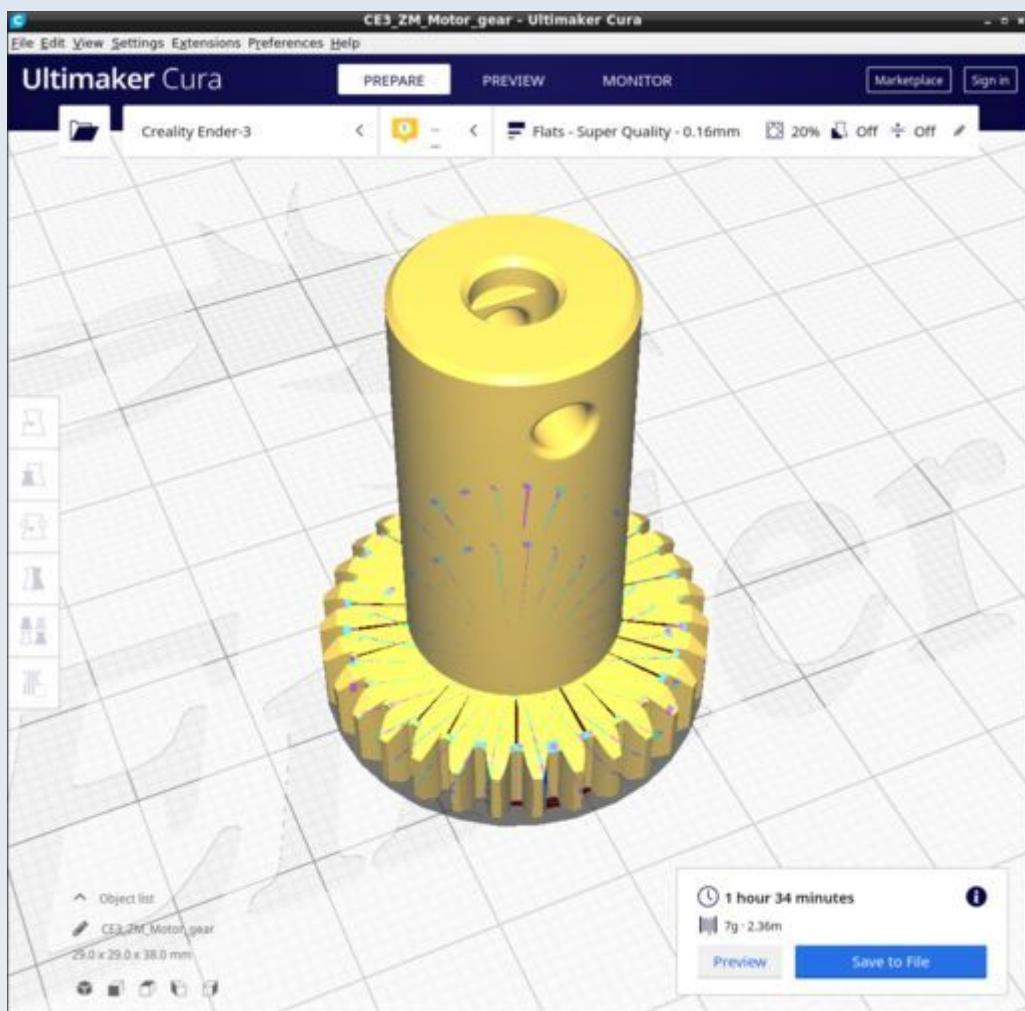
Z-Motor	Time_Hr	Time_Min	PLA_Length(m)
ZM_Motor_attachment.stl	1	1	2.36
ZM_Motor_gear.stl	1	34	2.36
ZM_Z_Limit_Sw_Mount.stl	0	17	0.44
ZM_Z_Probe.stl	1	4	2.04
ZM_Z_Yoke.stl	0	25	0.72

## ZM\_Motor\_attachment.stl

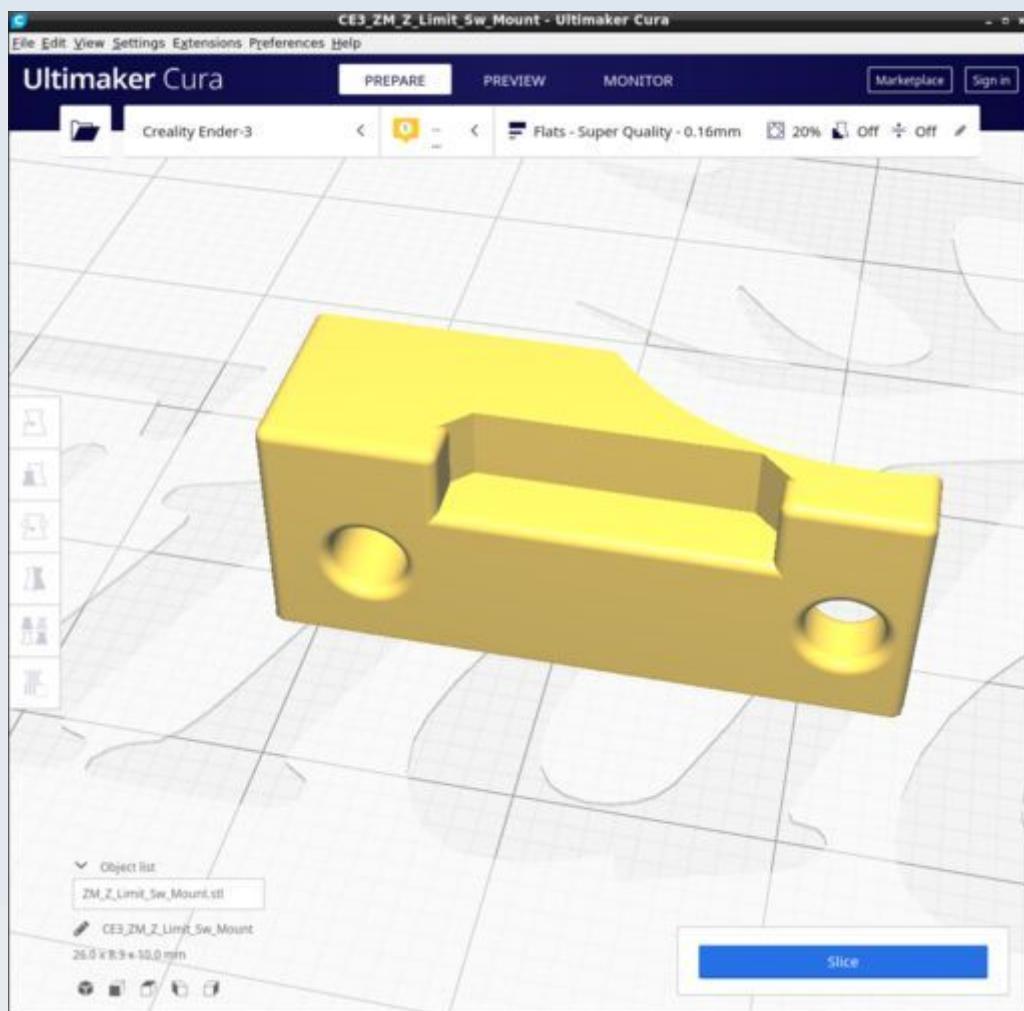


Ensure supports are disabled. It is not possible to properly rotate this in Cura using the method described below (for ZM\_Z\_Limit\_Sw\_Mount.stl) so the mesh is rotated 235 degrees in FreeCAD prior to saving to get the flat parts of the front surface aligned to the X-axis.

## ZM\_Motor\_gear.stl



## ZM\_Z\_Limit\_Sw\_Mount.stl

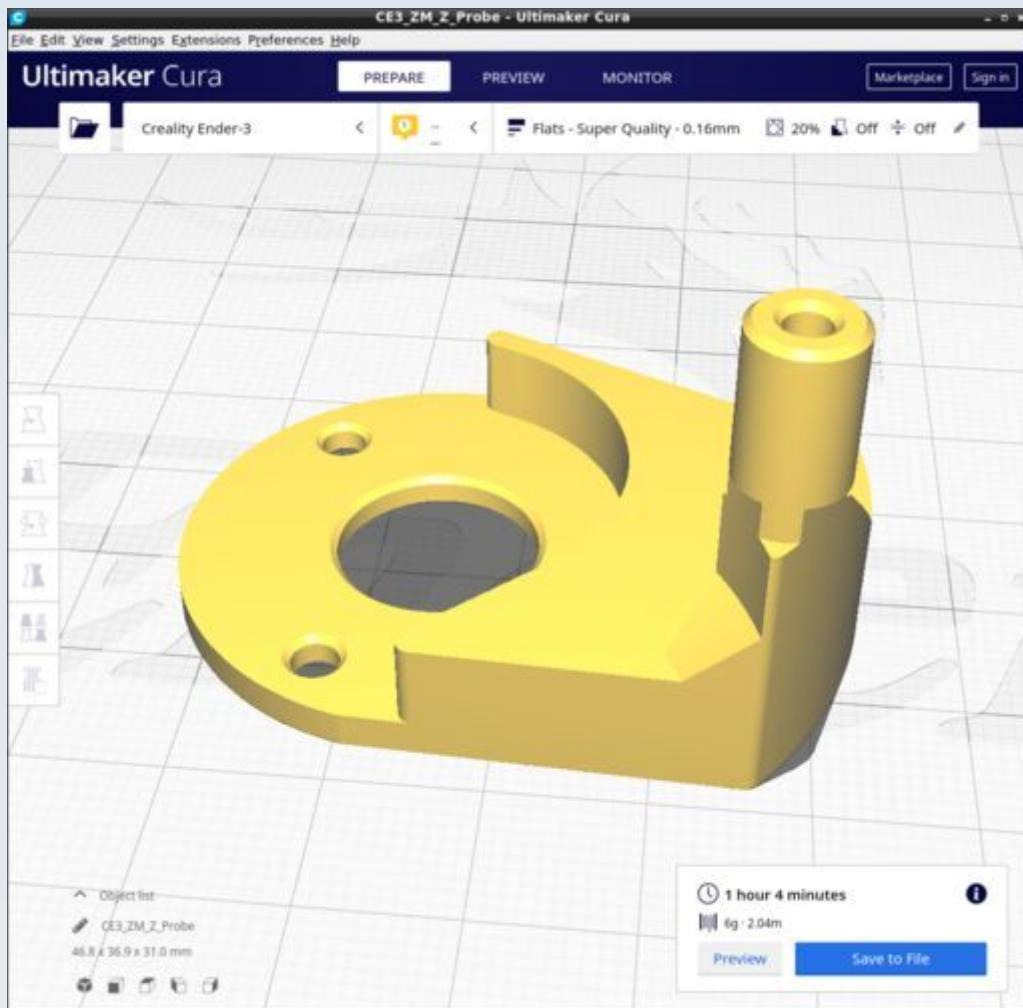


Ensure supports are disabled. It is difficult to get the flat outer surface exactly in line with the X-axis of the printer. To do this follow these steps:

1. Load into Cura.
2. Rotate it so the flat surface with the screw holes faces the buildplate then use the 'Lay flat' option of Cura to calculate the exact rotation to make that surface flat against the build plate.
3. When done, simply use snap rotation to 90 degrees about the long axis of the model so that the flat surface that was laying on the build plate now faces to the front of the printer.

The resulting position is as shown in the figure.

## ZM\_Z\_Probe.stl



Ensure supports are disabled. It is difficult to get the flat outer surface exactly in line with the X-axis of the printer so a method similar to that described above for 'ZM\_Z\_Limit\_Sw\_Mount.stl' is used. The result is as shown in the picture.

## ZM\_Z\_Yoke.stl

