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The Jig Design

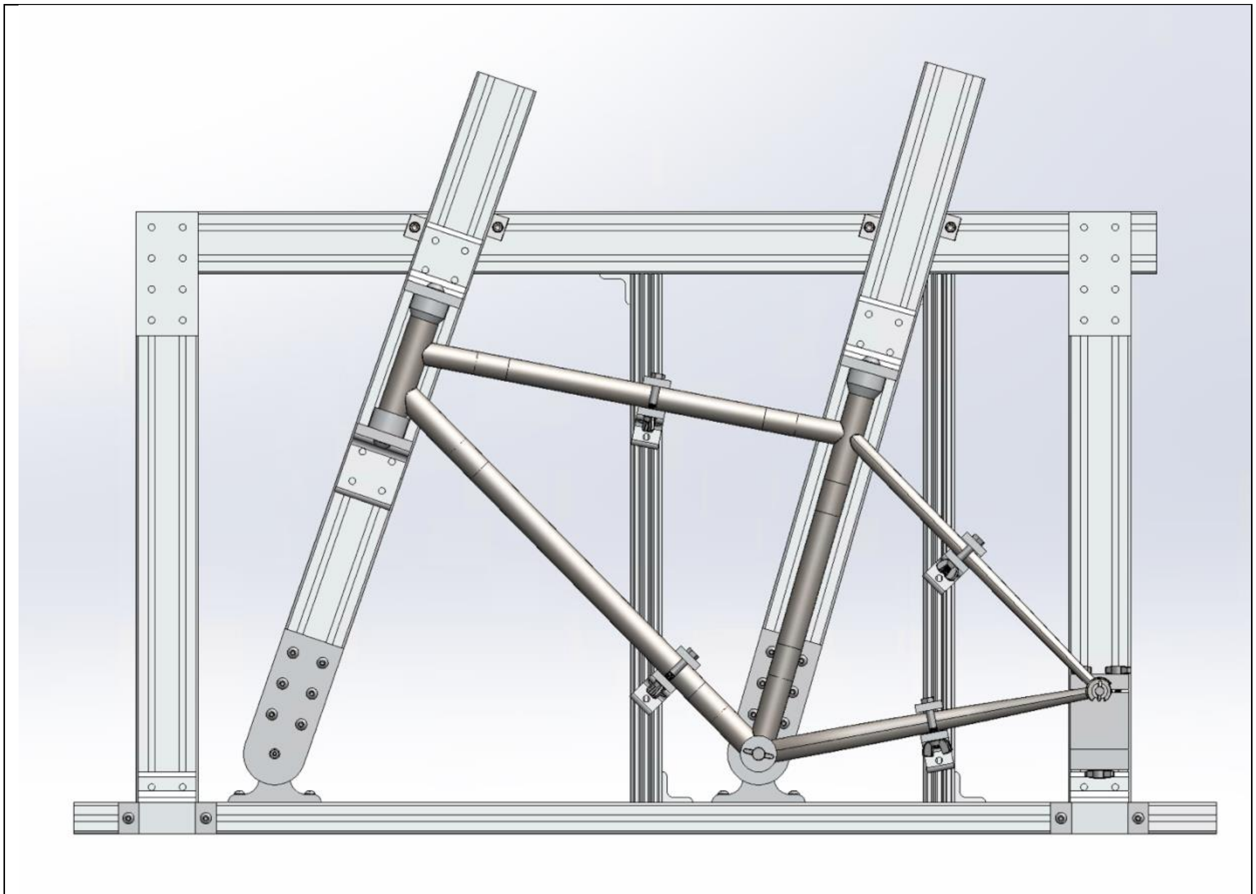
Introduction

In order to make a bike frame, you'll need a way to hold the tubes together in place for welding - that's what the jig is for. We needed to create a jig that would allow us to make adjustments to fixture any diamond shaped bike frame geometry. In other words, this jig will be able to hold together anyone's own bike frame design. We did lots of research into the various bike jig designs that other frame builders have come up with and analyzed their simplicity and feasibility of manufacturing. Eventually, we stumbled across a design that best fit the criteria and used it as inspiration for our jig design. Below is a picture of the jig that inspired our design. Here's a link to an article where you can read about how this frame builder created their jig: https://www.instructables.com/The-simplest-bicycle-framebuilding-jig-I-could-com/.

The bike frame jig that inspired our own design [1]

And here are pictures of the bike frame jig when we built it as well as the SolidWorks model.

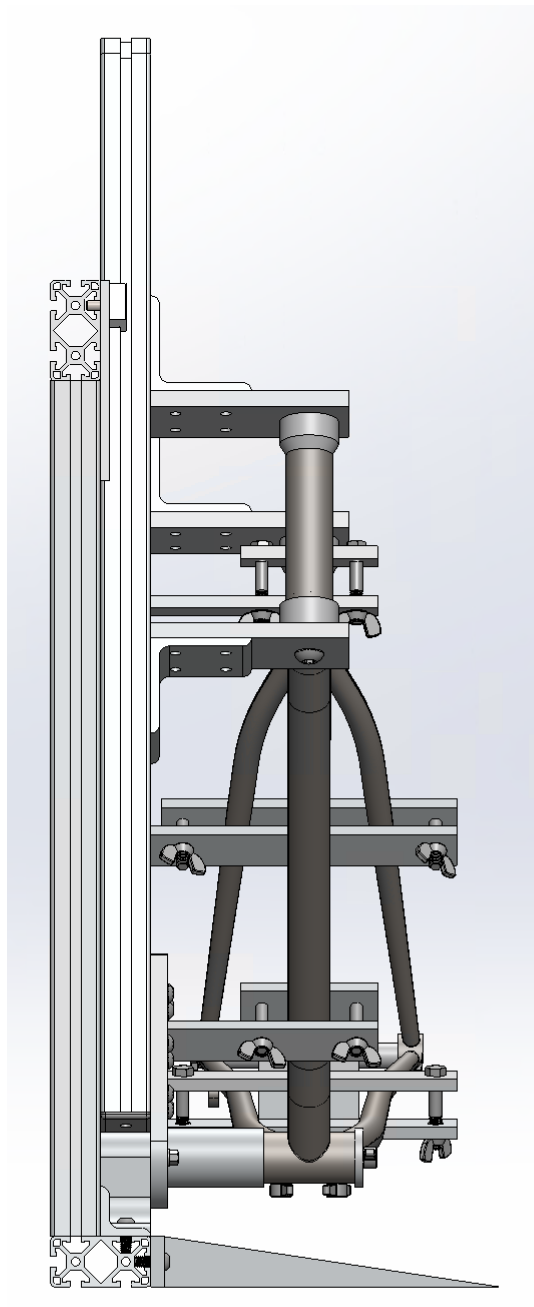
The bike frame jig that we designed and built in the IDEAs Clinic


The bike frame jig design in SolidWorks

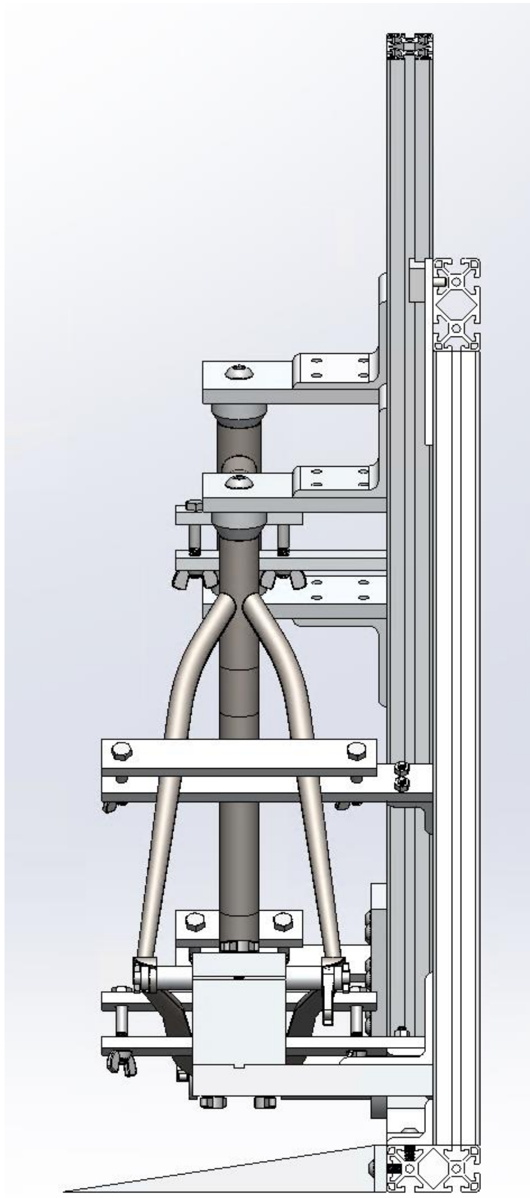
The Frame

The entire frame is composed of hollow 1.5" by 3" double rail and 1.5" single rail extrusions. We decided to use double rail extrusions for majority of the frame because it would prevent any significant amount of twisting and turning of any sliding adjustment features (as these would be fastened into both the rails). The frame was designed to be supported by two feet in front of it to prevent it from tipping forwards and the bottom extrusion was made a bit longer on either end so that it can be clamped to a table to ensure it doesn't wobble. When we actually manufactured the jig however, we decided to use an extra piece of double rail extrusion as the feet instead to make life easier. The single rail extrusions were chosen to hold the tube clamps as having a single rail would allow for the clamps to be rotated so that they're tangential to whatever tubes need to be supported. Lastly, all the extrusions are hollow simply to minimize weight and costs.

A very important design feature of the jig is that it needs to hold all of the tubes in such a manner that the center axes of all the tubes lie on the same plane and the stays and dropouts would need to be symmetric about this plane. As we designed the jig, we took into account which extrusions each adjustment feature would be connected to and then made the dimensions of those components accordingly. We also needed to consider what the normal distance from the extrusion to this imaginary plane should be so that nothing is obstructing the welder's reach. The images below show this idea clearly.



Left view of the jig digital twin shows all tubes are aligned or symmetric about the same plane



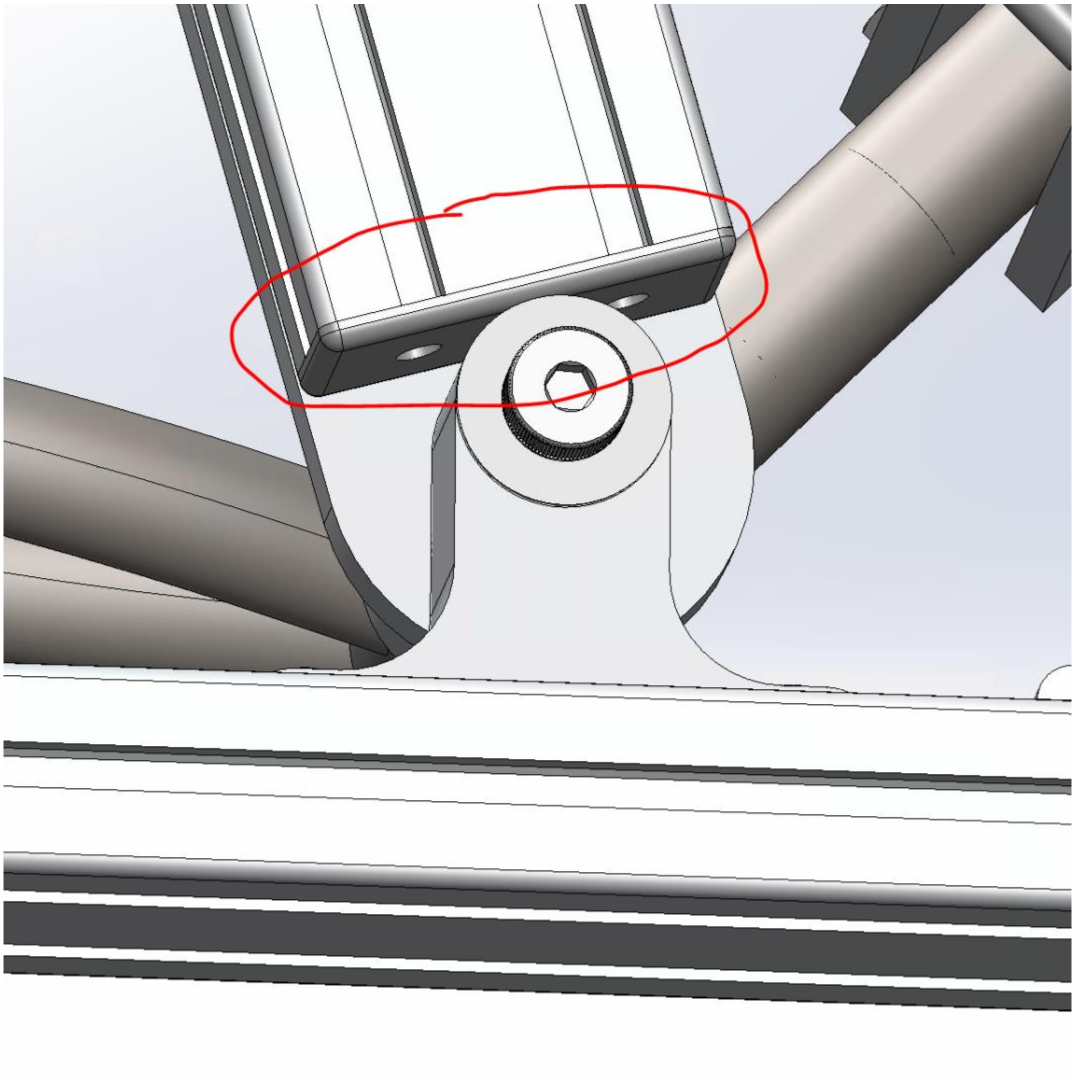
Right view of the jig digital twin shows all tubes are aligned or symmetric about the same plane

The Pivot Mechanism

There are two sliding pivots that sit along the bottom extrusion which allow us to position the head and seat tube angles as well as the separation between them. These sliding pivots have a radius to allow the extrusions that sit on top to rotate to the desired head and seat tube angles. They can slide along the rails in order to position the separation between the head and seat tube.

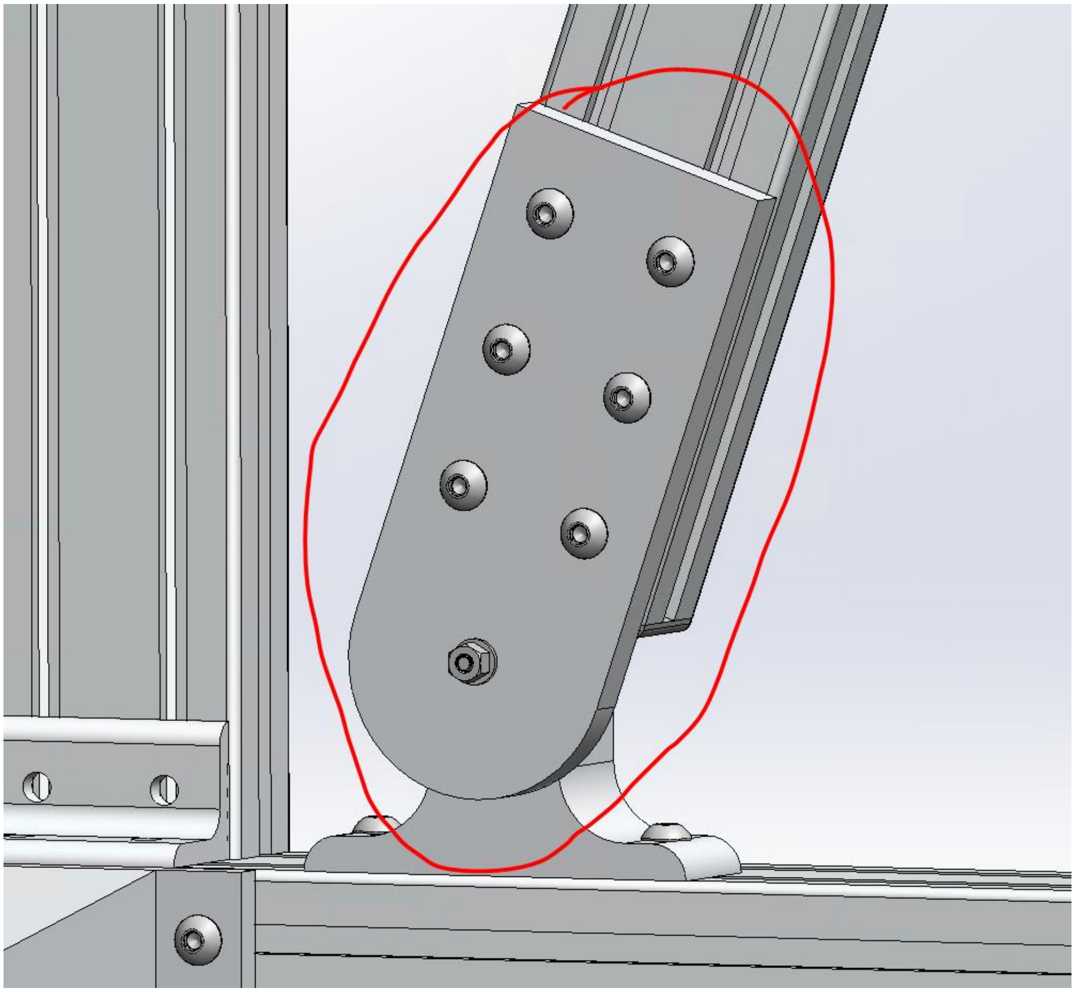
The sliding pivots for positioning the seat tube and head tube

There are also plastic end-caps riveted into the extrusion on the face that is directly in contact with the sliding pivots. This is to prevent the extrusion from scratching and grinding away at the radius of the sliding pivot and to also ensure that it rotates smoothly.



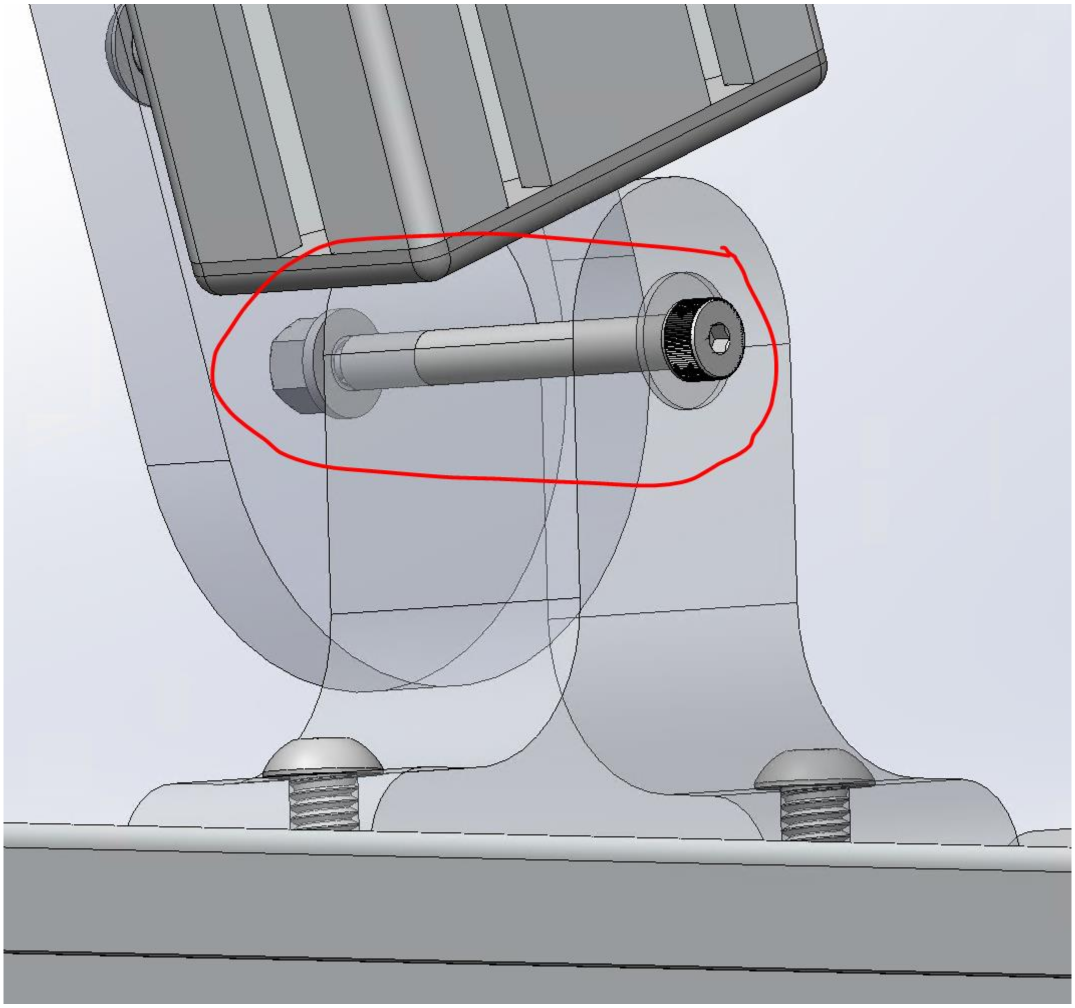
Plastic end-cap riveted into the bottom of the angled extrusion

The surface brackets connecting the extrusion to the sliding pivots keeps the centre axis of the extrusion and the centre of the top radius of the sliding pivot coincident so that the extrusions can be angled correctly.



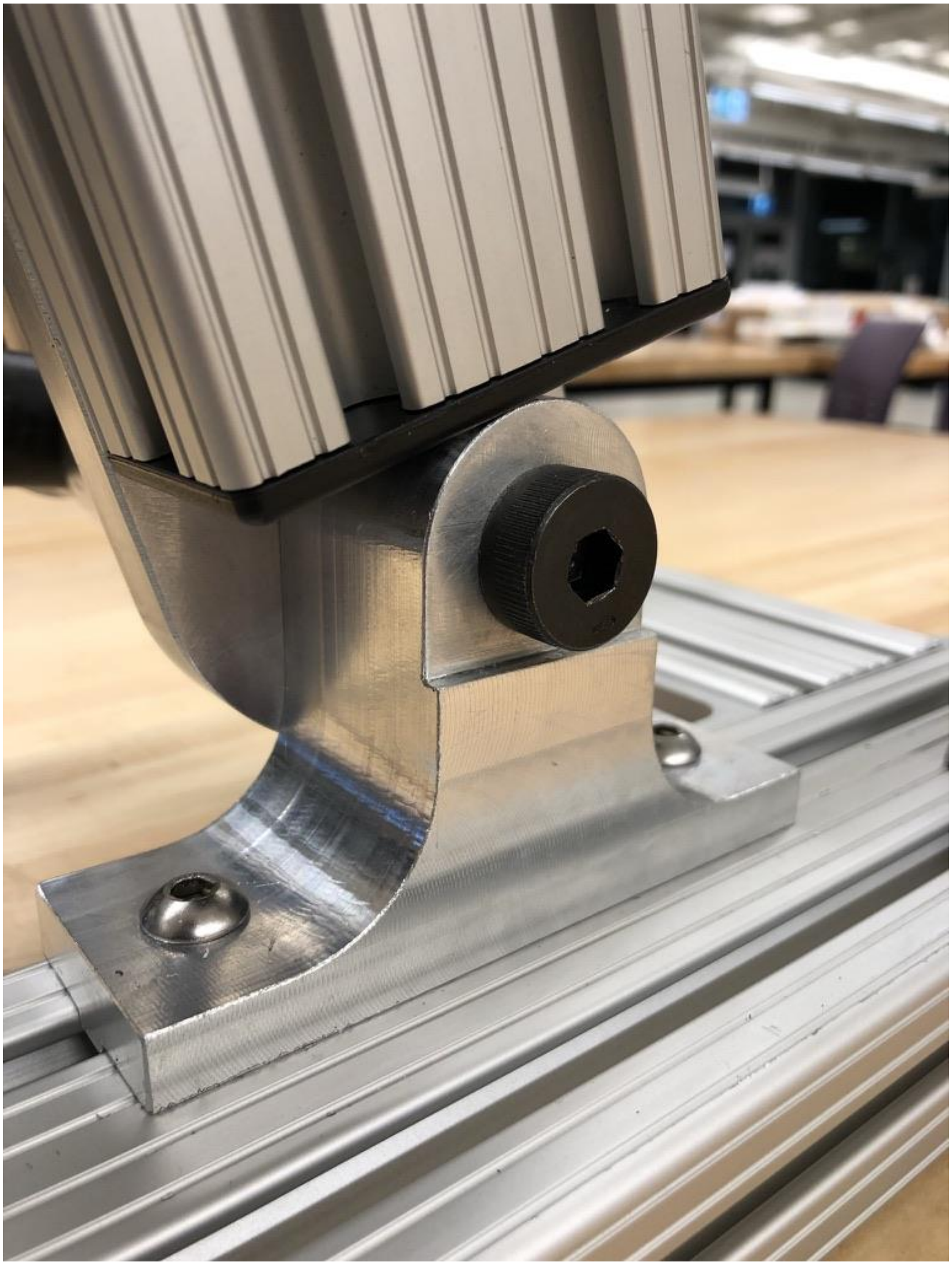
Surface bracket connects the extrusion to the sliding pivots

Additionally, shoulder bolts were used to fasten the surface brackets to the sliding pivots for the head tube section; the setup is the same for the pivot at the bottom bracket section except the shoulder bolt used there also fastens to the bottom bracket post. We decided to go with shoulder bolts because the shoulder would allow the surface bracket to rotate about the sliding pivots.



Shoulder bolt connects the sliding pivot to the surface bracket

In theory, this sounded like it would work perfectly but it wasn't until we were finished machining these components and tested out the mechanism that we realized there were issues with this design. The first issue is that the surface bracket and the sliding pivot were not rotating as we had expected. The shoulder bolt was actually causing the surface bracket and the sliding pivot to tighten when rotated clockwise and loosen when rotated counter clockwise. To fix this problem, we had to fasten the shoulder bolts as tightly as possible into the female threads that they would be mated with (the bottom bracket post or a flange nut). Then we measured the gap between the inner face of the shoulder bolt heads with the inside face of whatever component it was threaded to. Next, we measured the total thickness of the surface bracket and the sliding pivot and machined off the difference between this total thickness and the gap measured earlier. This eliminates the problem of the surface bracket and the sliding pivots from tightening and loosening with each other when they're rotated. Below is an image that shows the cut out along the head of the sliding pivots to fix this.

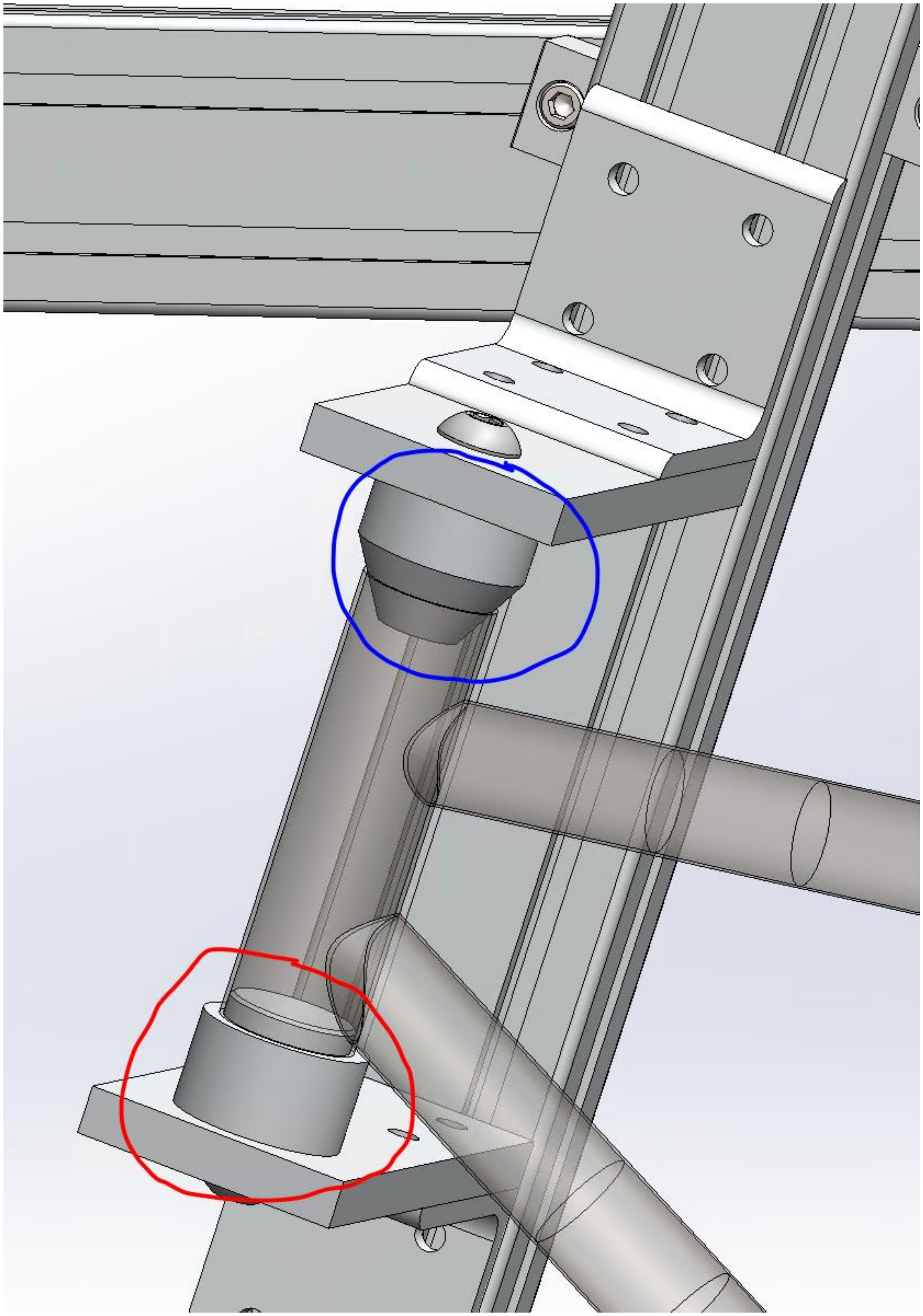


Small cutout on the top of the sliding pivot to eliminate the shoulder bolt problem

The second issue we noticed was that the surface bracket and the sliding pivots were picking up on each other, more appropriately termed "galling". This is a phenomenon that occurs when two like metals rub against each other and is particularly worse for aluminum. This effect was fairly noticeable before we fixed the problem previously mentioned due to the increased rubbing of the metals when they were being tightened as they rotated, but once we fixed that problem, the galling issue was improved. Though the galling isn't completely gone, it is not much of a concern since the surface bracket won't be rotating around the sliding pivots that frequently considering its intended application.

The Tube Inserts

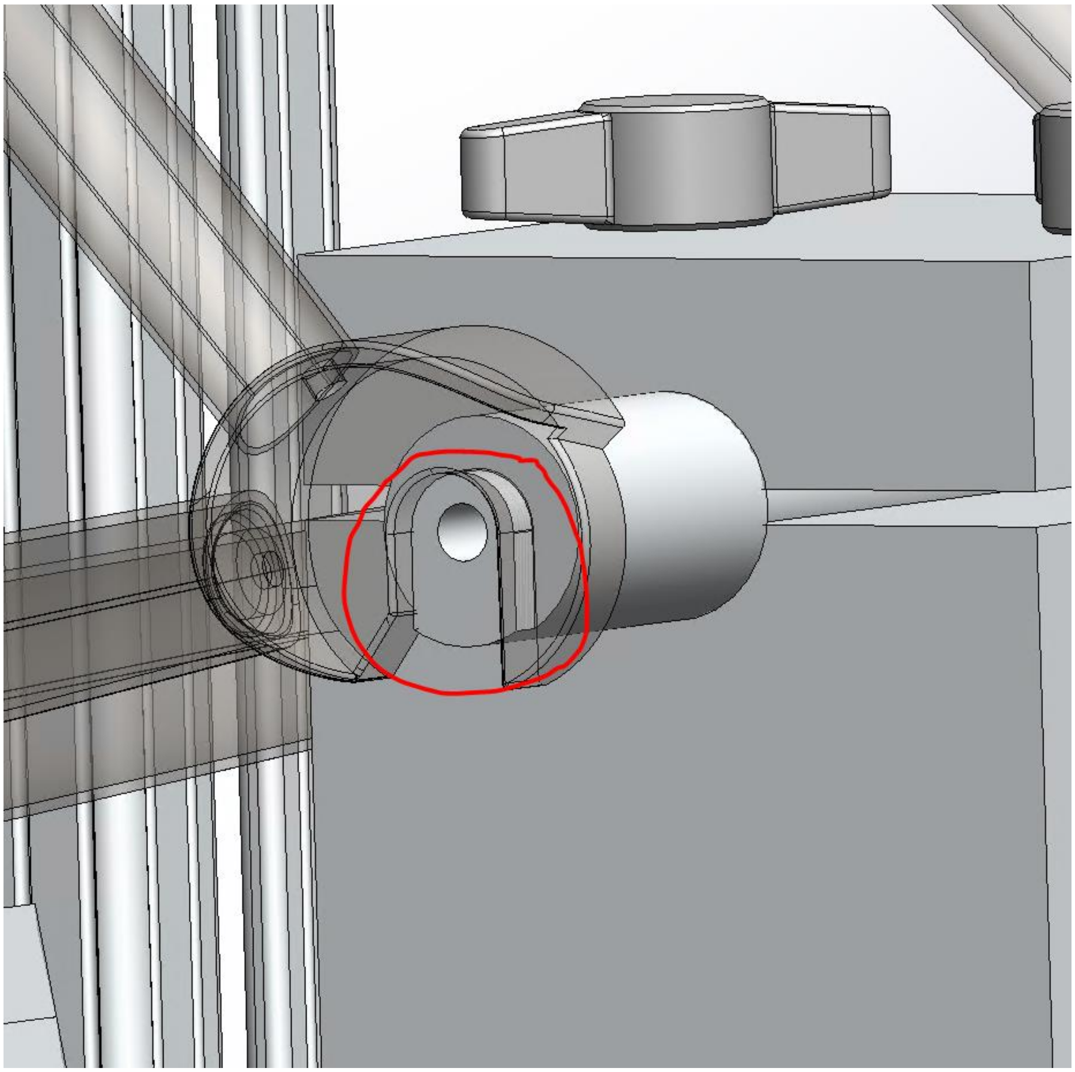
The jig uses two different style tube inserts to hold the head and the seat tubes. The first tube insert (circled in red) has a small boss that matches the inside diameter of the head tube and allows the bottom face of the tube to rest on a flat surface. The reason for this flat surface is to allow us to position the head tube more accurately compared to a conic insert since it won't be sliding up and down a chamfer. The downside to this is that you'll need to replace it with a different insert if you're making a frame with a different diameter head tube. The second tube insert design (circled in blue) is used for the top ends of the head and seat tubes and features a conic shape instead. This design allows the insert to be used for a variety of different diameter tubes as they will simply rest along the region of the chamfer that matches their diameter. The corner brackets that hold the tube inserts allows them to be adjusted along the angled extrusions so that they can be positioned as desired.



The two tube inserts that hold the head tube in place

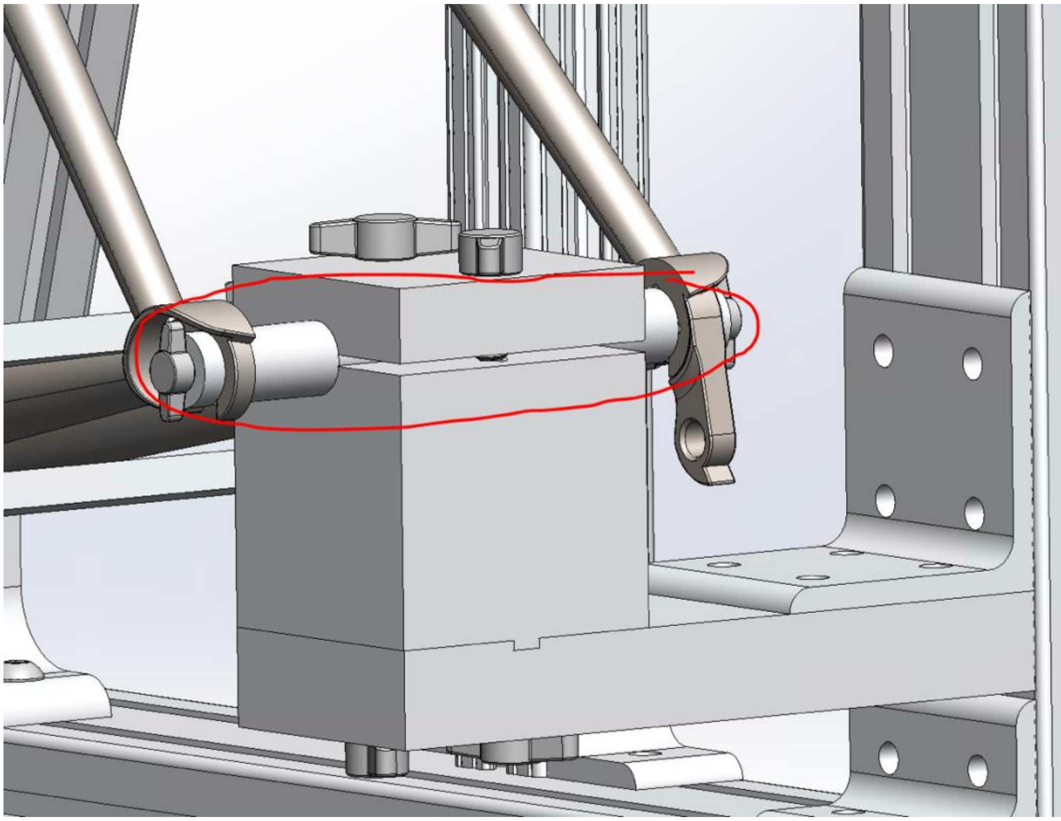
The Rear Dummy Axle

The distance between the inner faces of the rear dropouts is critical as this will dictate what wheel hubs can be used on the bike. We plan to use 135 mm rear hubs so we had to make sure that our jig can hold our dropouts at this exact distance - that's where the dummy axle comes in. The dummy axle has tabs on either end which can be inserted into the slots on quick release Breezer-style dropouts.



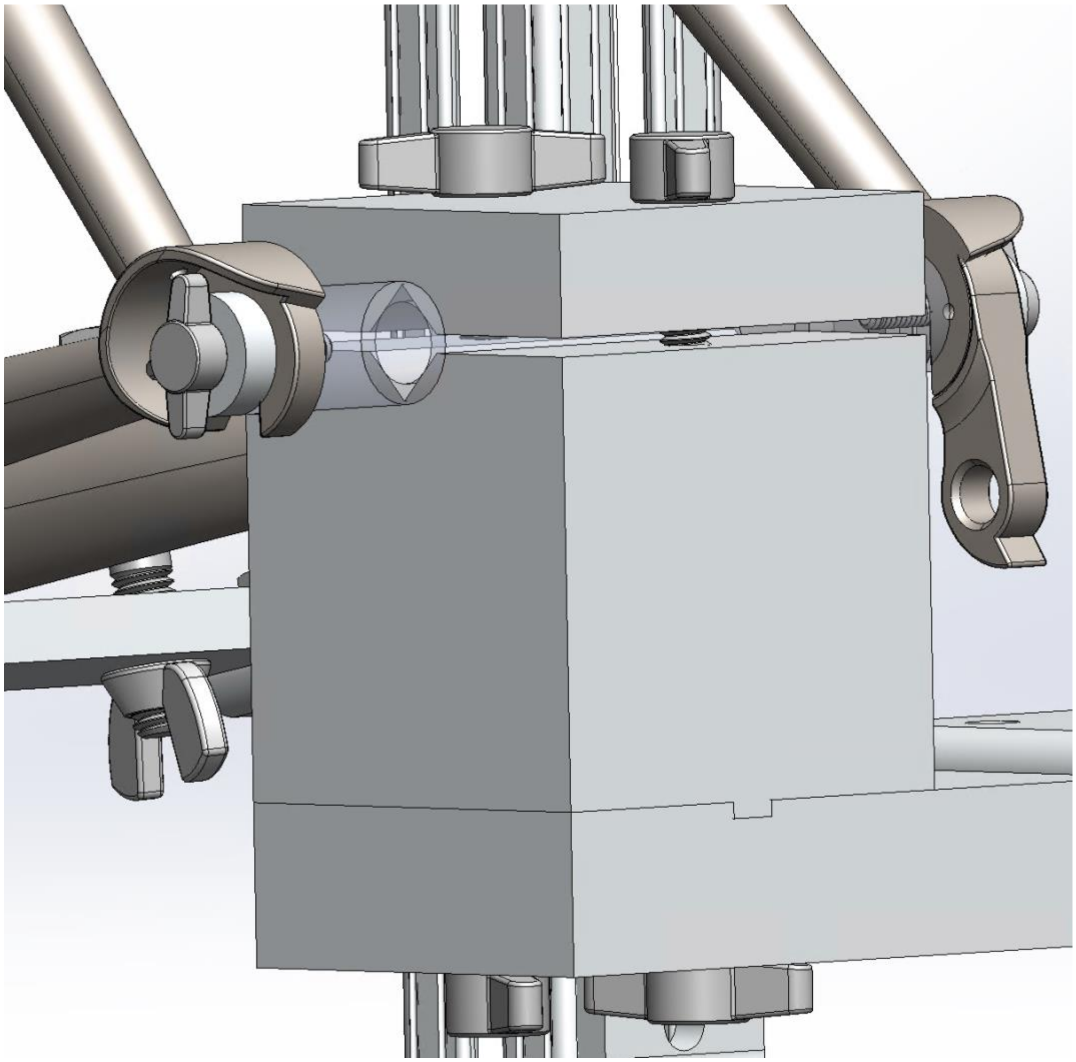
The dropouts are slotted onto a dummy axle to position their separation at precisely 135 mm

The dropouts are then secured in place using small endcaps that are fastened into the dummy axle.



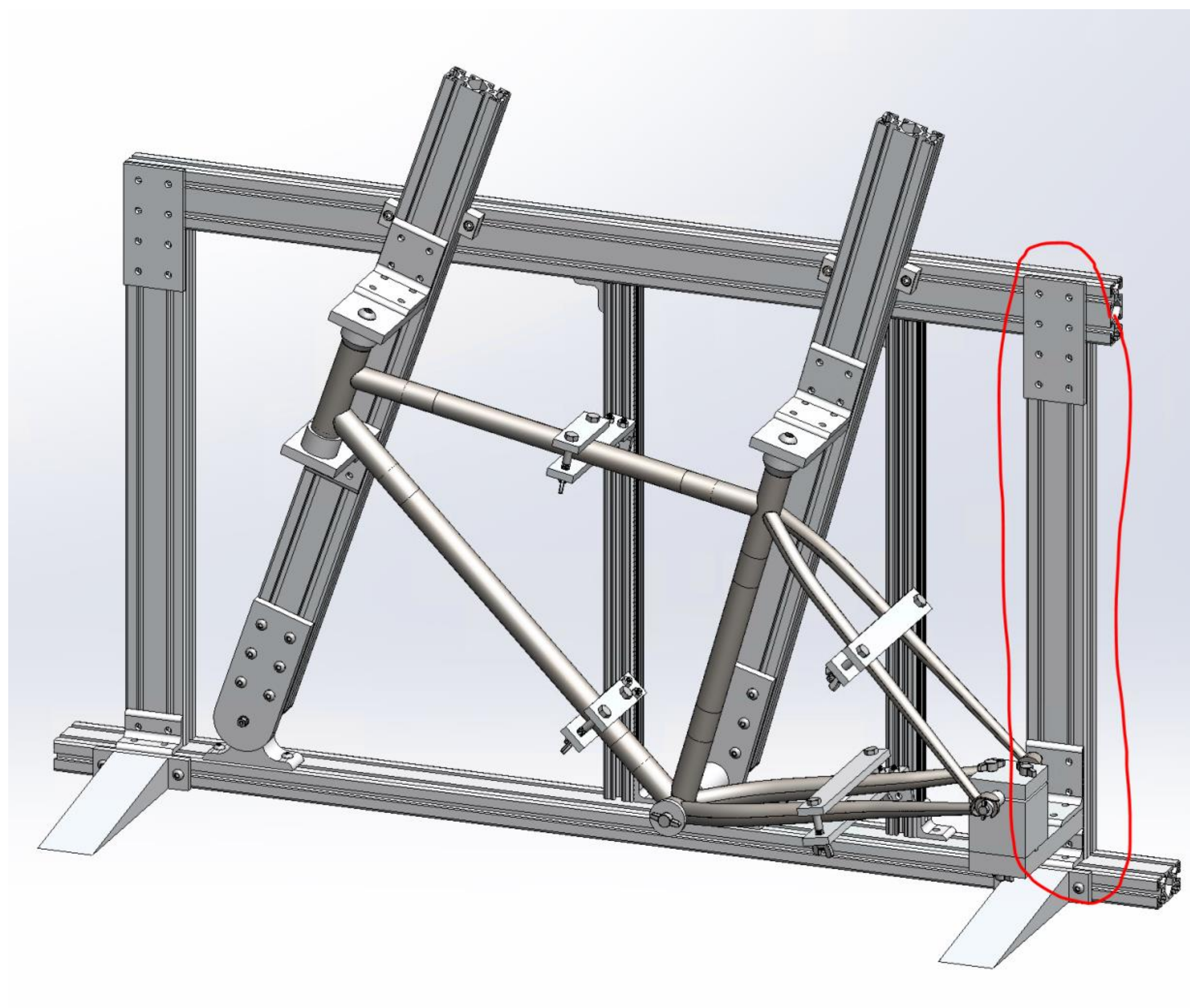
Two end-caps on either side screw into the dummy axle to secure the dropouts in place

A vice with v-notches holds the dummy axle in place and allows you to lock the rotation of the dummy axle after it's been positioned in the correct orientation. The bottom of the vice has a small tab to help quickly align it with the plate underneath so their holes match to make fastening the thumbscrews underneath easier. Another great thing about this design is that you can swap out the dummy axle for another dummy axle to fit different sized hubs as long as the dummy axle fits snug within the vice.



V-notches and thumbscrew in the vice lock the dummy axle's rotation

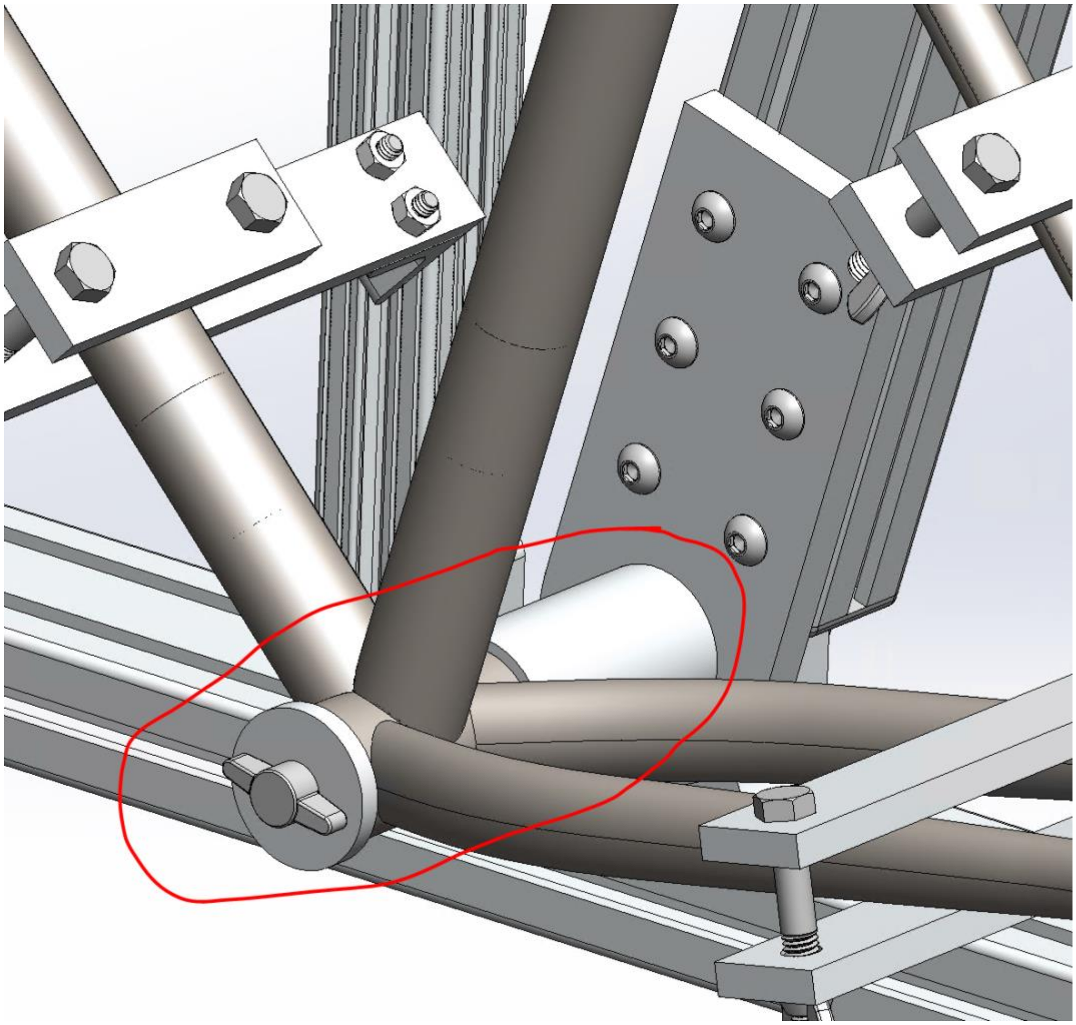
The location of the dummy axle holder can also be adjusting horizontally and vertically by untightening the corner brackets and surface brackets.



The circled extrusion can be translated horizontally and the dummy axle can be translated vertically along it

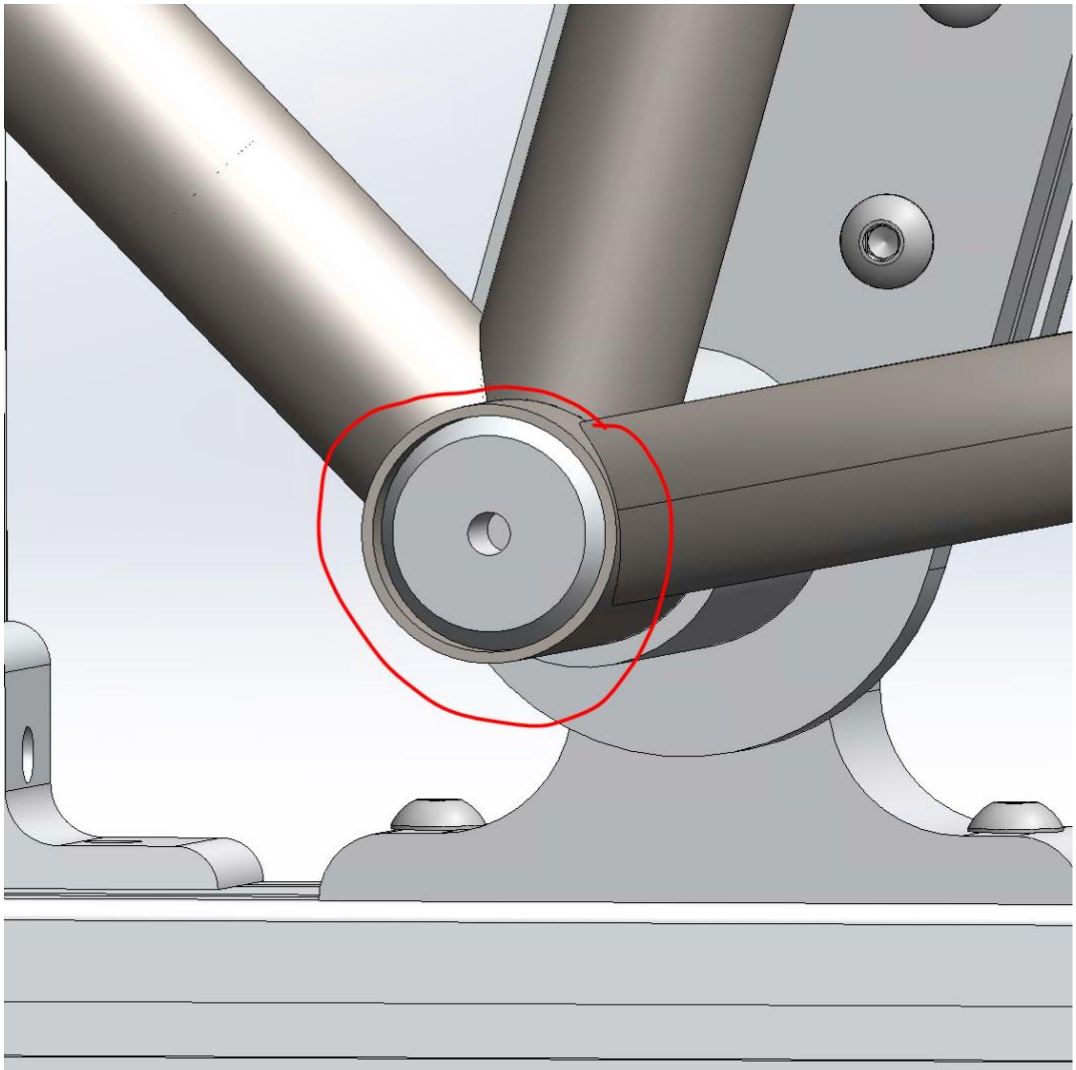
The Bottom Bracket Post

The bottom bracket post is used as the datum for figuring out the positions of the tubes on the jig so it is critical that it stays fixed as we make other adjustments. This means that the sliding pivot connected to the bottom bracket post is not meant to be moved (though it can be if necessary). Adjusting the seat tube angle will also not move the bottom bracket out of position because the post is concentric with the shoulder screw. The bottom bracket is then secured in place using a cap on the outside which is fastened using a thumbscrew.



Bottom bracket post is used as the datum for figuring out the positions of the rest of the frame tubes

The inside cylinder of the post matches the inside diameter of the bottom bracket shell. There is also a chamfer on the end of the post to make sliding the bottom bracket shell on a little easier.

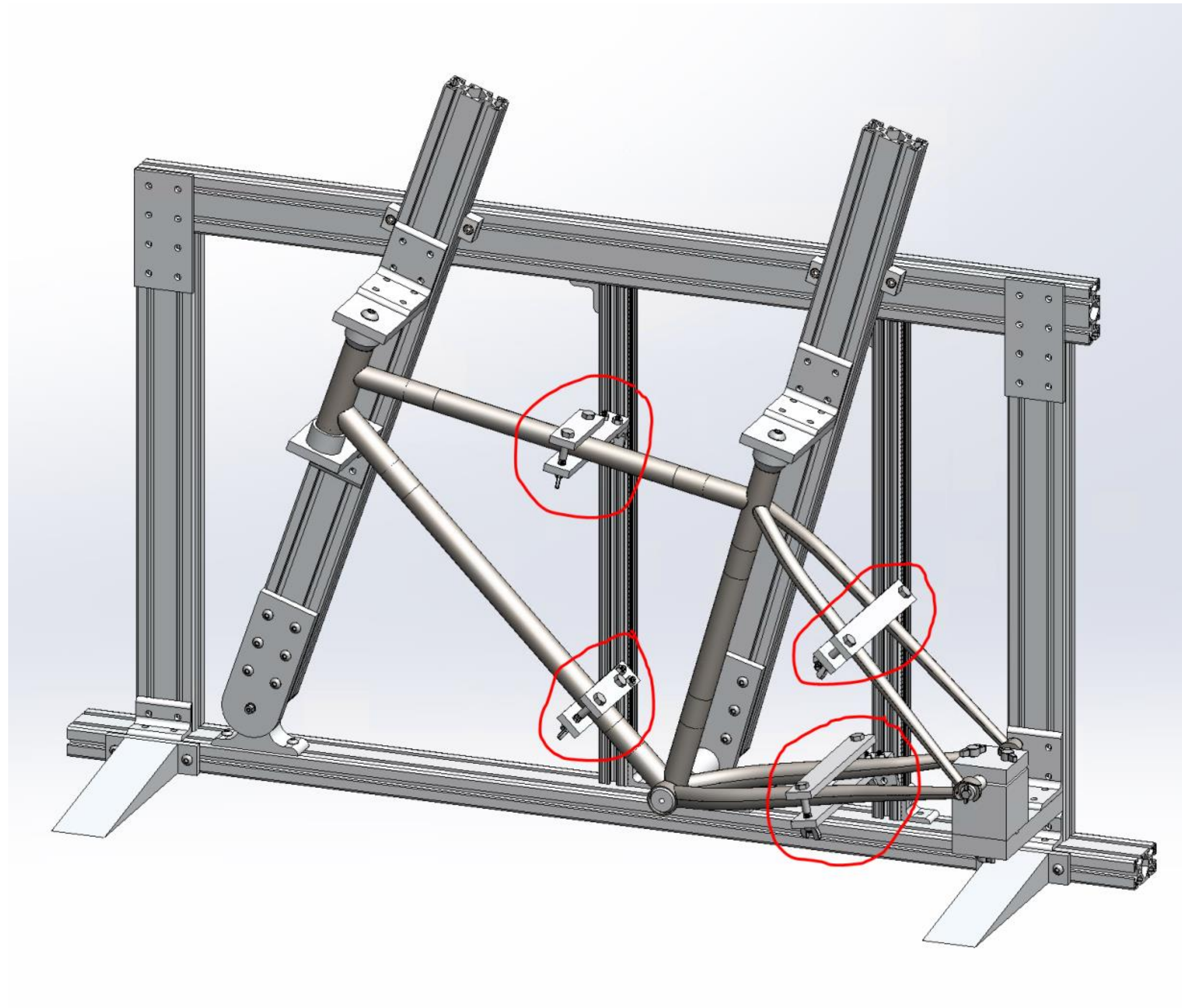


Bottom bracket shell is slid onto the bottom bracket post

A drawback to this design is that it will only work for 68 mm bottom brackets, any other length will not work for this jig. If we were to improve this design to make it more versatile, then one possible solution is to cut the outside diameter of the post down and add in precision spacers depending on the bottom bracket you use. This would be fairly easy to do since bottom brackets commonly come in three sizes: 68, 73, and 100 mm.

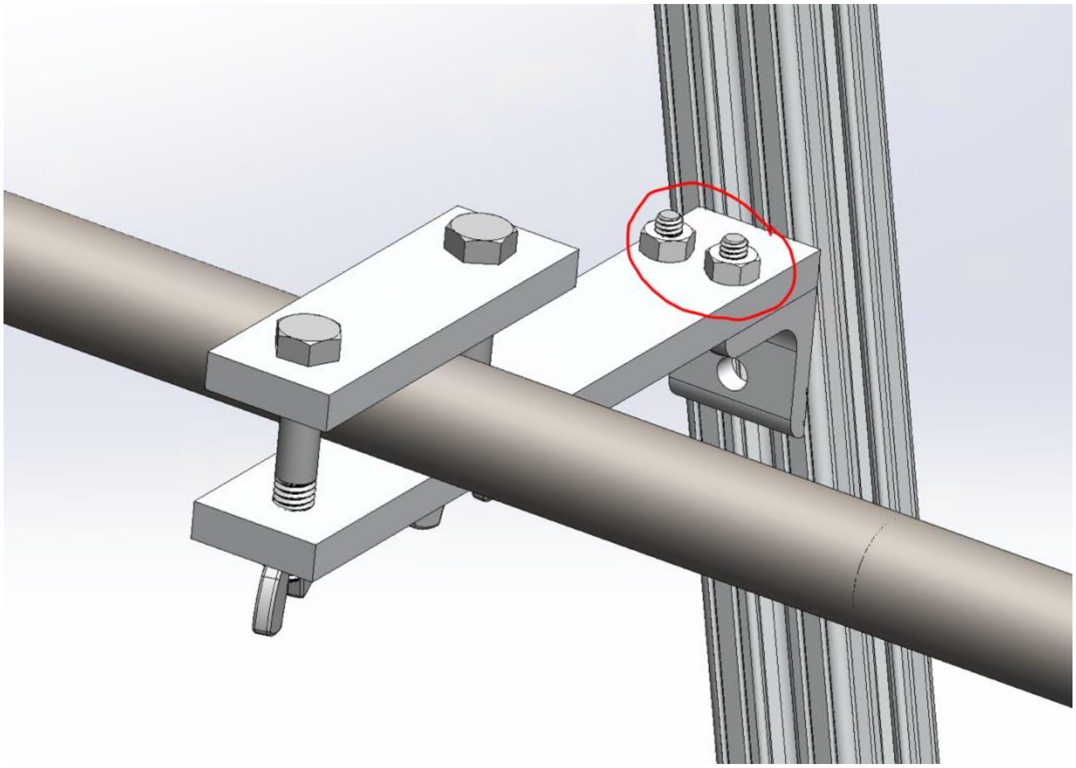
The Tube Clamps

To make sure that the tubes don't wiggle or fall out of place on the jig, we created clamps to secure them. As mentioned earlier, the single rail extrusions allow the tube clamps to be rotated so that they're tangential to whatever tubes need to be supported. The extrusions can also be translated horizontally so that the clamps grip onto a different region on the tubes. Once the bottom clamp is positioned tangent to the tube, the top clamp is fastened to the bottom clamp using a wing nut and bolt. This design will be able to hold any diameter tubes and angled in position. But something to be cautious of is to not tighten the clamps too much or you might dent your tubes. Adding rubber padding would be a possible improvement and would also provide more friction to prevent the tubes from sliding.



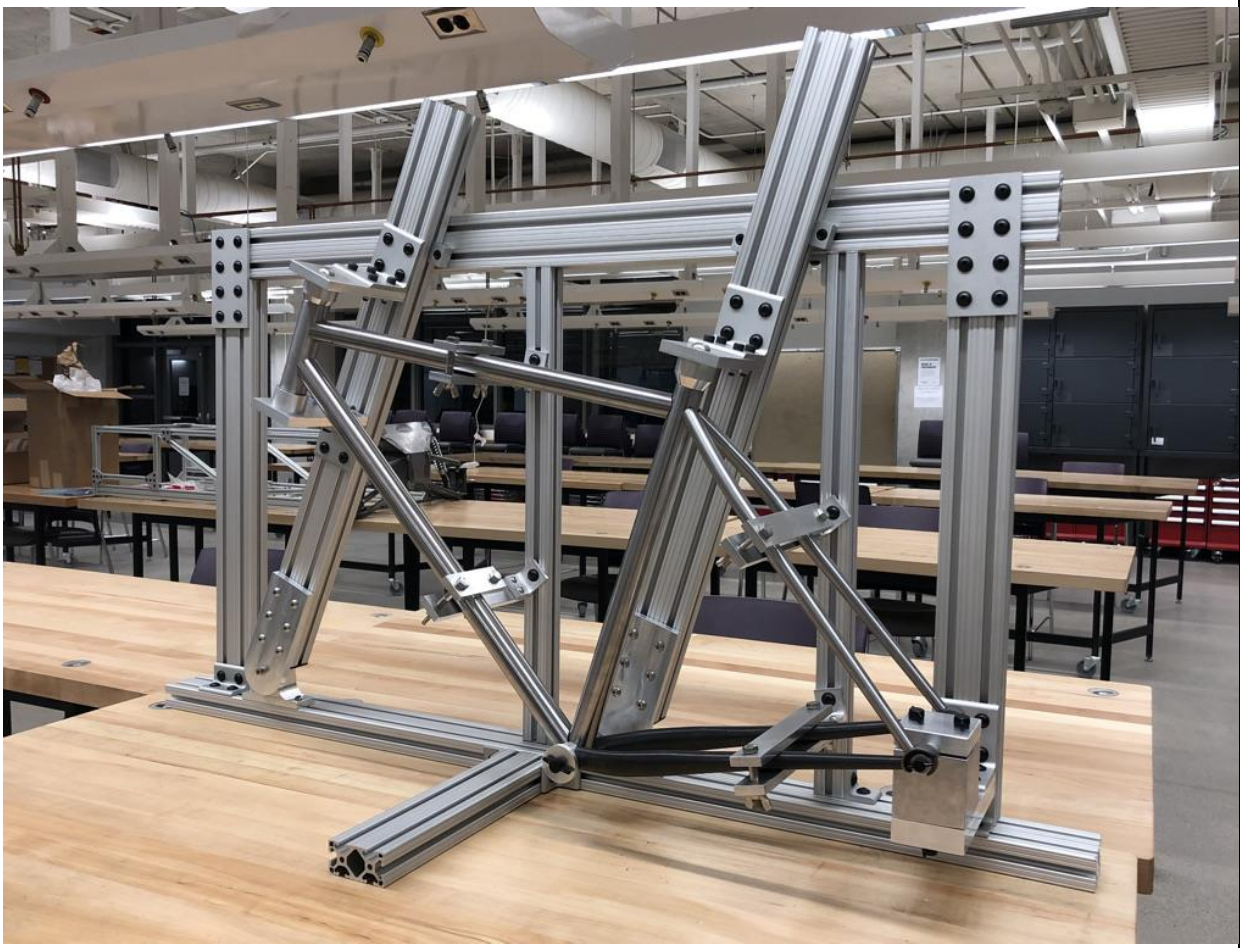
Tube clamps secures the top and down tube; and seat and chain stays

You may have also noticed that the end of the bottom clamps are fastened to a corner bracket with two holes on the mating face. This is simply to prevent the bottom clamp from twisting so it stays in position relative to the corner bracket.

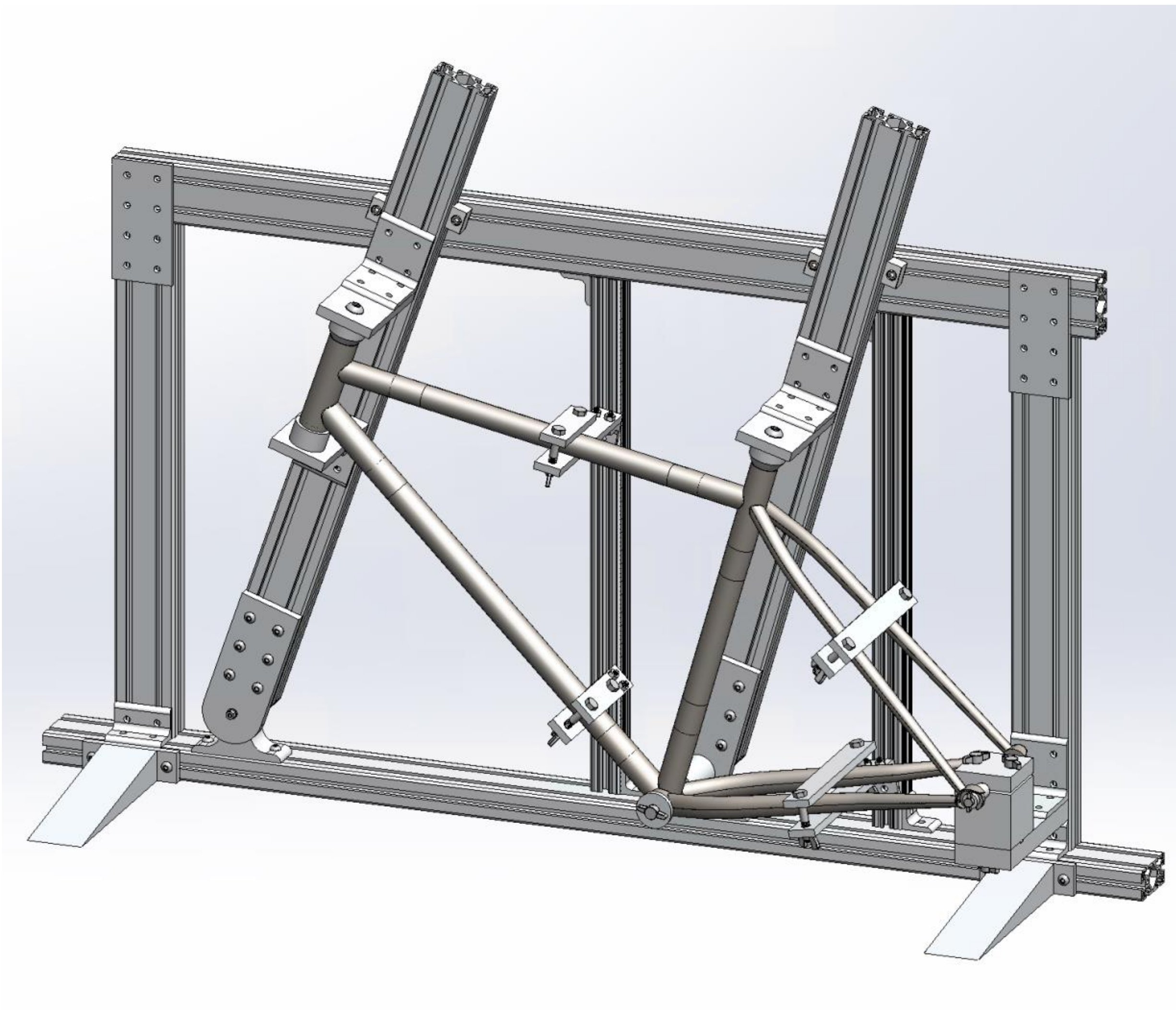


Bottom clamps are fastened to a corner bracket with two holes to prevent twisting

Different Views of the Assembled Jig and the Digital Twin

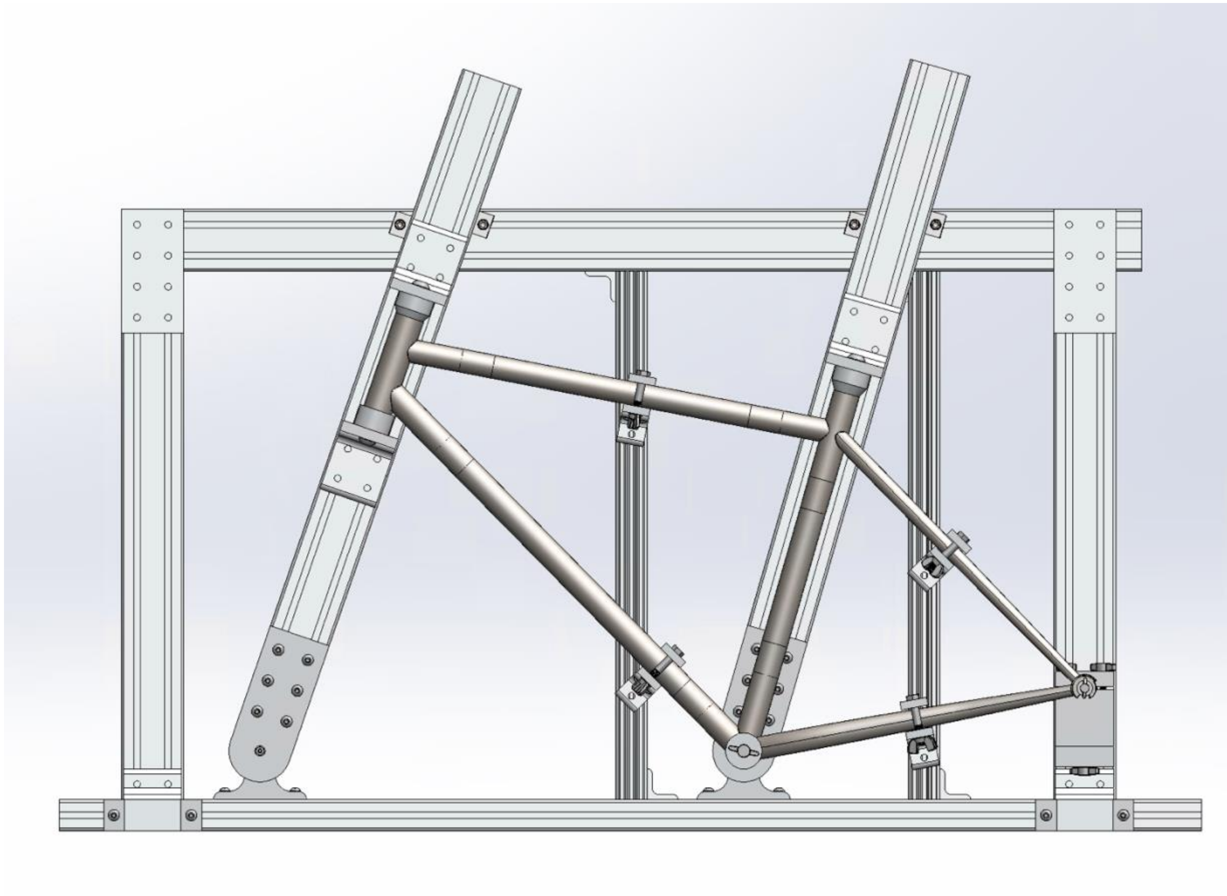


Dimetric view of the fully manufactured jig



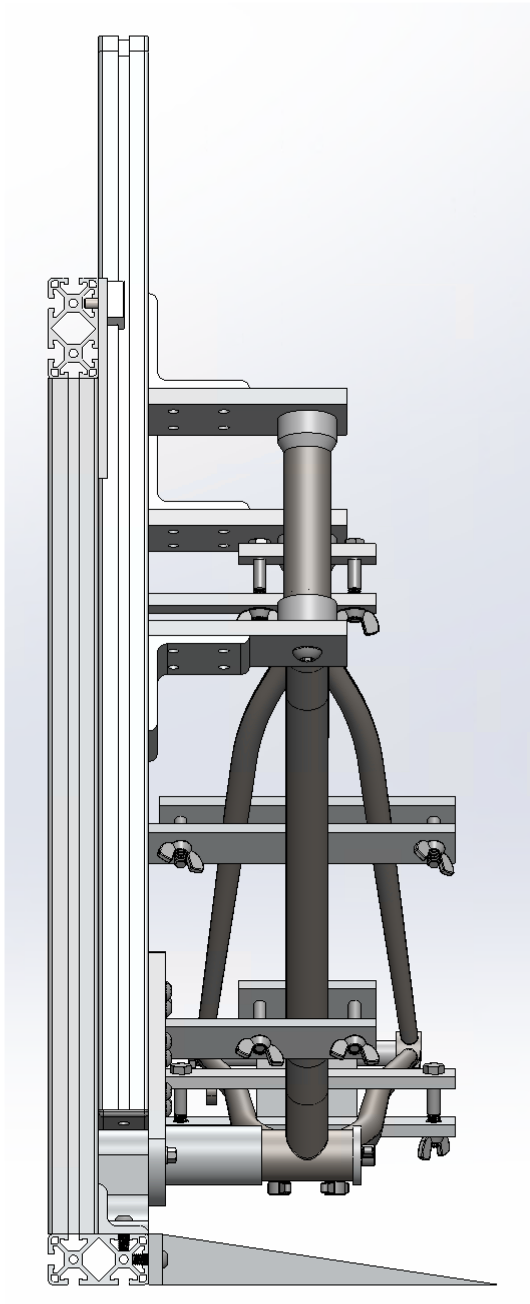
Dimetric view of the jig digital twin

Front view of the fully manufactured jig

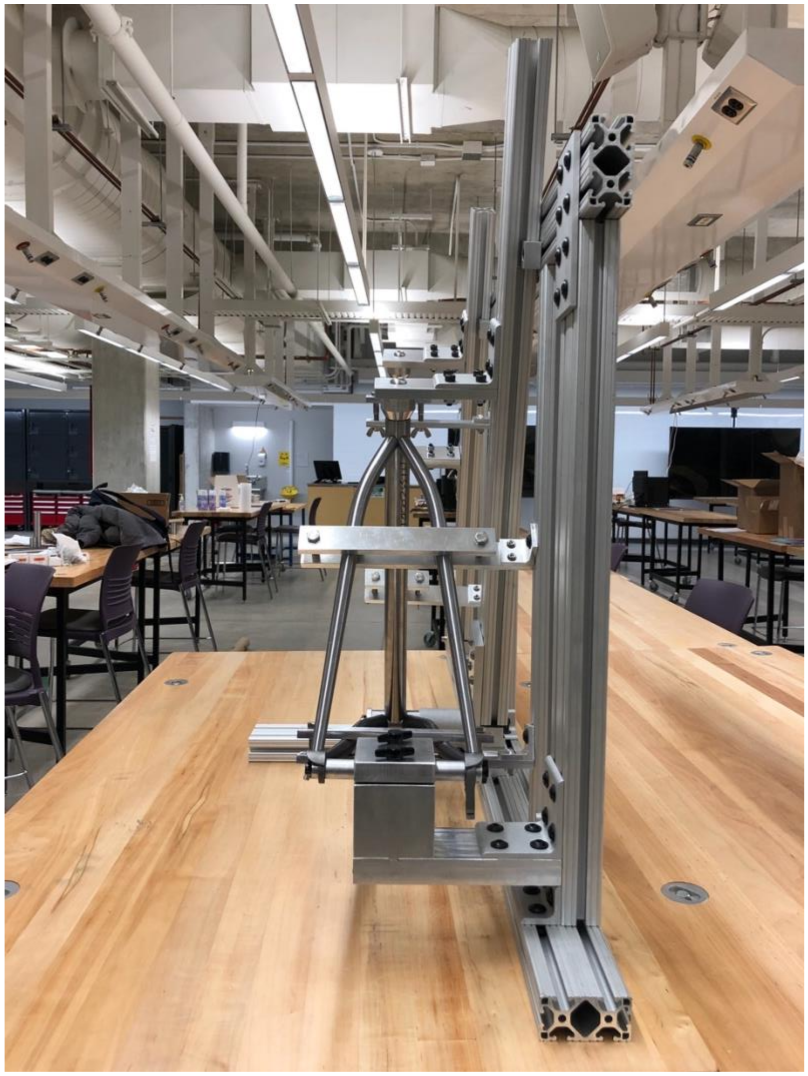


Front view of the jig digital twin

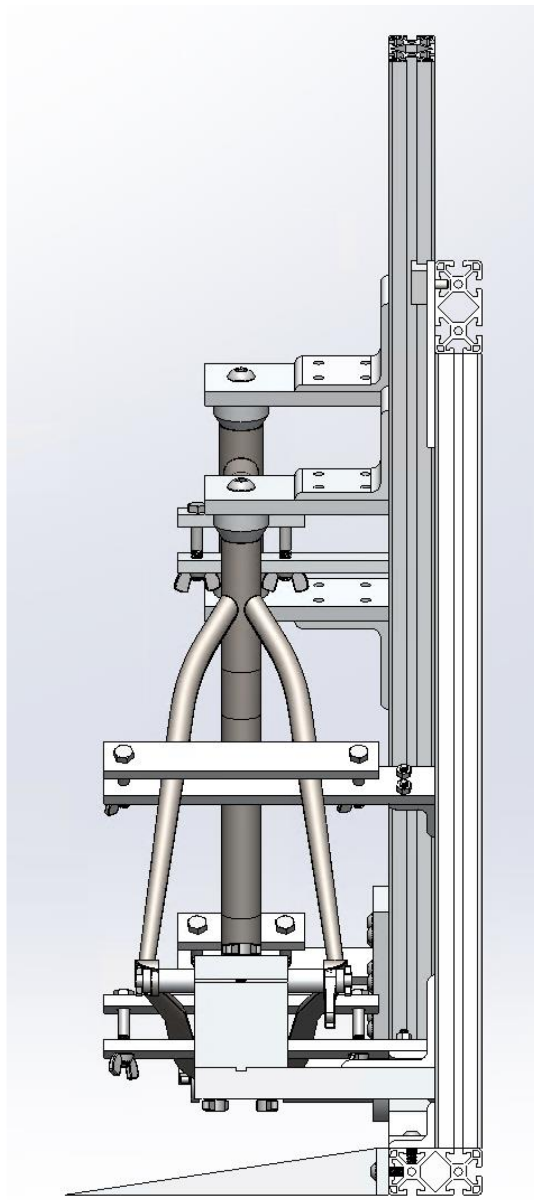
Left view of the fully manufactured jig



Left view of the jig digital twin

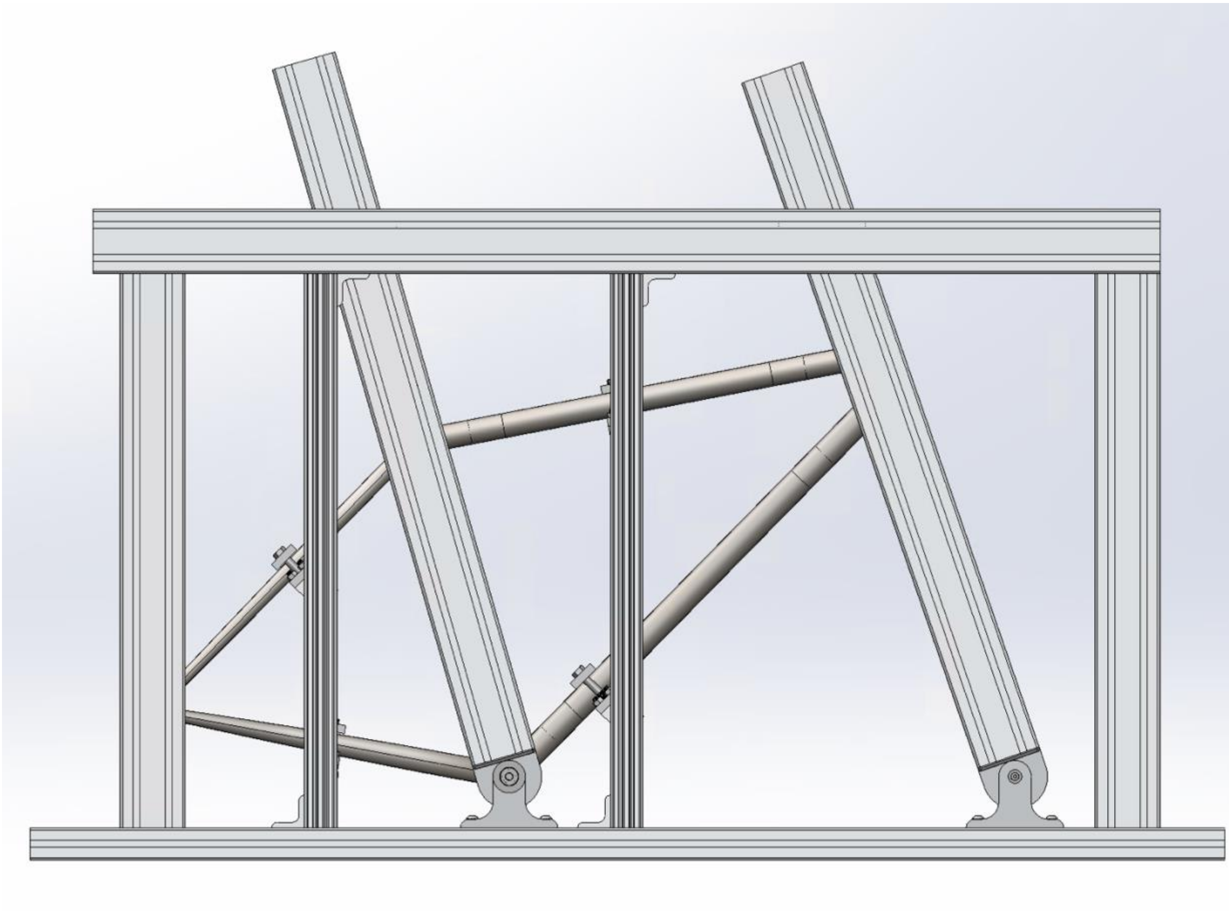


Right view of the fully manufactured jig



Right view of the jig digital twin

Back view of the fully manufactured jig



Back view of the jig digital twin

References

[1] drwelby, *The Simplest Bicycle Framebuilding Jig I Could Come Up With...* [Online]. Available: https://www.instructables.com/The-simplest-bicycle-framebuilding-jig-I-could-com/. [Accessed: 13-Dec-2020]