ULTRASCOPE

Part 1: 3D Printing and Laser Cutting

ULTRASCOPE EXPLORER SERIES

Technical Documentation

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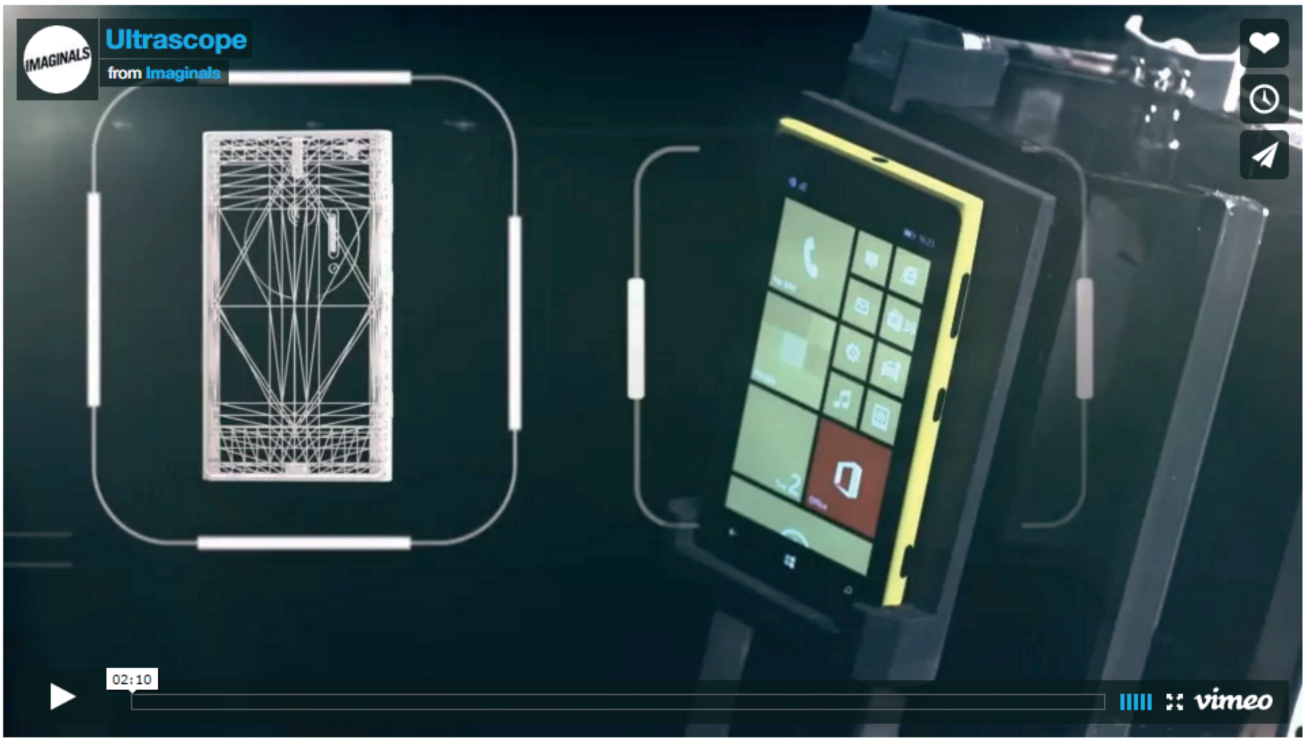
ULTRASCOPE

Ultrascope is an open-source robot telescope - or ARO (Automated Robotic Observatory) - controlled by a smart phone. It empowers citizen scientists with a low cost and open source robotic telescope to assist the work of professional astronomers.



Citizen Science
Ultrascope is a global citizen science initiative developed to radically reduce the cost of contributing to real science by enabling DIY engineers and amateur astronomers to perform useful measurements - specifically light curve photometry, which generates useful data for a number of scientific applications, including planet finding and asteroid hunting. Together, we're building up a network of scopes to solve address challenges faced by the larger scopes, like reduced bandwidth and coverage limited to the Northern Sky.

Ultrascope allows astronomers to contribute to citizen science projects and conduct celestial photography and photometry by joining a network of peers, who by working collectively are able to generate data with a high degree of fidelity.

Smart phone Controlled
Ultrascope Explorer (or UEX) uses a high mega-pixel smart phone as the camera and input/output device (i/o) using 4G LTE. At the moment, our Ultrascope software is limited to Windows Mobile. Our recommend handset is thus the Nokia Lumia 1020.

Make It Yourself
We wanted to develop a kit-set telescope that would reduce the cost of pro-level astronomy by an order of magnitude. Ultrascope is 3D printed and laser cut, so it could be built in your home.

If you're a maker, DIY engineer, citizen scientist or just a long-time aspiring astronaut with stars in your eyes, this scope is for you to build.

ASTEROID
CHALLENGE LAB

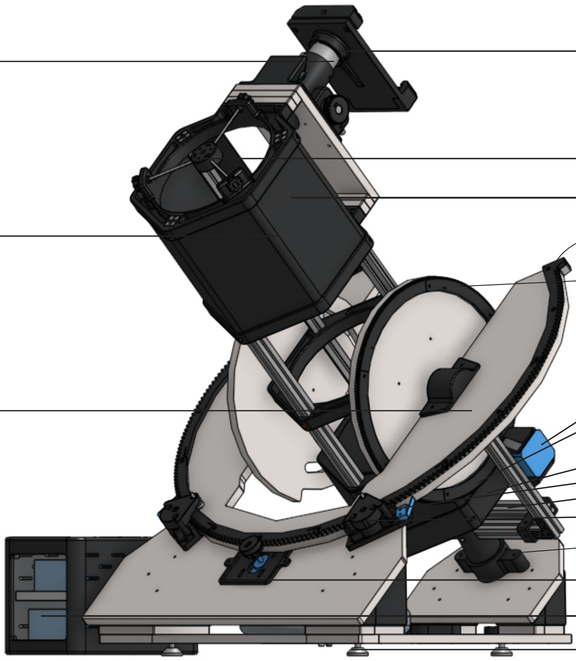
VISION: CONTRIBUTING TO THE ASTEROID CHALLENGE LAB
The Asteroid Challenge Lab is the outreach and citizen engagement effort of NASA's Asteroid Grand Challenge -

"TO FIND ALL ASTEROID THREATS TO HUMAN POPULATIONS AND KNOW WHAT TO DO ABOUT THEM"

The amateur community present a potential solution in supporting and supplementing NASA's NEO hunting mission. However, the high cost of equipment and lack of requisite skills presents a barrier to genuine contribution. We're here to change that with the Ultrascope.

Our growing global network of Ultrascopes enables us to take action, together, towards planetary defence by contributing to NASA's Asteroid Challenge Lab.

About ULTRASCOPE Explorer



Ultrascope Explorer - or UEX - is able to resolve objects around magnitude 9 on the 'H' scale used by professionals.

UEX can thus be used to teach the core principles of asteroid characterization - or asteroid hunting - by conducting light curve analysis of main belt objects such as VESTA and CERES - very large asteroids around H 9 that are in the orbit between Mars and Jupiter.

A larger version of the Ultrascope (called 'Ultrascope Odyssey', or UOD) will have the ability to collect data from objects in the H 11-12 region. This will allow users to help characterize NEOs (Near Earth Objects) which are much smaller and darker.

UEX, however, makes an excellent learning device for beginners and there are a number of citizen science initiatves that welcome data gathered from a scope that can capture data from Magnitude 9 objects.

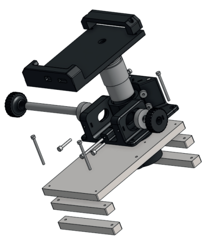
3D Printing and Laser Cutting

This guide is part 1 in the series of instructions to make an Ultrascope Explorer.

1. **Part 1: 3D Printing and Laser Cutting**
2. **Part 2: Focuser & Tube Build + Optical Path**
3. **Part 3: Split Ring Build**
4. **Part 4: Base Build**
5. **Part 5: Electronics**
6. **Part 6: Observation of Celestial Bodies**

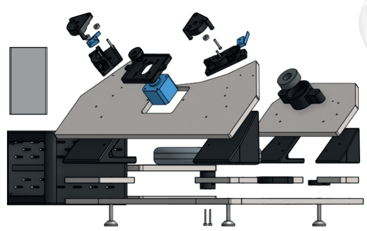
The steps in this guide focus on the 3D printing and laser cutting of the parts needed to build Ultrascope Explorer. When you complete all the steps in this document, you'll have the parts you need for **Part 2: Focuser and Tube Build + Optical Path**, where you will start assembling your scope.

Tube



Focuser

Split Ring



Base

Step 1.1: Materials and Supplies

What you'll need to build this scope

Tools:

1. 3D printer*
2. Laser cutter*

*or access to one.

Materials:

±2200g or 275m of PLA/ABS Filament

Ready to build your Ultrascope?

Getting Started: Laser Cutting

What you should know about laser cutting before you get started

First things first, you'll need a laser cutter. If you don't have one, you could either buy one, rent one or find a business that will laser cut for you. We recommend finding a business to do the laser cutting for you. See https://www.wevolver.com/osa.projects/ultrascope/ for recommended vendors.

Check Your Ratios

When you open your file, ensure that units are converted to mm.
1 unit should equal 1mm. 1 unit should **not** equal 1px.

Laser Cutting Safety

- Do not look at the laser whilst it is cutting
- Ensure there is a 3mm gap between the material surface (at highest point) and laser head
- Use the Emergency stop button if you need to shut down the laser cutter immediately
- Always stand by the laser cutter when cutting so if necessary it can be stopped immediately
- Materials and their finishes can burn excessively, catch fire or generate toxic fumes, seek advice first from a technician before cutting
- Check that the extractor fan is working and the fume vent is open

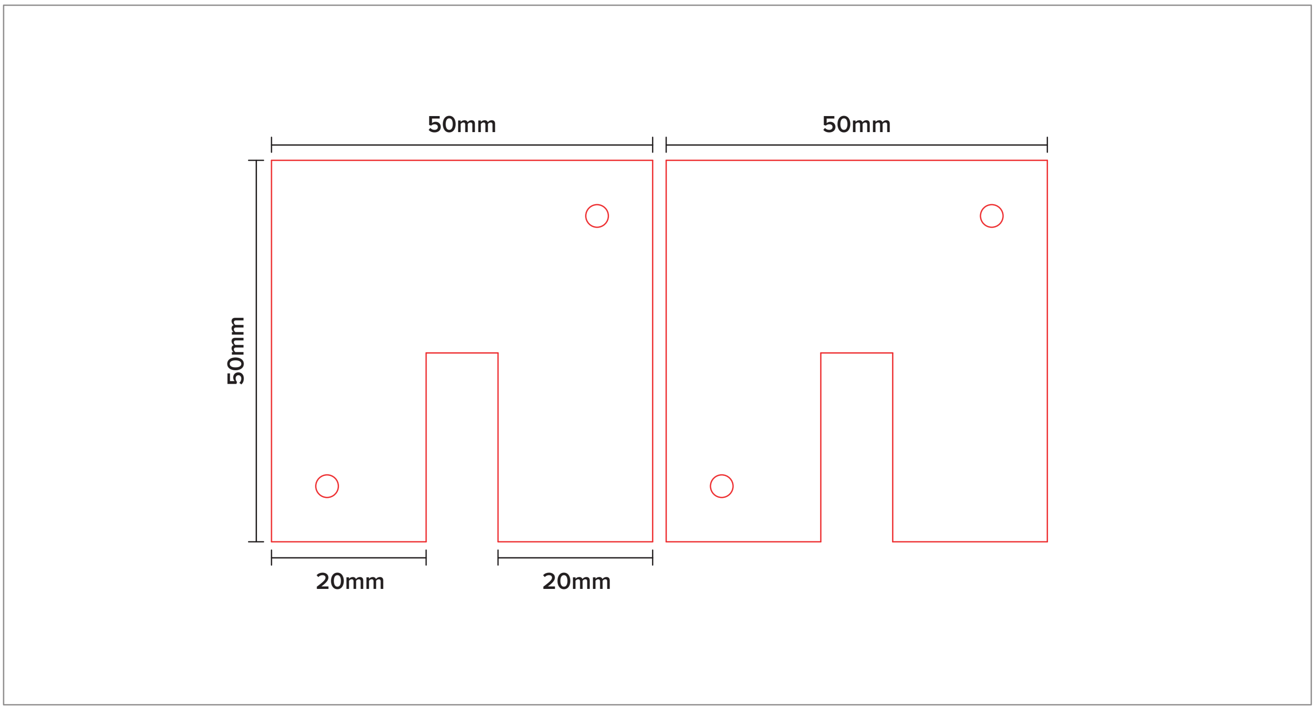
The document is set up for a curve of 0.31m

Step 1.2: Laser Cutting Test

Check dimensions and kerf

Before cutting the full set of parts, cut and print the Laser Cutting Test Components to check your dimensions and kerf.

Using 10mm acrylic, cut **Laser-Cutting-Test-Components.ai**
This file contains two parts and looks like this:



Laser-Cutting-Test-Components.ai

Check Dimensions

Measure your parts according to the diagram above or print this page (A4) and place the sample pieces on their outline to confirm the sizes are correct. Ensure that hole size and positioning are accurate.

Check Kerf

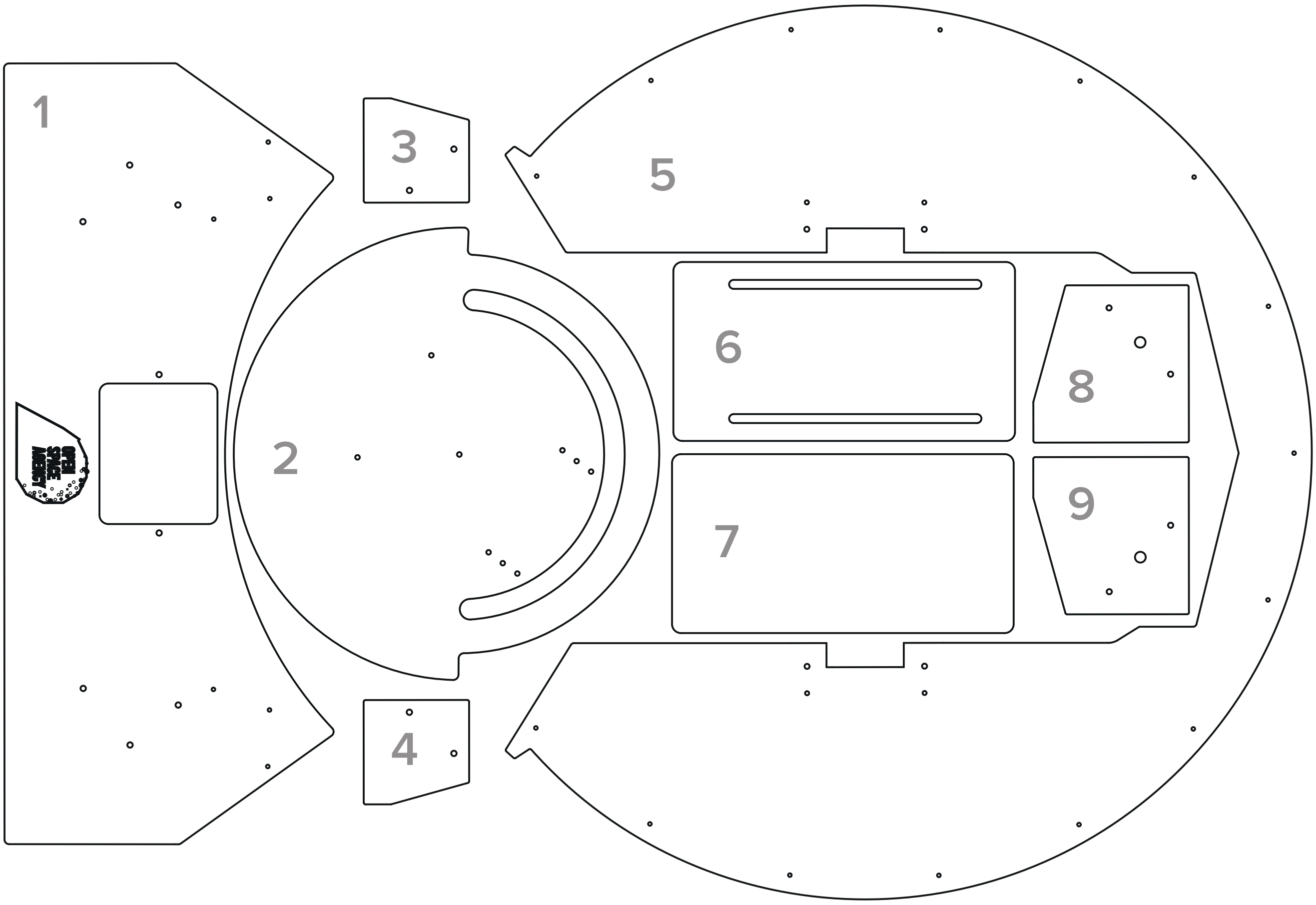
The two sample parts should be able to snuggly fit together. If there is too much space or not enough, iterate on the laser cutter's speed and power settings to get the right material burn.

Once you have checked the size and quality of your laser cutting, continue to the next step and cut the remainder of your parts.

ULTRASCOPE

Step 1.3: Laser Cutting Group A

Cut these components using the 10mm acrylic. You'll need 750mm x 500mm.



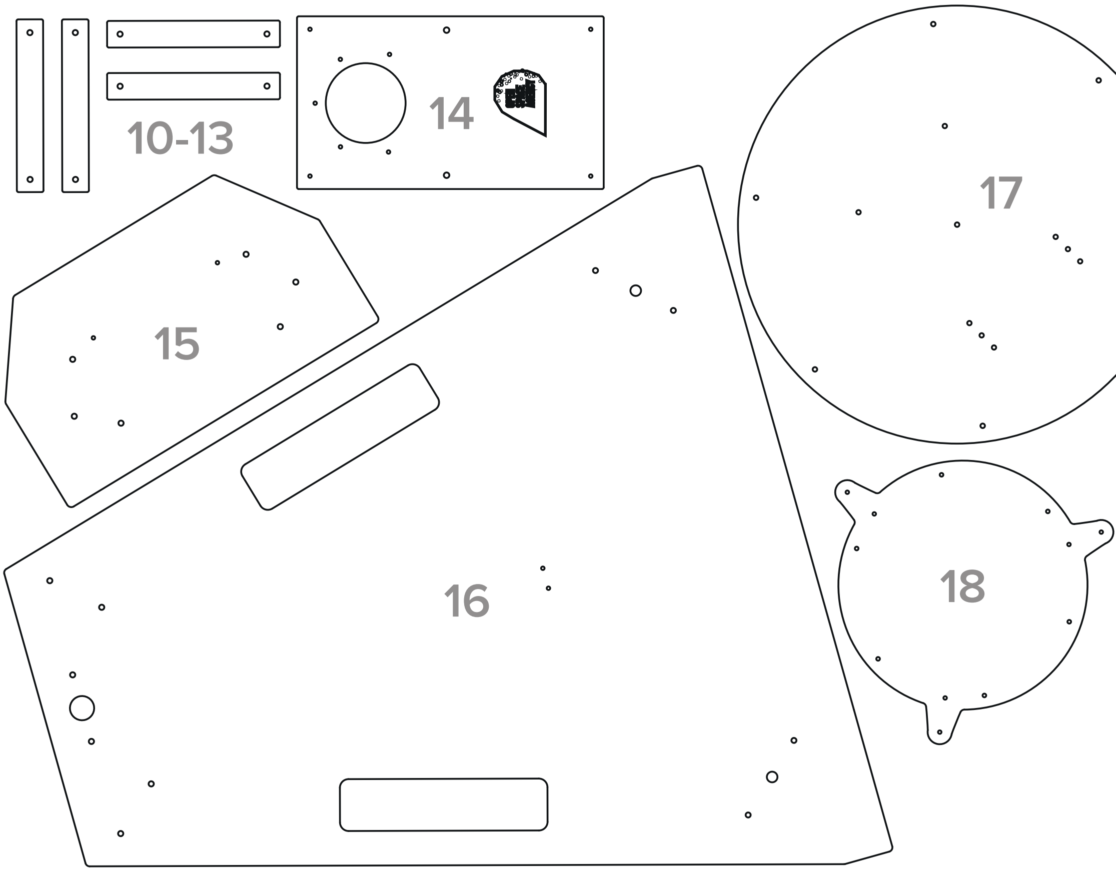
UEX Laser Cut Sheet Group A.ai

Parts:

1. Base Front Plate
2. Guide Wheel
3. Front Base Spacer R
4. Front Base Spacer L
5. Split Ring
6. Raspberry Pi Shelf
7. Arduino Shelf
8. Base Back Spacer R
9. Base Back Spacer L

Step 1.4: Laser Cutting Group B

Cut these components using the 10mm acrylic. You'll need 700mm x 500mm.



UEX Laser Cut Sheet Group B.ai

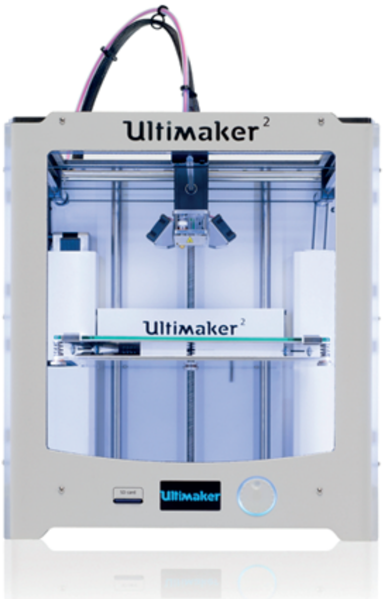
Parts:
10. Focuser Spacer Plate 1
11. Focuser Spacer Plate 2
12. Focuser Spacer Plate 3
13. Focuser Spacer Plate 4
14. Focuser Plate
15. Base Back Plate
16. Base
17. Guide Wheel
18. Primary Mirror Adjust

Getting Started: 3D printing

What you should know about 3D printing

3D Printing is a process for making a physical object from a three-dimensional digital model, typically by laying down many successive thin layers of a material.

This scope can be printed on a wide range of 3D printers. The time and material estimations in this guide are based on an **Ultimaker 2** 3D Printer and Cura 3D slicing software.



If you decide to use another 3D printer, check the size of the bed to ensure the parts will fit. Parts have been sized to fit on most hobby-scale printers.

The settings outlined on the following pages (layer height, shell thickness, fill density, etc) are found under the advanced basic print settings in Cura.

Before the print

- Selecting filament: Choose the colour and type of filament you would like to use. Go for a structurally strong filament where possible. PLA is generally easier to use for beginners.

During the print

- What should you do if the print fails: If the material does't stick to the bed, or if the material doesn't stick, or if the material appears to float - cancel and start again. See the troubleshooting guide.

After the print

- Finishing with sandpaper: Wait until the bed is cooled before you move the part. Use a thin layer of glue (from a regular glue stick) on the print bed to get the print to stick to the bed.

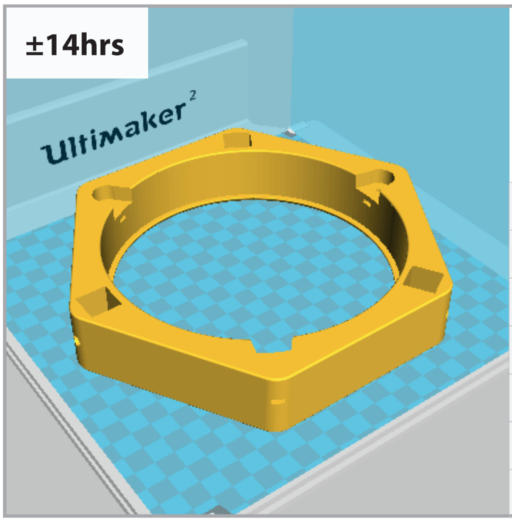
Safety

- Keep fingers, hands, arms, faces, etc. away from the build plate when heated.
- Do not touch the extruder - it heats to approx 230° C to melt the filament.

Step 1.5: 3D Printing Group A - Tube

Print these components

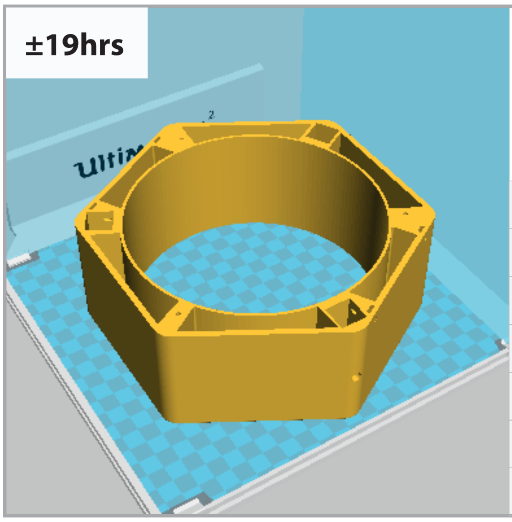
Total approx print time for Printing Group A: 103hrs



1. Hexagon-1.stl

This is the primary mirror cell located at the end of the tube.

Material	15.77m or 125g
Layer Height	0.15mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20%
Print Speed	50mm/s
Support Type	None



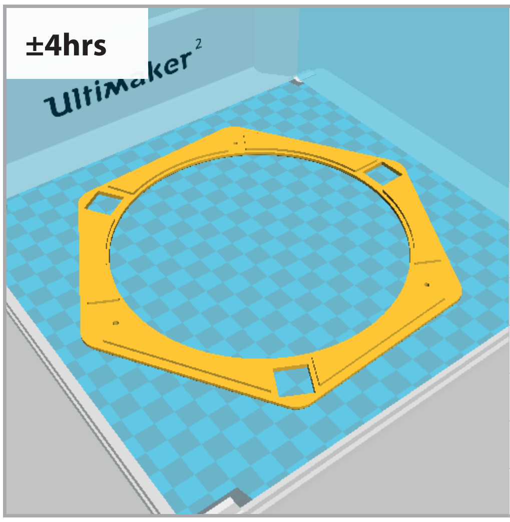
2. Hexagon-2.stl

Partial counterweight, attachment point for the guide wheels and a mirror protector while the lid is in place.

Material	29.66m or 235g
Layer Height	0.25mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Printing Group A Continued

±4hrs

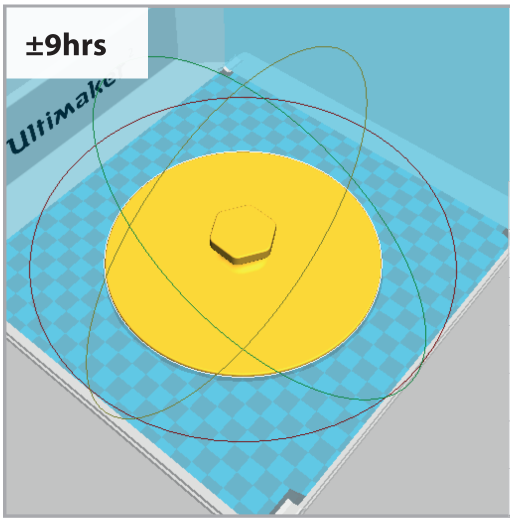


3. Hexagon-2-Cap.stl

Hexagon 2 Cap seals the lead shot inside Hexagon 2.

Material	2.91m or 23g
Layer Height	0.15mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±9hrs

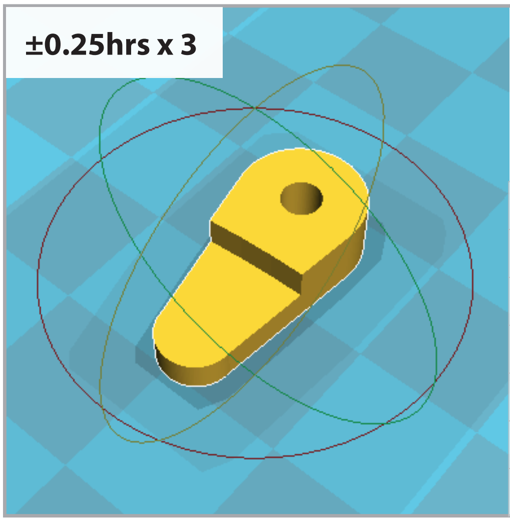


4. Mirror-Protecting-Lid.stl

The mirror lid protects the mirror when the Ultrascope is not in use.

Material	6.86m or 54g
Layer Height	0.8mm
Shell Thickness	0.6mm
Bottom/Top Thickness	0.15mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

±0.25hrs x 3



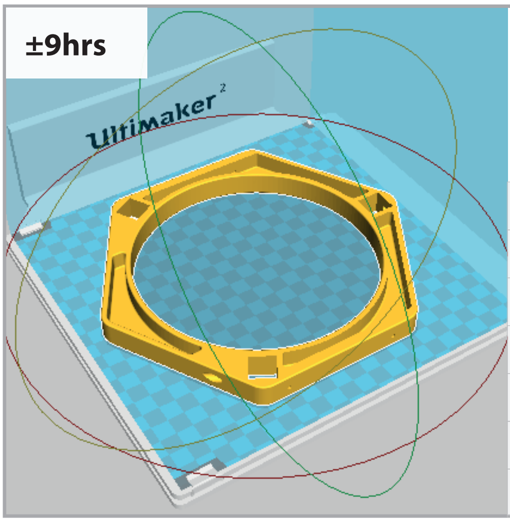
5. Mirror-Lid-Peg.stl (Print 3)

3 mirror lid pegs secure the mirror lid.

Material	(0.07m or 1g) x 3
Layer Height	0.8mm
Shell Thickness	0.6mm
Bottom/Top Thickness	0.15mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Printing Group A Continued

±9hrs

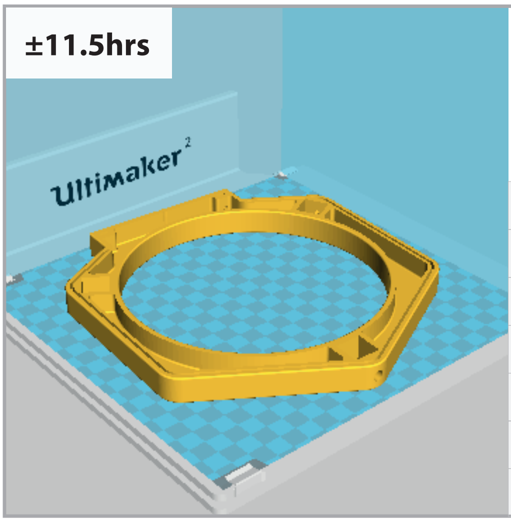


6. Hexagon-3.stl

Hexagon 3 stiffens the tube and provides attachment points for the guide wheels.

Material	7.76m or 61g
Layer Height	0.8mm
Shell Thickness	0.6mm
Bottom/Top Thickness	0.15mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±11.5hrs

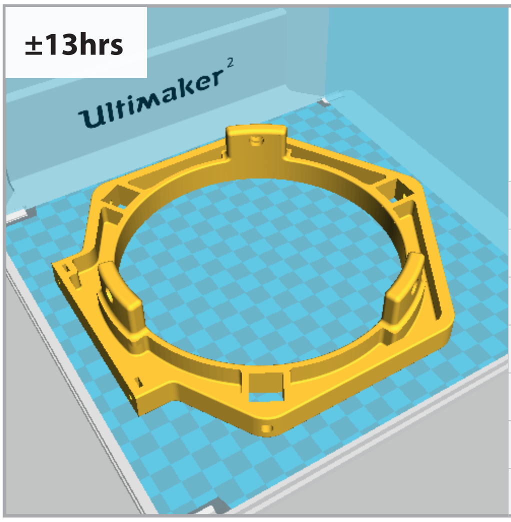


7. Hexagon-4.stl

Hexagon 4 stiffens the tube and provides an attachment point for the focuser plate.

Material	9.15m or 71g
Layer Height	0.15mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±13hrs



8. Hexagon-5.stl

Stiffens tube, provides focuser plate attachment points and includes mounting points for the adjustable spider.

Material	10.53m or 83g
Layer Height	0.15mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Printing Group A Continued

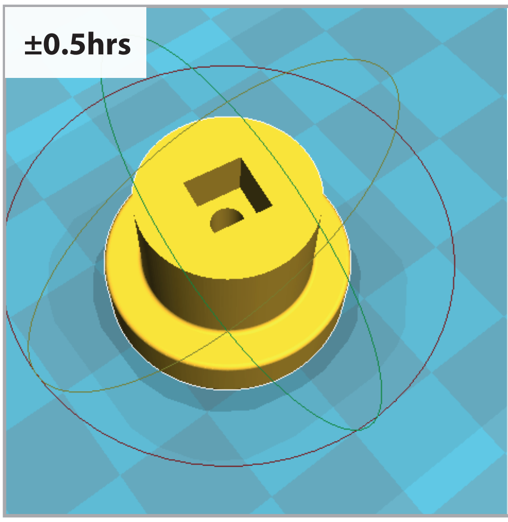
±0.5hrs x 3

9. Spider-Knobs.stl (Print 3)

3 spider knobs hold the secondary mirror spider in place and allow 3 point adjustment.

Material	(0.16m or 1g) x 3
Layer Height	0.06mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±0.5hrs



10. Tube-Axel-L.stl

Tube Axel L secures the taper bearing to the tube.

Material	0.35m or 3g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±0.5hrs

11. Tube-Axel-R.stl

Tube Axel R secures the taper bearing to the tube.

Material	0.47m or 4g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Printing Group A Continued

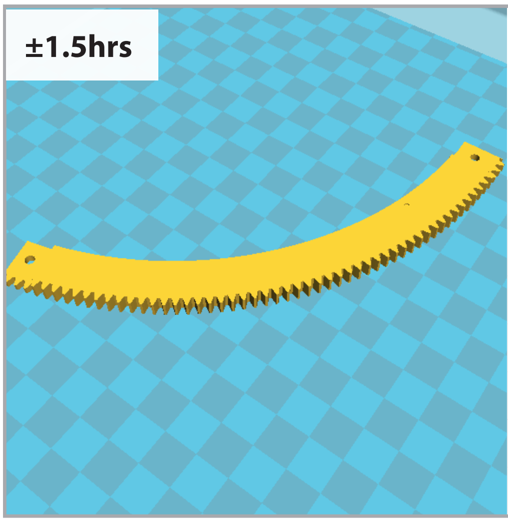
±1hr

12. Tube-Stepper-Gear.stl

The Tube Gear is mounted a stepper motor and drives the DEC axis.

Material	0.26m or 2g
Layer Height	0.06mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±1.5hrs

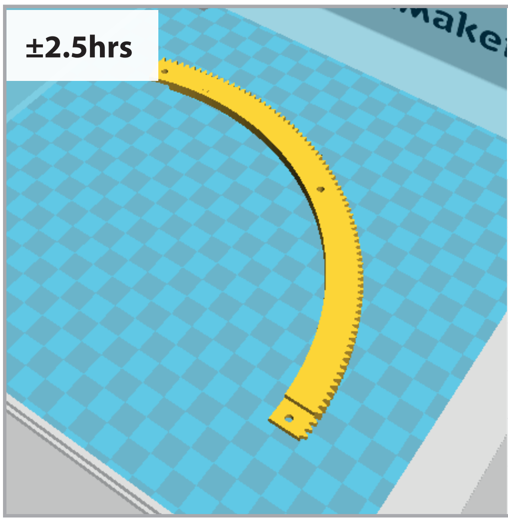


13. Tube-Gear-Section-1.stl

The Tube gear has been split into sections so they can be printed on a hobby scale printer.

Material	0.92m or 7g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±2.5hrs



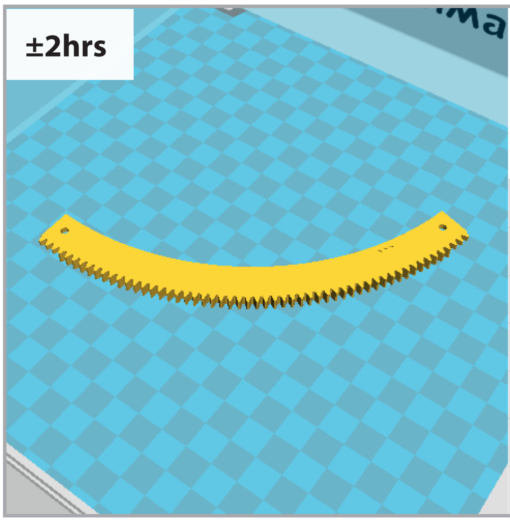
14. Tube-Gear-Section-2.stl

These gear sections mesh with the tube stepper gear to allow fine, smooth movements in the DEC axis.

Material	1.27m or 10g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Printing Group A Continued

±2hrs

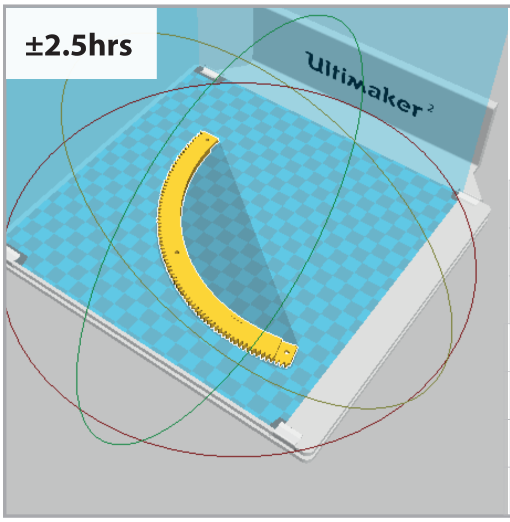


15. Tube-Gear-Section-3.stl

The Tube gear has been split into sections so they can be printed on a hobby scale printer.

Material	0.92m or 7g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±2.5hrs



16. Tube-Gear-Section-4.stl

These gear sections mesh with the tube stepper gear to allow fine, smooth movements in the DEC axis.

Material	1.31m or 10g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±1hr

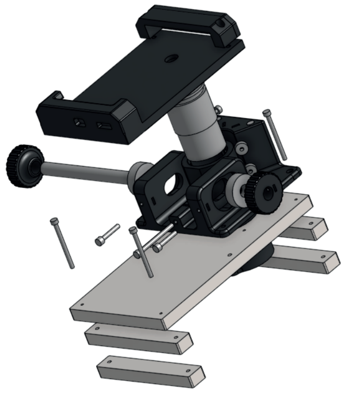
17. Secondary-Mirror-Spider.stl

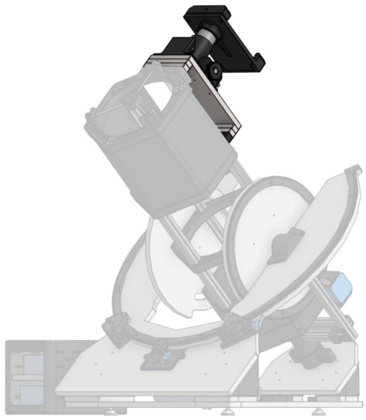
Holds the secondary mirror and is adjustable at 6 points for lightpath alignment.

Material	0.82m or 6g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Step 1.6: 3D Printing Group B - Focuser

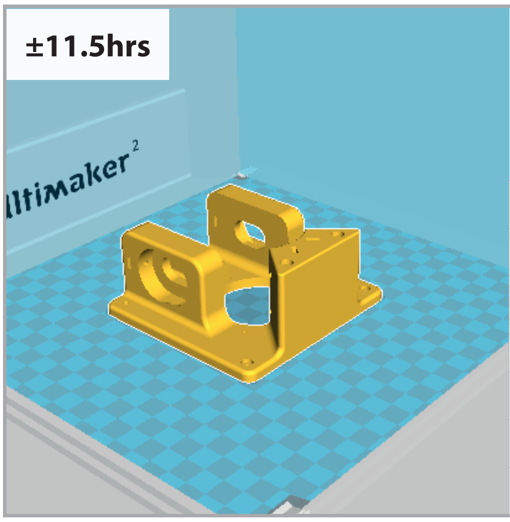
Print these components





Total approx print time for Printing Group B: 22hrs

±11.5hrs

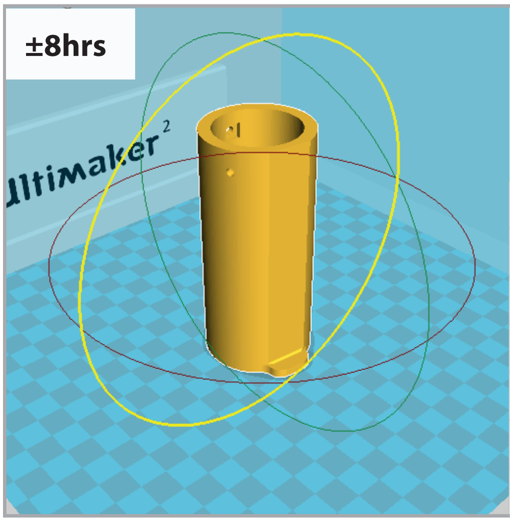


18. Focuser-Body.stl

A mounting body for the bearings that allow for accurate, smooth motion while focusing on celestial bodies.

Material	7.35m or 55g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

±8hrs



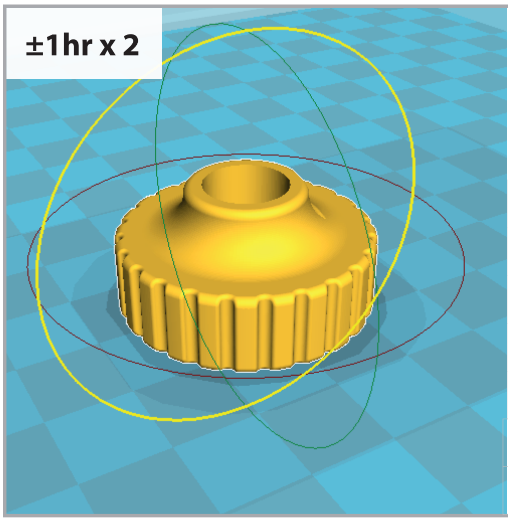
19. Focuser-Tube.stl

Mounts the eyepiece and uses increased friction on the flat plane to secure the focuser in place.

Material	3.84m or 30g
Layer Height	0.06mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Printing Group B Continued

±1hr x 2

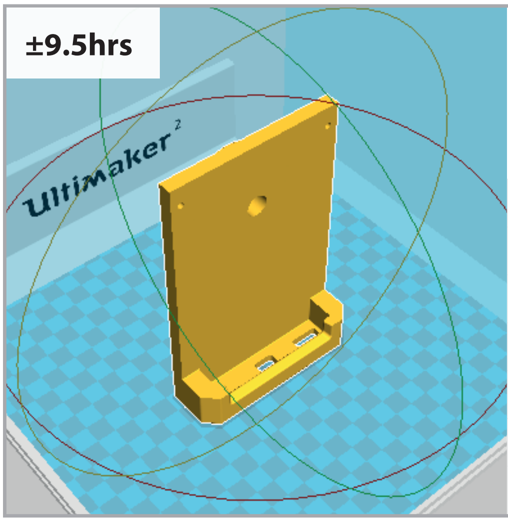


20. Focuser-Knobs.stl

Focuser Knobs are mounted onto the steel rod and are oversized to ease accurate movement.

Material	0.56m or 4g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±9.5hrs

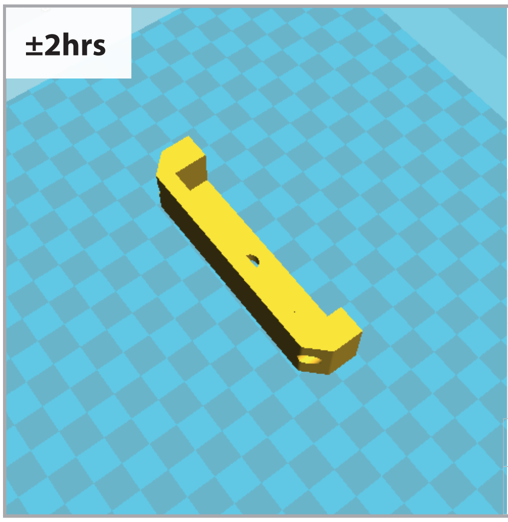


21. Phone-Mount.stl (Lumia 1020)

Mounts to the eyepiece, can be adjusted at 3 points for lightpath alignment, allows full functionality of the phone.

Material	7.24m or 57g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

±2hrs



22. Securing-Plate.stl (Lumia 1020)

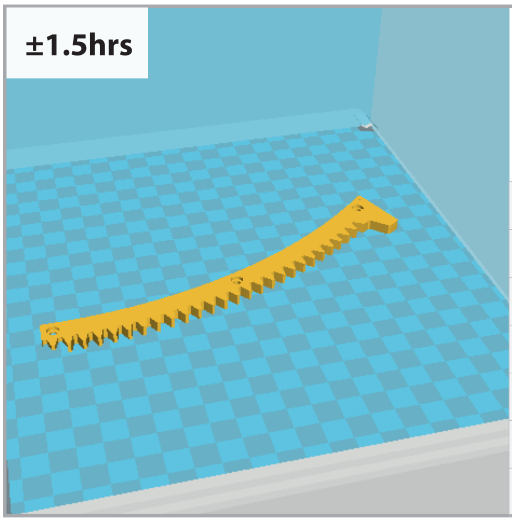
1020 Securing Plate secures the smartphone in place on the phone mount.

Material	1.27m or 10g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Step 1.7: 3D Printing Group C - Split Ring

Print these components

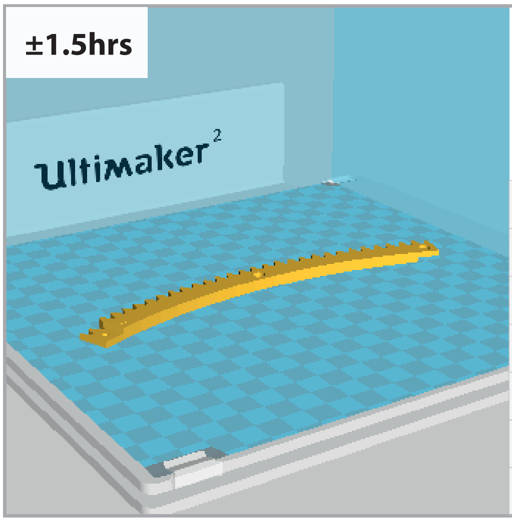
Total approx print time for Printing Group C: 36.5hrs



23. Split-Ring-Gear-Section-1.stl

The Split Ring Gear has been split into sections so they can be printed on a hobby scale printer.

Material	0.99m or 8g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

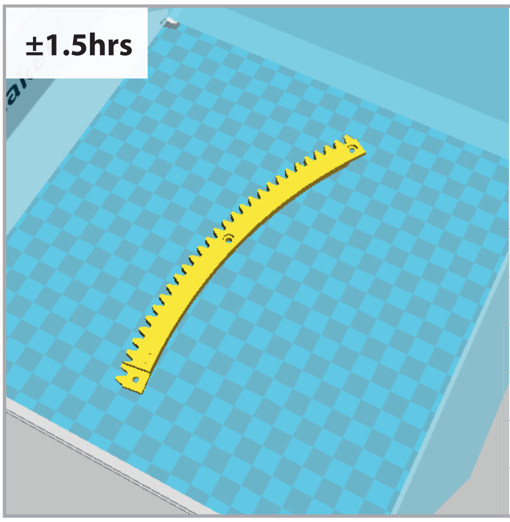


24. Split-Ring-Gear-Section-2.stl

These gear sections mesh with the Split Ring Gear to allow fine, smooth movements in the ALT axis.

Material	0.90m or 7g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

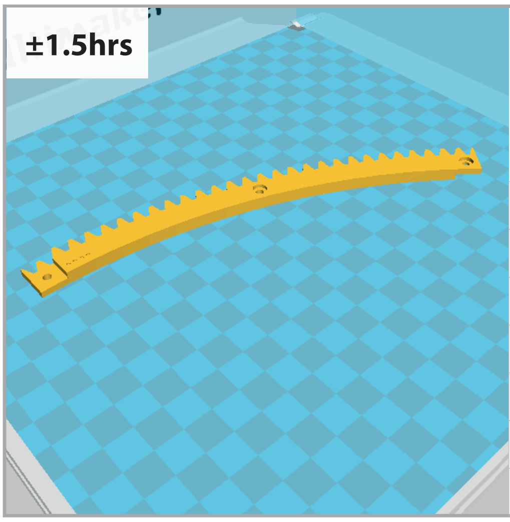
Printing Group C Continued



25. Split-Ring-Gear-Section-3.stl

The Split Ring Gear has been split into sections so they can be printed on a hobby scale printer.

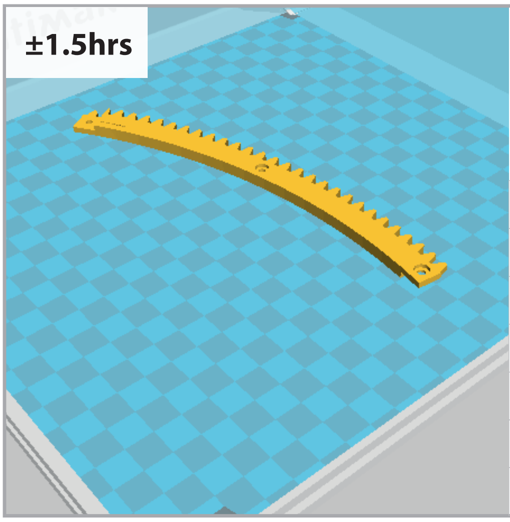
Material	0.90m or 7g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere



26. Split-Ring-Gear-Section-4.stl

These gear sections mesh with the Split Ring Gear to allow fine, smooth movements in the ALT axis.

Material	0.90m or 7g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

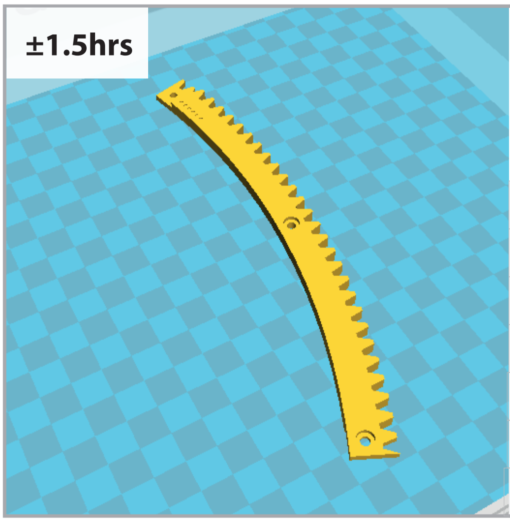


27. Split-Ring-Gear-Section-5.stl

The Split Ring Gear has been split into sections so they can be printed on a hobby scale printer.

Material	0.90m or 7g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

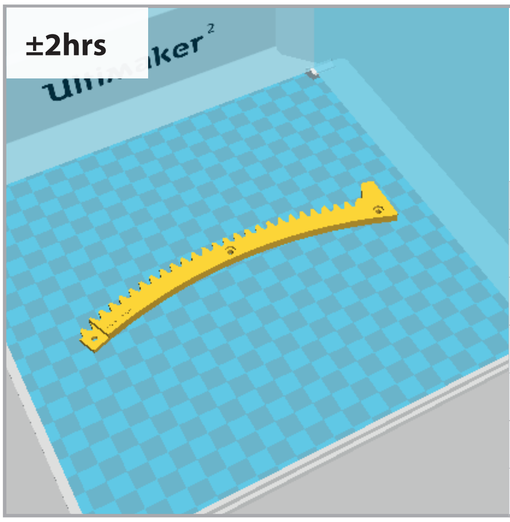
Printing Group C Continued



28. Split-Ring-Gear-Section-6.stl

These gear sections mesh with the Split Ring Gear to allow fine, smooth movements in the ALT axis.

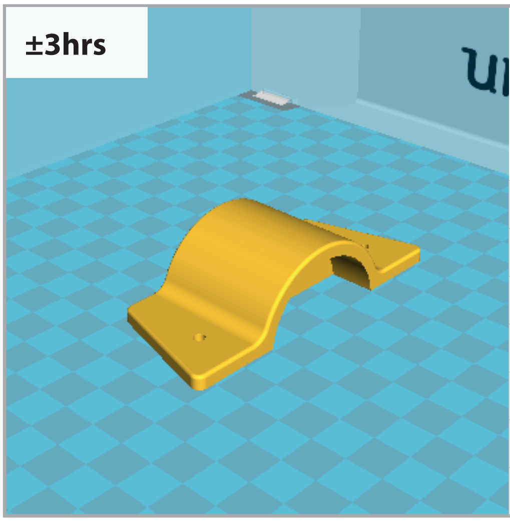
Material	0.90m or 7g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere



29. Split-Ring-Gear-Section-7.stl

The Split Ring Gear has been split into sections so they can be printed on a hobby scale printer.

Material	0.99m or 8g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

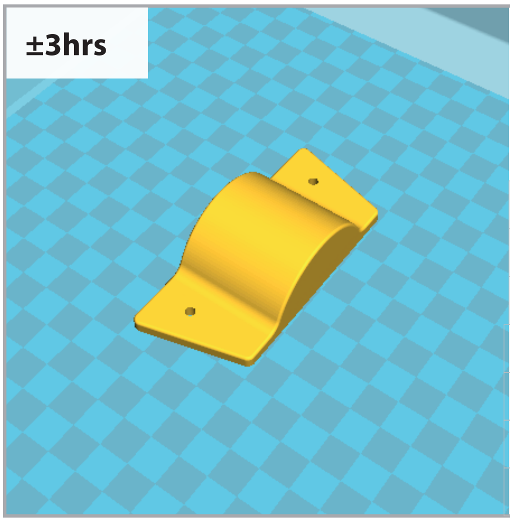


30. Upper-Split-Ring-Brace-L.stl

Stiffens the split ring and houses the tube bearing in combination with the Lower Split Ring Brace L.

Material	1.92m or 15g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

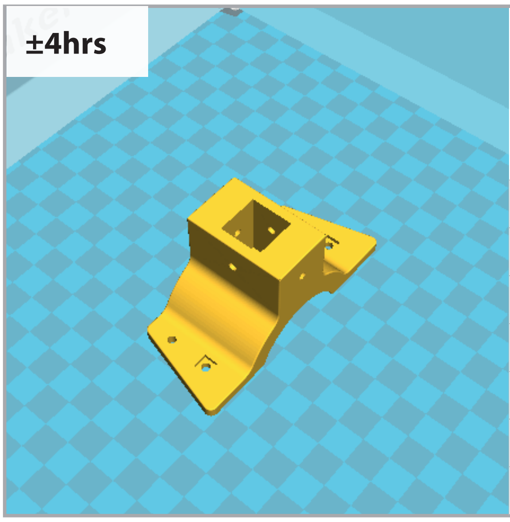
Printing Group C Continued



31. Upper-Split-Ring-Brace-R.stl

Stiffens the split ring and houses the tube bearing in combination with the Lower Split Ring Brace R.

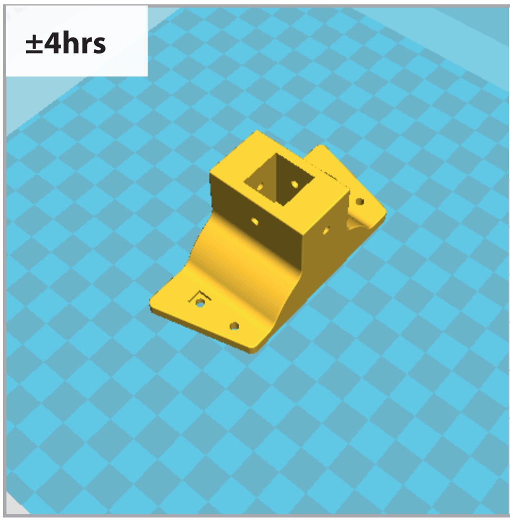
Material	1.89m or 15g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere



32. Lower-Split-Ring-Brace-L.stl

Provides a mounting point for the openbeam split ring bracket and houses the tube taper bearing.

Material	2.73m or 22g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

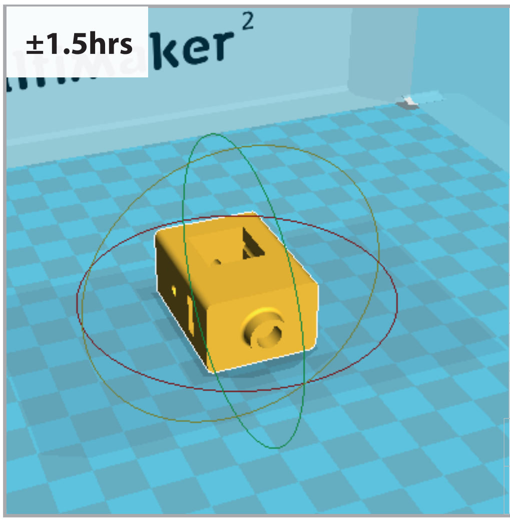


33. Lower-Split-Ring-Brace-R.stl

Provides a mounting point for the openbeam split ring bracket and houses the tube taper bearing.

Material	2.74m or 22g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere

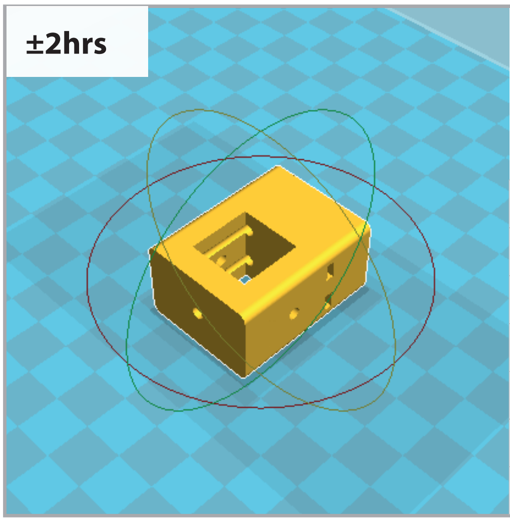
Printing Group C Continued



34. Break-Stop.stl

Protects the DEC Limiter Switches while the scope is off or in the event of a potential power cut.

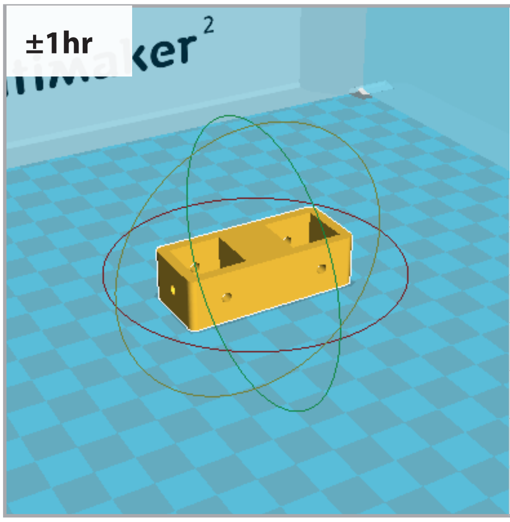
Material	1.15m or 9g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None



35. DEC-Limited-Switch-Mount.stl

Positioned on the split ring openbeam and is used as a mounting platform for the DEC Limiter Switches.

Material	1.17m or 9g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

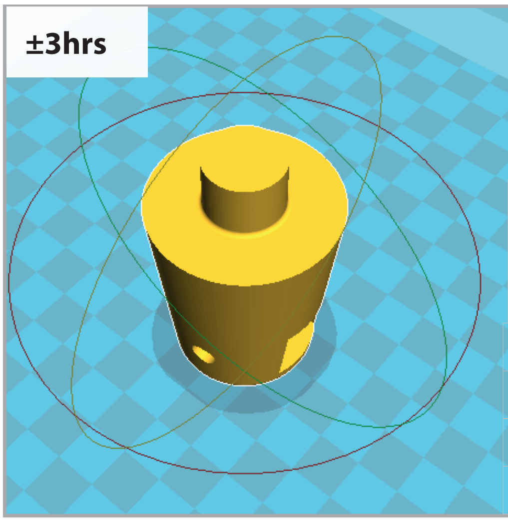


36. Open-Beam-Brackets.stl (Print 2)

Attach to the split ring openbeam to provide a scaffold to stiffen the Split Ring.

Material	0.79m or 6g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

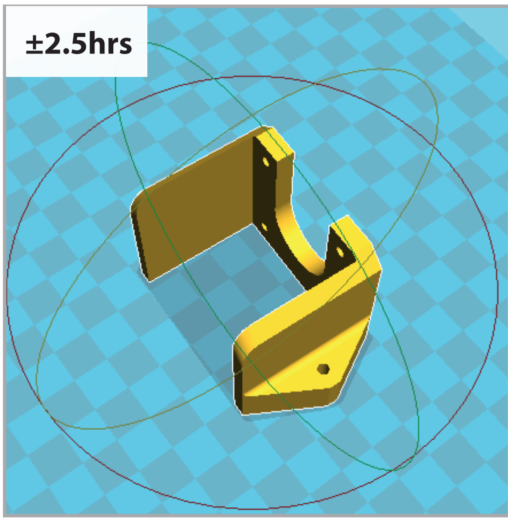
Printing Group C Continued



37. Pivot.stl

The Pivot connects to the split ring openbeam assembly to the base taper bearing.

Material	2.35m or 19g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere



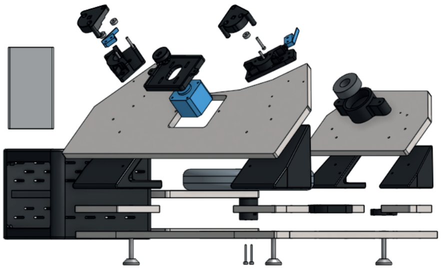
38. DEC-Stepper-Mount.stl

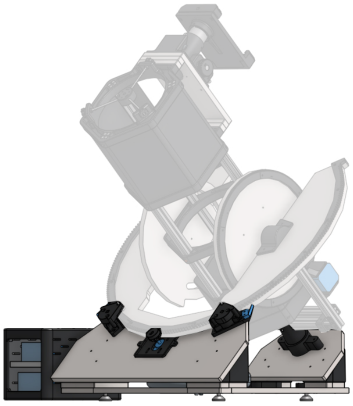
Attaches to the DEC stepper to the Split Ring openbeam assembly.

Material	1.74m or 14g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

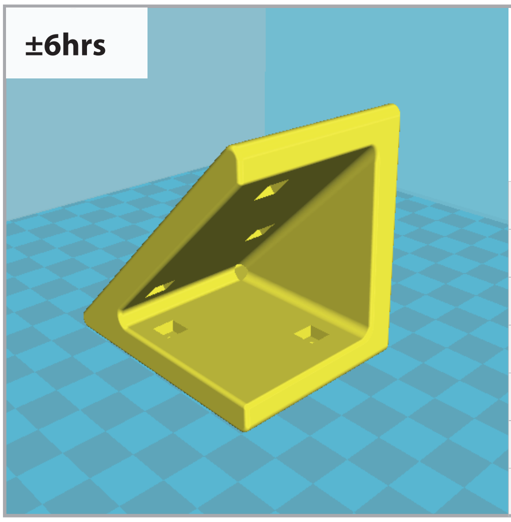
Step 1.8: 3D Printing Group D - Base

Print these components





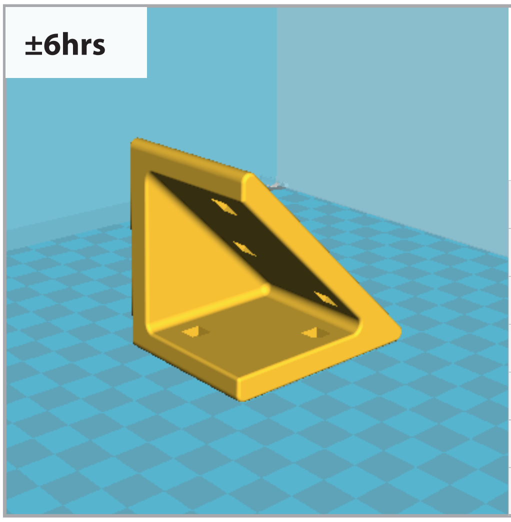
Total approx print time for Printing Group D: 103hrs



39. Back-Angle-Bracket-L.stl

Sets the 45 degree angle of the base plates in combination with the other Base Angle Brackets.

Material	4.15m or 33g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

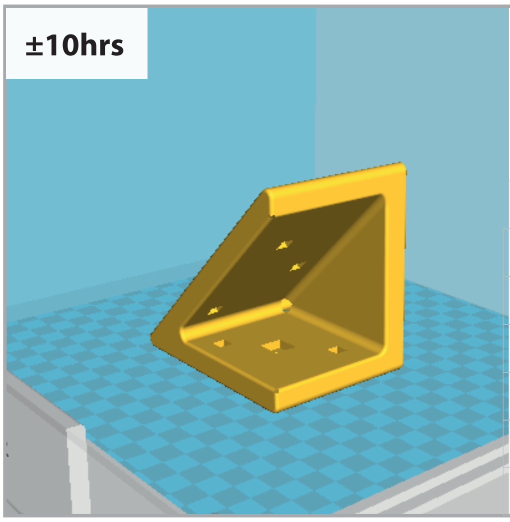


40. Back-Angle-Bracket-R.stl

Sets the 45 degree angle of the base plates in combination with the other Base Angle Brackets.

Material	4.14m or 33g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

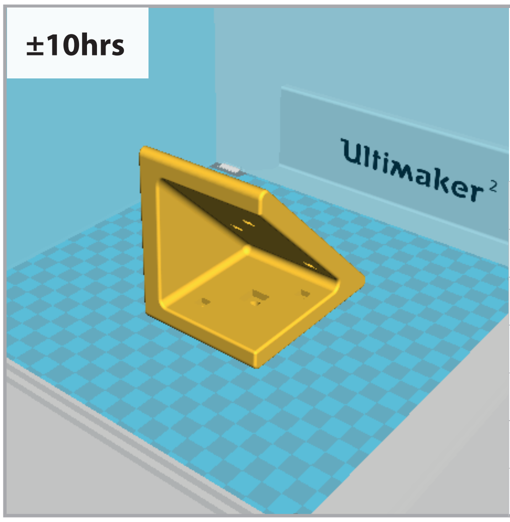
Printing Group D Continued



41. Front-Angle-Bracket-L.stl

Sets the 45 degree angle of the base plates in combination with the other Base Angle Brackets.

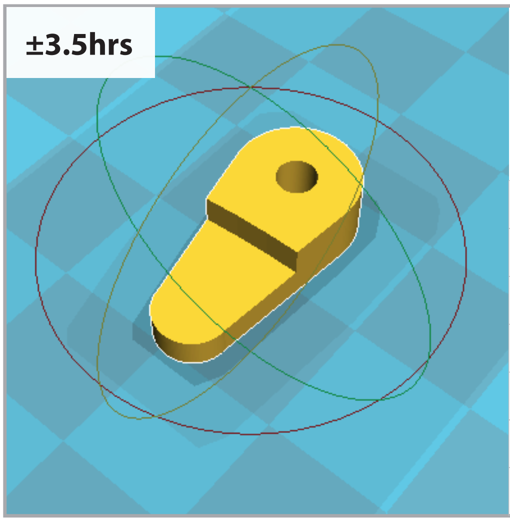
Material	11.79m or 93g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	Everywhere



42. Front-Angle-Bracket-R.stl

Sets the 45 degree angle of the base plates in combination with the other Base Angle Brackets.

Material	11.79m or 93g
Layer Height	0.15mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

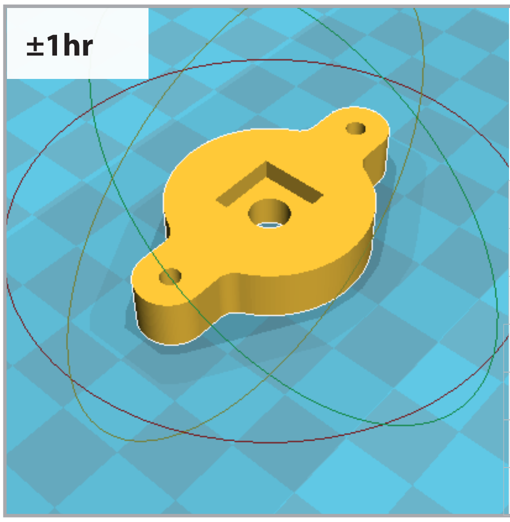


43. ALT-Stepper-Mount.stl

Attaches the ALT stepper mount to the base. The stepper motor can slide to fine tune the gear meshing.

Material	1.98m or 16g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

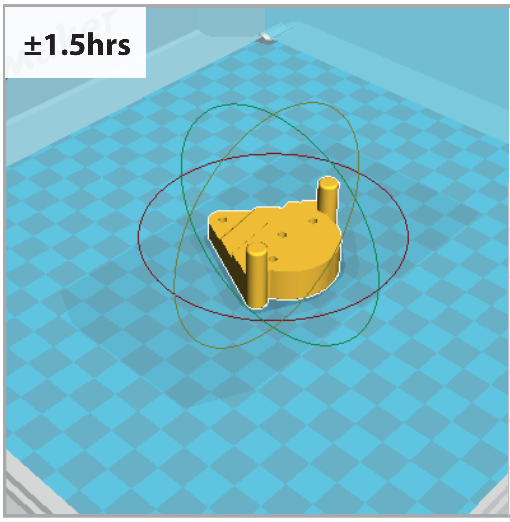
Printing Group D Continued



44. Back-Foot-Housing.stl

The Back Foot Housing houses the M6 square nut for the adjustable foot.

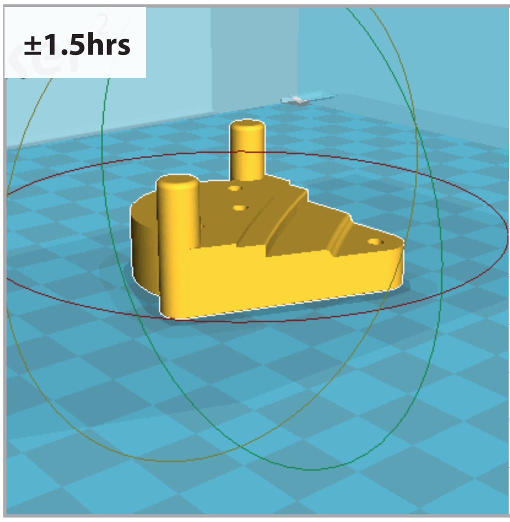
Material	0.49m or 4g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None



45. Base-Upper-Bearing-Lock-L.stl

Houses bearings for split ring track & clamp mechanism. Provides a low friction guided track for the split ring.

Material	1.02m or 8g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

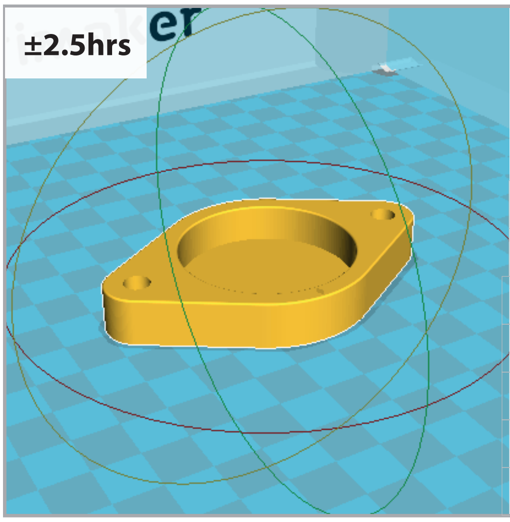


46. Base-Upper-Bearing-Lock-R.stl

Houses bearings for split ring track & clamp mechanism. Provides a low friction guided track for the split ring.

Material	1.01m or 8g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

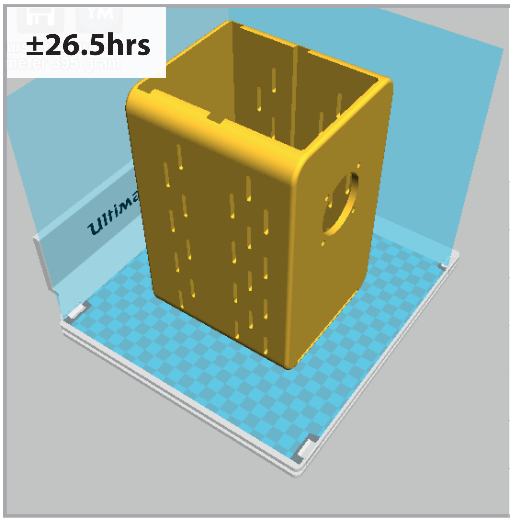
Printing Group D Continued



47. Compass-Mount.stl

Located on the base and used for aligning the scope to the pole star.

Material	1.32m or 10g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None



48. Electronics-Housing.stl

Contains the Arduino assembly and Rasberry Pi with active fan cooling.

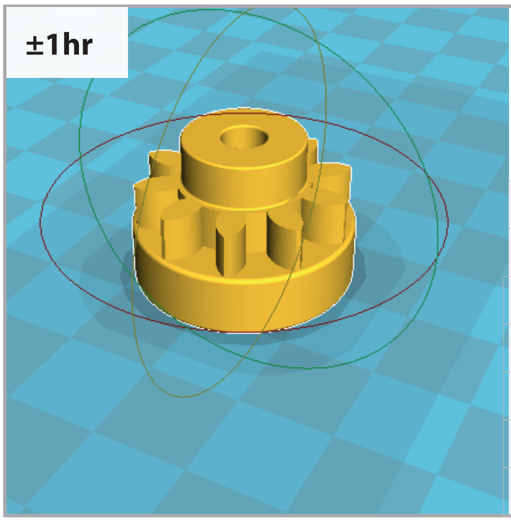
Material	49.87m or 395g
Layer Height	0.25mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

49. Pivot-Mount.stl

Houses the split ring taper bearing and connects the Split Ring to the base.

Material	2.63m or 21g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

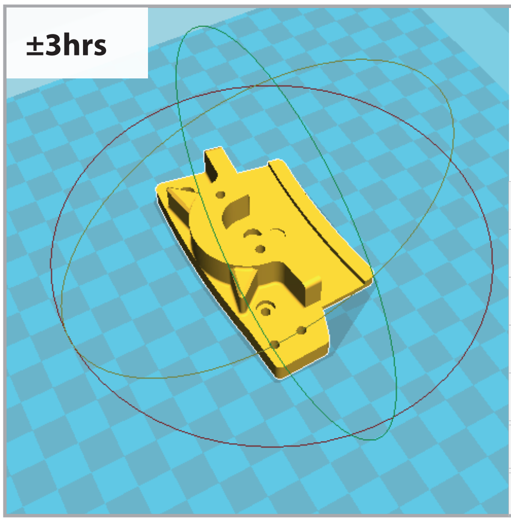
Printing Group D Continued



50. Split-Ring-Gear.stl

Mounted on the ALT Stepper Motor and meshes with the Split Ring Gear.

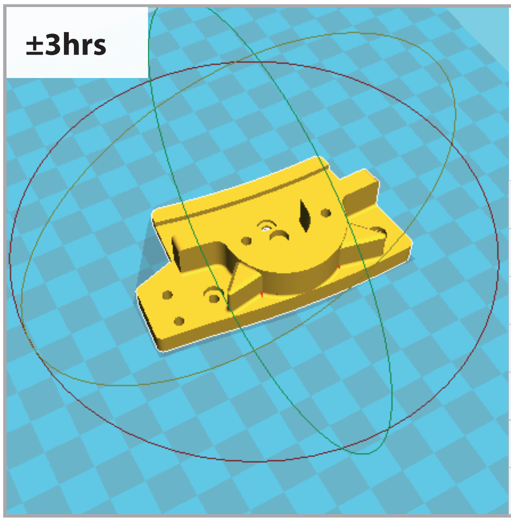
Material	0.42m or 3g
Layer Height	0.06mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None



51. Split-Ring-Bearing-Mount-L.stl

Provides the mounting platform for the The Base upper Bearing Lock L and connects to the base.

Material	1.83m or 14g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

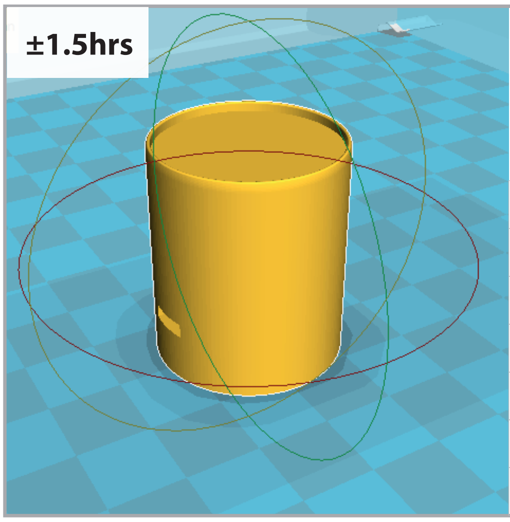


52. Split-Ring-Bearing-Mount-R.stl

Provides the mounting platform for the The Base upper Bearing Lock R and connects to the base.

Material	1.84m or 15g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Printing Group D Continued



53. Spirit-Level-Mount.stl

Acts as a holding nodule for the 5Kg weight plate and houses a bulls eye spirit level for levelling adjustable feet.

Material	1.5m or 12g
Layer Height	0.1mm
Shell Thickness	0.8mm
Bottom/Top Thickness	0.6mm
Fill Density	20% Fill
Print Speed	50mm/s
Support Type	None

Step 1.9: Check Your Kit

Make sure you have everything you need

1. Peel the plastic off the laser cutting
2. Check the quality of the prints. Reprint parts if necessary.
3. Finish off the rough edges of the 3D printing
4. Ensure that every part is dust free and completely dry

Laser Cut Parts Checklist

- [ ] 1. Base Front Plate
- [ ] 2. Guide Wheel
- [ ] 3. Front Base Spacer R
- [ ] 4. Front Base Spacer L
- [ ] 5. Split Ring
- [ ] 6. Raspberry Pi Shelf
- [ ] 7. Arduino Shelf
- [ ] 8. Base Back Spacer R
- [ ] 9. Base Back Spacer L
- [ ] 10. Focuser Spacer Plate 1
- [ ] 11. Focuser Spacer Plate 2
- [ ] 12. Focuser Spacer Plate 3
- [ ] 13. Focuser Spacer Plate 4
- [ ] 14. Focuser Plate
- [ ] 15. Base Back Plate
- [ ] 16. Base
- [ ] 17. Guide Wheel
- [ ] 18. Primary Mirror Adjust

3D Printed Parts Checklist

- [ ] 1. Hexagon-1.stl
- [ ] 2. Hexagon-2.stl
- [ ] 3. Hexagon-2-Cap.stl
- [ ] 4. Mirror-Protecting-Lid.stl
- [ ] 5. Mirror-Lid-Peg.stl (Print 3)
- [ ] 6. Hexagon-3.stl
- [ ] 7. Hexagon-4.stl
- [ ] 8. Hexagon-5.stl
- [ ] 9. Spider-Knobs.stl (Print 3)
- [ ] 10. Tube-Axel-L.stl
- [ ] 11. Tube-Axel-R.stl
- [ ] 12. Tube-Stepper-Gear.stl
- [ ] 13. Tube-Gear-Section-1.stl
- [ ] 14. Tube-Gear-Section-2.stl
- [ ] 15. Tube-Gear-Section-3.stl
- [ ] 16. Tube-Gear-Section-4.stl
- [ ] 17. Secondary-Mirror-Spider.stl
- [ ] 18. Focuser-Body.stl
- [ ] 19. Focuser-Tube.stl
- [ ] 20. Focser-Knobs.stl
- [ ] 21. Phone-Mount.stl (Lumia 1020)
- [ ] 22. Securing-Plate.stl (Lumia 1020)
- [ ] 23. Split-Ring-Gear-Section-1.stl
- [ ] 24. Split-Ring-Gear-Section-2.stl
- [ ] 25. Split-Ring-Gear-Section-3.stl
- [ ] 26. Split-Ring-Gear-Section-4.stl
- [ ] 27. Split-Ring-Gear-Section-5.stl
- [ ] 28. Split-Ring-Gear-Section-6.stl
- [ ] 29. Split-Ring-Gear-Section-7.stl
- [ ] 30. Upper-Split-Ring-Brace-L.stl
- [ ] 31. Upper-Split-Ring-Brace-R.stl
- [ ] 32. Lower-Split-Ring-Brace-L.stl
- [ ] 33. Lower-Split-Ring-Brace-R.stl
- [ ] 34. Break-Stop.stl
- [ ] 35. DEC-Limited-Switch-Mount.stl
- [ ] 36. Open-Beam-Brackets.stl (Print 2)
- [ ] 37. Pivot.stl
- [ ] 38. DEC37. Pivot.stl-Stepper-Mount.stl
- [ ] 39. Back-Angle-Bracket-L.stl
- [ ] 40. Back-Angle-Bracket-R.stl
- [ ] 41. Front-Angle-Bracket-L.stl
- [ ] 42. Front-Angle-Bracket-R.stl
- [ ] 43. Alt-Stepper-Mount.stl
- [ ] 44. Back-Foot-Housing.stl
- [ ] 45. Base-Upper-Bearing-Lock-L.stl
- [ ] 46. Base-Upper-Bearing-Lock-R.stl
- [ ] 47. Compass-Mount.stl
- [ ] 48. Electronics-Housing.stl
- [ ] 49. Pivot-Mount.stl
- [ ] 50. Split-Ring-Gear.stl
- [ ] 51. Split-Ring-Bearing-Mount-L.stl
- [ ] 52. Split-Ring-Bearing-Mount-R.stl
- [ ] 53. Spirit-Level-Mount.stl

Troubleshooting

What to do if something goes wrong

If your laser cutting doesn't come out the right size.
Check the ratio's, 1 unit should equal 1mm, not 1px.

The holes in my laser cutting aren't lining up perfectly, they look oval.
You'll need to finish them with a drill in the next step of this guide.

If a print fails
Abort and restart the print based on the printer specifications.

If the print fails a few times in a row at exactly the same point
The CAD file may be corrupt. Please contact us to check.

The print is extruding irregularly accross large areas
Reprint the part.

FAQ

Q. What kind of filament should I use?
PLA/ABS - choose what you feel comfortable with. Choose a structurally solid filament.

Q. Can I print these files myself or should I get them printed professionally?
Yes the parts are sized for a hobby-scale printer. Printing the files yourself will be significantly cheaper. Printing the scope is an investment - if you print this yourself you'll invest more time but less money. If you print this professionally it will be faster but more expensive.

Q. When will all of the steps be released?
Sign up at http://openspaceagency.com/ultrascope or keep an eye on the Wevolver page to be notified about the next steps in this guide.

Q. What if I'd like to use imperial measurements?
Scientific projects like this use the metric system, but se this guide to convert measurements: http://www.worldwidemetric.com/measurements.html

Q. How much is this going to cost?
Refer to the BOM on Wevolver: https://www.wevolver.com/osa.projects/ultrascope/

Q. What type of scope is it?
Newtonian with a split ring equatorial mount.

Q: Is the scope portable?
Yes. It breaks down to 3 easy to carry pieces by undoing 8 screws. Once you arrive, you'll need to check the light path for correctness.

Q. What are the specs of the mirror?
The mirrors are sourced from Orion optics. The primary mirror is 6" with a 600mm focal length, classified as f4. Secondary mirror is a 40mm eliptical flat. Orion optics are leaders in their field and supply optics to BAE (http://baesystems.com/).

Q. What are the magnitude capabilities of this scope?
The maximum magnitude of our optics is 12, but with our current design and smart phone we're achieving a magnitude of about 9 or 10.

Q. What 3D printer do you use and which ones am I able to use?
We used a professional sls printer for the scope pictured, but all of the parts are sized and have been printed on an Ultimaker 2 with a build volume of 223mm x 223mm x 205mm.

Q. What other resources will I need?
You'll need to download Cura - layer slicing software.

What the are dimensions of the completed project?
500mm x 550mm x 650mm

If you have any more questions, tune in to our weekly webinar to get advice from John, Leo and Jordan or send us an email at [email]. Details for the webinar can be found on http://openspaceagency.com/ultrascope

Glossary

UEX
Ultrascope Explorer - the scope you are building with this guide. Capable of conducting light curve analysis of objects with a magntiude of around H 9.

UOD
Ultrascope Odyssey - a larger version of the Ultrascope with the ability to collect data from objects in the H 11-12 region.

ARO
Automated Robot Observatory - an astronomical telescope and detector system that makes observations without the intervention of a human.

NEOs
Near Earth Objects - asteroids and comets whose orbits come between 0.983 and 1.3 AUs from the Sun. The Earth is 1 AU from the Sun.

Photometry
Photometry is a technique of astronomy concerned with measuring the flux, or intensity of an astronomical object's electromagnetic radiation.

Asteroid Characterization
Characterization involves determining the type of asteroid in order to know how to deal with it. The primary objective is planetary defense.

H Magnitude
An asteroid's absolute magnitude is the visual magnitude an observer would record if the asteroid were placed 1 Astronomical Unit (AU) away, and 1 AU from the Sun and at a zero phase angle.

Light Curve Analysis
A light curve is a graph of light intensity of a celestial object or region, as a function of time.

Made for you by OSA

The Open Space Agency is dedicated to unlocking the talent, insight and creativity of citizen space explorers around the world.

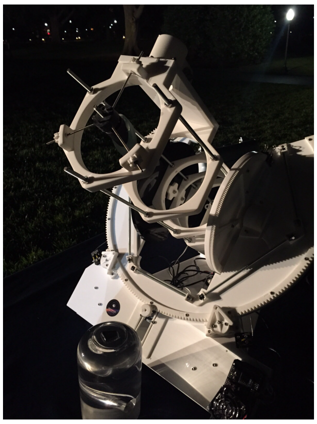
We're part of a growing community of 'Astropreneurs' who believe that the technology, skills and industrial base to meaningfully contribute to space exploration are now within the reach of small teams of passionate individuals.

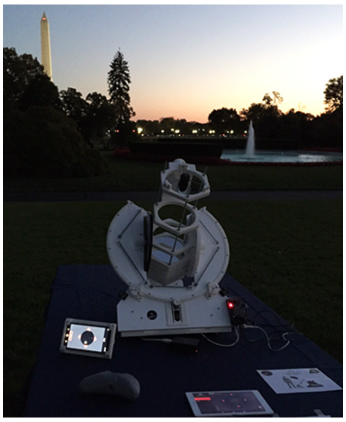
This dream would have been almost impossible just 24 months ago. The levels of precision required for a maker-made scientific quality scope would have resulted in compounding errors conspiring to make observations frustrating for aspiring citizen scientists. However the emergence of low-cost 3D printers and Laser-cutting, paired with microcontroller platforms such as Arduino and Lumia 1020- with its 41 Megapixel CCD - mean that a project such as this is now eminently possible.

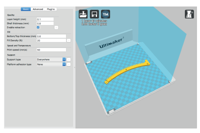
Visit http://www.openspaceagency.com/ultrascope to register as a beta tester.

Ultrascope at the San Diego Maker Faire

Ultrascope at The White House







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