GoPro FPV Drone

LUND UNIVERSITY

Viggo Koch, School of Industrial Design, 2022

Degree Project for Bachelor of Fine Arts in Design

GoPro FPV Drone

By Viggo Koch

Degree Project for Bachelor of Fine Arts in Design
Main field of study Industrial Design
From Lund University School of Industrial Design, Department of Design Sciences

Examiner:
Professor Claus-Christian Eckhardt

Supervisors:
Professor Claus-Christian Eckhardt
Lecturer Anna Persson
Senior Lecturer Jasjit Singh
Senior Lecturer Charlotte Sjödell

External contributors:
FabLab Halmstad (3D printing)

2022
ISRN: LUT-DVIDE/EX--22/50616-SE

Abstract

This project is the culmination of my time as a design student in Lund, and heavily influenced by many years of experience and knowledge gained as a professional drone pilot.

The decision to work with drones for my bachelor project was an easy one. It was my last chance in this education to design something that I already had quite extensive knowledge about.

Despite that, I learned alot and the process was more difficult than I anticipated. Making a drone design that could actually be a viable product and applying an existing design identity was challenging and it deeply affected the outcome of this project.

Sammanfattning

Detta projekt är som ett kulmen av min tid som designstudent i Lund, och starkt influerat av de erfarenheter och lärdomar jag fått som en professionell drönarpilot.

Valet att jobba med drönare i detta projektet var enkelt. Det var min sista chans i denna utbildning att designa något som jag hade mycket förkunskaper om.

Trots det lärde jag mig mycket och designprocessen var svårare än jag förväntade mig. Att designa en drönare som skulle kunna vara en riktig produkt och applicera en varumärkesidentitet var utmanande och hade stor påverkan på slutresultatet.

Table of contents


Motivation & Background

What is FPV?

FPV is short for ‘First Person View’. That means that the pilot doesn’t fly the drone by looking at it, but instead use a pair of video goggles to watch a live video feed from its camera. There is no noticable delay in the video feed from the drone, and combined with the immersion that video goggles offer, the pilot has excellent spatial awareness.

This makes it possible to fly drones that are very fast and agile with good precision. One can fly close to things at high speed, even far away from the pilot or behind visual obstructions.

This unlocked a huge potential in the world of video making, and eventually FPV drones became a legitimate and popular tool for filmmaking.

Me flying FPV during the ‘Race Of Champions’ live TV broadcast

Personal connection

I have been doing this since the early days when FPV was just a small hobby. I built my first drone in 2013 and in 2014 I built my first FPV drone. In 2016 I started racing in the ‘Swedish Drone Cup’ and in 2018 I competed with the swedish team in the World Championship in China.

Around that time I started making videos for fun, and gradually I stopped racing to focus fully on videomaking, and in 2019 I started freelancing as a professional FPV pilot. I’ve done some big projects since then, such as live broadcast motorsport events and feature films.

Racing car filmed with FPV drone

The problems with current FPV drones

Ever since FPV systems became popular for hobbyists, it has almost been exclusive to the very technical world of custom made and ‘hobby grade’ drones. But in 2021, the industry leader DJI released an FPV drone that was made for the avarage consumer. It had an array of sensors and a suite of safety systems so inexperienced people could fly it, and step by step, disable the safety systems to eventually fly like a pro.

This was a good aproach to introduce FPV drones to the masses, but the DJI FPV drone had some issues that the hobby community was quick to identify, which gave the DJI FPV drone a bad reputation among hobbyists, so it was not dificult to find bad reviews of it.

A big part of FPV flying is to fly close to things, at high speed or making tricks, sometimes all at once. So taking risks and pushing limits are a fundamental part of FPV flying and crashes will happen sooner or later.

Most “hobby grade” FPV drones are very durable, and relatively easy to repair (apart from soldering) because of a modular and simple design.

The DJI FPV drone is very fragile and the design is quite complicated, so it’s more time consuming to replace most parts compared to Hobby drones.

Another issue with the DJI FPV drone is that the propellers are visible in the camera, which forces the user to crop the edges of the video. That results in a reduced field of view which can reduce the sense of speed in the final video.

Lastly, the DJI FPV drone has quite poor performance and flight dynamics compared to most ‘hobby grade’ fpv drones. It’s slow in comparison and the sloppy flight dynamics make it shaky in windy conditions or demanding situations such as sharp turns etc.

DJI FPV

- Less performance than hobby drones.
- Fragile
- Propellers visible in video
- Complicated design

Hobby grade

- Technical and not user friendly.
- Very unrefined design, “bare-bones” and exposed elec-tronics.
- No active safety systems which makes it unforgiving
- Extarnal video camera (extra weight)

Brief

Design an FPV drone that is as good as the DJI across the board, and **better** in terms of **performance, video quality & durability**

Research

Market position

The drone market is relatively new and still evolving quickly, but FPV has always been it's own, largely unknown parallell market. But since FPV drones started getting popular for videomaking, they have become more known by people outside the hobby and slowly getting more mainstream.

Nowadays, high performance FPV drones are available at all levels in the drone industry, all the way from toys to ones that carry high end cinema cameras. However, The FPV market is still way overrepresented by hobbyists and professionals like myself. The DJI FPV drone is still the only true 'consumer grade' FPV drone on the market, and as previously mentioned, it's far from perfect.

One thing they got right though, is the size. It has ~5 inch propellers which is by far the most popular and most versatile size of high performance FPV drones.

Toy FPV drone

Toy drone

Beginner camera drone

"Prosumer" camera drone

"Hobby grade" FPV drone

~5 inch propellers

"Consumer grade" FPV drone

Heavy-lift FPV drone

Heavy-lift camera drone

Target group

- Same as dji fpv drone
- Hobbyists that are tired of the technical aspects and / or are very design-consious
- Thrill seekers / adrenaline junkies
- Creative photographers / videomakers
- Action sport athletes
- Anybody who wants to try FPV and get the experience without the technical side of it

To satisfy the target group, the drone has to have a certain featureset and capabilities. These features dictate what components will be needed.

Features & components

Features

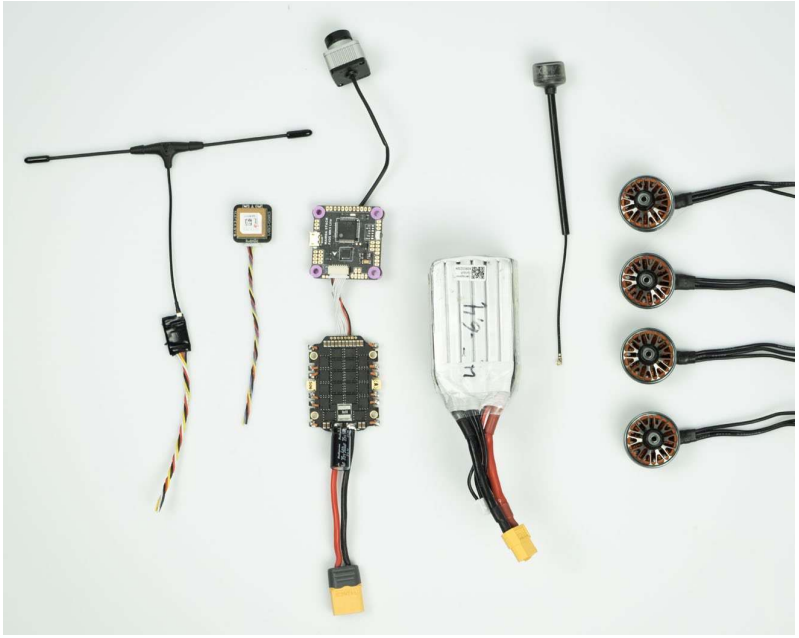
- Return to home
  When signal is lost or pilot gets lost etc
- Obstacle avoidance
  Automatically stop when it gets too close to an obstacle
- Remotely adjutable camera angle
- ~150km/h top speed
- Durable
- Easy to repair
- No propellers in video
- Minimum 10 min flight time
- Easy battery swap

Specific components

- GPS
- Distance sensors
- Servo / Gimbal motor

General components

- Motors
- ESC (powers the motors)
- Flight controller
- Camera
- FPV system
- Propellers
- Control reciever



Motors, battery, ESC, camera, flight controller, antenna, reciever & GPS module

GoPro as brand?

While researching target groups and thinking about the usecases for FPV drones in the hands of normal consumers, I realized that the target group is quite similar to GoPro users.

And I think FPV drones could fit GoPro's brand image. GoPro cameras can do what normal cameras can't, and in a similar way FPV drones can fly like normal drones can't.

Brand values

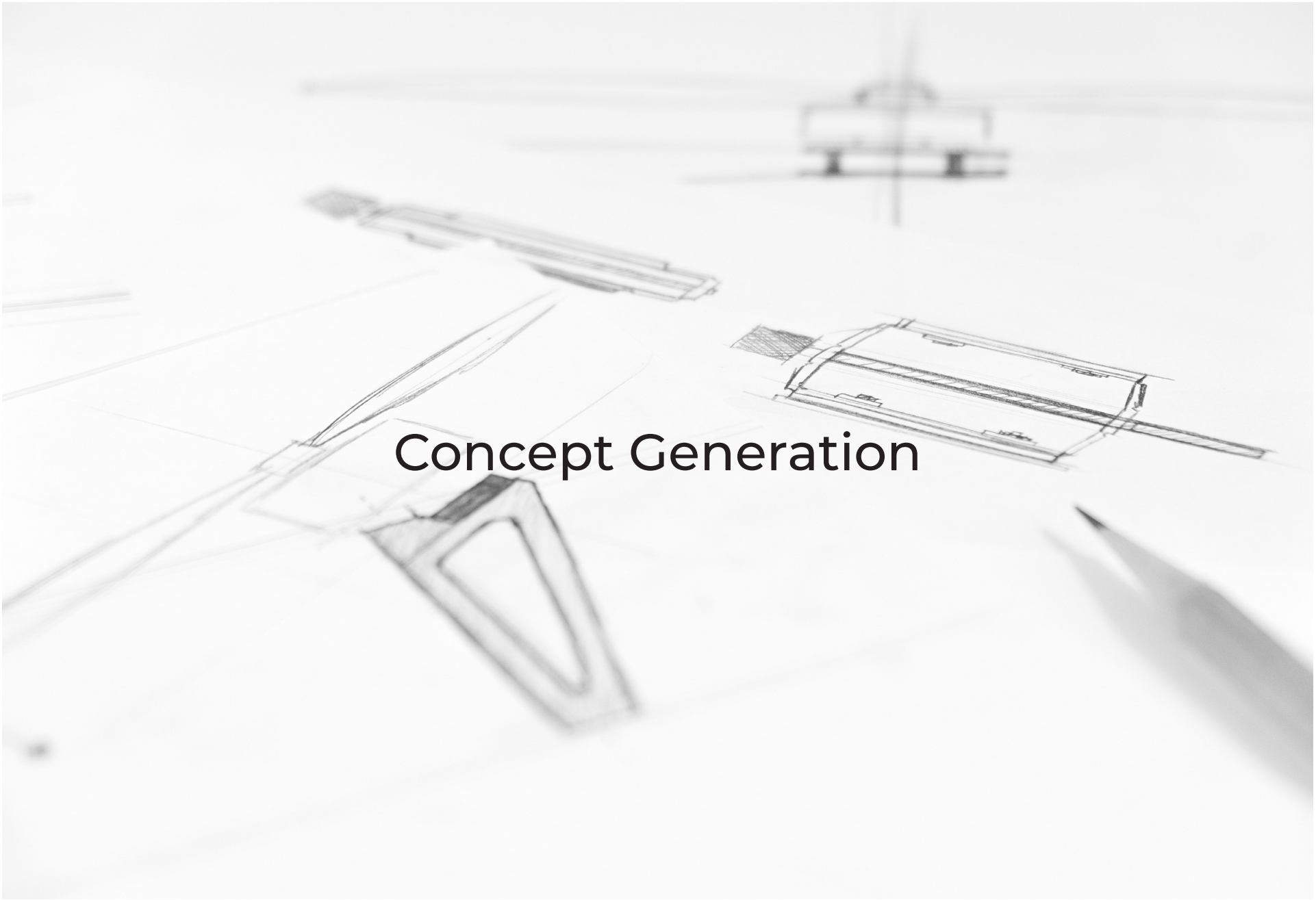
"GoPro helps the world to capture and share itself in immersive and exciting ways. We are a force for positivity, celebrating all things awesome while inspiring people to pursue their passions."

Design identity

Rugged - Versatile - Playful - Minimalistic - Fit for purpose - Cool

Colour, material & finish

- Black, dark grey & blue accents
- Soft touch rubberized plastic
- Hard textured plastic
- Matte black anodized aluminium



Concept Generation

Drag reduction

For a few years, even before DJI released their FPV drone, I've had some ideas on how drag can be reduced on fast drones. Minimizing frontal area is important for obvious reasons, and true for all objects that move through the air.

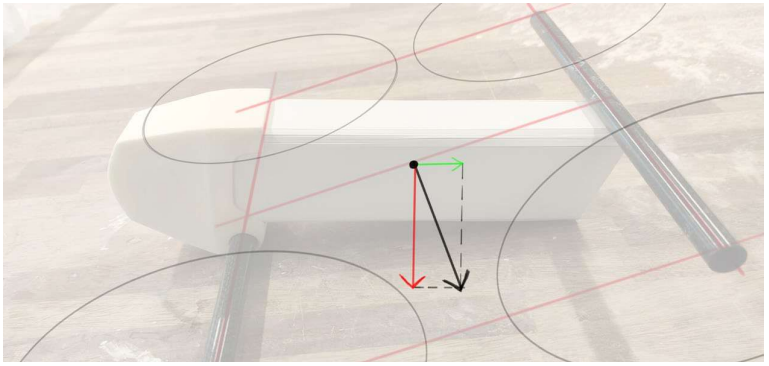
How can this be achieved on a drone?

Firstly, let's talk about some basic drone physics.
A drone can fly because the downward thrust from the propellers pushes the drone upwards to overcome gravity. In order to fly forward for example, the drone has to tilt forward to direct some of that downward thrust backwards. So basically, a drone goes in the direction it tilts.

That is only true for traditional drones however. There has been some (mostly unsuccessful) attempts of drones with thrust vectoring, meaning the motors can tilt independently of the drone body to change the direction of the thrust. It's a good idea at first glance, but the more i think about it, the more it falls apart. There's many problems with that approach. But the two main ones are that the added complexity and weight is not worth the drag reduction.

So the only way to recuce drag is to reduce the size and drag coefficient of the drone. There's not much that can be done about the size because the electronics and battery are the limiting factors. So what we're left with is to optimize the drag coefficient.

The idea I mentioned above is a solution to this problem, and it's actually very simple and logical. By re-arranging the structure off the drone so the elongated body is tilted relative to the propellers and thus aligning it with the airstream, drag will be conciderably reduced in fast forward flight.



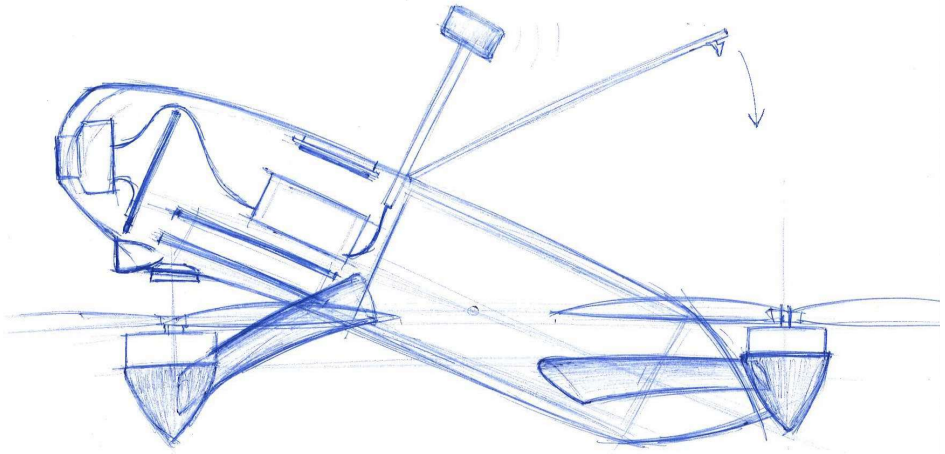
Durability & materials

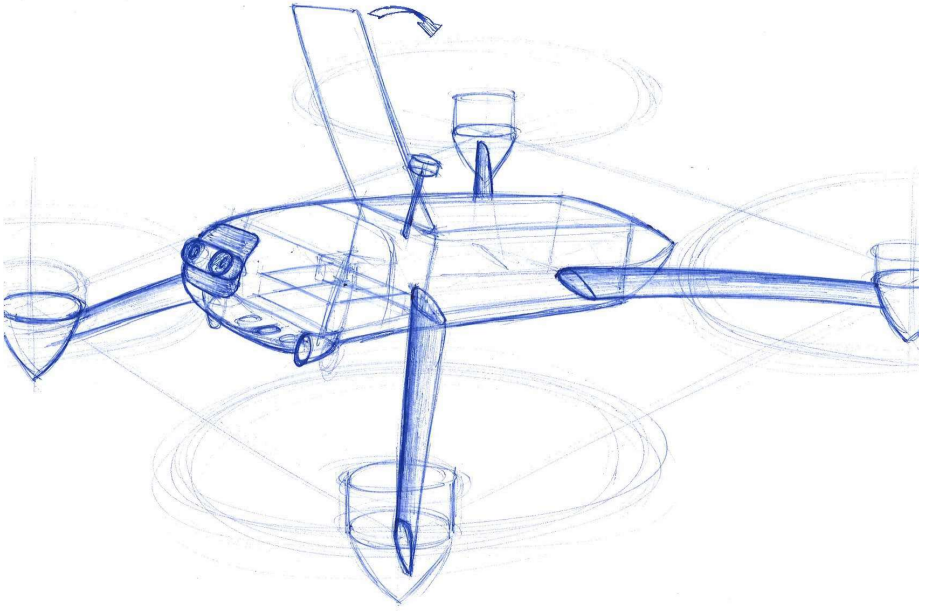
I've been mentioning that FPV drones has to be durable. One might think that flexible or semi-flexible materials such as soft plastics and rubber could be used to achieve this. But, that won't work. The drone needs to be as stiff as possible in order to have good flight characteristics. So thanks to basic material properties, there will need to be a compromise between flight characteristics, weight and durability.

Hobby drones and professional camera drones are often made mainly from carbon fiber and aluminium fasteners etc. Carbon fiber is very stiff, lightweight and very strong, and objectively the best for the application (not considering cost). I was a bit small-minded and stubborn, so that is what I aimed to use in this project.

Concept 1

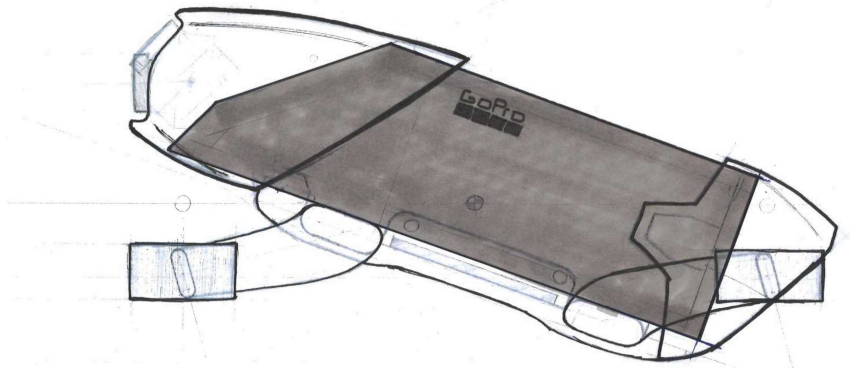
Carbon fiber is an amazing material, and relatively affordable in standard formats like sheets and tubes (compared to advanced moulded parts). I was thinking to make this concept as one part with hollow arms, but quickly realized that it would be way to complicated to be made in carbon fiber and still be affordable, and probably too weak to be made of plastic (if even possible). Also, a one piece design would not be good for repairability.

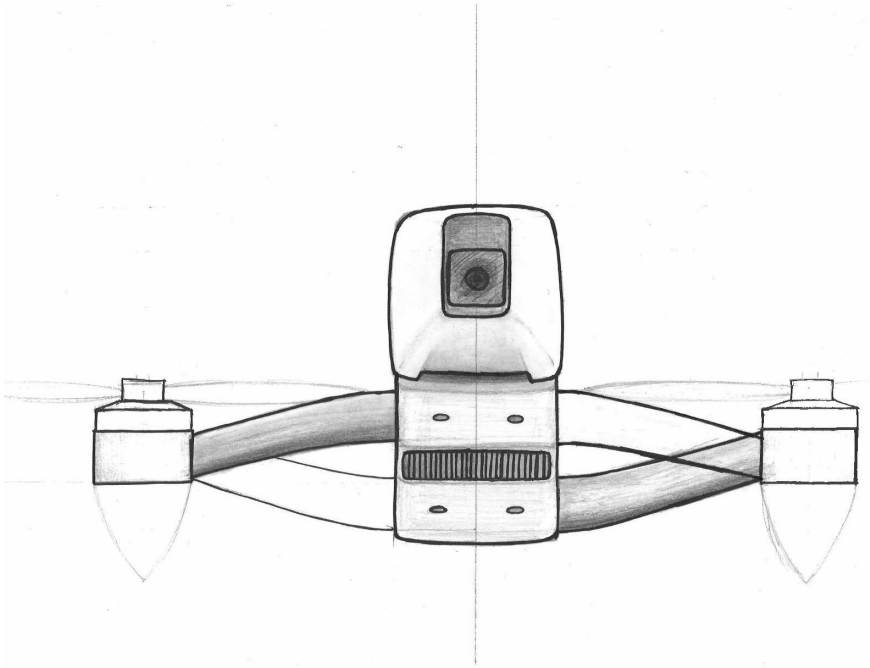




Concept 2

This concept is based on Concept 1, but I was trying to simplify it and make it modular. The idea was that the main body could be a standardised rectangular carbon fiber tube with thin plastic panels and covers. The bent arms however would still be complicated and expensive to make.



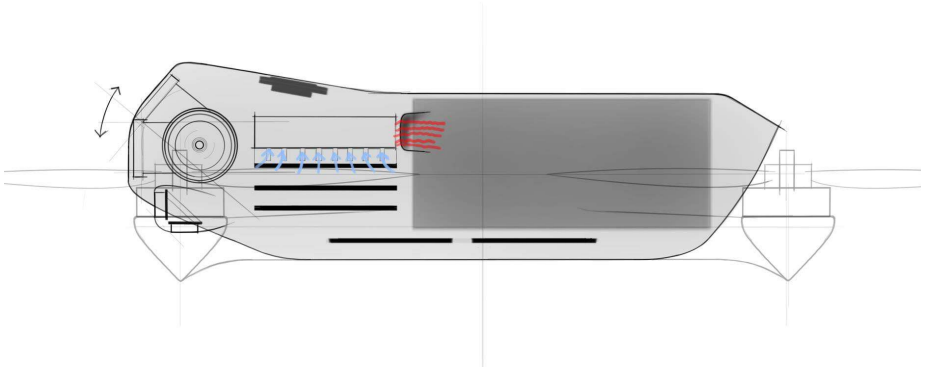


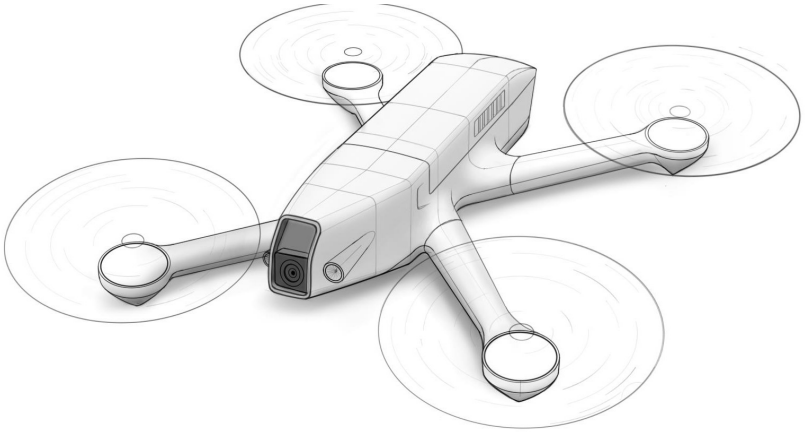
Concept 3

As I suspected, the downside of tilting the body relative to the propellers is that it's more difficult to make a strong & simple structure.

This concept is more traditional, easier to package the internals and it's simpler to produce. It could probably be made of two plastic halves and still be stiff enough for good flight characteristics. And a flat carbon fiber baseplate could be incorporated seamlessly between the two halves to make it stiffer and really durable.

I like this concept for its simplicity, but it's not really what I wanted to do. I really wanted to make the tilted body idea work, so I kept thinking about how it could be done.

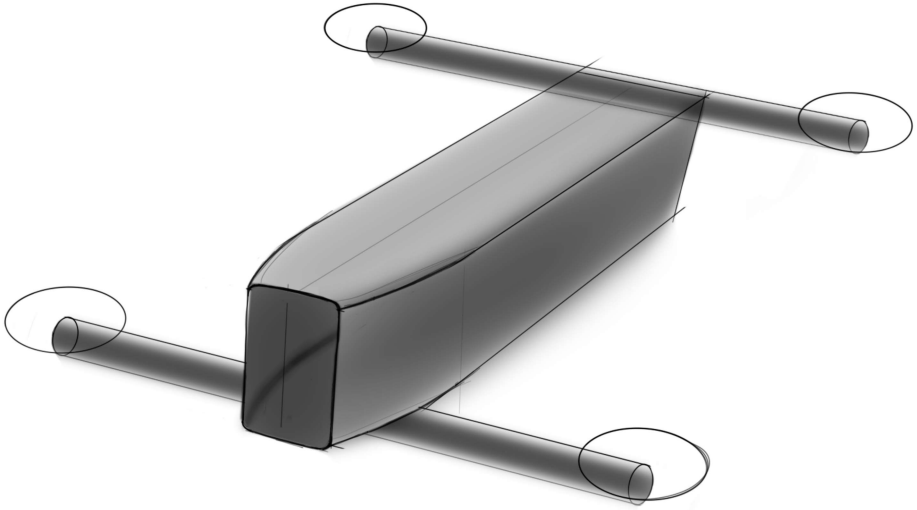


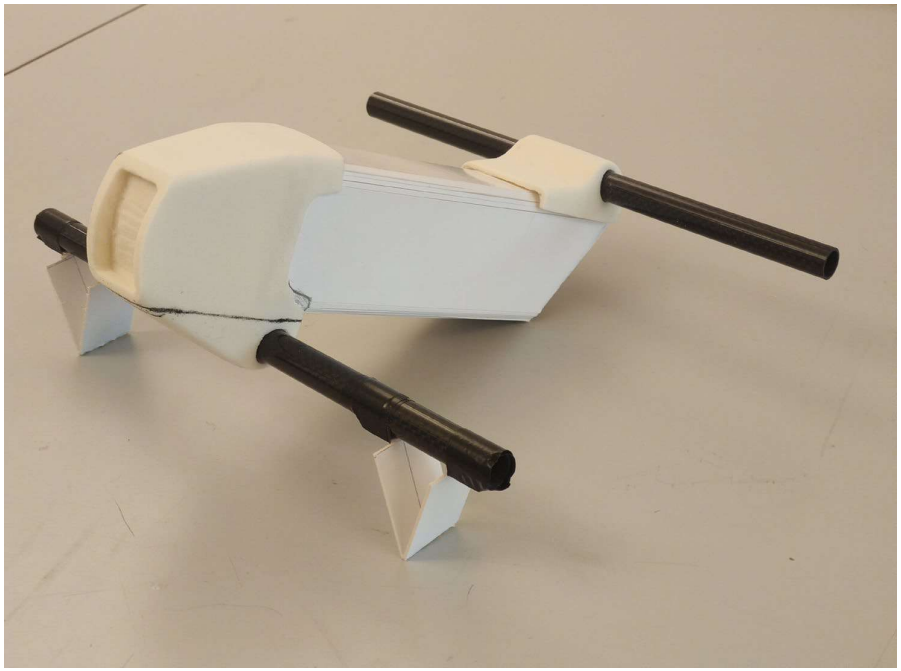


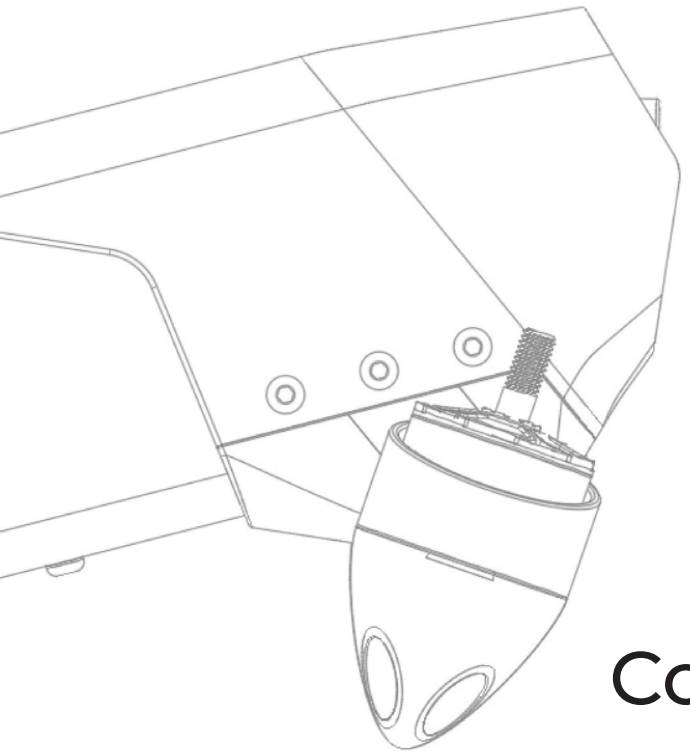
Concept 4 - This is the one

I continued to think about how to tilt the body relative to the propellers while keeping it simple and sleek. Then I had this idea and I was annoyed I didn't think of it earlier, it's so simple. And it meets all my criteria, tilted body, simplicity & modularity. So I made a full scale mockup to figure out how the arms might be attached. I was thinking that the connection could be like clamps / blocks holding the arms firmly to the body.

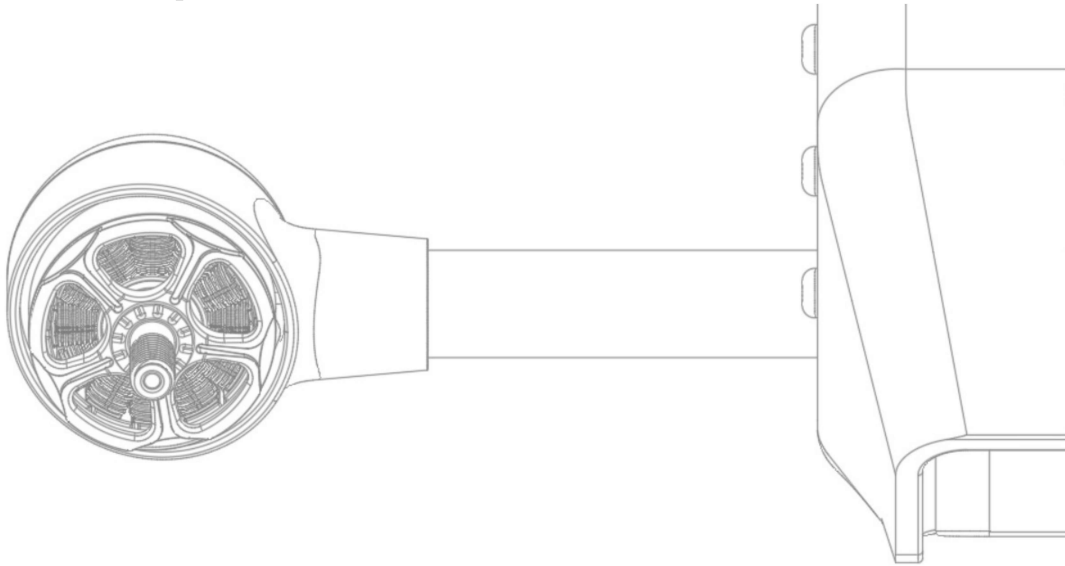
I also realized that landing legs in the front would be necessary to lift the front propellers off the ground.







Concept Development

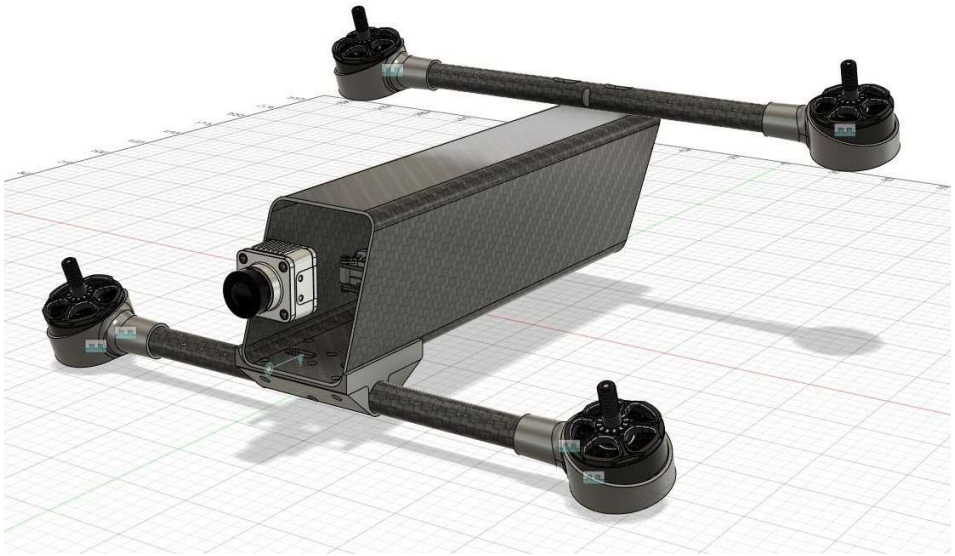


Thermal management

I was pleased with concept 4 and started to make it in CAD to figure out the details. At this point I was still thinking to base it on a rectangular carbon fiber tube with round tubular front & rear arms.

I realized that some electronics inside needs cooling and I saw two ways to make that happen. Air cooling by making holes for the air to pass through the body, or aluminium heatisnks to transfer the heat to the outside. I didn't want to make the electronics unnecessarily exposed to the elements, so I decided to go with heatsinks.

I made some sketches over the basic cad model on how the plastic covers could look like and how to incorporate the heatsinks.



In a meeting with my supervisor I explained my ideas on the previous page, and was asked why the body could not be made of aluminium, since it's much cheaper than carbon fiber (even standardised parts like a rectangular tube). Aluminium is also more eco-friendly, because it can be recyceled and does not contain toxic polymers.

I thought about it for a while and then I had a brainwave. If the body is aluminium there is no need for separate heatsinks. The whole body is a heatsink. And if it's made by extrusion, it can have a custom profile.

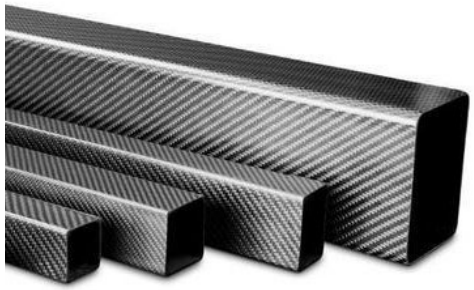
I started working on this idea and made it thicker where the screws would screw in and incorporated fins to increase the surface area for heat dissipation, like a heat sink.

Until this stage, my progress had been quite slow and I was not really where I needed to be and the possibility that I would not finish in time for the final presentation was real.

I started working a lot and made good progress. I was so focused and stressed that I forgot to document some of my steps and thoughts behind them. But soon, the design was pretty much finished.

Aluminium heatsink

+



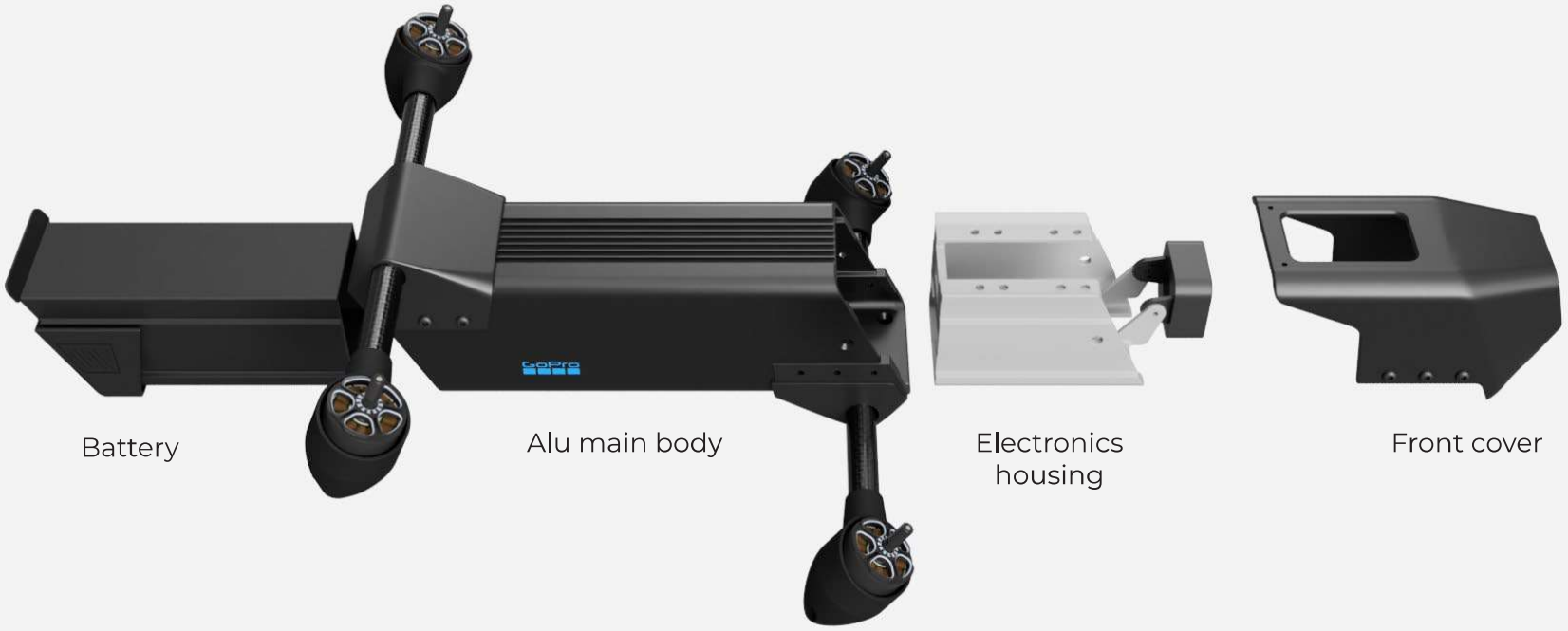
Carbon fiber rectangular tube

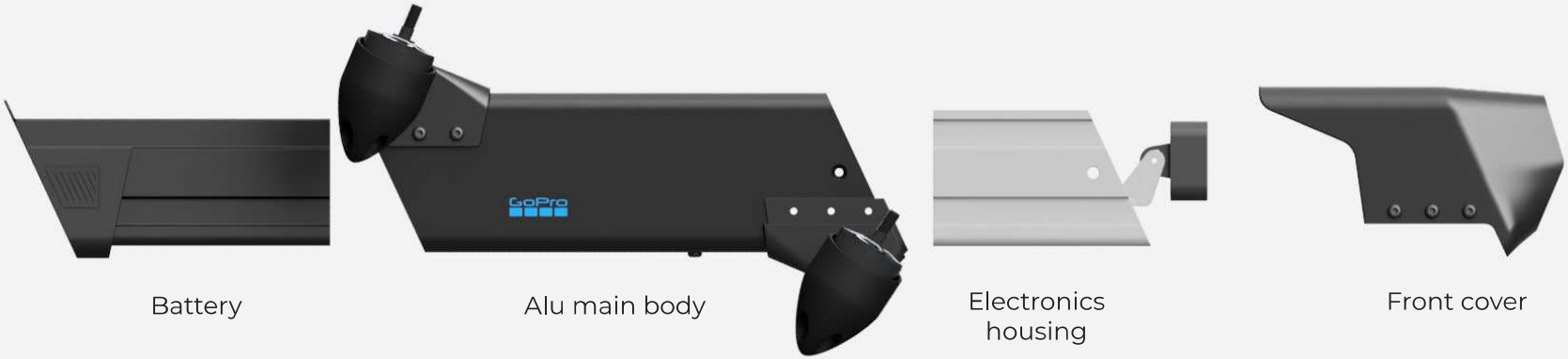
=

Aluminium extrusion

Finished 3D model

Modular design



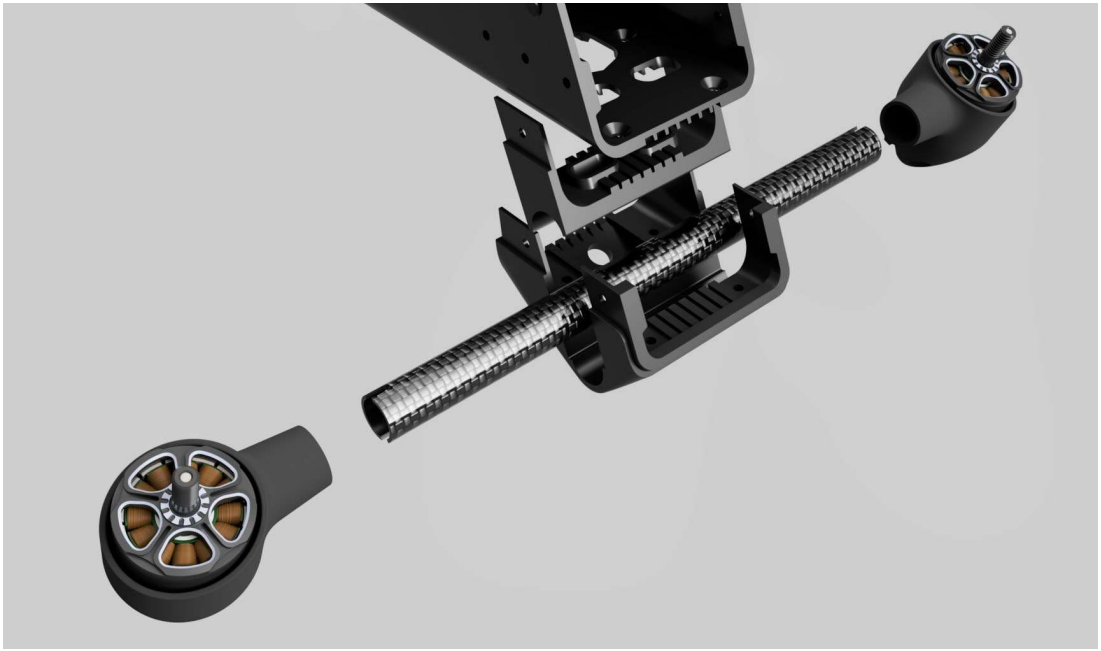

Battery
Alu main body
Electronics housing
Front cover

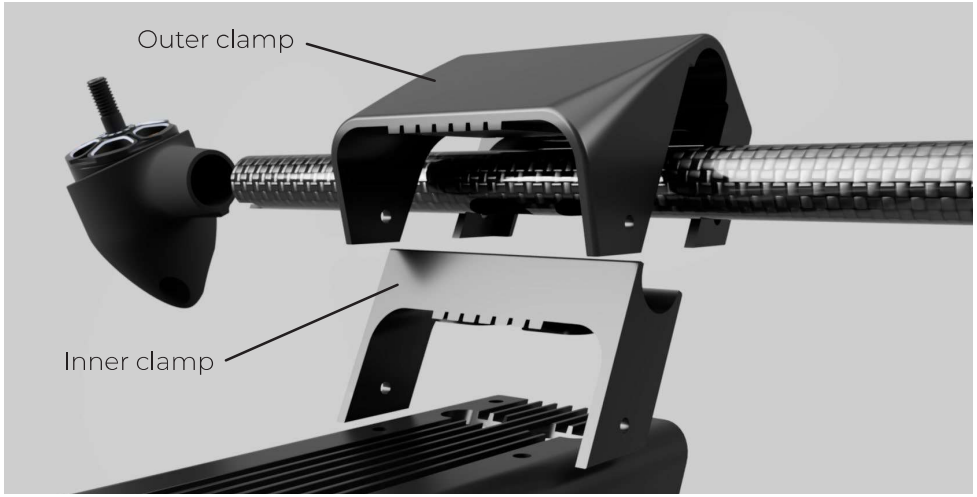

GoPro

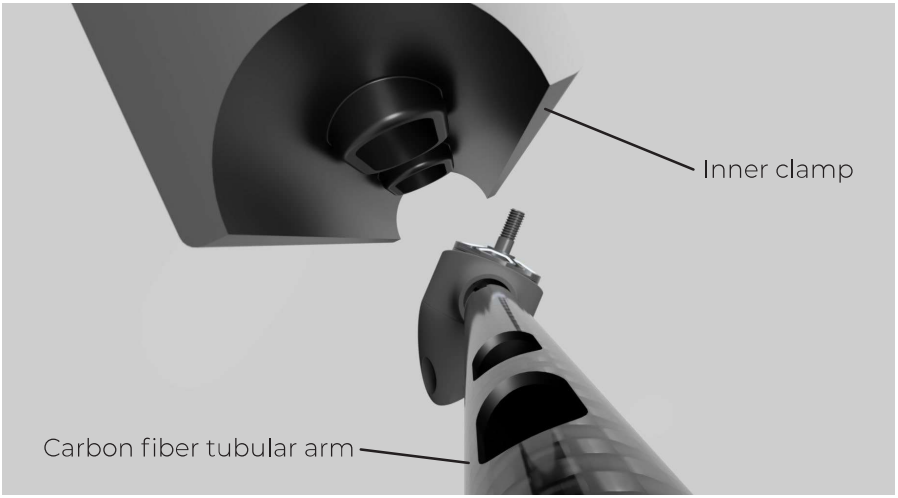
Arm mounting solution

The most challenging part of this design was how to mount the round arms to the body and keep them aligned while making room for cables to pass from the motors through the arms, inner clamp and main body to the ESC on the inside.

I made oval holes in the carbon fiber tubes and corresponding & hollow “pegs” in the inner clamp to keep the arm completely locked and to provide a passthrough for the motor cables to the inside. The outer clamp is very slightly undersized and fastened with screws to hold the arms firmly in place







Motor mounting solution

The motor mounts were quite straightforward to design. It is just a plastic piece with a hole pattern to mount the motor. They will be glued to the arms and they also indent in a notch in the end of the arms to ensure they are aligned.

Under the motor mount is a hollow fairing to reduce drag under the motor by displacing the empty space that would otherwise crete a low-pressure area. The fairing is simply mounted by having the four motor screws go through them and sort of “sandwich” the motor mount. On the front motors they also double as landing legs.

Regarding durability and stiffness, I think plastic is ok in this application since there is not much room for flex because it’s such a small part. And thus the plastic doesn’t have to be very stiff, so it can have good impact resistance instead.

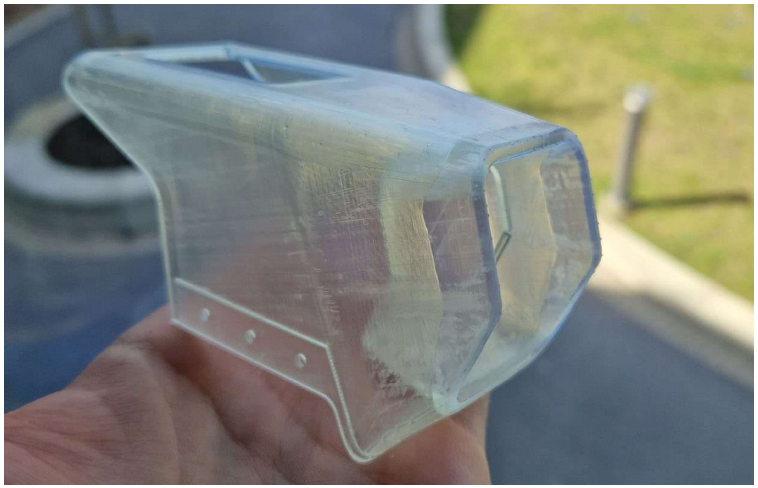
Prototype Making

3D printing

As mentioned, I needed to make rapid progress to finish this project in time. Thanks to my brother at 'Högskolan i Halmstad', I got access to their workshop called FabLab. It's a great workspace with a lot of machines and 3d printers available for use. Luckily there was not much activity, so at one point I had about six or eight 3d printers running simultaneously. I was there for two days working flat out and refining some parts in multiple iterations. That's what I call rapid prototyping!

They even had some SLA resin printers which I used to make the front cover after being dissapointed with the quality i got from a regular filament printer.

In total, the drone consists of 18 components and 12 different designs (motor mount and landing leg are multiples)



Cutting holes and notches in the arms

Basic layout

Sanding and filing for fit & finish

Painting

The paint job was a bit last minute and I couldn't find the colours I wanted. So it was just semigloss black over the base coat, which was the best I could get my hands on at the moment. I tried to make the covers appear more matte than the main body by making it slightly textured with an "incorrect" technique. It was not as good as I hoped, but better than nothing.

Ofcourse i wanted to use the proper colors to make it blend in with other GoPro products, but I simply didn't have the time.

Things not developed

Memory card slot

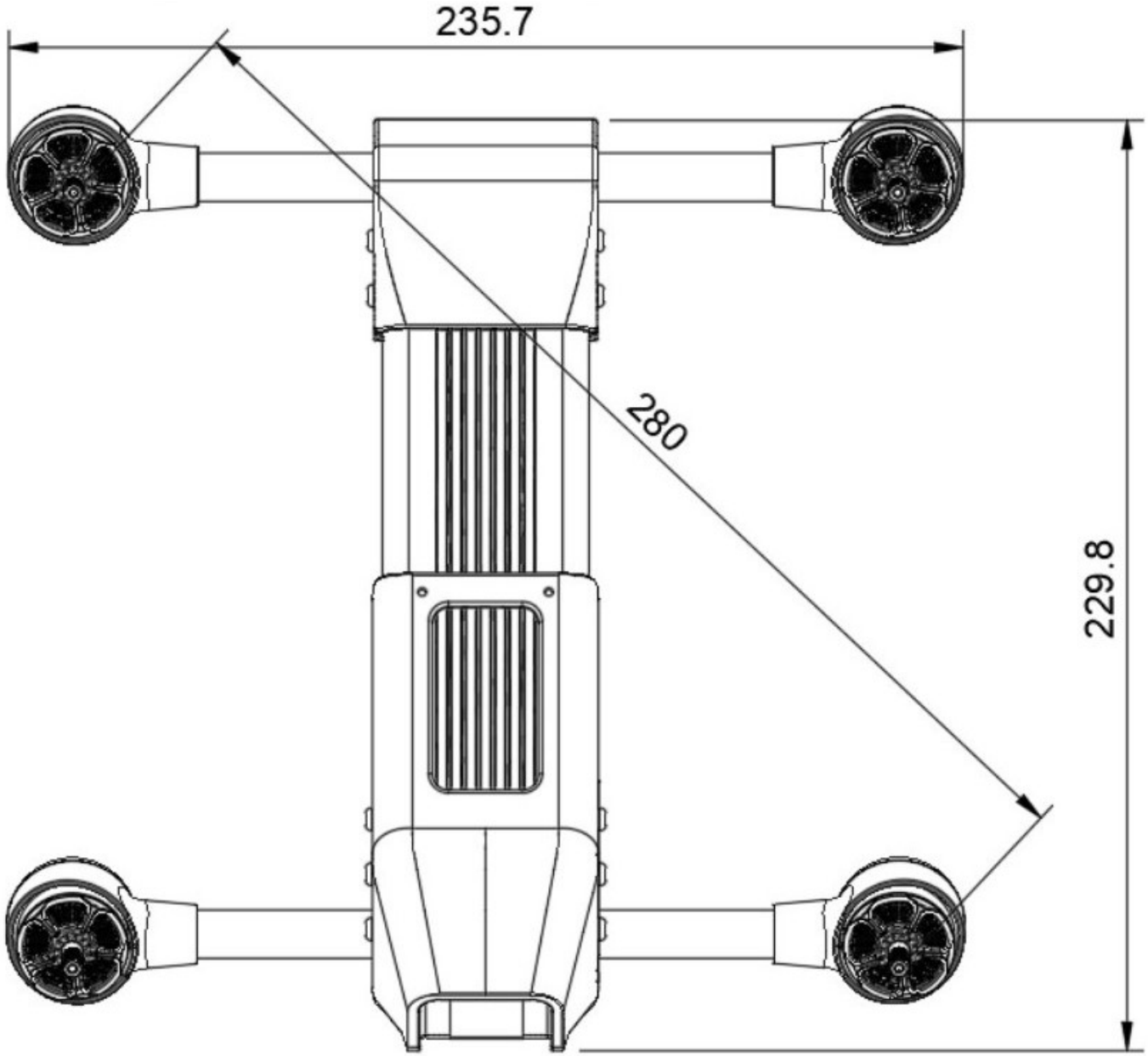
USB port

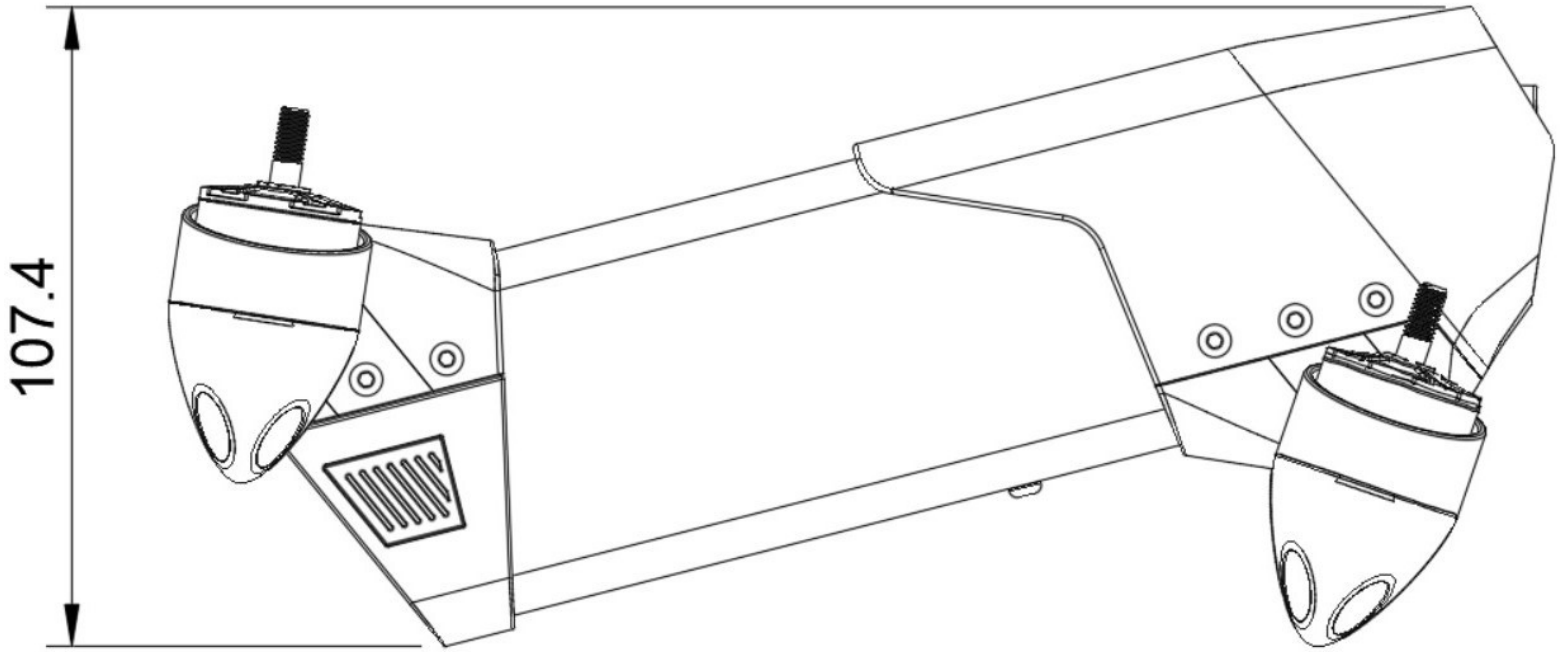
Antenna & sensor placement

Result

Very streamlined in this angle

Easy battery swap


235.7
280
229.8


107.4

On display at the degree show

Reflection

Learnings

Overall, I'm happy with my work in this poject. It's the best I have done so for in this education, but it's by no means perfect.

I wish I worked with more urgency and enthusiasm in the beginning to not be so pressured by time in the end. I think I might have ended up with quite a different concept or the same concept but much more refined.

I'm happy about the guidance and feedback I've recieved from my supervisors, they had some good ideas along the way and also some crazy ones. I wish I had investigated them more, instead of dismissing them as too far "out there".

My previous experience with drones was definitely a good thing in this project. FPV drones are more complicated than they might seem, and without actual experience, I'd probably have made some bad technical desicions. On the other hand, I would have probably made a better job of documenting and conveying some of them because they would probably seem more significant if I had less knowledge.

This was a good challenge for me. I have designed many 'hobby grade' FPV drones before, and the technical aspects are relatively easy on their own. But it was difficult to combine it with all the things that are necessary for something to be a viable product.

Sources

Photos

https://www.getfpv.com/lumenier-qav-pro-lifter-cinequads-edition-rtf.html

https://www.amazon.se/BETAFPV-3-bladig-rekvisita-propellrar-quadcopter/dp/B081DNQKPQ

https://www.trustedreviews.com/news/images-and-specs-for-the-gopro-hero-10-black-have-leaked-4160703

https://www.verkkokauppa.com/fi/product/708170/GoPro-3-Way-2-0-Mount-taittovarsi

https://www.netonnet.se/art/hem-fritid/dronare-actionkameror/gopro-karma-grip-handle/245077.9017/

https://www.freeride.se/prylar/dronare/gopro-karma.html

https://www.amazon.se/GoPro-Session-actionkamera-f%C3%B6rnyad-modell/dp/B06XWLWH6Y

https://gprosul.com.br/loja/acessorios-originais-gopro/mochila-daytripper-gopro/

https://pin.it/7HlFSKg

https://pin.it/2jRsG57

https://pin.it/5p0cbjf

https://pin.it/5KXPBGh

https://pin.it/5ymwlJR

https://pin.it/3dogh76

https://pin.it/27jBahs

https://pin.it/pCblHfe

https://pin.it/3BtCInp

https://pin.it/4H21iLv

https://pin.it/62duahu

https://pin.it/3ZF3QXl

https://pin.it/7tR3Qux

https://pin.it/30Grcc6

https://pin.it/79IcgpM

Online material

GoPro quoute: https://gopro.com/en/us/legal/about-us


GoPro