Drone Challenge (UAV)

2024 National TSA Conference

Orlando Florida

Team Identification: # 1881-1

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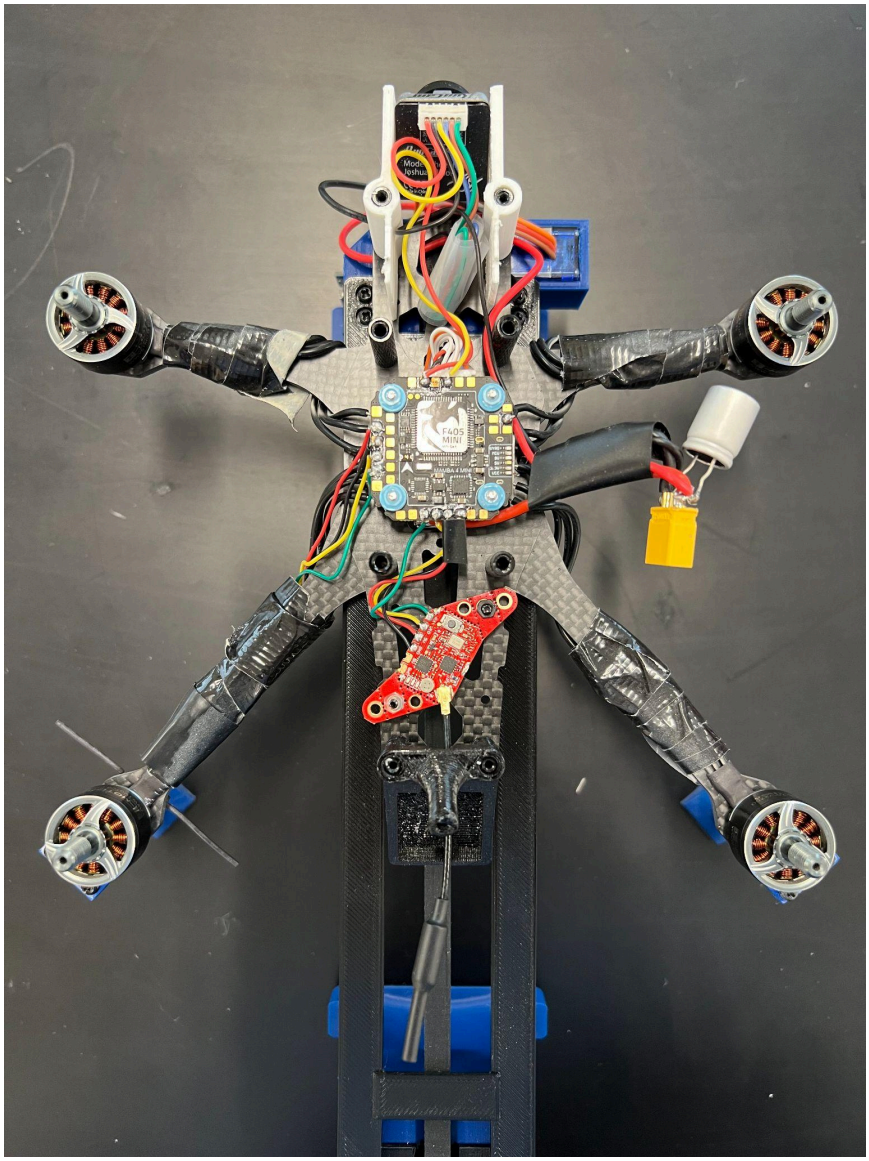
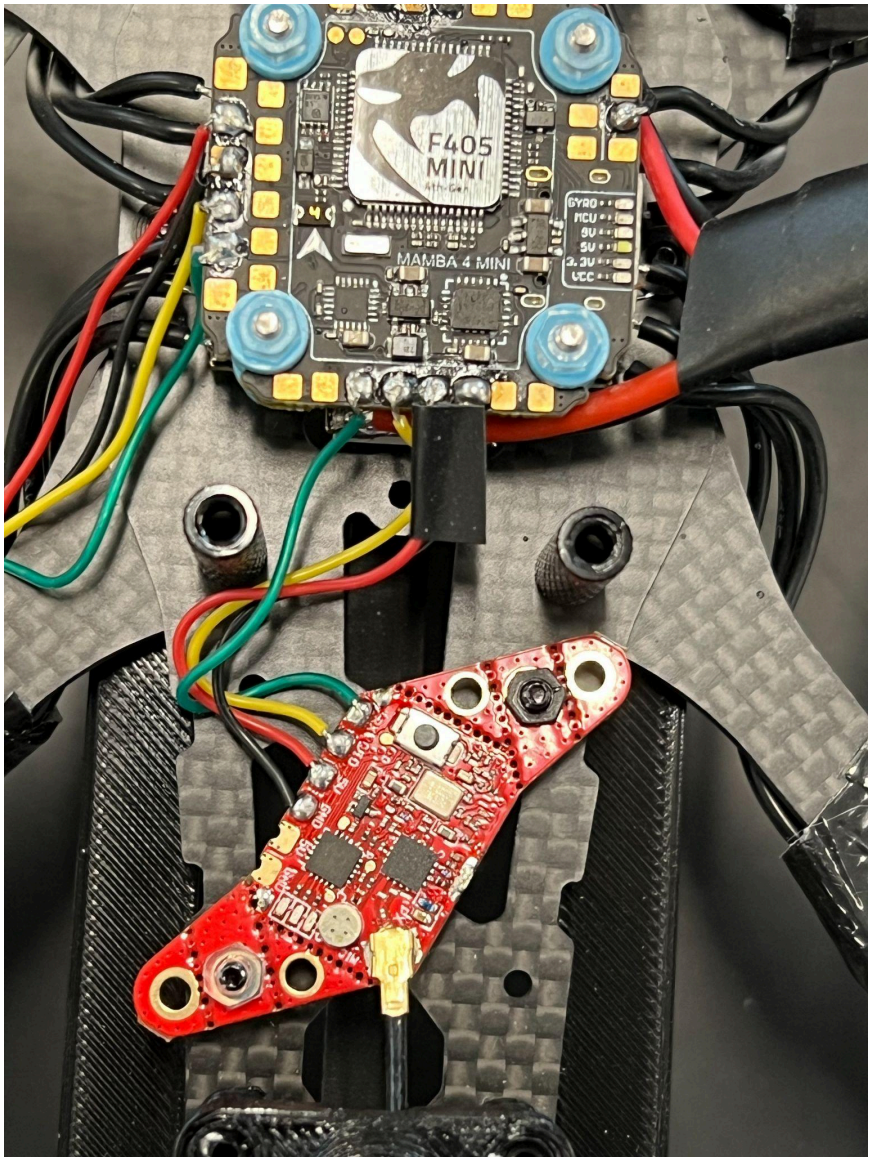
Photo Log:

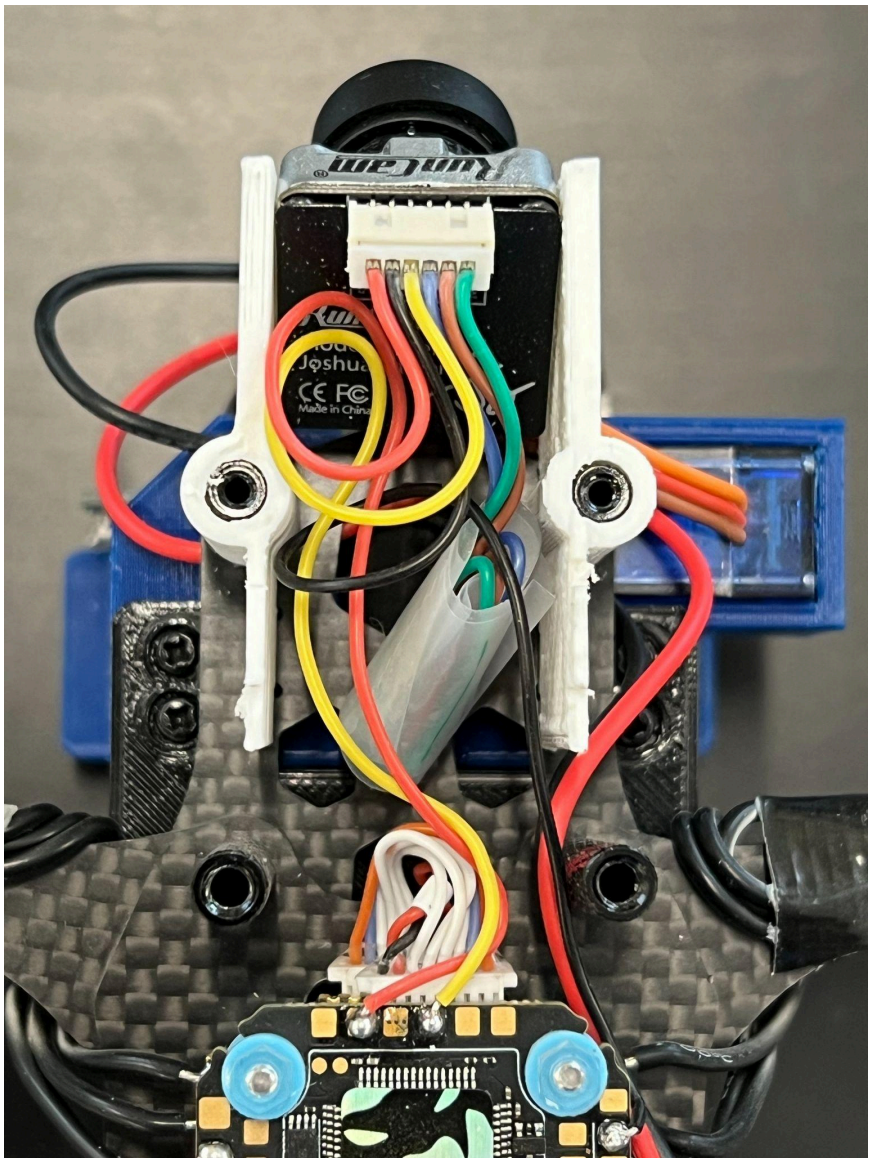
Motors mounted to the drone frame. Black wires from the motor pass underneath carbon fiber arms and are soldered to the ESC/FC stack.



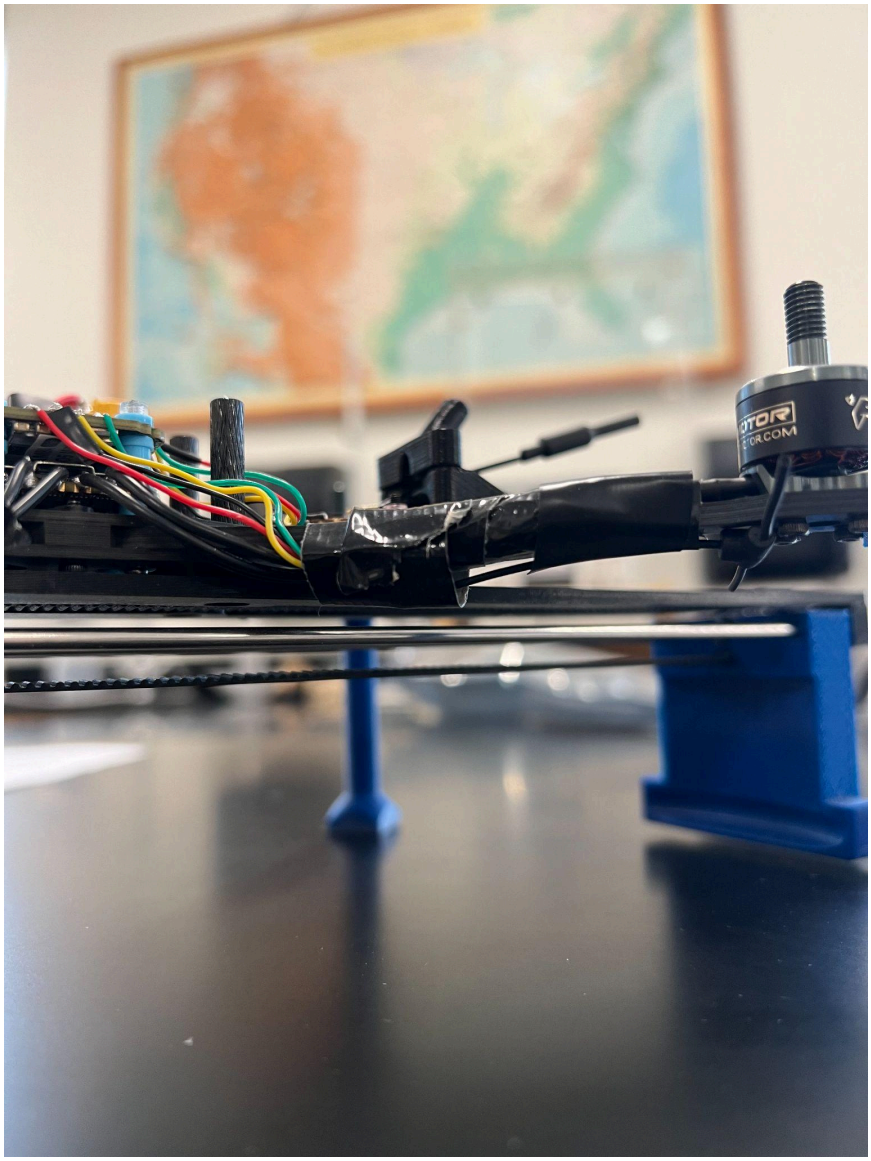
The VTX is mounted using two screws to the carbon fiber frame. The VTX is soldered to the FC as shown below. Electrical tape used to protect the power and ground wires from shorting each other. The VTX antenna is pressed onto the VTX board itself, then passed through the back of the frame.



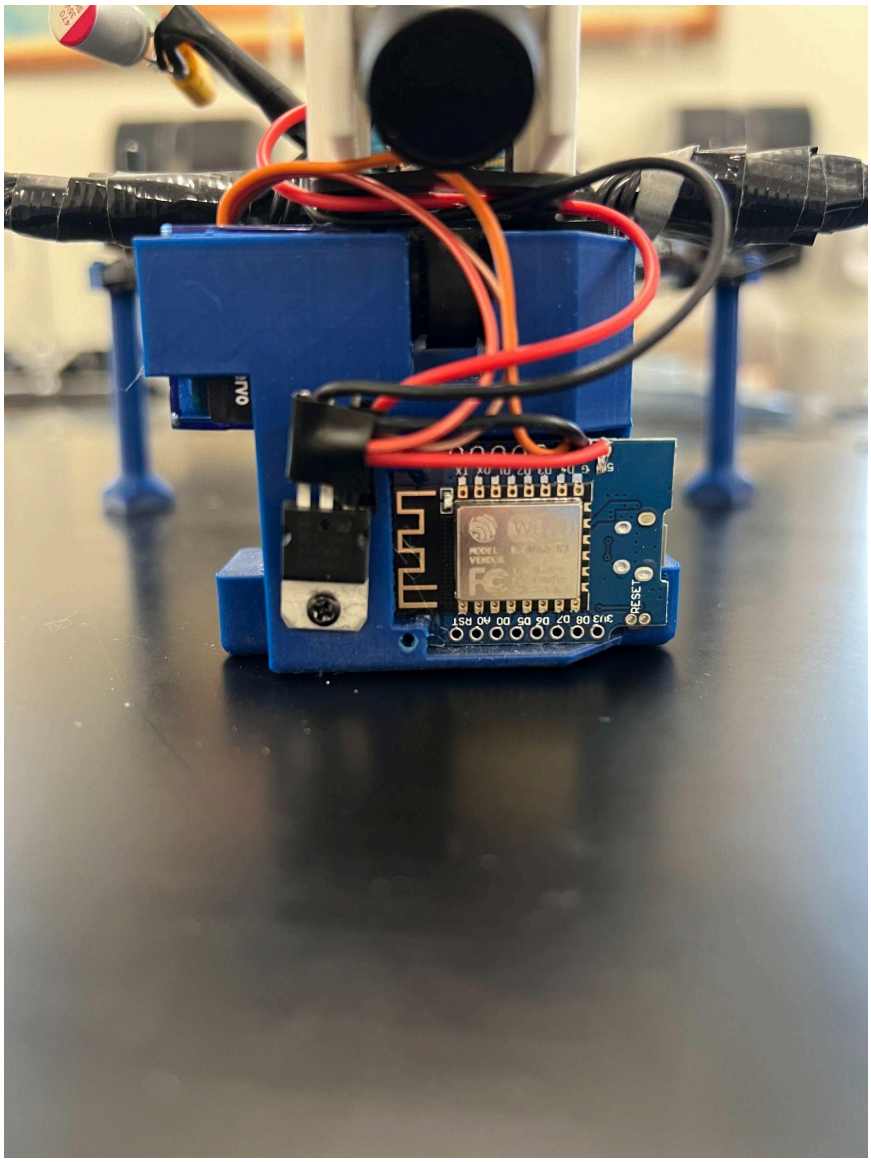
The 3D printed camera mount slides onto the two front standoffs. Three of the camera wires were unnecessary for our project, which we sealed away in a layer of tape. The red, yellow, and black wires are soldered to the FC as shown below. Below the FC is our FC to ESC cord, which allows the FC to control the motors.



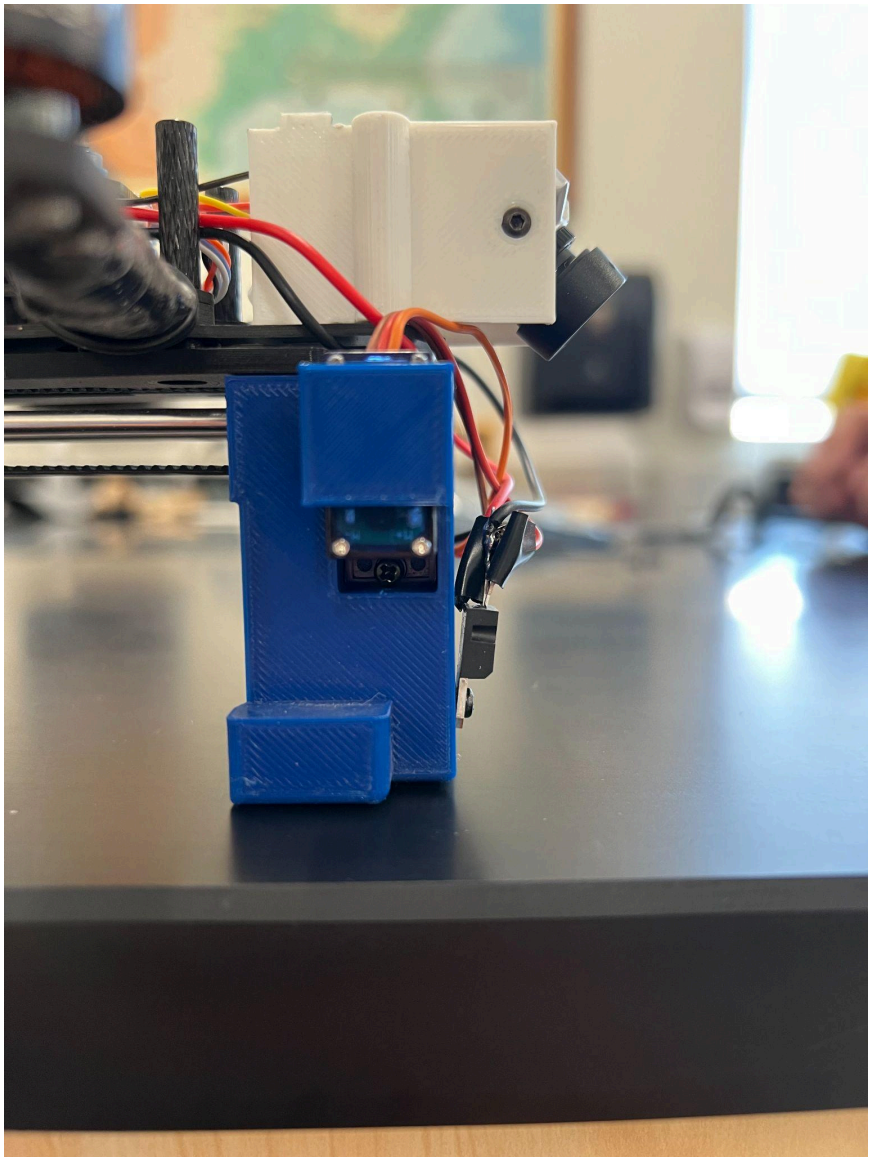
Although not currently visible, our receiver (RX) is sealed in a piece of shrink wrap, then fastened underneath the back-right arm of the drone using electrical tape. The antenna is mounted in a similar fashion to our VTX antenna, and the RX is soldered onto the far left side of the FC.



A full illustration of our assembled pickup mechanism is listed below in the Engineered Drawings section. Shown below is our wiring and mounting of the 5v regulator and Wemos D1 Mini. The 5v regulator, in charge of limiting the voltage to our servo controller, is mounted using a small screw. The input wires from the battery are soldered directly to its terminals, and then wrapped in electrical tape. The Wemos D1 mini (servo controller), is glued into place.



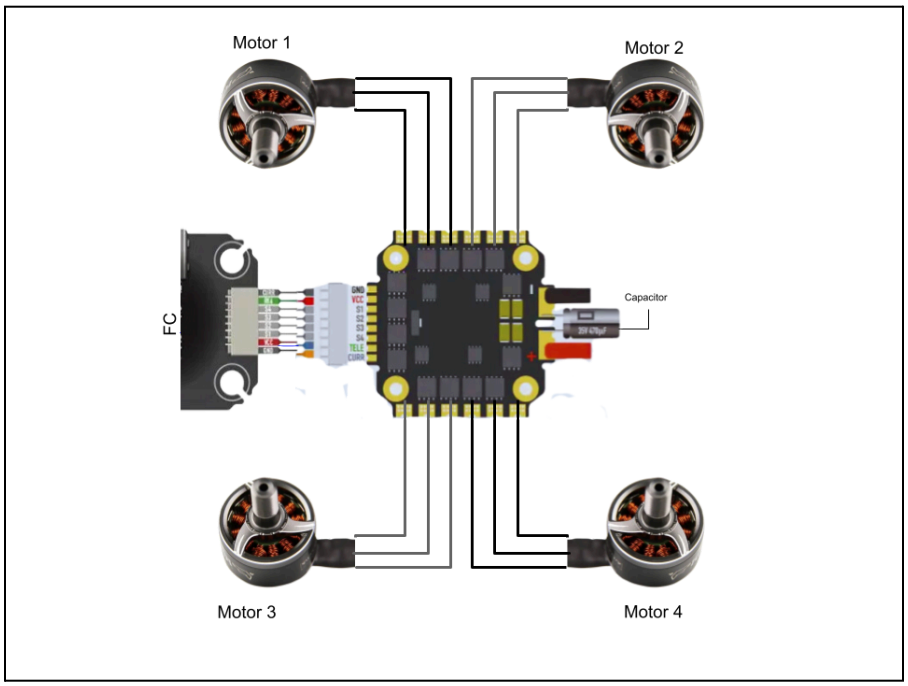
This angle shows how we mounted our servo, and fastened the camera to our camera mount. The servo is simply screwed into place, as well as the camera. By loosening the camera screws, we can adjust the angle of the camera.



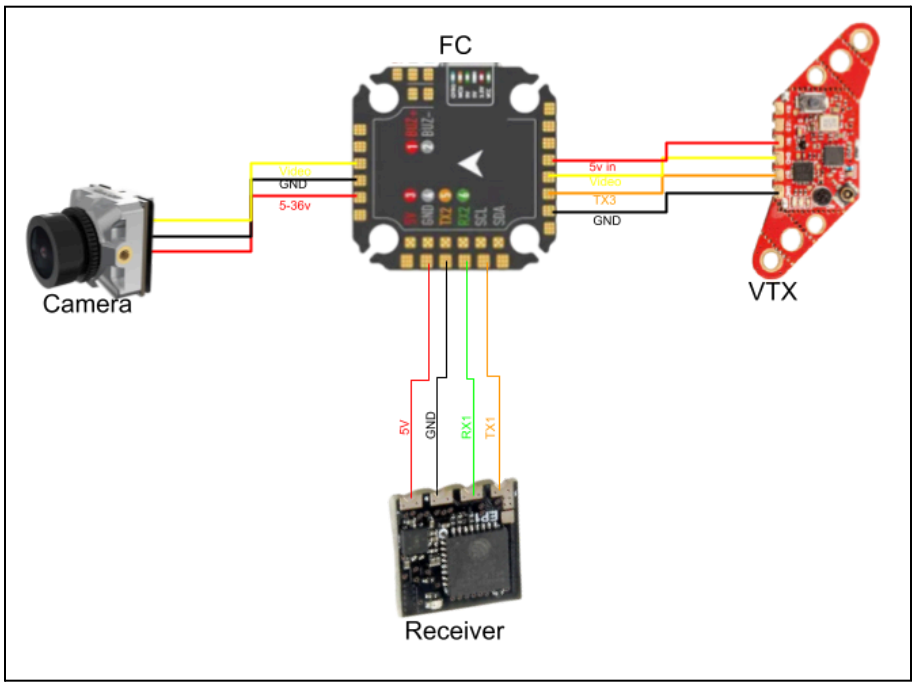
This picture shows how we mounted the back landing legs. The bottom piece is 3d printed, and then inserted into a small hole at the end of the carbon fiber frame. The leg is secured in place using two small screws and a “screw plate” that goes on top of the frame. Drawings of these parts can be found in the Engineered Drawings section.

Wiring Schematics:

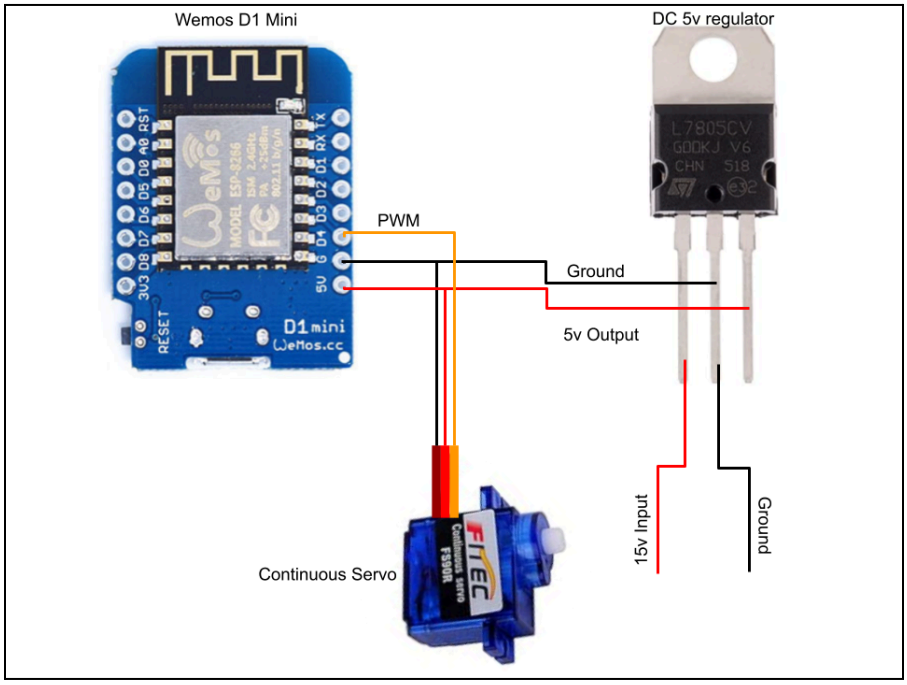
This first schematic shows our ESC wiring. All four of the motors attach to their 3 corresponding pads on the ESC. To the left, we have our FC to ESC cable, which allows the two boards to communicate with each other. On the right, we have the wiring diagram for our capacitor and battery terminals. All voltages on this schematic are roughly 15v, with the exception of the 5v FC to ESC cable.



This Schematic shows how we wired our Camera, VTX, and Receiver. Voltages are listed next to each wire, and the wires are colored according to the actual drone.



This schematic shows how we wired the servo controller mechanism. To the left is our Wemos D1 mini, a small wifi enabled microcontroller. This takes the 5v coming from the voltage regulator and uses it to power the continuous servo and generate a PWM signal that controls the servo. The voltage regulator simply takes the 15v coming from the drone battery and converts it to a more manageable voltage for the Wemos D1 mini.



Programming Software Explanation:

Controlling our UAV drone is a betaflight flight controller. To program this type of flight controller, we used software called Betaflight Configurator, an open source utility used for configuring drones. To use this software, one must first connect to the drone's flight controller via USB. As long as the appropriate drivers have been installed on your computer, betaflight configurator should be able to talk with the drone. Once connected to the drone, betaflight configurator gives you many tools for configuring your drone, which are organized into tabs on the left side of the UI. While there are more than a dozen tabs available, the following tabs were most significant to our configuration of the drone:

- Ports
    - This controls the various physical control ports (UART's) on the drone.
    - We used this tab to set up things like the video transmitter chip, receiver, and Electronic Speed Controller.
- Motors
    - This tab was crucial in the configuration of our motors.
    - From here we controlled which motor protocols we used, such as Bi-directional D-shot.
    - We also used this tab to conduct an initial spin test on the motors, as well as choosing which directions the motors would spin.
- Receiver
    - Once the motor's had been troubleshooted, we used this tab to ensure that our radio controller was talking to the drone.
    - Preliminary to using this tab, we also used some software called ExpressLRS Configurator, explained below.
- Modes
    - Once the receiver module was set up, we used this tab to determine which switches would do different things on the drone.
    - For example, we used the back left switch to arm the drone, and the front right switch to choose the flight mode.
- OSD
    - At this point in the configuration of the drone, it was theoretically possible to fly. However, without a properly tuned On Screen Display, we wouldn't even know when our batteries would run out.
    - Using this tab we controlled the position of different OSD elements, like a voltage indicator and altitude indicator.
- Video Transmitter
    - In order for our work in the OSD tab to mean anything, we needed to ensure our video transmitter was even working.
    - Using this tab we configured the protocol that the VTX would transmit on, the transmitting power, and the channels we would be transmitting on.

- PID Tuning
    - The final step of getting our drone ready to fly was PID tuning.
    - Using this tab we controlled the sensitivity of the drone.
    - For example, we limited our throttle stick to 50% of its capacity.

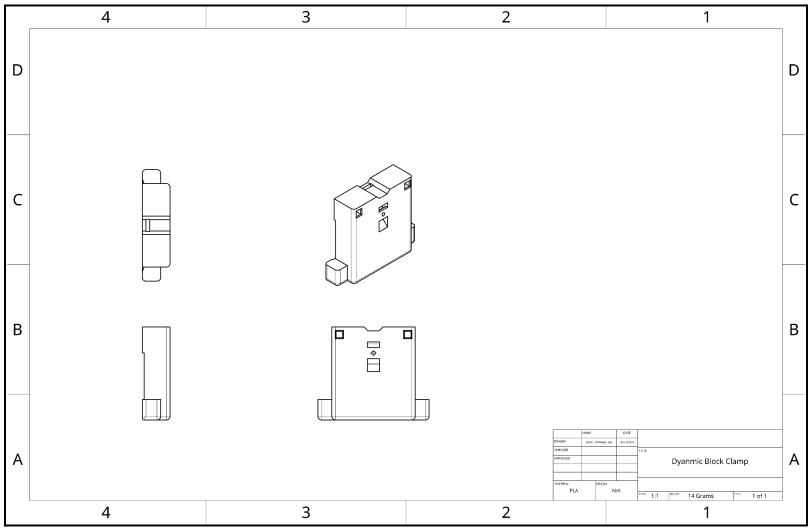
As mentioned in the list of tabs above, we also used some software called ExpressLRS configurator as well. This configurator is much simpler to use than Betaflight Configurator. We essentially selected our model of transmitter and receiver, and then hit the install button. Just as with the betaflight configurator, we had to ensure the right drivers were installed beforehand.

The second part of our programming was all centered around the wifi-controlled pick up mechanism. We ended up using a completely separated control board for our servo motor, so that we could avoid damaging our flight controller with extra soldering and timer usage. This board we used was a low cost, Arduino-style board called a Wemos D1 mini that we already had on hand. This board controls our motor via the PWM protocol, and communicates with the wifi enabled control device via websockets. A websocket is a type of wifi connection that allows very fast communication of small amounts of data. This was perfect for our type of mechanism, which needs fast communication. Only open source, free libraries were used in the programming process.

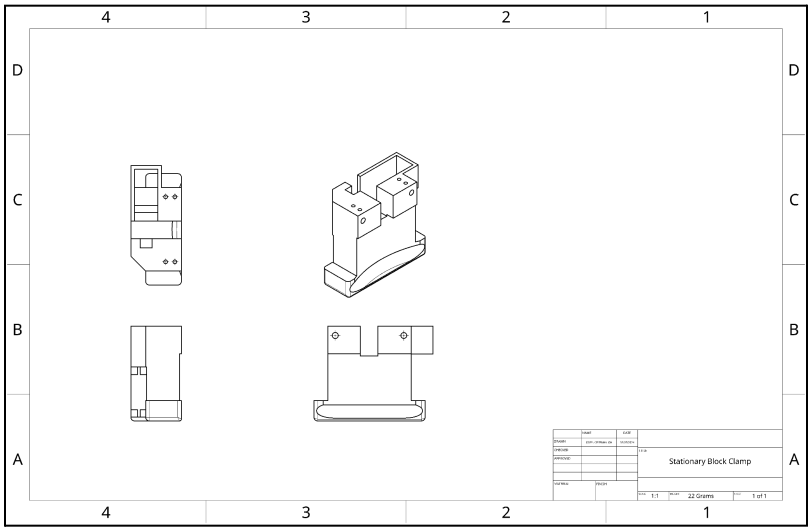
Engineered Drawings:

*Note: All drawings originate in the required “B” size paper, but are scaled down to 24.55% of their original size. For example, one quarter inch in the portfolio represents roughly an inch in the design. This is required to fit all drawings in the maximum quantity of 4 pages as listed in the documentation requirements. Due to the small nature of the drawings, individual measurements of parts were left out.

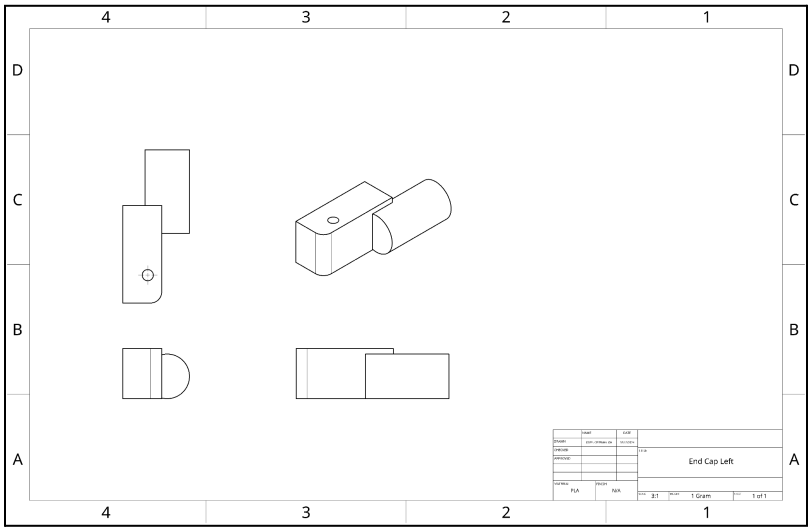
Dynamic Block Clamp:



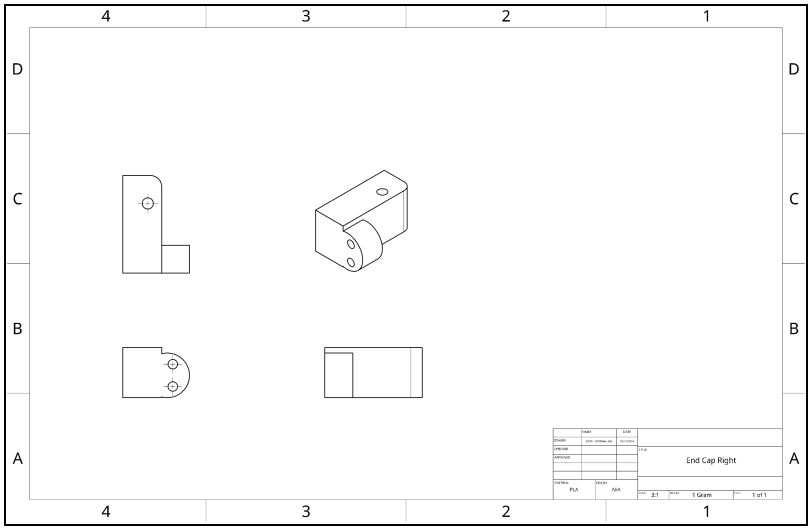
Stationary Block Clamp:



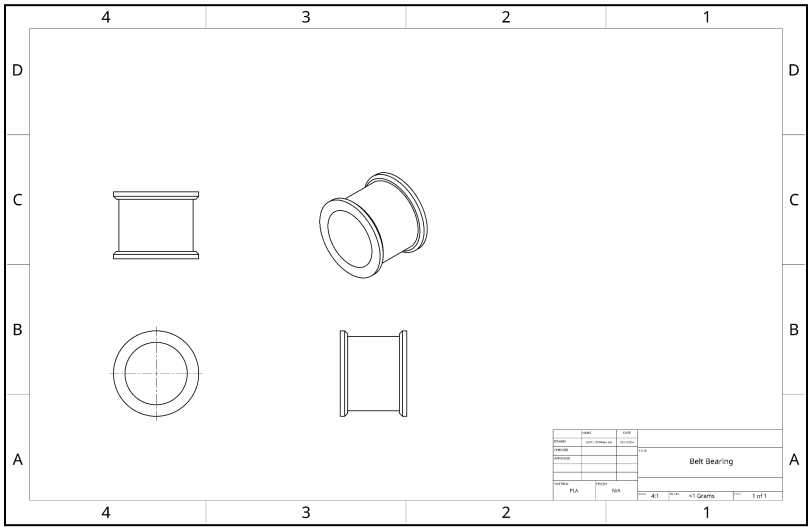
Left End Cap:



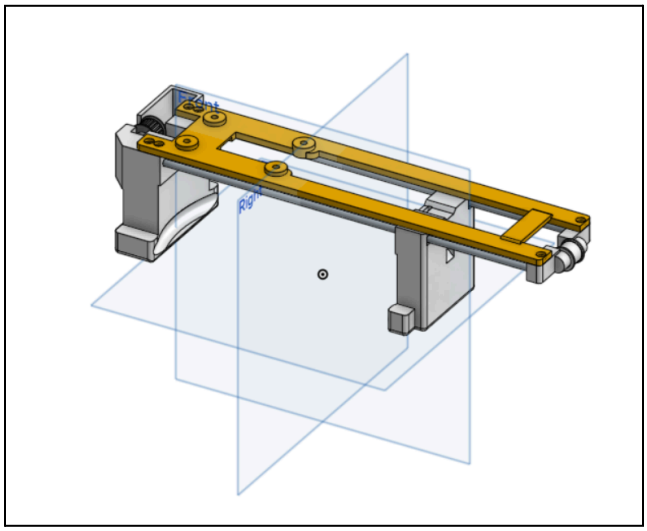
Right End Cap:



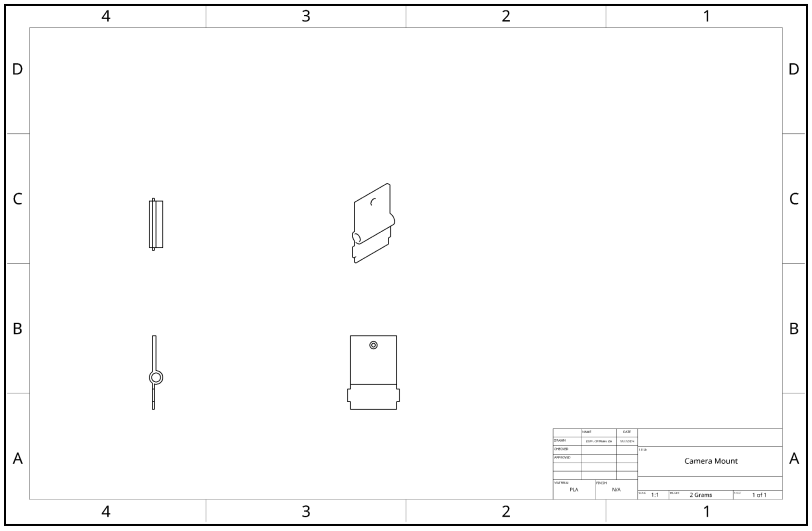
Belt Bearing:



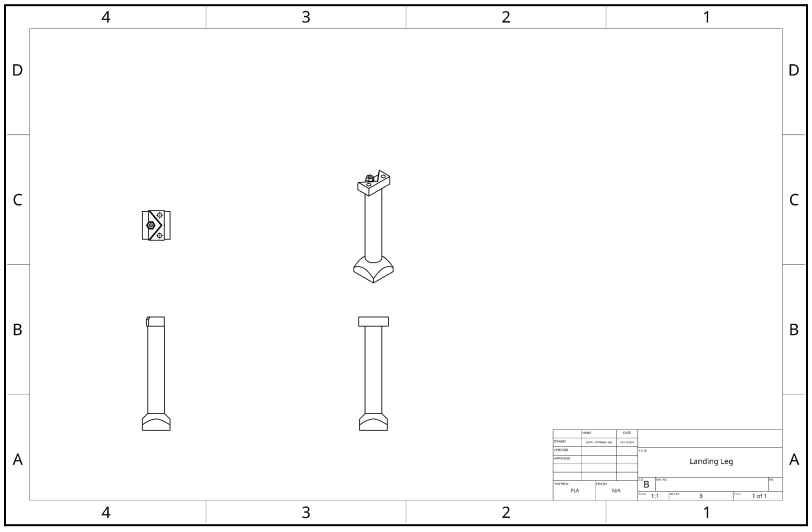
Screenshot of pickup mechanism when assembled in CAD (not displayed in “B” size):



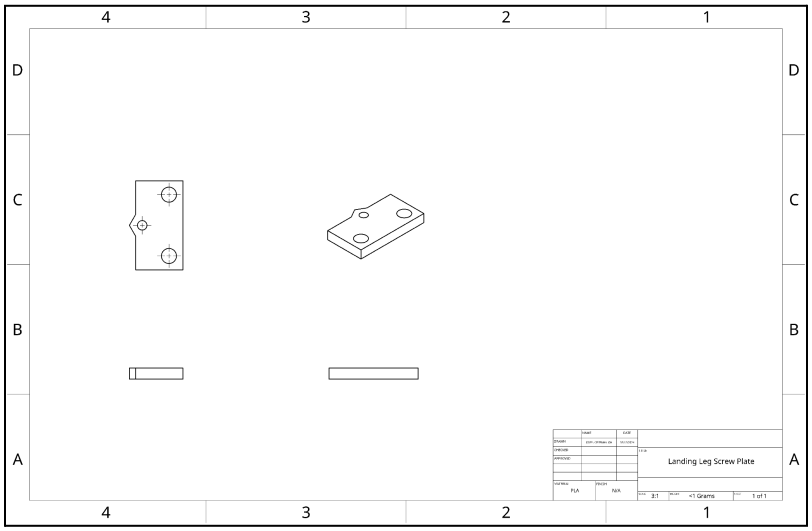
Camera Mount:



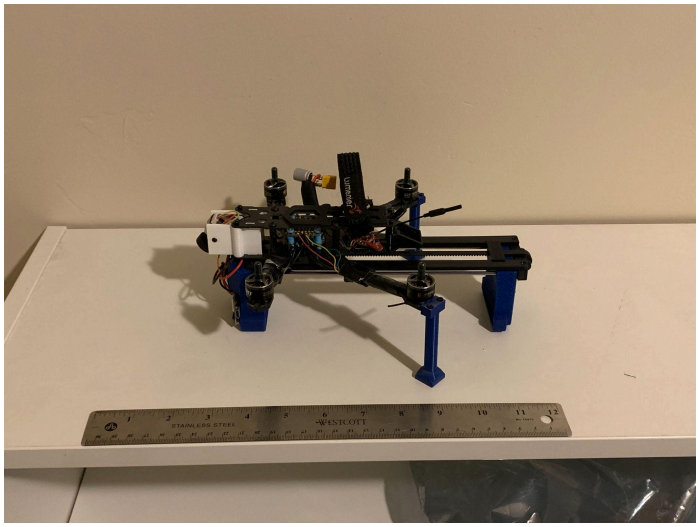
Landing Leg:



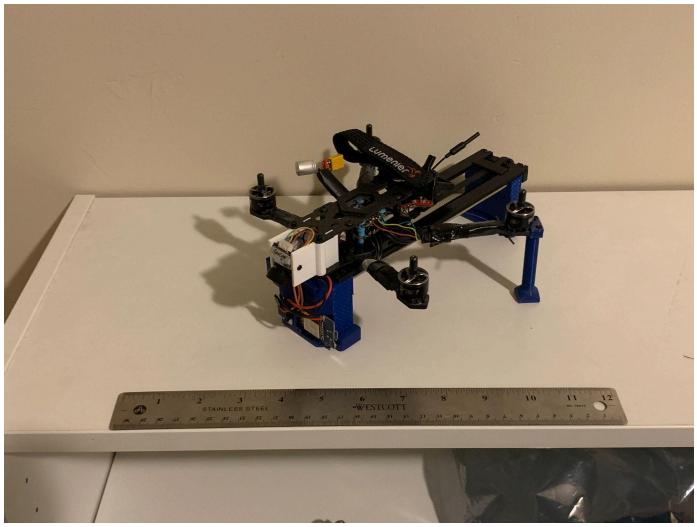
Landing Leg Screw Plate:



Drone with assembled landing gear, camera mount, pickup mechanism, and sizing reference:



Other angle:



Bill of Materials:

*Note: all tax estimates are based on a flat 8% tax rate. Total cost overall is highlighted in yellow.

Item	Price	Shipping	Subtotal	eTax	Total	Grams
Lumenier QAV-S MINI 4" Freestyle Quadcopter Frame	$44.99	$0.00	$44.99	$3.60	$48.59	60.00
T-Motor F1507 V1 2700KV/3800KV Motor (5 of them)	$99.95	$0.00	$99.95	$8.00	$107.95	60.80
850mAh 4S Lipo Battery (2PCS)	$35.80	$0.00	$35.80	$2.86	$38.66	110.00
Diatone Mamba Stack - MK4 F405 FC + 30A 3-6S BLHeli_S ESC - Mini 20x20	$84.99	$0.00	$84.99	$6.80	$91.79	12.00
Gemfan Hurricane 4023 Durable Tri-Blade 4" Prop (2 of them)	$5.98	$5.99	$11.97	$0.96	$12.93	8.00
HGLRC Zeus Nano 350mW 16mm/20mm/25.5mm VTX	$18.99	$5.99	$24.98	$2.00	$26.98	1.30
Happymodel ExpressLRS Nano 2.4GHz EP1 RX	$16.99	$0.00	$16.99	$1.36	$18.35	1.00
Battery Charger and Fireproof Bag	$29.99	$0.00	$29.99	$2.40	$32.39	0.00
Runcam Phoenix 2 1000TVL 2.1mm FPV Camera - Joshua Bardwell Edition - Silver	$32.99	$0.00	$32.99	$2.64	$35.63	9.00
Smokestopper	$12.99	$0.00	$12.99	$1.04	$14.03	0.00

3mm stainless steel rods	$8.99	$0.00	$8.99	$0.72	$9.71	22.00
4.5v continuous servos (2 Pack)	$13.98	$0.00	$13.98	$1.12	$15.10	10.00
6mm timing belt	$8.99	$0.00	$8.99	$0.72	$9.71	0.00
Replacement ESC	$22.99	$5.99	$28.98	$2.32	$31.30	0.00
5v Regulators For Pickup Mechanism	$7.99	$0.00	$7.99	$0.64	$8.63	1.00
1KG of 3D printing plastic	$20.99	$5.99	$26.98	$2.16	$29.14	90.00
RadioMaster TX12 MKII 2.4GHz 16CH Radio Transmitter w/ Hall Gimbals - ELRS	$99.99	$0.00	$99.99	$8.00	$107.99	0.00
EMAX Transporter 2 5.8GHz FPV Goggles	$98.99	$5.99	$104.98	$8.40	$113.38	0.00
Wemos D1 Mini	$19.99	$0.00	$19.99	$1.60	$21.59	0.00
Digital Caliper (used in production of 3d printed parts)	$24.99	$0.00	$24.99	$2.00	$26.99	0.00
	$711.55	$29.95	$741.50	$59.32	$800.82	385.10

Drone Rules & Regulations:

Listed below is our research about the many drone regulations that apply to us. We researched regulations in the following categories: Local/Regional (Florida), Federal, and Technology Student Association.

Local/Regional Regulations (Florida):

- You aren't allowed to intentionally harm livestock with the use of a drone.
- It is a class B misdemeanor to attach a weapon to a drone.
- You aren't allowed to trespass through the use of a drone.
- In places where individuals are guaranteed privacy, drones must have a warrant to fly there.
- If the public isn't allowed to be in a certain area (for example, private property), your drone isn't allowed to be there either.
- Commercial drone pilots must comply with the Part 107 rules. These are somewhat similar to the rules for a TRUST license, with a few notable exceptions as listed below:
    - You can't pilot more than one drone at a time.
    - You aren't allowed to fly your drone from another aircraft.
    - You aren't allowed to fly your drone from a moving vehicle, unless the area you are in is very sparsely populated.
- Florida follows the same regulations as the rest of the country. However, a few notable rules that were emphasized at uavcoach.com were the following:
    - You can't take pictures of private property.
    - You can't fly in certain controlled areas, like state parks and city infrastructure.
    - You can't take pictures of a person or their property who isn't visible from non-private property on the ground.

Local/Regional Regulations (Orlando):

- City of Orlando | Municipal Law Sec. 37-12. (2016)
- This law states that no drone shall fly within 500 ft of city-owned buildings and other structures. That includes schools, parks, and venues. The 500ft flight restriction also applies to gatherings that exceed greater than or equal to 1000 persons. Some exceptions are available for permit holders, costing $20 per flight. Annual permits are also obtainable for $150.

Federal Regulations:

- If flying drones for commercial purposes (or any other purpose than fun), it is required that you fly with a Part 107 drone license.
- If you aren't flying commercially, then you only need to get a TRUST license from the FAA. This requires taking a short online course with a test that follows.
- There are also other drone rules that must be followed when flying drones. While most of these are common sense type rules, one of the more significant ones is that if your drone weighs more than 250 grams, it must be registered with the FAA.
- Under the TRUST license which we are flying under, these are the more significant rules that

apply to us (faa.gov):

- Fly only for recreational purposes (personal enjoyment).
- Keep your drone within the visual line of sight or use a visual observer who is co-located (physically next to) and in direct communication with you.
- Give way to and do not interfere with other aircraft.
- Fly at or below 400 feet in Class G (uncontrolled) airspace.
- Take The Recreational UAS Safety Test (TRUST) and carry proof of test passage when flying.
- Do not operate your drone in a manner that endangers the safety of the national airspace system.

TSA Regulations:

- The drone flight cannot take any longer than ten minutes.
- The drone cannot carry more than one payload at a time.
- All propellers must be removed from the drone outside of the flight area.
- Drone pilots must take the drone through the chosen path before any payload drops will count.
- If a tie occurs at the competition, the time taken to complete the task will be used as a tiebreaker.
- Competitors are required to wear safety glasses and a high visibility vest.
- Drone may only be powered on at the discretion of the Event Coordinator.
- When a drone is outside of the competition area, the drone's stack must not be connected to power of any kind. This should include the Electronic Speed Controller (ESC).
- These rules apply regardless of it being a practice session or not.
- Any breaking of rules will result in automatic disqualification.

In response to the rules that we researched, we have taken at least the following actions:

- All three of our team members have officially passed the TRUST test, and at least the pilot will have a copy of one on hand at the competition.
- Although our drone weighs less than 250 grams in ideal conditions, with a large enough battery it weighs slightly over this. Legally, the battery counts as part of the weight, and so we have also registered our drone with the FAA. Its registration number is listed on the drone.
- We will be wearing our high visibility vest at the competition, as well as the safety glasses.

Resources:

There were a variety of different sources of information used in the production of our drone. While a big source of information was past experience from peers and teachers, there were a few notable online sources that we used extensively throughout the drone production process. Some of these sources took the form of online drone stores like getfpv.com, while others took the form of well known influencers like Joshua Bardwell. With that being said, here is a comprehensive list of the more significant online sources that had a big influence on the drone production:

- Getfpv.com
    - Getfpv is a popular online store for literally everything in the FPV drone world, as well as a huge source of information on the latest drone technology, and even the basics of drone building. This website served as our go-to store for nearly everything we used in the drone. A quick look at our bill of materials demonstrates this very clearly.
- Oscarliang.com
    - We didn't use this website for purchasing any of the actual parts used in our drone, but the quality of our drone would be significantly lower if it weren't for the knowledge that came from this site. It has very in depth information on most topics you'll come across in the drone world. Especially in the earlier phases of developing our drone, this site was helpful in deciding frame size, motor specs, propeller sizes, and many more things.
- Racedayquads.com
    - This site wasn't too extensively used, but it was helpful in finding parts that weren't listed on getfpv.com. If something was out of stock at Getfpv, this was often a site we looked to next.
- Joshua Bardwell
    - JB is not only an amazing source of information regarding drones, but is also a very fun person to watch. He has a youtube channel where he regularly posts his videos. We have probably watched more than 24 hours of his content throughout the drone production process. His videos were our main source of guidance when it came to the physical building of the drone, as well as troubleshooting. For example, he has an amazing video that teaches the proper way to solder components onto drones.
- Tsaweb.org
    - This was an obvious resource for us as we were developing the drone, after all its purpose was to compete in the UAV Drone Challenge. This site provided us with things like rules for the competition, details about the obstacle course, and a judging rubric to guide the documentation process.

As noted earlier, there were countless sources of information used throughout this project, but the ones listed above were some of the most significant and important to us.

Plan of Work Log:

Date:	Description:	Time spent:
10/18/2023	We discussed the competition and got an overview of what it was	1 hour
10/25/2023	We discussed times of freedom to attempt to construct a schedule	0.5 hours
11/15/2023	We planned design of drone and pickup mechanism	2 hour
11/20/2023	We began purchasing components to continue the design of the drone itself	2 hours
12/13/2023	We finished our prototype of the pickup mechanism	3 hours
12/20/2023	We finalized parts we were going to buy	3 hours
1/8/2024	We assembled the frame	1 hour
1/9/2024	We practiced soldering.	4 hours
1/17/2024	We received all the parts & checked if the pickup mechanism fit the frame	1 hour
1/24/2024	We began soldering the power cord	5 hours
2/7/2024	We soldered the motors	2 hours
2/13/2024	We finished soldering everything else	4 hours
2/17/2024	We began attempting to program and checked if all components worked	5 hours
2/20/2024	We resumed troubleshooting motors and ordered new ESC	4 hours
2/21/2024	We soldered new ESC & continued to troubleshoot motors with new ESC	6 hours
2/26/2024	We Fixed ESC problem by turning off bi-directional Dshot	3 hours
3/6/2024	We tested propellers and programed new ESC	3 hours
3/7/2024	First flight of drone, calibration	1 hour
3/11/2024	Practiced flying	6 hours
3/13/2024	Practiced flying	2 hours
3/14/2024	Practiced flying	2 hours
3/15/2024	Practiced flying	2 hours
3/18/2024	Practiced flying	2 hours
6/2/2024	Practiced flying	1 hour
6/7/2024	Practiced flying	1 hour
6/9/2024	Practiced flying	1 hour
6/12/2024	Practiced flying	1 hour
6/15/2024	Practiced flying	1 hour

Copyright Checklist:

STUDENT COPYRIGHT CHECKLIST *(for students to complete and advisors to verify)*

STUDENT: Answer question 1 below.

1) Does your solution to the competitive event integrate any type of music and/or sound? ☑ YES ☐ NO
   If NO, go to question 2.
   If YES, is the music and/or sound copyrighted? ☐ YES ☑ NO
   If YES, move to question 1A. If NO, move to question 1B.
   - 1A) Have you asked for author permission to use the music and/or sound in your solution and included that permission (letter/form) in your documentation? If YES, move to question 2. If NO, ask for permission and if permission is granted, include the permission in your documentation.
   - 1B) Is the music/sound royalty free, or did you create the music/sound yourself? If YES, cite the royalty free music/sound OR your original music/sound properly in your documentation.

CHAPTER ADVISOR: Sign below regarding your student's answer(s) to the use of music/sound in his/her competitive event solution. Even if your student answers "NO" to question 1, please sign below noting that you have evaluated the competitive event solution and the student answered the question(s) accurately.

I, Peter Edmondson (chapter advisor), have checked my student's solution and confirm that any use of music/sound is done so with proper permission and is cited correctly in the student's documentation and/or the solution has been found to have no music/sound included.

STUDENT: Answer question 2 below.

2) Does your solution to the competitive event integrate any graphics/videos? ☑ YES ☐ NO
   If NO, go to question 3.
   If YES, is(are) the graphics/videos copyrighted, registered and/or trademarked? ☐ YES ☑ NO
   If YES, move to question 2A. If NO, move to question 2B.
   - 2A) Have you asked for author permission to use the graphics and/or videos in your solution and included a permission (letter/form) in your documentation for graphic/video used? If YES, move to question 3. If NO, ask for permission and if permission is granted, include the permission in your documentation.
   - 2B) Is(are) the graphics/videos royalty free, or did you create your own graphic? If YES, cite the royalty free graphics/videos OR your own original graphics/videos properly in your documentation.

CHAPTER ADVISOR: Sign below regarding your student's answer(s) to the use of graphics/videos in his/her competitive event solution. Even if your student answers "NO" to question 2, please sign below noting that you have evaluated the competitive event solution and the student answered the question(s) accurately.

I, Peter Edmondson (chapter advisor), have checked my student's solution and confirm that the use of graphics/videos with proper permission and is cited correctly in the student's documentation and/or the solution has been found to have no graphics/videos included.

STUDENT: Answer question 3 below.

3) Does your solution to the competitive event use another's thoughts or research? ☑ YES ☐ NO
   If NO, this is the end of the checklist.
   If YES, have you properly cited other's thoughts or research in your documentation? ☑ YES ☐ NO

   CHAPTER ADVISOR: Sign below regarding your student's answer(s) to having integrated any thoughts/research of others in his/her competitive event solution. Even if your student answers "NO" to question 3, please sign below noting that you have evaluated the competitive event solution and the student answered the question(s) accurately.

   I, Peter Edmondson (chapter advisor), have checked my student's solution and confirm that the use of the thoughts/research of others is done so with proper permission and is cited correctly in the student's documentation and/or the solution has been found to have all original thought with no use of other's thoughts/research.

Student Name: Matthew Hammer, Owen Greenhalgh, [signature] (Jonas Gallant)

Chapter Advisor Signature: [signature]