BPS.space R2-74mm TVC Mount Instructions

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1. Introduction

This document will walk through how to set up your thrust vector control(TVC) motor mount. These files are meant to be printed in plastic for use in low to mid power model rockets. The design has been flight-proven over several years and is used in most BPS.space rockets. The mount is built to be used with 29mm rocket motors. With proper print settings, it can sustain at least 40 Newtons of axial force, though you should target no more than 5-20 Newtons of constant thrust on average. The mount is designed to be used inside 74mm thin walled airframes like these.

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The last part here is safety! Model rockets are a lot of fun, but if you're not careful they can also cause harm to you or others. If you don't have experience launching rockets with thrust vector control, I recommend extensively testing your setup on the ground before attempting any untethered flight. Always check with your local and federal rocketry regulations beforehand to ensure your flights are legal and safe.

2. What You'll Need

You'll need a few extra items to make this TVC mount work. Here are a few links, but most of these items can be purchased on several different websites.

1. Two 9 gram servos, one for each axis of control. There are 10 here, I usually buy in bulk, if you anticipate a few wobbly flights it'll be good to have extras.
2. Four M3.5 x 6mm screws, Four M3.5 x 12mm screws, and Four M2 x 10mm screws also bought in bulk
3. About 10cm of 1.2mm pushrod
4. One 1.3mm Linkage Stopper
5. Servo Extension Cables Having several different lengths is helpful depending on the size of the rocket you build
6. A bit of 29mm motor mount tube. This acts as a liner to insulate the plastic from the heat of the rocket motor. I like these tubes.

3. 3D Printing Settings

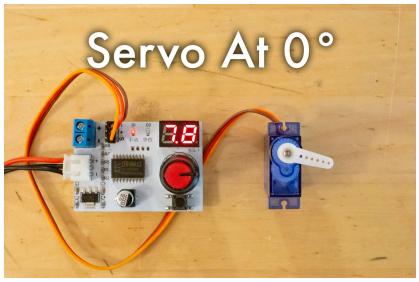
You'll want to print these files with some decent infill and outer layers. I print in PLA because the fumes are pretty harmless compared to other filaments, but you can use whatever you'd like. Feel free to experiment here, but these settings are known to work well.

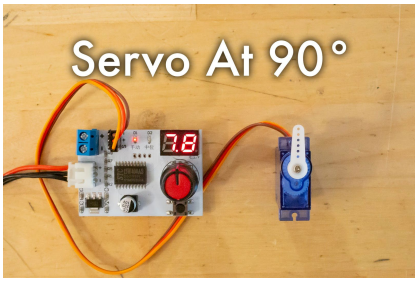
- 25% infill
- 3 shell layers
- 0.2mm layer height
- 30% density support material
- Heated Bed at 65C and extruder at 200C
- Extruder fan turns on after layer 1
    - Super helpful for the top of the inner gimbal part
- Print speed no faster than 100mm/s
- Print perimeters at 80% speed

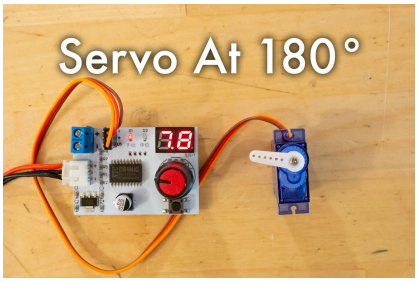
Depending on your 3D printer, your mileage may vary - if you're having trouble, check out this page: https://www.simplify3d.com/support/print-quality-troubleshooting/

4. Servo Alignment

Most 9 gram servos don't come with their servo horns(the plastic hole-y parts) attached. We need to get the one-sided horn attached so it's pointing straight up when the servo is at 90 degrees. To do this, plug in the servo to a microcontroller or servo test board, set the servo to hold its position at 90 degrees, and attach the servo horn like the photos below.

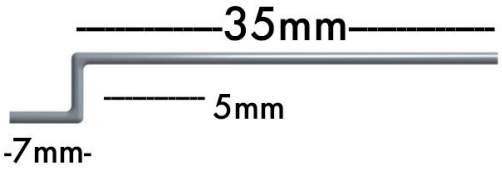


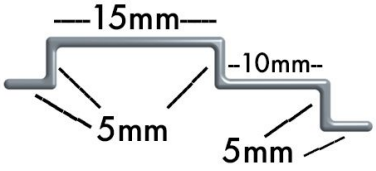




5. TVC Pushrod Bending

The pushrods used to connect the TVC servos to the actuation points on the 3d printed parts need to be bent slightly. In order to do this, you might want to use a Z bend tool like this. A few needle-nose pliers can also work. Here are the measurements of the two rods in their final bent formation. It's okay if the rods are a few mm off, but try to keep this as close as possible.

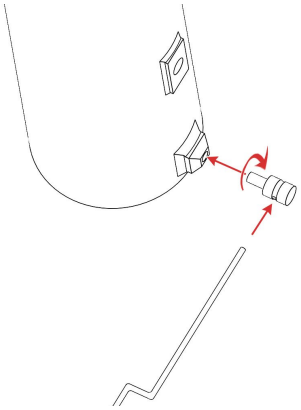




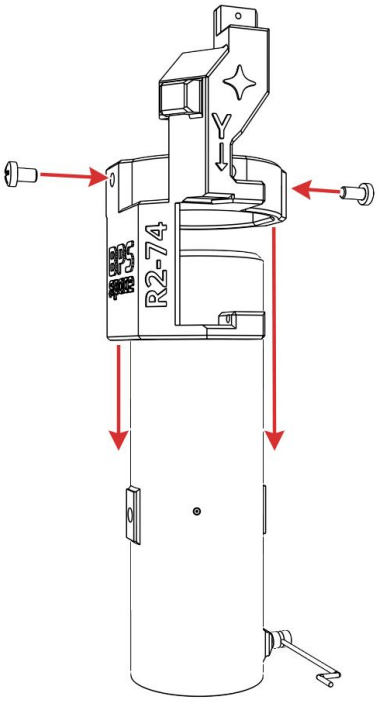
6. TVC mount assembly

[You can use this video to help during assembly!]

6a. Motor mount



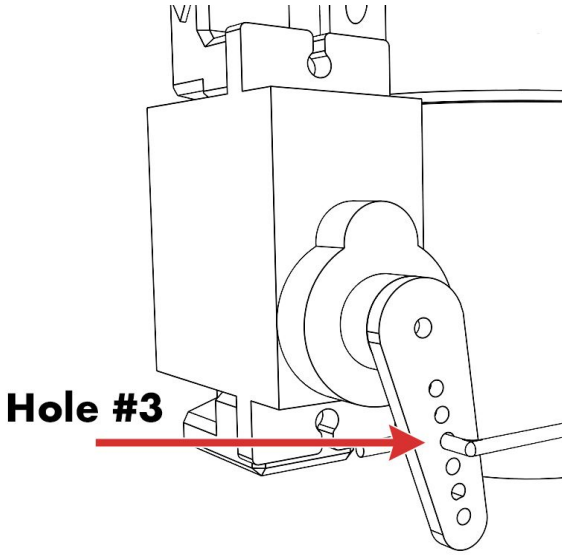
1. Screw the linkage stopper into the motor mount. It should be quite snug, completely screwed in, and somewhat hard to turn with just your fingers.
    a. You can insert the straighter pushrod here too, don't worry about tightening the linkage stopper to lock in the pushrod yet, we'll take care of that later.
2. Cut a small (10cm or so) length of 29mm cardboard motor mount tube to use as a liner for your motors. Wrap it several times in tape(masking tape works well) until it fits snug inside the 3d printed motor mount.
3. If you have one, insert a spent 29mm motor into the mount. The 3d printed motor sleeve flexes quite a bit without it, but can hold its structure well once a motor is inserted.



6b. Inner gimbal

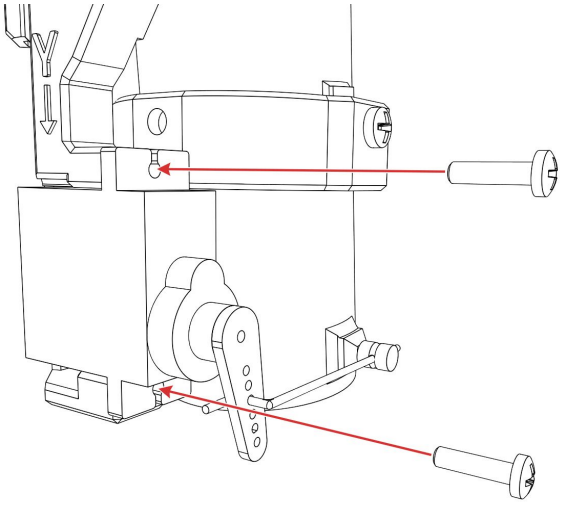
Next, let's attach the inner gimbal to the motor mount.

1. Remove any pieces of 3d printed support material.
2. Slide the inner gimbal over the motor tube. Make sure the star on the inner gimbal faces the same direction that the pushrod points.
3. Screw into place using two of the M3.5 x 6mm screws. It should be a tight fit.



4. Grab one of the 9g servos. Count 3 holes from the attachment point of the servo horn, and insert the bent end of pushrod.

5. Attach the servo to the inner gimbal using two of the M2 screws. The servo horn should be pointing down, away from the center of the TVC mount, along with cable coming out of the servo housing. It should be slightly hard to screw in, but the screws will hold the servo very tightly in place during flight.



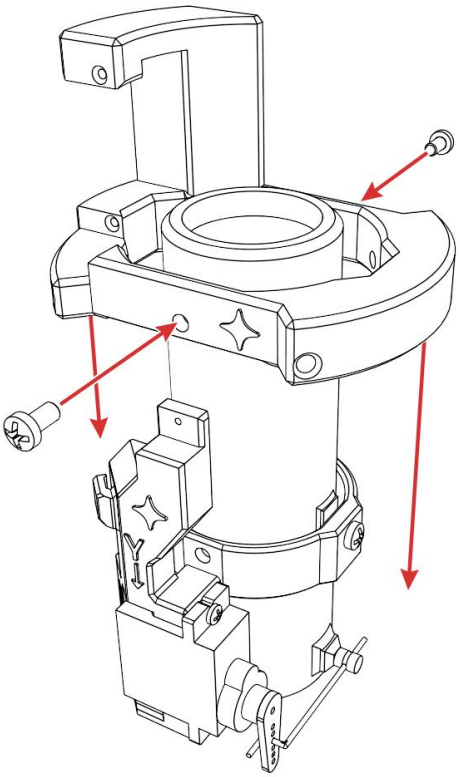
6. Depending on your 9g servo, you may need to change which hole is used. If the 3rd hole is not directly aligned with the actuation point on the motor mount, your TVC gear ratio won't be exactly 6:1 as it should be with this mount.
7. Finally, use a 1.5mm hex wrench to unscrew the linkage stopper a bit. Align the servo horn to its center position (pointing straight down), move the motor mount to its center, so that it's parallel with the servo, and tighten the linkage stopper. The mount doesn't need to be exactly centered, but try to get things pretty well-aligned. Make sure it's very tight, we don't want this coming loose!

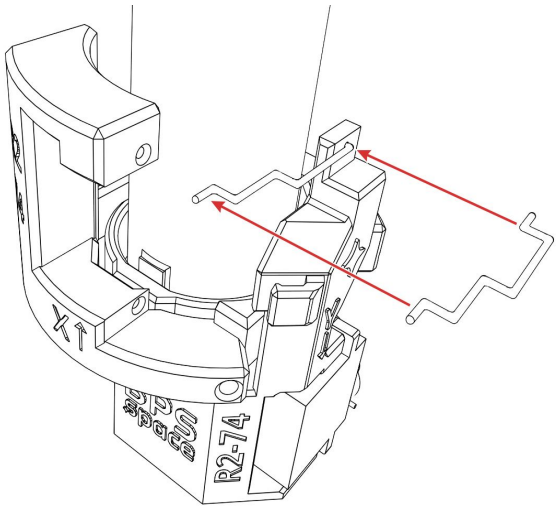
6c. Outer gimbal

This is the last major piece of the TVC mount!

1. Just like before, remove any pieces of support material.

2. Make sure the stars are aligned, facing forward, and slide the outer gimbal into place. The outer gimbal should snap into place, since it's another slightly tight fit. Screw the outer gimbal into the inner gimbal with two M3.5 x 6mm screws.

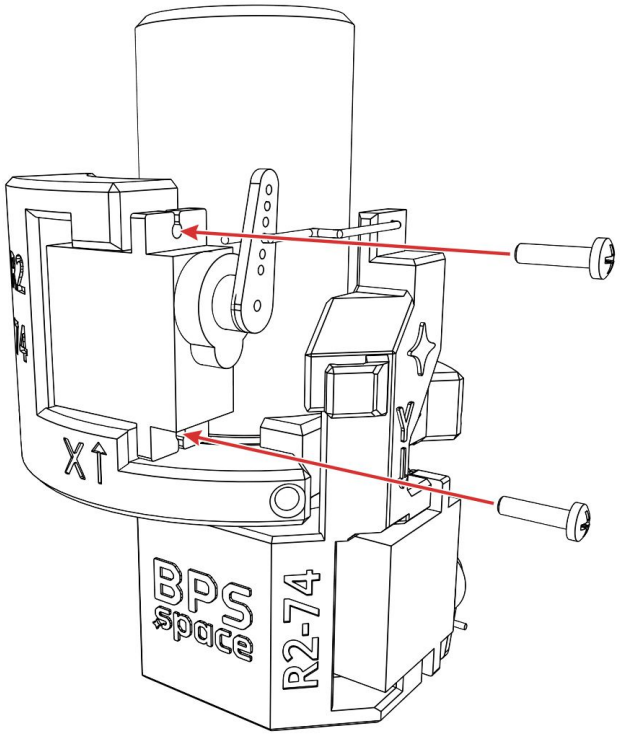




3. Grab the more bent pushrod, and insert it into the very top hole of the inner gimbal. This is tricky to do, and may require some force or pliers. Be careful not to damage the inner gimbal stem in the process.

4. Count 3 holes from the attachment point of the servo horn, and insert the other side of the pushrod. The servo and inner gimbal should now be attached.

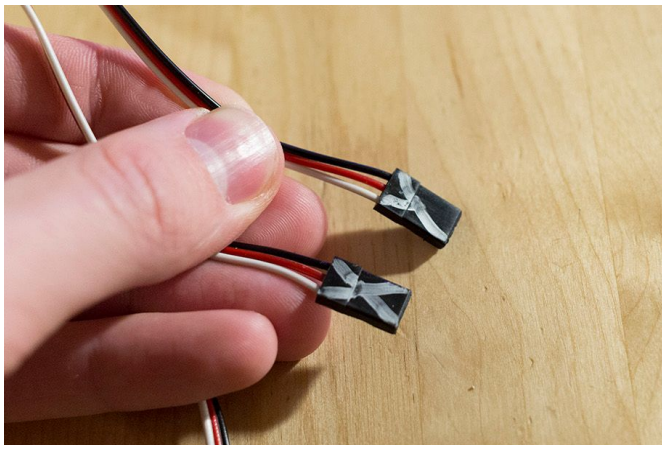
5. Use the two M2 screws to attach the servo to the outer gimbal, this time with the cable and servo horn pointing up. Make sure the servo cable is threaded in toward the motor mount, not away from it. If this isn't done correctly, the cable may interfere with the rocket's airframe during integration. This should be a tight fit - the bottom screw (closest to the center of the TVC mount) may be a little hard to get into place.



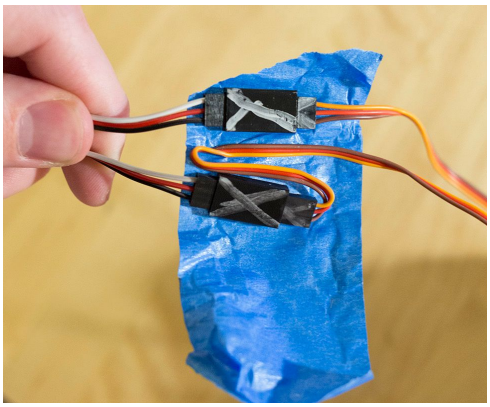
6d. TVC extension cabling

The TVC mount is almost finished! To complete the build, we'll need to take care of some wiring.

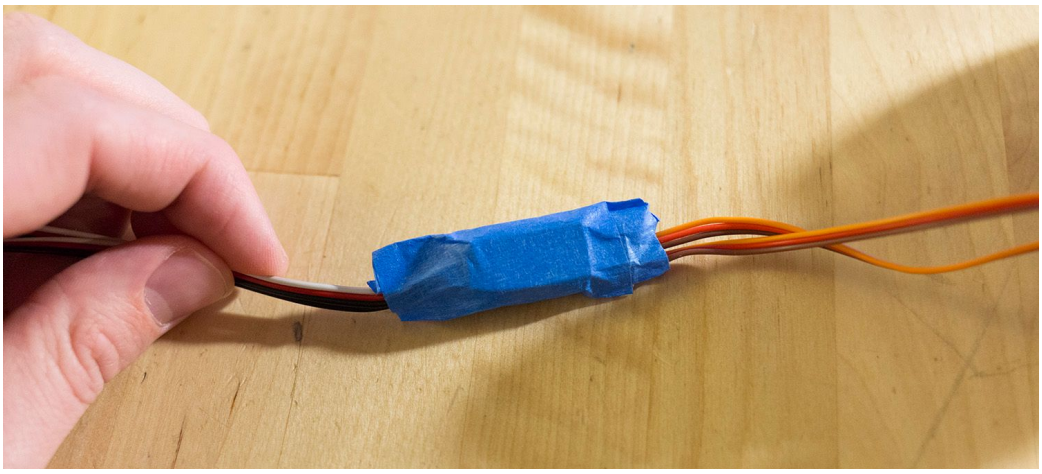
1. Thread the TVC Y servo (labeled on the mount) cable up in between the X servo pushrod and the motor sleeve.
2. Use a marker directly on the black plastic headers of the servos, and label them appropriately according to their markers on the TVC mount. With the mount standing upright, Y should be the bottom servo, X should be the top.



3. Do the same for the TVC extension cables - label one X on both ends, and the other Y. It's worth being thorough on this, rockets are all about precision.
4. Connect the TVC extension cables to their respective servos, and make sure they are connected tight! The two cable colors should correspond. Orange to white, red to red, and black to black.



5. Fold the TVC X servo cable around the extension cable/servo cable joint, and wrap a good deal of masking tape around the assembly. With the tape wrapped around the wire joint, both cables should have little or no slack when pulled by their extensions.
6. If you were to stretch out the TVC extension cables, they should now be equal length at the end, since the slack in the X cable was wrapped in tape. This is important, slack in the X cable could result in a TVC jam.



7. Using the drill/cut guides

These files come with drill and cut guides for the thrust vectoring mount. These guides will be wrapped around the airframe of your rocket to ensure you place the holes and cutouts in the correct place. They can be printed on a regular 8.5x11 inch US letter paper, just make sure they're printed at 100% scaling, otherwise you'll put your cuts in the wrong places. Slight clipping may occur on some printers. If you need visual assistance, you can follow along with this video.

You'll want to start out with a brand new body tube for this to work well, though a painted one can work too.

1. Wrap the TVC cutout guide around the airframe, pulling it tight. Ensure that "Line 1" can be seen through directly beneath the three tics by the number 4. This is to simply make sure you're using the correct guide on the correct airframe.
    a. I recommend lining up the bottom edge of the paper labeled "dirt" with the bottom of your airframe for most ~10 cm long motors. You can move it up or down slightly depending on the length of the motor you use. For instance, the Aerotech G8 motor is 15 cm long, and requires about 5cm more clearance if you don't want it to stick out from the bottom of the rocket. It's helpful to hold the loaded thrust vectoring mount up next to TVC guide on the airframe to get an idea of where things will sit once you make the cuts.
2. Carefully hold the paper against the airframe and unwrap it enough to apply tape on the edge indicated, "Tape to vehicle here".
3. Once again, wrap the guide around the airframe, this time taping down the other edge of the paper, so the rocket remains covered when you let go.
4. Apply small pieces of tape on the top and bottom of the TVC guide to help secure it a bit more.
5. Make your drills first - these are all for the M3.5 screws. Drill directly in the center of each red dot, through the airframe. If you're using a cardboard or a somewhat flexible airframe, I recommend drilling holes at 2.5 or 3mm, so that the hole taps itself when the screw is inserted. Otherwise, do not drill larger than 3.5 mm.
6. Cut on the red lines with a sharp hobby knife.
    a. On the guide, red lines outline the minimum required cut out area, mostly for the TVC servos and pushrods.
7. That's it! Your rocket is now ready to house the TVC motor mount!

8. What next?

These files will solve most of the mechanical challenges surrounding TVC in model rockets. However, you'll still need a flight computer to control these servos! That's where nearly all of the complexity lies. If you'd like to get started building a computer, consider checking out the Blip PCB that BPS.space is building as part of the Landing Model Rockets video series. The files and part lists to build Blip are not yet available for direct purchase, but you can get access to them right now through the BPS.space Patreon page.

As the series progresses, we'll write up some basic flight software to use with thrust vector control mounts like these. As it's still in its early stages, the series hasn't covered that far yet. That said, if you're writing your own flight software, here are a few things to note!

- The gear ratio of this TVC mount is 6:1. This means that every time either servo moves 6 degrees, the motor mount will move 1 degree. This breaks down a bit after 3 degrees or so, but has not been problematic in flights so far - most flights don't need more than ±3 degrees of gimbal range.
- Speaking of which, the maximum range for each axis is 10 degrees. Wherever the center point of the mount is, it can actuate ±5 degrees from that point. I strongly recommend setting hard limits in your flight software so you don't drive the servos further than they can actually move.
- In order to calibrate a center point on the TVC mount, just add or subtract a few degrees from 90 on each axis until things look lined up. Inevitably, there will be some misalignment between different TVC mounts, so using a flexible variable for your centerpoint in the flight software is important.
- You are welcome to cover up the TVC servos with your own 3d printed or handmade parts! So long as you are careful not to restrict any of their motion, placing objects or covers over them is just fine.
- You can paint the TVC mount too - if you're painting your rocket and want to disguise your the TVC cutouts, you can paint the rocket while the TVC mount is inside. The paint will have little or no effect on its ability to gimbal the motor.
- If you need help troubleshooting your TVC mount or have questions, the BPS.space Discord is filled with folks working on similar projects. I'm unable to respond to every email right now, so you'll get a more reliable response there. There's no requirement to join, but that can be accessed through the BPS.space Patreon page.

Troubleshooting

Problems	Causes/solutions
One of the TVC servos seems to move slowly when used in the mount.	● You may have a faulty or damaged servo ● The TVC mount may be jammed - check for loose debris or wiring near the joints
The TVC mount seems to move slowly, the joints between parts do not move without considerable force	● The TVC mount may be jammed, see above ● The TVC mount may not be worn in, use a drill or screwdriver to over-tighten the M3.5 x 6mm screws by a few turns to loosen it up
The TVC mount has a lot of 'play' - it's able to wiggle back and forth in one or both axis while not moving the servos. A small amount of this will always be present, but 1.5+ degrees will start to affect the quality of flights	● The TVC actuation points(screw holes) are too loose ● Long term solutions ○ Print out a new TVC mount - the mount points will wear down after extensive use ● Short term solutions ○ Coat the M3.5 screws in a layer of epoxy, CA, or another strong type of glue to make them larger. Wait for the glue to fully dry, and replace them in the mount. ○ Wrap a piece of paper around the screws as they enter the screw holes, for the same effect as the glue.

User Requirements

The following constitute the guidelines that you agree to follow when using these designs and files. The BPS.space TVC mount is referred to here as "The Product". **If you do not follow these, you void any associated guarantees or warranties, and neither Joe Barnard nor BPS.space have any liability.**

- I will use and fly The Product only during high visibility conditions
- I will not use or fly The Product under the influence of drugs or alcohol
- I will alert all persons in the general vicinity of the rocket and The Product before I launch
- I will ensure an audible countdown to ignition is conducted from at least 5 seconds
- I will never use or launch The Product in the direction of people, property, or anything other than open space
- I will never launch The Product with the intent to harm
- I will only launch The Product in accordance with FAR 101 by the FAA, the NAR's MRSC, and the Tripoli Safety Code.