



UAV Challenge

Spokane, Washington

2025

22437-1

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Photo Log



M3 inserts are set into the 3D printed middle plate. The inserts ensure that the PLA can't strip.



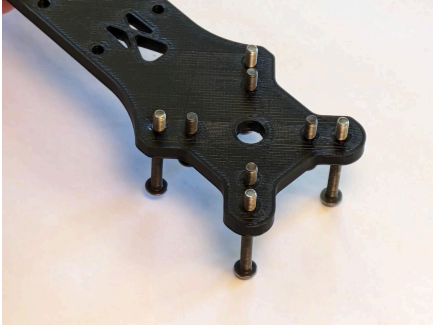
We used carbon fiber arms instead of 3D printed plastic arms. This change allowed us to customize and expand our frame while retaining the rigidity and durability of a traditional full carbon fiber frame.



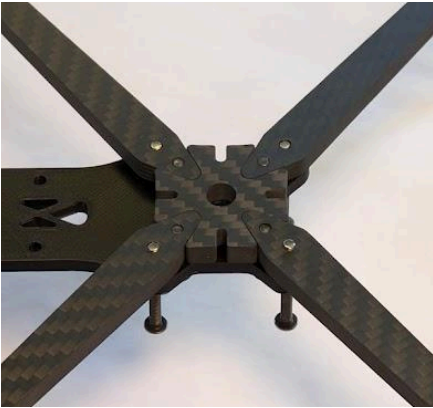
3D printed landing gear are attached to each arm. These were used for initial assembly and testing and will later be swapped for more durable landing gear with metal inserts.



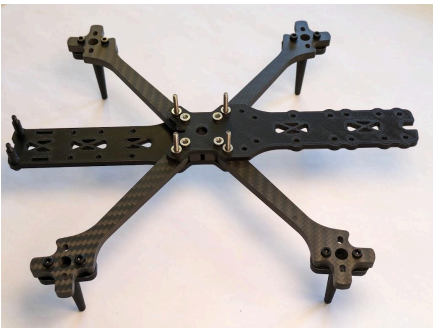
The bottom plate was also 3D printed for expandability. M3 standoffs were added to the edge for later construction.



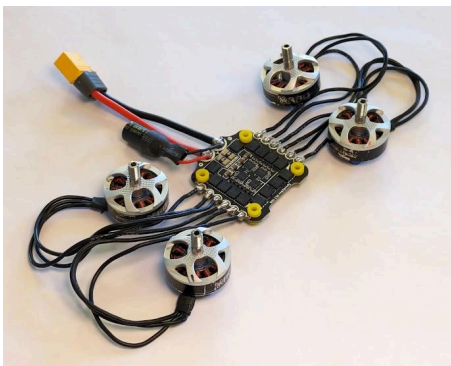
Components start to get screwed together.



The arms are mounted to the bottom plate. The center brace is also made of carbon fiber for better horizontal rigidity.

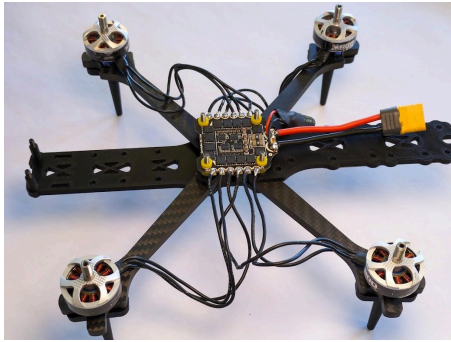


The top plate is attached to the chassis. The four protruding screws in the center are where we will mount the flight controller (FC) and electronic speed controller (ESC).



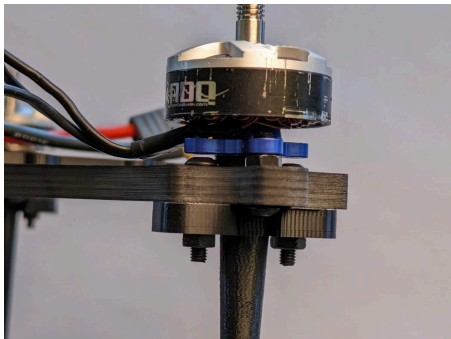
The motors are soldered to the ESC.

The XT60 LiPo connector and a capacitor are soldered to the ESC. The capacitor smooths voltage spikes to prevent brownouts and dirty power for the FC.

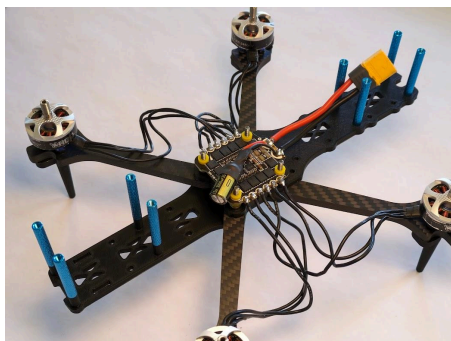


The ESC is attached to the top plate.

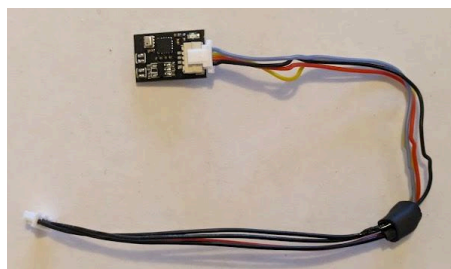
The motors are attached to the arms.



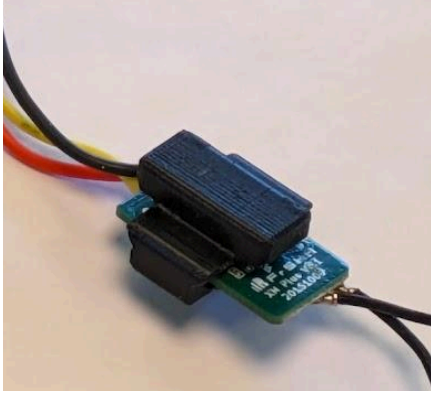
Each arm has four screw holes on the end. Two are for the motors and two are for the landing gear. The M3 spacers between the motor and the arm allow this to happen.



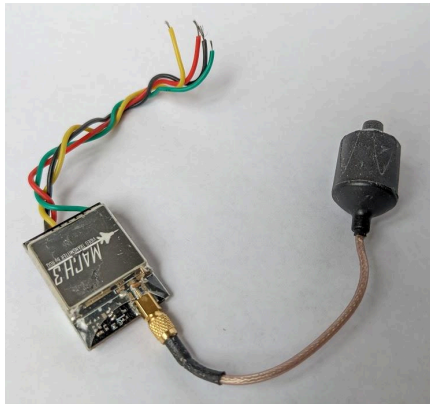
M3 space standoffs are added to the chassis plates. Later, the top plate will be attached to these standoffs.



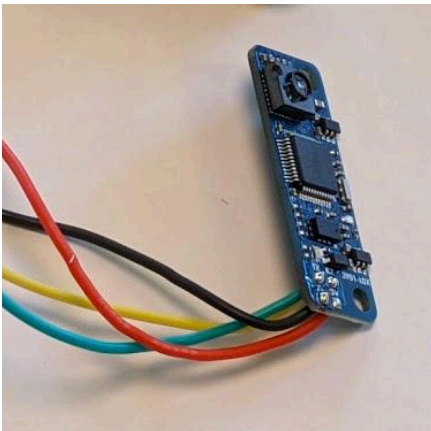
The combined barometer and magnetometer, or compass, is plugged into a custom-soldered wiring harness.



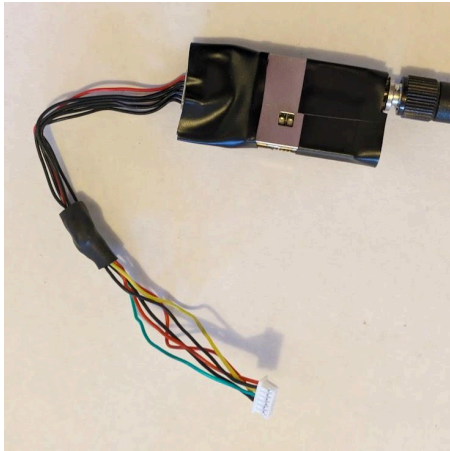
The XM+ receiver is placed in a 3D printed mount and has wires soldered onto it.



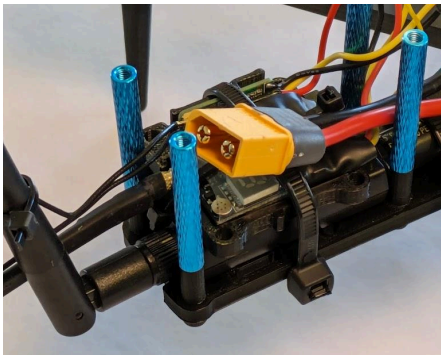
The RDQ Mach 3 video transmitter (VTX) has wires soldered onto it.



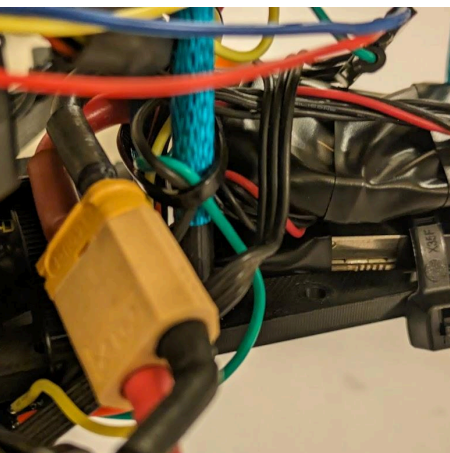
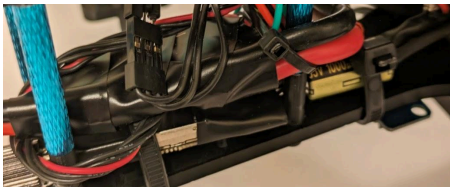
Wires are soldered onto the combined LiDAR/optical flow sensor. We are only using the optical flow function because the built-in LiDAR sensor doesn't have a long enough range.



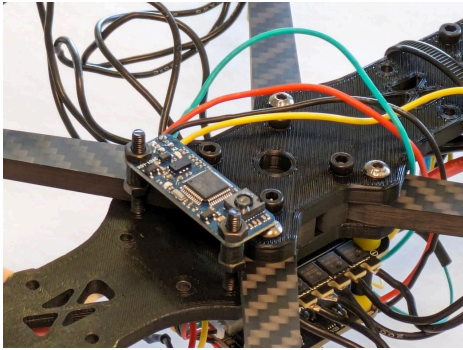
The telemetry radio is plugged into a custom-soldered wiring harness. This radio allows wireless configuration of the quadcopter, as well as the ability to see telemetry data in real time.



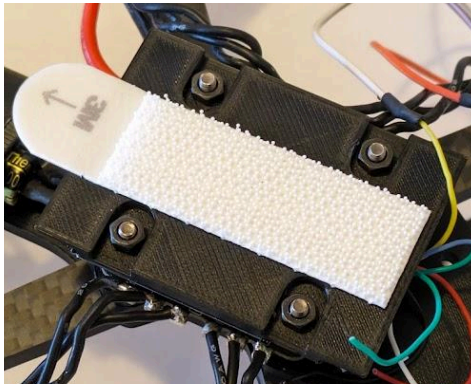
The telemetry radio and receiver are attached to the bottom plate of the chassis using a zip tie.



The power module is attached. This module provides clean power at a standard voltage for the Pixhawk.



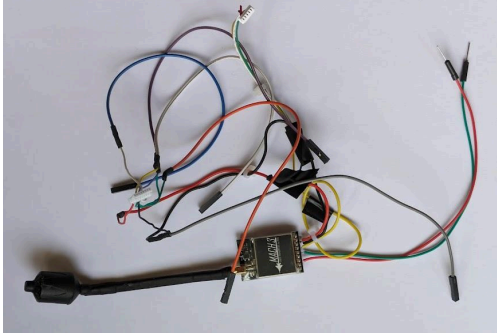
The LiDAR/optical flow sensor is attached to the underside of the bottom frame.



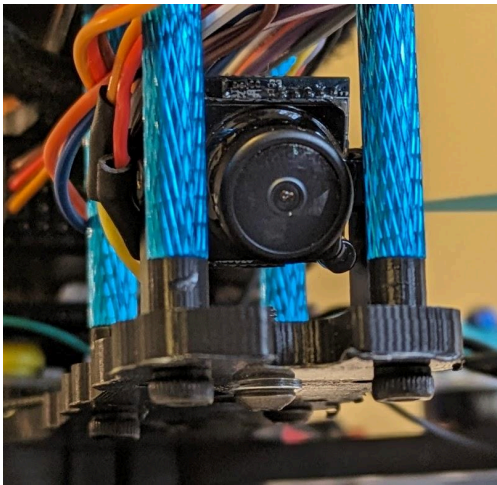
The custom 3D printed mounting plate for the Pixhawk flight controller is attached to the ESC. With velcro attached, the Pixhawk will hook in place for simple removal.



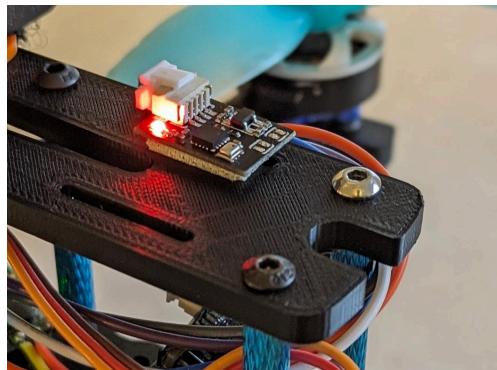
The camera is attached to a mount that we will then attach to the quadcopter.



The wiring system for the video transmitter, camera, and servo motor is soldered up. See more details in the wiring diagram.



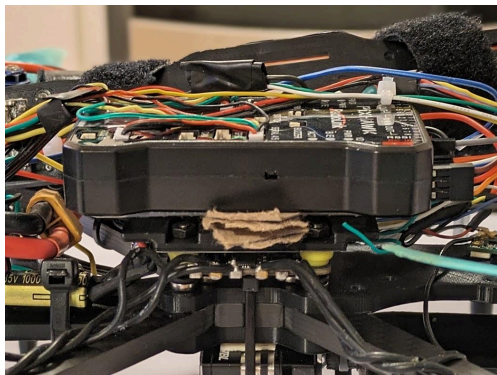
The motor and its mount is attached to the middle chassis plate.



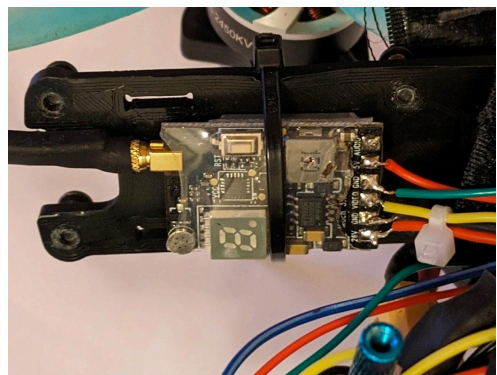
The magnetometer/barometer is attached to the top chassis plate. It has been attached far away from large metallic objects and from battery/motor cables to prevent electrical interference.



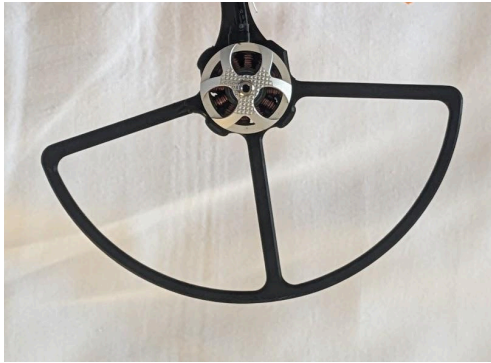
The external, more powerful LiDAR sensor is attached to the bottom of the quadcopter.



The Pixhawk is attached to the Pixhawk mount. Cardboard between the mount and the Pixhawk dampen vibrations.



The VTX is zip-tied in place to the top chassis plate.



Propeller guards are attached to the arms.



The propellers are attached to the motors.

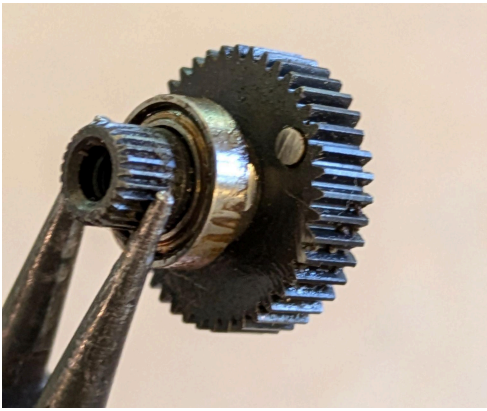


We made this new version of the landing gear with metal inserts and screws throughout, improving durability.

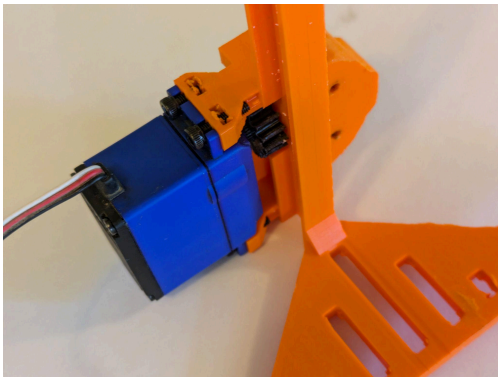


Typical servos are limited to a total of about 180 degrees. Continuous rotation servos exist, but many are too weak for our use. To overcome this, we have modified a standard servo to convert it to continuous rotation.

First, the servo is opened.



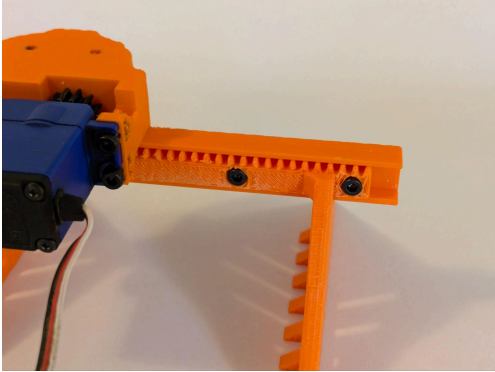
The servo is typically limited by the small light-gray pin. In the photograph, you can see that we have ground it down with a dremel to remove the limit. Additionally, we have ground down the potentiometer and glued it in place.



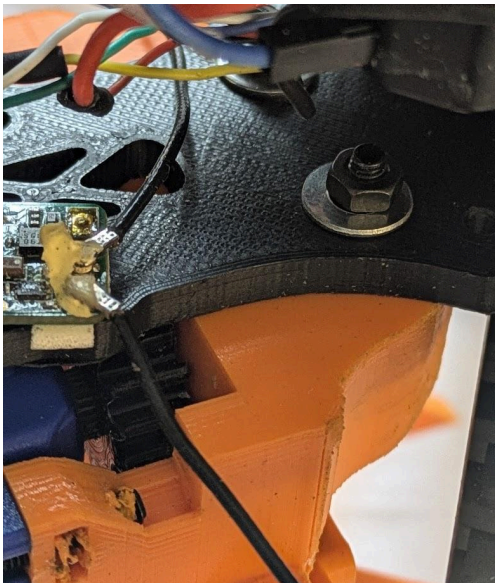
The modified servo is attached to the gripper base, and a gear is attached to the servo spline.



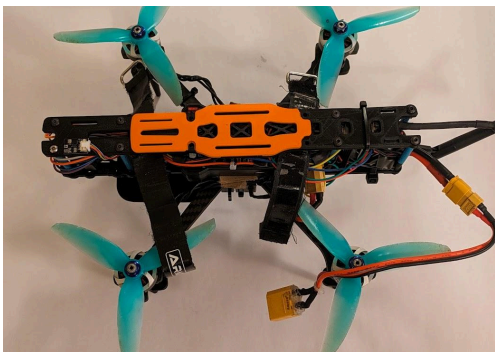
Throughout the gripper's construction, it is lubricated with candle wax for smooth operation.



The second half of the gripper and the rack is attached.

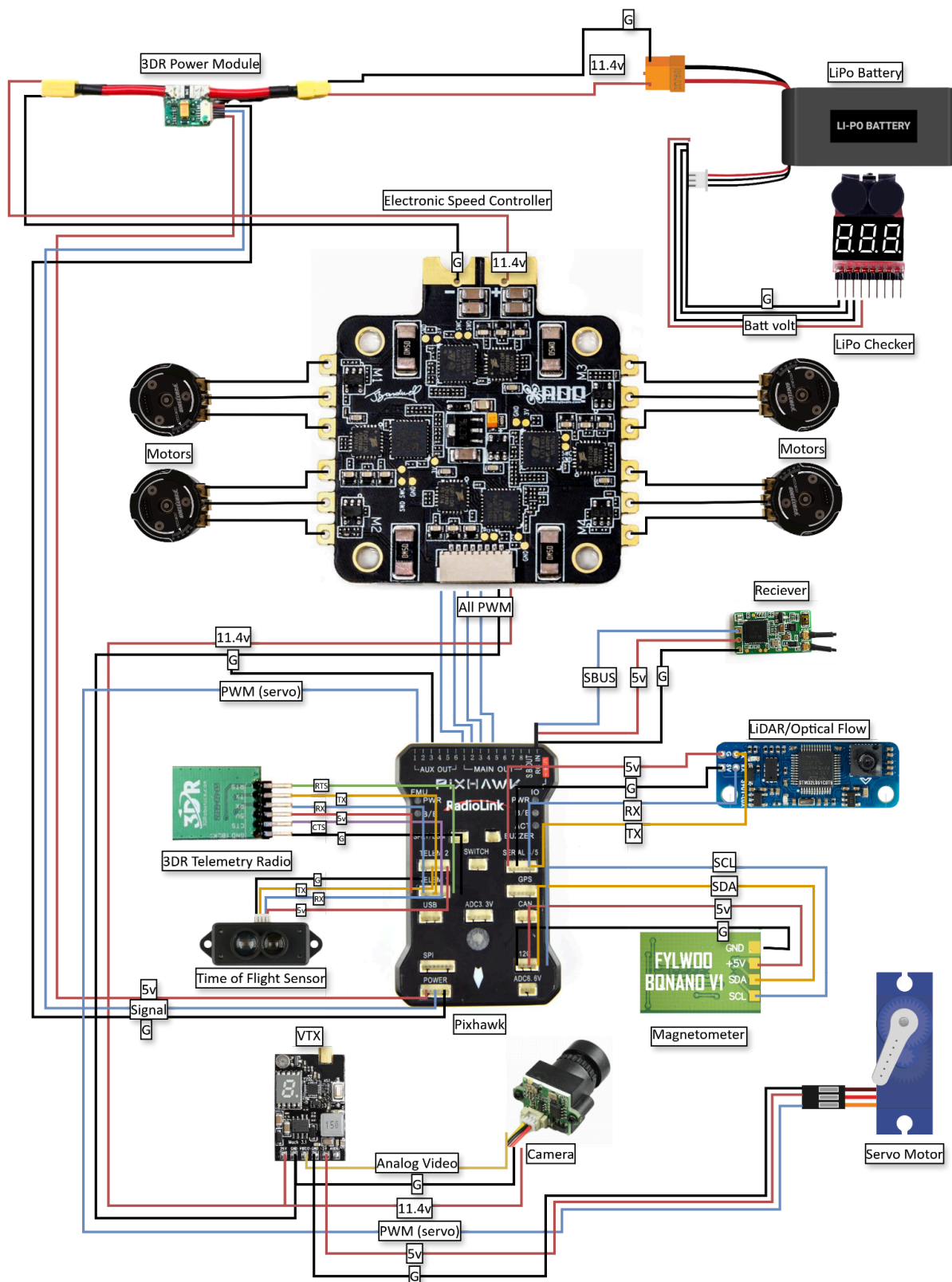


The gripper assembly is attached to the middle plate of the quadcopter. Washers and nuts keep it in place.



The top plate is attached. The orange part on top of the plate is to prevent the battery from becoming punctured by the screws that go through the top plate.

Wiring Schematic



Explanation of Code

ArduPilot

ArduPilot is an open-source piece of software that is used for flight control and autonomous navigation. This software runs on the Pixhawk. Our ArduPilot setup used a number of sensors for flight operations:

- Accelerometers, gyroscopes, and compasses: to understand its acceleration, speed, and changes in angle in a 3-dimensional space. These were built into the Pixhawk and did not have to be configured. One external compass was connected over I2C to keep it away from high-current, electromagnetically-noisy battery lines. All of those sensors were calibrated in Mission Planner for accuracy.
- LiDAR: to measure altitude from the ground. This sensor is placed facing down and times how long a beam of light takes to bounce off of the ground to measure the quadcopter's height. This allows for accurate altitude control, enhancing control. The LiDAR sensor is connected over UART to the TELEM 2 port and configured in Mission Planner.
- Barometer: to measure air pressure to find altitude; is a backup to the LiDAR. However, the LiDAR is more accurate and is unaffected by propeller wash, unlike the barometer. If the LiDAR and barometer measure dramatically different altitudes, ArduPilot uses other sensors to determine which is most accurate. The barometer is built into the I2C compass module.
- Optical flow: to measure movement, essentially a camera pointed at the ground—like a computer mouse sensor. Our goal is to enable position holding—i.e. the ability to remove all controller inputs and have the quadcopter hover, motionless. This task requires precise location measurements, and accelerometers are not accurate on their own to accomplish this—they tend to drift. A GPS receiver would usually be required for position holding, but GPS does not work indoors. However, an optical flow sensor is, of course, able to operate inside and is capable of enabling position holding, increasing the quadcopter's stability. The sensor is connected over UART to the SERIAL 4 port and configured and calibrated in Mission Planner.

There were two popular alternatives to ArduPilot that we considered and dismissed: BetaFlight and iNav. Betaflight is intended for racing drones, and, as such, it lacks the ability to use optical flow or LiDAR sensors and cannot hold altitude, much less

position. On the other hand, iNav seemed very promising: It is very easy to configure, and the quadcopter flew well without tuning. However, iNav is less powerful and less configurable than ArduPilot. For example, it is impossible to take off in Position Hold mode in iNav. Instead, the pilot must take off in Altitude Hold mode and switch to Position Hold mode in the air, which is not a limitation in ArduPilot. This limitation creates a few hazardous seconds where the pilot is not fully in control. Additionally, iNav has worse hardware compatibility than ArduPilot. Therefore, ArduPilot was the best option for our quadcopter.

Still, Ardupilot led to some challenges. There were strong oscillations in-flight, and completing pre-arm checks were difficult. Oscillations were solved by turning down PID loop sensitivity, making the drone feel “floaty” but led to a controlled flight. ArduPilot normally looks for GPS, battery sensors, and more before allowing the pilot to arm. We disabled those checks because we are flying in a close space where those features are unnecessary. Finally, configuring all sensors took time but was doable with help from our resources.

Mission Planner

Ardupilot is configured through the use of parameters—hundreds of values that refer to specific settings. To configure something specific in ArduPilot, the user must edit one of those parameters. To tell ArduPilot that our optical flow sensor uses the MSP communications protocol, for example, we must set the `RNGFND1_TYPE` parameter to the value of 32, which internally represents MSP. This is where Ground Control Station—or GCS—software comes in. This software allows the user to easily change parameters in a human-readable format. Furthermore, many GCS software choices let the pilot view live telemetry data, access flight logs, and more. There are two primary GCS choices for Ardupilot: Mission Planner and QGroundControl. QGroundControl is cross platform and has a more user-friendly interface. However, its capabilities are more limited than Mission Planner, so we decided to use Mission Planner.

If we were operating with GPS, Mission Planner would let us create waypoints and define commands for autonomous use—but, of course, we aren’t performing those operations. However, Mission Planner still gives real-time telemetry data using the 3DR radio, which tracks the vehicle’s altitude, speed, battery voltage and draw, and sensor readings. Using this information, fine adjustments can be made to the drone using Mission Planner in conjunction with ArduPilot. Flight logs are also recorded for review later on, which can give us important insights about the drone's behavior.

Bill of Materials

Quantity, Price	Product Name	Notes
4, \$3.99	RDQ Source One V5 5" 6mm Arm	The RDQ Source One V5 5" 6mm Arms are durable carbon fiber arms.
1, \$1.49	RDQ Source One V5 Cross Plate	All the arms lock into this central piece. It is a crucial structural component of the quadcopter.
1, \$149.00	Radiolink PIXHAWK Flight Controller with Power Module	The flight controller is a circuit board that controls all aspects of the drone; the sensors and all flight information pass through the flight controller. The power module steps the battery voltage down to 5v for the Pixhawk.
1, \$49.99	Joshua Bardwell 32BIT 4-IN-1 3-6S 30A ESC	The electronic speed controller takes the battery voltage and "listens" to the flight controller to give the motors power. It alternates between powering each of the three wires of the motor to cause motor rotation.
1, \$26.99	RDQ Mach 3 VTX	The video transmitter is a board that is used to transmit video feed from the quadcopter's camera into radio waves so that they can be displayed on a digital screen like a computer or goggles.
1, \$119.00	FrSky QX7 TX	The transmitter is used to control the drone's movement. It also controls the drone's arming status and flight modes (like Altitude or Position Hold mode).
1, \$17.30	FrSky XM Plus Receiver	The mini receiver is a small board that receives signals from the transmitter and sends it through the flight controller. This receiver communicates with the flight controller using the SBUS protocol.
1, Unavail- able	3DR 500MW Radio Telemetry Kit, 915Mhz	This telemetry radio lets the Pixhawk communicate with the PC running Mission Planner, and vice versa.
4, \$15.99	RDQ 2306 2450Kv Brushless Motors	The motors are used to spin the propellers at a certain speed to provide the correct amount of lift.
4,	HQ Prop 5x4.3x3	The propellers are spun by the motors to create lift.

\$3.69	V1S Tri-Blade 5" Props	
1, \$14.99	RunCam Nano 2 Camera	The camera records an analog video feed that is sent to the video transmitter so that it can be broadcast to the pilot.
1, \$14.99	VAS Minion U.FL 5.8GHz Antenna	The antenna converts electrical signals into electromagnetic waves to broadcast the video.
1, \$32.39	Zeee 3S Lipo Battery 5200mAh 11.1V 80C	The LiPo battery powers the quadcopter.
~52, \$9.99	M3 Black Steel 280 Piece Nut & Bolt Kit	The steel anodized screws hold the drone together.
16, \$2.99	M3 Knurled Aluminum Standoff	These are used to separate the top plate from the middle and bottom plate.
1, \$8.49	Pyrodrone Solder Spool - 63/37	The spool of solder is used to connect electrical components.
1, \$129.99	Traxxas 2075 servo motor (modified)	The servo is connected to the bottom of the drone and to the tray and controls the gripper.
1, \$29.99	Mateksys Optical FLOW 3901-LOX	This combination sensor provides horizontal and vertical positioning information.
1, \$52.99	Benewake TFmini Plus	The LiDAR sensor provides more accurate vertical positioning information.
1, printed	Bottom Plate	This is the lowest of the three frame plates. It is an original design.
1, printed	Middle Plate	This is the middle frame plate. It is an original design.
1, printed	Top Plate	This is the top frame plate. It is an original design.
1, printed	Tray	This is the tray where the payload will reside. It is an original design.
4, printed	Landing Gear	This is attached to the bottom of the arms. It is an original design.

Rules and Regulations

FAA Regulations

The Federal Aviation Administration has established regulations for recreational drone operations under 55 lbs under Part 44809. To fly drones outdoors for recreation, ten requirements must be met (shown below). Note, though, that we are flying in an enclosed area at the State Conference, meaning that it is *not* considered national, navigable airspace. **Because we are flying indoors, we are exempted from Part 44809 regulations.** During outdoor tests, we followed these ten regulations. Below, we have explained how they would be applied in Spokane, WA if we were flying outdoors:

1. **Operate drones solely for recreation:** Yes, our team is not profiting from this event.
2. **Follow the safety guidelines of an FAA-recognized Community Based Organization:** Yes, we are following the regulations of the FAA-recognized FPV Freedom Coalition.
3. **Maintain visual line-of-sight with the drone or use a visual observer who is in direct communication with the operator:** Yes, we have a “spotter” on our team who watches the quadcopter.
4. **Give way to and avoid interfering with other aircraft:** Yes, the only aircraft in the competition area are other quadcopters, and only one will fly at a time.
5. **In controlled airspace, obtain prior FAA authorization through LAANC or DroneZone and fly at or below FAA-authorized altitudes:** LAANC approval is unavailable in the Spokane Convention Center area. However, we are flying indoors, so this does not apply to us. We flew with LAANC approval during outdoor test flights leading up to the event.
6. **In uncontrolled (Class G) airspace, fly at or below 400 feet:** This regulation is overridden by regulation #5, as the resort is not located in Class G airspace.
7. **Pass the Recreational UAS Safety Test (TRUST) and carry proof of passage during flight operations:** Yes, our pilot has passed the TRUST Test and will carry a certificate during flight. The certificate authentication token is IAMA63320937138.
8. **Register drones with the FAA, mark them with the registration number, and carry proof of registration during flight operations:** Yes, the registration number is FA3CRFYHLH, and we flew with the number attached during outdoor tests. Because the competition area is indoors and is not FAA-controlled airspace, we do not need to mark the quadcopter while competing.

9. **Ensure drones broadcast Remote ID information unless flown within a FRIA (FAA-Recognized Identification Area):** If we were flying in navigable airspace, we would need a Remote ID module. However, we are flying the quadcopter in an enclosed location and do not need to follow FAA regulations, as explained above.
10. **Operate drones in a manner that does not endanger the national airspace system:** Yes, following these regulations and exercising common sense ensures that our quadcopter would not be a danger to aircraft.

Overall, most of the above requirements are only applicable if the quadcopter is flown in FAA-controlled airspace. Because the competition takes place inside, it is not FAA-controlled airspace. We met many of those requirements purely for the principle of it.

Ham Radio

When using anything that broadcasts a radio signal, The Federal Communications Commission requires that it follows certain rules and regulations. In the instance of flying a UAV that transmits video, an amateur technician class radio operator's license is needed because the video transmitter has the potential to disrupt other signals. Possession of this license shows that the person understands the FCC rules and can be trusted to safely operate radio broadcasting equipment. One of our team members has passed the Ham radio exam and is able to legally operate the video transmitter.

Washington Regulations

Generally, the drone regulations present in the state of Washington protect people's privacy and prohibit drones without a permit on state-managed lands such as state parks. Commercial drones must be registered with the Washington Aviation Division. We will not be breaking these laws at the UAV Challenge event.

Spokane Regulations

Because of the quantity of airports and manned aircraft in Spokane, airspace and LAANC approval is highly limited. Because we are competing indoors, we will not be breaking these laws at the UAV Challenge event.

Resources

ArduPilot. "ArduPilot Discord Server." *ArduPilot*, 2022, ardupilot.org/dev/docs/ardupilot-discord-server.html. Accessed 31 Mar. 2025.

The ArduPilot Discord server was used in a similar way as other forums; it provided access to quick support and troubleshooting tips. We used the provided help channel to make sure we did not bother other areas of the server.

ArduPilot Community Members. "ArduPilot Discourse." *ArduPilot*, 2025, www.discuss.ardupilot.org.

The ArduPilot forums were used to ask other people questions about building drones and to get information on drones in general.

ArduPilot Developer Team. "ArduPilot Copter Documentation." *ArduPilot*, 2024, www.ardupilot.org/copter/index.html.

The ArduPilot landing page gave information about system components, how to fly, and how to land. The ArduPilot wiki was used to find information on radios, wiring, hardware, framing, configuring flight controller software, etc.

Bardwell, Joshua. "2022 Freestyle FPV Drone Build (DIY Kit for Total Beginners)." *YouTube*, 2022, www.youtube.com/watch?v=2T_JC4v5T3E. Accessed 21 Feb. 2023.

The FPV Drone build video on Joshua Bardwell's YouTube channel helped with learning how to build the frame for the quadcopter.

---. "Most FPV Pilots Need to Watch This Soldering Tutorial." *YouTube*, 6 Nov. 2021, www.youtube.com/watch?v=GoPT69y98pY.

The Soldering Tutorial on Joshua Bardwell's YouTube channel helped with learning how to solder the components of the drone; many of small tutorials like this were very helpful during the construction of the quadcopter.

IntoFPV Community. "IntoFPV Forum." *IntoFPV*, 2025, www.intofpv.com/index.php.

The IntoFPV Forum was used to gather information from other people about FPV drones. The IntoFPV Forum was used a lot during the beginning of building, designing, and troubleshooting the drone.

Liang, Oscar. "How to Build an FPV Drone Tutorial (DJI & Analog)." *Oscar Liang*, Feb. 2023, www.oscarliang.com/how-to-build-fpv-drone/.

The “How to build an FPV Drone” tutorial helped with the intro to building quadcopters; it also provided lots of information about quadcopters in general..

PX4. “PX4 User Guide.” *PX4 Documentation*, 2025, docs.px4.io/main/en/.

The PX4 User guide docs were used in a very similar way as the IntoFPV Forum; it was mainly used to gather information from other users on the platform. The PX4 User guide was very useful for troubleshooting small problems when it came to the construction of the quadcopter and small parts of the quadcopter.