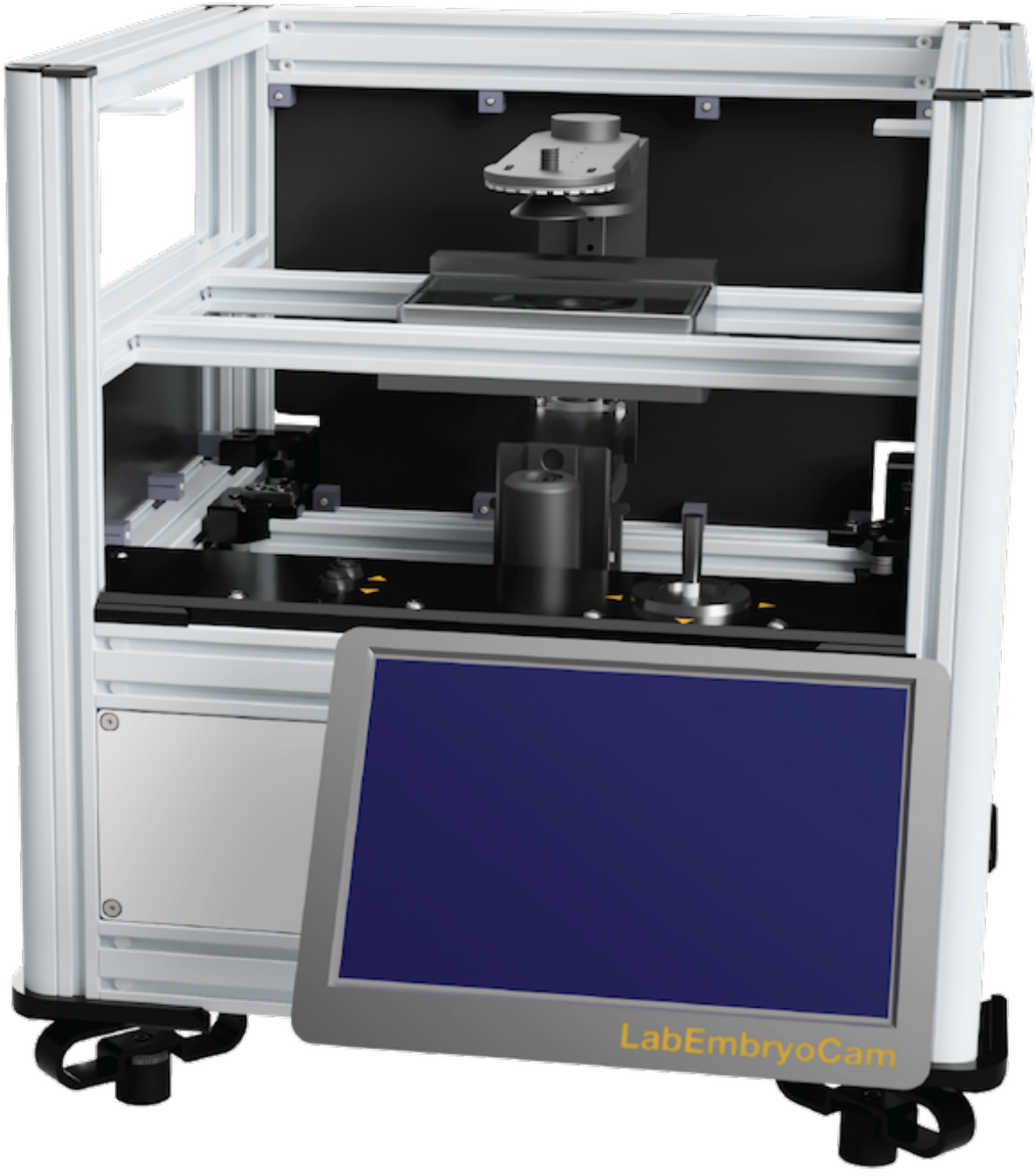
LabEmbryoCam Build Guide

An opensource platform for automated measurement of developing animals

The LabEmbryoCam is a project originating with the EmbryoPhenomics research group at the University of Plymouth, UK. It has been made possible by support from UKRI, NERC, BBSRC and Plymouth Science Park.



1.0 BACKGROUND

The LabEmbryoCam provides:

- Automated movement of a camera and lighting in the X, Y and Z direction, over prolonged periods making it well suited to recording the process of embryonic development in aquatic animals.
- A custom user interface for easy setup of experiments, within a multiwell plate format, but also has sufficient flexibility for other culture formats - petri dishes, or even custom culture solutions.
- Incorporates an optional humifidification chamber to significantly reduce evaportation thereby solving one of the key challenges of long term timelapse imaging of aquatic animals.
- Vibration dampening addressing vibration, the enemy of timelapse imaging.
- LabEmbryoCam incorporates sorbothene feet, 3D printed leafsprings and cable dampeners to minimise its effects on your imaging.
- A low cost, modular and versatile phenotyping platform taking advantage of 3D printed parts, single board computers, microcontrollers, stepper motors and lower cost cameras and lenses.
- Hackability this is an active project - if in doubt about any aspect of this instrument and its suitability to your activities, just ask.

The LabEmbryoCam consists of both hardware and software, and the process of building both is described in the following series of pages.

Required Materials

Building a LabEmbryoCam requires a range of mechnical and electrical parts, and 3D printed parts.

- **Components Required**
- **Fixings required**

The LabEmbryoCam is built using commonly available and low-cost consumer electronics, mechanical parts and 3D printed parts. Links and prices are provided as a guide, but prices vary and there is also significant scope for changing components, or suppliers due to availability, price, or user requirements.

A significant assortment of screws, nuts and washers are required to build a LabEmbryoCam (Bill of materials for fixings in **Required Materials**. To simplify the process of sourcing these parts, a kit of the required fixings can be bought here: https://www.modelfixings.co.uk/embryophenomics.htm (note this kit is not completely up-to-date)

To reduce the number of orders required to source these parts, parts are grouped to a few key suppliers and these are indicated in the bill of materials. Most parts are, however, available from a range of suppliers. There is considerable scope for changing parts to suit your use case.

A CAD model of the LabEmbryoCam is accessible here: https://a360.co/3ZnY7k5

1.1 Assembly Structure

The LabEmbryoCam project is organised as a range of different parts, and the numbering of parts indicates which assembly the part belongs to.

ASSEMBLY	DESCRIPTION
LEC_001	Rexroth Aluminium Frame
LEC_002	Bottom Corners
LEC_003	Back Corners
LEC_004	Front Corners
LEC_005	Y Carriage
LEC_006	X Carriage
LEC_007	Z Carriage
LEC_008	Electronics

1.2 Build Sequence

1. Frame
2. Back corners
3. Front corners
4. Y-carriage
5. X-carriage
6. Belts/Front top
7. Z-carriage
8. Bottom corners
9. Electronics
10. Panels

1.3 3D Printed Parts

STLs are the 3D model files, provided for producing the 3D printed parts. There are > 70 3D printed parts, with many requiring multiple copies. The (n) in the name of some parts indicates the number of that part that needs printing. For each section in this build guide, the required parts are listed. See the build guide for further information on 3D printing these parts.

Unless otherwise stated in **Specific Print Settings** parts should be printed using PETG with a minimum of 30 % infill, with 6 perimeters, 6 bottom layers and 6 top layers.

Parts	Quantity	Specific Print Settings
LEC_002_P_01_FR/BL_BOTTOM-CORNER	2	
LEC_002_P_01_FR/BR_BOTTOM-CORNER	2	
LEC_002_P_03_LEAFSPRING	4	
LEC_003_P_01_BACK-CORNER_L	1	
LEC_003_P_02_BACK-CORNER_R	1	
LEC_003_P_03_PULLEY_L	1	
LEC_003_P_04_PULLEY_R	1	
LEC_003_P_05_KNOB	2	
LEC_004_P_01_BOTTOM-CORNER_L	1	
LEC_004_P_02_BOTTOM-CORNER_R	1	
LEC_004_P_03_LOW-CORNER-BRACKET_L	1	
LEC_005_P_01_YAXIS-LOWER_L	1	
LEC_005_P_02_YAXIS-LOWER_R	1	
LEC_005_P_03_YAXIS-UPPER_L	1	
LEC_005_P_04_YAXIS-UPPER_R	1	
LEC_005_P_05_YAXIS-LIMSWITCH_MOUNT	1	
LEC_006_P_01_Z-AXIS-CARRIAGE-UPPER	1	
LEC_007_P_01_TOP-CORNER_L	1	
LEC_007_P_02_TOP-CORNER_R	1	
LEC_006_P_02_Z-AXIS-CARRIAGE-LOWER	1	
LEC_008_P_01_Z-CARRIAGE	1	CF-PETG
LEC_008_P_02_LIGHT-BRACKET-TOP	1	
LEC_008_P_03_LIGHT-BRACKET-BOTTOM	1	
LEC_008_P_04_OPTICS-MOUNT	1	
LEC_008_P_05_CAM-MOUNT	1	
LEC_008_P_06_RAIL-INSERT	1	
LEC_008_P_07_OPTIC-SCREW	1	
LEC_008_P_08_ZLIM-TRIGGER	1	

LEC_008_P_09_BACK-ROD-SECURE	2	
LEC_008_P_10_FRONT-ROD-SECURE	2	
LEC_008_P_11_LIGHT-MOUNT	1	
LEC_008_P_12_LIGHT-KNOB	1	
LEC_008_P_13_LIGHT-DIFFUSER	1	
LEC_009_P_01_MOUNTING-PLATE	1	

1.4 Fixings

The LabEmbryoCam is assembled using a number of fixings. These are listed in the table below, but in the build guide itself, they are split between the assembly sections.

Parts	Quantity
M2.5	
M2.5_10mm_SOCKETHEAD-SCREW	6
M2.5_10mm_BUTTONHEAD-SCREW	4
M2.5_12mm_BUTTONHEAD-SCREW	4
M3	
M3_10mm_SOCKETHEAD-SCREW	3
M3_10mm_SUNKENHEAD-SCREW	40
M3_12mm_SOCKETHEAD-SCREW	19
M3_15mm_SOCKETHEAD-SCREW	6
M3_16mm_BUTTONHEAD-SCREW	4
M3_16mm_SOCKETHEAD-SCREW	2
M3_18mm_BUTTONHEAD-SCREW	4
M3_35mm_SOCKETHEAD-SCREW	16
M3_50mm SOCKETHEAD-SCREW	2
M3_HEX-NUT	20
M3_SLIDE-NUT	40
M3_WASHER	30

M4	
M4_40mm_HEX-BOLT	2
M4_HEX-NUT	2
M5	
M5_10mm_BUTTONHEAD-SCREW	20
M5_10mm_SOCKETHEAD-SCREW	9
M5_14mm_SOCKETHEAD-SCREW	2
M5_16mm_SOCKETHEAD-SCREW	1
M5_20mm_BUTTONHEAD-SCREW	2
M5_HEX-NUT	2
M5_SLIDE-NUT	42
M6	
M6_12mm_BUTTONHEAD-SCREW	4
M6_45mm_BUTTONHEAD-SCREW	4
M6_HEX-NUT	4
Other	
FAST-CONNECTOR-SCREW	56
FAST-CONNECTOR-SLIDE-PIN	56
END-RAIL-COVER	4
END-RAIL-COVER-ROUNDED	4
PANEL-FIXINGS	44
CABLE-TIE-3mm	4
CABLE-TIE-5mm	8

1.5 Components

The LabEmbryoCam is built using an array of components - in most instances, these are readily available online and not custom. The two exceptions are i) the IGUS rails are cut to 250 mm length and this can have a short leadtime (one week typically), and ii) the electronics enclosure has custom machined panels for the ports, and PCB mountings.

All required components are listed in the table below, and are organised by the different assemblies.

Parts	Quantity
LEC_002_C_01_SORBOTHENE-FEET	4
LEC_003_C_01_F623ZZ-BEARING	4
LEC_004_C_01_F623ZZ-BEARING	8
LEC_004_C_02_XY-STEPPER	2
LEC_004_C_03_TIMING-PULLEY	2
LEC_005_C_01_YAXIS-CARRIAGE_L	1
LEC_005_C_02_YAXIS-CARRIAGE_R	1
LEC_005_C_03_YAXIS-RAIL_L	1
LEC_005_C_04_YAXIS-RAIL_R	1
LEC_005_C_F623ZZ-BEARING	8
LEC_006_C_01_Z-AXIS-RAIL-UPPER	1
LEC_006_C_02_Z-AXIS-RAIL-LOWER	1
LEC_006_C_03_Z-AXIS-RAIL-CARRIAGE-LOWER	1
LEC_006_C_04_Z-AXIS-RAIL-CARRIAGE-UPPER	1
LEC_006_C_05_LEADSCREW-NUT	1
LEC_006_C_06_LINEAR-BEARING	4
LEC_006_C_07_LIM-SWITCH	1
LEC_007_C_GT2-BELT	1
LEC_008_C_01_Z-STEPPER	1
LEC_008_C_02_CAM	1
LEC_008_C_03_LENS	1
LEC_008_C_04_KFL08	1
LEC_008_C_05_FLEX-COUPLING	1
LEC_008_C_06_Z-SCREW	1
LEC_008_C_07_F-ROD	2
LEC_008_C_08_R-ROD	2

LEC_008_C_09_LED-RING	1
LEC_009_C_01_THOR-CUST-BASE-PLATE	1
LEC_009_C_02_THOR-CUST-PORT-PLATE	1
LEC_009_C_03_THOR-CUST-FAN-PLATE	1
LEC_009_C_04_THOR_EC2030BR	1
LEC_009_C_05_RPI4	1
LEC_009_C_06_USB-HUB	1
LEC_009_C_07_PSU-SEASONIC300SUG	1
LEC_009_C_08_DUET	1
LEC_009_C_09_ARDUINO	1
LEC_009_C_10_RJ45-CONN	1
LEC_009_C_11_SWITCH	1
LEC_009_C_12_HDMI-CONN	2
LEC_009_C_13_USB-CONN	2
LEC_009_C_14_DB15-M-CONN	1
LEC_009_C_15_DB25-M-CONN	1
LEC_009_C_16_ATX-BREAKOUT	1
LEC_009_C_17_FAN	1

1.6 CAD

The LabEmbryoCam is modelled using the CAD software Autodesk Fusion360 - freely availabile for hobbyist use, or with an educational license.

INTERACTIVE AND DOWNLOADABLE CAD MODEL: https://a360.co/3ZnY7k5

2.0 ASSEMBLY

3.0 ALUMINIUM EXTRUSION FRAME

The LabEmbryoCam frame is constructed using aluminium extrusion of different cross-sections and lengths. Aluminium extrusion is aluminium of a shape that enable fixing parts to be connected, for connecting extrusion together, or for attaching parts to the extrusion. Here we use Bosch Rexroth extrusion and the accompanying fast connectors to build the frame.

Parts	Shorthand Name	Quantity
Extrusion		
LEC_001_E_01_2040-EXTRUSION-356MM	2040-356MM	8
LEC_001_E_02_2040-EXTRUSION-336MM	2040-336MM	2
LEC_001_E_03_2020-EXTRUSION-418MM-ROUNDED	2020-418MM-ROUNDED	2
LEC_001_E_04_2020-EXTRUSION-416MM	2020-416MM	4
LEC_001_E_05_2020-EXTRUSION-356MM	2020-356MM	2
Fixings		
LEC_001_F_01_FAST-CONNECTOR-SCREW	FAST-CONNECTOR-SCREW	56
LEC_001_F_02_FAST-CONNECTOR-SLIDE-PIN	FAST-CONNECTOR-SLIDE-PIN	56
LEC_001_F_03_2020-END-COVER	2020-END-COVER	4
LEC_001_F_04_2020-ROUNDED-END-COVER	2020-ROUNDED-END-COVER	4
LEC_001_F_05_PANEL-FIXINGS	PANEL-FIXINGS	44
LEC_002_F_01_M5-10MM-BUTTONHEAD-SCREW	M5-10MM-BUTTONHEAD-SCREW	12
LEC_002_F_02_M5-SLIDE-NUT	M5_SLIDE-NUT	12
LEC_002_P_01_FR/BL_BOTTOM-CORNER	FR/BL_BOTTOM-CORNER	2
LEC_002_P_01_FR/BR_BOTTOM-CORNER	FR/BR_BOTTOM-CORNER	2

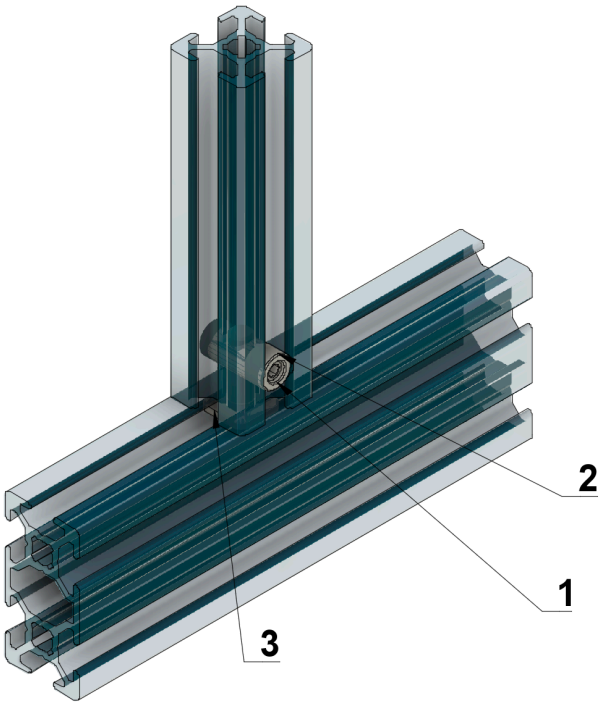
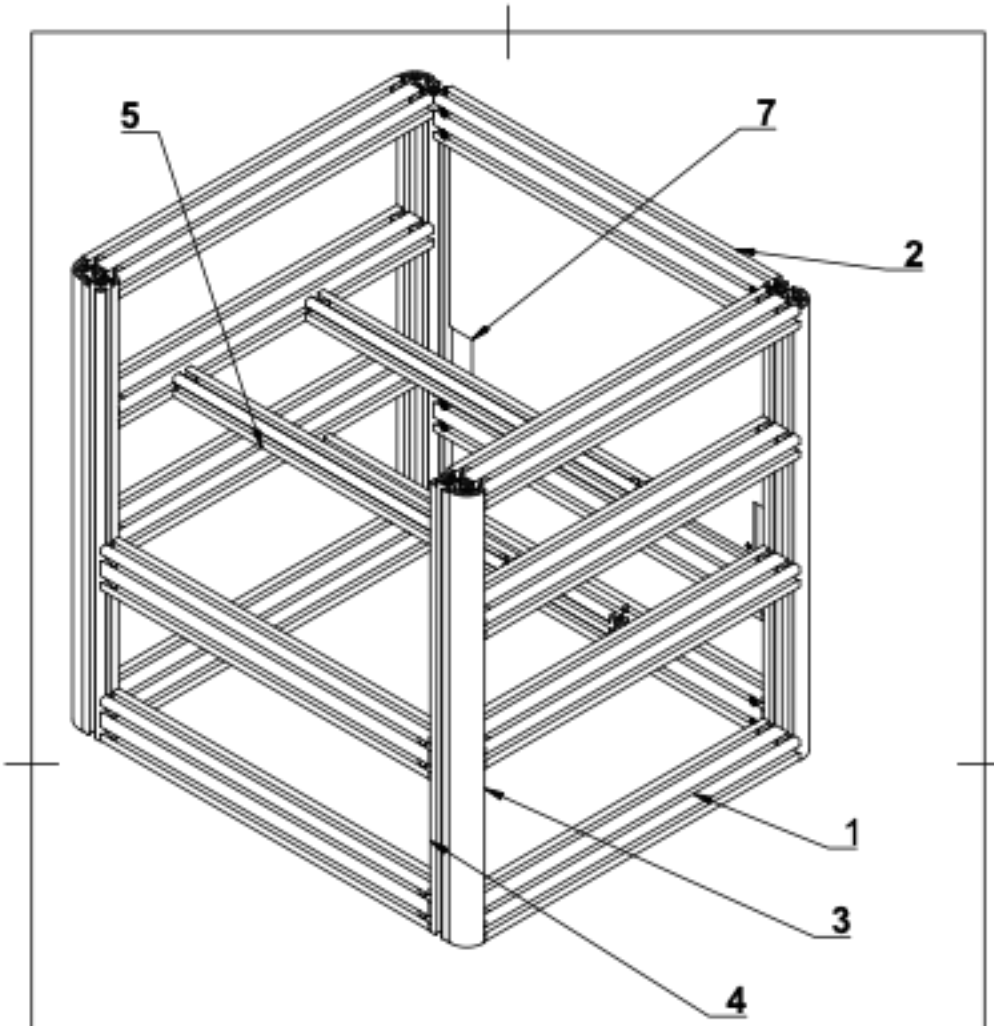


Figure 3. Connecting lengths of aluminium extrusion together. **Fast connector screw** (1 and 2), used to tighten into the **fast connector slide pin** (3).

In the guide we refer to 2020 extrusion, which is 20 mm x 20 mm in cross section, whereas 2040 extrusion is 20 mm x 40 mm in cross section. 2020 extrusion with a rounded corner is also used on each outer upright corner of the instrument..



1	2040	356 mm
2	2040	336 mm
3	2020-rounded	418 mm
4	2020	416 mm
5	2020	356 mm
6	2020	318 mm
7	back-panel	

Figure 2. Frame design.

1. Start by constructing the rear of the frame (2 x **2040-336mm-RAIL**, 2 x **2020-416mm-RAIL**. Take each **2020-416mm-RAIL**, and into the inside groove slide in 4 **FAST-CONNECTOR-SLIDE-PIN** into each rail. Insert the **FAST-CONNECTOR-SCREW** into each **2040-336mm-RAIL**, move these in position following the diagram in Figure 2, and then tighten each screw using the 3mm allen key.

2.Then add the horizontal rails into this rear frame (8 x **2040-356mm-RAIL**, 2 x **2020-418mm-ROUNDED-RAIL**). Lie down the assembled rear frame on the back face and then insert 4 **FAST-CONNECTOR-SLIDE-PIN** into the upward facing grooves. Insert the **FAST-CONNECTOR-SCREW** into each **2040-356mm-RAIL**, and insert these rails into the **FAST-CONNECTOR-SLIDE-PIN**. Do not tighten the allen keys at this stage, otherwise you will be unable to carry out the following steps. Insert 2 **FAST-CONNECTOR-SLIDE-PIN** into each **2020-418mm-ROUNDED-RAIL**. Insert the **2020-418mm-ROUNDED-RAIL** inline with the rear **2020-416mm-RAIL**. The spacing of each of the horizontal **2040-356mm-RAIL** must be established to fit each of the side panels. Use each of the side panels to adjust the spacing of these rails. Once all of these are in place, tighten all screws using the 3mm allen key.

3.Take each of the **2020-356mm-RAIL** and insert the **FAST-CONNECTOR-SCREW**. Then insert each of the **FAST-CONNECTOR-SLIDE-PIN** into the ends of the **2020-356mm-RAIL**. The **2020-356mm-RAIL** used to mount the humidification chamber must be inserted so that the fast connectors are facing horizontally, i.e. the screws used to tighten the fast connectors are facing forwards, not upwards. This means there is then space at the end of each of these rails to attach the humidification chamber. Make sure to orient the slide pins so that the grooves are in line with the **FAST-CONNECTOR-SCREW**. Slide the rails and the **FAST-CONNECTOR-SLIDE-PIN** into the 2nd from the top **2040-356mm-RAIL**. Do not tighten these screws as they will have to be aligned with the humidification chamber mounts later in the build.

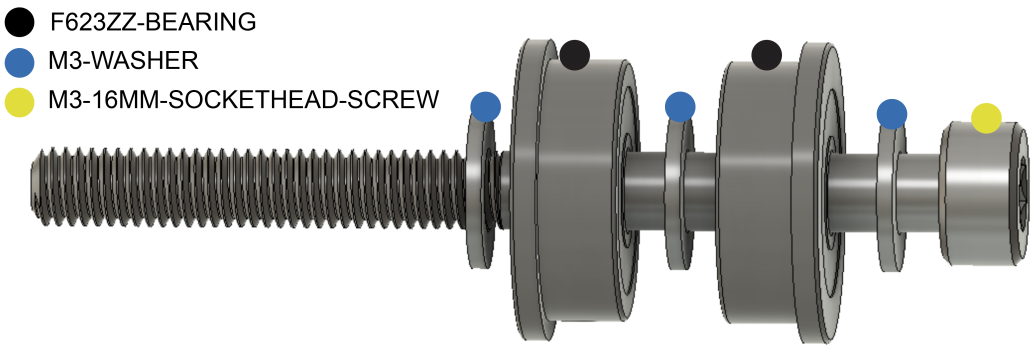
4.Next, assemble the front of the frame. Take the remaining 2 x **2020-416mm-RAIL** and insert 2 **FAST-CONNECTOR-SLIDE-PIN** into the inward facing grooves on each rail. Inset the **FAST-CONNECTOR-SCREW** into the 2 remaining **2040-336mm-RAIL**, and assemble these as per the diagram. Again, use the front panel to adjust the spacing between the top and bottom **2040-336mm-RAIL**. Insert **FAST-CONNECTOR-SCREW** and **FAST-CONNECTOR-SLIDE-PIN** into the ends of each of the horizontal **2040-356mm-RAIL**. Then slide in the assembled front rails into **FAST-CONNECTOR-SLIDE-PIN** in the horizontal **2040-356mm-RAIL**. Do no tighten the screws. Finally, slide into place the 2 remaining **2020-418mm-ROUNDED-RAIL** alongside the front frame. Once all are in place, tighten the **FAST-CONNECTOR-SCREW** using the 3mm allen key.

5. To finish, insert the plastic end rail covers (4 x **END-RAIL-COVER** and 4 x **END-RAIL-COVER-ROUNDED**). **PANEL-FIXINGS** can then be added to each of the railings. These are added on the underside and bottom of the **2040-356mm-RAIL** and **2040-336mm-RAIL**, and can be spaced out using the complementary panels. Do not fix the panels yet as they will get in the way of subsequent steps.

4.0 BACK CORNERS

The back corners are central to effective routing of the belts that create X and Y movement of the instrument. The knobs at the rear of the back corner contribute to this functioning by allowing adjustment of the tension of each of the two belts in the instrument.

Parts	Shorthand Name	QUANTITY
Printed		
LEC_003_P_01_BACK-CORNER_L	BACK-CORNER_L	1
LEC_003_P_02_BACK-CORNER_R	BACK-CORNER_R	1
LEC_003_P_03_PULLEY_L	PULLEY-L	1
LEC_003_P_04_PULLEY_R	PULLEY-R	1
LEC_003_P_05_KNOB	KNOB	2
Components		
LEC_003_C_01_F623ZZ-BEARING	F623ZZ-BEARING	4
Fixings		
LEC_003_F_01_M3-16MM_SOCKETHEAD-SCREW	M3-16mm_SOCKETHEAD-SCREW	2
LEC_003_F_02_M3-WASHER	M3-WASHER	6
LEC_003_F_03_M4-40MM_HEX-BOLT	M4-40MM_HEX-BOLT	2
LEC_003_F_04_M4-HEX-NUT	M4-HEX-NUT	2
LEC_003_F_05_M5-10MM_BUTTONHEAD-SCREW	M5-10MM_BUTTONHEAD-SCREW	8
LEC_003_F_06_M5-SLIDE-NUT	M5-SLIDE-NUT	8



8. The back corners of the LECs are used to feed through the belts, and to adjust the tension of these. Start by constructing each of the rear tensioners, and the associated tensioner knobs. Into the **PULLEY_L** and **PULLEY_R**, screw in the **M4_40mm_HEX-BOLT** so that the thread is sticking out of the back. Next, screw in the **M3_16mm_SOCKETHEAD-SCREWS** into just the base of each and screw each of the components into the inside of the pulleys in this order: **M3_WASHER**, **F623ZZ-BEARING**, **M3_WASHER**, **F623ZZ-BEARING**, **M3_WASHER**.

9. Next, we need to attach the **BACK-CORNER_L** and **BACK-CORNER_R**. Start by adding the **M5_SLIDE-NUTS** into the frame. For each side, add 2 **M5_SLIDE-NUTS** into the inside top groove of the **2040-356mm-RAIL** that is 2nd from the bottom, and 2 **M5_SLIDE-NUTS** to the back of the **2020-416mm-RAIL**. Then fix the **BACK_CORNER_L** and **BACK_CORNER_R** in place. Line up the **M5_SLIDE-NUTS** inline with the screw holes on each 3D printed part, and screw these place using the **M5_10mm_BUTTONHEAD-SCREWS**.

10. Finally, push each of the assembled pulleys into the groove of the **BACK-CORNER_L** and **BACK-CORNER_R** so that the thread of the **M4_40mm_HEX-BOLTS** is coming out of the back of the machine. Insert **M4_HEX-NUTS** into the groove at the rear of the **KNOB**, and then loosely screw on each of the knobs to the thread of the **M4_40mm_HEX-BOLTS**.

5.0 FRONT CORNERS

The front corners are complex parts that are crucial for effective functioning of the instrument. The belts must follow the outlined routes, and in the correct orientation, for the LEC to work as it should.

Parts	Shorthand name	QUANTITY
Printed		
LEC_004_P_01_BOTTOM-FRONT-CORNER-LEFT	BOTTOM-CORNER-L	1
LEC_004_P_02_BOTTOM-FRONT-CORNER-RIGHT	BOTTOM-CORNER-R	1
LEC_004_P_03_TOP-FRONT-CORNER-LEFT	TOP-CORNER-L	1
LEC_004_P_04_TOP-FRONT-CORNER-RIGHT	TOP-CORNER-R	1

Components		
LEC_004_C_01_F623ZZ-BEARING	F623ZZ-BEARING	12
LEC_004_C_02_XY-STEPPER	XY-STEPPER	2
LEC_004_C_03_TIMING-PULLEY	TIMING-PULLEY	2
Fixings		
LEC_004_F_01_M3-15MM-SOCKETHEAD-SCREW	M3-15MM-SOCKETHEAD-SCREW	6
LEC_004_F_02_M3-35MM-SOCKETHEAD-SCREW	M3-35MM-SOCKETHEAD-SCREW	6
LEC_004_F_03_M3-WASHER	M3-WASHER	18
LEC_004_F_04_M3-HEX-NUT	M3-HEX-NUT	6
LEC_004_F_05_M5-10MM-SOCKETHEAD-SCREW	M5-10MM-SOCKETHEAD-SCREW	2
LEC_004_F_06_M5-20MM-BUTTONHEAD-SCREW	M5-20MM-BUTTONHEAD-SCREW	2
LEC_004_F_07_M5-SLIDE-NUT	M5-SLIDE-NUT	8

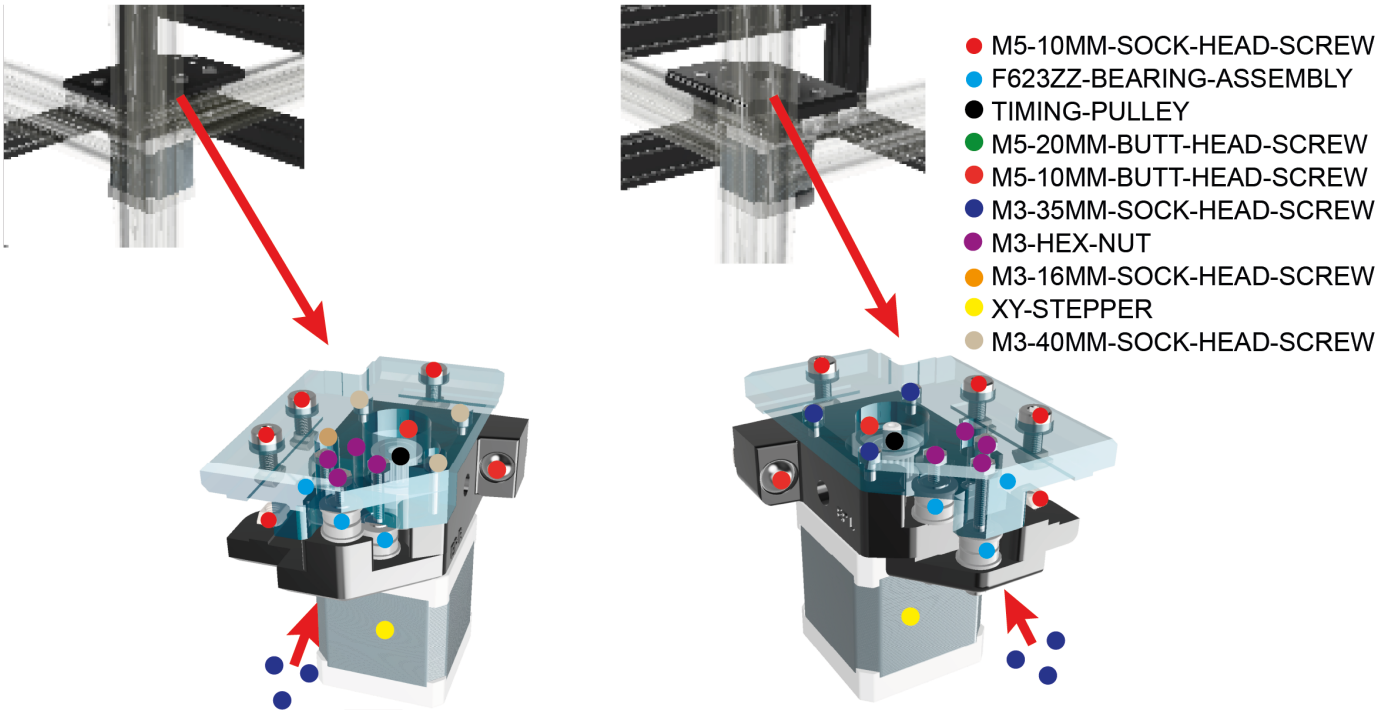


FIGURE XX. Front corners, with the

11. The front corners are used to route the XY belts through the stepper motors. Start by adding the **BOTTOM-CORNER_L**, **BOTTOM-CORNER_R** and **LOW-CORNER-BRACKET_L** to the front corners of the frame. These are attached using **M5_10mm_SOCKETHEAD-SCREW**, **M5_20mm_BUTTONHEAD-SCREW** and **M5_SLIDE-NUT**. To attach these, screw each of the screws in place, and loosely screw the slide nuts onto the thread of these. Push the entire piece into place in the frame and then tighten the screws using an allen key.

12. Next, we need to assemble the bearings and stepper motors used to route the belts into the bottom front corner pieces. Start by attaching each of the **XY-STEPPER** to the bottom corner pieces. When viewed from the top, this will mean screwing a **M3_15mm_SOCKETHEAD-SCREW** into the top left and top right of the left and right bottom corner pieces, and **XY-STEPPER** screw holes respectively. Leave the **XY-STEPPER** attached by the single screw.

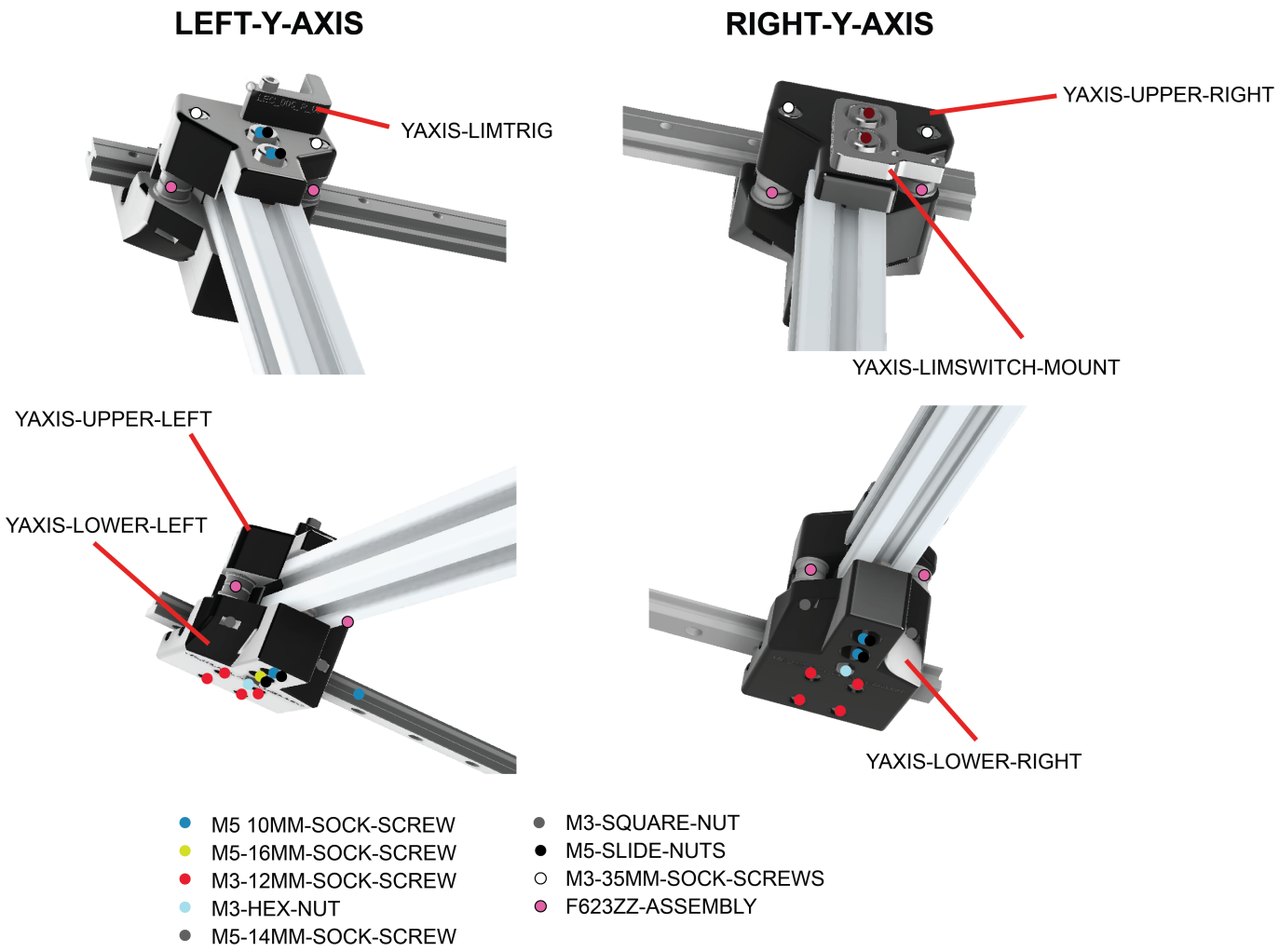
13. Next, screw in 3 **M3_35mm_SOCKETHEAD-SCREW** into the underside of the **BOTTOM-CORNER_L** and **BOTTOM-CORNER_R**. Screw these in leaving approximately 12mm of thread facing vertically out of bottom corner pieces. Onto each of these threads, add these fixings in this order: **M3_WASHER**, **F623ZZ-BEARING**, **M3_WASHER**, **F623ZZ-BEARING**, **M3_WASHER**. Then, to the thread of the stepper motor, add the **TIMING-PULLEY**. The top of the timing pulleys should be at approximately the same height as the bottom corner pieces, and are screwed in place using an allen key.

14. The top corner pieces are left out at this point, as we must assemble other components (**LEC_005_A_Y-CARRIAGE**, **LEC_006_A_X-CARRIAGE**, **LEC_007_A_BELTS**) first.

6.0 Y-AXIS

The y-carriage is responsible for front to back movement of the instrument. It relies on two linear rails mounted on either side of the instrument. Proper mounting of these two linear rails is important to prevent binding of the instrument during movements along the y-axis.

Parts	Shorthand Name	QUANTITY
Printed		
LEC_005_P_01_YAXIS-LOWER-L	YAXIS-LOWER-L	1
LEC_005_P_02_YAXIS-LOWER-R	YAXIS-LOWER-R	1
LEC_005_P_03_YAXIS-UPPER-L	YAXIS-UPPER-L	1
LEC_005_P_04_YAXIS-UPPER-R	YAXIS-UPPER-R	1
LEC_005_P_05_YAXIS-LIMSWITCH-MOUNT	YAXIS-LIMSWITCH-MOUNT	1
Components		
LEC_005_C_01_YAXIS-CARRIAGE-L	YAXIS-CARRIAGE-L	1
LEC_005_C_02_YAXIS-CARRIAGE-R	YAXIS-CARRIAGE-R	1
LEC_005_C_03_YAXIS-RAIL-L	YAXIS-RAIL-L	1
LEC_005_C_04_YAXIS-RAIL-R	YAXIS-RAIL-R	1
LEC_005_C_05_F623ZZ-BEARING	F623ZZ-BEARING	8
Fixings		
LEC_005_F_01_M3_10MM-SOCKETHEAD-SCREW	M3-10MM-SOCKETHEAD-SCREW	20
LEC_005_F_02_M3_12MM-SOCKETHEAD-SCREW	M3-12MM-SOCKETHEAD-SCREW	8
LEC_005_F_03_M3_35MM-SOCKETHEAD-SCREW	M3-35MM-SOCKETHEAD-SCREW	4
LEC_005_F_04_M3_50MM-SOCKETHEAD-SCREW	M3-50MM-SOCKETHEAD-SCREW	1
LEC_005_F_04_M3_60MM-SOCKETHEAD-SCREW	M3-60MM-SOCKETHEAD-SCREW	1
LEC_005_F_05_M3_WASHER	M3_WASHER	12
LEC_005_F_06_M3_HEX-NUT	M3_HEX-NUT	2
LEC_005_F_07_M3_SLIDE-NUT	M3_SLIDE-NUT	20
LEC_005_F_08_M5_10MM-SOCKETHEAD-SCREW	M5-10MM-SOCKETHEAD-SCREW	3
LEC_005_F_09_M5_14MM-SOCKETHEAD-SCREW	M5-14MM-SOCKETHEAD-SCREW	2
LEC_005_F_10_M5_16MM-SOCKETHEAD-SCREW	M5-16MM-SOCKETHEAD-SCREW	1
LEC_005_F_11_M5_SLIDE-NUT	M5_SLIDE-NUT	8



15. Now, the Y-carriage components need to be added to the frame. Take both the **YAXIS-RAIL_L** and **YAXIS-RAIL_R** and slide on the **YAXIS-CARRIAGE_L** and **YAXIS-CARRIAGE_R** to the end of each of these.

16. Attach the **YAXIS-LOWER_L** and **YAXIS-LOWER_R** to the **YAXIS-CARRIAGE_L** and **YAXIS-CARRIAGE_R** respectively, using **M3_12mm_SOCKETHEAD-SCREW**. Into both the **YAXIS-LOWER_L** and **YAXIS-LOWER_R**, screw in **M5_10mm_SOCKETHEAD-SCREW** and **M5_16mm_SOCKETHEAD-SCREW**, and loosely screw on **M5_SLIDE-NUT** to the ends of these.

17. To attach these to the frame, insert **10mm_COUNTERSUNK-SCREW** into each of the rails, and loosely screw on **M3_SLIDE-NUT** to the threads of these. Insert the assembled rails and slide nuts into the grooves on the underside of the horizontal rails inbetween the front and back corner 3D printed parts. Make sure to push these up against the front corner pieces, and then using an allen key screw these into place. Once attached, the assembled carriages should move freely along the rails.

18. Next, construct the complimentary upper sections to the carriages. Take the **YAXIS-LIMSWITCH_MOUNT** and screw it into the **YAXIS-UPPER_L** using **M5_14mm_SOCKETHEAD-SCREW**. Then loosely screw on **M5_SLIDE-NUT** to the threads of these. Next, partically screw in **M3_35mm_SOCKETHEAD-SCREW**, so that the threads of the outer two screws are protruding equidistant with the height of the **YAXIS-**

LOWER_L, and so the central is not protruding at all. Onto the threads of the outside two **M3_35mm_SOCKETHEAD-SCREW**, add these fixings in this order: **M3_WASHER**, **F623ZZ-BEARING**, **M3_WASHER**, **F623ZZ-BEARING**, **M3_WASHER**.

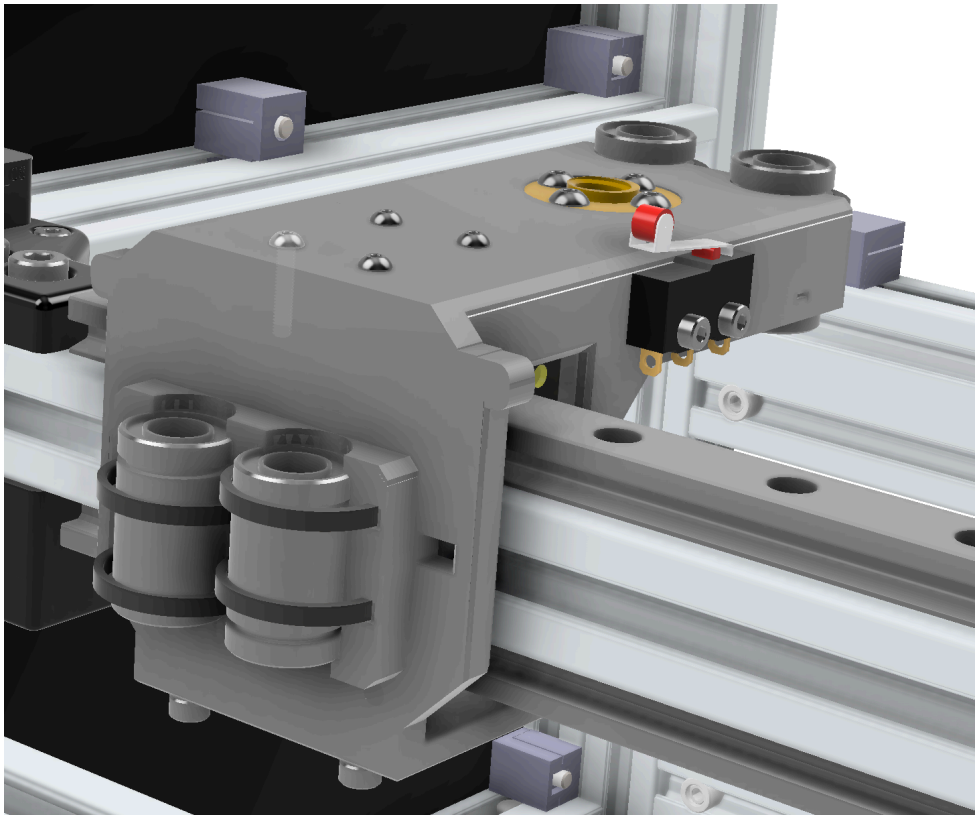
19. For the **YAXIS-UPPER_R**, these steps are slightly different. Screw in **M3_10mm_COUNTERSUNK-SCREW**, and loosely screw on **M5_SLIDE-NUT** to the threads of these. Next, take the **YAXIS-LIMTRIG** and screw this partically into the **YAXIS-UPPER_R** using **M3_50mm SOCKETHEAD-SCREW**, so that the thread does not protrude from the opposite hole. Screw in two more **M3_35mm_SOCKETHEAD-SCREW** either side of this, and assembled the fixings as per step **18**.

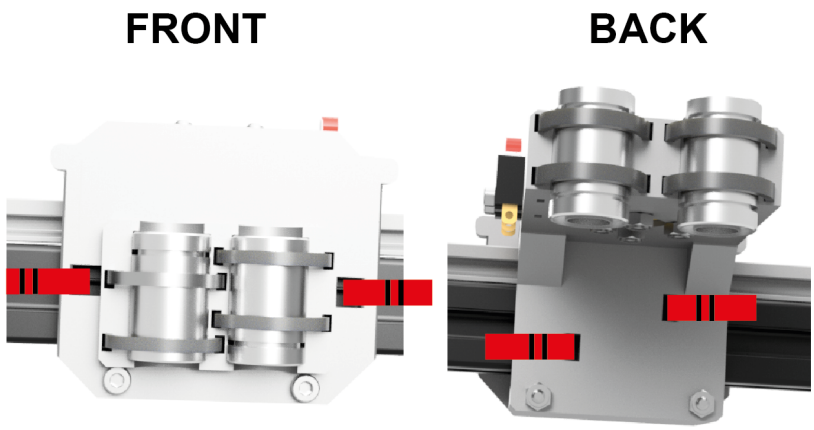
20. You should be left with 2 main assembled complimentary upper parts from steps **18** and **19**. Leave these to one side for now, we will attach these once the X-carriage in the next section has been assembled.

7.0 X-AXIS

The x-carriage is the point of attachment for each end of the two belts responsible for X and Y motion. It slides from side to side on the linear rail attached to the 2020 piece of extrusion that creates the y-carriage.

Parts	Shorthand Name	QUANTITY
Extrusion		
LEC_006_E_01_2020-318MM	2020-318MM	1
Printed		
LEC_006_P_01_X-AXIS-CARRIAGE	Z-AXIS-CARRIAGE	1
Components Z		
LEC_006_C_01_X-AXIS-WS-RAIL	X-AXIS-WS-RAIL	1
LEC_006_C_02_X-AXIS-WS-CARRIAGE	X-AXIS-WS-CARRIAGE	1
LEC_006_C_03_LEADSCREW-NUT	LEADSCREW-NUT	1
LEC_006_C_04_LINEAR-BEARING	LINEAR-BEARING	4
Fixings		
LEC_006_F_01_M4-8MM-SOCKETHEAD-SCREW LEC_006_F_06_M4-8MM-SOCKETHEAD-SCREW	4	
LEC_006_F_02_M4-16MM-BUTTONHEAD-SCREW	M3-16MM-BUTTONHEAD-SCREW	4
LEC_006_F_03_M4-SLIDE-NUT	M5_SLIDE-NUT	4
LEC_006_F_04_M3-HEX-NUT	M3_HEX-NUT	4
LEC_006_F_05_M3-16MM-BUTTONHEAD-SCREW	M3-16MM-BUTTONHEAD-SCREW	4
LEC_006_F_06_CABLE-TIE-3MM	CABLE-TIE-3MM	12





21. The X-carriage is used to mount the Z-carriage. Start by taking the **Z-AXIS-RAIL-UPPER** and **Z-AXIS-RAIL-LOWER** and sliding on the **Z-AXIS-RAIL-CARRIAGE-LOWER** and **Z-AXIS-RAIL-CARRIAGE-UPPER**. Insert **M3_10mm_SUNKENHEAD-SCREW** into the rails and loosely screw on **M3_SLIDE-NUT** to the threads of these. Attach each of the assembled rails to the **2020-318mm-RAIL** and screw this in place.

22. Next, attach the **2020-318mm-RAIL** to the Y-carriage. Start by slotting the rails into the lower M5 slide nuts from the Y-carriage assembled in stage 16, and screw these in place. Next, turn the entire frame upside down, this will help with the following steps. Take the complimentary upper sections of each side of the Y-carriage assembled in step **18**, and screw these in place, by screwing in the 35mm M3 screws containing the washers and bearings, and M5 screws with attached slide nuts. The X and Y axis should now move freely.

23. To construct the Z-axis carriage, start by screwing the **LEADSCREW-NUT** into the **Z-AXIS-CARRIAGE-UPPER** using **M3_16mm_BUTTONHEAD-SCREW** and **M3_HEX-NUT**. Next, take each of the **LINEAR-BEARING**, and fix these in place using **CABLE-TIE-5mm**. Make sure that the thread hole of the cable tie is on the outer side of the carriage. Leave this to one side for now, as we need to attach the belts before attaching this to the rail carriages.

8.0 X-Y AXIS BELTS

Toothed belts are responsible for creating movement in the X and Y directions, from the movement of the shafters of the X and Y stepper motor shafts. The routing of the belts is important. So too is ensuring that the belts are attached to the x-carriage by looping back around on themselves teeth to teeth, to prevent slipping.

Parts	Shorthand Name	QUANTITY
Printed		
LEC_007_P_01_TOP-CORNER_L	TOP-CORNER_L	1
LEC_007_P_02_TOP-CORNER_R	TOP-CORNER_R	1
LEC_007_P_03_Z-AXIS-CARRIAGE-LOWER	Z-AXIS-CARRIAGE-LOWER	1
Components		
LEC_007_C_GT2-BELT	GT2-BELT	2
Fixings		
LEC_007_F_01_M2.5-10MM_BUTTONHEAD-SCREW	M2.5-10MM-BUTTONHEAD-SCREW	4
LEC_007_F_03_M2.5-12MM_BUTTONHEAD-SCREW	M2.5-12MM-BUTTONHEAD-SCREW	4
LEC_007_F_06_M3-18MM-BUTTONHEAD-SCREW	M3_18MM-BUTTONHEAD-SCREW	4
LEC_007_F_01_M3-35MM-SOCKETHEAD-SCREW	M3_35MM-SOCKETHEAD-SCREW	6
LEC_007_F_02_M5-10MM-SOCKETHEAD-SCREW	M5_10MM-SOCKETHEAD-SCREW	2
LEC_007_F_03_M5-SLIDE-NUT	M5_SLIDE-NUT	6
LEC_007_F_04_CABLE-TIE-5MM	CABLE-TIE-5MM	8

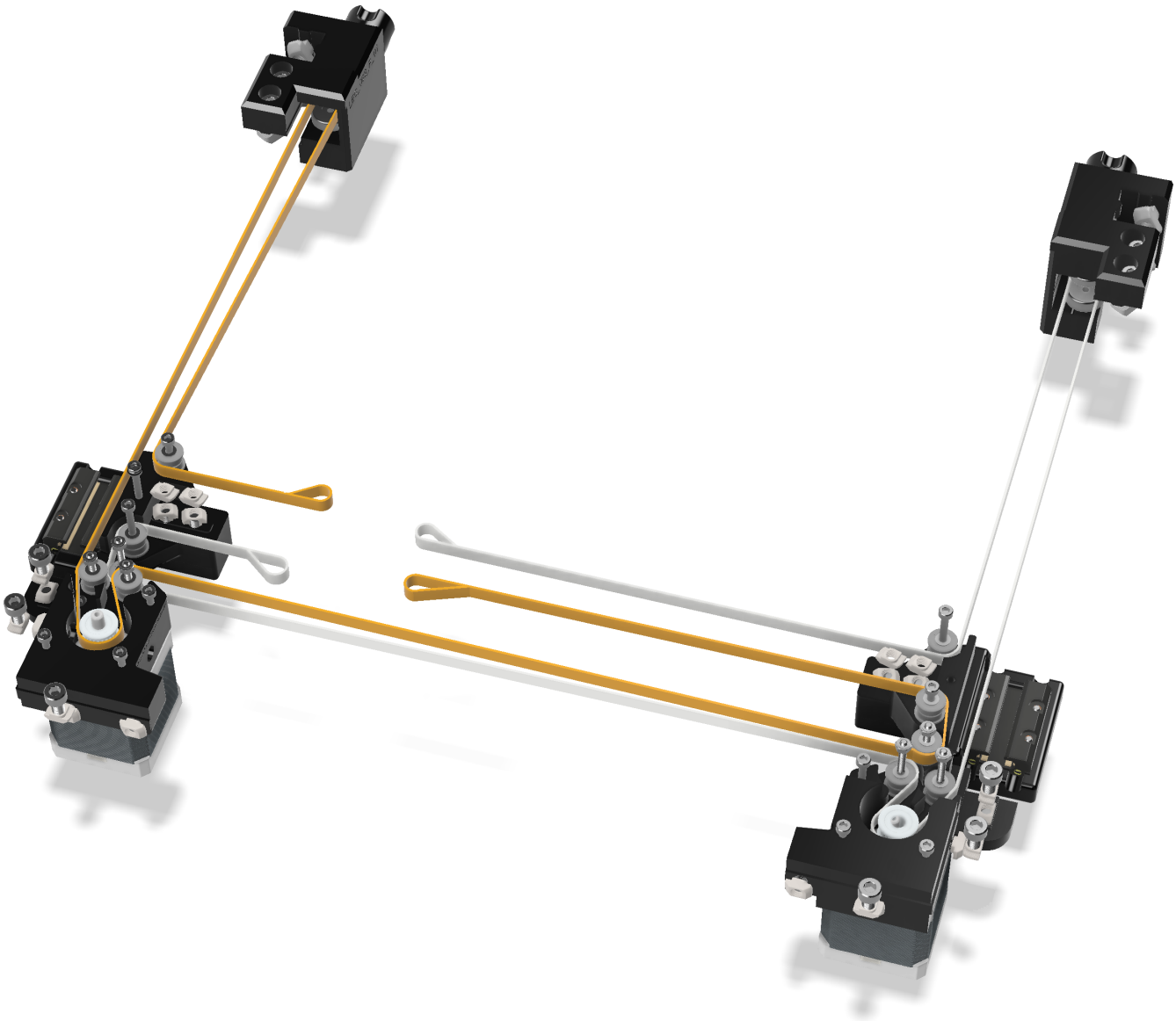


Figure X. Belt routing with top front corner parts removed for clarity, and belts coloured to aid clarity. Belts attach to the x-carriage

NOTE: Each belt, loops through the belt tensioners at the back of the instrument. Once the belt has followed the path, loop around the carriage in the same way as for the other end. At this stage, make sure that the belt tensioner is inserted into the rear of the instrument, and the tensioner knob is screwed on loosely. This is important, to ensure sufficient belt before cutting. Pull the belt tight with a pair of pliers along its route and then secure with a cable tie. Now you can cut the belt.

24. You should start with two **GT2-BELTS**. Take one end, and pass it through the hole on the Z-carriage constructed in step **23**, and loop it back on itself. The teeth of the **GT2-BELT** should lock into eachother. Secure this in place using two **CABLE-TIE-5mm**. Do the same with the second belt on the opposite end of the carriage. Route the belts through the front corner, Y carriage and back corners as per the diagram, and secure each belt to the back of the z-carriage using the same method described earlier in this step. When routing the belts through the Y-carriage, you may need to use a pair of tweezers to pull the belt through.

25. Now the belts have been routed and attached to the Z-axis carriage, attach the Z-axis carriage to the upper rail carriage on the upper X rail using **M2.5_12mm_BUTTONHEAD-SCREW**. Screw the **Z-AXIS-CARRIAGE-LOWER** to the lower rail carriage using **M2.5_10mm_BUTTONHEAD-SCREW**. The **Z-AXIS-CARRIAGE-LOWER** is also screwed to the Z-carriage constructed in step **23** using

M3_18mm_BUTTONHEAD-SCREW.

ADD STEP TO ATTACH THE FRONT CORNERS. LEFT HAND SIDE NEEDS SMALLER M3 SCREWS TO ATTACH STEPPER MOTORS, 35MM CURRENTLY TOO LONG. IDEALLY NEED 30MM.

26. Once the belts and Z-carriage are in place, tighten the belts using the back corner knobs constructed in step **10**.

The belt should then be tightened, by using the tensioner knobs at the back of the instrument, pulling the belts backwards. They should be sufficiently tight so as not to be sagging, but not 'guitar string' tight.

9.0 Z-AXIS

The z-carriage carries the optics - including the camera, lens and light, and enables movement up and down. The carriage is mounted on the x-carriage and slides up and down on rods, driven by a leadscrew attached to the z-axis stepper motor

Parts	Shorthand Name	QUANTITY
Printed		
LEC_008_P_01_Z-CARRIAGE	Z-CARRIAGE	1
LEC_008_P_02_LIGHT-BRACKET-TOP	LIGHT-BRACKET-TOP	1
LEC_008_P_03_LIGHT-BRACKET-BOTTOM	LIGHT-BRACKET-BOTTOM	1
LEC_008_P_04_OPTICS-MOUNT	OPTICS-MOUNT	1
LEC_008_P_05_CAM-MOUNT	CAM-MOUNT	1
LEC_008_P_06_RAIL-INSERT	RAIL-INSERT	1
LEC_008_P_07_OPTIC-SCREW	OPTIC-SCREW	1
LEC_008_P_08_ZLIM-TRIGGER	ZLIM-TRIGGER	1
LEC_008_P_09_BACK-ROD-SECURE	BACK-ROD-SECURE	2
LEC_008_P_10_FRONT-ROD-SECURE	FRONT-ROD-SECURE	2
LEC_008_P_11_LIGHT-MOUNT	LIGHT-MOUNT	1

LEC_008_P_12_LIGHT-KNOB	LIGHT-KNOB	1
LEC_008_P_13_LIGHT-DIFFUSER	LIGHT-DIFFUSER	1
Components		
LEC_008_C_01_Z-STEPPER	Z-STEPPER	1
LEC_008_C_02_CAM	CAM	1
LEC_008_C_03_CAM-HDMI	CAM-HDMI	1
LEC_008_C_04_LENS	LENS	1
LEC_008_C_05_KFL08	KFL08-BEARING	1
LEC_008_C_06_FLEX-COUPLING	FLEX-COUPLING	1
LEC_008_C_07_Z-SCREW	Z-SCREW	1
LEC_008_C_08_F-ROD	F-ROD	2
LEC_008_C_09_R-ROD	R-ROD	2
LEC_008_C_10_LED-RING	LED-RING	1
LEC_008_C_11_Z-LEADSCREW	LEADSCREW	1
Fixings		
LEC_008_F_01_M2.5-10MM-SOCKETHEAD-SCREW	M2.5-10MM-SOCKETHEAD-SCREW	4
LEC_008_F_02_M3-10MM-SOCKETHEAD-SCREW	M3-10MM-SOCKETHEAD-SCREW	3
LEC_008_F_03_M3-12MM-SOCKETHEAD-SCREW	M3-12MM-SOCKETHEAD-SCREW	11
LEC_008_F_04_M3-HEX-NUT	M3-HEX-NUT	8
LEC_008_F_05_M5-10MM-SOCKETHEAD-SCREW	M5-10MM-SOCKETHEAD-SCREW	2
LEC_008_F_06_M5-HEX-NUT	M5-HEX-NUT	2
LEC_008_F_06_M2.5-12MM	M2.5-12MM-SOCK-SCREW	2

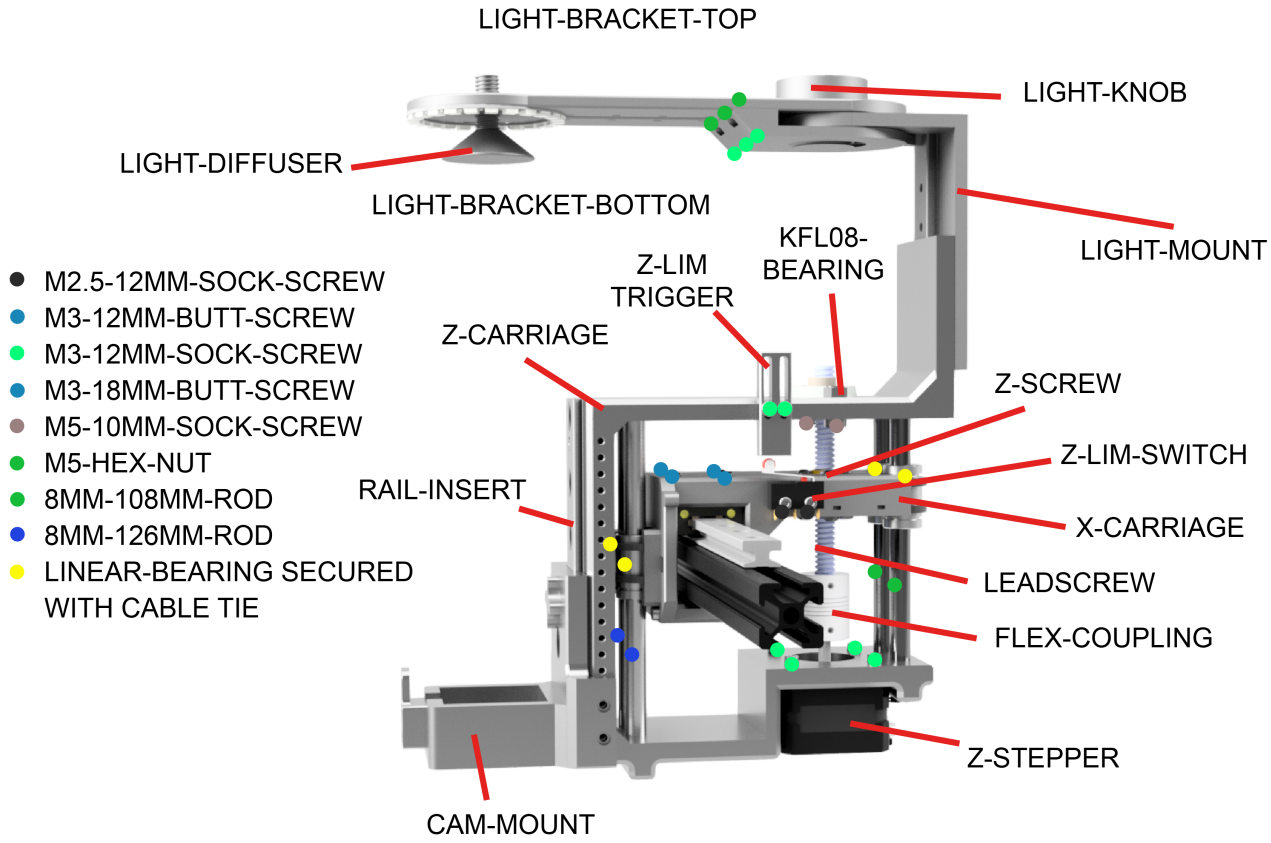
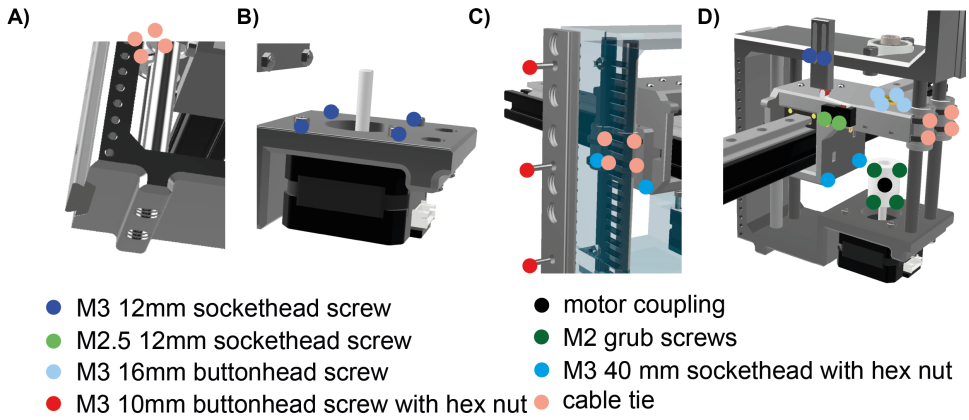


Figure 4. Z-axis assembly



27. Start by attaching various printed parts and components to the **Z-CARRIAGE**. Start by screwing the **RAIL-INSERT** to the **Z-CARRIAGE** using **M3_12mm_SOCKETHEAD-SCREW**. Next, attach the **ZLIM-TRIGGER** using **M3_12mm_SOCKETHEAD-SCREW**, attach the **KFL08** using **M5_10mm_SOCKETHEAD-SCREW** and **M5_HEX-NUT**, and attach the **Z-STEPPER** using **M3_12mm_SOCKETHEAD-SCREW**. Finally, attach the **FLEX-COUPLING** to the drive shaft of the **Z-STEPPER**, which should be secured using ..

28. Next, we need to attach the **Z-CARRIAGE** to the Z-carriage on the X-rail. To do this, orient the **Z-CARRIAGE** as per the diagram, and pass the two **F-ROD** (longer rods) through the holes on the front underside of the **Z-CARRIAGE**. The rods need to pass through the linear bearings attached to the Z-carriage on the Z-rail, before slotting into the grooves on the underside of the top face of the **Z-CARRIAGE**. Gently tap these into place, and screw in the **FRONT-ROD-SECURE** to secure these rods in place. Do the same for the **R-ROD** (shorter rods) and secure these using **BACK-ROD-SECURE**. Finally, pass the **Z-SCREW** through the **KFL08** and screw it into the **FLEX-COUPLING**. Secure this in place by screwing the **Z-SCREW** into the

KFL08. Gently turning the **FLEX-COUPLING** should now move the **Z-CARRIAGE** up and down.

29. Next, attach the **OPTICS-MOUNT** and **LIGHT-MOUNT** by slotting them into the front and of the **Z-CARRIAGE** respectively. Screw the **OPTIC-SCREW** into the **CAM-MOUNT**, and screw the **CAM-MOUNT** into the **CAM-MOUNT** using **M2.5_10mm_SOCKETHEAD-SCREW**.

30. Finally, assemble the bracket for the light ring. Attach the **LIGHT-BRACKET-TOP** to the **LIGHT-BRACKET-BOTTOM** using **M3_10mm_SOCKETHEAD-SCREW** and **M3_HEX-NUT**. Leave this assembly to one side for now, as we need to solder and wire up the light ring before attaching it to the **LIGHT-MOUNT**.

11.0 ELECTRONICS

The electronics of the LabEmbryoCam are concentrated in the electronics enclosure mounted on the rear of the instrument. A number of wiring looms and individual cables, connect this to different parts of the instrument, via labelled ports on the electronics enclosure

PARTS	SHORTHAND NAME	QUANTITY
3D PRINTED		
LEC_009_P_01_MOUNTING-PLATE	MOUNTING-PLATE	1
LEC_009_P_02_PORT-PLATE	PORT-PLATE	1
LEC_009_P_03_FAN-PLATE	FAN-PLATE	1
LEC_009_P_04_FRONT-BREAKOUT-MOUNT	FRONT-BOARD-MOUNT	1
LEC_009_P_05_CABLE-MOUNT	CABLE-MOUNT	8
LEC_009_P_06_R-FRONT-PANEL	R-FRONT-PANEL	1
LEC_009_P_07_L-FRONT-PANEL	L-FRONT-PANEL	1
LEC_009_P_08_ELEC-MOUNT-BOTTOM	BOTTOM-ENCLOSURE-BRACKET	1
LEC_009_P_09_ELEC-MOUNT-TOP	TOP-ENCLOSURE-BRACKET	1
LEC_009_P_10_MICROCONTROLLER-BRACKET	MICROCONTROLLER-BRACKET	1
LEC_009_P_11_DISPLAY-FASCIA	DISPLAY-FASCIA	1
LEC_009_P_12_DISPLAY-REAR	DISPLAY-REAR	1
LEC_009_P_13_DISPLAY-ARM	DISPLAY-ARM	1
LEC_009_P_14_DISPLAY-BRACKET	DISPLAY-BRACKET	1
LEC_009_P_15_CABLE-BRACKET	CABLE-BRACKET	10
COMPONENTS		
LEC_009_C_01_THOR-ELEC-ENC	ELECTRONICS-ENCLOSURE	1
LEC_009_C_02_THOR_ELEC-ENC-BASEPLATE	ELECTRONICS-BASE-PLATE	1
LEC_009_C_03_RPI4	RPI4	1
LEC_009_C_04_USB-HUB	USB-HUB	1
LEC_009_C_05_PSU-SEASONIC300SUG	PSU-SEASONIC300SUG	1
LEC_009_C_06_DUET	DUET	1
LEC_009_C_07_ARDUINO	ARDUINO	1

LEC_009_C_08_RJ45-CONN	RJ45-CONN	1
LEC_009_C_09_SWITCH	SWITCH	1
LEC_009_C_10_HDMI-CONN	HDMI-CONN	2
LEC_009_C_11_USB-CONN	USB-CONN	3
LEC_009_C_12_DB15-M-CONN	DB15-M-CONN	1
LEC_009_C_13_DB25-M-CONN	DB25-M-CONN	1
LEC_009_C_14_ATX-BREAKOUT	ATX-BREAKOUT	1
LEC_009_C_15_CASE-FAN	CASE-FAN	1
LEC_009_C_16_RPI_FAN	RPI_FAN	1
LEC_009_C_17_CSI-HDMI-CAM-HAT	CAM-HAT	1
LEC_009_C_18_RPI-HQ-CAM	CAM	1
LEC_009_C_19_LENS	LENS	1
LEC_009_C_20_HDMI-F-F-COUPLER	HDMI-COUPLER	1
LEC_009_C_21_USB-C-R-ANGLE-CABLE	USB-C-R-ANG	2
LEC_009_C_22_MICRO-HDMI-R-ANGLE-CABLE	U-HDMI-CABLE	1
LEC_009_C_23_USD-CARD	USD-CARD	1
LEC_009_C_24_USBA-ARDUINO	ARD-USB	1
LEC_009_C_25_USBMIC-DUET	DUET-USB	1
LEC_009_C_26_DISPLAY-HDMI	DISP-HDMI	1
LEC_009_C_27_DISPLAY-USB	DISP-USB	1
LEC_009_C_28_DISPLAY	DISPLAY	1
FIXINGS		
LEC_009_F_01_M3_12mm_COUNTERSUNK-SCREW	M3_12mm_COUNTERSUNK-SCREW	3
LEC_009_F_02_M3_DB-JACK-SCREW-HEAD	JACK-SCREW	4
LEC_009_F_03_M3_NYLOC-NUT	NYLOC-SCREW	4
LEC_009_F_04_M3_USB-SCREWS	NYLOC-SCREW	1
LEC_009_F_05_TRIPOD-SCREW	CAM-SCREW	1
LEC_009_F_06_M4-HEX-40MM-SCREW	DISPLAY-HEX-SCREW	2
LEC_009_F_07_M4-NYLOC-HEX-NUT	DISPLAY-HEX-NUT	2
LEC_009_F_08_M2.5-8MM-SOCKETHEAD-SCREW	DISPLAY-M2.5-SOCKETHEAD	4
LEC_009_F_09_M5-6MM-BUTTONHEAD-SCREW	DISPLAY-M5-BUTTONHEAD	4
LEC_009_F_10_M3-8MM-SOCKETHEAD-SCREW	DISPLAY-M3-SOCKETHEAD	4
LEC_009_F_11_M5-6MM-BUTTONHEAD-SCREW	CABLE-BRACKET-M5-BUTTONHEAD	10
LEC_009_F_12_M5-SLIDENUT	M5-SLIDENUT	14
ELECTRONICS ASSEMBLIES		
LEC_009_A_01_ELEC-ENC	ELECTRONICS-ENCLOSURE	1
LEC_009_A_02_25PIN-M-ELEC-ENC	25PIN-ENC	1
LEC_009_A_03_25PIN-F-EXT	25PIN-EXT	1
LEC_009_A_04_15PIN-M-ELEC-ENC	15PIN-ENC	1
LEC_009_A_05_15PIN-F-EXT	15PIN-EXT	1
LEC_009_A_06_FRONT-BOARD-ASSEMBLY	FRONT-BOARD	1

LEC_009_A_07_Z-BOARD-ASSEMBLY	Z-BOARD	1

11.1 Overview

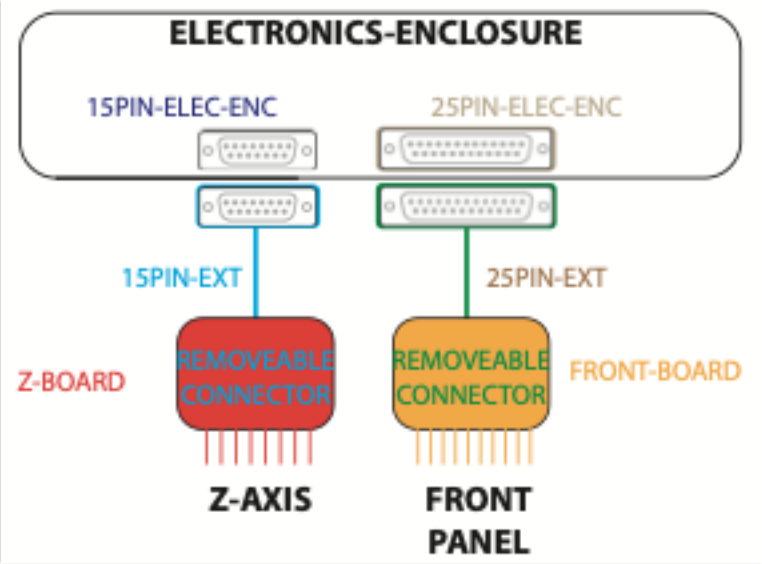
The LabEmbryoCam build requires six wiring looms, which are treated here as 'assemblies'.

1. 25 pin wiring loom
   a) Inside the electronics enclosure (25PIN-EXT, 11.X)
   b) From the electronics enclosure to the front panel (25PIN-ELEC-ENC, 11.X)
   c) Front circuitboard assembly (FRONT-BOARD 11.X)
2. 15 pin wiring loom
   a) Inside the electronics enclosure (15PIN-EXT, 11.X)
   b) From the electronics enclosure to the front panel (15PIN-ELEC-ENC, 11.X)
   c) Z-axis circuitboard assembly (Z-BOARD, 11.X)

For most builders, these will have been provided as already built 'assemblies', and can simply be attached to the relevant parts of the instrument. Nonetheless, for the assembly to be complete, the full details of how to create these wiring assemblies are provided at the end of the electronics section of the build guide, in the sections given for each part above.

11.2 Electronics Enclosure

Electronics are mounted inside a metal enclosure, with 3D printed endplates, which is attached to the rear of the instrument.


ELECTRONICS-ENCLOSURE
15PIN-ELEC-ENC
25PIN-ELEC-ENC
15PIN-EXT
25PIN-EXT
Z-BOARD
REMOVEABLE CONNECTOR
REMOVEABLE CONNECTOR
FRONT-BOARD
Z-AXIS
FRONT PANEL

Electronics Enclosure (LEC_009_A_01)

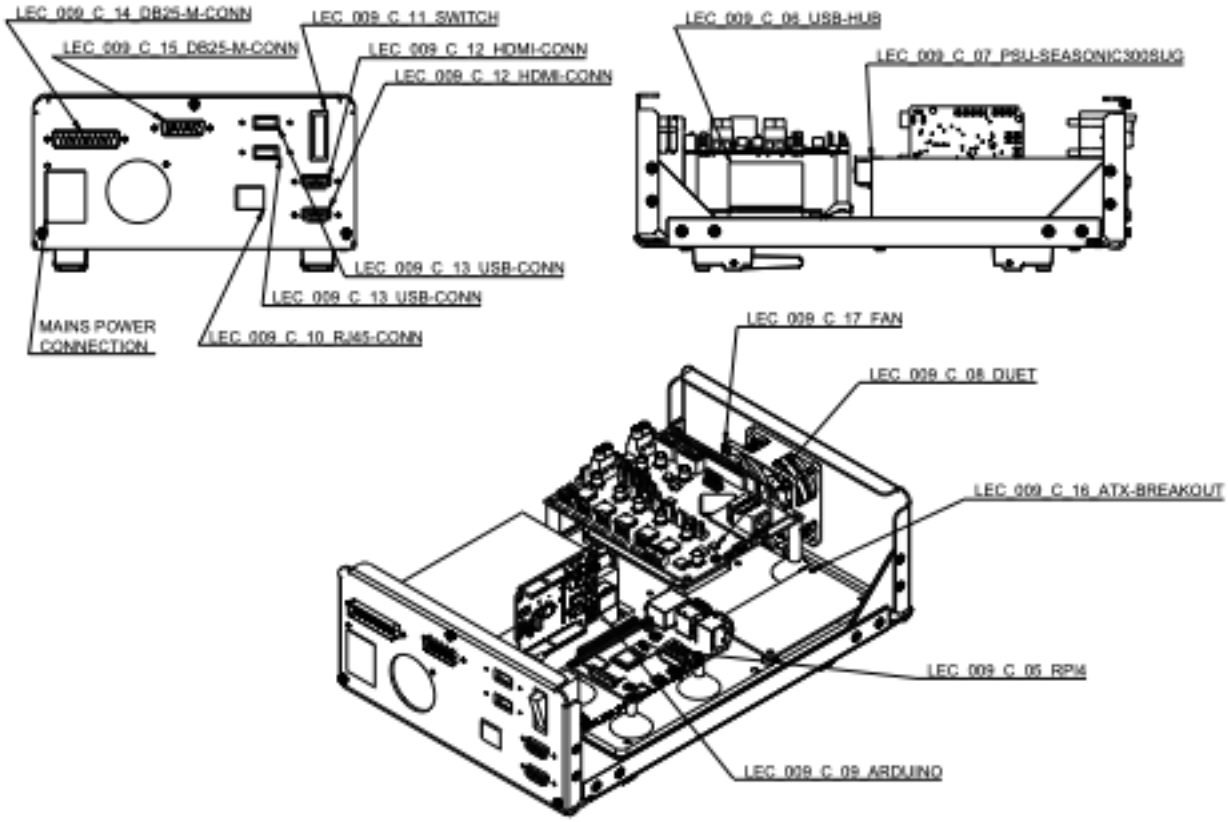


FIGURE XX Electronics enclosure assembly

Attaching Internal Components

Connect the 3D printed plastic MOUNTING-PLATE to the metal plate of the electronics enclosure. Using M3 XX mm screws.

Begin by attaching the power supply, PSU-SEASONIC300SUG, with four screws - two to attach it to the front panel, and two to attach the back to the MOUNTING plate.

Attach the FAN to the rear fan plate of the electronics enclosure, using the four fan screws, included with it.

Install the USB-HUB using xx MM screws, with the USB-A ports facing the fan, and the USB-C ports facing the PSU.

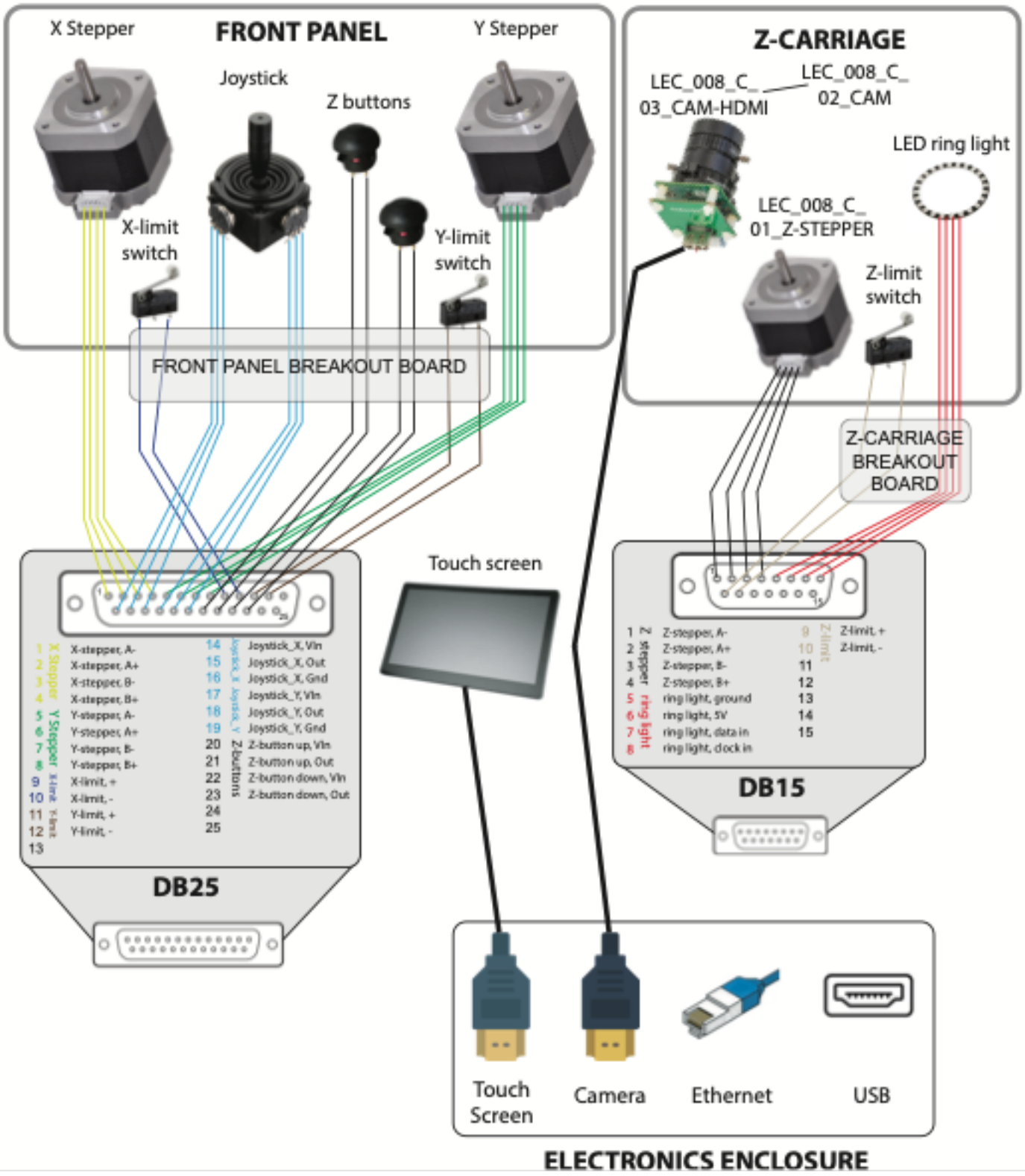
Attach the ATX-BREAKOUT to the MOUNTING-PLATE using XX MM screws.

Connect the ARDUCAM HDMI-CSI adapter to the top of the RPI4, and then the RPI to the MOUNTING-PLATE, using M2.5 screws.

...FIG..

11.3 Wiring Loom

FIGURE XX Wiring loom


X Stepper
FRONT PANEL
Y Stepper
Joystick
Z buttons
X-limit switch
Y-limit switch
FRONT PANEL BREAKOUT BOARD
Z-CARRIAGE
LEC_008_C_ 03_CAM-HDMI
LEC_008_C_ 02_CAM
LED ring light
LEC_008_C_ 01_Z-STEPPER
Z-limit switch
Z-CARRIAGE BREAKOUT BOARD
Touch screen
X-stepper, A-
X-stepper, A+
X-stepper, B-
X-stepper, B+
Y-stepper, A-
Y-stepper, A+
Y-stepper, B-
Y-stepper, B+
X-limit, +
X-limit, -
Y-limit, +
Y-limit, -
Joystick_X, Vin
Joystick_X, Out
Joystick_X, Gnd
Joystick_Y, Vin
Joystick_Y, Out
Joystick_Y, Gnd
Z-button up, Vin
Z-button up, Out
Z-button down, Vin
Z-button down, Out
DB25
Z-stepper, A-
Z-stepper, A+
Z-stepper, B-
Z-stepper, B+
ring light, ground
ring light, 5V
ring light, data in
ring light, clock in
Z-limit, +
Z-limit, -
DB15
Touch Screen
Camera
Ethernet
USB
ELECTRONICS ENCLOSURE

Two wiring looms connect the majority of the electronic components in the LabEmbryoCam to the electronics enclosure on the rear of the instrument.

Begin by cutting the wires detailed below to the necessary lengths, for each of the looms. Each wire must be terminated with the appropriate conncetion types, and labelled acording to the guide below.

11.3.1 Wiring Loom 1 - DB25

Runs from front of instrument and terminates to a DB25 female connector, that connects to the receptive male port on the electronics enclosure

WIRES REQUIRED		
Wire type	**Function**	**Length**
4 Multicore ribbon	X_Stepper_Motor	125cm
BLACK		
BLUE		
GREEN		
RED		
3 Multicore ribbon	Joystick_X	135cm
RED		
BLUE		
*G*REEN		
3 Multicore ribbon	Joystick_Y	135cm
GREEN		
BLUE		
RED		
4 Multicore ribbon	Y_Stepper_Motor	135cm
BLACK		
BLUE		
GREEN		
RED		
2 Multicore ribbon	Z_Button_Up	135cm

BLUE		
YELLOW		
2 Multicore ribbon	Z_Button_Down	135cm
BLUE		
YELLOW		
2 Multicore ribbon	Y_Limit_Switch	60?cm
BLUE		
YELLOW		
2 Multicore ribbon	X_Limit_Switch	80?cm
BLUE		
YELLOW		

11.3.2 Front Panel Wiring Hub

-- change z-but colours

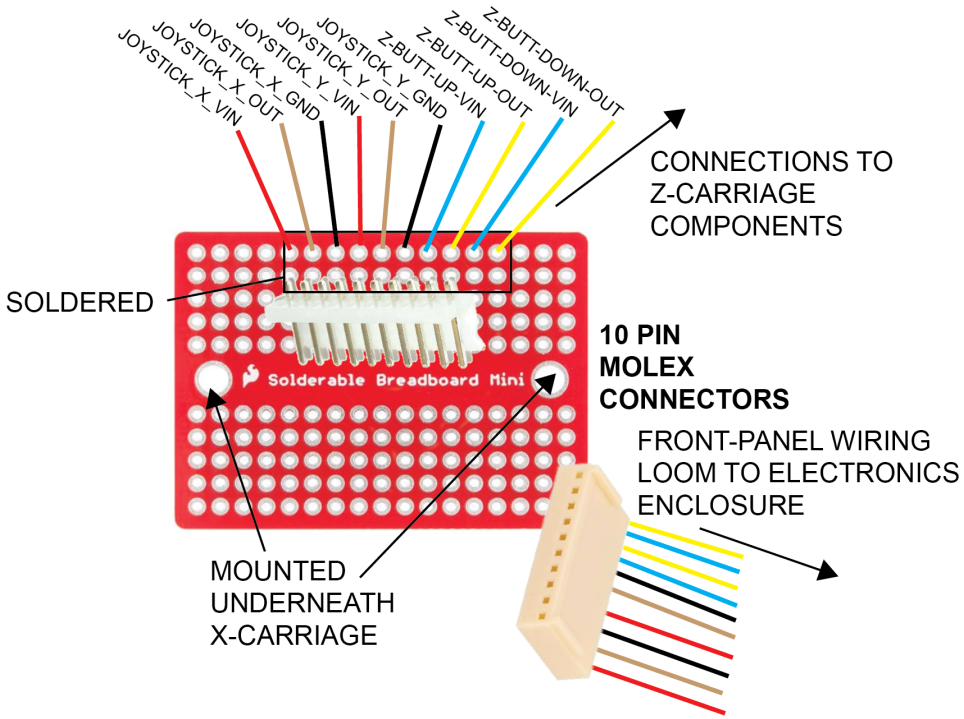


Figure XX. ...

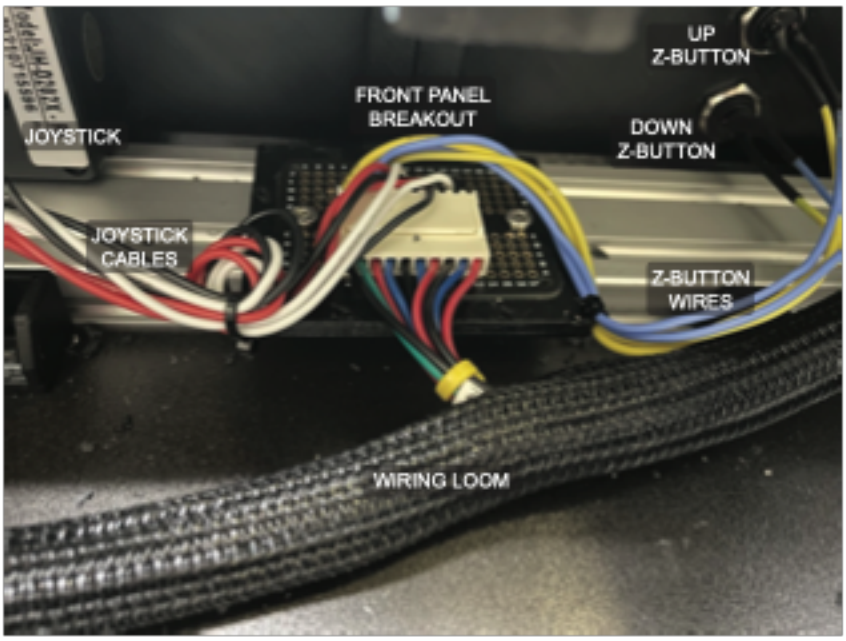


Figure XX. FRONT PANEL BREAKOUT ...

11.3.3 Wiring Loom 2 - DB15

Runs from Z-carriage to a DB15 female connector, that connects to the receptive male port on the electronics enclosure

WIRES REQUIRED		
Wire type	**Function**	**Length**
4 Multicore ribbon	Z_Stepper_Motor	85cm
2 Multicore ribbon	Z_Limit_Switch	50cm
4 Multicore ribbon	LED	50cm

WIRES REQUIRED			
Wire type	**Function**	**Length**	**Termination A**
4 Multicore ribbon	LED	50cm	BARE
2 Multicore ribbon	Z-limit		25cm
** double check these z-carriage lengths**			

Black, Blue, Green, Red

diagram/lengths needed

11.3.4 Z Wiring Hub

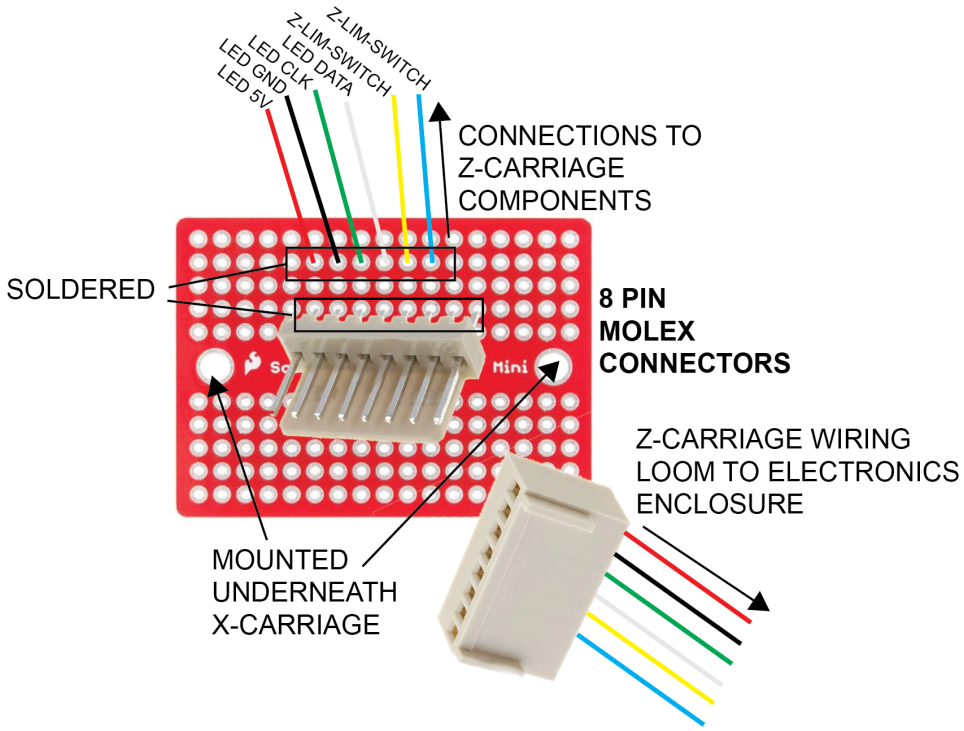


Figure XX. Z-AXIS-BREAKOUT

diagram/lengths needed

11.3.5 Electronics Enclosure Wiring

WIRES REQUIRED	Function	Length	Termination	Routing
DB25				
4 Multicore ribbon	X Stepper motor	20cm	Wire -> MOLEX	DB25->DUET
4 Multicore ribbon	Y Stepper motor	20cm	Wire -> MOLEX	DB25->DUET
1 x Blue, 1 x Yellow	X Limit switch	25cm	Wire -> MOLEX	DB25->DUET
1 x Blue, 1 x Yellow	Y Limit switch	25cm	Wire -> MOLEX	DB25->DUET
4 Multicore ribbon	Z buttons	20cm	Wire -> Wire	DB25->ARDUINO
3 Multicore ribbon	X Joystick	20cm	Wire -> Wire	DB25->ARDUINO
3 Multicore ribbon	Y Joystick	20cm	Wire -> Wire	DB25->ARDUINO
DB15				
1 x Blue, 1 x Yellow	Z Limit switch	25cm	Wire -> MOLEX	DB15->DUET
4 Multicore ribbon	Z Stepper motor	20cm	Wire -> MOLEX	DB15->DUET
4 Multicore ribbon	LED	20cm	Wire -> MOLEX	DB15->ARDUINO
Integrated Cables				
HDMI	Camera signal	XX	HDMI->HDMI	UPPER_HDMI_PORT->PI-CSI_BOARD
HDMI	Control panel	XX	HDMI->HDMI	LOWER_HDMI_PORT->RPI4 MICROHDMI
USB	Solid State Drive	XX	USB->USB	USB PORT->RPI-USB3
USB	Accessory	XX	USB->USB	USB PORT->USB-HUB
ETHERNET	Networking	XX	RJ45->RJ45	RJ45-PORT->RPI4-RJ45

Up/down buttons

RG - up

BB - down

direction on circuit board needs changing..? or microcontroller?

12.0 VIBRATION-INSULATION

The bottom corners should be attached to the instrument towards the end of the build, to prevent damage during the build process.

Each corner encompasses two vibration insulation components - a sorbothene foot, and a 3D printed leafspring. Once assembled, care should be taken not to apply too much pressure onto the instrument.

Parts	Shorthand Name	QUANTITY
Printed		
LEC_002_P_01_FR/BL-BOTTOM-CORNER	FR/BL_BOTTOM-CORNER	2
LEC_002_P_01_FR/BR-BOTTOM-CORNER	FR/BR_BOTTOM-CORNER	2
LEC_002_P_03_LEAFSPRING	LEAFSPRING	4
Components		
LEC_002_C_01_SORBOTHENE-FEET	SORBOTHENE-FEET	4
Fixings		
LEC_002_F_01_M5_10MM-BUTTONHEAD-SCREW	M5_10MM-BUTTONHEAD-SCREW	12
LEC_002_F_02_M5-SLIDE-NUT	M5_SLIDE-NUT	12
LEC_002_F_03_M6-12MM_BUTTONHEAD-SCREW	M6_12MM-BUTTONHEAD-SCREW	4
LEC_002_F_04_M6-45MM_BUTTONHEAD-SCREW	M6_45MM-BUTTONHEAD-SCREW	4
LEC_002_F_05_M6-HEX-NUT	M6_HEX-NUT	4

6. The bottom corners are attached to the base of the frame and are required to attach components used to insulate against vibrations, that may cause interference with acquired video footage. Start by attaching the 2 **FR/BL_BOTTOM-CORNER** and 2 **FR/BR_BOTTOM_CORNER** pieces to the underside corners of the assembled frame, using **M5_10mm_BUTTONHEAD-SCREWS** and **M5_SLIDE-NUTS**.

7. Next, construct the vibration insulating feet to each of the bottom corners. Start by screwing the **SORBOTHENE-FEET** to the **LEAFSPRING** using **M6_12mm_BUTTONHEAD-SCREWS**. Then place **M6_HEX-NUTS** into the grooves within each **LEAFSPRING**. Screw in each of the assembled feet into the bottom corner pieces, using the **M6_HEX-NUTS** and **M6_45mm_BUTTONHEAD-SCREWS**.

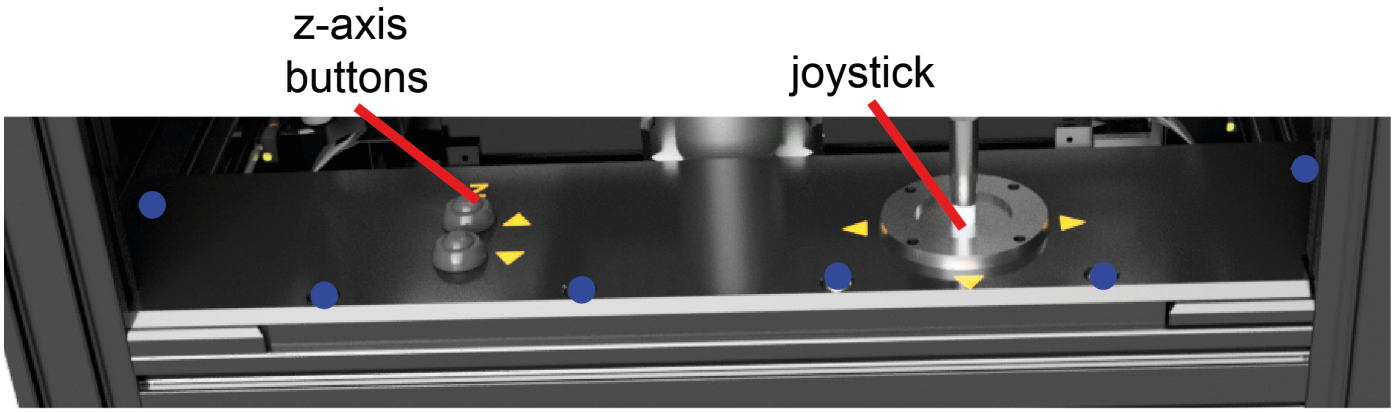
Panel attachment

While not essential, attaching plastic panels to the LabEmbryoCam is encouraged as for little cost, they help to keep the instrument clean, protect moving parts and cables and they keep it looking tidy. Note the size of the panels required in the bill of materials and their
locations above. Before installing the panels, insert M3 square nuts into the holes at the top and bottom of each spacer. The square nuts should slide as far as they can be pushed, using a small allen key or similar, so that the hole in the nut aligns with the hole in the 3D printed spacer.

Manual Controls

PARTS REQUIRED	
Component description	**Qty required**
Red wire	755 cm
Green wire	520 cm
Blue wire	620cm
Black wire	595 cm
Yellow wire	350 cm
White wire	325 cm
XY Joysticks	1
Z axis buttons	2
3D Prints	
Joystick_panel_right	1
Joystick_panel_left	1

Once the joystick and buttons are attached to the front panels, the front panels can then be attached to the LabEmbryoCam.



- M5 16mm sockethead screw

Solder cables to each of the pins on the joystick (2 x 3 cables per axis), and two buttons (2 x 2 cables) and then attach the buttons and joystick to the 3D printed front panels. Ensure the cables are labelled to ensure they can be connected
appropriately to the microcontroller.

.. note:: Although not essential, joystick and button labels are provided as seperate STLs and can be printed in different colour filaments i.e. begin the print with the label colour, before switching to the colour used for the main body of the part.

DISPLAY INSTALLATION

Display installation

Parts	Shorthand Name	QUANTITY
Printed		
LEC_002_P_XX	XX	2
LEC_002_P_XX	XX	2
LEC_002_P_03_LEAFSPRING	LEAFSPRING	4

10.0 LID

While not essential, the lid keeps the instrument clean and offers some protection from interference during an experiment.

PARTS	SHORTHAND NAME	QUANTITY
COMPONENTS		
LEC_010_C_01_HINGE	HINGE	2
LEC_010_C_02_TOP-LID-PLASTIC-311X315	TOP-LID-PLASTIC	1
LEC_010_C_03_FRONT-LID-PLASTIC-315X59	FRONT-LID-PLASTIC	1
LEC_010_C_04_HANDLE	HANDLE	1
LEC_010_C_05_CUBE-CONNECTORS	CUBE-CONNECTORS	6
EXTRUSION		
LEC_010_E_01_2020-312MM	2020-312MM	2
LEC_010_E_02_2020-303MM	2020-303MM	3
LEC_010_E_02_2020-60MM	2020-60MM	2
FIXINGS		
LEC_010_F_01_M5-8MM-SOCKETHEAD-SCREW	M5-8MM-SOCKETHEAD-SCREW	2

11.0 TESTING

This section is still a work in progress - with testing procedures.

11.1 Duet Board Testing

The Duet XYZ board has a control interface not routinely used in the operation of the LEC, but useful during initial setup.

To access it, connect the board directly to a network connection via the ethernet port on the board itself (not the ethernet). Turn on the LEC, and navigate to the Terminal and type `cutecom`.

This will open a window allowing us to determine the IP address of the Duet board on the network. Once open - choose the Device `/dev/tty/ACMX`, with X usually being either 0, 1 or 2 from the dropdown.

Click 'Open'. If joystick or light is returned, this means you have selected the wrong Device - so try another.

Type `M115` and if all is working, you should see the current firmware version.

If so, type `M552 S0`, followed by `M552 S1` to deactivate, and then reactivate the network connection.

You should see 'Network running. IP address = XXX.XXX.X.XXX', with the XXX corresponding to the address of your own instrument on your network.

You can now access the Duet board of the LabEmbryoCam on your network via this IP address, from any other device connected to the same network. You will be prompted for a password. The default password for LabEmbryoCams is `radix`