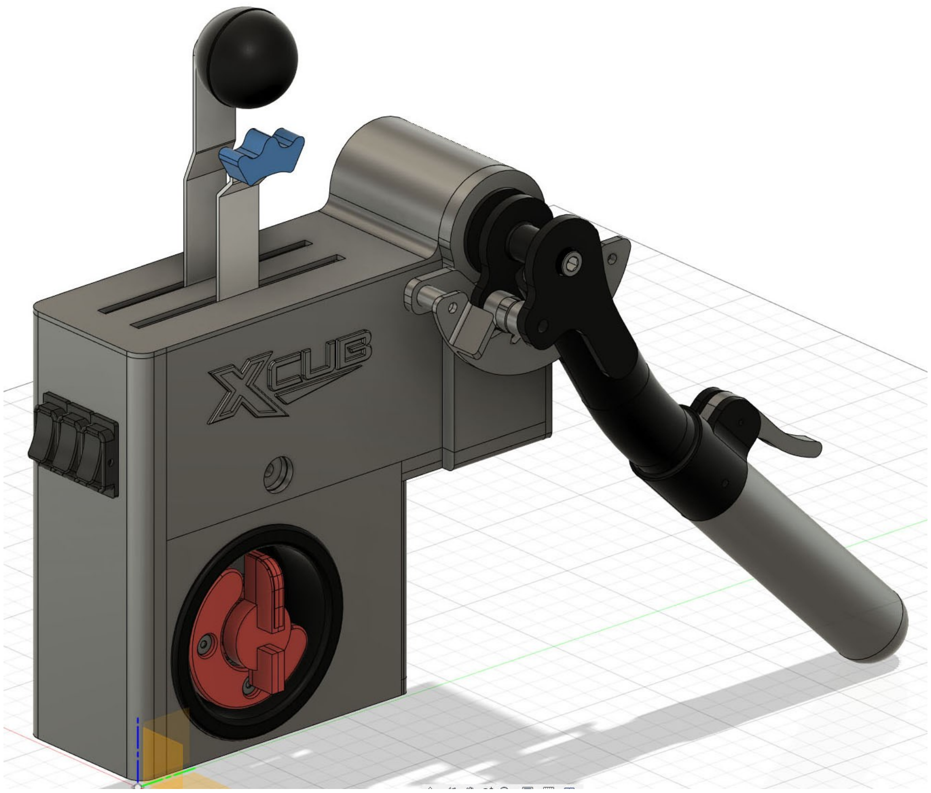
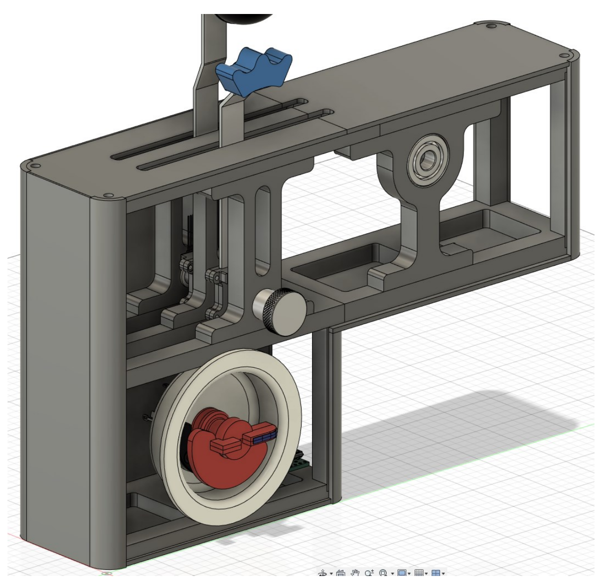
The CarbonSpark XCub Throrttle Unit



The purpose of this document is to share with you my experiences with designing and building my first 3D printed Home Cockpit assembly. What it is not intended to be is a how to guide for printing and assembling this controller. Everyone will have different experiences with 3D printing, engineering, and electronics. This was a project I did for educational purposes, and quite honestly, I didn't even know if it was going to work when it was done. To my amazement it did work and on the first try. Now there are some of you who may like to try making one yourself. Let me share my experiences with you on this endeavor.

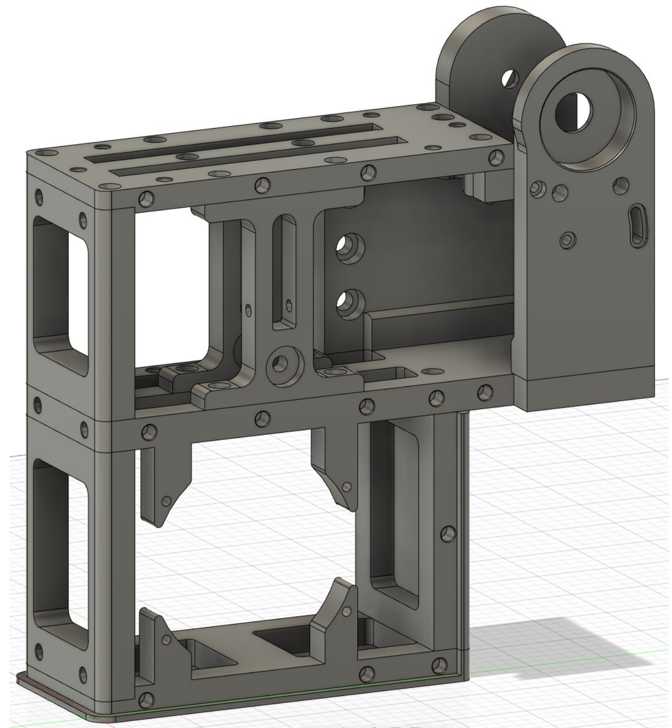
1. The Design of the Unit.



Going into the project I had an idea of what I wanted in an aircraft dedicated unit. I just didn't know how to execute my idea. I only had one limiting factor, it had to look like it was lifted out of an Xcub. At the time I had quite a bit of experience working with Autodesk Fusion 360 so I knew what I was designing the unit with. I took notes on what size I wanted it to be in relation to my desk and seating position so I settled on some rough dimensions and got to work.

Let's just say the first draft of the unit was much larger than the final.

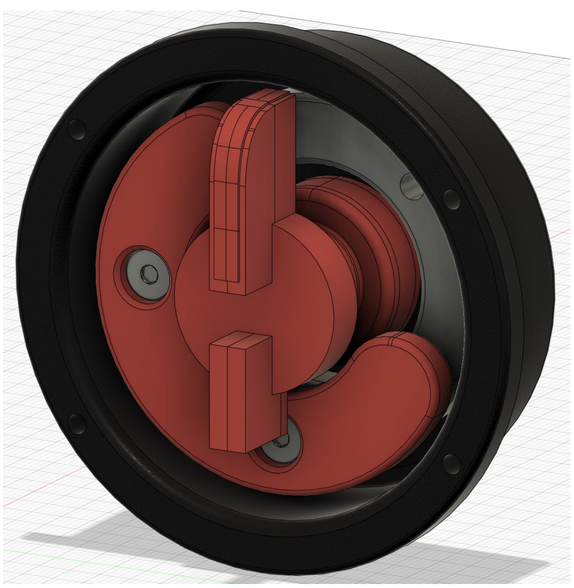
After about a few weeks into the design (I do this in my spare time), I knew that at it's size the initial unit was going to be too big to print efficiently. So I went back to the drawing board and came up with a new design. The new design was a lot smaller and more feasible to print at home.



The frame of the unit is just that, the backbone of the design. Everything attaches to the frame at some point. The hardest part of the frame was figuring out how it was going to be assembled. I found this answer in the form of Heat Set Inserts, more on this later.

The new frame was a three week endeavor.

Once the frame was designed I started adding the parts that I would use to control the aircraft with. The first part designed was the fuel selector switch. And it is the only part on the unit that was from the original design.



As with the flap lever, the fuel switch got its start from a publication at Cubcrafters. There was a service bulletin that showed the components of the fuel system and I used the drawings to reference the final design. The actual knob used was lifted from the MSFS XCub model using Blender and then heavily edited for scale and printability.

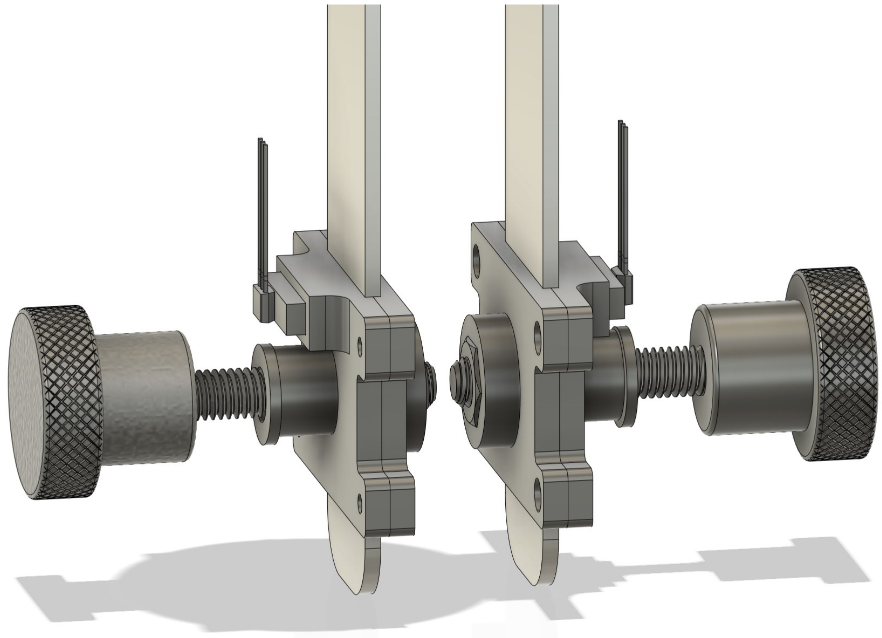
The Guard is spring loaded and a pain in the butt to operate. The fuel selector switch will not move past the guard unless you press with one hand on the two holes for the shoulder bolts to disengage the guard and rotate the switch with the other hand to cut-off. It was designed this way. If you want to shut off the fuel you have to work for it.

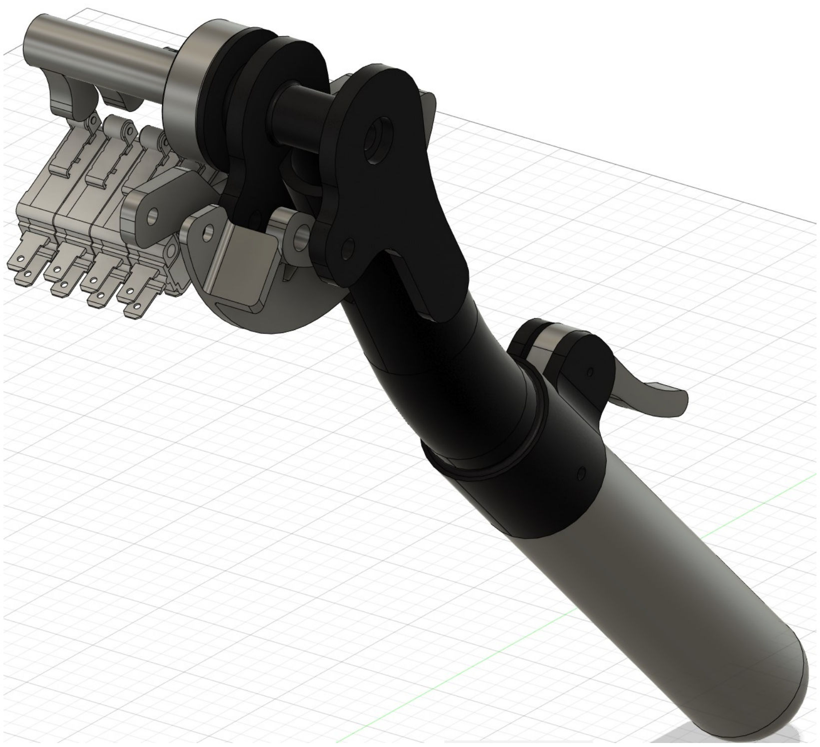
Once the Fuel Selector was completed I moved onto the Throttle and Prop Levers. In my initial plan on the unit, I knew from the start that I did not want these two axis on a potentiometer. The decision was base on a couple of factors. One: size of the unit. Since it was going to be very compact in size, the only way to transfer the axial rotation to a potentiometer was with gearing. Gear driven units are good but there can be backlash in the gears if they are not manufactured properly. Second: I wanted to try and use hall effect sensors for the throttles on this unit. I have a couple of flight sim controllers that use them and love the smooth response from them. So I went to work.

The throttle and prop axis bars are sandwiched between two 3D printed plates. The plates are held together with M2 screws. A M5 hole allows for the knurled knob to be used as axle for the lever. To reduce friction between the plates and the Left/Right Throttle Frames, a lubricant filled nylon washer is used. I also used them to space the knobs away from the frames as well.

The 1/8" square by 1/2" neodymium magnets that drive the hall effect sensors are epoxied into place on the plates.

The Throttle and Prop Knobs also found their origins from the MSFS Xcub model.





I was now onto what has been the most complicated part of the design: The Flap Arm. The Flap Arm is designed as a replica to the actual Xcub flap arm, just a lot smaller. It also works almost exactly as the flap arm would in the actual plane. The inspiration on this design came from the parts diagram from the Cubcrafter EX-3 Kit plane. I figured out how the system worked by studying the drawings and a couple of Youtube videos.

The arm I designed is way over engineered for what its doing, but here is how it works.

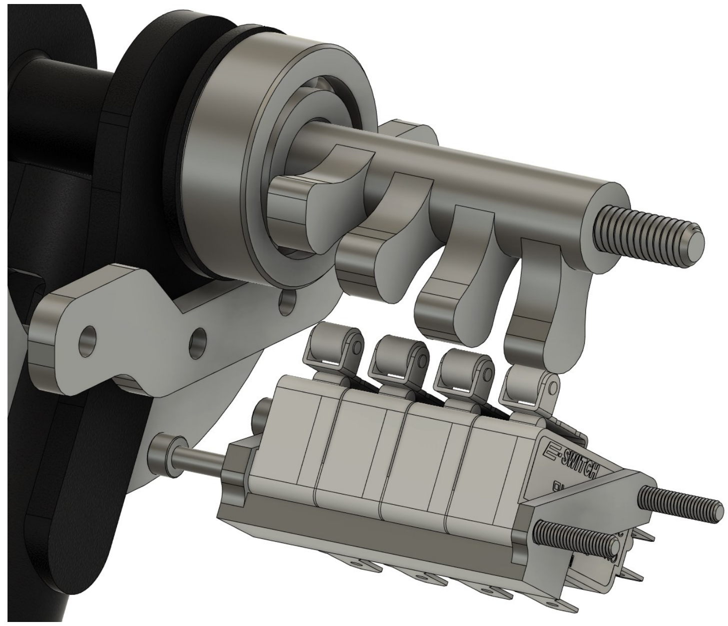
Inside the arm are two printed parts, the Upper Push Rod Guide at the top and the Spring Plate at the bottom near the trigger. Also inside the arm is a 5mm aluminum rod called a push rod. One end of this rod rests against the trigger. This side has a 17mm compression spring with a 2.8lb load rating. The spring is held in place between the trigger and the spring plate. On each end of the spring is a 5mm oversized washer to keep the spring centered on the rod and prevent binding. The spring and washers are kept from falling off using the 5mm push on retaining ring.

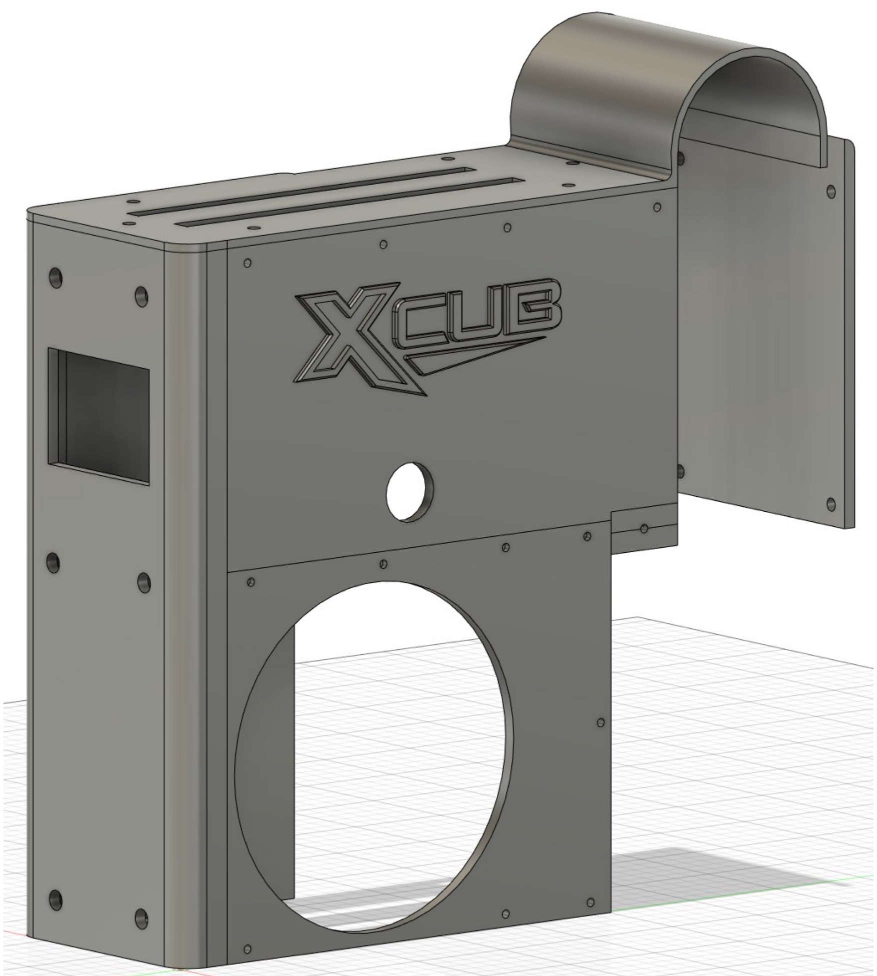
At the top of the Flap Arm the push rod comes up through the Upper Push Rod Guide. This guide is just there to keep the rod relatively centered in the arm and pointing at the Detent Pawl. When you press the trigger to retract the flaps, the push rod moves up to disengage the pawl. This motion is only about 5mm. When the trigger is released the spring returns the rod back to its original position. The Detent Pawl will fall back into place with the assistance of a M4 nut epoxied to the top of the foot. The use of the trigger is not needed to lower flaps. All you have to do is pull the arm into place. You use the trigger to retract the flaps.

The transfer of motion in the flap arm to the electronics is accomplished by a cam axle. Inside the unit are four, snap action limit switches with a roller lever. The image to the right shows the cam axle integrating with the switches. As you move through the range of motion of the Flap Arm, each of the cam lobes will activate one switch at a time. This is recognized as a button press in the sim.

The four switches sit in a cradle that is adjustable to get the proper amount of “mesh” between the cam and the actuator on the switch.

The nice part about these switches is, there is an audible click when the switch contacts connect and disconnect. This helps in letting you know when you have engaged the next flap detent.





The last parts I designed were the covers to the whole unit. These were pretty simple to do. I did make a few additions to the covers. One is obviously the Xcub logo on the front. I also added a place for three rocker switches on the long side cover. These are for controlling Water Rudders and Landing Gear on the float variant of the Xcub. The third switch is for the Parking Brake. This was a nice addition as the switch in the sim is almost impossible to see properly and it keep the hands off the keyboard and on the controls.

In total, there was around 150 hours of design work over three months to get the controller to a printable state.

There are a total of 38 .stl files to work with to generate the 40 printed components.

Now, on to the notes for printing.

How I Prinited the Xcub Throttle Quadrant Components

Let me preface this section on the fact that I did not print all of these components myself. This was for a couple of reasons. Time, Quality of the printed parts, engineering tolerances for critical parts. The parts I did print, took nearly a week and a half on my Creality Ender 3. This was all of the frames and a few of the covers. The rest of the parts I used Shapeways as my printer of choice.

Most of the covers, the entire flap arm assembly and its related parts, fuel selector switch parts, throttle and prop knob, and the four halves of the lever plates were printed using Selective Laser Sintering “Versatile Nylon Plastic” with Shapeways. Shapeways printing quality has significantly improved over the last year and the tolerances between printed parts can’t even come close on FDM printing.

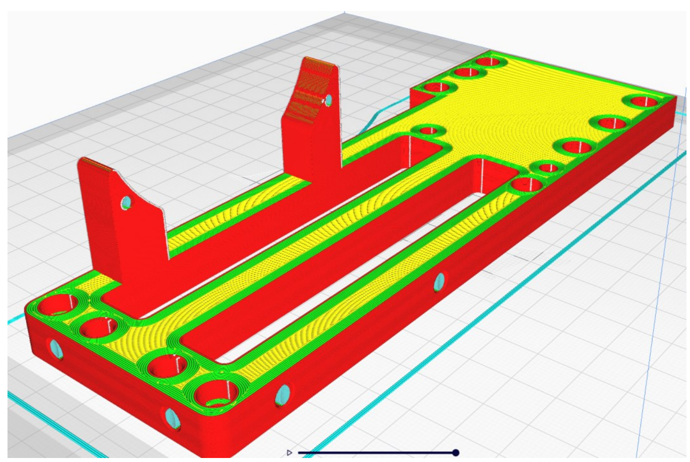
Printing with Shapeways, especially large complex parts, is NOT cheap. The total of the parts I had printed for the prototype was $430 USD as some were printed in color. Was it worth it. It certainly was as the quality is second to none. All I had to do was upload my .stl files to Shapeways, select my print options, give them a kidney, and my parts arrived about 10 business days later.

Printing The Frames

I opted to print the frames to save a pile of money. Printing was done on my lightly modified Creality Ender 3. I used Overture 1.75mm Black PLA filament .

Since the frames are structure critical parts I changed some settings in my slicer (Ultimaker Cura) to suit the design and also assist in the use of Heat Set Inserts.

The most important thing when taking Heat Set Inserts into consideration with a heat fused material is how much material is around the insert. The more material the less chance of heat deforming the print. I found this out by printing several of the “Top Frame Bracket” parts to use as a test bed to get my print settings dialed in. Since it is a small part it wont take several hours to print two, or five, to get the process dialed in.



My Best Settings:

Wall Line Count: 6(Min) - 8(Max)

I used 8 Wall Lines for my prints.

Layer Height: 0.20mm

0.20mm was more than enough.

Supports: Yes

Orient your parts for minimal supports.

Top and Bottom Layers: 4

Adds significant structural rigidity.

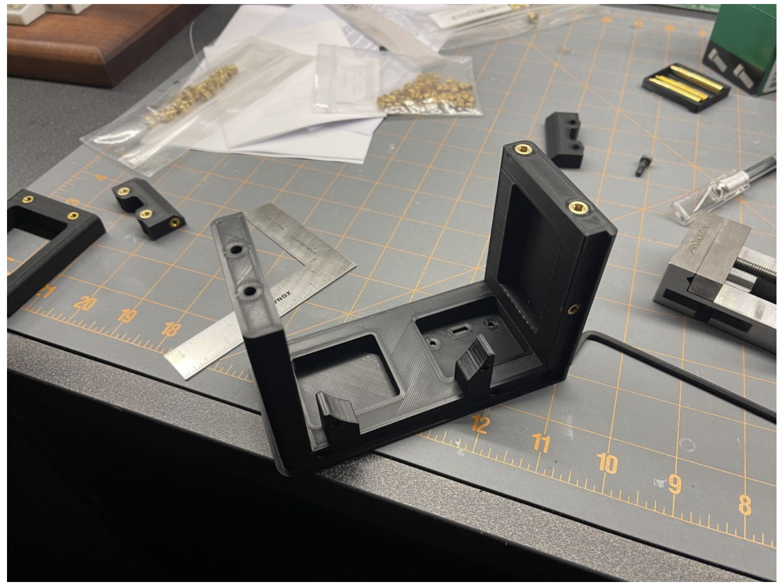
Heat Set Inserts

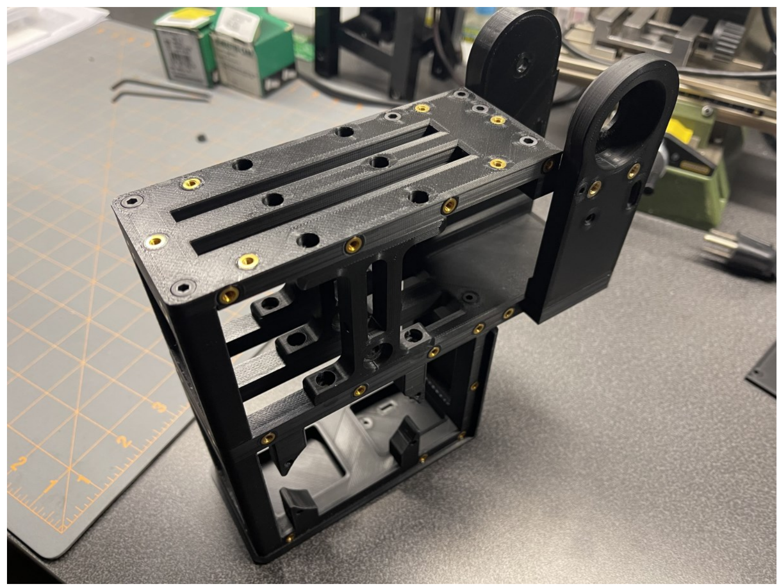
Heat Set Inserts were a key component in this design. These are brass insert that are threaded internally to accept a screw and press into a hole using a special insert tip on a soldering iron. They are commonly used in injection molding and are very popular with 3D Printing for attaching parts.

They are tricky to use at first and take some practice. The key to them is to get them inserted as quickly as possible in your PLA print and remove the heat from both the inert and the plastic as fast as possible. I accomplished this by using a small precision vise as a heat sink and a way to set the insert flush with the face of the print.

There are quite a few videos on YouTube covering the process of how to install these. I also sourced all of my inserts and the installation tip from Amazon.

It took me approximately a week in the evenings to print the frames and install all of the 70 inserts used in the project.





Holes for Screws

Most of the through holes for screws are printed undersize. This was done on purpose. Holes printed in a horizontal orientation tend to come out oval, even on the best printers. Since I needed round holes for screws I had them printed undersized and drilled them out to the correct diameter. Some other holes may need to be opened depending on fitment.

The following holes must be drilled to accept their appropriate fastener:

Cover Panel Holes: need to be drilled to 3.2mm (All Cover Panels)

Trigger Axle Pin: 3.1mm (Two tabs at the end of the Flap Arm on either side of the Trigger)

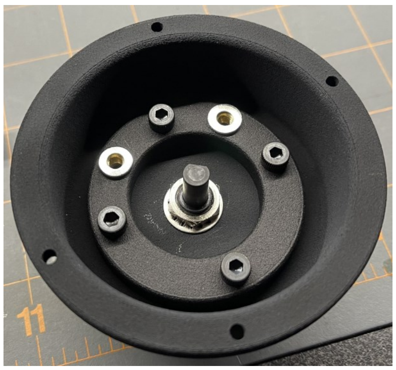
Trigger Stop Pin: 3mm (Small hole below the Trigger Axle Pin)

Detent Pawl Pin Holes: 6mm (This is the pin for the Detent Pawl and Spacers on the back of the Flap Arm)

Assembling the Prototype

Since I had spent the better part of three months designing the Throttle I had already gone over how to put it together numerous times. It was all just a matter of getting the parts together and doing it. The following photos show some of that assembly in progress.

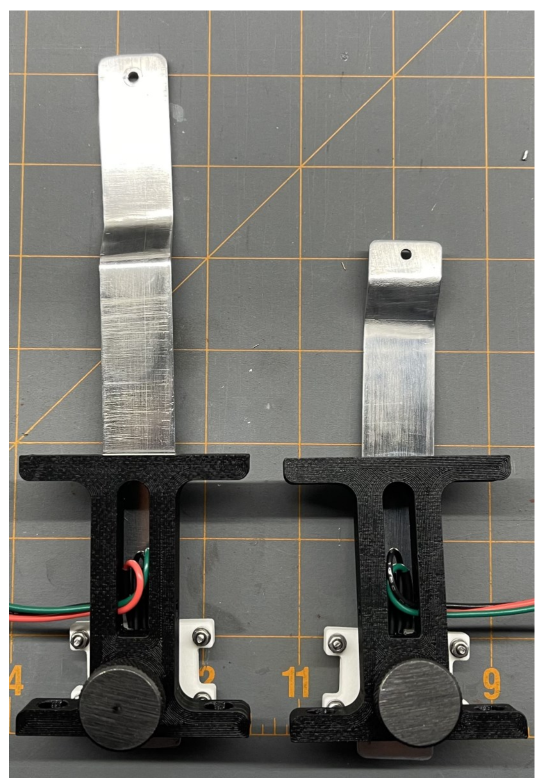
All of the parts that would be handled during use were clear coated with a flat clear prior to assembly. Also some of the parts were painted to reflect their final colors. Prop knob, fuel selector switch and guard, flap trigger and handle extension were all painted to their final color and given a coat of flat clear.

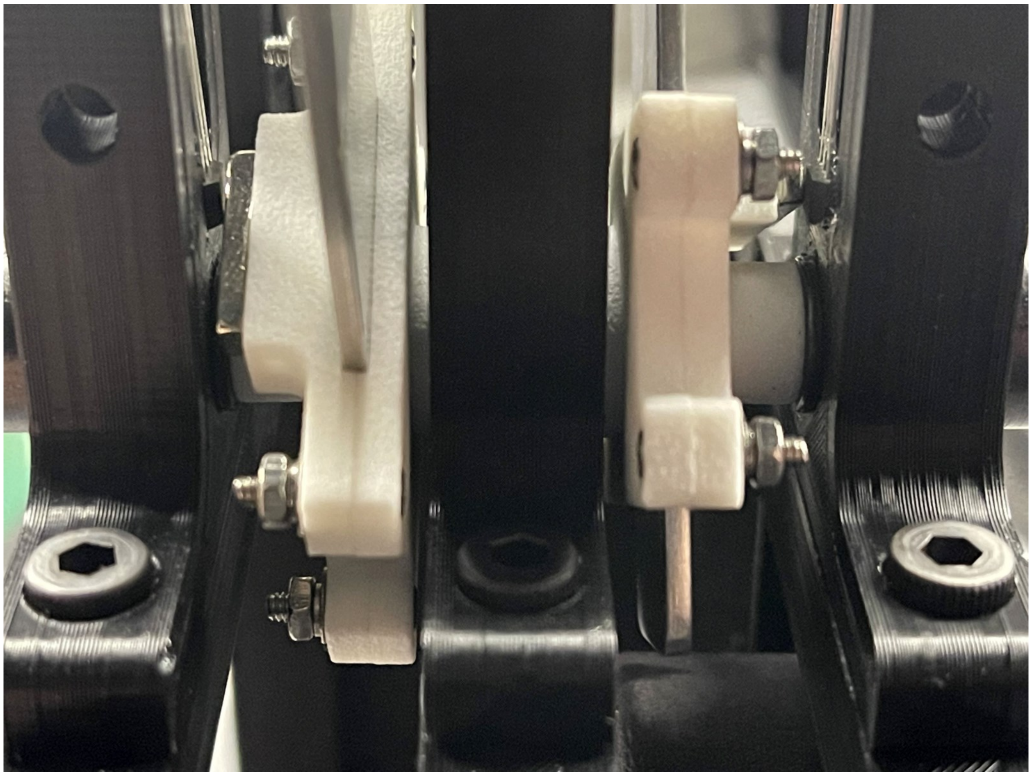


Fuel Switch Components during assembly.

When Wiring the Rotary switch, the center pin was used for ground. I wired pins 1 and 10 together as those are the pins for the cutoff.

Throttle and Prop Levers. 3/4” x 1/16” Aluminum bar stock was bent, shaped, and lightly polished before the front and back mounting plates were installed.

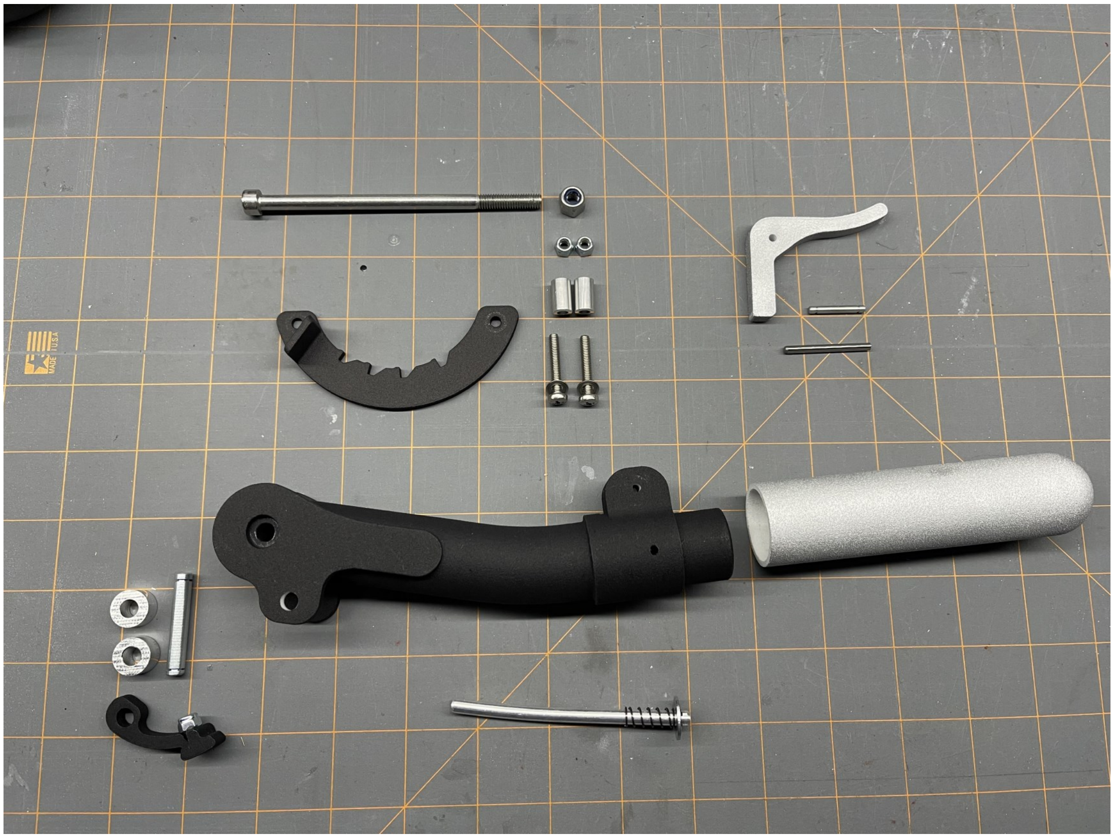




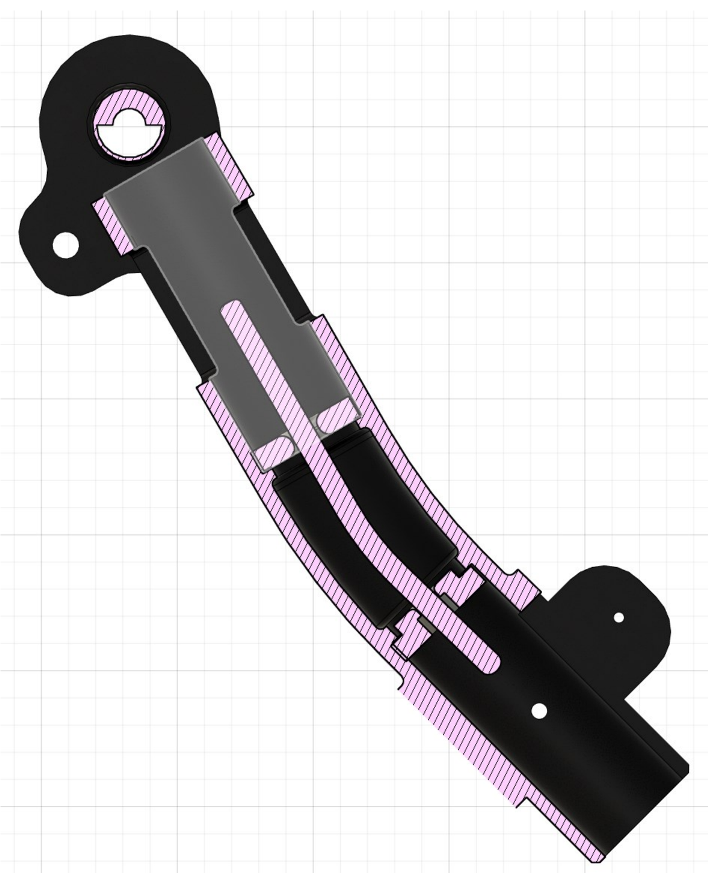
Assembled Throttle and Prop Levers in the frame. While you can't really see it in the photo. The space between the Honeywell hall effect sensor and the neodymium magnets is approximately the thickness of a decent business card. This gap is maintained through the entire range of motion on the levers.

Three accessory switches installed into the long side cover.

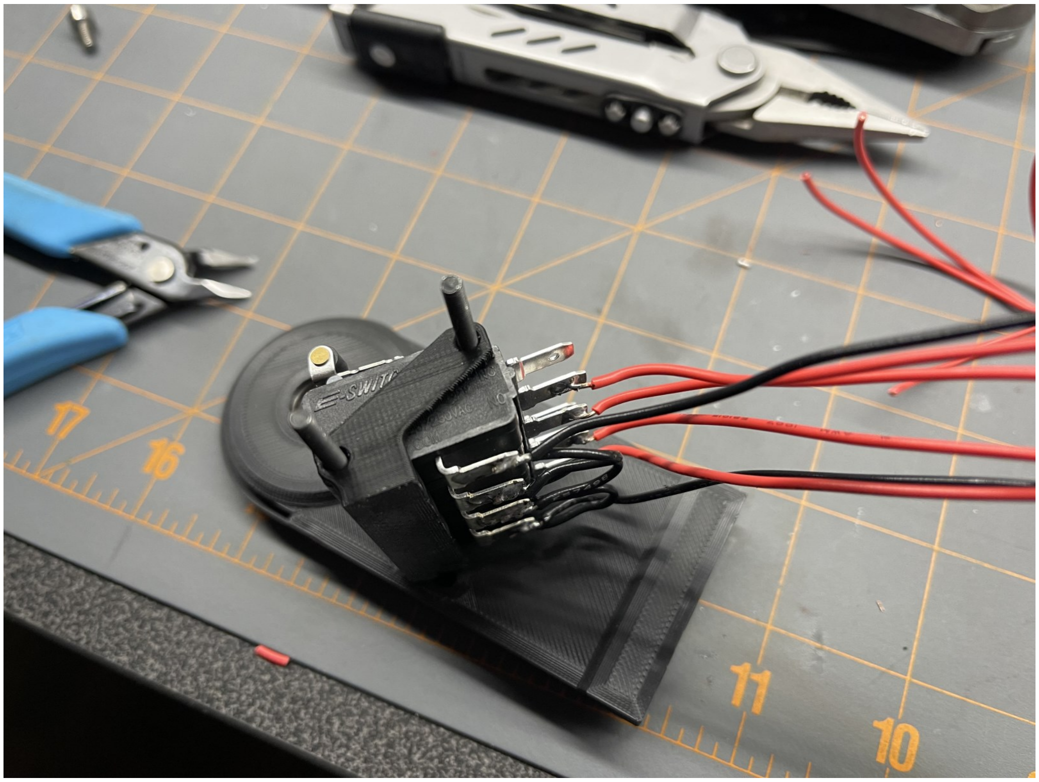
These are for your Water Rudders, Gear, and Parking Brakes.



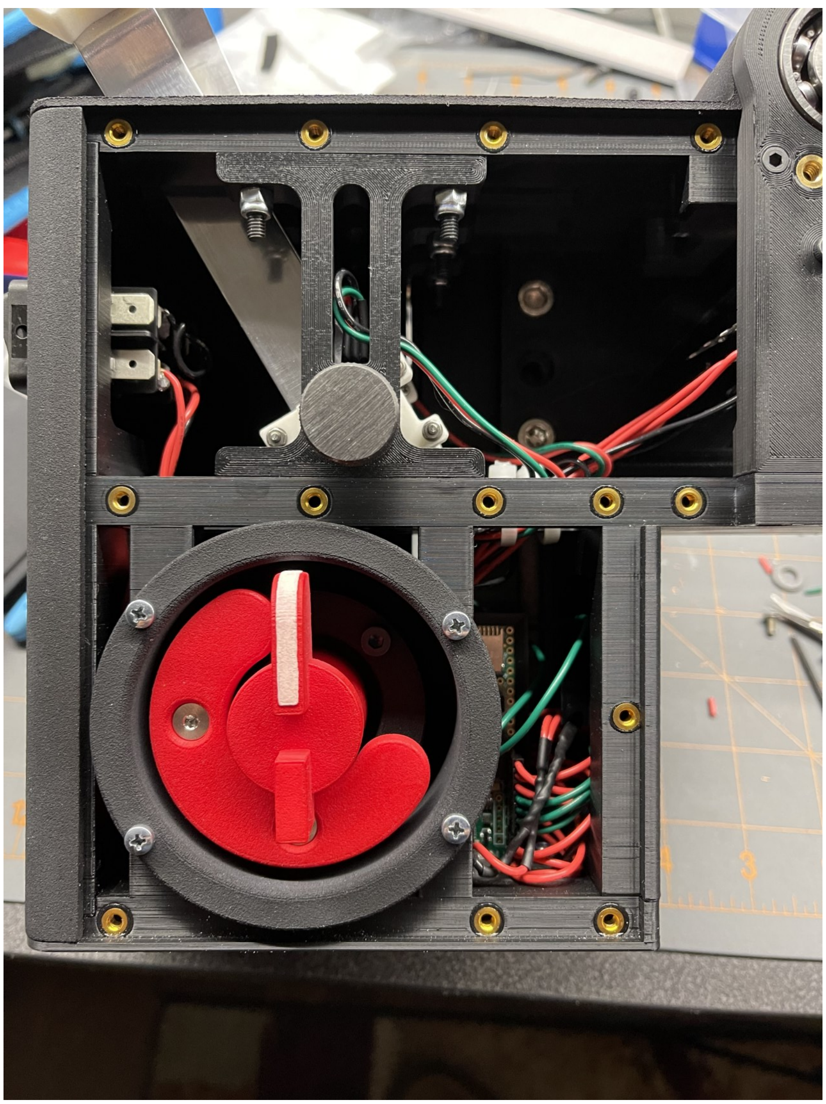
Overview of the components of the Flap Lever Arm. *Not shown are the Upper Push Rod Guide and Spring Plate. These are already installed into the arm.



Cross section of the flap arm which shows the Upper Push Rod Guide and Spring Plate in relation to the Push Rod. There are two internal grooved these plates land at inside the arm. These plates are printed oversized and require sanding to get them to fit into the arm with a medium to heavy friction fit.



Wiring the flap position switches. The red wire is soldered onto the "NO" (Normally Open) position of the switch.



Completion of the wiring phase. All of my wires were left long on purpose. The extra length gives me some room to wrap them around and in front of the Arduino. Any excess wire was tucked in behind the fuel switch.

This is the final completed and assembled unit in a online test flight with Bush League Legends crew. The Xcub logo on the top side cover was hand painted white. I opted to use stainless steel screws to attach my covers for appearance.

Arduino Teensy 4.1

One thing I learned when it comes to programming, I am not a coder. You may not want to use a Teensy 4.1 like I did, so the controller side of the project is up to the builder. Here is what I used for pins on my Teensy.

Analog side of the Controller:

GND: Wire both grounds of your hall effect sensors to this pin

3.3V: Wire both of the power feeds for your hall effect sensors to this pin.

A0: Signal wire from one of your hall effect sensors to this pin.

A1: Signal wire from the second hall effect sensor to this pin.

Digital side of the Controller:

GND: All of your physical switches ground to this pin.

0-9: This is the power side for your switches. Try to keep your switches in order as this will make assigning them is MSFS easier.

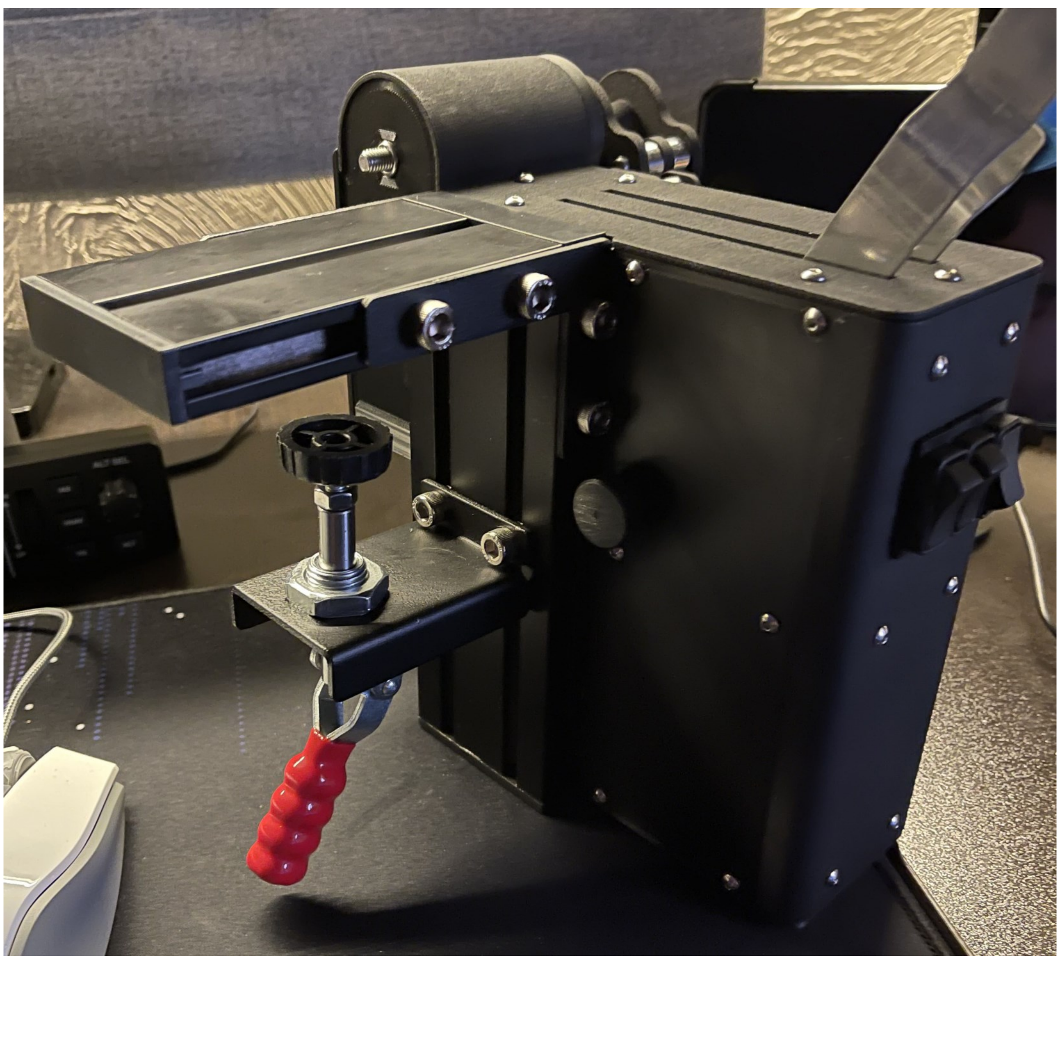
If you opt in for the Teensy 4.1 I have already included the code in the GitHub used for the controller to interface the components with Windows. You will just need to set up the Arduino software for Teensy 4.1 and upload the code to the board.

I did not write the code. It was a sample code included with the Arduino program that has, so far, been working flawlessly with the prototype unit. The only thing I have to do is calibrate the controller when I plug it in to allow Windows to read the full range of the hall effect sensors. In the future I will probably dive into the coding and develop a custom code for the board that will allow for better control over the sensors and even rename the controller. For now I'm just going to enjoy the fact that this was nearly plug and play.

So, What about a mount?

When I was designing the throttle I had no idea how I was going to mount it to my desk. In late August of 2021 I purchased a economical "MezaMount" style joystick mount from Amazon from the brand "J-Pein". It was a cheap $50 mount and it works great for a joystick. I decided that the throttle was more important and modified the mount by trimming it down. Aluminum extrusion cuts really easy with a carbide toothed miter saw.

You may have noticed the back of the unit has three holes for M6 socket head screws. This is for the mount. This also why there isn't a full cover on the back as the mount acts as part of the cover.



Do You Want to Build One?

So you have come this far in the document, do you want to build one?

If you answered yes, then you will have a fair amount of printing ahead of you. Take your time with it and If you have any questions please feel free to ask me in Discord.

The total cost to produce the prototype throttle was around $700 USD. The bulk of this price is the printing with Shapeways. That price does not include the mount. If you have plans to print this entirely yourself then the costs will be significantly lower.

For the foreseeable future this project is entirely open source. You are free to edit the .stl files if you need to adjust something for printing. If you do indeed build one, keep us updated in the Bush League Legends Discord on your build progress.

I only have one restriction on the use of the project. I would like to keep this project as an open source item for creators and flight simulation enthusiast. If you are intending on manufacturing something like this as an item for sale then a please contact me directly and we can work out a plan for you to do so.

Good Luck and Happy Flying!

CarbonSpark