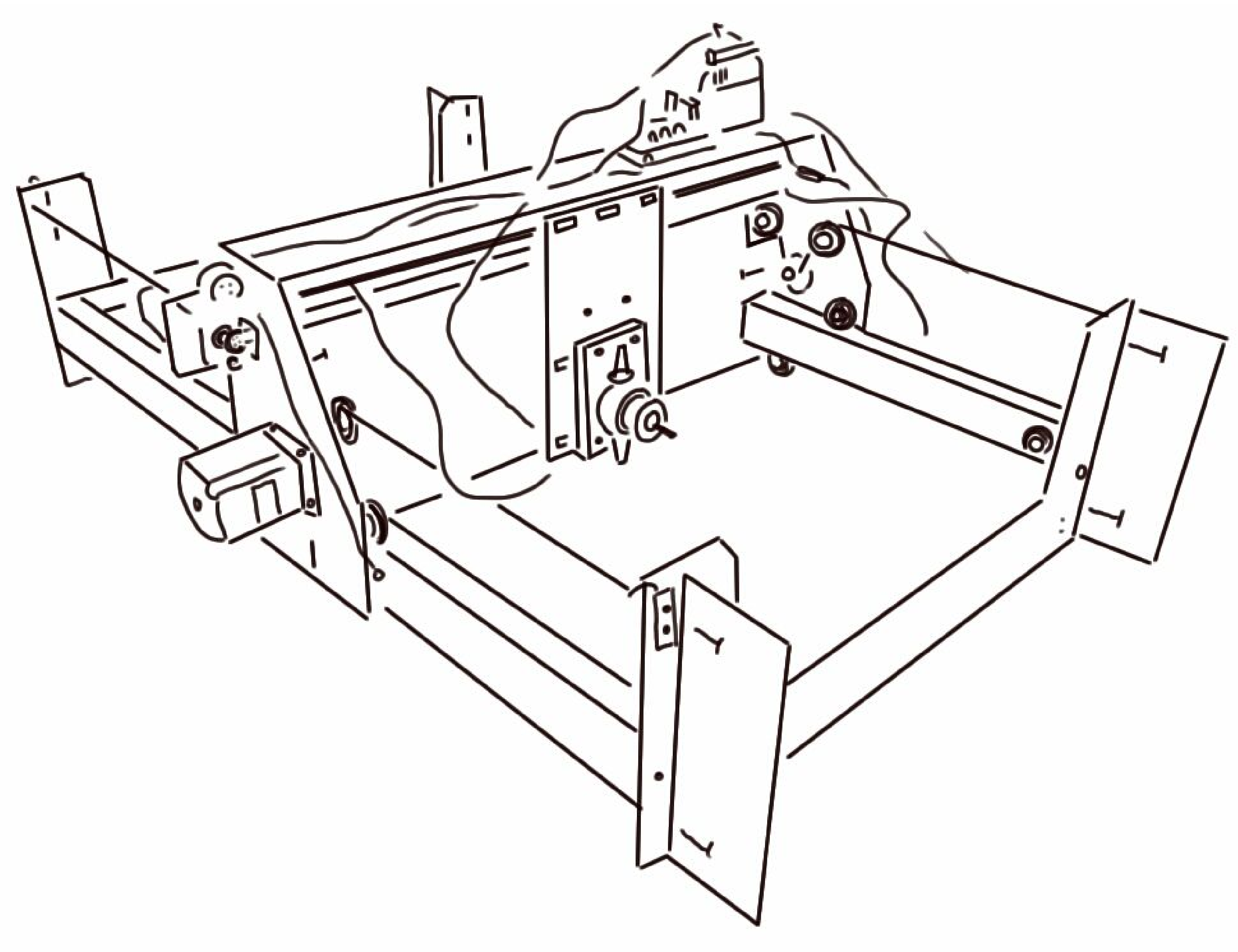
# CNC Beaver...

## The CNC sheet metal cutting Beaver!

Fabacademy 2018 - Mechanical Design week, May 2-9, 2018
Fabacademy 2018 - Machine Design week, May 9-16, 2018



# Table of Contents


**CNC Beaver... 1**

**The CNC sheet metal cutting Beaver! 1**

- Introduction 4
- Meet the team 5
- Logo and name development 6
- Design specification 6
- The BEAVER CNC concept 7
- Bill of Materials 8
    - Bought-in components 9
- Created Parts - download latest version of parts here (version 15/318) 9
- Part design evolution 11
- Simplified Failure Mode Effects Analysis/Issues Tracking 12
- Project management and development processes 14
- Major milestones Week 1 15
- Major milestones Week 2 16
- Future developments 17
- Week 2: Day 5 (Tuesday) Fitting the nibbler mount and clamp tests 18
    - Nibbler mount for the sliding carriage 18
    - Timing belt for the nibbler turning mechanism 20
    - Drill suspension frame 21
- Butterfly nuts for clamps 22
- Week 2: Day 4 (Monday) Material clamp and updated holder for nibbler 23
    - Material clamping system 23
    - Updated nibbler holder 24
- Week 2: Day 3 (Saturday) Endstop buttons, connecting belts and driving X&Y 25
    - Connecting the belts to the pulleys 25
    - Endstops buttons, connections and testing 28
    - Control system for the machine 32
    - Machine testing movement in X and Y 34
- Week 2: Day 2 (Friday) Making stabilizers and programming the motors 36
    - Making stabilizers 36
    - Programming the stepper motors 37
- Week 2: Day 1 (Thursday) frame design, belt holder and programming 38
- Week 1: Day 5 (Wednesday) Making Pulley Holders and connecting belts and pulley system to gantry 40
    - Pulley holders 40
    - Connecting belts to sliding carriage 41
- Week 1: Day 4 (Tuesday) 43
    - Changing the position of holes 43

Making the Stepper Motor holders 43
Basic testing with the nibbler attached to the drill with the flexible drive. 44
Converting 2D Rhino drawings to 2D Solidworks sketches 48
Week 1: Day 2 (Friday) - gantry design, cutter mount system and pulley design 50
Gantry design and sliding carriage backing plate and sliding mechanism 50
Week 1: Day 1 (Thursday) - frame design & gantry roller system 52

---

## Introduction

Metal cutting can be a dangerous, expensive, or in accurate undertaking. We were aiming to create a CNC metal cutter for thin sheets of aluminium and steel that we could use for project work. Ideally the machine would be quite small in order to fit into the lab, but we are aiming to make it scalable to larger sizes. We were fascinated by the nibbler tool when we saw it, thinking that if mounted to a computer controlled machine, it could make a relatively accurate, low-cost metal cutter for our lab. After a little research, we did not find any other attempts at this, so either we are breaking new ground here, or there are some very good reasons why this is not a good idea!

Here's a video we did showing the nibbler cutting motion in action: https://youtu.be/KbpkV0H_qNc

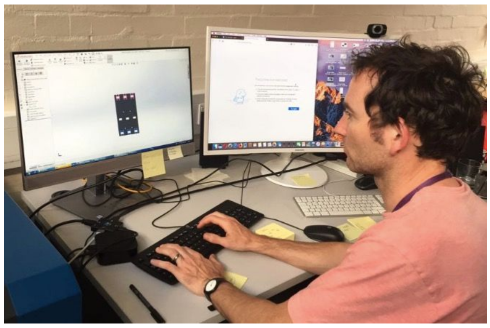
And here's us cutting an aluminium sheet using the nibbler: https://youtu.be/J7C8W5ltbns

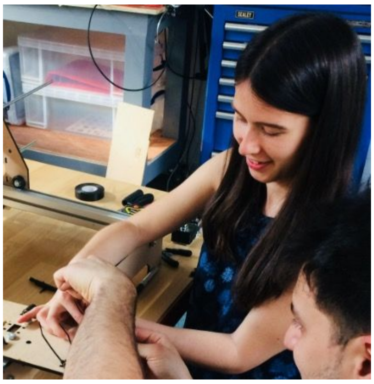
## Meet the team

**Luiz Bueno** (like the Chocolate) is a tireless maker, hacker, designer and expert skip salvager. He graduated from Fab Academy in 2016 in Barcelona.

His major contribution to the project will be in prototyping, resource management. He is the instructor for our fablab, and has been tireless in his support for our projects. He has an uncanny ability to look at a problem and say, hey you need a “insert appropriate complex solution here”. luizbueno.fabcloud.io/me

**Des Covill** is an eccentric lecturer in engineering and product design who specialises in CAE. His hero and fellow countryman is Dave from the EEVblog youtube channel. He sees himself as a curious bee flying around pollinating projects that are of interest in sports engineering (mostly bicycles) and medical device manufacturing. He loves playing sport, riding bikes and eating chocolate. In this project his major contribution is in developing the CAD and compiling documentation for the project.





**Poppy Mosbacher** is a life-long maker, working on a range of helpful social projects with the community. She recently completed her MA in Sustainable Design with her major project focusing on developing a low cost scanner.

## Logo and name development

Let’s get our priorities right and start with the logo and team name! Here’s a series of progressively angry vagabond (or dishevelled?) beaver logo mugshots to show how it’s developed over the weeks...clearly we went for the first one we drew….it’s always the first one that works best!

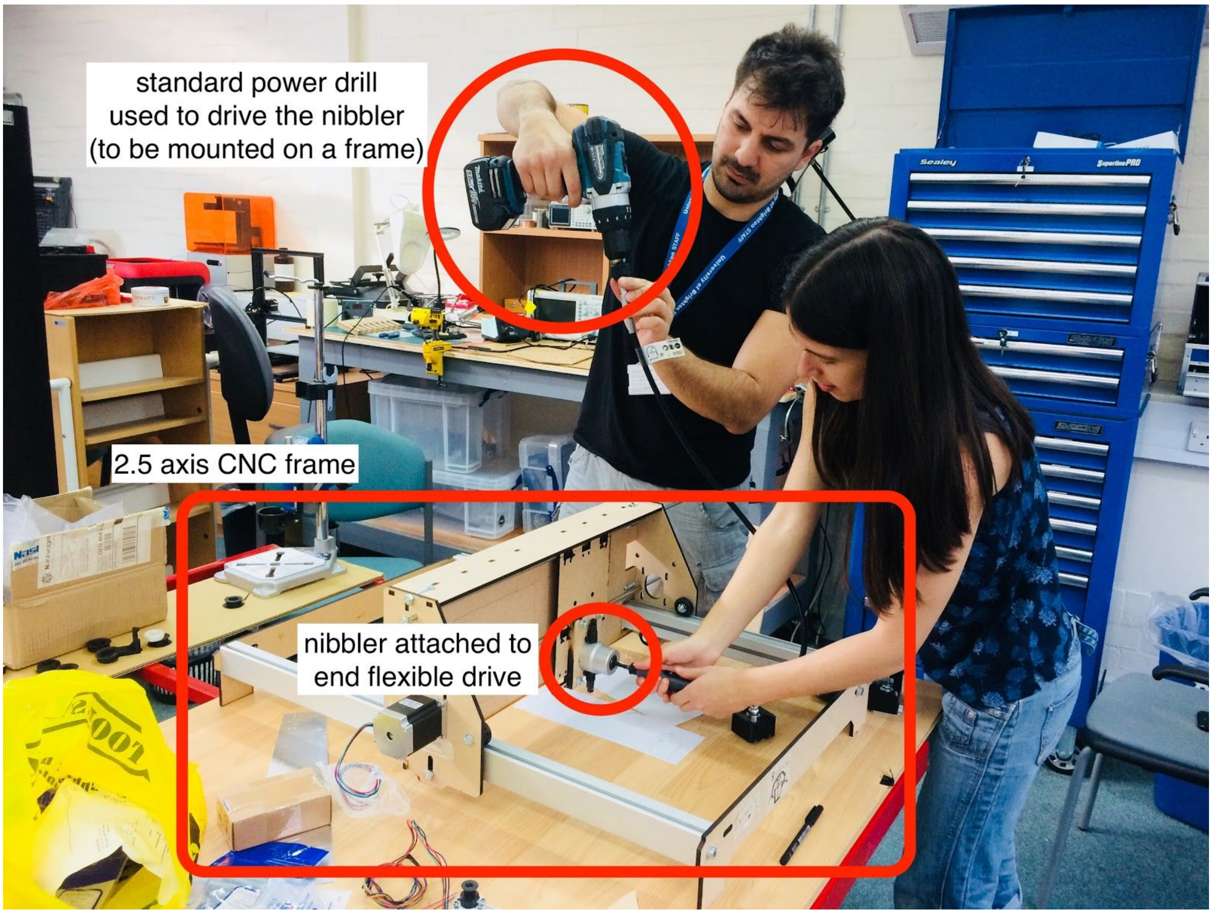
Originally we were going for *The CNC Beaver Factory*, but that had too many undesirable connotations, then we thought about *The Cheeky Nibbler*, but that was far too english and not enough CNC, then we thought about *The CNC Hole Punch for Sheet Metal* but that sounded a bit nerdy, so we went for *The CNC Beaver*...done.

## Design specification

Here are our key design specifications for the B-Va CNC. The machine will:

1. Cut sheet aluminium (min 2 mm thick) and steel (min. 1 mm thick) in sheets at least 500 x 500 mm.
2. Be driven by a standard cordless/corded drill (power > 500 W). Needs to hold a range of cordless/corded drills (specific details or range needed here).
3. Have an accuracy of +- 1 mm.
4. Cut using g-code or directly from dxf
5. Control cutting speed according to material settings
6. Be open source and have sufficient documentation for others to replicate and build upon
7. Have a safety cut off feature and/or emergency stop feature

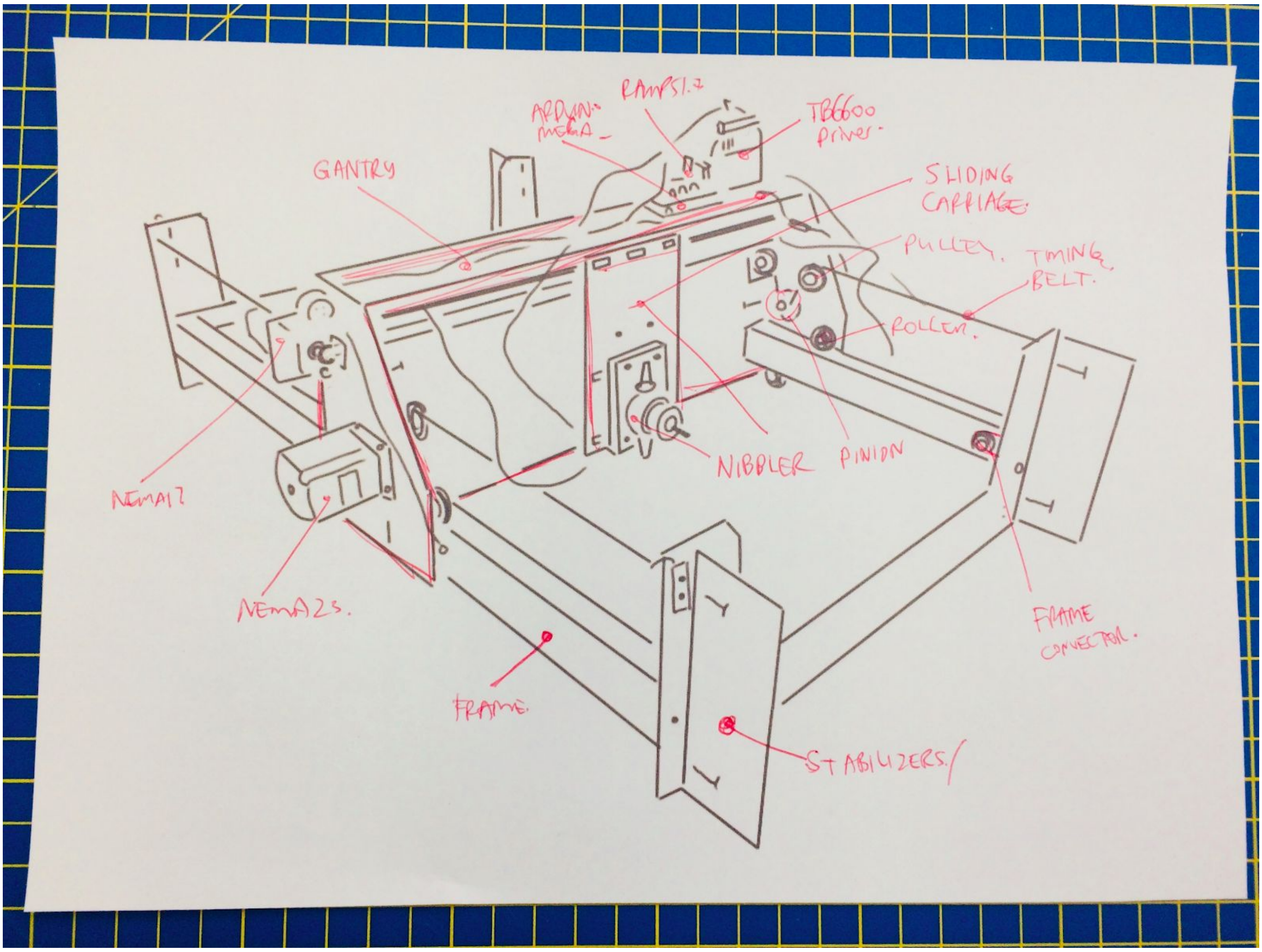
## The BEAVER CNC concept




The nibbler is powered using a standard power drill which is mounted above the machine, and attached to the nibbler using an end flexible drive. The flexible drive allows the drill to be located away from the action, so it doesn't take up working space.

The nibbler will move on the X and Y axis, using pulleys controlled by stepper motors.

Where possible the parts have been laser cut and 3D printed and maybe one day, a metal version could be made using this machine, in a similar way to the RepRap 3D Printer.




CAD model of assembly goes here

# Bill of Materials

## Bought-in components

| Item | Size | Source | Notes |
|---|---|---|---|
| Stepper Motor | Nema 23 75mm L | Amazon | 4A / 9-42V |
| Nibbler | | Amazon | |
| MDF | 600x400x6mm | | |
| Bearings | 8mm internal diam | | |
| Rods | 8mm diameter | | |
| Drill | Bosch | | |
| Flexible Shaft | 1m long | Amazon | Transfers rotation motion |
| Nema 23 Driver | 100 x 70 x 30 mm | Amazon | TB6600 4A 9-42V |

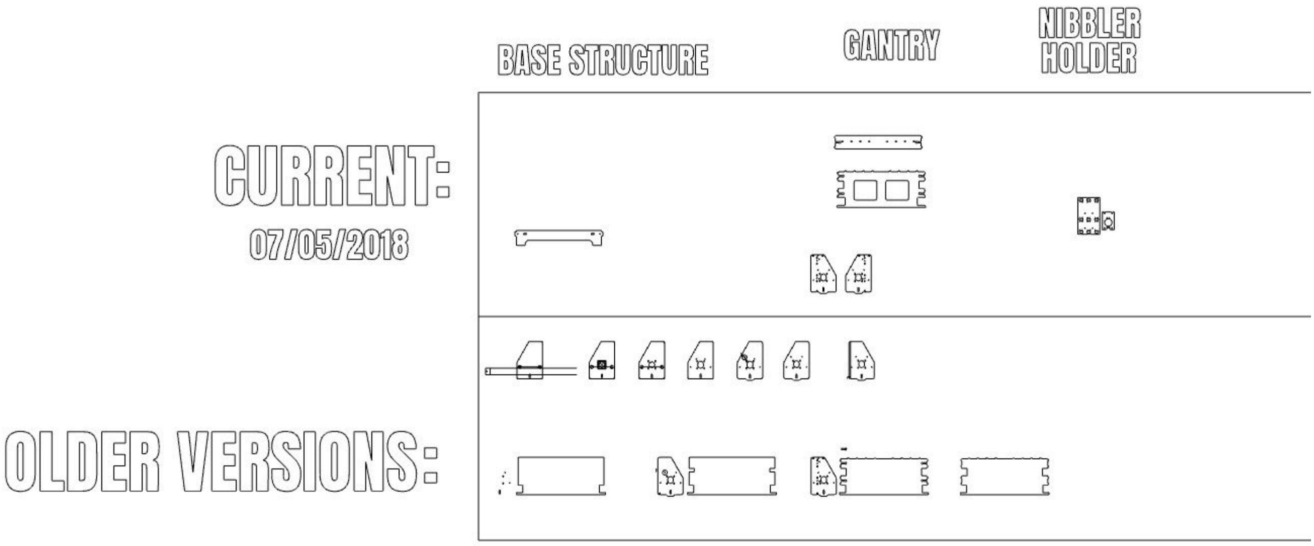
## Created Parts - download latest version of parts here (version 15/318)

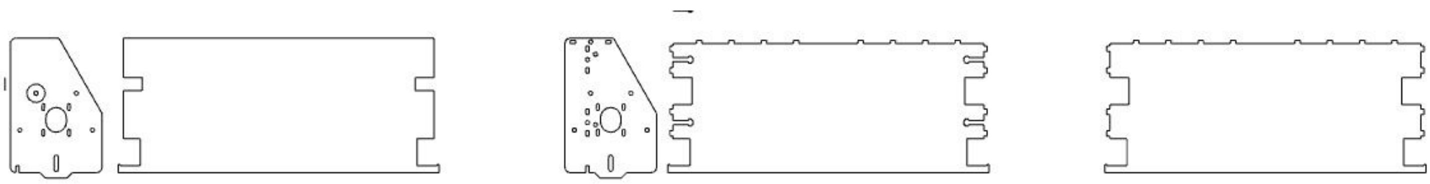
| Sub assembly | Parts |
|---|---|
| FRAME STRUCTURE | FRAME FRONT PANEL<br>FRAME FRONT STABILISER<br>FRAME JOINER |
| GANTRY | GANTRY BACK PLATE<br>GANTRY SIDE PLATE X2<br>GANTRY TOP PLATE<br>PULLEY MOUNT<br>PULLEY |
| SLIDING CARRIAGE | SLIDING CARRIAGE PLATE<br>NIBBLER MOUNT |
| Nibbler holder | |
| Pulleys | |
| Pulley supports | |

# Part design evolution

[download the latest Rhino file](#) here which shows the part evolution

We also wanted to keep track of how the parts in this machine evolved in time, so we created an overarching model file in Rhino where we would copy in the designs as we go. It looks cool to see it all evolving!



# Simplified Failure Mode Effects Analysis/Issues Tracking

| Severity | Potential Failure Mode/Issue | Potential Effect(s) of Failure | Potential Cause(s)/ Mechanism(s) of Failure | Action |
|---|---|---|---|---|
| HIGH | Sheet not sufficiently supported/clamped causing sheet bending/twisting, vibration. | Inaccurate cutting, dangerous moving material. | Cutting algorithm not leaving TABS, part not sufficiently clamped or supported | Have tab generation algorithm including cul-de-sac protocol.<br><br>Need suitable material clamp and supporting structure.<br><br>Possibly have clever swarm/following supporting structure underneath |
| HIGH | Gantry not sliding properly | Rollers not aligned well or not sufficiently smooth in rolling | | Wrapped linear bearings in insulation tape (10x) to reduce interference.<br><br>More robust solution needed to mount roller bearings into sliding carriage. |
| MED | Pulley drive motor mounts cracking | Crack developing along edge | Pulley drive motor mounts have no fillets and are slightly oversided. | Redesign needed for pulley mount. |
| MED | Flexible drive shaft comes loose | Cutting stops, potential damage to workpiece? | Flexible drive not connected tightly enough or too much vibration in the sliding carriage. | Find way to make sure connection is tight (torque wrench or equivalent?)<br><br>Stiffen structure make it more secure, and dampen vibrations somehow in the sliding carriage. |
| MED | Frame flexing | Reduced tolerance and poor quality finish | Structural members or joints not stiff enough | Measure stiffness and potentially redesign members and/or joints |
| HIGH | Endstop buttons not registering | Machine crashes and damages itself | Endstop mounts not secure/reliable | Design reliable mounts for endstops and/or mill our own PCB for the endstop. |
| HIGH | Sliding carriage or cutter detatching. | Machine/workpiece damage (e.g. bent rails, motor shafts, broken carriage mounts etc). | Too much vibration/movement/play in system.<br><br>Blunt cutting tool. | Have suitably stiff and strong joints/connectors<br><br>Monitor static and dynamic movements (displacement, |

| | | | | |
|---|---|---|---|---|
| | | | Fatigue and wear.<br><br>Control of speed, movement not correct. | velocity, acceleration profiles). Have error and progressive failure monitoring and reporting mechanisms in place. |

## Project management and development processes

We used a variety of tools to develop the Beaver CNC:

- Shared google drive with all CAD files. We used a system where the current files were in the main directory, with
- A whatsapp group where
- This google docs document was used to document the project in full to capture things as they happen in terms of documenting ideas, descriptions, reflections, issues, diagrams, pictures, videos.
- we also used our own individual websites to document what we did for the project.
- At the beginning of each week we set out a list of major milestones/tasks that we want to meet that week. Typically these were prioritised with most important ‘mission critical’ tasks first.

In terms of project management, we were aiming for a spiral approach, where we would aim to get things made, quickly and roughly first in order to test the principle out. We wanted to make progress fast, rather than spending lots of time on detail early on.

We focused on developing sketch models, out of cardboard, out of paper, out of scrap pieces that were drilled or hacked, in order to get something physical in front of us to discuss and evaluate. Then once we have a functioning system we could look at the problems, and prioritise our efforts on the areas that were most critical to meet the specification and improve robustness. Then we could look to improve longer term issues, such as design for manufacture and assembly (DFMA) to reduce the part count, cost and complexity and make it easier to assemble.

## Major milestones Week 1

Week one was all about getting the mechanical design up and running. We knew at times that some of our designs were crude and suboptimal, but we ploughed on mostly in order to get something.

red=to be done
amber=currently doing
green=done

| Task | Status |
|---|---|
| 1. Make sturdy frame | Done - completed day 1 |
| 2. X-Y gantry is moving on rollers - done day 2 | Done - completed day 2. Note: rollers are not so smooth yet. |
| 3. Mount cutting tool to gantry - done day 3 | Done - day 3. |
| 4. Connect belt to gantry to drive in X & Y - | Done - day 4 |
| 5. Connect motors to drive gantry in X & Y | Motors connected day 5, but not actually powered yet. Now powered! Saturday in Week 2. |
| 6. Make frame to hold drill - | We now have the flexible drive and a drill that we can use, but not designed the frame for this. It only needs to be a simple hanging stand. Since this is not crucial for the operation of the machine, we have put this down the list of priorities. |
| 7. Create full assembly in CAD - | As of the end of the first week, we only all parts, but some are in Rhino, some Solidworks. We've started migtrating parts over, but don't have a full assembly model yet. Since this is not crucial for the operation of the machine, we have put this down the list of priorities. |
| 8. Review issues tracking to prioritise improvements to be made | Started, but more detail needed. More added at the end of week 1 and early week 2, generally ongoing. |

# Major milestones Week 2

| Task | Status |
|---|---|
| 1. Belt holder for movement in Y-axis. | Done day 1 (Thursday). A nice simple design to start with. |
| 2. Connect Arduino Mega with RAMPS shield to driver and power supply to control motors using GRBL or Marlin firmware. Test with basic programme to move motors/ | Done - Day 2 (Friday). We used Marlin, and note we needed 15 V to move the motors. |
| 3. Develop fuller programme to generate G-Code and control the motors. Begin with basic X-Y tests and integrate suitable stopper limits. | Currently doing early week 2. Done Saturday of week 2. |
| 4. Calibrate machine more accurately, carry out basic cutting tasks in X and Y. Start with very thin/easy materials (e.g. card), then move onto aluminium. | Currently doing. We want to do this now with the material clamped to the machine (see 5. below).<br><br>Done! Luiz went back and changed the calibration settings for the drivers so movement was more accurate. We've got some sample materials, ready to test on the final day. |
| 5. Develop system to clamp workpiece to frame | Currently doing.We've developed a system, and have tested it out with a single clamp, but now we need to roll this out. |
| 6. Develop turning mechanism for the nibbler to allow for curved profiles | Currently doing. We've developed a new nibbler mount that is capable of including the stepper belt-drive system which will turn the nibbler.<br><br>DONE!! Luiz cracked it, designed it, made it test it...so good! |
| 7. Develop stand for drill | Done. Using a microphone stand to hang the drill from was a stroke of genius! We know working with all the music/media folks would come in handy! |
| 8. Tidy documentation on group and individual sites...and add latest version of all CAD files, RAMPs file, and links onto group site. | Currently doing. We've found a way to package our google doc into a fully functioning website too. This will carry on right up to the end...and beyond as we plan to keep going with this project in the coming months. |
| 9. Develop programme to convert CAD to G-Code - Grasshopper? | Currently doing, but not complete yet. |
| 10. Rigorous testing protocol with critical evaluation | Final stage for the two weeks. |
| 11. Develop full CAD model of assembly | |
| 12. Connect the drill to a relay, and then create basic programme to turn on-off. | |

## Future developments

- Develop stand for drill
- Connect the drill to a relay, and then create basic programme to turn on-off.
- Develop means to move the cutter vertically (Z) turning the machine into a 2.5D CNC (rather than just a 2D CNC).

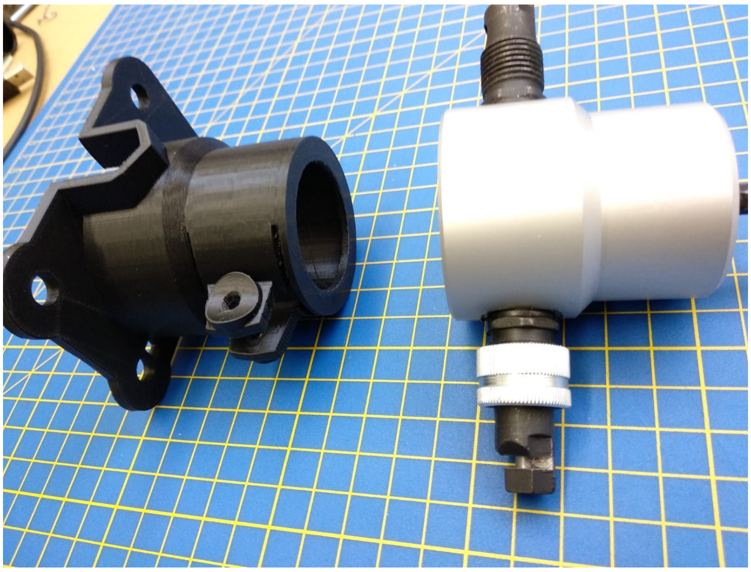
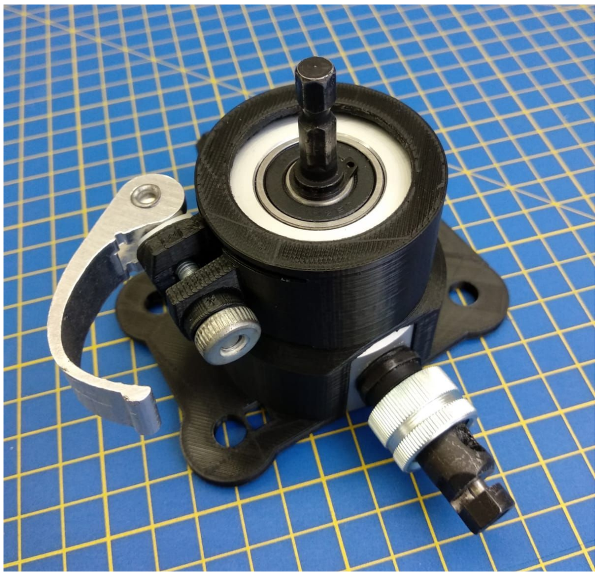
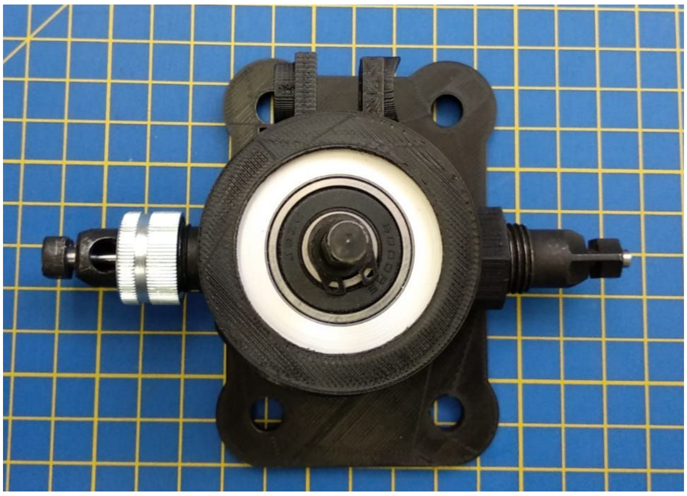
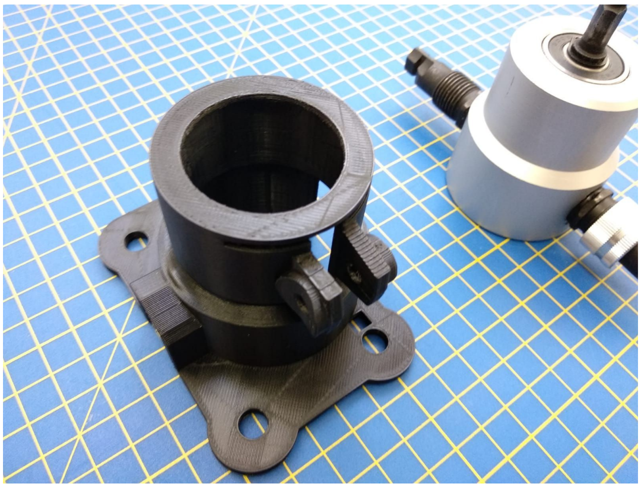
# Week 2: Day 5 (Tuesday) Fitting the nibbler mount and clamp tests

The aims for today:

- Fit the nibbler mount and test with the stepper motor to drive it's rotational movement
- Clamp various materials and carry out test cuts driving the CNC beaver using Pronterface
- Try to develop a mount to suspend the drill above the machine
- Being work on the grasshopper definition that will interpret CAD and turn it into G-Code for the machine to run

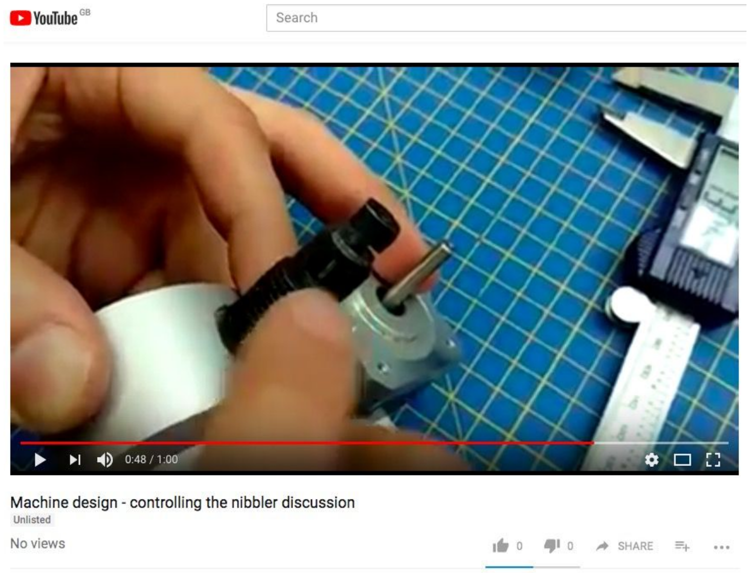
## Nibbler mount for the sliding carriage

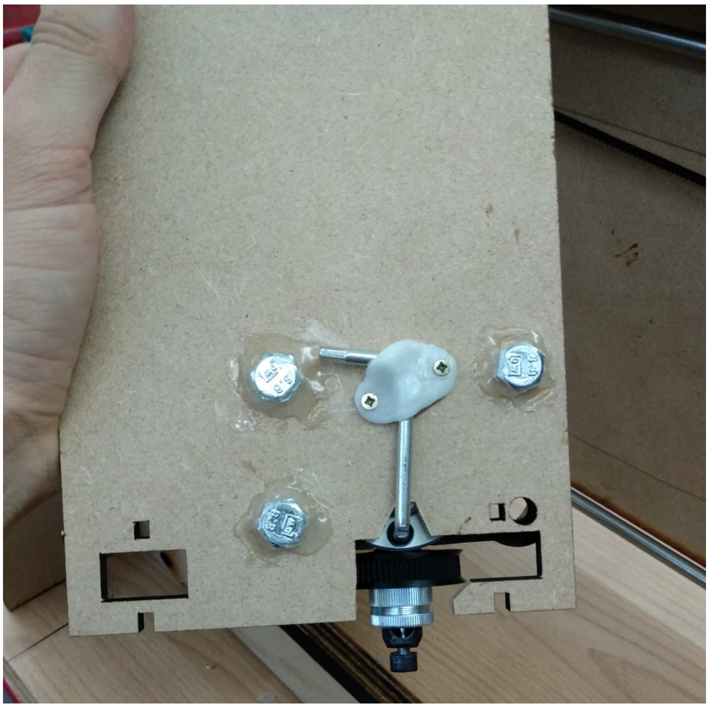
Overnight we printed the nibbler mount and we've now managed to heat shrink the nibbler into it. Fits like a glove! We used an old bicycle quick release to help clamp it too, to ensure it doesn't move about. Luiz did some sterling work to design this part and to get it to fit perfectly on the first attempt.

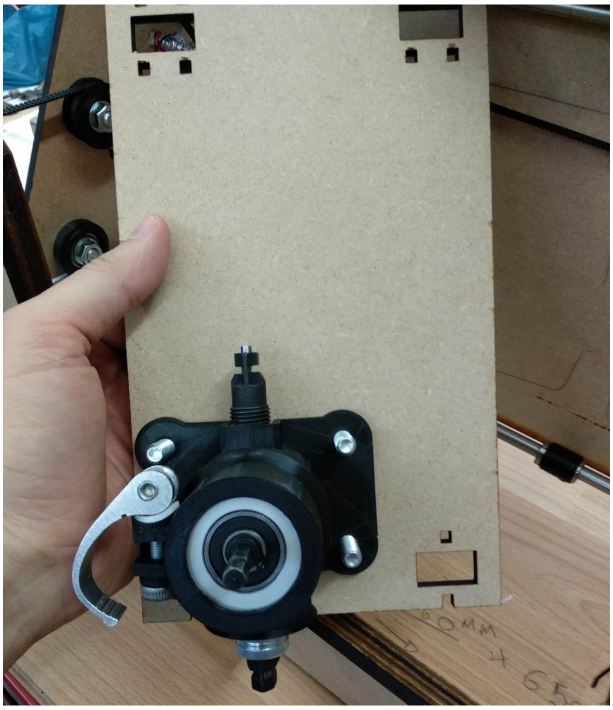





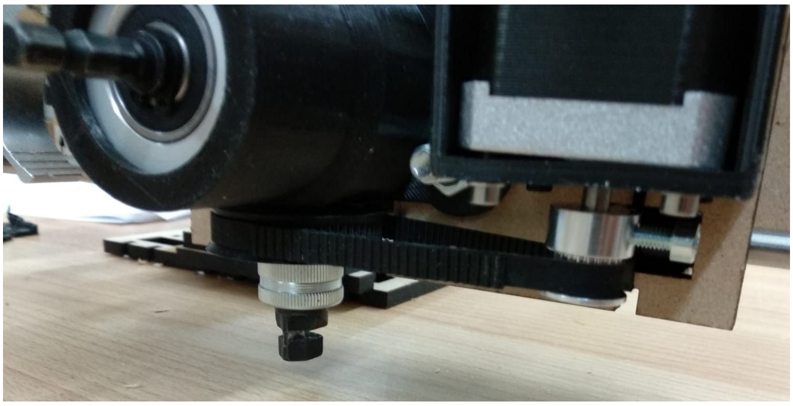
The mount was then mounted onto the sliding carriage, with a workaround fasteners on the back to keep the nibbler's locking bolt from falling out. Crude, but it works!

Here's a video with a bit of a discussion about controlling the nibbler: https://youtu.be/QRlkiJAskgo



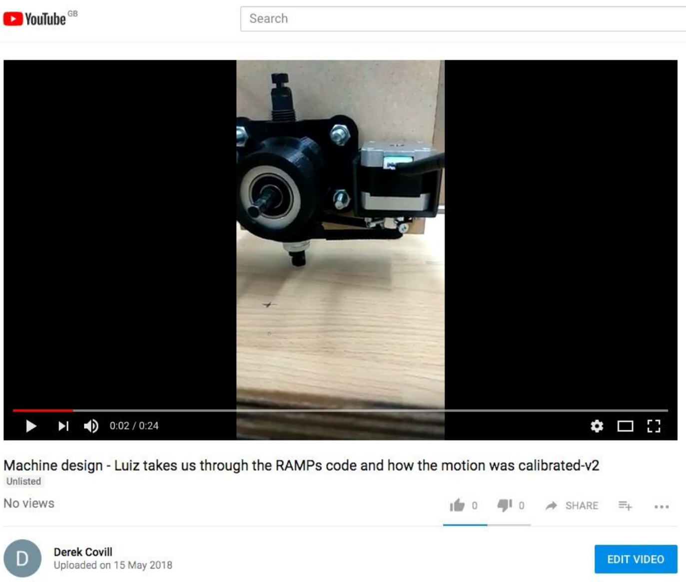




## Timing belt for the nibbler turning mechanism

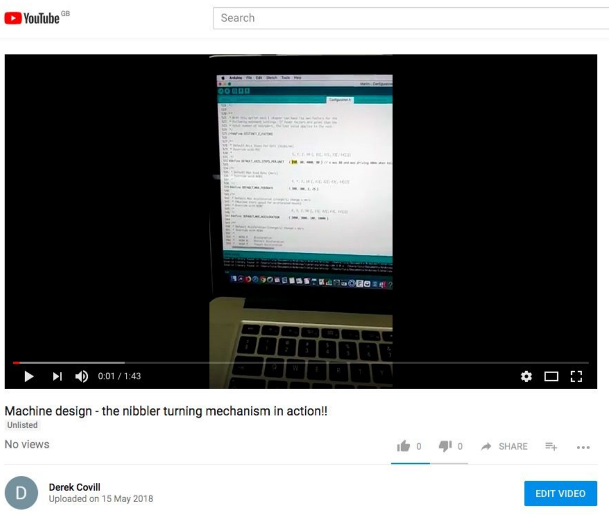
A timing belt was cut in an S shape to create a kind of in-plane-butt-lap joint to join the two ends together. In time we will try to 3D print a new timing belt, but for the time being this works fine.


The development of a steering mechanism was perhaps our biggest challenge in this project. We would be happy without it, a machine that could be programmed to cut in straight lines was still a useful machine. The concept of a turning nibbler was our holy grail, our 'bonus' phase...and well, Luiz finally cracked it! The nibbler can be turned using a timing belt connected to a bespoke pinion on the nibbler steerer which is connected to the Nemo 17 stepper motor.  Here's a video showing it in action.



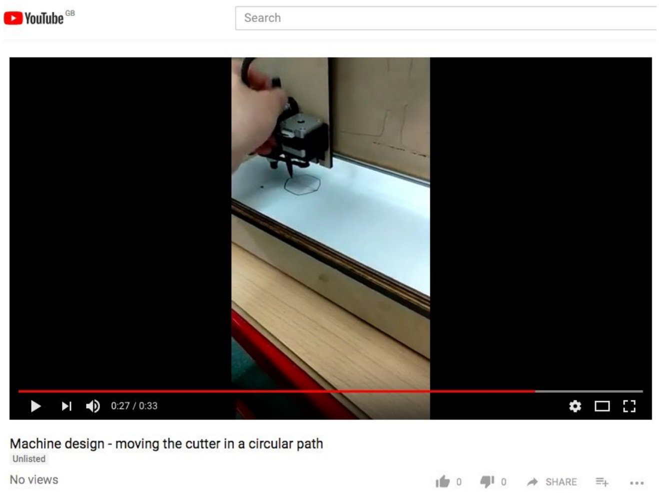

https://youtu.be/O8GwxeUBjuo

Then we're also given a tour of how the RAMPS 1.4 code was adjusted to sort out calibration for the movement of the machine. We are also introduced to the concept of 'calculate and cake'...lovely!




https://youtu.be/4HpYwMIOekk

And here' sthe result of a test to control the motion of the machine machine to move in a circle:



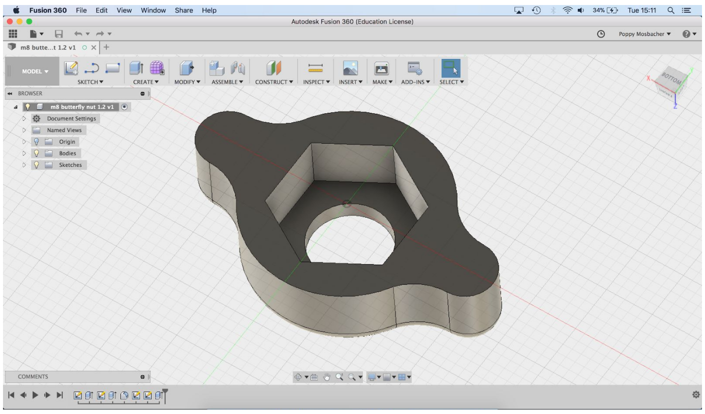

https://youtu.be/Ku9P3B1-fBg

## Drill suspension frame

Next step was to develop/find a suitable mount to suspend the drill above the machine. A microphone stand that was lying about in the lab worked a treat!


## Butterfly nuts for clamps

As part of the process for developing the clamps, Poppy developed some beautiful butterfly nuts to sit on the end of the nuts to allow us to tighten up the clamps quickly and comfortably...and without tools!




# Week 2: Day 4 (Monday) Material clamp and updated holder for nibbler

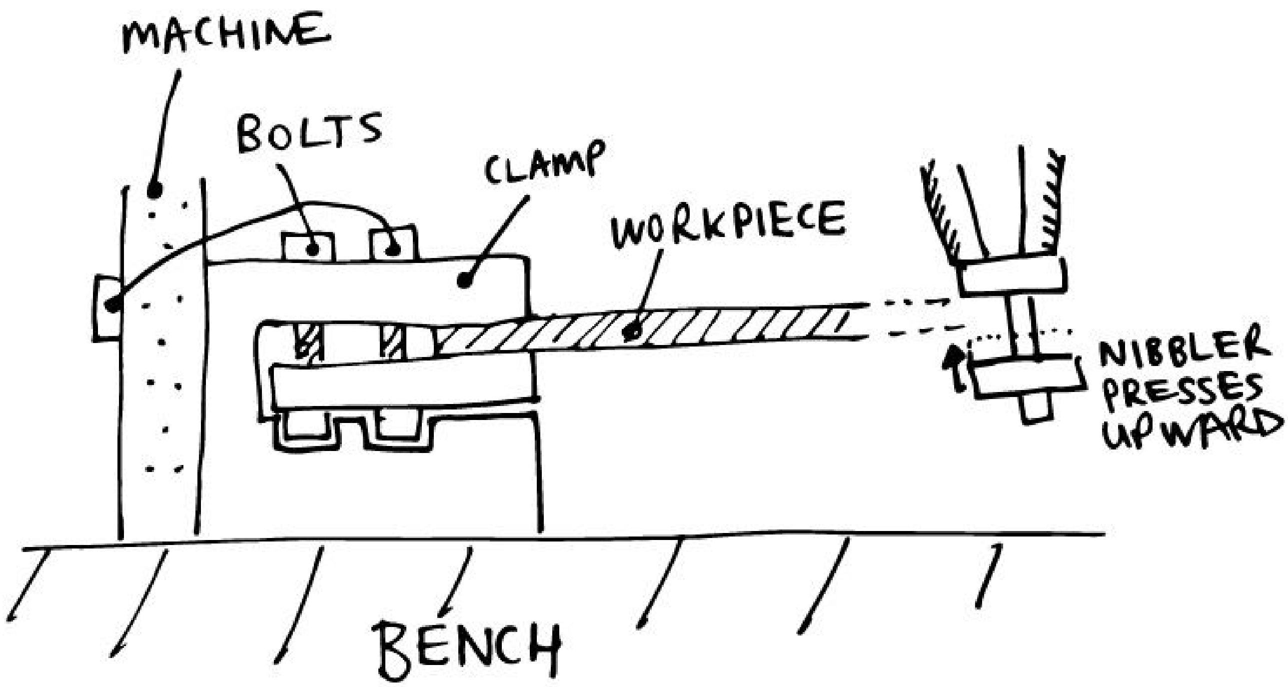
The aims for today:

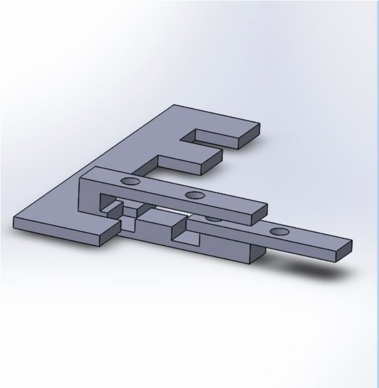
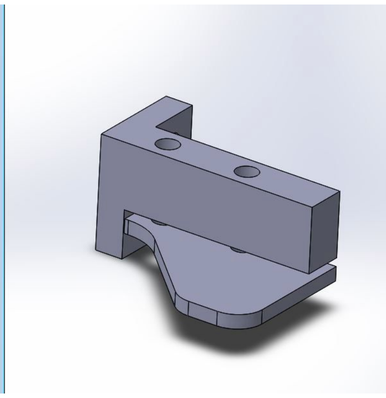
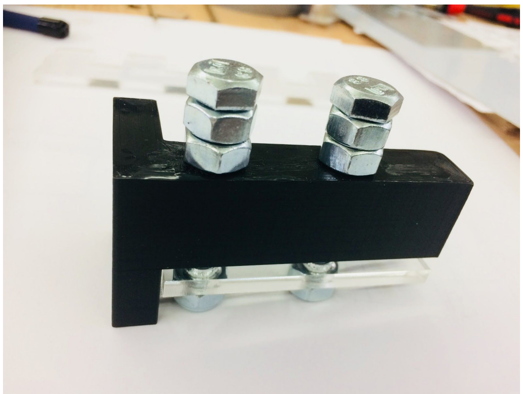
- Develop a system to clamp the sheet material to the machine.
- Develop an updated holder for the nibbler cutter that could accommodate a dynamic turning mechanism.

## Material clamping system

We really needed a system to clamp the workpiece to the machine itself. Either that, or we need to clamp the workpiece to the worktop...and clamp the machine down too! In time, that may well be a suitable solution, but clearly we want to give ourselves some challenges, so we went for the former option. Anyways, we think we've come up with a neat solution that:

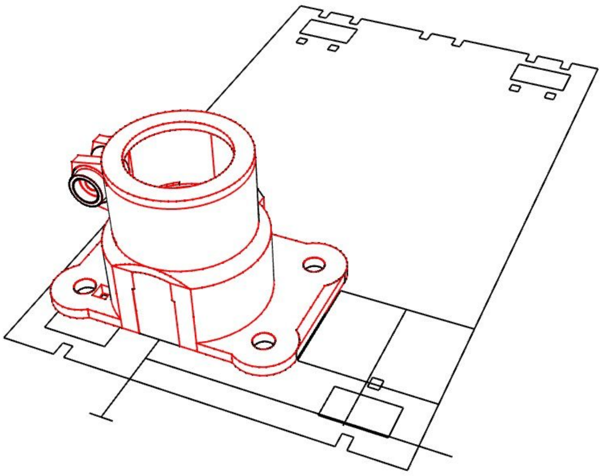
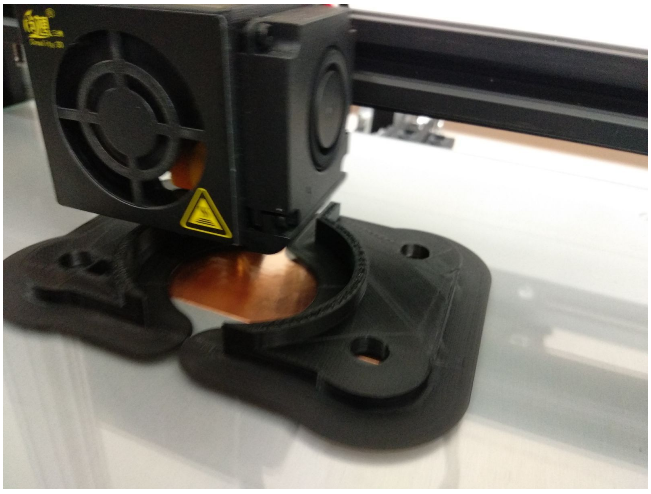
- Clamps securely to the same Y-position at one end of the machine
- Keeps the vertical height the same, relative to the underside of the clamp (the nibbler pulls the workpiece upwards when it is cutting)
- Clamps the workpiece securely from both sides. These aren't currently clamped to each other (acceptable) or the machine (ideal), but that is a future development. For the time being we're able to clamp/screw these to the make-shift floorboard bench for added stability.



## Updated nibbler holder

The nibbler is a beautiful thing, but like any beautiful thing, it is hard bloody work. It bucks and kicks and requires precision design to fit and move and glide along the workpiece. So our silky south american european chocolate bar of a team leader decided to grab this bull by the horns and redesign the mount that holds the nibbler and fastens it to the sliding carriage...a complex array of cable ties simply would not do. So here’s what he came up with, a beautiful nibbler mount/holder that will also allow for the collar of the nibbler to be connected the pinion on a stepper motor using a timing belt…..that’s the next step. But for the time being, we’ve started printing the holder this evening, tomorrow we fit it.

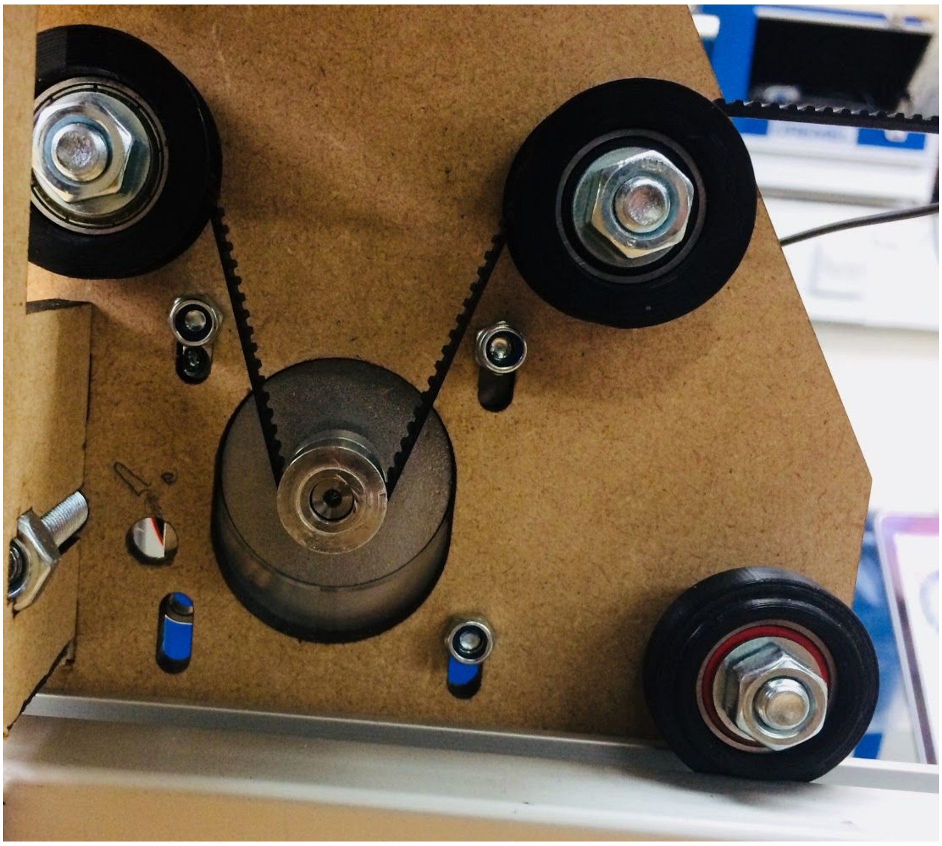
# Week 2: Day 3 (Saturday) Endstop buttons, connecting belts and driving X&Y

The aims for today:

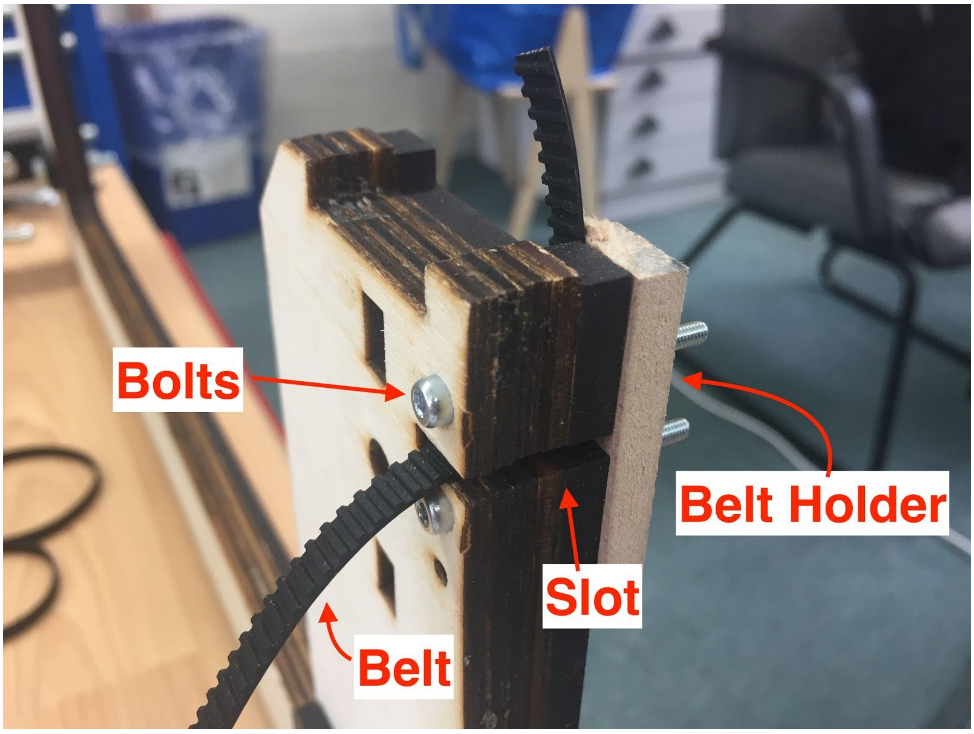
- Attach buttons which will act as endstops in both X and Y and check these in the software
- Connect belts and do basic straight line tests to drive gantry (Y) and sliding carriage (X) and both (XY).

## Connecting the belts to the pulleys

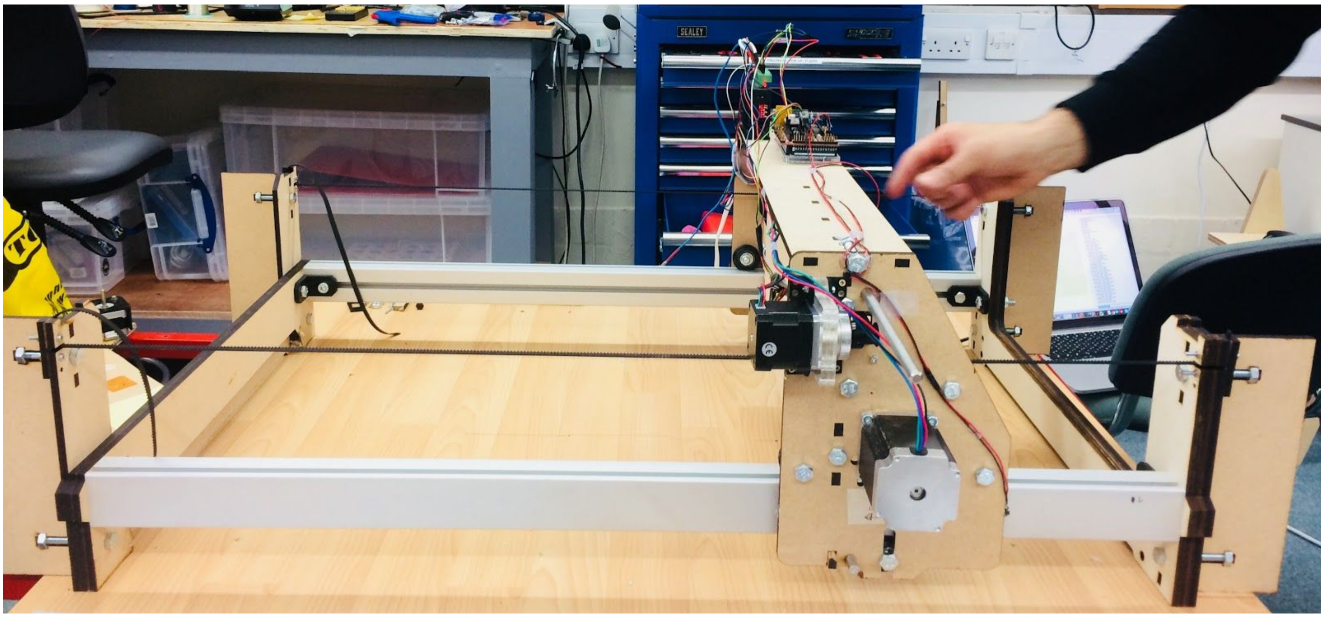
In anticipation of our attempts to drive the machine today we attached the other ends of the belts, feeding them through the pulleys and around the motor pinion. It's starting to look like a real machine now, ready for actuation!



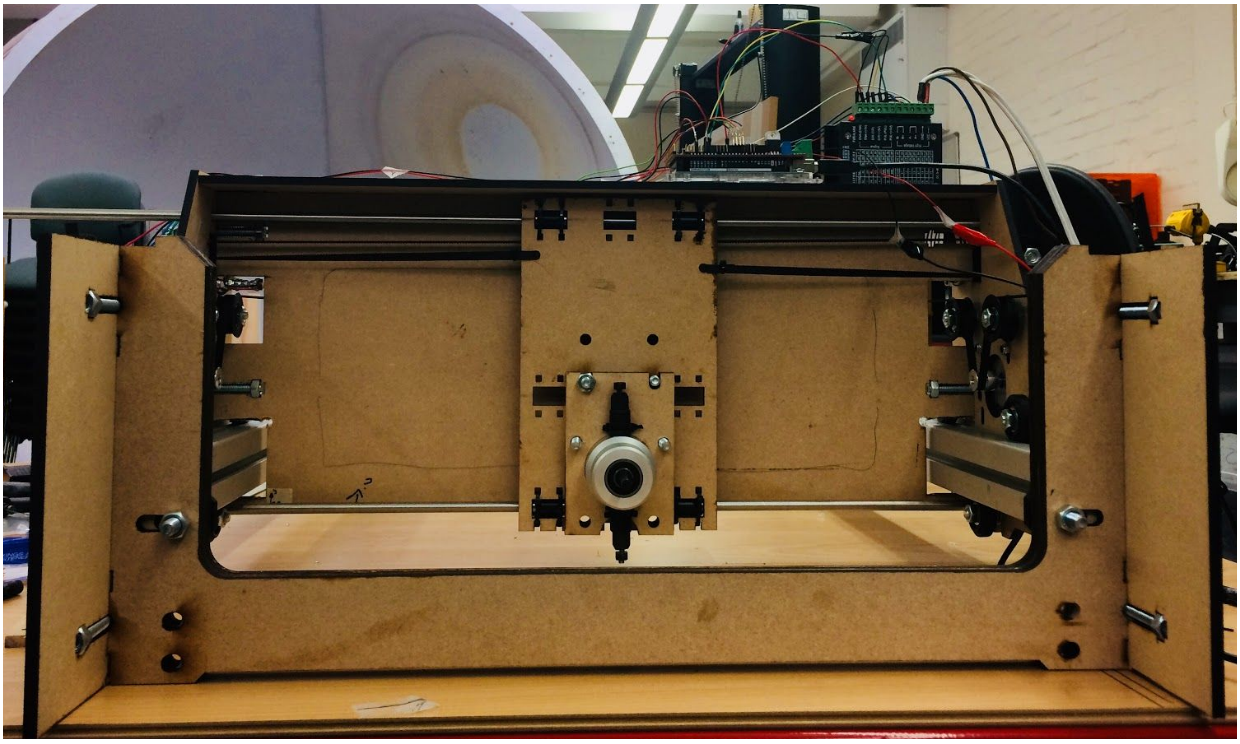
Once everything was in the right place, we then pulled the unconnected end of the belt so that it was tight but with a little give and connected it using the belt holder like at the other end. Come to think of it, both belts were tensioned slightly differently, we should have a system to ensure consistency here.




Here's the side view of the machine showing the belts all nice and tight.



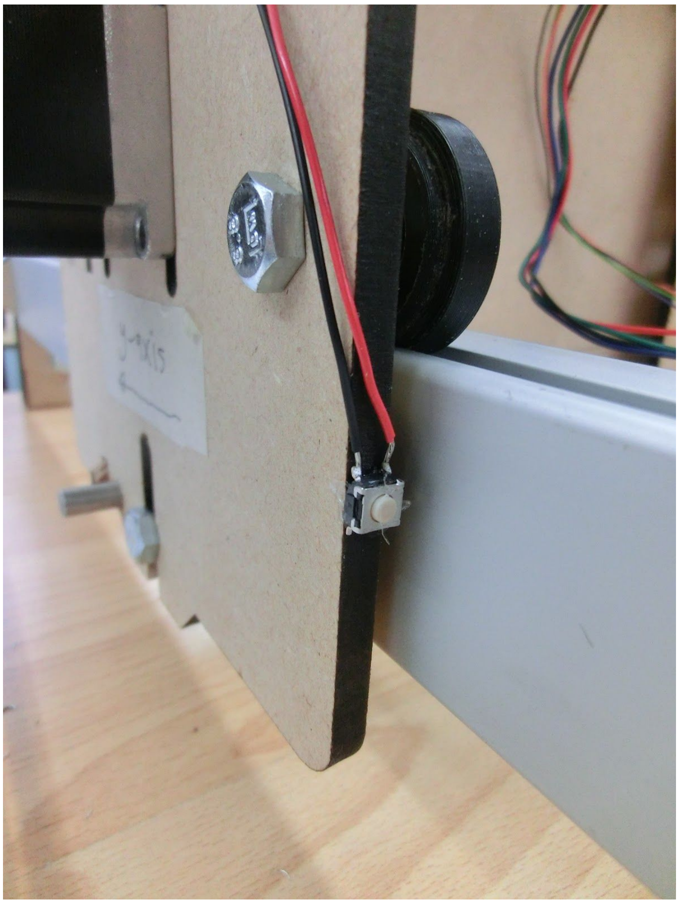
And here's the front view of the machine showing the belts all nice and tight to move the sliding carriage with the cutting tool.

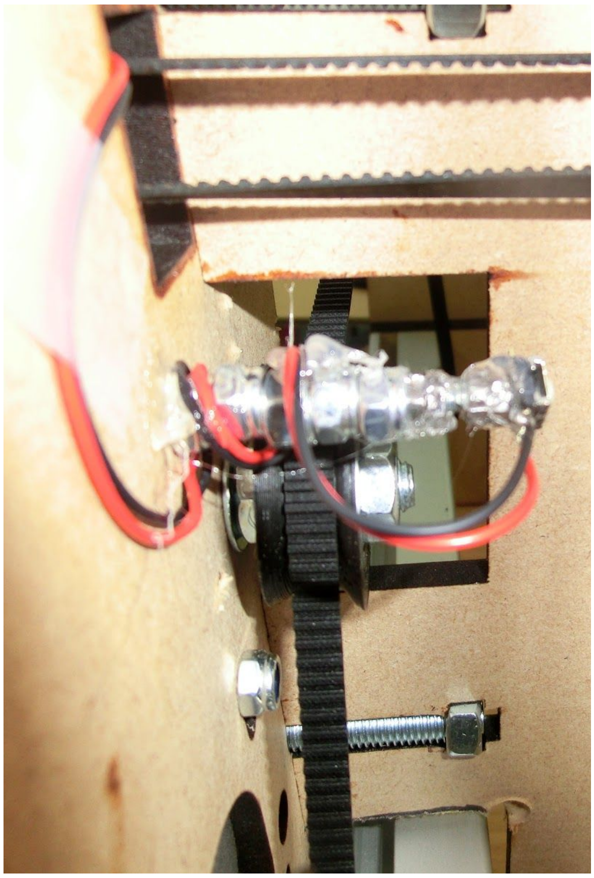


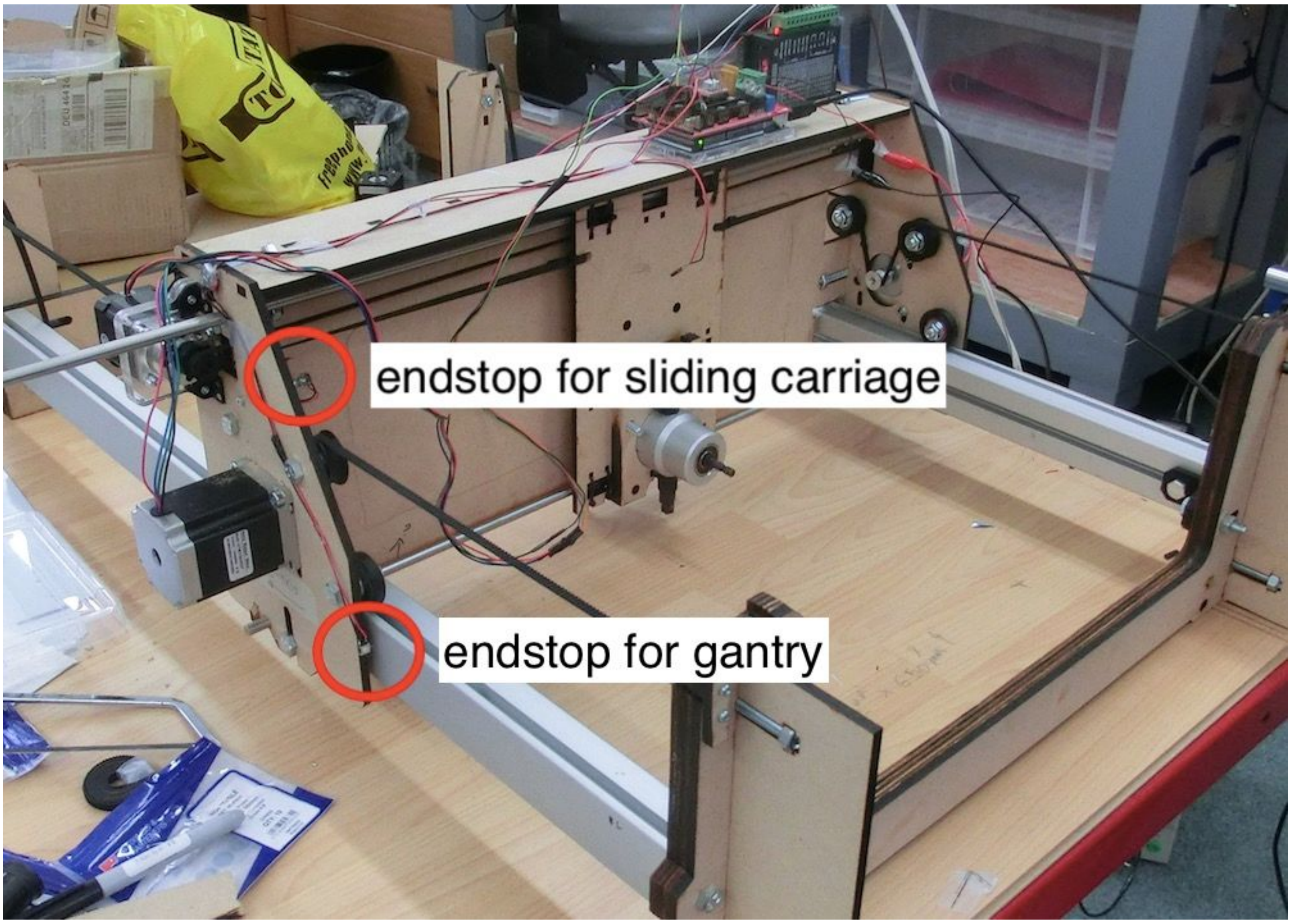
## Endstops buttons, connections and testing

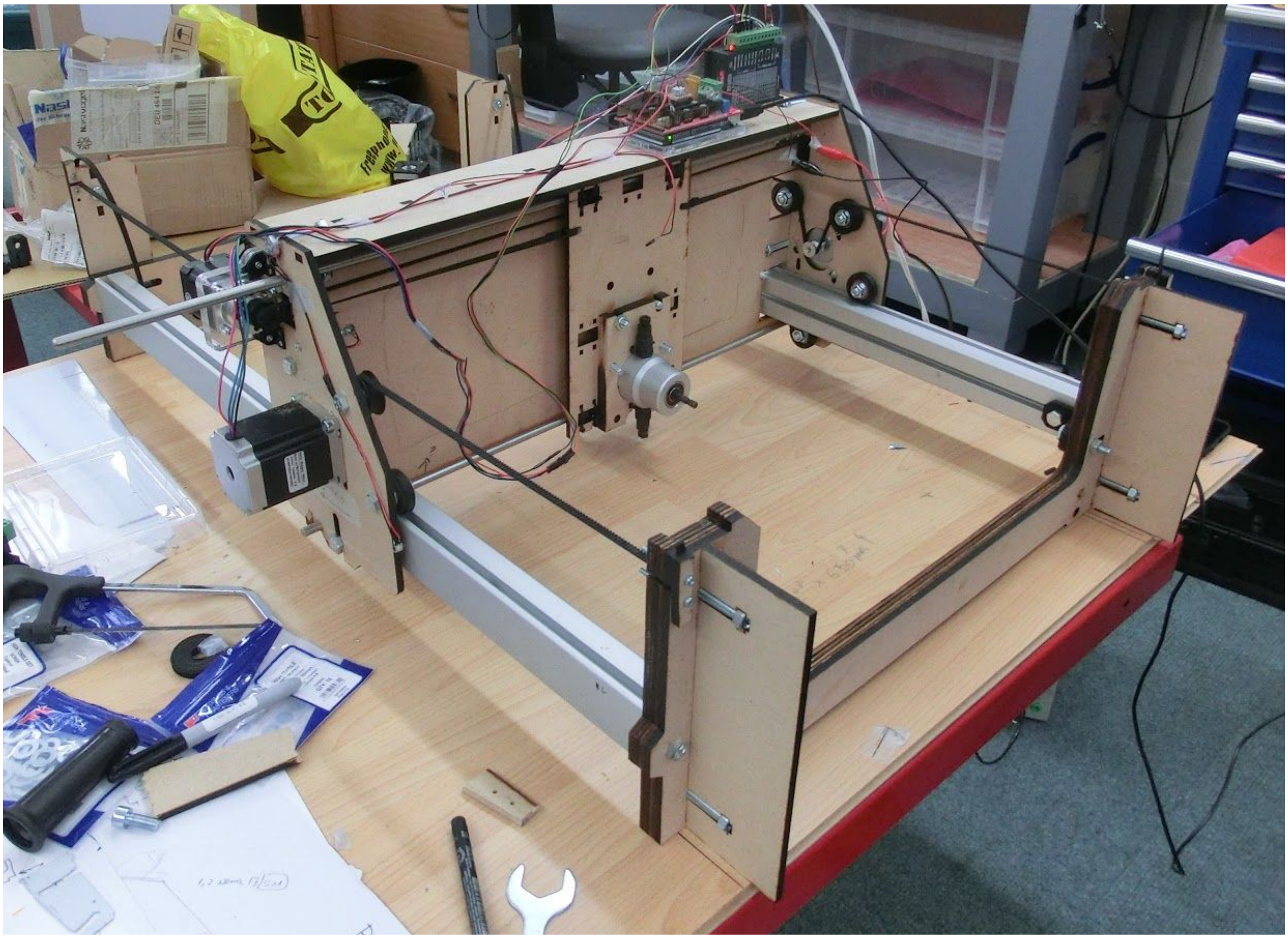
A basic way to trigger the machine to understand when it's at the end of the road is to use a button attached to the gantry, so that when it collides with the end the button is pressed, telling the software that it's at the end. This will also be used to reset the zero values each time the machine goes to HOME.

We used a hot glue gun to mount the buttons on to the gantry itself (long axis - shown on the left below) and onto the end of a long bolt mounted inside the gantry (short axis - shown on the right below). While this was crude, it should work, and in time we'll devise a more robust system. It needs to be done properly in time, as this is a crucial step each time the machine is used.

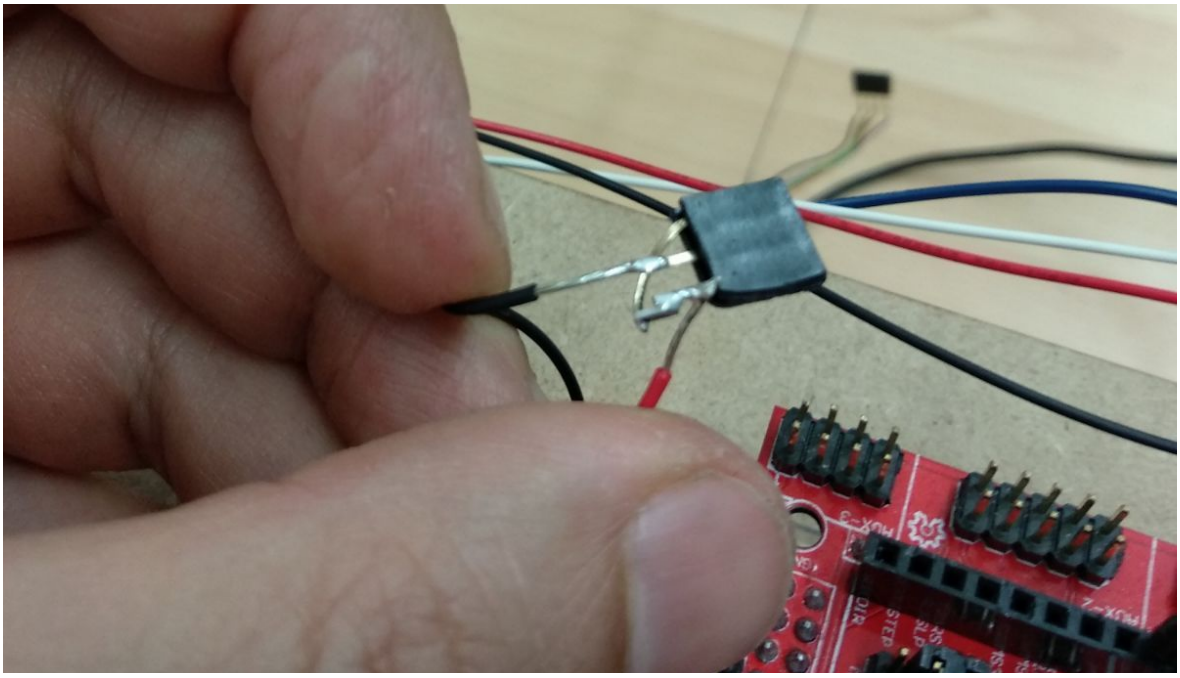


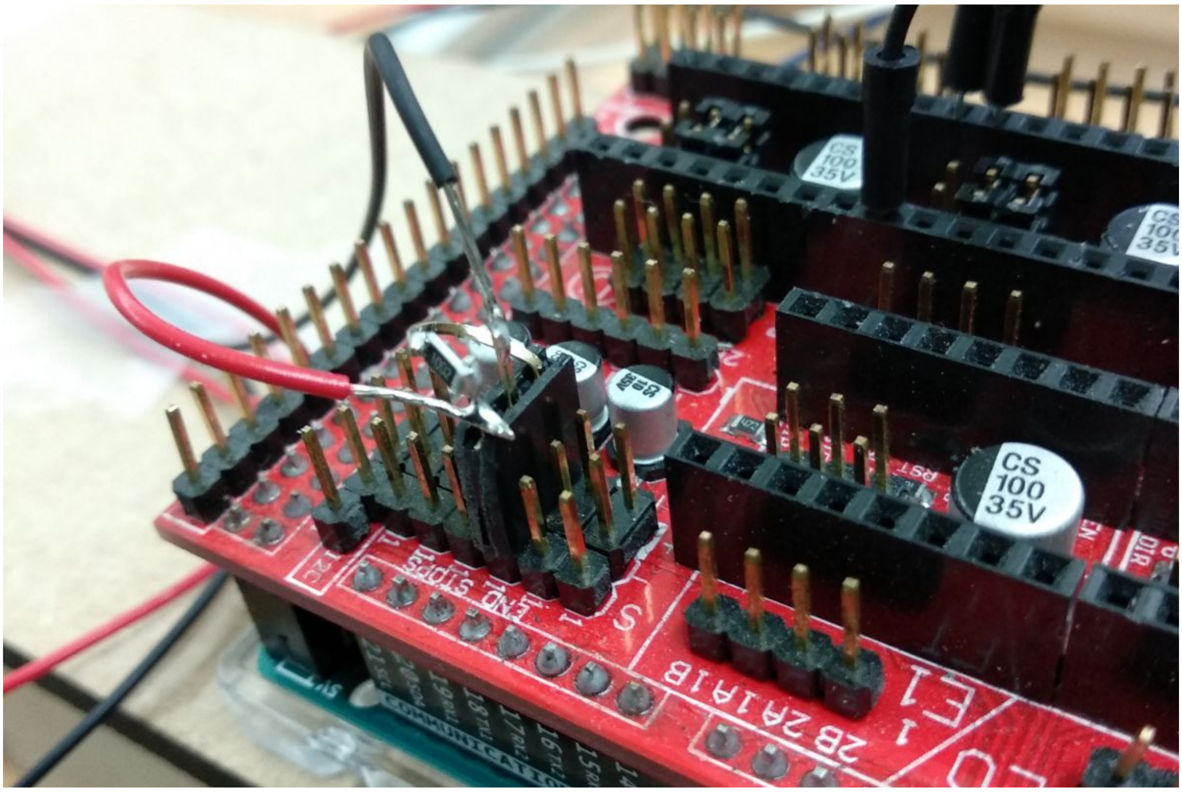



endstop for sliding carriage
endstop for gantry

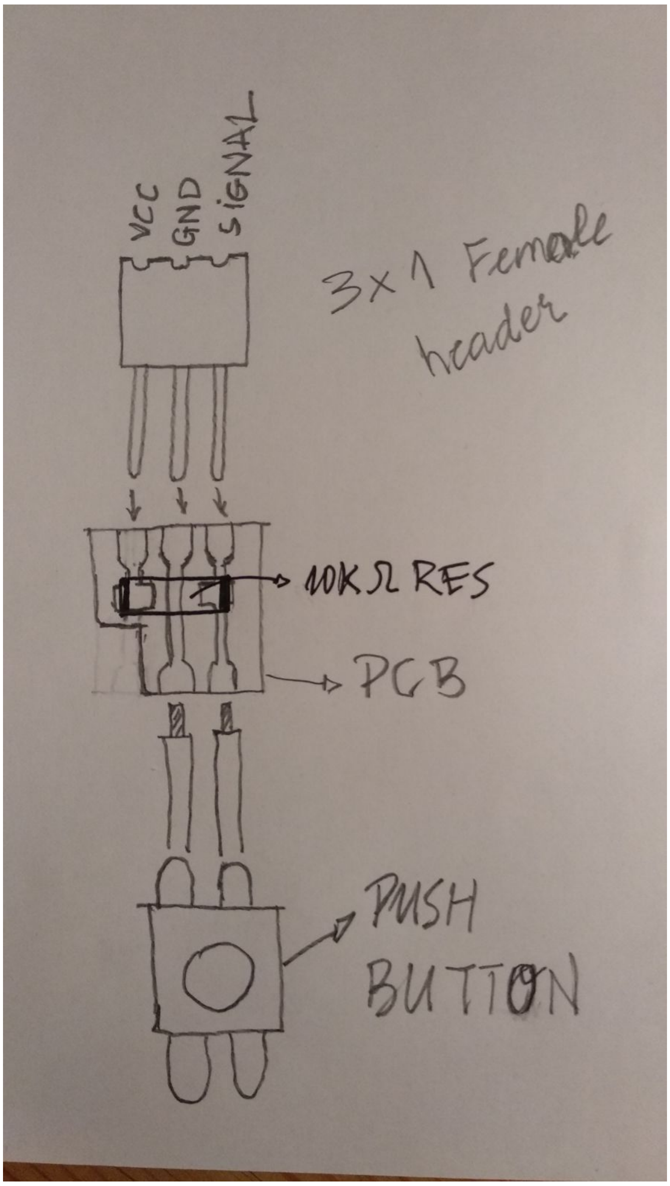


We realised that we actually needed a pull-up resistor (100 Ohms) with the endstop buttons after we were getting spurious responses in the software.





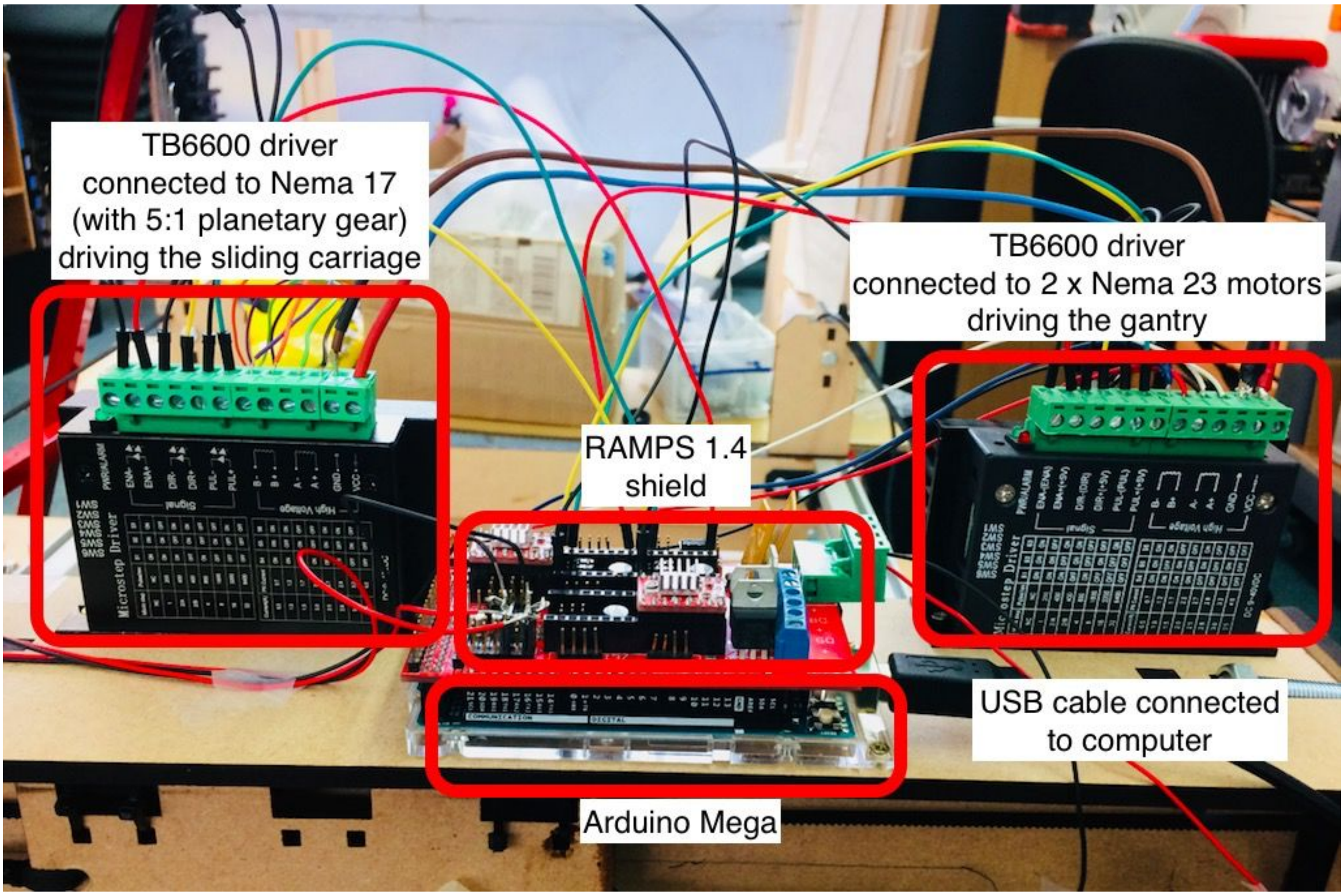
Hmmm, there was also talk of milling a PCB for our endstops, we will try to do this.



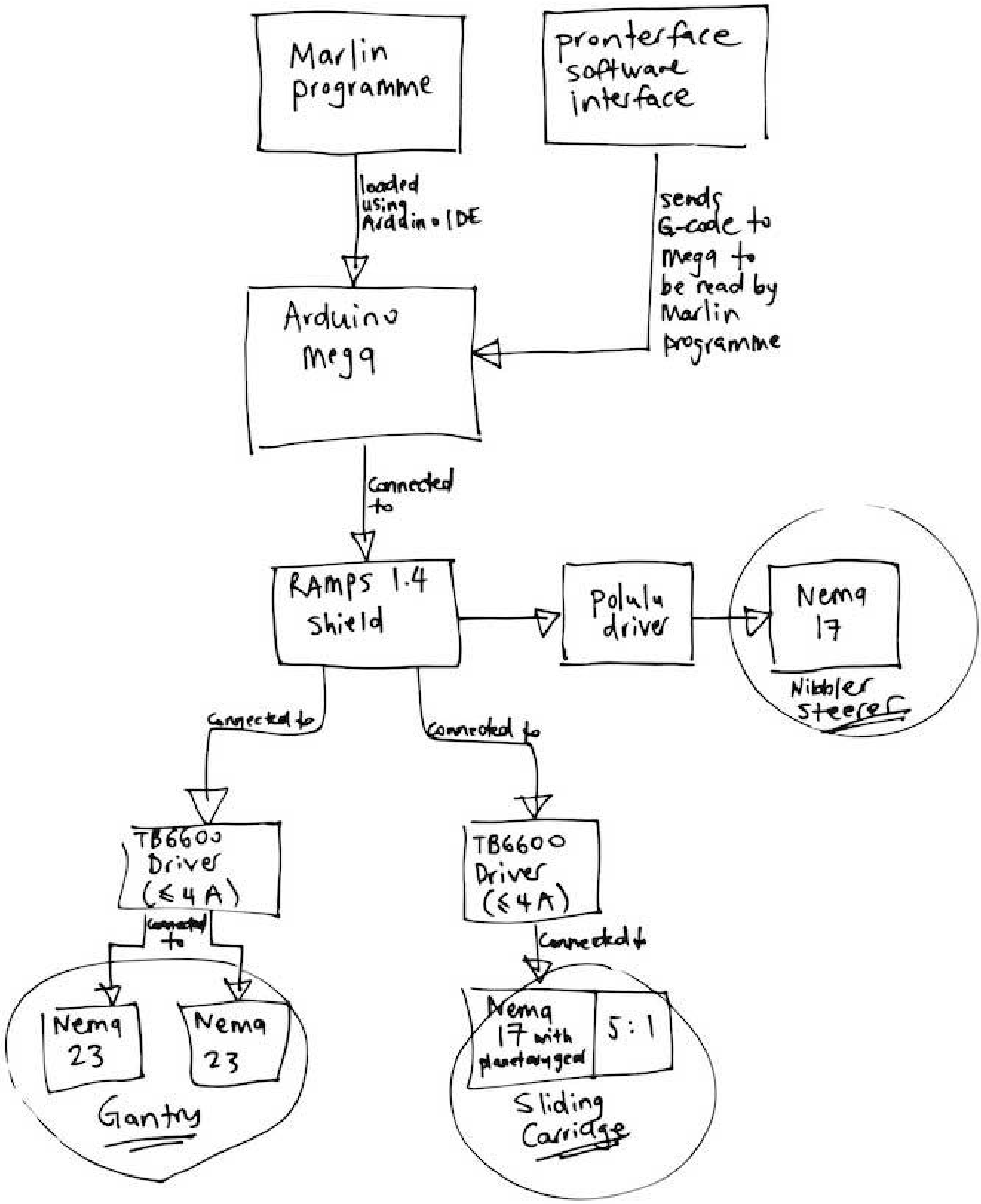
## Control system for the machine

It's worth saying a bit about this here. In order to control the machine there was a complex system of hardware and software to co-ordinate. Here's a quick description of how it all interfaces:

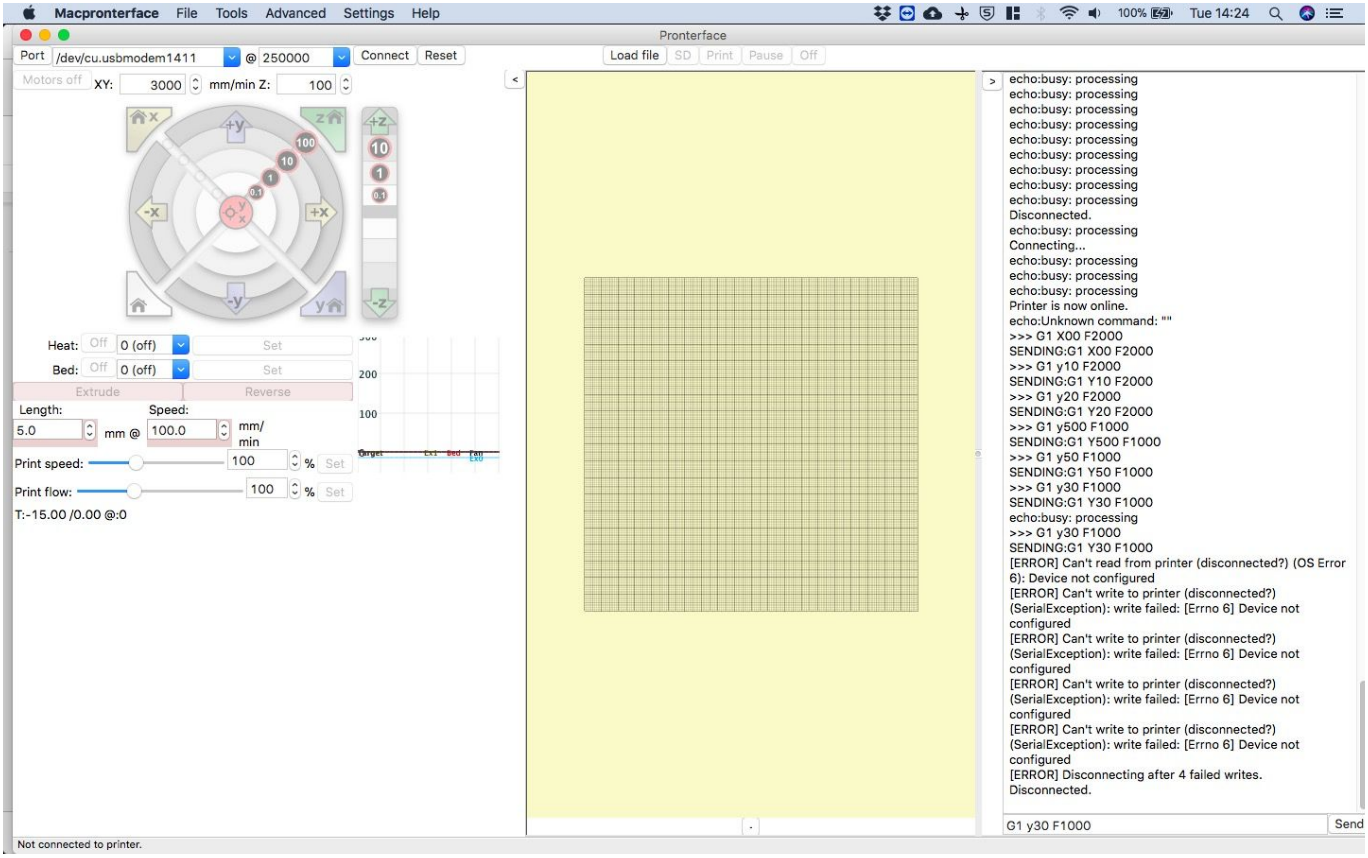
- We wrote a Marlin programme which would control the motors. This was loaded into the Arduino IDE, which we then used to send the programme onto the Arduino Mega board.
- The Mega board was connected to the RAMPS 1.4 shield
- On the RAMPS shield there is the Polulu driver mounted on it, which is used to drive the Nema 17 motor which will control/steer the nibbler.
- Connected to the RAMPS shield are two larger drivers (TB6600)
- The first TB6600 was used to control the Nema 17 motor, which would drive the sliding carriage
- The second TB6600 was used to control both the Nema 23 motors (mounted at either ends of the gantry) to control the movement of the gantry from both sides. That way the movement would be symmetrical. We could use a direct drive in future.




The following flowchart shows how things are connected:


Marlin programme
pronterface software interface
loaded using Arduino IDE
sends G-code to mega to be read by Marlin programme
Arduino mega
connected to
RAMPS 1.4 shield
Polulu driver
Nema 17
Nibbler steerer
connected to
connected to
TB6600 Driver (≤4A)
TB6600 Driver (≤4A)
connected to
connected to
Nema 23
Nema 23
Gantry
Nema 17 with planetary gear
5:1
Sliding Carriage

The Pronterface software is used to send the G-code to the board. At the moment, we simply enter in the G-code in the command line and then the gantry (X) or sliding carriage (Y) will move (or both!). This is what the pronterface GUI looks like.




## Machine testing movement in X and Y

We really wanted to do some testing today, and here's what we did:

- Test the movement in Y through various set distances to move in a straight line
- The same in X
- Then to test movement in both at the same time (ie move in a diagonal)

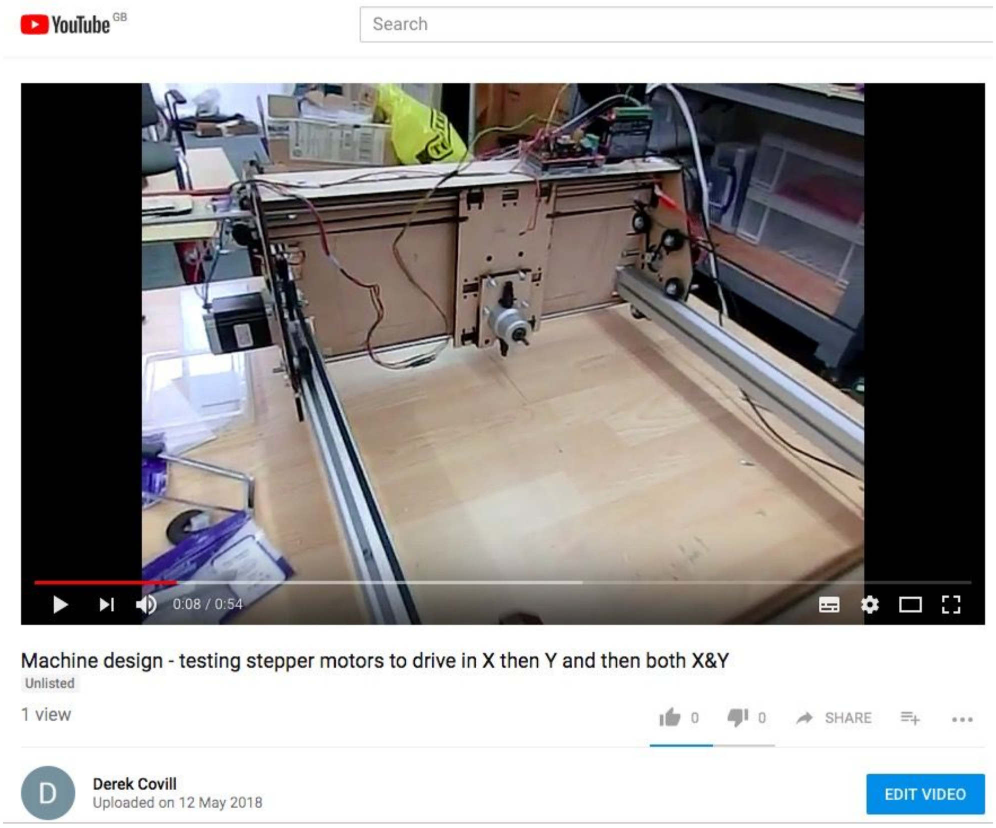
These were all successful tests. We had an issue with everything being inverted initially, but that was corrected with a '-' added into the code.

Here's our first test to control the machine drawing straight line: https://youtu.be/VtHxrZ-eZ-w

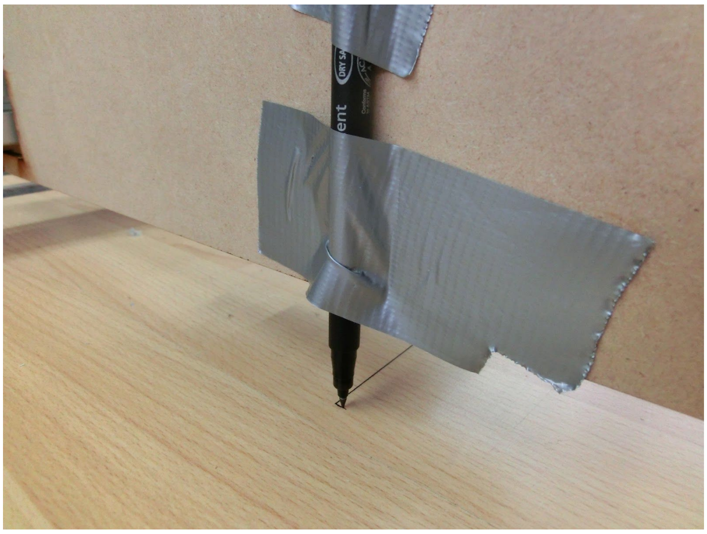
And some more testing: https://youtu.be/9TLye3N5O40

Here's a video of us testing the stepper motors to drive in X then Y and then both X&Y: https://youtu.be/Dzj0A8pTles

We've achieved actuation!!




Here is some initial testing for machine calibration using a pen to draw a line that can be measured.
[https://youtu.be/f2wb1Zc-vFM](https://youtu.be/f2wb1Zc-vFM)



We noted that a 100 mm line was actually coming out as about 110 mm, so we'll need to do more checks on this and adjust the calibration settings.

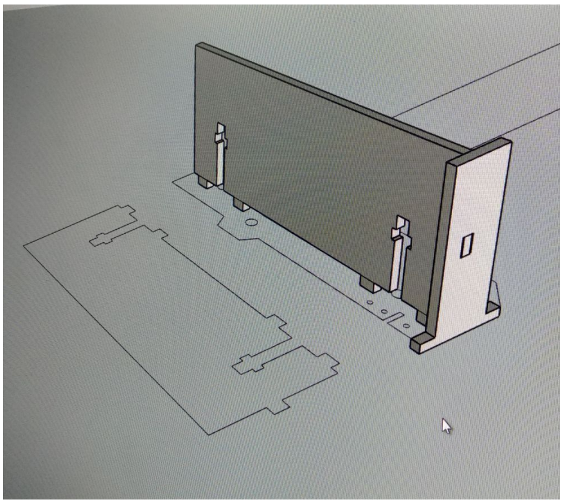
# Week 2: Day 2 (Friday) Making stabilizers and programming the motors

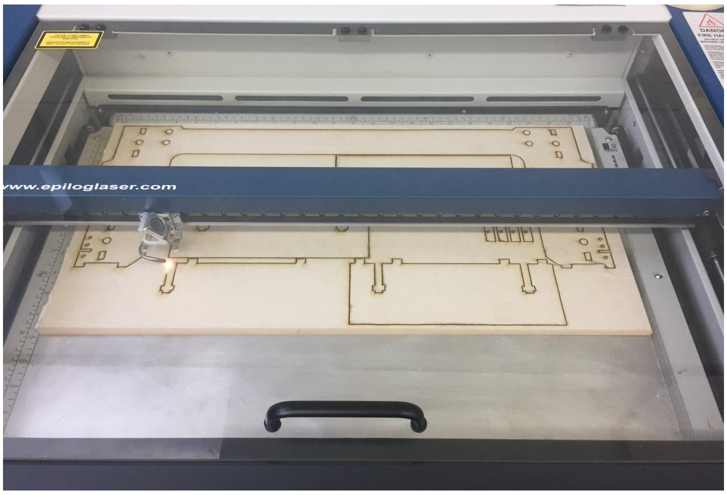
The aims for today are to:

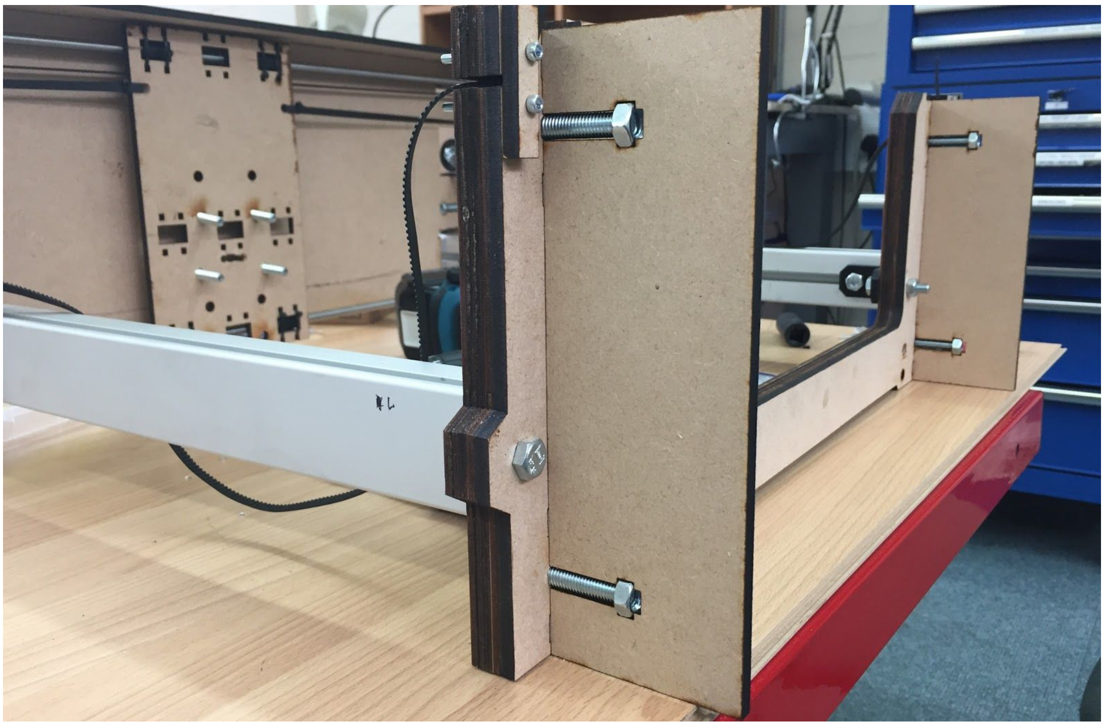
- Make some stabilizers/stiffeners for the frame to firm it up and minimise flexure from the parallel-ness
- Continue on the programme to drive the stepper motors and ideally test this and put onto the machine to drive the Y axis.

## Making stabilizers

The pulleys could distort the structure by applying force in one direction at a time, so to counteract this we have added stabilizers.







## Marlin for RAMPS 1.4

Lines changed or consider changing in the Configuration.H file:

```
77: #define STRING_CONFIG_H_AUTHOR "(BeaverCNC Team 10/May/2018)"// Who made changes when.
122: #define MOTHERBOARD BOARD_RAMPS_14_EFB // Where we declared Ramps1.4 as the Mother
Board we're using
127: #define CUSTOM_MACHINE_NAME "Beaver CNC" // Naming the machine
137: #define EXTRUDERS 1 // no extruders but use the E command in G code to control
direction of the Nibbler
289: #define TEMP_SENSOR_0 1 // add later thermistor to control temp on the tip of the
nibbler's head - Also had to have this to one. Zero failed to compile.
341: //#define PIDTEMP // uncomment this to enable PID. Do it if a a nozzle is installed
342: #define BANG_MAX 0     // Limits current to nozzle while in bang-bang mode; 255=full
current; I set it to 0 to limit current to nozzle, since we havnt got one
394: #define MAX_BED_POWER 0 // limits duty cycle to bed; 255=full current; I set to zero
421: //#define PREVENT_COLD_EXTRUSION // Uncomment when adding hot-end
422: //#define EXTRUDE_MINTEMP 0 // was 170

//Endstops:
475: //#define USE_ZMIN_PLUG // UnCommented it since no working - Had to have this on. Why?
Maybe add a jump wire to have Z end stop always on
476: #define USE_XMAX_PLUG // I Uncommented it to include xmax endstop
477: #define USE_YMAX_PLUG // I Uncommented it to include ymax endstop
//End-Stops:
495: #define X_MIN_ENDSTOP_INVERTING true // set to true to invert the logic of the endstop.
I changed this to True. Pushed Endstop was reading Open.
496: #define Y_MIN_ENDSTOP_INVERTING true // set to true to invert the logic of the endstop.
I changed this to True. Pushed Endstop was reading Open.

498: #define X_MAX_ENDSTOP_INVERTING true // set to true to invert the logic of the endstop.
499: #define Y_MAX_ENDSTOP_INVERTING true // set to true to invert the logic of the endstop.
- Compare these (till 559) below with the next table "feeds and speeds"
532: #define DEFAULT_AXIS_STEPS_PER_UNIT   { 80, 80, 4000, 80 }
539: #define DEFAULT_MAX_FEEDRATE          { 500, 500, 5, 500 }
547: #define DEFAULT_MAX_ACCELERATION      { 800, 800, 100, 800 }
557: #define DEFAULT_ACCELERATION          300    // X, Y, Z and E acceleration for printing
moves
558: #define DEFAULT_RETRACT_ACCELERATION  300    // E acceleration for retracts
559: #define DEFAULT_TRAVEL_ACCELERATION   300    // X, Y, Z acceleration for travel (non
printing) moves
569: #define DEFAULT_XJERK                 5.0 // was 5
570: #define DEFAULT_YJERK                 5.0 // was 5

751: #define INVERT_X_DIR false // Keep that in mind if invert DIR needed
752: #define INVERT_Y_DIR true // Keep that in mind if invert DIR needed
753: #define INVERT_Z_DIR false // Keep that in mind if invert DIR needed
760: // For direct drive extruder v9 set to true, geared extruder set false.
761: #define INVERT_E0_DIR false // For the E motor for the Nibbler's rotation
774: // Direction of endstops when homing; 1=MAX, -1=MIN // If needed
774: // :[-1,1]
```

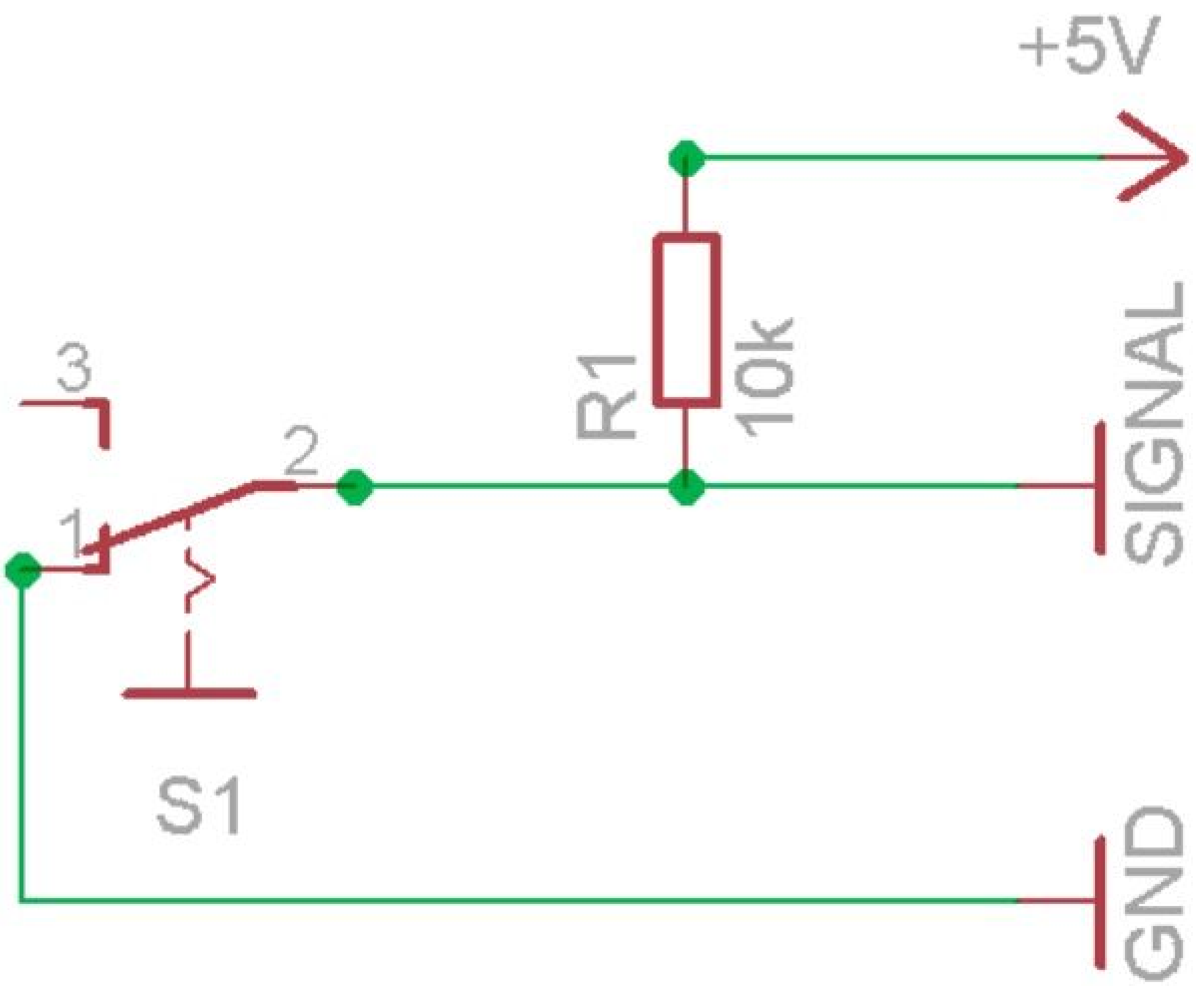
```
776: #define X_HOME_DIR -1
777: #define Y_HOME_DIR -1

1109: // EEPROM
//
// The microcontroller can store settings in the EEPROM, e.g. max velocity...
// M500 - stores parameters in EEPROM
// M501 - reads parameters from EEPROM (if you need reset them after you changed them
temporarily).
// M502 - reverts to the default "factory settings".  You still need to store them in EEPROM
afterwards if you want to.
```

**We should keep this table in mind when trimming Feeds and Speeds:** Starts at line 507 of Configuration.H of Marlin Firmware (Open with Arduino IDE)

```
//===========================================================================
//============================= Movement Settings ============================
//===========================================================================
// @section motion

/**
 * Default Settings
 *
 * These settings can be reset by M502
 *
 * Note that if EEPROM is enabled, saved values will override these.
 */

/**
 * With this option each E stepper can have its own factors for the
 * following movement settings. If fewer factors are given than the
 * total number of extruders, the last value applies to the rest.
 */
//#define DISTINCT_E_FACTORS

/**
 * Default Axis Steps Per Unit (steps/mm)
 * Override with M92
 *                                      X, Y, Z, E0 [, E1[, E2[, E3[, E4]]]]
 */
#define DEFAULT_AXIS_STEPS_PER_UNIT   { 80, 80, 4000, 500 }

/**
 * Default Max Feed Rate (mm/s)
 * Override with M203
 *                                      X, Y, Z, E0 [, E1[, E2[, E3[, E4]]]]
 */
#define DEFAULT_MAX_TE          { 300, 300, 5, 25 }

/**
 * Default Max Acceleration (change/s) change = mm/s
 * (Maximum start speed for accelerated moves)
 * Override with M201
 *                                      X, Y, Z, E0 [, E1[, E2[, E3[, E4]]]]
```

```
 */
#define DEFAULT_MAX_ACCELERATION      { 3000, 3000, 100, 10000 }

/**
 * Default Acceleration (change/s) change = mm/s
 * Override with M204
 *
 *   M204 P    Acceleration
 *   M204 R    Retract Acceleration
 *   M204 T    Travel Acceleration
 */
#define DEFAULT_ACCELERATION          3000    // X, Y, Z and E acceleration for printing
moves
#define DEFAULT_RETRACT_ACCELERATION  3000    // E acceleration for retracts
#define DEFAULT_TRAVEL_ACCELERATION   3000    // X, Y, Z acceleration for travel (non
printing) moves

/**
 * Default Jerk (mm/s)
 * Override with M205 X Y Z E
 *
 * "Jerk" specifies the minimum speed change that requires acceleration.
 * When changing speed and direction, if the difference is less than the
 * value set here, it may happen instantaneously.
 */
#define DEFAULT_XJERK                 10.0
#define DEFAULT_YJERK                 10.0
#define DEFAULT_ZJERK                  0.3
#define DEFAULT_EJERK                  5.0
```

The reason there are 3 pins for Endstops is for a pullup resistor. I hacked a Pullup system using a SMD 10k Ohms Res, soldered it from the VCC pin to the Signal pin, and GND in the middle:
|VCC|GND|SIGNAL|

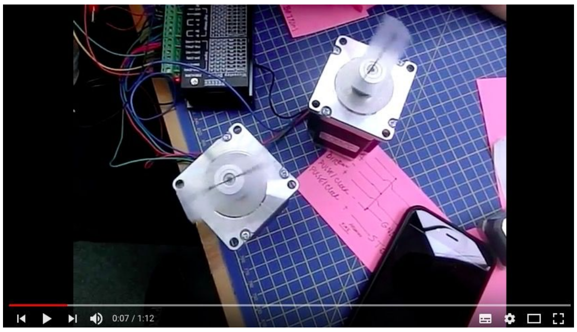



Good link for Ramps wiring also:
https://www.drdflo.com/food-printer-frame/http://reprap.org/wiki/File:Rampswire14.svg
http://reprap.org/wiki/RAMPS_1.4http://doc.3dmodularsystems.com/electronic-wiring/

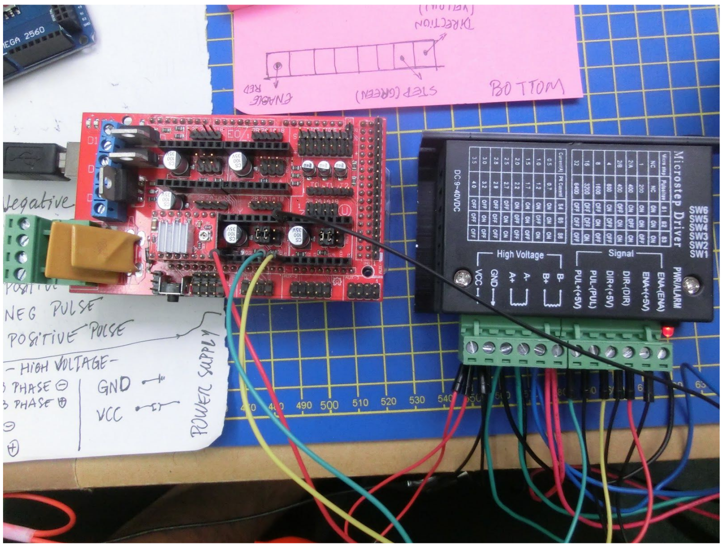
What to do with it: Metal Etching

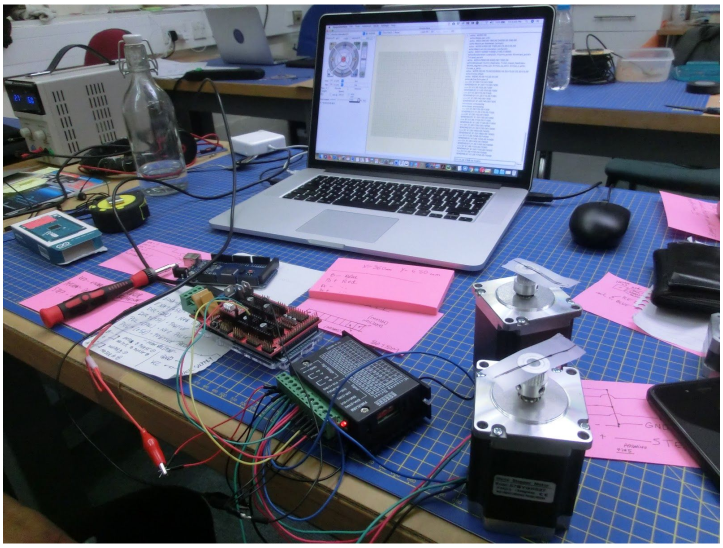
## Programming the stepper motors

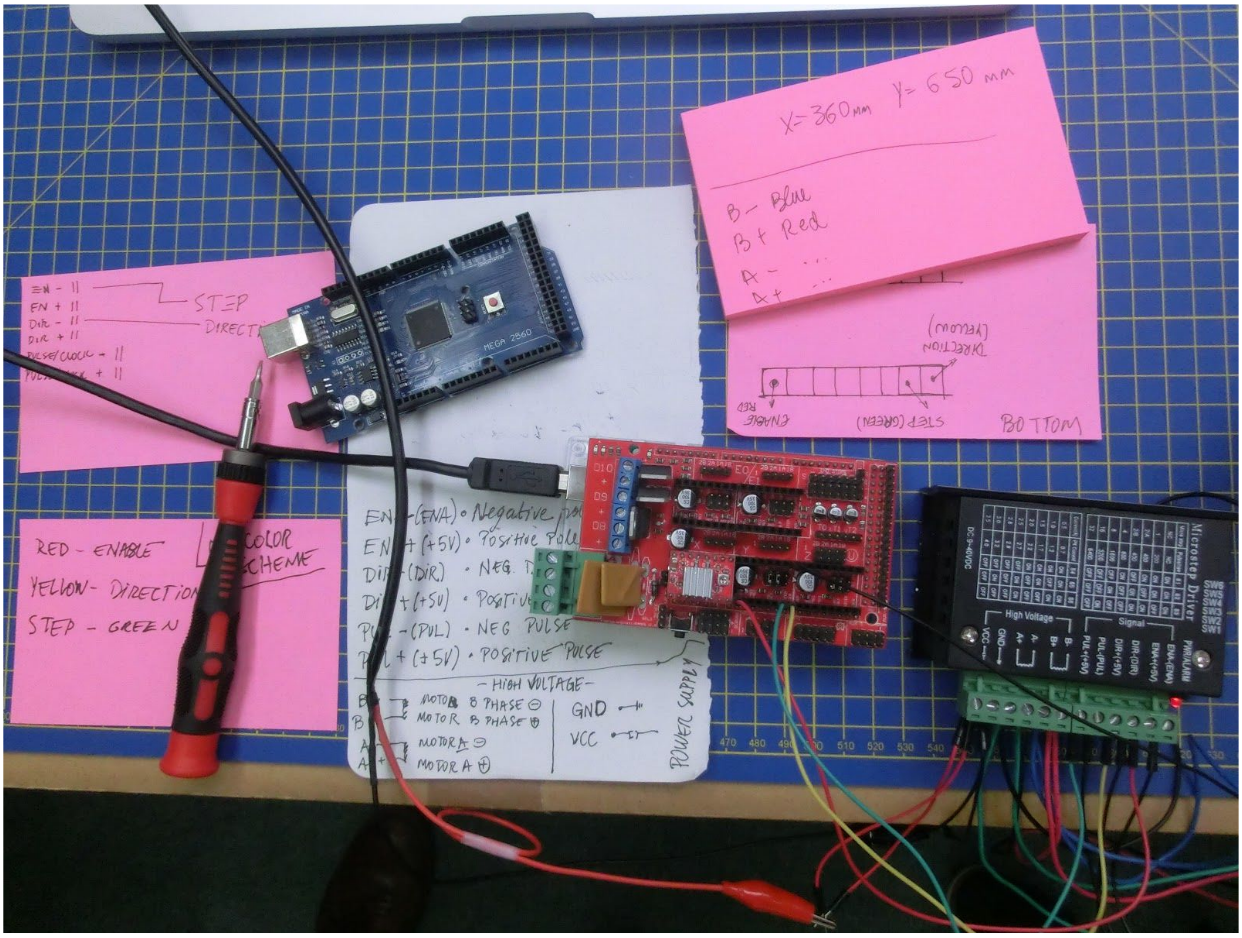
After some tweaking, we managed to get the stepper motors to drive in sync. We realised that we needed to overclock them with 15V to get them moving, rather than the 12V we started with. Here's a video of it all working: https://youtu.be/TYEfGrtis_o



And here’s the setup, with the Arduino Mega, RAMPS 1.4 shield (the red board piggy backing on the mega), and the motor driver (TB660).






## Week 2: Day 1 (Thursday) frame design, belt holder and programming

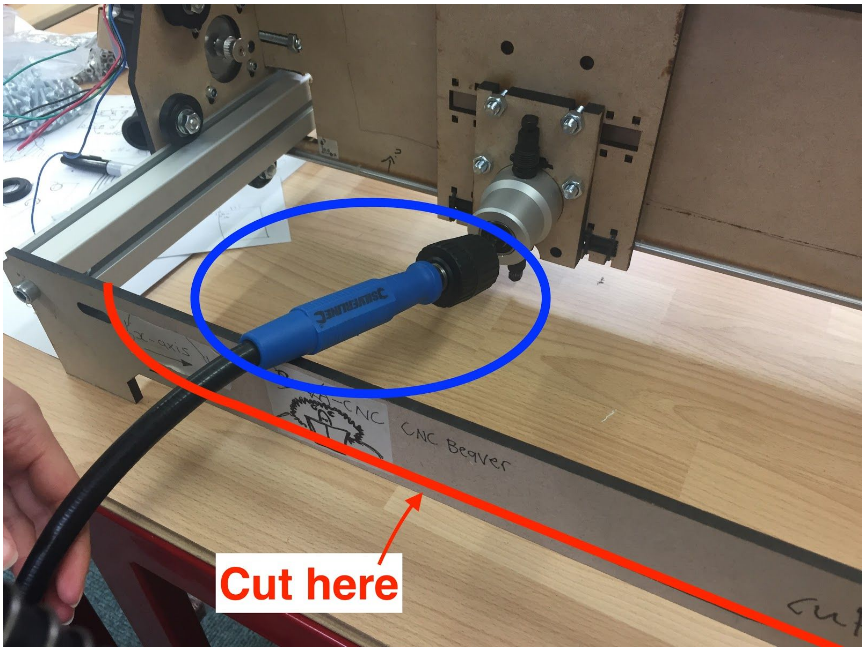
The aims for today are to:

- reflect on the first week
- improve the frame design
- create a belt holder for movement in Y-axis
- start on the programming to drive the motors

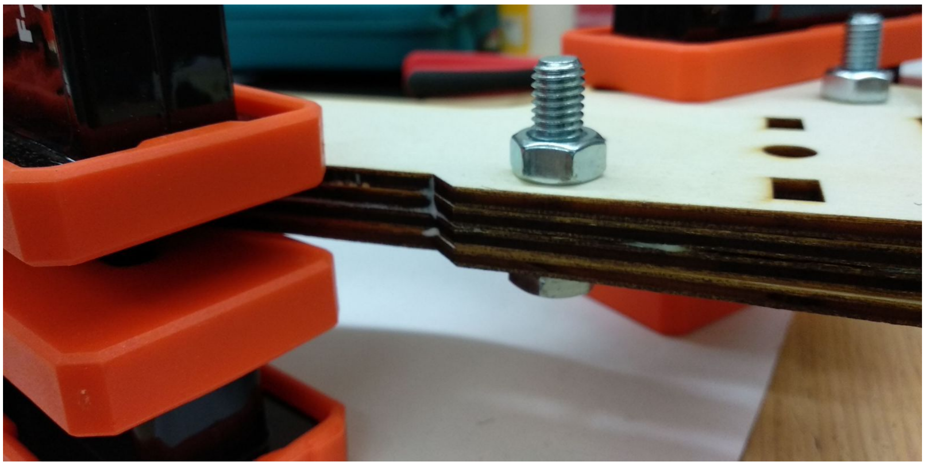
## Reflection on the first week

## Improving the Frame

The rigid collar on the flexible drive reduces the working area by over 200mm, because it is restricted by the the front panel of the frame. So we reduced the height of the panel. At the same time, we increased the strength by gluing together multiple layers.

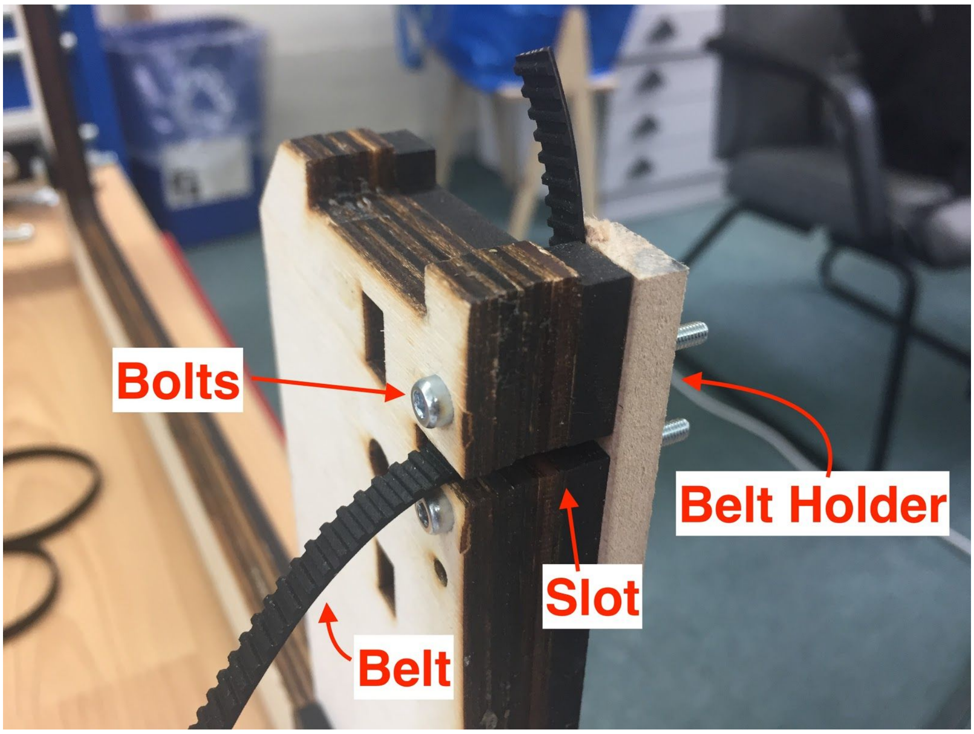



To ensure the layers were lined up accurately, we laser cut holes so they could be screwed together with nuts and bolts while the glue was drying. And then added clamps.



## Creating a belt mount for movement in Y-axis

When we remade the front panel we added a slot for the belt to go through, that gets secor


Bolts
Belt Holder
Slot
Belt

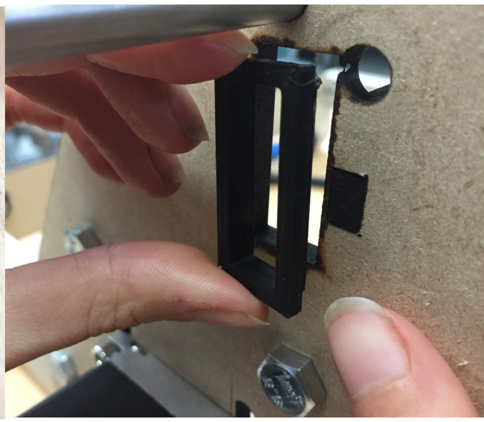
## Week 1: Day 5 (Wednesday) Making Pulley Holders and connecting belts and pulley system to gantry

The aims today were:

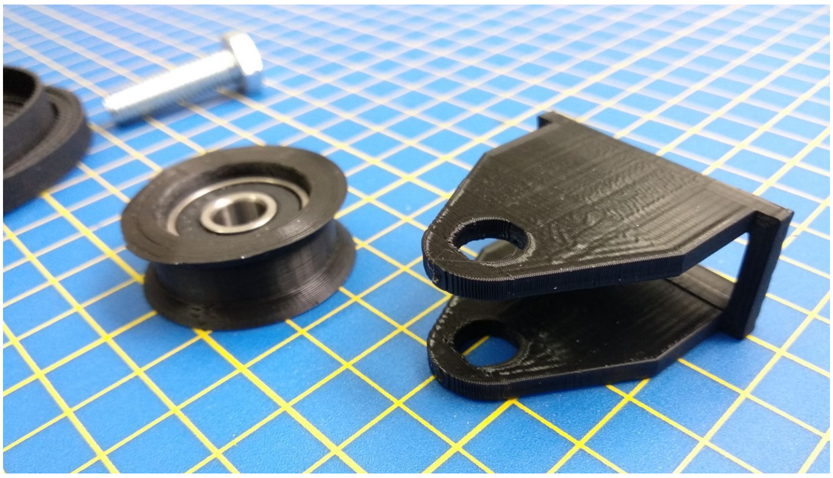
- To design, make and fit some holders for the pulleys
- To connect the belts to the gantry to move the gantry in the Y axis, and to move the cutter along the X-AXIS
- To update and tidy our documentation, including backfilling images and videos.

### Pulley holders

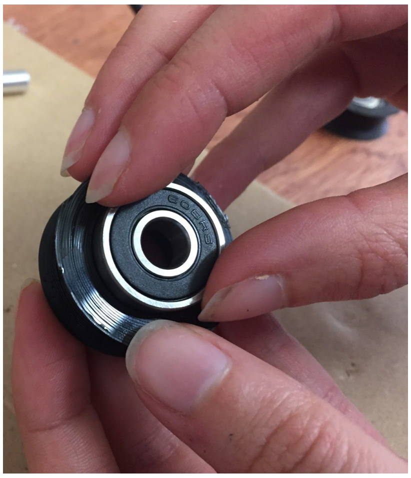
The first step was to design the holders for the pulleys. The idea here was to design them in a way that would allow them to loosely pressed into the rectangular slot in the side of the gantry, with the tension in the belt then used to keep the holder pressed into the gantry. To test the fit, we made a small rectangular part which included only the bottom section of the part and inserted it into the slot.


It fit well enough, so then we produced the entire part.




We heated the pulleys with a heat gun to make it flexible enough to push the bearings in with a tight fit.

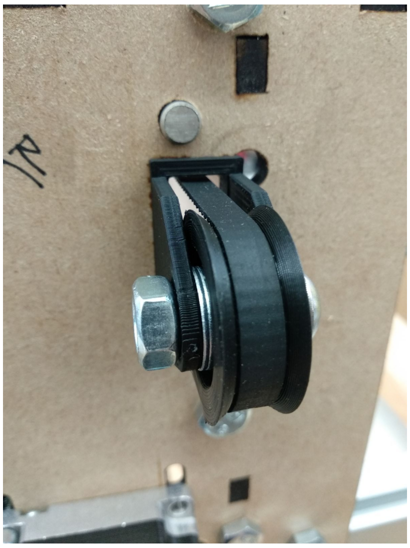
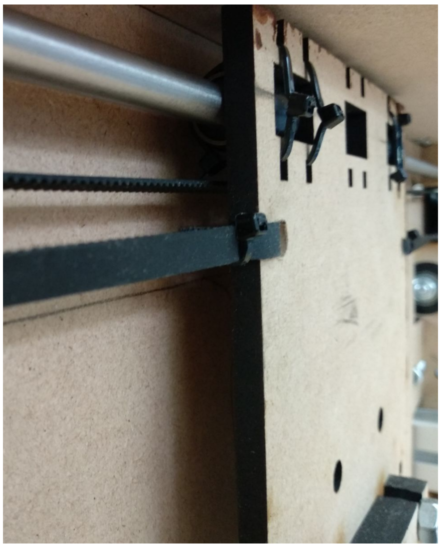
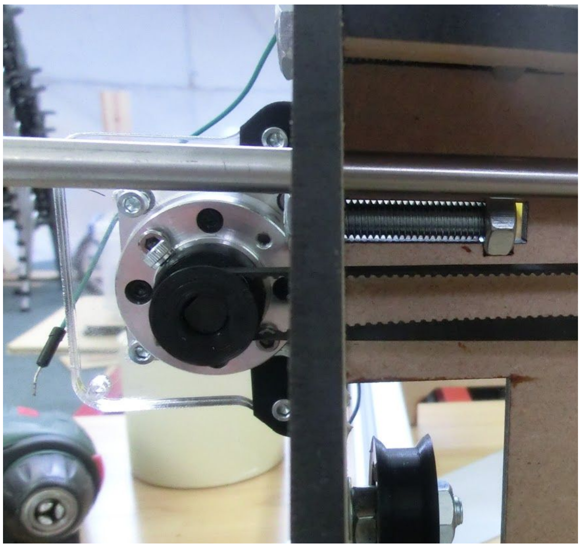



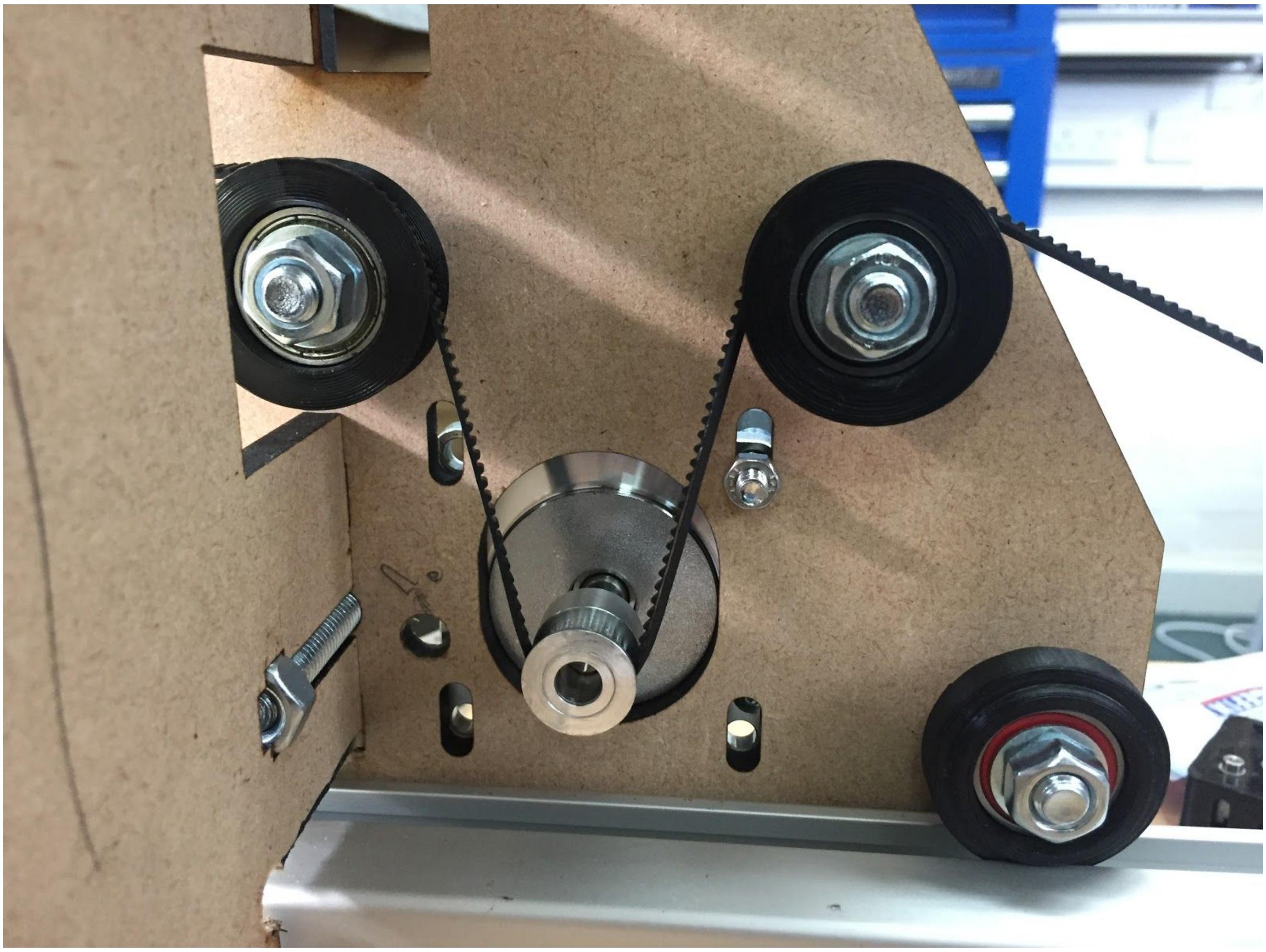
## Connecting belts to sliding carriage

We then connected it all up, tying the belt to both sides of the sliding carriage on the gantry (which holds the cutter), and wrapping it around the pulley on the stepper motor. The movement is smooth but quite tight, we'll check this when we power the motors up!

Here's a video showing the pulley and belt connected to sliding section of gantry and stepper motor:

[https://youtu.be/XYRg3z_IdjI](https://youtu.be/XYRg3z_IdjI)

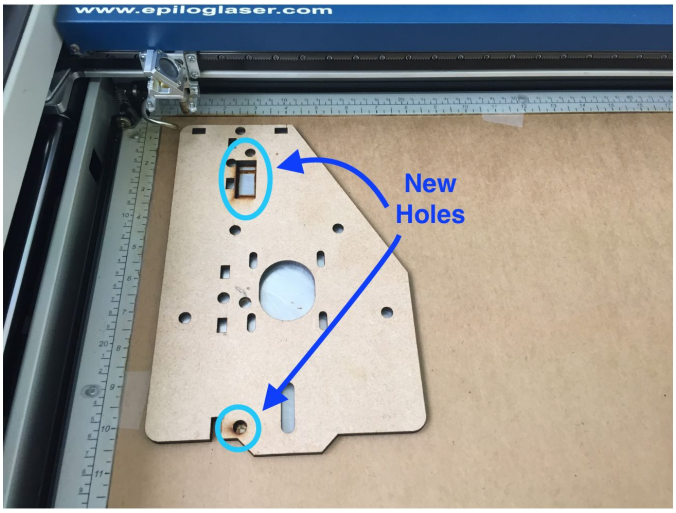


# Week 1: Day 4 (Tuesday)

The aim of today was to adapt the machine to make it more secure and put the stepper motors in place.

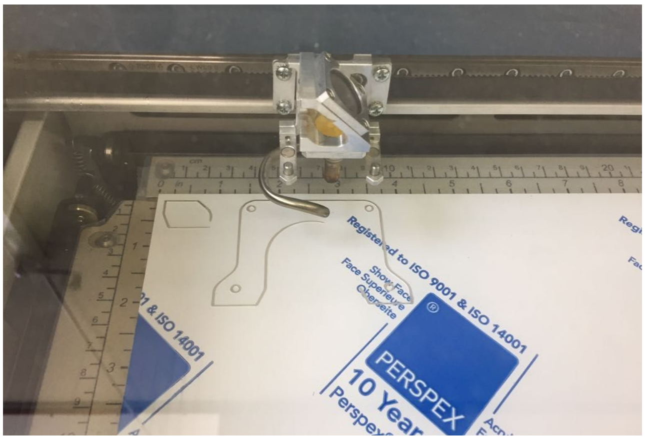
## Changing the position of holes

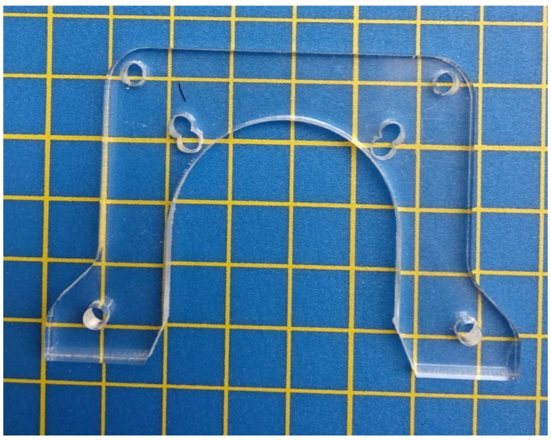
The rails were original positioned above the nibbler, but this created vibrations when the nibbler was turned on, so we moved the bottom rail down. To avoid having to recut each piece to make new holes, we laser cut a jig using cardboard. This meant we could accurately align the piece in the laser cutter and then just cut the new holes for the rails.


## Making the Stepper Motor holders

Laser cut the flat parts and 3D printed the right angled parts with countersunk screw holes.
On one side of the Stepper Motor the 3D printed parts fitted perfectly, but on the other side the motor casing protruded more, so we snipped the parts using wire cutters.



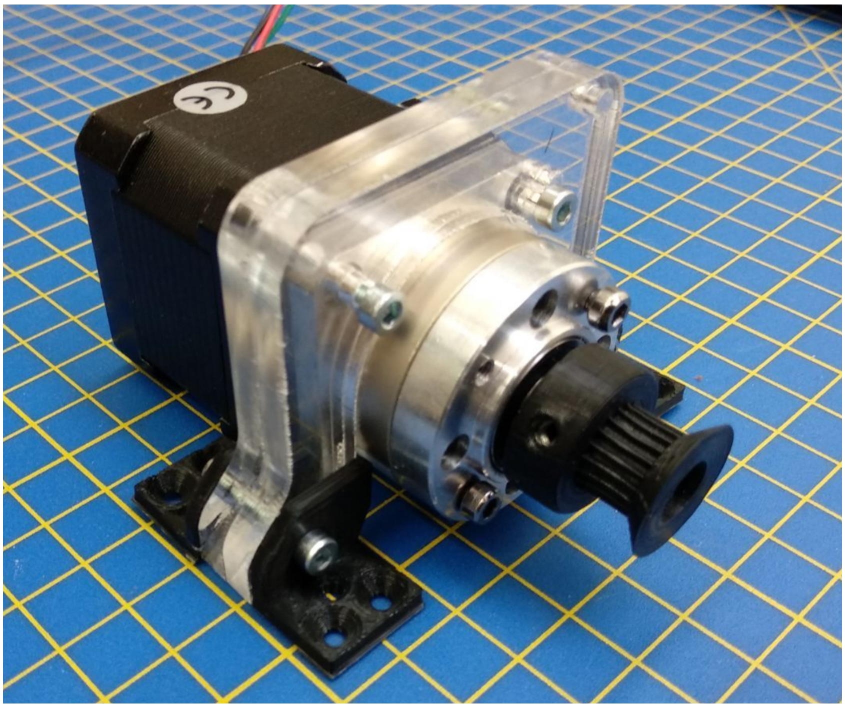



## Laser Cutter Settings - CHECK THIS!!!

| | |
|---|---|
| MDF (6mm) | Speed 8% |
| | Power 100% |

| | |
|---|---|
| | Frequency 800Hz |
| Acrylic (5mm) | Speed 8% |
| | Power 100% |
| | Frequency 5000Hz |

Basic testing with the nibbler attached to the drill with the flexible drive.



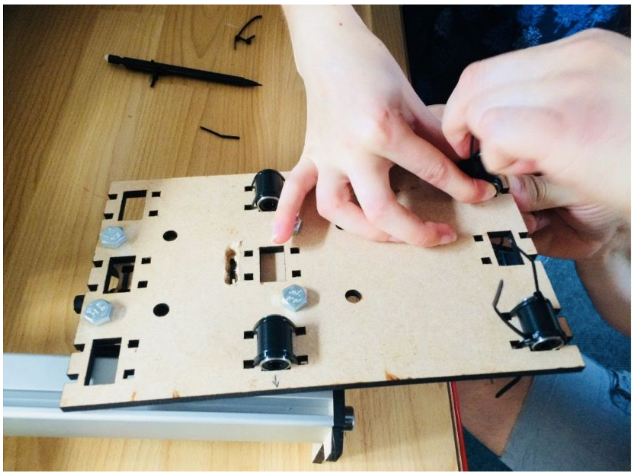
Here are a few videos of some testing from today:

- test 1 cutting aluminium straight line with flexible drive and cutter connected: https://youtu.be/JYhZIStOjtY
- test 2 cutting aluminium straight line with flexible drive and cutter connected:https://youtu.be/QGSSPiFeL00
- test 3 cutting aluminium straight line with flexible drive and cutter connected: https://youtu.be/tOzIRH8lI54

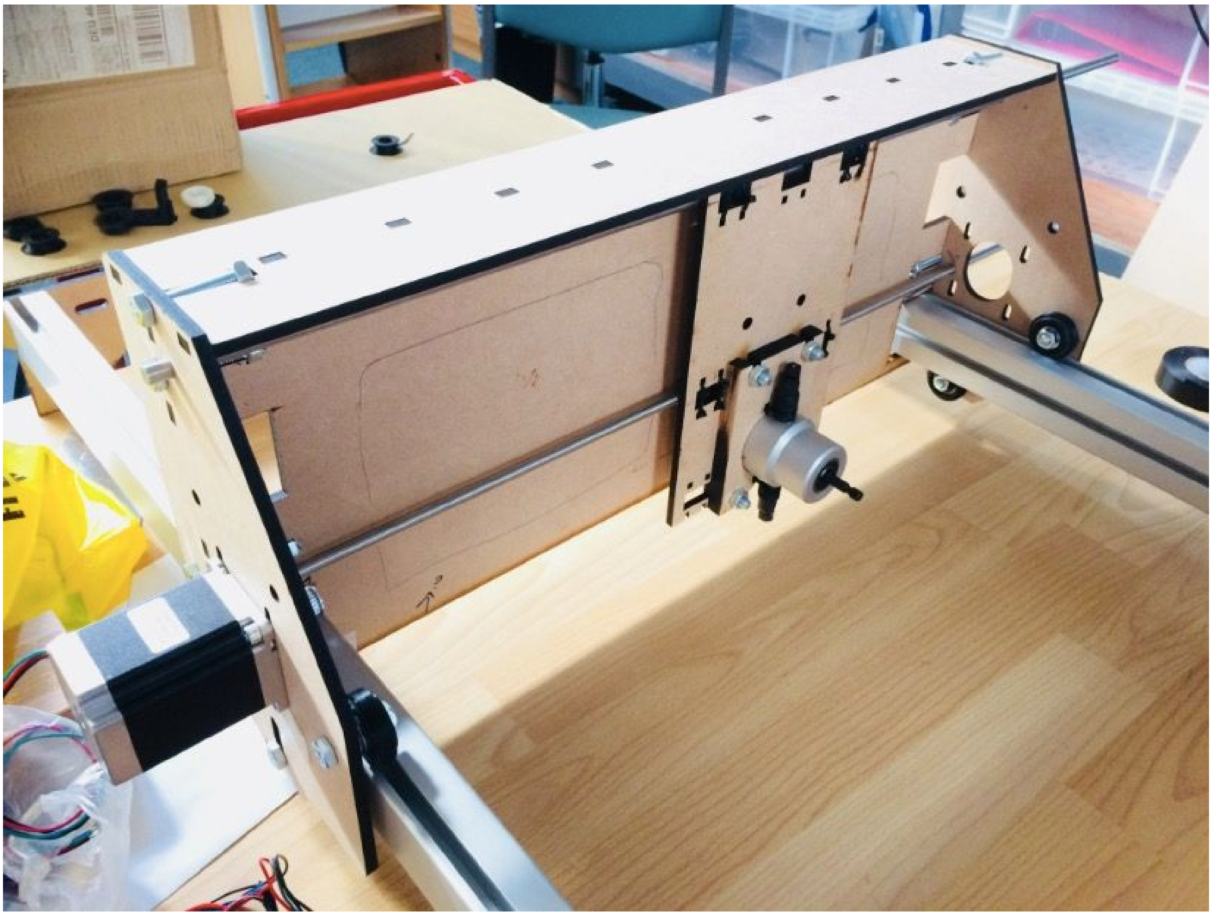
This has made us realise that there could be a problem with ensuring the connections between the flexible drive and the cutter are secure. In the tests we found that the dynamic movement of the cutter made the flexible drive unwind from the cutter.

## Week 1: Day 3 (Monday) - redesigning the gantry mount, mounting the cutter, basic movement tests

The first step today was to redesign the mount that connects the cutter to the gantry. This was rubbing on the shaft and we wanted to redesign it to allow for multiple fixing points. Here we are mounting in the linear bearings, and we also had to wrap tape around these to give sufficient space.



We then tested the basic mechanical movement of the gantry, here's a video:
[https://youtu.be/QvXVOni-kVc](https://youtu.be/QvXVOni-kVc)



We then connected the drill directly to the cutter, just to test things in situ.

Here’s a video where we connected drive (drill) to the machine: https://youtu.be/ByoBALwkgI0

And here’s a video of the machine’s first cut!: https://youtu.be/EJaNofjdOJ4

Before our flexible drive arrived, we simulated how it would work using a flexible drive from our Dremel. Here’s a video showing this conceptual demonstration of prototype: https://youtu.be/y2nCkGRQ164

And then our flexible drive arrived in the post!!!

## Converting 2D Rhino drawings to 2D Solidworks sketches

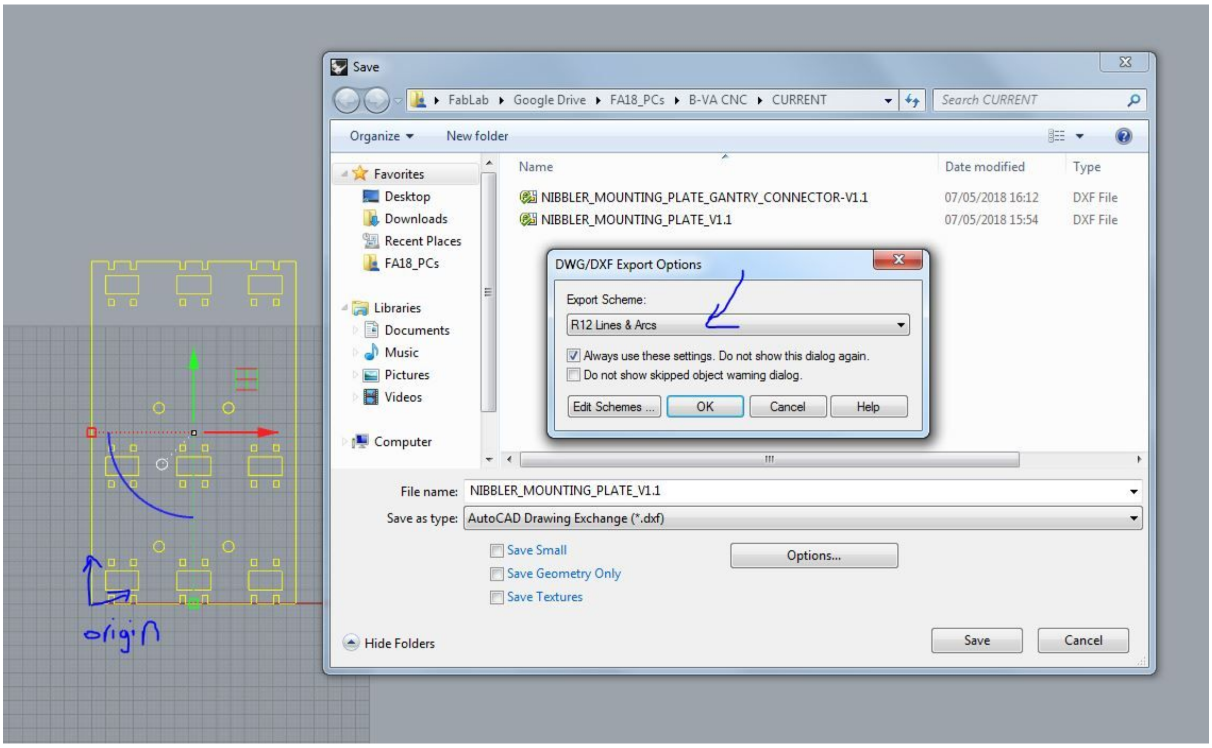
One of the key tasks this week has been dealing with multiple skill sets and resources. Working between our offices, homes and the fablab has thrown up the challenge of: how to juggle CAD?

Well early on, we started modelling in Rhino, simply because it was available in the lab and on our laptops, but as the week has progressed we've tried to model things in Solidworks also. Ultimately we want to have everything modelled in Solidworks: it's parametric and easier to make changes...and to show it as an assembly and produce drawings. So currently, we have some parts in both, but it one of DC's responsibilities is to convert models into Solidworks and produce a full assembly with drawings etc.

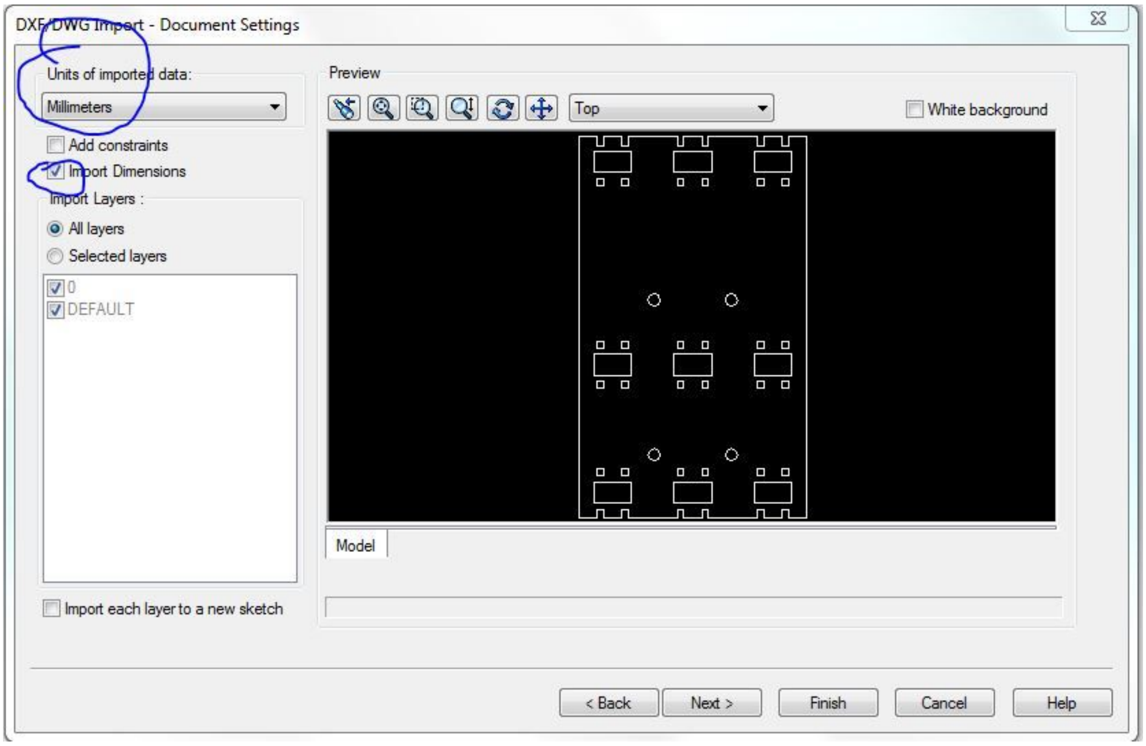
But a here's a useful workflow to convert the 2D Rhino drawings into Solidworks sketches (and then parts).

The first step is to save the Rhino file as a .dxf. We suggest doing a few things to make life easier:

- Moving your part to the origin using the MOVE command. That way when you bring it into Solidworks, it will have the same origin.
- We tend to use the 'save selected' option, that way if you have multiple parts in the same file, you can simply select the part you want and export that.
- In the export options, use the R12 Lines and Arcs scheme.




In Solidworks, goto File > Import and find the .dxf file you saved in Rhinoceros. Make sure that the Units are in mm (the default is inches), and check the 'import dimensions' option.




In solidworks, a good workflow is as follows:

1. Create a new sketch on the same plane than the imported .dxf drawing sketch
2. Recreate all the lines, arcs, rectangles, circles etc on this sketch.
3. Click on the 'show relations' tool in the sketch tab
4. Delete all the coincident relations that link the current sketch to the imported .dxf drawing sketch.
5. Dimension all the relevant sketch entities as needed.
6. Exit sketch, then delete or suppress the imported .dxf drawing sketch.

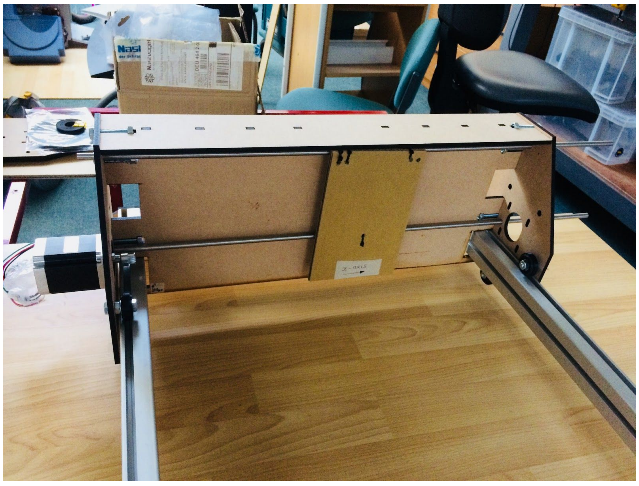
# Week 1: Day 2 (Friday) - gantry design, cutter mount system and pulley design

Aims for today:

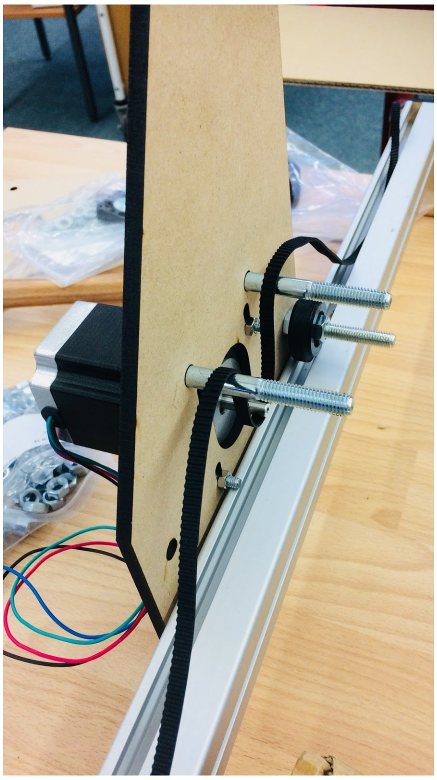
- Finish the design for the gantry (sliding open box) and mock up the belt-pulley system at the end of the gantry
- Mock up the backing plate for the sliding carriage using cardboard mounted onto the bearings

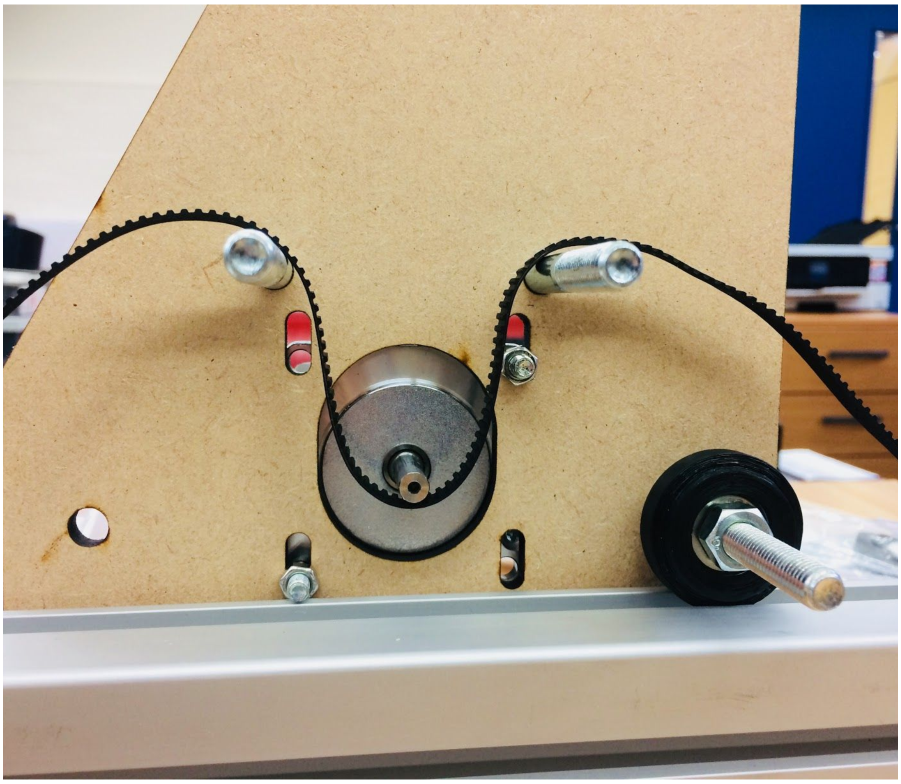
## Gantry design and sliding carriage backing plate and sliding mechanism

The gantry is a crucial part of the design and today we made some good progress to get the rollers and motors mounted onto the gantry. It slides quite well, a little bumpily, but we might try to smooth out the rollers some more. The sliding rods were mounted in the gantry, and then we cable tied some linear bearings to the back of some cardboard to mock up how the sliding carriage would move along the gantry...nice! We realised that the top sliding rod was too high though, with the nibbler positioned right down the bottom of the sliding carriage, the moment created will want to twist the gantry along its long axis, so we will need to move the top rod down to the bottom of the gantry to remove this moment and make the nibbler sit between the rods.



We used a Pulley Generator from Thingiverse (https://www.thingiverse.com/thing:16627) to generate some pulleys on one of the motors. Here's how it would be threaded.





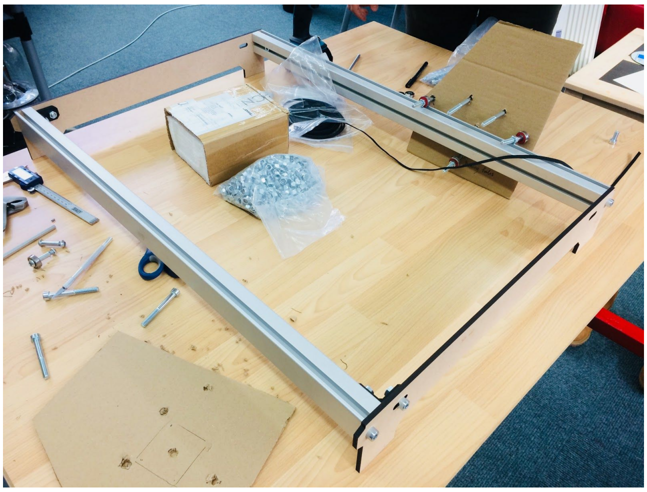
We ventured over to the machine shop where Rick (what a star!!) agreed to bore out the internal diameter of our stepper motor pinion from 5.0 mm up to 6.35 mm… after some teething problems he did us proud, and the new pinions are now happily mounted to the Nemo 23s...lovely!

Machine design - turning aluminium pulley -  remove part and check: https://youtu.be/S6gZdknRDLM

Machine design - turning aluminium pulley - boring 6 35mm hole with coolant: https://youtu.be/0YOwZA_tHjo

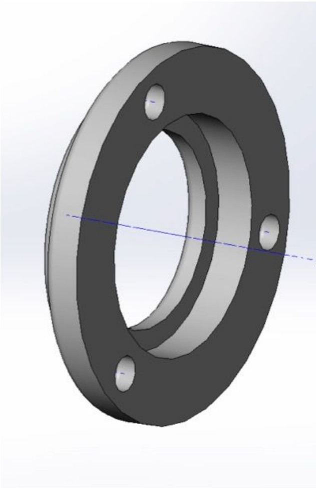
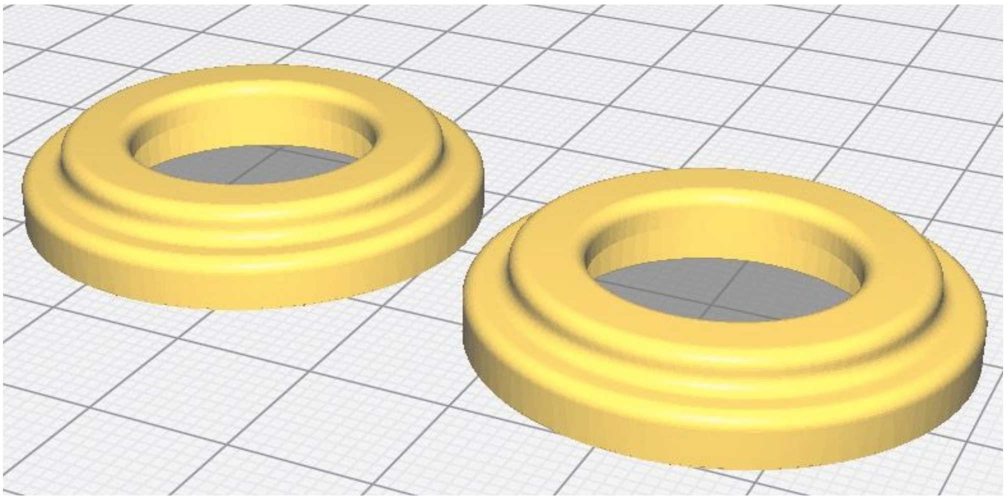
# Week 1: Day 1 (Thursday) - frame design & gantry roller system

Day one, we put together a simple frame using two pieces of extruded aluminium we had floating about in the lab and some 6 mm MDF ends.

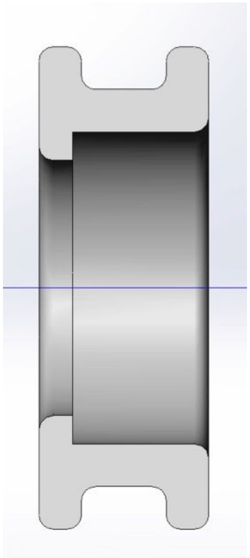
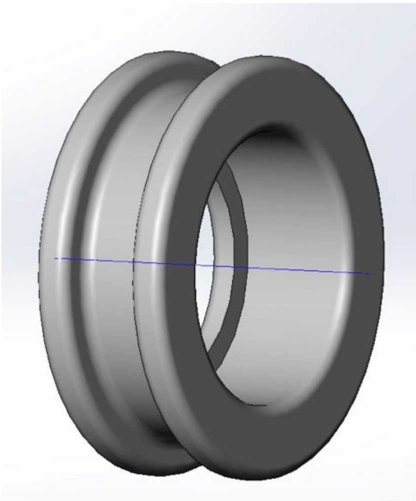
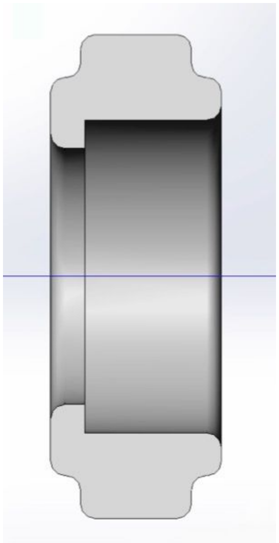
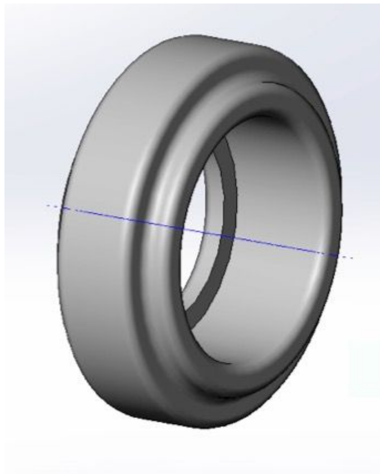



We then cut out some gantry ends to mount the motors on, and designed some L-shaped brackets that we could 3d-print to brace the aluminium sides with the MDF front and back faces. When it comes to small brackets, you've gotta love 3D printers!

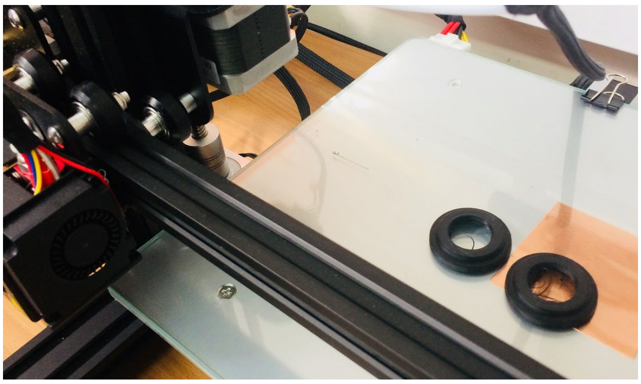

We then designed some groovy rollers (pulleys) and mohawks (bearing cases) to be press-fitted over the bearings. Originally we designed them like this, so that they were easy to print and could be pressed together over the top of the bearing using some simple steel pins.

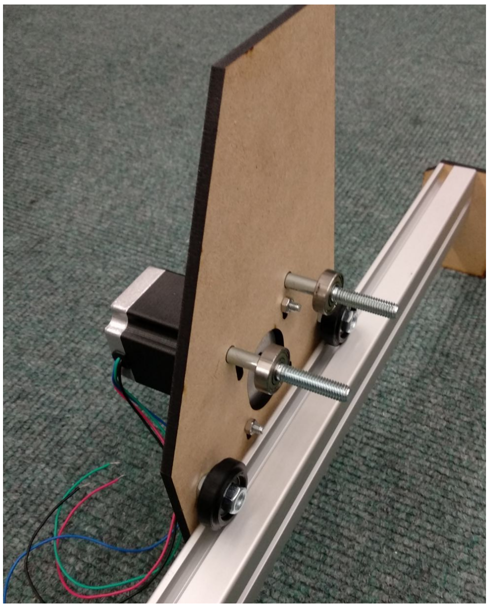
But that wasn't the best idea, too many parts and a bit fiddly. We redesigned them to be a pressed over the bearing with one side open and the other closed. We then heated the open end up with the heatgun and then slide them over the bearings and cooled them with some blowing. It worked a treat!!!

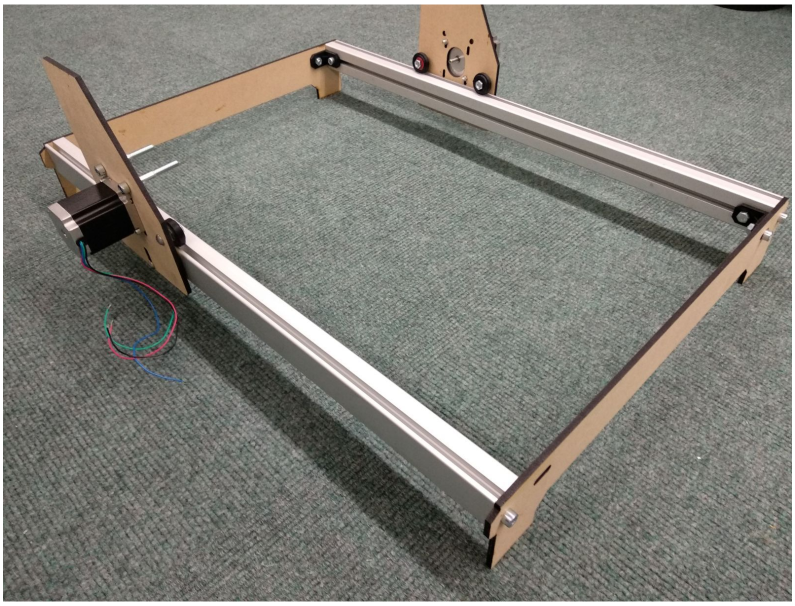





We also used our lovely CR10 3d printer which printed these bearing cases beautifully, and to save time we thought we'd resurrect the old makerbot replicator 2X. What a brute, it eventually printed, with some forceful extrusion, but the final result was rubbish. The surface was rough, the geometry was not regular, it looked aweful...so we stuck with the CR10.




Then we assembled them onto the gantry ends and messed about rolling them along the aluminium extrusions. A nice start we thought for day one.





Mechanical design - day 1 summary - basic frame made with rollers for gantry
https://youtu.be/KRrjbk1Bzbo