

Water Drone Handoff Document

Pinyon Environmental
Colorado School of Mines



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Operation Guide

Ground Station & Radio Configuration

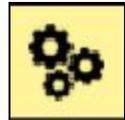
The ASV is designed to use QGroundControl (QGC) as its ground station software. This is the software that is used to plan missions and configure settings on the ASV. QGC runs on the ground station computer (*not* the ASV itself).

QGC is open-source and runs on Windows, Mac OSX, Linux, Android, and iOS. We recommend using a laptop as your ground station computer if possible. Though it *should* work with an iPad or mobile device, we have not tested that functionality. Please follow [the QGC installation instructions](#) for your device.

QGC is not to be confused with ArduPilot, which is the *firmware* that runs on the PixHawk 4. QGC is used for planning missions; ArduPilot executes the missions on the ASV. Your direct interaction with ArduPilot will be limited to the occasional firmware update (see corresponding tutorial below).

Accessing Configuration

To access the QGC configuration menus, select the gear icon in the top left corner of the screen. All other instructions in this section begin from this step.



Sensor Calibration

1. Navigate to the Sensors page on the left sidebar.
 2. Unplug everything from the PixHawk except the GPS module (labeled GPS)
 3. Plug the PixHawk into your laptop via USB. It should make a lot of sound to indicate it is connected.
 4. Accelerometer Configuration
 - a. Select the Accelerometer option and follow the instructions in QGC.
 5. Compass Configuration
 - a. Select the Compass option and follow the instructions in QGC.
-

Radio Configuration

You should not need to make any changes to the radio configuration. We have adjusted the ASV parameters so that the transmitter remote should work out-of-the-box. If you need to make adjustments to the radio configuration, please see [QGC's documentation](#) and this helpful guide.

On the right side of the Radio settings page, there is a graphical display of the current switch states. This may be helpful for debugging problems with the remote.

Airframe Selection

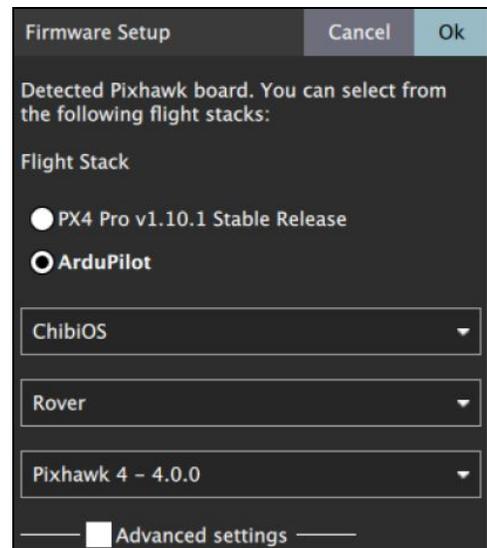
The 'airframe' tells QGC what type of vehicle you are using. You should not need to edit any of the Frame settings. This section is provided for reference and troubleshooting only.

1. Select "Frame" in the left sidebar.
 2. Select the "Boat" frame.
-

Updating the Firmware

There are periodic updates to the ArduPilot firmware. Follow these steps to update the firmware on the PixHawk to the newest version.

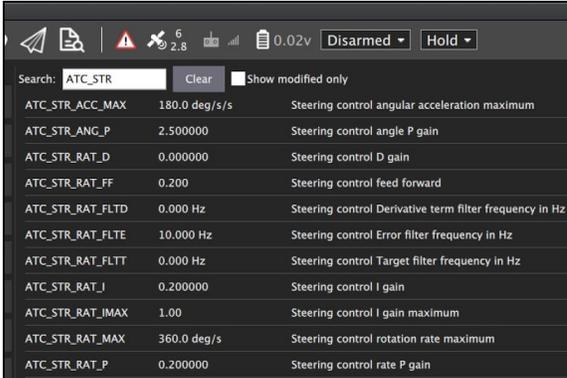
1. Navigate to the Firmware page on the left sidebar.
2. Make sure the PixHawk 4 is connected to your computer via USB.
3. Follow the instructions on the screen to conduct the firmware update. This will not overwrite any of the vehicle parameters.
 - a. Select the ArduPilot radio button on the right sidebar when it appears.
 - b. Make sure the dropdown menu options are "ChibiOS", "Rover", and "Pixhawk 4".



Tuning the Control System

The ASV runs on a software-implemented PID control system. The control system is defined by tunable parameters, which determine the amount of power sent to the motors based on the current GPS position, speed, etc. Once the parameters are set properly once, they should not need to be adjusted again (barring major changes to the ASV). Without the ability to perform extensive, in-person testing of the ASV, we could not properly tune the control parameters. These steps will show you how to adjust them in QGC.

1. This tuning operation will need to be done with the boat in the water. Some tests will just be watching the manual performance, but others may require putting in a simple 1-2 waypoint mission.
2. Bring the ASV to a lake or pond – any outdoor body of water over 100 ft in one dimension should work.
3. Open QGC on the ground station computer. Make sure that the telemetry radio is plugged into USB so that you can interact with the ASV while it is in the water.
4. Open the QGC configuration page and navigate to “Parameters” on the left sidebar (see image on right).
5. You will probably need to adjust the parameters that control: (a) [steering](#), and (b) [speed](#). Click the links to find guides on how to adjust each parameter.
 - a. The video guides use a different mission planner (*i.e.* not QGC) than our system. That is okay – you can still follow the methods shown in the video and apply them to the QGC interface. They are quite similar.
 - b. We suspect the speed control parameters need only minor adjustments. They may even work out-of-the-box.
 - c. Make sure that the ASV is stationary and the remote is disarmed before tweaking the parameter values in QGC.
 - d. It may take many trials of adjustment and testing before you settle on the best parameter values.



The screenshot shows the QGC Parameters page with a search filter set to 'ATC_STR'. The parameters listed are:

Parameter Name	Value	Description
ATC_STR_ACC_MAX	180.0 deg/s/s	Steering control angular acceleration maximum
ATC_STR_ANG_P	2.500000	Steering control angle P gain
ATC_STR_RAT_D	0.000000	Steering control D gain
ATC_STR_RAT_FF	0.200	Steering control feed forward
ATC_STR_RAT_FLTD	0.000 Hz	Steering control Derivative term filter frequency in Hz
ATC_STR_RAT_FLTE	10.000 Hz	Steering control Error filter frequency in Hz
ATC_STR_RAT_FLTT	0.000 Hz	Steering control Target filter frequency in Hz
ATC_STR_RAT_I	0.200000	Steering control I gain
ATC_STR_RAT_IMAX	1.00	Steering control I gain maximum
ATC_STR_RAT_MAX	360.0 deg/s	Steering control rotation rate maximum
ATC_STR_RAT_P	0.200000	Steering control rate P gain

Flight Modes

You should not need to edit any of the Flight Mode settings. This section is provided for reference and troubleshooting only.

1. Make sure that the Flight Mode Channel is set to Channel 5, or to the channel corresponding to the switch on the RC remote you want to control the flight mode with.
2. Make sure that Flight Mode 1-5 are set to "Manual", and Flight Mode 6 is set to "Guided". These should be the only important flight modes.
3. Make sure that Channel option 6 and 7 are set to "ArmDisarm" and "Motor Emergency Stop", respectively. You could also map them to a different switch with corresponding channel if desired.

Flight Mode Settings		Switch Options	
Flight mode channel:	Channel 5	Channel option 6 :	ArmDisarm
Flight Mode 1	Manual PWM 0 - 1230	Channel option 7 :	Motor Emergency Stop
Flight Mode 2	Manual PWM 1231 - 1360	Channel option 8 :	Do Nothing
Flight Mode 3	Manual PWM 1361 - 1490	Channel option 9 :	Do Nothing
Flight Mode 4	Manual PWM 1491 - 1620	Channel option 10 :	Do Nothing
Flight Mode 5	Manual PWM 1621 - 1749	Channel option 11 :	Do Nothing
Flight Mode 6	Guided PWM 1750 +		

Power Configuration

You may or may not need to edit these settings. If you add a second battery to the vehicle in a parallel configuration, you will need to adjust the mAh (miliamp-hour) rating on this screen accordingly. For additional resources on power configuration, [view this guide](#). Note that the guide's author is not using QGC as their ground station software. Though the interface may be slightly different, the method is the same in QGC.

Charging the Battery

It is imperative that the battery be handled properly. Please follow these safety guidelines:

- **Never** directly connect the +/- battery terminals, submerge the battery in water, or reverse the polarity of the charging cables.
- **Never** bridge any two terminals on top of the battery. Best practice is to only use one hand when making connections on top of the battery. Keep the plastic terminal covers on the battery any time you are not making measurements with a digital multimeter or monitoring the charge status LEDs.
- **Never** allow a battery cell to drop below 2.5V.
- **Never** allow the total battery voltage to drop below 12V (or 14.5V with 5 cells).
- **Never** charge a battery cell above 3.8V.
- **Never** charge the battery unsupervised.
- **Always** follow the steps under "Charging the Battery for Storage" if you do not plan to use the battery for more than one week.

Charging the Battery for Use

Follow these instructions if you will be using the ASV within the next week. Otherwise, follow the instructions for "Charging the Battery for Storage".

1. Connect the battery charger to wall power.
2. Find the battery charging cable. One side is split into two banana plugs. The other side is a yellow XT60 connector.
3. Plug the red and black banana plugs into the matching jacks on the front of the battery charger. Make sure to use the left-side jacks (labeled with a 1).
4. Double-check that the black wire is plugged into the black jack, labeled "-", and that the red wire is plugged into the red jack, labeled "+". **Explosion and injury may occur if you reverse the polarity.**
5. The top LCD screen should read "PROGRAM SELECT". All following instructions refer to the top LCD screen and the buttons next to it.
6. Use the +/- keys to navigate to the "LOAD MEMORY" option. Press enter/play.

7. Navigate through the options using the +/- keys until the screen reads:

```
LS> LiFe CHARGE
10.0A 13.2V(4S)
```

8. Press enter/play to select the program. The screen should read "LiFe Charge".
9. Plug the XT60 connector into the battery. You do not need to worry about reversing the polarity here, because it only fits in the correct direction.
10. Hold down the enter/play button until the device beeps, then let go.
11. Press enter/play button once more to confirm settings and begin charging.
12. The battery is fully charged when both LEDs on each battery cell are on. Allow the battery to continue charging for about 10 minutes after the LEDs turn on, then power off the charger and unplug the battery.
 - a. Please read *Advanced Battery Charging* before proceeding.
 - b. The battery voltage goes down slightly when the charger is disconnected. That is why we recommend leaving it plugged in for 10 minutes after the LEDs come on.

Advanced Battery Charging

1. If the battery is left charging unsupervised, some cells may become overcharged. This is *not good*.
2. If you suspect the battery may be overcharged, monitor the voltage across each cell with a digital multimeter. The voltage on each cell should be between 3.6V and 3.8V.
3. If one or more cells are charged higher than 3.8V, permanent damage may occur. You must allow the battery to passively discharge through the balancing PCBs.
 - a. Press the "Stop" button on the battery charger.
 - b. Let the battery sit until all cells read below 3.6V with a digital multimeter.
 - c. Follow steps 8-10 under "Charging the Battery for Use".

Charging the Battery for Storage

1. Follow steps 1-7 under “Charging the Battery for Use”.
 2. Use the +/- keys to navigate to the “LiFe Storage” option. Press enter/play.
 3. Follow steps 8-10 under “Charging the Battery for Use”.
-

Configuring the Battery Charger for the 5S Configuration

At the time of writing, the battery is in a 4S (4 cells connected in series) configuration. It was our intention to upgrade the battery to a 5S (5 cells connected in series) configuration.

When the battery is upgraded to a 5S configuration, the charger settings will need to be changed. Please follow the charger’s user manual to configure the battery for “LiFe CHARGE // 10.0A 16V(5S)”.

Troubleshooting the Battery Fuse

If you notice that power to the PixHawk is fading in and out, check the connections to the battery fuse. We have had problems with the screw-terminal connections on the fuse coming loose in the past. It can be quite tricky to diagnose if you’re not looking for it.

About the Battery

This battery is capable of continuously supplying upwards of 40A of current – if handled improperly, it could be very **dangerous**. Exercise caution at all times when handling it. Treat it like you would a car battery or a box full of day-old kittens.

The battery is (as of April 2020) an “LiFe 12.8V 40Ah 4S” battery.

Let’s dissect what that means:

- LiFe → Lithium Iron, refers to the construction of the battery.
- 12.8V → this is the total nominal voltage across all four cells of the battery.
- 40Ah → Ah is short for ‘amp-hours’. This is a measure of how much charge the battery can store. This battery could supply 40A of current for 1 hour before being fully discharged.
- 4S → this means that we have connected 4 cells in series. Each cell is 3.2V nominally. Since we connected the cells in series,

the overall battery voltage is the sum of the cell voltages. If we instead connected them in parallel, the overall battery charge capacity would be the sum of the cell charge capacities.

The term *nominal voltage* is a bit confusing. When the battery is fully charged, it will exceed the nominal voltage by a little bit. When the battery is discharged, it will be below the nominal voltage by a larger margin. You might think of it as the 'average' voltage across the battery terminals.

If you ever need battery advice, we recommend calling the experts at [AA Portable Power Corp.](#) Their phone number is 510-525-2328. We spoke to them multiple times when designing the battery, and found them to be extremely helpful.

Autonomous Mission Planning

The information in this section will help you set up autonomous missions and upload them to the ASV.

Planning a New Mission

1. Open QGC on your ground station computer.
2. Make sure the PixHawk is *not* connected to the ground station computer via USB.
3. Click on the Waypoint icon in the top menu bar of QGC. It is between the Gear icon and Paper Airplane icon.
4. To plan a new mission, select "Blank" under the "Create Plan" header.
5. Use your mouse to find the mission location (e.g. Cherry Creek Reservoir) on the satellite map.
6. Click the "Takeoff" button in the left sidebar, then click on the map to set the starting waypoint for the mission.
 - a. The starting waypoint is the point where autonomous mode will be activated (not necessarily the exact location where you put the ASV in the water).
 - b. We recommend choosing a position slightly offshore from the launch site. You can then put the ASV in the water, activate it in Manual Mode, drive it to the Takeoff waypoint, and engage Autonomous Mode.
7. To add waypoints, choose the "Waypoint" icon in the left sidebar. Clicking on the satellite map will add successive waypoints.

- a. You may click and drag waypoints to reposition them.
 - b. To add a waypoint between two existing waypoints, click the white + on the orange connecting line.
 8. Once you are done adding waypoints, select the "Return" button. The path will automatically be rerouted to end at the Takeoff location chosen earlier.
 9. In the right sidebar, select "Mission", then "Mission Start" in the dropdown. Set the altitude to 0.
 10. Follow the steps under "Uploading a Mission to the ASV".
-

Editing an Existing Mission Plan

1. Open QGC on your ground station computer.
 2. Click on the Waypoint icon in the top menu bar of QGC. It is between the Gear icon and Paper Airplane icon.
 3. To edit an existing mission plan, select "Open..." under the "Storage" header.
 4. Edit the mission plan as described under "Planning a New Mission"
-

Advanced Waypoint Options

This guide demonstrates how to configure the ASV to hold its position as or pass through a waypoint.

1. While editing an autonomous mission, select a waypoint.
 2. To have the ASV hold position at the waypoint:
 - a. In the right sidebar, set the Hold time for the waypoint.
 3. To have the ASV pass through the waypoint at a specified speed:
 - a. In the right sidebar, set the Flight Speed for the waypoint.
 4. Repeat as necessary for each waypoint.
-

Planning a Survey Mission

1. Follow steps 1-6 under "Planning a New Mission"
2. In the left sidebar, select "Pattern".
3. A new menu will appear near the top of the screen. Select "Trace".
4. Use the mouse to select the outline of the area you would like to survey on the satellite map.
5. Adjust the settings in the right toolbar as needed.
 - a. Make sure Altitude is set to 0.00.

- b. Set Turnaround dist to 0.00.
 - c. You will likely want to configure Spacing and Angle as well.
 - d. Trigger Dist determines how frequently the ASV takes photos. Since we do not have a camera setup, you can set this to 0. However, it may come in useful in the future. See the section on data collection in the "What We Didn't Get To" section of this document.
-

Uploading a Mission to the ASV

1. After you have set all the waypoints and return point for the mission, select "File" in the left sidebar.
 - a. If you would like to upload an existing mission, open the mission in the "File" menu and skip step 2.
 2. Choose "Save As..." and save the mission file wherever you like on the ground station computer.
 3. Plug the PixHawk in via USB (if it is not already). Hit the "Upload" button in the top right corner of the screen.
-

Conducting a Mission

Turning on the Remote

1. Press and hold the power button until the four squares light up on the LCD screen. If you do not hold down the power button long enough, it will beep and turn off.
 2. A "SWITCH WARNING" message will appear. Press any button to ignore the warning.
 3. The LCD screen should read "water bot". Continue to step 5.
 4. If the LCD screen reads "Throttle not 0", simply reset the left joystick to the 0-position.
 5. Arm the remote by flipping the Arm Lever all the way forward (towards you). Note that the lever has three positions, and the middle one is not used.
-

Conducting a Manual Mission

1. Follow all steps under "Turning on the Remote".
2. Flip the Mode Switch to the back position (away from you). This puts the ASV in Manual Mode.

3. Use the remote to pilot the ASV. You do not need to have QGC open when operating in manual mode, though it may be helpful to view the ASV's location, speed, etc.

Conducting an Autonomous Mission

1. Make sure that the correct autonomous mission has been uploaded to the PixHawk (see instructions above).
2. Follow all steps under "Turning on the Remote".
3. Flip the Mode Switch to the forward position (towards you). This puts the ASV in Autonomous Mode.
4. The ASV will automatically conduct the Autonomous Mission.
5. If at any time, you wish to regain manual control (e.g. the ASV gets stuck on an obstacle), simply flip the Mode Switch to the back position (away from you). You can now pilot the ASV with the remote control.

Killswitch

Flipping the Killswitch at any time during ASV operation will immediately turn off the motors. If desired, you may then put the ASV mode in Manual Mode and reset the Killswitch to recover it from a sticky situation.

Manual Trim Control

It is possible to adjust the trim settings on the remote manually. We have found this is quite easy to do by mistake, and may lead to reduced vehicle performance.

The manual trim adjustment switches are located on either side of the power button, and just above the LCD screen on the radio transmitter.

Check the LCD screen. You will see small 'scrollbars' along the sides and at the bottom. There is a small icon on the bar, which has either one or two dashes in it. If the icon shows two dashes, it means that the trim is set properly. If the icon shows one dash, adjust the corresponding trim switch until the icon is centered on its respective bar and displays two dashes.

Construction Guide

Wiring Guide

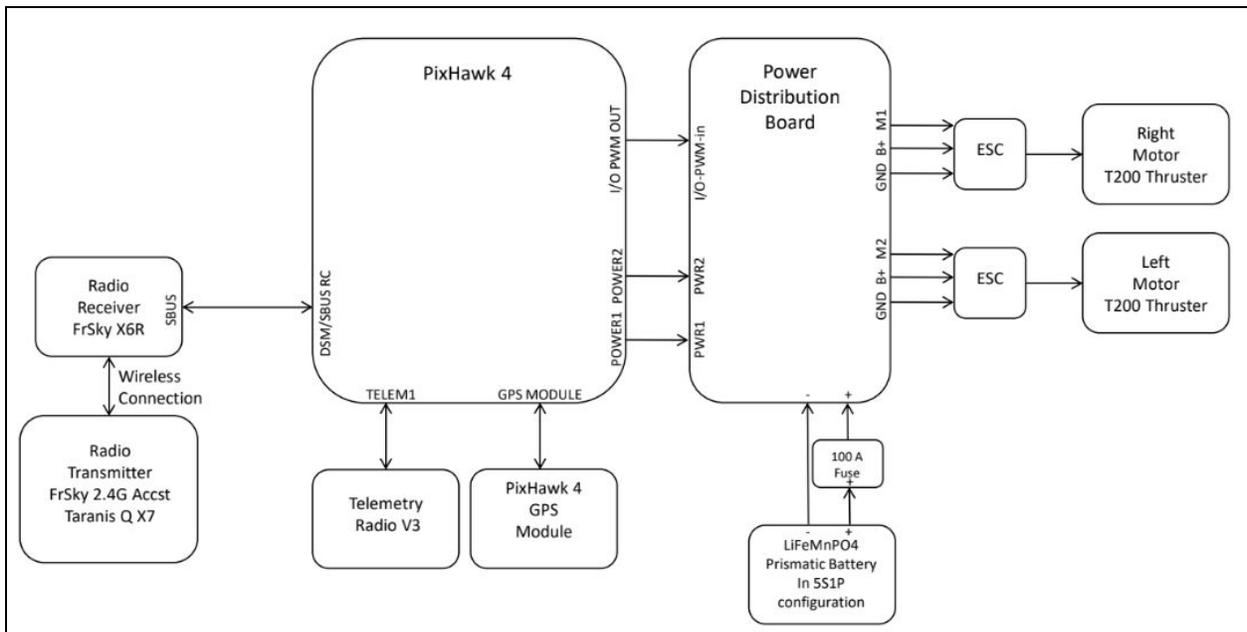
For a detailed visual representation of the wiring involved, refer to the Blackbox Wiring Diagram and the Visual Wiring Diagram (below).

The Blackbox Wiring Diagram names the specific connections connecting the individual electronic systems. The Visual Wiring Diagram presents a top-down view of the entire electronics package wired, with labels of the individual parts.

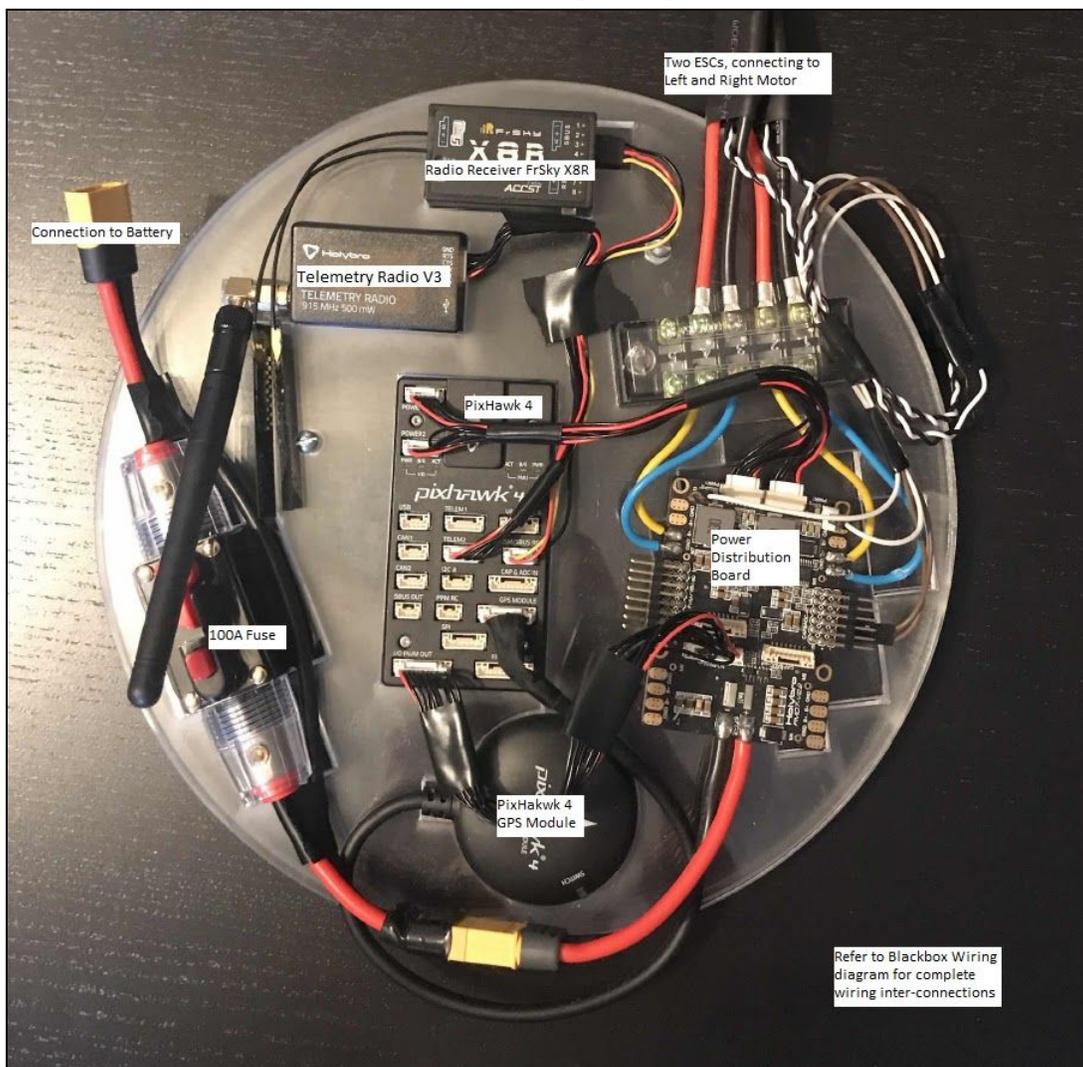
Refer to both diagrams when constructing the electronics. For example if the Blackbox Wiring Diagram tells you there is a connection between the PixHawk 4 and the Telemetry Radio V3 through the TELEM1 port, you can refer to the Visual Wiring Diagram to see which parts those refer to.

There is no specific order or method for connecting the electronic components, other than to connect the power source (battery or USB) last.

Blackbox Wiring Diagram



Visual Wiring Diagram



Assembly Guide

Bill of Materials – Mechanical Parts

Bill of Materials – Electronic Parts

What We Didn't Get To

Measurement Devices

We were unable to connect the sensor array to the prototype before the COVID-19 closures. Though we were not able to fully flesh out a process for integrating the sensor array, we would like to share what we were thinking and sketch a general plan forward.

The typical use-case for ArduPilot and QGC is autonomous aerial drone photography. As such, there are many built-in features related to camera operation. QGC is able to program a vehicle to hold position at certain waypoints and take images. We suspect that this feature, available in the mission planning screen of QGC, could be exploited to operate the sensor array. Our idea is that the electrical signal generated by the 'Capture Image' command could be re-routed to activate the sensor array. Since the sensor array takes some time to perform a reading, it will be desirable to have the ASV hold position at a waypoint while this occurs.

Your best bet for connecting the PixHawk to the sensor array is probably I2C. I2C is a way for two chips to send commands to each other. There are two I2C-capable ports on the PixHawk. Both the Raspberry Pi and the Arduino in the sensor array are capable of communicating over I2C. It would probably be simplest to connect the PixHawk to the Raspberry Pi.

Configure the PixHawk to send an I2C signal to the Raspberry Pi when it 'captures an image'. Write a simple program for the Raspberry Pi which polls the I2C interface to check for a message. When it receives a message from the PixHawk, run the F2018 team's sensor array program.

Hopefully, a future Senior Design team includes an Electrical Engineer who has taken EENG 383 or EENG 450 - I2C protocol is taught in both of those classes. If not, Dr. Chris Coulston in the Electrical Engineering department is an excellent resource for learning about I2C.

The F2018 team did not leave sufficient documentation for us to understand or know how to assemble or operate the sensor array in full working order. We have kept the materials and organized them as best we can from the documentation we do have. This frustration was the

major motivation for our creation of this document. We hope it serves you well.

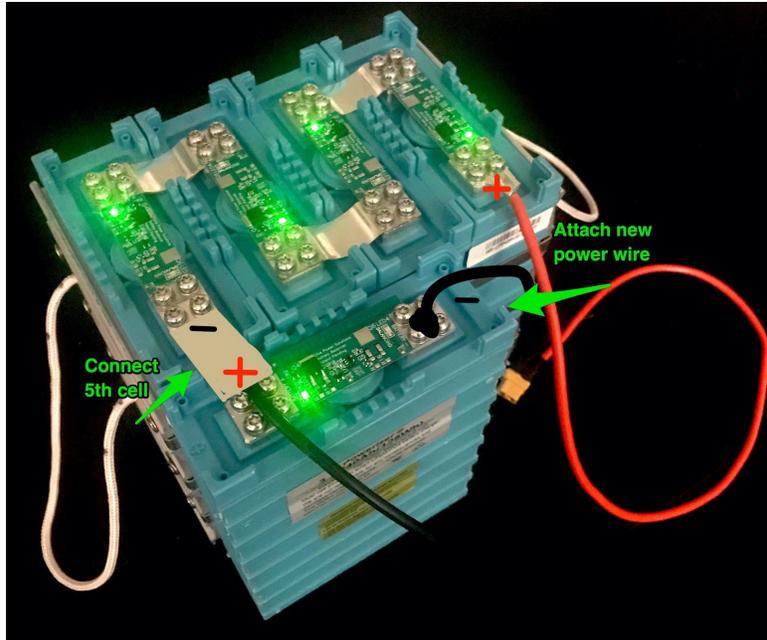
Mounting Additional Equipment

We have left the center space between the catamaran hulls open, so that Pinyon and/or future Senior Design teams may mount additional sensor equipment there.

Completing the Battery

As referenced in the "Charging the Battery" section, the battery is incomplete as presented in our final prototype. We ordered 10 battery cells, with the intention of creating two 5-cell batteries. Currently, two 4-cell batteries are assembled. Mounting brackets will need to be 3D-printed in order to secure all five battery cells together. We intended to make this part, but were unable due to the COVID-19 closures.

Notice that in order to fit the battery through the top porthole, you will need to orient the fifth cell differently than the others. The photo on the next page demonstrates the orientation we had in mind.



You will also need to order two additional battery connectors. We intended to do this, but were unable due to the COVID-19 purchasing freeze. Move one of the battery terminals to the fifth cell, and place a connector between the fourth and fifth cells of each battery. See the corresponding part listing in the Bill of Materials.

Casting and 3D Printing Parts

Some components in our design are custom casted/3D-printed. This section is a guide for you to create additional copies of these custom parts as needed.

1. SolidWorks models of casted parts are called out in the Bill of Materials, and included in the file folder titled "3D Printed Models".
2. Download the SolidWorks models. They will be used to print casting molds.
3. We have identified a service that offers 3D printing, casting, and machining of custom parts. Follow this link to their website: <https://www.jwreffel.com/>.
4. Contact J.W. Reffel and ask if they are currently 3D printing molds for casting.

- a. If NO: Have the molds printed by a 3D printing shop in Denver. We have identified <https://the3dprintingstore.com> as a good option. Proceed to step 5.
 - b. If YES: proceed to step 5.
 5. The vendor will ask for your SolidWorks .STL files. Use the following information to have the molds printed:
 - a. Printing material does not matter – choose a cheaper option.
 - b. If they ask, low infill density is acceptable.
 6. Have the J.W. Reffel foundry cast the parts in aluminum.
 - a. Pick up molds from the other 3D printing shop if necessary.
 - b. Give the foundry the 3D-printed molds and the (5) 7/64" pins. These are for the Forward and Back Hull Mounts only.
 - c. If they ask about where to put the spew and risers, tell them they can be placed wherever it would be easy to cut them off.
 - d. The foundry should know what to do once you hand them the molds and the pins.
-

Ballast

The vehicle tends to veer in the direction of the side which holds the battery. We recommend putting a ballast in the other hull to even out the weight distribution. We recommend sand or a sandbag, since it will shift during vehicle motion.

Wiring

There are some wires which pass between the two hulls. You may end up adding more of these when you install the sensor system. It was our intention to run these wires on the inside of the connecting rods. Currently, they are wrapped around the rods and insulated with electrical tape.

The wiring of the electronics module is messy in general. Due to the specialized connectors used, we opted not to cut/splice most of the cables. However, it is probably possible to redesign the electronics mounting plate to achieve better cable organization. Our access to the laser cutter was cut-off by the COVID-19 closures, so we were unable to iterate on the design.

Shear Pins

Further research proved that there exists a better option of the shear pins contained in the SolidWorks Hull Assembly. Currently, the assembly utilizes dowel pins to hold components together. Aside from pressure, nothing is preventing the pins from vibrating out of position. We have found that replacing the dowel pins with Clevis and cotter pins will provide for greater pin security.

1004-1045 Carbon Steel Clevis Pins will be a better option for the shear pins responsible for keeping the rods attached to the assembly:

Part #: 98306A108 (McMaster Carr) \$6.32 per pack of 25

1004-1045 Carbon Steel Clevis Pin

- 3/16" Diameter, 1-5/15" Usable Length

Requires purchase of a hairpin cotter pin to keep the Clevis Pin seated:

Part #: 98335A034 (McMaster Carr) \$5.77 per pack of 100

Zinc-Plated 1050-1095 Spring Steel Cotter Pins

- Hairpin, 3/16" to 1/4" Clevis Pin Diameter, .047" Wire Diameter

Die

In order to use similar threading throughout the hull assembly, we recommend buying the following die on Amazon rather than the one found in the Bill of Materials:

Irwin Tools 7406 Irwin Pipe Threading Die Hex 2" W Across 3/4"-14NPT

- Part #: 7406, \$28.95
-

Miscellaneous Bugs, Possible Bugs, and Small Improvements

There are some minor aspects of the design that we meant to look into, but either ran out of time for or were unable due to the closures. These are minor bugs, suspected bugs, and small improvements that could use your attention.

- We are unsure whether or not the GPS module's compass and the PixHawk's internal compass need to be oriented in the same direction for autonomous navigation to work. If the device has trouble navigating, investigate this as a cause. You will need to partially redesign the electronics mounting plate to make the change permanent. We could not test this hypothesis in the Gazebo simulation.
- It is difficult to have the PixHawk plugged into USB while it is on the electronics mounting plate. Consider adding an extra cutout to account for this.
- Since the GPS module is located to one side of the vehicle, you will need to follow [this guide](#) to adjust the navigation parameters accordingly.
- Be aware that ArduPilot creates log files that record data whenever the system is armed. These can be downloaded in QGC under the *Log* tab. Unfortunately, they are saved as .bin files that are difficult to open. You can open the files using software called *MissionPlanner* (available from the ArduPilot website) on Windows, or APMPanner (same provider) on Linux. There is currently not a way to open these files on Mac OS X. The most useful information provided in the logs is the vehicle speed and battery charge level.

Testing & Verification

We originally outlined twelve testing procedures in the Intermediate Design Report, including:

- Vehicle Speed Test
- Vehicle Turning Test
- GPS Navigation Tracking Test
- Multiple Waypoint Completion Test
- Operation Range Test
- Operation in Algae and Debris Test
- Load Capacity Test
- Usable Attachments Analysis

- Hold Position Test
- Successful Water Quality Measurement Test
- Off-the-Shelf Parts Analysis
- User Usability Test

We were able to modify some of these tests to work in Solidworks simulation (etc Vehicle Speed Test) and the Gazebo/ArduPilot simulation (etc GPS Navigation Tracking Test, and Multiple Waypoint Completion Test). In the future it is our recommendation that the original tests be used from the IDR outline to more rigorously test the capabilities of the ASV.

Solar Charging Station

At the beginning of our Senior Design cycle, Pinyon mentioned an interest in constructing an on-site solar charging station for the ASV. We quickly decided that this would fall outside the scope of the project in our Senior Design cycle. However, we think it is an idea worth exploring and would like to keep the dialog going by offering some thoughts.

There are two main challenges with the solar charging station idea:

1. Safely making and breaking an electrical connection between the charger and battery
2. Detecting when the battery is fully charged and balanced

We have no suggestions for how to tackle challenge #1. Our best guess is that you could accomplish such a feat with wireless power transmission. This is a big problem in autonomous vehicles in general – Tesla is currently working to solve a similar problem with charging their vehicles. Though we know little about wireless power ourselves, we can point you towards Dr. Payam Nayeri in the Electrical Engineering Department, should you want to investigate the issue further. Wireless power transmission is one of Dr. Nayeri's primary research interests, and he is typically very happy to help students with projects.

Challenge #2 is a little bit easier. We suspect that you could use I/O pins on the sensor array's Raspberry Pi to detect the voltage across each cell of the battery, and write a program to monitor those

voltages. Break the electrical connection when the Raspberry Pi detects a full charge.