Blackbox CE Mechanical Assembly:

07. FDM Tool

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Change Log

Versio n	Description
1	Initial release for Blackbox Refresh.

Tools

Description
Electric Drill
M3x0.5mm Tap
Hex Wrenches
Medium Strength Thread Locker (Blue Loctite)
Reamers
Small Hand Vise or Small Arbor Press
Soldering Iron with Heat Set Insert Tip Installed
Heat Sinking Paste
Lightweight Oil
Open End Wrenches or small pliers (for nozzle installation)

Parts

QTY	Description
1	Aluminum Tool Plate
2	8mm Steel Bearing Ball
1	Bondtech Drive Gear Set (1.75/5mm)
1	Bondtech BMG Shaft Assembly
2	MR85ZZ Ball Bearing – 5x8x2.5
1	Bondtech Thumbscrew Assembly
1	SLS 51 Tooth Driven Gear - Iglide
1	M3x2mm Set Screw (included with Bondtech Shaft Assembly)
10	M3x4.6x4mm Heat Set Insert
1	DIN912_M3_16mm_SHCS
4	DIN7991_M3_16mm_FHHS
1	DIN7991_M3_10mm_FHHS
1	DIN7991_M3_8mm_FHHS

1	DIN916_M3_6mm_Set_Screw
3	DIN916_M3_4mm_Set_Screw
3	Neodymium_Cylinder_Magnet_5x4mm
1	Linear_Shaft_3x20mm
1	Linear_Shaft_3x22mm
1	E3D_EmbeddedBowdenCoupling_ForMetal
1	CNC_ToolCooler_Block (as configured)
1	Heat Break (as configured)
1	Hot End Heater Block (as configured)
1	Nozzle (as configured)
2	ISO7380_M3_18mm_BHHS
1	ISO7380_M3_10mm_BHHS
1	1.75mm Bowden Tubing (4mm O.D.) / Meter
1	0.65M Length of Spring Steel (Music) Wire – 0.78mm Dia.
2	DIN7991_M3_6mm_FHHS (Optional)
1	Single Edge Razor Blade (Optional)
1	2mm x 6mm Dowel Pin

Printed Parts

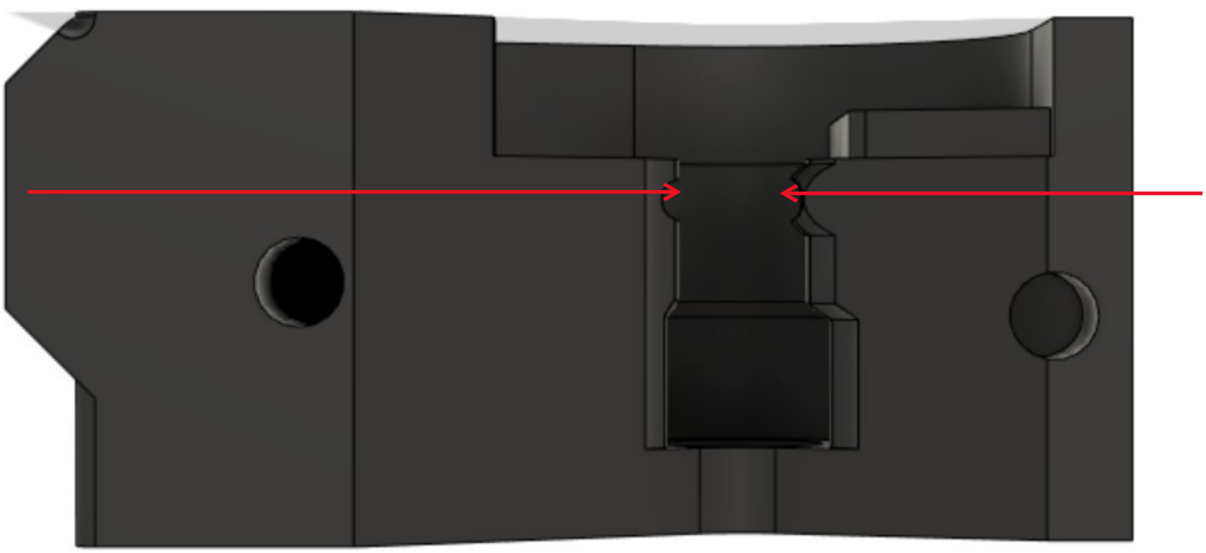
QTY	Description	Material	Ver	Link
1	FDM Tool STL Kit – Each kit covers FDM Tool (includes all models listed below)		1	Link
(1)	Bowden Cutting Tool STL Kit – OPTIONAL	Any	1	Link
1	CNC_Print_ToolHead_part01	PC-PBT	19	
1	Print_ToolHead_part02	PC-PBT	14	
1	Print_51t_Extruder_Custom_Mating_Gear (Included in CE Kit)	IGLIDE SLS	5	
1	Print_Toolhead_Part06	PC-PBT	2	
1	Print_ToolHead_part03	PC-PBT	52	
1	Print_ToolHinge	PC-PBT	12	
1	Print_Toolhead_Part05	PC-PBT	5	
1	Print_ToolHead_part04	PC-PBT	4	
1	Print_Jig_51T_Gear_Setter	Any	2	
1	Print_Jig_SpringWire_Tool_Part_A	Any	2	
1	Print_Jig_SpringWire_Tool_Part_B	Any	1	

Step 1 – Preparation

Assembling your FDM tools with precision and care will lead to long-term reliable tool changes and operation. When compared to the rest of the machine inaccuracies in either geometry or assembly can result in significant effects to printed part quality and extrusion consistency. BE SURE TO PRINT AND PASS THE BLACKBOX READINESS TEST PRINT HERE IF YOU HAVE NOT ALREADY. If at any point you lose confidence in assembly now is the time to rectify things!

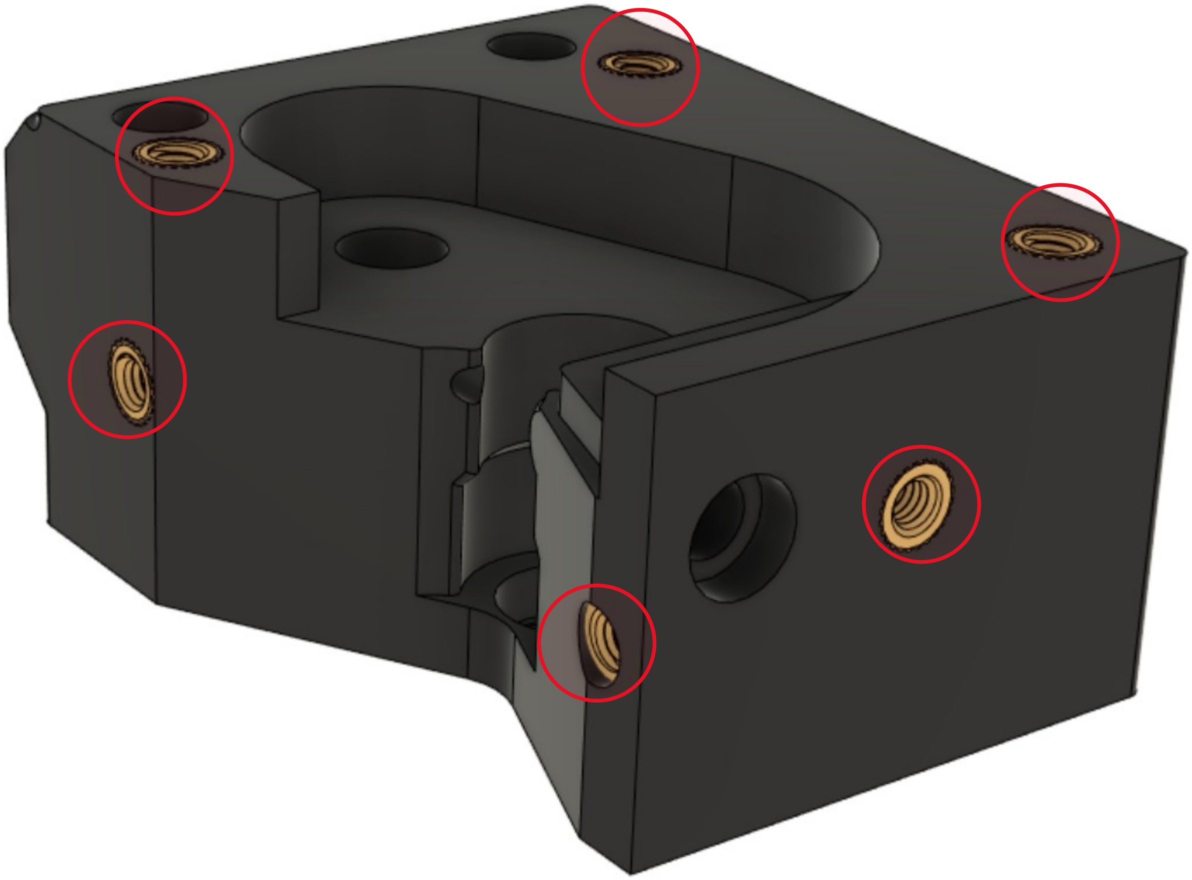
Step 2 – Main Body Preparation

Locate printed part 03. When printed in the correct orientation the filament path is a vertically printed hole. Run a 2mm reamer through the filament path shown below.



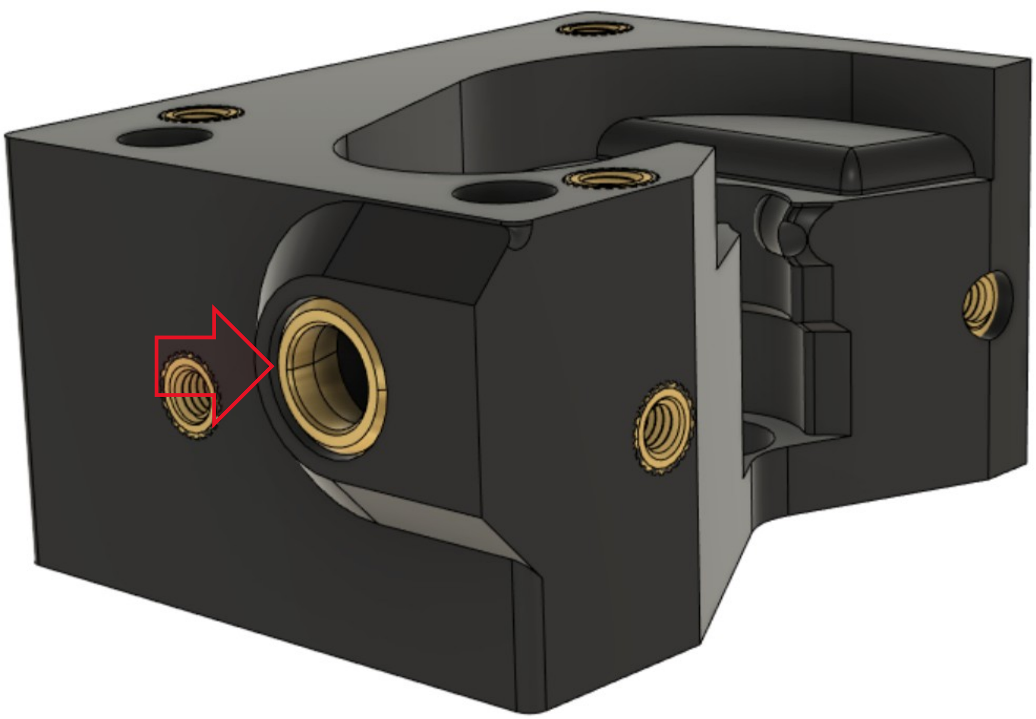
Install M3 heat set inserts (8) in the following locations:

Firstly, six here:

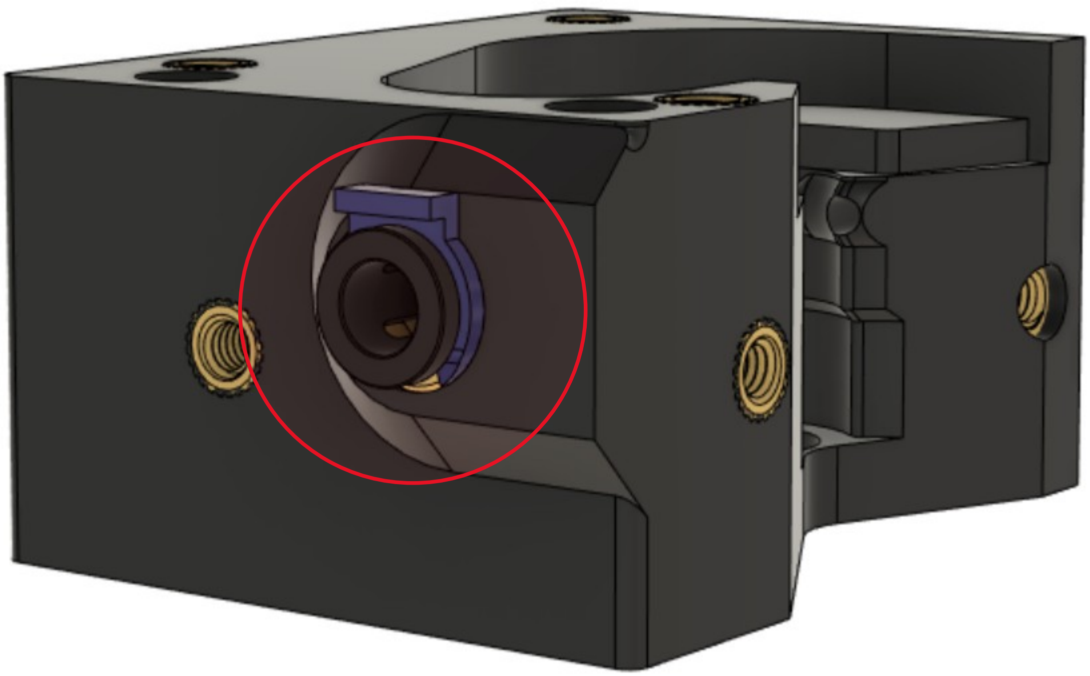


Flip and rotate and install the remaining heat set inserts here:

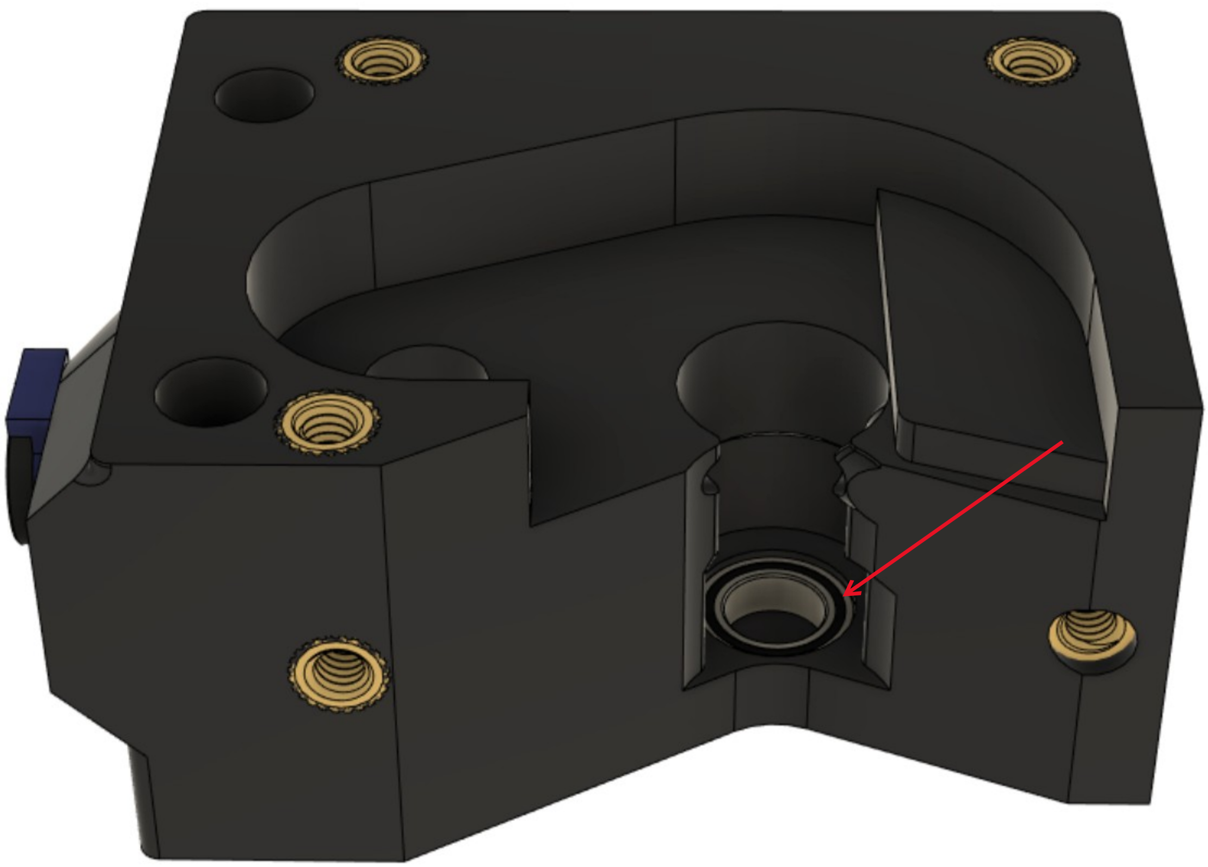
Install the embedded Bowden coupling. Be sure to take note of its direction in the image below. The "bottom" or inward facing portion of the insert has a chamfer feature. Reaming the bore in which it sits will aid in easy installation. If seating is difficult with the tools at your disposal, it can also be treated as a standard heat set insert and installed that way. When fully seated the insert will be flush with the printed part.



Install the Bowden collet and clip as shown.



Locate and Install (1) MR85ZZ bearing into the bottom pocket as shown. Be sure the bearing is fully seated. Note that the plastic behind the bearing is on the thinner side. For this reason, it is advised that the bearing be pushed into the printed part via its outer race with a suitable tool and the assembly resting against your work surface. Never push or pull a ball bearing from the inner race, as this can damage it.

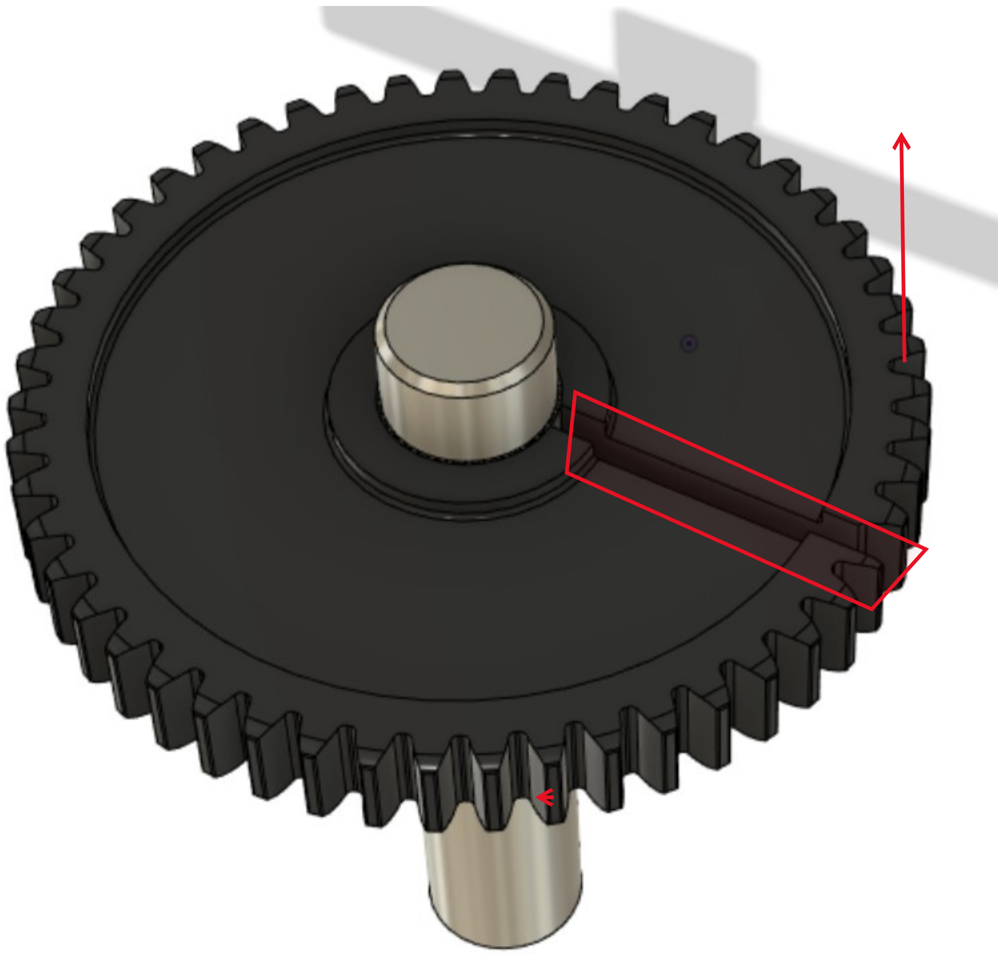


This step requires mechanically removing and replacing the standard 51 tooth gear from the main 5mm Bondtech drive shaft assembly. This is required to mesh reliably with our carriage mounted extruder motor/gear. Please exercise good safety practices as needed for your chosen method of removal.

Removal Options:

1. Press – If you have access to a press with pass-through functionality you can simply support the gear at the shown locations and press the shaft downward (with a suitable driver) and out of the gear itself.

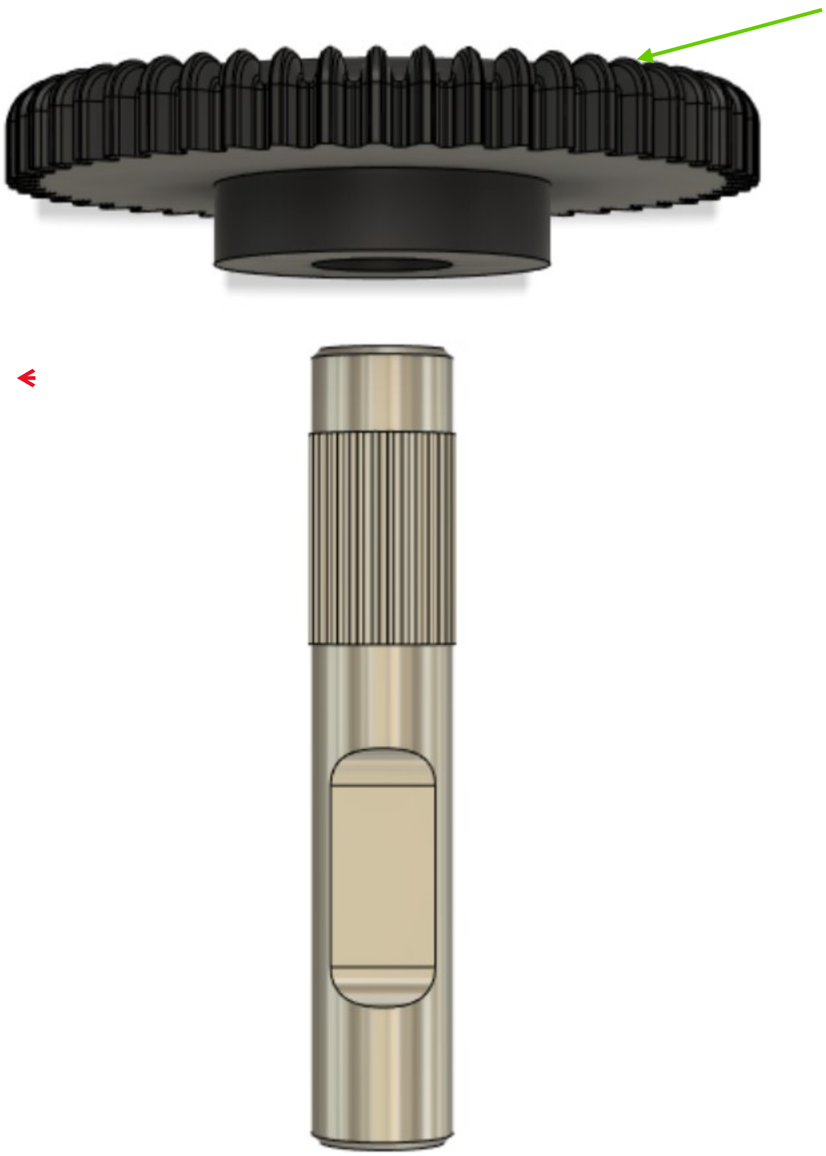
2. Cutting – The plastic gear can also be sliced down to the shaft and then spread apart for removal. A Dremel with a cutting wheel or even a small hacksaw makes quick work of the plastic. Use a pair of pliers to twist the gear and deform away from the shaft.



We will now be installing the new SLS printed 51 tooth gear onto the shaft. Note that SLS printed parts have a larger demanded tolerance allowance than FDM printed parts. For this reason, some driven gears may require reaming, whereas others may not. ALWAYS attempt installation before removing any material, as once reamed or modified we can't add it back!

Begin by starting the engagement of the driven gear onto the shaft in the following orientations.

NOTE: The crown of the driven gear has teeth that protrude past the surface of the face of the gear. Never drive the shaft into the gear with force whilst the driven gear is face-down on a work surface as this can damage the teeth. If the gear cannot be started by hand a chamfer can be added to aid in this. Alternatively, you can move onto the next step using the printed tool as the pressing surface.



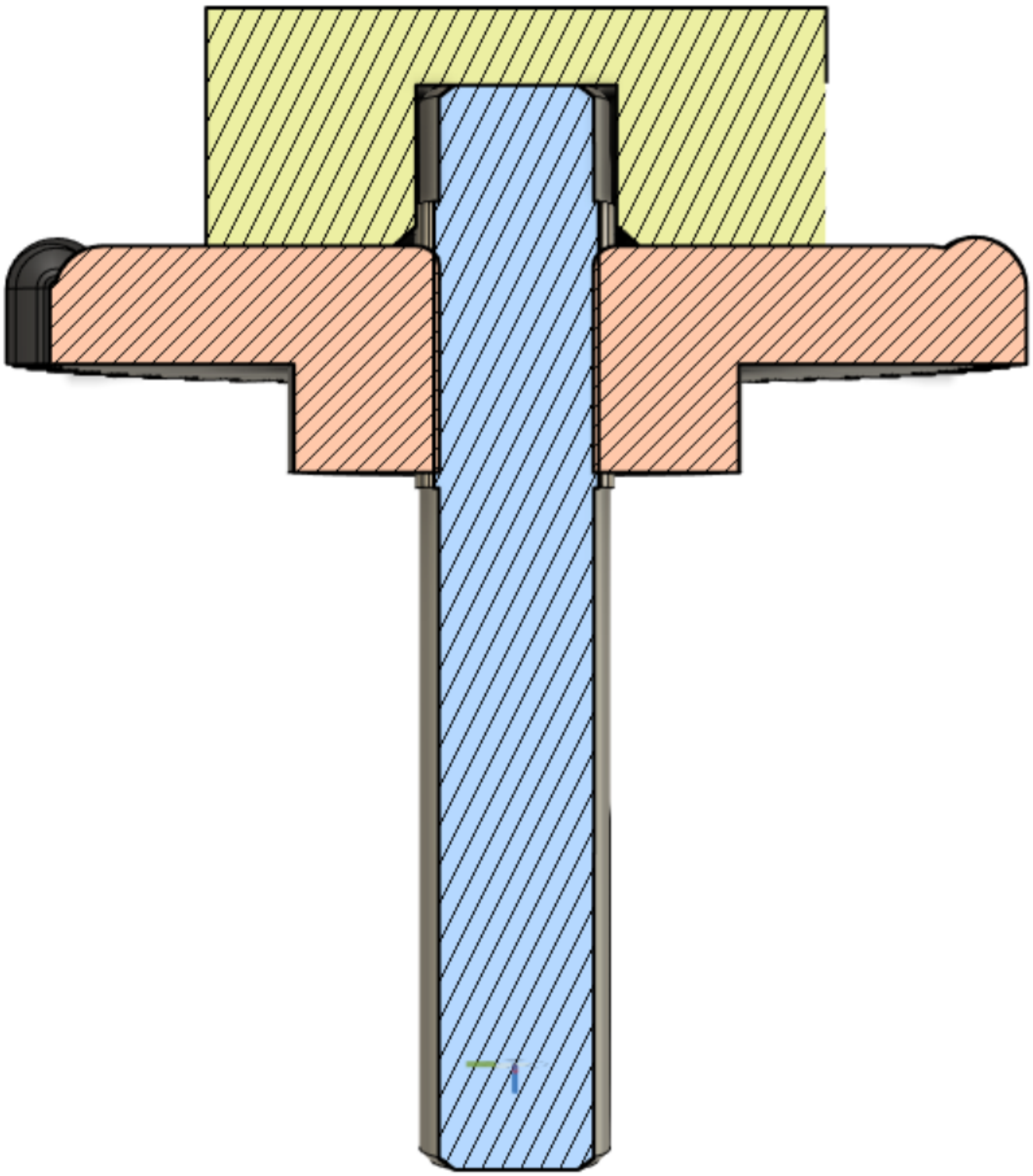
Locate the printed gear pressing tool and note the orientation of parts below. We will cover a few different methods of assembly.

1. Press – If you have access to a press, this will be the simplest way forward. Simply drive the printed tool downward into the shaft until it stops.

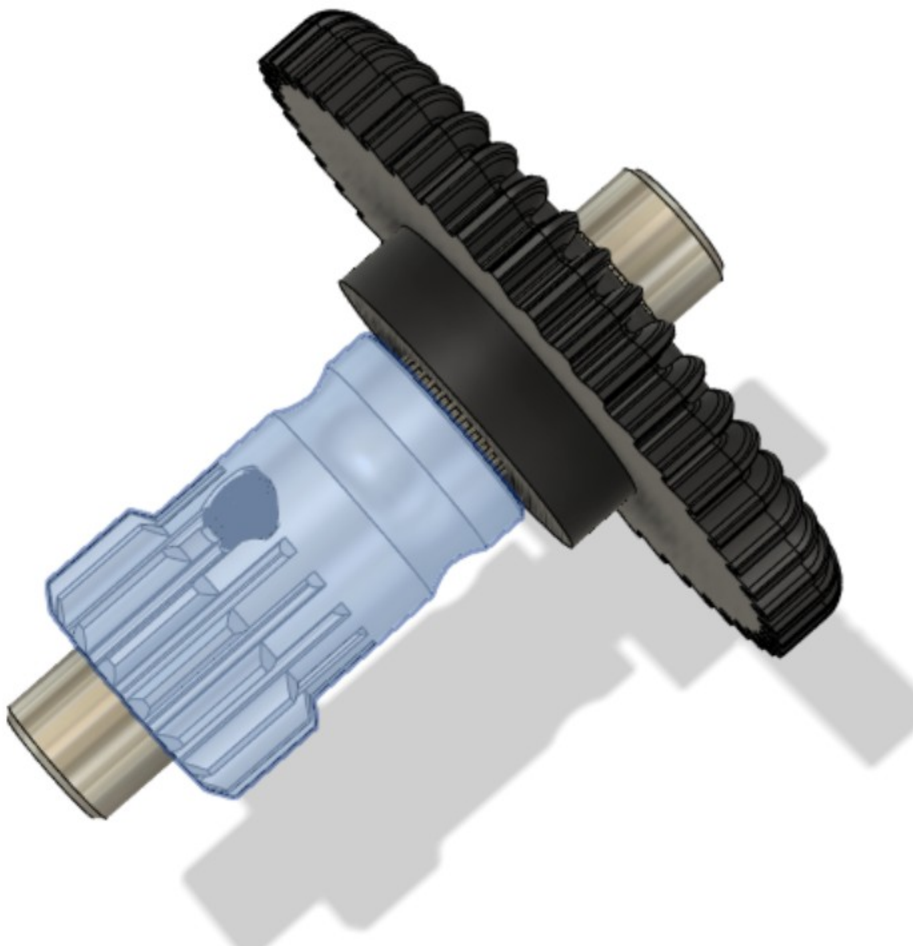
2. Squeeze – With a large pair of pliers or a bench vise you can also simply squeeze the parts together from both ends until movement stops.

3. HammerTime – With the printed tool on the work surface the shaft can be driven into 51 tooth gear with careful use of a dead blow or brass hammer. Please, no air hammers.

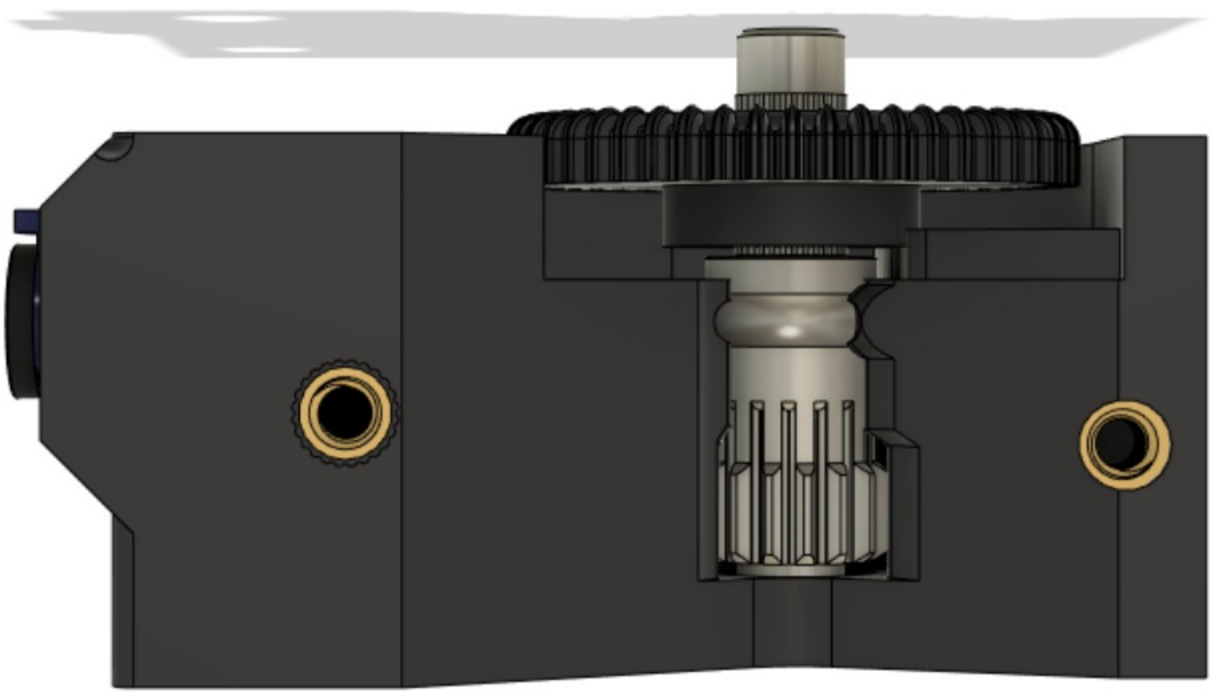
A view of a correctly installed/seated assembly.



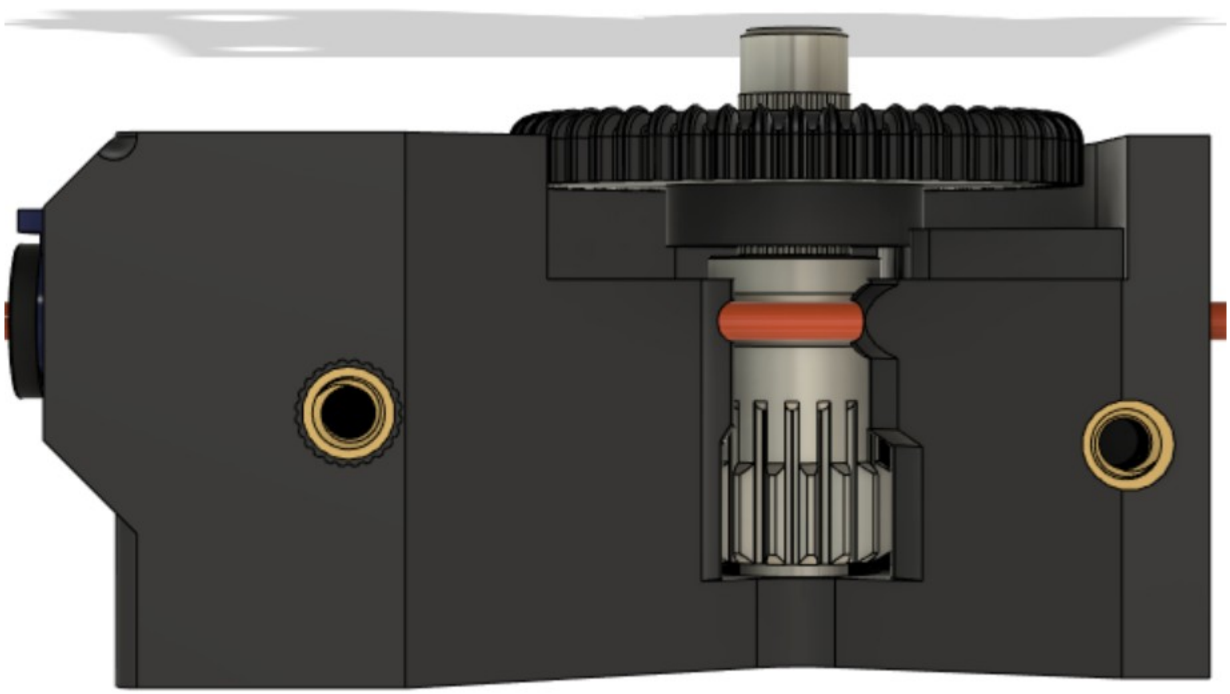
Install the Bondtech drive gear onto the shaft in the below orientation. Install an M3x2mm set screw into the drive gear being sure to catch the flat spot milled into the shaft. For now, we will be loosely tightening this set screw and omitting any Loctite. We'll finalize the gear's position a bit later.



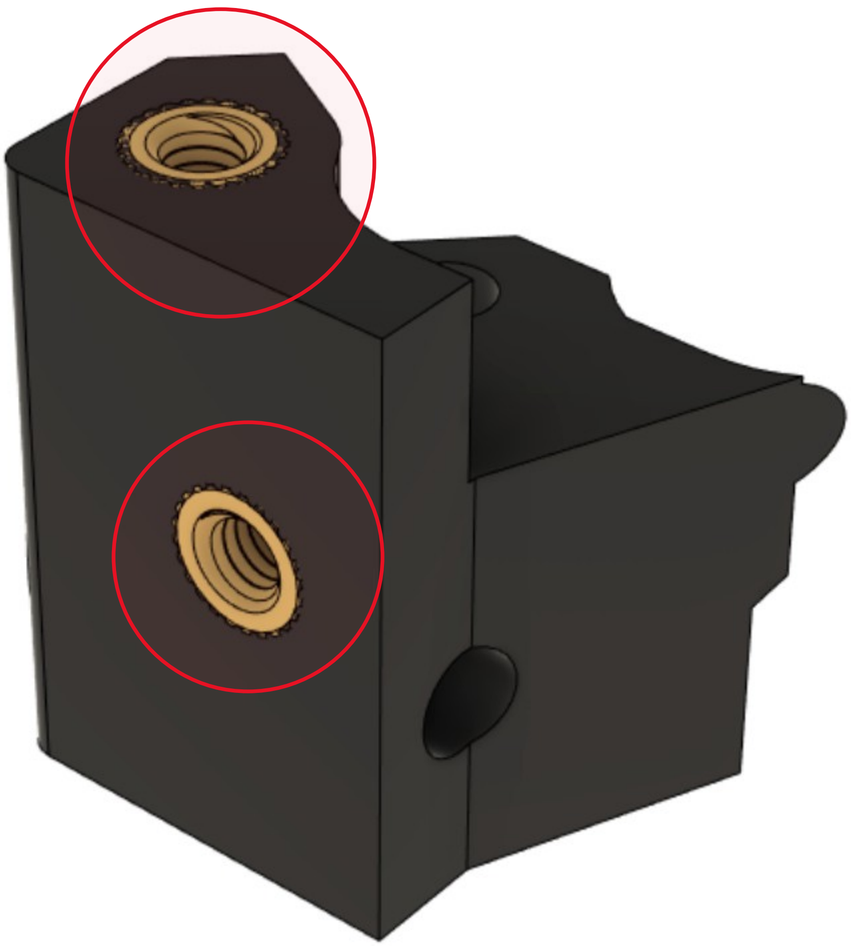
Place the entire assembly into the tool housing being sure that the shaft properly engages the bearing we installed previously.



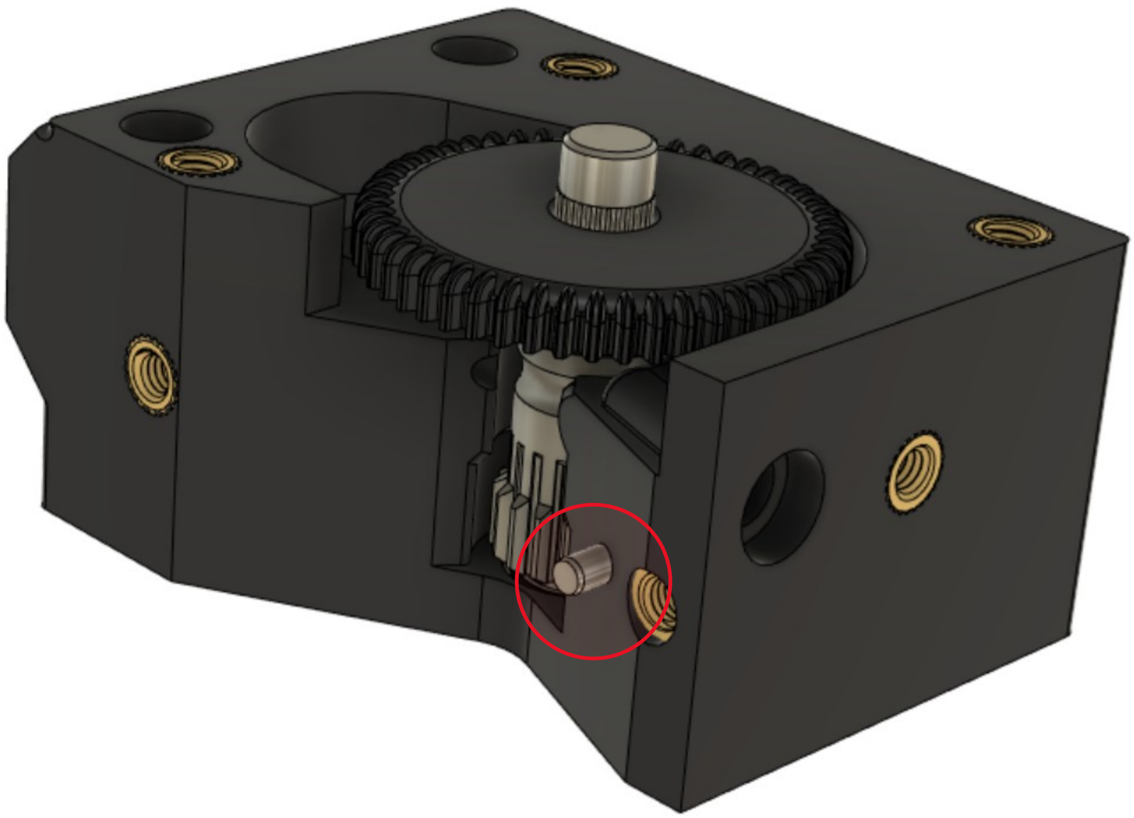
Slide a (ideally straight) length of 1.75mm filament through the entirety of the tool housing. Use the exposed length of filament at the drive gear interface to position the height of the drive gear. Rotate the drive gear so that the set screw is exposed, and tighten the set screw.



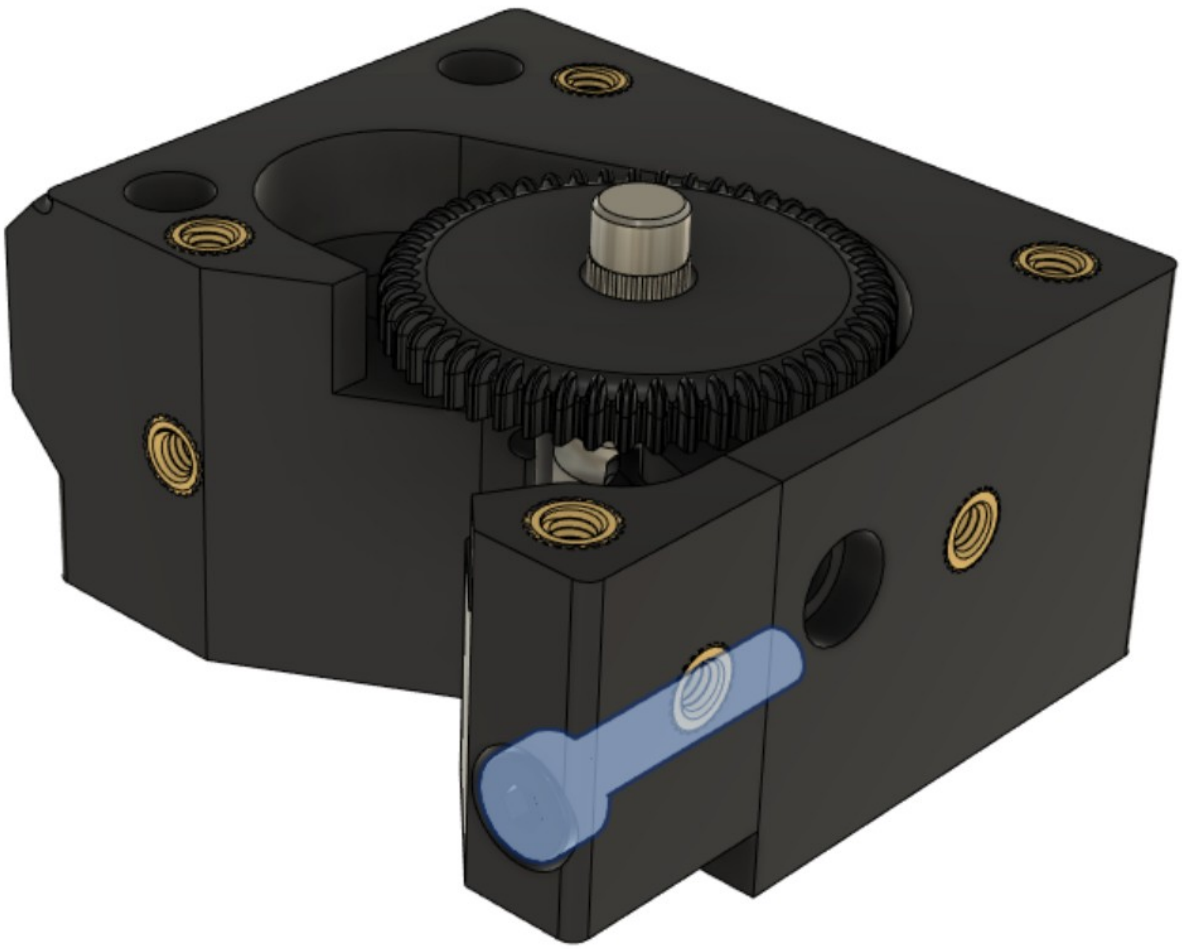
Locate Printed Part 06 and install 2 heat set inserts at these locations:



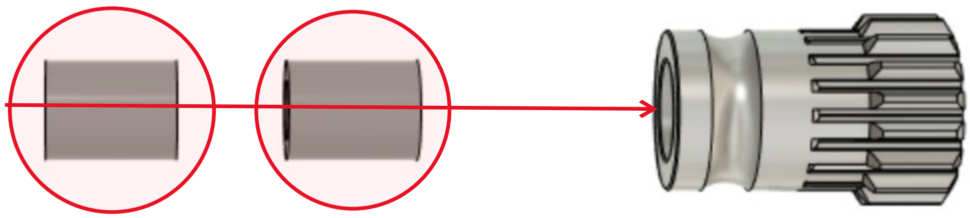
Insert a 2mm (6mm length) dowel pin into the locating bore on Print_Toolhead_Part03 as shown.



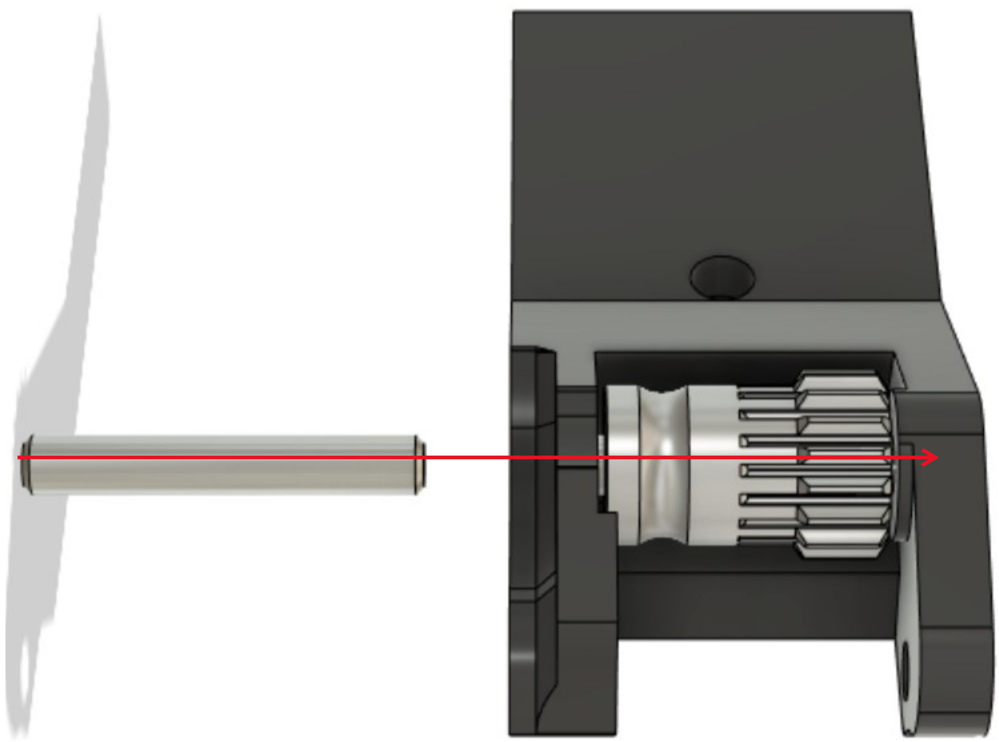
Secure Part 06 to Part 03 using an M3x16 SHCS



Install (2) needle bearings into the Bondtech idler gear with a light oiling.

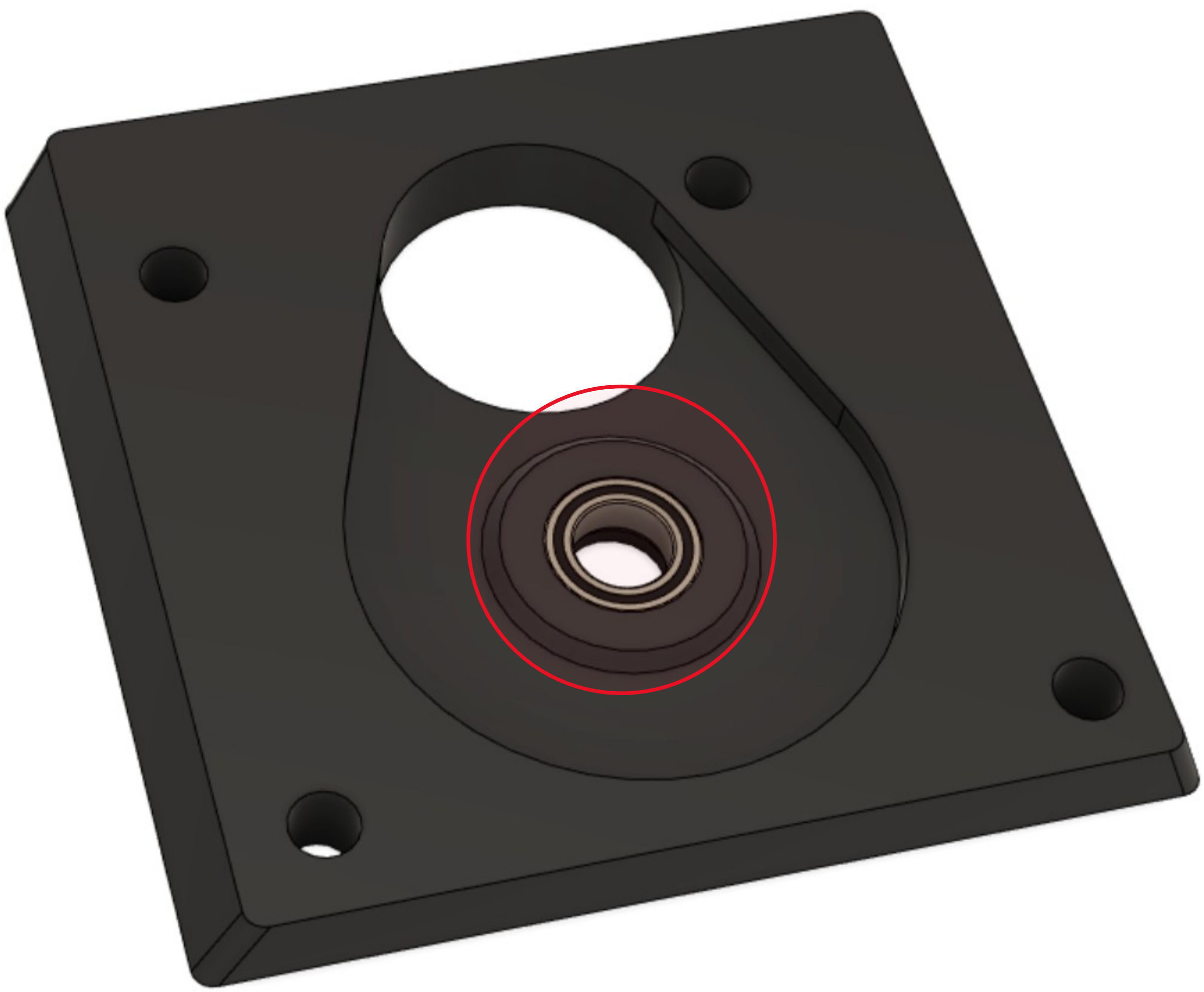


Place idler gear into the printed hinge noting the below orientation. Capture the idler with a 3x20mm shaft.

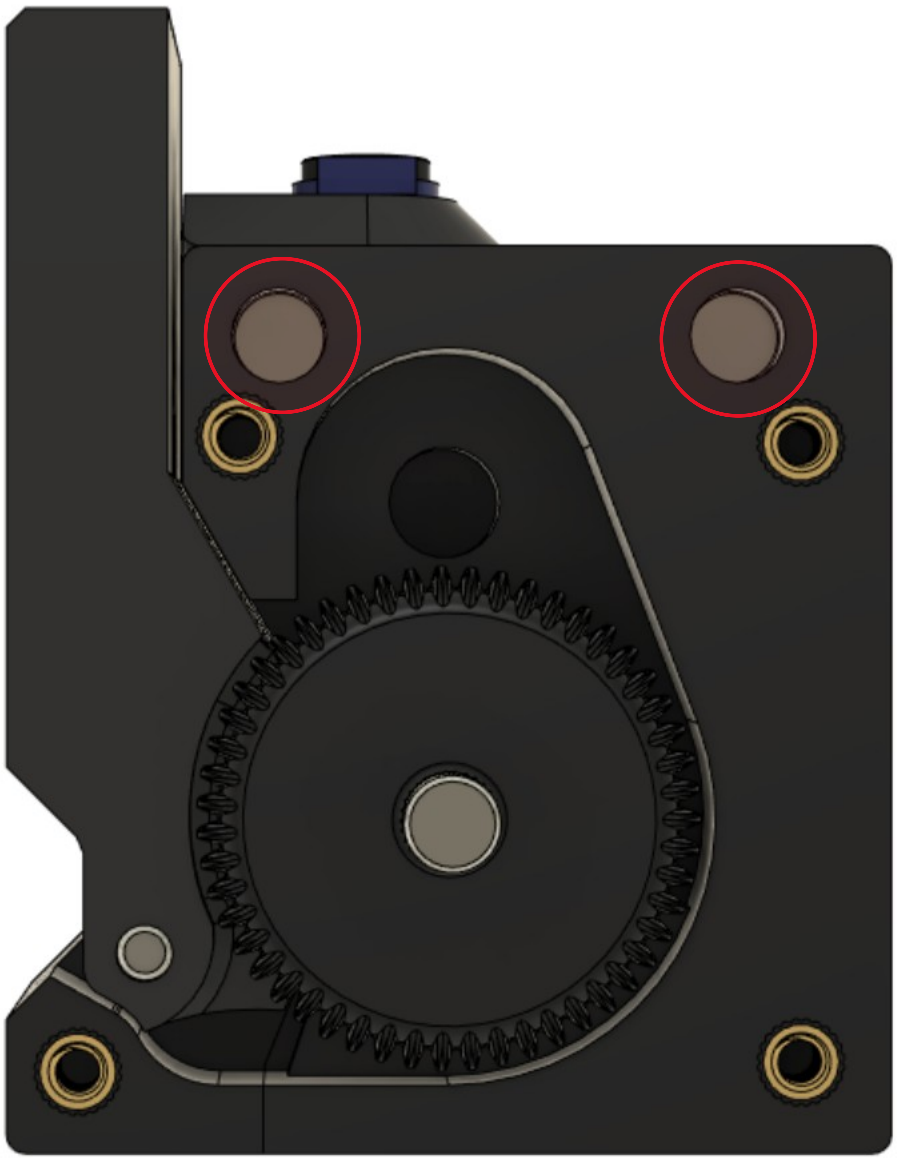


Align the hinge with the main tool body and capture with a 3x22mm shaft at the shown location.

Locate Printed Part 02 and insert the remaining MR85ZZ bearing into the pocket shown. Ensure the bearing is fully seated.

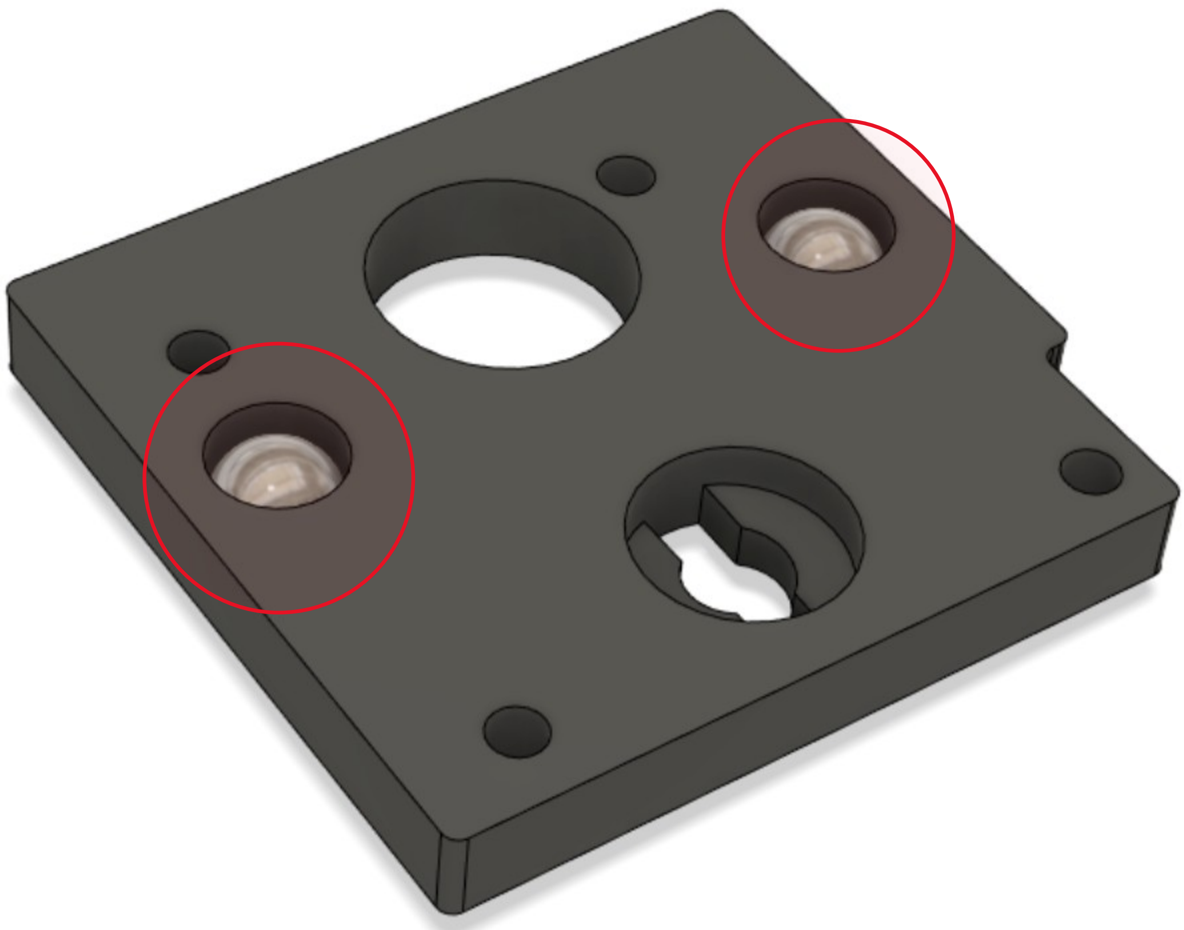


Place (2) 5x4mm magnets into the shown locations. The magnets should rest against the printed stop ring resulting in a below-flush position.



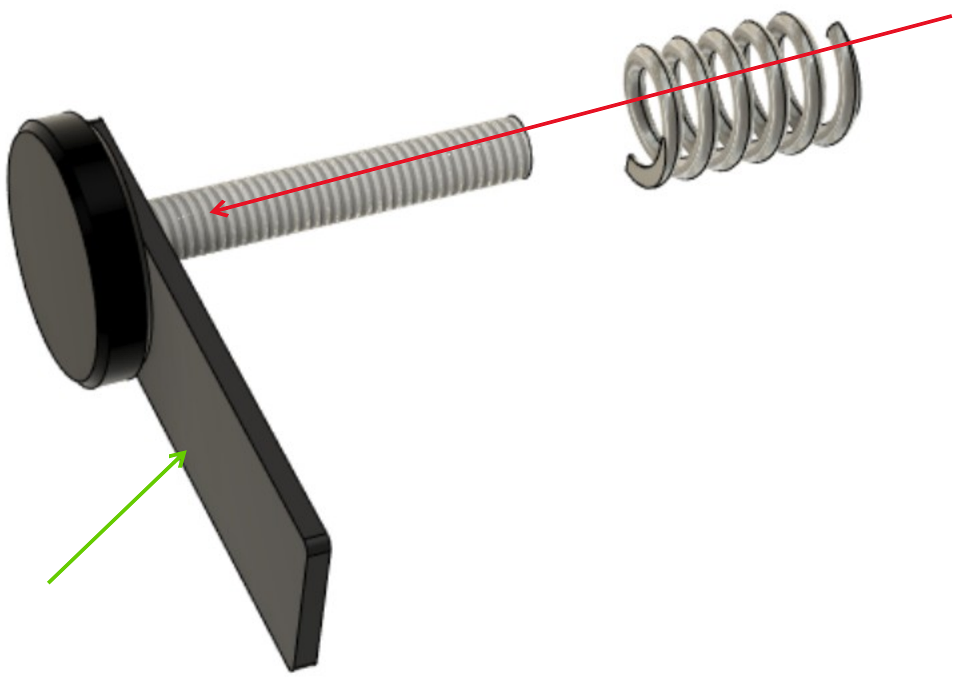
Align and seat Printed Part 02 being sure to squarely engage the bearing with the main 5mm shaft.

Locate CNC Tool Plate and install (2) 8mm balls in the shown locations.

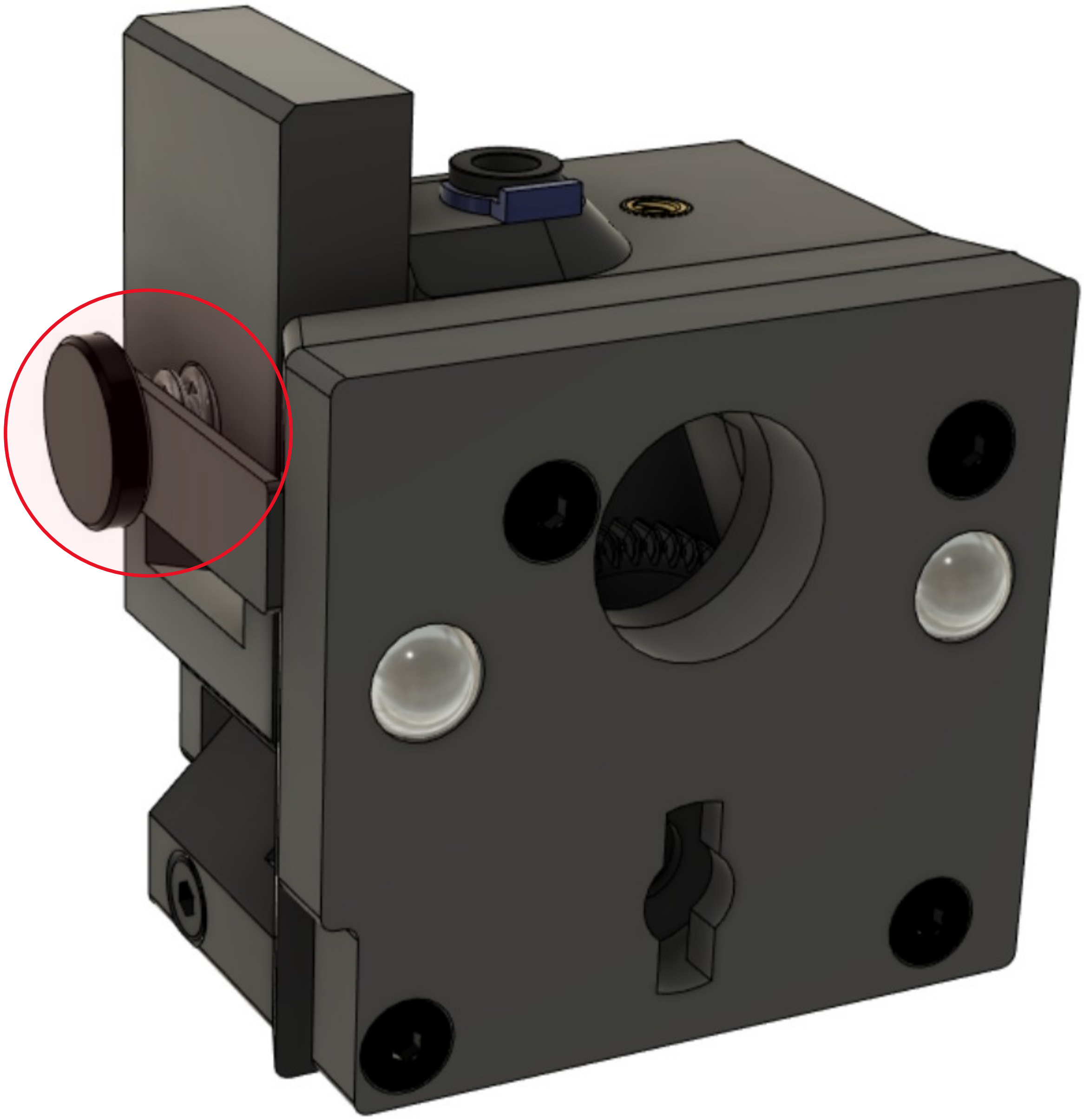


Loosely secure the tool plate with the main body using (4) M3x16 FHHS

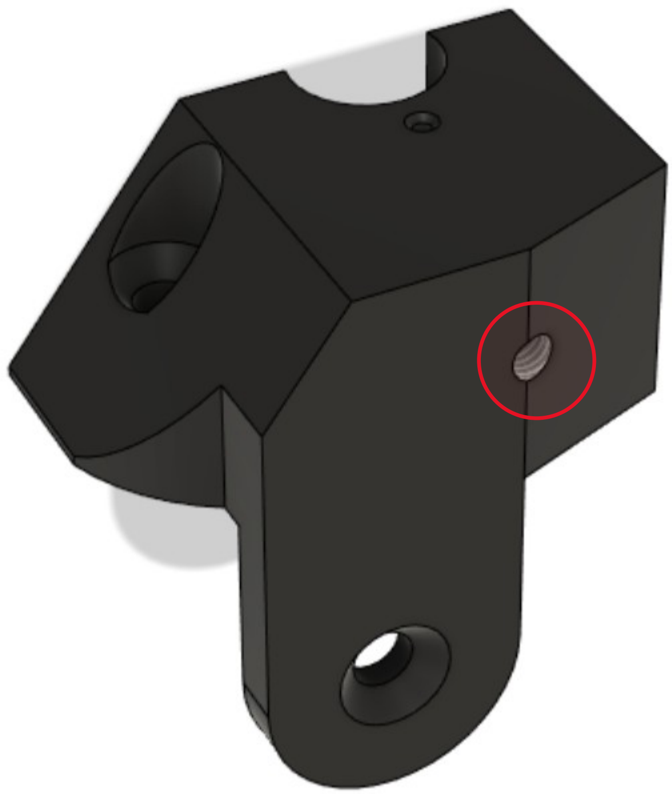
Locate the Bondtech thumb screw and temporarily remove the spring (and small spring retention washer. Install Printed part 05 against the inside face of the thumbscrew and reinstall the spring and retention washer.



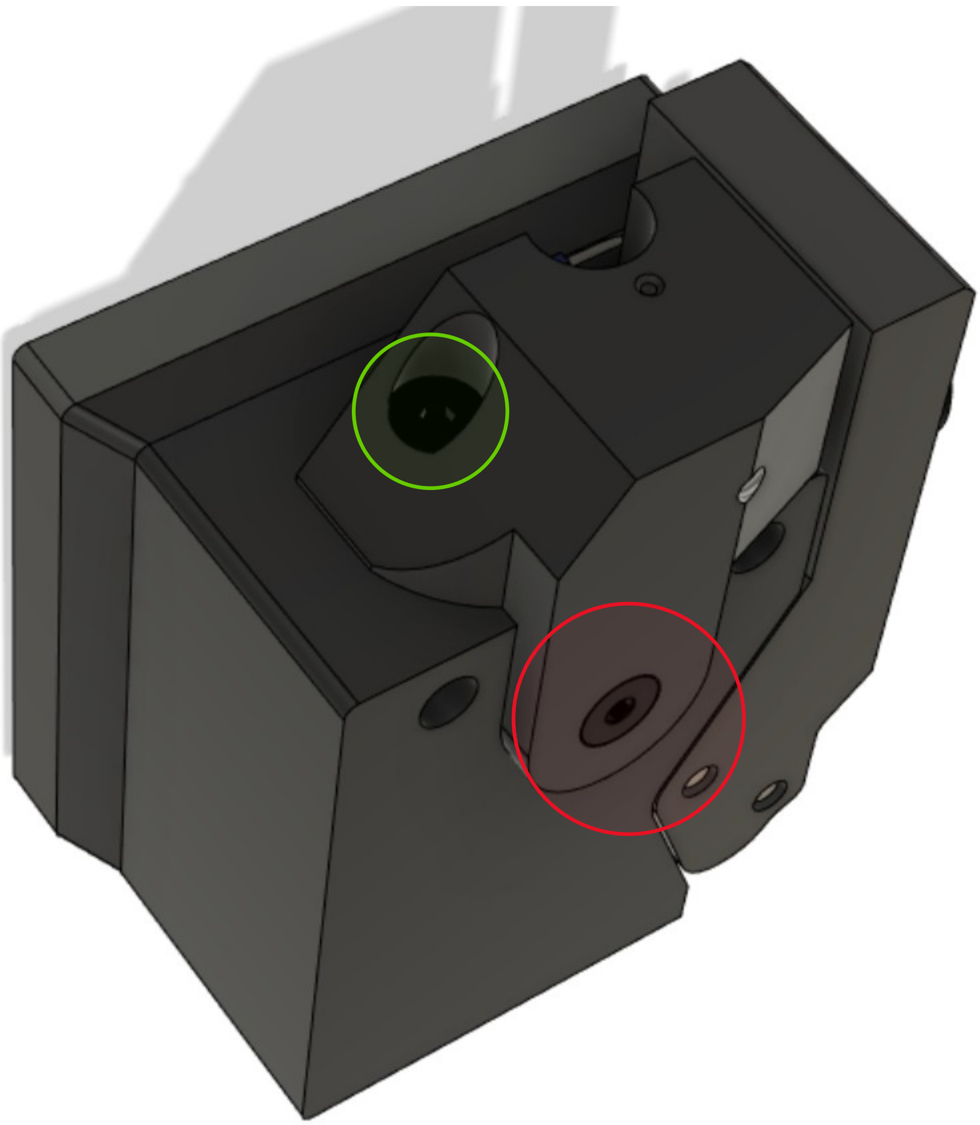
Loosely install thumb screw through the latch and into the heat set insert of the main tool body.



Locate Printed Part 04 and use an M3x-.5mm tap to create threads at the shown location. Temporarily install an M3x6mm set screw in this location for use later in assembly.



Fit part 04 to the main tool body as shown. Secure using an M3x8mm FHHS at the location in red, and an M3x10n FHHS at the location in green.



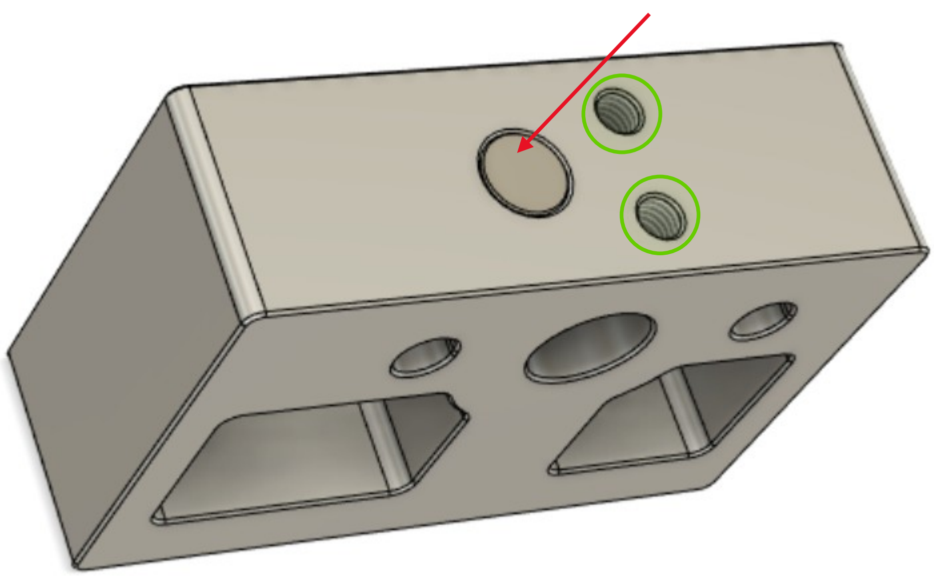
Locate CNC Tool Cooler Block and orient as shown.

IMPORTANT: Magnet polarity matters! Once installed it is very difficult to remove this magnet without permanent damage to the tool cooler block. The shown face below at which we will be installing the magnet will ultimately face and interact with the tool dock. The magnet must be installed so that it attracts the previously installed 5x10 magnets along the idle tool cooler bar.

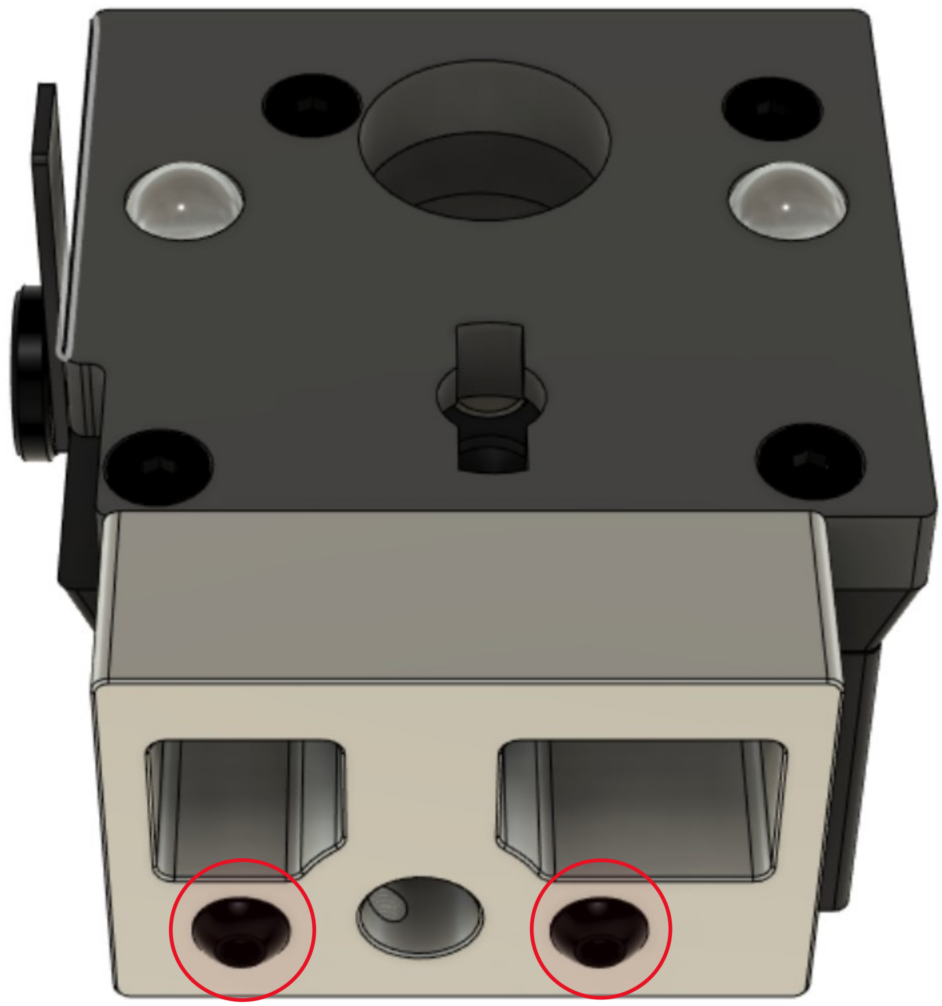
NOTE: Shown below is a standard tool cooler for use with slide-in heat breaks such as the Chimera/Kraken from E3D. If you are using instead a threaded tool cooler the two threaded set screw locations in green will not exist.

Press a 5x4mm magnet into the bore shown in red and be sure the magnet is fully seated. It must be confirmed that the magnet sits either flush with or below the surface of the CNC tool cooler.

Tip: Avoid the use of sharp objects or harsh blows to the magnet itself. Neodymium magnets are extremely brittle. A 5mm reamer may be used if needed, but generally this is not the case. For best success consider warming the cooler block before inserting the magnet. This can be done with safe use of a small butane/propane torch or even setting the block on the build plate of another 3D printer at 60-70C.



Secure the tool cooler assembly LOOSELY to the main tool body as shown using (2) M3x18 BHHS



THIS SECTION CONTAINS OPTIONAL TOOLS/WORKFLOWS. Already have a reliable method for precise Bowden tubing cutting? See "Target Length" below and skip the next six pages.

Prepare a short length of Bowden tubing for use between the heat break and tool body in the following steps.

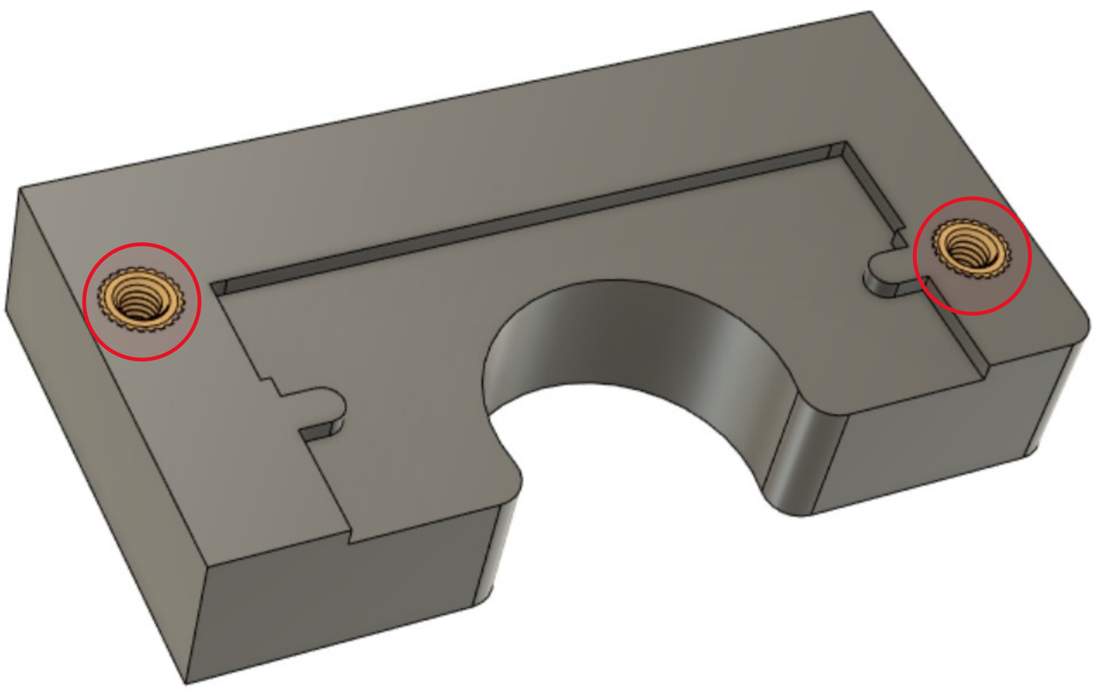
NOTE: This is not applicable to E3D Revo equipped tools!

Target Length (nominal)

Standard Smooth Bore Cooler Block with Kraken/Chimera Heat Break = 12.8mm

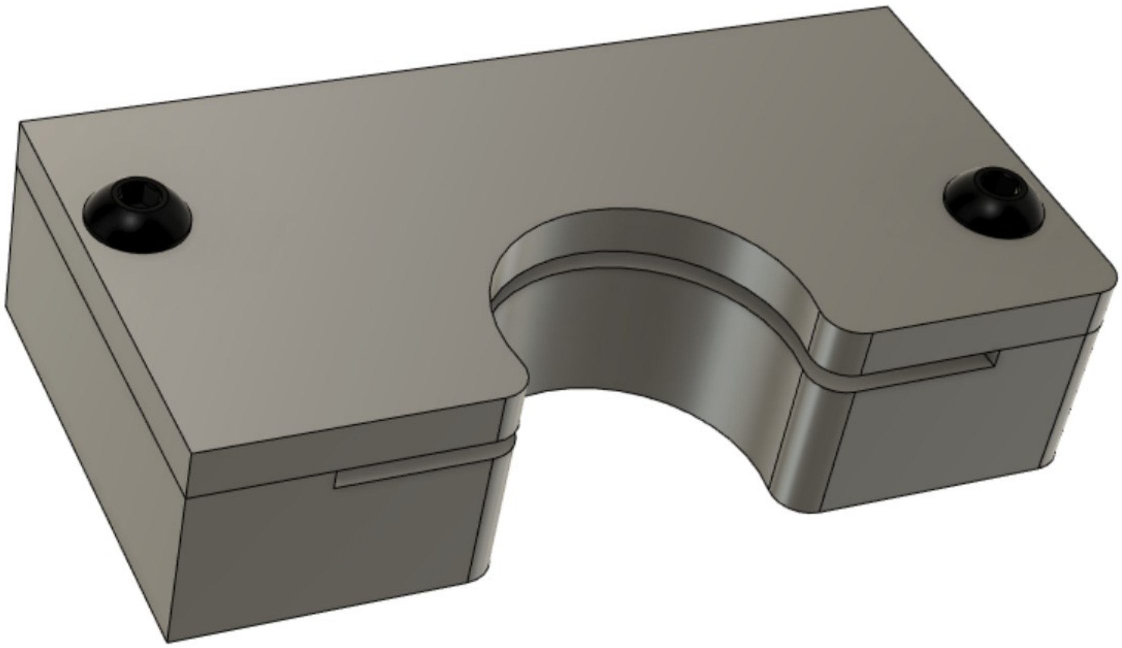
Threaded Tool Cooler Block with E3D Titanium Heat Break = 13.2mm

Being by installing (2) M3 heat set inserts into Bowden_Tool_Part_A:



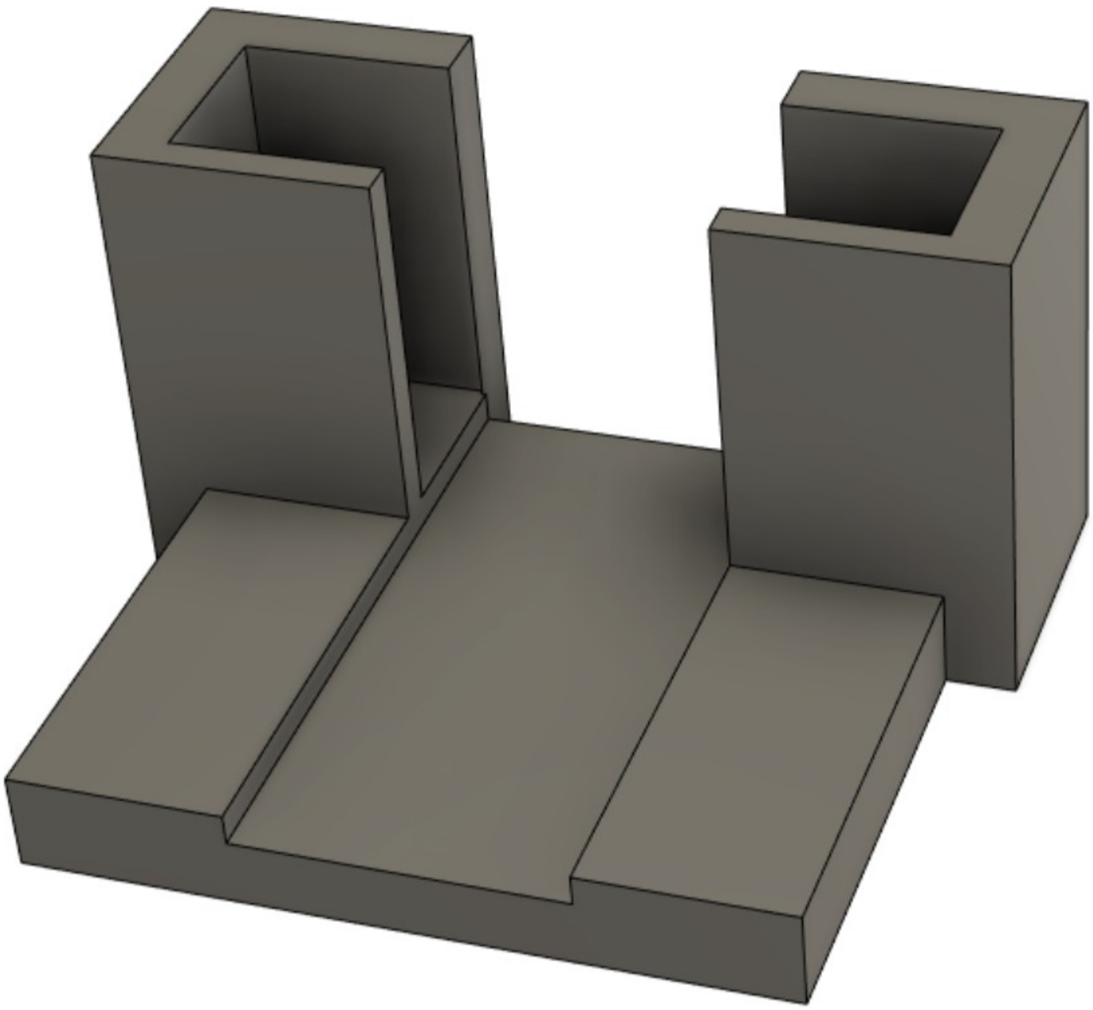
Place a standard hardware store razor blade into position. Be Careful!

Install Bowden_Tool_Part_B and secure using (2) M3x6mm BHHS.

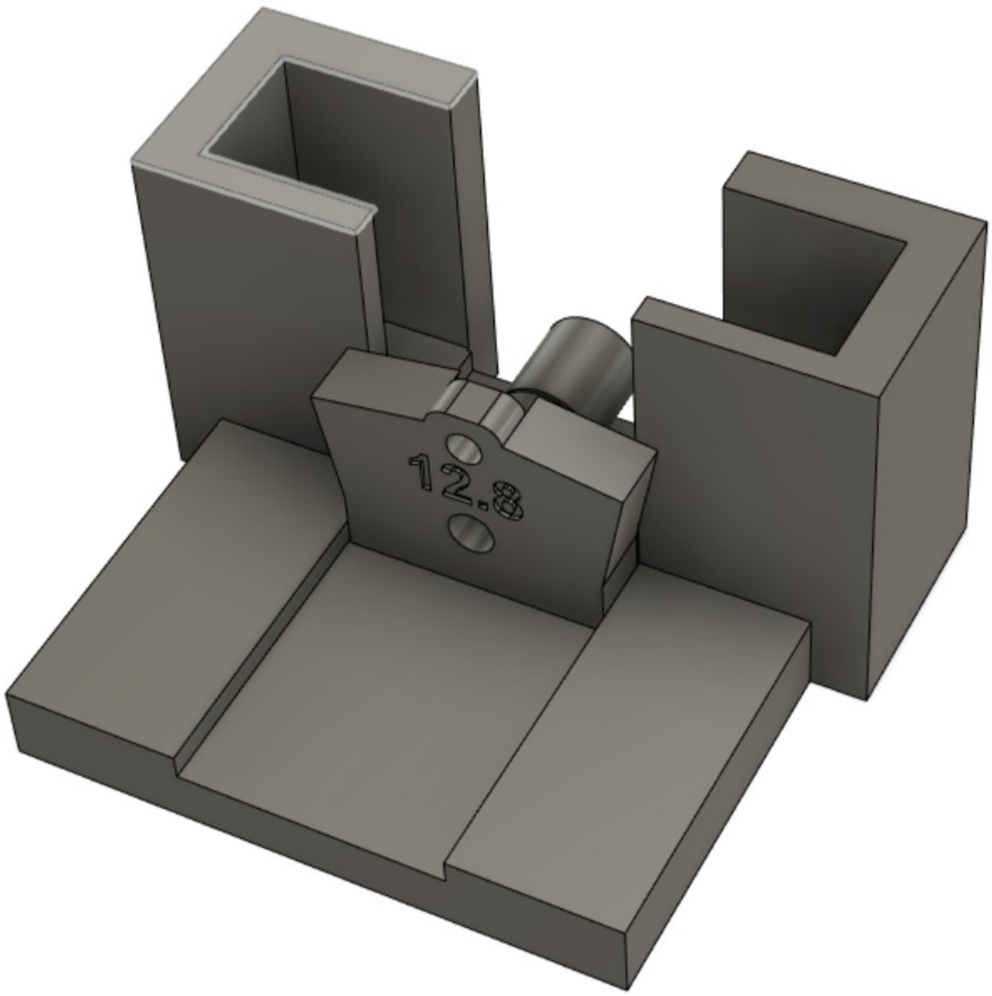


Set aside.

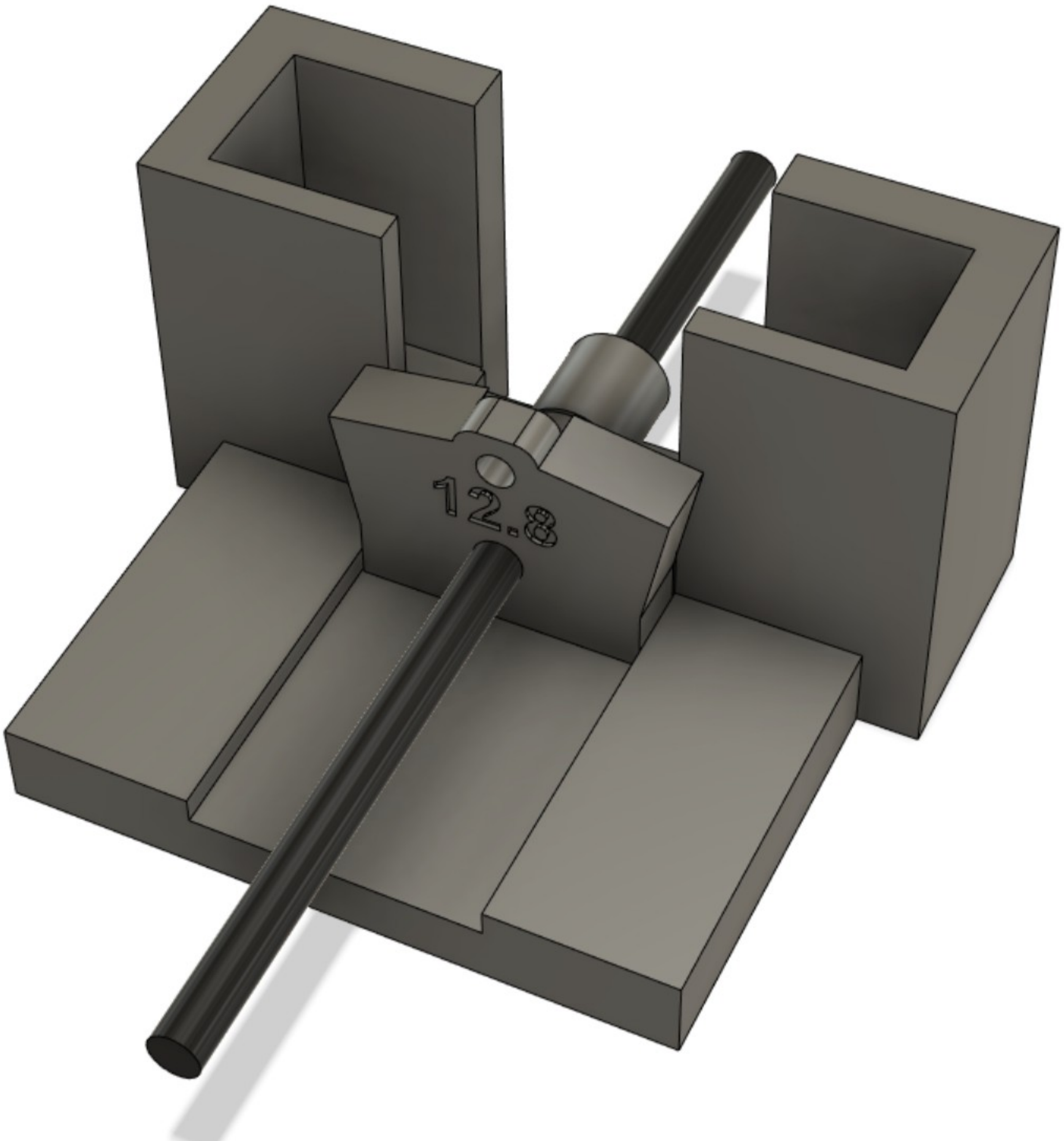
Locate Bowden_Tool_Part_A and orient as shown on your work surface:



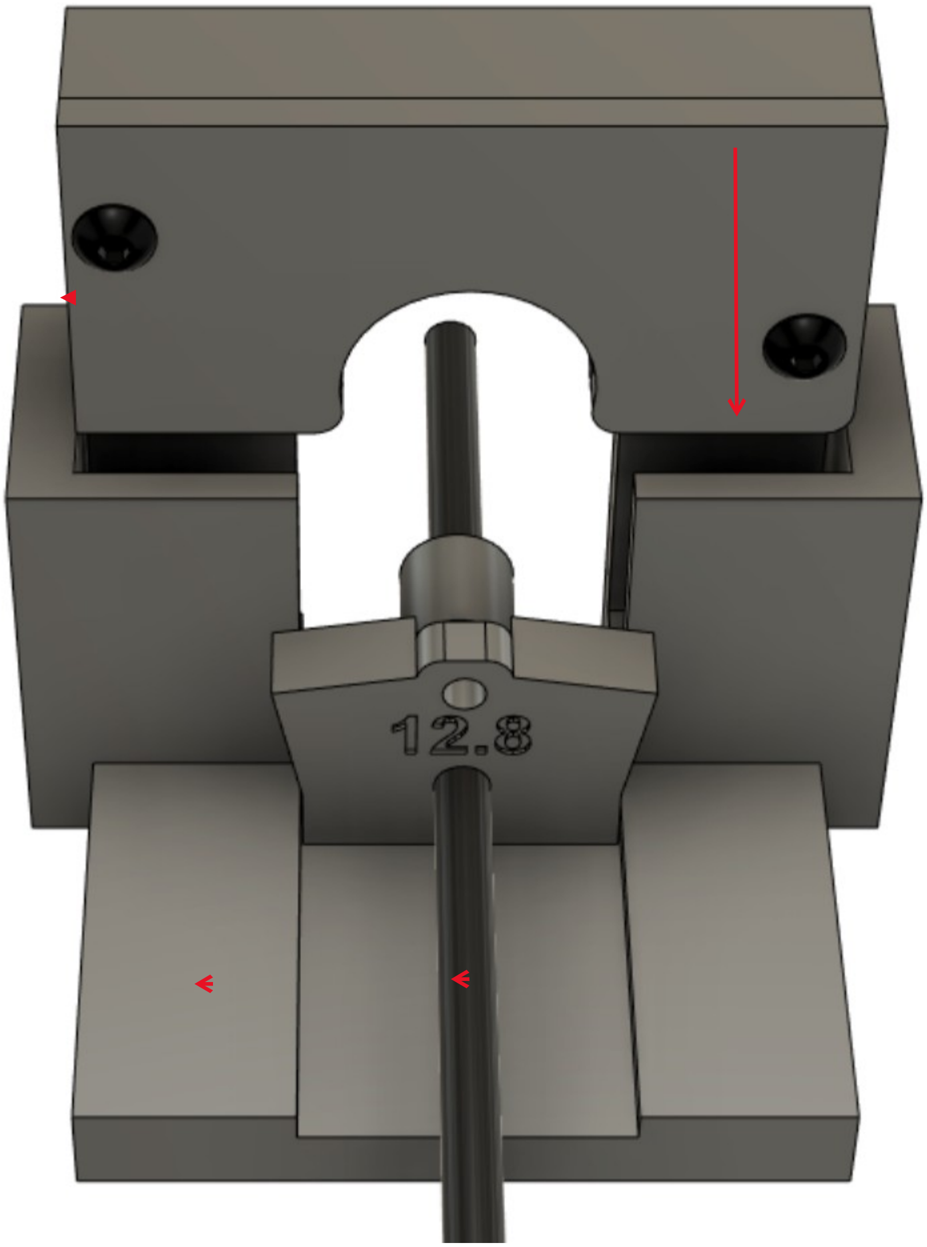
Locate Bowden_Tool_Part_D and place into Part A as shown below. Note that there are two or more optional STL's for Part D. Be sure to print and use the STL that has the correct nominal length appended to the file name. Note that for walk-though purposes we will be using the 12.8mm die for standard smooth bore heat breaks.



Slide a length of Bowden tubing through the die. We will begin by performing a first cut to square up the end of the Bowden tube. For this cut the exact position of the tube is not important.

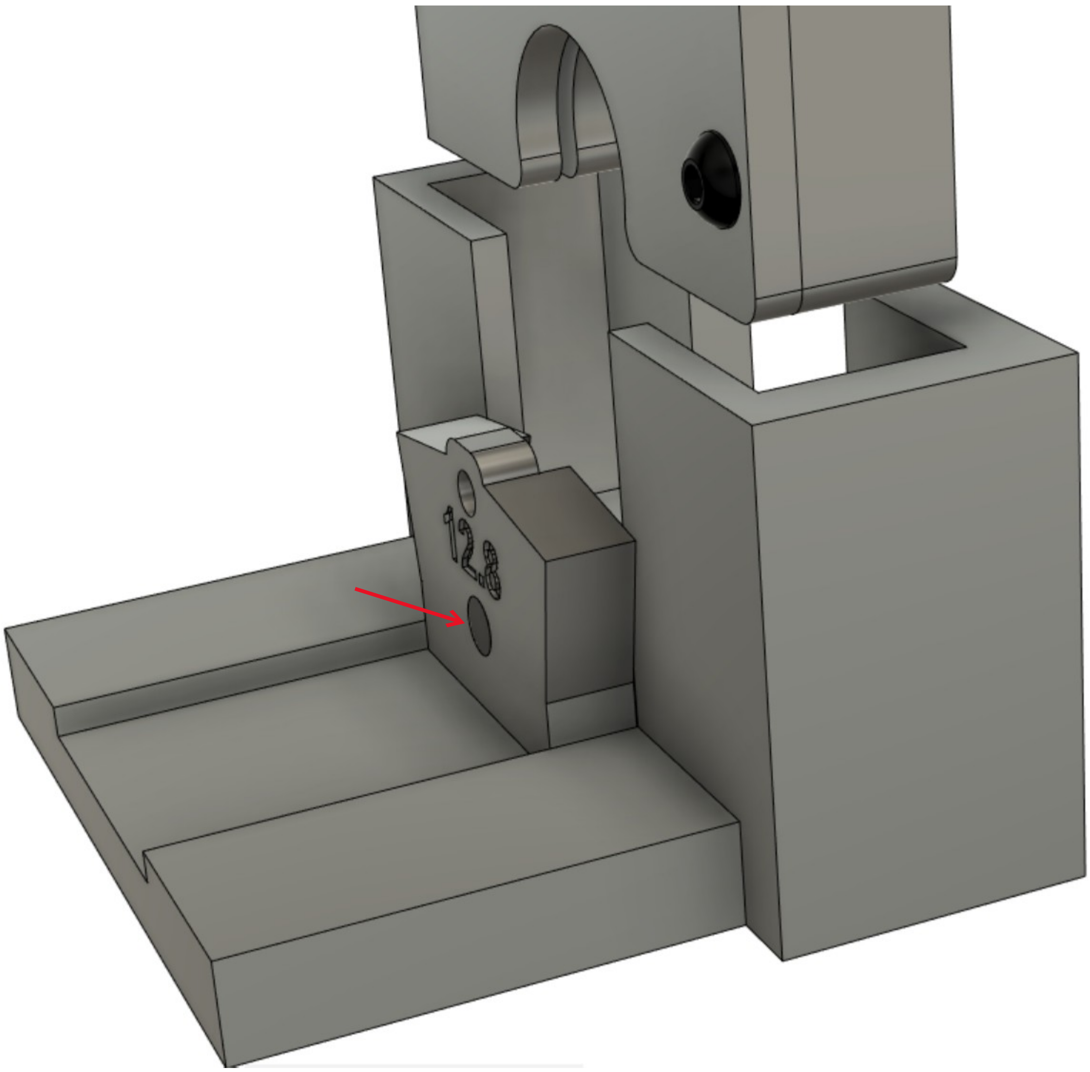


Slide the blade equipped cutting tool downward into the housing while keeping light inward pressure on the die so that it remains seated against the housing. Push downward completely to perform the first cut.



Remove the cutting tool and Bowden tubing from the jig.

Repeat the setup for the second cut but this time our goal is to position the end of the Bowden tube that was previously cut with the face of the die as shown below.

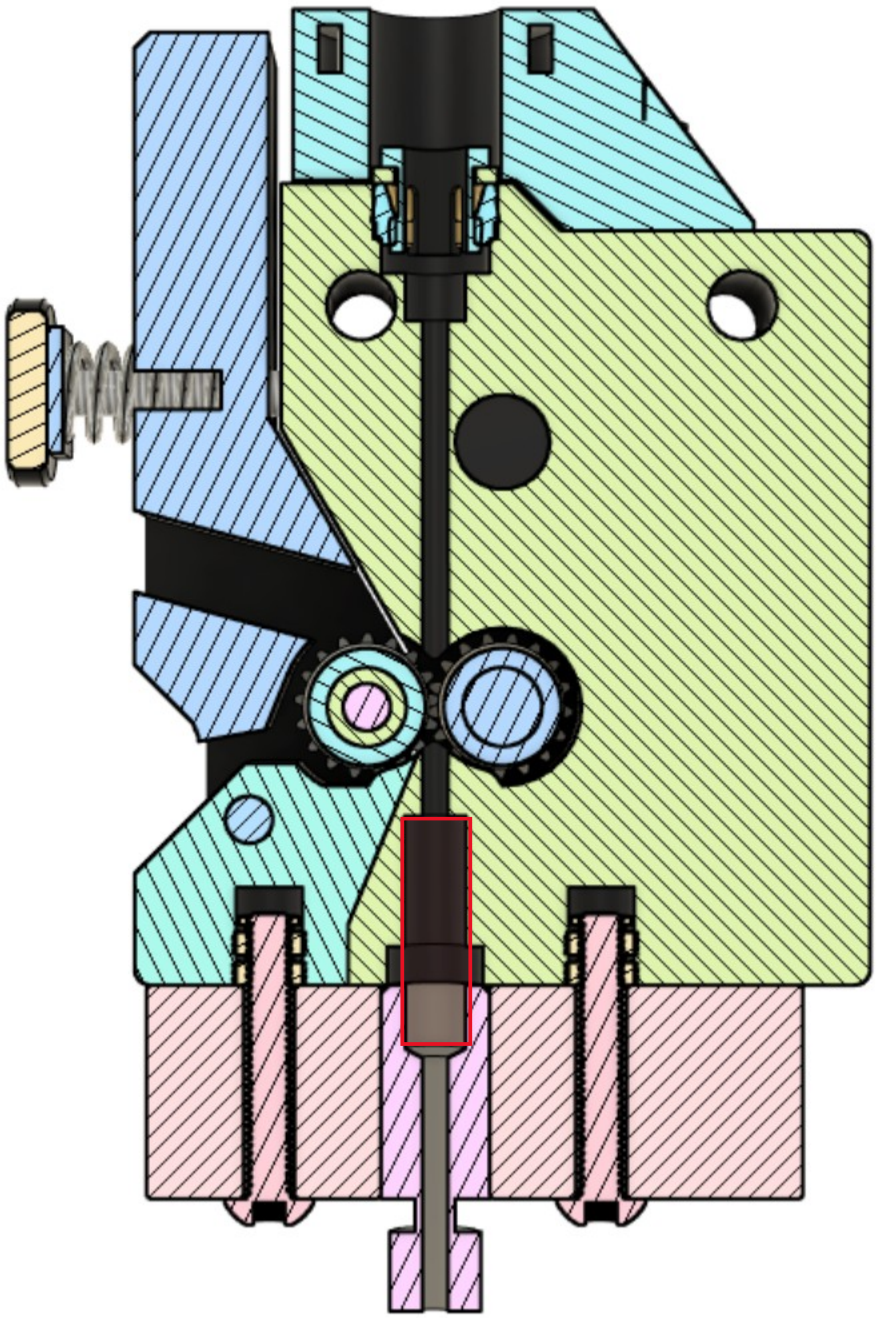


Perform the second cut. The resulting length of Bowden tubing should closely match the nominal value and have visually clean and reasonable square ends on both sides.

Did you know?

This tool is designed parametrically in Fusion 360. Included in your STL kit download is a .F3Z file that allows you to automatically create new die lengths for future projects simply by changing the “Length” value under Modify > Change Parameters!

Insert the previously cut length of Bowden tube into the main tool body and make sure it is fully seated. The below cutaway shows the correct location for the tube when fully assembled. Our goal here is too completely fill this void in the filament path with a length of Bowden tube WITHOUT causing the tube to collapse or deform due to too much length/material.



Apply a light coating of thermal paste to the heat break. This step is relevant to all styles of heat break.

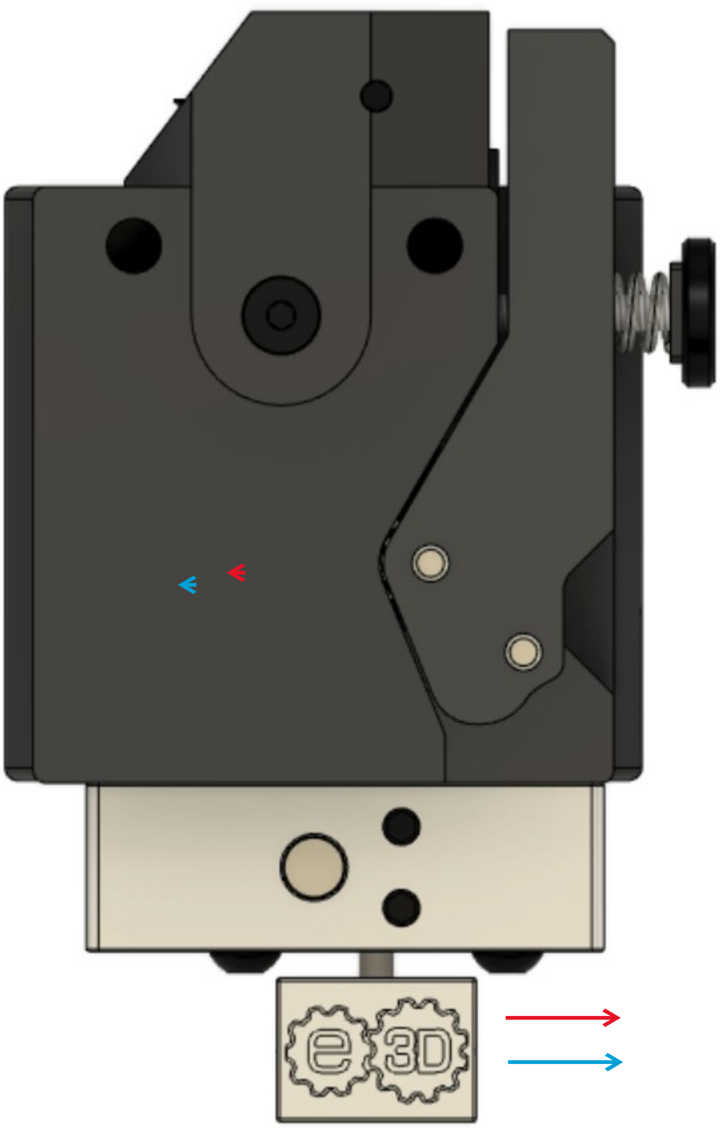
Push upward on the heat break and tighten the two M3x18 BHHS shown in red. Secure the heat break with (2) M3x4 set screws shown in green.

Thread on the heat block using the image below for a height reference showing the ideal final location of the hot block.

Not shown here:

We will also now install the heater cartridge using an M3x10 BHHS to pinch the heater block around the cartridge itself. Finally, install and secure the thermistor using an M3x4 set screw. showing wires exiting the correct side. Reference the V6 assembly guide from E3D for further information.

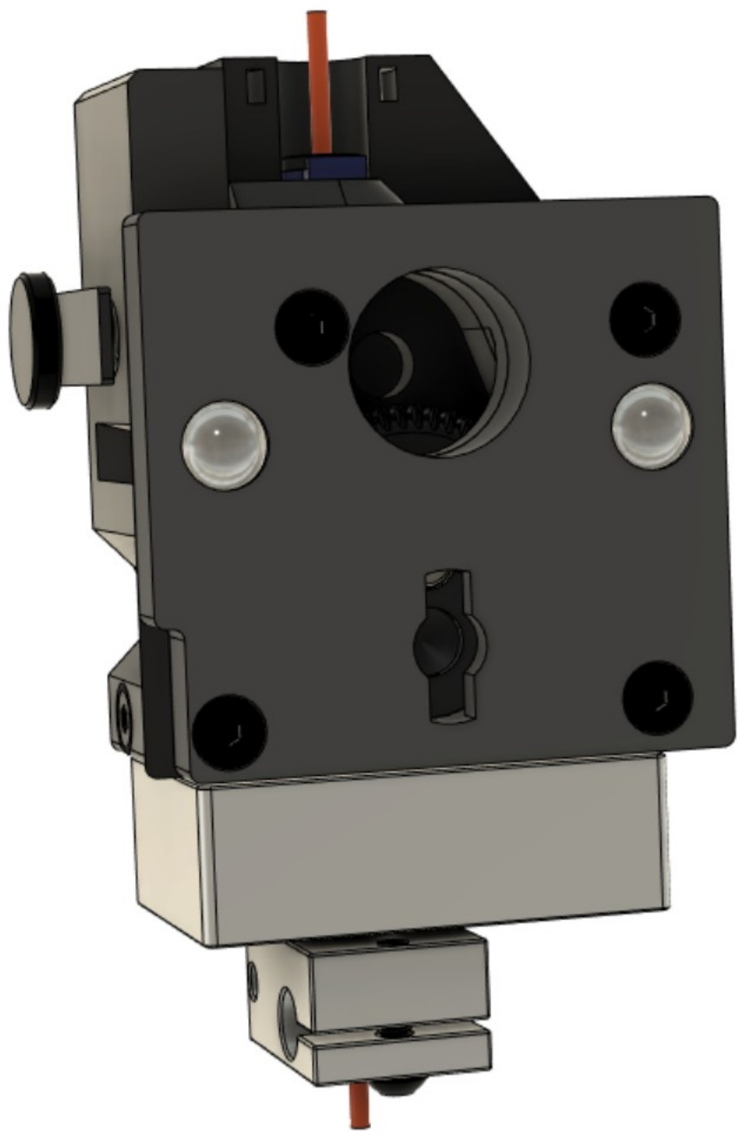
The wires themselves should exit the right side as reference from the image below.



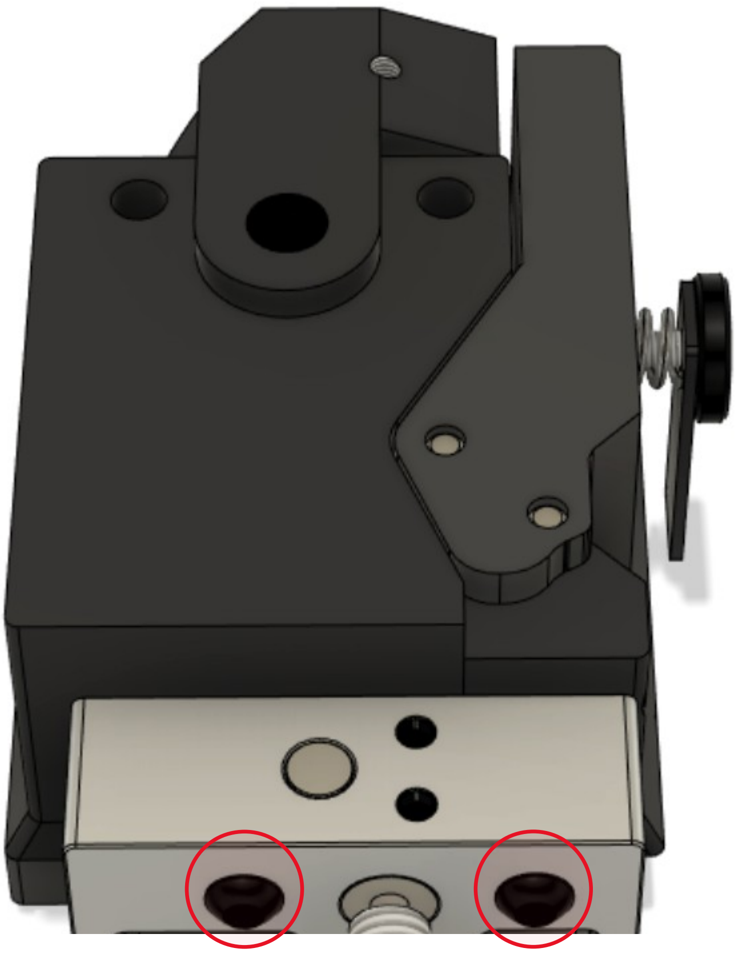
Before proceeding take the time now to ensure that filament enters and exits the drive gears smoothly with no hang ups. A properly assembled tool with a clean filament path will allow you to push a length of filament through the entire tool without snags or high resistance.

Things to consider:

1. The amount of tension on the latch arm may need to be adjusted for this dry run test.
2. You can rotate instead the 51 Tooth gear through the SLS drive gear hole with a finger to gain some mechanical advantage.
3. Take the tool apart if you need to! Now is the time for these adjustments.



Loosen again the M3x18 BHHS.

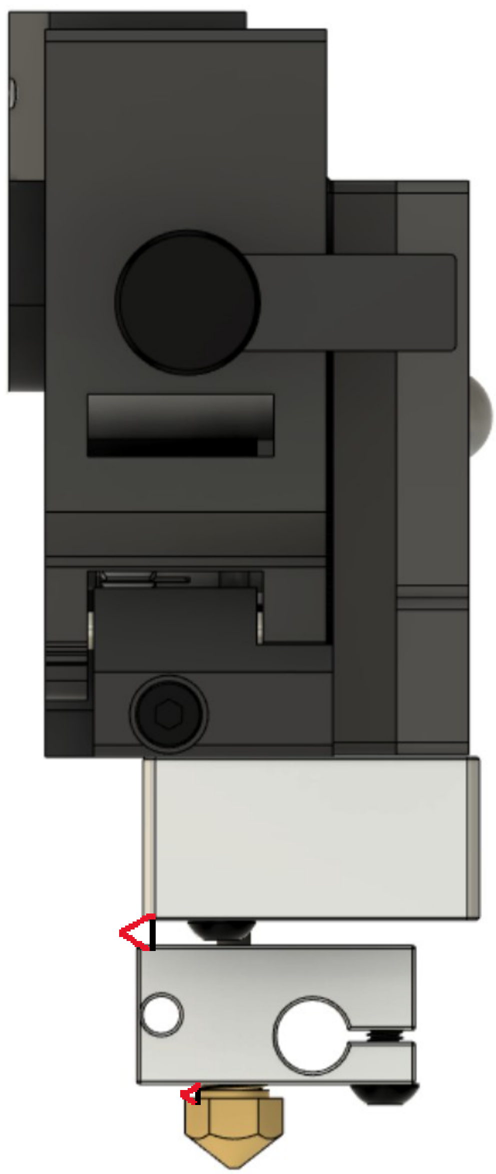


Install a nozzle and torque against the heat break.

This process is identical to the buildup of a standard V6 hot end and many other hot ends on the market. See E3D's V6 Build Guide for help if you're not familiar.

Things to consider:

1. Maintain a gap between the hot block and the cold block.
2. Maintain a gap between the hot block and nozzle face.
3. When fully tightened be sure the heater block is nicely square.
4. Do not install any silicone boots at this time.



Step 3 – FDM Tool Alignment & Adjustment

We will now be making some adjustments to the FDM tool. One of the consequences of using the tool cooler's contact with the X plate as a point of constraint is that our printed parts and other hardware tolerances must be accounted for.

An overview of the steps performed in the next few pages:

Position the complete FDM tool against the X plate.

Adjust the angle of the tool so that the distance marked in Red is equal on both sides using a printed tool.

Adjust the tool cooler block so that it is flush with the X plate (marked in Blue) while maintaining the equal distance marked in Red.

Tighten the (2) tool cooler fasteners marked in green.

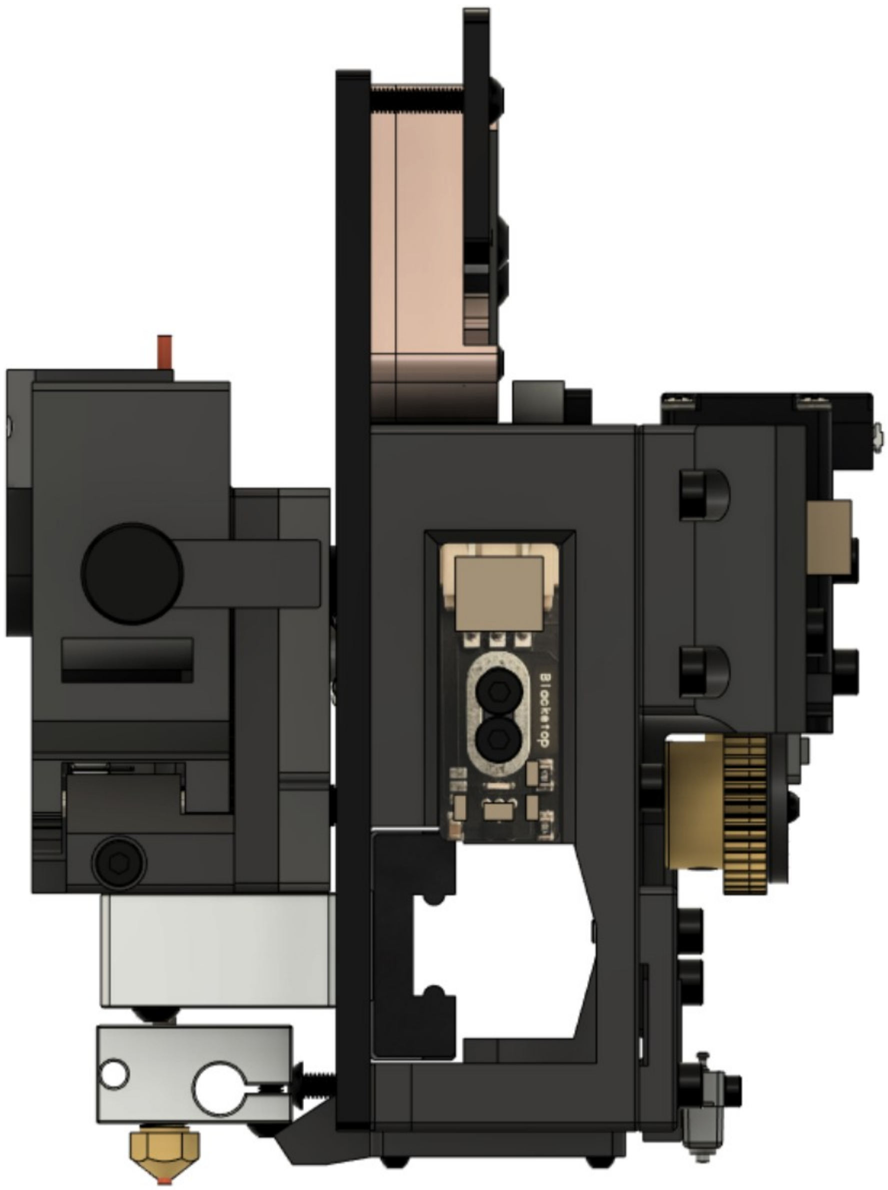
These adjustments are extremely important! If after tightening all fasteners any of the above conditions are not repeatable, address this now!

Position the tool against the X-Plate:

There are 3 total contact points between the tool and the X plate.

1. Kinematic Coupling Left (3 point)
2. Kinematic Coupling Right (2 point)
3. Cold Side of hot end to X-Plate (1 point)

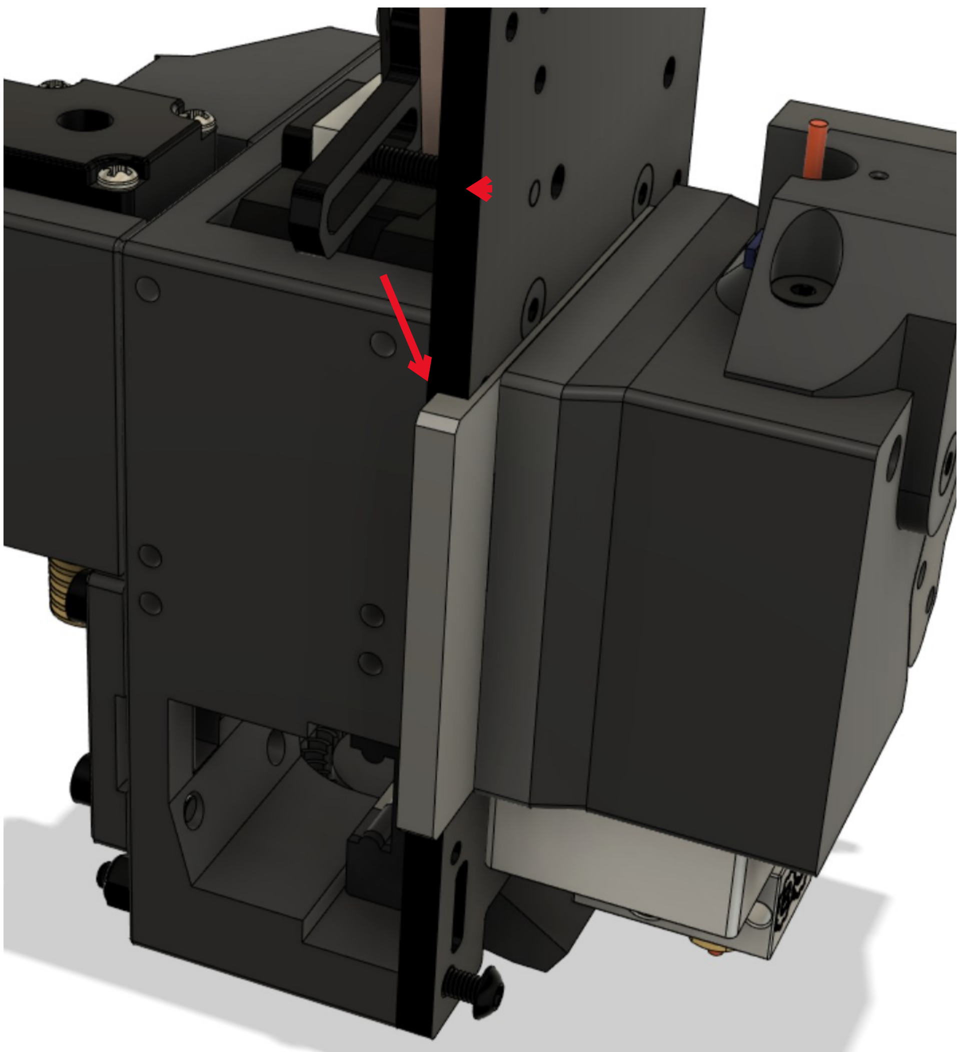
Ensuring that your tool lock is in the vertical position, place and hold the FDM tool onto the X-Plate using the two steel balls and pockets as a guide. This should require no effort, and the tool should not stay in place without holding it. See next page.



Install printed tool and tension:

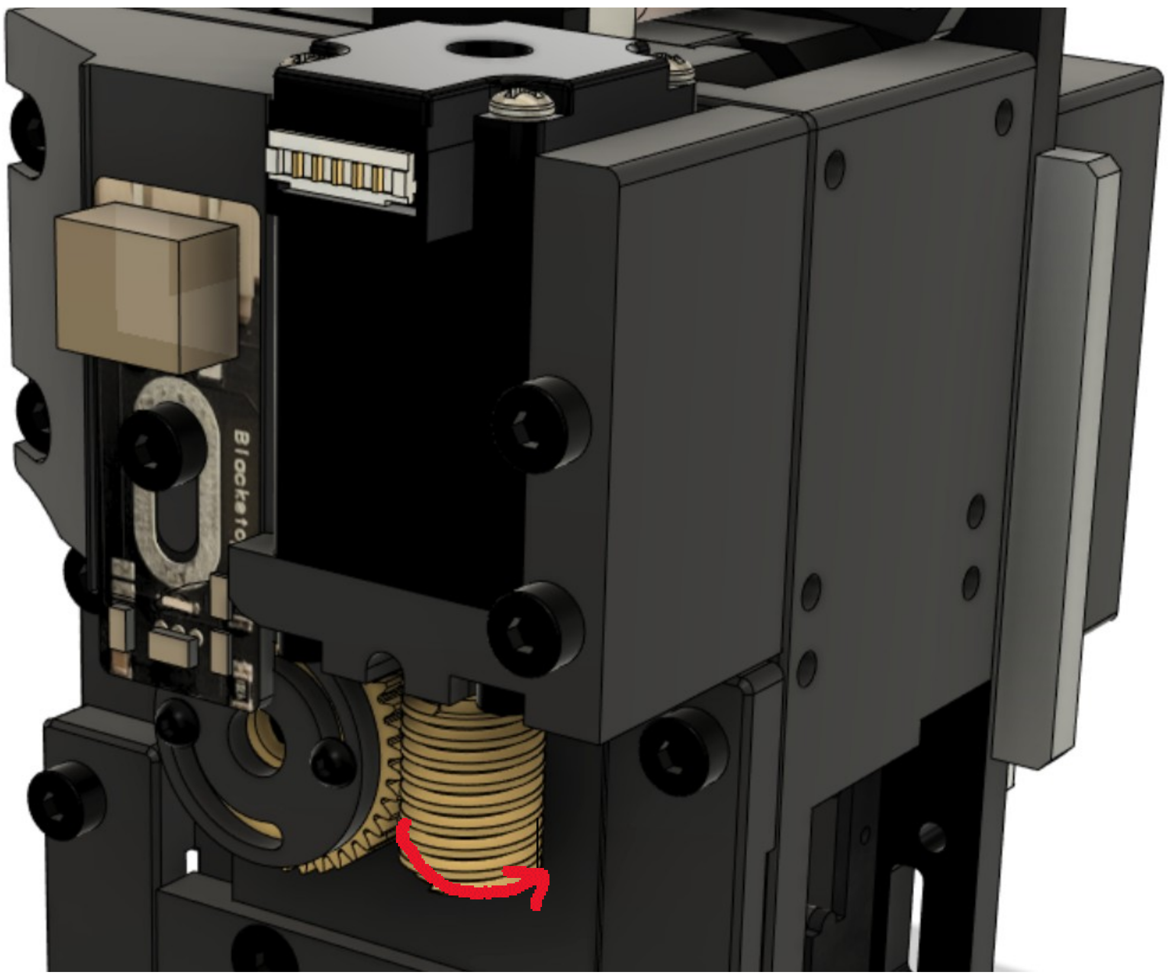
Locate Print_AssemblyTool_KinematicSpacer and insert in the below shown location. Note that the position of the tool is flush with the top of the tool while the flange is flush with the X-Plate.

Continue supporting the tool through the next page.



Tensioning:

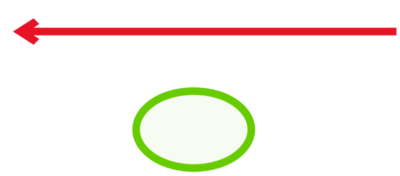
Rotate the tool lock drive (worm) gear attached to the Nema 8 motor in the counter-clockwise direction until you can feel the tool-lock begin to draw in the tool assembly. Continue rotating until a light tension force is achieved. When this happens, the tool will support itself against the printed tool and kinematics without any gaps or excessive play when referencing the Tool Plate to the X-Plate. The next page will adjust the Tool Cooler Block’s position.



Adjustment:

Apply light force to the tool cooler block in the direction of the X-Plate. The cooler block should reach the X-Plate without the tool body lifting or moving out of place against the printed tool. Additional tension can be added to the tool lock if this occurs.

While maintaining force against the tool cooler block, fully tighten the (2) M3x18 BHHS shown in Green.

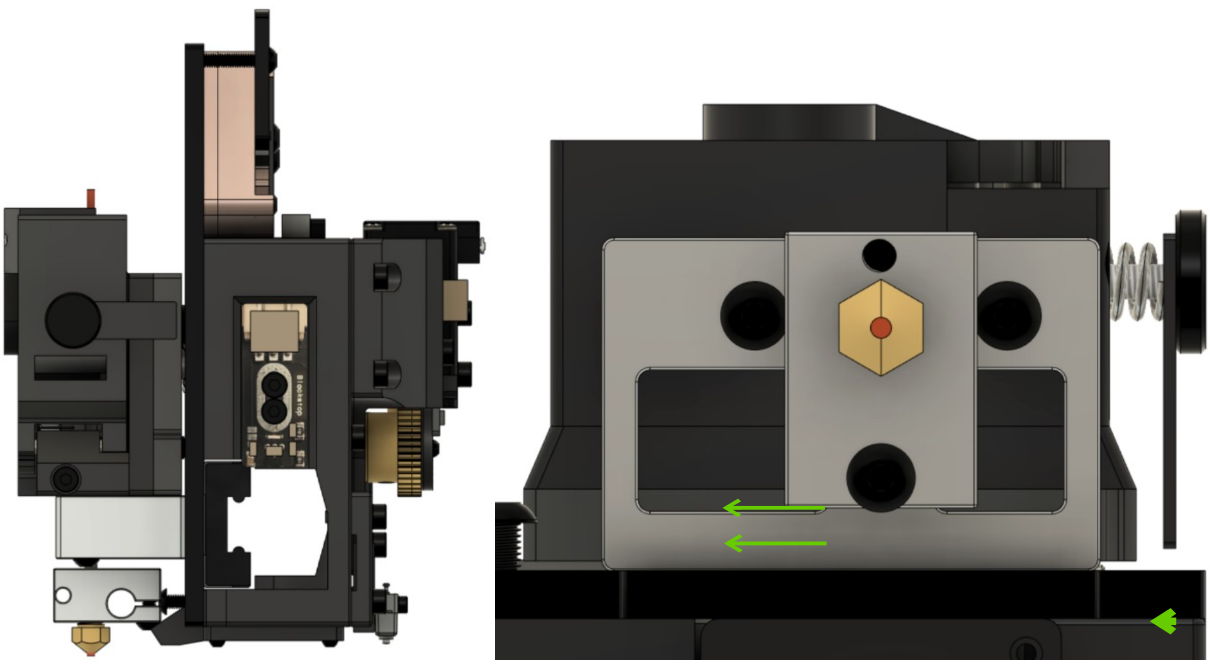


Check and Repeat:

Slightly loosen the tool lock's tension on the tool body. Remove the printed tool. Re-tension the tool body with the tool lock (without the tool in place) until a moderate tension force is achieved.

Check that all the following are true:

1. The Tool Cooler Block is resting squarely against the X-Plate in both directions. Use a flashlight ahead of your chosen viewing angle to confirm that no light shines through this interface. This interface is what will cool your hot end during printing!



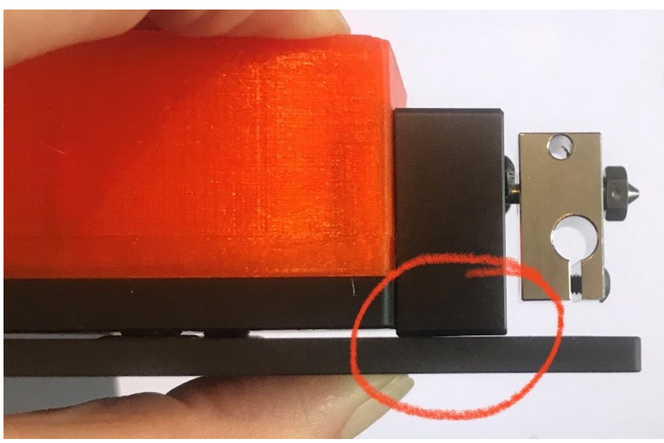
2. Grab hold of the Tool body while mounted and ensure that there is no clearance/play in any direction when the below shown motion is applied. Note that with high hand force you may be able to over-power the tool lock tension and thus the balls will move from their sockets. With light force however no free play should be present in this system.

If you were able to confirm the above – Congratulations! This is a testament to your assembly discipline up to this point! Move onto the next step.

If you were not able to confirm the above:

Both above checks rely on overlapping variables, so a failure of one test will usually result in failure of both tests. Here are some things to consider (working your way from the top down):

1. Before proceeding – Try Again. Be sure you understand what we're aiming for and why. This will help you address issues. Your printed tool should measure ~ 0.6mm thick at all locations. Make sure the tool has no high spots from retraction or and over extruded top layer.
2. Try without the printed tool – The printed tool has a geometry that expects a high level of printed part accuracy to be useful. The process can be done without it by using your eyes to maintain the distance shown in red on the first photo of this step. If the final checks pass, it doesn't matter how you get there.
3. Printed part precision – The printed parts used in this guide are some of the most important when it comes to being geometrically accurate. If you have not produced a passing Blackbox Readiness Test Print there is a higher chance that the printed parts are causing deviations that cannot be adjusted for. See below.
4. The total thickness of the assembled tool is one of the most important factors in achieving a flush tool cooler. If you find that your kinematics operate properly but your tool cooler is at an angle (when looking from the front or rear of the machine) you likely need some small adjustment that can be carried out without reprinting. See Below.



In this example a gap exists toward the bottom side of cooler block. This is a result of an overall too-short print height in the Z direction when printing FDM_Tool_Part_03 and FDM_Tool_Part_02. While shims can be added to address this (simple paper gaskets can work) it is usually best to instead consider a reprint of Part_02 after determining the reason for the short Z. Note that a single layer can make a difference here in some materials!

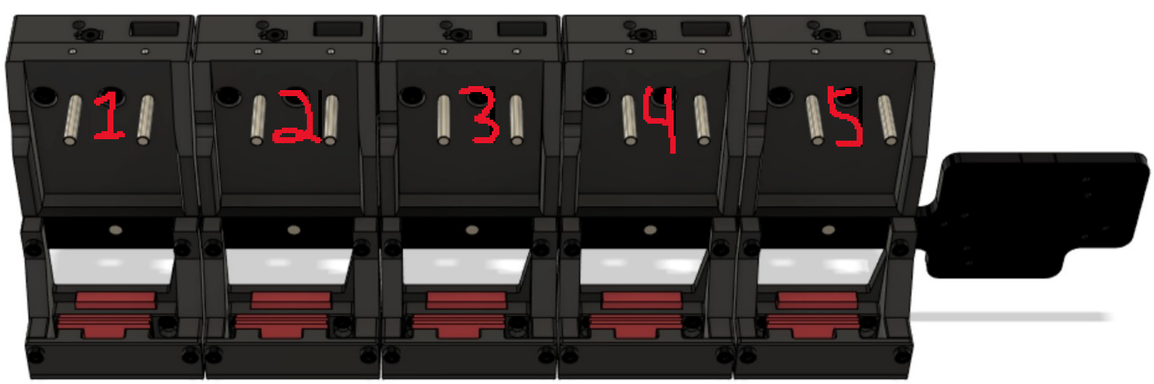
If however your gap is opposite this, your printed parts are too tall. Removing the Tool Plate and lightly face sanding Part 02 and/or Part 03 in incremental guess-and-check amounts will solve this.

Step 4 – FDM Tool Dock Adjustment

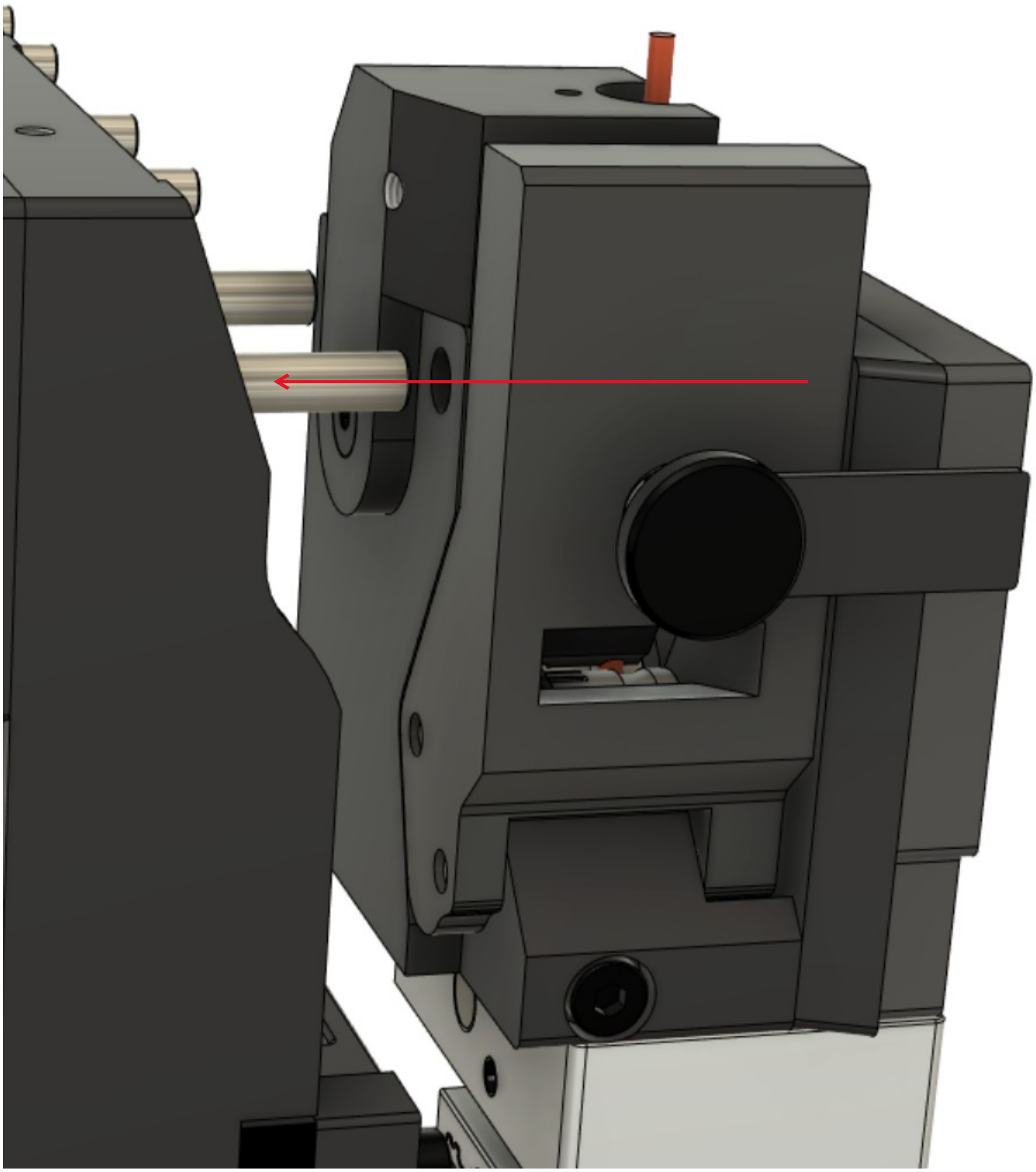
Going forward from here we will now be “marrying” a particular tool to a particular dock. This is because the adjustments made in the step may not be relevant for all tools.

A brief note on tool numbers:

When working in firmware tools have a zero-based index. This means that the first tool is referred to as “T0.” For the purpose of this guide (and general naming convention) we will use the name “Tool 1” when referring to the first tool, despite its true identifier in firmware being T0.

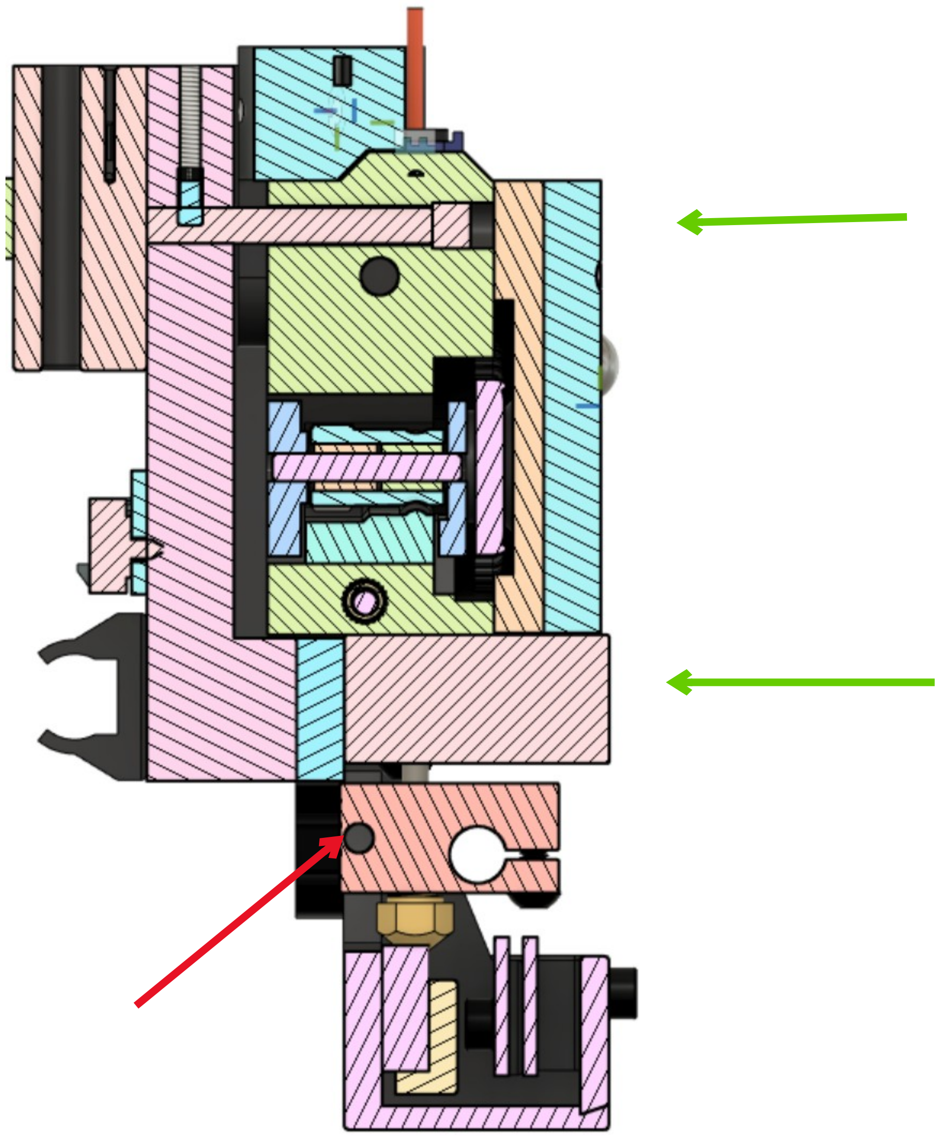


Begin by placing an assembled and adjusted tool onto a tool dock via engaging the 4mm shafts.



Attempt to seat your tool securely to the inward most possible position. This should take very little effort. Compare your tool's docked position to the following check list:

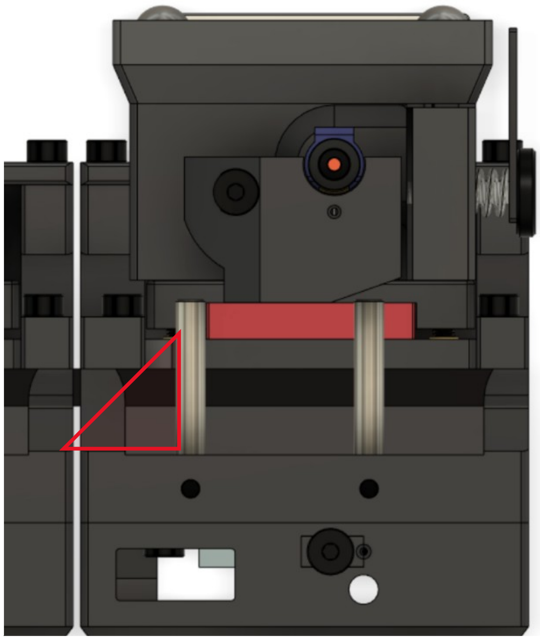
1. When approached squarely the tool should slide smoothly on the 4mm shafts. It's worth noting that our hands are not as precise as the motion system we just built. You may have to change your point of reference and/or angle of approach to achieve smooth motion.
2. As the tool approaches the inner most part of the dock a natural pulling force should begin to pull the two components together via the 3 magnetic contact points.
3. With the tool in its final docked position the tool cooler block should evenly contact the idle tool cooler bar, just as did the X-plate during the previous step's adjustments. See this location in Red below.
4. With the tool in its final docked position there should not be any resulting movement in the tool itself when light alternating pressure is applied to and of the locations shown in Green below.

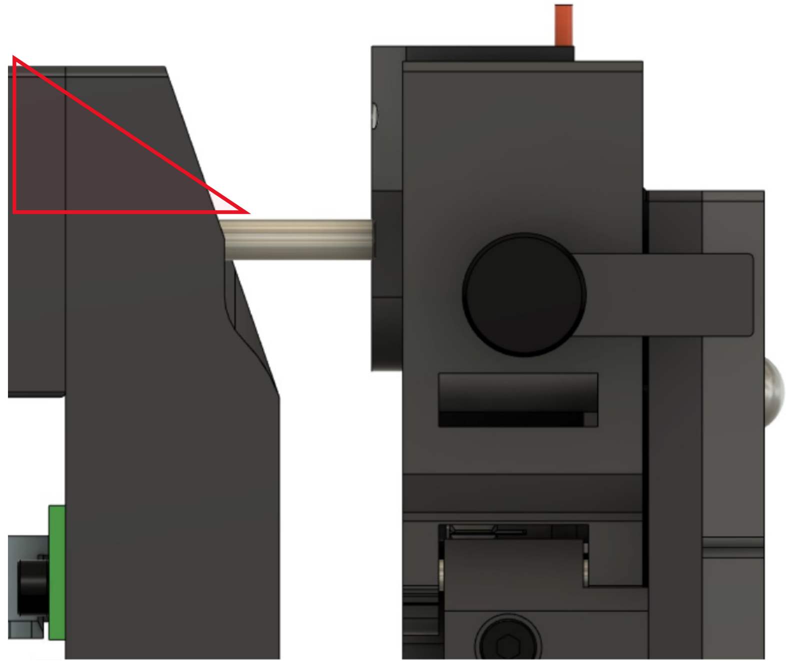


If any of the above checklist items fail, see the corresponding tips below for troubleshooting guidance.

Test Point 1 failure:

1. Ensure that the 4mm shafts protruding from the tool dock are visually perpendicular to the face of the dock itself when viewed from both the side and the top of the machine.





2. Ensure that no contact is occurring elsewhere causing the binding. This can come from heater/thermistor wires out of place, a nozzle leak blocker set too high, ETC.

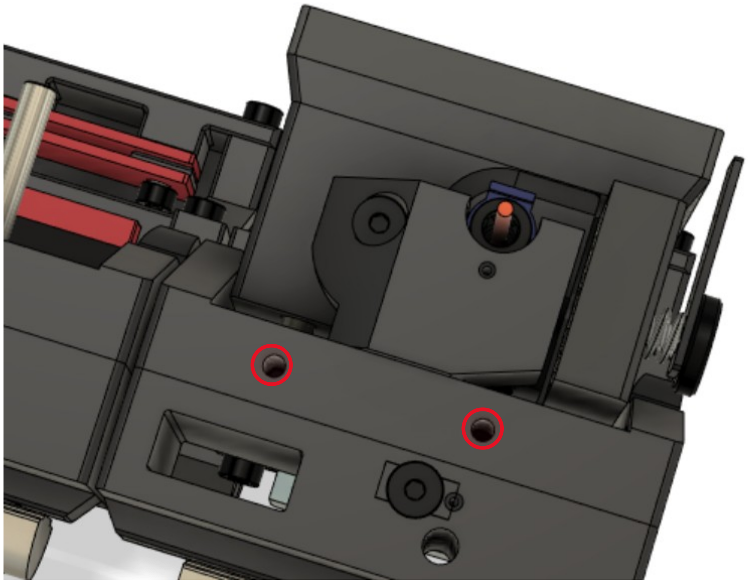
3. If all else is OK, use a 4mm or 4.5mm reamer to clean/expand the bores in the tool that accepts these shafts.

Test Point 2 failure:

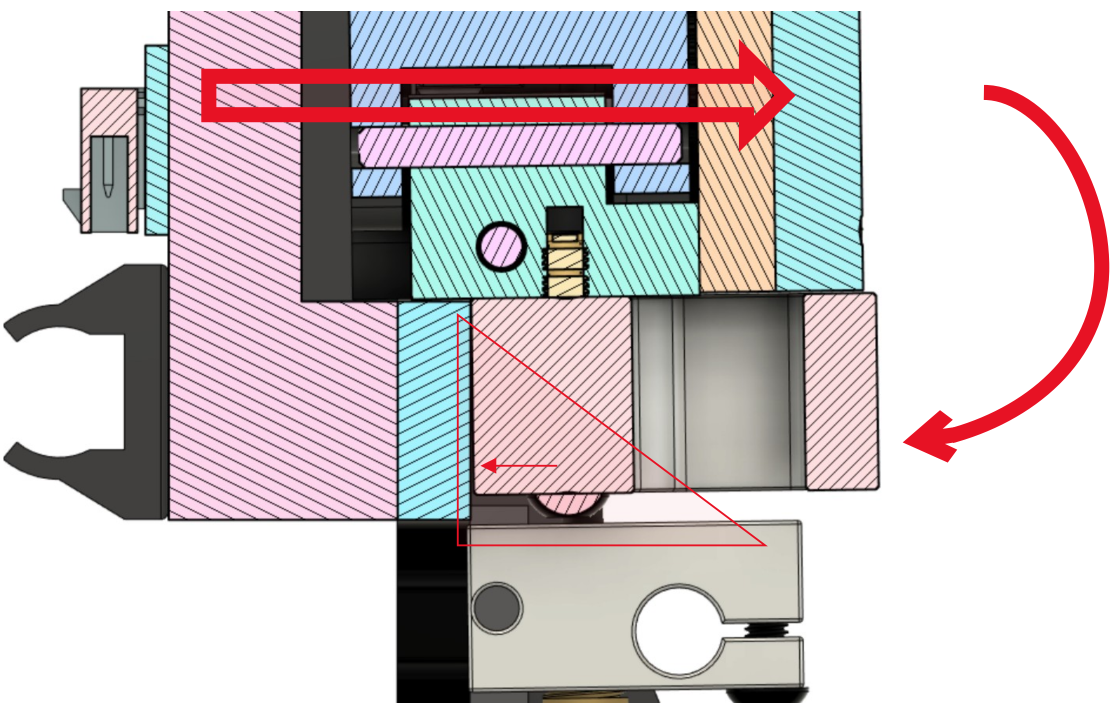
1. Test point one can be directly causing an issue in test point two!
2. The polarity between the lower 5x10 (dock side) and 5x4 (tool side) magnets may be reversed if the lower half of the tool has a resistance to seating. Due to the relatively high constraint offered by the 4mm posts this may not be obvious at first. If a polarity issue is confirmed the only serviceable magnet is the 5x10 type on the dock side. See the previous guide for information.
3. Ensure that no contact is occurring elsewhere causing the binding. This can come from heater/thermistor wires out of place, a nozzle leak blocker set too high, ETC.

Test Point 3 and/or 4 failures:

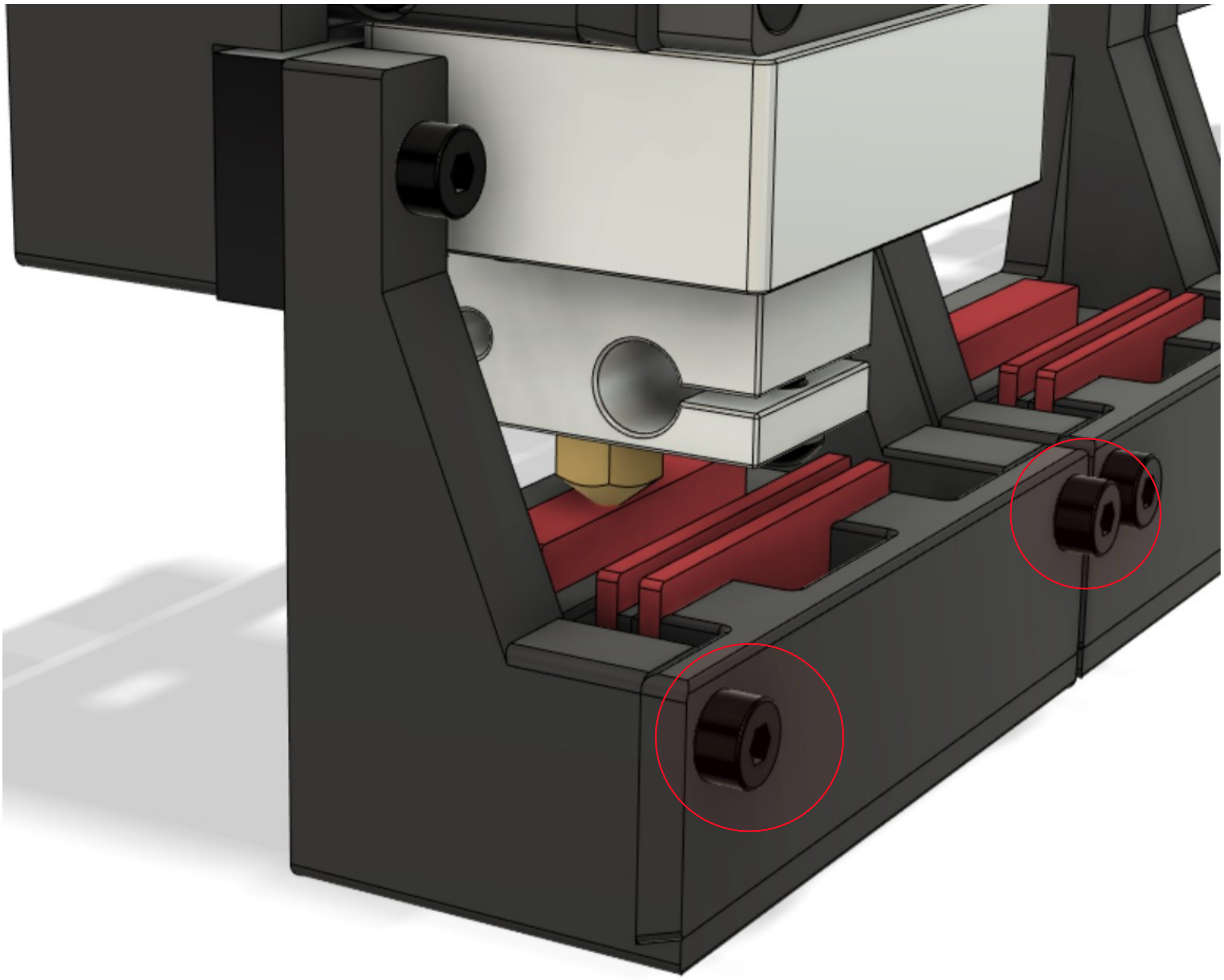
1. An adjustment exists for solving this issue in the form of adjusting the overall protruding length of each (or both) posts. Loosening the set screws shown in Red below will allow us to move the posts inward or outward to attain a proper 3-point plane for the tool when docked.
2. Use the below image to visualize the triangle of support that should be aimed for. The posts should ideally be of an identical length to each other resulting in perpendicularity to the X axis and frame. On some occasions printed part variations can force exceptions here.
3. The most important part of a properly docked tool is a flush point of contact between the Tool Cooler block and the Idle Tool Cooling Bar. Without proper contact here the cold block will accumulate heat and likely result in excessive drooling and/or clogs.



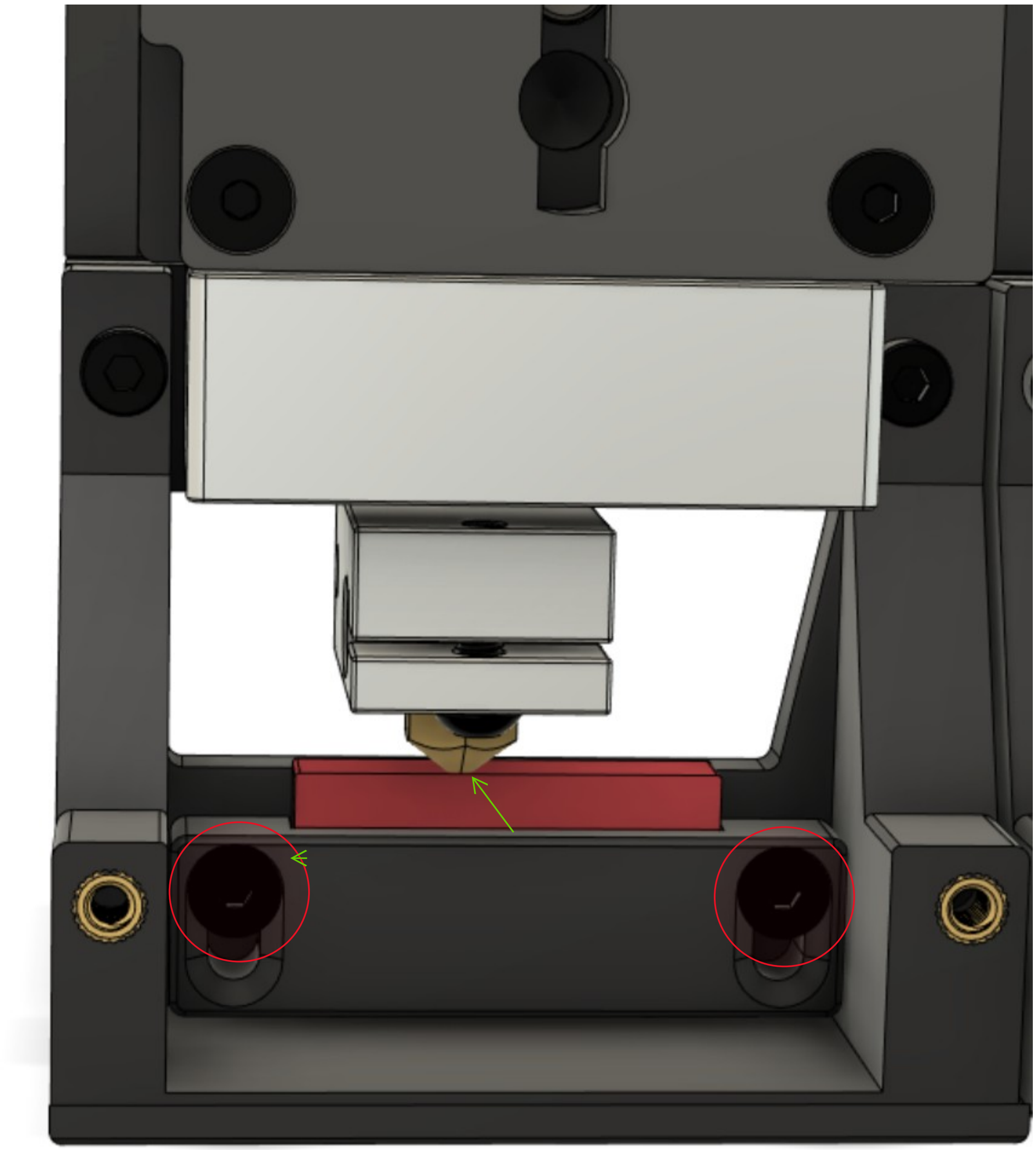
Example: This tool has contact only at the top of the cooling interface due to poor alignment. Moving the two upper posts outward by a uniform amount solves this.



Set the height of the leak blocker and nozzle wipers by first removing the fasteners and nozzle wiper assembly shown below:



Loosen the shown fasteners and adjust the height of the leak blocker. It is only recommended to raise the leak blocker until it just begins to contact the nozzle face. If too much height is added the tool will not dock properly. Retighten the fasteners to lock in place and confirm the tool can be installed and removed by hand with no excessive leak blocker contact.



Perform the same adjustment to the nozzle wipers before reattaching the nozzle wiper assembly to the tool dock.

Step 4 – FDM Tool Umbilical

There are very few wires/connections that connect directly to each tool. In totality they are:

1. Bowden Tubing (reverse) for filament feed path.
2. Thermistor wiring (2 circuits)
3. Heater wiring (2 circuits)
4. Spring steel wire for umbilical “hoop” support

During this guide we will be installing items 1 and 4.

CAUTION: Working with spring steel music wire can be dangerous! With inherently sharp edges and unpredictable movement it is important that you exercise safe handling practices.

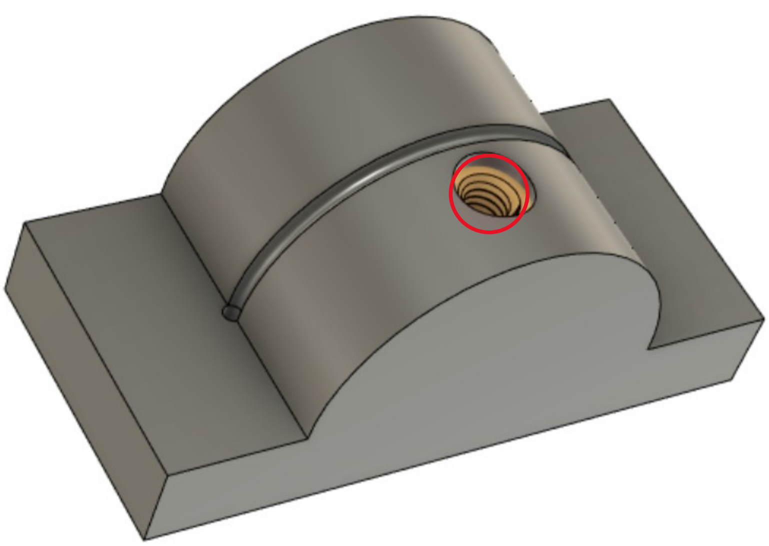
Begin by preparing a 1 meter length of Bowden tubing for the tool being installed. Only one end of the tubing needs to be cut with a clean and square face (the side that will interface with the tool)

Prepare also a 65cm length of spring wire.

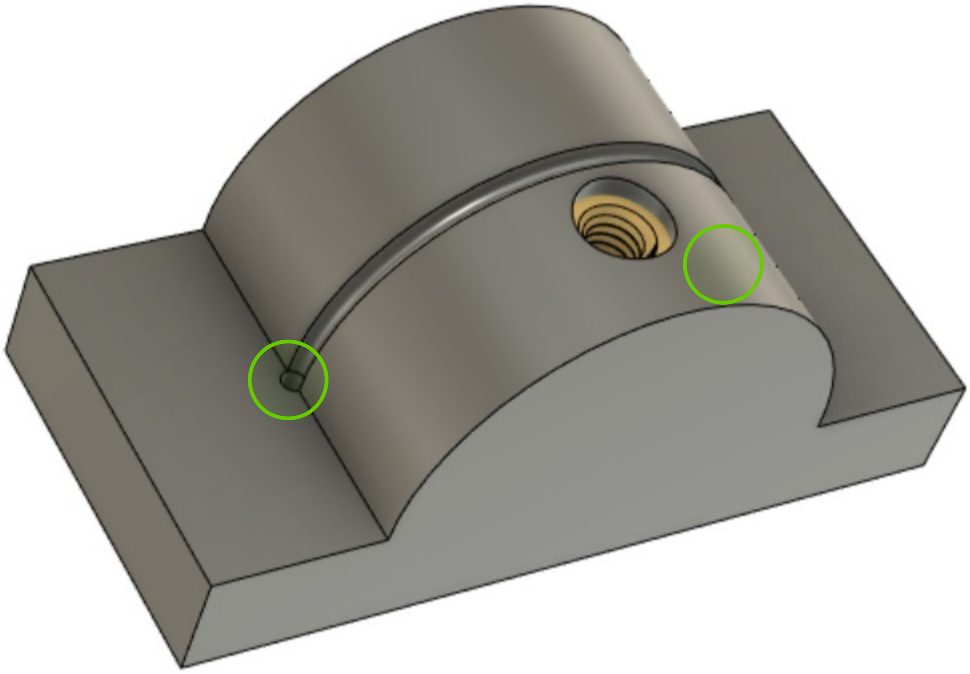
TIP: Spring wire is supplied most often in the form of a wire coil. Click here for a YouTube video that shows very nicely a process for straightening this music wire without expensive tools. We will need a straightened length of wire to begin this process:

Locate the mid-point of the 650mm spring wire length and mark the mid-point.

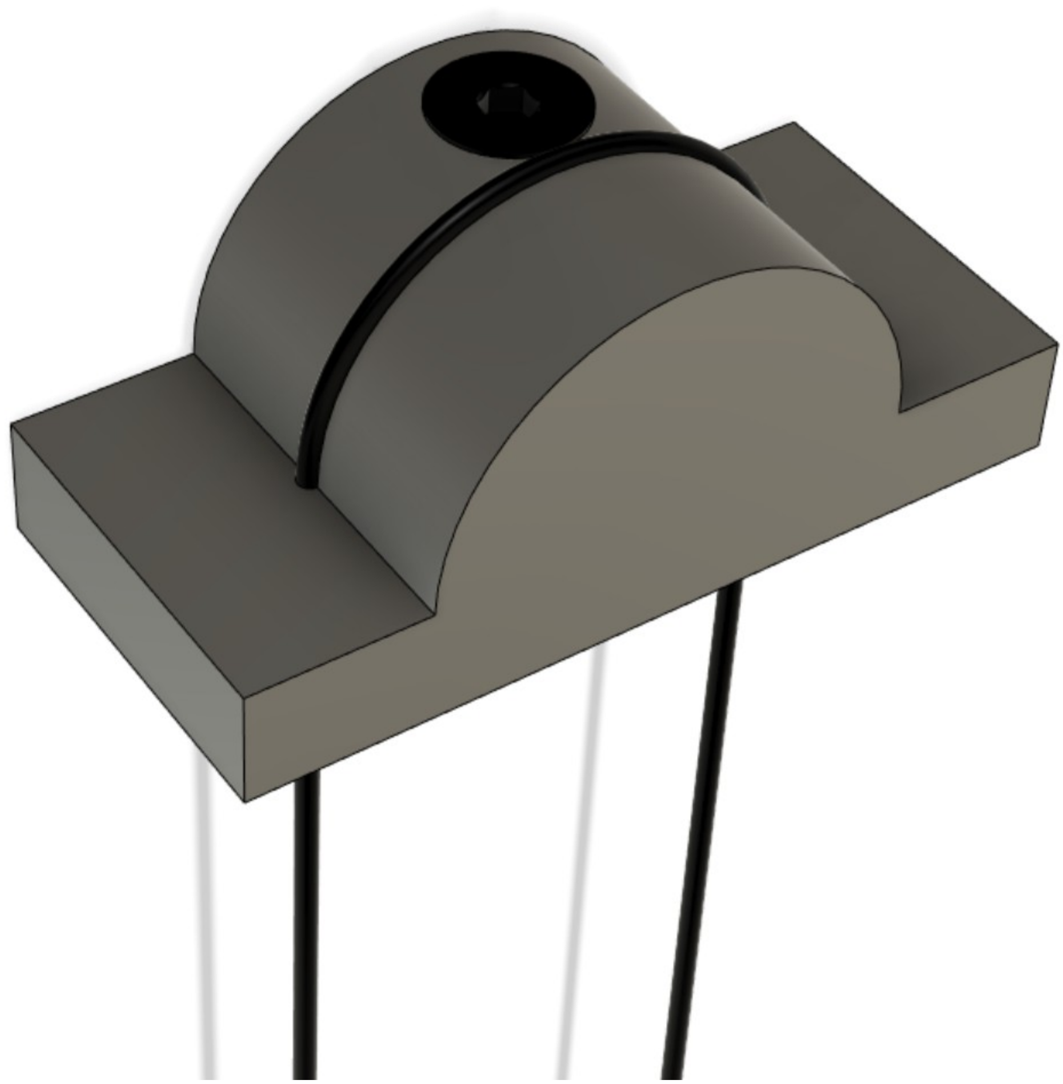
Locate Spring Wire Tool Printed Part A and install an M3 heat set insert into the shown location at a depth of 1mm beyond flush.



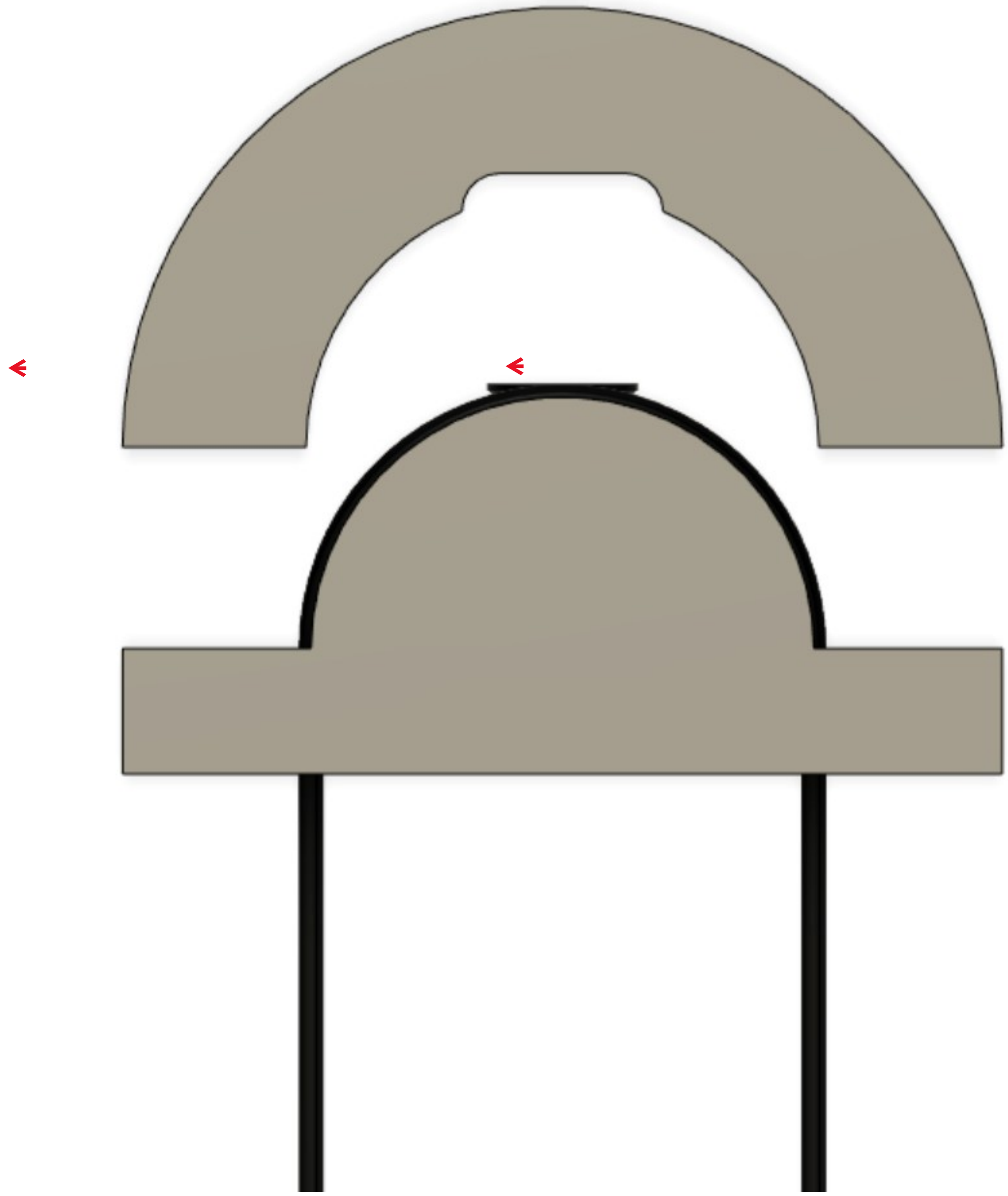
Feed both ends of the spring wire through the printed holes shown in green below.



Align the previously marked mid-point of the spring wire with the previously installed heat set insert and install an M3xN FHHS fastener (length is unimportant) to secure the wire to the printed tool. Pull any excess spring wire through the body of the printed tool.

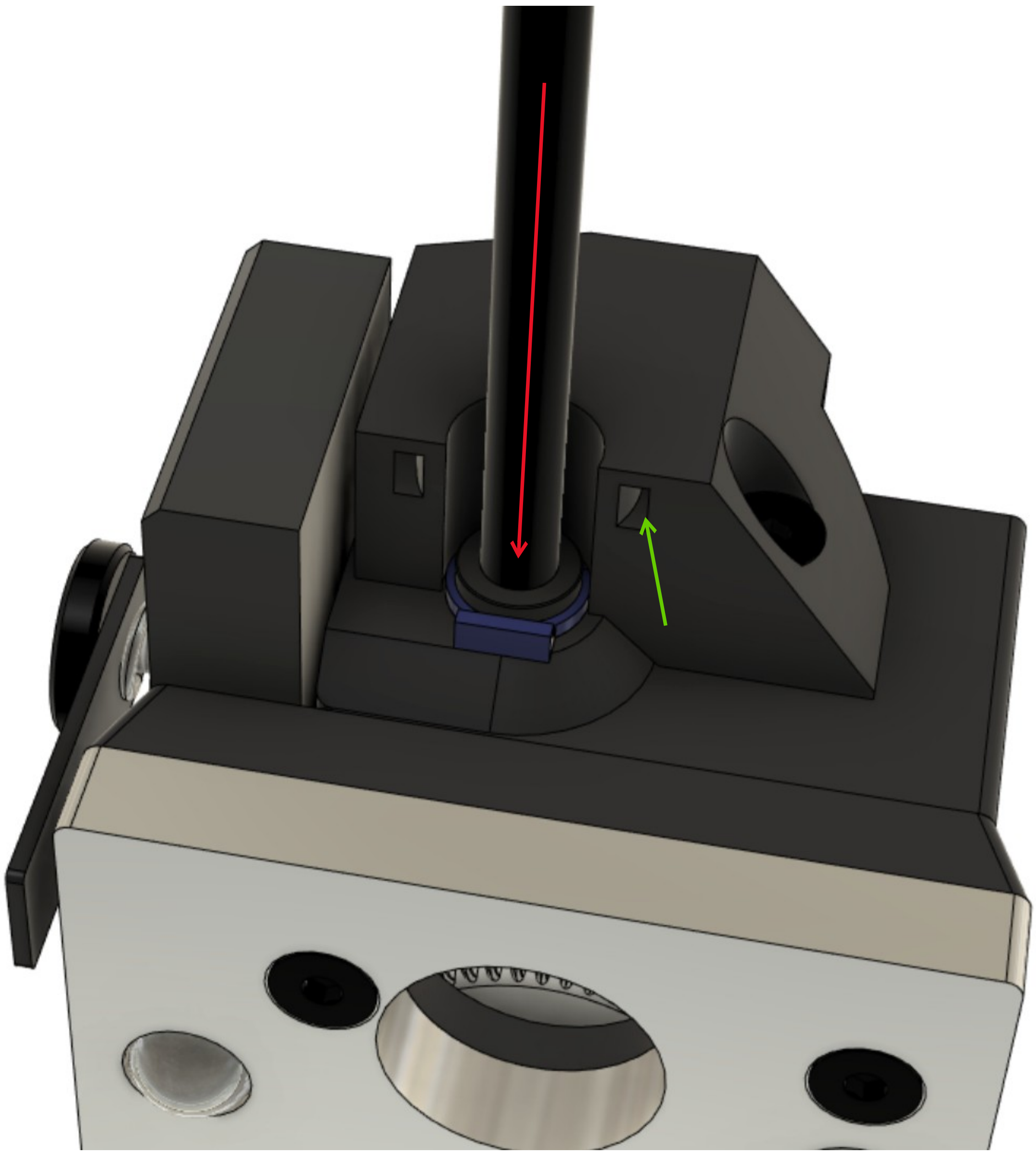


Use Spring Wire Printed Tool Part B to force a radius into memory of the wire as shown below:



Release the tool and remove the spring wire from the printed die. The newly introduced radius will serve as the peak of a tool's umbilical cable. Don't worry if the wire legs are not parallel after this process. They don't have to be.

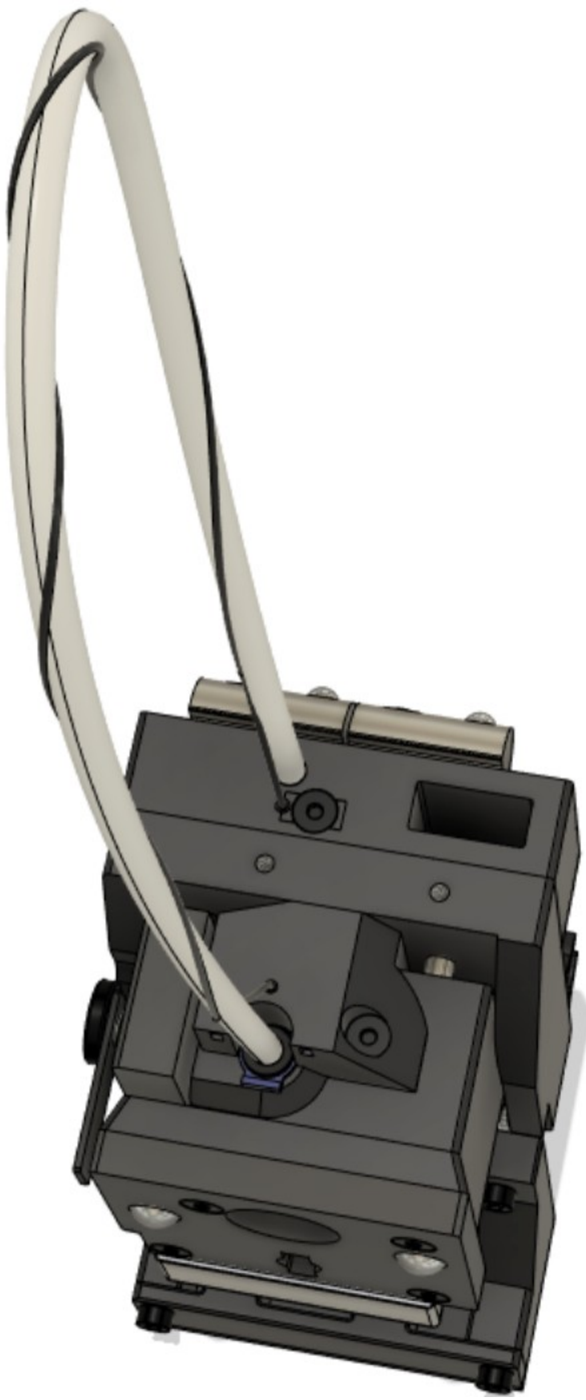
Insert the squarely cut end of the previously prepared Bowden tubing into the coupling on top of the FDM tool. Be sure to seat completely. Insert a small tie-wrap into the printed channel shown in green and secure – pulling the Bowden tube against the FDM Tool Part 04.



Feed the other end of the Bowden tube into the below shown pass-thru bore in the dock to which this tool has been adjusted to fit. The length on either side of the tool dock spacer is not yet important.

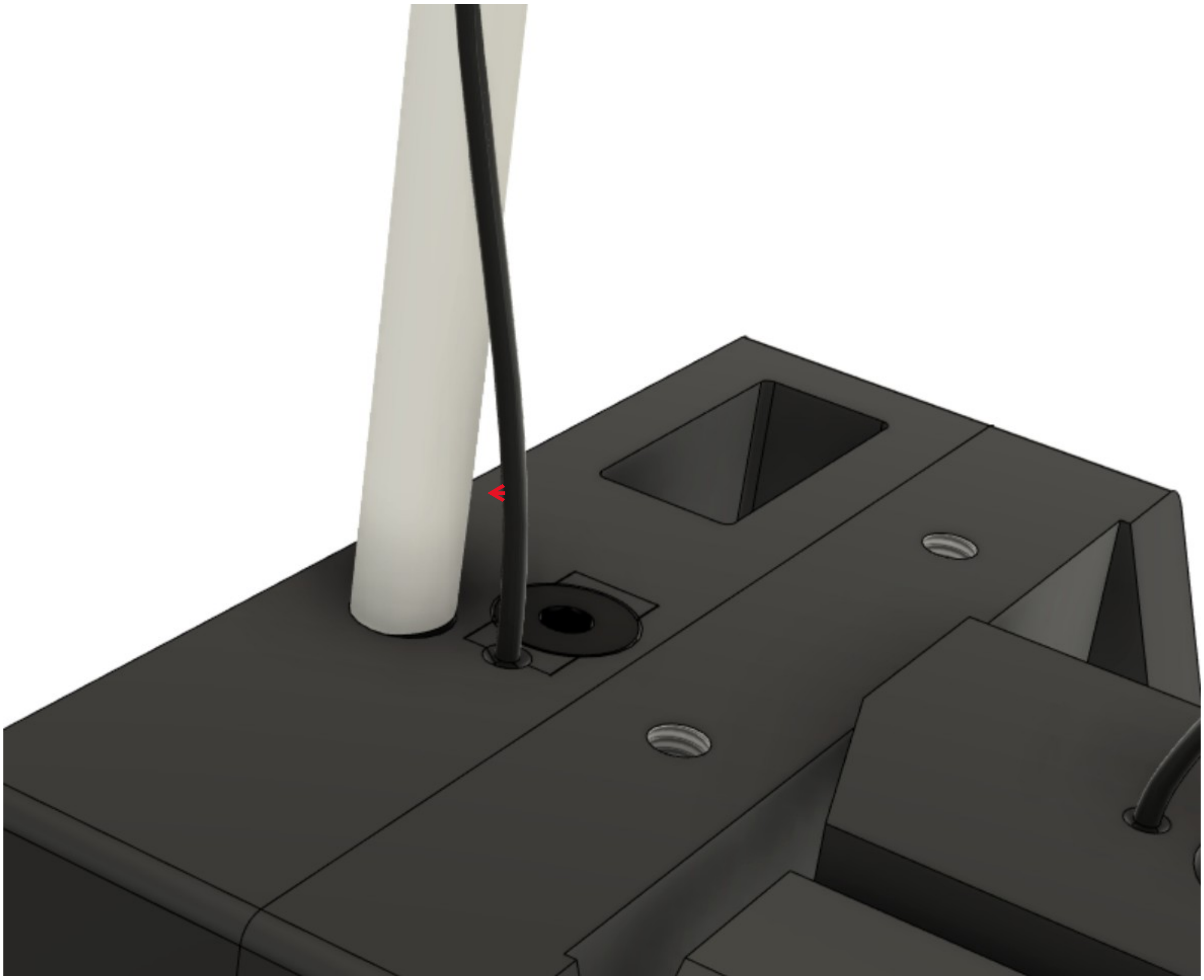
Insert one end of the previously prepared spring wire into the FDM tool bore shown in red. Secure in place using the previously installed set screw shown in green.

Wrap the spring wire around the Bowden tube 4-5 rotations as shown in the image below. Maneuver the Bowden tube when positioning the peak of the spring wire where we previously introduced a radius into the wire's memory.



Raise the FHHS fastener and wire retention printed part and insert the remaining loose end of the spring wire into the bore located on the top of the associated tool dock spacer.

Push down on the FHHS fastener (and thus the retention piece) while holding the spring wire in place. Tighten the FHHS. This will arrest the spring wire.



Here is an image for reference demonstrating the overall shape of umbilical hoops when a given tool is docked.