QAV 250

Goals and Components Selection

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Document by Leonardo AVONI, avonileonardo@gmail.com

Part of the 03 First Drone Build GitHub public sub-folder

Typical quadcopter build aimed for this project; image from Holybro

1) Goal of the Project

1.1) Context

This document was written to sum-up the component selection procedure for a QAV 250 (250mm motor-to-motor diagonal quadcopter).

For context, I (Leonardo AVONI, 25 y.o.) am currently a 3rd year PhD Student in Toulouse (FRANCE), within ISAE-Supaero and ENAC, with access to drone team people in ENAC. I have a Bachelor + Master in mechanical engineering from EPFL. My PhD is about design and control of flexible aircraft (fixed-wing). My experience is mechanical-engineering oriented, so I need an electronics/control project (personal life) for completeness

I know that I won't learn this skill if I don't get my hands on a drone myself and spend some money in it. I know I will do mistakes, but there are no 36'000 possibilities for learning a new skill, I need to get started.

1.2) Goal

The goal behind this first quadcopter build is getting familiar with software and hardware linked with common UAV, as a useful add-on to my already wide theoretical knowledge; while extending my guidance and control knowledge.
The goal is not to optimize a flying object for efficiency or endurance, but rather to make something that flies in practice.
I wanted something not too heavy since the heavier the drone, the tighter the regulations. Also, heavier drones can be more dangerous (more kinetic energy for the same velocity, and larger propellers).
Here the idea is to have a first drone so that I can train myself with the following parts of UAV theory/practice:

- **UAV Component Selection:** how to pick the various components, what differences are there software-wise / hardware wise…
- **UAV Practical Build:** actually getting experience in assembling everything while paying attention not to short anything (I need to learn and be careful since I'm no electronic engineer; I need to get my hands on that)
- **UAV Ground Station Setup:** I want to be able to know what the drone is doing from my (ground) computer
- **UAV Manual Flight:** learning how to actually have the Radio Controller in my hand and pilot the drone in a safe way
- **UAV Software Setup:** how to calibrate properly the drone for manual flight
- **UAV Autonomous Navigation:** once manual flight is covered, how to plan a mission and make the drone move autonomously

If I manage to achieve all those objectives, I am pretty satisfied with this first project.

Since I will be buying parts with my own money, I would like to spend as little as possible while fulfilling my goals, and while not having shitty products.
For the moment, an onboard camera would be a nice but non mandatory addition. I also decided to skip the onboard computer for the same reason. It would be nice to have in the future; but one thing at a time.

1.3) Credits

I would like to sincerely thank Murat BRONZ for the help he provided during the component selection process, as well as for taking the time to review the wiring diagram, including the I²C, serial, and PWM connections.

I am also grateful for his guidance and insights throughout the development process. I wish that anyone looking to start developing drone hardware has the opportunity to discuss their project with someone as talented and knowledgeable as he is.

2) Nomenclature

2.1) Nomenclature: UAV

The following components will be referred to throughout component selection:

- **Flight Controller (FC):** it's a computer made to run specifically stability and control algorithms for the drone
- **Power Module:** board connected to the battery, used to provide decent voltage to the FC
- **Electronic Speed Controller (ESC):** board needed to take the battery power (high power) + RPM info (very low power) from the FC and convert it to 3 sinusoidal signals (high power) to send to the brushless motor. There can be one EC per motor, or so called 4in1 ESC, that send 12 sinusoidals signals (speecifically or quadcopters)
- **Battery:** this one's pretty obvious
- **Frame:** holds everything together
- **GPS:** gives location info (~1m accuracy) to the FC
- **Telemetry radio:** radio connected to the FC used to send telemetry data (how much battery is left, what the drone is doing…) to the ground station (a computer on the ground, where the pilot is)
- **VTx:** video transmitter unit, basically takes the camera signal and send it to the pilot, that typically has some kind of receiver capability (like FPV Goggles)
- **Camera:** you know what this is, come on
- **OSD board:** OSD = On Screen Display; it's a board that takes the camera signal before it is sent to the VTx, to overlay on the video some telemetry information (coming from the FC) the pilot might want to see on the goggles while flying, like remaining battery percentage, attitude…

- **Motors and propellers:** typically we use brushless motors to run quadcopters. They are provided with voltages, max currents… but most importantly: the kv number (that number times the battery voltage gives you the RPM of the motor). That number, along with the pitch of the propeller, the number of blades… will determine how the drone behaves
- **Radio Receiver:** the radio command signal must be received by the drone, that's the antenna module that takes care of that, and makes the signal available to the FC

We are not going into the details of the sensors present alongside the FC, used to control the aircraft, since those (accelerometer, pressure sensor, magnetometer…) are included within Pixhawk board.

2.2) Nomenclature: Non-UAV

To fly a drone one also needs a series of additional components, generally considered to be long-term investments:

- **Radio Controller (RC) Transmitter:** is used by the pilot to control the drone. It must be compatible with the receiver.
- **Battery charger:** may be useful when battery runs low
- **Battery Safe:** Care should be used when working with LiPo batteries. If damaged, they can take fire and be very dangerous (not extinguishable with water). So special pockets are designed to limit problems
- **Battery tester:** tool used to check how full/empty the battery is
- **FPV Goggles:** to see what the drone sees in case of FPV (First Person View) flight
- **Safety equipment:** drone propellers spin fast and may hurt/kill people. Wearing safety glasses is a good idea

3) Methods and Preferences

While it is possible to select an infinite amount of different components fulfilling the above specifications, and to spend 6 months optimizing the design, I had other preferences, specified below.

3.1) General Mindset for Component Selection

I could also have spent years optimizing each component to use, but as previously specified, I needed something that could fly, **so that I could learn**. The idea here was not to select precisely each component, but rather to make sure that the components I bought could work together as ok as possible. Either way, **most of the time I had no real experience that would help me refine the component choice in a different-than-random way.**

When I had no idea about which components to choose, I used ChatGPT (or similar AIs like Grok, Gemini…), work colleagues, online reviews… Of course, AI was used to give suggestions and everything was doublechecked with proper references. If I was undecided between several equivalent components, I just picked one and that's it. No deeper optimization.

Of course, important things however, like hardware holes positions, or compatibility of everything, min-max voltages and max amperages, electrical cable pins locations… were checked before buying the components

Among inspiring reviews, the few I can list are the following:
- what hardware not to pick

3.2) Where to Buy and Other Infos

Initial research for product information was done online, mainly through product reviews. I strongly advise you to have a look at Oscar Liang Website, which details more or less everything you need to know to understand what you are doing.

For buying the components, I bought everything off AliExpress + Amazon, but depending on your region, Banggood, Drone-FPV-Racer, GetFPV or simply a Google online search for the component you are looking for will lead to possible resellers. Note that this document does not list all links used to purchase the components, since those can evolve with time.

Note: for AliExpress, for cost estimation, LOG IN TO YOUR ALIEXPRESS ACCOUNT since the real price may be higher for some articles. Also pay close attention to the actual article you are purchasing with Aliexpress, as often the same article is offered with several variants, all present on the article pictures

3.3) Hardware Build

As a mechanical engineer already familiar with mechanical design, CAD, 3D printing… I mainly wanted to focus for this drone project in Guidance and Control + Electronics. So I knew that I wanted to buy even the drone frame. Plus, nowadays, frames are really cheap.

Also, my goal here was NOT to do aerodynamic optimization of this drone but to make something that flies, since anyway, quadcopters are very inefficient wrt fixed wing drones.
Meaning: I could spend days/weeks doing CFD optimization of the frame to win some endurance points, but at the end of the day, drone autonomy will still be less than 1h. I prefer to use that time to study Guidance and Control problems.

I also knew that development kits were available from Holybro. Ideally, I wanted to buy the QAV250 kit but it was discontinued. Online I could not find reasonably priced versions of the kit, so I ended up picking each component separately. Note however that I took strong inspiration from that kit, and from other similar builds, while adapting the components for nowadays availabilities (1,2,3).

3.4) Autopilot

First, an autopilot software capable of autonomous navigation had to be picked. Not all autopilots and hardware are compatible among themselves. Among those, possible options are INAV, Ardupilot (Arducopter in this case), PX4, Paparazzi. The following list sums-up things. Although Betaflight does not have navigation capabilities by default, it was included for completeness.

- PX4: autopilot used by industry and academia. Runs only of Pixhawk flight controller boards
- Ardupilot: very similar to PX4, with tons of online community of hobbyists. Can run on Pixhawk or third party flight controllers
- INAV: I don't have enough knowledge
- Paparazzi: ENAC and TUDelft autopilot software
- Betaflight: privileged for freestyle quadcopter flight

Note that there is a difference in the licence between PX4 and Ardupilot which apparently justifies the "why" startups tend to use PX4. Since I would like to go within industry, I decide to start with PX4 even though apparently the learning curve will be pretty steep. But I mean: how hard can it be? *(I need to pay attention to karma, and also "famous last words")*

Note that within autopilot selection, I have beed advised to use Paparazzi, since everybody uses that within ENAC. I preferred not to as to pick something more worldwide-widespread than Paparazzi with more online community, but this does not remove any qualities that Paparazzi may have.

Note also that all above autopilots handle fixed wings and quadcopters, some with even more possible combinations; apart from Betaflight that only handles quadcopters.

My final pick was for PX4 (software) + Pixhawk (hardware). Choosing PX4 does not exactly allow me to choose something else from Pixhawk, which is actually way more expensive than other cheaper autopilots. For instance, I could have selected Ardupilot, then I would have had the chance to pick any among those FC's.
Keep in mind though that Pixhawk FC's can be flashed with PX4 or Ardupilot, and have also more redundancy in them. A minor decisional factor is maybe the fact that, as a high end product, I will probably have less problems working with Pixhawk than with some other brand… but since I will be jerry-rigging a lot of various brands components on the drone I am not sure about the validity of this argument.

So to close the FC discussion, I decided to aim for Pixhawk, flashed with PX4. If I have problems I may switch to Ardupilot.

Note: for somebody who wants to build a drone on a tight budget, Pixhawk is not a good decision.

3.5) Drone Size

Concerning the actual drone size, after some research online, some coworker discussions and some ChatGPT advice, I resorted in building a 5'' drone, 250mm motor-to-motor diagonal quadcopter

(QAV250). The drone is expected to exceed the 250g-limit under which it would require no regulation, so I need to have a look at the regulations in place in France.

3.6) UAV Regulation

As to align with local (France, Europe) drone regulation, I am planning in taking the appropriate licence. For this drone build, I try to aim for a weight less than 800-900g. I also need to select the appropriate frequencies for drone-to-ground communication:

- LBT for the RC
- 433MHz for telemetry

4) Drone Components & Selection

4.1) Flight Controller

For the flight controller, I needed a Pixhawk with a small aspect ratio, so I picked the only available aka the Pixhawk 6C mini. I hardly avoided old Pixhawk 2.4.8 for compatibility issues + suspicious manufacturers. Note that I picked model A and not model B (less compact with-respect to the selected frame, since PWM outputs exit on top. More infos on the 6C mini can be found here.

Pixhawk 6C Mini Model A

While the Pixhawk 6C Mini counts also CAN ports (CAN1 and CAN2), one I2C port, the FMU debug port, the DSM and the PPM/SBUS RC, those were not addressed in current assembly.
Instead, current QAV250 only relied on the GPS1, GPS2, TELEM1, TELEM2 and POWER ports.

The connections will be detailed in the `02_First_Drone_Build_Wiring_Scheme.pdf` within the original GitHub Link

4.2) ESC

Other previously mentioned Pixhawk 250 quadcopter builds used 4 ESC's; one for each motor. I preferred to try to use a 4in1 ESC. After doing some quick research, it would make sense that the ESC is capable of at least 35-45 A (for my drone)

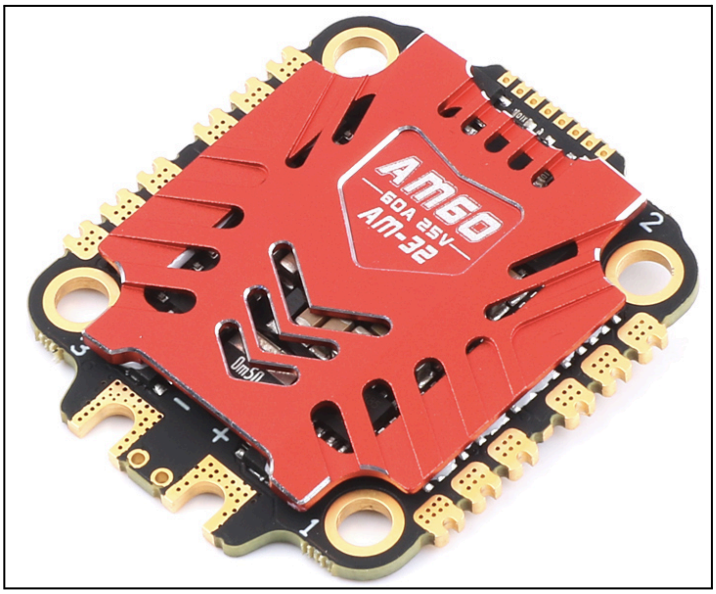
The following articles can be useful: infos on ESCs, more on ESC firmware.

For me, I had the following picks fo possible 4in1 ESCs. I could not find something that handled less than 45A.

- Tekko32 F4 4in1 50A
- ESC 4en1 V45A Lite - T-Motor
- T-Motor Velox V45A V2 (T-Motor 32-bit, 45 A)
- SpeedyBee 50A 3-6S BLHeli_S 4-in-1 ESC - 30x30
- Skystars AM60 AM_32 60A 32Bit 3-6S 30.5mm 4in1 ESC

At the end, I selected the **Skystars 60A ESC**, the only one accepting batteries from 3 to 6s, with AM_32 firmware. Apparently there have been recent not so good developments within BLHeli firmware so I preferred to avoid.

The ESC mounting is on 30.5mm-square holes, according to previous QAV builds using the same frame. Also, it does not seem that the selected ESC is of suspicious quality.



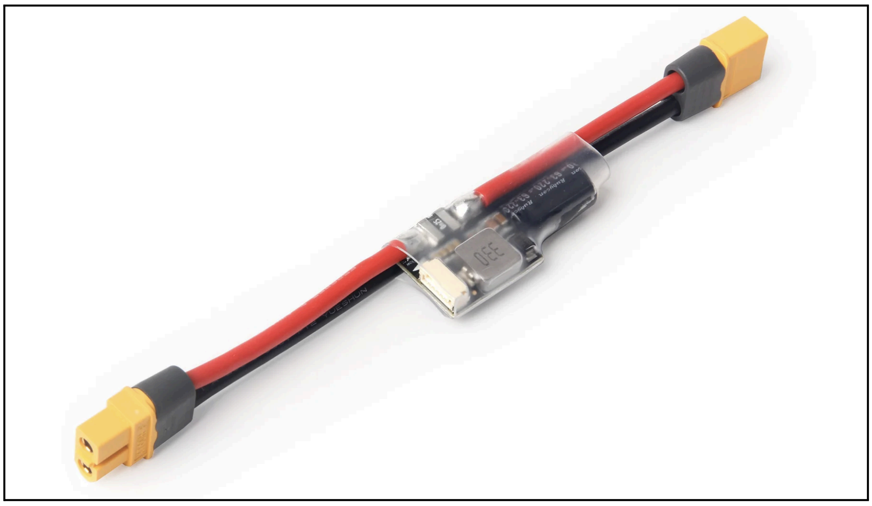
Skystars AM60 AM_32 60A 32Bit 3-6S 30.5mm 4in1 ESC

4.3) Power Module

People strongly discourage powering the Pixhawk FC through the ESC power, as the voltage varies too much. So a PM02 V3 power module was selected. The idea was to connect that between the battery and the ESC, to provide regulated power to the Pixhawk.

Previous QAV250 used the PM06, but after further notice, I realized those provided 4 voltage inputs for individual ESC's. I on the other hand only want the output for a 4in1 ESC.
Hence, I resorted to use the PM02 V3. There are no examples online of PM02 V3 connected to a 4in1ESC. However, the PX4 Development Kit - X500V2 used by this guy (2m11s) uses a battery, connected to the PM02 V3, connected to a power distribution board, connected to the 4 esc's. Since the PDB is nothing else than copper lines (connecting all + together and all - together) then my setup and the one from this guy are equivalent, and I can use the 4in1 esc with the PM02 V3 module.

This reddit link can help; Official doc can also help



Holybro PM02 V3 Power Module

4.4) Battery

Initially I wanted to use 6S batteries, but for starters the drone could be dangerous. So after discussing with my coworker, I downgraded to 3S, while keeping the same capacity. The actual size was hinted by both AI and my coworkers; I ended up selecting a sufficiently good quality: Gens Ace G-Tech Battery LiPo 3S 2700mAh, as to avoid weird/dangerous battery phenomena. It costed around 30 euros.

After discussing with airport people (security checks), I feel the drone battery will be the part I will have to pay closer attention in case I take the airplane and want to carry the drone.

Previous 6S choices were the following:

- Batterie Lipo 6S 1700mAh 150C - Série Ultra - Dogcom
- Batterie Lipo 6S 1300mAh 150C - Dogcom

Note that I checked all the components so that if, in the future I decide to switch to 6s, I can.

More details on UAV batteries are provided here

Gens ace G-Tech Soaring 2700mAh 11.1V 30C 3S1P LiPo Battery Pack with XT60 Plug

4.5) Radio Receiver

For the radio receiver, I selected a somewhat known brand, then selected know receivers compatible with ELRS protocol. I was thinking about RadioMaster RP1 or RP2-· I ended up selecting the RP3 V2, which should be more robust, with dual antenna. This was a typical scenario where I did not optimize excessively the component, but rather picked something that was ok enough for me.

The LBT version was selected, compatible with the RC Transmitter. Note that the LBT is because I am in europe. Apparently there’s the difference between FCC and LBT; picking one or the other depends on the region of the world we are.

Diversity is a smart way to fight multipath fading and signal dropouts by using two (or more) complete receiver chains instead of just sticking two antennas on a single receiver chip.

- If a receiver uses 2 antennas, it’s called “Antenna Diversity” (as is the case for the RP3 V2)
- If a receiver uses 2 complete receiver circuits, it’s called “true diversity”

In this case, the antenna diversity of RP3 V2 is more than enough since we are not building a super high range drone that flies through buildings (compromised signal)

[RadioMaster RP3 V2]

4.6) Telemetry Radios

Telemetry antennas were selected as the regular Holybro Pixhawk-compatible antennas, the Holybro SiK Telemetry Radio V3, typically used for drone-ground station communication. Since I am in Europe, I selected the 433Mhz, 100mW version

Holybro SiK Telemetry Radio V3

4.7) Motors and Propellers

For motor and propellers, apparently (AI), a good guess of the Motor kv/Propeller is the following:

- 1750KV + 5x4x3 propellers
- 1950KV + 5x3x3 propellers

The “rule” is that a motor that spins faster will require a smaller propeller pitch and vice versa. Again, here we are about having a product that flies, rather than optimizing the thrust, handling, efficiency… so for the moment this should be sufficiently ok
At the end, I selected the 1950KV combination; the selected components are the following:

- Moteur Velox V2207 V3 - 1750KV - T-Motor + HQ Prop 5x4x3
- Moteur Velox V2306 V3 - 1950KV - T-Motor + HQProp ETHIX P3 Peanut Butter & Jelly 5.1x3x3 - PC (2x CW + 2xCCW)

Note: after talking to people at ENAC and ISAE-Supaero, and seeing them fly their drones, I realized that 3-blade propellers generate less noise than 2 blades; although they are less efficient. Since I like the idea of not loosing my eardrums, I picked 3-bladed propellers.
There is a physical reason behind “why” more blades lead to less noise for the same thrust (I guess less thrust per blade -> less pressure -> less pressure waves…) but again let’s not make a fluid mechanics exercise out of a Guidance and Control project

Concerning the brands, apparently (ENAC people) T-motors and HQProp are good brands

Moteur Velox V2306 V3 - 1950KV - T-Motor

HQProp ETHIX P3 Peanut Butter & Jelly 5.1x3x3 - PC (2x CW + 2xCCW)

4.8) GPS

For the GPS module, I liked the idea of placing just a small sensor on the drone, among those tested by Oscar Liang. This way I could avoid placing a bigger GPS sensor, such as those.
Among the models reviewed by Oscar Liang, the idea was to select one with th M10 chip, which is apparently really good. Those three seemed nice, and I finally bought the Goku

- ~~GPS GEPRC série GEP-M10~~
- ~~Module GPS M100-5883 - HGLRC~~
- GPS GOKU GM10 PRO V3 w/ Compass - Flywoo

With time and experience, I will see whether I need different GPSs

[GPS GOKU GM10 PRO V3 w/ Compass - Flywoo]

4.9) VTx, Camera and various Video Equipment

While the following components were specified, they were not bought at first. This way, I could focus more on the first drone build, making sure everything worked fine initially, and then put the camera-related things.

Note that, for camera systems, there are a lot of different options, mainly split in 2: Analog and Digital.
Within Analog, components are cheap, but image quality is potato.
Digital components provide more clear image quality, but are more expensive.
In my mind, I wanted to send the camera image to the ground control; which apparently is something that you can do if you make it pass first through the goggles; btw this is only feasible in a decent way with digital systems. More infos on the various available systems can be found here.

I think changing from analog to digital, one has to update the VTx, not necessarily the camera sensor itself.

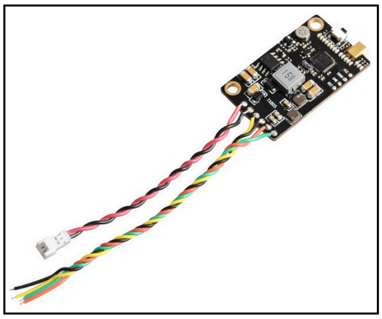
After a lot of ChatGPT, online reviews, this webpage and this webpage I decided to use, at first, the following components:

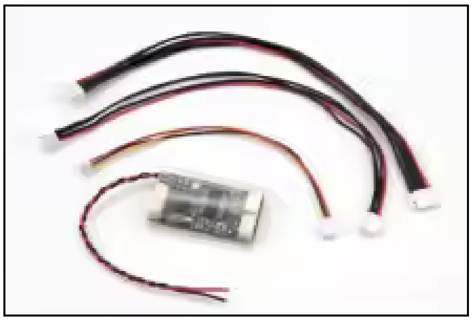
- Camera: Caddx ANT Nano 4:3
- VTx: Eachine TX805 VTX
- OSD Module: Micro OSD V2

Note that to customize the OSD module specs, one needs a FTDI Adapter.

The camera sensors are available in 4:3 or 16:9. For some reason, people/ChatGPT advised to use 4:3.

Caddx ANT Nano 4:3


Eachine TX805 VTX


Micro OSD V2

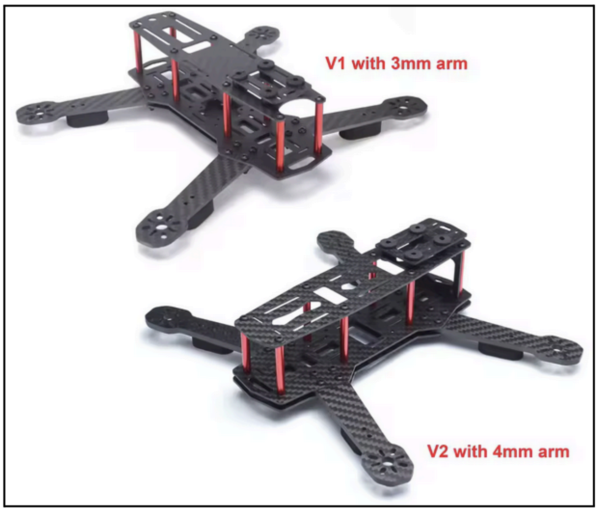
In the end, for the first build I ended up not buying the camera systems. Moreover, in the future it is possible that I switch to digital without even selecting analog components in the first place.

4.10) Frame

For the frame, I decided to pick exactly or a very similar type of frame used within the QAV250 kit by Holybro. When selecting, pay attention cause not all frames sold by AliExpress are the same. For instance: I picked the following:

- HolyBro QAV250 Frame (almost); I picked the 4mm arm-thickness version

When selecting I tried to make sure that everything was in the kit. The version used by Holybro for their QAV250 kit is assembled without a pair of red columns, to make space for Pixhawk.



HolyBro QAV250 Frames aligned with previous Holybro QAV250 kit.
I picked the 4mm version for extra stiffness

5) Non-Drone Components & Selection

5.1) FPV Goggles

For budget-related reasons, I had to pick the most budget-but-still-ok FPV goggles for Analog system. I hence selected the Eachine EV800D. Yes, I look like a microwave.
More about FPV goggles can be found here. I did not do wide research honestly, but I like the fact that the screen of the goggles can be used without the headset by itself; making it possible to have it next to the ground station during drone operation.

Anyway, it was not bought initially.

Eachine EV800D

5.2) LiPo Charger

I needed a LiPo charger. Yes, I could have simply always used the ENAC chargers, but I like the idea of being able to change the batteries at home if I need to. For the final element, I took advice from Oscar Liang and selected a charger among those proposed by him. I took a charger that could take 220V AC input on top of DC input, so that I did not need to buy a AC/DC converter. Yes, the power output in AC is less than DC, but for starting I am ok.
I ended up taking the SkyRC D200 Neo, but hesitated for the iSDT 608AC. The iSDT would have been slightly better for traveling, but when we look at the dimensions they are not that different from one another:

- iSDT: 110 x 110 x 31 mm
- SkyRC D200 Neo: 116 × 110 × 79 mm

Yeah, the thing that changes is just the height. And the price. Basically, for twice the price I get 2xcharging capacity + additional features if I pick the Neo. To avoid problems, also since it’s a long term investment, I selected the Neo

[SkyRC D200 Neo](), images from [Oscar Liang]()

[iSDT 608AC](), images from [Oscar Liang]()

5.3) RC Transmitter

The choice of a RC transmitter was done from online reviews, videos and [this page](). At the end I hesitated against the [RadioMaster Pocket,]() [Jumper T20]() and [Radio Master gx12]().
I liked the fact that the T20 and GX12 had a shit ton of features; but for starting, I felt that I would not be needing all the switches possible and imaginable; plus, I liked the idea of having a small controller, that could be transported noproblemo and at a very competitive price point.
For extra style points, I selected the white-colored version of the Pocket, called [Radiomaster Pocket Crush](), for around 70 euros including batteries. This is the ELRS, LBT version, so I had to pick an ELRS receiver.
By the way: several different RC protocols exist; the non-crush version of the RadioMaster Pocket is available in either ELRS or something that allows you to change the protocol. I think ELRS will be pretty ok for now, apparently it's nice, idk though.

[Radiomaster Pocket Crush]()

After purchasing the radio and using it for a while with the Liftoff simulator, I think it is worth the price. It is very small/compact, and people at the airport had no issues with me carrying it on the cabin, even with batteries inside. Sticks unscrew and store on the back of the controller, making the whole thing very small. I feel it's way more designed for thumbers than for pinchers though, and the upper latching switches/switches actions are not incredible (no big deal in my opinion) but apart from that I have no complaints.

5.4) Additional

Additional stuff, to make things easier and safer is shown below. No specific model in mind, since those items took 0.000001 seconds to select. On second thought, I should also have bought some ear protection (you know, my passion of not loosing my eardrums…)

Lipo safe

Glasses

LiPo Tester

6) Final considerations

6.1) QAV Sizes, Mass and Design

Before confirming current setup, a sizing test (to make sure everything could fit) was performed real quick; plus, hardware holes were checked (yes, the ESC can fit the frame, and so do the motors)

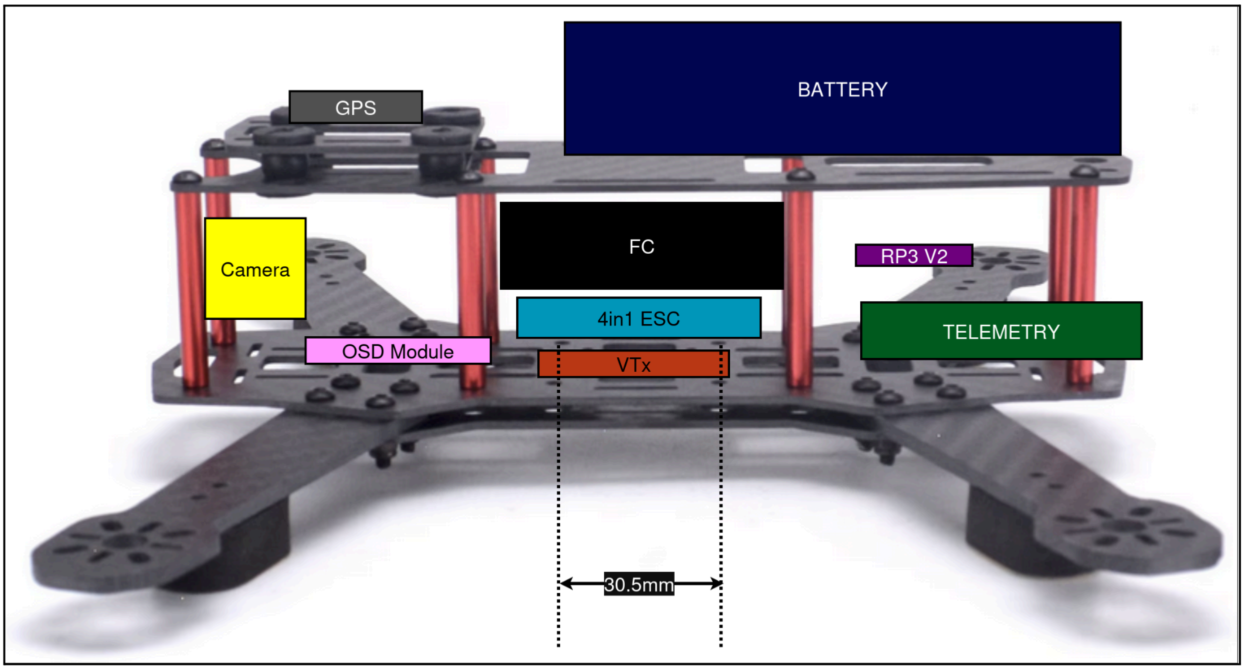
The dimensions of all the drone components, apart for motors and propellers, are summarized below:

- **Flight Controller:** 53.3 x 39 x 16.2 mm
- **Power Module:** (unknown dimensions)
- **4in1 ESC:** 41 x 46 x 7.6 mm
    - M4 30.5x30.5mm (M3 grommets included)
- **Battery:** 105 x 35 x 25mm
- **GPS:** 25 x 25 x 6mm
- **Telemetry:** 28 x 53 x 10.7mm
- **RC Receiver:** 22 x 13 x 4mm
- **Camera:** 14 x 14mm (bracket 19 x 19mm)

- **VTx:** 36 x 22 x 5mm (holes 30.5mm)
- **OSD Module:** 17.5mm x 35mm, (unknown thickness)

A very quick conceptual sketch, accounting for each component dimension, is shown below.

The mass estimate, not considering screws and wirings, is the following (QAV only):
- 592g (no OSD board, VTx and camera)
- 610g (with OSD board, VTX and camera)



Conceptual sketch of internal drone components. Motors and propellers are not shown. Dimensions were scaled using the known 30.5mm square in the frame, and the dimensions of each component. All parts are supposed centered with-respect-to the left-right drone plane

6.2) Electronics and Wirings

Concerning electrical connections, in order to avoid shorting expensive components, I decided to create a full wiring scheme (`02_First_Drone_Build_Wiring_Scheme.pdf` within [the original GitHub Link](#)), including also the video elements. (although those were not bought initially)
Plus, I checked if all elements were ok for batteries going from 3s to 6s; and if the max amperages were respected: note the following points:
- While the amperage of the PM02 V3 Power Module is accepted up to 60A, the XT60 Plug and 12AWG wire only accept 30A; different wires will have to be used

There are still doubts on how to connect the VTx system, but since I am not buying that stuff right now it's of less concern for the moment. The issue arises because of the limited number of ports on the Pixhawk 6C mini; but we will manage to make it work for a first drone.
At the moment, Pixhawk has the following ports, used by the following components:

Pixhawk Port	Connected Component
POWER	Power Module PM02 V3
TELEM1	SiK Telemetry Radio
TELEM2	Radio Receiver RP3 V2
GPS1	GPS GOKU GM0 …
GPS2	4in1 ESC Skystars AM60 AM_32…

I may have problemos fitting the camera OSD and the ESC telemetry. It's one or the other due to the limited amount of compatible Pixhawk ports. Note that when asking what to do, AI's (ChatGPT) tend to suggest to use the debug port; but it does not seem a good idea.

The other option is to buy a CAN gps module and connect it to CAN1, then connect the OSD to the freed GPS1 Pixhawk port

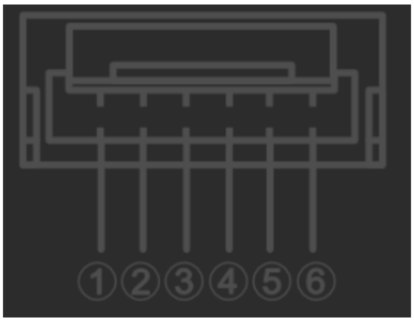
6.3) Detailed Wiring

While some wiring considerations were exposed in **6.2) Electronics and Wirings**, an update had to be written, to specify actual build practices. The standards by Holybro were applied (full page, standards, connector standards,)

As expressed previously, only 4 types of Pixhawk ports are relevant for current assembly. Here are detailed the generic pin names (specific names are written in the official Pixhawk ports guide), preceded by the pin number:

- **Telemetry (1 and 2):** counts (1)VCC, (2)TX, (3)RX, (4)CTS, (5)RTS, (6)GND pins
- **Full GPS (GPS 1):** counts (1)VCC, (2)TX, (3)RX, (4)I2C1 SCL, (5)I2C1 SDA, (6)SAFETY SWITCH IN, (7)SAFETY LED, (8)VDD_3V3, (9)BUZZER, (10)GND pins
- **Basic GPS (GPS 2):** counts (1)VCC, (2)TX, (3)RX, (4)I2C1 SCL, (5)I2C1SDA, (6)GND pins
- **Power:** counts (1)VCC, (2)VCC, (3)CURRENT, (4)VOLTAGE, (5)GND, (6)GND pins

The indication of the number of Pixhawk pin is shown below



Pixhawk connector counting six pins, with relative labeling of the pins

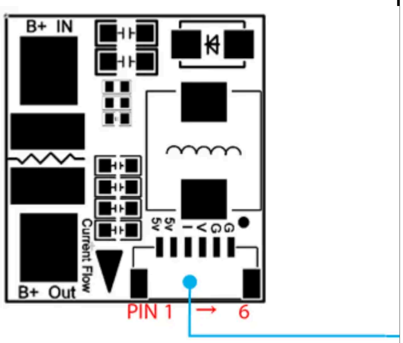
While we define the way to connect each component, we also have to define the different types of communication methods in place with Pixhawk.

- There's the UART4 method, counting VCC, GND, TX and RX; basically the Pixhawk TX is connected to the component RX and vice versa
- There's the I2C (or IIC) method, composed of a serial data line (SDA) and a serial clock line (SCL). The Pixhawk SDA and SCL are connected with the component SDA and SCL respectively

The various components connected (at the moment) to the Pixhawk board are: the SiK Telemetry Radio, the power module, The RC Receiver, the ESC and the GPS.

The Power Module

Change the XT60 plug. Meanwhile, just use the provided 6-pin cable to connect the PM02 v3 to the Pixhawk's POWER port. No specific manipulation to have here, both are from Holybro. Below are Holybro's documentation screenshots of the power link pins.

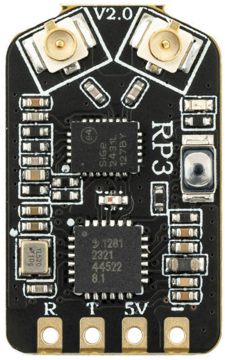
<table>
<tr>
<td>
<table>
<tr><th>Pin</th><th>Signal</th></tr>
<tr><td>1 (red)</td><td>VCC</td></tr>
<tr><td>2 (blk)</td><td>VCC</td></tr>
<tr><td>3 (blk)</td><td>CURRENT</td></tr>
<tr><td>4 (blk)</td><td>VOLTAGE</td></tr>
<tr><td>5 (blk)</td><td>GND</td></tr>
<tr><td>6 (blk)</td><td>GND</td></tr>
</table>
</td>
<td>names from 1 to 6:
1. VDD5V_BRICK1,
2. VDD5V_BRICK1
3. CURRENT1
4. VOLTAGE1
5. GND
6. GND</td>
<td>
</td>
</tr>
<tr>
<td>Pixhawk POWER port Pinout (generic name)</td>
<td>Pixhawk POWER port Pinout (real name, from official doc)</td>
<td>PM02 V3 Pinout</td>
</tr>
</table>

The SiK Telemetry

Same thing as with the Power module. Using the provided cable, we link the telemetry with the TELEM1 port. The pin order is the same; and already accounts for RX-TX switch. Maybe just check if the power and GND pins are in the proper spot

<table>
<tr>
<td>
<table>
<tr><th>Pin</th><th>Signal</th></tr>
<tr><td>1 (red)</td><td>VCC</td></tr>
<tr><td>2 (blk)</td><td>TX (OUT)</td></tr>
<tr><td>3 (blk)</td><td>RX (IN)</td></tr>
<tr><td>4 (blk)</td><td>CTS (IN)</td></tr>
<tr><td>5 (blk)</td><td>RTS (OUT)</td></tr>
<tr><td>6 (blk)</td><td>GND</td></tr>
</table>
</td>
<td>names from 1 to 6:
1. VCC
2. UART7_TX
3. UART7_RX
4. UART7_CTS
5. UART7_RTS
6. GND</td>
<td>
</td>
</tr>
<tr>
<td>Pixhawk TELEM1 or TELEM2 port Pinout (generic name)</td>
<td>Pixhawk TELEM1 port Pinout (real name, from official doc)</td>
<td>Pins on the component side, for the telemetry SiK radio (915MHz and 433 MHz have the same pins)</td>
</tr>
</table>

The RC Receiver

<table>
<tr>
<td>
<table>
<tr><th>Pin</th><th>Signal</th></tr>
<tr><td>1 (red)</td><td>VCC</td></tr>
<tr><td>2 (blk)</td><td>TX (OUT)</td></tr>
<tr><td>3 (blk)</td><td>RX (IN)</td></tr>
<tr><td>4 (blk)</td><td>CTS (IN)</td></tr>
<tr><td>5 (blk)</td><td>RTS (OUT)</td></tr>
<tr><td>6 (blk)</td><td>GND</td></tr>
</table>
</td>
<td>names from 1 to 6:
1. VCC
2. UART5_TX
3. UART5_RX
4. UART5_CTS
5. UART5_RTS
6. GND</td>
<td>

(R, T, 5V, -) ports</td>
</tr>
<tr>
<td>Pixhawk TELEM2 (or TELEM1) port Pinout (generic name)</td>
<td>Pixhawk TELEM2 port Pinout (real name, from official doc)</td>
<td>Pins on the component side, for the RC receiver by RadioMaster</td>
</tr>
</table>

For the RC receiver/Pixhawc connection, the following pins will have to be connected:

- Pixhawk VCC to RC receiver 5V
- Pixhawk UART5_TX(out) to RC receiver R
- Pixhawk UART5_RX(in) to RC receiver T
- Pixhawk GND to RC receiver -

All other pins on Pixhawk's side should be left floating

The GPS

<table>
<tr>
<td>
<table>
<tr><th>Pin</th><th>Signal</th></tr>
<tr><td>1 (red)</td><td>VCC</td></tr>
<tr><td>2 (blk)</td><td>TX (OUT)</td></tr>
<tr><td>3 (blk)</td><td>RX (IN)</td></tr>
<tr><td>4 (blk)</td><td>I2C1 SCL</td></tr>
<tr><td>5 (blk)</td><td>I2C1 SDA</td></tr>
<tr><td>6 (blk)</td><td>SAFETY SWITCH IN</td></tr>
<tr><td>7 (blk)</td><td>SAFETY LED</td></tr>
<tr><td>8 (blk)</td><td>VDD_3V3 (powers switch and led)</td></tr>
<tr><td>9 (blk)</td><td>BUZZER (driven by a buzzer driver)</td></tr>
<tr><td>10 (blk)</td><td>GND</td></tr>
</table>
</td>
<td>names from 1 to 10:
1. VCC
2. TX1(out)
3. RX1(in)
4. SCL1
5. SDA1
6. SAFETY_SWITCH
7. SAFETY_SWITCH_LED
8. IO_VDD_3V3
9. BUZZER-
10. GND</td>
<td>

(TX, RX, GND, 5V, SCL, SDA) ports</td>
</tr>
<tr>
<td>Pixhawk GPS1 port Pinout (generic name)</td>
<td>Pixhawk GPS1 port Pinout (real name, from official doc)</td>
<td>Pins on the component side, for the Goku GPS</td>
</tr>
</table>

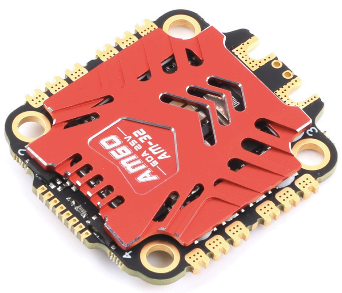
To connect the GPS to Pixhawk, the following pins will have to be connected

- Pixhawk VCC to Goku 5V
- Pixhawk TX1(out) to Goku RX
- Pixhawk RX1(in) to Goku TX
- Pixhawk GND to Goku GND
- Pixhawk SCL1 to Goku SCL
- Pixhawk SDA1 to Goku SDA

Concerning the remaining four Pixhawk lines (SAFETY_SWITCH, SAFETY_SWITCH_LED, IO_VDD_3V3, BUZZER-); the idea will be to place an LED, a buzzer and a safety switch somewhere on the QAV250, and connected as follows:

- IO_VDD_3V3 to LED to SAFETY_SWITCH_LED
- IO_VDD_3V3 to SWITCH to SAFETY_SWITCH
- BUZZER- to BUZZER to GND

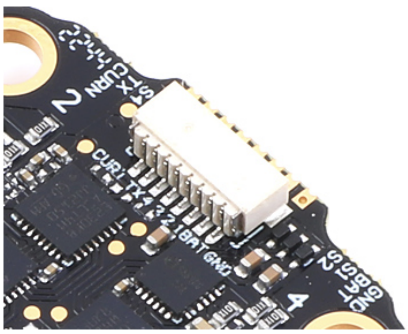
The ESC

	Overall ESC: on the left: all connectivities; on the top right, PM02 v3 power input (and capacitor slot); and all around the soldering pads for the four motors

From a wiring point-of-view:

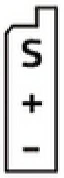
- Each motor is soldered to each 3-slot group around the ESC
- The PM02 V3 is attached to the top (input power) along with the capacitor (probably, unless the pre-included PM02 V3 capacitor is ok on its own)

The 8 small pins should then be connected using the description below

<table>
<tr>
<td>
<table>
<tr><th>Pin</th><th>Signal</th></tr>
<tr><td>1 (red)</td><td>VCC</td></tr>
<tr><td>2 (blk)</td><td>TX (OUT)</td></tr>
<tr><td>3 (blk)</td><td>RX (IN)</td></tr>
<tr><td>4 (blk)</td><td>I2C1 SCL</td></tr>
<tr><td>5 (blk)</td><td>I2C1 SDA</td></tr>
<tr><td>6 (blk)</td><td>GND</td></tr>
</table>
</td>
<td>names from 1 to 6:
1. VCC
2. UART8_TX(out)
3. UART8_RX(in)
4. I2C2_SCL
5. I2C2_SDA
6. GND</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pixhawk GPS2 port Pinout (real name, from official doc)</td>
<td>Closeup view of the ESC, revealing ports GND, BAT, S1,</td>
</tr>
</table>

Pixhawk GPS2 port Pinout		S2, S3, S4, TX, CURN

The TX pin is connected to the UART8_RX of the Pixhawk. In theory, the ESC ground is already carried to the Pixhawk via the PWM wirings, so we should not require it.
If it works, we would receive telemetry from the ESC. If not, we will simply free the TELEM2 Pixhawk port, and use it for something else later (for example OSD Board later).

<table>
<tr>
<td></td>
<td>The 1 to 4 FMU PWM OUT ports are connected as follows (for PWM connector i, with i={1,2,3,4}:
● the Si pin is connected to the ESC Si pin
● the + pin is left disconnected
● the - pin is connected to the ESC GND pin</td>
</tr>
</table>

6.4) Cost

In November 2025, making ship all components to Toulouse, France, I managed to buy everything but the video equipment (VTx, Micro OSD, Camera, FPV Goggles) through AliExpress + Amazon, for around **540 euros** (620 USD).

6.5) Simulator

While waiting for the components other than the RC controller to ship and arrive, it is possible to connect the RadioMaster Pocket Crush to the computer using the upper USB port, to use the controller with a drone simulator. The complete RC controller setup, including a mode for FPV simulator, is detailed by OscarLiang.

After some research, I ended up installing Liftoff, but be aware there are tons of simulators online. For my side, I decided to pick one of the most realistic ones; uncrashed is another possible option.

Within Liftoff, one can use pre-designed drones, or modify them to build one of our own. Pixhawk FCs are not available, as Liftoff is made for FPV drones (Betaflight mainly), and the components are limited to what is available in the game; however I managed to have a Liftoff drone similar to the one I am planning to build, in terms of mass, propellers, motors, frame and battery voltage. An example of such drone is shown below; doing this allowed me to practice manual flight.

QAV 250 drone, as build in Liftoff. Using a 3S battery instead of default FPV drone 6S battery leads to lower drone reactivity (higher maneuverability)