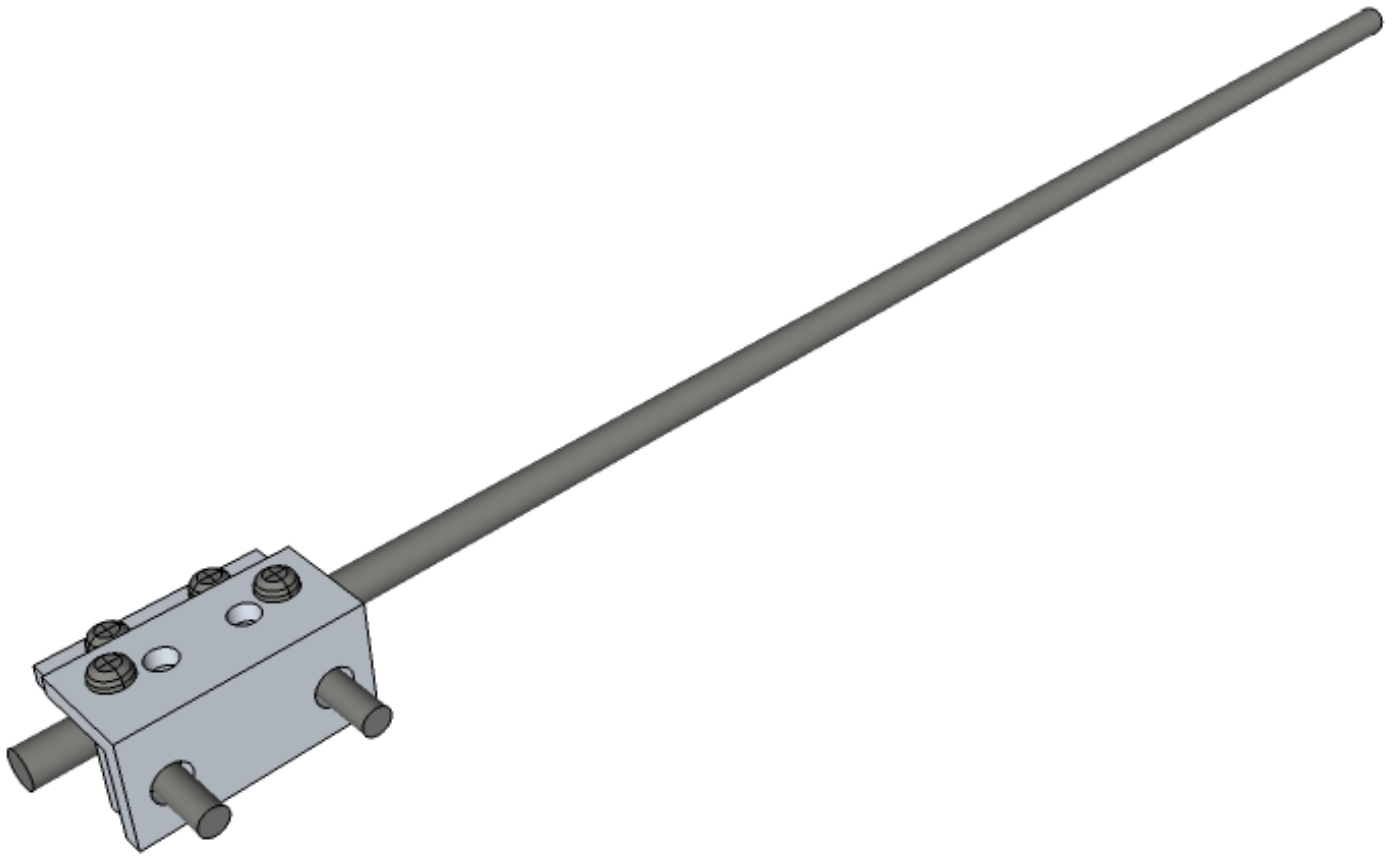


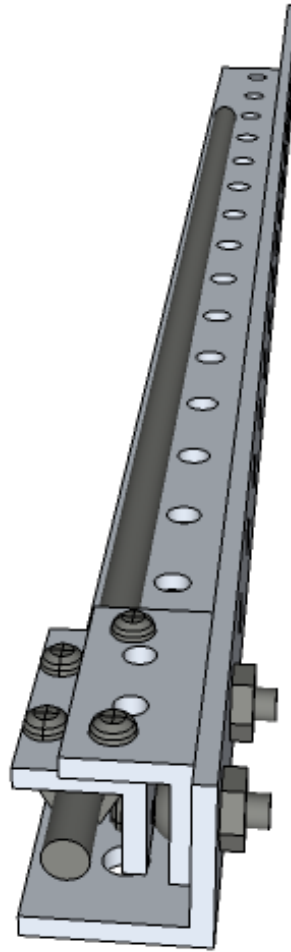
001-Lead-nut-assembly

Insert a pair of 10-24 1/2" screws into lead nut mount and attach it to the coupling nut clamp using a pair of small 6-32 1/4" screws.



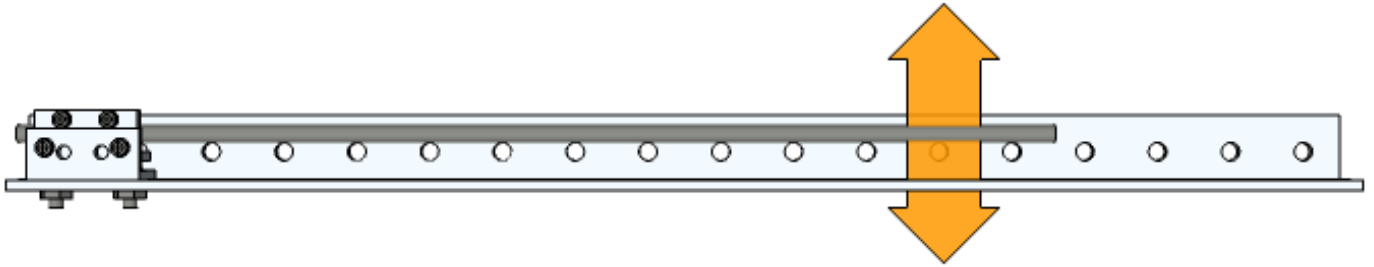
002-Lead-nut-assembly

Position lead nut assembly at the end of the threaded rod.



003-Lead-nut-assembly

Attach lead nut with the threaded rod to angle-18.

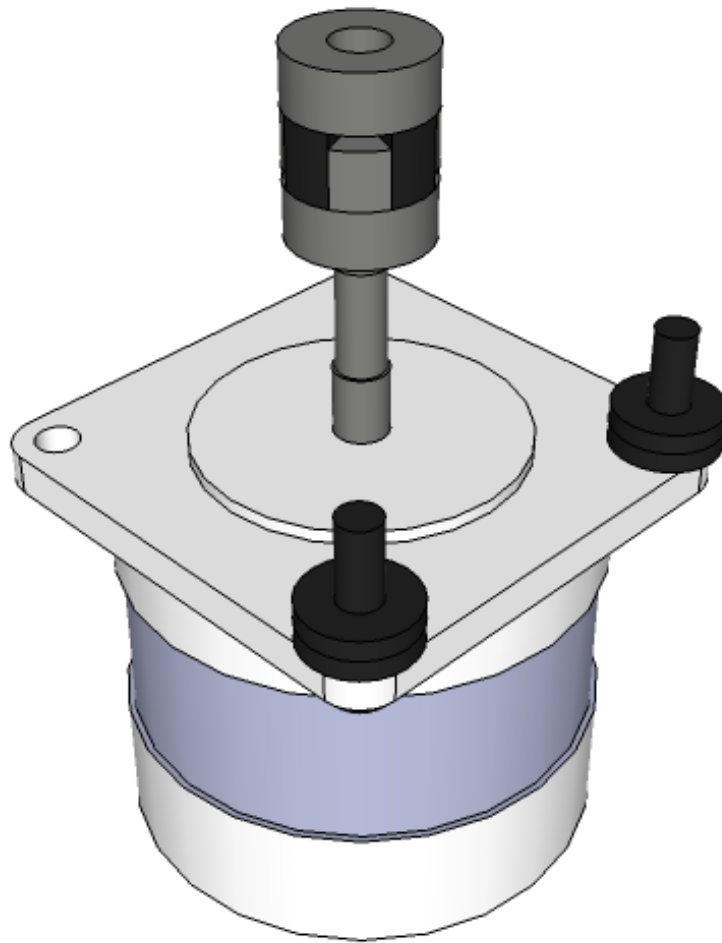


004-Lead-nut-assembly

Loosen the small screws on the lead nut mount. Align coupling nut clamp relative to lead nut mount so that the threaded rod is parallel to the angle-18 when looking from the top. Tighten the small screws.

Lead nut assembly should now be aligned. Remove angle-18. Threaded rod does not need to be removed.

Repeat the process for all lead nuts.

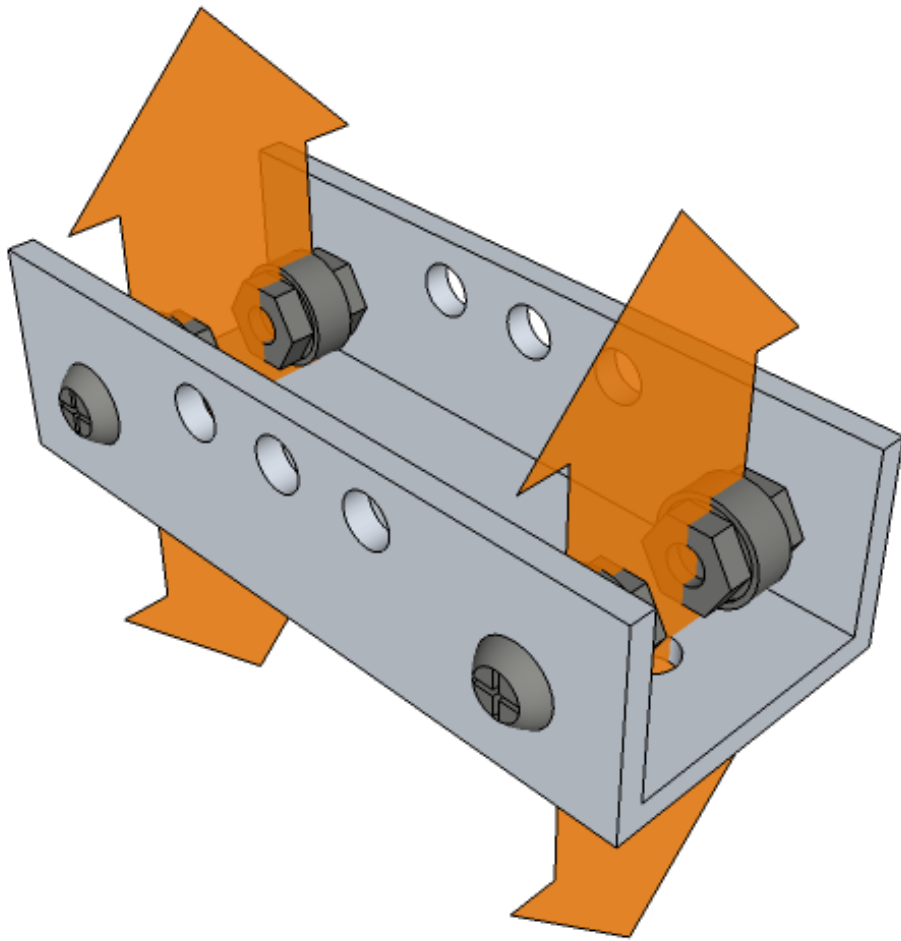


005-Motor-preparation

Install a pair of nylon screws (10-24 3/4") and add two neoprene washers to each screw.

Install and fix the jaw coupling onto the motor.

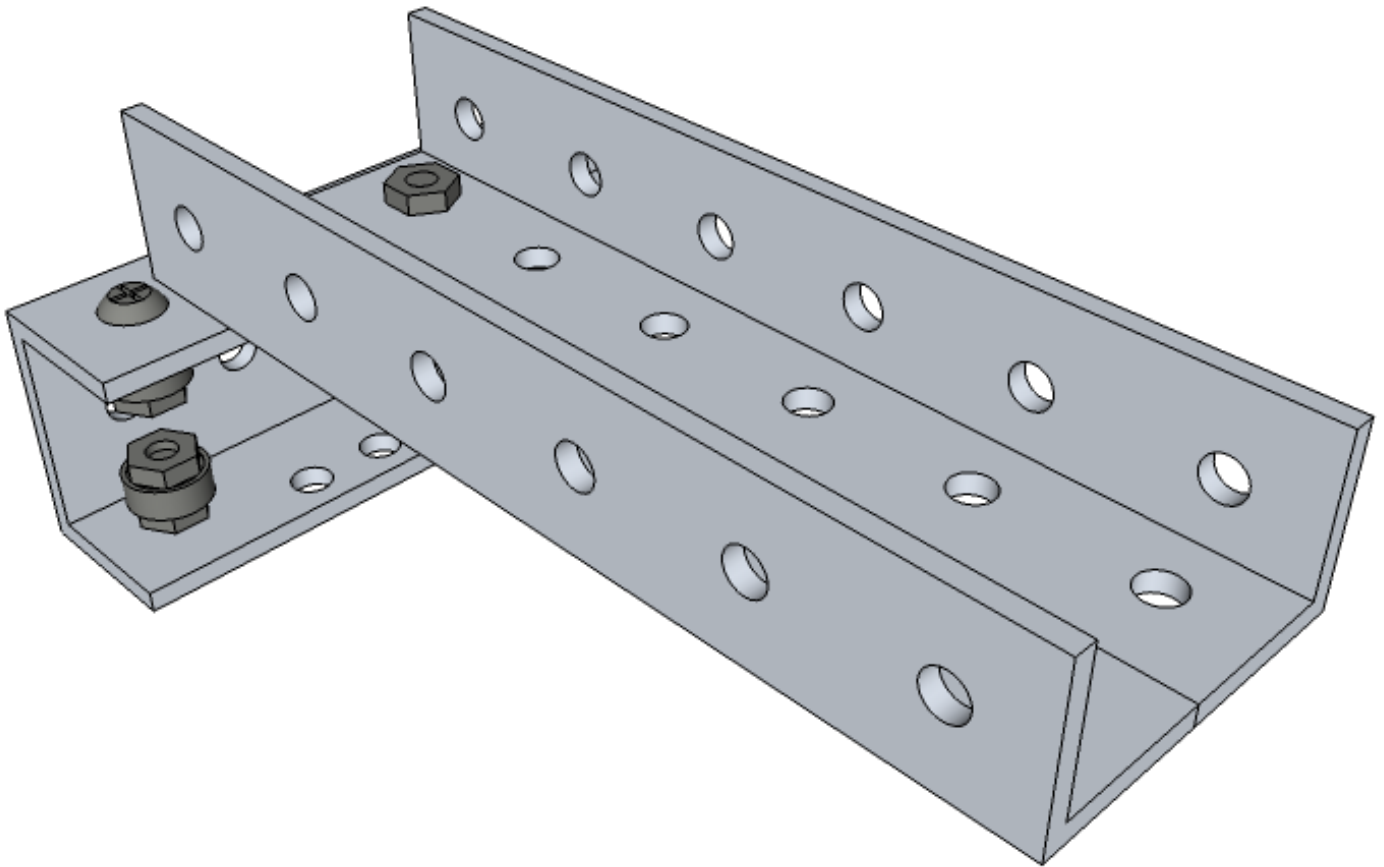
Repeat for all motors.



006-X-axis-assembly

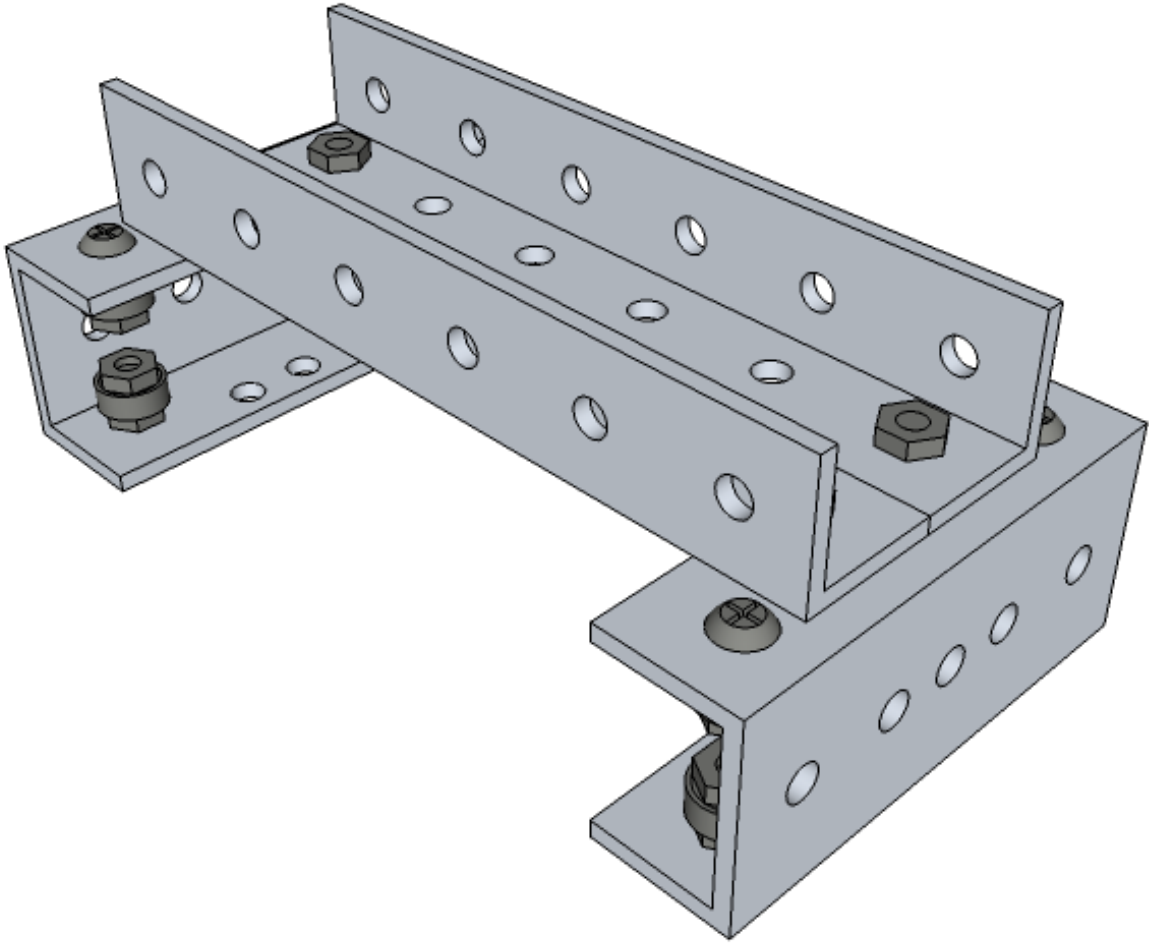
Ensure the ball bearings are aligned as described here:

<http://www.conraptor.org/make-linear-bearings#assembly>



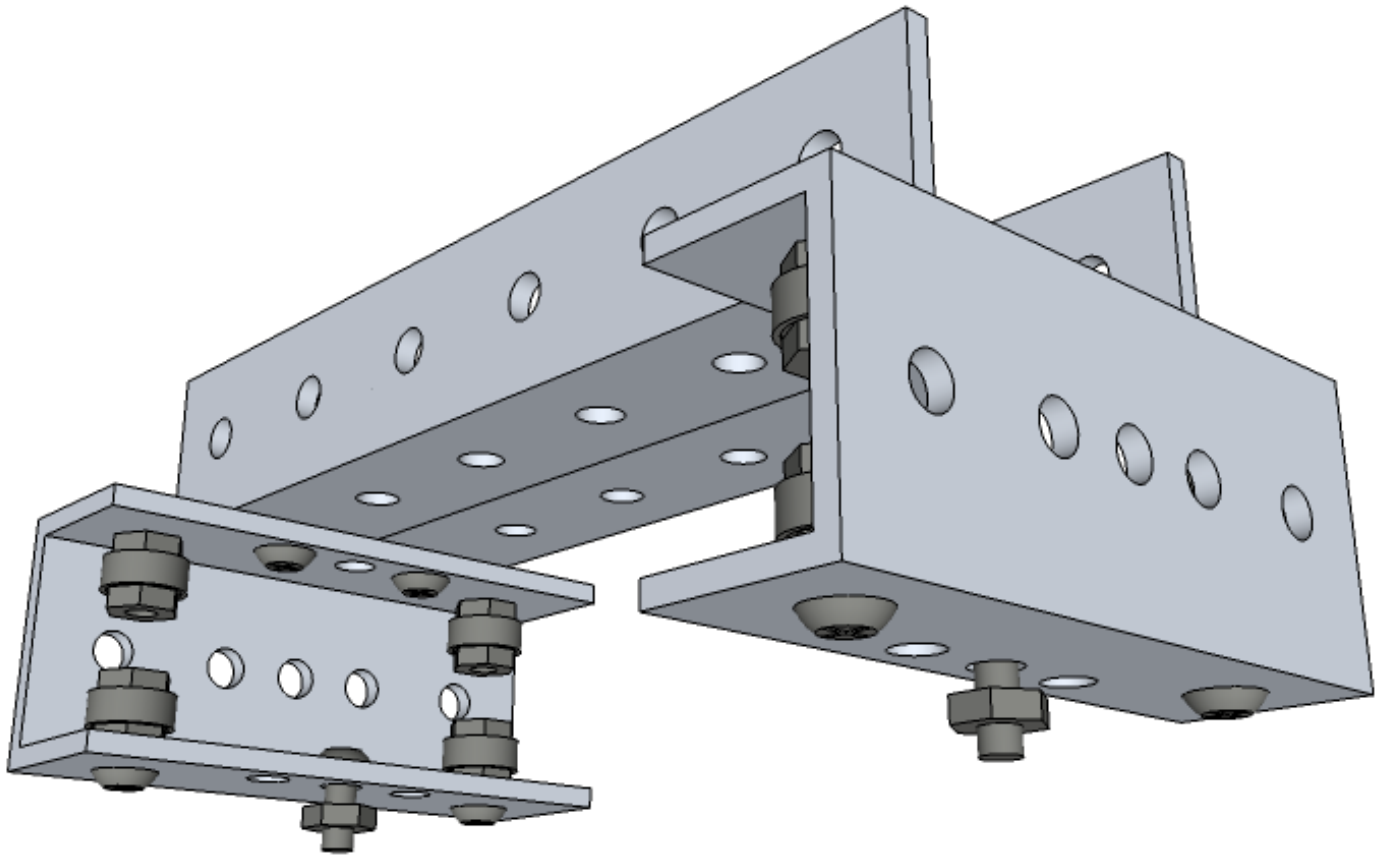
007-X-axis-assembly

Attach a pair of angle-6 to one linear bearing. Ensure they are roughly orthogonal to the linear bearing and tighten the nuts.



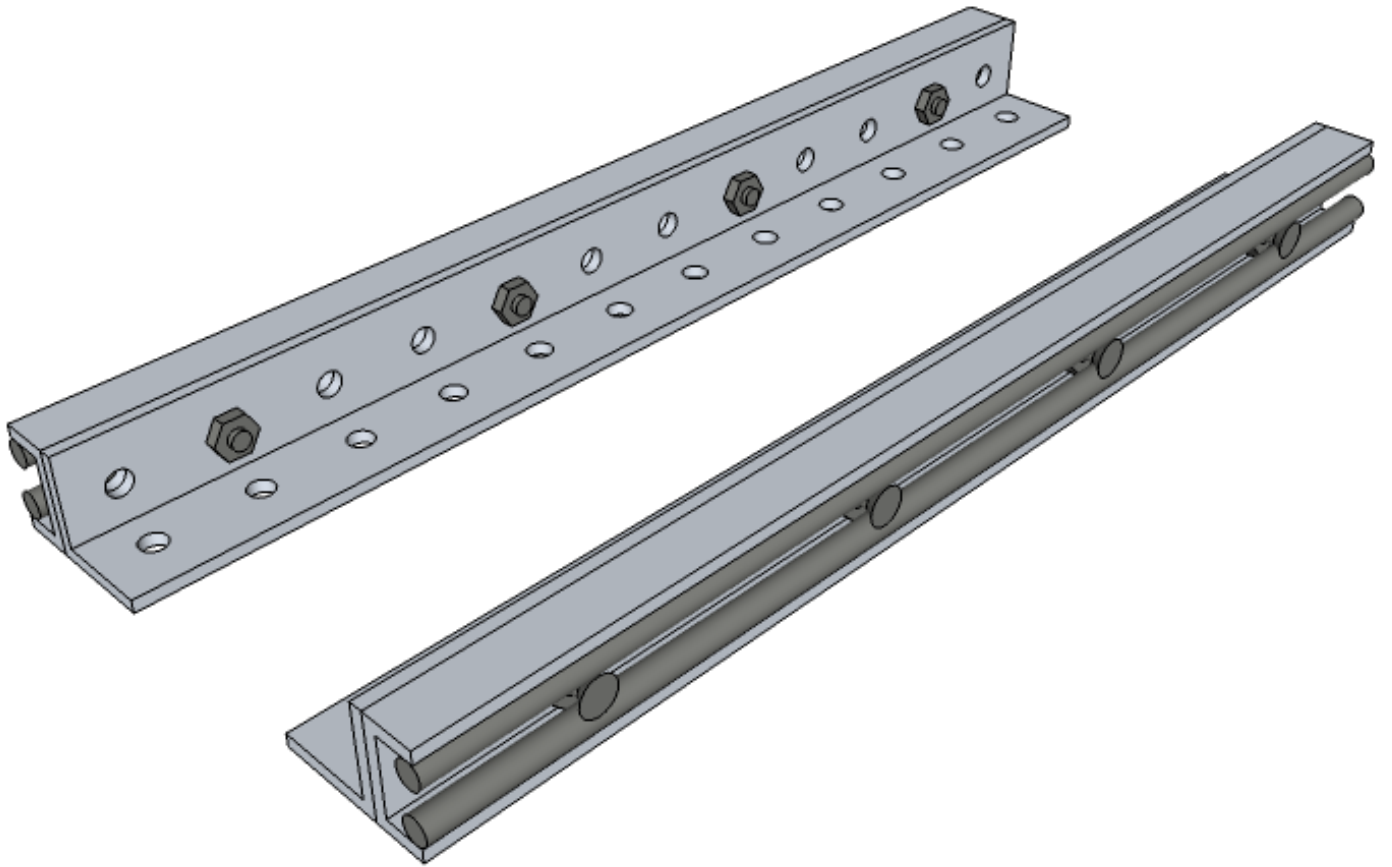
008-X-axis-assembly

Attach the other linear bearing and finger tighten the nuts.



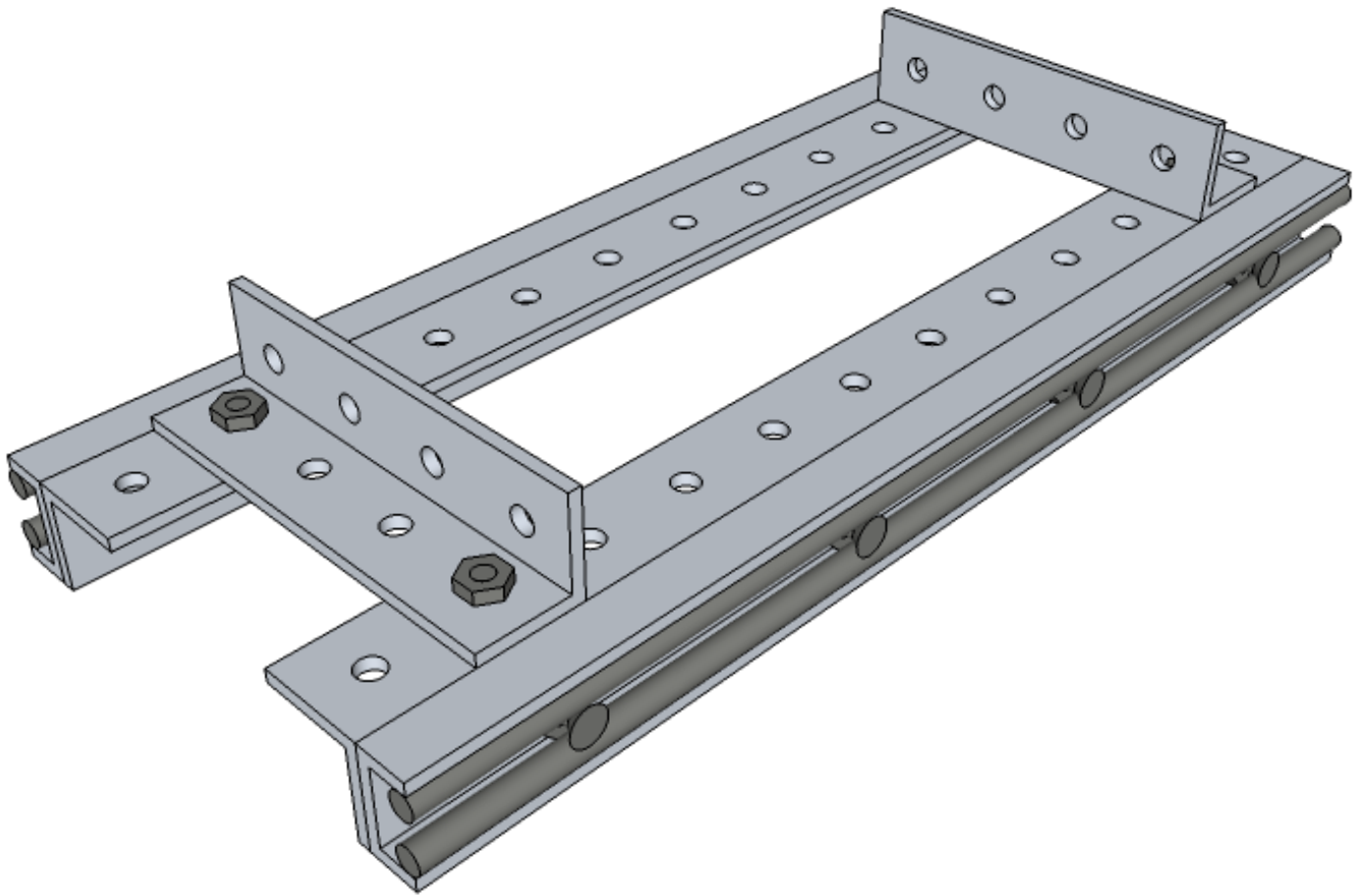
009-X-axis-assembly

Add screw and nut pair to the middle of each linear bearing on the opposite side.



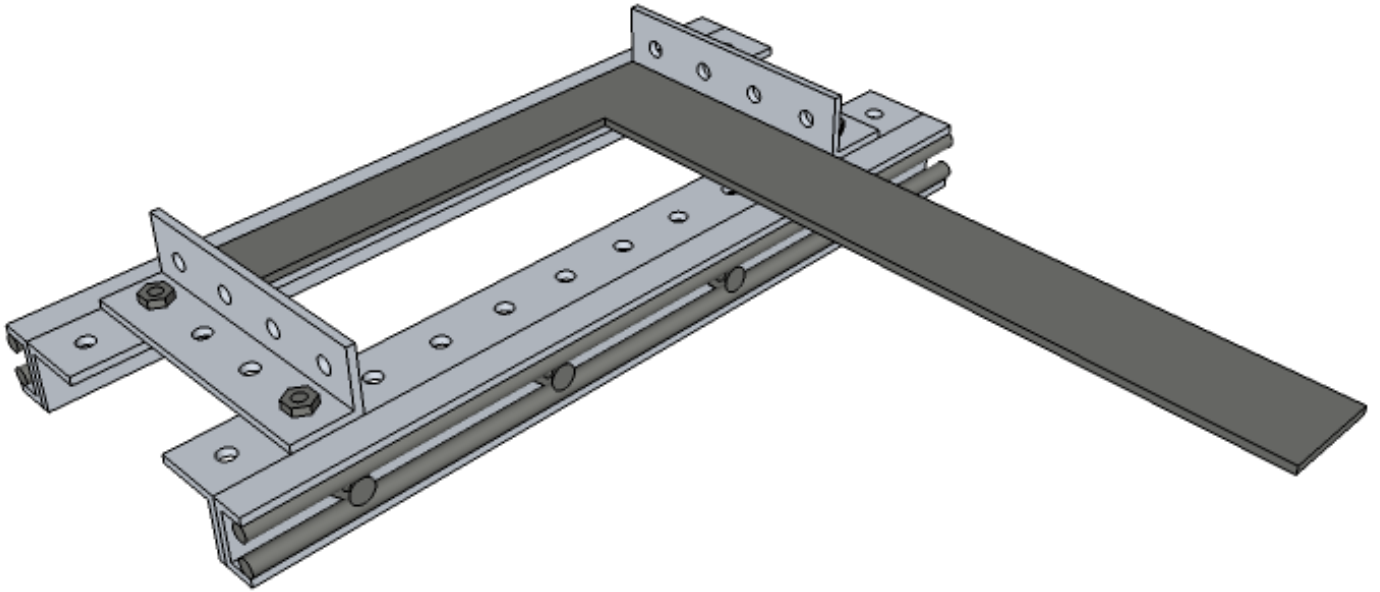
010-X-rail-assembly

Assemble linear rails



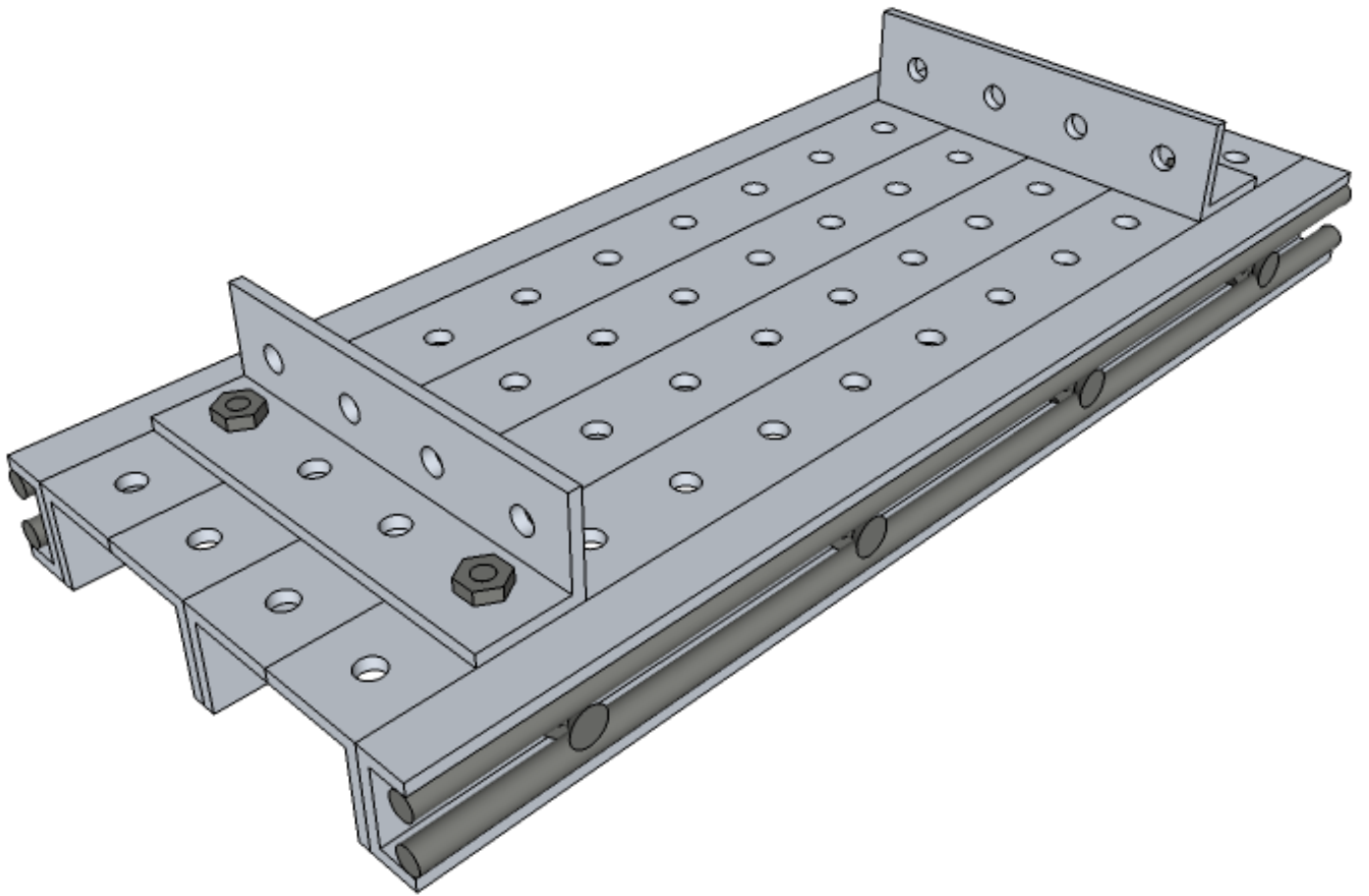
011-X-rail-assembly

Attach linear rails to angle-4s using 3/8" screws and finger tighten.



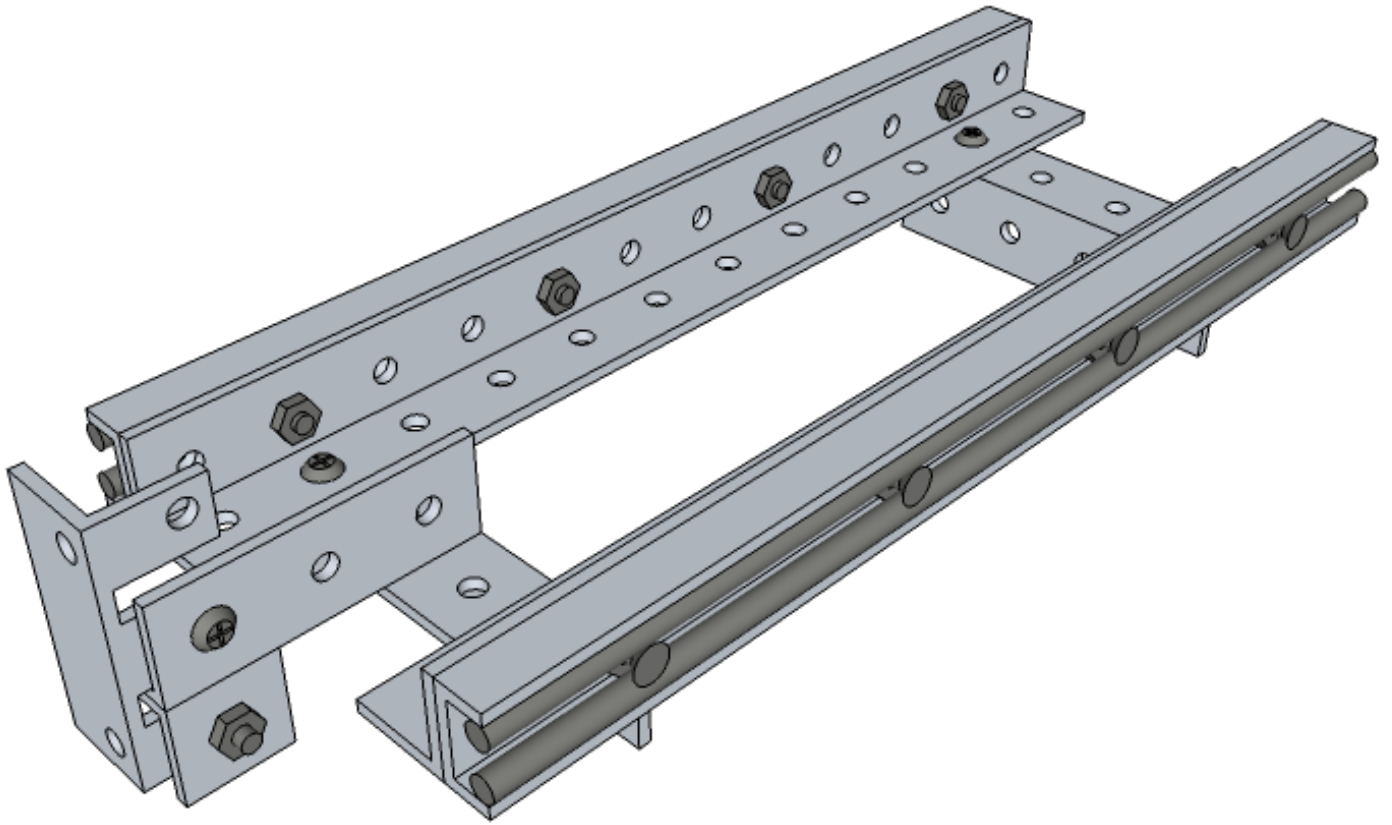
012-X-rail-assembly

Make sure one of the linear rails is square with both angle-4s and tighten the nuts on that rail.



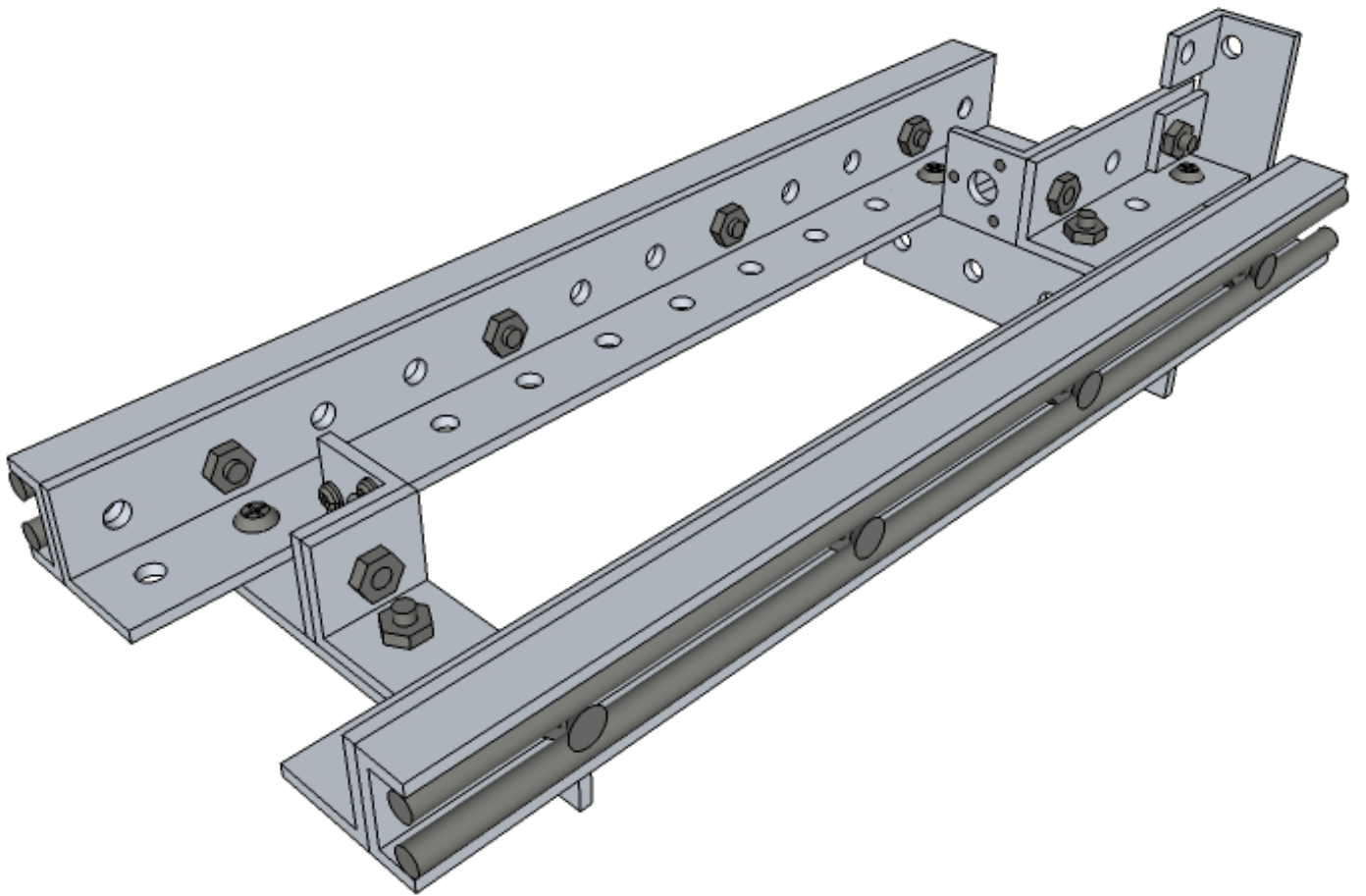
013-X-rail-assembly

Using a pair of angle-12s, ensure that the rails are parallel and tighten the nuts on the other rail.



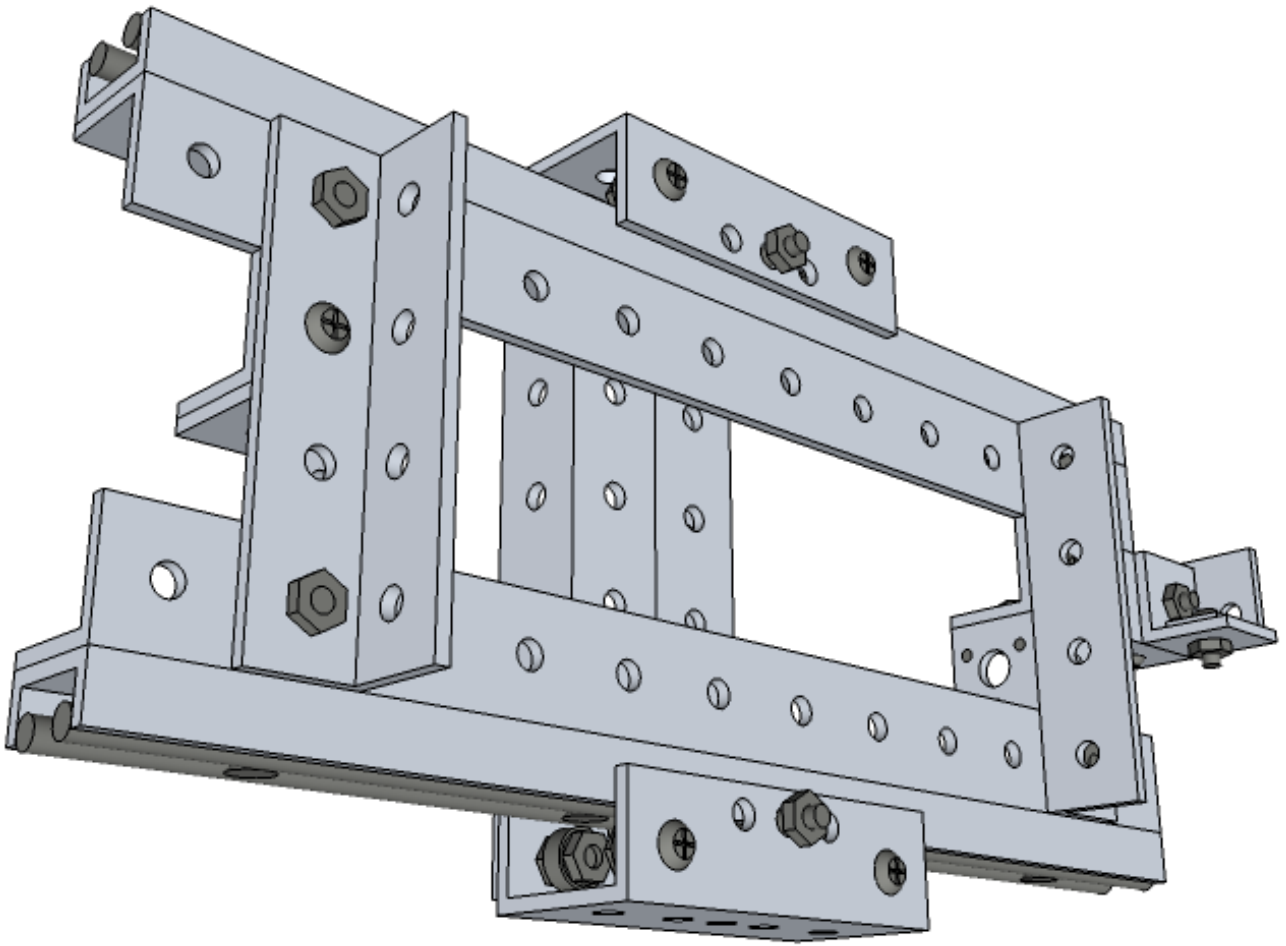
014-X-rail-assembly

Install motor mount.



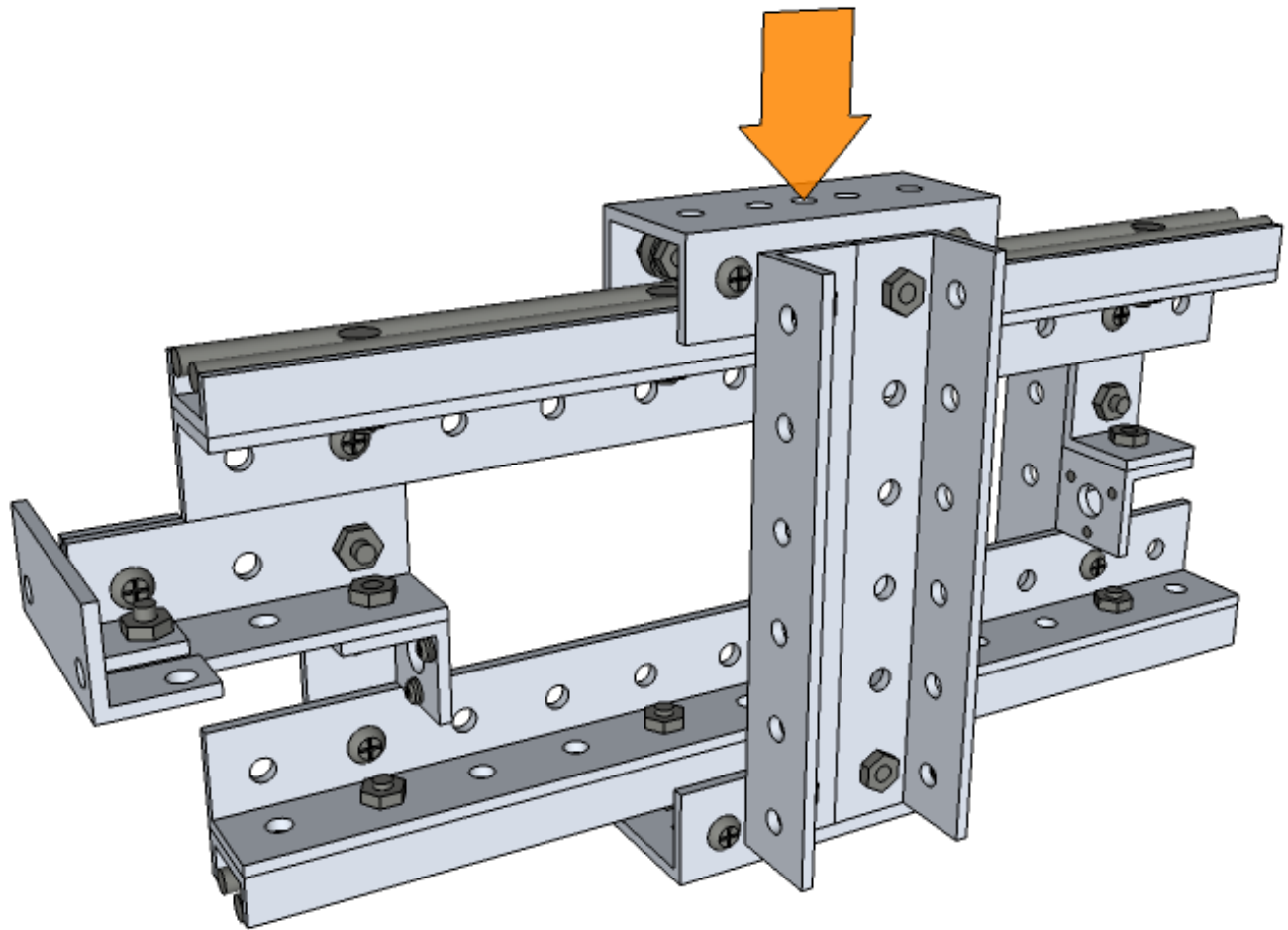
015-X-rail-assembly

Install shaft mounts.



016-X-axis-assembly

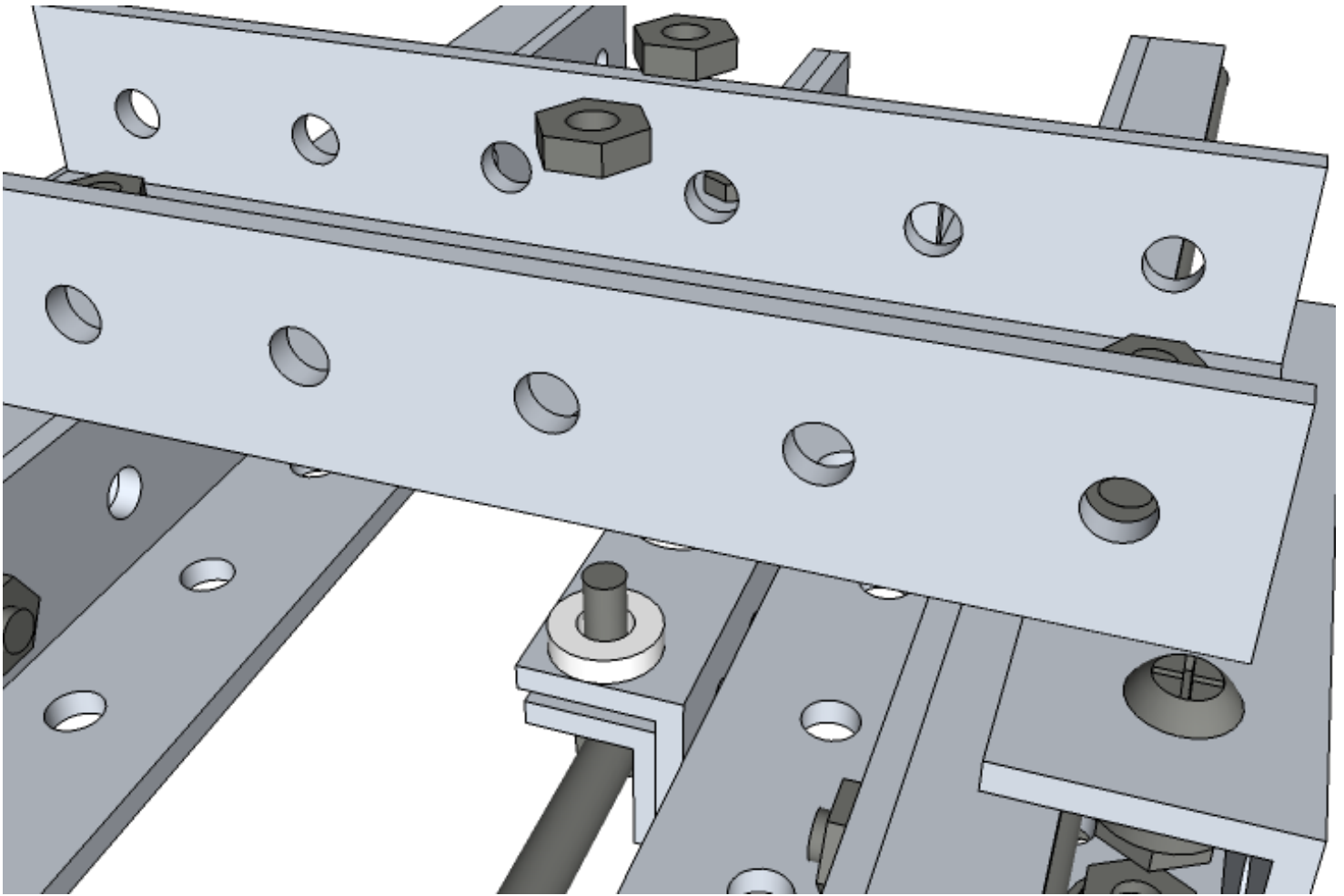
Slide the X stage onto the X rail and stand it upright on a flat surface.



017-X-axis-assembly

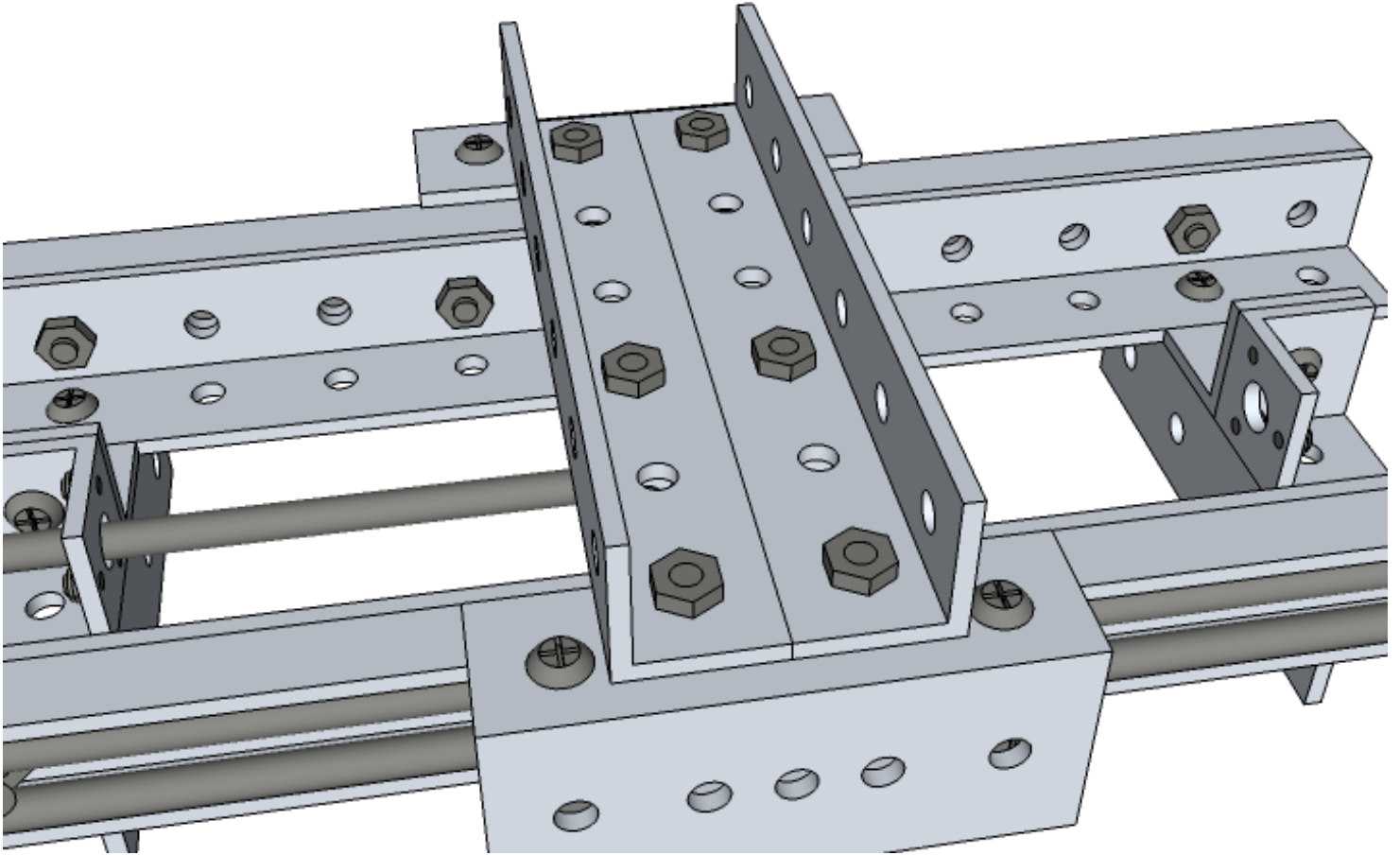
Apply sufficient pressure on the top linear bearing to ensure there is no slack in the rails and tighten the nuts on the stage.

The stage should glide on the rail. If you are unable to remove the slack, go back to the alignment of linear bearings.



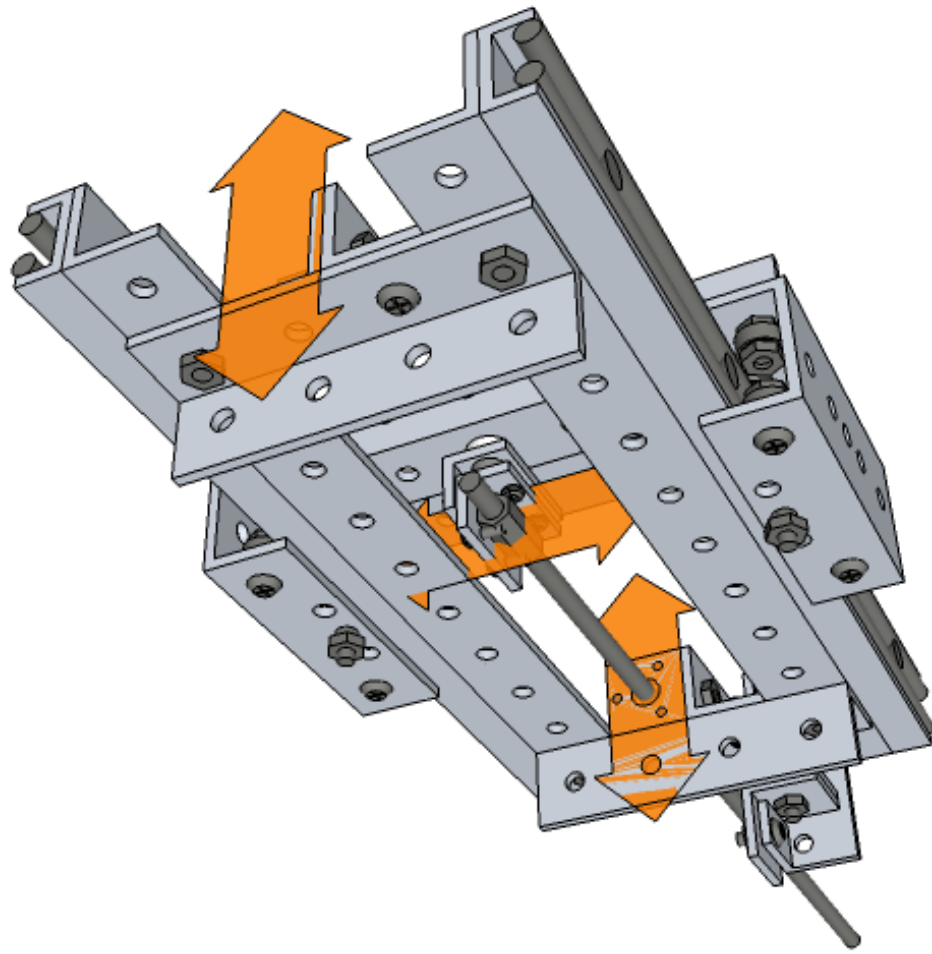
018-X-axis-alignment

Lead nut assembly should be attached to Y stage with a pair of 1/8" nylon spacers in between.



019-X-axis-alignment

Attach the lead nut assembly to Y stage and finger tighten the nuts.



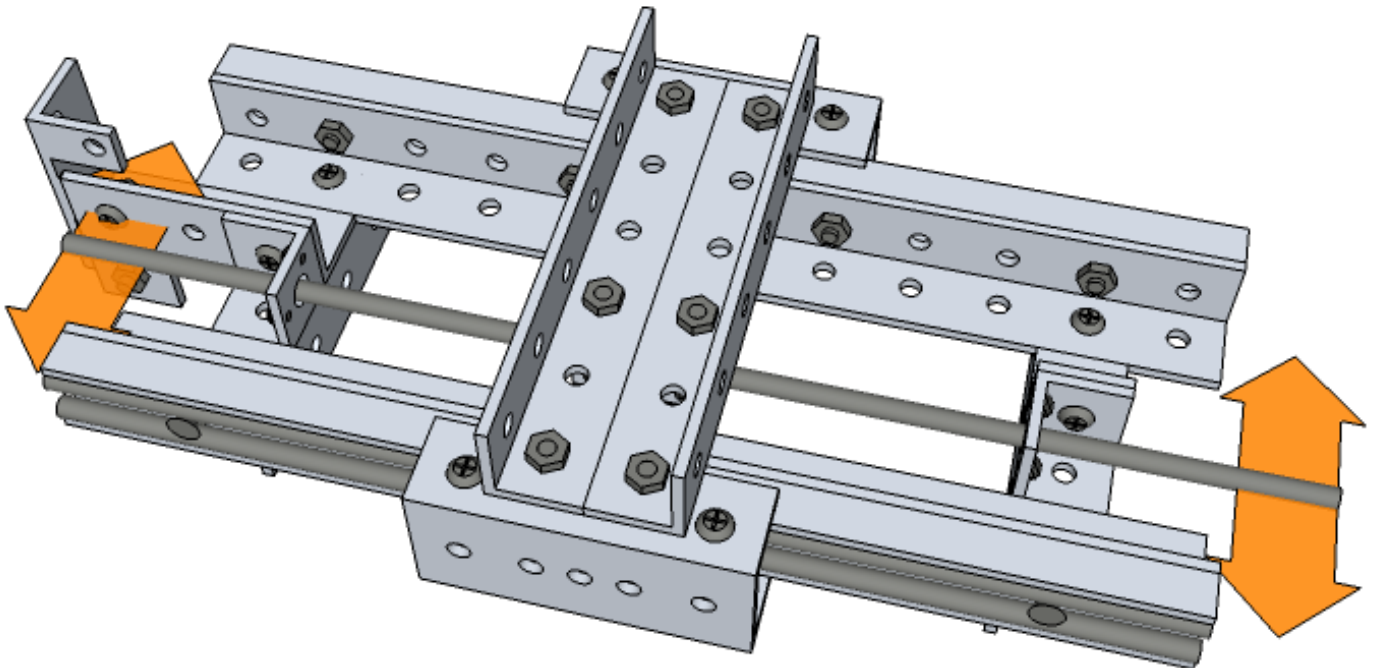
020-X-axis-alignment

The next step is to align the lead nut and shaft mounts so that their centers are on the same axis. This is probably the most intricate part of the assembly.

This step is very important because misalignment will cause threaded rod to bend and require more torque to turn it, leading to skipped steps.

The alignment is performed by adjusting the lead nut side-to-side and the shaft mounts up-down, until desired result is achieved.

The success criteria is that you must be able to easily rotate the threaded rod with your fingers once it is constrained by the bearings. Free rotation must be present throughout entire length of stage travel, including extreme positions of the stage.

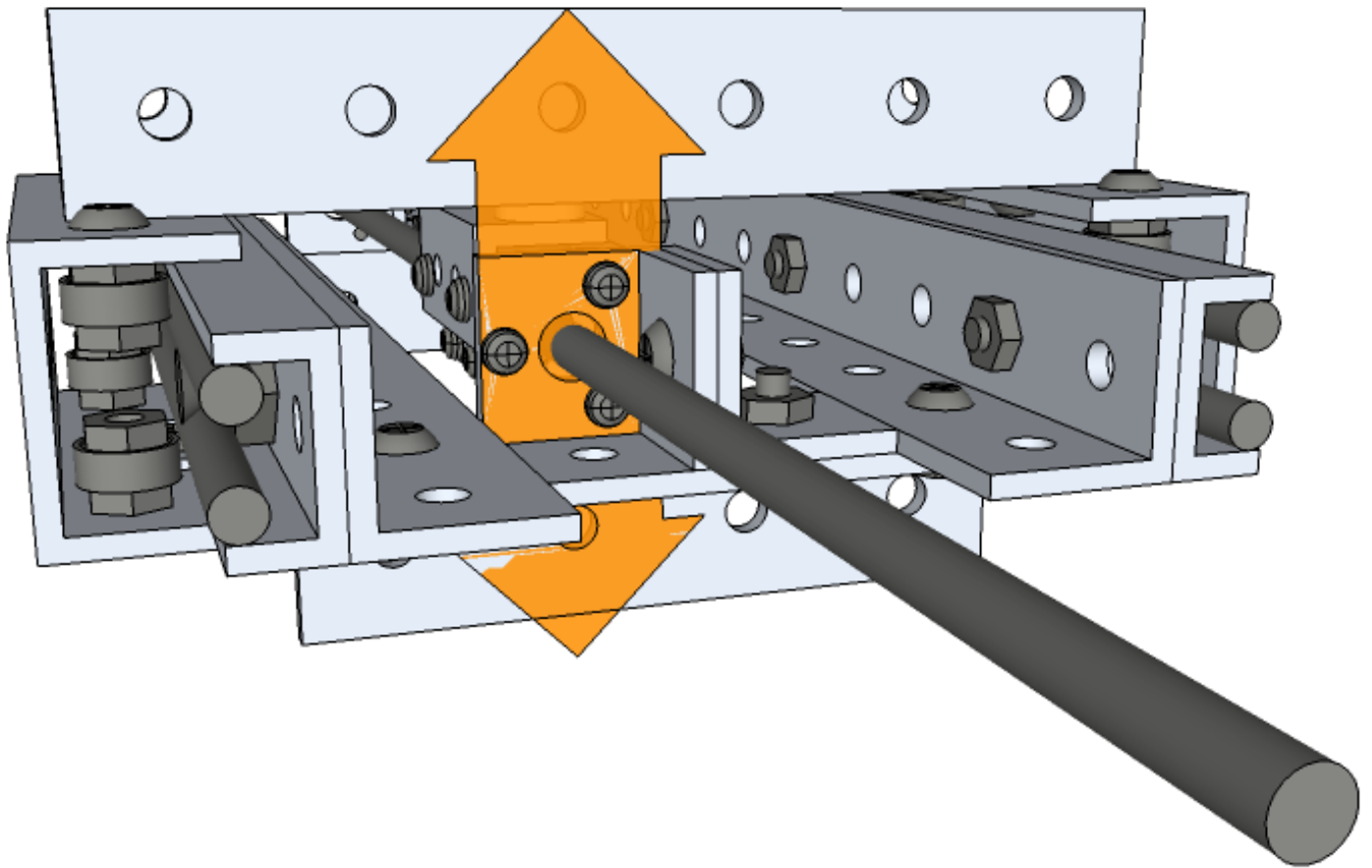


021-X-axis-alignment

Center the stage relative to shaft mounts and turn the threaded rod until the lead nut is in the middle of it. Use cordless/power drill to do this quickly.

Loosen the lead nut and position it so that the threaded rod passes through the centers of both shaft mounts in the horizontal plane, then carefully tighten the lead nut in this position. This part is tricky as the leadnut will want to turn/move as you tighten it, in the direction of tightening. You can compensate for it by holding the threaded rod slightly off center in the opposite direction. It is normal for this to take several attempts.

Keep in mind that the rod may be very slightly bent, in which case its ends may be a bit off the true center axis. Rotate the rod a couple of turns to see where the true center axis is.



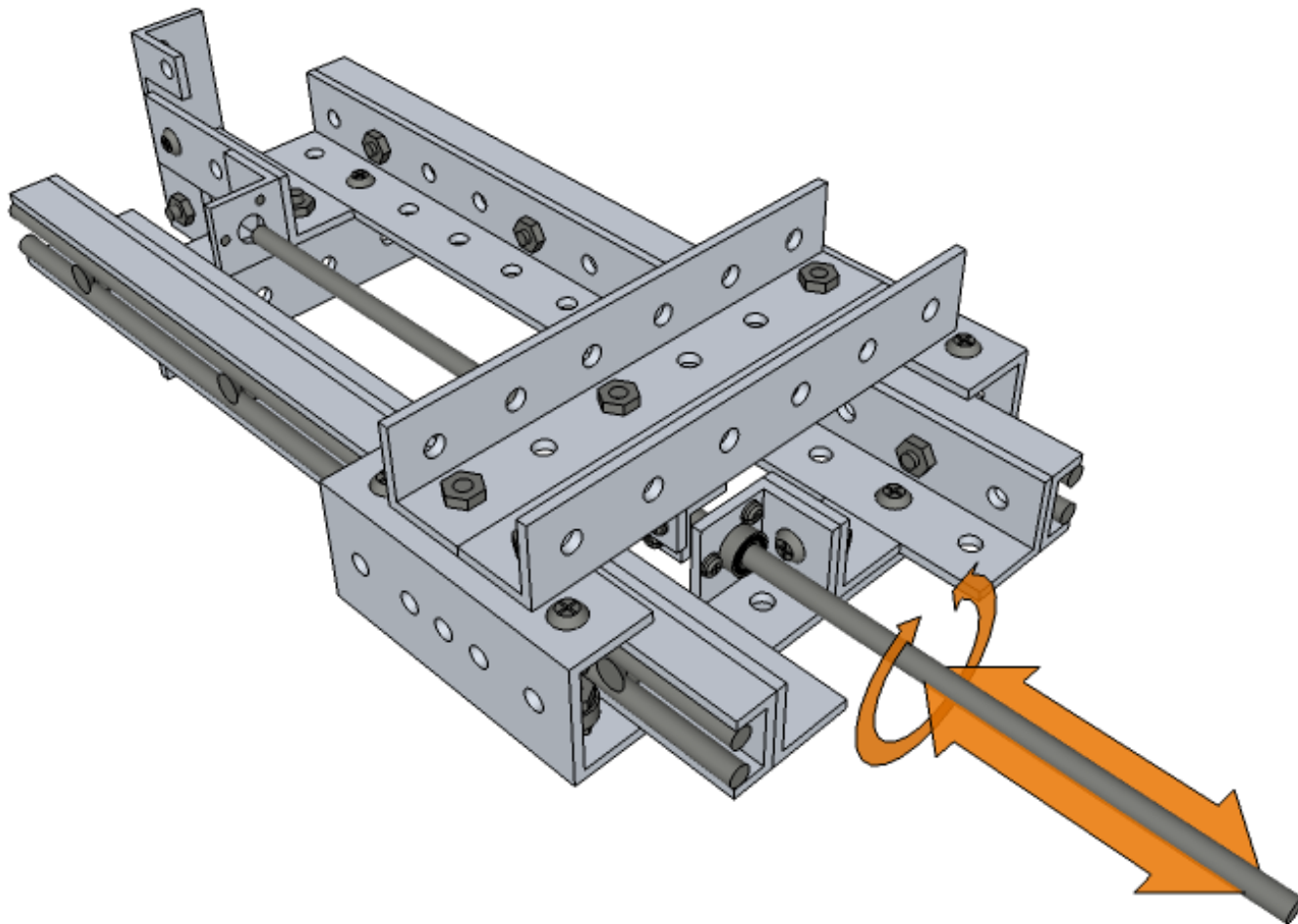
022-X-axis-alignment

Move stage to one of the extreme positions of the axis - misalignment is more evident at extreme positions.

Move the stage away to access the mounting screw and adjust the shaft mount up-down so that the threaded rod passes through its center in the vertical plane. Be sure to keep the shaft mount square to the threaded rod.

Verify that threaded rod is still centered in the horizontal plane (sideways). If not, go back to previous step.

Move the stage to the opposite end of the axis and do the same with the other shaft mount.

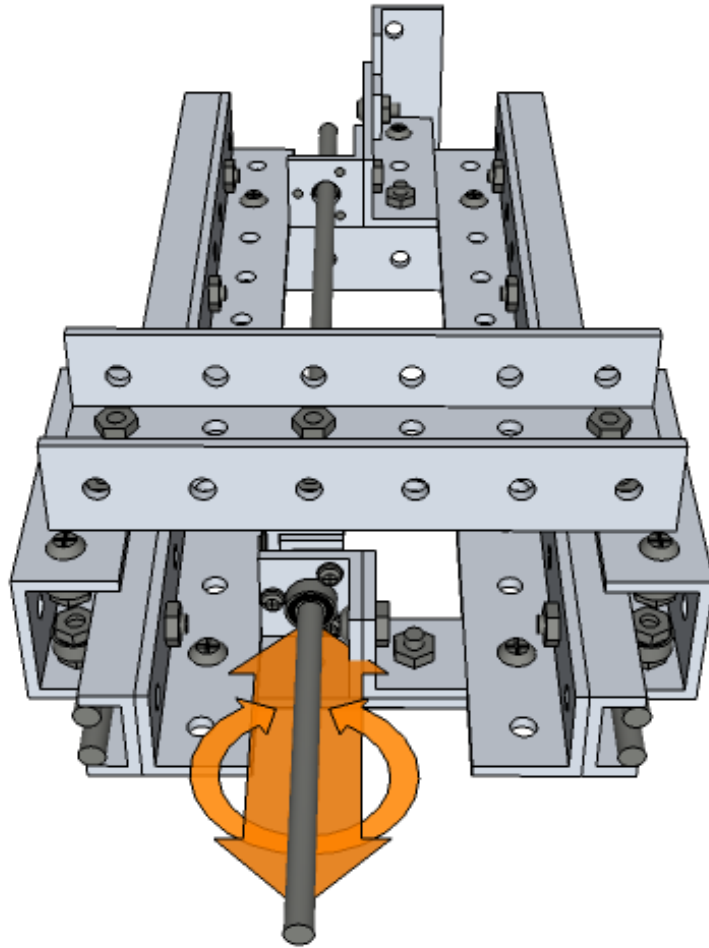


023-X-axis-alignment

Add 1/4" ID bearing to one of the shaft mounts and move the stage until it hits that shaft mount. The threaded rod should easily slide in and out of the bearing (a) and you should be able to freely turn it with your fingers (b).

If either of the above tests fail, identify which side is causing trouble and go back one or two steps to improve alignment.

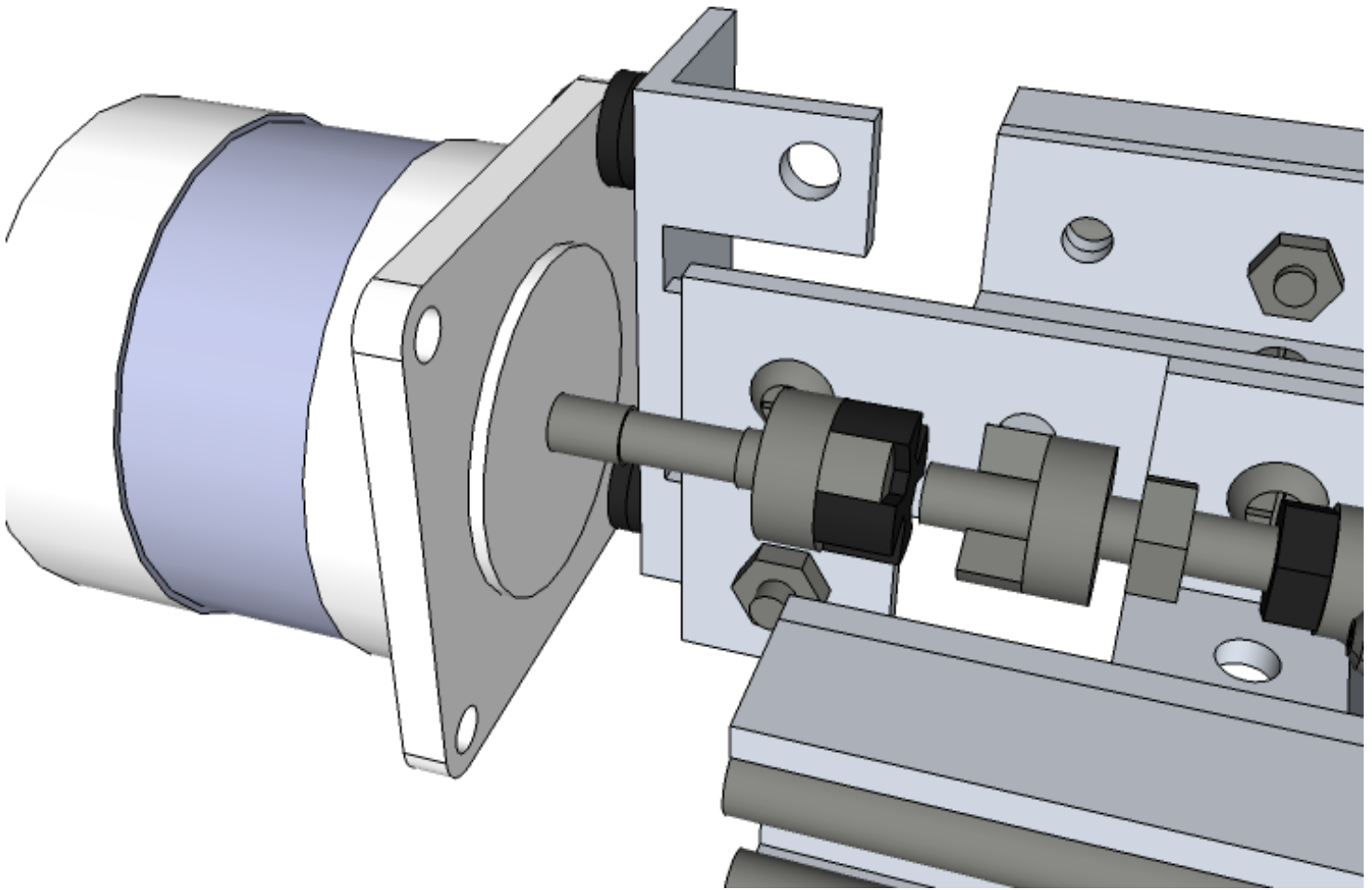
If both tests pass, remove the bearing, move stage to the opposite end of the axis and do the same with the other shaft mount.



024-X-axis-alignment

Repeat the tests (a) and (b) from the previous step with both shaft mount bearings installed, stage at each of the extreme positions, and threaded rod passing through both bearings. Use cordless/power drill to quickly turn the threaded rod.

Generally, if tests are passing for each of the shaft mounts individually, they should pass with both bearings installed. If they do not, this may indicate that the threaded rod is not straight. Unfortunately, threaded rod quality is hit and miss; fortunately, they are cheap and widespread (in the US) to be easily replaced.

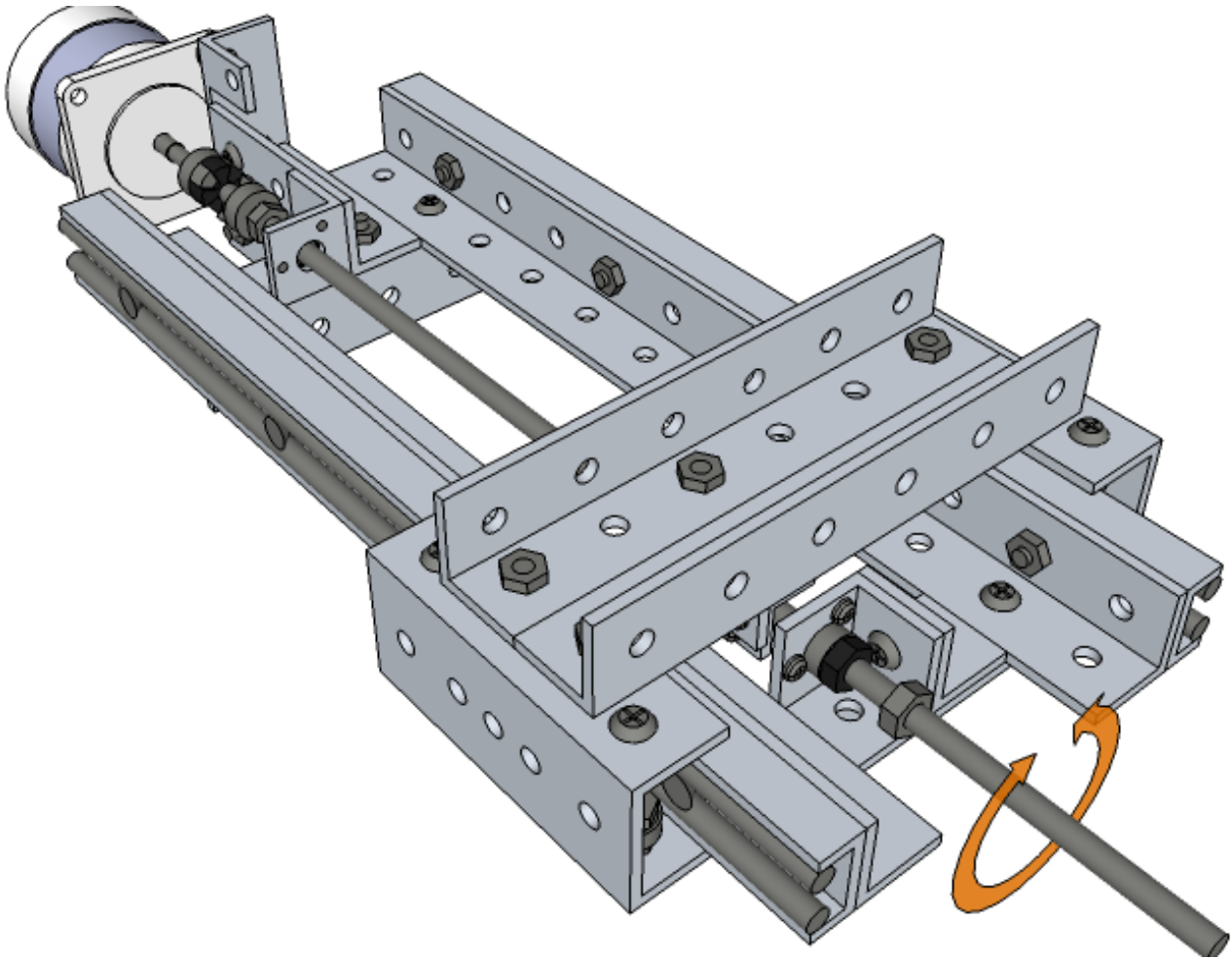


025-X-axis-alignment

Thread the plastic nut and a steel nut on the motor end of the threaded rod.

Test-fit the motor to the motor mount and turn the plastic nut until it is flush with the shaft mount bearing.

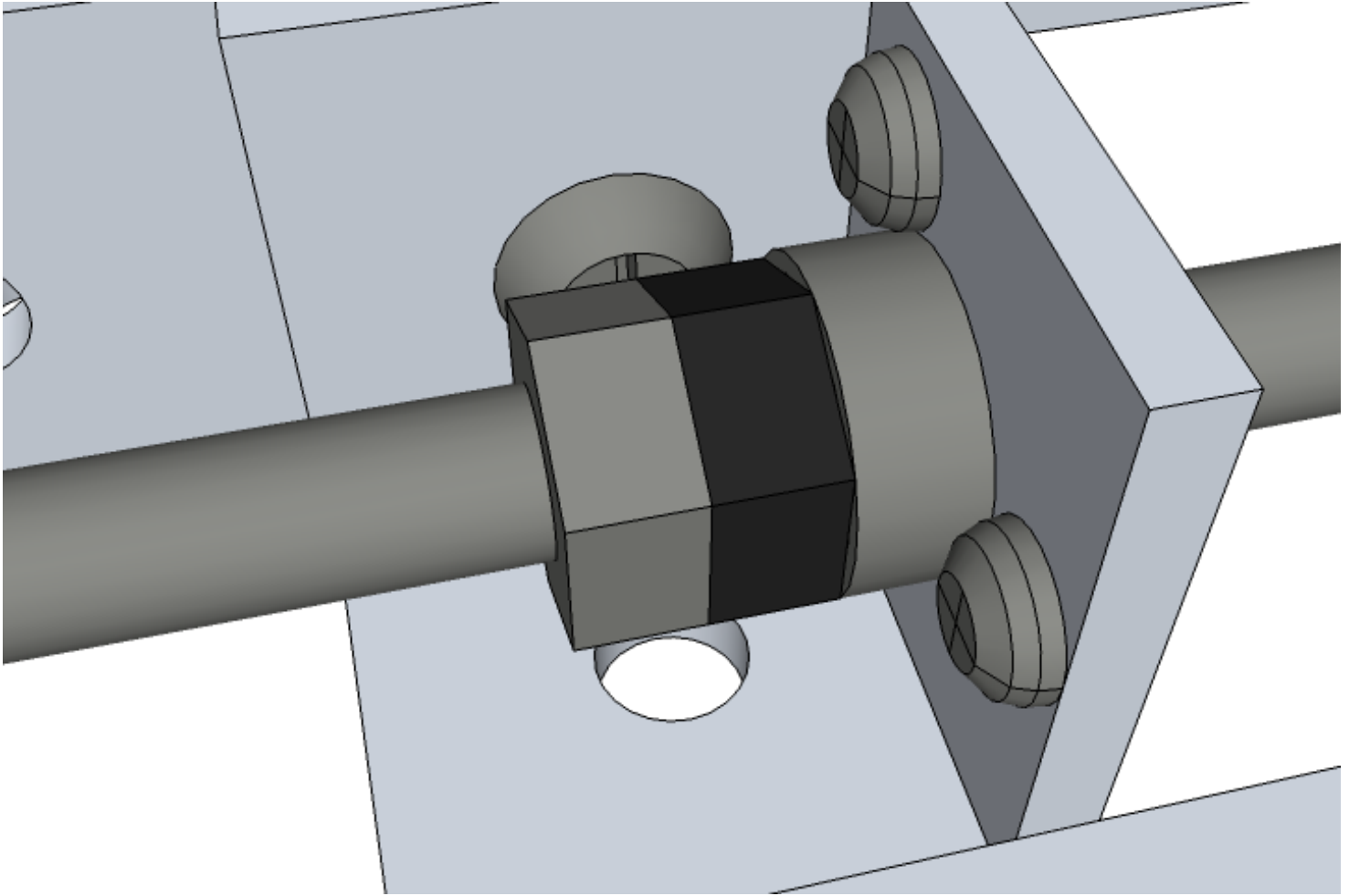
It is best to leave a small gap (1/16") between the rod and the rubber spider of the coupling.



026-X-axis-alignment

Thread the plastic nut and a steel nut on the free end of the threaded rod. Turn the plastic nut until it is flush with the shaft mount bearing.

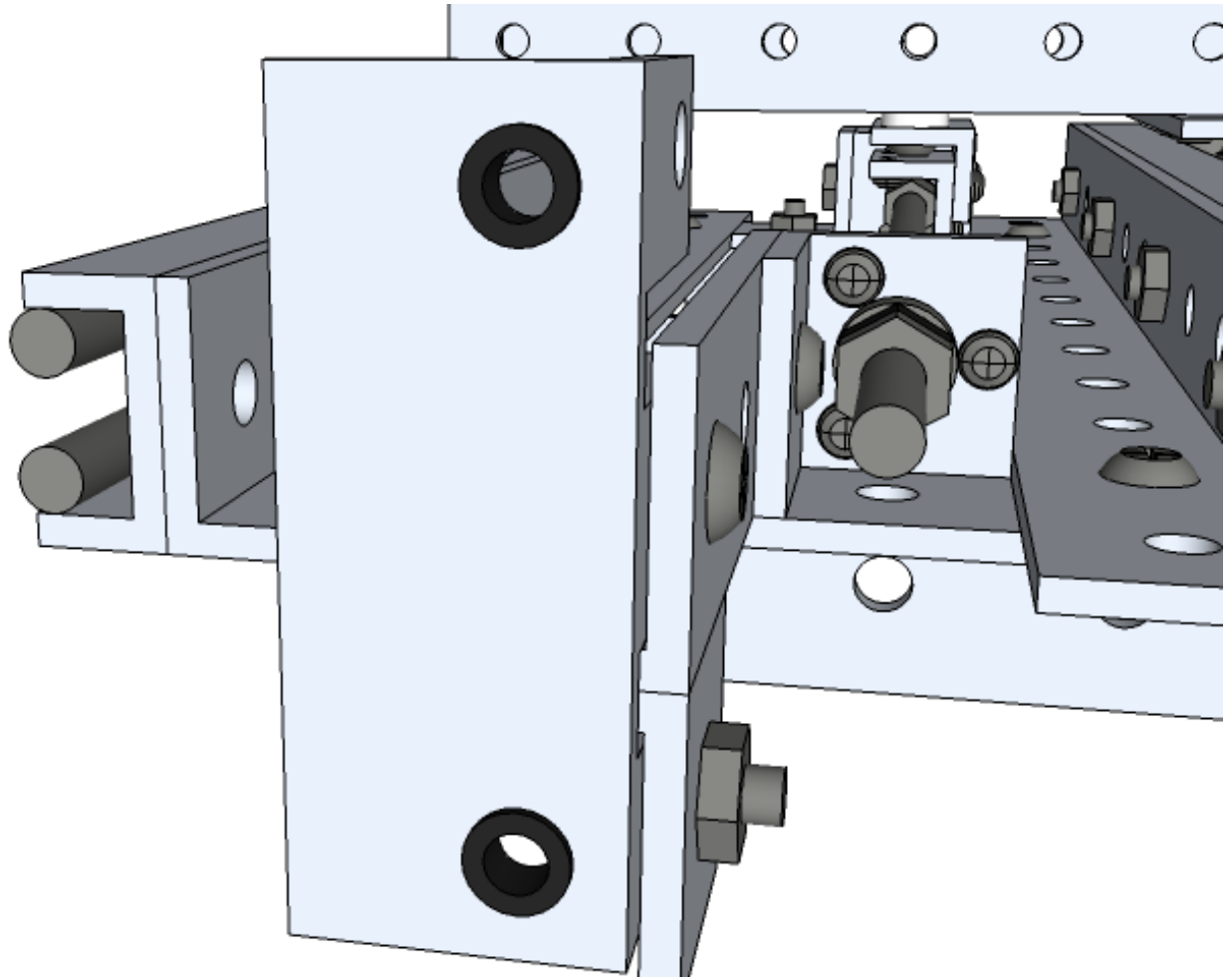
Verify free rotation of the rod at extreme stage positions.



027-X-axis-alignment

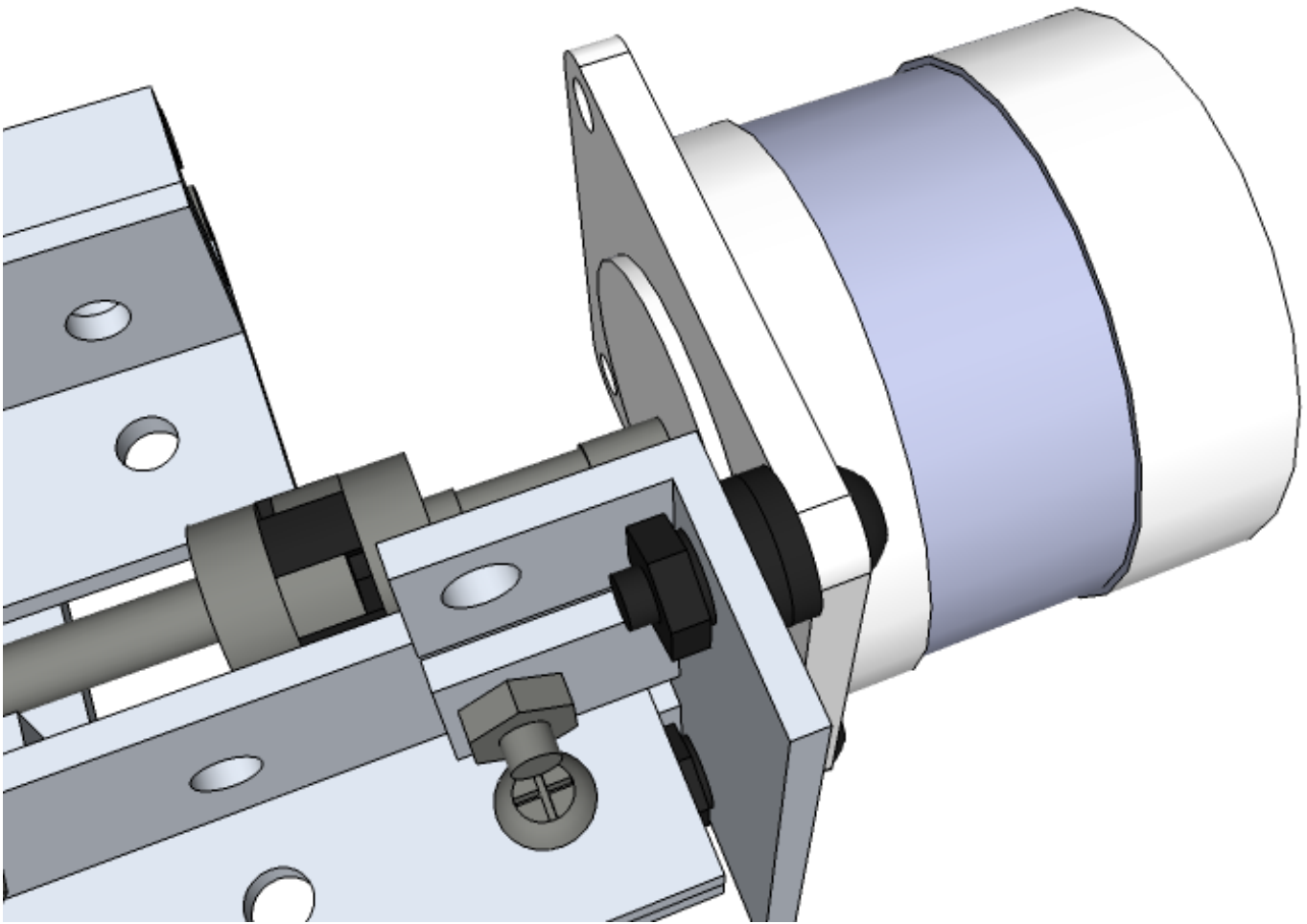
Turn and tighten the steel nuts against the plastic nuts to fix the position of the plastic nuts. Generally, a quarter of a turn should be sufficient.

[Link to video showing tightening of the nuts on the threaded rod.](#)



028-X-axis-alignment

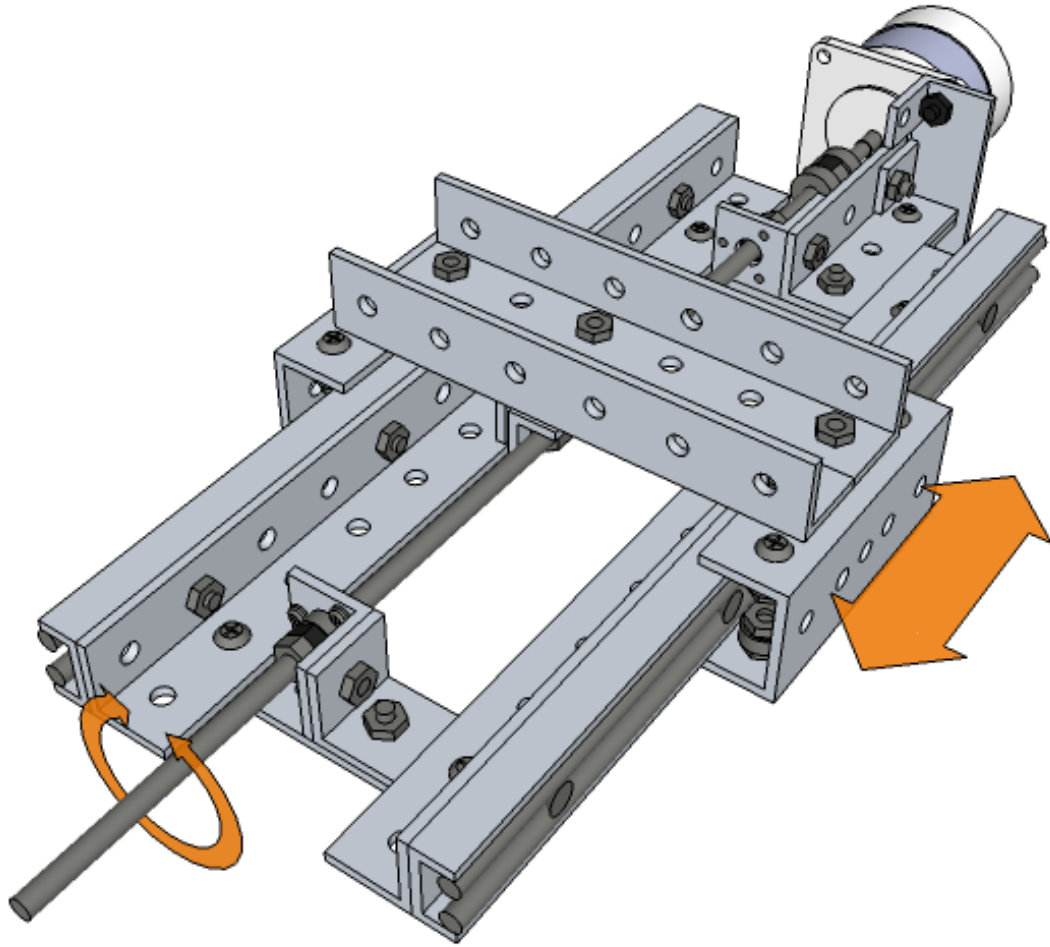
Install rubber grommets into the mounting holes of the motor mount.



029-X-axis-alignment

Install the motor. The plastic screws should be turned with a flat screwdriver so that the grommets don't pop out.

Do not tighten the coupling hub on the leadscrew yet.

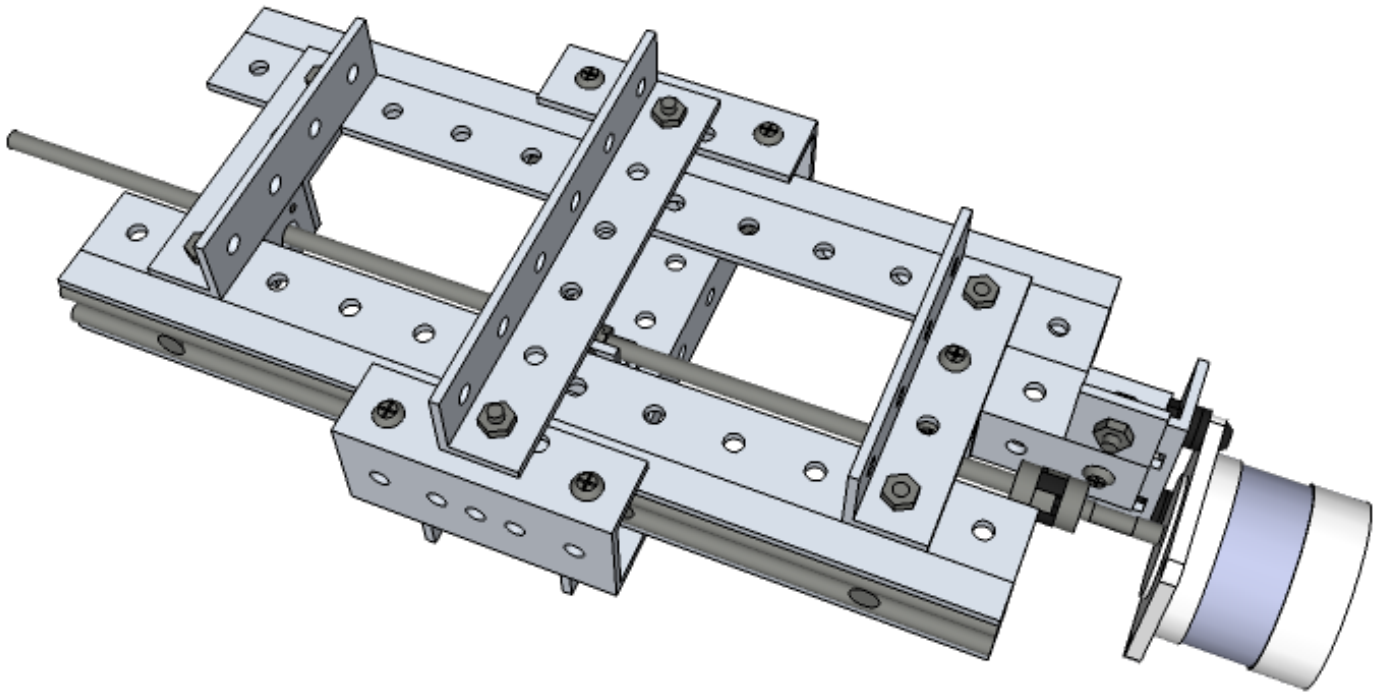


030-X-axis-alignment

Manually verify free rotation of the threaded rod throughout the stage travel. It's important that there are no spots on the rod where you need to apply extra torque to turn it.

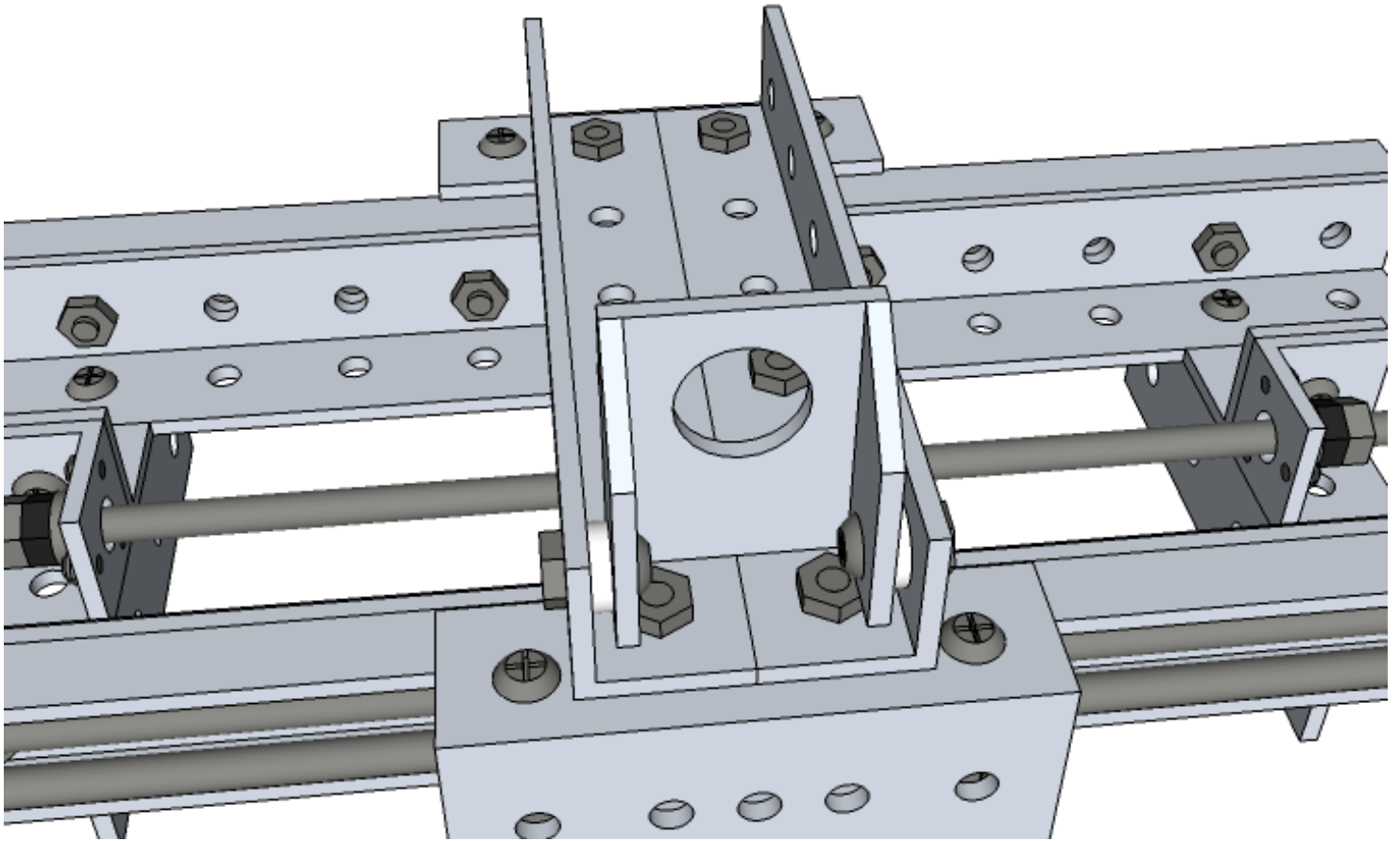
Finally, tighten the coupling hub on the leadscrew. Congratulations, the axis should now be well aligned.

Optionally, connect the motor to the stepper driver and verify that everything works.



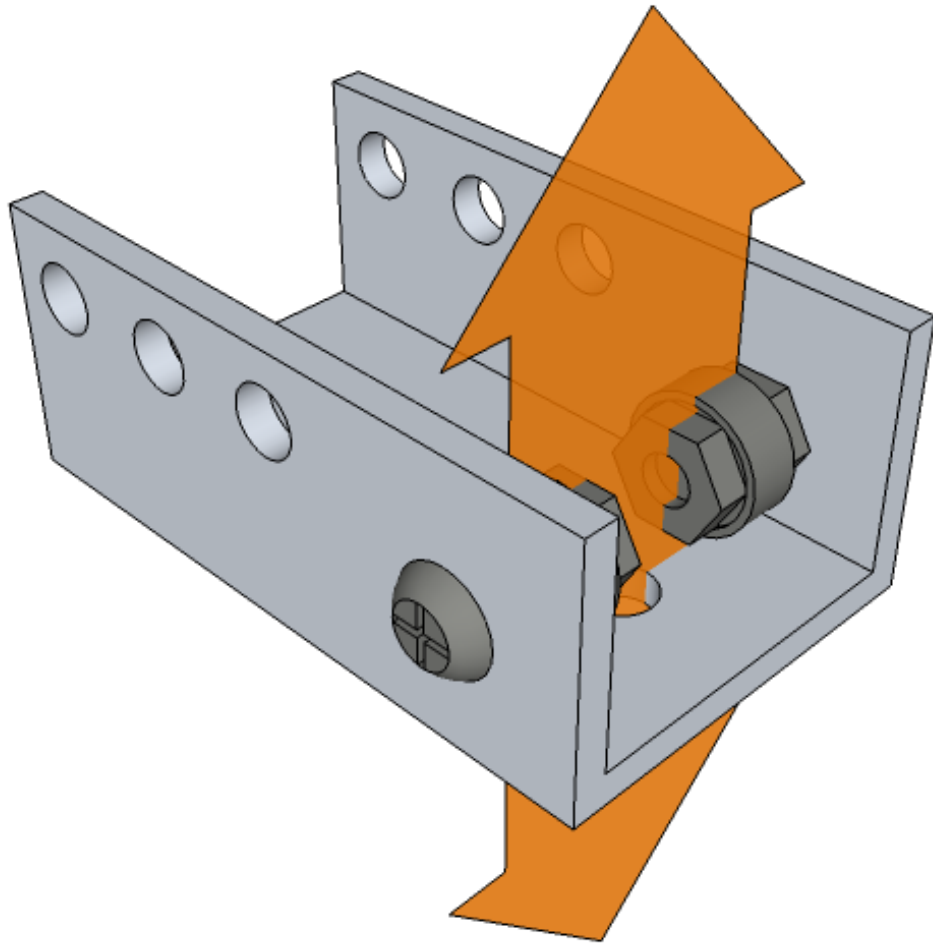
031-X-axis-assembly

Remove nuts from linear bearing screws in the back of the axis. Install angle-6, replace nuts and tighten.



032-X-axis-assembly

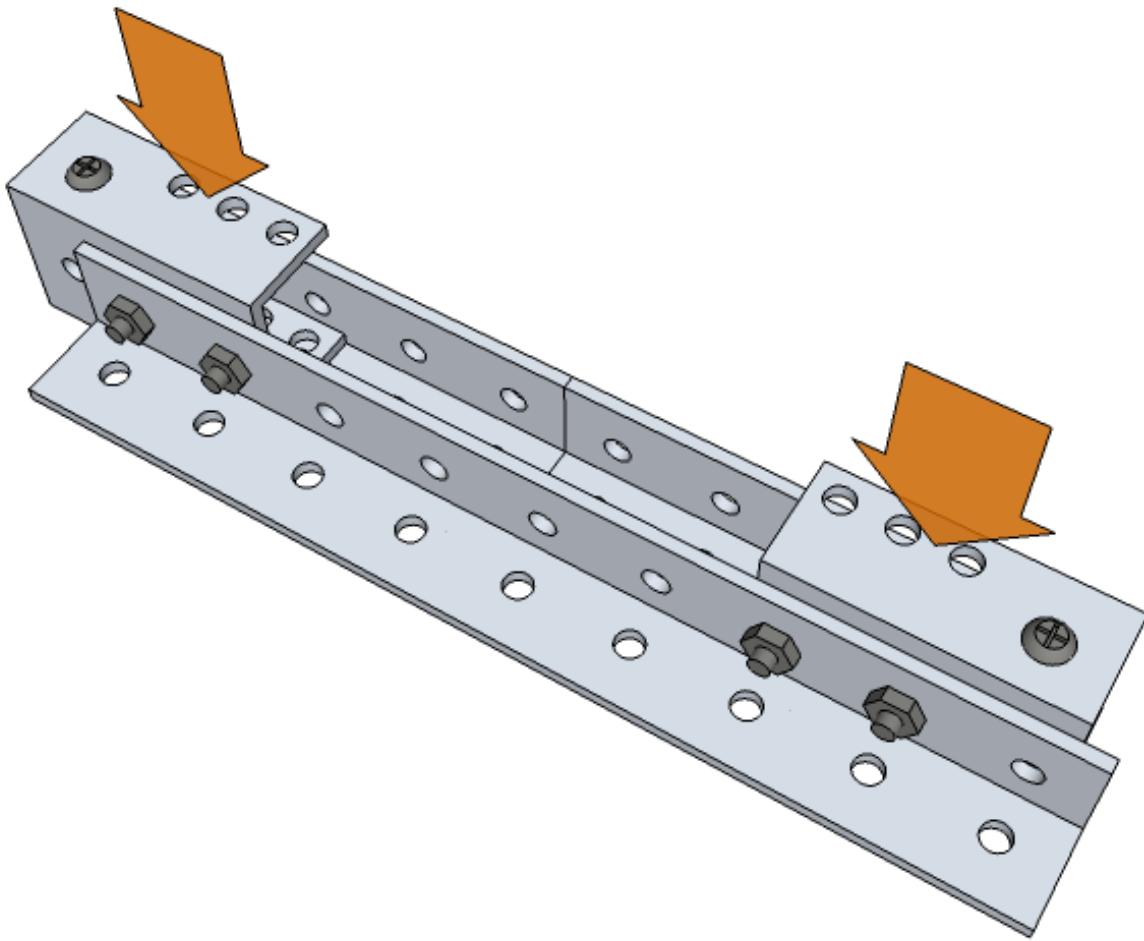
Add dremel mount to X stage with a screw, 1/8th inch spacer and a nut.



033-Y-stage-bearing-assembly

Ensure the ball bearings are aligned as described here:

<http://www.conraptor.org/make-linear-bearings#assembly>

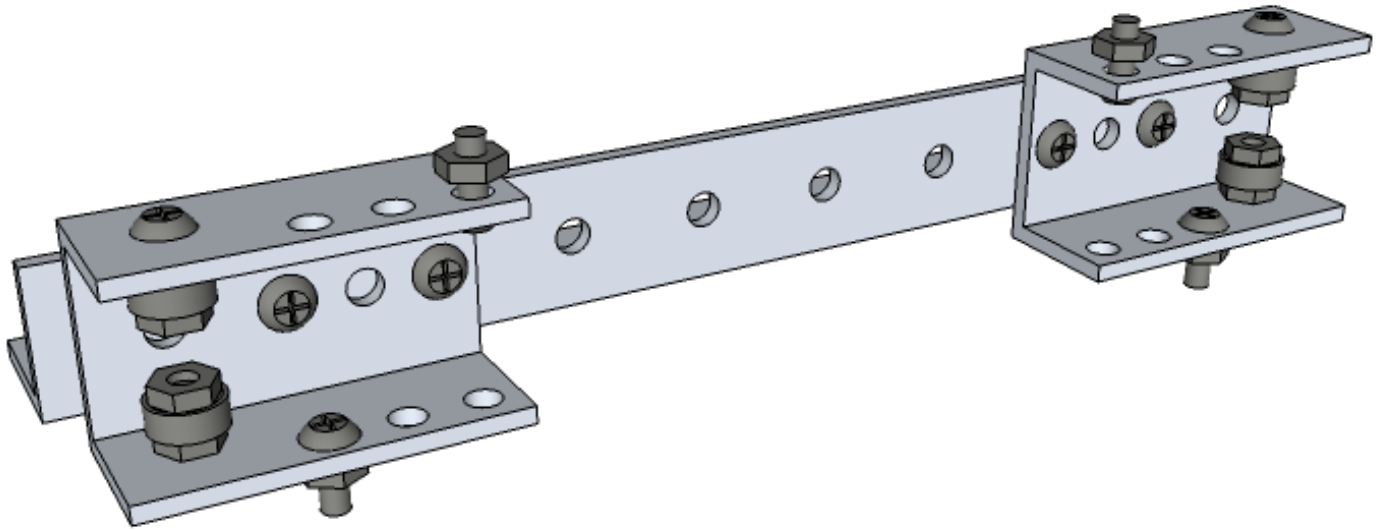


034-Y-stage-bearing-assembly

Connect two linear bearings to angle-9. Do not tighten the nuts yet.

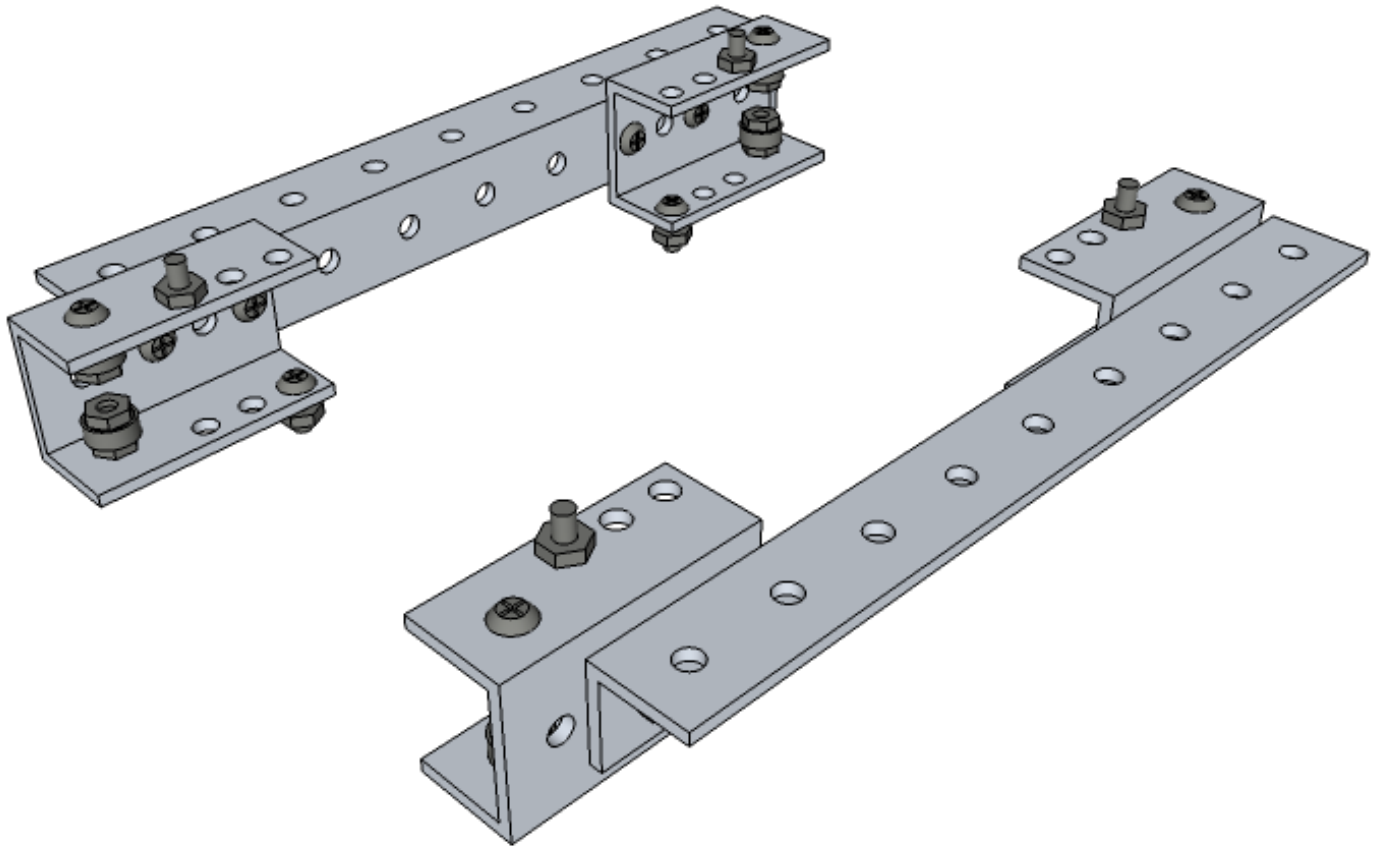
On a flat surface, place an angle-4 under each bearing and push down on the bearings while tightening the nuts with hex socket.

This will ensure the bearings are oriented along the same line. The angle-9 does not have to be parallel to the bearings.



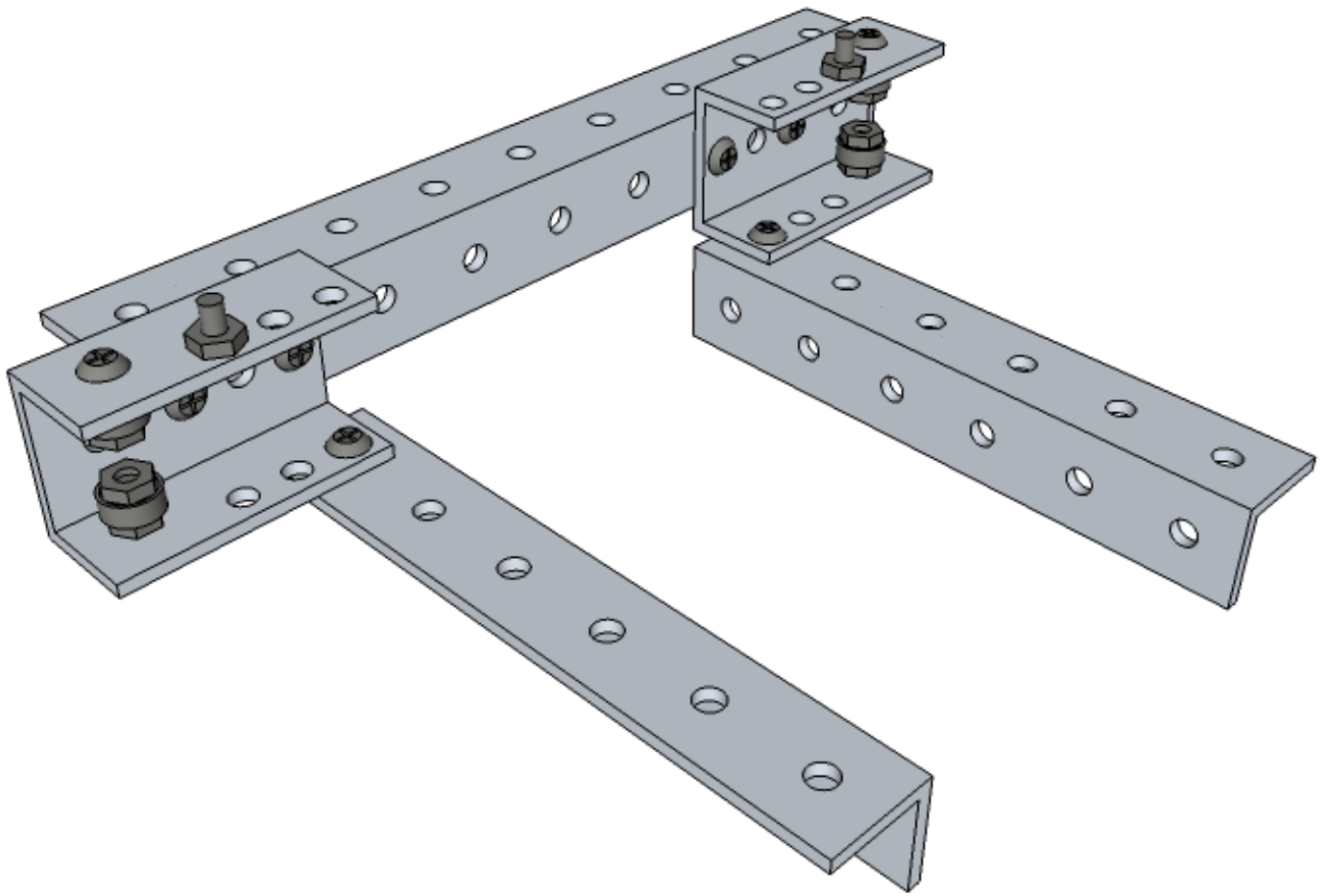
035-Y-stage-bearing-assembly

Add screw + nut pairs to each bearing as shown.



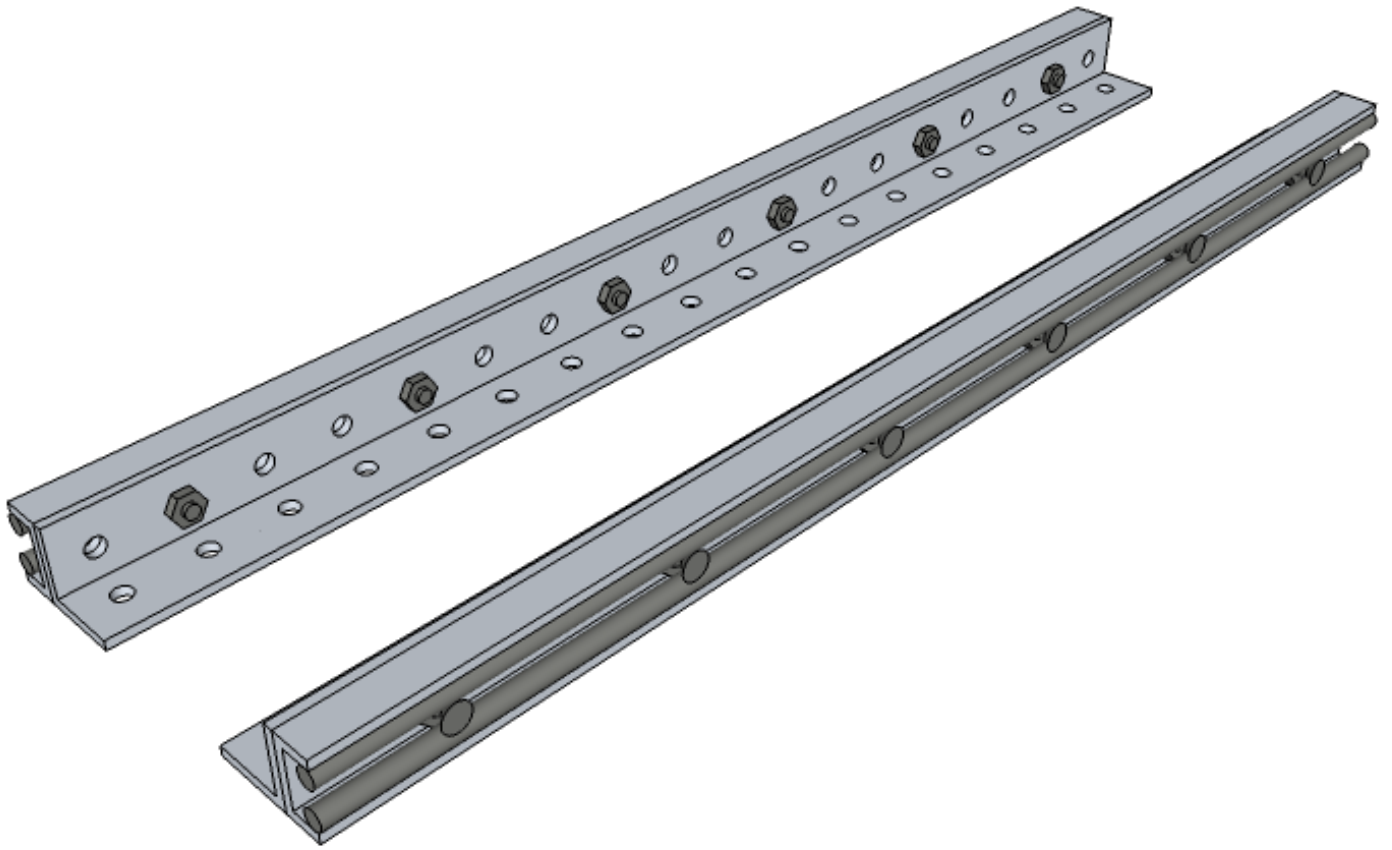
036-Y-axis-assembly

Assemble the opposite linear bearing.



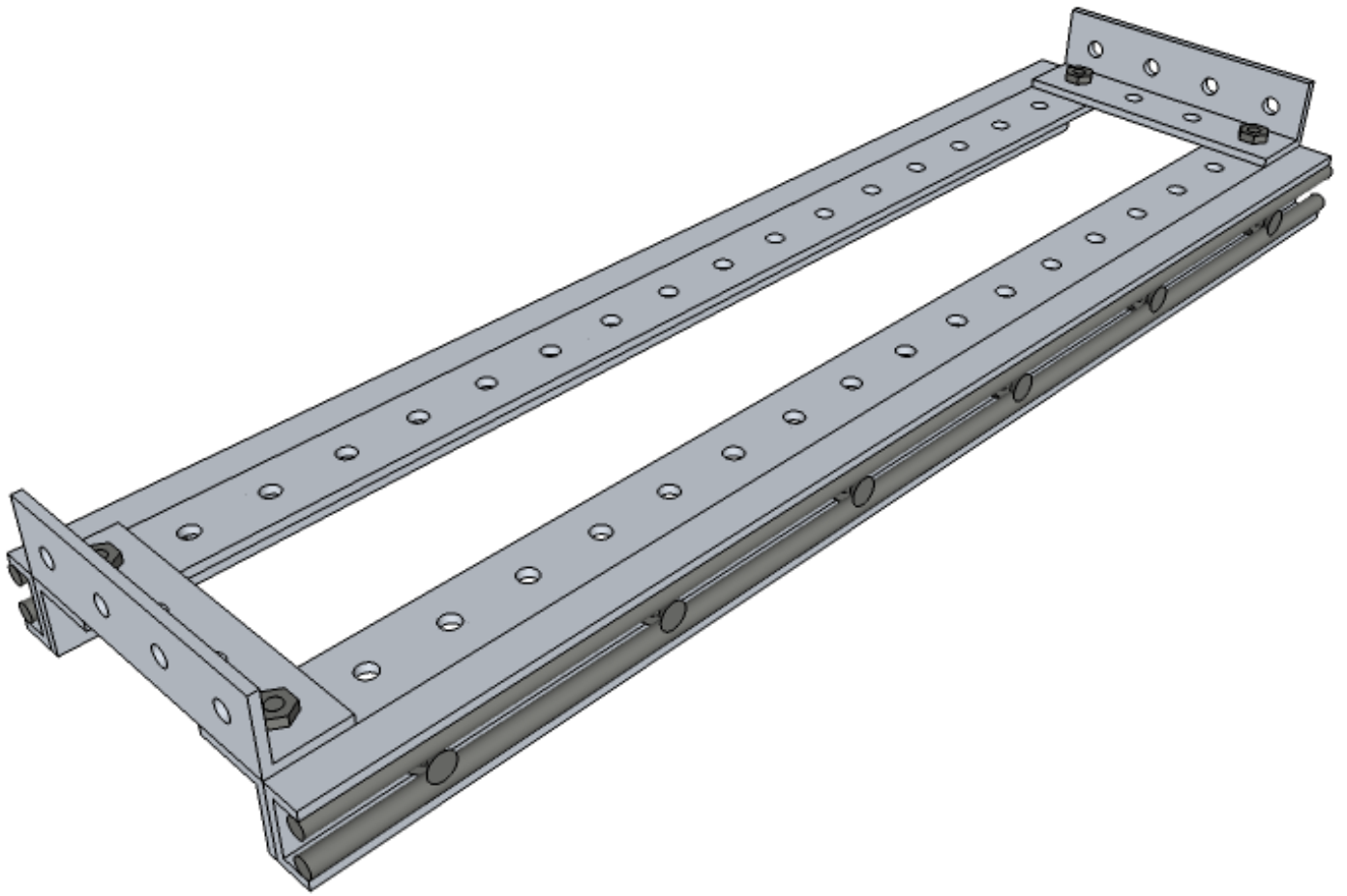
037-Y-axis-assembly

Attach a pair of angle-6 to one linear bearing. Ensure they are roughly orthogonal to the linear bearings and tighten the nuts.



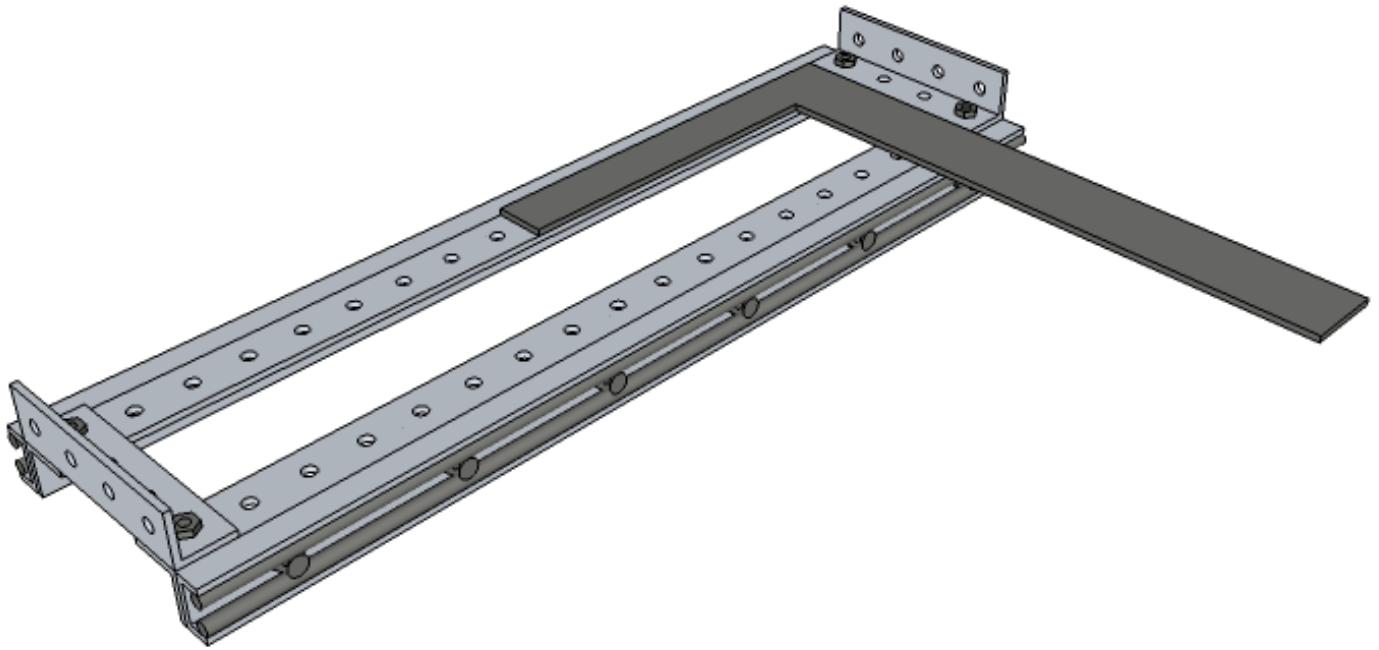
038-Y-rail-assembly

Assemble linear rails



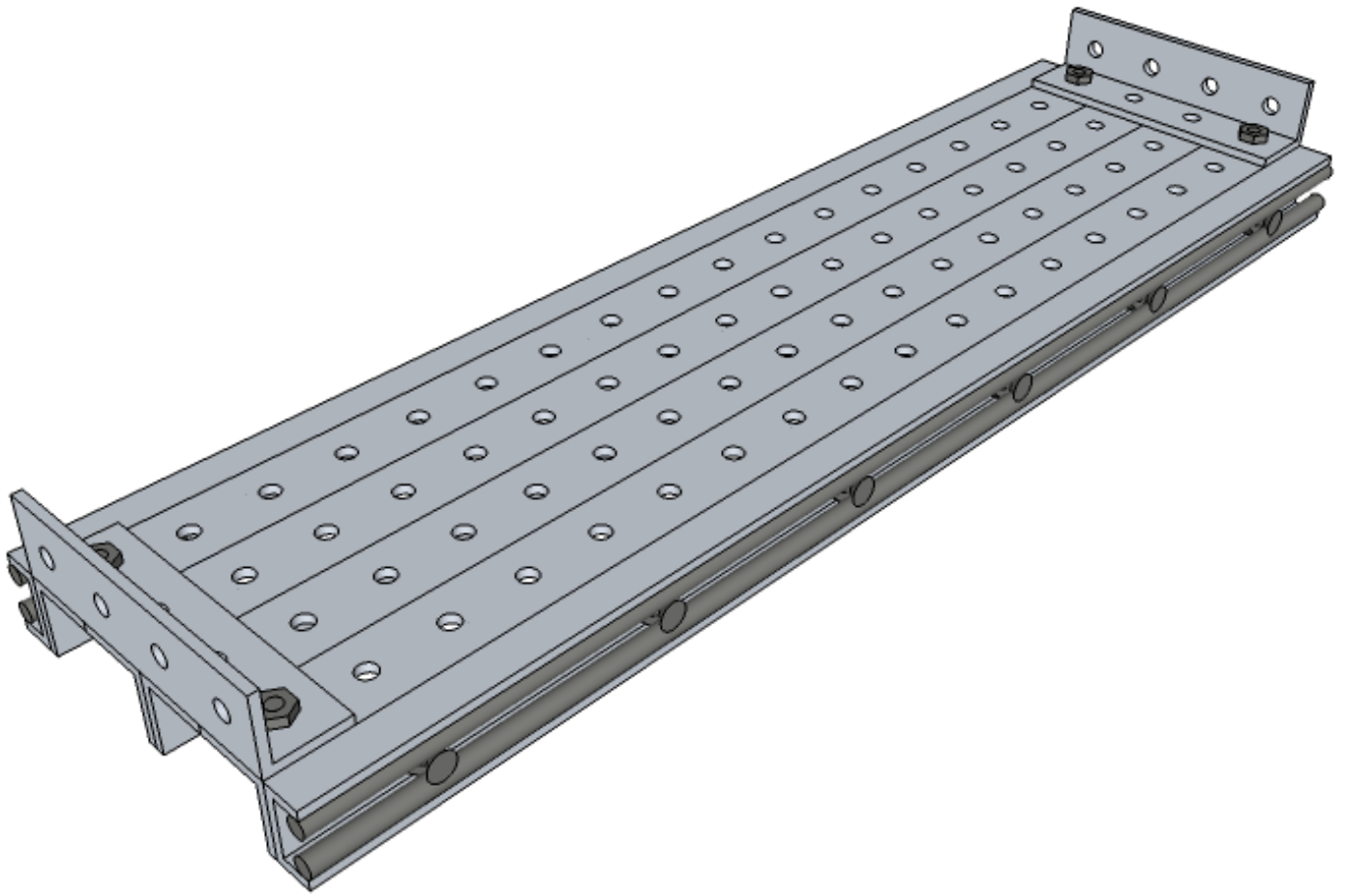
039-Y-rail-assembly

Attach linear rails to angle-4s using 3/8" screws and finger tighten.



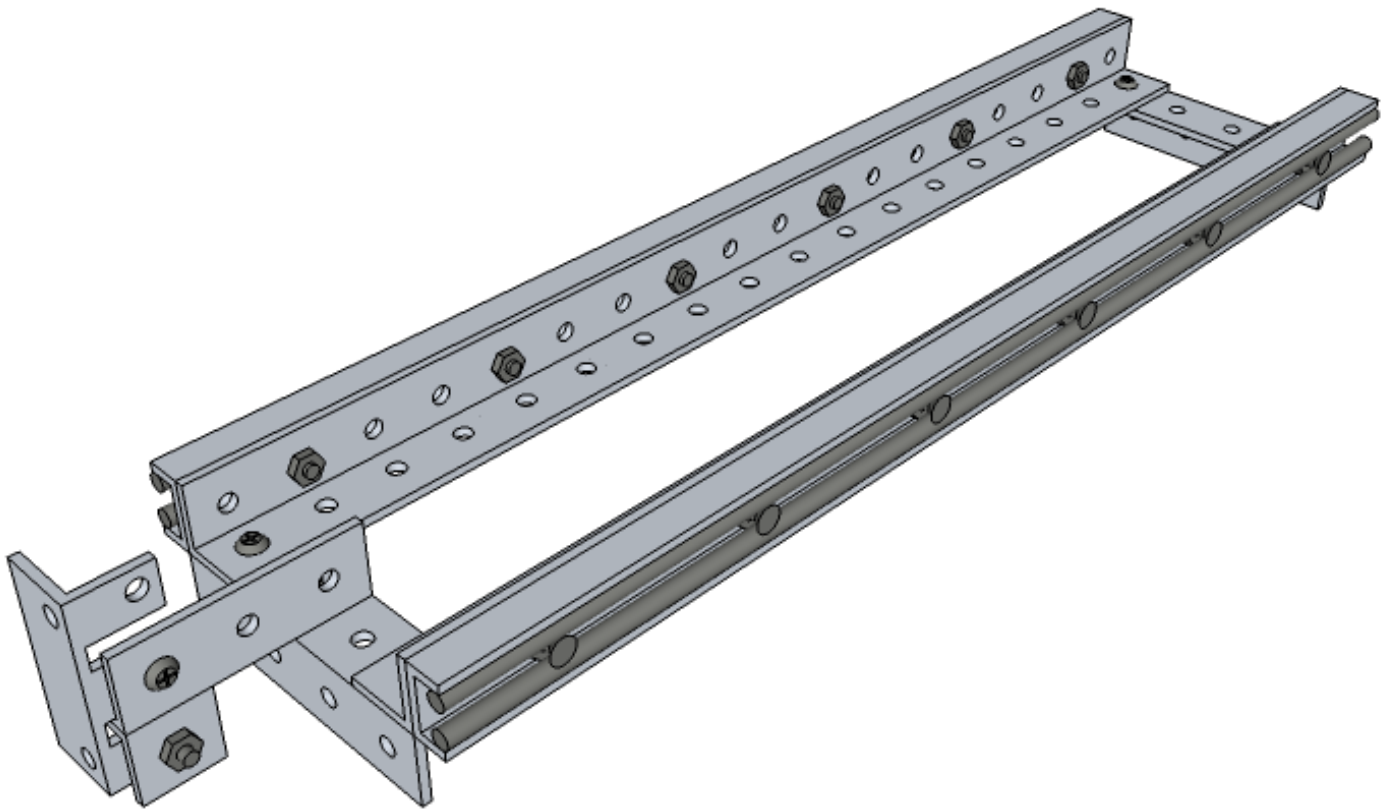
040-Y-rail-assembly

Make sure one of the linear rails is square with both angle-4s and tighten the nuts on that rail.



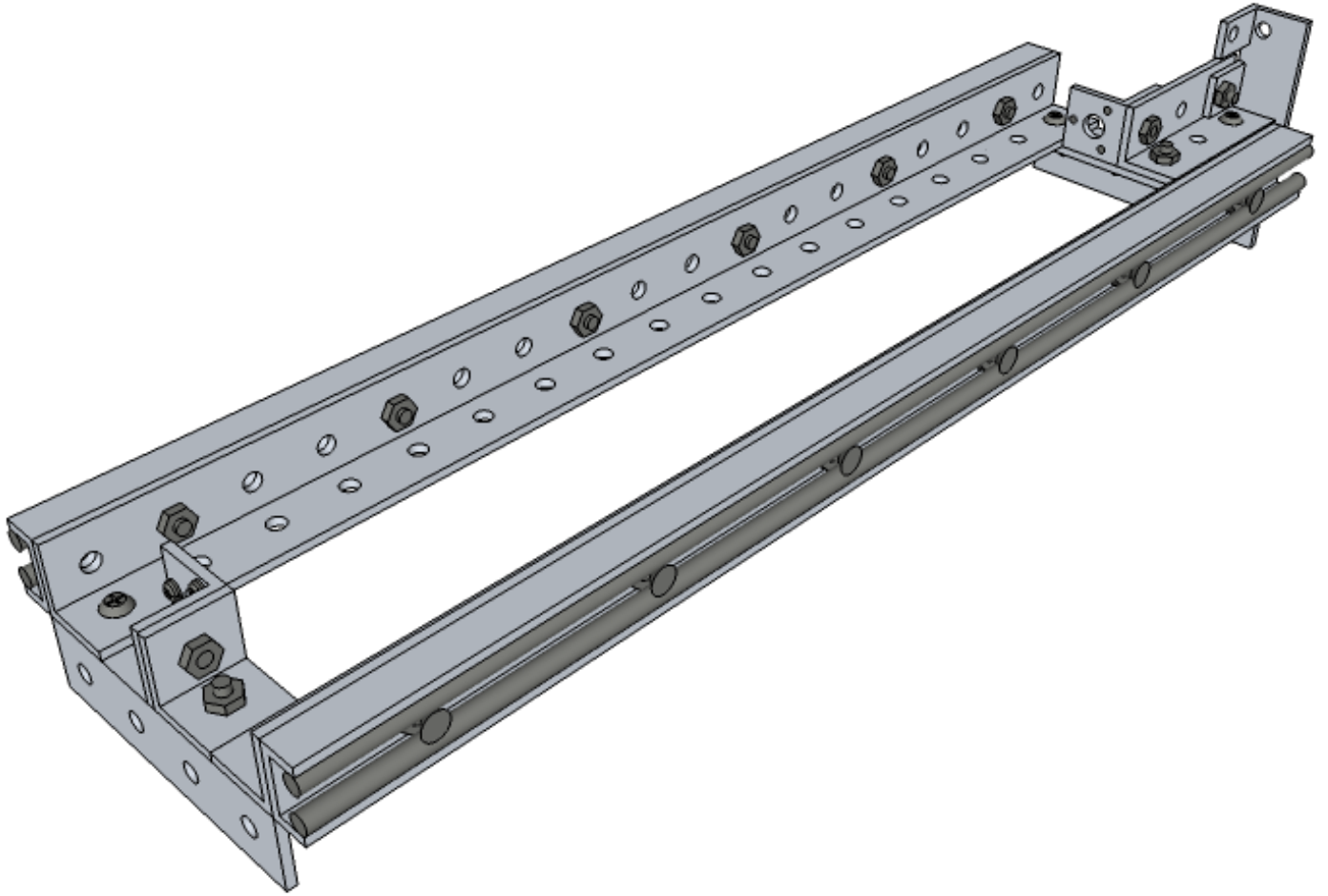
041-Y-rail-assembly

Using a pair of angle-18s, ensure that the rails are parallel and tighten the nuts on the other rail.



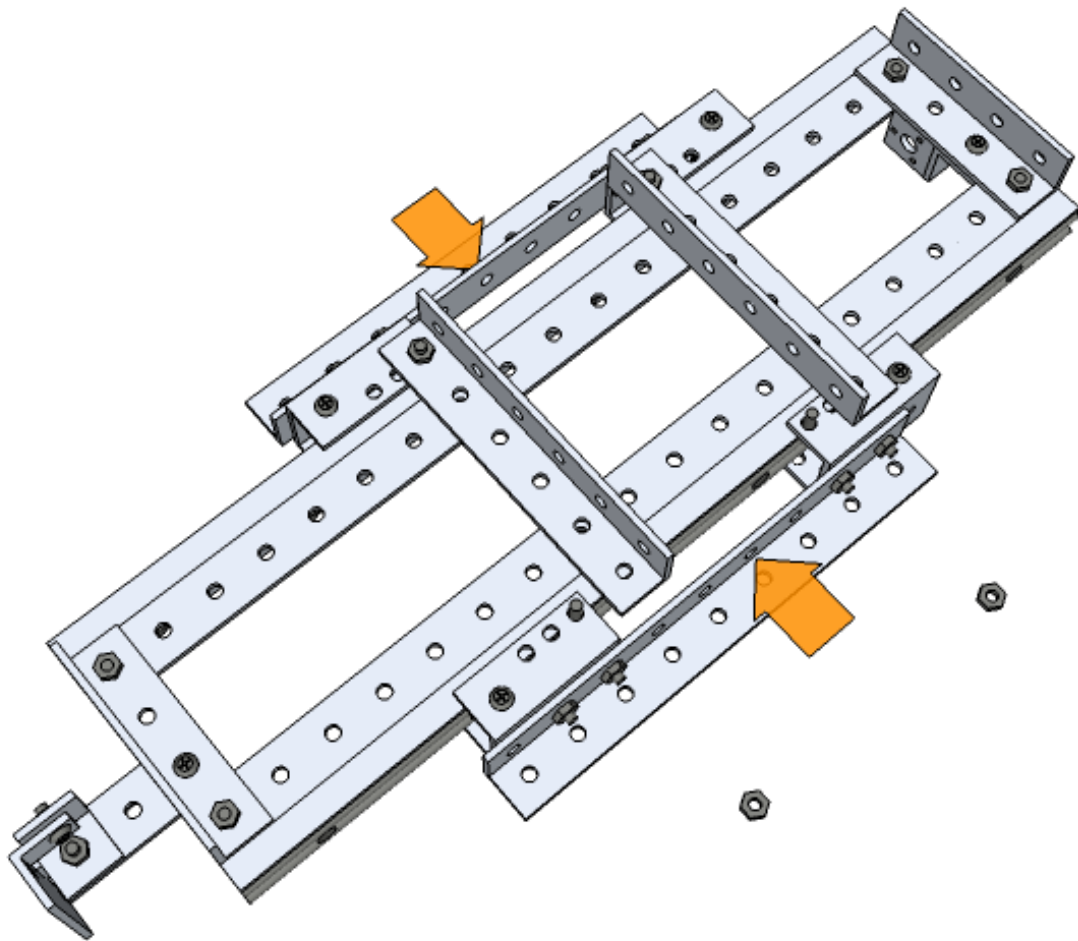
042-Y-rail-assembly

Install motor mount.



043-Y-rail-assembly

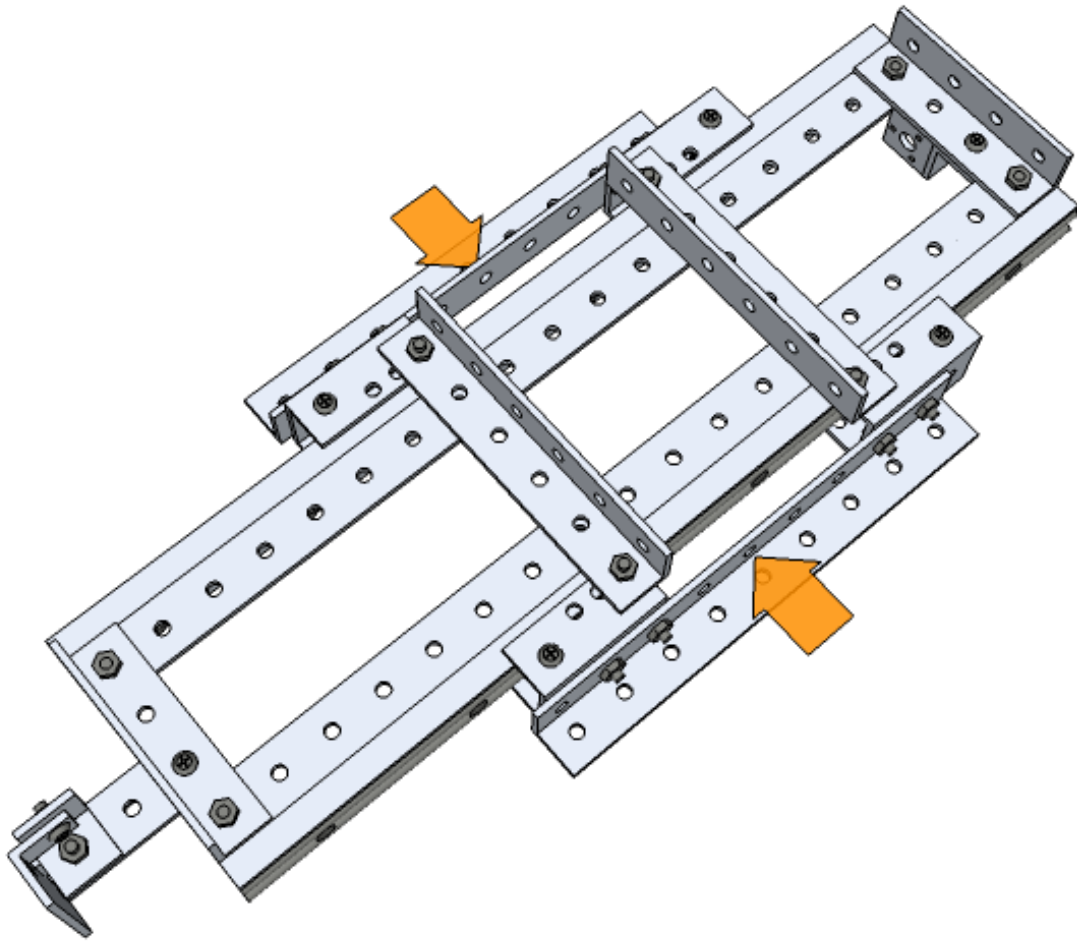
Install shaft mounts.



044-Y-axis-assembly

Arrange and hold two pieces of Y stage on Y rail as shown.

Remove two nuts from the standalone linear bearing - the screws should stay in place being restricted by the rail assembly.

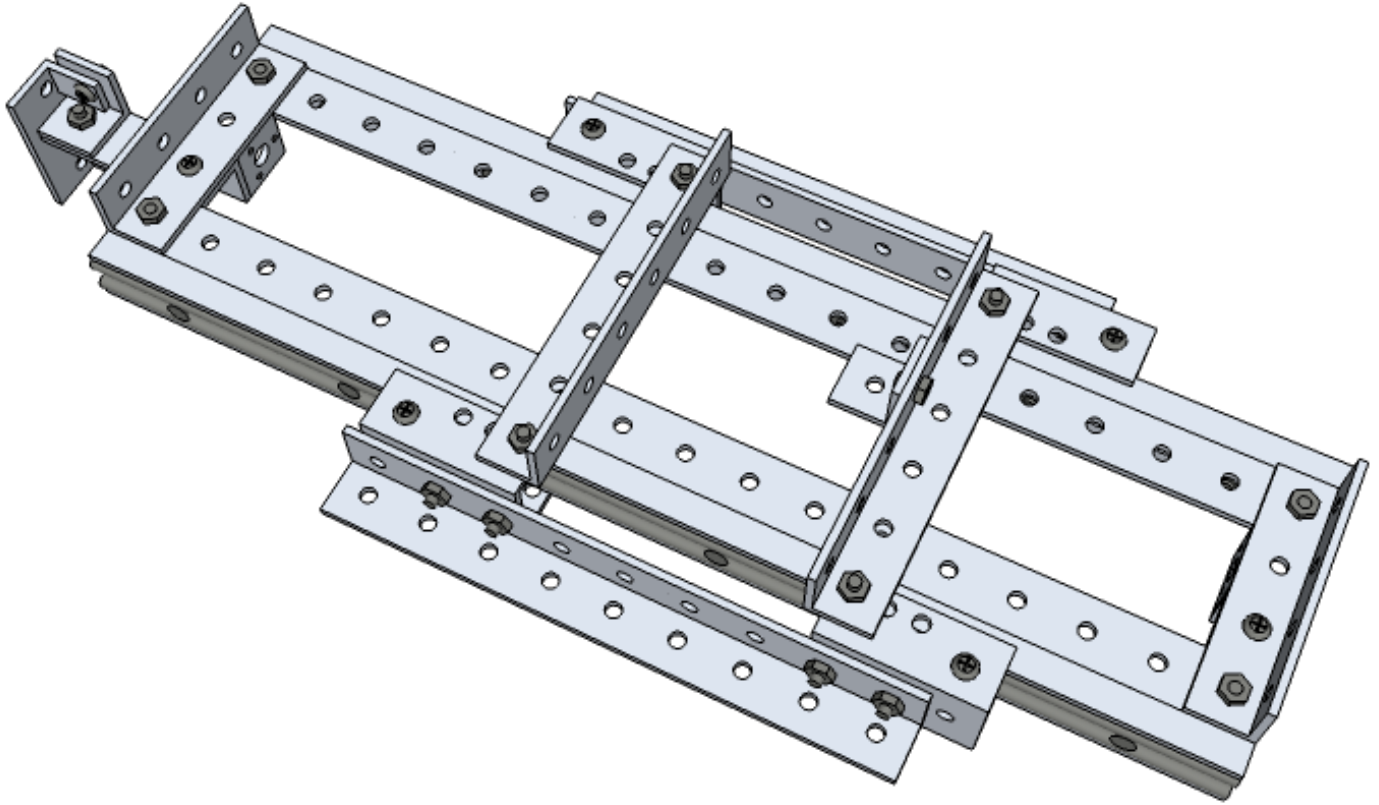


045-Y-axis-assembly

Slightly raise the free ends of angle-6 and slide them over and onto the screws.

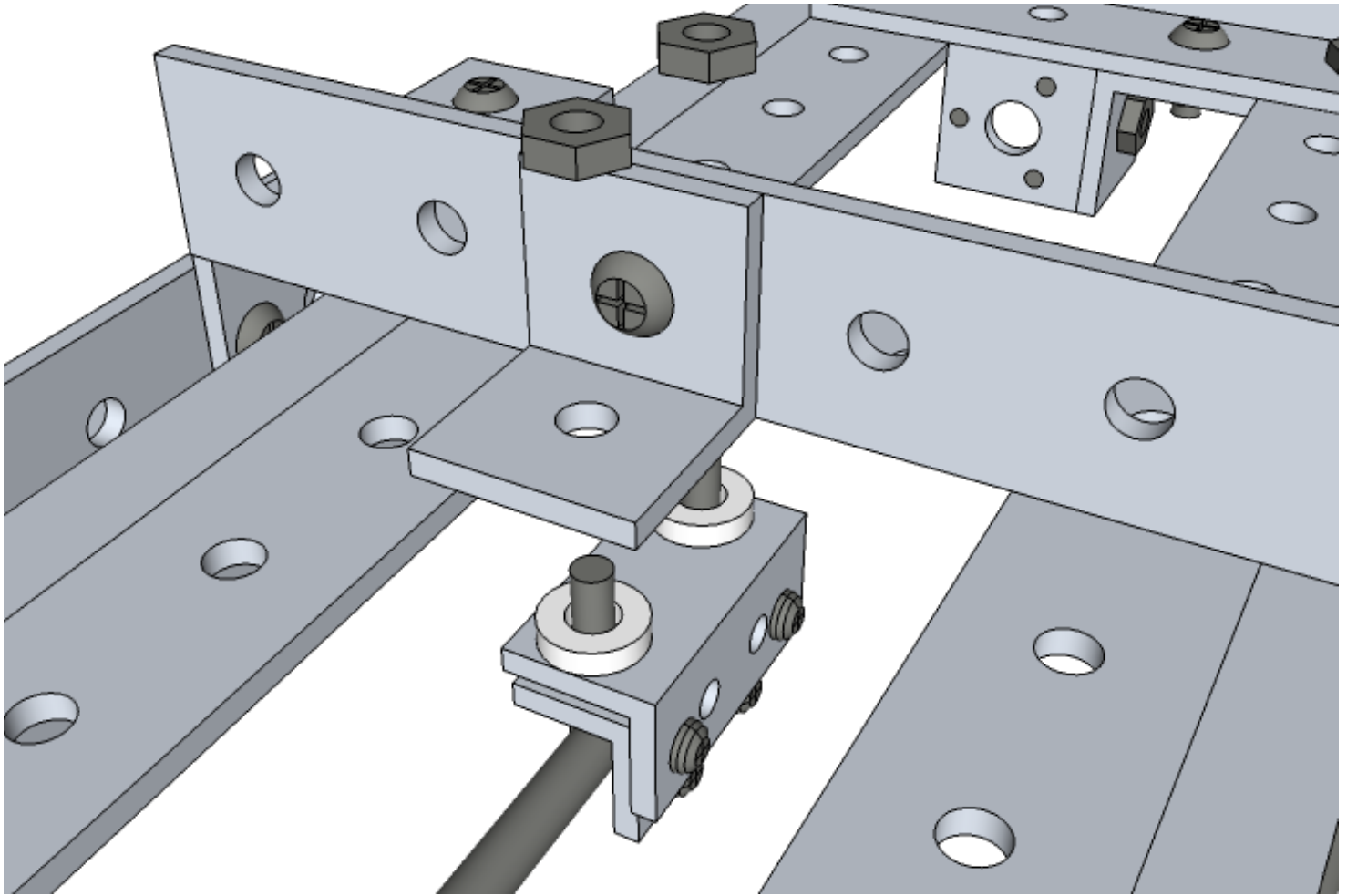
Put the nuts back on the screws. Apply sufficient pressure on the linear bearings to ensure there is no slack and tighten the nuts.

The stage should glide on the rail. If you are unable to remove the slack, go back to the alignment of linear bearings.



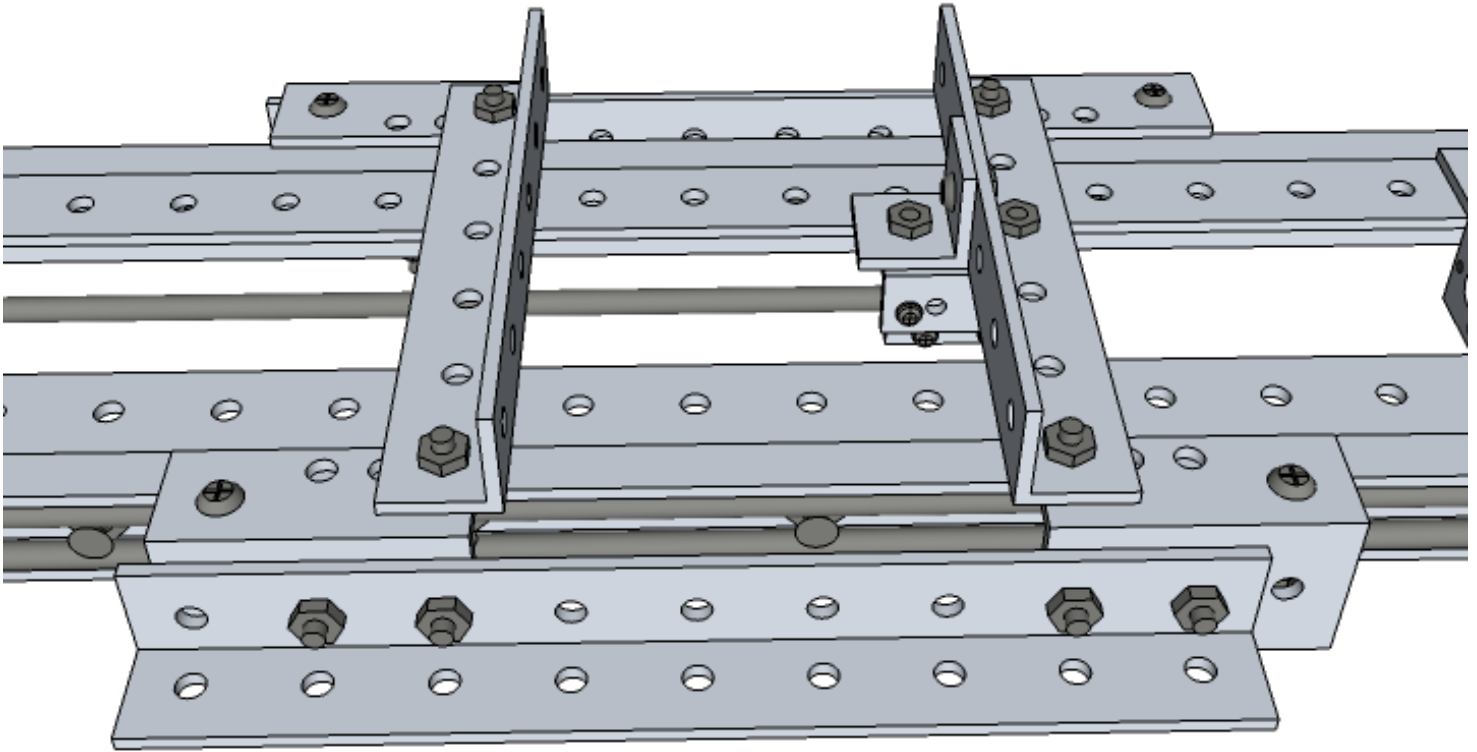
046-Y-axis-assembly

Attach angle-1 to angle-6 using 3/8" screw.



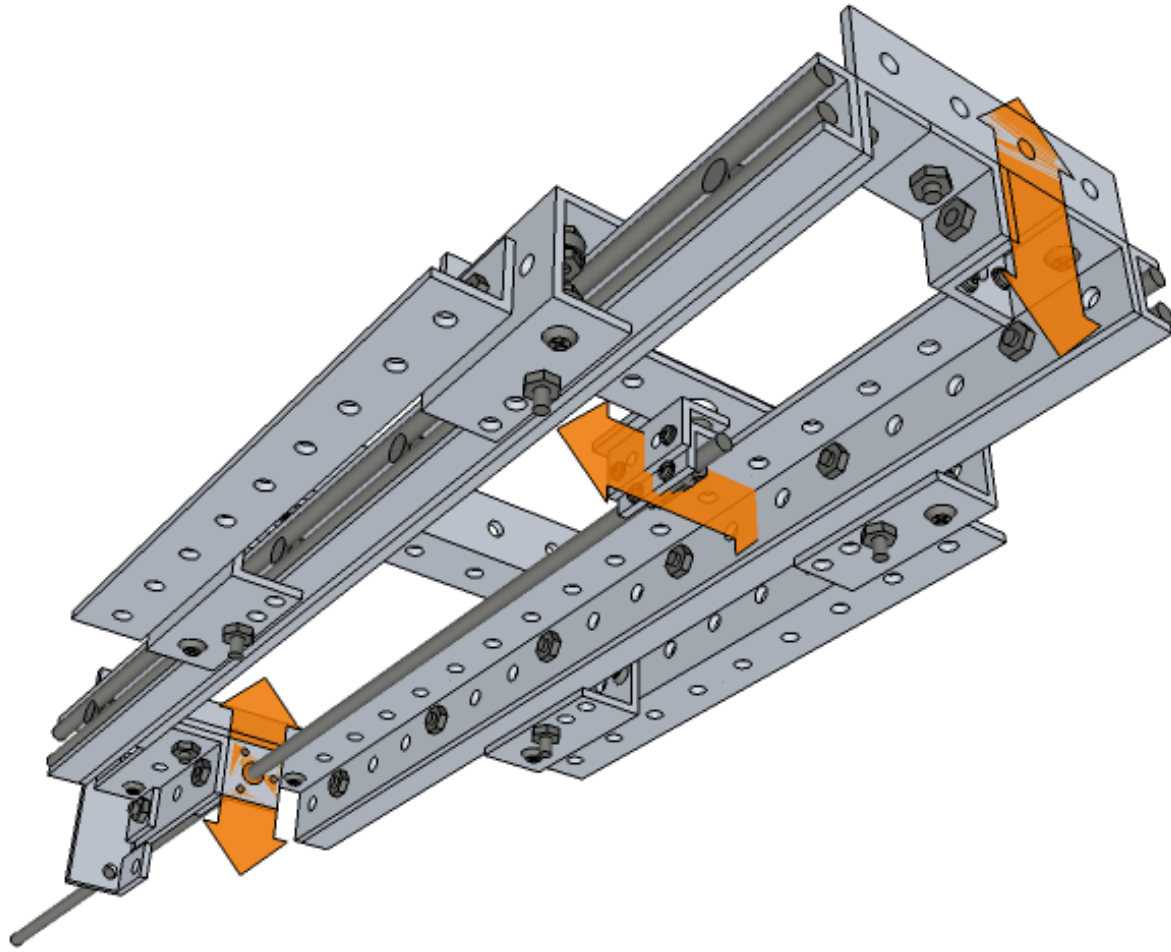
047-Y-axis-alignment

Lead nut assembly should be attached to Y stage with a pair of 1/8" nylon spacers in between.



048-Y-axis-alignment

Attach the lead nut assembly to Y stage and finger tighten the nuts.



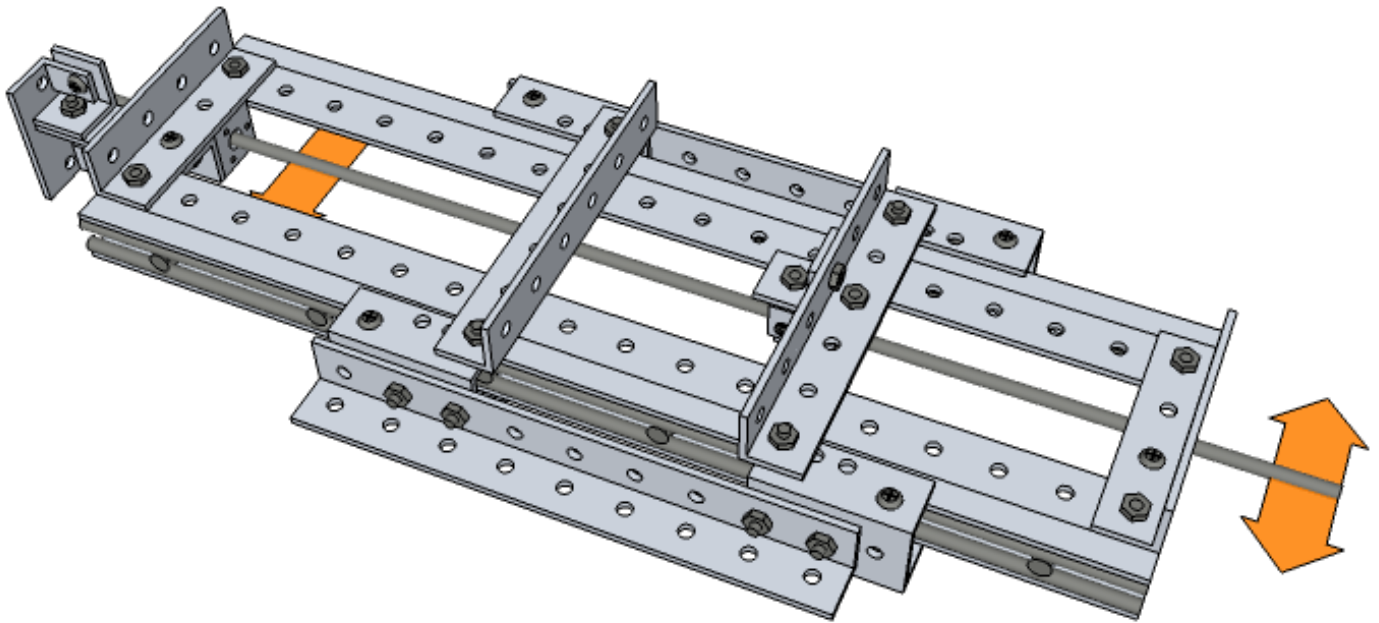
049-Y-axis-alignment

The next step is to align the lead nut and shaft mounts so that their centers are on the same axis. This is probably the most intricate part of the assembly.

This step is very important because misalignment will cause threaded rod to bend and require more torque to turn it, leading to skipped steps.

The alignment is performed by adjusting the lead nut side-to-side and the shaft mounts up-down, until desired result is achieved.

The success criteria is that you must be able to easily rotate the threaded rod with your fingers once it is constrained by the bearings. Free rotation must be present throughout entire length of stage travel, including extreme positions of the stage.

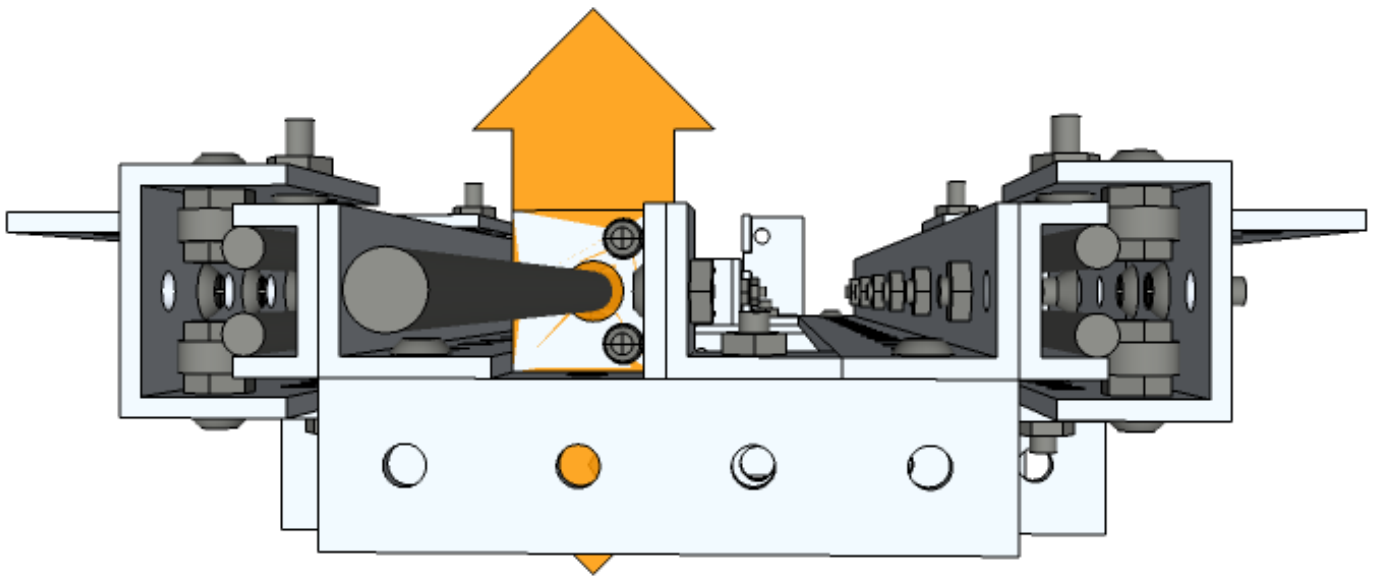


050-Y-axis-alignment

Center the stage relative to shaft mounts and turn the threaded rod until the lead nut is in the middle of it. Use cordless/power drill to do this quickly.

Loosen the lead nut and position it so that the threaded rod passes through the centers of both shaft mounts in the horizontal plane, then carefully tighten the lead nut in this position. This part is tricky as the leadnut will want to turn/move as you tighten it, in the direction of tightening. You can compensate for it by holding the threaded rod slightly off center in the opposite direction. It is normal for this to take several attempts.

Keep in mind that the rod may be very slightly bent, in which case its ends may be a bit off the true center axis. Rotate the rod a couple of turns to see where the true center axis is.



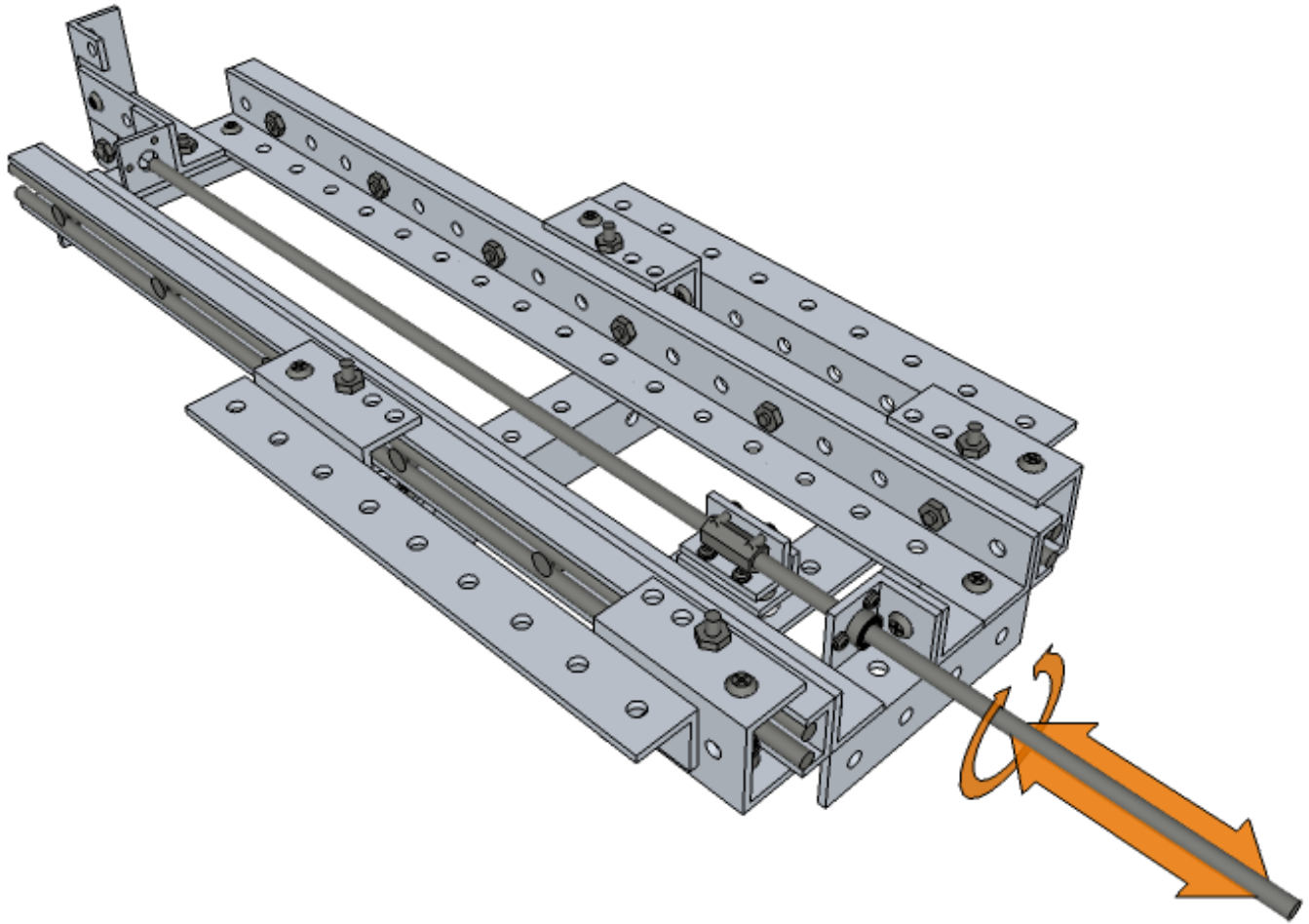
051-Y-axis-alignment

Move stage to one of the extreme positions of the axis - misalignment is more evident at extreme positions.

Move the stage away to access the mounting screw and adjust the shaft mount up-down so that the threaded rod passes through its center in the vertical plane. Be sure to keep the shaft mount square to the threaded rod.

Verify that threaded rod is still centered in the horizontal plane (sideways). If not, go back to previous step.

Move the stage to the opposite end of the axis and do the same with the other shaft mount.

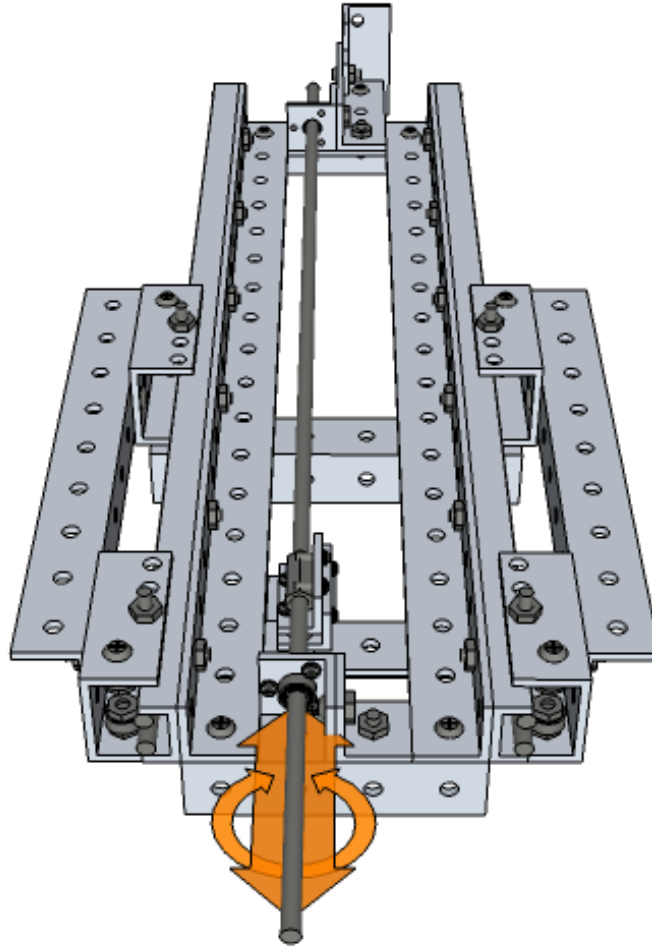


052-Y-axis-alignment

Add 1/4" ID bearing to one of the shaft mounts and move the stage until it hits that shaft mount. The threaded rod should easily slide in and out of the bearing (a) and you should be able to freely turn it with your fingers (b).

If either of the above tests fail, identify which side is causing trouble and go back one or two steps to improve alignment.

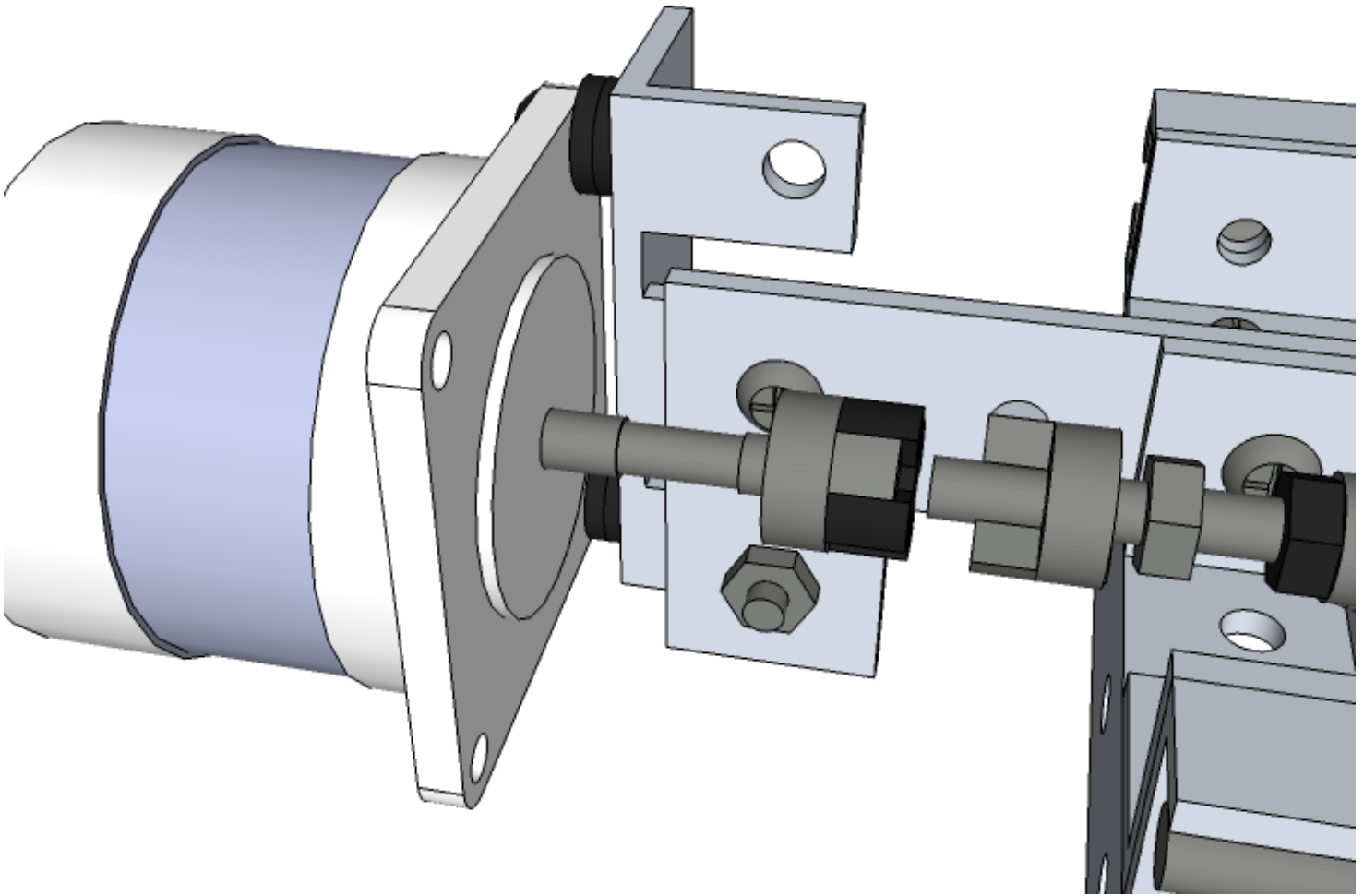
If both tests pass, remove the bearing, move stage to the opposite end of the axis and do the same with the other shaft mount.



053-Y-axis-alignment

Repeat the tests (a) and (b) from the previous step with both shaft mount bearings installed, stage at each of the extreme positions, and threaded rod passing through both bearings. Use cordless/power drill to quickly turn the threaded rod.

Generally, if tests are passing for each of the shaft mounts individually, they should pass with both bearings installed. If they do not, this may indicate that the threaded rod is not straight. Unfortunately, threaded rod quality is hit and miss; fortunately, they are cheap and widespread (in the US) to be easily replaced.

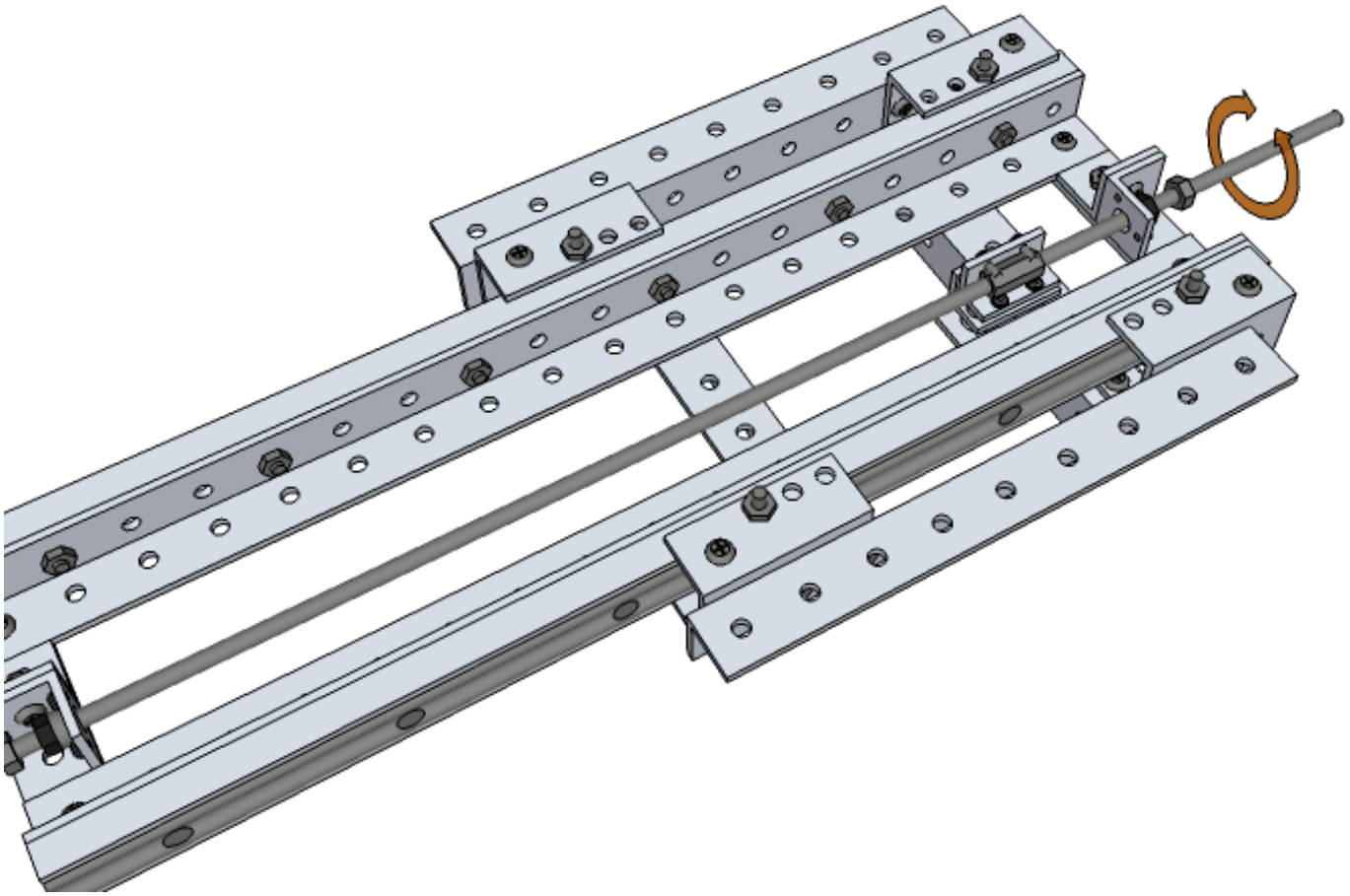


054-Y-axis-alignment

Thread the plastic nut and a steel nut on the motor end of the threaded rod.

Test-fit the motor to the motor mount and turn the plastic nut until it is flush with the shaft mount bearing.

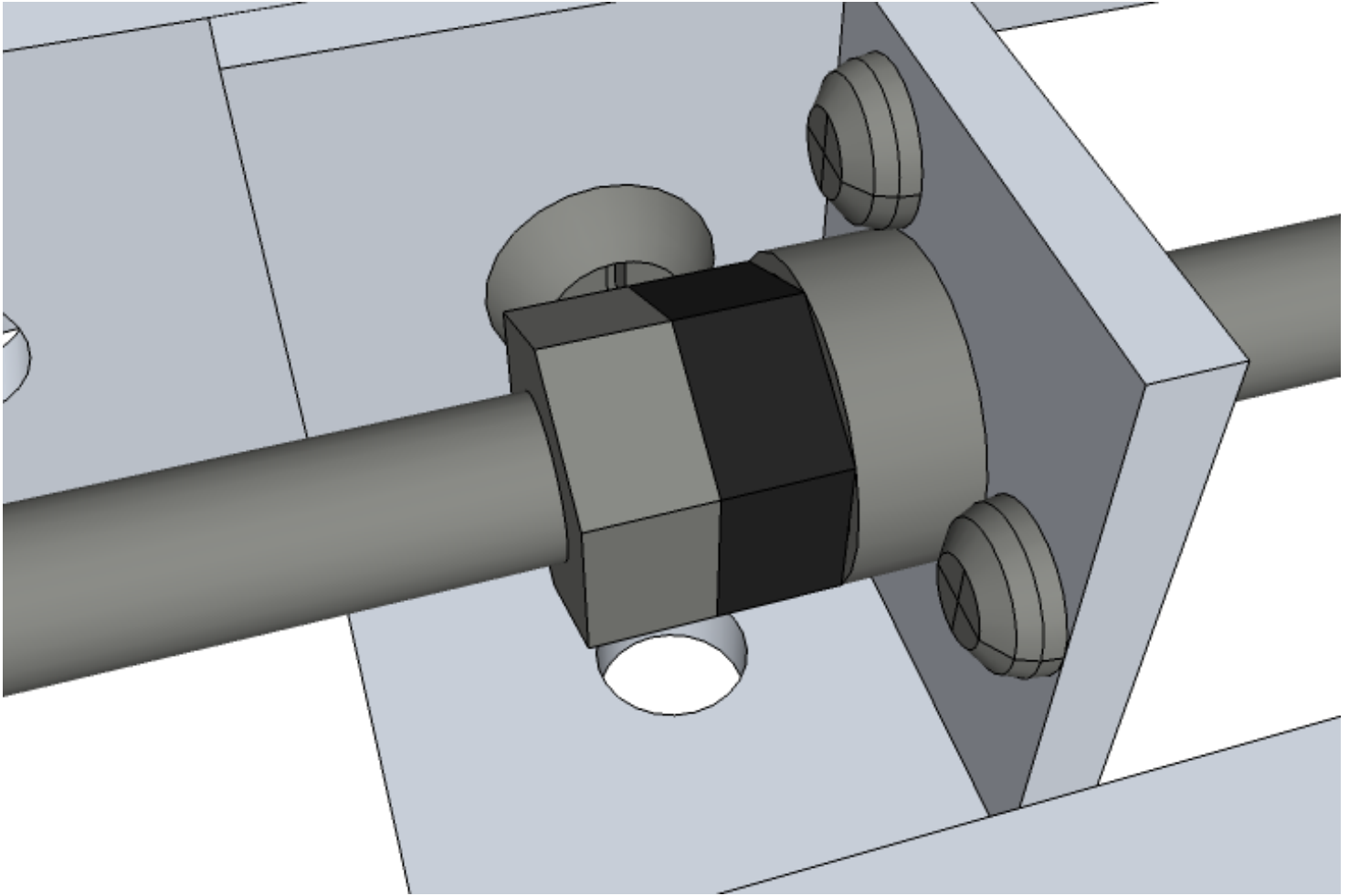
It is best to leave a small gap (1/16") between the rod and the rubber spider of the coupling.



055-Y-axis-alignment

Thread the plastic nut and a steel nut on the free end of the threaded rod. Turn the plastic nut until it is flush with the shaft mount bearing.

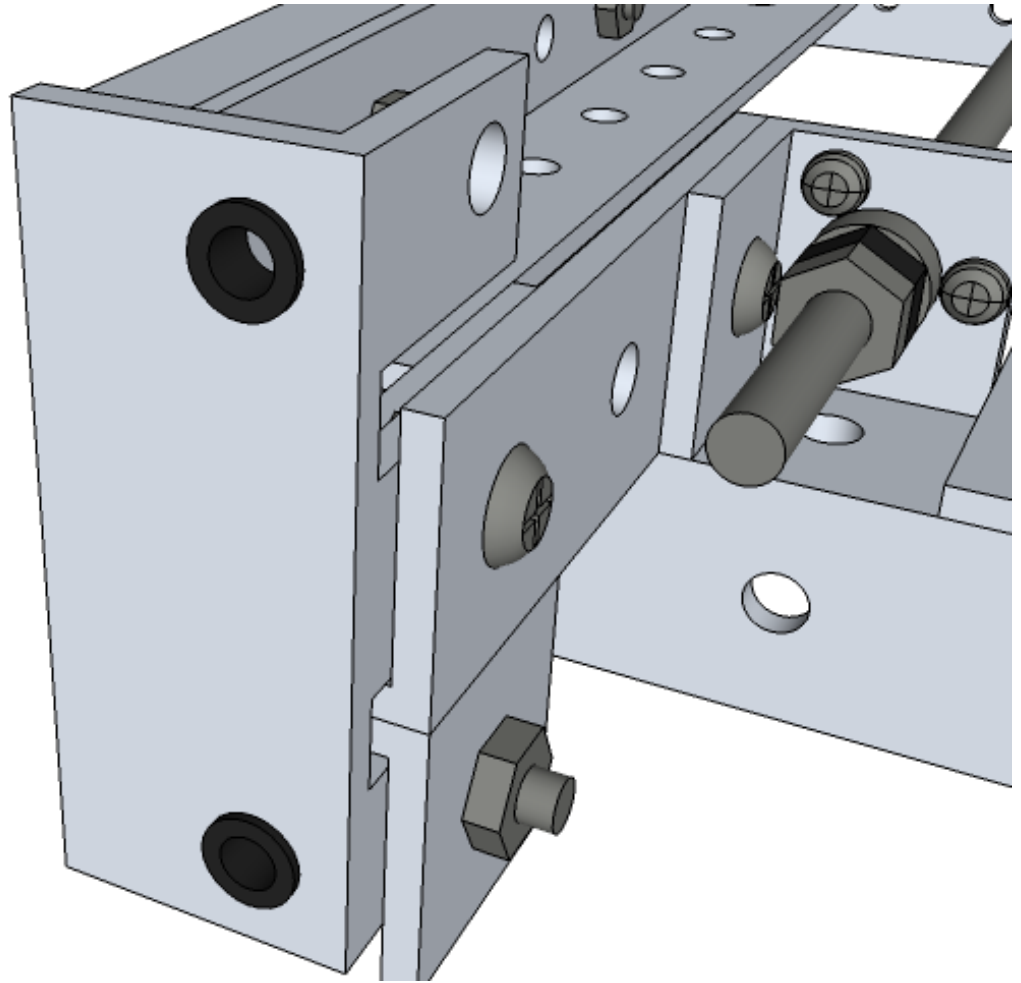
Verify free rotation of the rod at extreme stage positions.



056-Y-axis-alignment

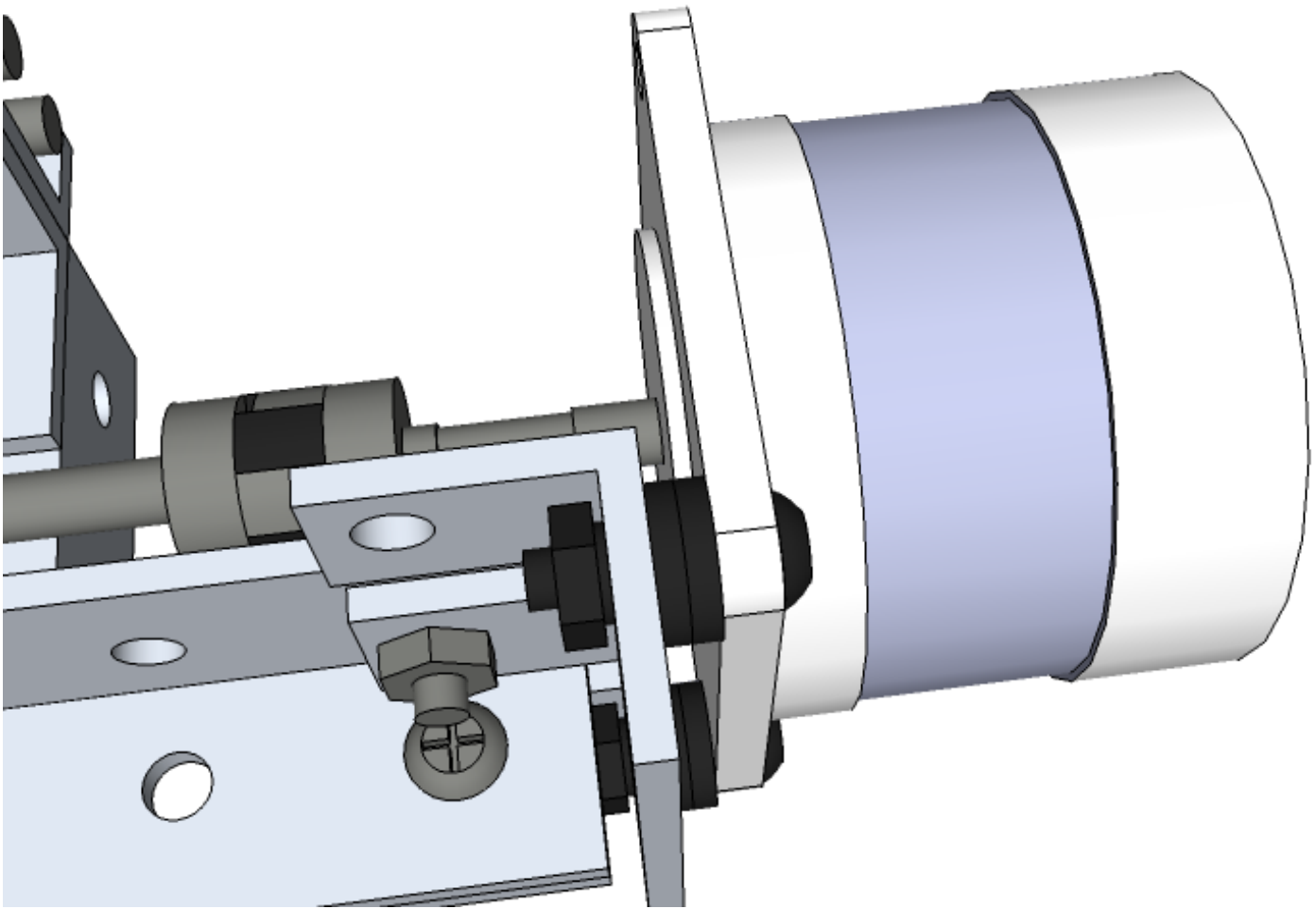
Turn and tighten the steel nuts against the plastic nuts to fix the position of the plastic nuts. Generally, a quarter of a turn should be sufficient.

Link to video showing tightening of the nuts on the threaded rod.



057-Y-axis-alignment

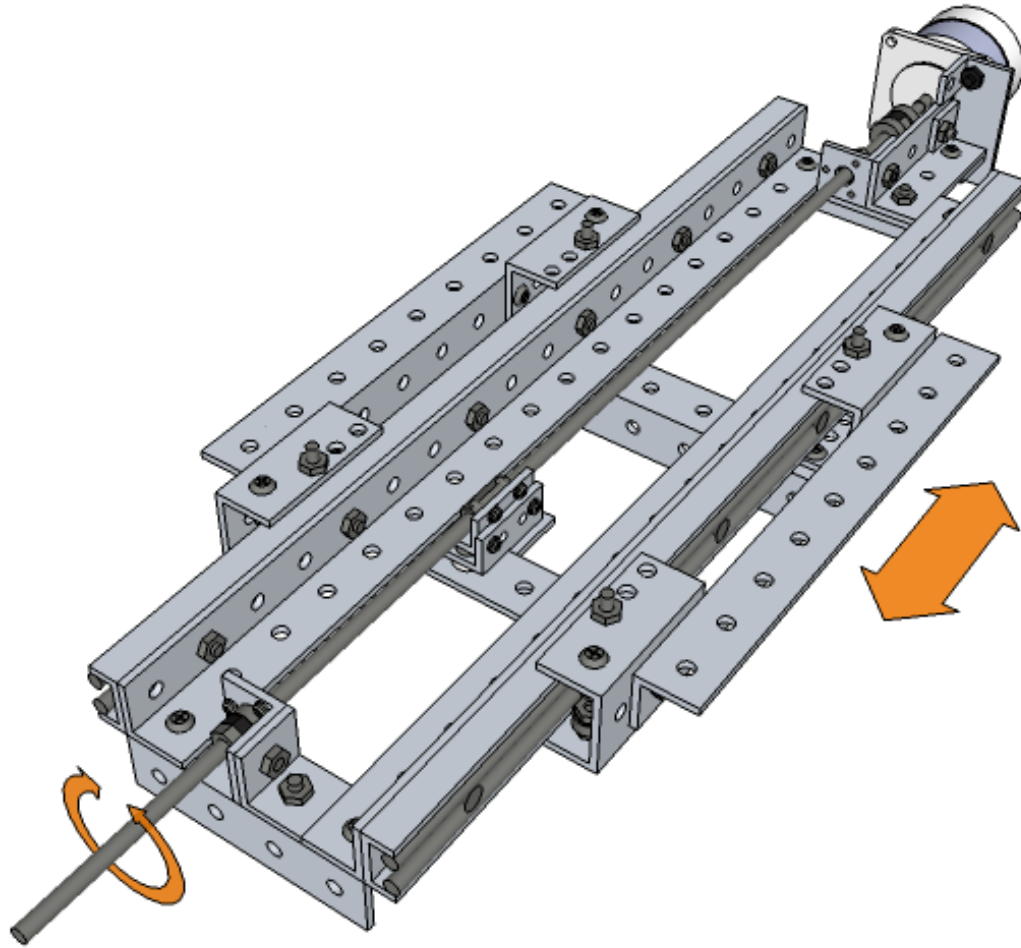
Install rubber grommets into the mounting holes of the motor mount.



058-Y-axis-alignment

Install the motor. The plastic screws should be turned with a flat screwdriver so that the grommets don't pop out.

Do not tighten the coupling hub on the leadscrew yet.

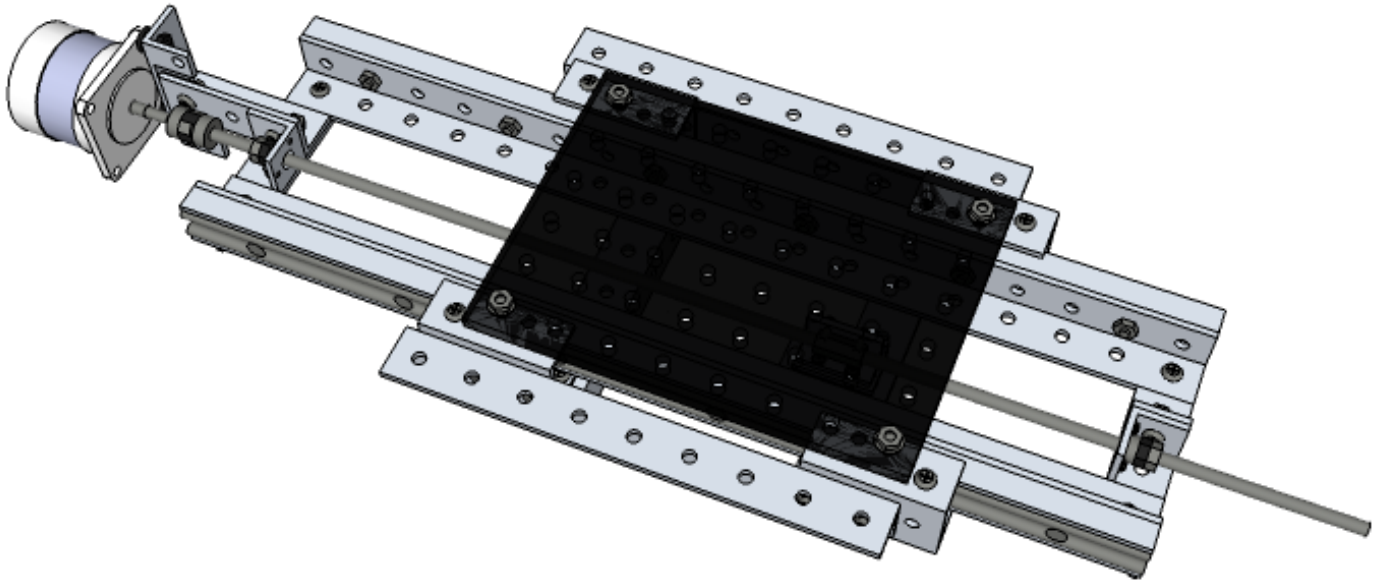


059-Y-axis-alignment

Manually verify free rotation of the threaded rod throughout the stage travel. It's important that there are no spots on the rod where you need to apply extra torque to turn it.

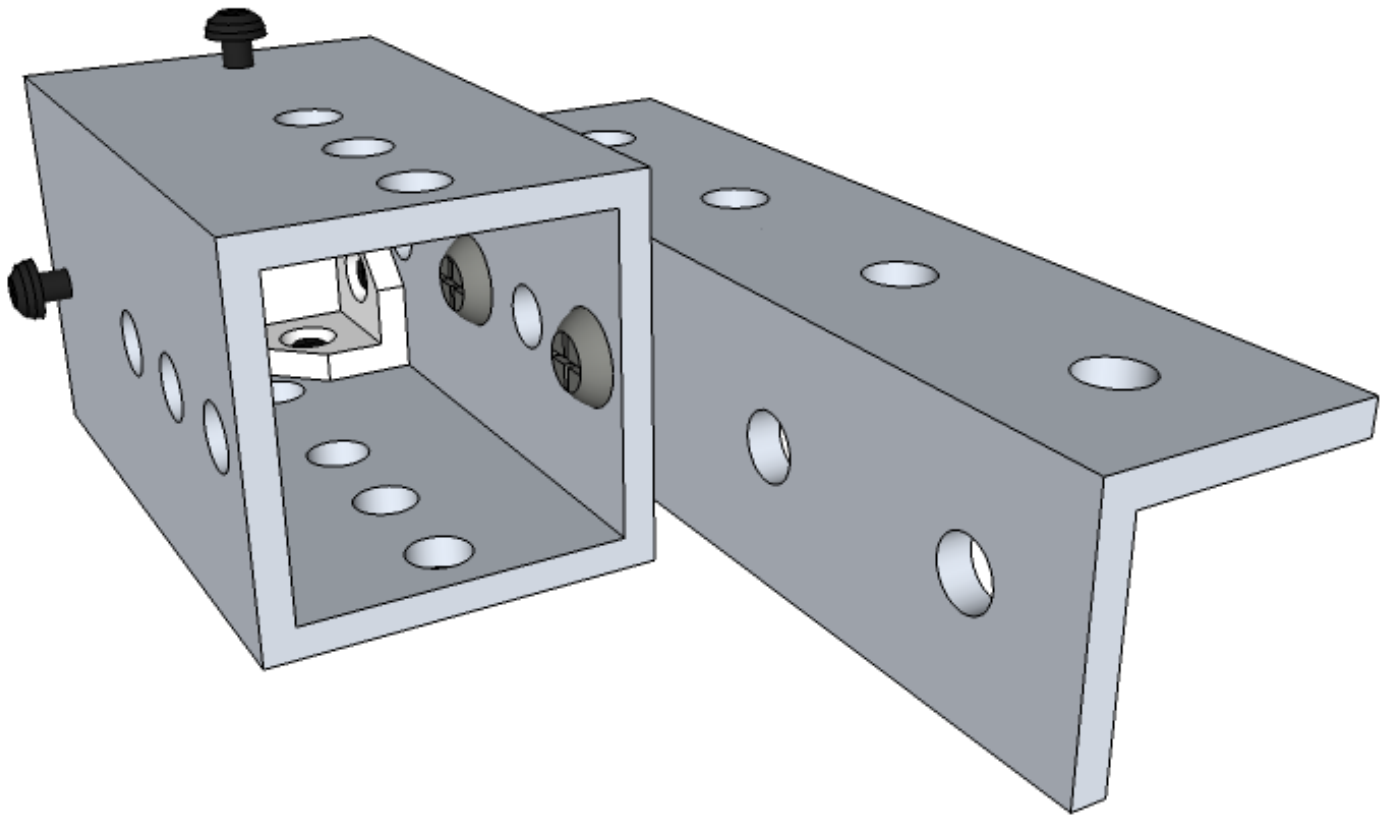
Finally, tighten the coupling hub on the leadscrew. Congratulations, the axis should now be well aligned.

Optionally, connect the motor to the stepper driver and verify that everything works.



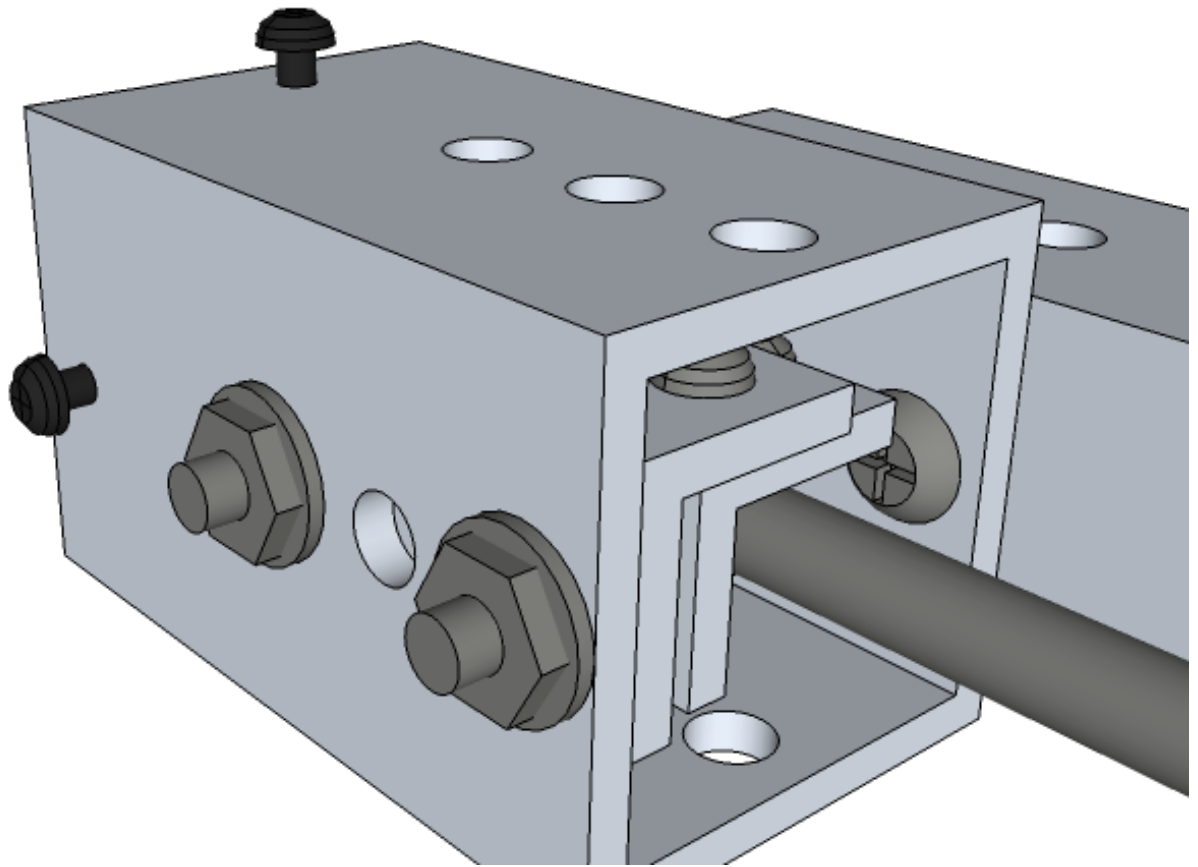
060-Y-axis-assembly

Remove four nuts from the top screws in the linear bearings and install the table. Attach the table with washers and nuts.



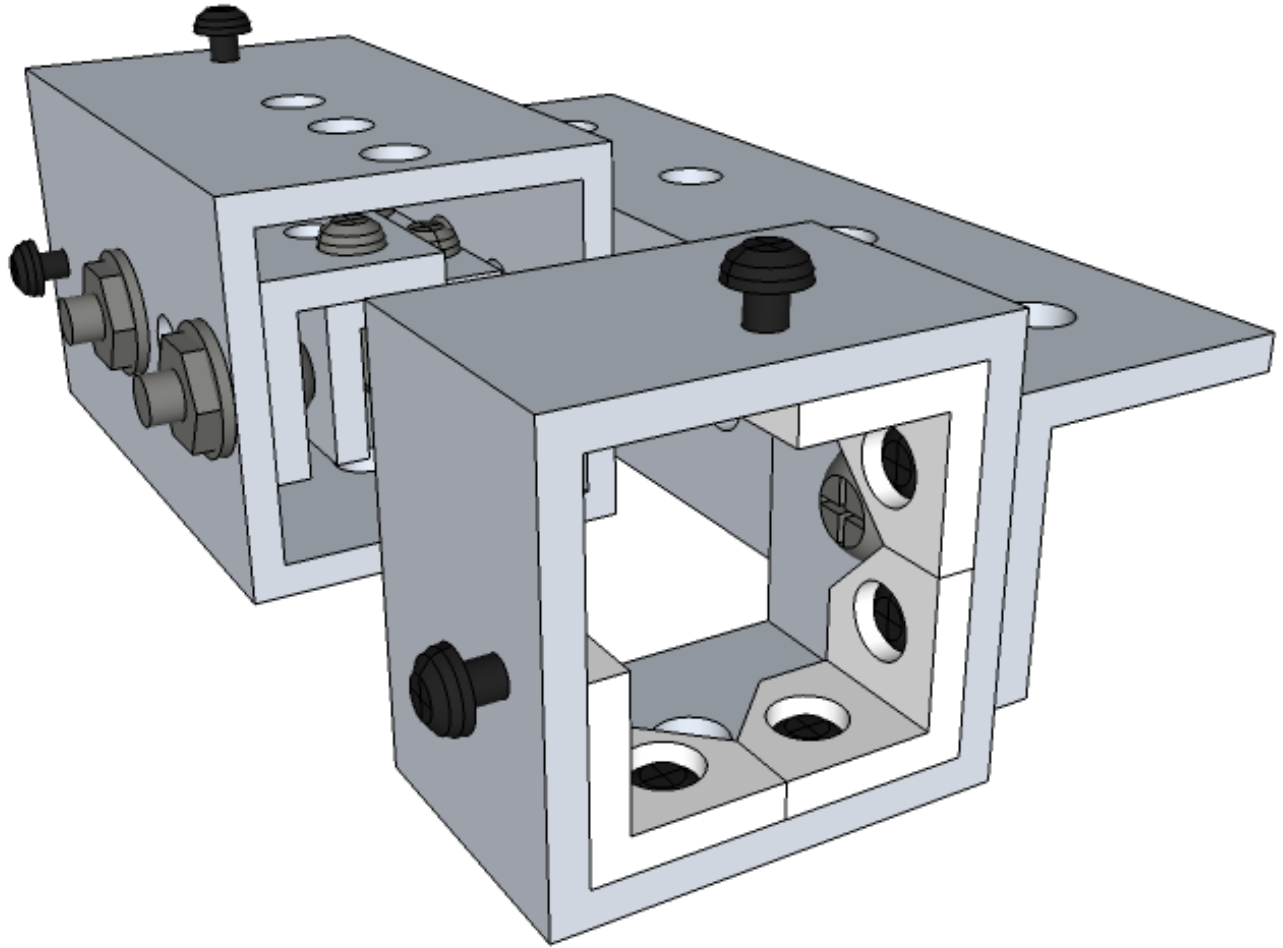
061-Z-stage-bearing-assembly

Attach sliding-element-2.5 to angle 4 and finger tighten the nuts.



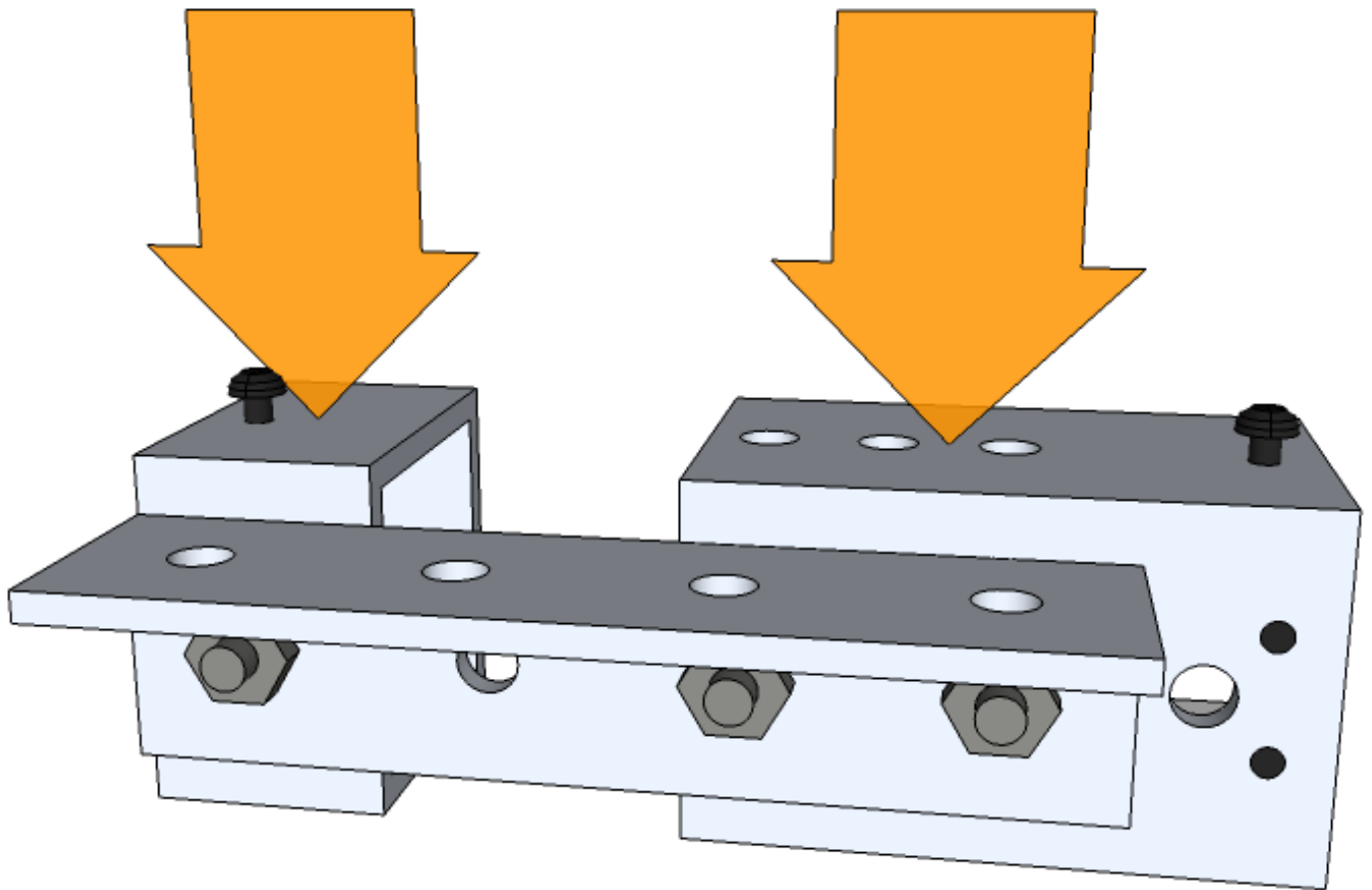
062-Z-stage-bearing-assembly

Insert lead nut assembly into the sliding element, add washers and nuts, finger tighten.



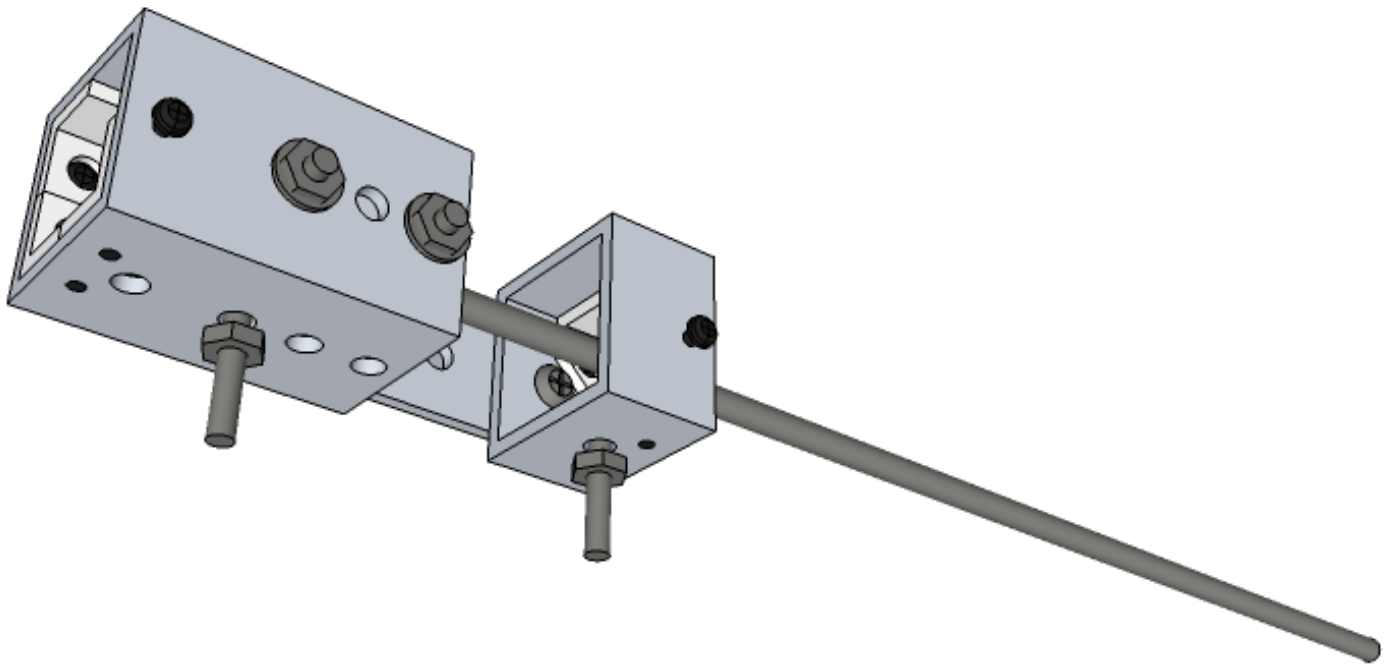
063-Z-stage-bearing-assembly

Remove the leadscrew and attach sliding-element-1 to angle-4 as shown.



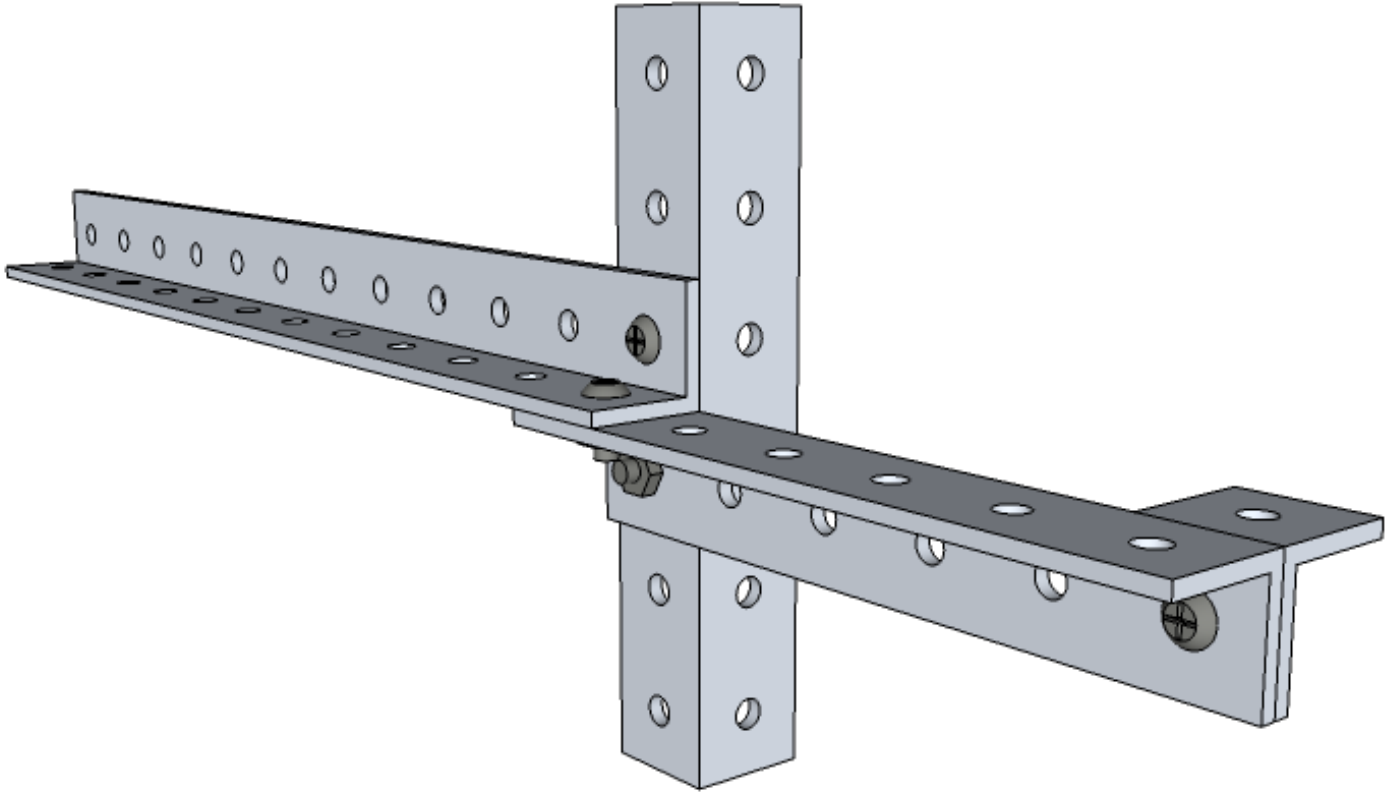
064-Z-stage-bearing-assembly

Place assembly on a flat surface and push on top of the sliding elements while tightening the nuts to ensure that sliding elements are on the same axis.



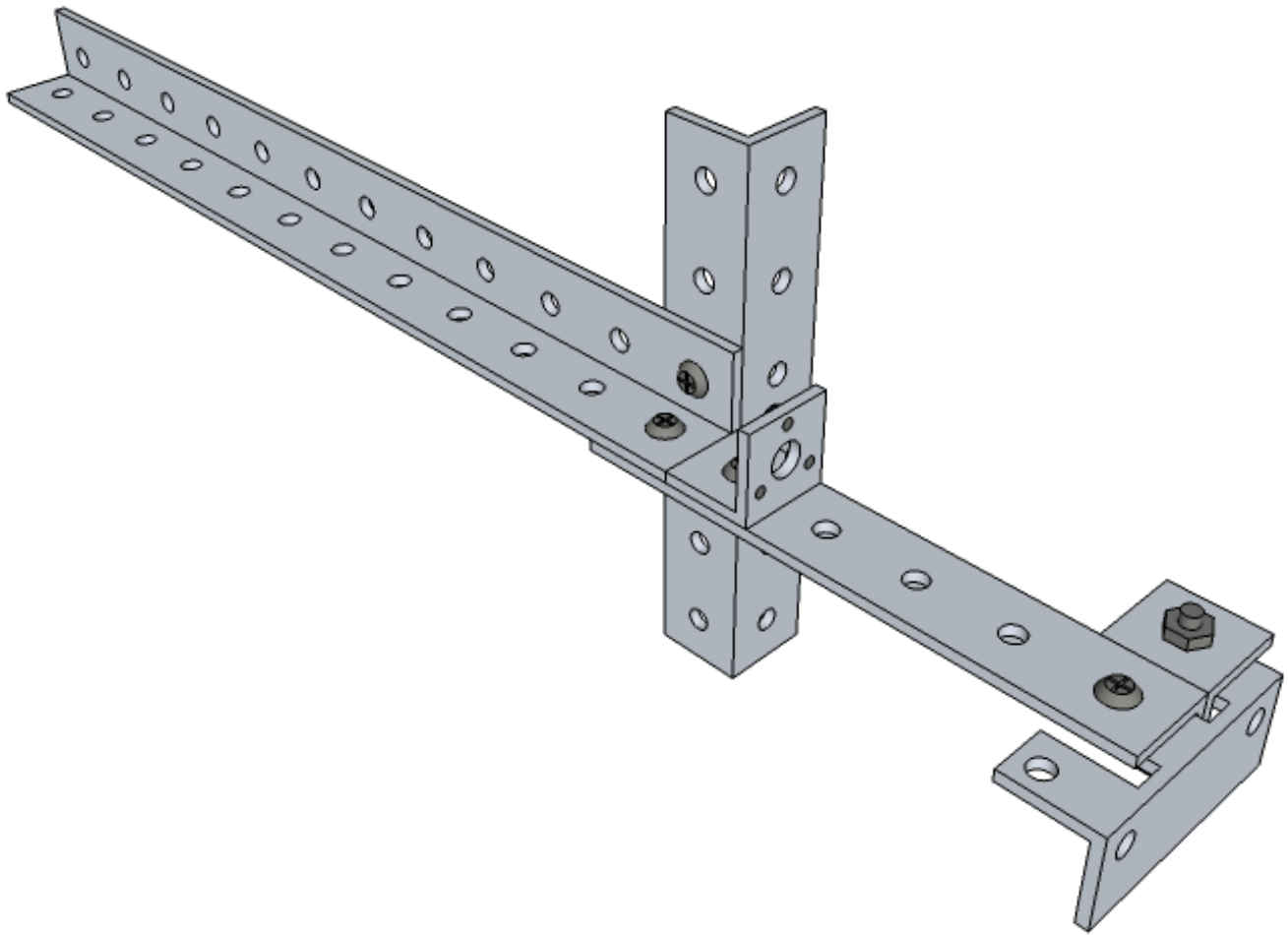
065-Z-stage-bearing-assembly

Add 1 inch long screws and nuts to the bottom of the sliding elements. Insert the leadscrew back into the sliding-element-2.5.



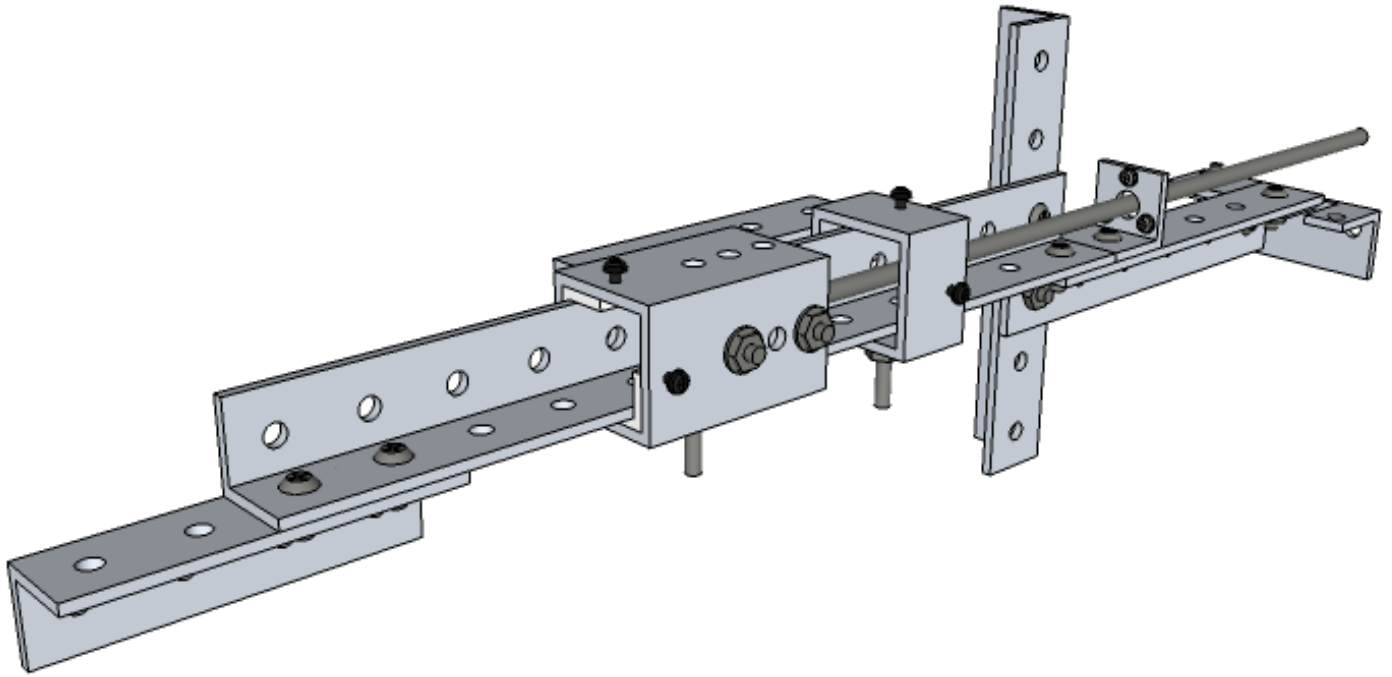
066-Z-half-axis-assembly

Assemble rail structure.



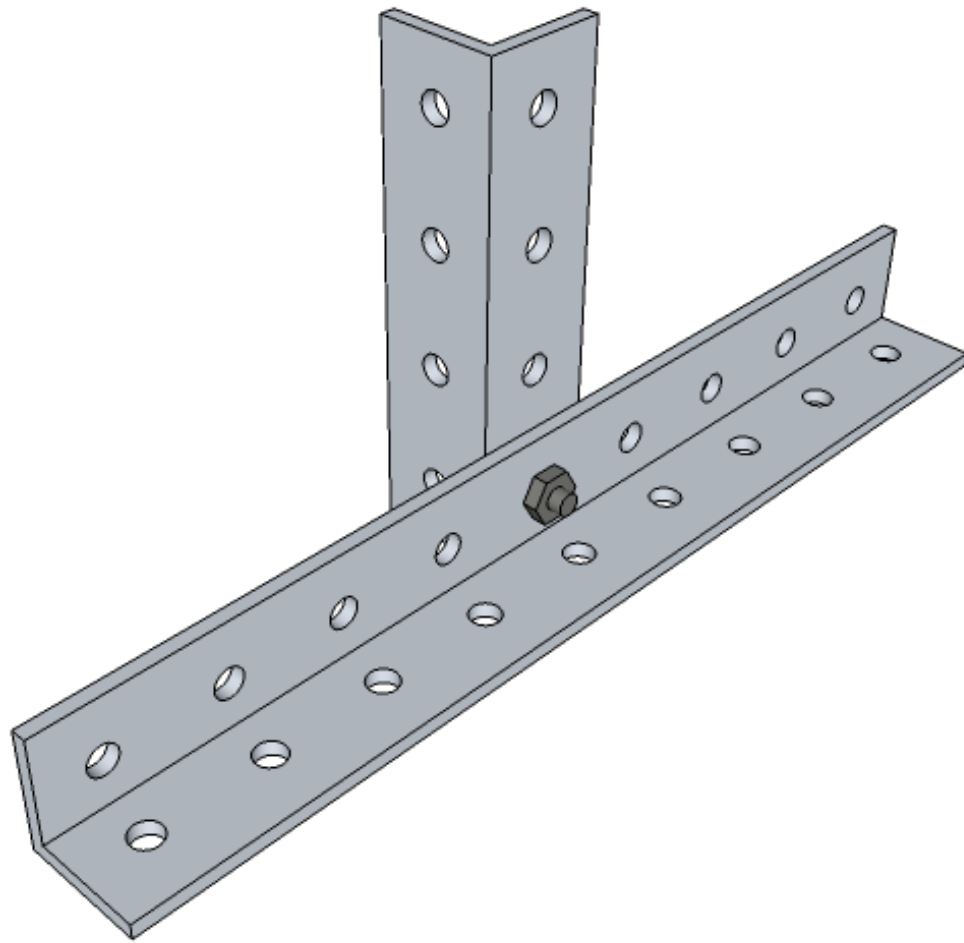
067-Z-half-axis-assembly

Add shaft mount and motor mount.



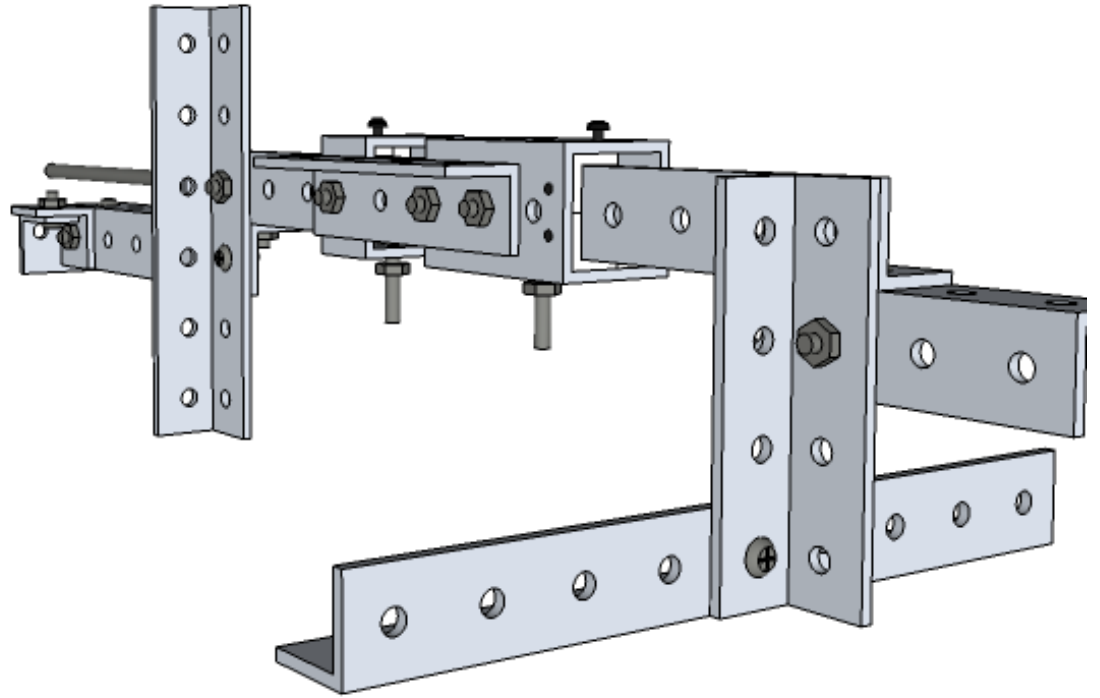
068-Z-half-axis-assembly

Slide Z stage bearing on the rail and add angle-4 at the end of the rail.



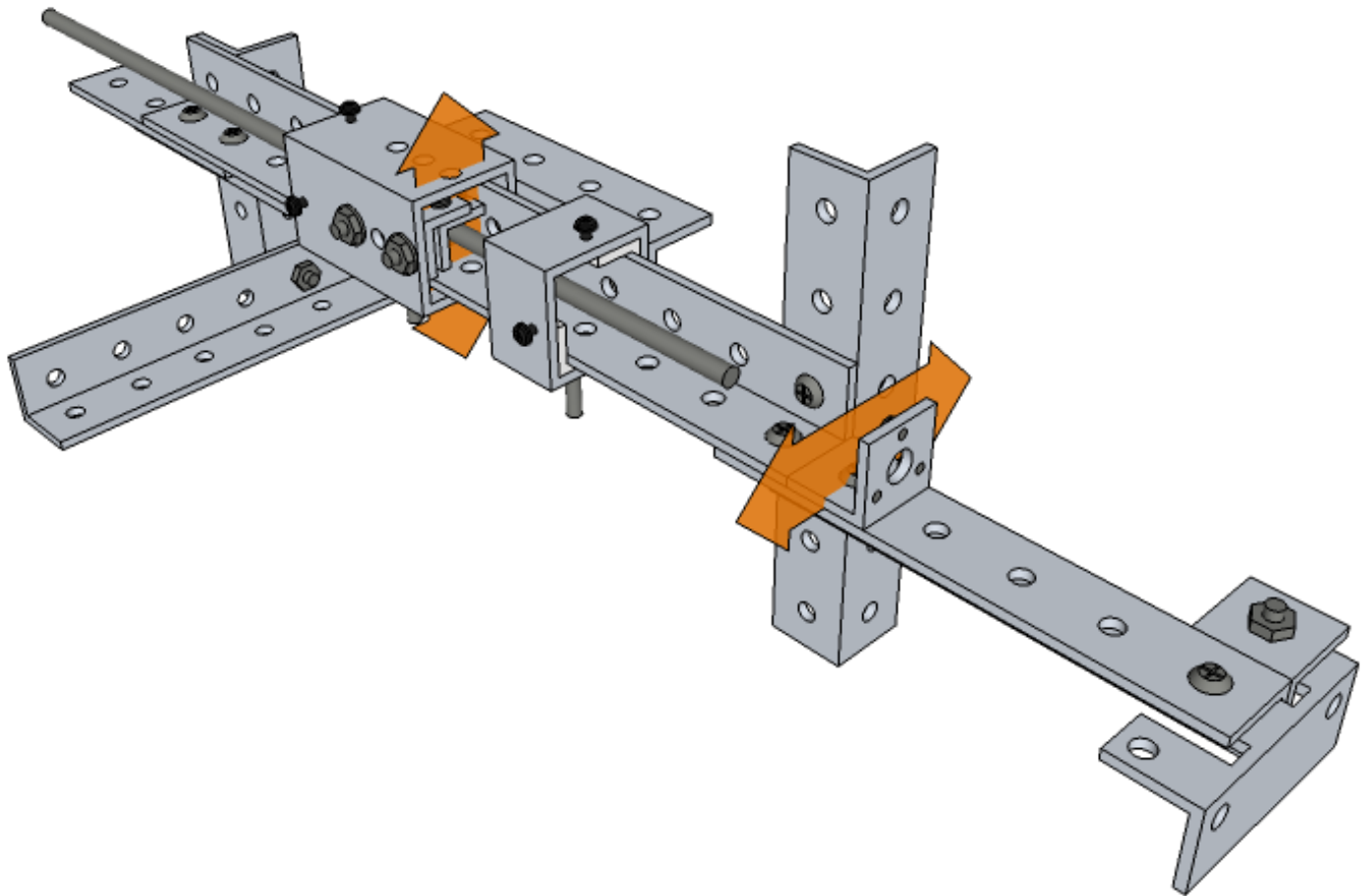
069-Z-half-axis-assembly

Assemble helper stand.



070-Z-half-axis-assembly

Attach helper stand to angle-4.



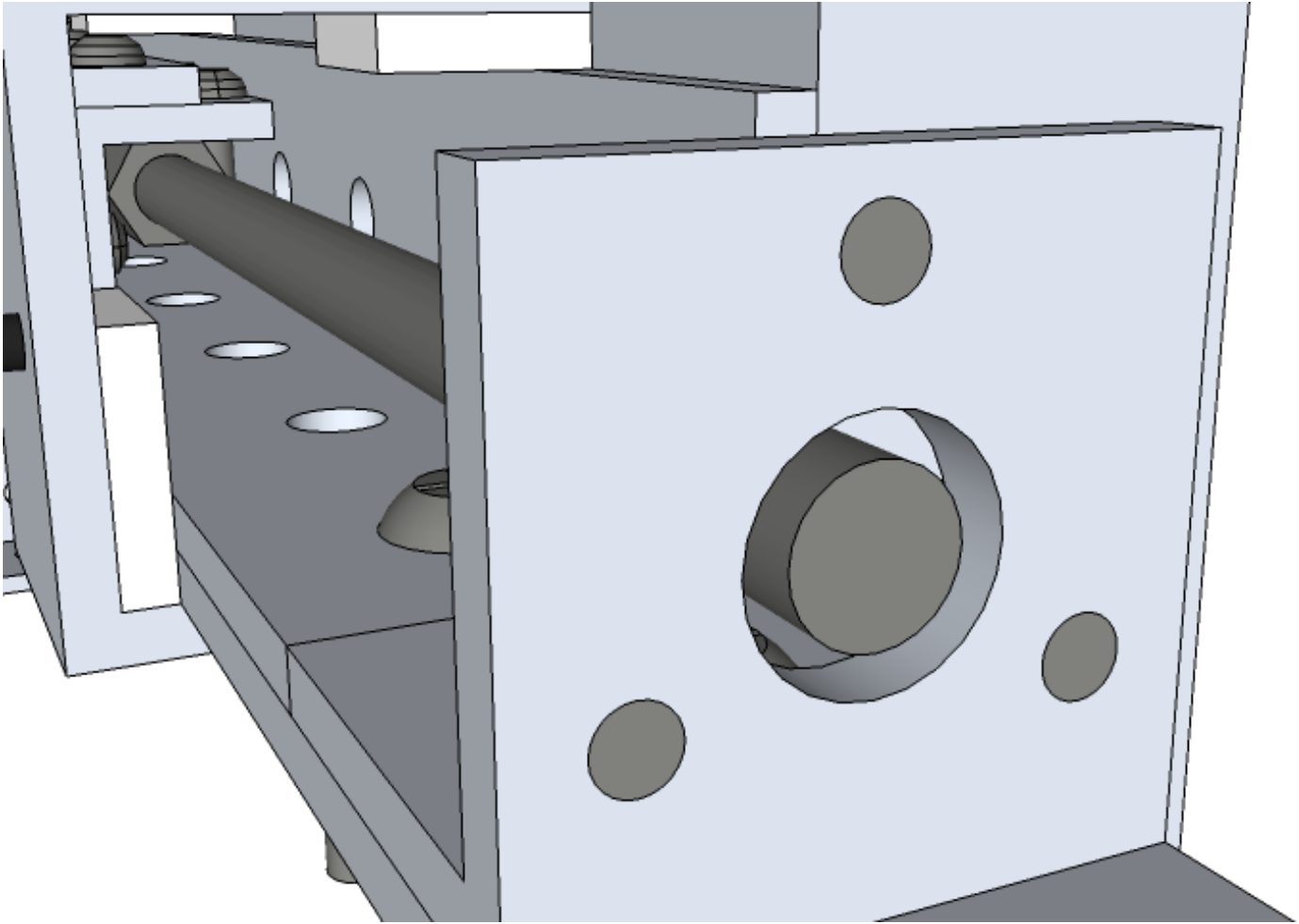
071-Z-half-axis-assembly

The next step is to align the lead nut and the shaft mount so that their centers are on the same axis.

This is very important because misalignment will cause leadscrew to bend and require more torque to turn it, leading to skipped steps, ruined cutting jobs and broken tools.

The alignment is performed in several iterations by loosening, repositioning and tightening the lead nut (up-down) and the shaft mount (side-to-side) until desired result is achieved.

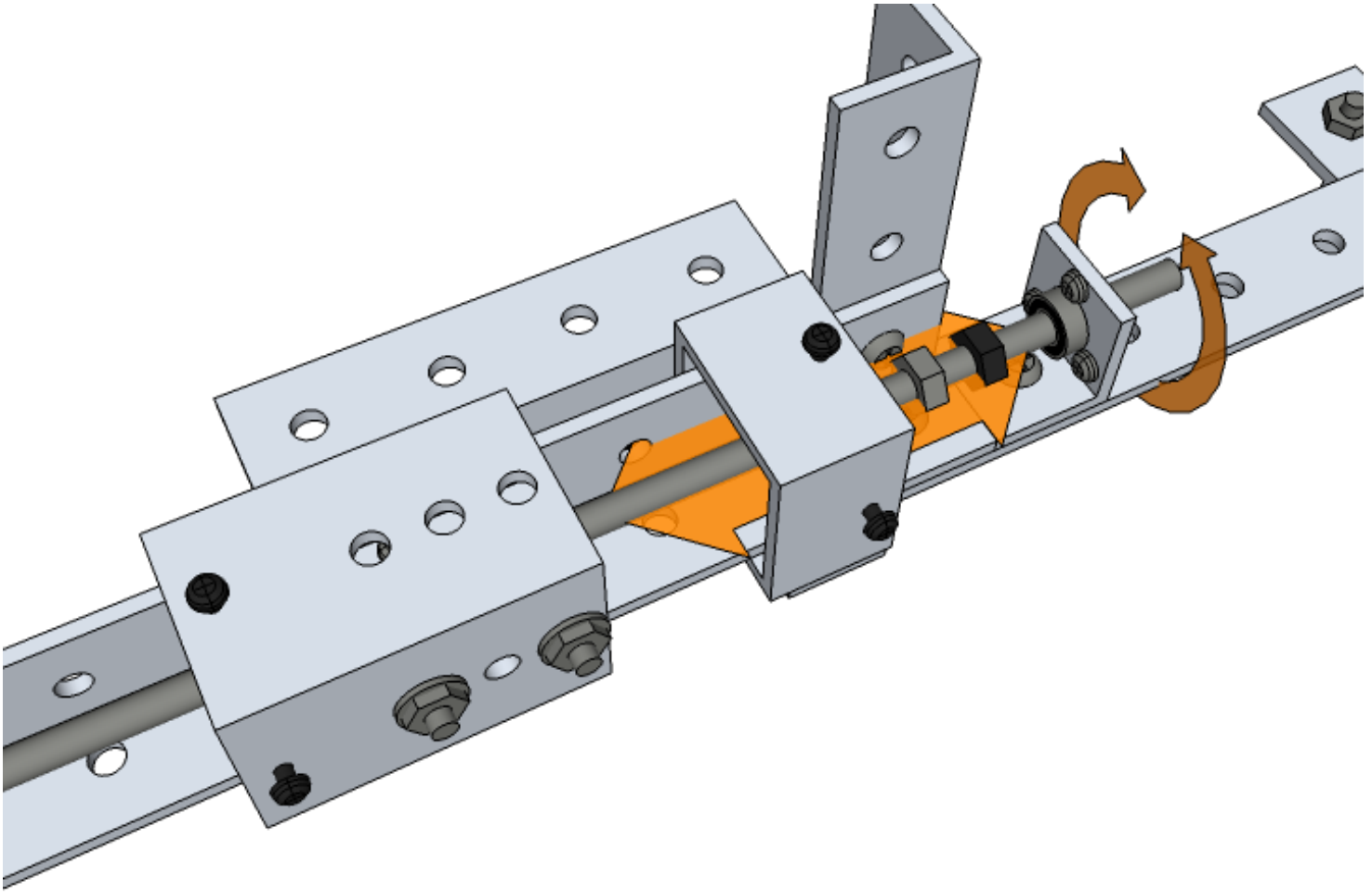
The general guideline is that you must be able to easily rotate the threaded rod with your fingers once it is constrained by the bearings.



072-Z-half-axis-assembly

Alignment can be inspected visually by moving the stage with the lead nut as close as possible to the shaft mount.

The leadscrew should pass through the center of the shaft mount hole. Rotate the threaded rod a couple of turns to ensure this is the case at every angle as the rod may be very slightly bent.

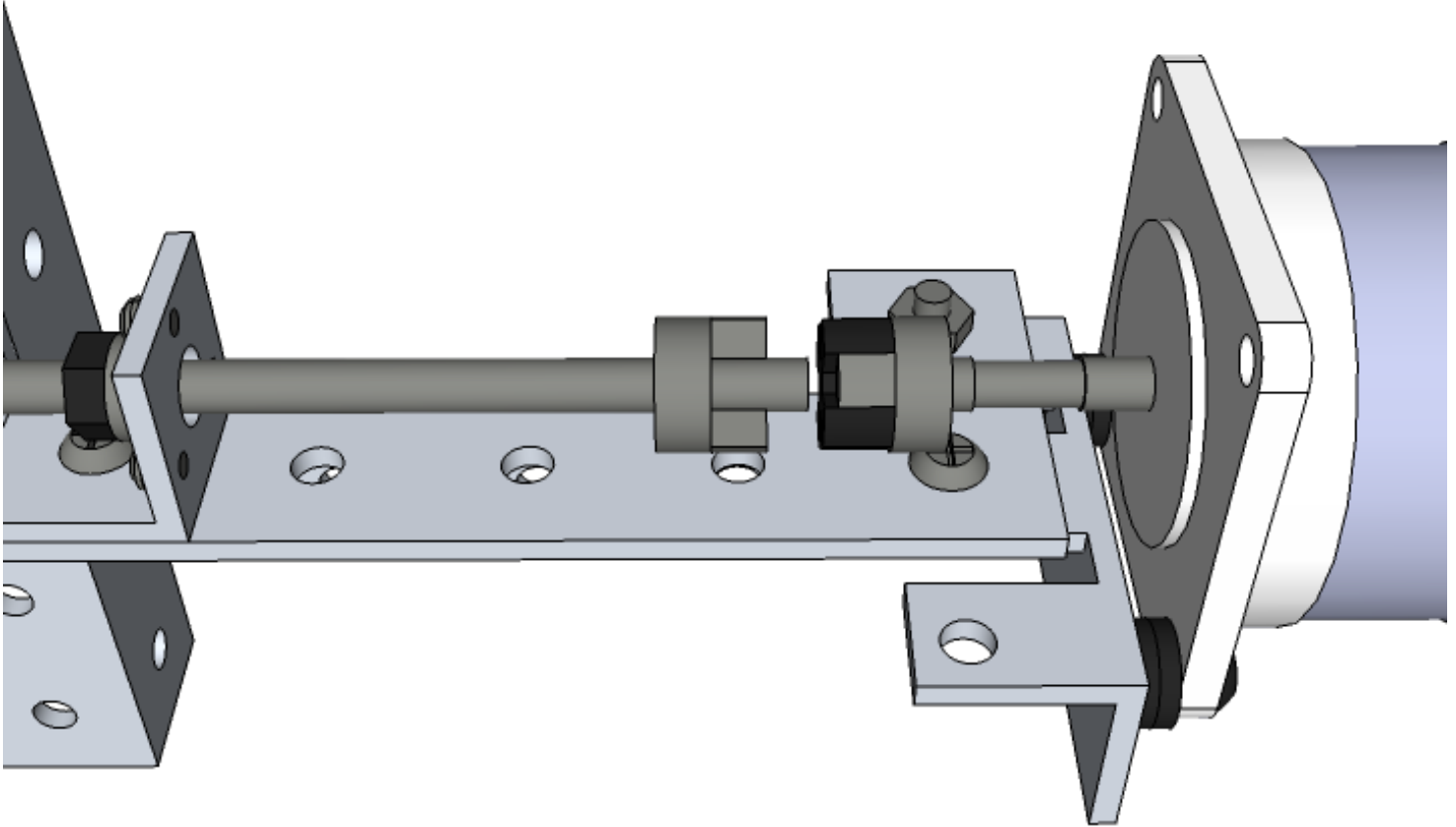


073-Z-half-axis-assembly

When threaded rod appears centered, put steel and plastic nuts (1/4-20) on the rod. Snap R188 bearing between the small screws of the shaft mount.

Move Z stage bearing as close as possible to the shaft mount and verify alignment again: threaded rod should easily slide in and out of the bearing, and with the plastic nut flush against the bearing, you should be able to freely turn the rod with your fingers.

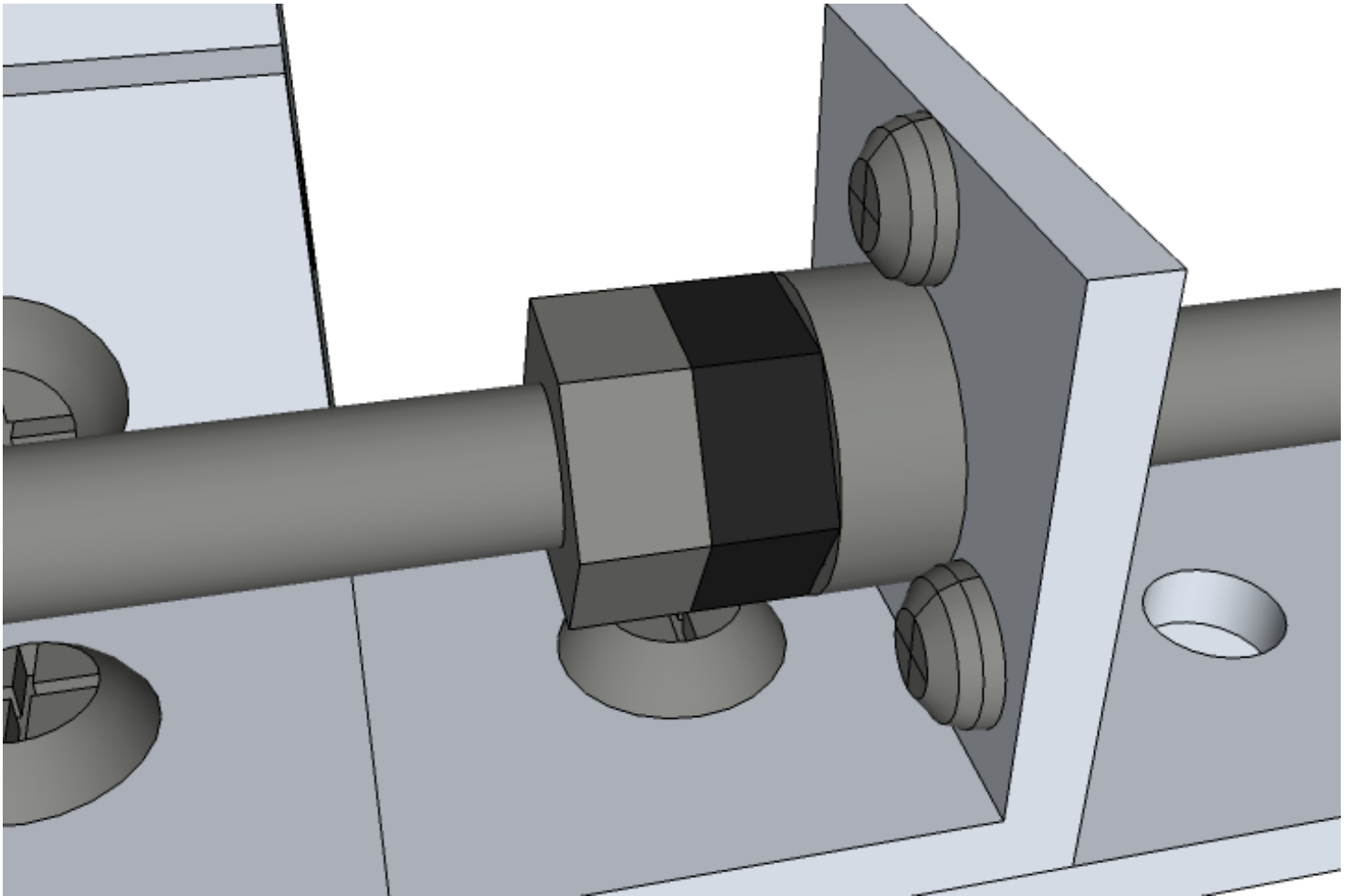
Go back two steps if either of the above is not the case.



074-Z-half-axis-assembly

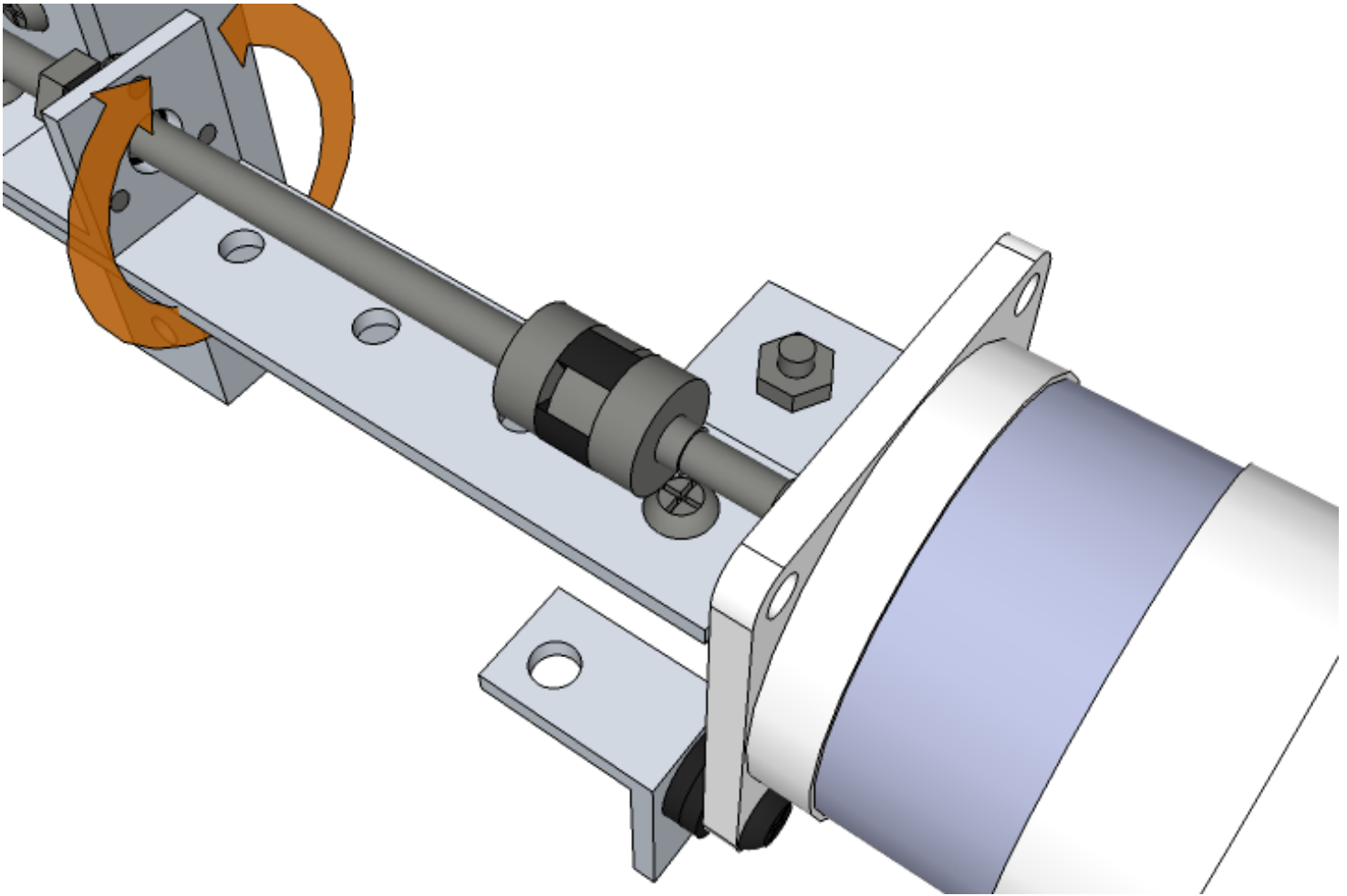
Test-fit the motor to the motor mount and position the threaded rod so there is a small gap (1/16") between the rod and the rubber spider of the coupling.

Hold the threaded rod in this position and turn the plastic nut until it is flush with the shaft mount bearing.



075-Z-half-axis-assembly

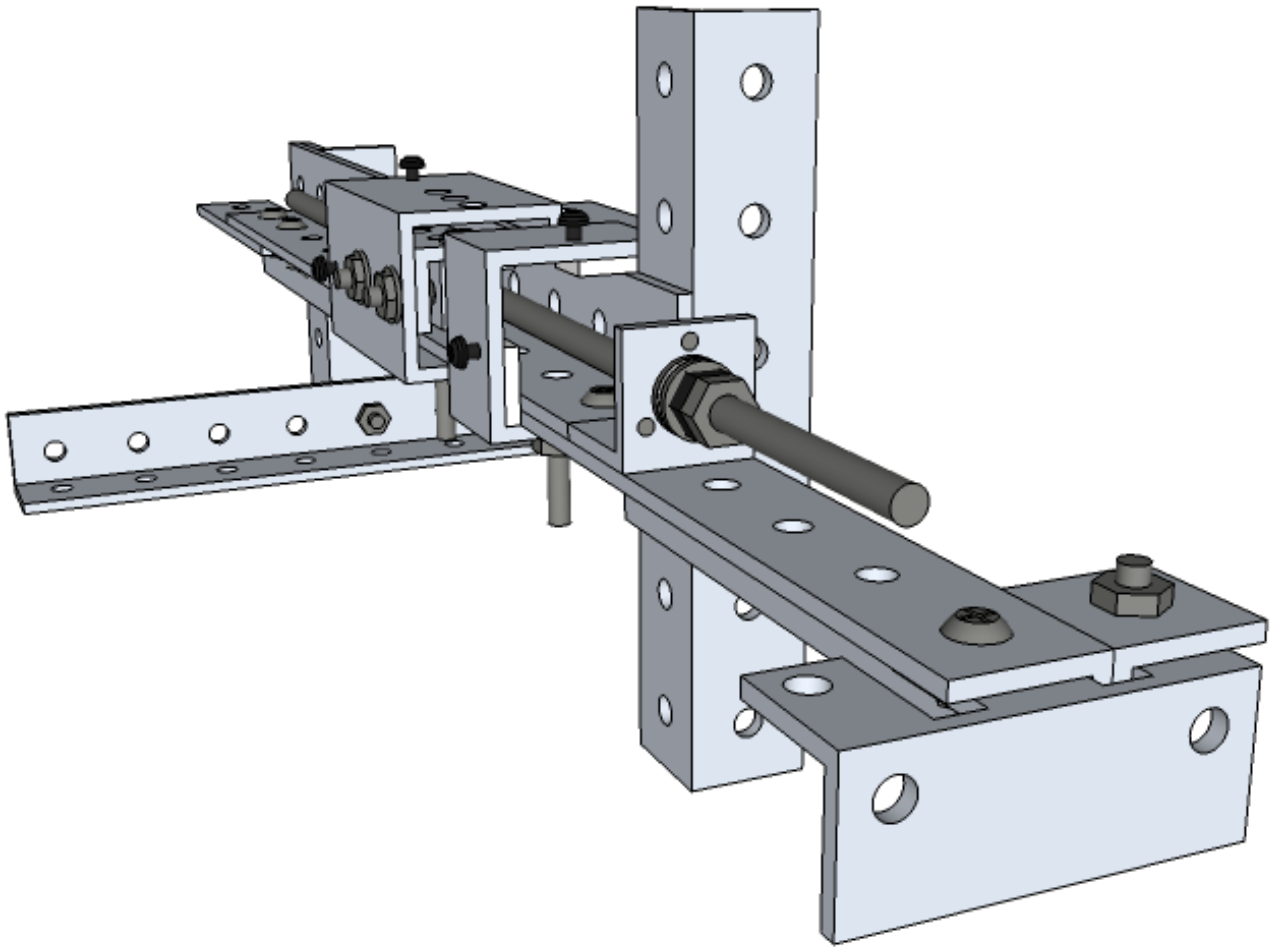
Turn and tighten the steel nut against the plastic nut to fix the position of the plastic nut. Do not overtighten or you may strip the threads on the plastic nut. Generally, a quarter of a turn should be sufficient.



076-Z-half-axis-assembly

Test-fit the motor again, and move the coupling hub onto the coupling spider to radially restrain the threaded rod. Do not tighten the coupling hub yet.

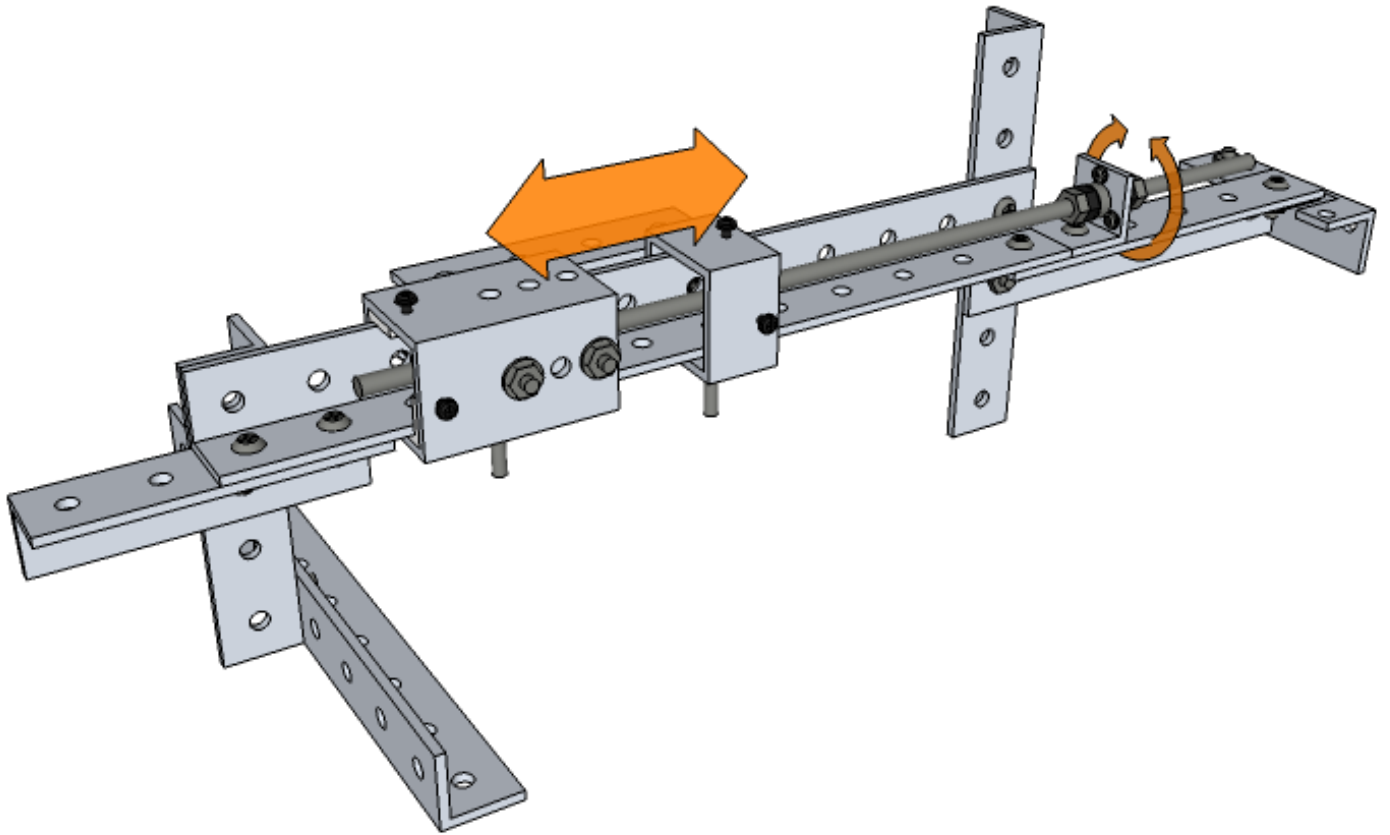
Check for free rotation again, slightly pulling the threaded rod away from the axis. If adding the motor makes turning the rod difficult, go back to the alignment process.



077-Z-half-axis-assembly

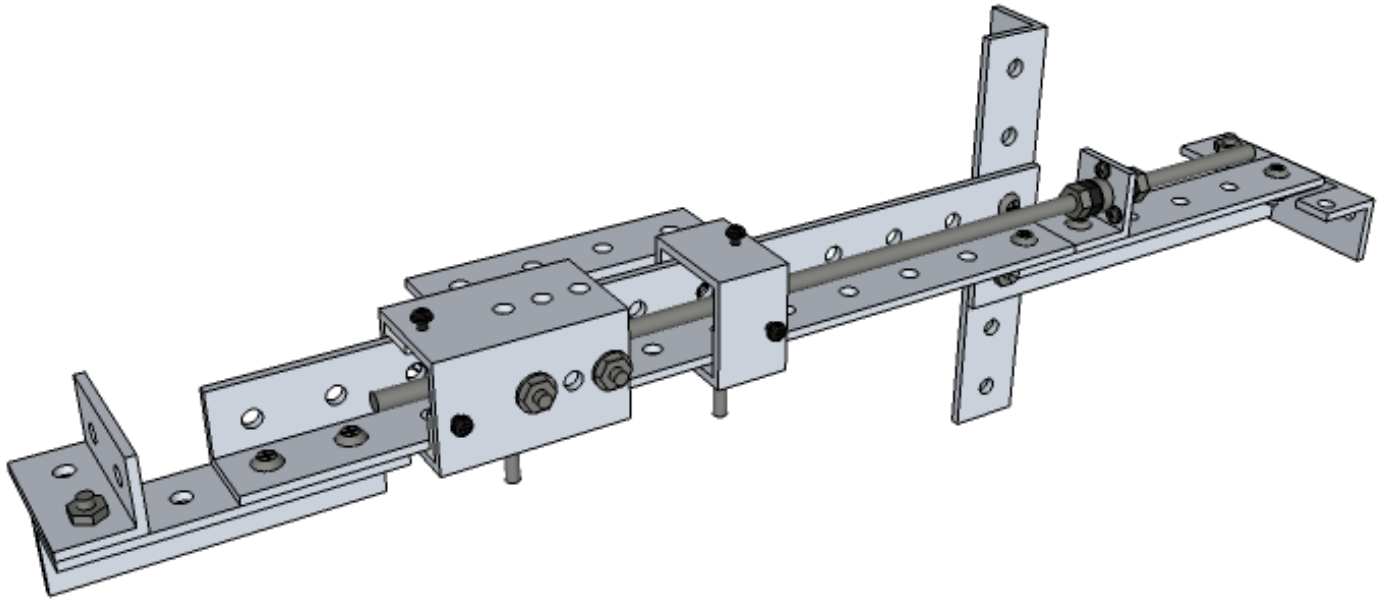
Install the thrust bearing. Add plastic nut and steel nut and tighten them so that the leadscrew is able to rotate freely.

There should be just enough axial slack - not visible but you should be able to hear it if you move the threaded rod back and forth along its axis.



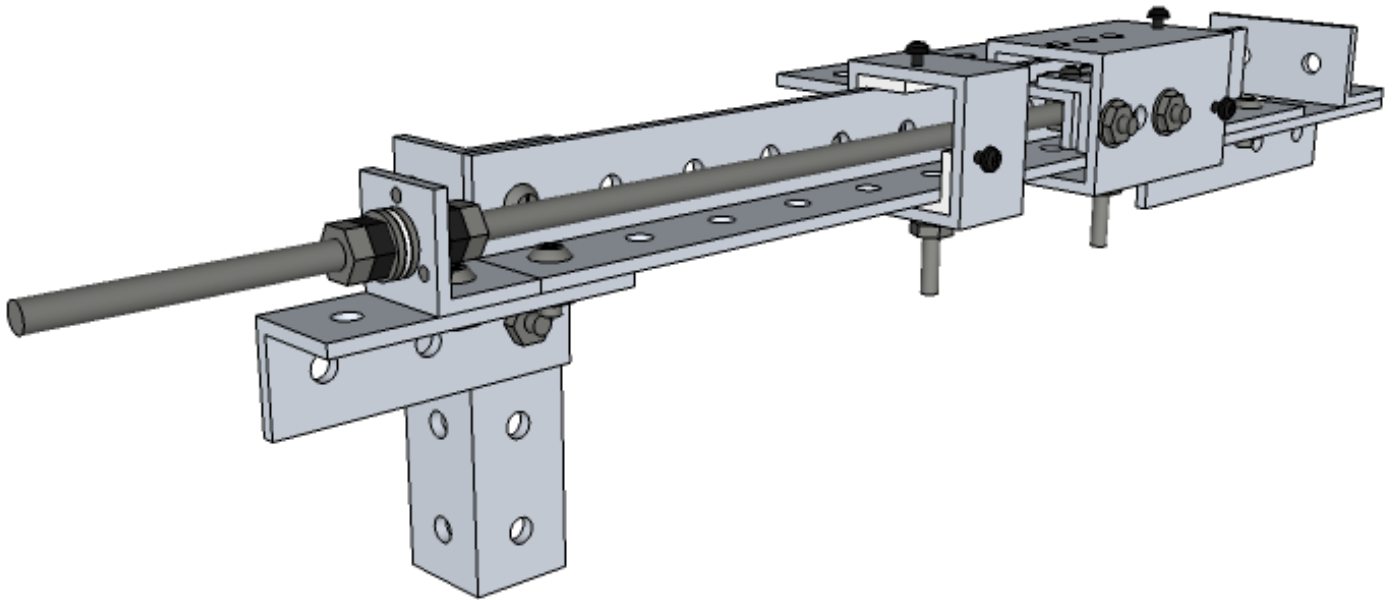
078-Z-half-axis-assembly

Manually verify free rotation of the threaded rod throughout the stage travel. It's important that there are no spots on the rod where you need to apply extra torque to turn it (see prep phase).



079-Z-half-axis-assembly

Remove helper stand and attach angle-2 to the end of the rail.

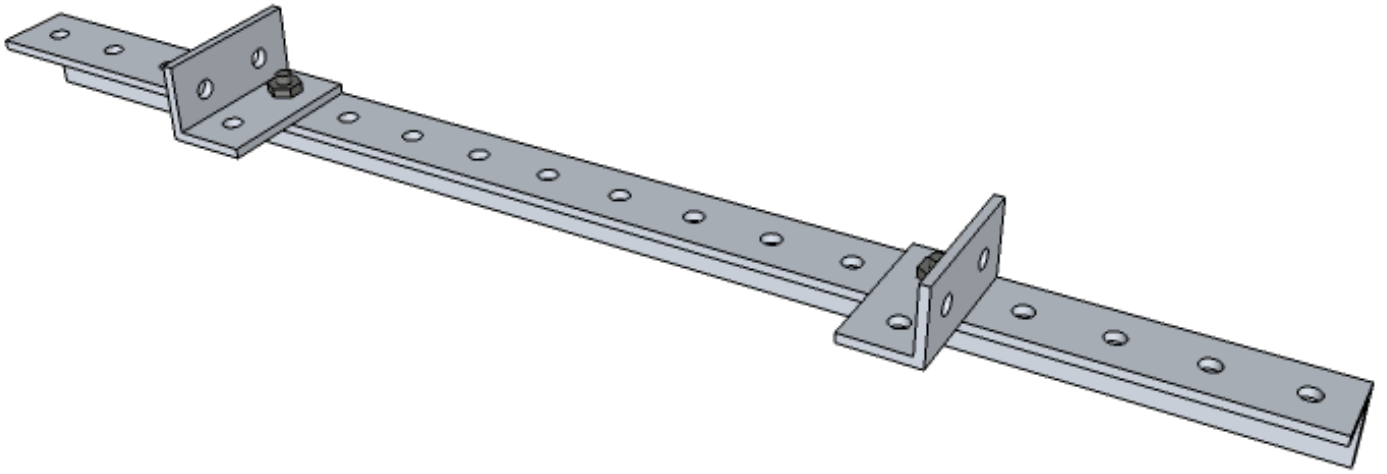


080-Z-axis-assembly

Assemble and align another half of the Z axis.

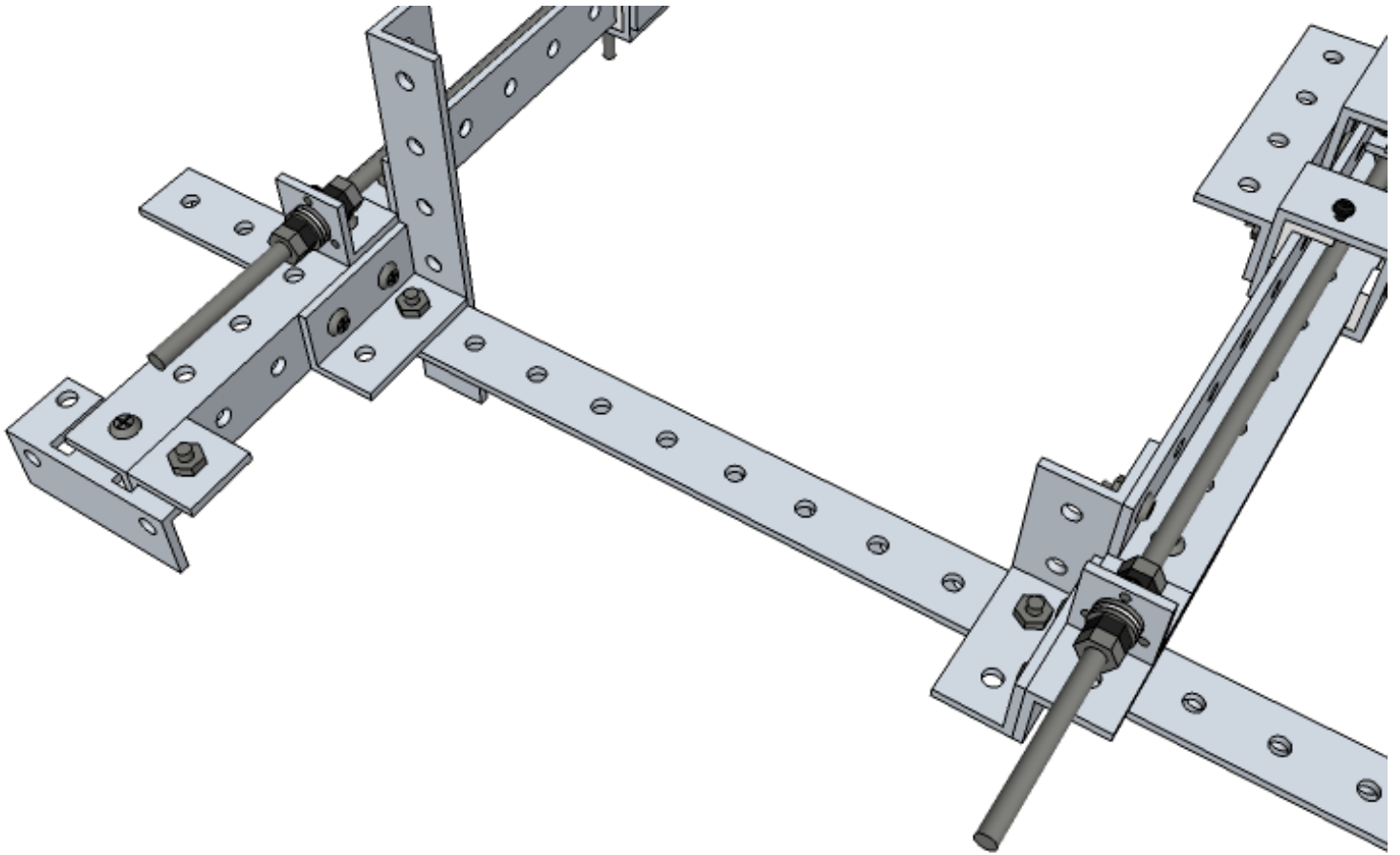
The other half is a mirror copy of the first half, except that it uses angle-4 and -3 in the rail assembly (instead of angle-6 and -6), and there is no motor mount.

The alignment process to follow is the same as for the first half.



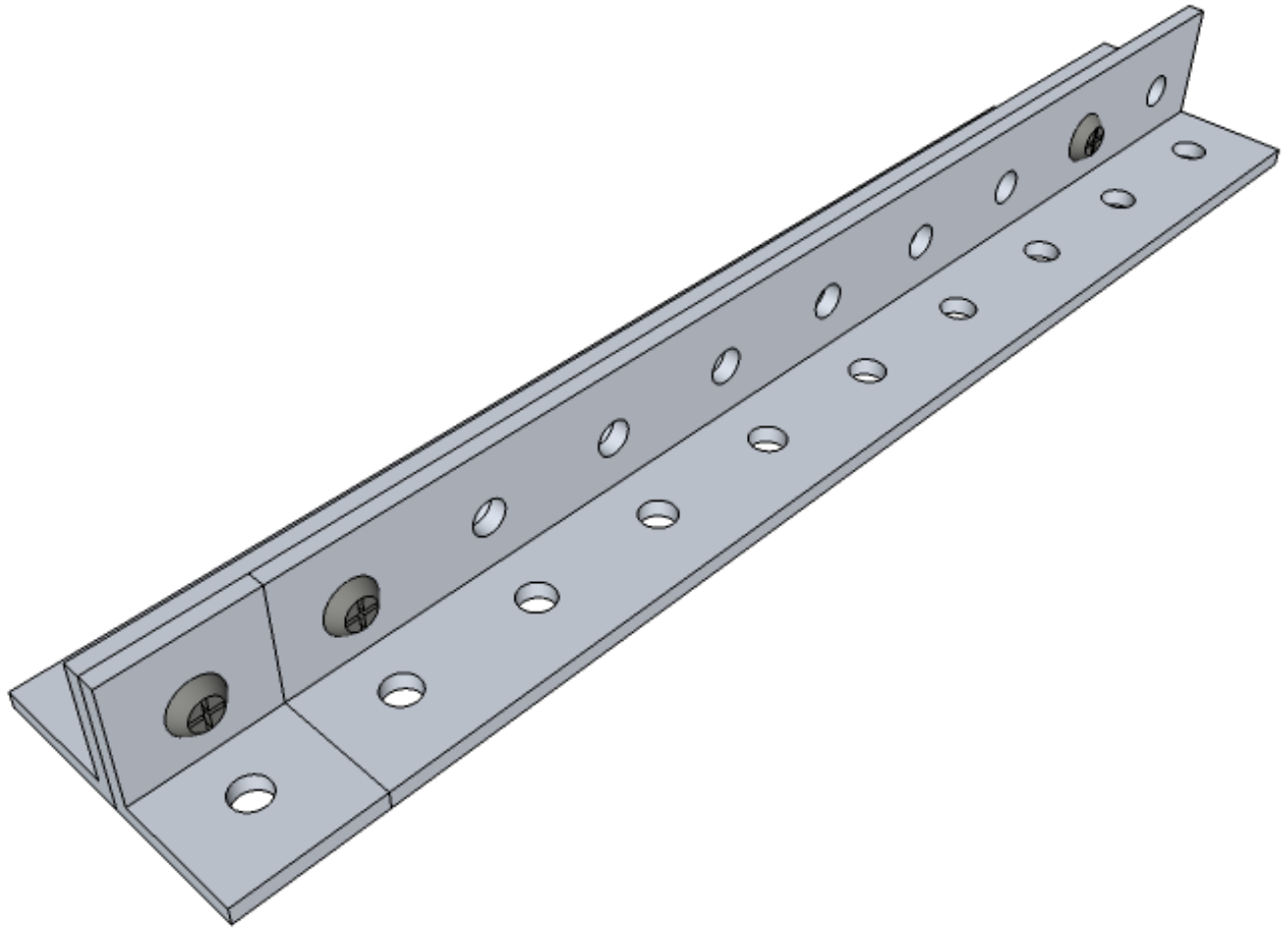
081-Z-axis-assembly

Build a helper assembly that will ensure that two halves of Z axis are parallel.



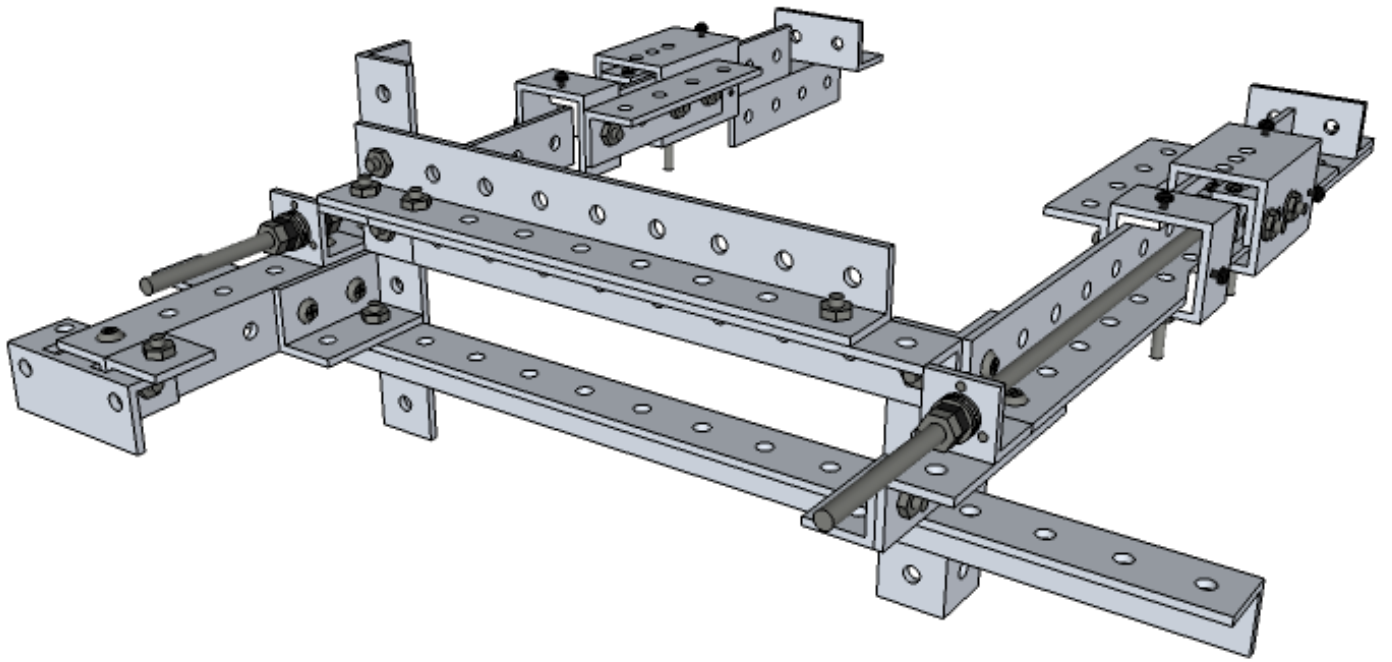
082-Z-axis-assembly

Attach helper assembly to each half of Z axis as shown and loosen the nut connecting the right angle-2 to angle-18.



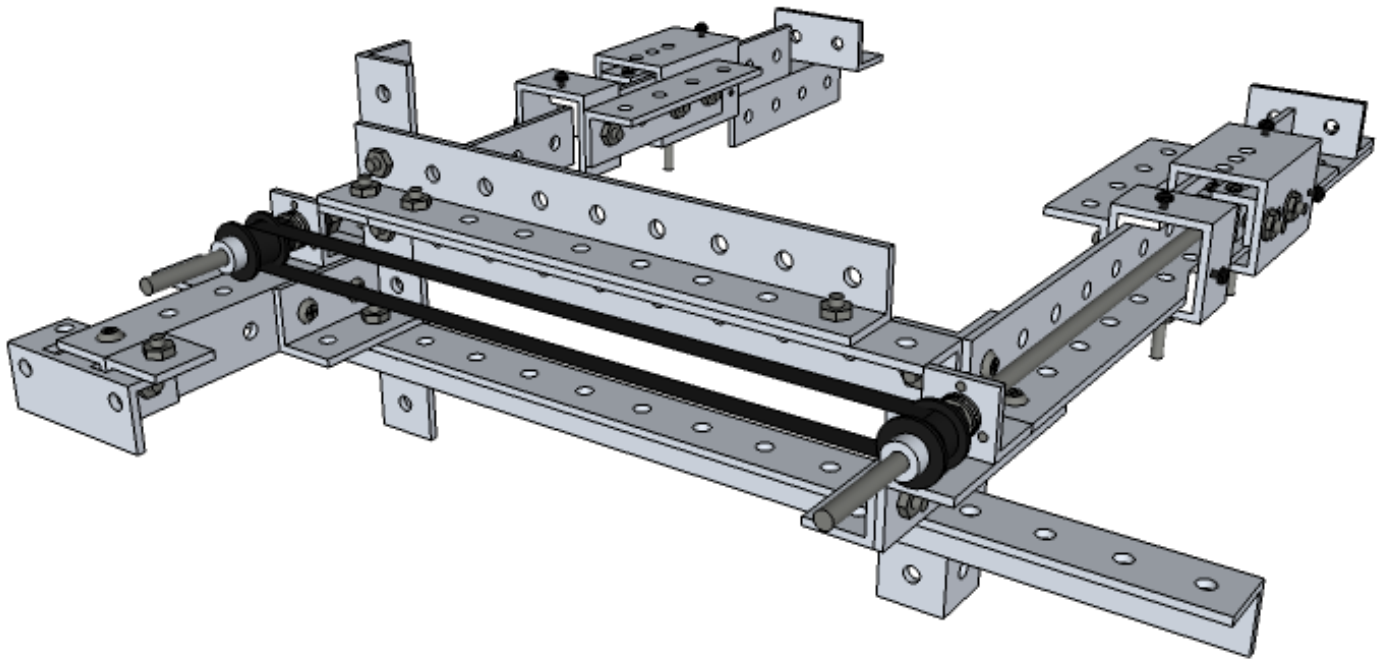
083-Z-axis-assembly

Assemble the top bar from two angle-9s and angle-1.



084-Z-axis-assembly

Attach the top bar assembly to Z axis but do not tighten the right side yet.

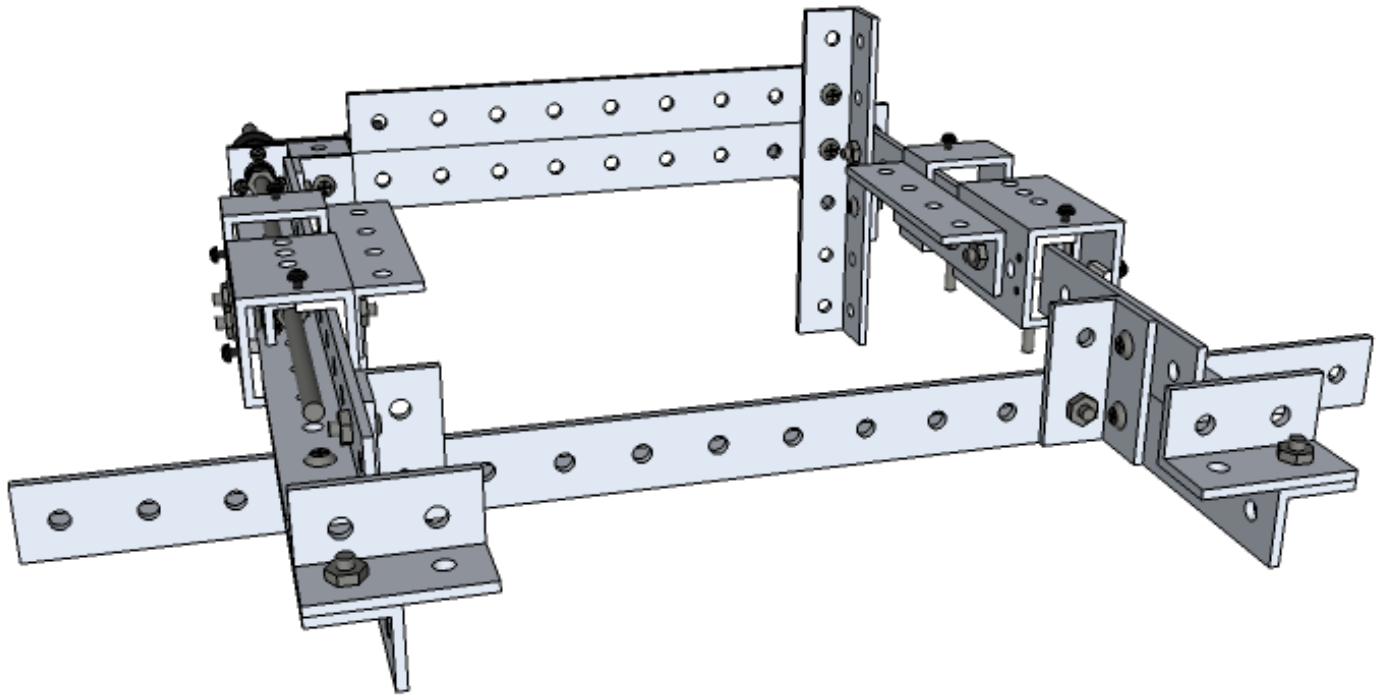


085-Z-axis-assembly

Take XL-240 belt and pair of pulleys, slide the pulleys with the belt onto the threaded rod ends. Do not tighten the pulleys yet.

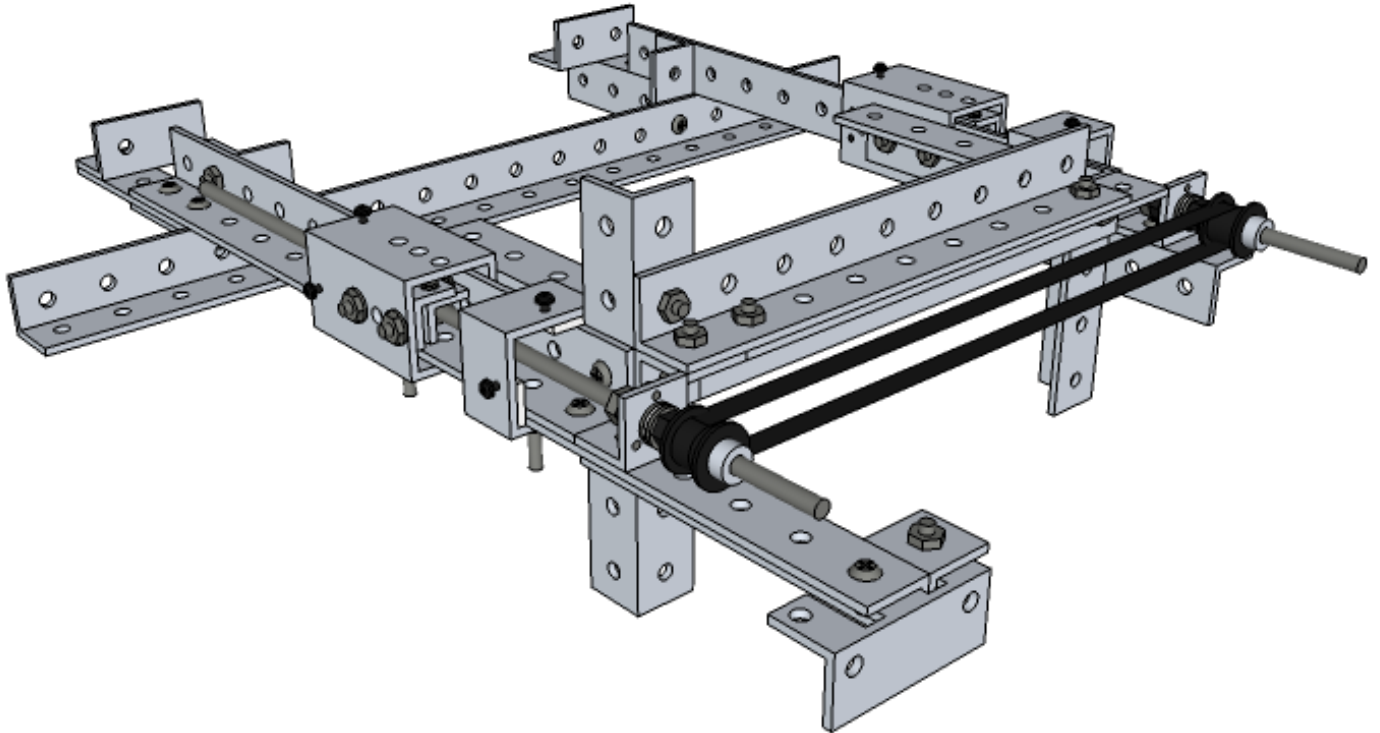
Move the right side to adjust the belt tension. The rods should not bend under tension but there also should not be a slop in the belt. You should still be able to rotate the threaded rods with your fingers.

Once the belt tension feels right, tighten the right side at the helper assembly and the top bar assembly.



086-Z-axis-assembly

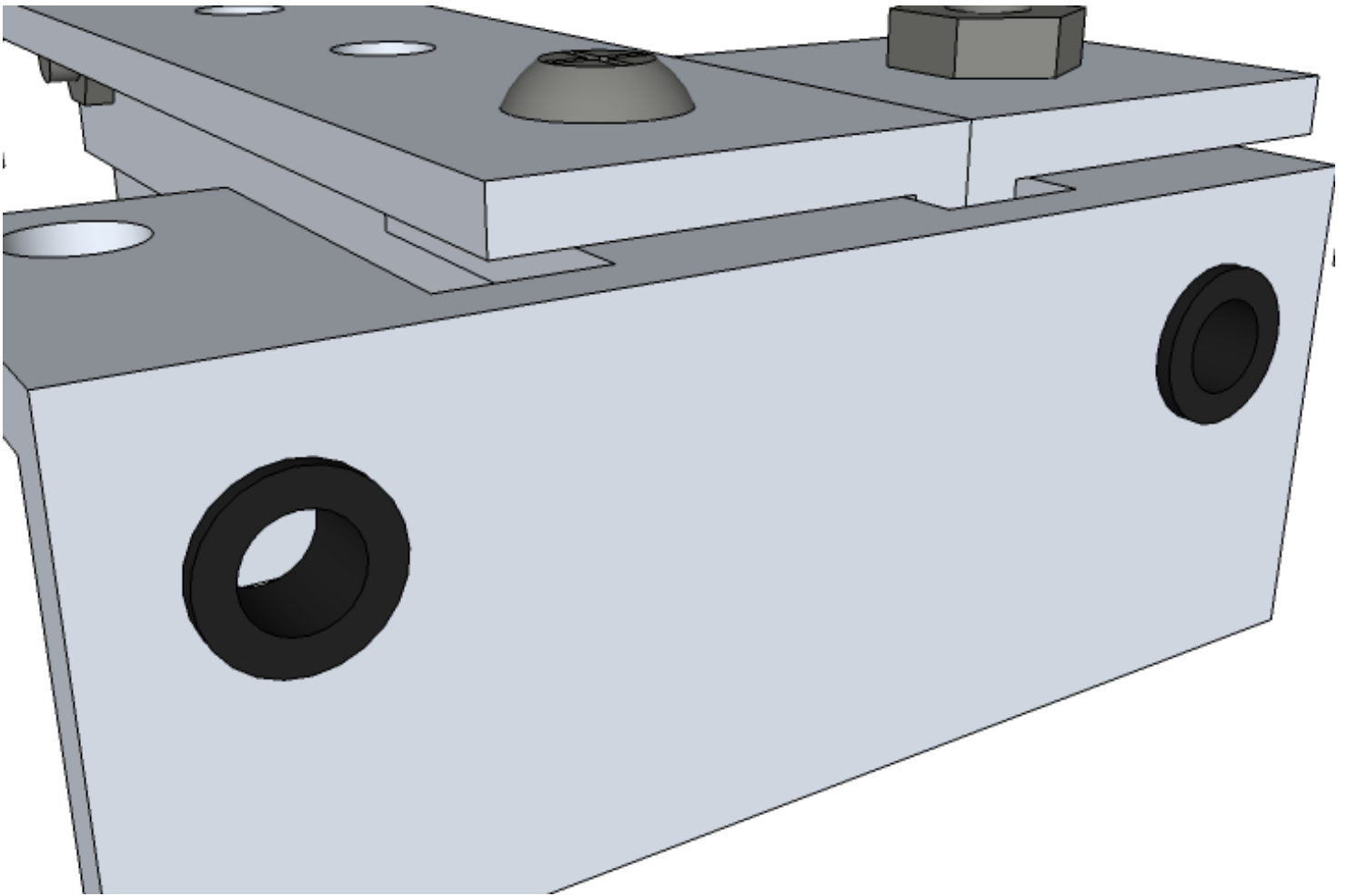
Disconnect the helper assembly (keep angle-2s attached and tightened to angle-18) and re-attach it at the other end of the axis as shown.



087-Z-axis-assembly

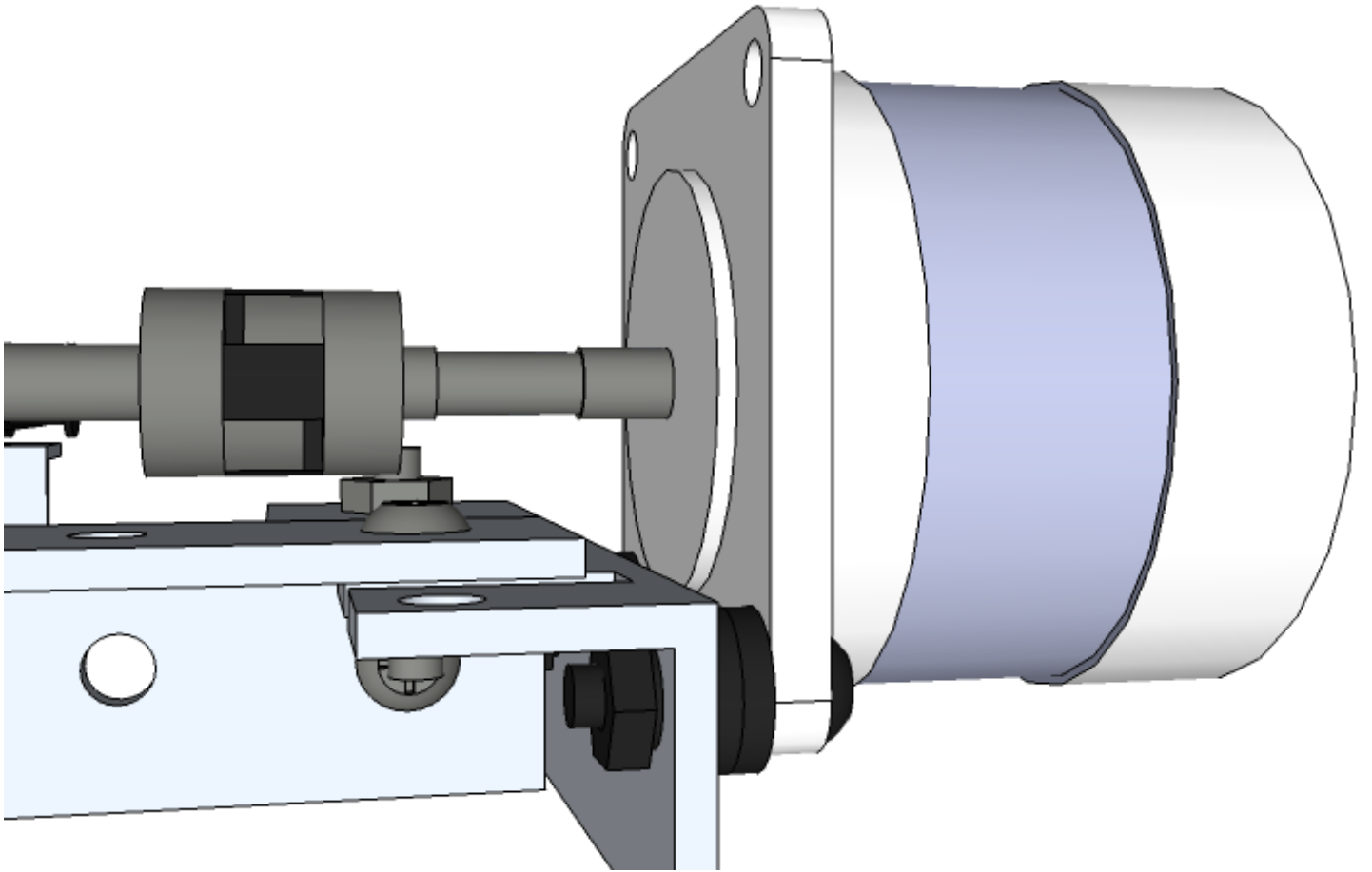
Move the linear bearings to one end of the axis and tighten the pulleys on the threaded rods.

Manually verify easy rotation of the belt-coupled threaded rods throughout the travel of the bearings. It's important that there are no spots on the rod where you need to apply extra torque to turn it.



088-Z-axis-assembly

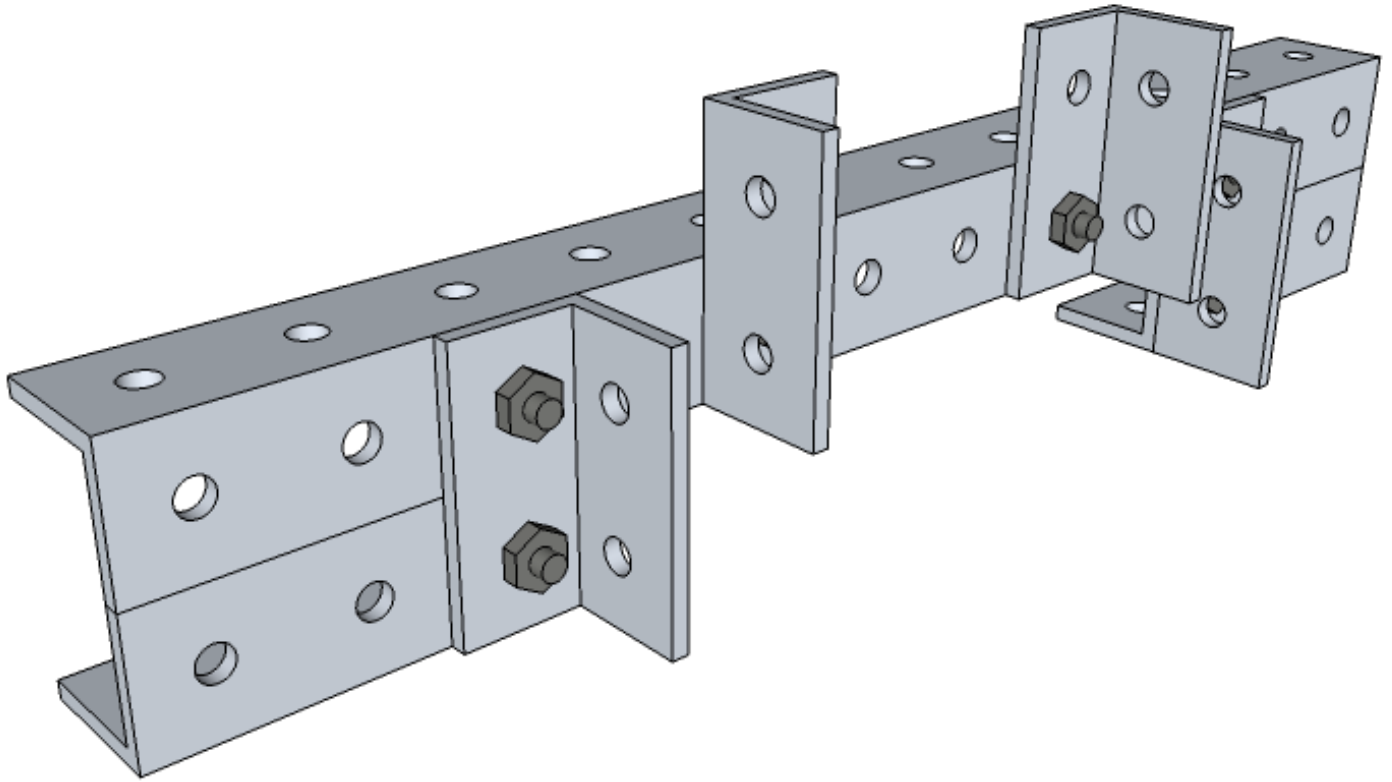
Install rubber grommets into the mounting holes of the motor mount.



089-Z-axis-assembly

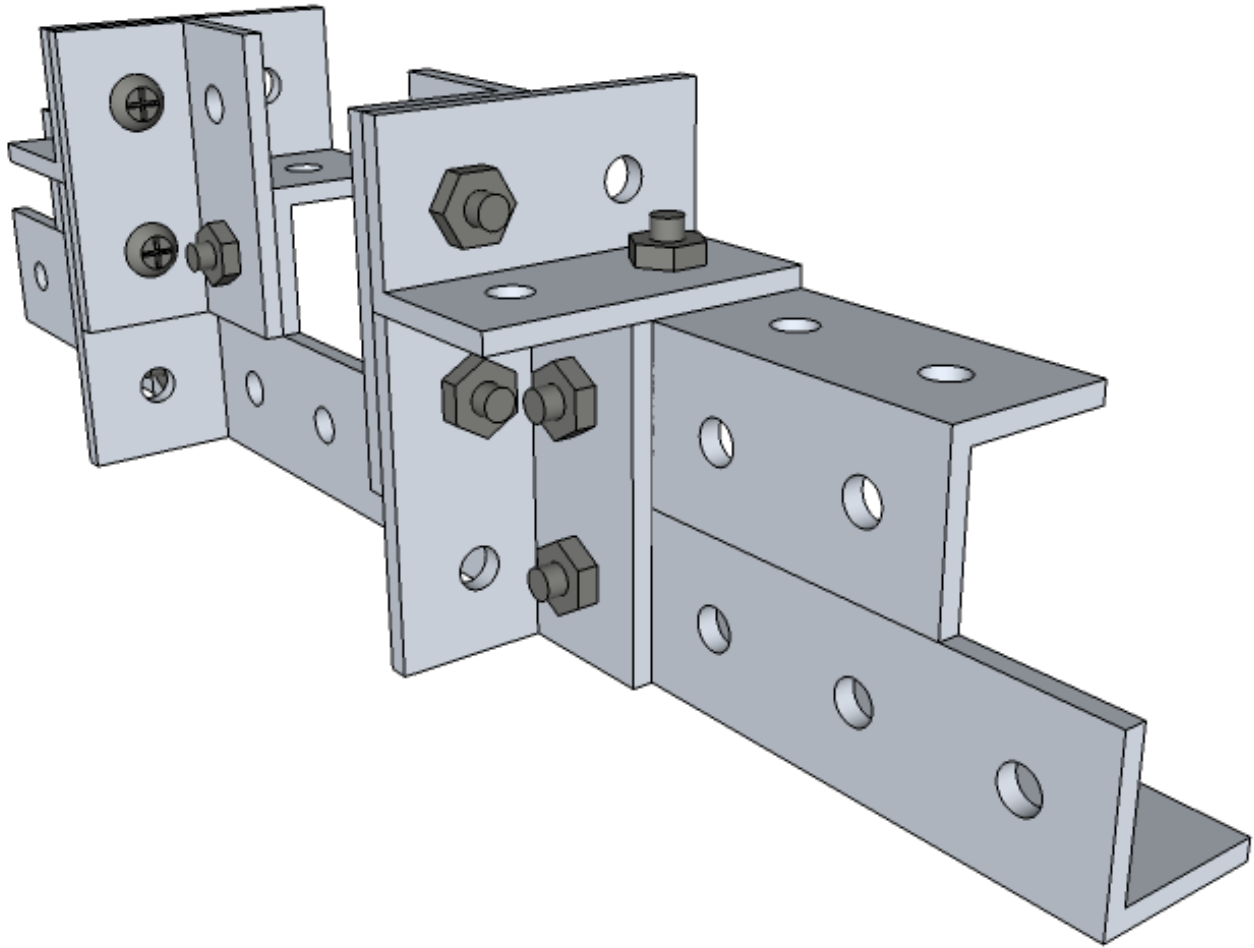
Install the motor. The plastic screws should be turned with a flat screwdriver so that the grommets don't pop out.

Do not tighten the coupling hub on the threaded rod yet.



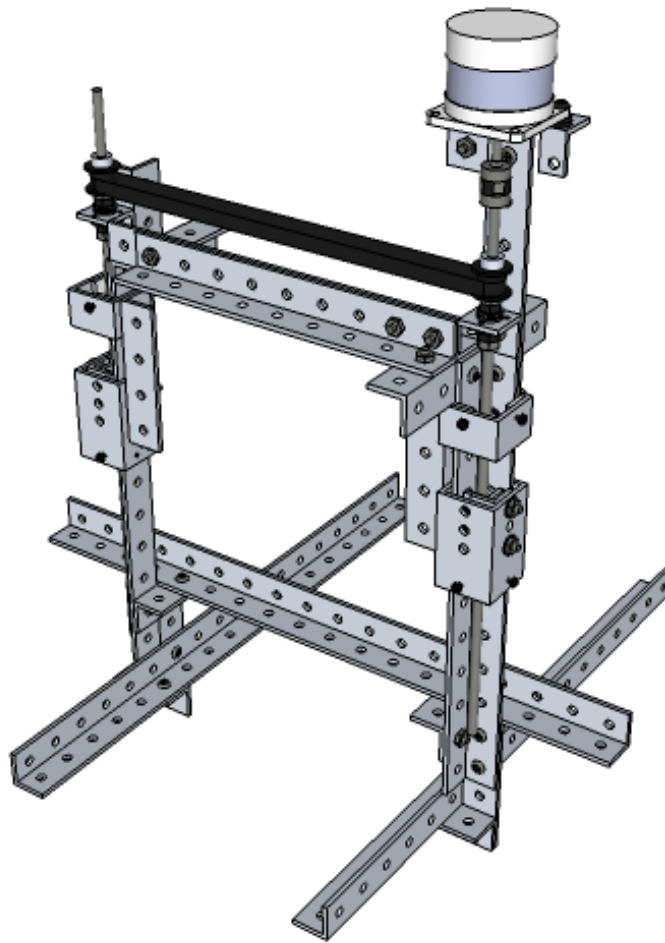
090-Base-assembly

Assemble base rear.



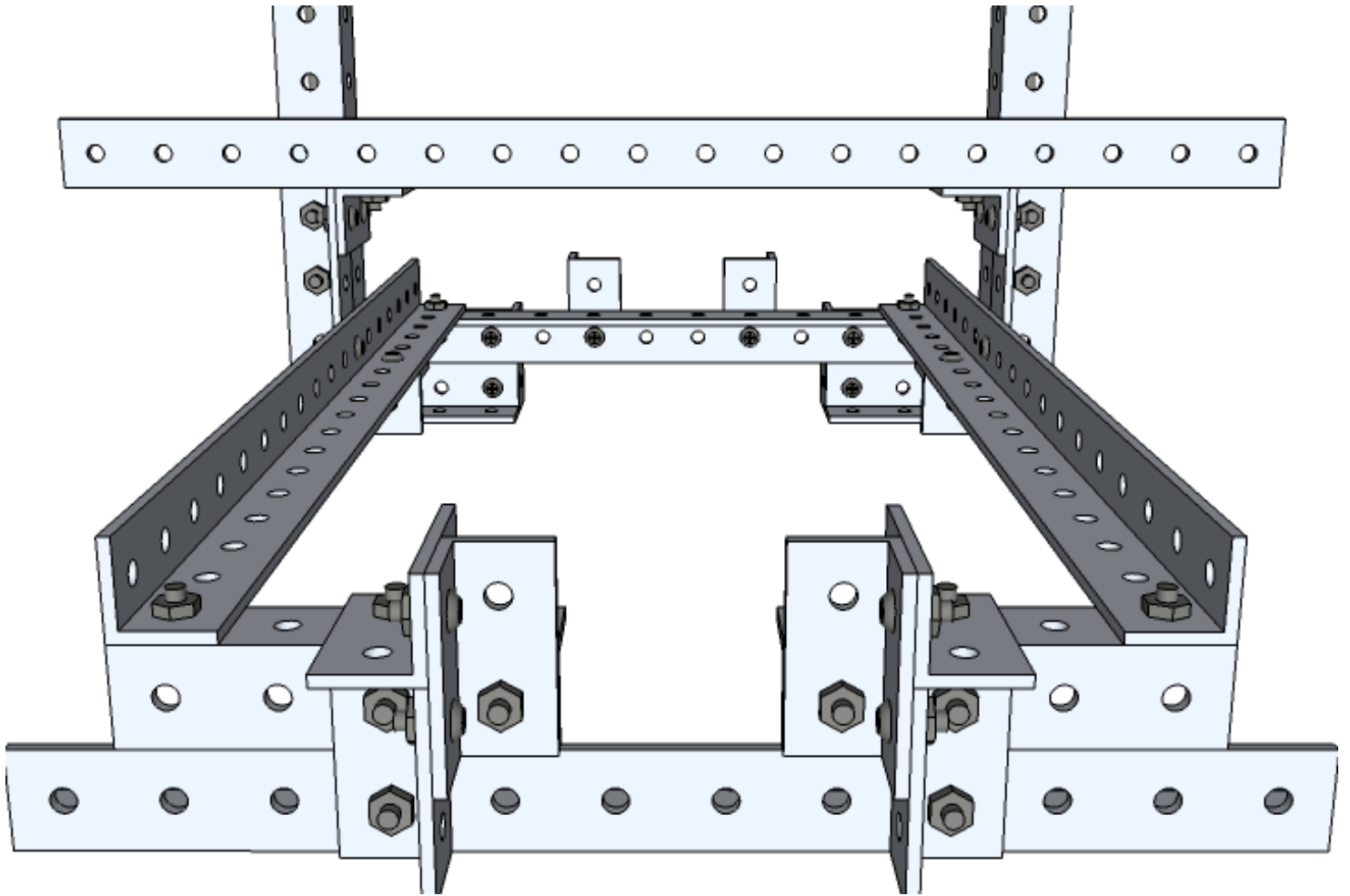
091-Base-assembly

Assemble base front.



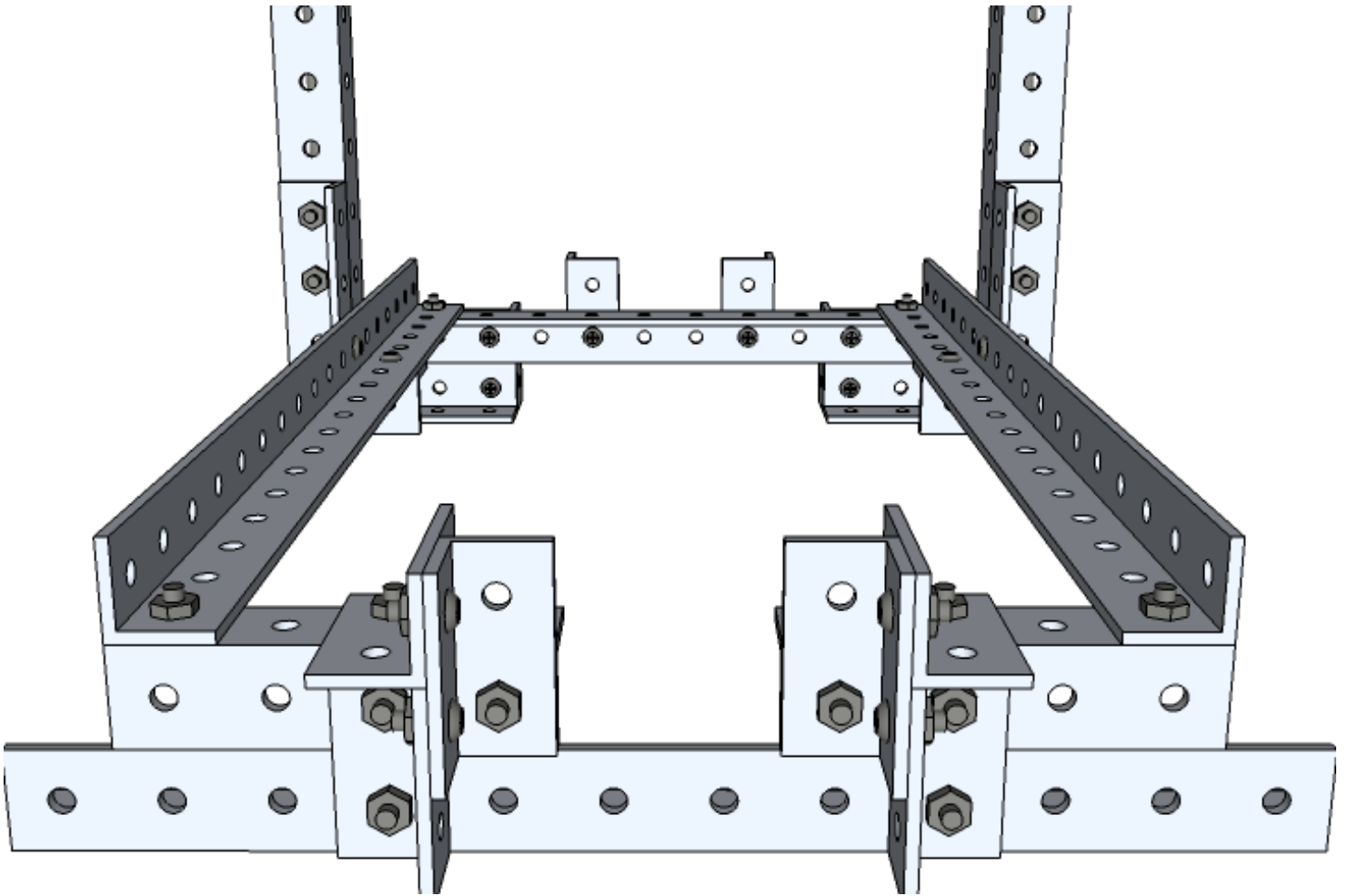
092-mini-CNC-assembly

Attach pair of angle-18s at 6th and 7th hole to the lower end of Z axis.



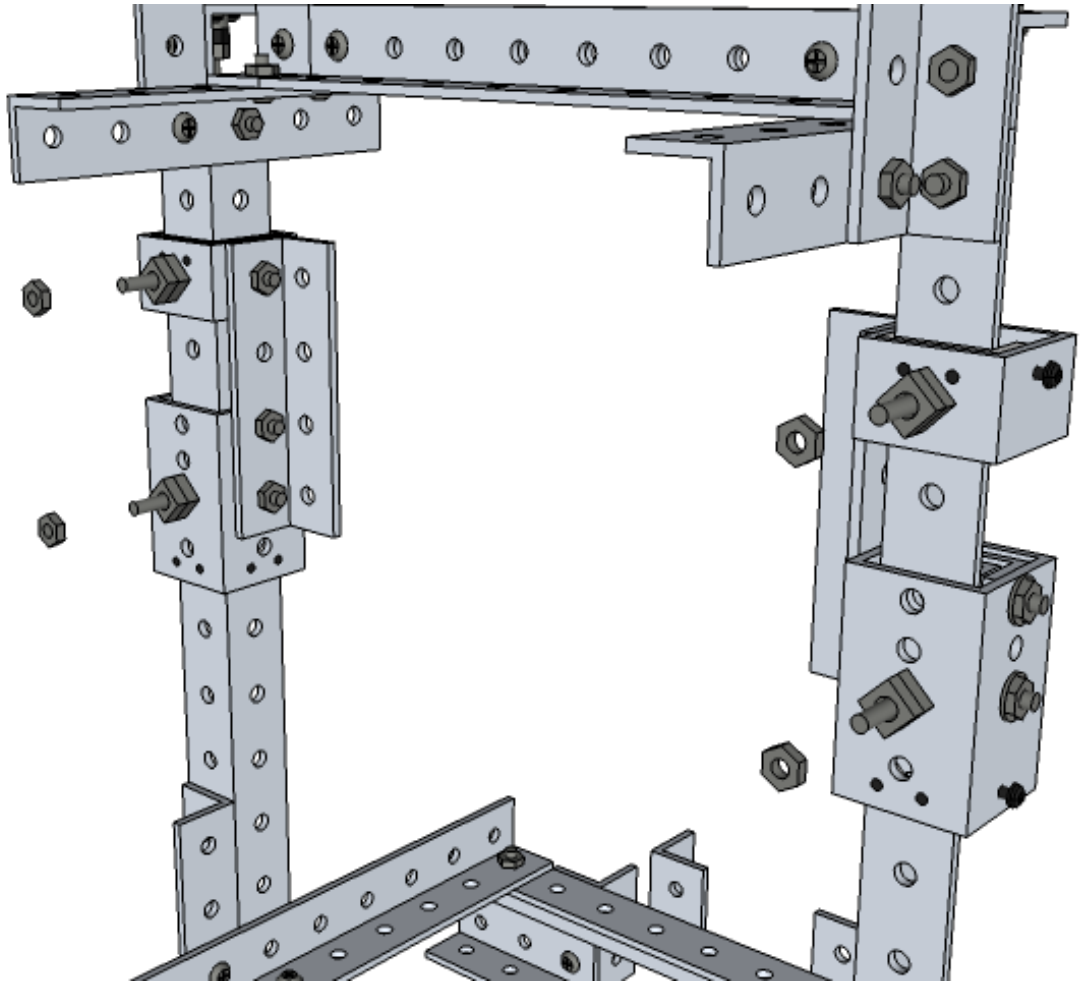
093-mini-CNC-assembly

Stand Z axis with angle-18s on top of front and rear base assemblies, attach at each corner and tighten.



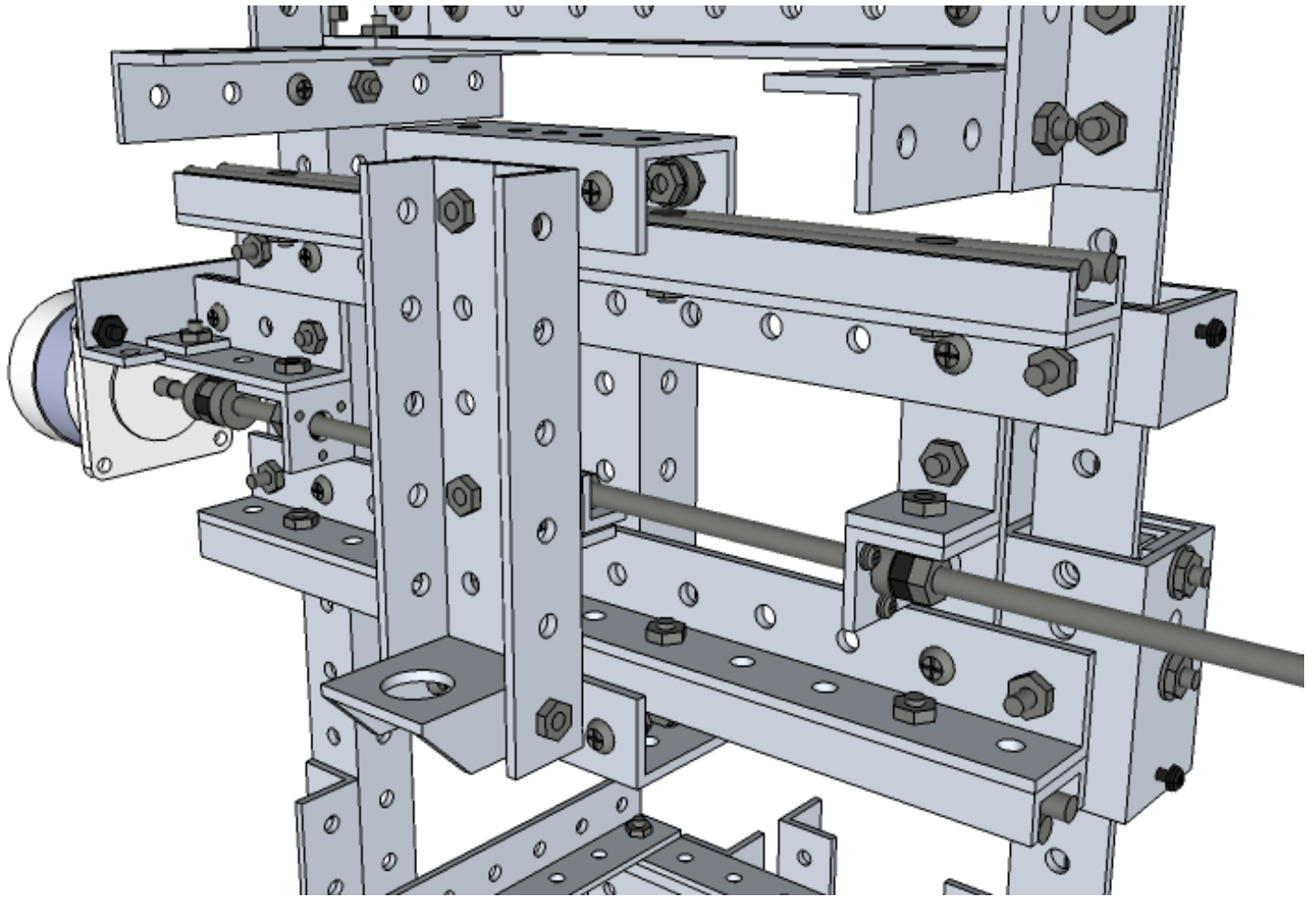
094-mini-CNC-assembly

Remove helper assembly.



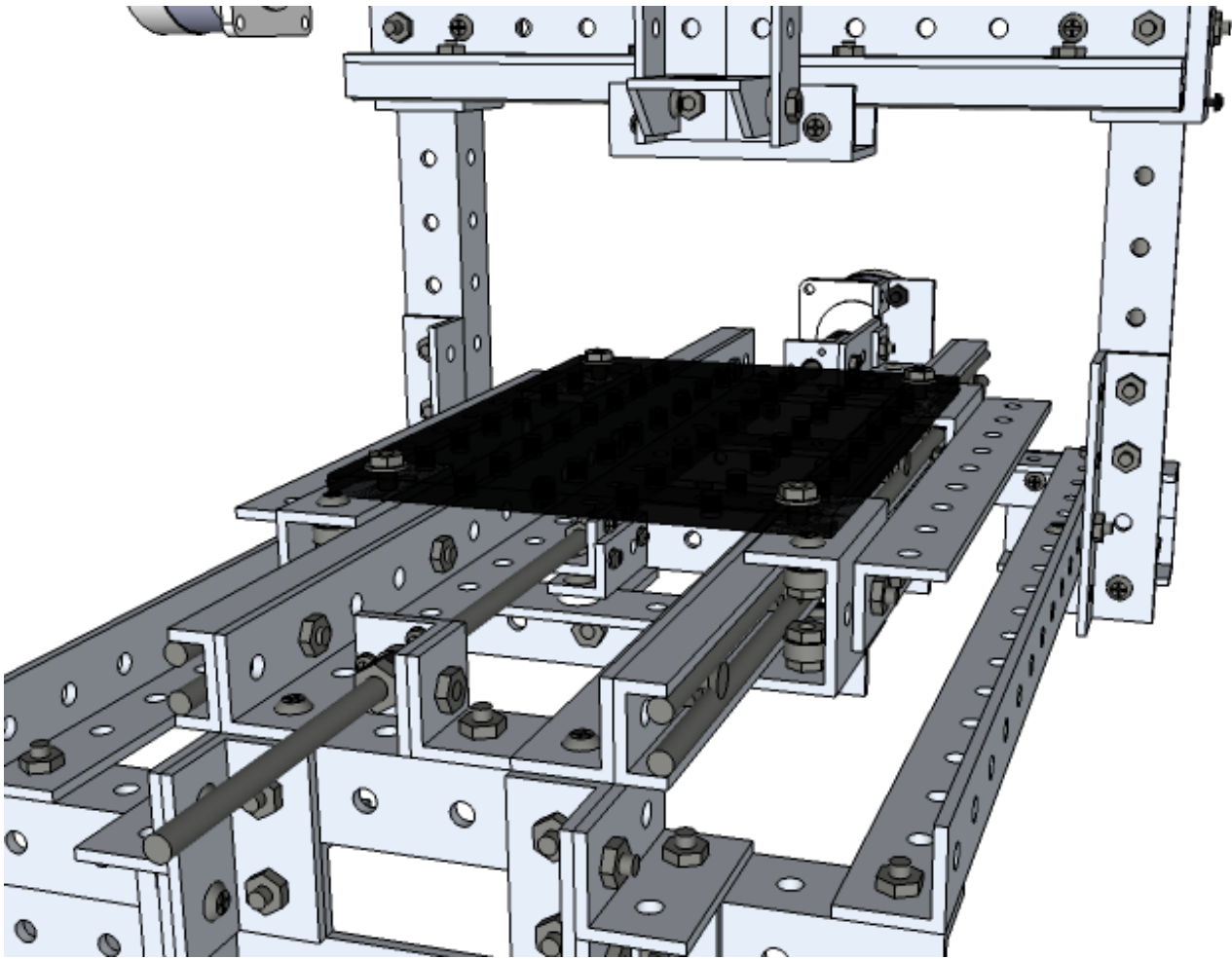
095-mini-CNC-assembly

Remove hex nuts from the long screws on Z stage bearings and add a pair of 1/4-20 square nuts to each screw.



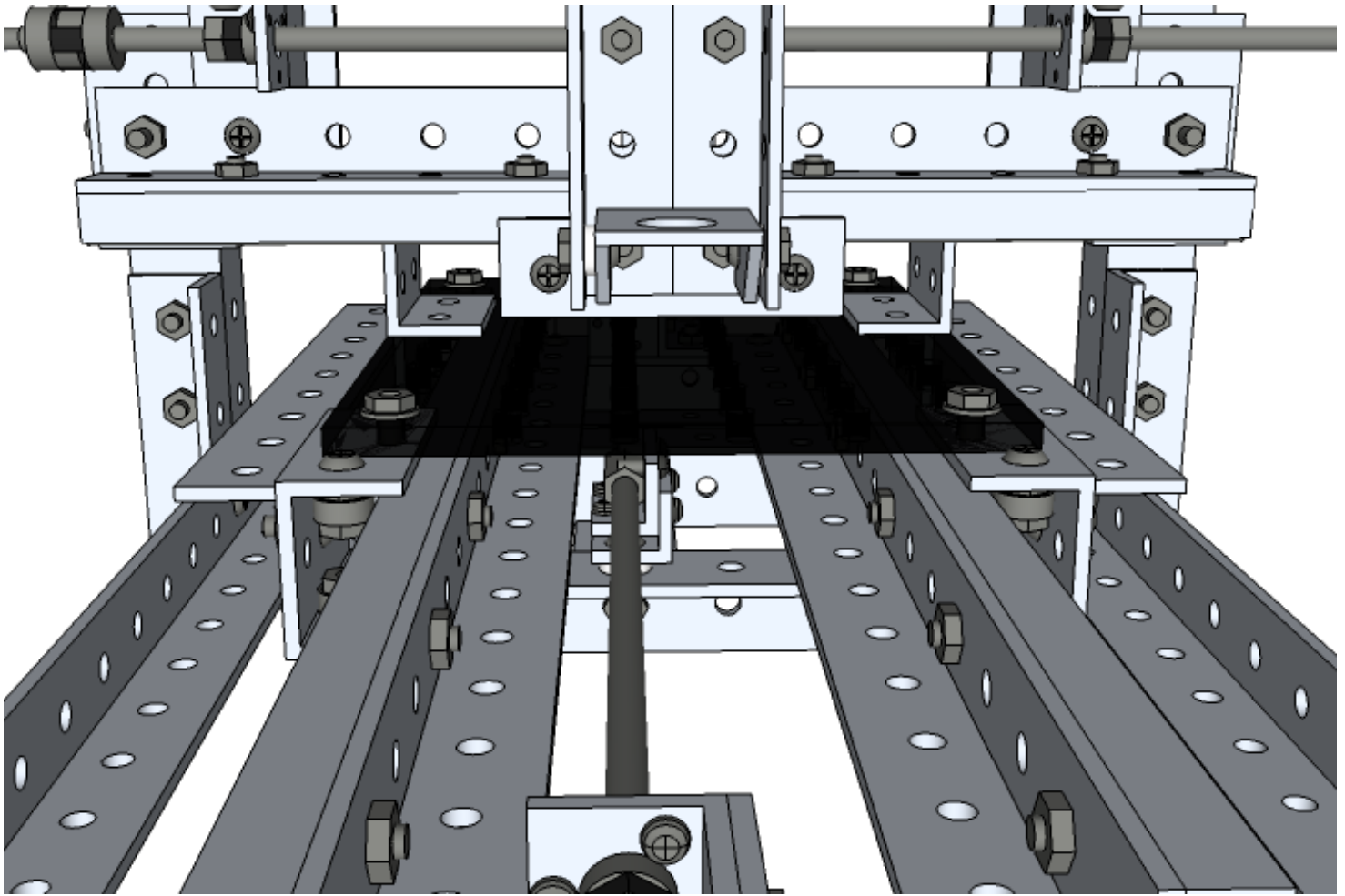
096-mini-CNC-assembly

Install X axis on the long screws and finger tighten the nuts.



097-mini-CNC-assembly

Install Y axis and tighten the nuts.



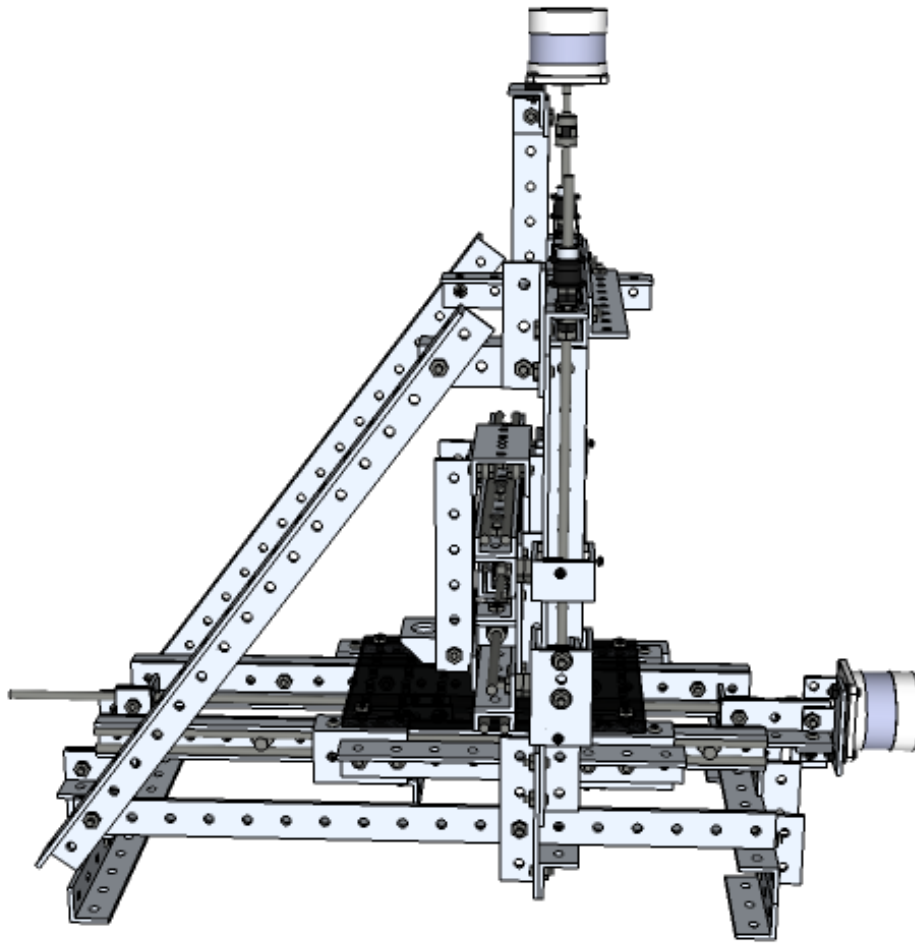
098-mini-CNC-assembly

Center the Y stage and put a pair of angle-2s on the opposite ends of the table.

Loosen the nuts connecting X axis to Z stage bearings and lower X axis until its bottom rail touches both angle-2s.

Carefully tighten X axis nuts in this position and verify that the pulley can be easily turned. You will feel more resistance when raising X axis (vs lowering it), but the torque needed to turn the pulley should be the nearly same at every angle. If you feel significant variation in torque through all or part of Z travel length, the belt may be overtightened. It's also possible that threaded rod may be bent or have some defects, but this would have been mostly ruled out by free rotation tests in Z half-axis assembly.

Tighten the motor coupling hub on Z axis (threaded rod side).



099-mini-CNC-assembly

Install angle-18 supports and tighten.
