2. System design

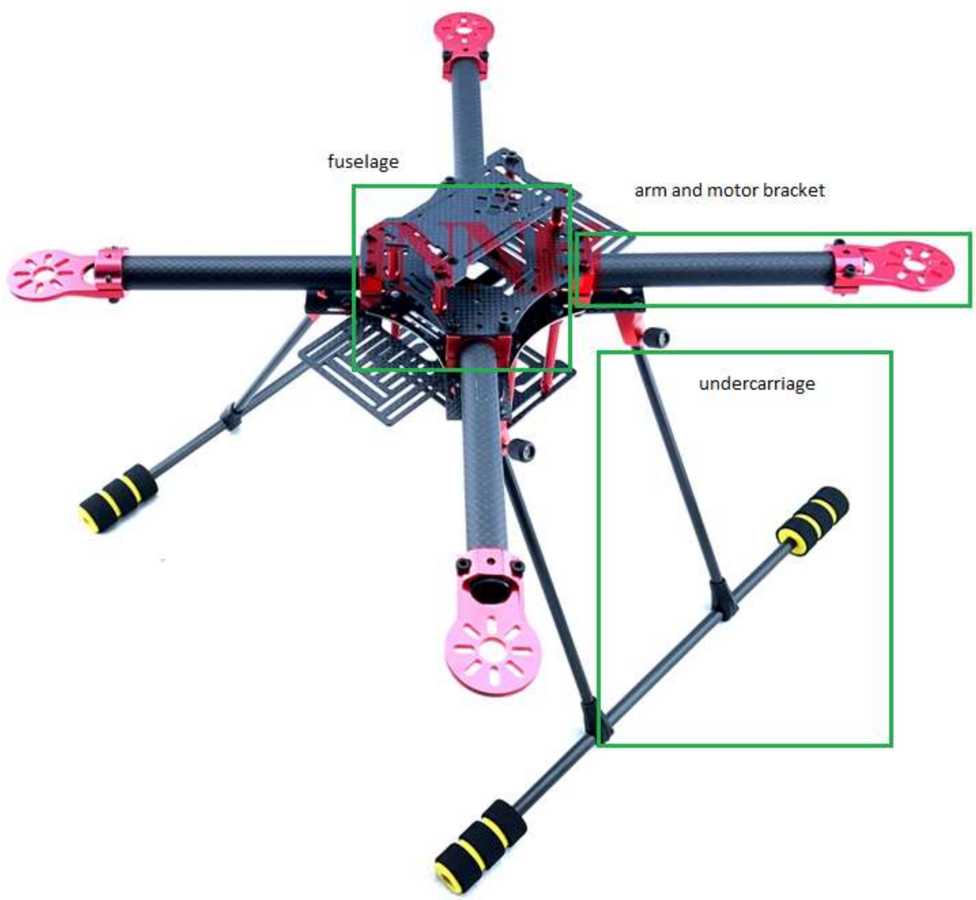
2.1 Airframe

According to design concept, a 350mm to 450mm airframe will be good for this design.

An airframe X400S can be easily purchase and the cost is very low, 400mm or 450mm can be selected:

The arm and motor bracket can be directly used.

The fuselage and undercarriage can be customized according to detailed design, Aluminum plate can also be used to make the thermal dissipation of ESC better.



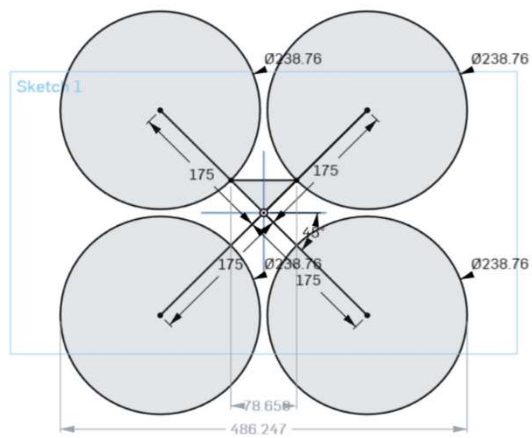
2.2 Propeller

At a 400mm airframe level, 9-inch ~ 11-inch propeller can be selected.

Some of the combination is listed below:

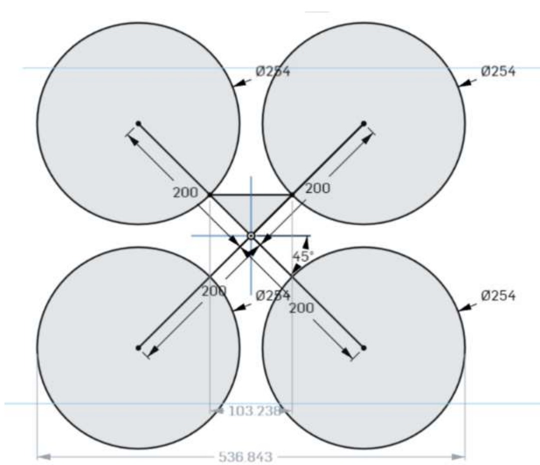
2.2.1 350mm airframe + 9.4-inch propeller (DJI PHANTOM 4)

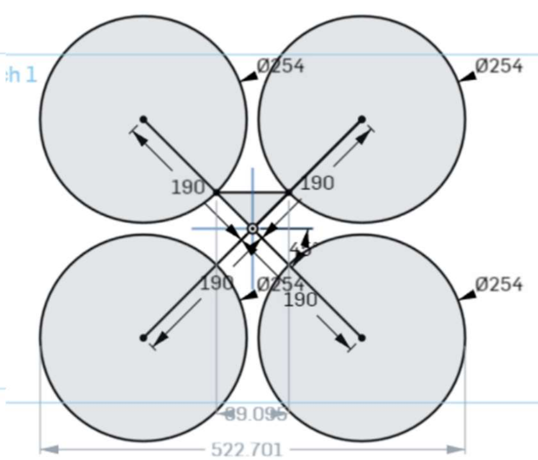
The propeller size and frame size are well matched, and the total size is acceptable(486mm), but 9.4-inch propeller is not widely used (only DJI use this size propeller), so this solution will not be selected.



2.2.2 400mm airframe + 10-inch propeller / 380mm airframe + 10-inch propeller

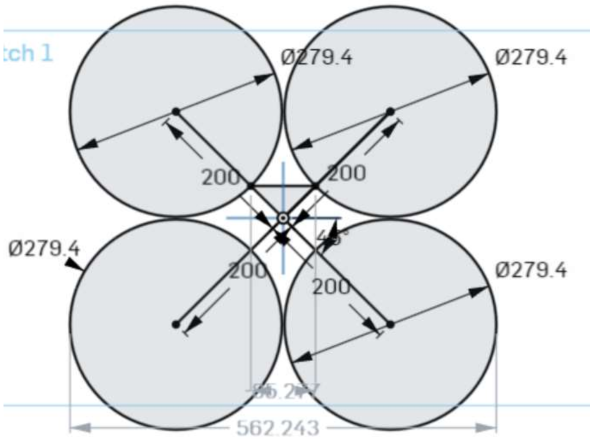
10-inch propeller and 400mm airframe are also matched but there is too much spacing between propellers, 380mm airframe is suitable for 10-inch propeller

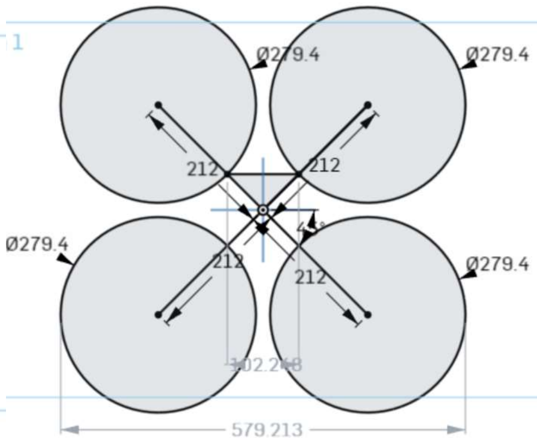




2.2.3 400mm airframe + 11-inch propeller / 424mm airframe + 11-inch propeller

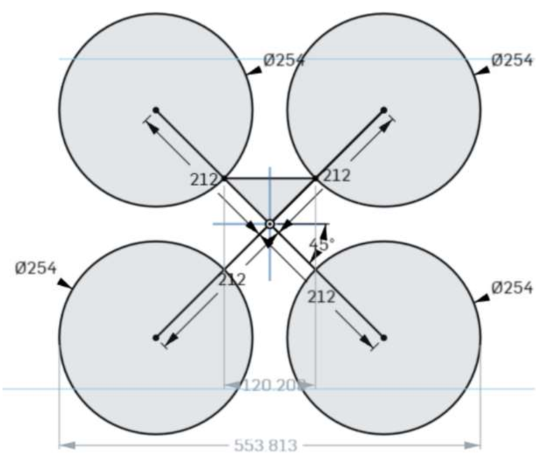
11-inch propellers are too close to each other, 424mm airframe is just suitable for 11-inch propeller.





2.2.4 424mm airframe + 10-inch propeller

Considering the possibility to upgrade to 11-inch later, a 424mm airframe and 10-inch propeller is selected. The layout and 3d design are as below:



424mm airframe can be shorten to 380mm when 10-inch propeller is used as well.

MR 1045 propeller is select because it has multiple colors, Green, Orange, Black

2.3 Motor

2.3.1 Motor selection

Since FOC type ESC will be used in this design, the motor should be remaining the same when upgrade 10-inch propeller to 11-inch propeller to avoid adjust motor parameter.

Sunnysky can be easily found in Taobao, since X2212 is used up to 10-inch propeller, X2216 KV880 is selected.

The parameter is as below:

Prop (inch)	Volts (V)	Amps (A)	Thrust (gf)	Watts (W)	Efficiency (g/W)	Load temperature in 100% throttle 全油门负载温度
APC11x4.7	11.1	0.7	100	7.77	12.87001287	54°
		1.8	200	19.98	10.01001001	
		3.1	300	34.41	8.718395815	
		4.4	400	48.84	8.19000819	
		5.9	500	65.49	7.634753397	
		7.7	600	85.47	7.02000702	
		9.7	700	107.67	6.501346708	
		11.7	800	129.87	6.16000616	
		14.7	900	163.17	5.515719801	
		16.8	1000	186.48	5.362505363	
		17.4	1030	193.14	5.332919126	
APC1047	11.1	0.7	100	7.77	12.87001287	62°
		1.9	200	21.09	9.483167378	
		3.2	300	35.52	8.445945946	
		4.6	400	51.06	7.833920877	
		6.4	500	71.04	7.038288288	
		8.2	600	91.02	6.591957811	
		10.4	700	115.44	6.063756064	
		12.6	800	139.86	5.72000572	
		14.4	890	159.84	5.568068068	
	14.8	0.6	100	8.88	11.26126126	
		1.5	200	22.2	9.009009009	
		2.5	300	37	8.108108108	
		3.7	400	54.76	7.304601899	
		5.2	500	76.96	6.496881497	
		6.8	600	100.64	5.961844197	
		8.4	700	124.32	5.630630631	
		10.1	800	149.48	5.35188654	
		12.3	900	182.04	4.943968359	
		14.2	1000	210.16	4.758279406	
		16.2	1100	239.76	4.587921255	
		21.4	1360	316.72	4.29401364	

When use 11-inch propeller, only 3s battery is supported, so 3s battery will be used in this design. And the analysis later will all based on 3s battery.

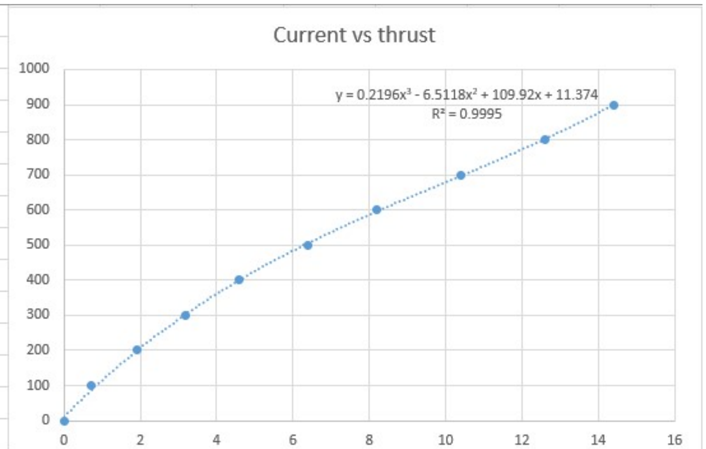
2.3.2 Propulsion analysis

Use APC1047 and 11.1V data for analysis, the analysis can be found in “General purpose drone propulsion concept design.xlsx”, and the result is:

y = 0.2196 x^3 - 6.5118x^2 + 109.92x + 11.374

y: thrust   x: current

x2216	Current	Thrust
3s	0	0
	0.7	100
	1.9	200
	3.2	300
	4.6	400
	6.4	500
	8.2	600
	10.4	700
	12.6	800
	14.4	900



A rough calculation of drone weight is as below:

3s 6000mAh

	Number	Weight(g)	Total weight(g)
Arm + motor mount	4	38	152
PDB	1	28	28
propeller	4	12	48
Motor	4	72	288
FMUv5+	1	50	50
FMUv5+ Base	1	20	20
undercarriage	2	32	64
Sony 18650	6	46	276
BMS	1	20	20
Light bridge	1	70	70
Antenna	1	52	52
bottom cover	1	28	28
top cover	1	19	19
Light bridge cover	1	10	10
Drone weight			1125

Based on 6*sony18650 battery, the total weight is about 1125g, it can meet 1200g design target.

The hovering time is:

Drone	weight(g)	1/4 weight(g)	Current(A)	hovering time(min)
General drone	1125	281.25	11.6	31.03448276

Based on 3* sony18650 battery, the total weight is about 987g.

The hovering time is:

Drone	weight(g)	1/4 weight(g)	Current(A)	hovering time(min)
General drone	987	246.75	10	18

2.4 Battery

2.4.1 Battery selection

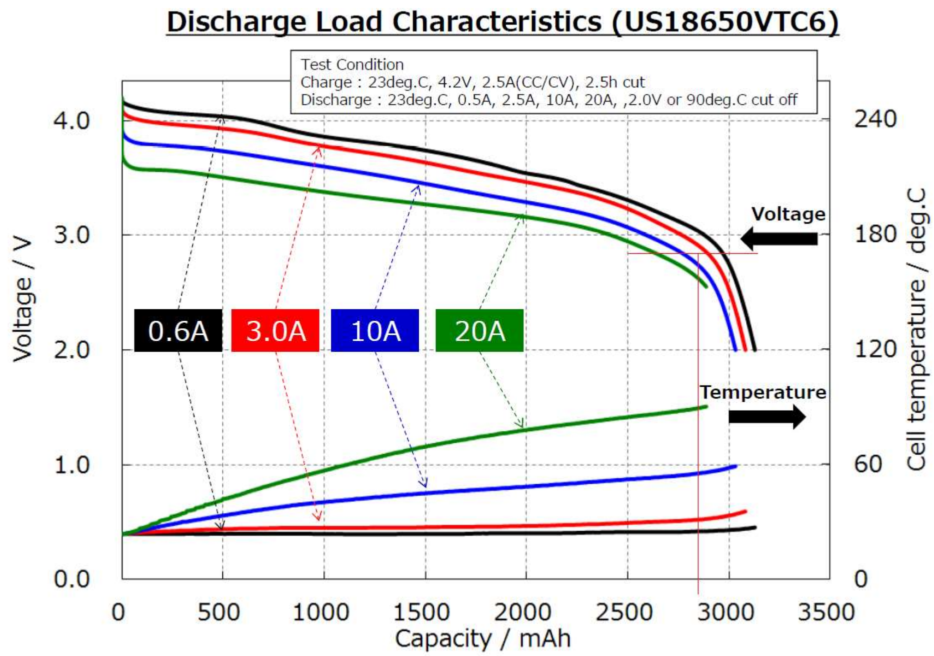
3s~4s battery is suitable for this design, and 3s 18650 cell is selected because of the size – 4s battery will be too long to mounted on the bottom of the drone.

And considering the hovering time discussed above, 2p will be used.

Battery datasheet is in *datasheet\battery*

2.4.2 Battery analysis

The discharge curve is shown as below:



Hovering time need to be adjusted according to usable capacity and average voltage:

Usable capacity

As one cell discharge current is 11.6A/2 = 5.8A, the discharge curve is between 3A and 10A curve, assume BMS low voltage cut off voltage is 2.8V(3s = 8.4V), the total usable capacity is about 2800mAh.

Average voltage

lithium ion battery has 18650 type and soft pack type, the voltage 11.1V used for calculation above is based on soft pack (cell voltage = 3.7V), and for 18650 cells, the average voltage is lower than soft pack.

The average voltage is (2.8V+4V) / 2 = 3.4V, so the average total voltage = 3.4V * 3 = 10.2V.

So, the adjusted hovering time is:

Drone	weight(g)	1/4 weight(g)	Current(A)	Current (adjusted)(A)	hovering time(min)
General drone	1125	281.25	11.6	12.62	28.96

2.5 RC (radio control)

DJI Lightbridge 2 will be used since it can also be used for HDMI video transmission, and it support SBUS as well.

DJI Lightbridge 2 can also support data link if DJI flight controller is used.

It can also be changed to another RC module easily if HDMI (video transmission) is not required, the only interface to flight controller is SBUS

DJI Lightbridge 2 SBUS test can be found in System_design\dji lightbridge2 sbus output test.xlsx

The 1st 2 bit of CH1 when “right lever right full” looks strange, it will be checked during RC integration test.

Right lever right full				
0	11110000	011	start	
0	11001010	011	CH1	1619
0	01100000	011	CH2	
0	00000100	111	CH3	
0	00000000	011		
0	11111100	011	CH4	1996
0	11000011	011	CH5	
0	01001010	111	CH6	
0	01010010	111		
0	11000010	111	CH7	
0	00011000	011	CH8	
0	00000000	011		

2.6 Flight controller

2.6.1 Flight controller selection

FMUv5 is a flight controller from CUAV, and it is fully open sourced.

Pixhawk 2.4.6 is a classic version of pixhawk and competitively low cost but it is not used in this project because:

1. The RGB LED driver TCA62724 from Toshiba is already EOL (end of life)
2. FMUv5 can support RTK but Pixhawk 2.4.6 does not.
3. FMUv5 is already a cube and the size is small, so customize is not required but customize it for cost down and mass production is still possible

The introduction page of FMUv5 is:

http://doc.cuav.net/flight-controller/v5-autopilot/zh-hans/v5+.html