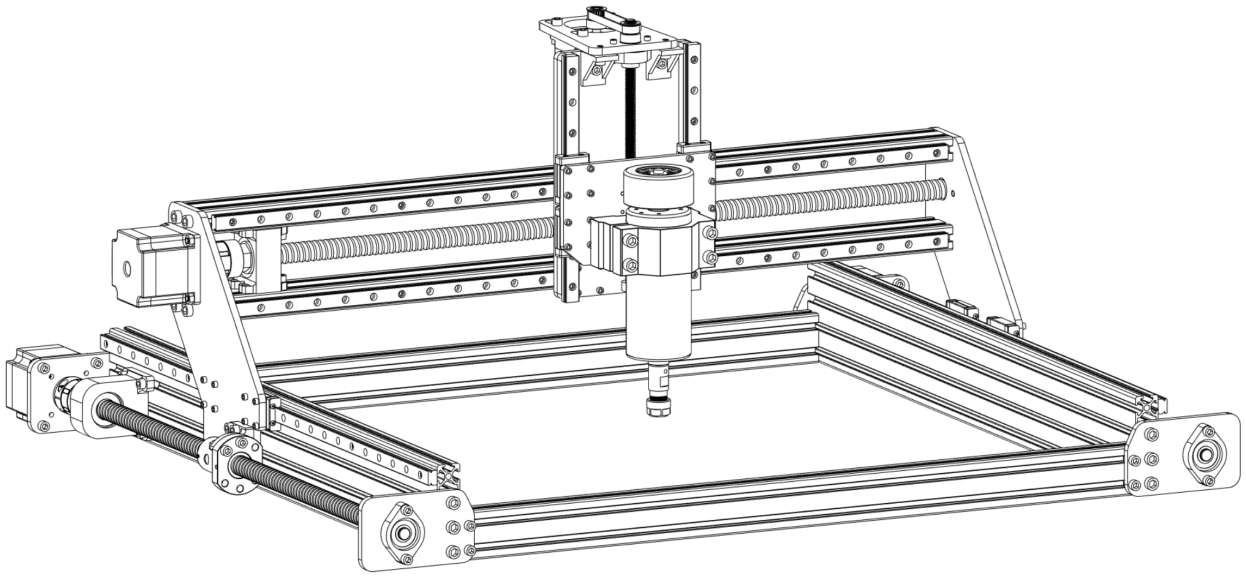
IndyMill



Build Instruction

Table of content

1. About IndyMill

IndyMill is an open source CNC machine that you can easily build yourself! After over a year of development I created all metal CNC machine focused on rigid construction, easiness of build and flexibility. Thanks to aluminium profiles and steel plates machine is very rigid so you can mill fast and precise. It's easy to build, I put a lot of effort to create nice documentation for my projects and make them as simple and minimalistic as possible. Design free of unnecessary components is always my goal. Why is it flexible? You can build it as big as you want, you can start with Nema 17 and later upgrade to Nema 23 as X and Y axis steel plates accommodate holes for both motor sizes. You can also use inexpensive trapezoidal lead screws and later upgrade to expensive ball screws. I will show you how to build a CNC with Nema 23 motors, ball screws 6 mm steel plates and IndyShield, that's recommended and tested setup but feel free to experiment and adjust this project to your needs. Keep in mind that by changing the thickness of steel plates you need to adjust length of some screws, same thing with aluminium profiles. If you change size of the machine you not only need to change aluminium profiles length but also length of rails and ball screws.

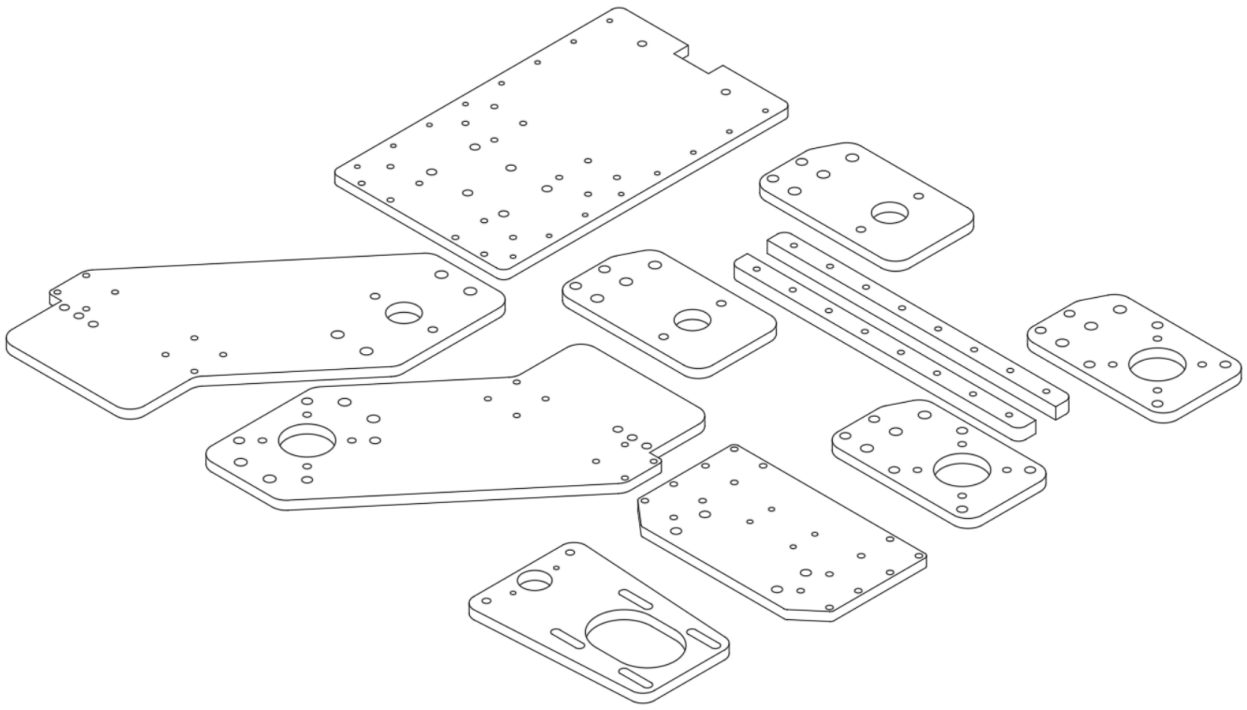
What can you mill with IndyMill?
Rigid construction combined with parts used in professional CNC machines let you mill a lot of materials. Of course you can easily mill any kind of wood and achieve nice results easily. I recommend starting with milling wood if you don't have any CNC experience, it's inexpensive and easy to cut.
Same thing with MDF but remember to wear mask while milling because MDF dust is dangerous. Acrylic is easy to melt so you have to keep federate high and spindle RPM low, it will most likely sound terrible and you will think that something is wrong but no worries, acrylic is easy to mill! How about metals? As for now I only tested IndyMill with aluminium and it works great, you can easily achieve nice surface finish with big milling bits. It's not tested yet but other soft metals should be easy to mill too.

2. Parts

While designing the IndyMill I wanted to use only parts that are easy to buy worldwide. At the same time you can use various components to finish your machine as described in previous section. Below you can find a list of parts that you need to build my version of IndyMill (with ball screws, Nema 23 steppers…). Let's divide this section to mechanical parts, electric parts. If you want list of parts with links you can always find up to date one at indystry.cc/indymill. Full table can be found at the end of this section.

Mechanics

Plates

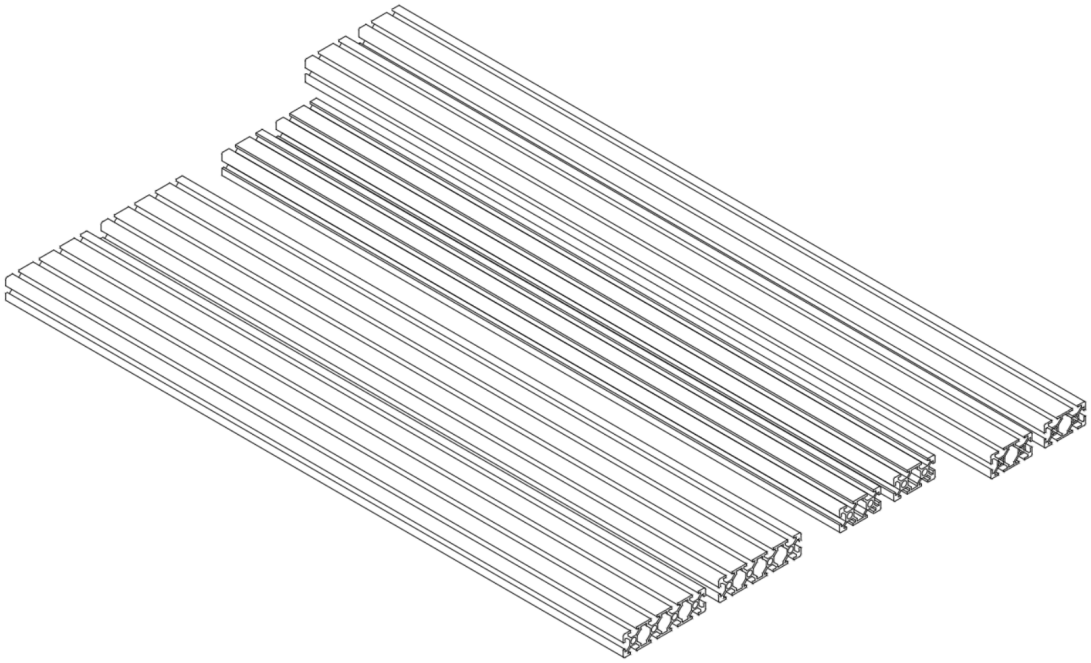


Plates may be the hardest thing to source for a lot of the builders. At my website you can find all the DXF files, if you have an access to laser cutter that is able to cut steel you can easily make those parts. Unfortunately such laser cutters are really expensive. Making those with plasma cutter is most likely not possible because plasma cutters are not precise enough. Water jet cutting is also a way to go and of course CNC milling is too. You may even try to hand made them on your own. When it comes to materials and thickness I used 8 mm steel in the first prototype version.

Second prototype was made with 6 mm steel (later powder coated to make it look cool!), it works fine and there is no noticeable difference between 6 and 8 mm steel. When it comes to aluminium, sure you can use it but I would definitely go rather with 8 mm than 6 mm in thickness.
You can also purchase a kit of those plates from my store (together with some other IndyMill connected products and parts):

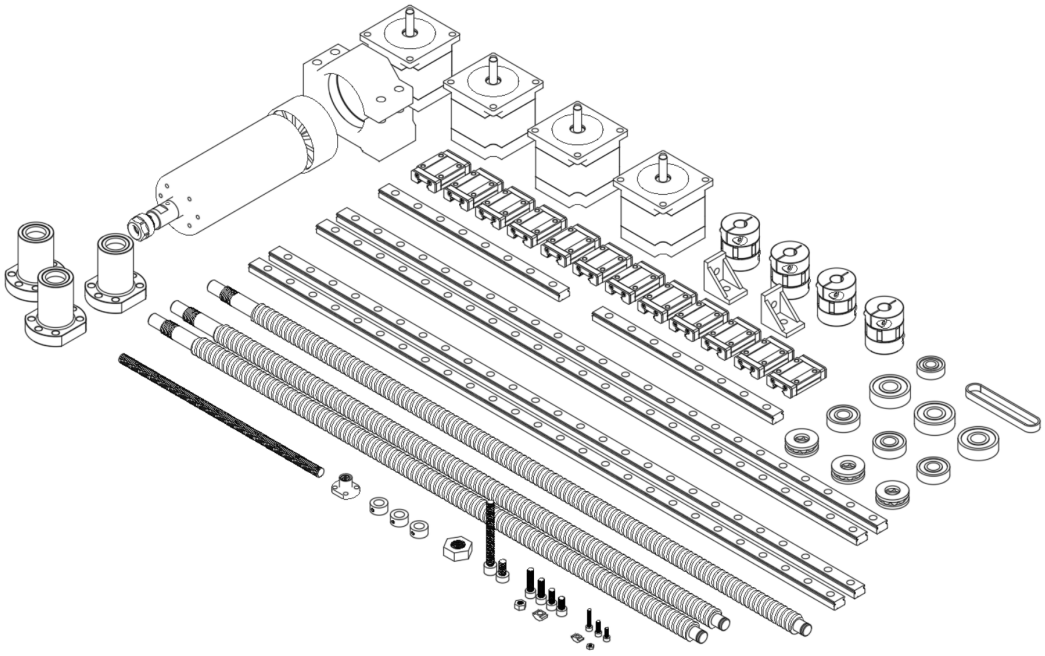
https://indystry.cc/store/

Aluminium Profiles



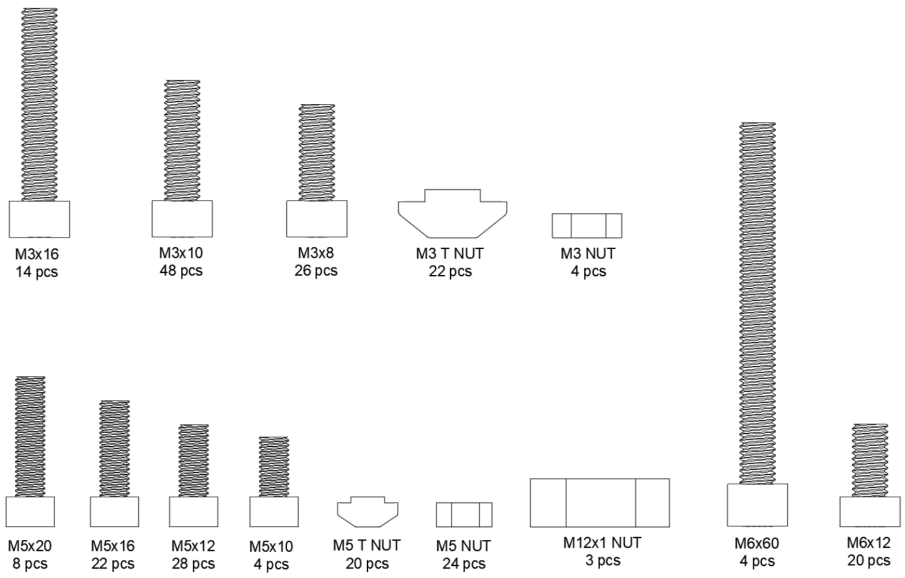
Main frame is build based on aluminium profiles a really inexpensive way of creating a solid and rigid construction. It consist of 2040 and 2080 type profiles (2040 means that the cross-section of a profile has dimensions of 20 mm by 40 mm). When it comes to length, I used such profiles:
2080: 600 mm (x2)
2040: 600 mm (x2), 666 mm (x2)
If you want to build a bigger or smaller machine you need to change the size of those profiles but remember also about adjusting length of linear rails and ball screws.

Other parts

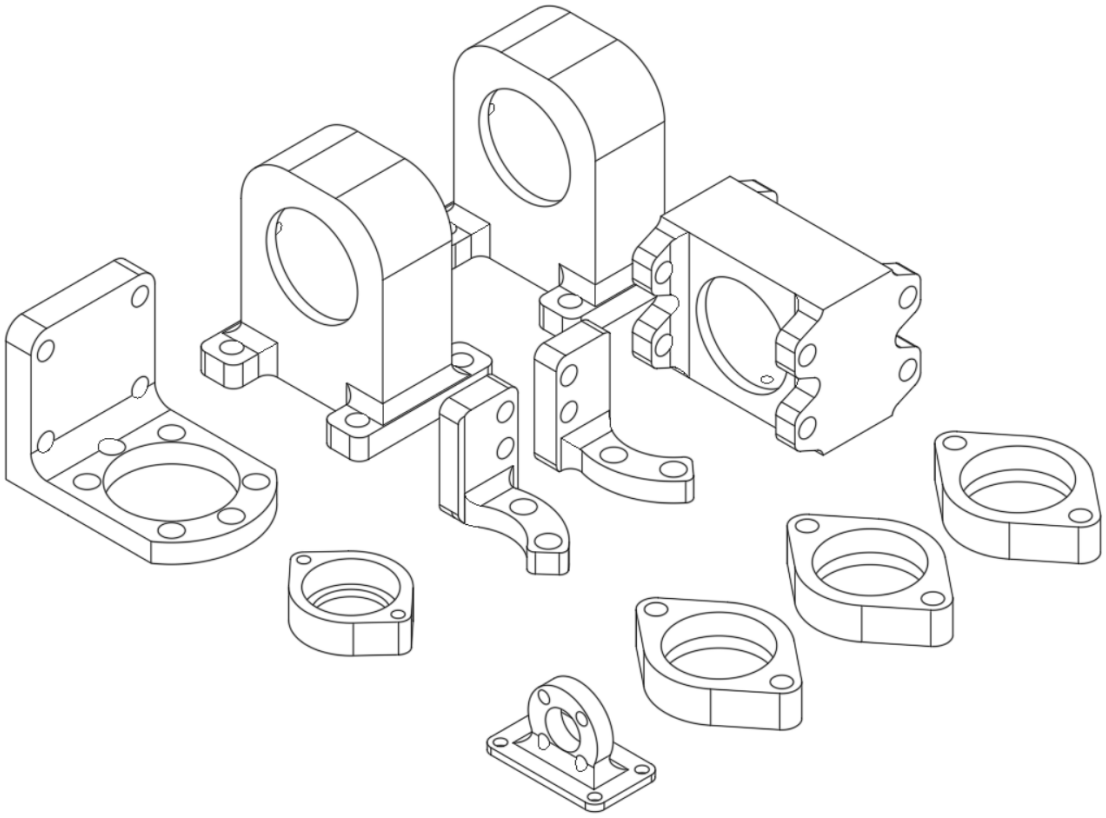


For the lack of a better name I called this section other parts, please don't treat it as "less important parts" those are also crucial for the project. You can find here bearings, linear rails and linear blocks, screws, 500W spindle, stepper motors and so on. Precise specification of all of those parts can be found in the table below.

Let's go a little bit more in detail with screws. Below you can find precise quantities of each screw but always buy a little bit more just in case. Please don't mind the scale as it is different for ever screw size. (Small hint: you will get M6x60 screws together with spindle and it's clamp so you actually don't need to buy those on your own).



3D Printed Parts



At this stage we need some 3D printed parts to finish the build. I am going to try to design something that will be manufacturable on IndyMill so that everyone will be able to upgrade 3D printed parts with self made aluminium parts. There is a lot of concerns about 3D printed parts used in this project but as for now I haven't noticed any problem with any of those. STL files can be found at my website. I printed all of those with infill of at least 40% and 3 perimeters, placed on the bed of a printer like on the drawing above.

Electronics

I don't have such nice drawings of electronics parts. This part of a project I kind of leave up to you, of course, I will show you how to copy my setup just keep in mind that it's not the best one and there are plenty of options when it comes to hardware to make a better CNC machine. I used the simplest and most affordable components (in terms of price and worldwide availability) like Arduino, IndyShiled (my simplified version of GRBL shield with screw terminals) and TB6600 drivers.

Mechanics

Part name	Quantity
Aluminium profile 20x40 mm 600 mm	2
Aluminium profile 20x40 mm 666 mm	2
Aluminium profile 20x80 mm 600 mm	2
Trapezoidal lead screw 220 mm	1
Ball Screw SFU1605 650 mm	1
Ball Screw SFU1605 600 mm	2
Linear Rail MGN12 650 mm	2
Linear Rail MGN12 600 mm	2
Linear Rail MGN12 200 mm	2
Linear Rail Block MGN12H	12
6000RS bearing	3
51101 thrust bearing	3
6201RS bearing	3
608zz bearing	1
8 to 10mm coupler	3
Closed GT2 Belt 200mm long	1
GT2 8 mm Pulleys	2
Trapezoidal lead screw lock collar	3
Corner connectors	2
M3x16 mm screws	10
M3x10 mm screws	48
M3x8 mm screws	26
M3 T nut	22
M5x20 mm screws	8
M5x16 mm screws	22
M5x12 mm screws	28
M5x10 mm screws	4
M5 T nut	20
M5 nut	24
M6x12 mm screws	20
M12x1 fine thread nut	3

Electronics

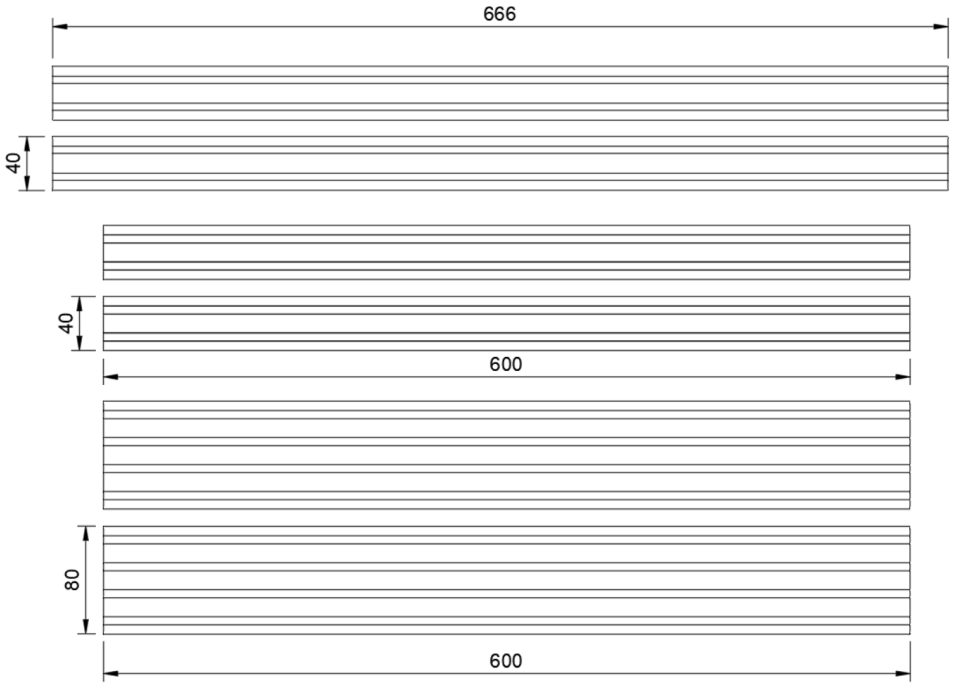
Part name	Quantity
Nema23 Stepper motor	4
IndyShield	1
TB6600 stepper drivers	4
Arduino Uno	1
Power supply 12V 30A	1
AC Socket	1
Cables	-
GX16 4 pin connectors	4
500W Spindle	1
1.5kW Spindle	1
Inverter for 1.5kW Spindle	1

3. Tools

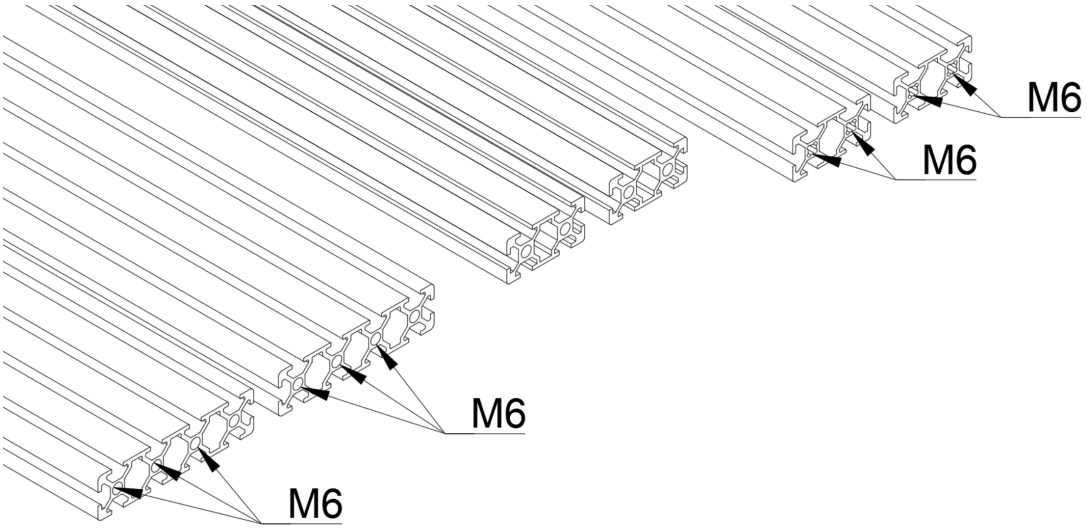
A really important questions is what kind of tools do you need in order to build this machine? Fortunately you don't really need fancy tools. You will obviously need some basics like a set of screwdrivers, allen keys and wrenches. A vise may be useful to put bearings in place. A drill or cordless drill to drill some holes here and there. If you are going to cut aluminium profiles on your own you will need a tool for that (guided hand saw is perfect, you can easily achieve a perfectly perpendicular cut, angle grinder will do the job too, maybe not that precisely). M6 tap to make threads at the end of aluminium profiles and if you sourced plates on your own also M3 and M5 tap. While connecting cables a soldering iron and crimp tool are pretty useful. Let's not forget about some small things like tweezers (super useful to put t nuts in place) and small tongs.

4. Preparing for assembly

Before we will start assembly process we need to prepare the parts to make assembly easier. This step is mostly about taping holes and cutting profiles to proper length.

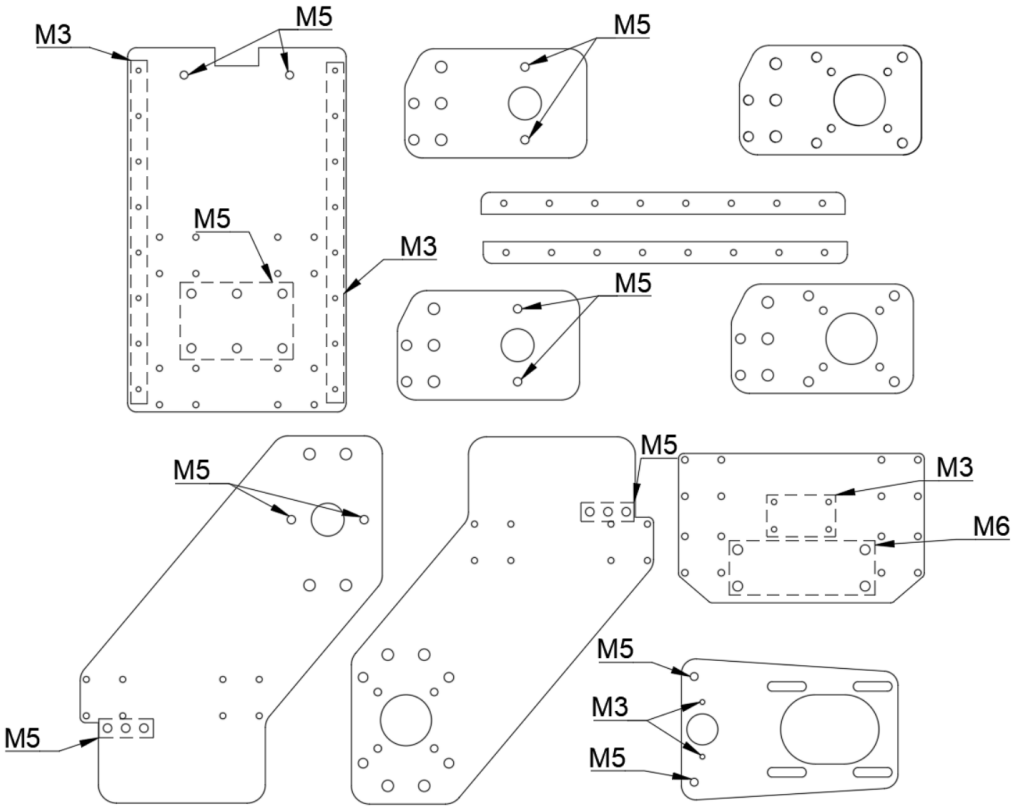


Above you can find once again dimensions of aluminium profiles that I used. Some stores can cut profiles to the proper length so that you don't have to do it on your own. After cutting you need to tap threads at the end of aluminium profiles according to the drawing below. It has



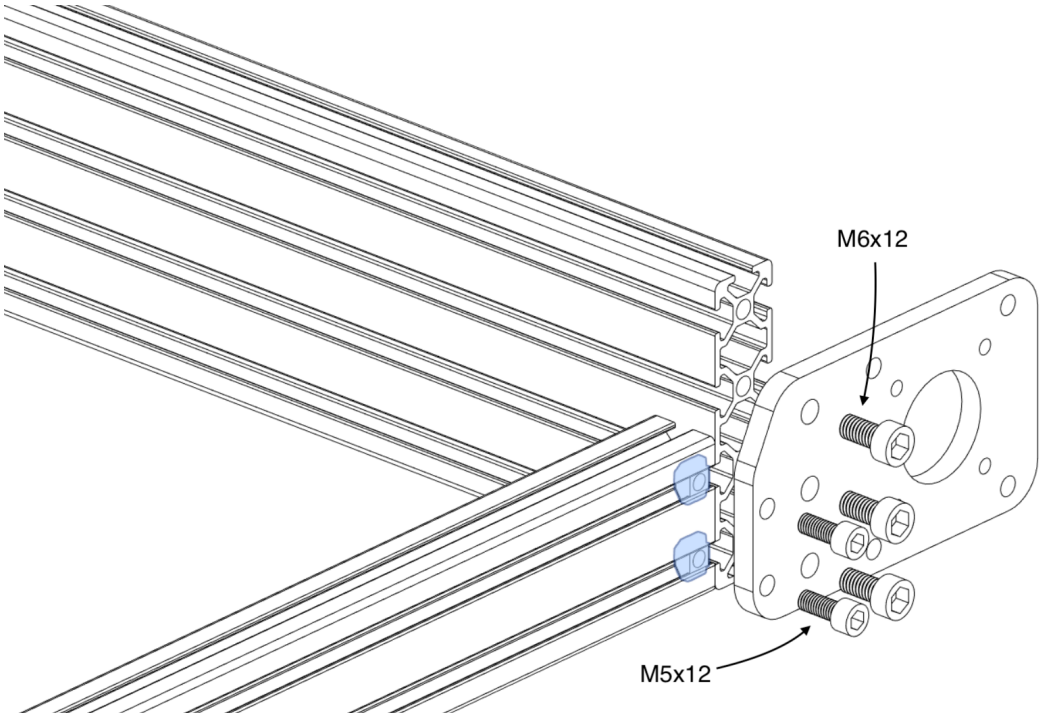
to be symmetrical so tap the same holes on the other side of each profile. As you can see 2040 600mm profile don't need threads.

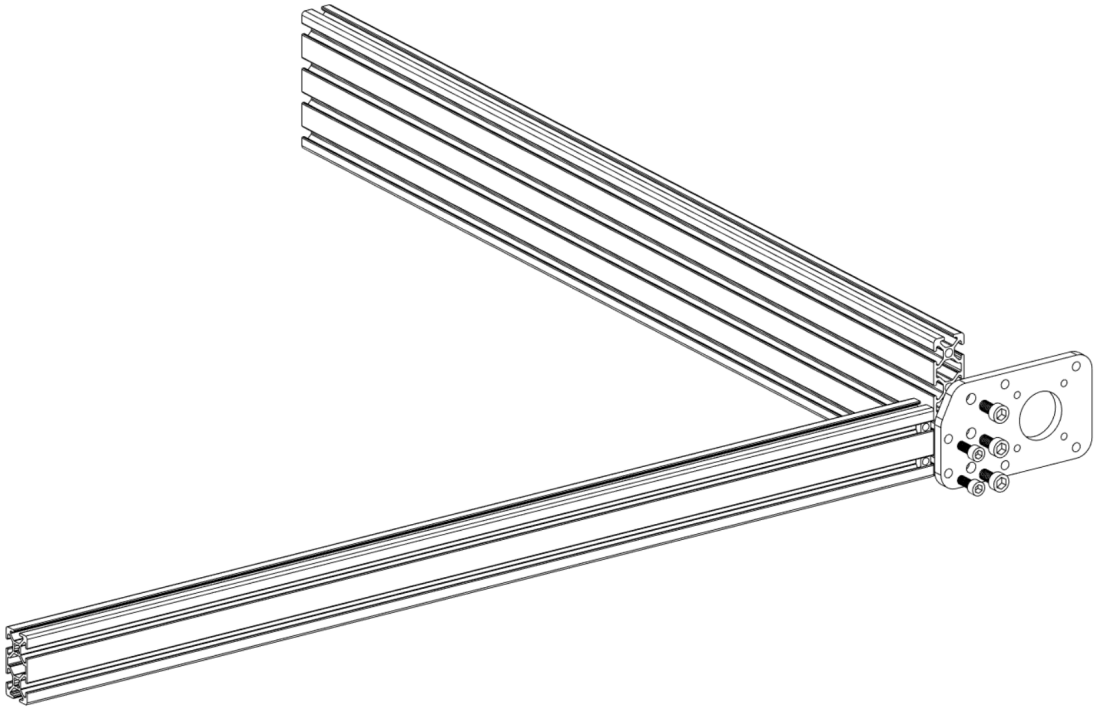
If you are making or ordering steel plates on your own you firstly need to paint them. Use paint that protects from rust and is made especially for painting steel, if you can, use powder coating for better surface finish and stronger paint. After painting you need to tap quite a lot of holes, please follow the drawing below.



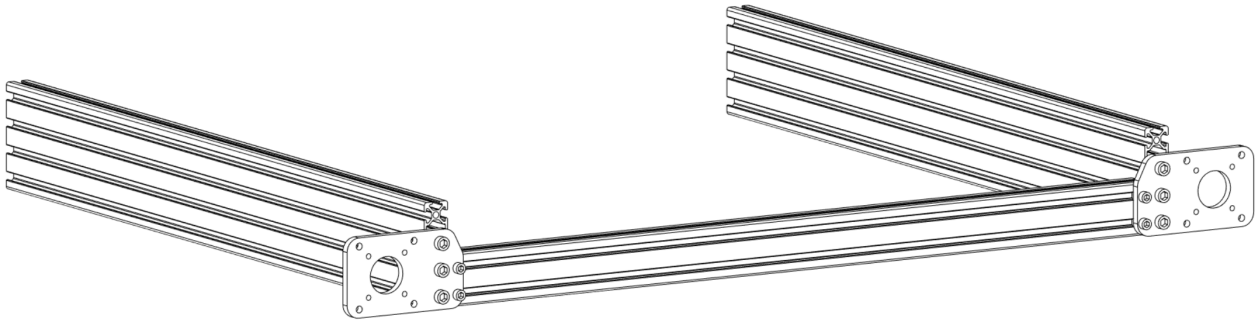
5. Main frame

We will start by assembling main frame that is composed out of 2080 600 mm and 2040 600 mm aluminium profiles. We will also need steel plates that act as connectors for profiles and later as support for motors and ball screws. Hidden T nuts in aluminium profiles will be labeled blue on the drawings for better visibility.

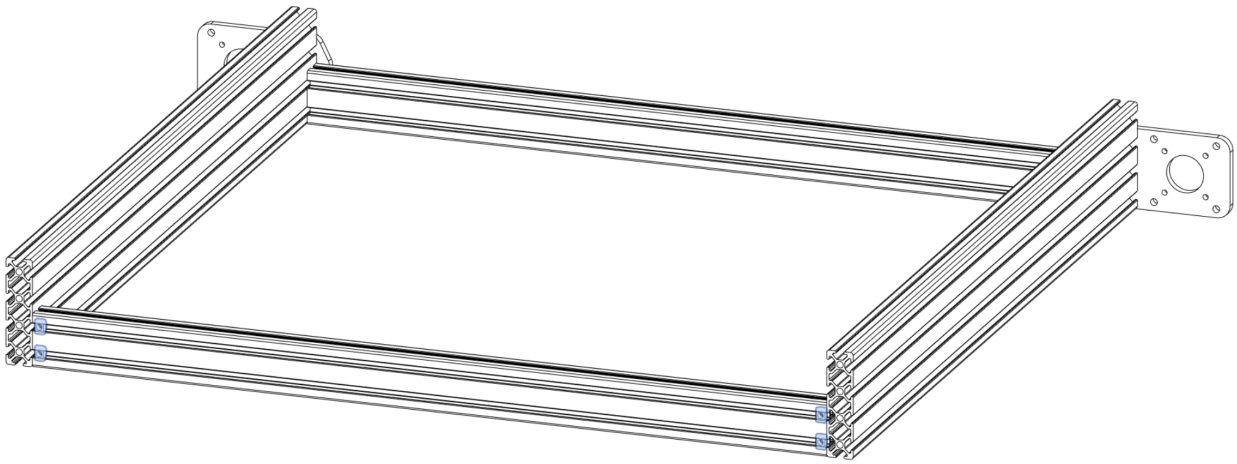


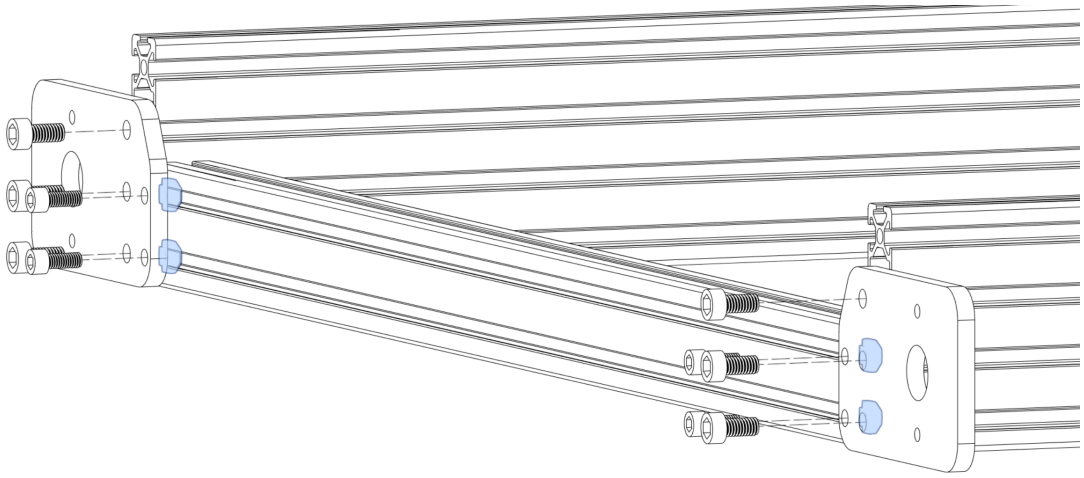


Same thing must be done on the opposite side of the machine (I will refer to it as a right side, it's the right side when you stand in front of the machine).



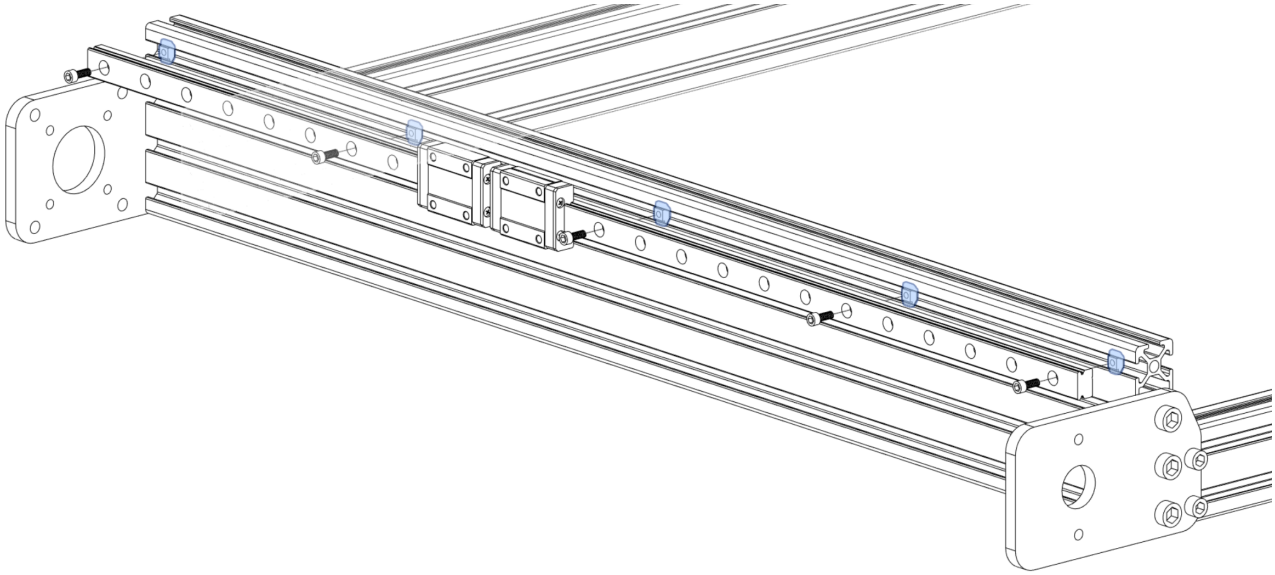
This is the back view of the machine, we will later attach motors here to steel plates. Now we will move on to the front part. Start by putting 4 T nuts in a profile and slide the profile into the frame.

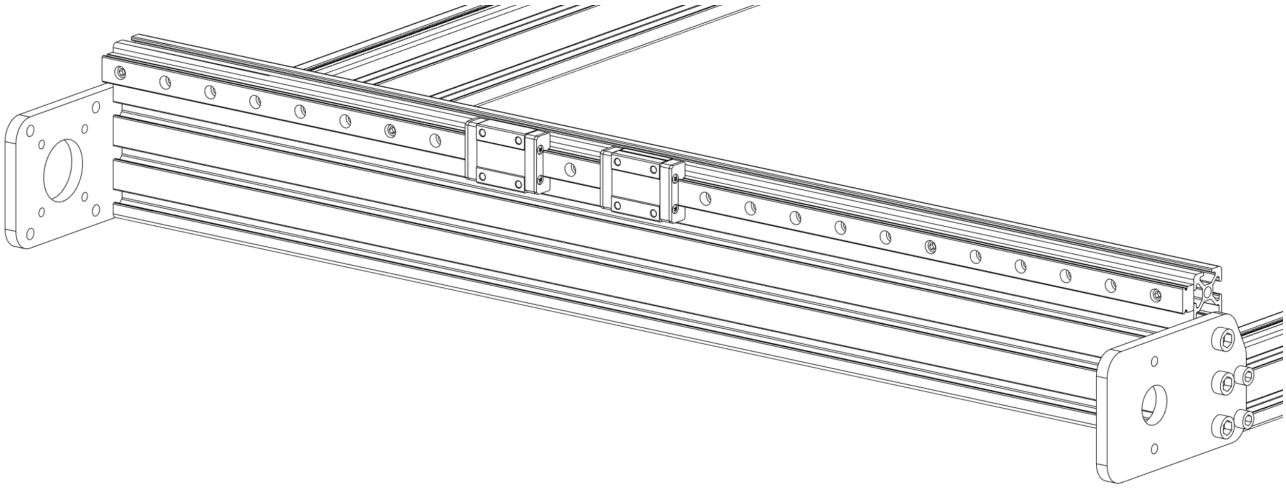


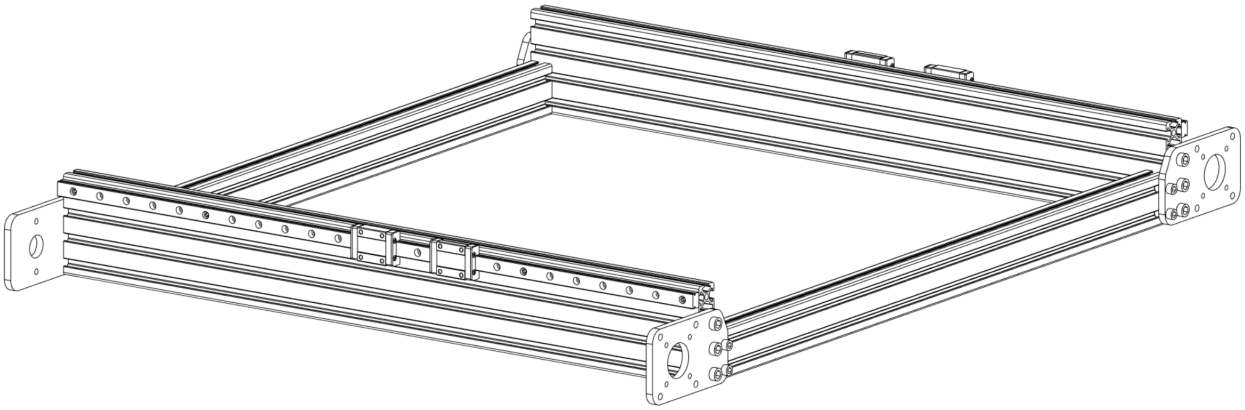


6. Y axis linear rails

Each axis has 2 linear rails and there are two rail blocks on each rail so together you have 6 rails and 12 blocks to install. I divided this to separate sections just to stick to step by step scheme. Y axis linear rails are 600 mm long and have 23 holes. There is nothing wrong with attaching a rail with 23 screws but that's definitely an overkill. I decided to use 5 screws (M3x8) and something between 4-10 should be totally ok. Before attaching each rail to a profile put on two blocks. You may try to fit different blocks to different rails in order to find best-working combination.

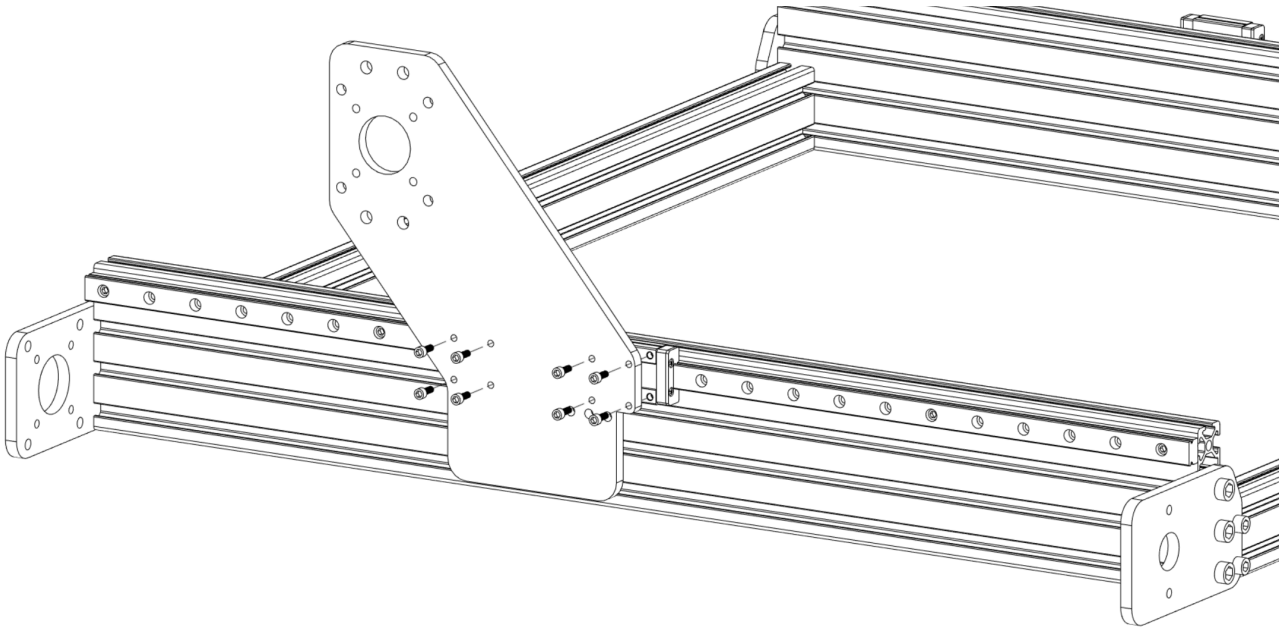




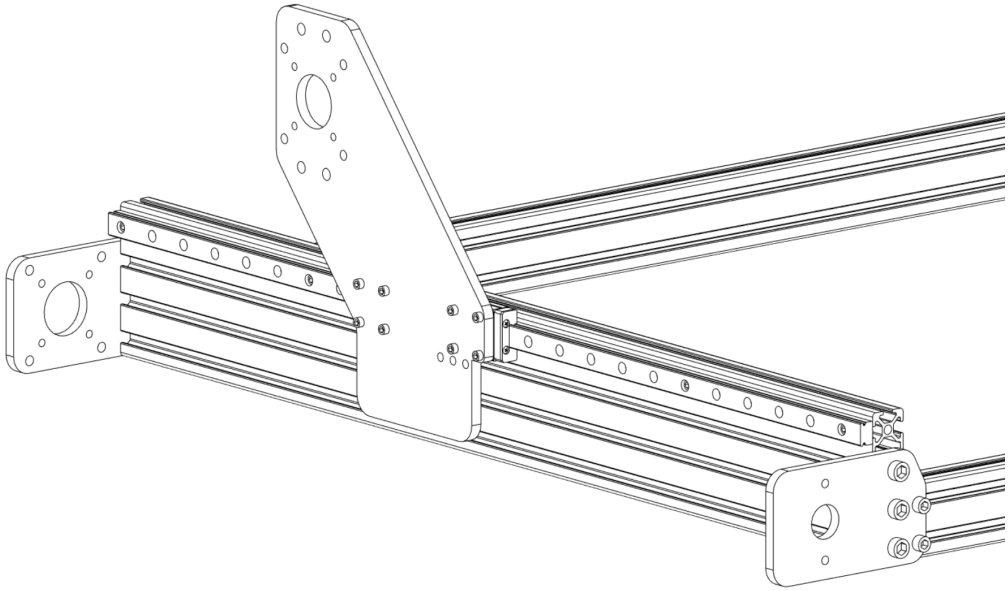


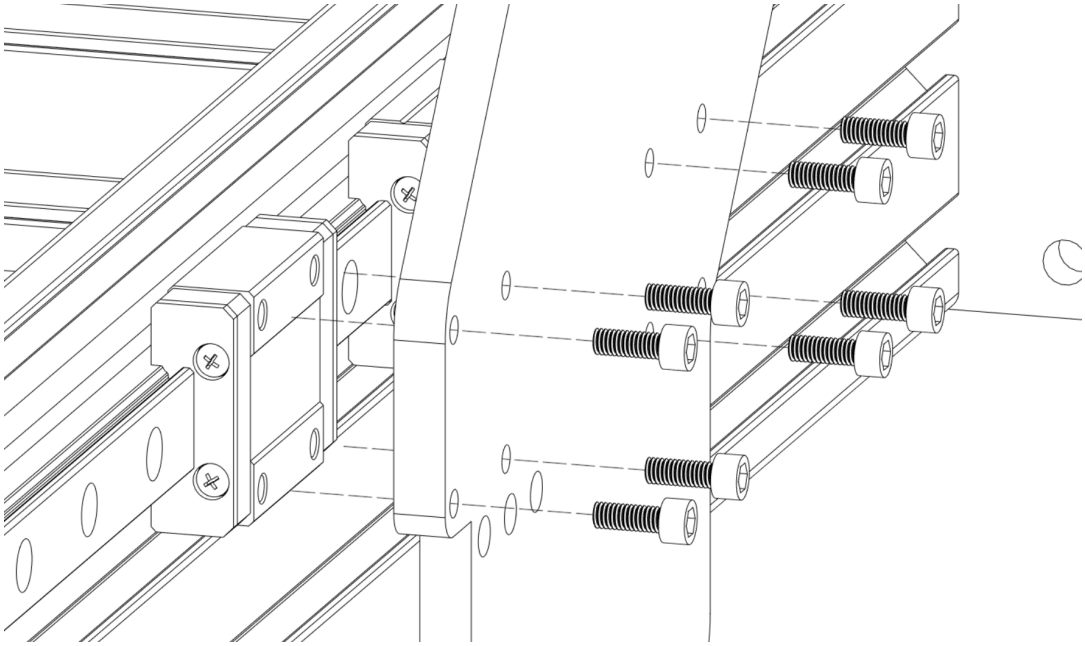
7. Y axis steel plates

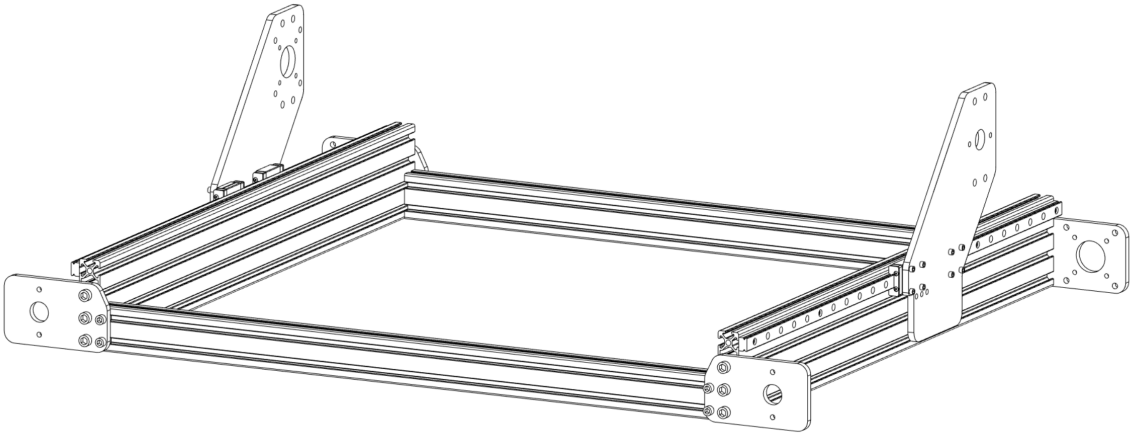
With 10mm M3 screws attach Y axis plates to rail blocks. If the thickness of your plates is different adjust screw length. I decided to put my X axis motor on the left side of a CNC, there is no problem with putting it on the right side if you want.



Attach the second plate on the other side of the CNC machine like so. Make sure that the rail blocks on both sides move smoothly on the rail.

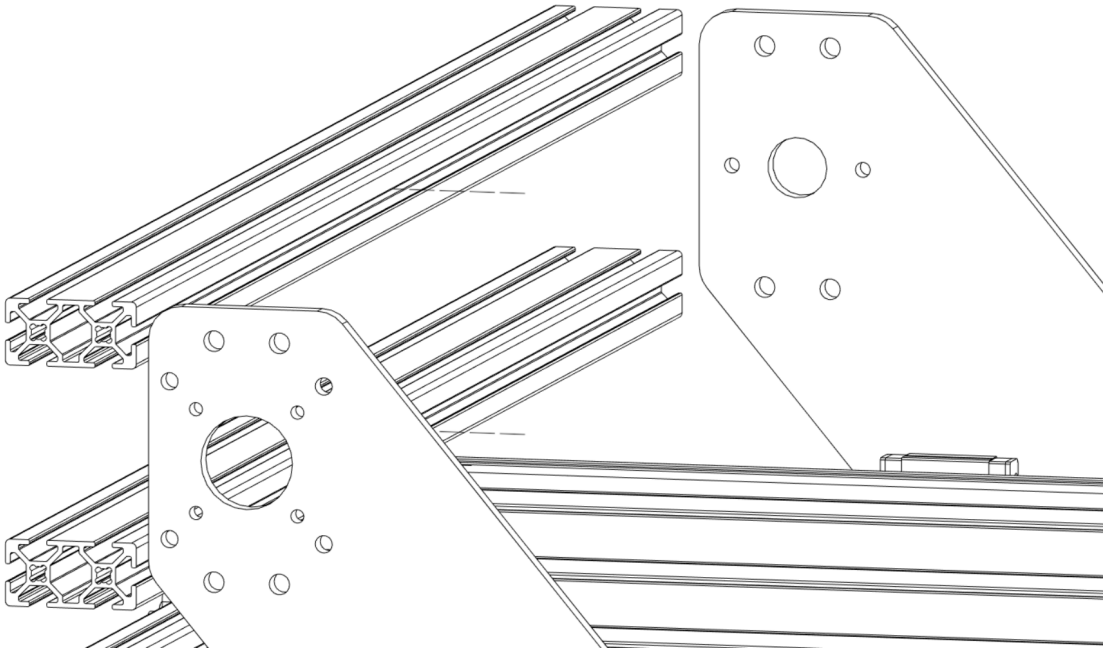


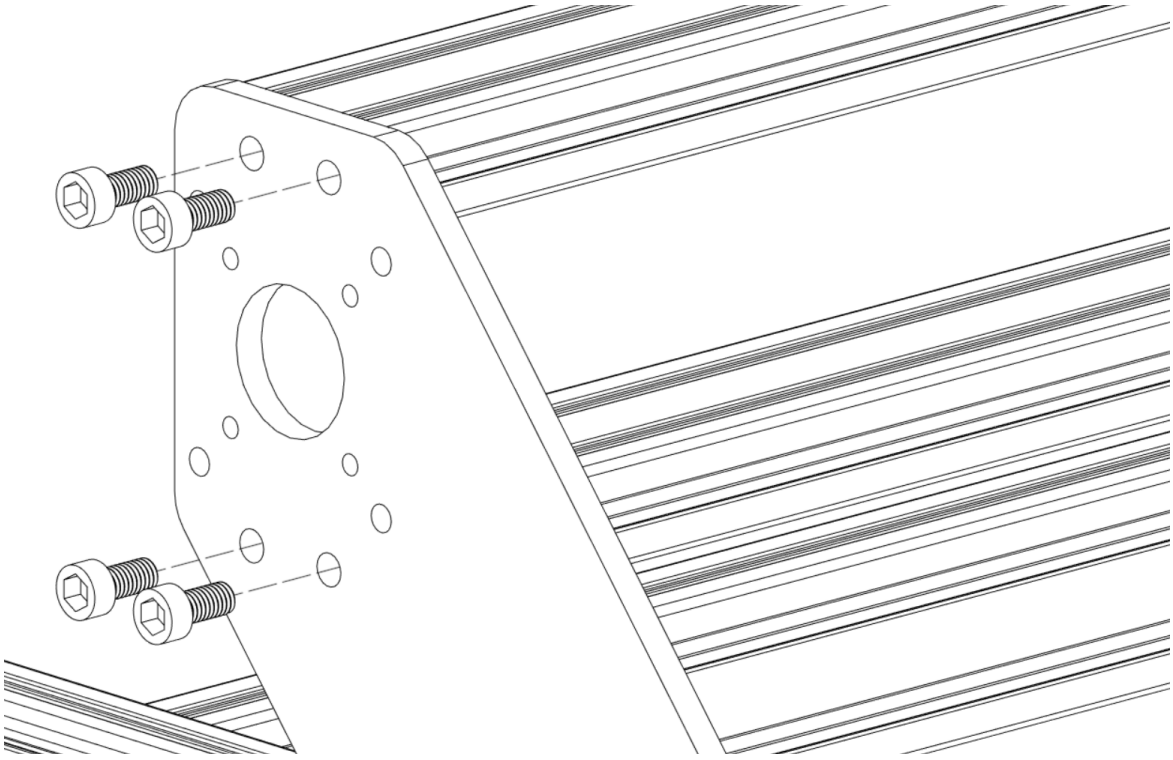


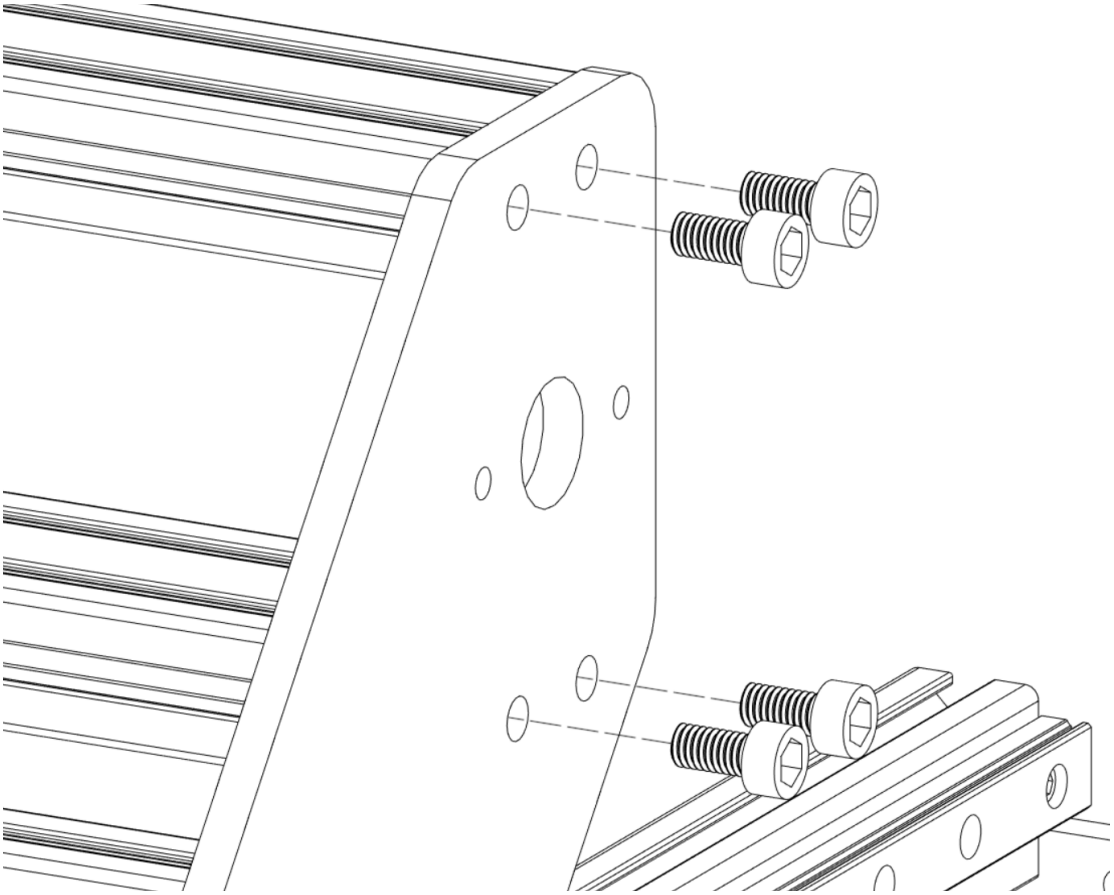


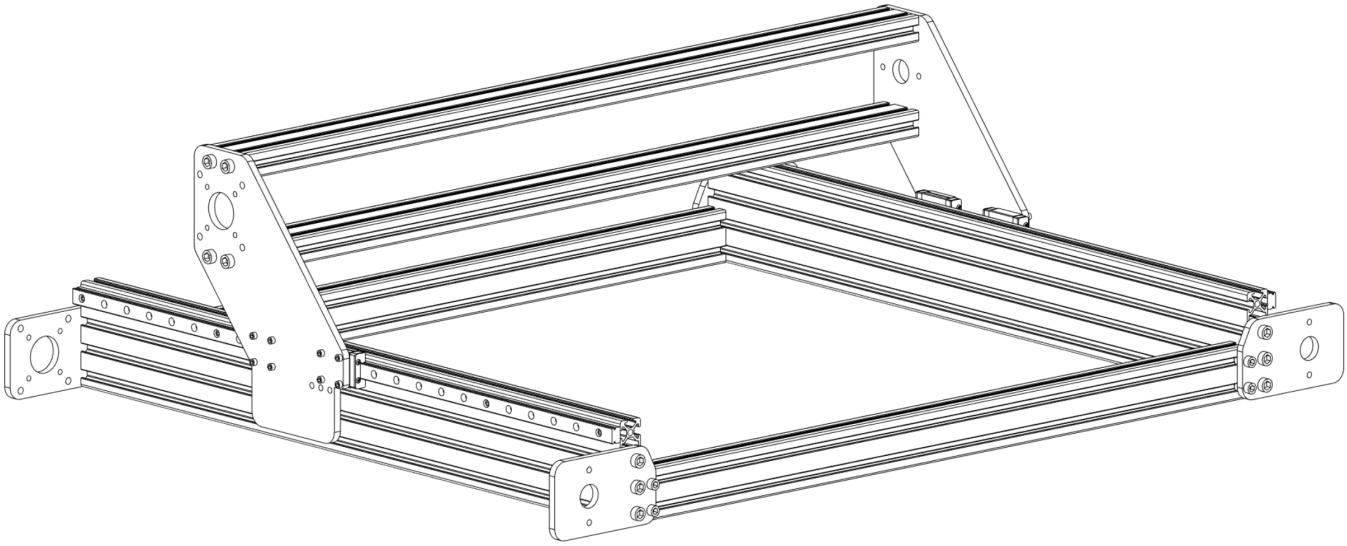
8. Gantry

Grab two 666 mm 2040 aluminium profiles and slide them in between Y axis plates. In the next step we will attach linear rail, so if you have T nuts that have to be inserted from the side of a profile it's a good time to do so. To attach profiles I will use 12 mm M6 screw.



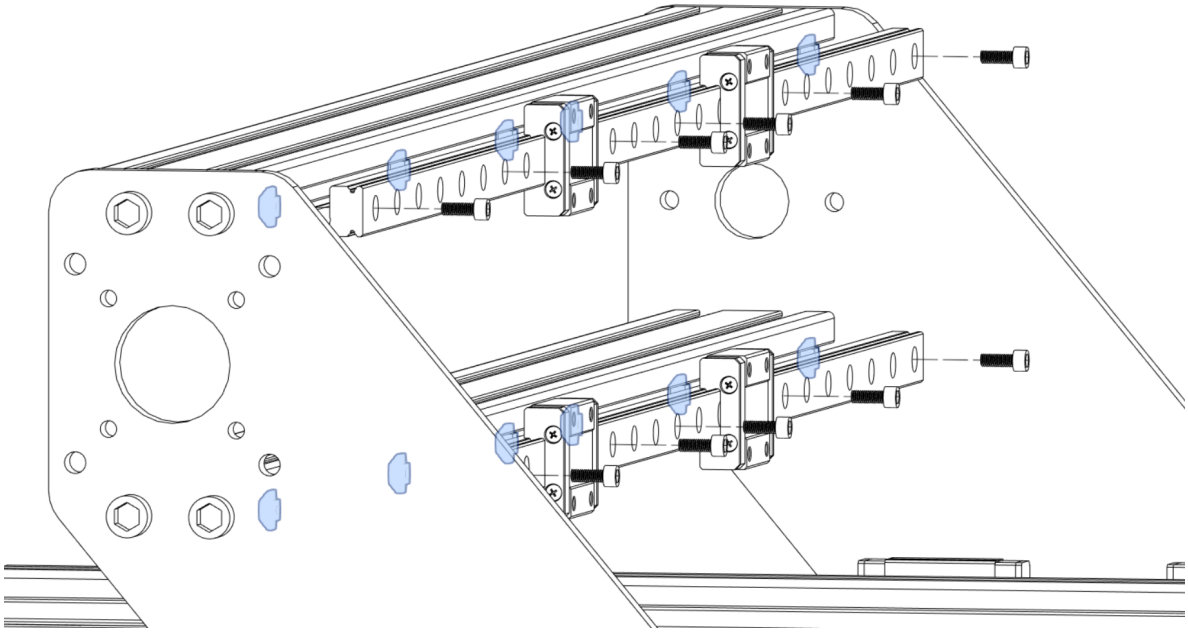


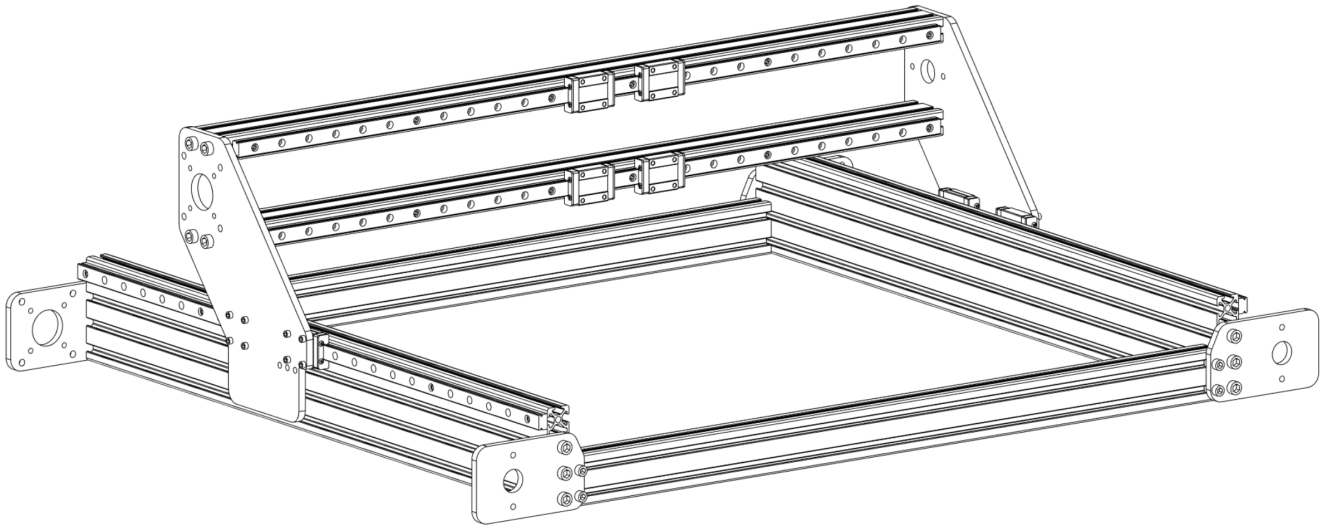




9. X axis linear rails

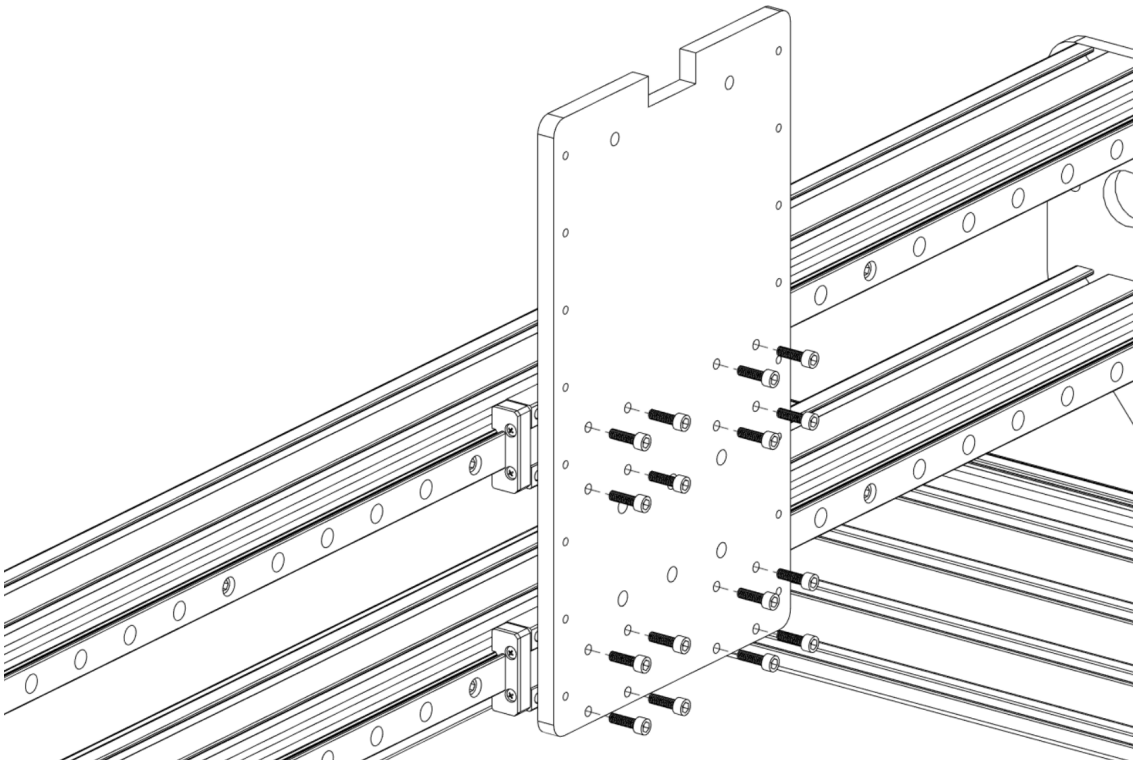
X axis linear rails are 50 mm longer on my machine so I attached them with 6 screws (M3x8) and T nuts, again something between 4-10 should do the job. Don't forget to install rail blocks before attaching rails.

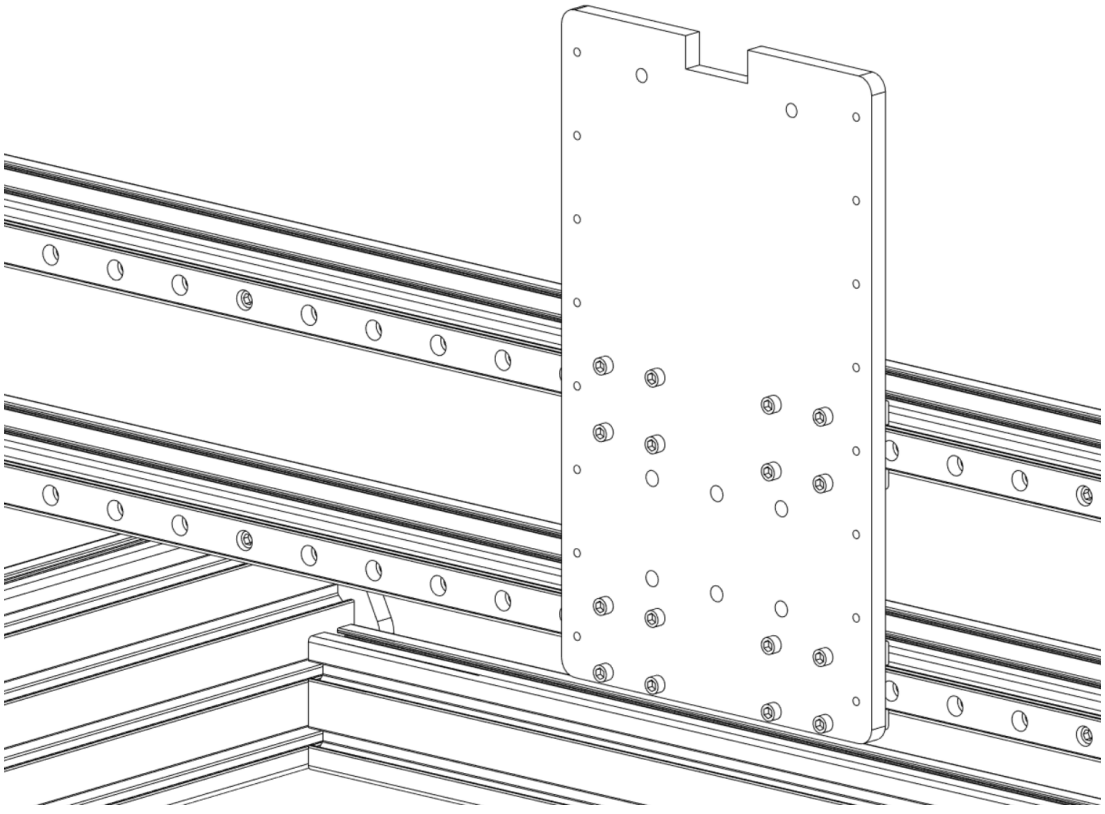




10. X axis plate

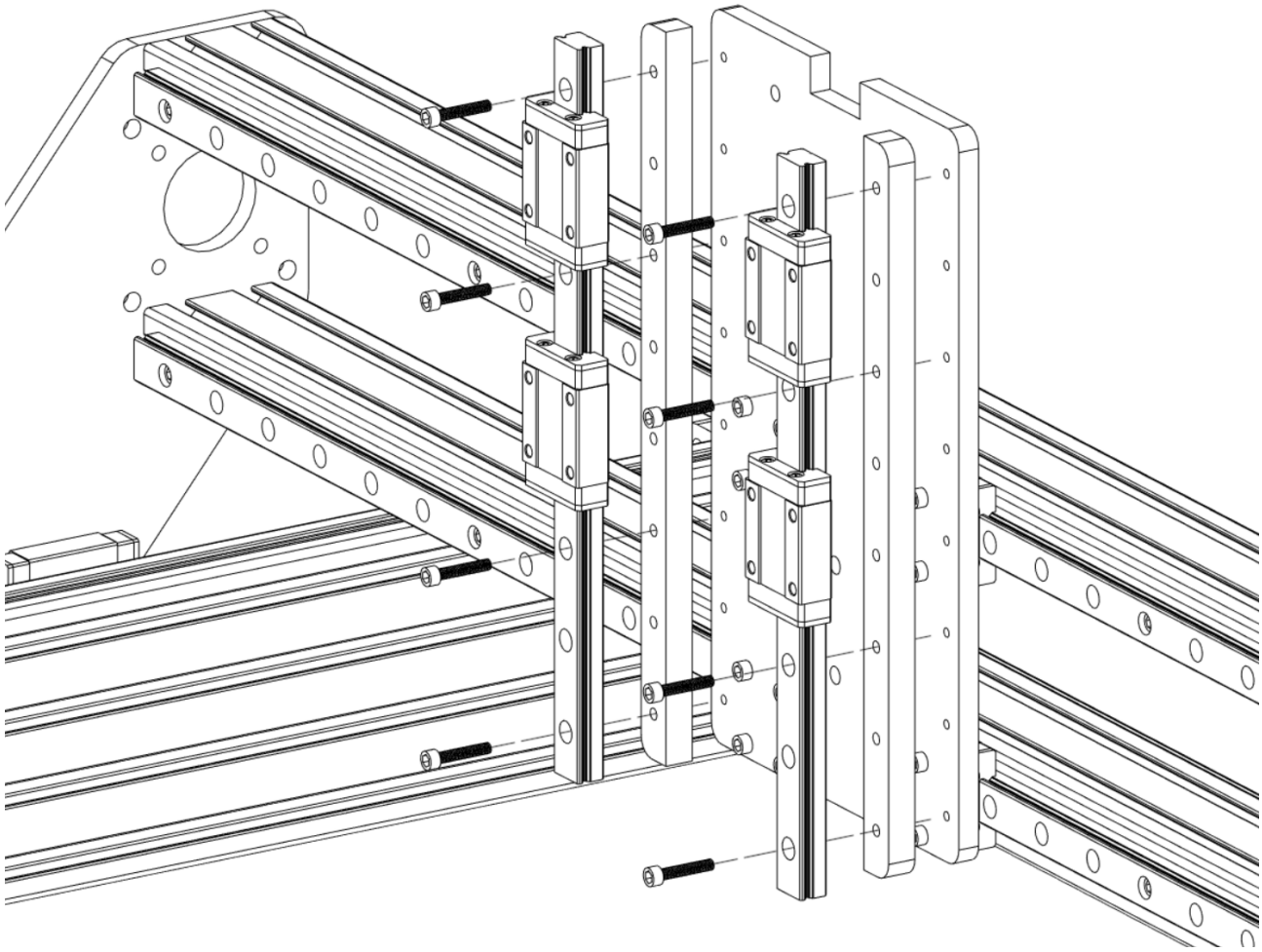
X axis plate is attached to linear blocks with 16 screws (M3x10). Tighten all screws evenly and make sure that X axis plate moves smoothly on the rails.





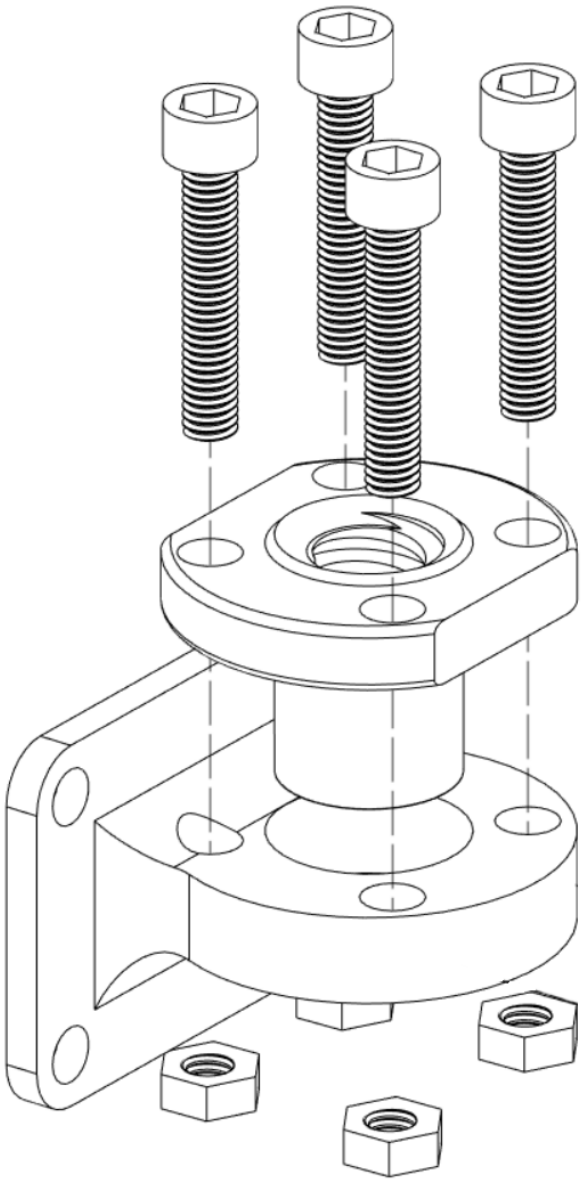
11. Z axis linear rails

Because we need to fit Z axis trapezoidal lead screw in-between X axis plate and spindle plate we need some separators. That's what Z axis rail support is for. That's the only element that is cut out of 8mm steel just to have some more space (with a different nut for a lead screw you can even make it with 6mm distances). Thanks to threads in X axis plat we don't need to use nuts to attach rails, we will only use M3x16 screw (8 of them, you can use more if you feel like it). Both rail support and rail are attached with the same screws (see drawing below). This time you can install rail blocks after installing rails as we have some space to put them in place later. Be careful because rail blocks can easily fall out on Z axis, at this point it is a good idea to put some kind of stopper at the bottom of each rail (small allen key or something similar in the rail hole).

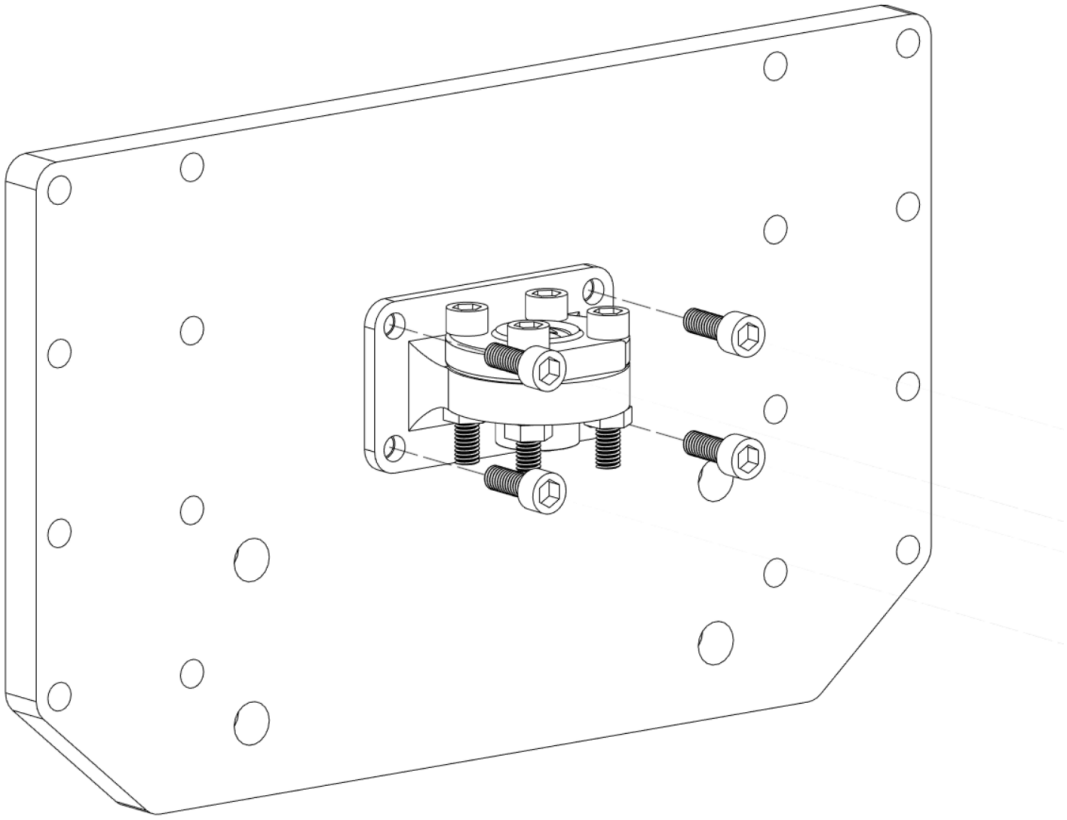


12. Spindle plate

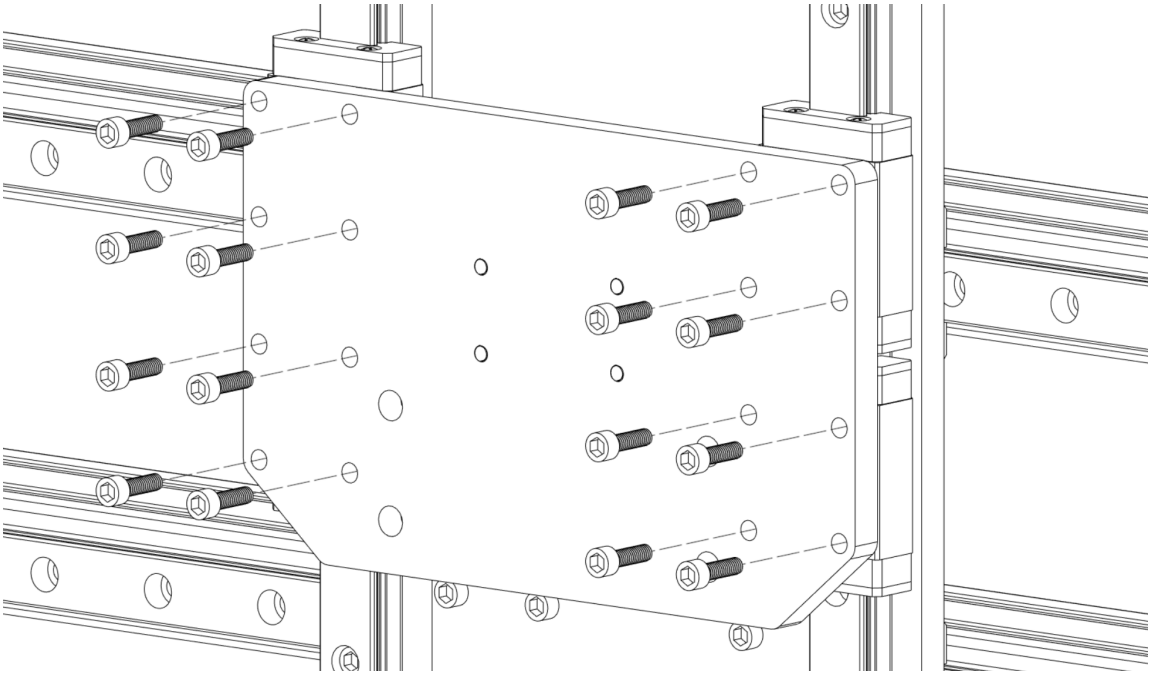
The spindle plate is designed to hold a 500W spindle (feel free to create different mounts for the spindle that you want to use, I will soon create a mount for a way bigger spindle).
Before we get into attaching a spindle plate we need to assemble the 3D printed Z axis nut holder with a lead screw nut and some screws (M3x16 and M3 nuts).



With M3x8 screws attach above assembly to a spindle plate.

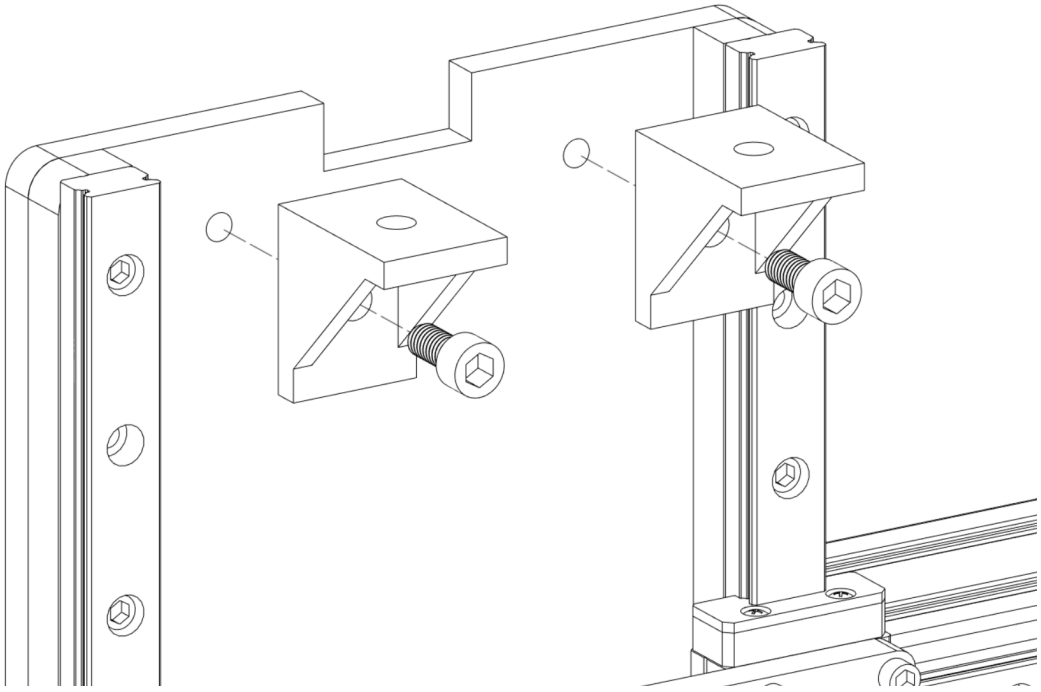


Using sixteen M3x10 screws attach spindle plate to rail blocks. Make sure that plate is moving smoothly.

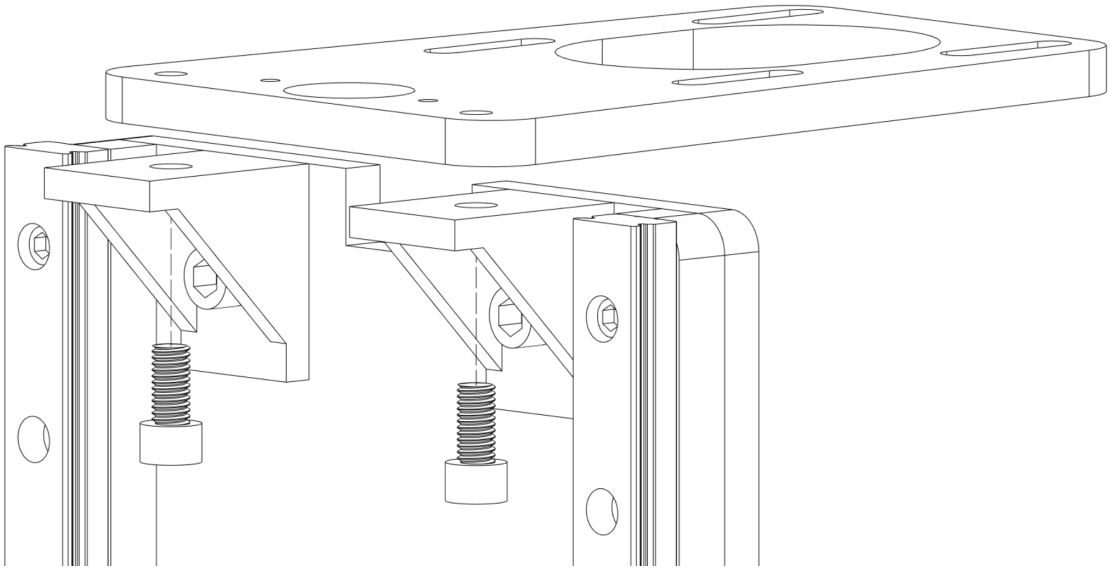


13. Z axis motor support

Before attaching the Z axis motor plate we need to attach two corner connector with M5x10 screws, there should be a thread in X axis plate so we don't need nuts for that.

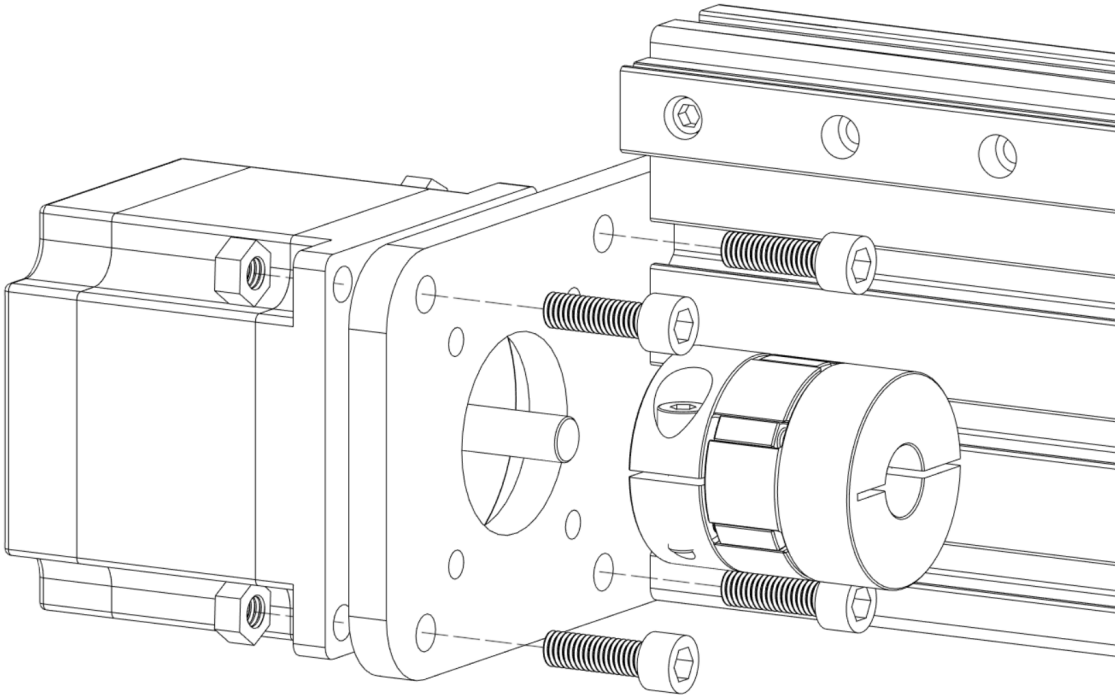


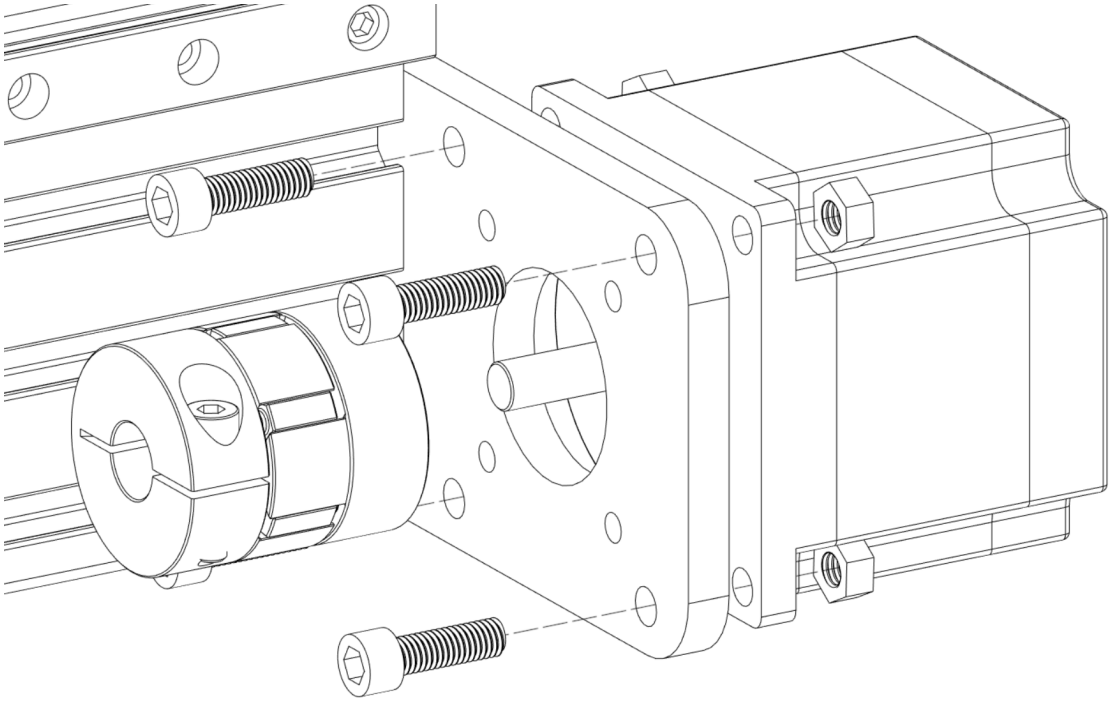
Z axis plate should be attached with the same two screws (M5x10) to corner connector again we don't need nuts.



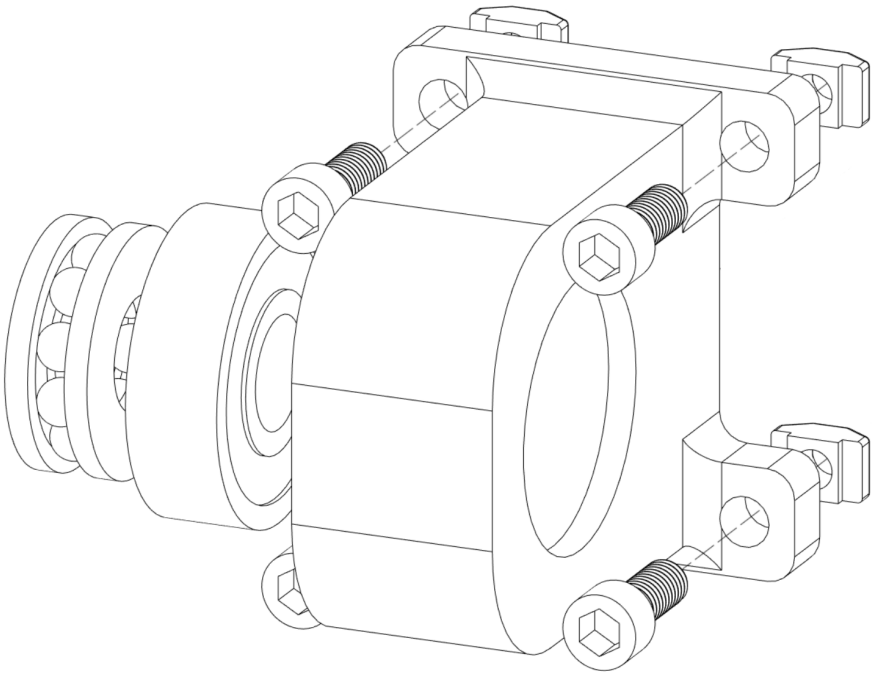
14. Y axis motors, couplers and ball screws

Time to attach motors, ball screws and other small parts. We will start with Y axis motors. Depending on the motor type you use you may need to use different screw length to attach them to the plate, I used M5x16 and M5 nuts. Don't forget to attach a motor on the right too.

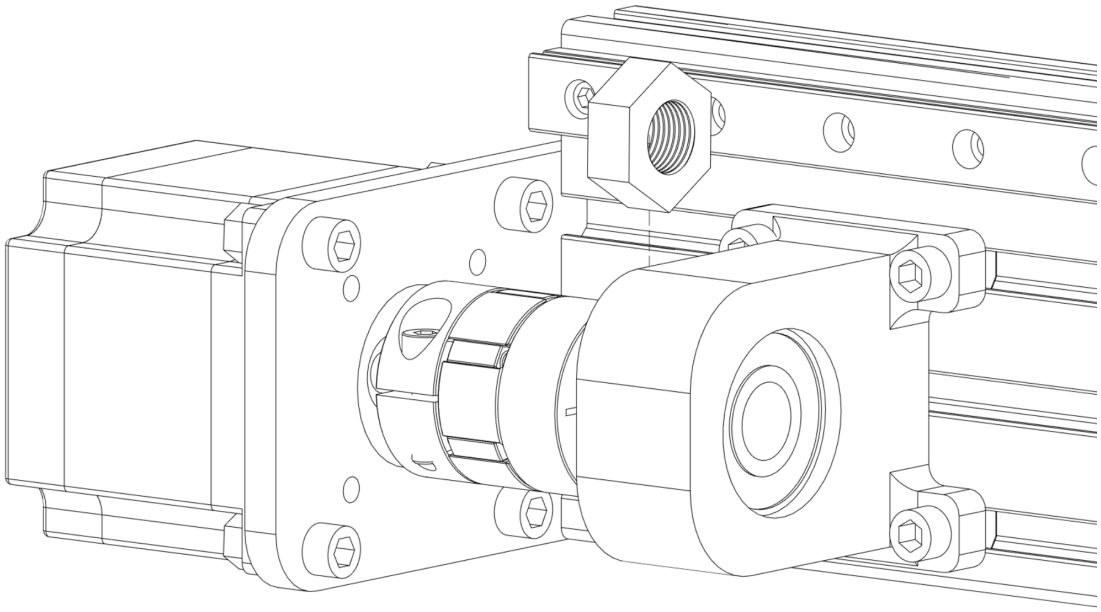




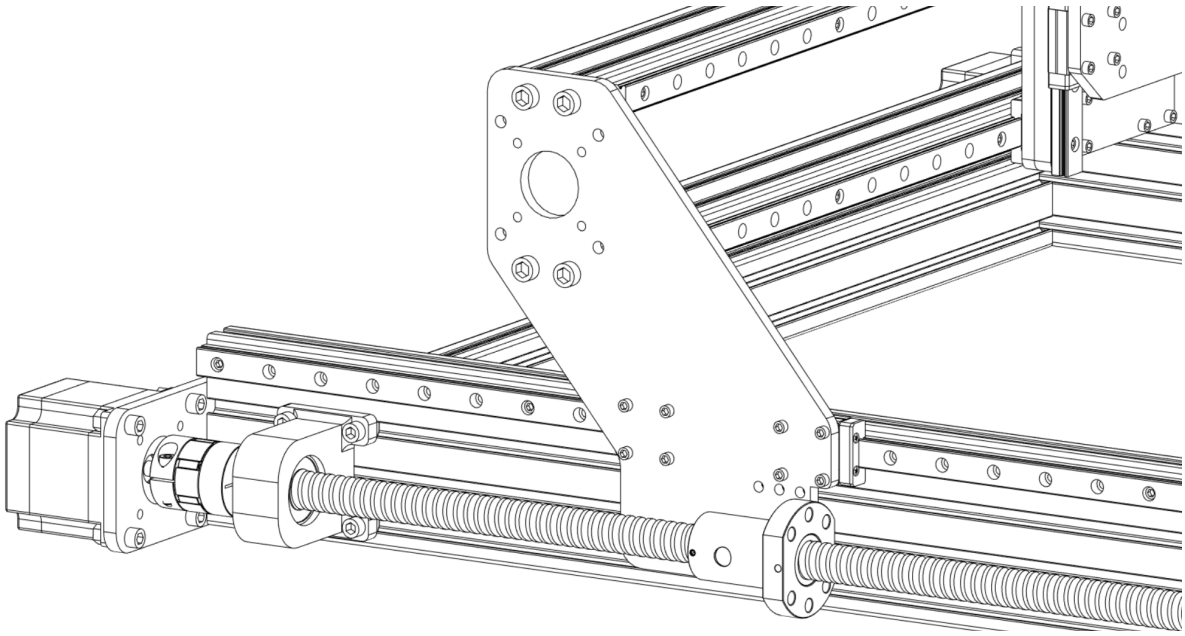
Now we will assemble the 3D printed ball screw holder. We will need 6201RS ball bearing and 51101 thrust bearing M5x12 screws and M5 T nuts.



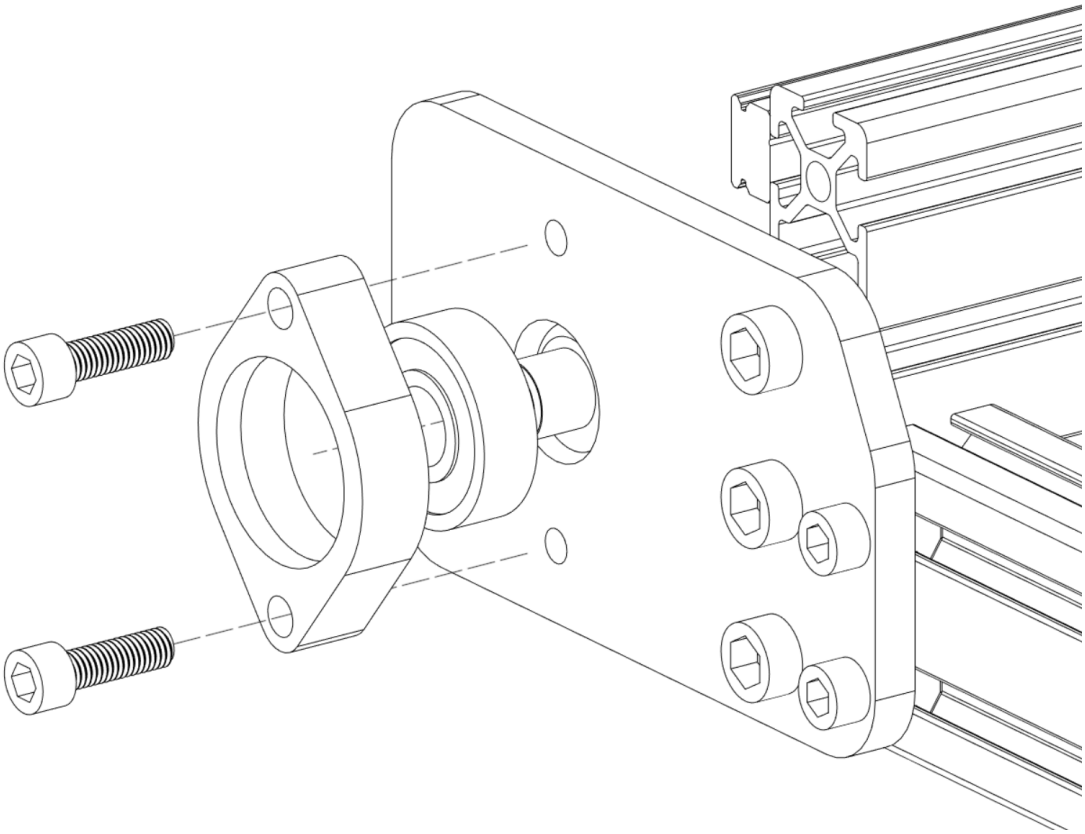
Then we can put it right in front of the coupler. Do not tighten the screws fully at this point. There should be enough space to fit a M12x1 nut (x1 means that it's a fine thread nut).



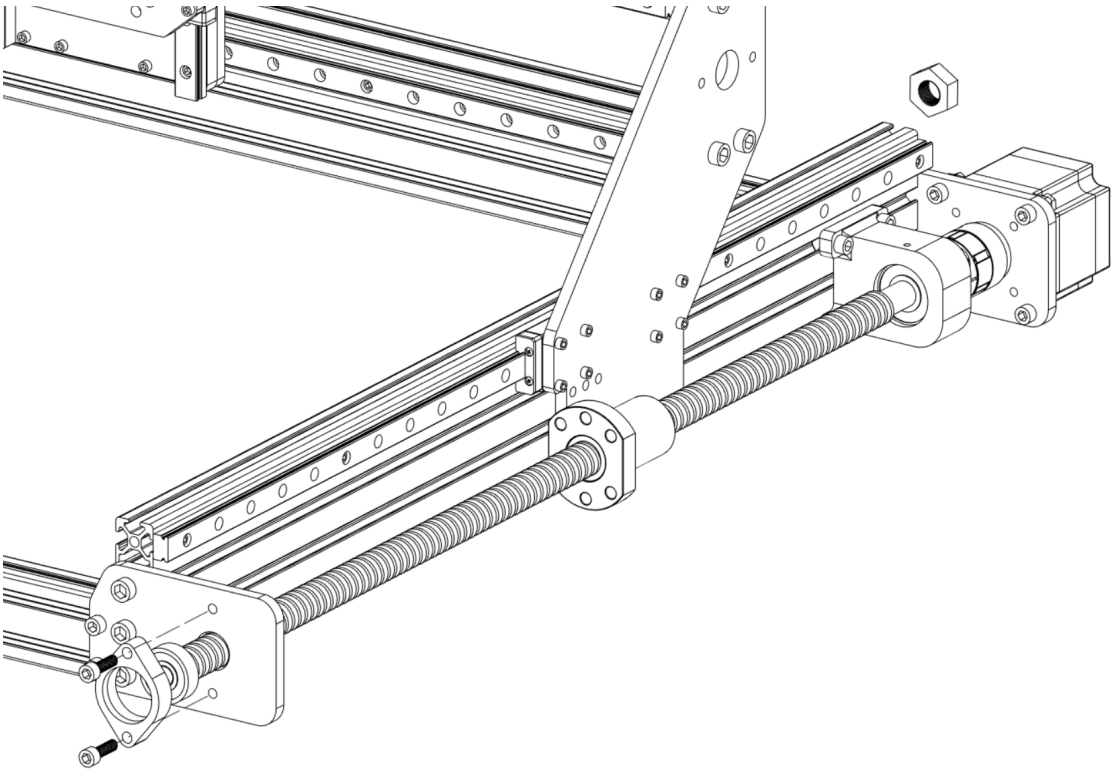
Slide in the ball screw with a ball nut. Put M12x1 nut on the ball screw and tighten it to lock the ball screw in place.



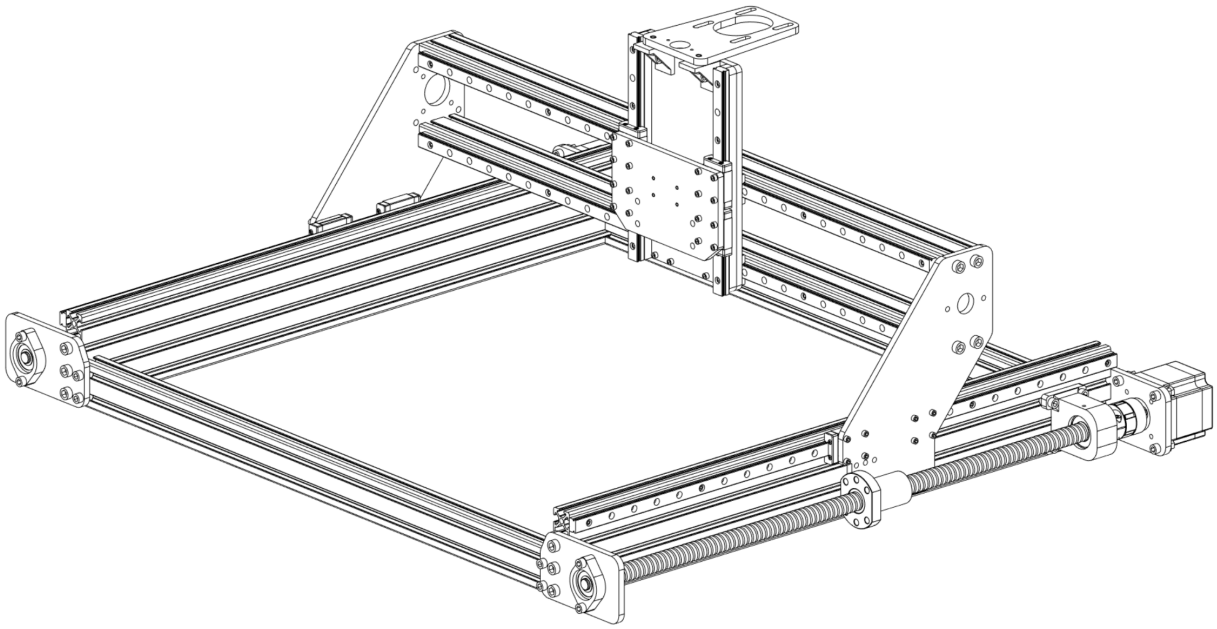
On the front of the machine attach the 3D printed bearing holder and 6000RS bearing with two M5x16 screws. This will support the ball screw on the other end.



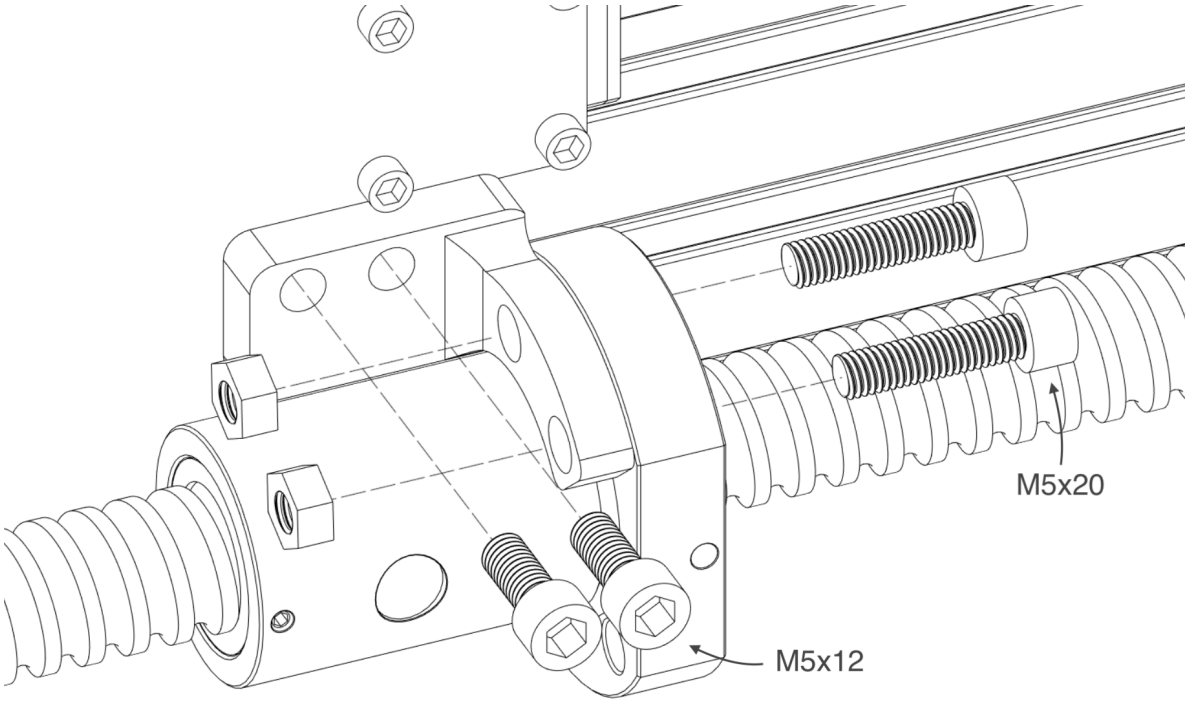
At this point don't forget to tighten the screws that hold the ball screw holder (element with two bearings that is really close to motor). And repeat same operations on the other side (right side) of the machine.

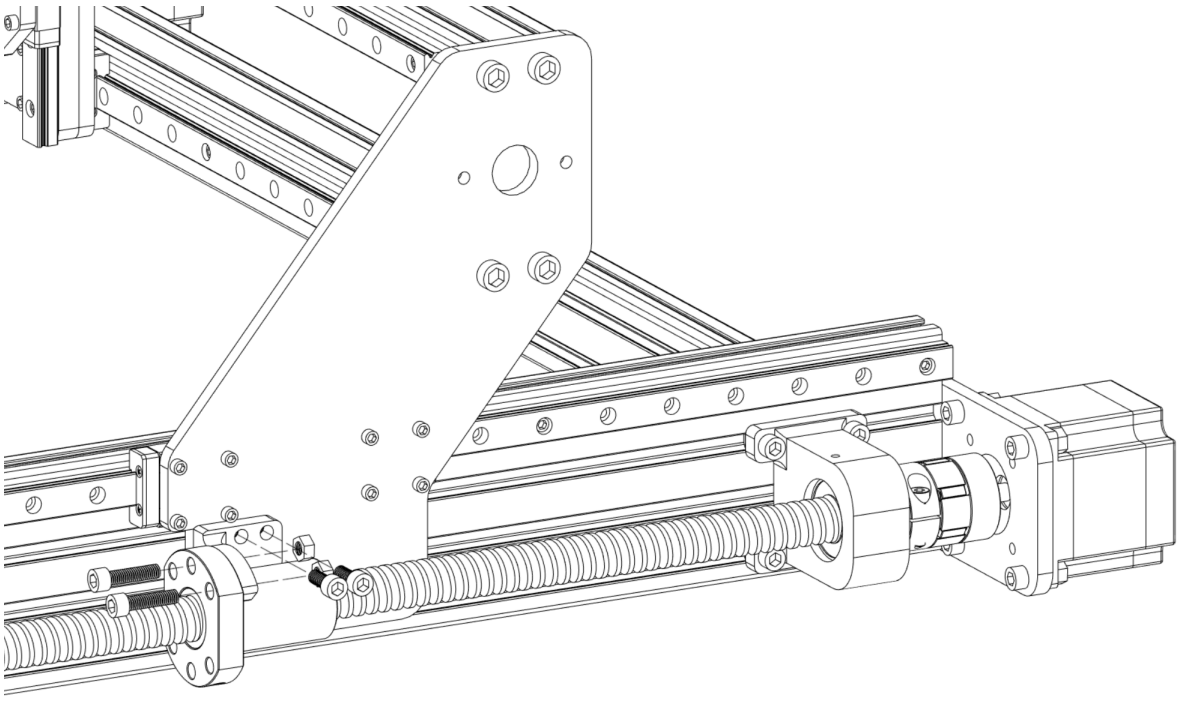


Let's take a look at what we have built so far.



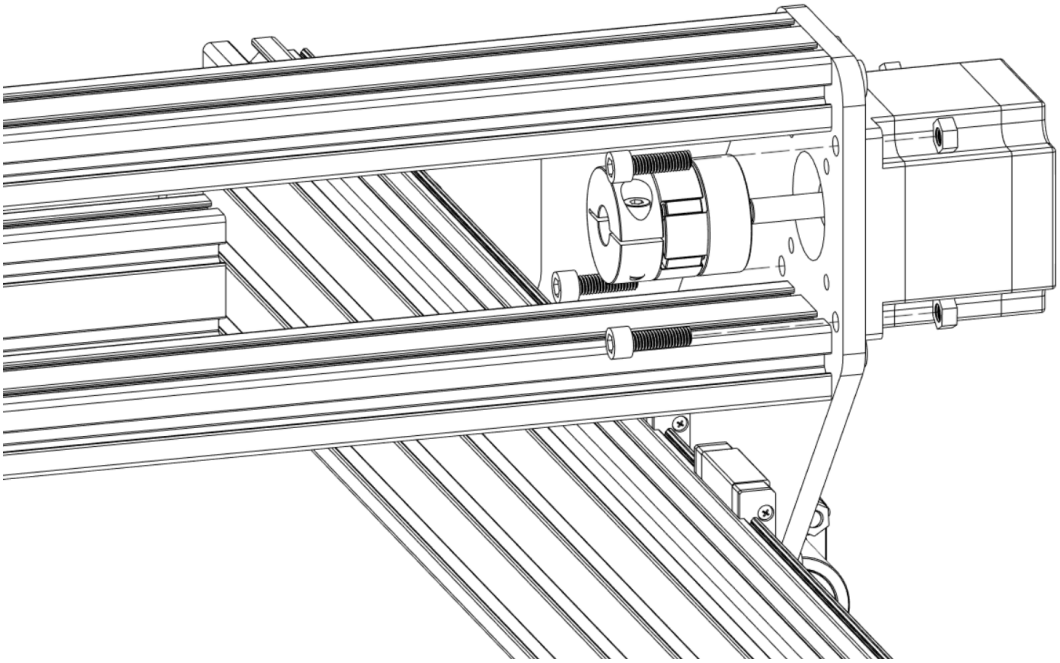
Last detail that we need to add in this section is a 3D printed element that attaches ball nut to the Y axis plate, we need to attach it on both sides. To do so I will use M5x20 and M5x12 screws and M5 nuts. At some point I will upgrade 3D printed elements with something made out of metal.



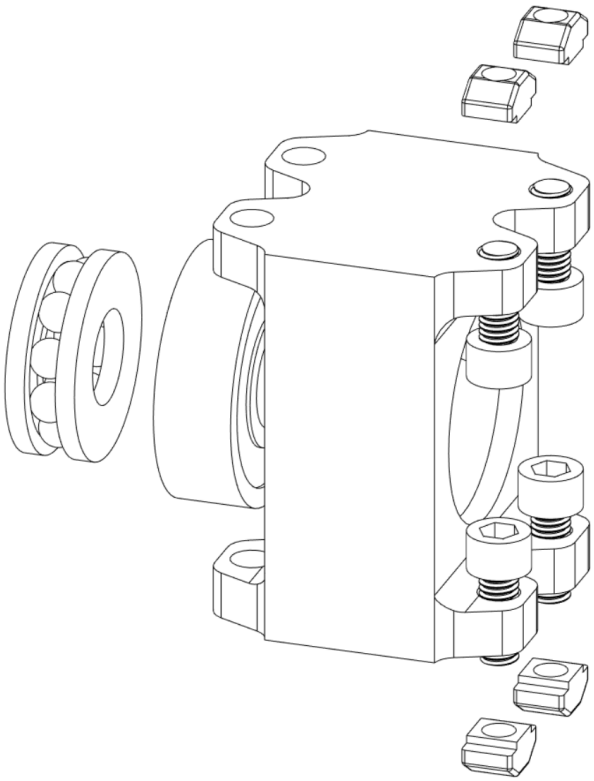


15. X axis motor, coupler and ball screw

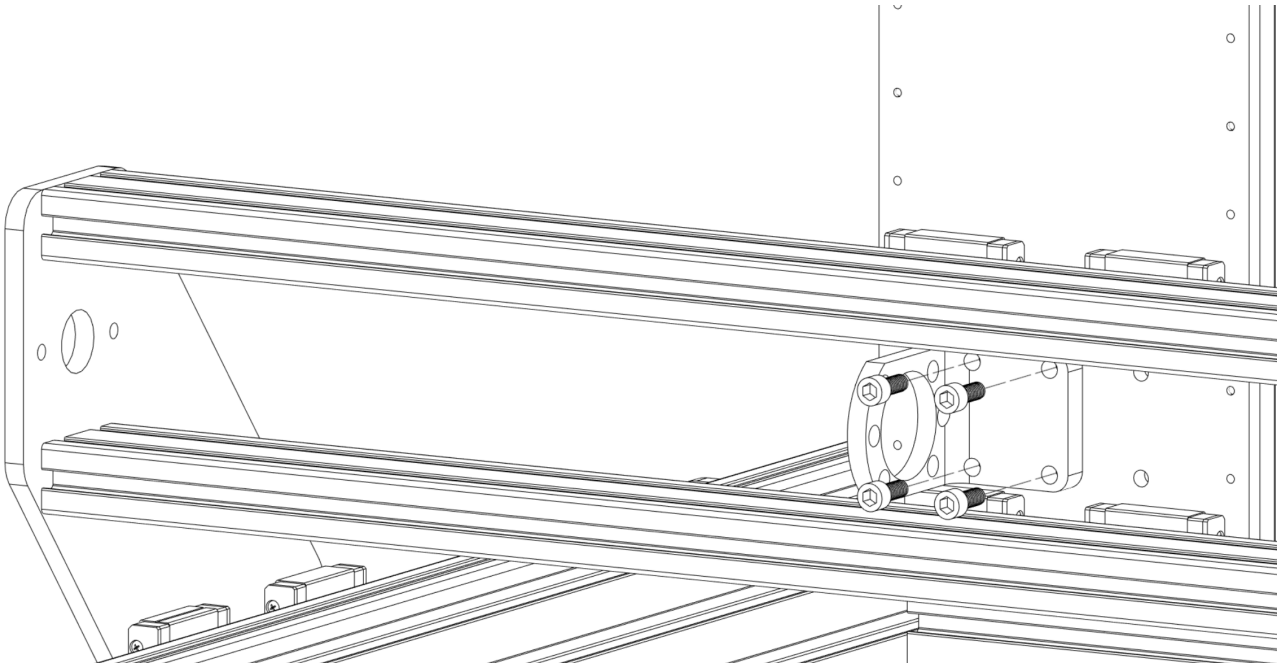
Similar procedure with different order and single ball screw for the X axis. Start by attaching a motor with 4 M5x16 screws and nuts.



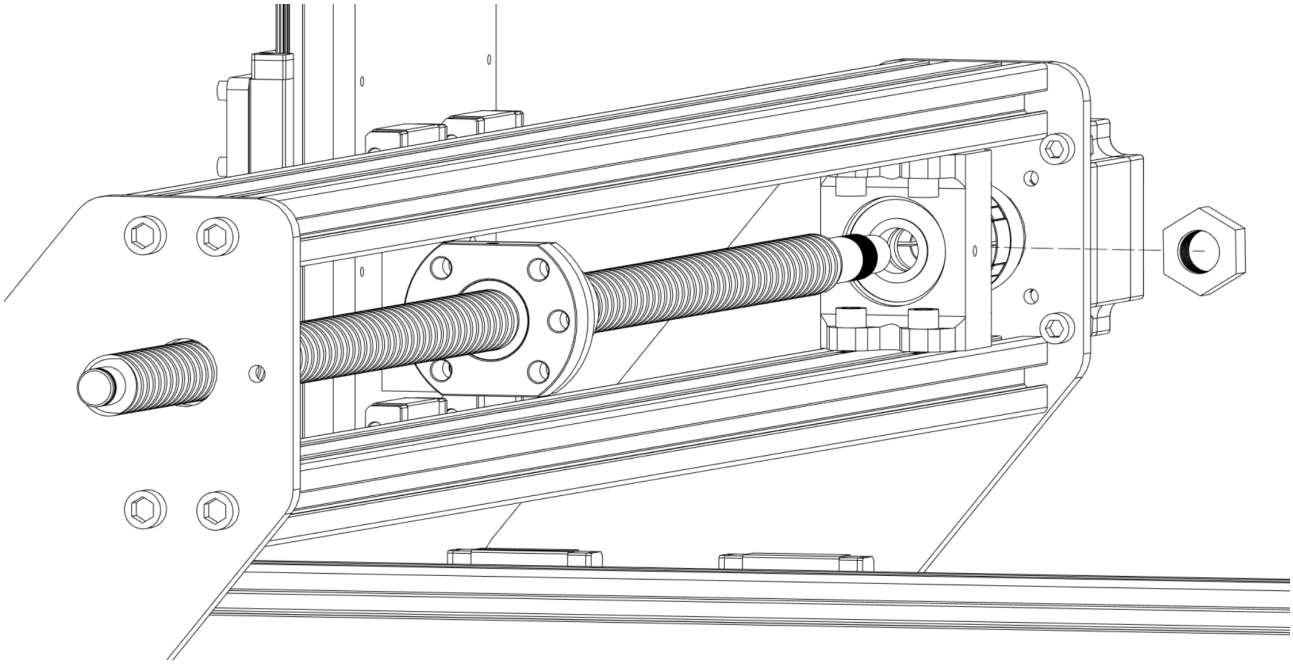
Here is a 3D printed ball screw support assembly with 6201RS ball bearing and 51101 thrust bearing. It will be attached to aluminium profiles with four M5x12 screws and T nuts (you can use 8 screws if you want).



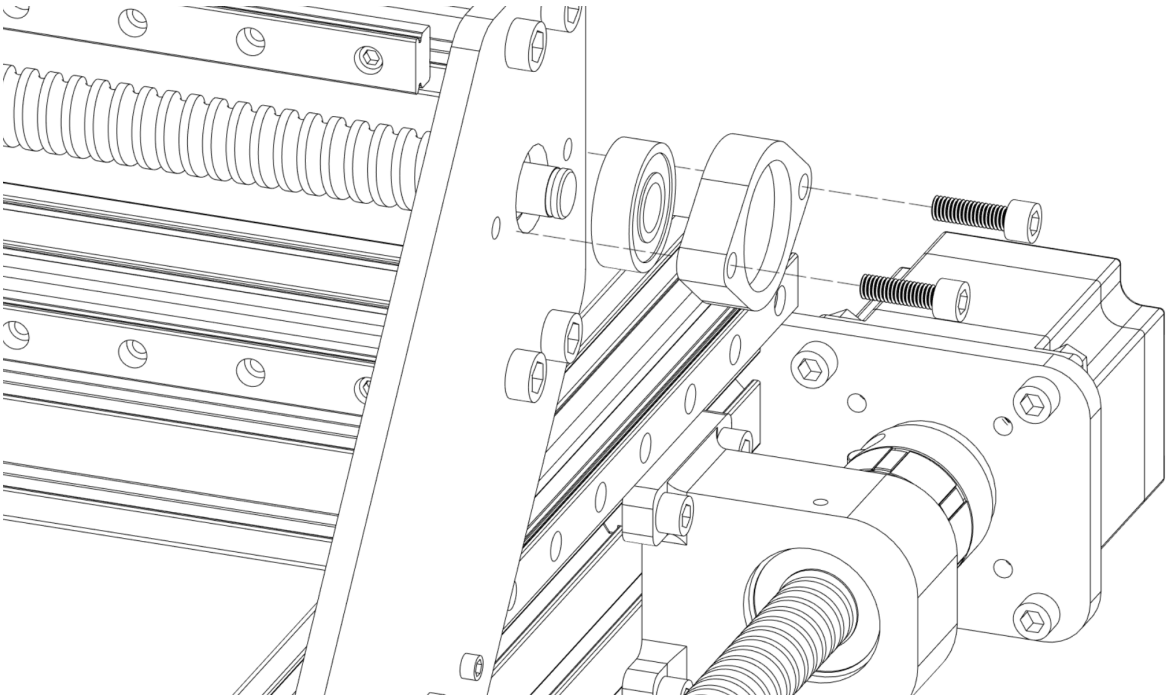
Attach 3D printed X axis ball screw holder to the back of X axis plate with four M5x12 screws.



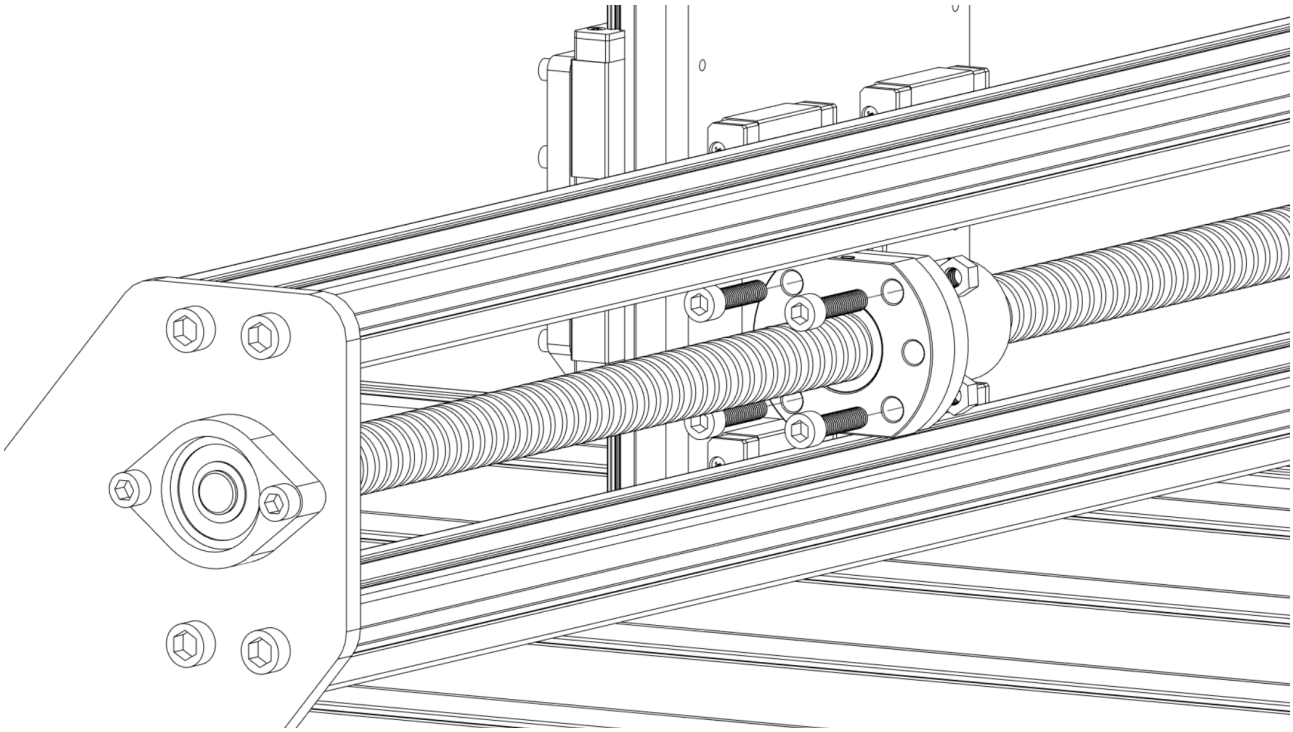
Slide in the ball screw and attach to the 3D printed support with M12x1 nut. Ball nut should be next to the 3D printed ball screw holder.



On the other end attach 6000RS bearing with a 3D printed holder with two M5x16 screws.

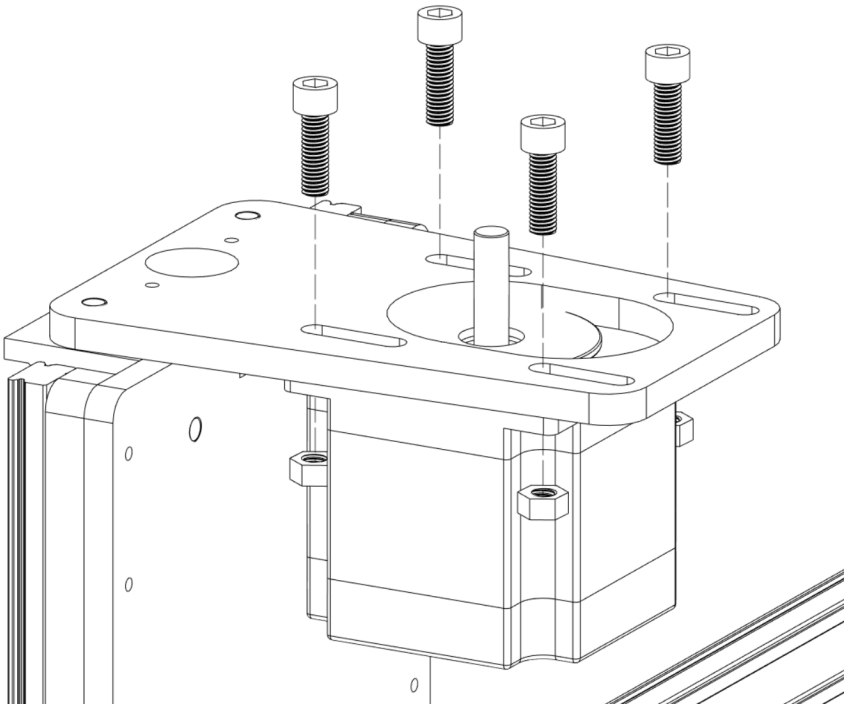


With four M5x20 screws and M5 nuts attach the ball nut to the ball screw holder previously attached to the back of X axis plate.

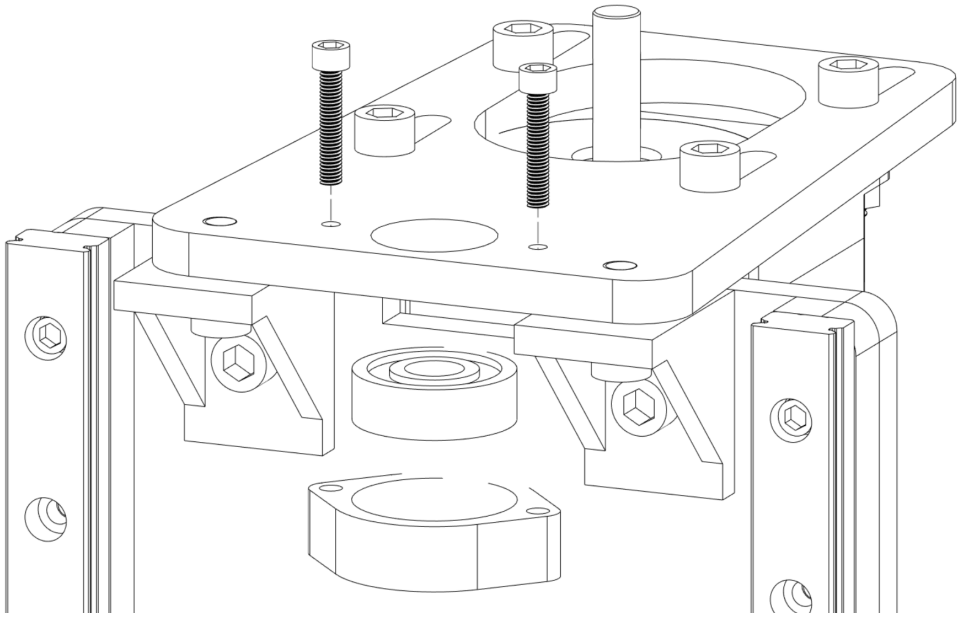


16. Z axis motor screw and pulleys

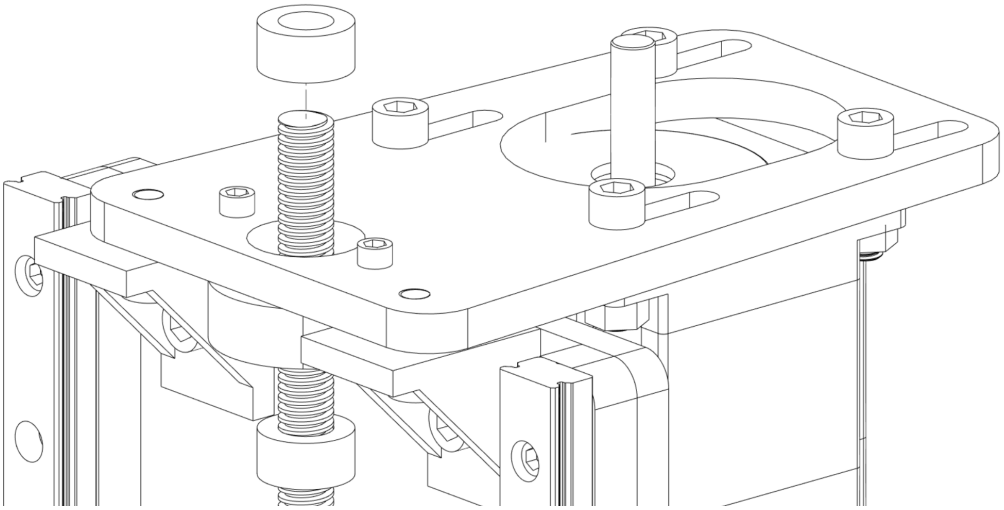
There is no ball screw on the Z axis, thanks to that construction is simplified. It's mainly about the diameter of a screw, trapezoidal lead screw is two times smaller than ball screw that I used.



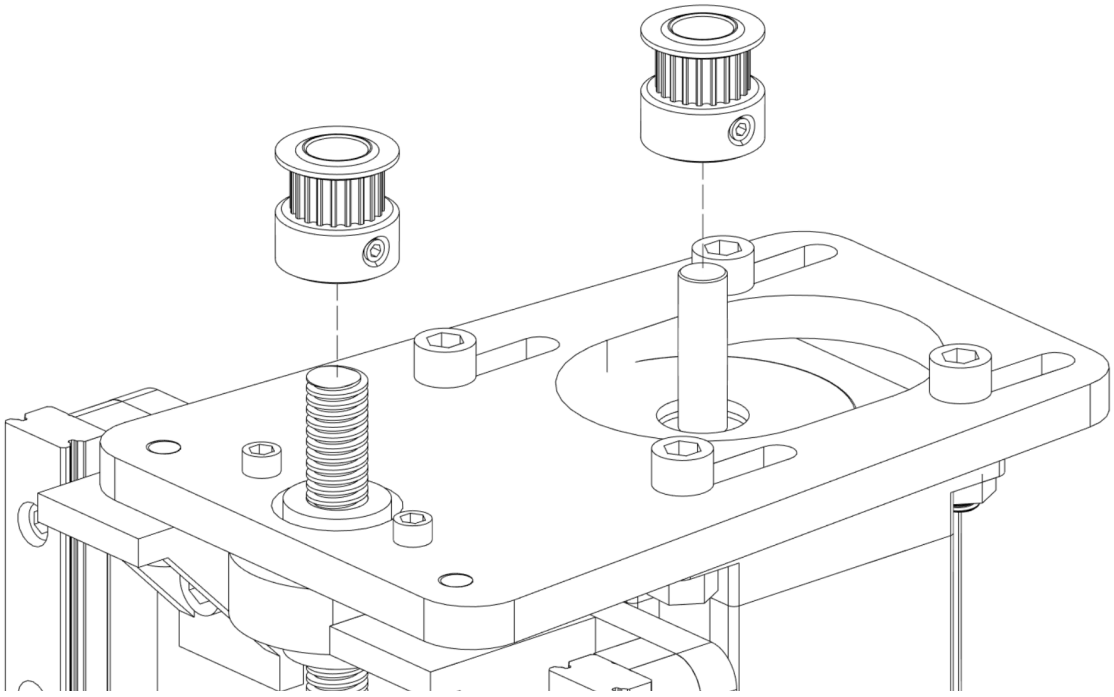
Smaller lead screw means smaller bearing, this time a very popular 608zz that should be attached with another 3D printed bearing holder and two M3x16 screws.



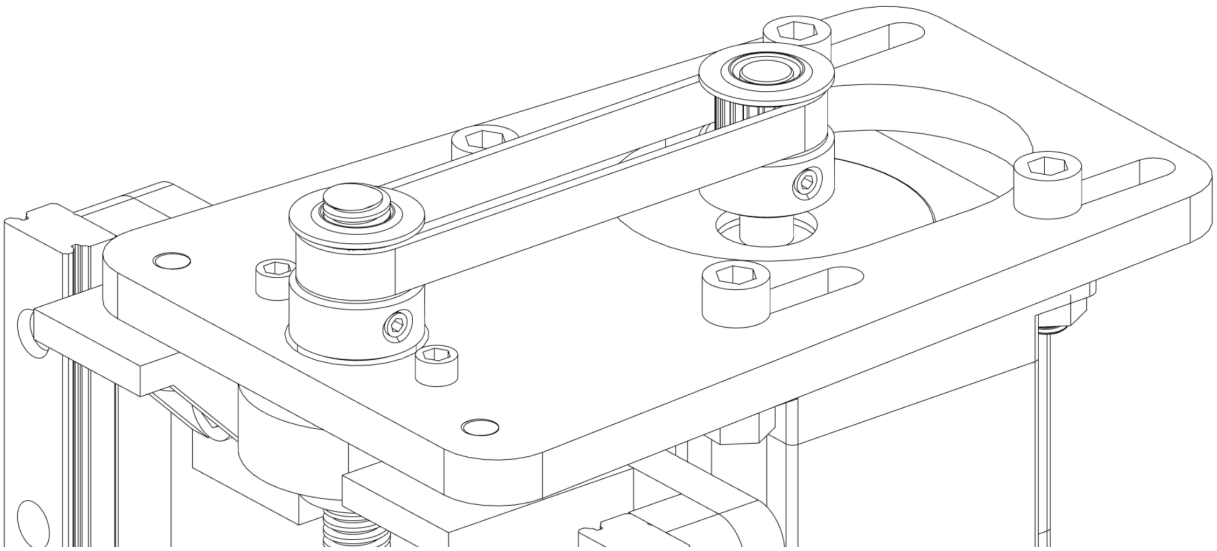
Now we will attach 220mm long trapezoidal lead screw. There should be two lock collars on the lead screw on both sides of the bearing so that it's locked and can't move up and down. Later we will add a third one on the bottom. The lead screw should screw into the nut attached to spindle plate. Screw small screw on the side of each lock collars and make sure that spindle plate moves easily when you rotate the lead screw.



Two GT2 pulleys with 8 mm hole and same teeth number should be attached to Z axis motor shaft and top of the lead screw, lock them with screws in place (screw should face flat side of a motor shaft).

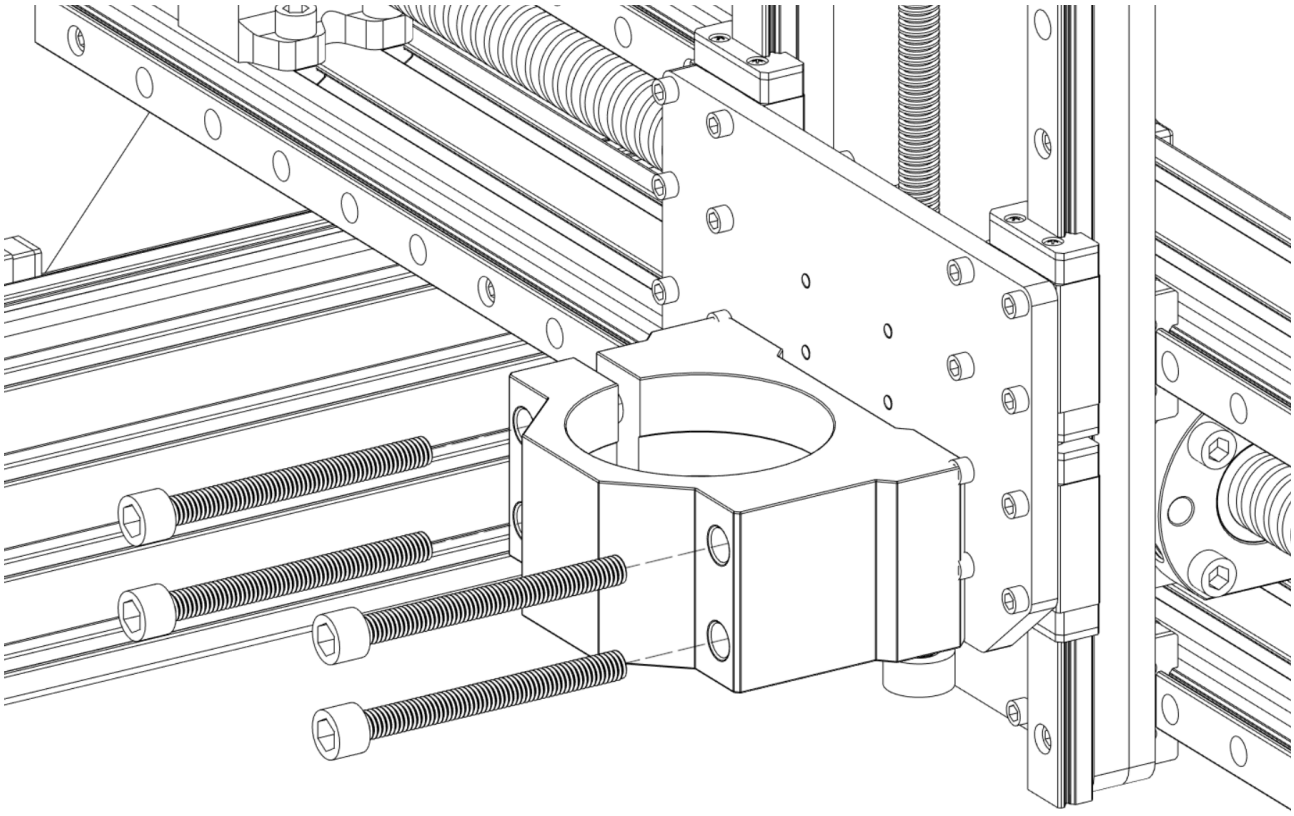


After that put a GT2 belt in place you may need to unscrew Z axis motor screws to do so. Don't forget to tighten the belt by moving the motor.

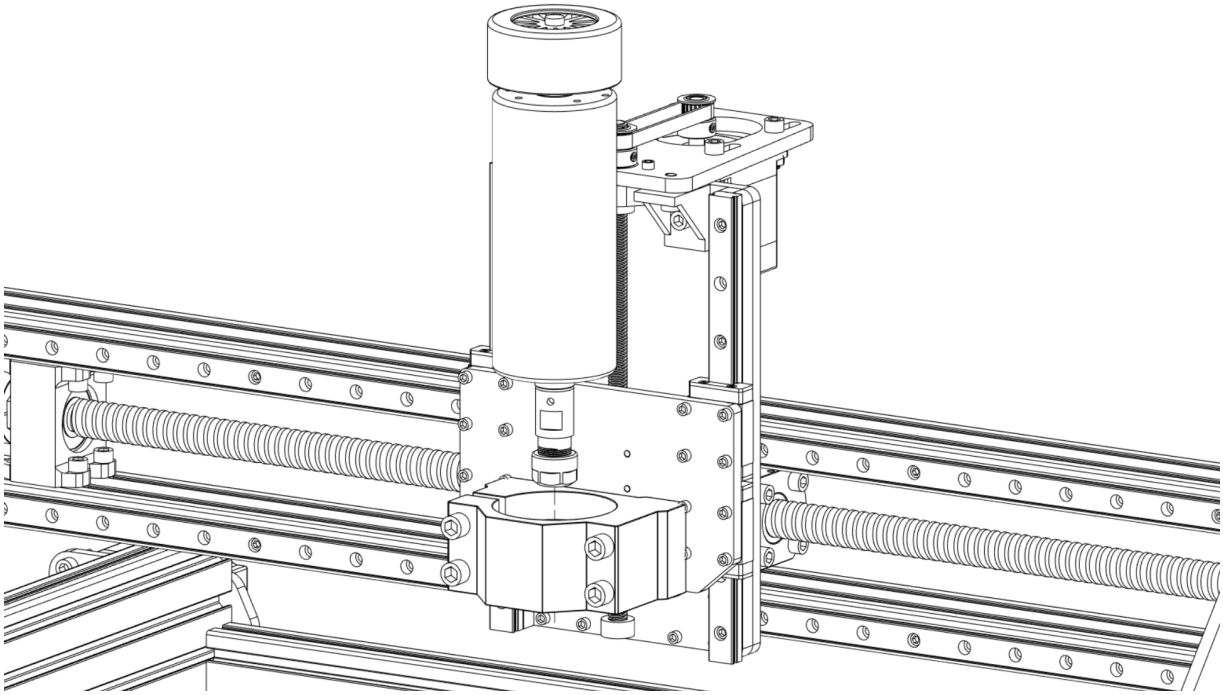


17. Spindle

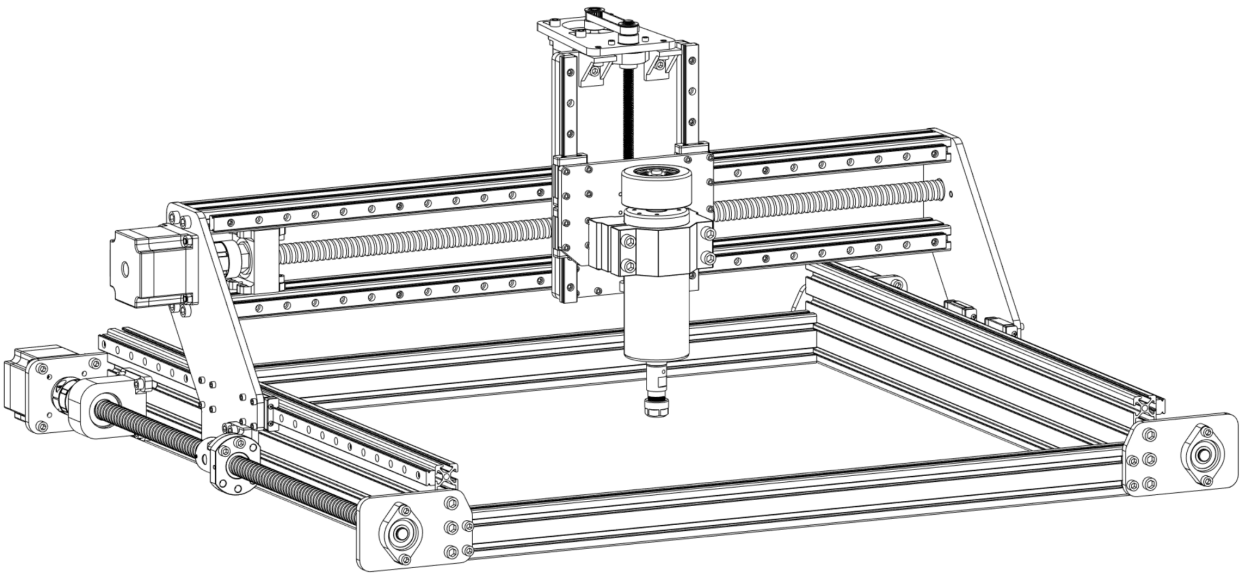
There is plenty of options when it comes to spindles. You can use a Dremel (or similar tool) but that doesn't make a lot of sense for such a machine. If you are going to machine mainly wood a router may be a good option. You can use 500W spindle which in my opinion is the best option for beginners, it's not crazy expensive, is powerful enough to mill metal and quite easy to connect and use. Or you can go as crazy as 1.5kW spindle which I will test soon and most likely use in the future with this machine. You can even make your own, for example by gearing down a 775 motor and adding precise RPM control system and some bearings you can make a decent spindle even for some light metal work. As for now I only designed spindle plate for 500W spindle and that's what I am using. You can also start with this spindle and move to something more powerful later, it's an easy upgrade. So let's focus on how to assemble the machine with 500W spindle. Start by attaching its mount. Don't tighten the screws totally yet, in a moment we will put a spindle inside this mount.



Put the spindle in place, you may use a screw driver to widen the mount a little bit. Put the spindle in the position that let you touch the washboard with the end of a milling bit.



That's it you made it through the whole assembly process! Congrats :)
In next sections we will focus on the electronics, software and milling bits.



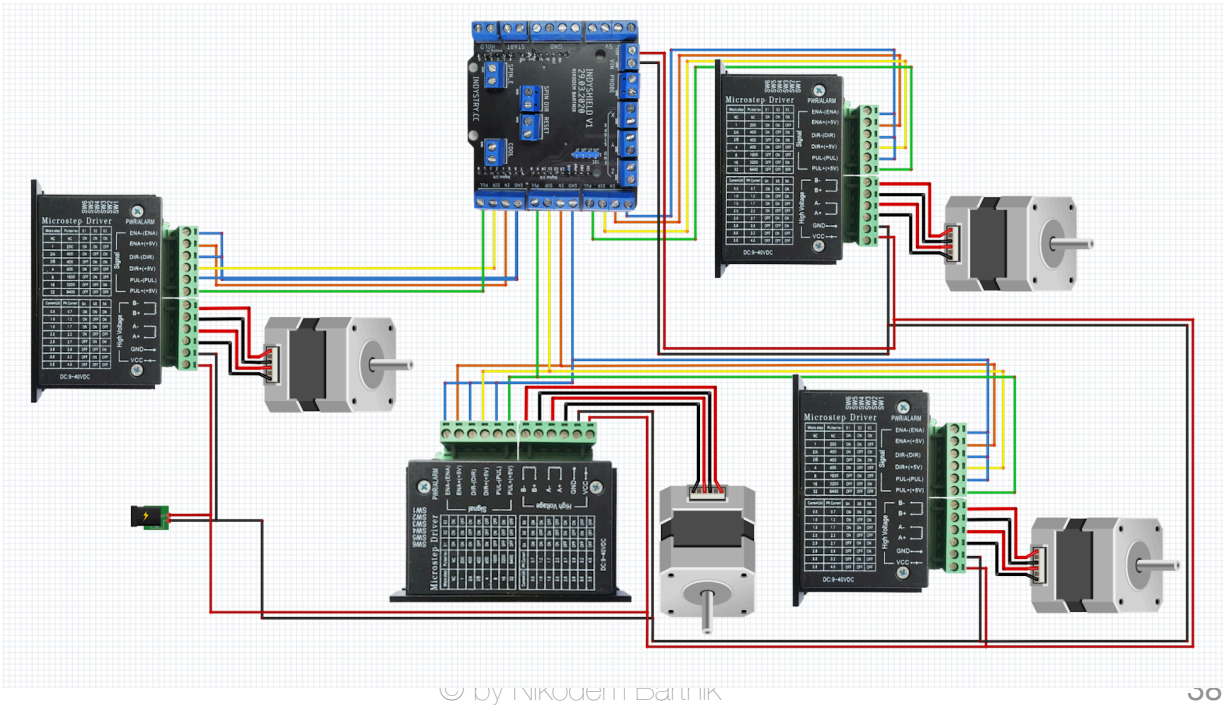
18. Electronics

As I mentioned my electronics setup is definitely not the best one but it's simple and shouldn't be intimidating for beginners. You can always upgrade later. I used a popular Arduino board as a main controller with a GRBL firmware installed. You can find more info on how to install GRBL on their GitHub page:
https://github.com/grbl/grbl

Instead of using popular GRBL shield I made my own with screw terminals so that it's easy to connect to everything else securely. I called that IndyShield you can find the design files on my website and I am also selling this PCB on my website. You don't have to use it and you can connect it however you want (just follow the schematic below). But the easiest way for nice clean connection is to use some sort of screw terminal shield for Arduino or a special CNC controller board.

TB6600 is stepper driver that I used, a lot of people complain about it, but I haven't faced any problems so far. I set it to 2A because that's a proper current for my motor and 1/16 micro-stepping.

My power supply is 12V 30A one, be very careful while connecting that! 220V is a dangerous voltage, if you have no experience with that, ask for help!!!
Unfortunately some basic electronics knowledge is required to connect everything. Follow the schematic below.



Once everything is connected we have to change the setup of the GRBL firmware. We just need to send a few commands through terminal (for example in CNCjs). Send one command at a time.

```
$1=255
```

This will keep stepper motors turned on all the time.

```
$100=640
```

This is the steps per mm setting, basically this tells the GRBL how many steps we need to do on each axis to move by one mm. We use a 1605 ball screw (5 at the end means that with one full rotation of the screw the nut will move by 5 mm) and our motor because of micro stepping has 3200 steps per revolution. When you divide 3200/5 you get 640 and that's why we have to set $100 to 640. That's setting for X axis.

```
$101=640
```

Here is a similar setting for Y axis, we use same ball screws here so the value is the same.

```
$102=400
```

That' setting for Z axis, we have a different lead screw so the value must be different.

```
$110=1000
$111=1000
$112=1000
```

This is the speed setting individual for each axis, I use 1000mm/min and after some testing it looks like it's as fast as you can go with those drivers.

```
$120=80
$121=80
$122=80
```

This is acceleration setting, again individual for each axis. This I is just an example value that I used, feel free to play with speed and acceleration to find best values for your machine. You can also read more about GRBL setting on their GitHub.

19. Cable management

Cable management is a very important part of every CNC machine. Using cable chain is probably the most professional and best working method. Good news is that if you have a 3D printer you don't have to buy those, you can easily print them. Sure it takes some time to print 1.5 meters of cable chain but it works great! Here is a link to Thingiverse of the cable chain that I used:

https://www.thingiverse.com/thing:1167746

Of course you can use anything else that works for you. I also used some cable wrap and zip ties.

20. Recommended software

There are two programs that you need in order to use your machine. The first one is a design software that has a built in CAM. Thanks to that we can design stuff and generate GCode for our CNC machine. You can choose what works best for you, my recommendation is Fusion 360:

https://www.autodesk.com/products/fusion-360

We also need some kind of a controller software to control our CNC machine. There are plenty of options free and paid. I really like using CNCjs it's free, open source and multi-platform. Unlike most of the other CNC controllers it has a nice, clean user interface:

https://cnc.js.org

21. Happy milling!

That's it for this instruction, but it's only the beginning of your journey with CNC machining! I hope you will make a lot of cool projects with IndyMill, don't forget to share what you have made on social media and use #indymill or #indystry. You can also send some pictures of your machine: nikodem@indystry.cc

Don't forget to follow my YouTube channel to be up to date with all updates and new projects and ask questions in the comments if you have any. At some point I may also create a Facebook group for IndyMill builders.

If you need more info check out indystry.cc and signup to the newsletter, I will let you know about most important updates through it.

If you have more questions or you found a mistake in this instruction and would like to help to make it even better, here is my email address: nikodem@indystry.cc

Thanks for reading happy milling!

Created by Nikodem Bartnik 08.2020

Updated 02.2021