

Telemetry System for T37

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Purpose

As a beginning T37 sailor I was having a hard time seeing what was going on with my boat out on the water. Having flown FPV (first person view) quadcopters, I was familiar with telemetry and video transmission from the quadcopter back to goggles I was wearing, and I thought the same technology might work for my boat.

I did not get immediately to the solution presented here, and I will spare you that journey. However, I did eventually achieve my aim and a prototype is now working on my boat.

This picture labels some of the components of the on-screen display (OSD). The OSD is highly customizable in terms of the data shown and their locations, and other elements could be added, for example heel angle.



You can see a video here: <https://youtu.be/XiOoWyjjWO0?si=PXzGXj9Ca1N40oUa>

If you are interested in developing similar capabilities for your boat (or any R/C vehicle), this article will describe in some detail the setup I have used. A word of caution however: this is not a “cookbook” process; you will encounter challenges along the way. You will need to learn some complicated technology and spend time debugging it and researching online to

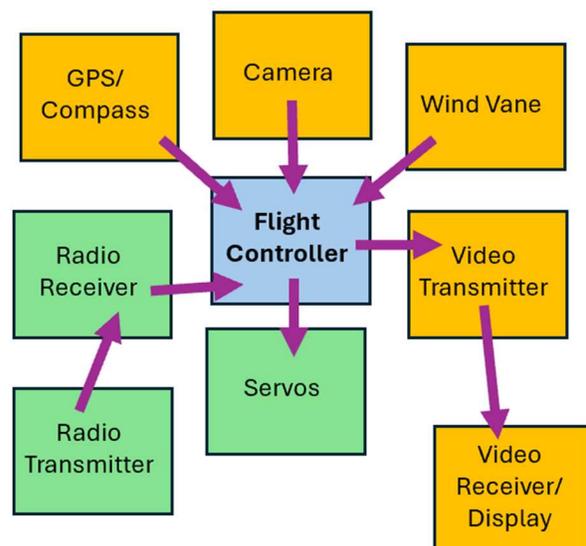
get it working (I'll be happy to help too but may not always have the answers). It took me about 3 months to get the prototype working – hopefully with the information presented here it won't take you as long, but be prepared! I also designed and 3D-printed several parts needed to install it in my boat. I will share those designs with you but you will need to print them or get someone else to do it (I cannot do this for you, but there are commercial outfits that can).

Let's get started!

Overview

This is a diagram of the system components.

The heart of the system is the **Flight Controller (FC)**. The FC is a small computer and it runs software called ArduPilot. For our purposes, it has several important functions. It collects data from the sensors – the **GPS/Compass** and the **Windvane**. It also collects the video image from the **Camera**. It has an OSD (on screen display) chip that overlays the sensor data on the video and sends it to the **Video Transmitter**, which in turn sends it to the **Video Receiver/Display** on shore.



In my system, the radio receiver is also connected to the FC, which in turn relays instructions originating from the transmitter to the servos. It is possible to create a system with the FC and sensors separate from the radio components (shown in green), meaning you can simply use the radio system you already have. However, integrating the radio with the FC opens up some exciting possibilities such as automatic return of the boat to the launch point if radio signal is lost, because ArduPilot was originally developed for autonomous aircraft and surface-based vehicles.

Component Details

You will likely want to do further research on the components, this is intended as an introduction rather than a comprehensive description. At the end of this article I will cite some online sources I trust, but there are many other worthy online sources. These components are mostly used with quadcopters. Note that many components besides the

ones I picked will likely work (and I might select different ones for my next boat), however, the setup might need to be modified for different components.

Flight Controller (FC)

This is the heart of the system and the choice of FC was driven by hardware and software considerations. FCs used in drones can use several different software packages, but only ArduPilot appears to have support for sailboats in general and windvanes in particular, and that was my priority when I started the project. As a bonus, ArduPilot is highly customizable and far more capable of autonomous operation than other packages, but it does not run on all FCs. I had no experience with it and was keen to learn it, but the learning curve turned out to be pretty steep!

In addition to this, I needed a FC with ADC (Analog-to-Digital Converter) inputs to work with my windvane. There are quite a few ArduPilot FCs that would have worked, but most are fairly bulky – I wanted something compact, and I prefer solder connections over plugs – so this narrowed down the choices. I have had good experience with Matek electronic components and online sources recommend Matek FCs for Ardupilot, so I chose the Matek H743 Slim V3. There are slightly smaller versions of the Matek H743 that I might choose another time, but I have been very happy with this FC.

Note that if you did not want a windvane or autonomous capabilities, you could use a much wider variety of FCs and (perhaps) easier software such as BetaFlight, because all quadcopter FCs can integrate GPS, compass and video data.

GPS/Compass

The GPS/Compass provides boat speed, heading and position data for the on-screen display; it is also considered essential hardware for ArduPilot, although you might get it to work without it. There are quite a few small GPS units available for quadcopters but not all of them have a compass. The one I used is a Walksnail WS-M181 and I am considering the slightly smaller NewBeeDrone M10Q for my next build. Matek also makes good GPS/Compass modules.

Video System

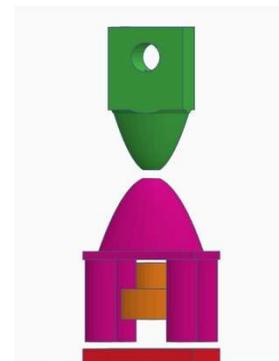
Quadcopter video systems can be digital or analog. I chose analog for this project because it is cheaper, simpler, and usually lighter than a digital system. Digital systems generally have higher resolution and greater range, but I'm not sure either is necessary in this application, although for now I have only tested my system at short

distances. I'm happy to discuss digital video with you if you are interested; there are currently 3 different and generally incompatible digital video systems to choose from, whereas all analog system components work with one another and there are many choices. Nevertheless, I am considering a digital system for my next build.

My video system includes a Runcam Phoenix 2 camera, a TBS Unify Pro32 HV video transmitter (VTX), and an Eachine Moneagle 5" monitor that I have mounted on top of my transmitter. I am happy with the camera and monitor but would use a different VTx for a couple of reasons. I do not think the choice of VTx is particularly critical. The VTx does need cooling (on a quadcopter this is provided by propwash) so I added a cooling fan.

Windvane

Last but by no means least is the windvane – this is actually the component I most wanted that drove me to make this system. The Ardupilot sailboat pages show a windvane based on a potentiometer, but I was keen to build one based on Hall sensors that would be lighter and have lower friction. I found the Hall sensor-based AS5600 chip online and designed the windvane around it. The signal it puts out varies as a magnet is rotated above the chip, so I just had to design a windvane that was connected to a magnet held above the chip. The chip is available pre-mounted on a PCB with other necessary components, which makes it pretty easy to use.



The windvane was based on the feather windvane developed by Will Lesh, and is shown at right. The feather is inserted through the hole at the top, and a wire connects the feather holder (green) to the magnet holder (orange) and pivots through the pink frame. The magnet holder rotates above the PCB with the AS5600 chip (red).

Radio

As noted above, you could use your existing radio if you just want the video feed and GPS/Compass data. My transmitter is a RadioMaster TX16S fitted with a TBS (Team Black Sheep) CRSF (Crossfire) module. I used it because I already had it and this transmitter currently costs about \$200 plus \$40 for the module. RadioMaster makes high quality radios and the TX16S is very popular, but it is probably overkill for a sailboat. The RadioMaster Boxer or TX12 are about half the price and would probably be fine too. TBS CRSF is a radio protocol that has a long range and was

considered the best for quadcopters when I bought the radio. These days a newer, open-source CRSF-based protocol called ELRS is available and probably better. You can now get RadioMaster radios with the ELRS protocol built in (no need to buy a separate module), and the receivers are often cheaper than TBS CRSF receivers. My receiver is a TBS CRSF Nano.

Servos

The servos you already have will work fine with this system.

Other Materials

Power Supply

Different components of this system use different voltages, it draws more current than a standard T37 system, and it probably benefits from stable voltage (all battery packs lose voltage as they are drained). So I wanted to use a battery with higher voltage than any of the components required, then step it down electronically. I also wanted to use a rechargeable battery and was familiar with and had the equipment to manage LiPo batteries. A 2-cell (2S) LiPo battery has a working voltage ranging from 8.4 volts when fully charged down to about 7.0 volts when discharged and my components needed 6.0V or less, so a 2S battery could power them reliably even when close to fully discharged.

The FC has the ability to step down the battery voltage to 3.3V or 5.0V, which took care of most of the needs, but the sail servo is happiest at 6.0V so I also used a power distribution board (PDB) that outputs 6.0V to ensure the servos always get optimum voltage. I added a small voltmeter so I could keep an eye on the battery voltage when the boat was powered on for a long time and know when I needed to swap out or charge the battery.

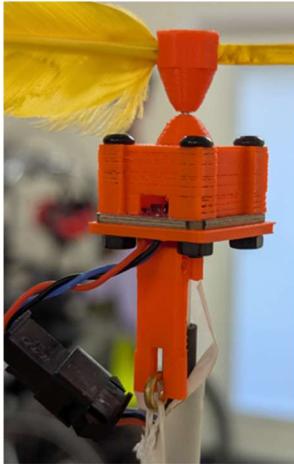
3D Printed Components

I won't go through these exhaustively, just highlight the issues that drove their design. I have posted all the 3D printed component designs on Thingiverse ([Windvane and telemetry system for T37 R/C sailboat by chrisjerome2 - Thingiverse](#)) and you can download them from there to review the designs and print them.

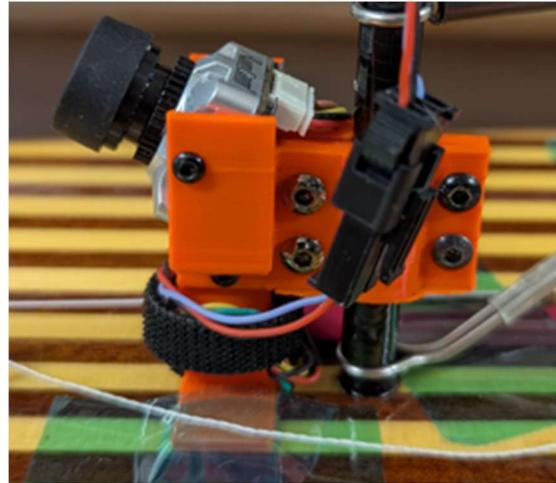
Almost all the components were printed in PLA (orange or black in the pictures here). There are a few components printed in TPU (green).

The biggest challenge that cropped up was that as normally built, the T37 mast rotates during movement of the main sail (at least, mine does!). I needed the mast

to be stable so that there was a stable base for the windvane and for the camera. In the end I mounted the camera to the mast and also keyed it to a small stand that was

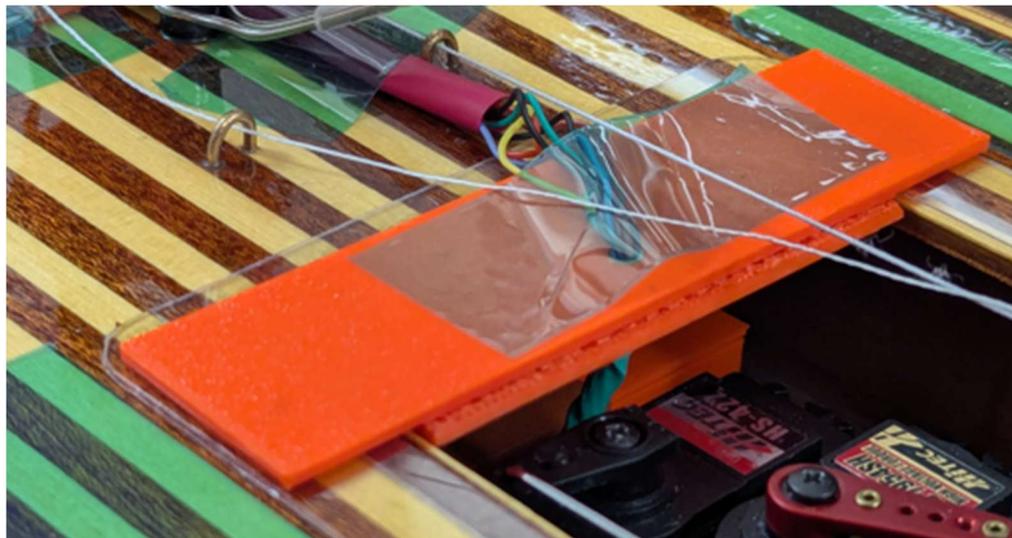


affixed to the deck using double-sided tape and thus prevented mast rotation (right).



I also added a small key that slotted over the screw eye at the top of the mast to prevent the base of the windvane from rotating on the mast (left).

I did not want to drill holes in my deck to pass the wires to the camera and windvane, at least until I was sure the system worked, so I designed an insert for the front of the hatch through which the wires could pass, and that had a slot in the back that the hatch could slide into (below).



The box that held most of the components was quite complicated in design. It included:

- Pegs to hold the FC in place that were captured by sockets in the lid.
- Supports for the VTx and fan.

- Holes in the lid for the cooling fan, an air outlet, and the GPS antenna.
- Shaped platforms for the GPS and radio receiver.
- Holes in the side for access to the FC USB port (so that changes to ArduPilot configuration can be made without removing the FC from the boat), and for the FC bootloader button.
- Holes in the front for the VTX and receiver antennas. These have small brackets for attachment of zip ties at an upward angle. The antennas are taped to the zip ties so that when the box is installed they are forced up to the underside of the deck.

A separate mount was printed that clipped to the top of the keel in front of the servo platform. This was attached to the bottom of the box with double-sided tape.

Other Materials

Of course other tools and materials are needed to complete a project like this. Please get in touch if I can help you with recommendations for these items.

A good soldering iron is essential and if you have not soldered small boards before, you will need to practice before possibly destroying your \$100 FC! There are good tutorials online and practice boards are available with similar soldering pads to those on an FC.

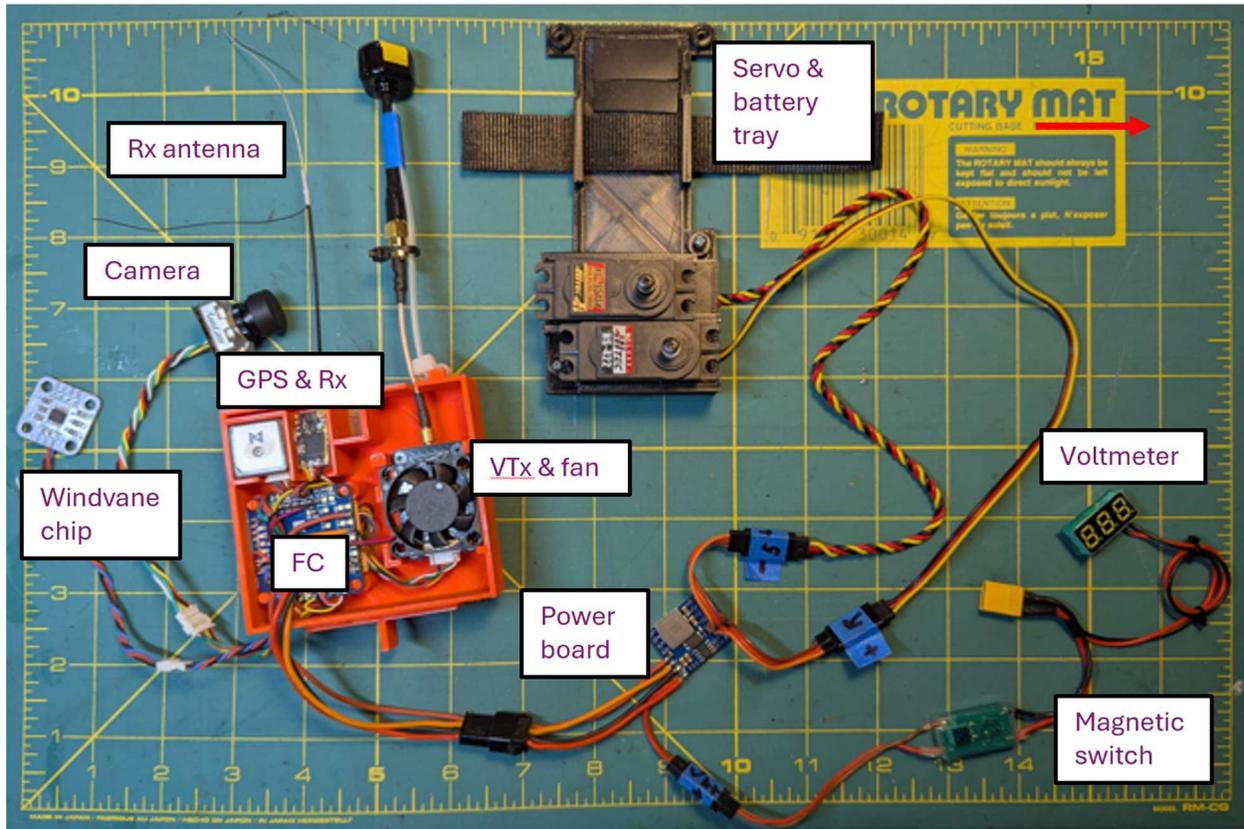
You will also need wire connectors and crimping tools to install them. You will see in the photos the ones I used (JST-SM connectors), but I will probably use smaller ones next time. I used 30G wire down the mast.

If you decide to use LiPo batteries you will need a good battery charger. You should also read up about the care and use of these batteries, they can cause a serious fire if not properly handled.

Finally, I'd recommend a "smoke-stopper". When you have your FC all soldered and ready to power up, you plug one of these between the power source and the FC before turning it on for the first time. The device detects over current such as that caused by a short circuit, and shuts off the connection hopefully before any damage is done. If that happens, you can go over the FC with a magnifying glass, find and fix the short, and try again.

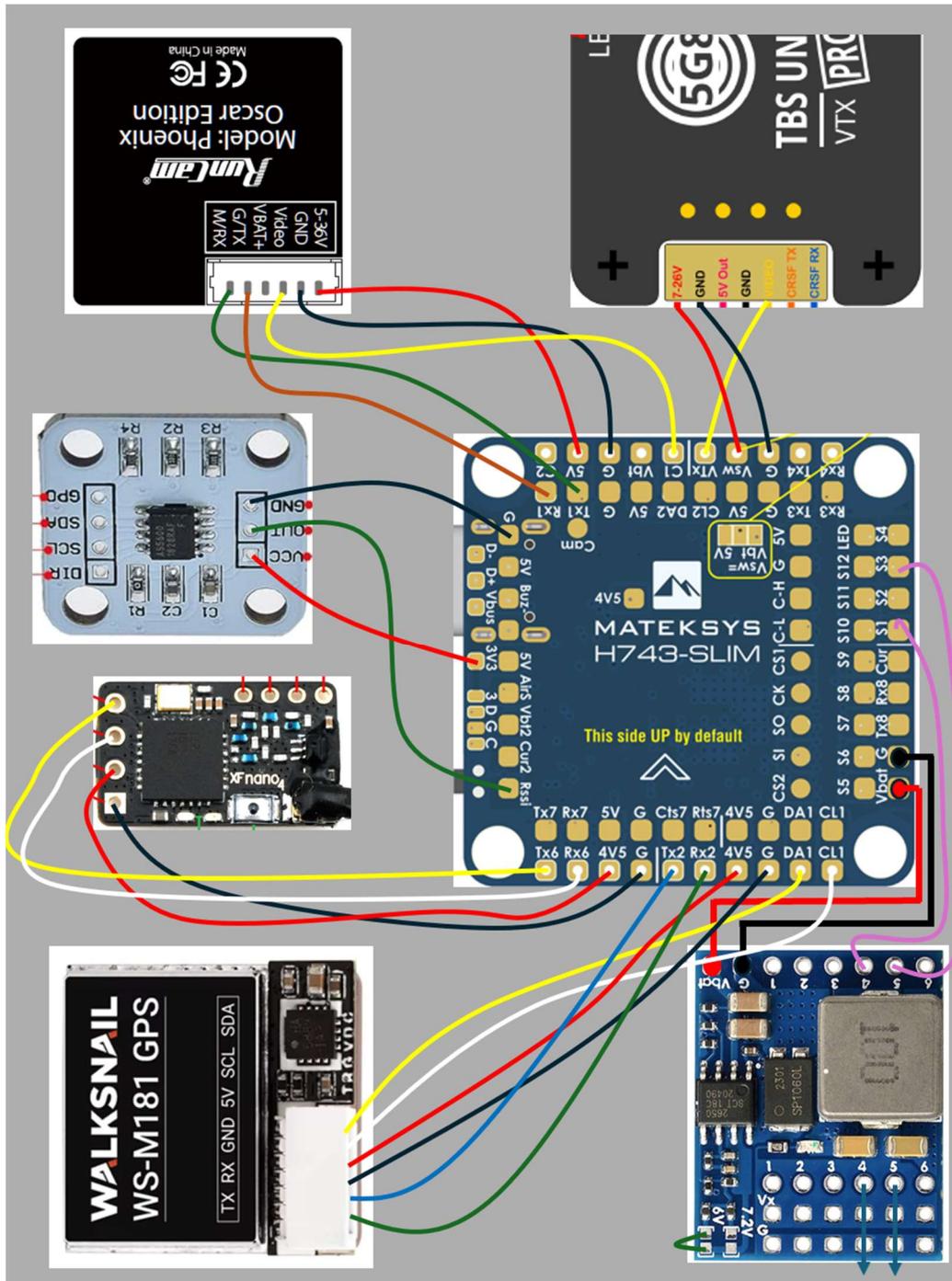
Putting it all together

Now you know about all the components, I think the following pictures will provide most of the information you need to assemble the system. Let's start with a picture showing most of the components connected on the bench:

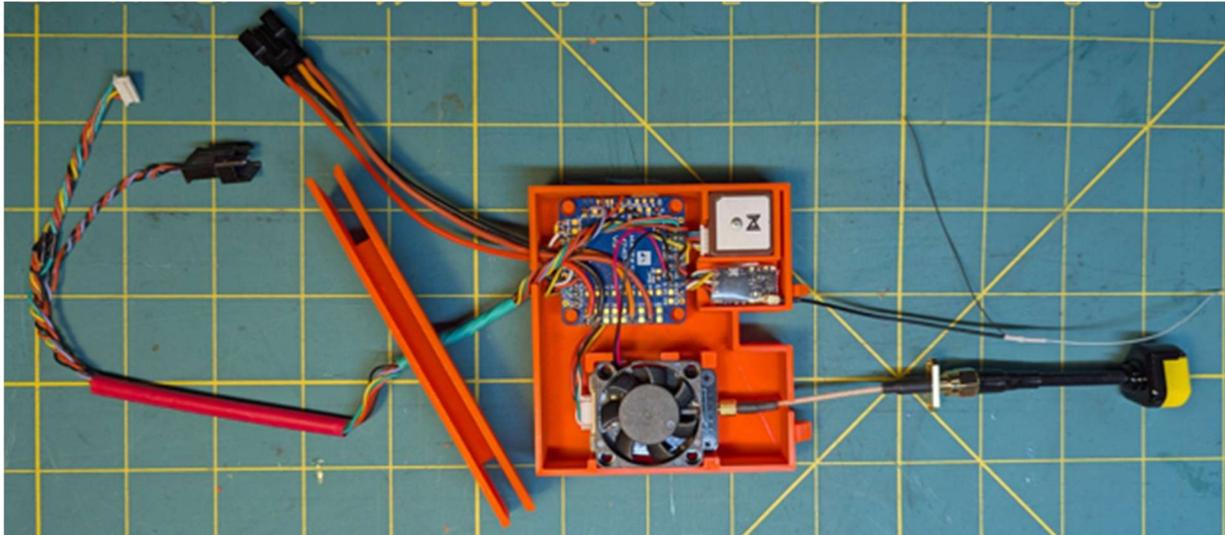


The servo and battery tray is useful because it allows the servos to be easily removed from the boat to gain access to the electronics box.

Following is a wiring diagram for the electronics. You will find instructions for wiring up these components on the manufacturers' websites and, often also on the ArduPilot website. I think the diagram is fairly self-explanatory but please contact me if you have questions.



The following picture shows the electronics box all wired up with the through-deck and connectors, ready for installation (it just needs the lid on the box). The four pin connector at the top left carries servo signals from the FC to the power distribution board (PDB) and also power from the board to the FC. I set up the PDB so that if desired or necessary I can disconnect this plug and remove these electronics, and install my usual receiver instead.

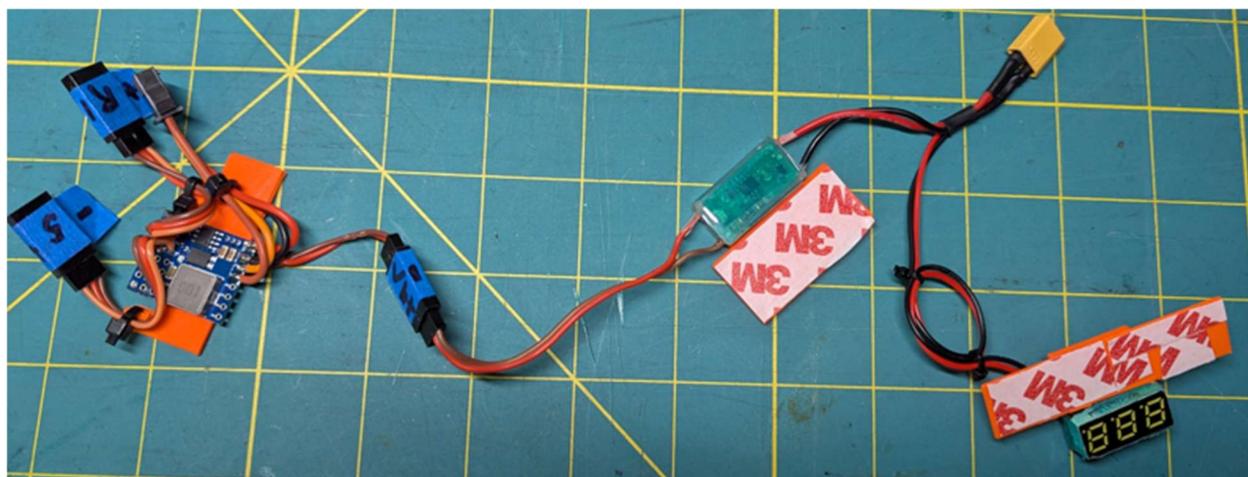


The white plug at left goes to the camera and the three-pin plug next to it connects to the cable that runs up the mast to the windvane.

This picture shows a 3D printed plug that hopefully will prevent water intrusion into the box if I leave a USB cable connected to the FC when it is installed in the boat. Having the cable there allows me to make adjustments to Ardupilot without having to remove the servos and the other electronics from the boat. As you can see I have taped over the hole for the FC bootloader button on the right as this is rarely needed.



The next picture (below) shows the PDB (left), the magnetic switch (middle), and voltmeter (right), mounted on printed mounts for installation under the deck on the port side of the



hatch. The servo and FC connectors are at far left. The connector at top right is an XT30 connector for the battery.

This picture (right) shows the components installed in the hull and the hatch in place. The voltmeter is at the back of the hatch and the magnetic switch on the port side next to it.

I have used waterproof tape over the wires and (not shown) over the base of the camera stand that is affixed to the deck to prevent the sheets and lines from getting caught up. There is a risk of the jib sheet getting caught on the camera that may need to be dealt with.

The total weight of the wind vane and the other components is about 5 oz. I think that weight can probably be reduced by 1 or perhaps 2 oz with different components and modified 3D designs.



Finally, at left is a picture of my TX16S radio with the video monitor installed on the top. This monitor has a SD card slot that can be used to record the video you receive from the boat (like the video I showed above).

You could also use goggles, just like quadcopter pilots, but I think it is better to use a monitor so you can directly view the boat as well.

Radio and ArduPilot Setup

I will not delve into the details of setting up your radio and ArduPilot here, it really is quite complex, and if you have this kind of radio and/or you are using ArduPilot, you are pretty much just going to have to learn how to use them.

Having said that, I am happy to help and/or send you details of my setup and a file of my ArduPilot parameters. You could load my parameters into your ArduPilot FC, and with a bit of luck you will be a good part of the way to getting on the water.

I will also provide links below to key parts of the ArduPilot documentation, and to some of my other trusted sources for setup information to get you started.

In order to set up ArduPilot you connect the FC to a PC running ArduPilot Mission Planner software (there are similar packages for other platforms). Although you do not need a PC connection to actually run the boat, in automated vehicle applications the vehicle is often controlled from a PC over a wireless link; however this adds another layer of complexity and is not necessary for what we are doing here.

A radio like the TX16S also generally needs to be connected to a computer to install its firmware, and TBS Crossfire devices like the CRSF module and the receivers usually also need to be configured from an external connection. Again, I will provide some links to trusted sources below.

Conclusion

If all this sounds complicated, well, it really is. There is a steep learning curve, but at the end of it you will have skills and be familiar with electronic systems that offer a world of possibilities for all kinds of radio-controlled and even autonomous vehicles. Many of the components used in this sailboat system can also be used in other vehicles (my TX16S for example can control about a dozen different drones that I own and has the capacity for many more). Please get in touch if you have questions and good luck if you decide to have a go at building your own system!

Links and other data

This is a good page to start: [Sailing Vehicles Home — Rover documentation](#) (Rover is the subset of Ardupilot software for surface vehicles). It describes in general what the ArduPilot sailboat software can do, and some hardware and other details specific for sailboats.

Here is the ArduPilot Sailboat Discourse page [Sailboat Support - ArduRover / ArduBoat - ArduPilot Discourse](#). This is a discussion group going back to the beginnings of the sailboat version of ArduPilot. It has a wealth of technical information and you can post questions on it if you get stuck. Most of the Ardupilot discourse threads get responses within a day or 2 in my experience.

Here is the home page for ArduPilot, and is a good place to start to get an understanding of what ArduPilot can do and how it works: [ArduPilot Documentation — ArduPilot documentation](#)

ArduPilot also has documentation specific to different types of hardware, for example, here is the ArduPilot page for the Matek H743 FC: [Mateksys H743-Wing/SLIM/MINI/WLITE — Copter documentation](#)

Here is the manufacturer's page for the FC: [Flight Controller H743-SLIM V3 – Matek Systems](#). The tabs above the pictures at the bottom will take you to a wealth of technical information to help you get the FC setup. One of the reasons I like Matek is the excellent info they provide online.

As I mentioned, many of these components are primarily intended for quadcopter FPV (first person view) systems. The following sources provide a wealth of good, reliable instruction on how to set up and use quadcopter components:

Joshua Bardwell is an amazing guy. His YouTube channel contains hundreds of videos on all kinds of technical subjects: <https://www.youtube.com/@JoshuaBardwell>. However, there are so many videos it can be hard to find the one you want. Once you find them though, they are entertaining and packed with good info, clearly explained. He also has a website: [THE ULTIMATE FPV SHOPPING LIST | JOSHUA BARDWELL - FPV-KNOW-IT-ALL](#) which helps you find the best components for your build – although of course its focus is quadcopters, not boats. Nevertheless, the pages on video systems (FPV systems) will give you good information about cameras and video transmitters, and the pages on LiPo chargers, controllers and receivers are also applicable to our project. He also has a site [FPV Product Search Engine | Search FPV Stores In One Place | SearchFPV.com](#) which can help you find the components you want at one of the many online stores. However, a few stores do not participate (one of my favorites, pyrodrone.com does not).

If you prefer text-based information over videos, check out **Oscar Liang** [Oscar Liang - FPV Drone Tutorials and Reviews](#). His site is very comprehensive and a great source of set up information. I often do a Google search such as 'Oscar Liang TX16S setup guide' and it will usually take you straight to what you need (in this case [How to Setup Radiomaster TX16S Radio First Time - Oscar Liang](#)).

Finally here's a link to the Smoke Stopper I use: [ViFly Short Saver 2 Smoke Stopper - XT30/XT60 — Pyrodrone](#). I put this here because it is a product you should get if you are going to solder expensive electronics, and because this particular listing is on www.pyrodrone.com, which is my go-to site for most of the components I used in this project. They are based in California so their shipments get here pretty quickly, and I have found them to be a great vendor all round. Having said that, I have also had good luck with getfpv.com and racedayquads.com (especially for batteries), among other vendors.

Here is a table of components and prices at the time of purchase for the system described here (not including the radio transmitter):

Walksnail WS-M181 GPS and Compass module	\$	16.99
TBS Crossfire Nano receiver and antenna	\$	24.95
Matek H743-Slim V3 Flight controller	\$	96.00
TBS Unify Pro32 HV Video transmitter	\$	44.96
RunCam Phoenix 2 JB Edition Micro camera	\$	29.70
Eachine Moneagle 5 inch monitor	\$	76.50
30mm 5v Fan	\$	2.50
AS5600 magnetic encoder chip for windvane	\$	4.00
Speedy Bee V2 5.8GHz RHCP Antenna	\$	14.05
Matek Servo Power Distribution board	\$	13.49
Total	\$	323.14