HYBRID FLYING CAR

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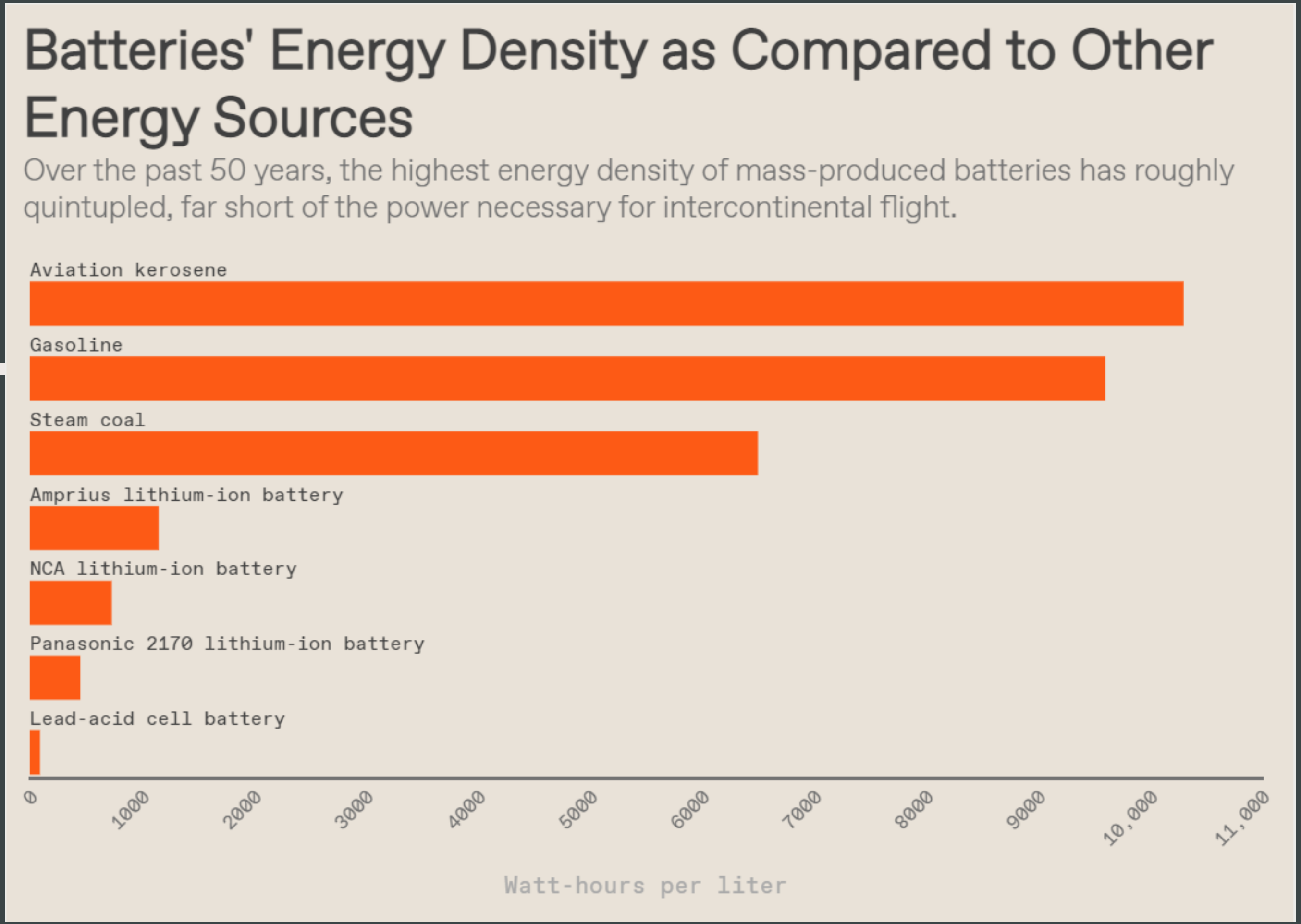
INTRODUCTION

- Flying Vehicle
- Sustainability
- Hybrid Technology



AGENDA

1. Motor and airframe selection
2. Coaxial arrangement considerations
3. Flight time comparisons
4. Design and fabrication
5. System and testing
6. Hybrid System

MOTOR SELECTION PROCESS

AUW

- Estimation of total weight of the vehicle.

Airframe Selection

- Hex vs Quad vs Octo
- Calculation of thrust per motor required for flight.

Motor Selection

- Shortlisting motors based on thrust required, power and current draw, and cost.

Flight Time

- Finalizing motor based on best flight time attained.

AUW AND AIRFRAME SELECTION

AUW	Thrust : Weight	Total Thrust	Thrust / Arm
42 kg	2:1	84 kg	21 kg

Estimated in the design section.

For sufficient control of the drone's maneuver and lift a 2:1 thrust-to-weight ratio is recommended [1].

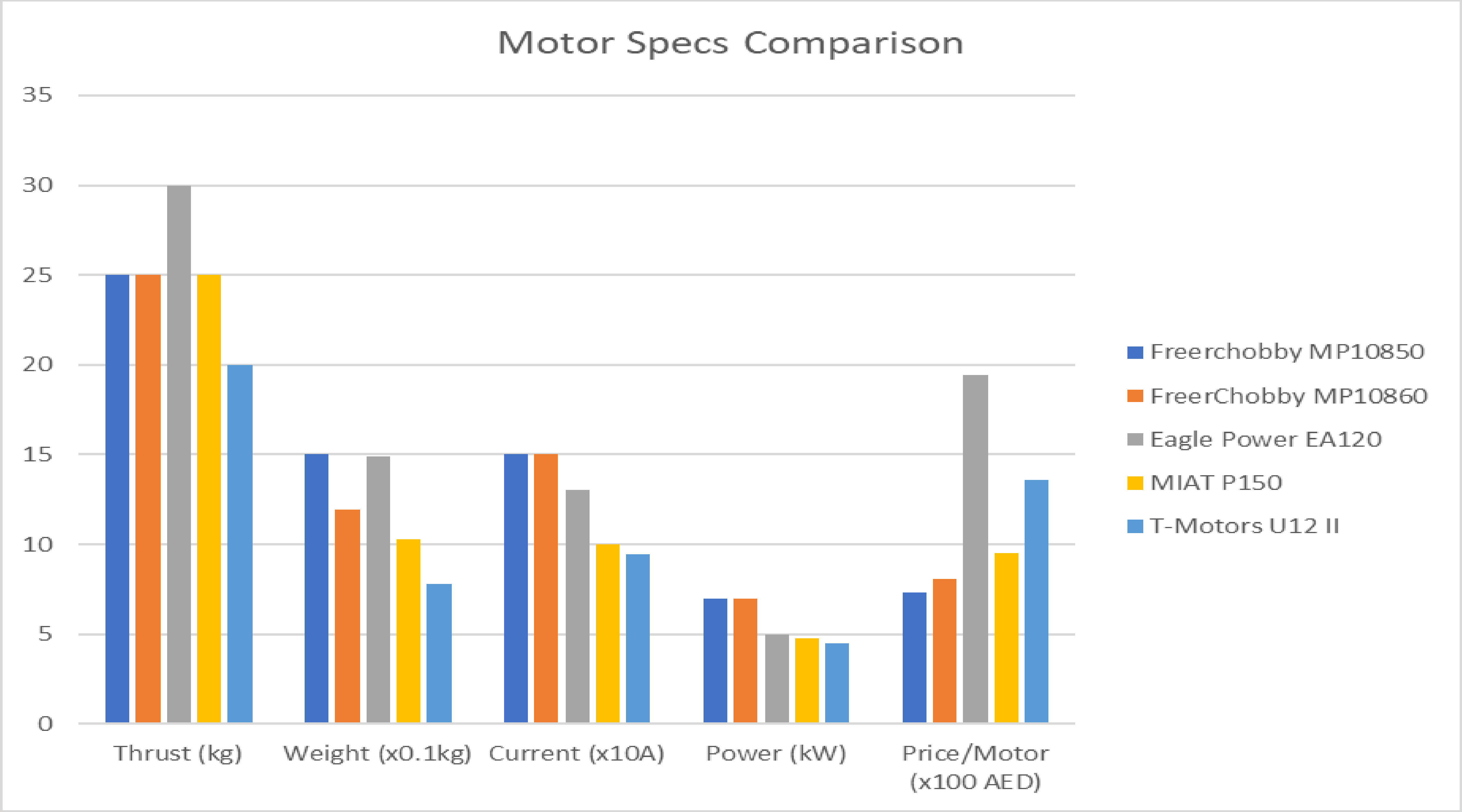
Hence total thrust required would be twice the AUW of our vehicle.

Our final selection of airframe was to use a quadcopter design.

Hence with 4 arms, we require ¼ of thrust to be generated from a single arm.

LIST OF 20 KG THRUST MOTORS

Motor	Thrust (kg)	Weight (kg)	Current (A)	Power (kW)	Price/Motor (AED)
Freerchobby MP10850 [2]	25	1.5	150	7	735
Freerchobby MP10860 [3]	25	1.19	150	7	808
Eagle Power EA120 [4]	30	1.49	130	5	1943
MIAT P150 [5]	25	1.03	100	4.8	951
T-motor U12 II [6]	20	0.778	94.3	4.5	1360



Motor Specs Comparison
35
30
25
20
15
10
5
0
Thrust (kg)
Weight (x0.1kg)
Current (x10A)
Power (kW)
Price/Motor (x100 AED)
Freerchobby MP10850
FreerChobby MP10860
Eagle Power EA120
MIAT P150
T-Motors U12 II

MOTOR SELECTION

Thrust (kg) (Max)	Weight (kg) (Min)	Current (A) (Min)	Power (kW) (Min)	Price/Motor (Min)
Eagle Power EA120	T-motor U12 II	T-motor U12 II	T-motor U12 II	Freerchobby MP10850

Highest thrust capacity

Costly

Heavy

Lowest power and current consumption

Lightest among the options

Lowest in thrust capacity, but enough for our project

Cost comparatively high than some other options

Cheapest

Current thirsty

Heavy

MOTOR SELECTION

U12 II KV120

- Selected motor for quad design.
- Consumes >50% of the budget.

MN605S KV170

- Available from the university.
- Quad => Octa quad (Coaxial)
- Cash positive.

FLIGHT TIME

- Many methods to calculate the flight time of a drone, but proceeded with the following equation [7]:

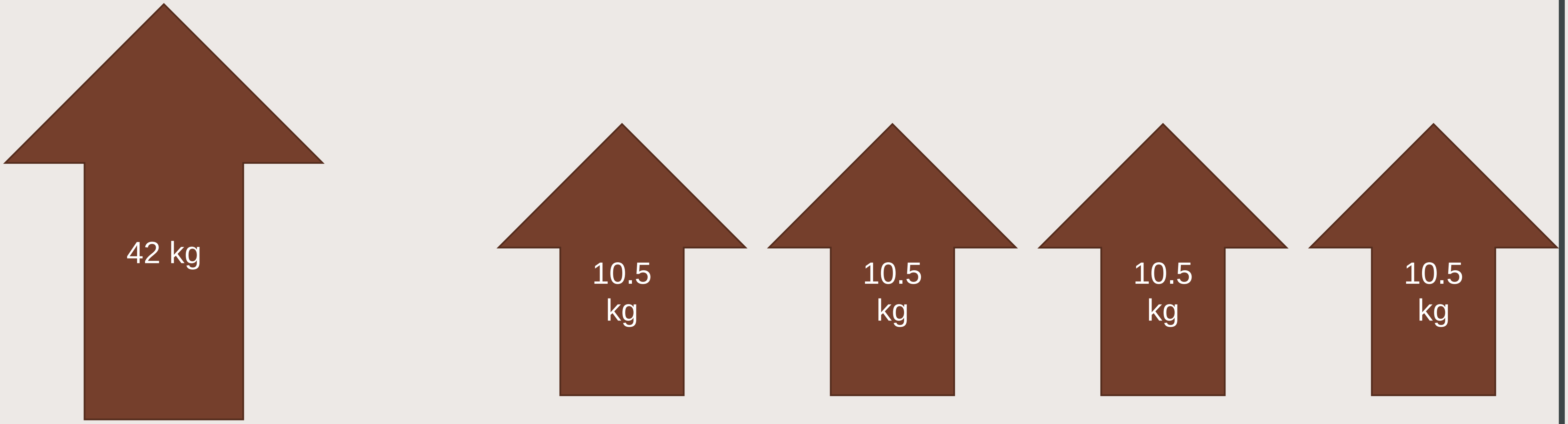
$$\text{Flight time(h)} = \frac{\text{Battery capacity (Wh)}}{\text{Power(W)}}$$

- However, they did not take into consideration a safety factor of 0.4 which is recommended for UAVs. Below is the final formula we utilized.

- $$Flight\ Time\ (mins) = \frac{Source\ Capacity\ (Wh) \times 60\ mins \times 0.4}{Consumption/Arm\ (Watt) \times No.of\ Arms}$$

MINIMUM THRUST REQUIRED

- Minimum thrust should be attained for hovering in the air.
- With 42 kg AUW, 10.5 kg is the required minimum thrust per arm.



PARAMETERS FOR FLIGHT TIME

U12 II

From the motor's test report, min thrust of 10.5 kg can be attained at a **65-70 %** throttle rate.

Therefore, **75%** throttle would be sufficient for in-air maneuvers and stability control.

In terms of consumption, each motor would consume about 2400 Watts.

MN605S

The motor's test report shows that the minimum thrust can be attained at **70-75 %** throttle rate for an ideal coaxial configuration.

However, the coaxial configuration reduces thrust efficiency as the below motors are in the prop wash of the top motors.

We need to remap the throttle rate incorporating the inefficiency of coaxial configuration to calculate the consumption.

CO-AXIAL ARRANGEMENT CONSIDERATIONS

More lift required

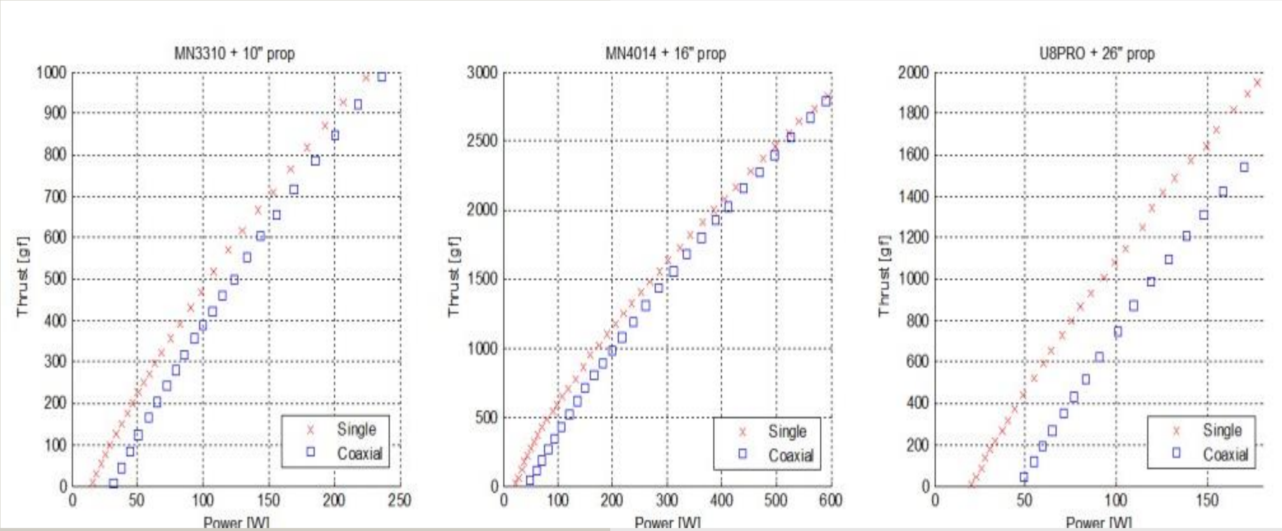
More lift with small increase in volume

Advantages:

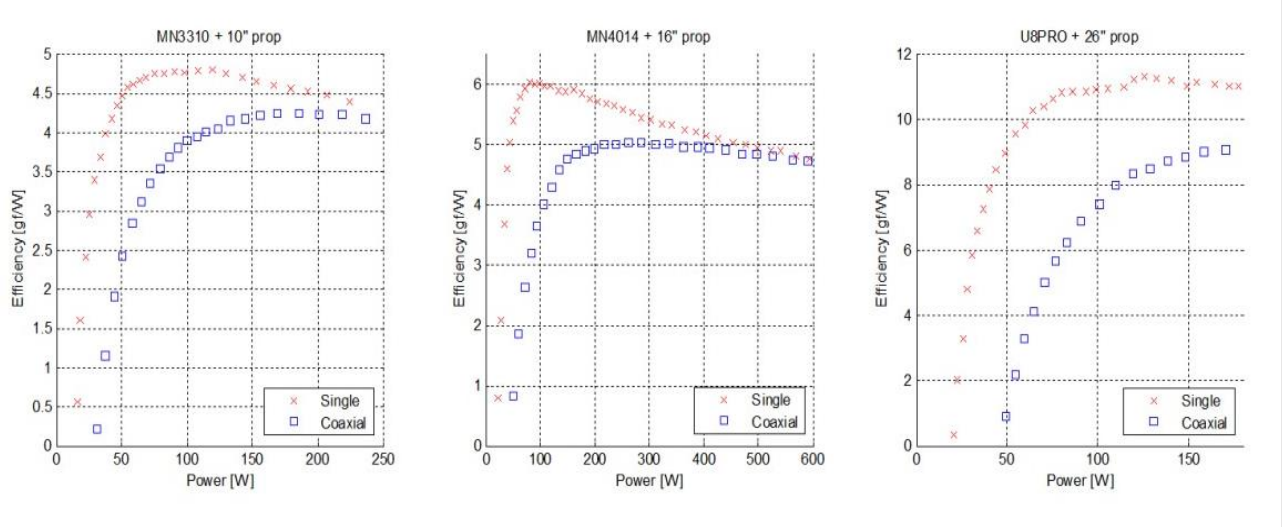
- *Lesser weight and volume added, compared to octocopter design*
- *More stability towards gusts*

Drawbacks:

- *About 20% loss in Thrust : Power consumed efficiency*



Bondyra, A. et al. (2016) “Performance of coaxial propulsion in design of multi-rotor UAVs,” Challenges in Automation, Robotics and Measurement Techniques, pp. 523–531. Available at: https://doi.org/10.1007/978-3-319-29357-8_46.



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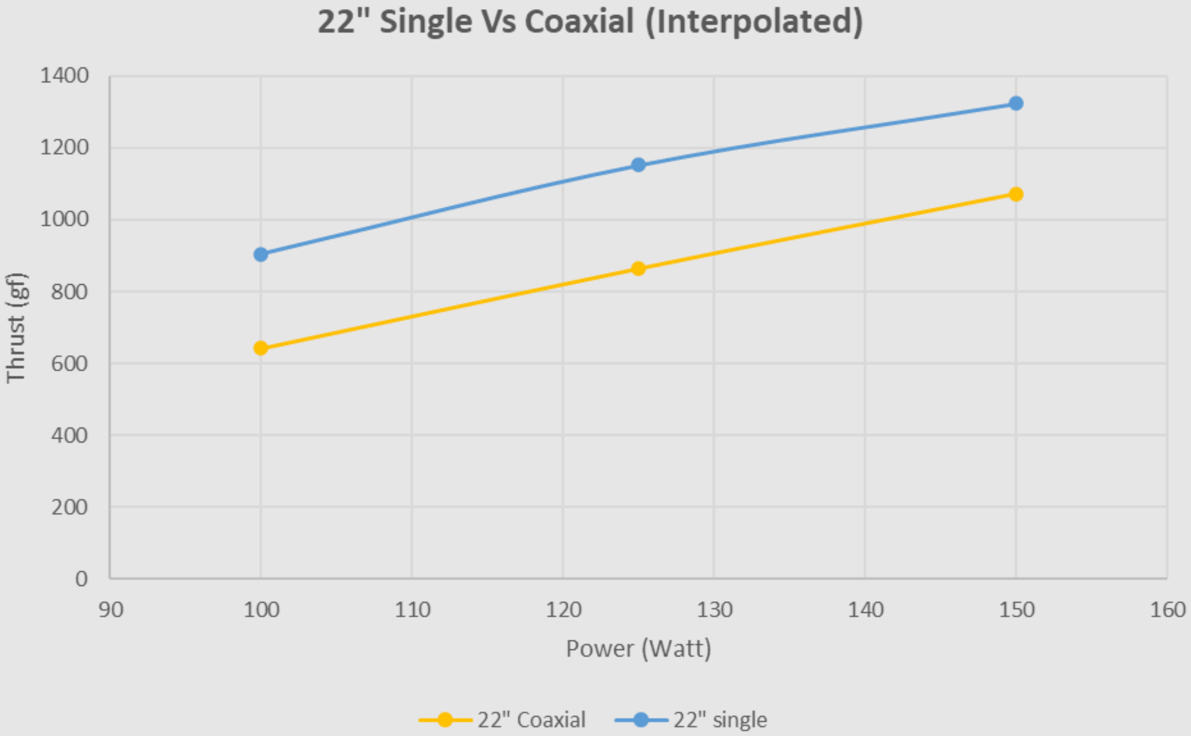
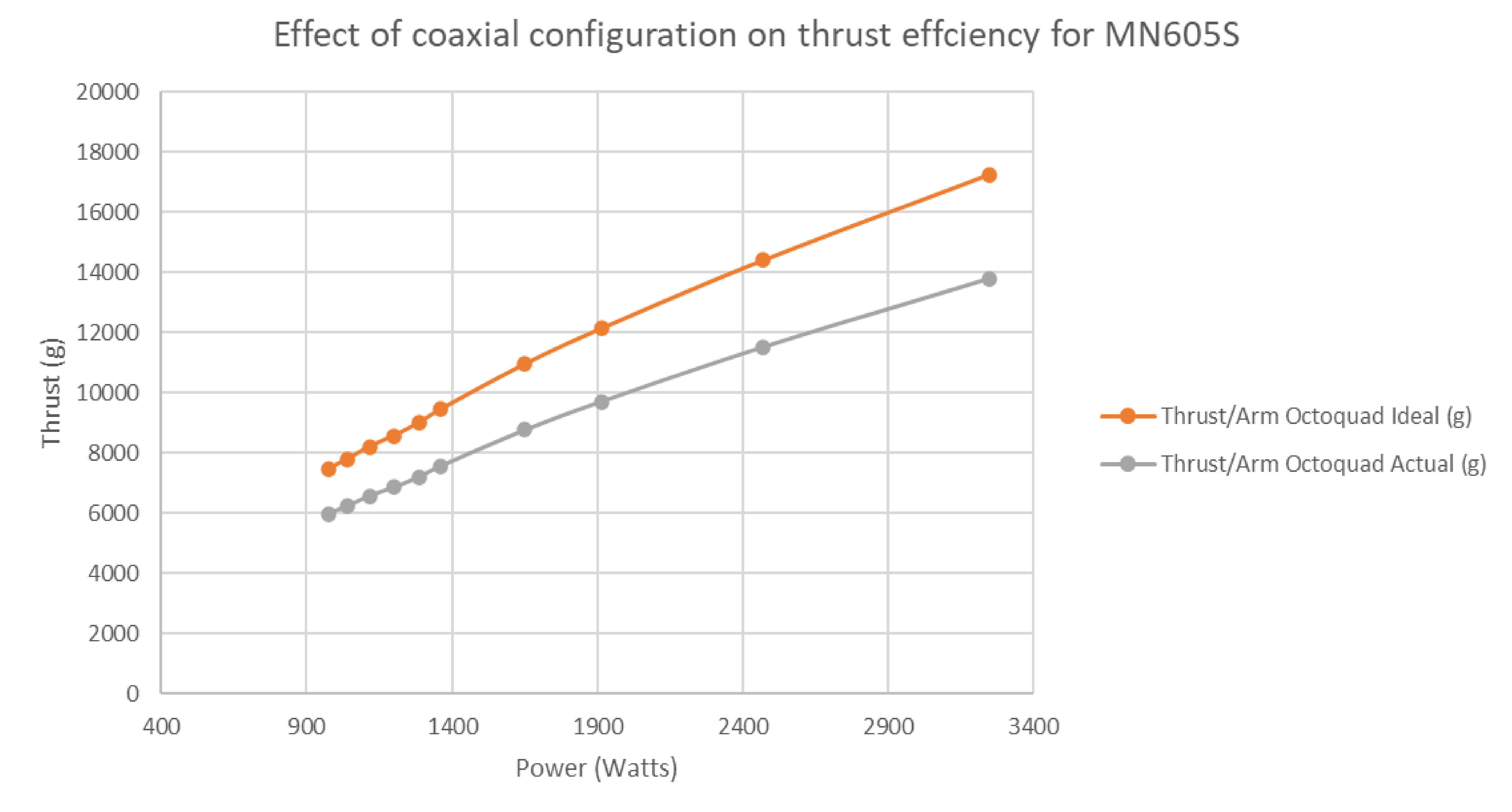


Configuration	Quadrotor (4x1)		Octoquad (4x2)		
	Thrust[gf]	Power [kW]	Thrust[gf]	Power[kW]	Thrust Gain [%]
MN3110 + 10” prop.	3940	0.89	5539	1.35	136%
MN4014 + 16” prop.	12904	2.57	18542	4.23	144%
U8PRO + 26” prop.	9399	0.71	13389	1.28	142%

Bondyra, A. et al. (2016) “Performance of coaxial propulsion in design of multi-rotor UAVs,” Challenges in Automation, Robotics and Measurement Techniques, pp. 523–531. Available at: https://doi.org/10.1007/978-3-319-29357-8_46.

Rotor	thrust (single) [gf]	power (single) [kW]	thrust (coaxial) [gf]	power (coaxial) [kW]	thrust/P (single) [gf/kW]	thrust/P (coaxial) [gf/kW]	efficiency
MN3110 + 10” prop	3940	0.89	5539	1.35	4426.966292	4102.962963	0.926811
MN4014 + 16” prop.	12904	2.57	18542	4.23	5021.011673	4383.451537	0.873022
U8PRO + 26” prop.	9399	0.71	13389	1.28	13238.02817	10460.15625	0.79016

Watt	Coaxial 10" (thrust)	Coaxial 16" (thrust)	Coaxial 26" (thrust)	22" (thrust)	single 10" (thrust)	single 16" (thrust)	single 26" (thrust)	22" (thrust)	efficiency
100	400	480	750	642	480	650	1075	905	70.94
125	500	510	1100	864	610	750	1420	1152	75
150	640	730	1300	1072	700	850	1640	1324	80.97


Effect of coaxial configuration on thrust effciency for MN605S
Thrust (g)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
400
900
1400
1900
2400
2900
3400
Power (Watts)
Thrust/Arm Octoquad Ideal (g)
Thrust/Arm Octoquad Actual (g)

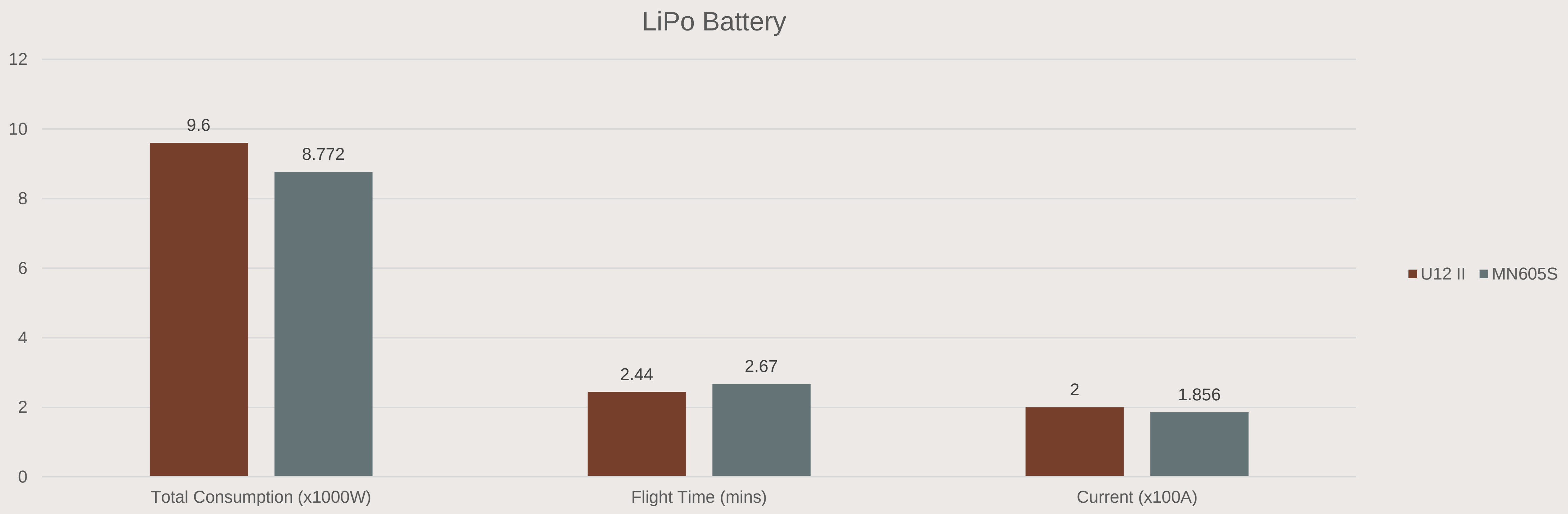
FLIGHT TIME COMPARISON

Source	Source Capacity	U12 II				
		Consumption/Arm (W)	# of Arms	Total Consumption (W)	Flight Time (mins)	Current (A)
Battery	976.8 Wh	2400	4	9600	2.44	200

Source	Source Capacity	MN605S				
		Consumption/Arm (W)	# of Arms	Total Consumption (W)	Flight Time (mins)	Current (A)
Battery	976.8 Wh	2193	4	8772	2.67	185.6

FLIGHT TIME COMPARISON

- The battery flight time is 9.43 percent higher.
- The power consumption by the MN605S is 8.63 percent lower than the U12 II.
- The current consumption is decreased by 7.2 percent for the MN605S.



DESIGN AND FABRICATION

Mohammed Abdul Mannan

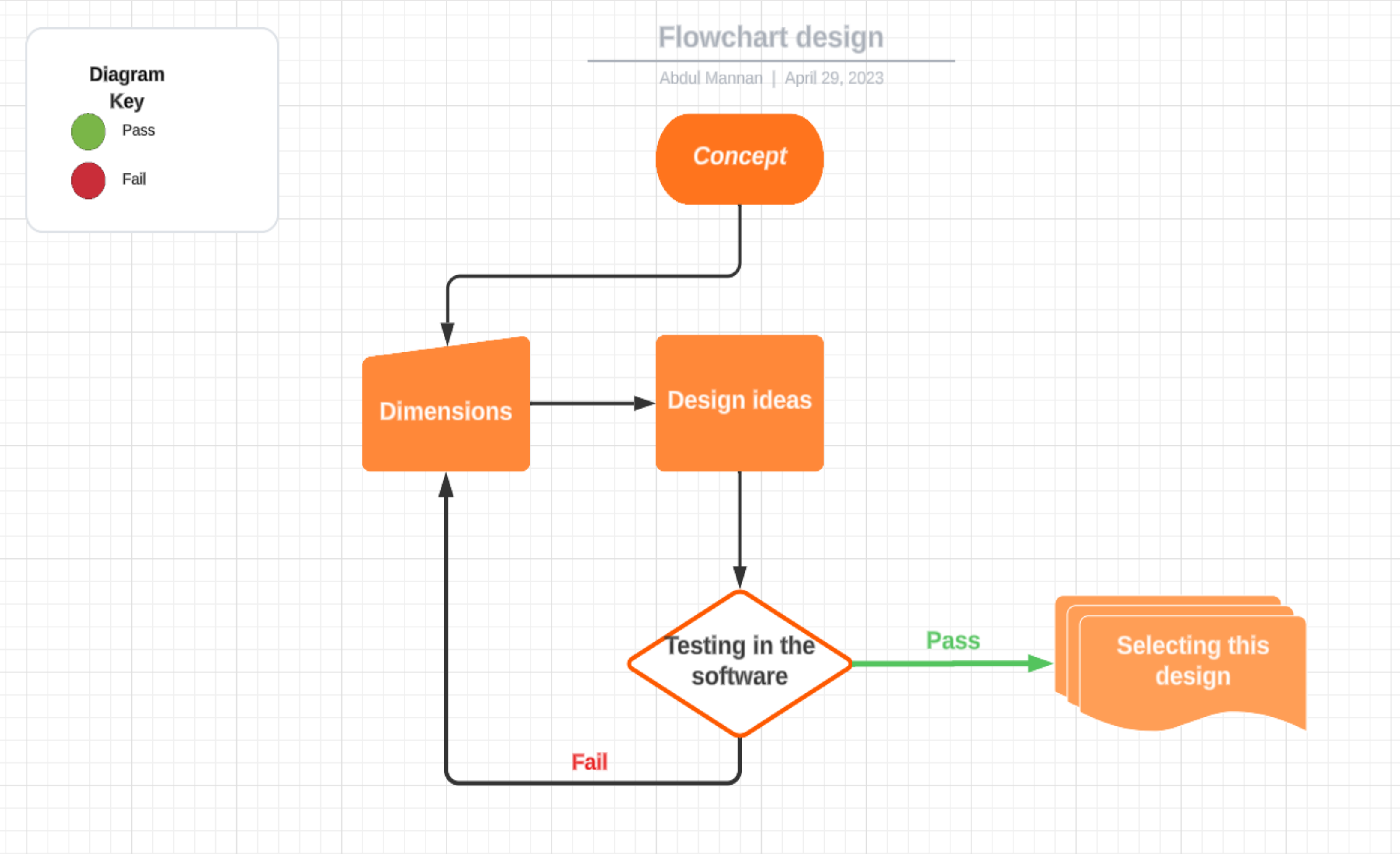
DESIGN

CONCEPT GENERATION

The concepts below are the main key constraints and the requirements that our HFC was applied to, to ensure we reach and have a stable structure that meets all the requirements for a typical hybrid flying car

1. **Have enough space to keep the generator and batteries.**
2. **Have the design look like a car**
3. **Ensure that the maximum weight of the whole prototype without the payload does not exceed 35 kg**

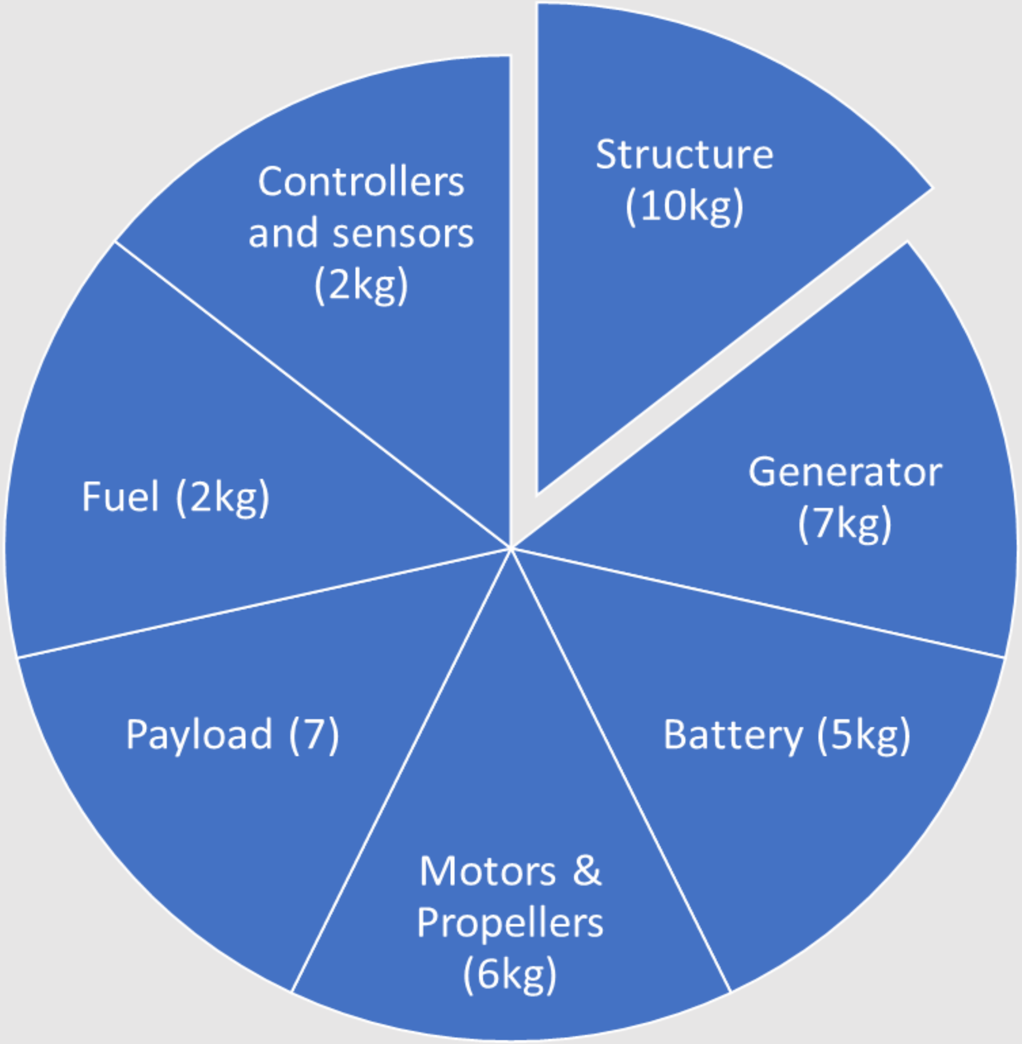
DESIGN PROCESS



STRUCTURE WEIGHT

The maximum weight of the structure should not exceed 10 kg

The total weight of the prototype is (35+7) = 42 kg



DESIGN PROGRESS TIMELINE

Design A
Sep 2022

Design B
Oct 2022

Design C
Nov 2022

Design D
Dec 2022

Design E
Jan 2023

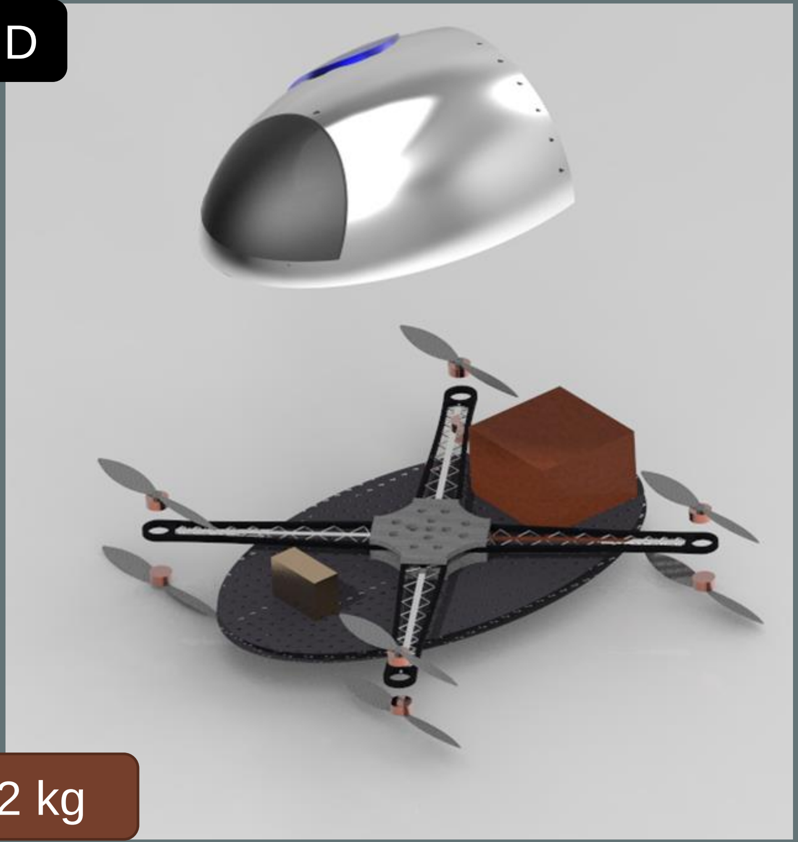
Design F
Feb 2023

Design G
Feb 2023

We will be focusing on these 4 latest designs

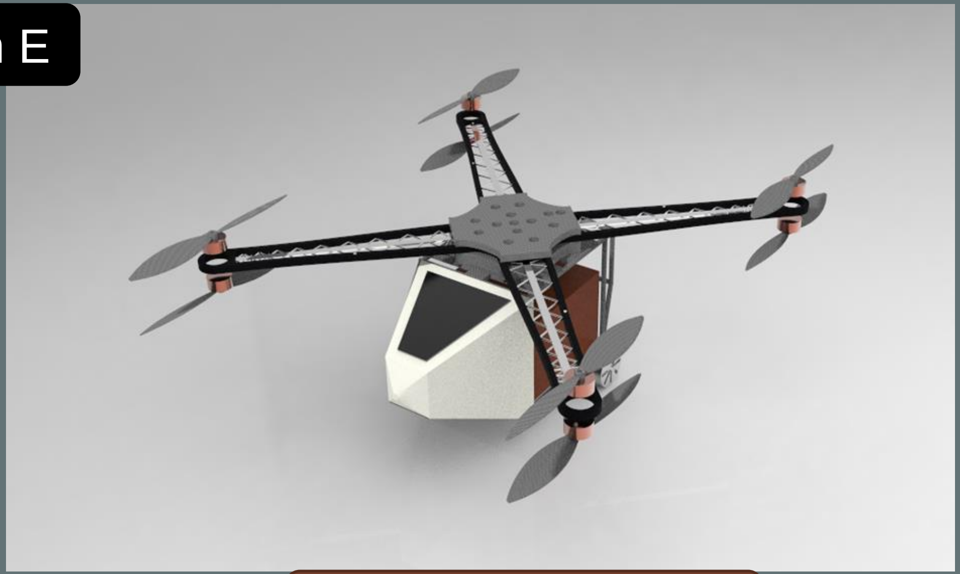
DESIGN D AND DESIGN E

Design D



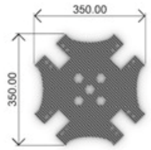
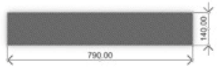
Weight : 33.72 kg

Design E

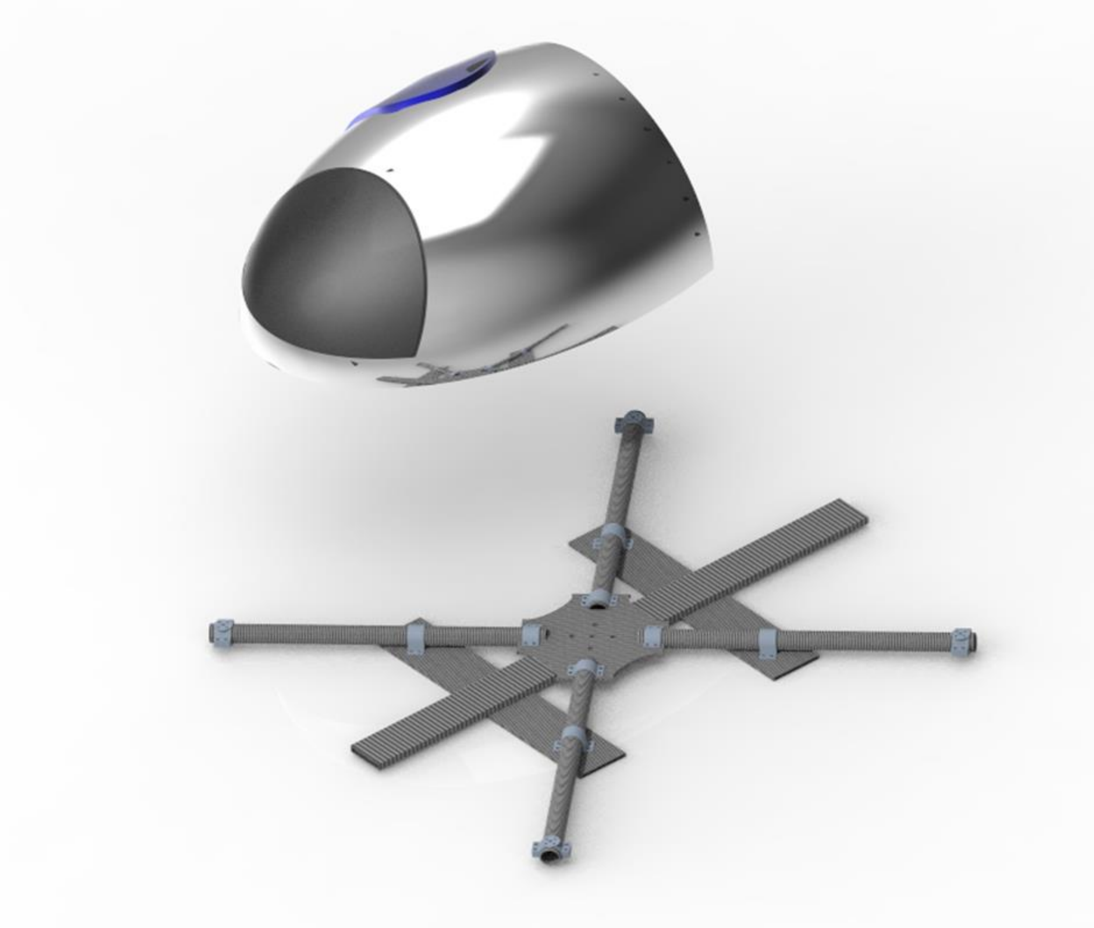


Weight : 21.87 kg

DESIGN F

Sr.No.	Item		Qty	Mold Cost	Unit rate	Part Cost	Amount
1	10mm CFRP panel with clear carbon finish		1	AED 0.00	AED 3,200.00	AED 3,200.00	AED 3,200.00
2	10mm thick sandwitch panel with gelcoat finish		2	AED 1,600.00	AED 1,500.00	AED 3,000.00	AED 4,600.00
3	20mm thick sandwitch panel with gelcoat finish		1	AED 2,300.00	AED 1,800.00	AED 1,800.00	AED 4,100.00
						Total Amount	AED 11,900.00

Cost : 11,900 Dhs !

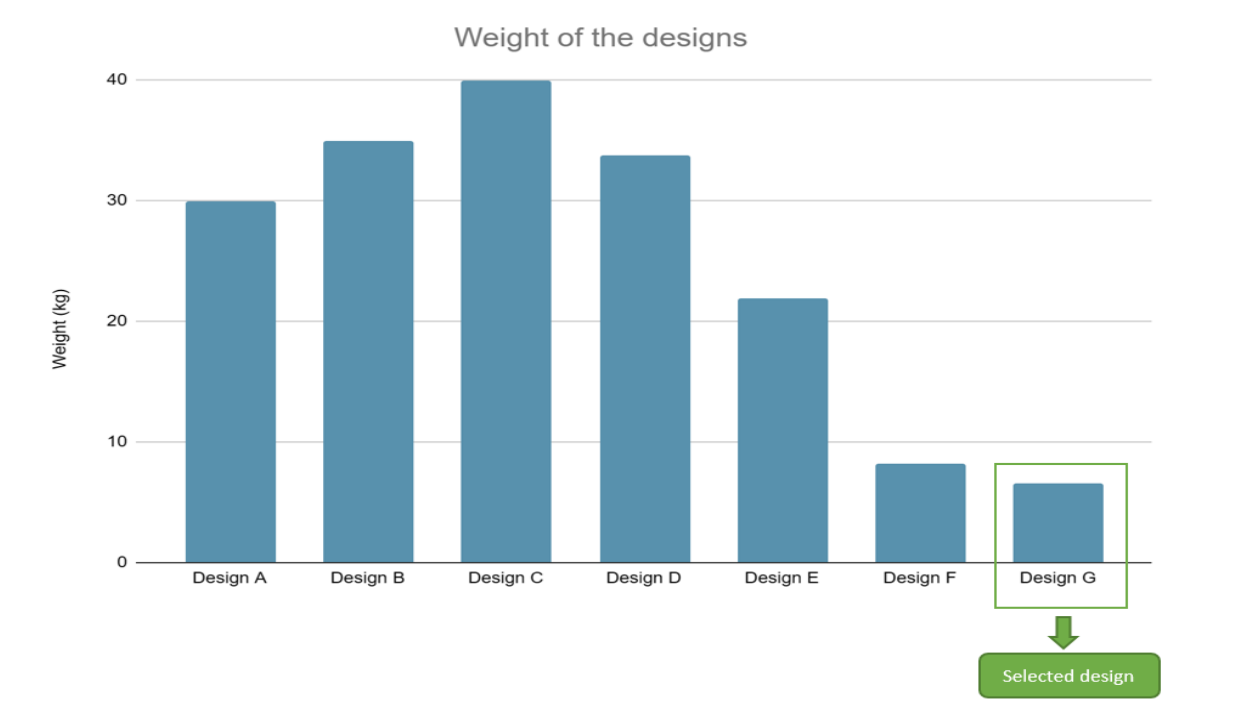


#	Name of the component	Number of components	Weight (kg)
1	Flight Frame	5	4.368
2	CF chassis bars	3	3.856
5	Shell	1	<0.005
Total weight of design F			**8.224 kg**

DESIGN G

Weight: 6.55 kg

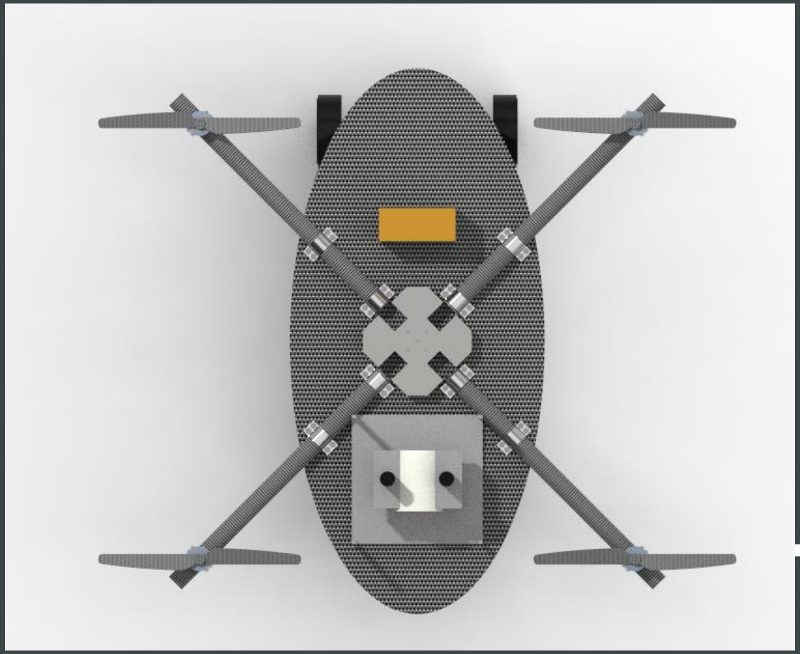
SELECTION OF DESIGN

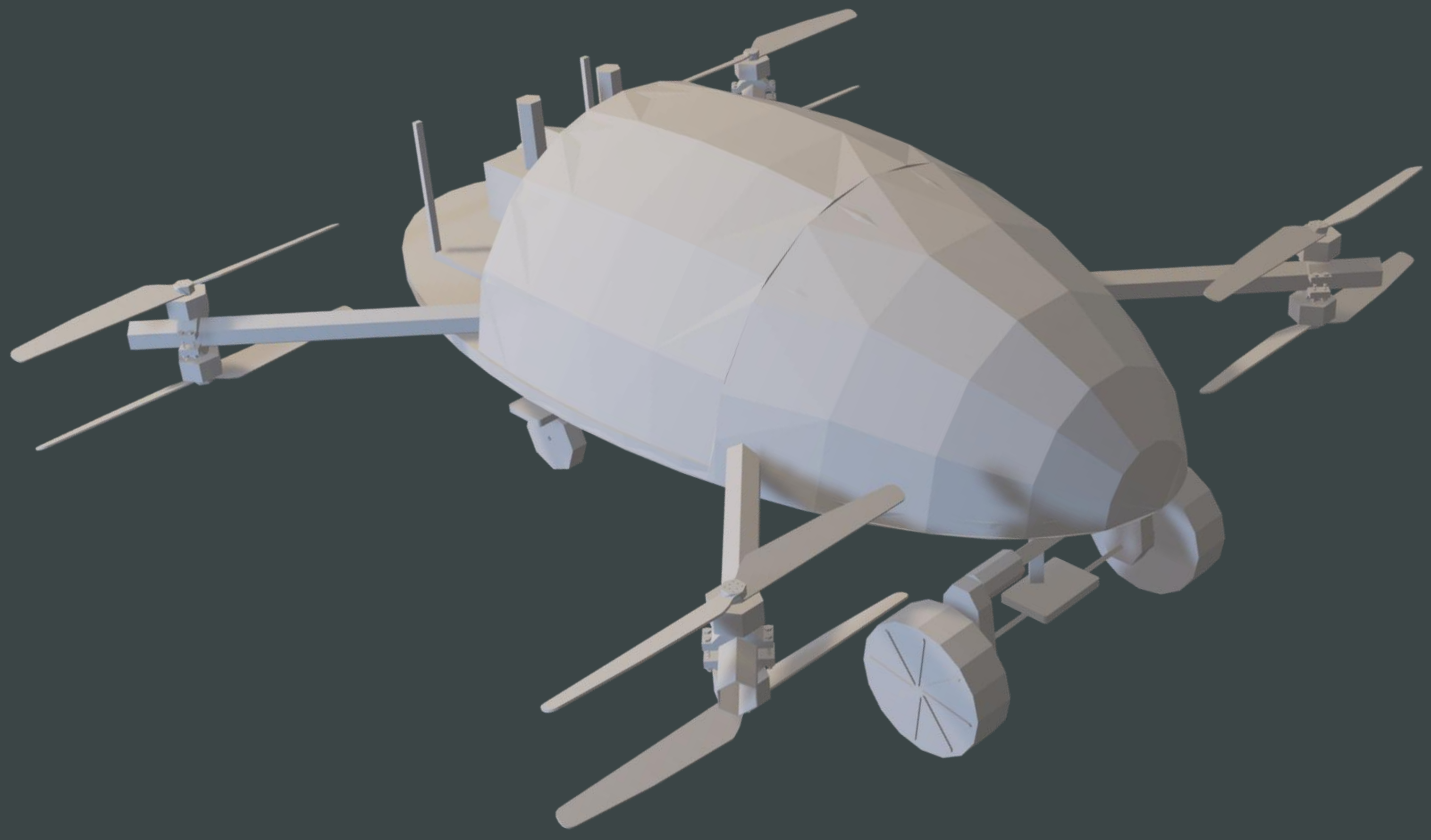


Design	Weight (kg)
Design D	33.72
Design E	21.87
Design F	8.22
Design G	6.56

SELECTED DESIGN

Design G



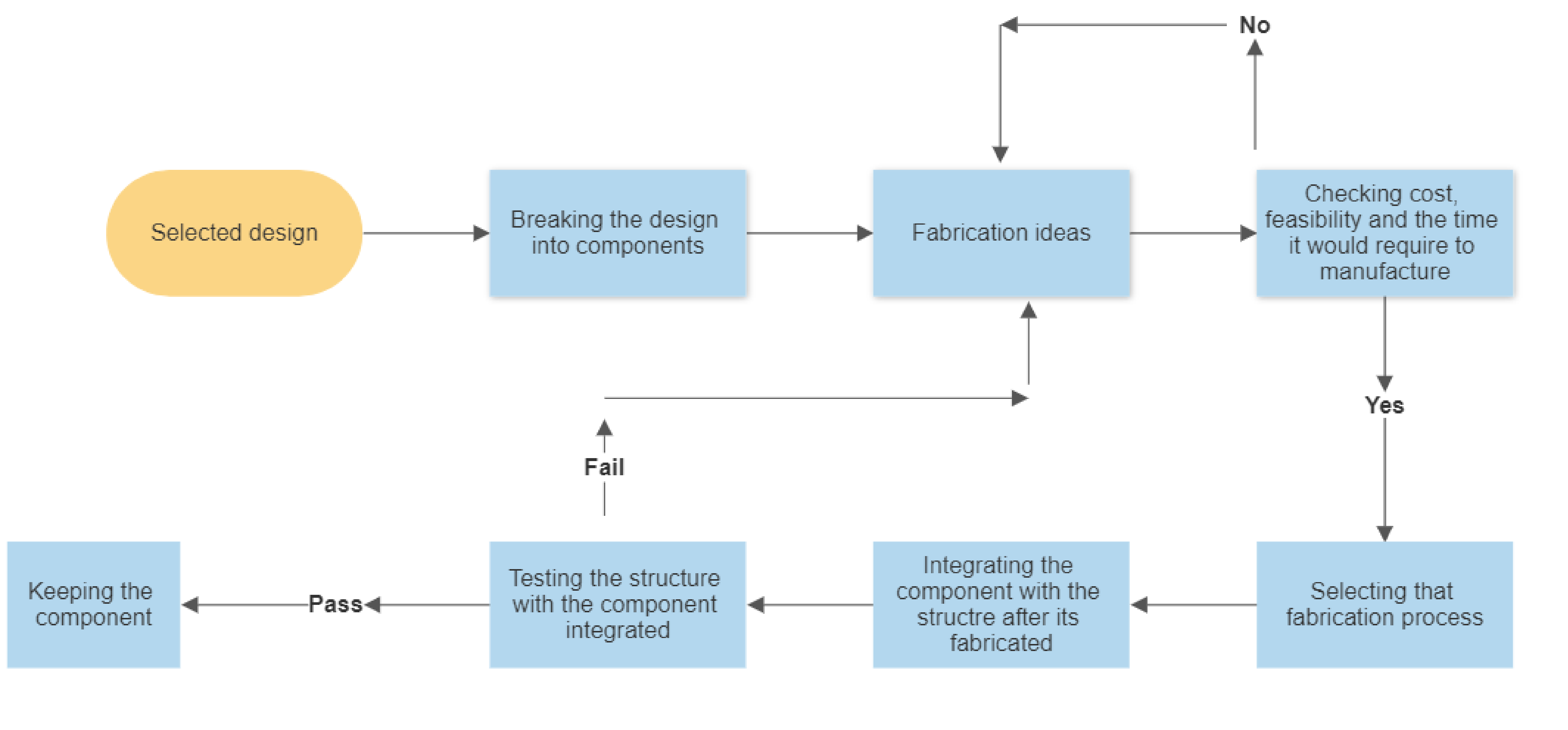


SELECTED DESIGN COMPONENTS

Name	Total Weight (kg)
Carbon fiber rods	1.32
Oval base	5
Central plate	0.1
Rod clamps	0.144
Bolts	0.5
Total weight	**7.064**

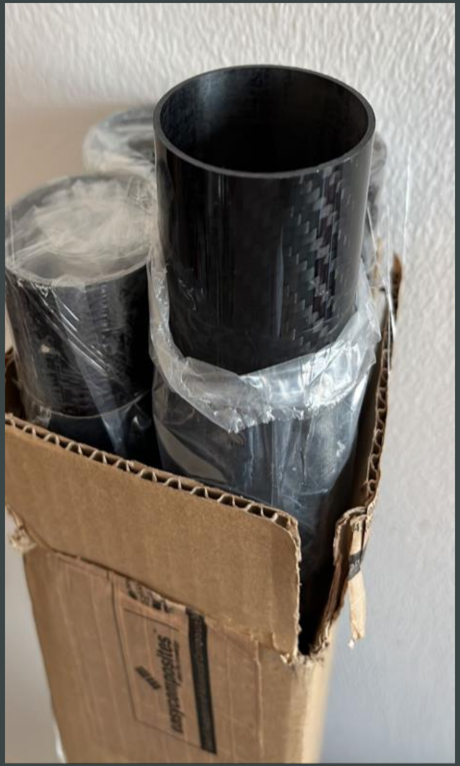
FABRICATION

FABRICATION PROCESS



FABRICATION OF WOOD TEMPLATE

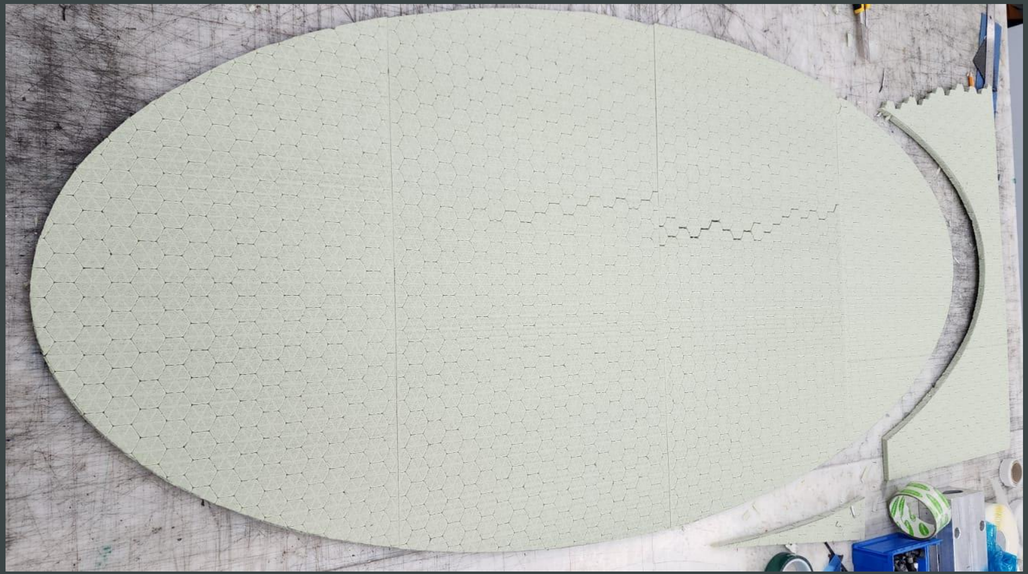
CARBON FIBRE RODS

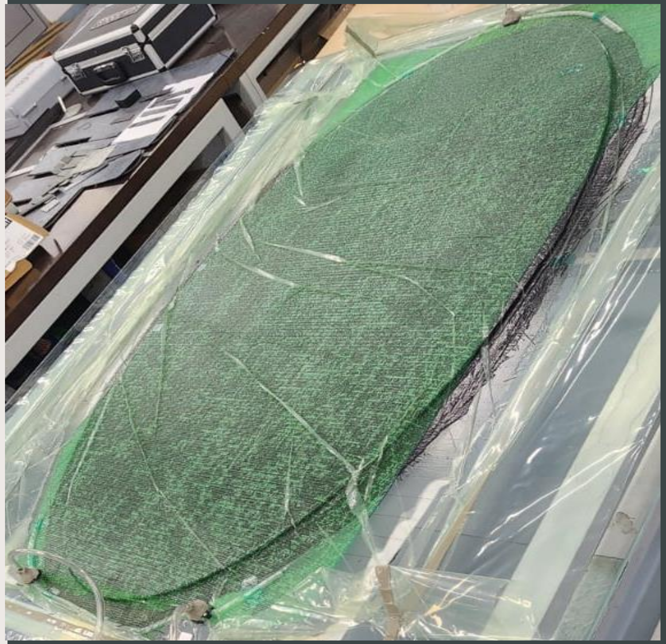


Carbon fibre rods designed in Creo
Length : 810 mm
Diameter : 50 mm

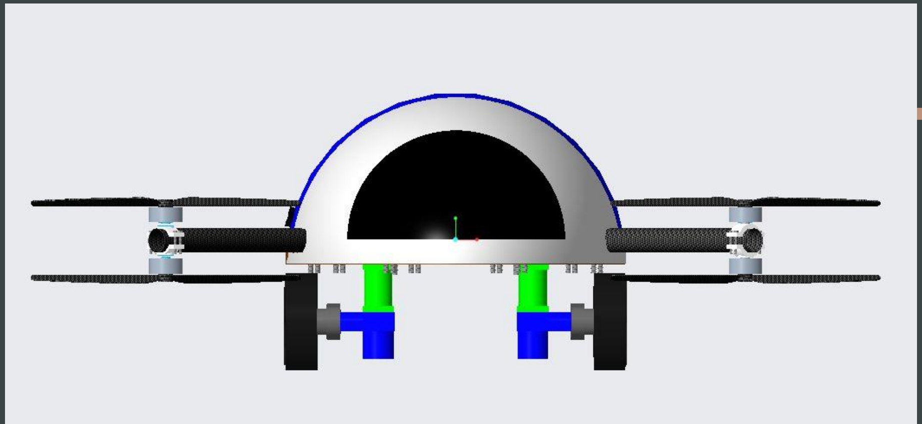
Carbon fibre rods ordered from UK
Length : 1000 mm
Diameter : 50 mm

FABRICATION OF CARBON FIBRE PLATE

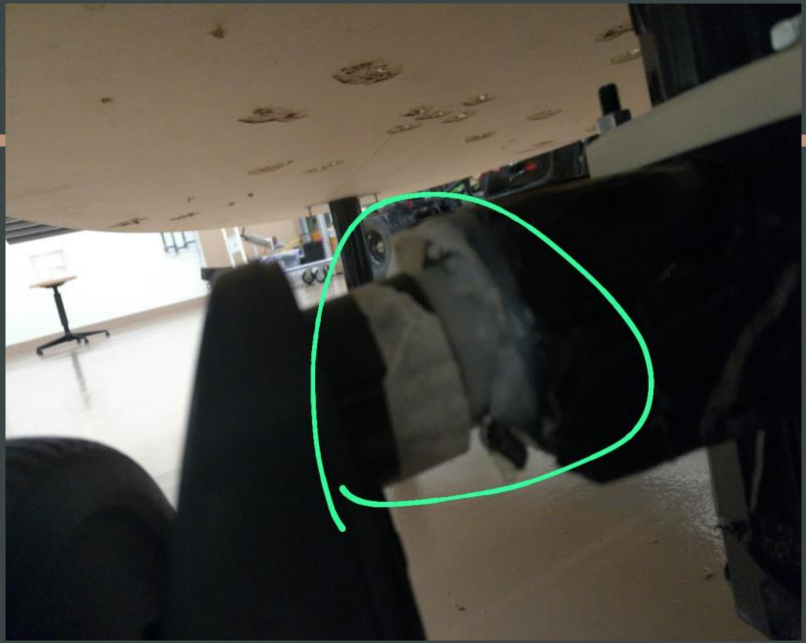




FABRICATION OF TAXING SYSTEM

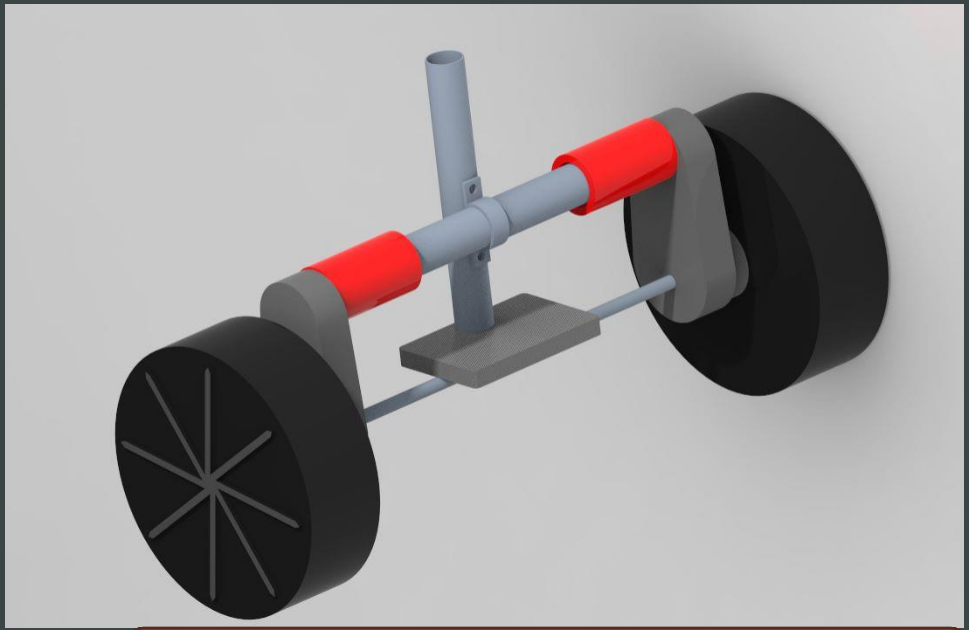


3D printed parts

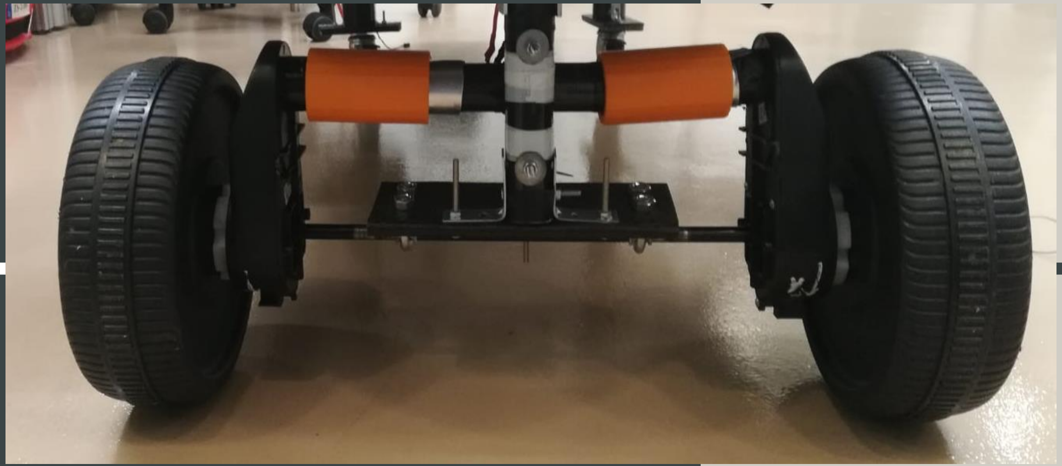


Redesigning as this part failed

FABRICATION OF THE NEW TAXING SYSTEM

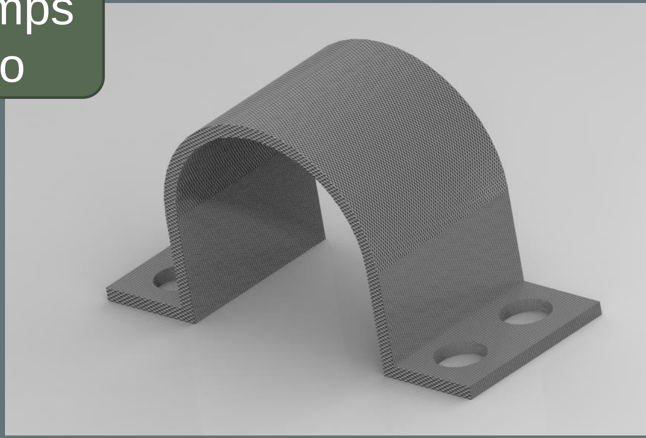


New Taxing system designed in Creo



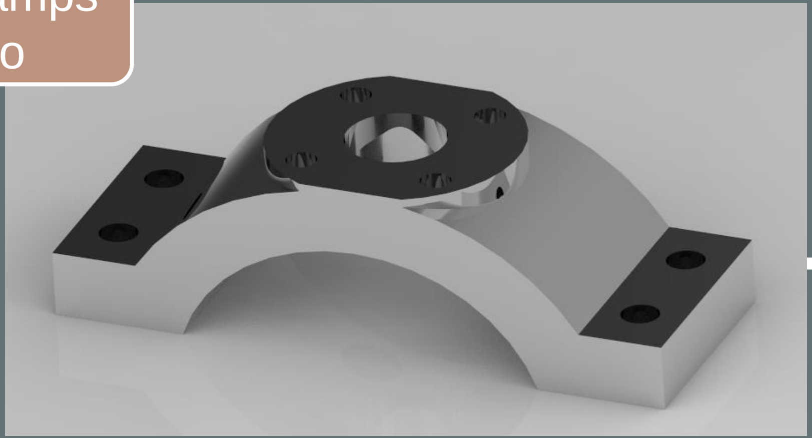
FABRICATION OF ROD CLAMPS AND MOTOR CLAMPS

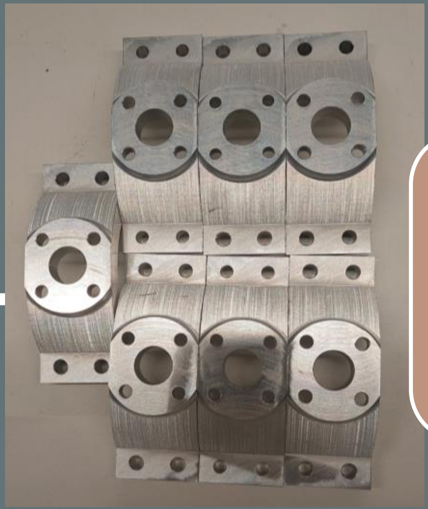
Rod clamps in Creo



Clamps made In the 3D printer using carbon fibre

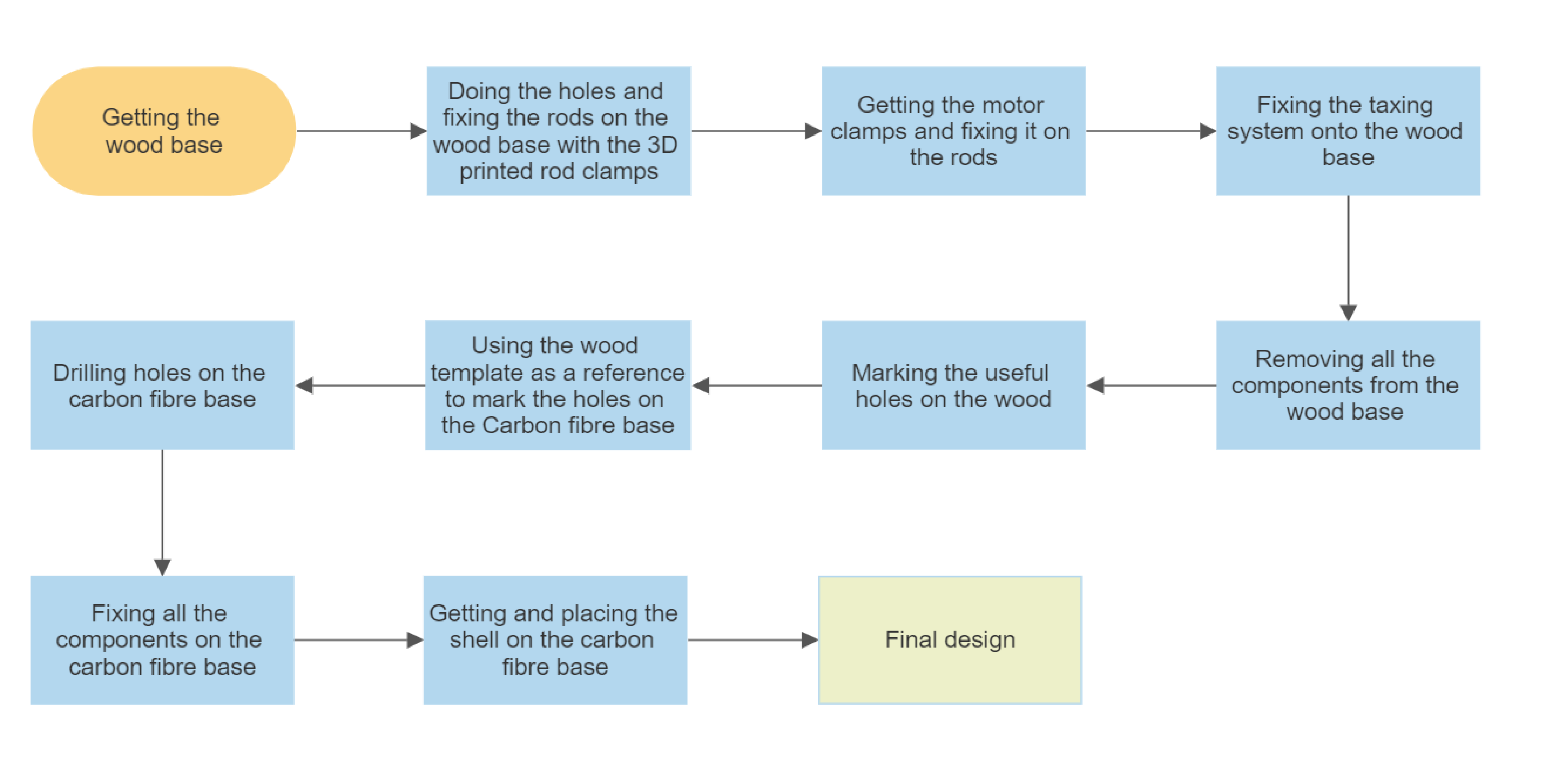
Motor clamps in Creo



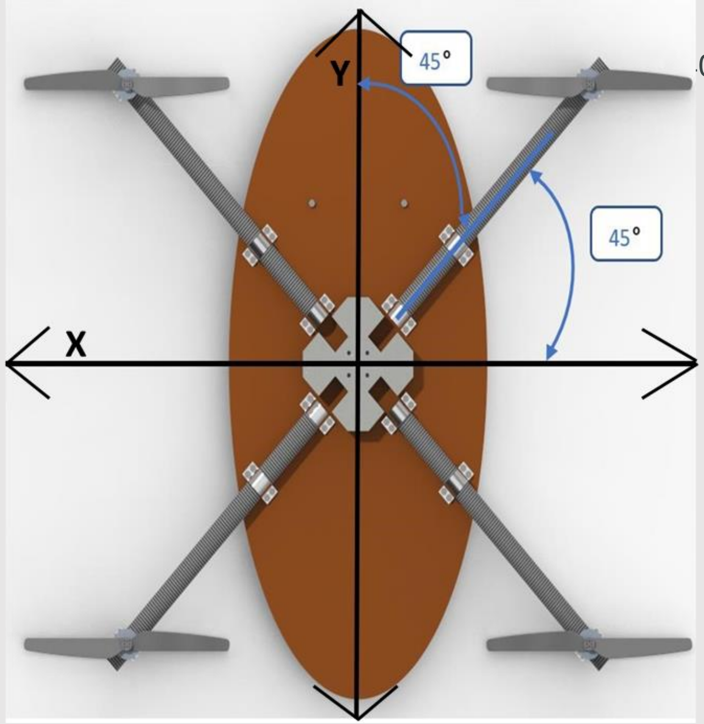


Motor clamps made in the CNC 6 axis machine

INTEGRATION OF THE COMPONENTS



BALANCE OF THE STRUCTURE:

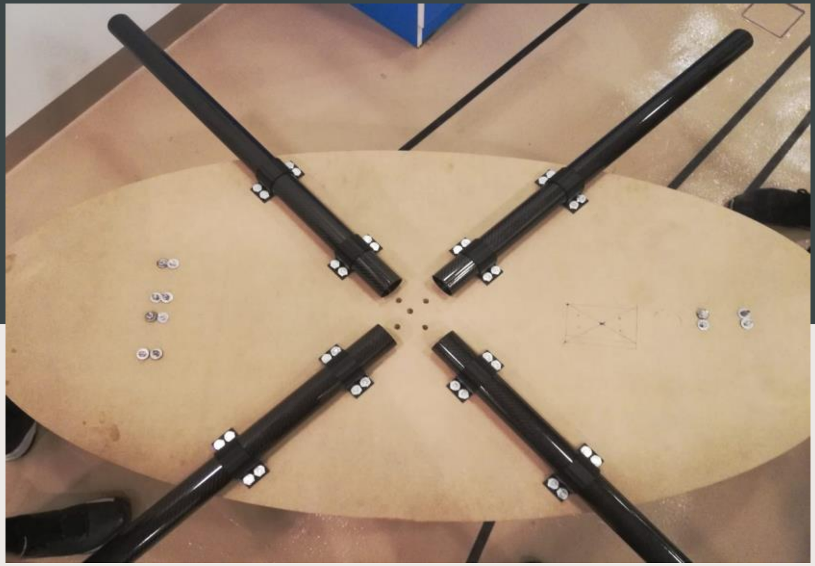


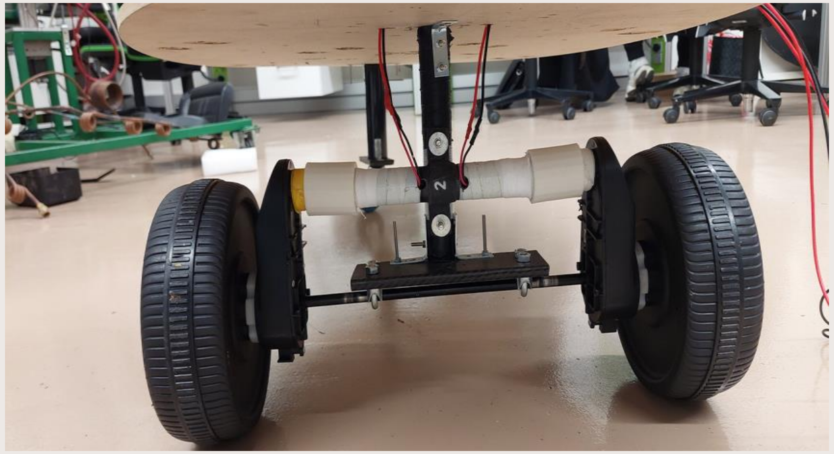
Static stability of the vehicle.

Moment Calculation around x-axis

Name	Weight (kg)	Distance from the center (cm)
Generator	7	-35.5
Battery	5	≈ 31.58
Electric Car Tyres (front)	2.278	57
Trolley tires (x2) (back	2 x 0.553 = 1.106	-35.5
Total weight	15.384	$\sum M_X = 0$

INTEGRATION OF THE COMPONENTS





Integration of battery, generator, motors, and the taxing system onto the carbon fibre oval plate

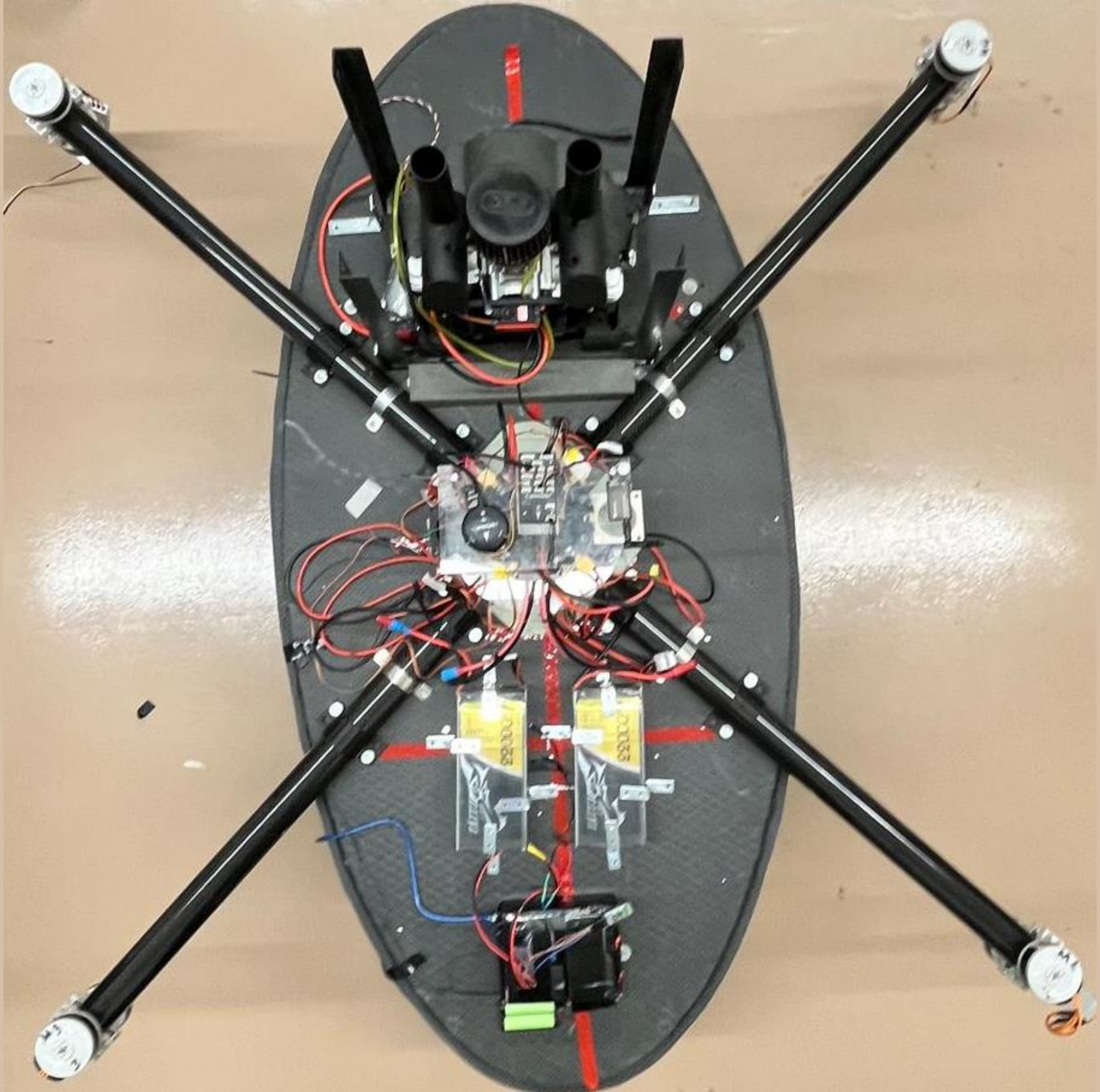
FINAL PROTOTYPE

FLIGHT SYSTEM

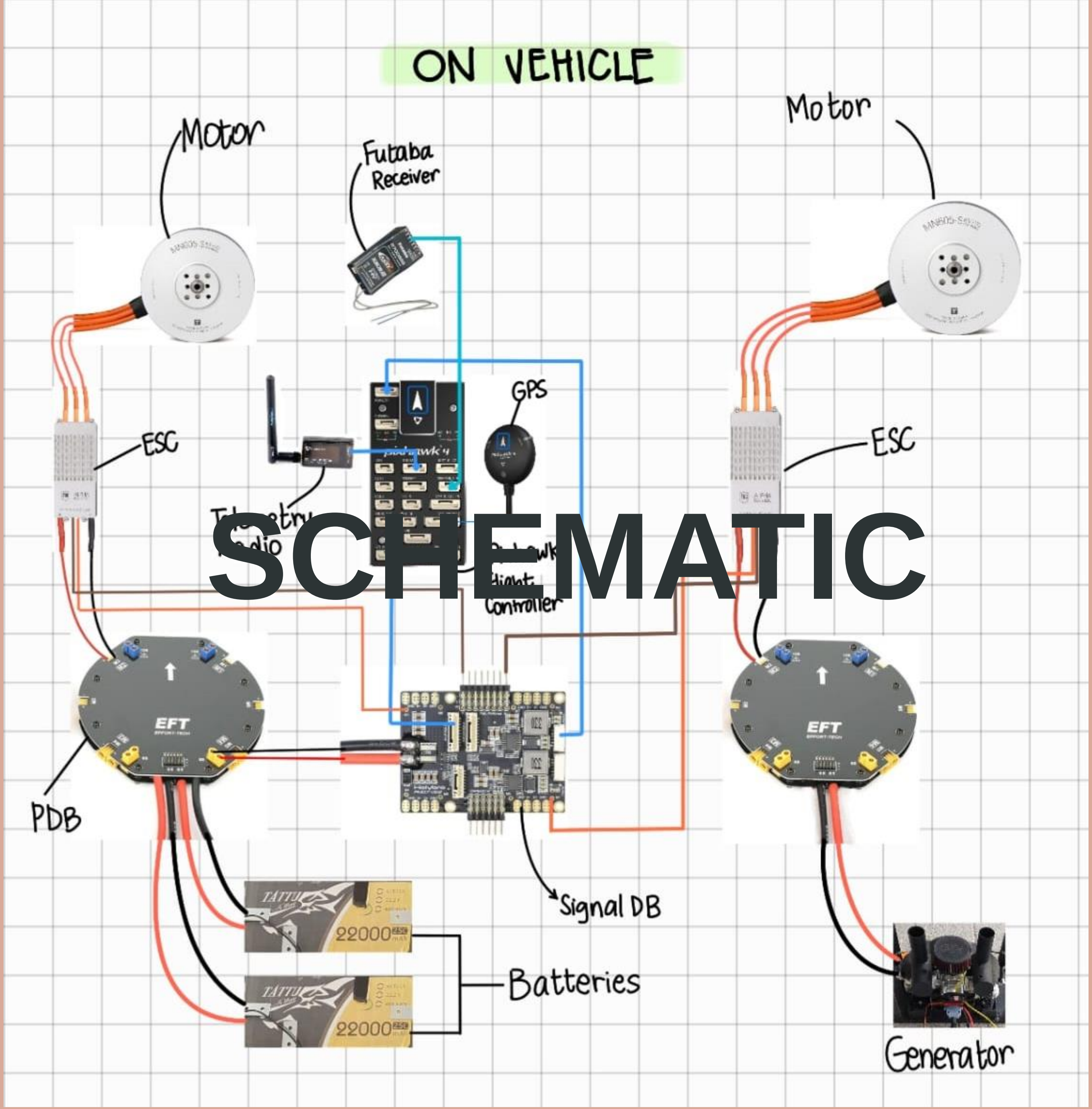
Schematic and working

FLIGHT CONTROLLERS

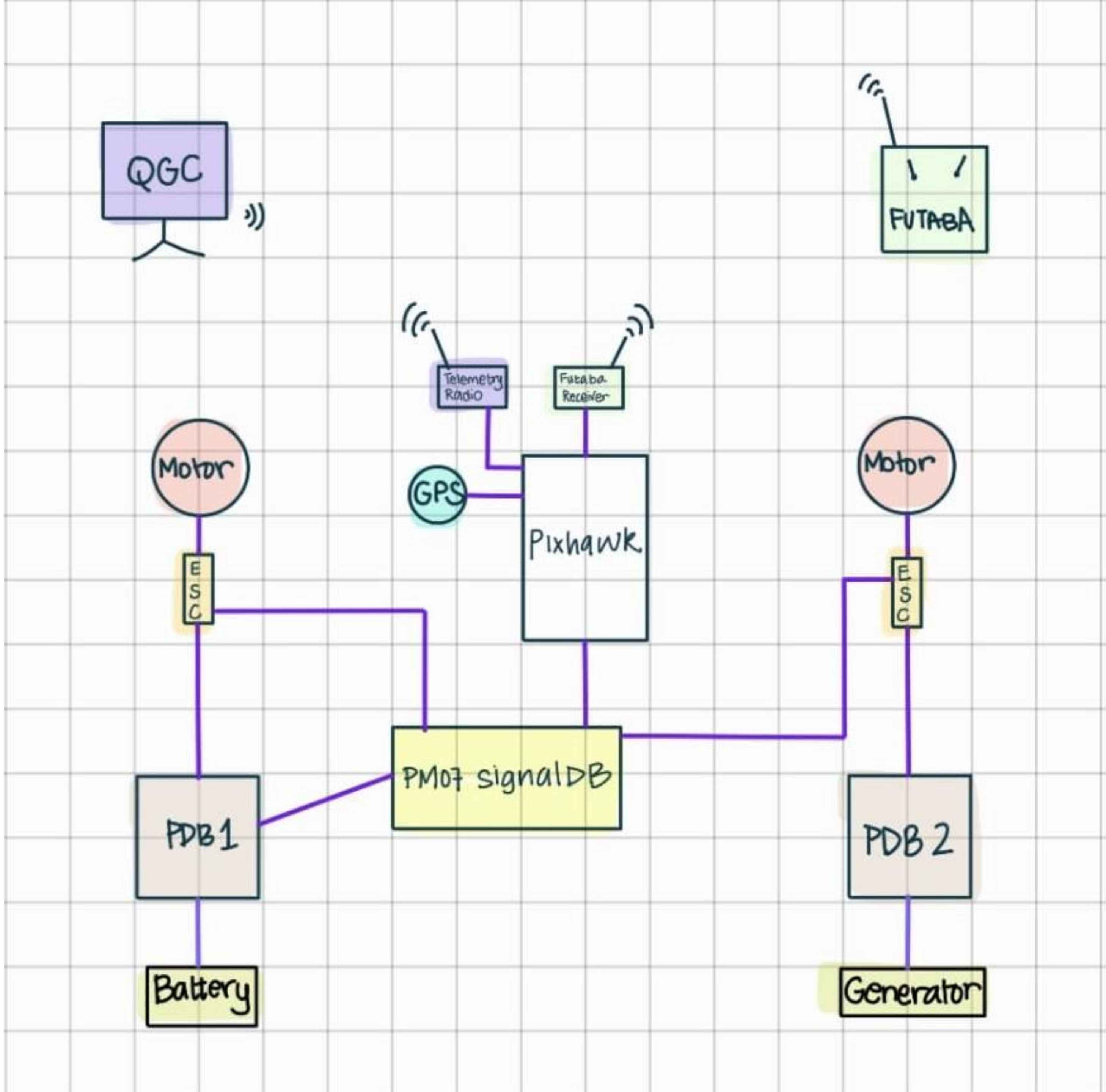
Factors	pixhawk	dji
Source	Open source	Closed source
Usability	Comparatively complex	User Friendly
Cost	Cheaper	Expensive
Purpose	Project, R&D	Videography, flower dropping

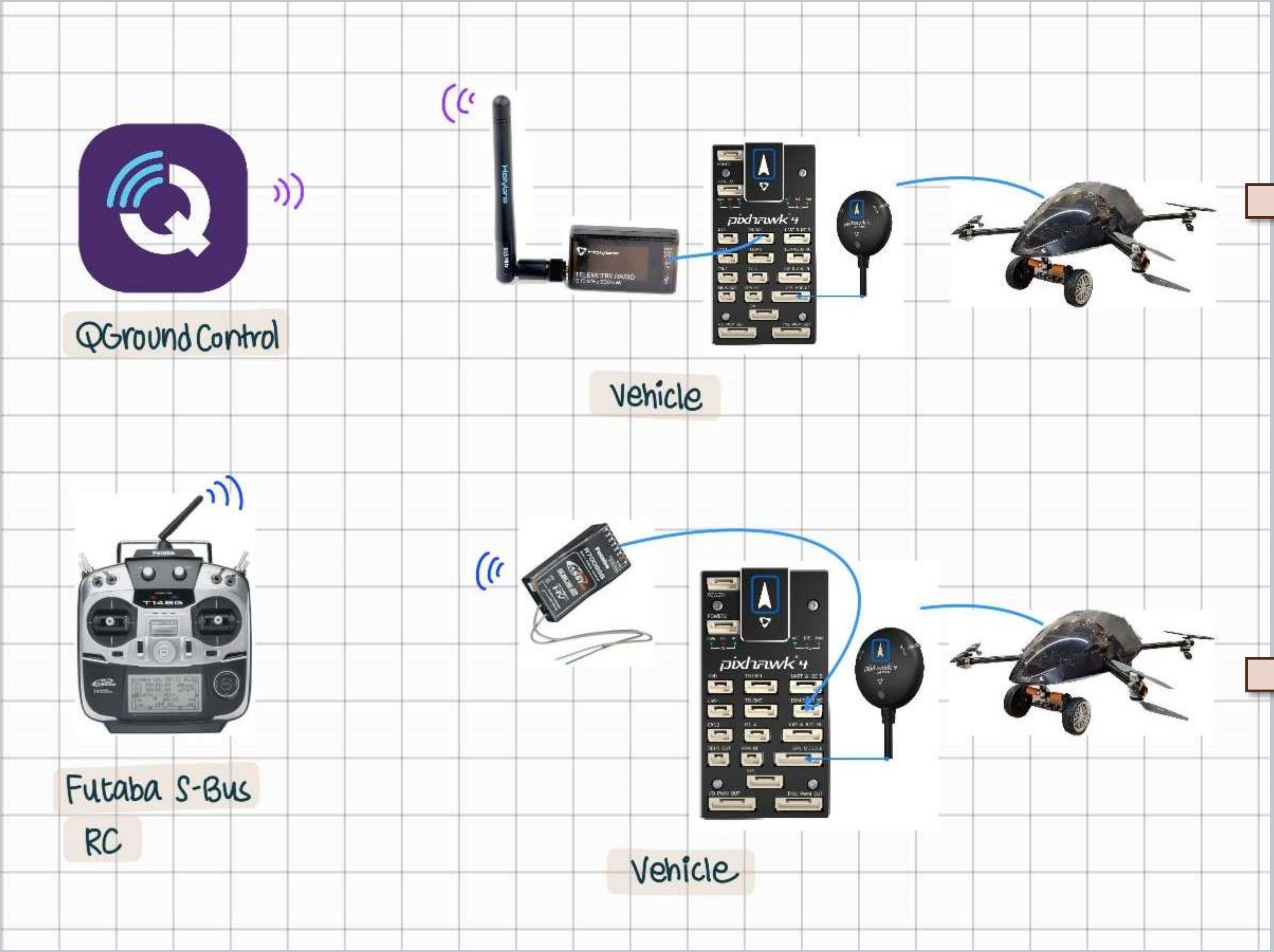


SCHEMATIC



ON VEHICLE
Motor
Futaba Receiver
Motor
GPS
ESC
ESC
Controller
PDB
Signal DB
Batteries
Generator

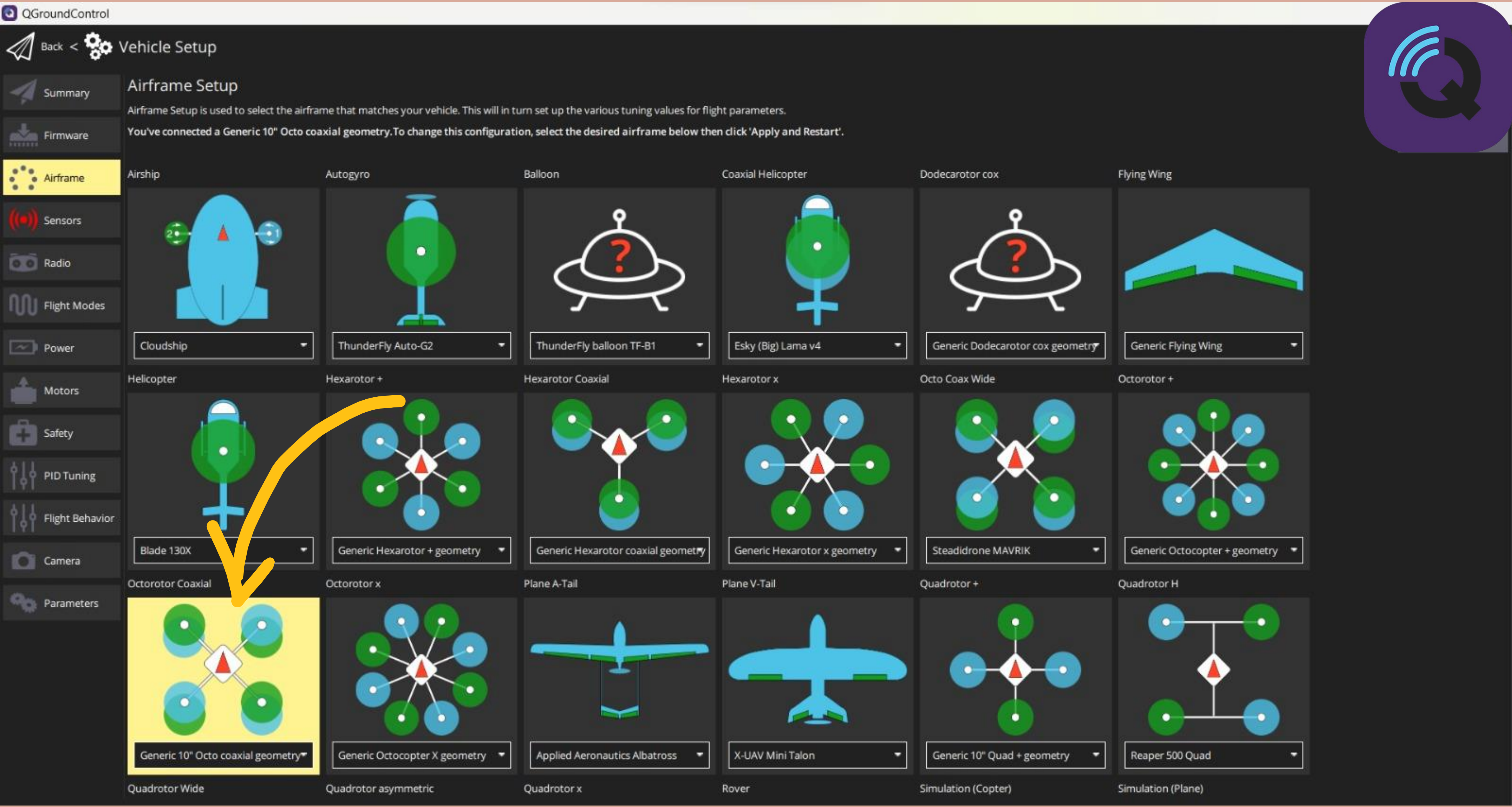

QGC
FUTABA
Telemetry Radio
Futaba Receiver
GPS
Pixhawk
Motor
Motor
E S C
E S C
PM07 signalDB
PDB 1
PDB 2
Battery
Generator

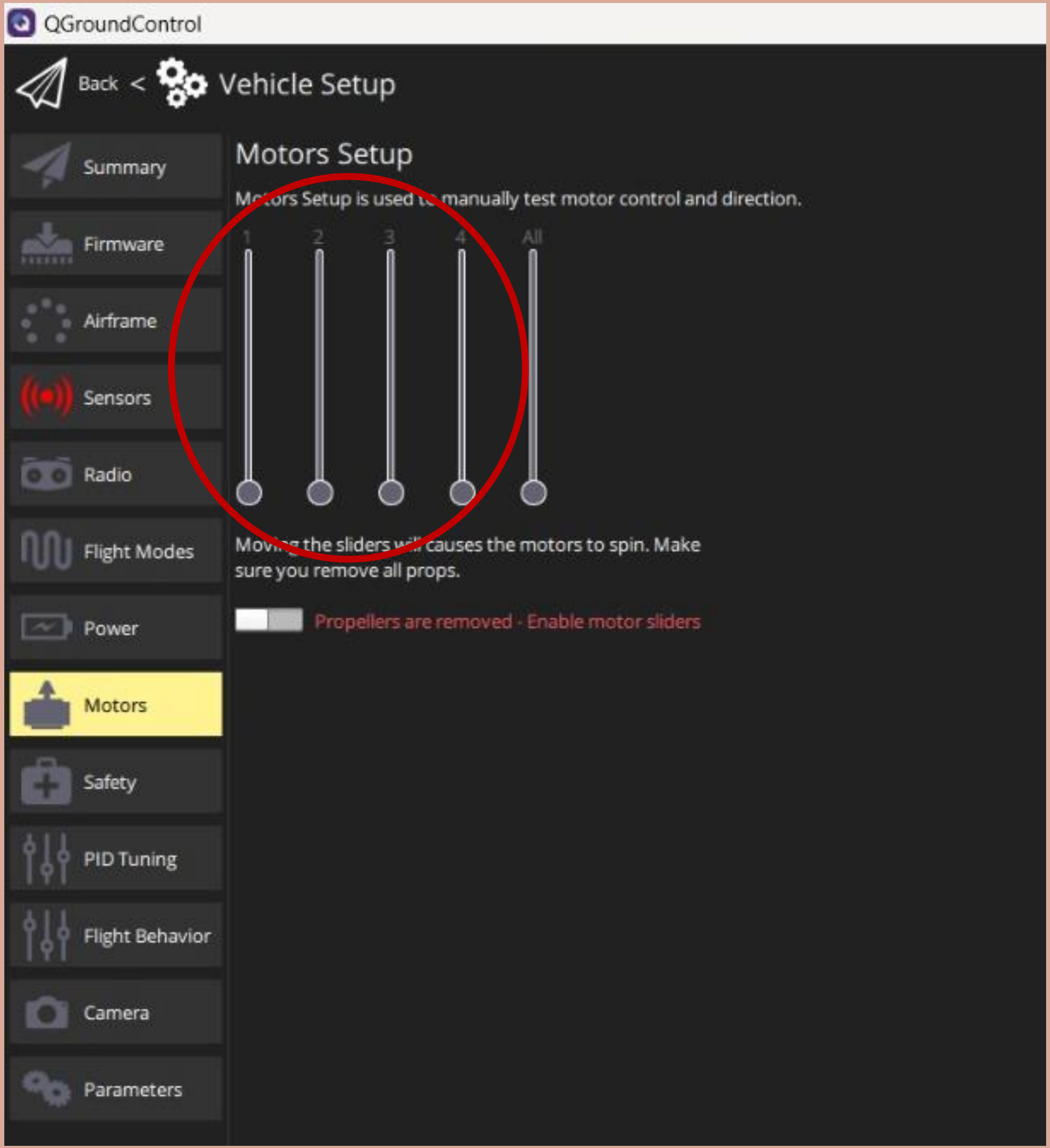


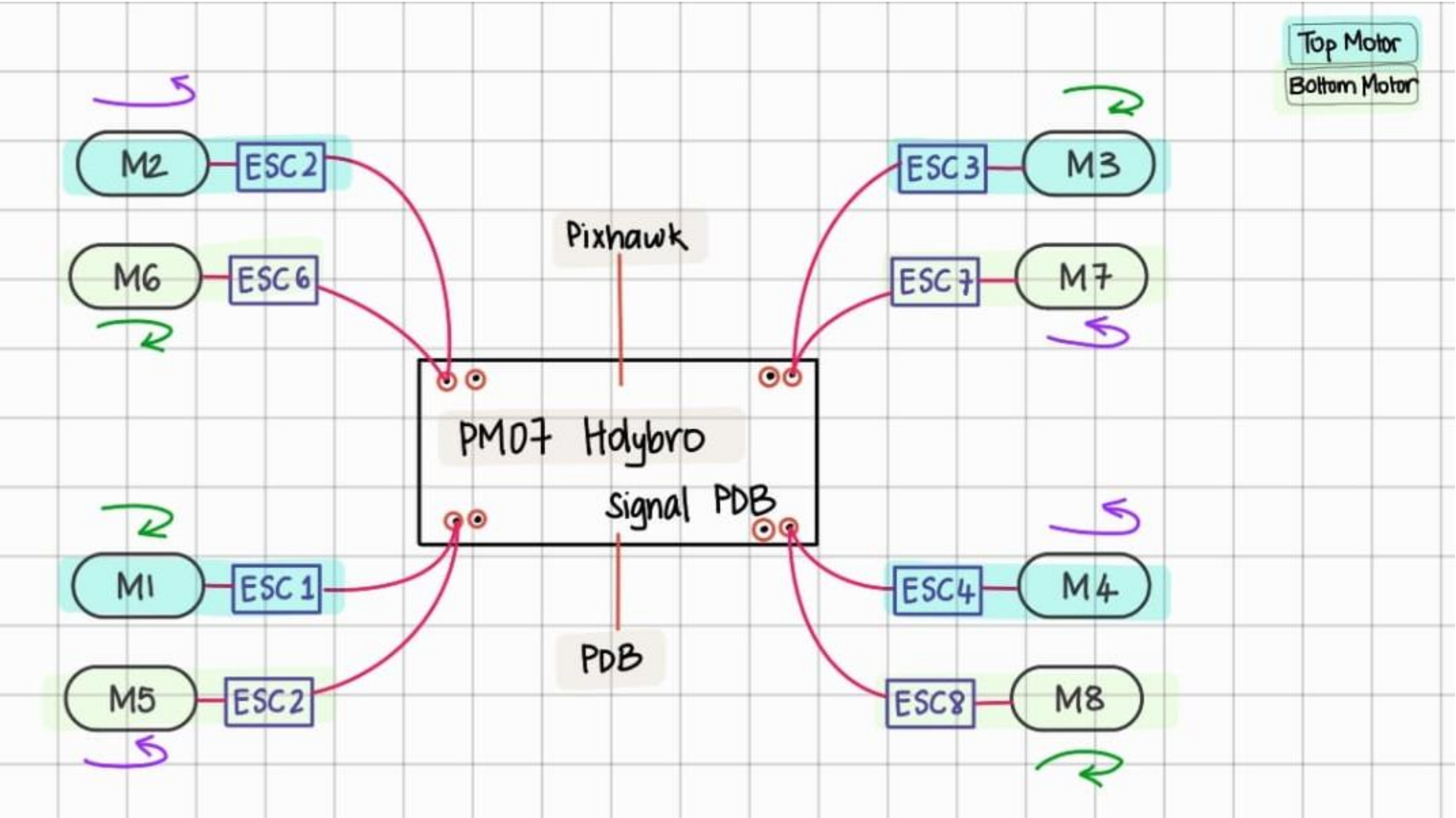
Setup, calibration, and planning.

Remote flight control.

TESTING


QGroundControl
Back < Vehicle Setup
Summary
Firmware
Airframe
Sensors
Radio
Flight Modes
Power
Motors
Safety
PID Tuning
Flight Behavior
Camera
Parameters
Airframe Setup
Airframe Setup is used to select the airframe that matches your vehicle. This will in turn set up the various tuning values for flight parameters.
You've connected a Generic 10" Octo coaxial geometry.To change this configuration, select the desired airframe below then click 'Apply and Restart'.
Airship
Cloudship
Autogyro
ThunderFly Auto-G2
Balloon
ThunderFly balloon TF-B1
Coaxial Helicopter
Esky (Big) Lama v4
Dodecarotor cox
Generic Dodecarotor cox geometry
Flying Wing
Generic Flying Wing
Helicopter
Blade 130X
Hexarotor +
Generic Hexarotor + geometry
Hexarotor Coaxial
Generic Hexarotor coaxial geometry
Hexarotor x
Generic Hexarotor x geometry
Octo Coax Wide
Steadidrone MAVRIK
Octorotor +
Generic Octocopter + geometry
Octorotor Coaxial
Generic 10" Octo coaxial geometry
Octorotor x
Generic Octocopter X geometry
Plane A-Tail
Applied Aeronautics Albatross
Plane V-Tail
X-UAV Mini Talon
Quadrotor +
Generic 10" Quad + geometry
Quadrotor H
Reaper 500 Quad
Quadrotor Wide
Quadrotor asymmetric
Quadrotor x
Rover
Simulation (Copter)
Simulation (Plane)

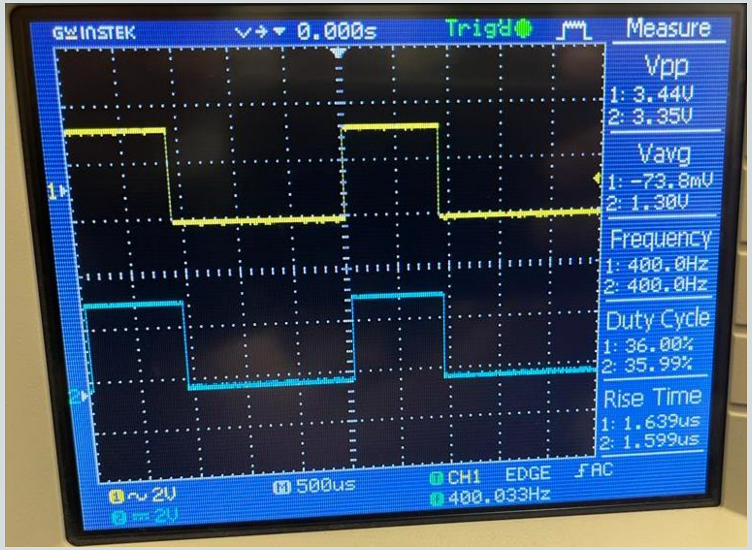

QGroundControl
Back <
Vehicle Setup
Summary
Firmware
Airframe
Sensors
Radio
Flight Modes
Power
Motors
Safety
PID Tuning
Flight Behavior
Camera
Parameters
Motors Setup
Motors Setup is used to manually test motor control and direction.
1
2
3
4
All
Moving the sliders will causes the motors to spin. Make sure you remove all props.
Propellers are removed - Enable motor sliders

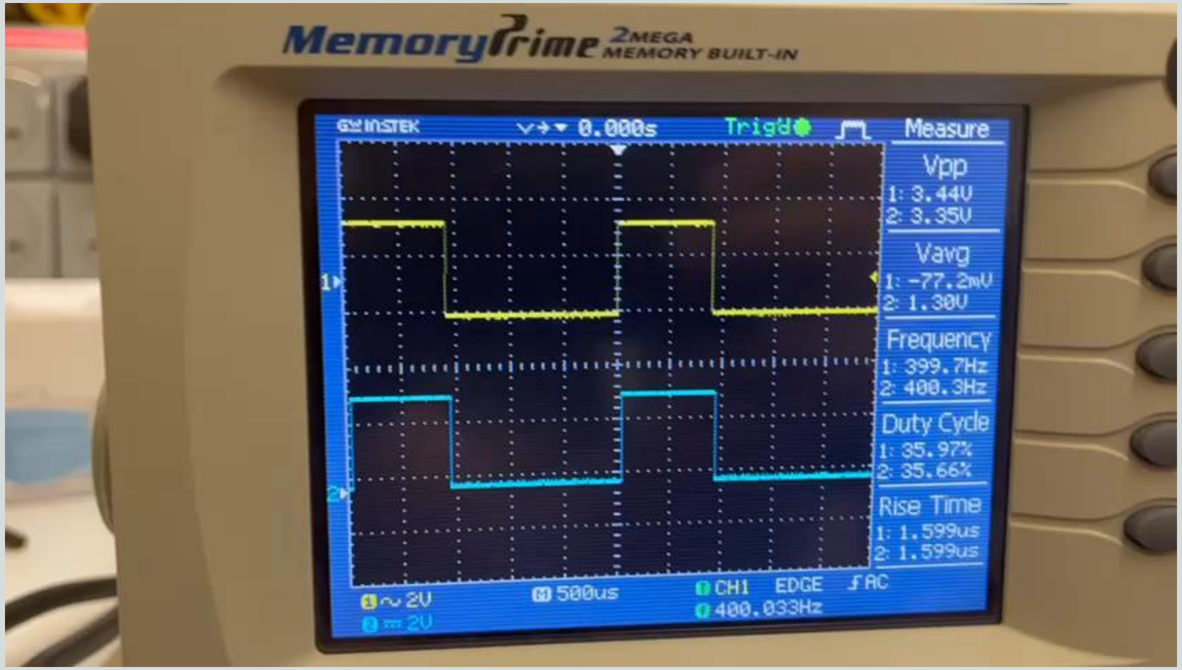

Top Motor
Bottom Motor
M2
ESC2
M6
ESC6
ESC3
M3
ESC7
M7
Pixhawk
PM07 Holybro
Signal PDB
M1
ESC1
M5
ESC2
PDB
ESC4
M4
ESC8
M8

OSCILLOSCOPE READING

1 motor 1 PWM

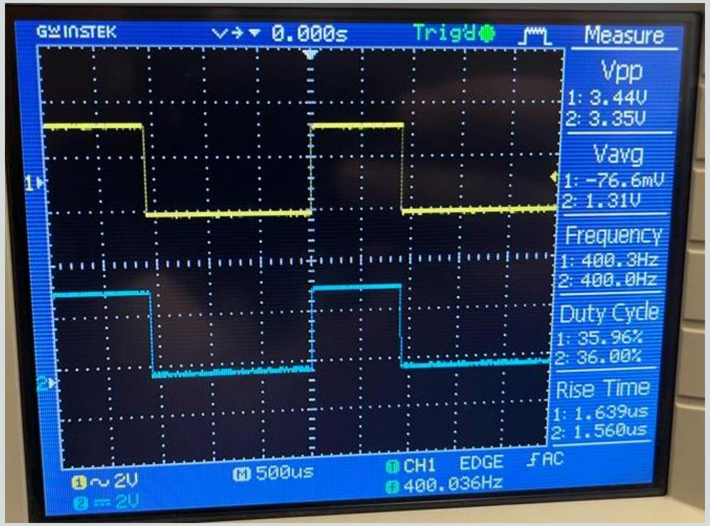
0% throttle

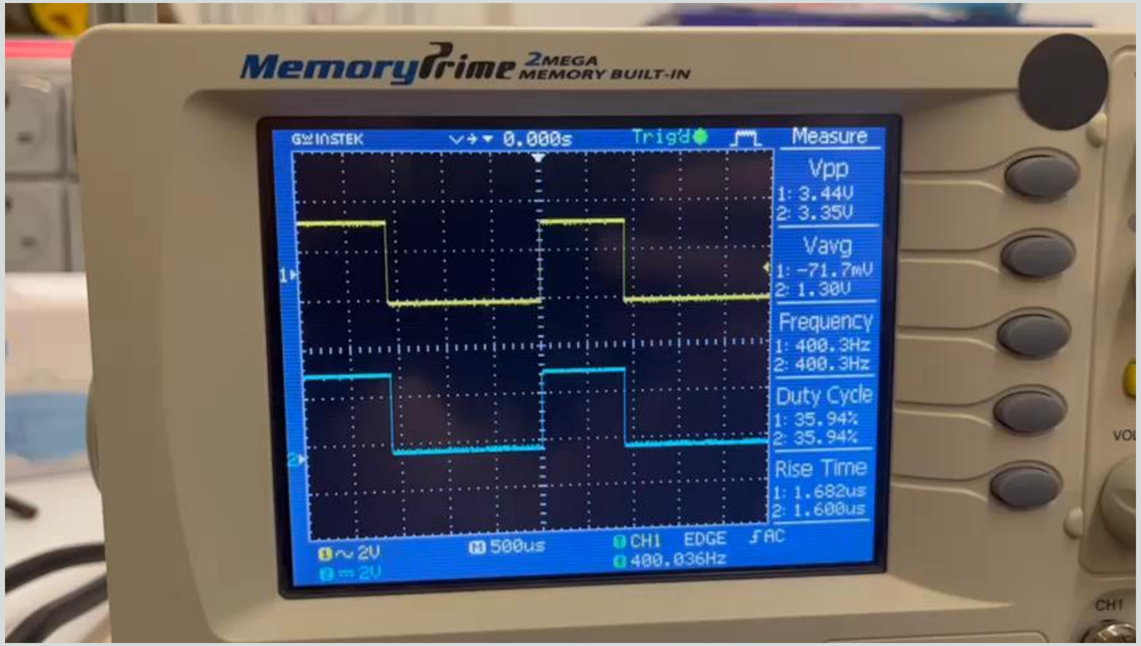




2 motors 1 PWM

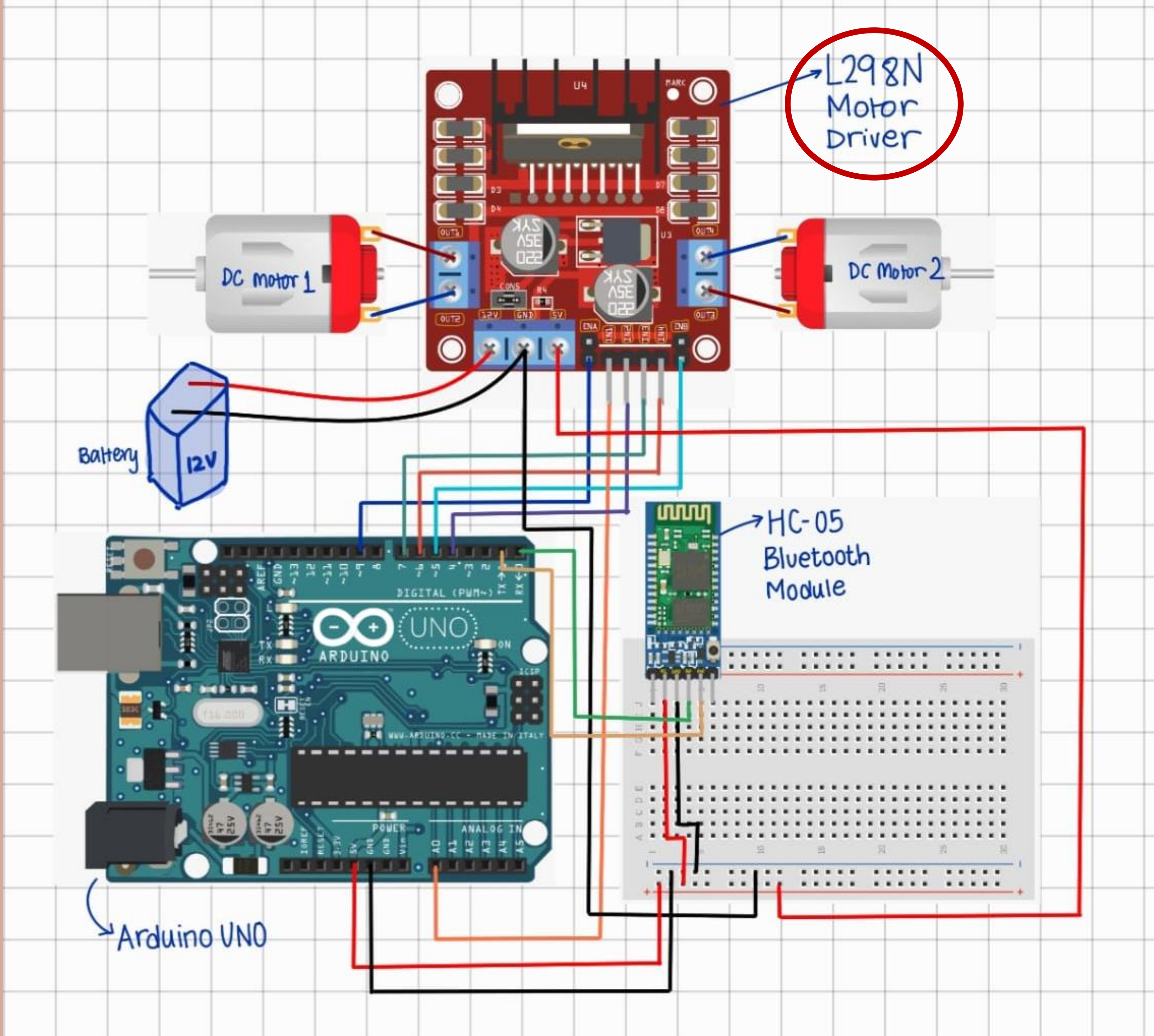
0% throttle

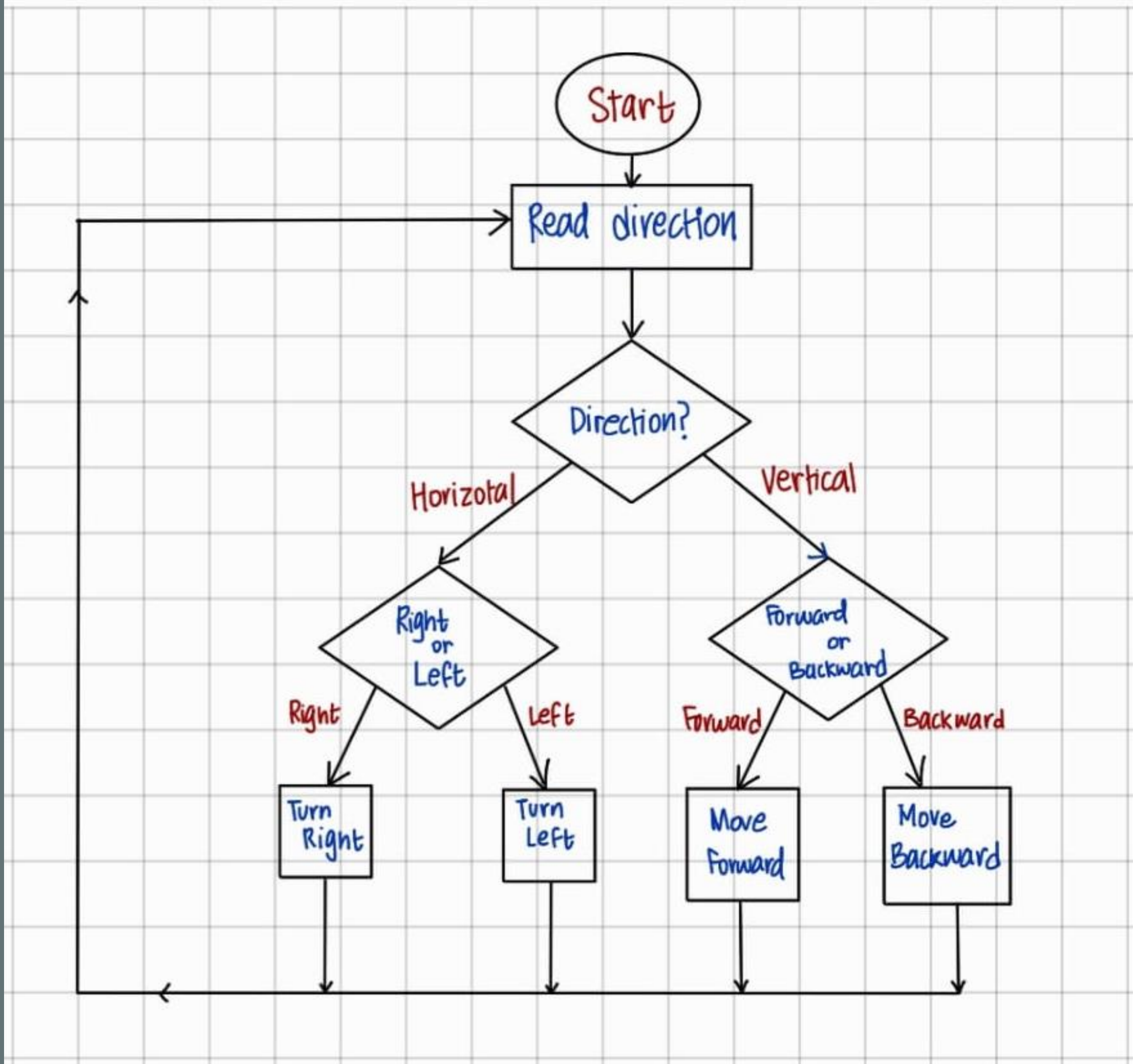




TAXIING SYSTEM

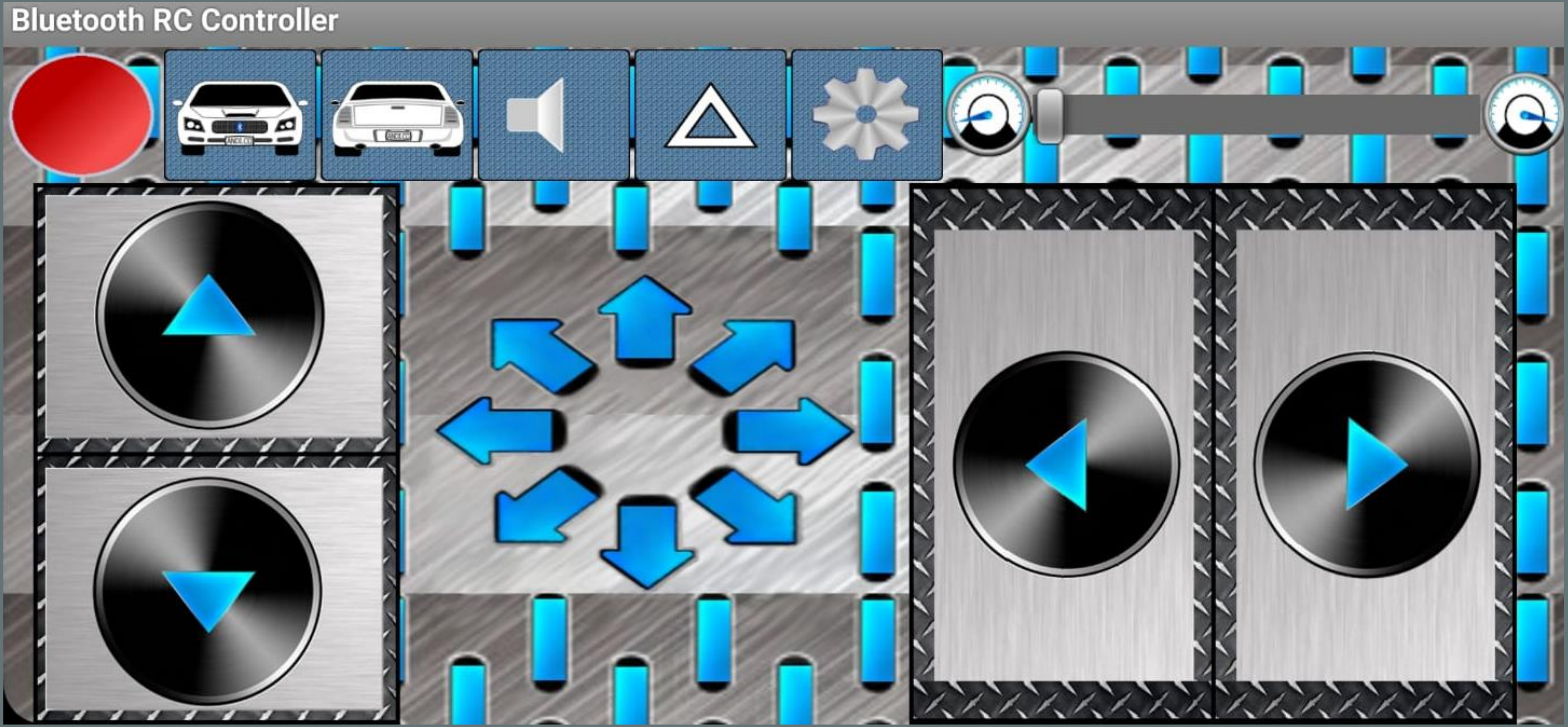
Brief description


L298N
Motor
Driver
DC motor 1
DC Motor 2
Battery
12V
HC-05
Bluetooth
Module
Arduino UNO



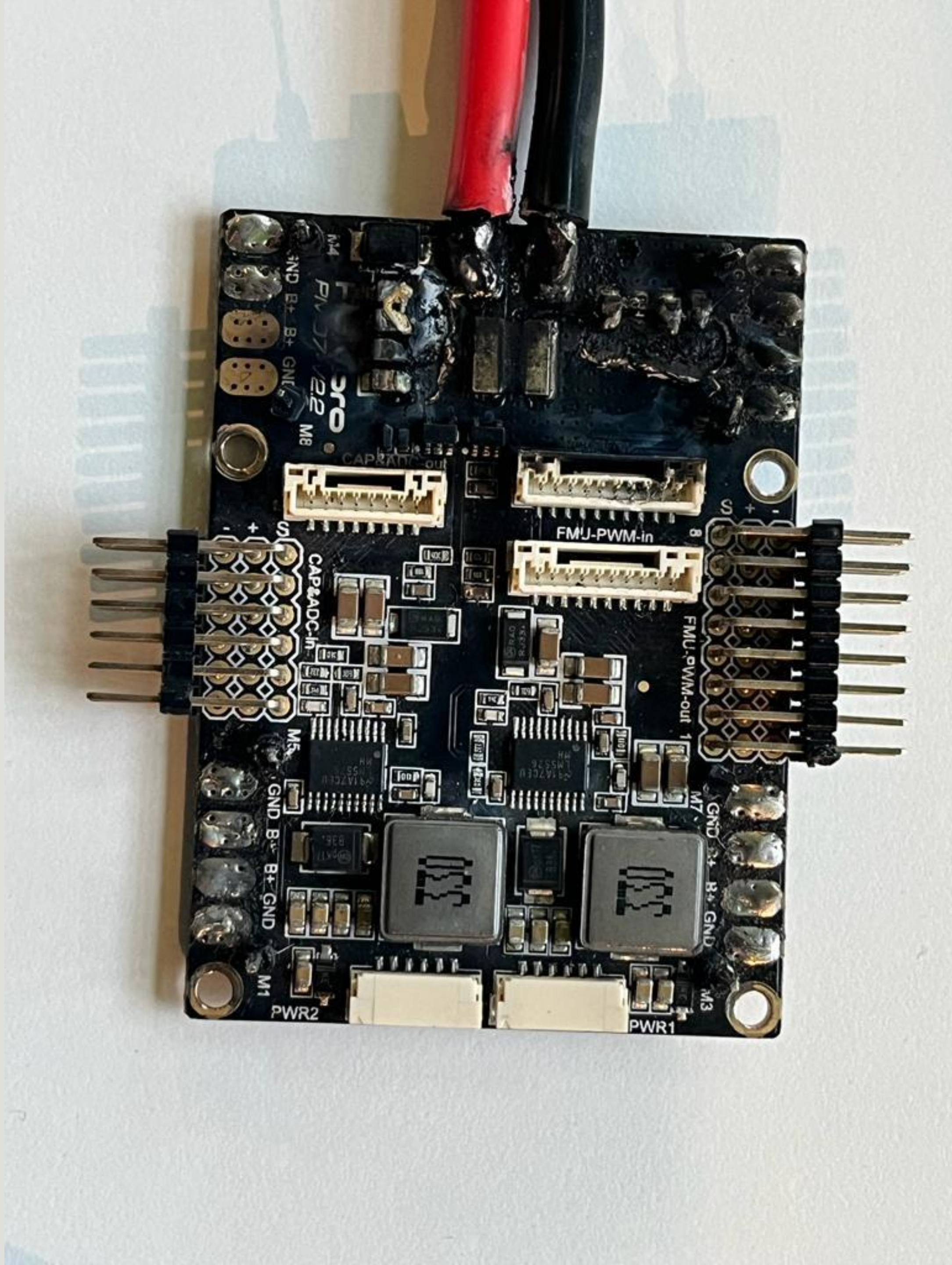
Start
Read direction
Direction?
Horizotal
Vertical
Right or Left
Forward or Backward
Right
Left
Forward
Backward
Turn Right
Turn Left
Move Forward
Move Backward

LOW


Bluetooth RC Controller

TESTING

TESTING FAILURES



PM07 module

Human error – short circuit

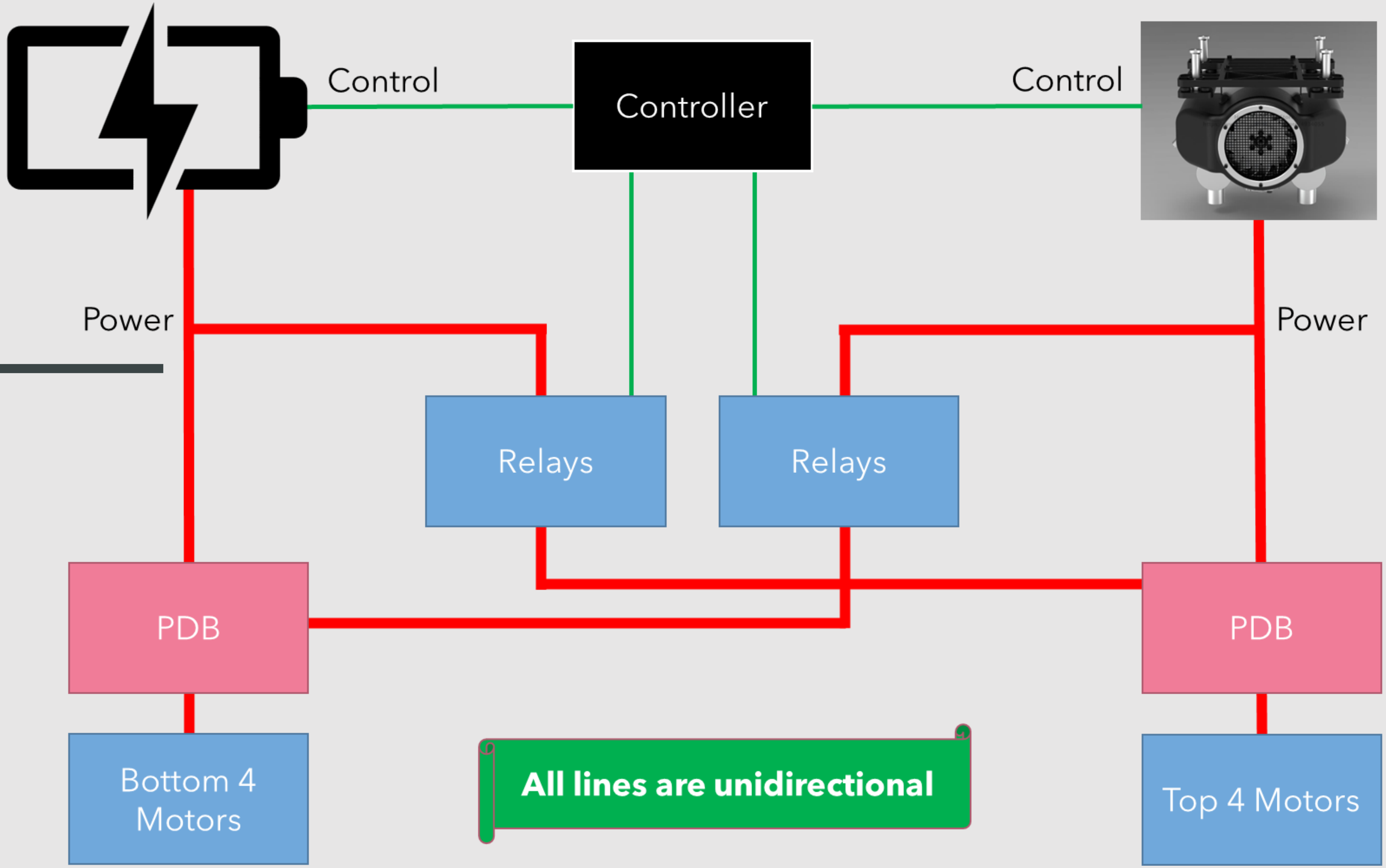
NRF24L01 RADIO

XBEE

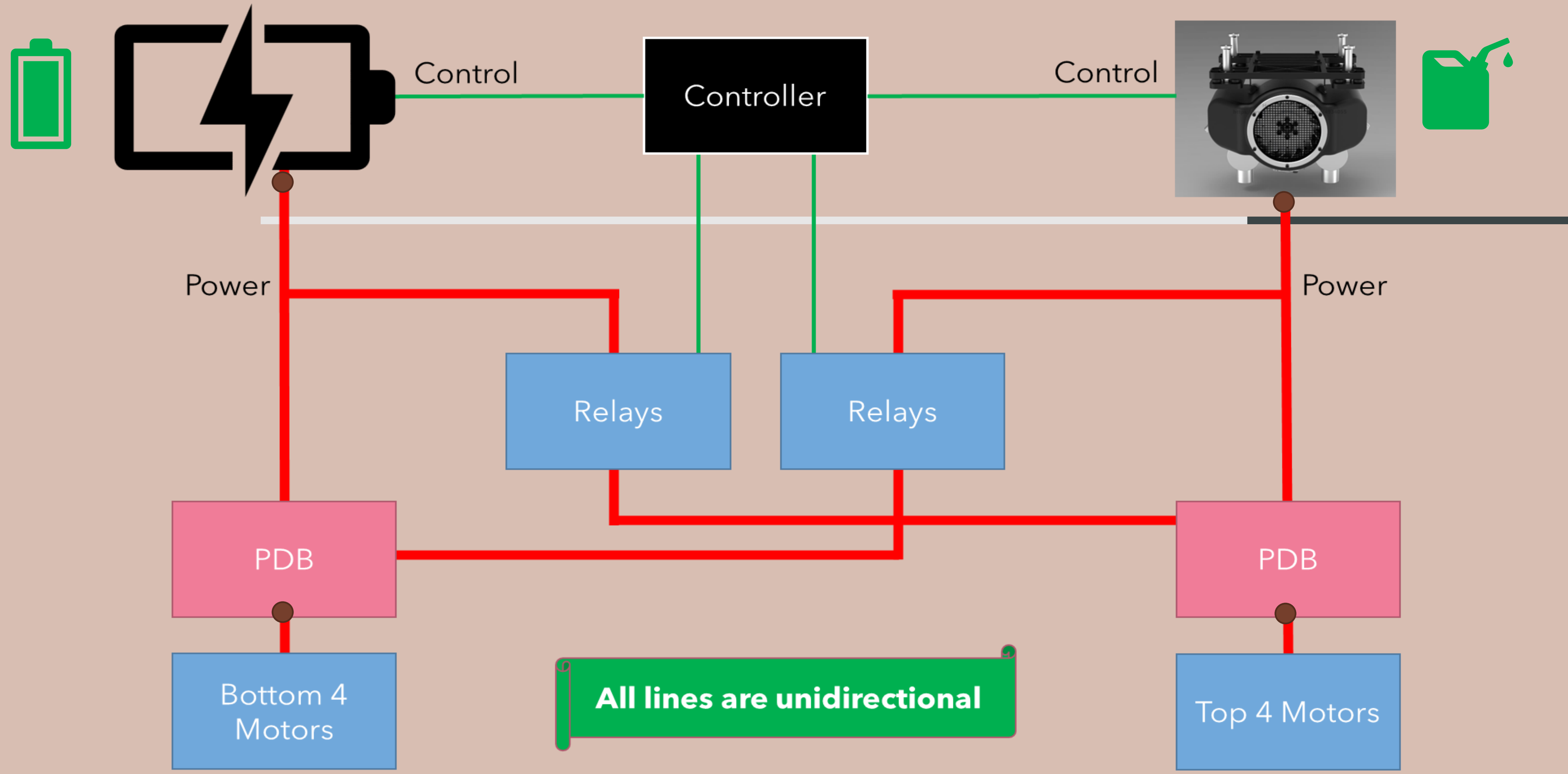
HYBRID SYSTEM DESIGN METRICS

- Must be efficient.
- Must have a better flight time when compared to other single-source options.
- Must be controlled to supply all motors effectively for a stable flight.

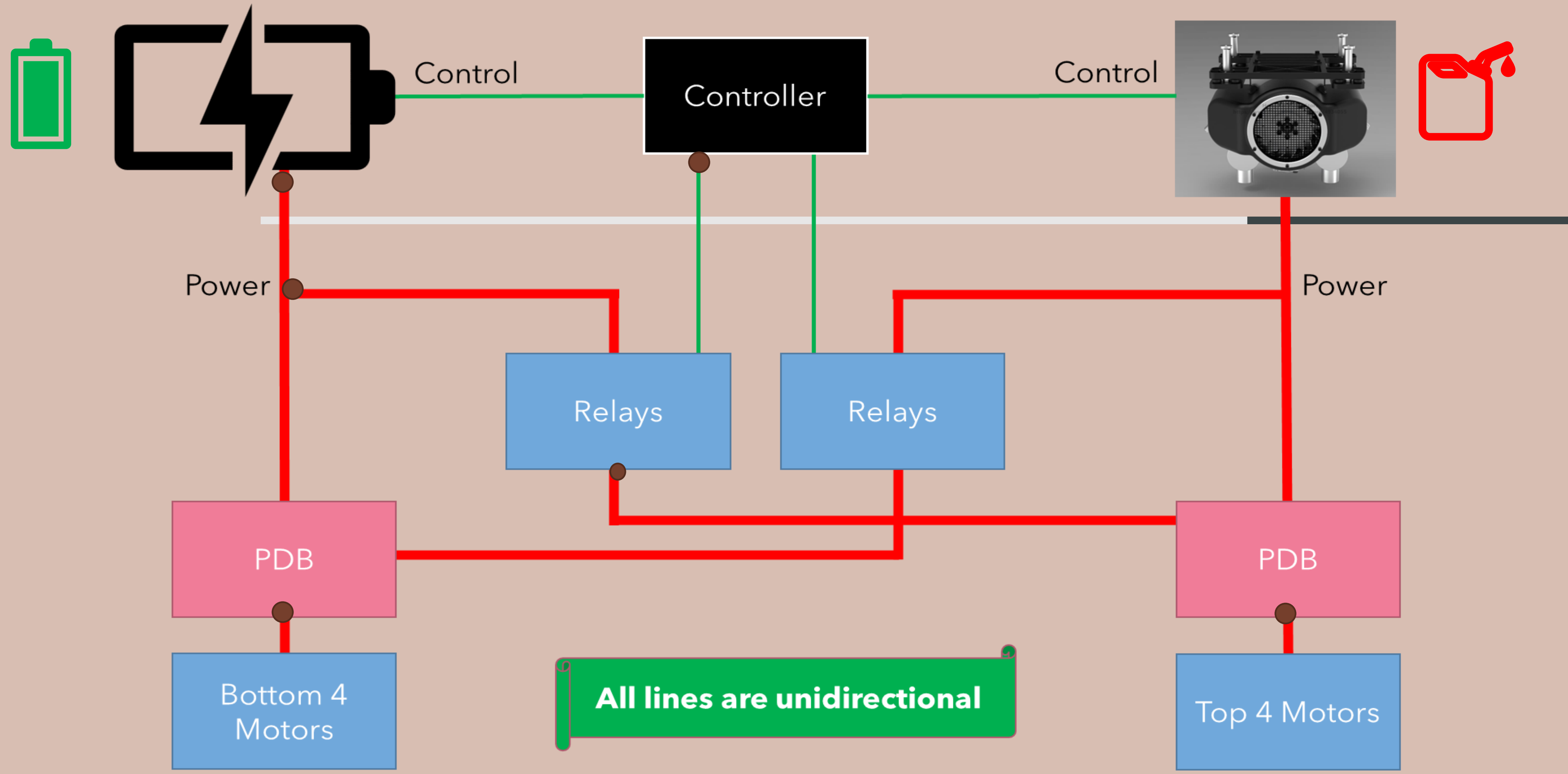
HYBRID SYSTEM DESIGN



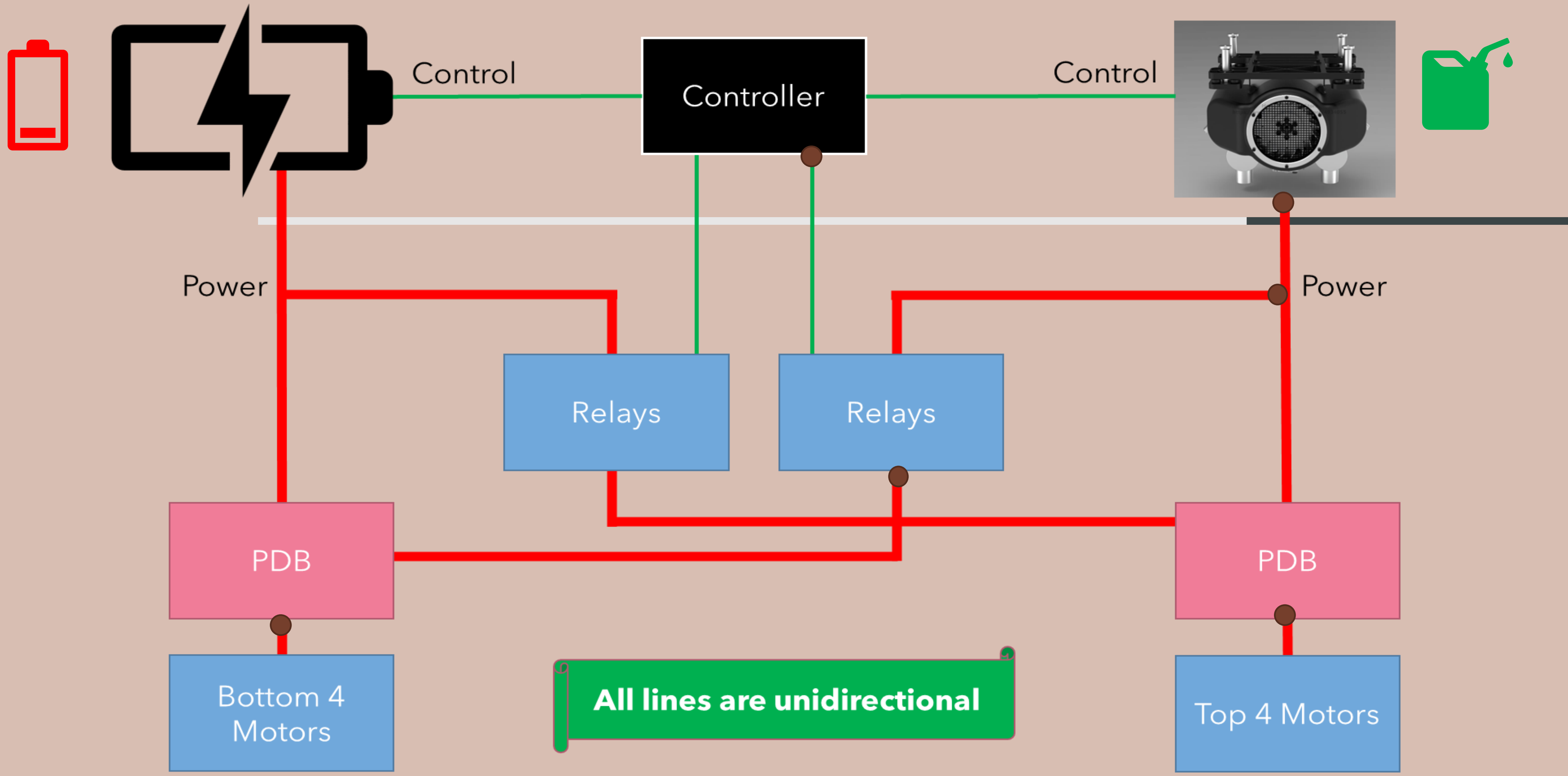
HYBRID SYSTEM DESIGN



HYBRID SYSTEM DESIGN (JUST BATTERY)



HYBRID SYSTEM DESIGN (JUST GENERATOR)



HYBRID SYSTEM DESIGN

Power Division

- Each source separately supplies power for 4 motors
- The power load per source is 4386W.

Generator and Battery Supply

- With a continuous 5000W supply, 4 motors can run for 12 mins with 2.5 lit fuel.
- With batteries, the rest of the 4 motors can run for 7-8 mins.

Flight Time

- Minimum flight time of 7-8 mins with the hybrid system.
- An additional 2-3 mins from the generator only can be added for a safe landing.
- Hence making a total flight time of 11 mins.

HYBRID VS GENERATOR

Generator can provide a continuum of 5000 watts.

However, the motors required 8772 watts for maneuvers and flight.

Hence, using the generator alone to power the flight is not feasible.

Additionally, stabilizing the generator's vibrations is challenging.

Practical Scenario

Reduce the number of motors used to 4.

→

Max thrust reduced, hence max AUW limited to 17.5 kg.

→

With this, we can only design a drone without any extra payload or features.

HYBRID VS BATTERY

We remove the generator and fuel.

AUW reduced from 39 to 30 kgs.

Flight time for using batteries alone

140 Amps required for maneuvers.	One 12S 22Ah pack can provide 3.77 mins of flight.

Added Weight

For 11 mins flight, extra 2 packs of the battery would be added, increasing the AUW to 42 kg.	Due to this increase, the flight time attained will be lower (about 9 mins).

SUMMARY OF COMPARISON

Hybrid system AUW is 39 kgs with 11 mins flight time.

- .

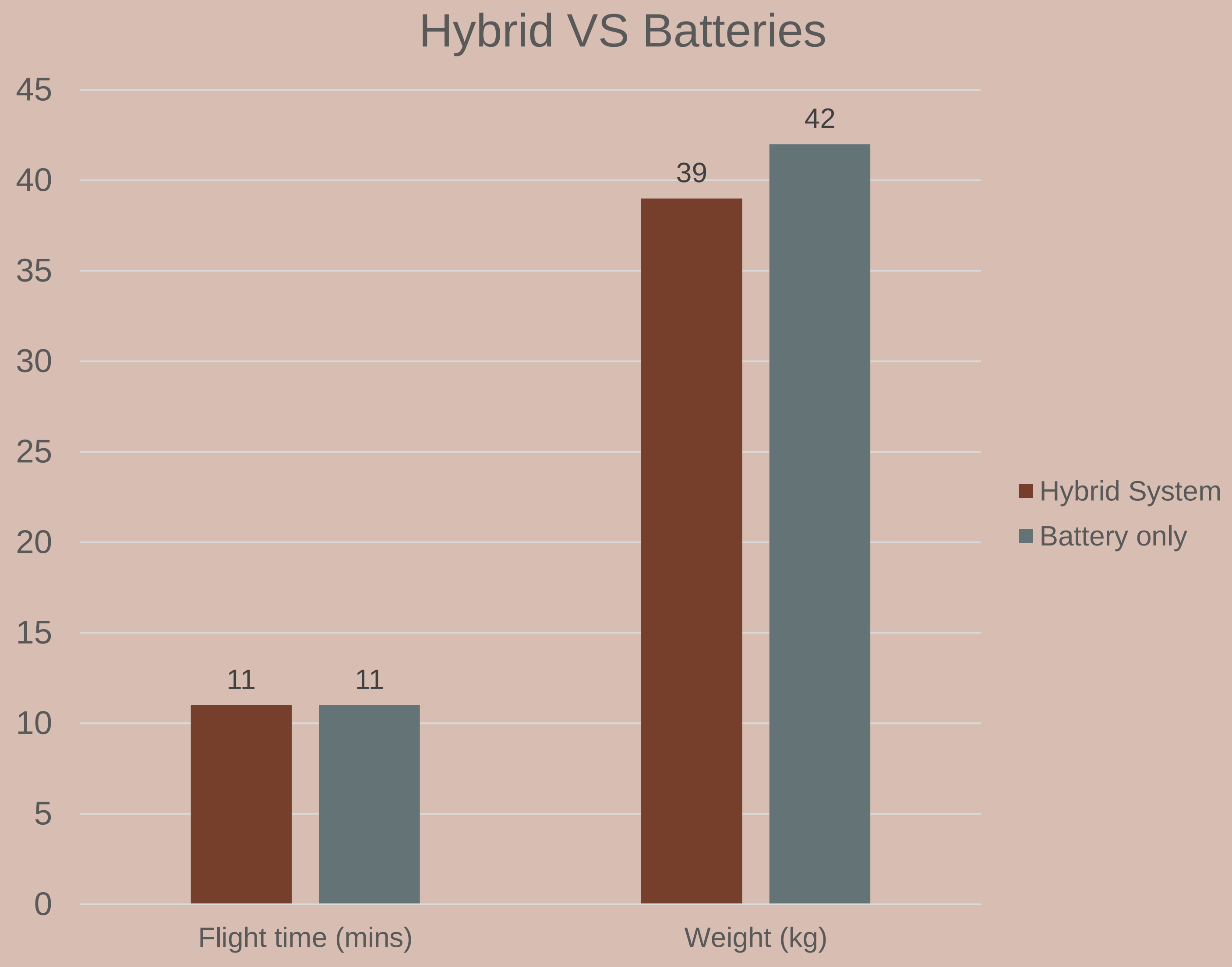
The generator is not possible, as it cannot simultaneously provide power for 8 motors.

- .

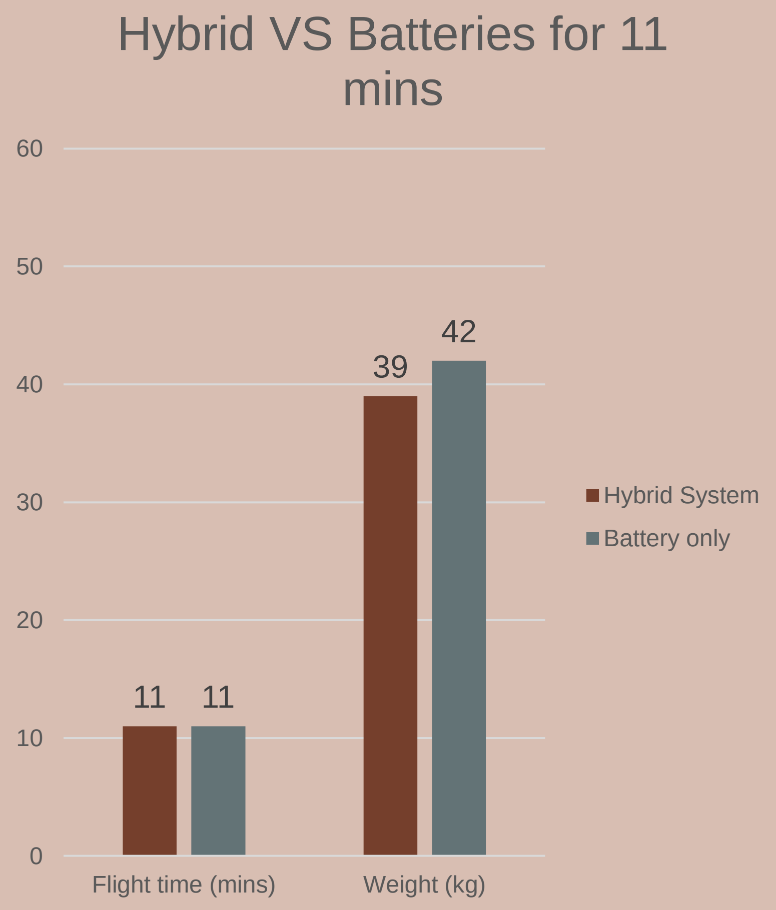
So, with battery only we are 3 kgs above the required weight.

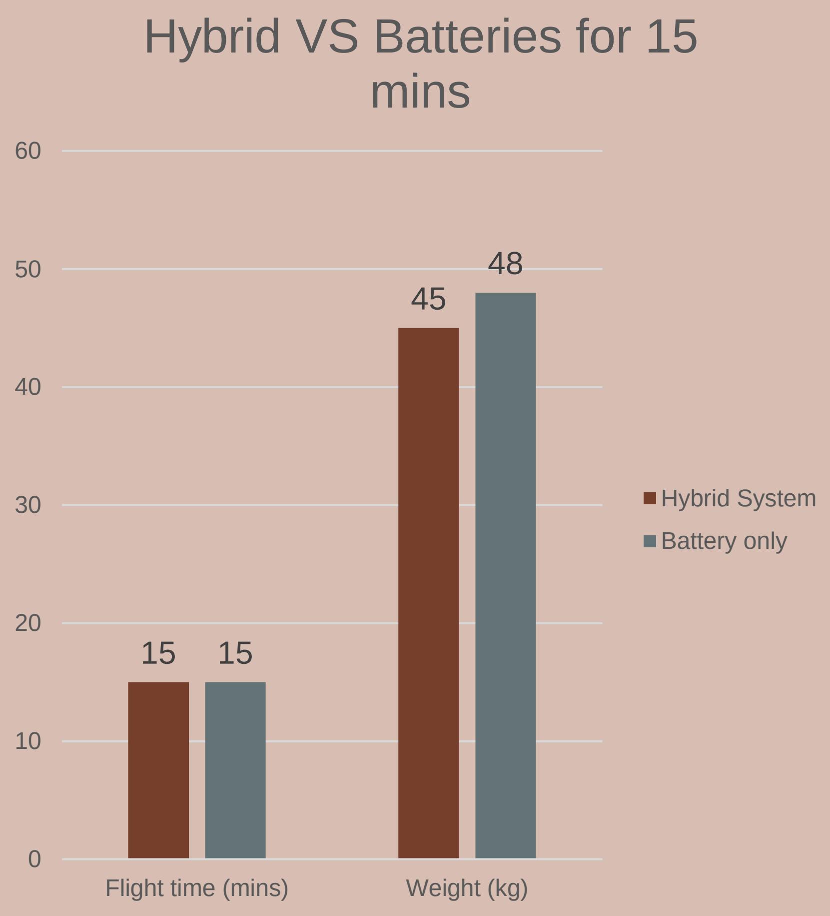
- .

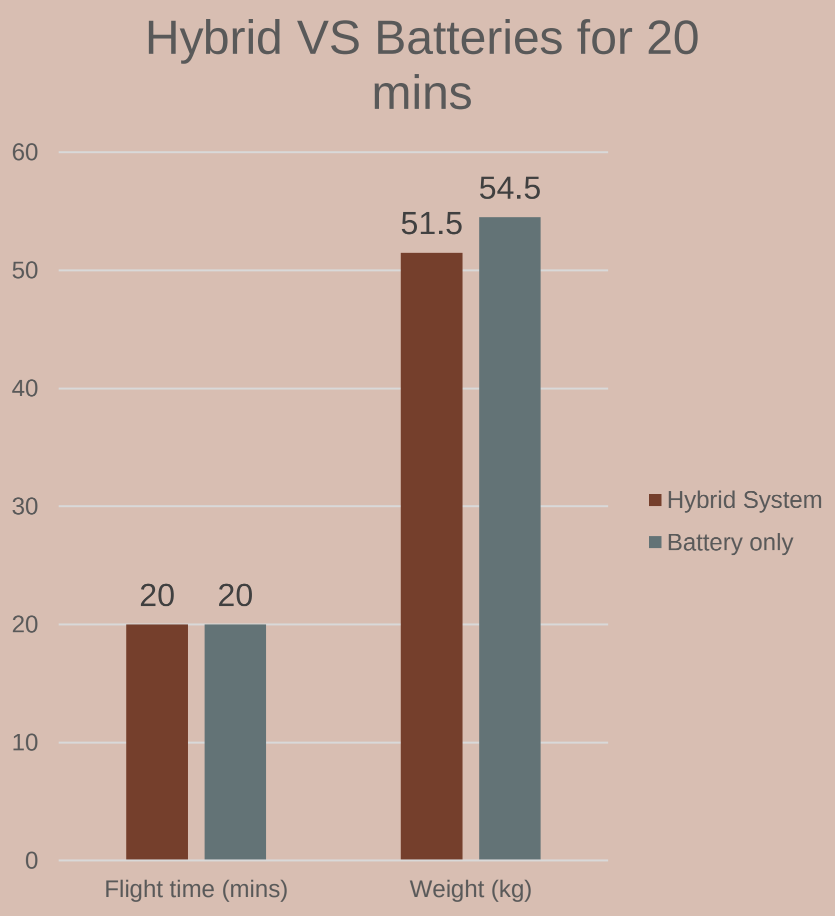
Additionally, we concluded that for the same flight time, batteries would increase AUW by 3 kgs.



FURTHER HYBRID VS BATTERY COMPARISON







We have concluded that the same flight time with only batteries adds up to 3 kgs when compared to our hybrid system.

FUTURE DEVELOPMENTS

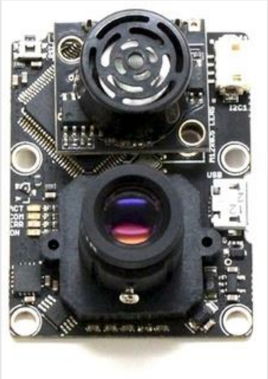
Camera, US sensor

SATELLITE COMMUNICATION

- Fly beyond visual line of sight (BVLOS)
- Higher range.

Iridium/Rock Block Satellite Communication System

DISTANCE SENSORS FOR SAFETY



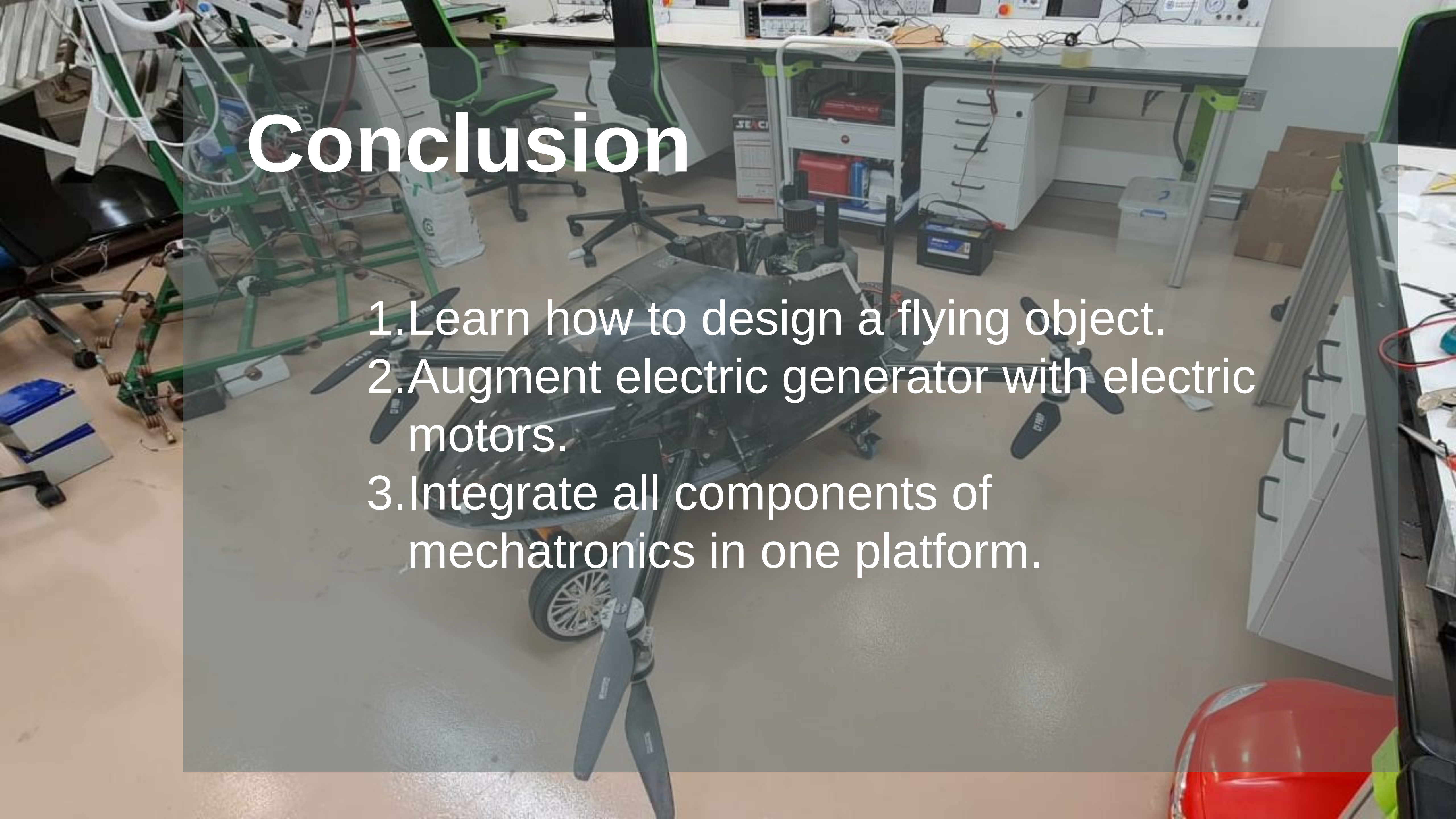
CAMERA INTEGRATION

FPV

Sensor camera

Real time footage

Location: precise mapping of images to GPS position for geotagging.



Conclusion

1. Learn how to design a flying object.
2. Augment electric generator with electric motors.
3. Integrate all components of mechatronics in one platform.

THANK YOU

QUESTIONS