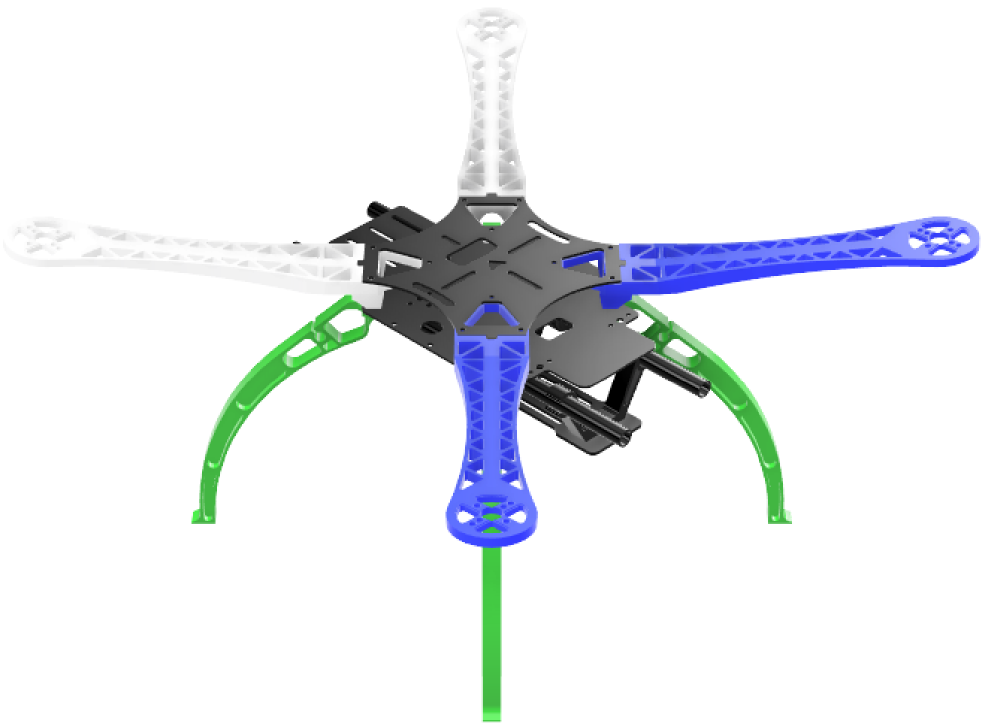
MECHANICAL DESIGN

1) Conceptual Design

Reference Design

There are many types of drone frames. According to competition requirements, a quadcopter having less then 4kg mass will be designed. Based on this requirement as a reference design S-500 frame is selected. Its size is 50cm which means that distance from the edge of one arm to the edge of across arm is 50cm.

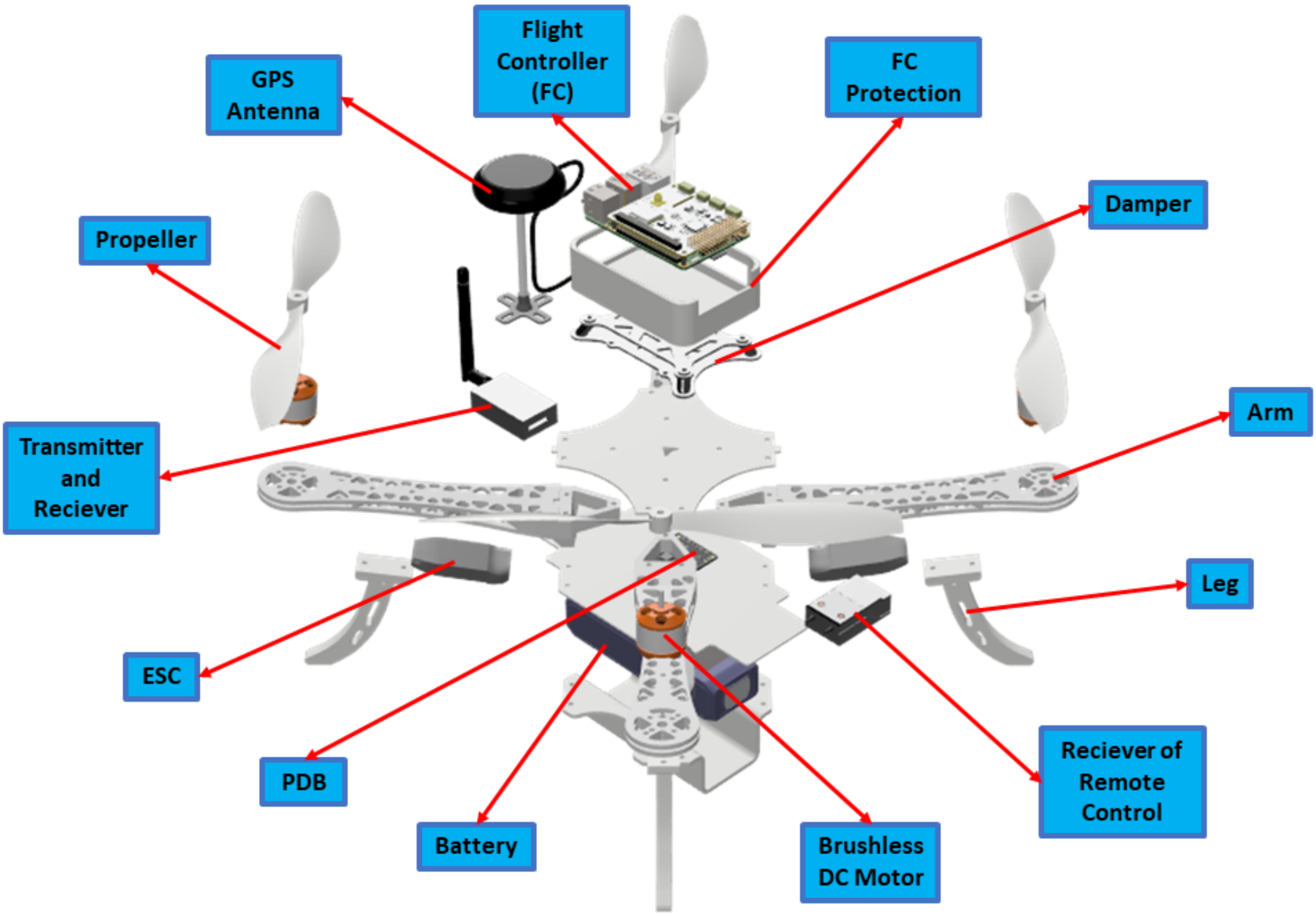


Reference Design

In this frame generally carbon fiber chassis, arms and legs are used. So, the stress level can be relatively higher than a plastic frame. Cross sectional area of arms should be increased if we want to design a plastic frame. Moreover, legs have a concave structure, but a convex structure will be safer for landing. The chassis have mass reduction spaces, different fastening holes or rails, etc. This type of properties should be specific to the design according to its electronical layout.

New Design

New Design

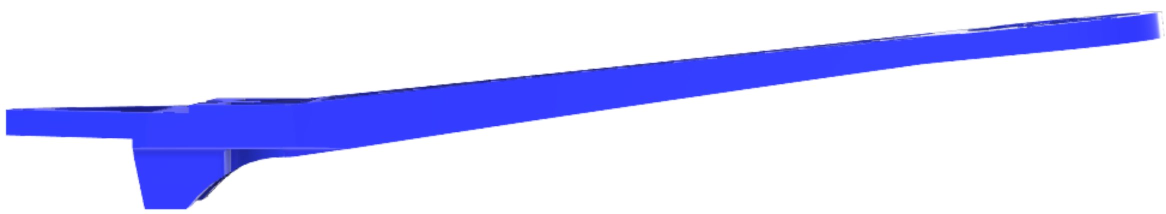


Exploded New Design

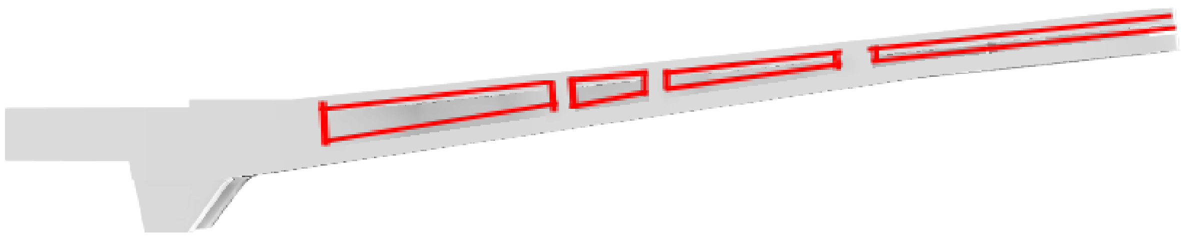
Overview

Many changes are done on reference design and at the end a distinctive design is appeared. In this design, arms are improved until stress level decrease to a certain level. Convex legs are designed from beginning. Chassis and the protective parts of the electronics are created according to the electronics which are chosen. Electronics mounting methods are considered.

Arm Design

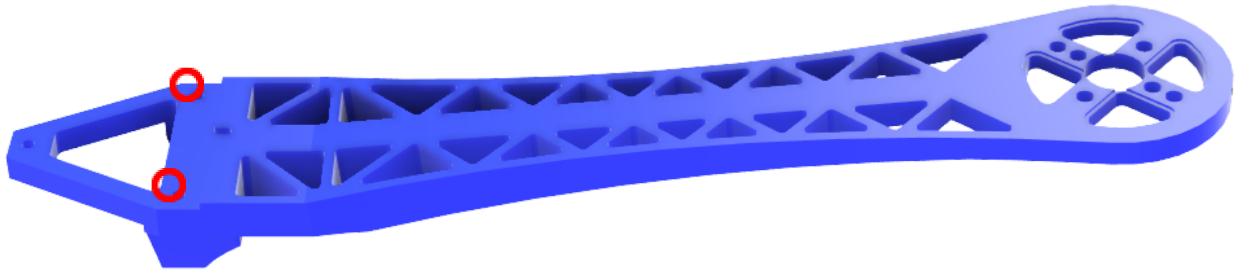


Reference Arm

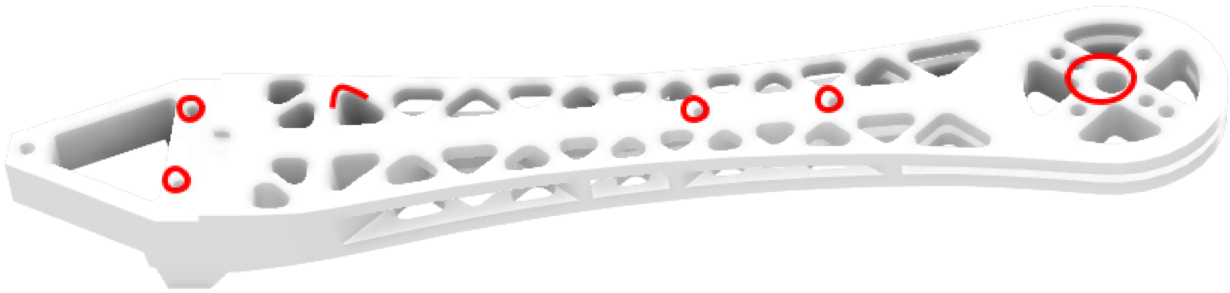


New Arm

The cross-sectional area of the arm is increased to increase second moment of area. While doing this, to avoid highly increase in mass red areas in the figure are evacuated. As a result, in certain conditions, mass didn't increase as much as stress level is decreased.



Reference Arm



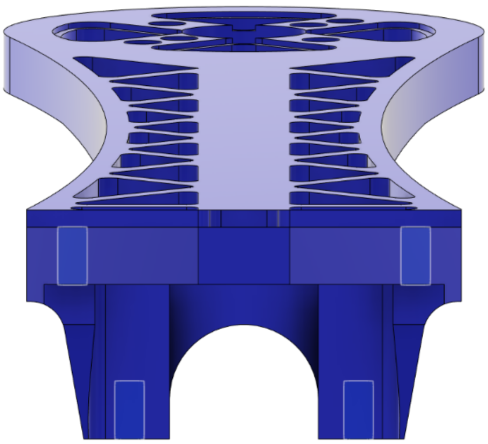
New Arm

In S500 Arm the holes that are used for connection to chassis by using screws were not thru holes and it is a condition that weaken the integrity of the frame. Hence, these holes are designed again as thru holes.

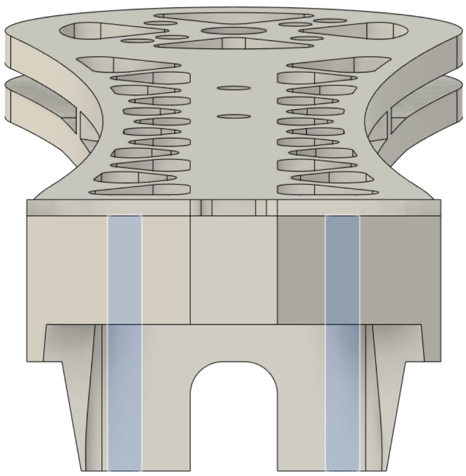
Inside cavities has fillets on their edges. In S500 fillet radiuses were not enough to dissipate the stress concentration at those points. Thus, fillet radiuses are increased in new design.

S500 design have Leg connections right under the chassis. To get more wide distances between connection points where the legs touch to the ground, leg connections are carried to the arms, and we get advantage of arms improved strength on this situation.

At the motor base of arm where the motor is fastened, inside hole's wall thickness is increased because while printing the arms, printing done on space, so it couldn't be completed. However, new design could deal with this problem. Also, strength is increased at that section.

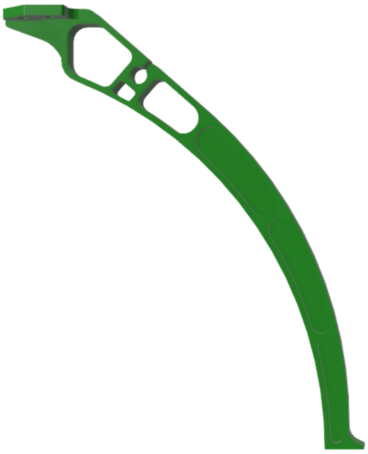


Blind Hole



Thru Hole

Leg Design

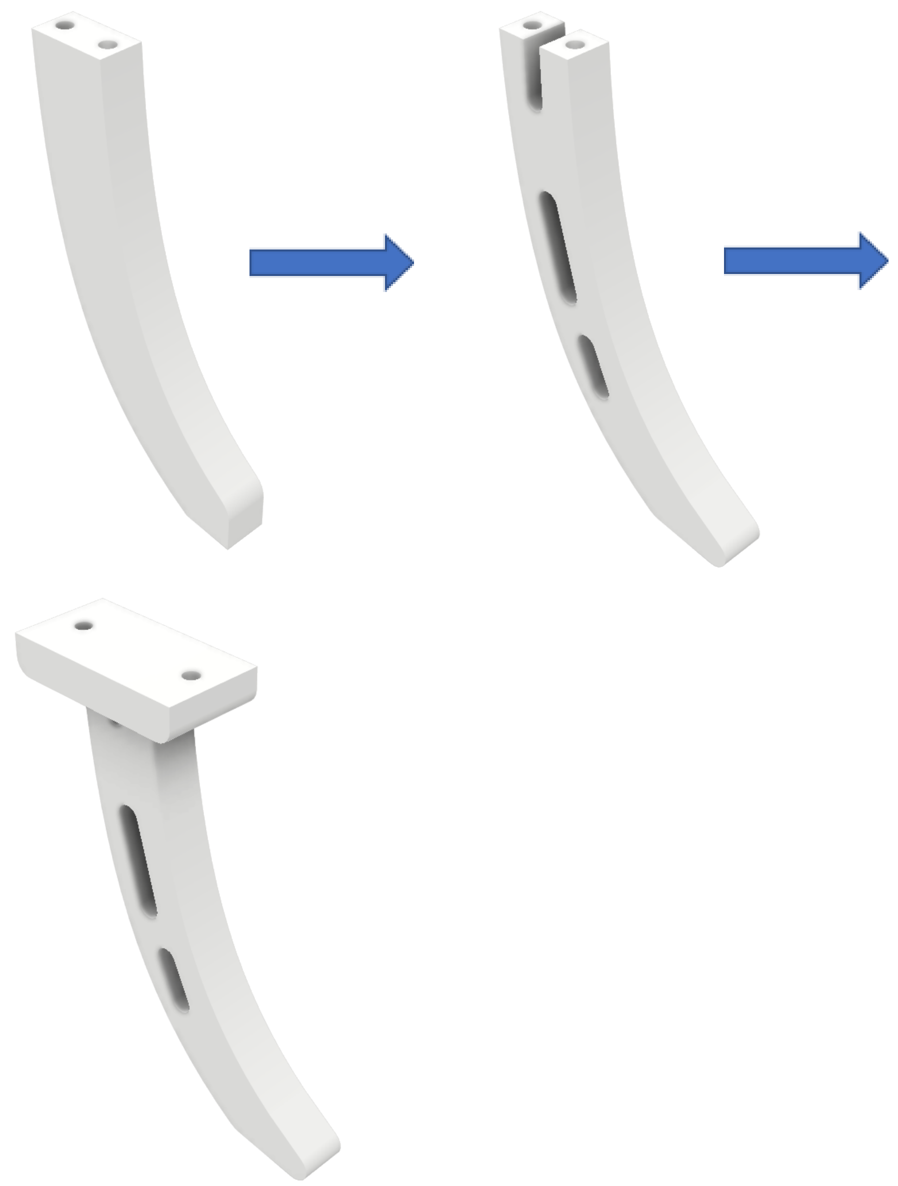


Reference Leg

New Leg

Mass of the reference leg is nearly equal to the new leg. However, the size and orientation of the leg has been changed. Small size provided more strong structure and convex structure instead of concave structure provided more stable landing capability because of the distance between one leg to the other.

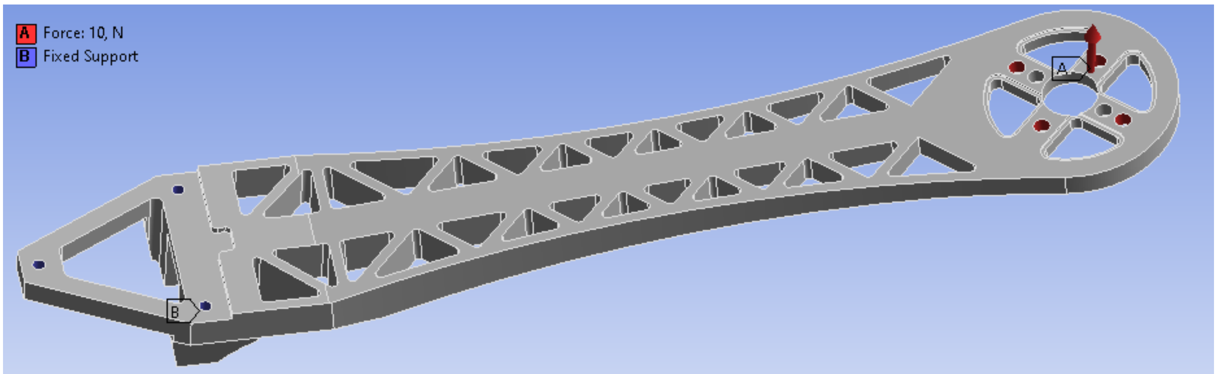
Design Stages

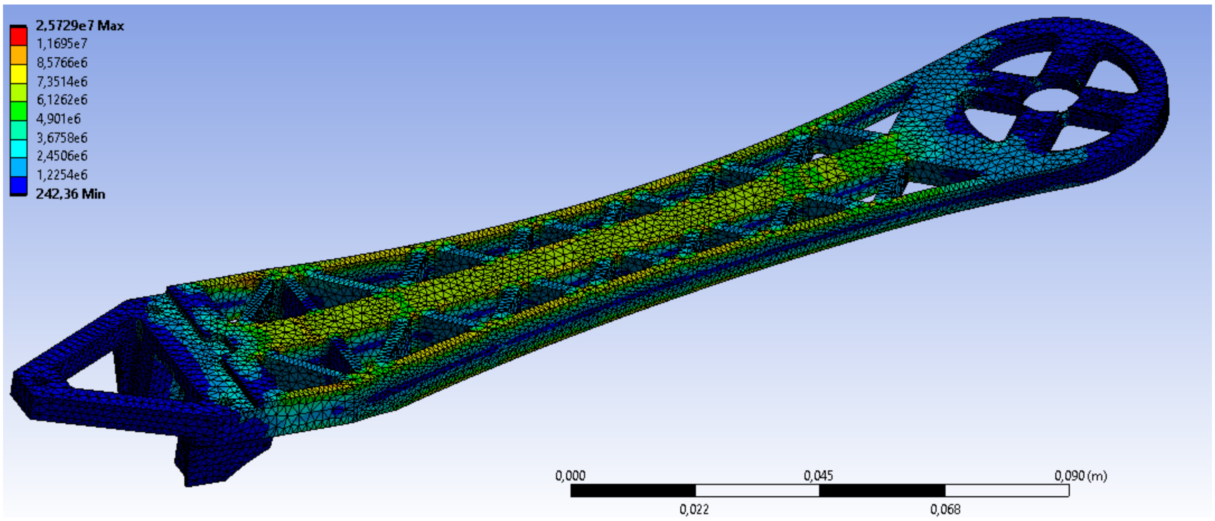


According to FEA results and topology optimization leg is designed stage by stage as shown.

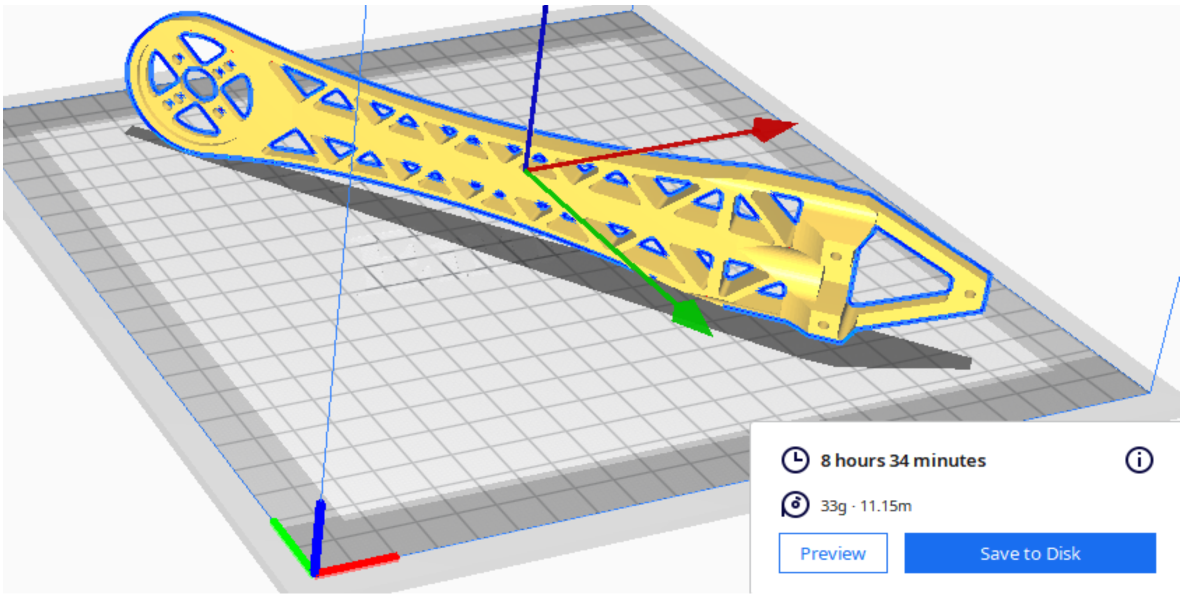
2) Strength Calculations

Arm

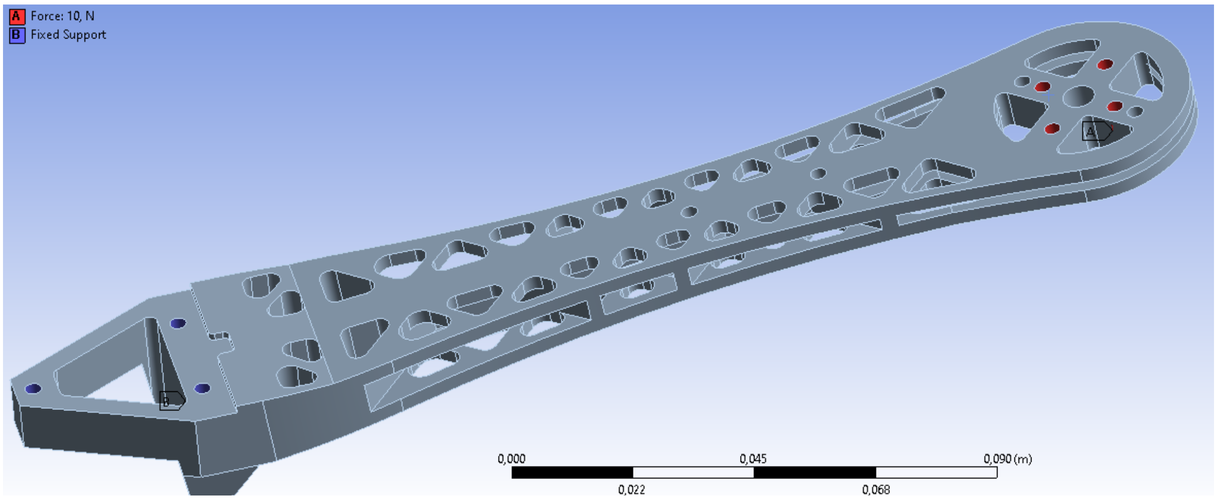


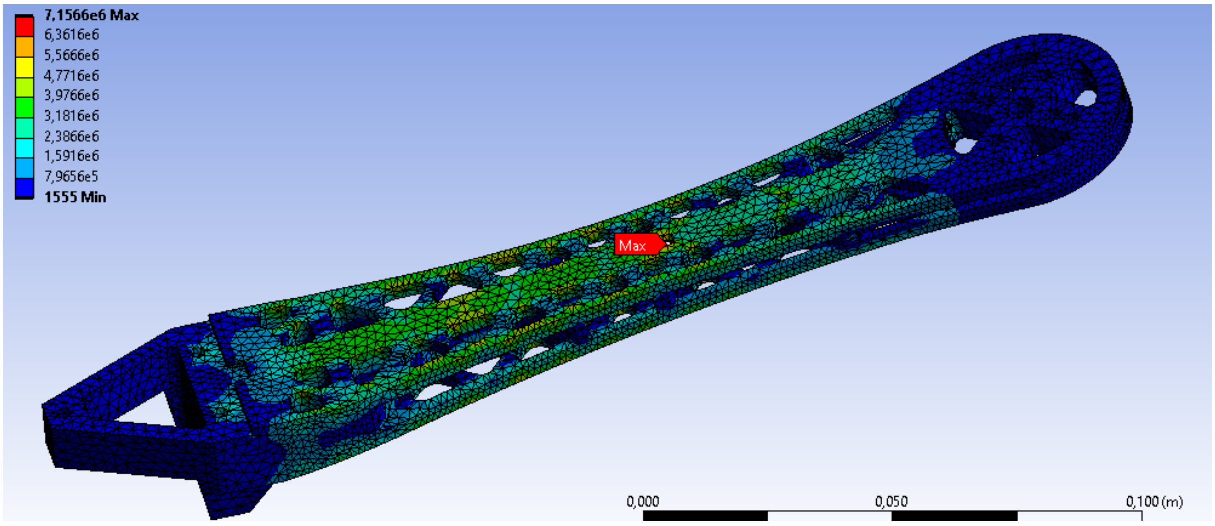


Under the certain boundary conditions the maximum equivalent von mises stress of reference arm is equal to 25.7MPa. The yield strength of the PLA filament around 50MPa in the market. According to these data factor of safety F.S.= 1.9.

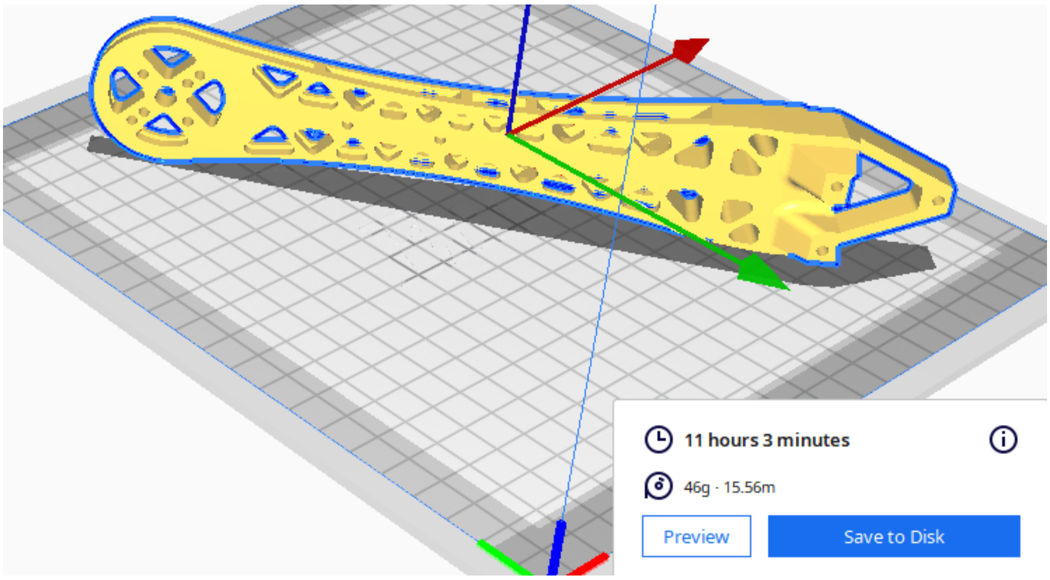


Mass of reference arm under certain printing conditions without supports is 33g.





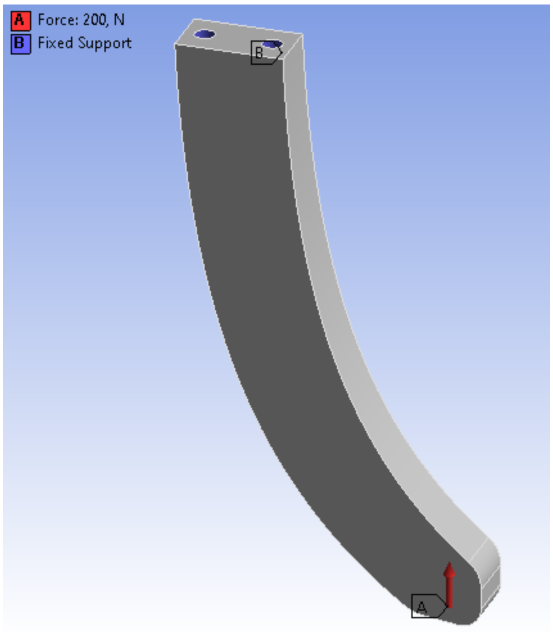
Under the certain boundary conditions the maximum equivalent von mises stress of new arm is equal to 7.1MPa. The yield strength of the PLA filament around 50MPa in the market. According to these data factor of safety F.S.= 7.

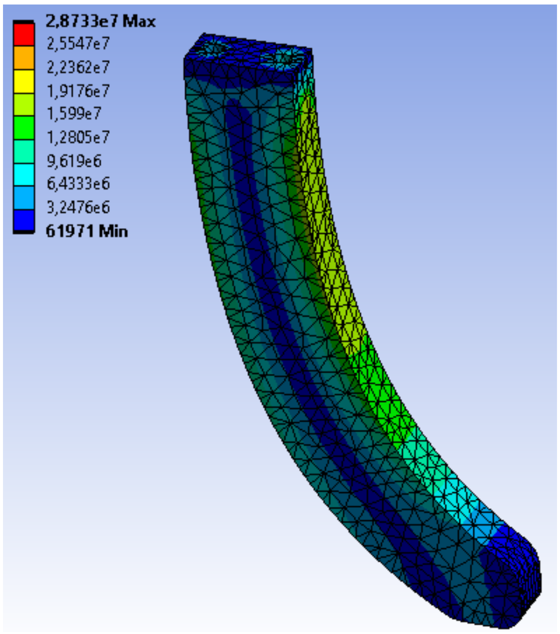


Mass of reference arm under certain printing conditions without supports is 46g.

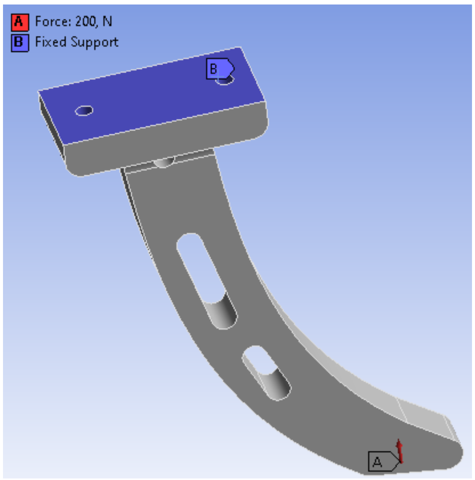
As a result, we can see that F.S. of the arm is increase from 1.9 to 7 which means 268% improvement. At this time the mass is increased from 33g to just 46g which means an only 39% increase.

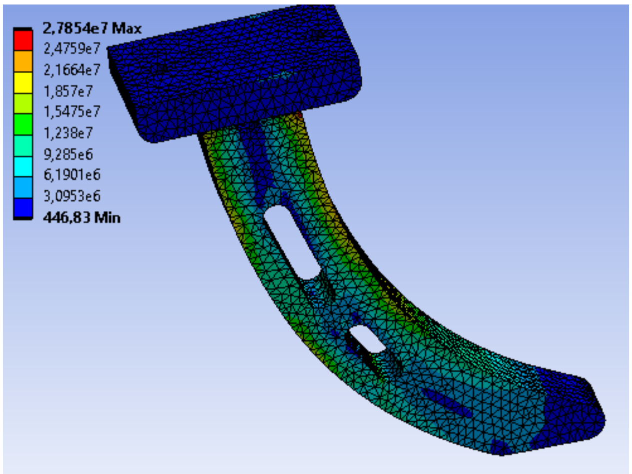
Leg



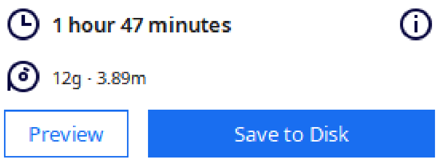


While designing a leg, first a coarse design is created. Under certain boundary conditions this designs' equivalent stress level is 29MPa. Thus, the factor of safety F.S. = 1.7.

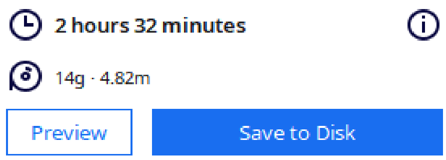




At final design we have mass reduction spaces but also, we have more strong and wide connection area. According to data shown the stress under certain conditions is 28MPa and the factor of safety F.S. = 1.8.



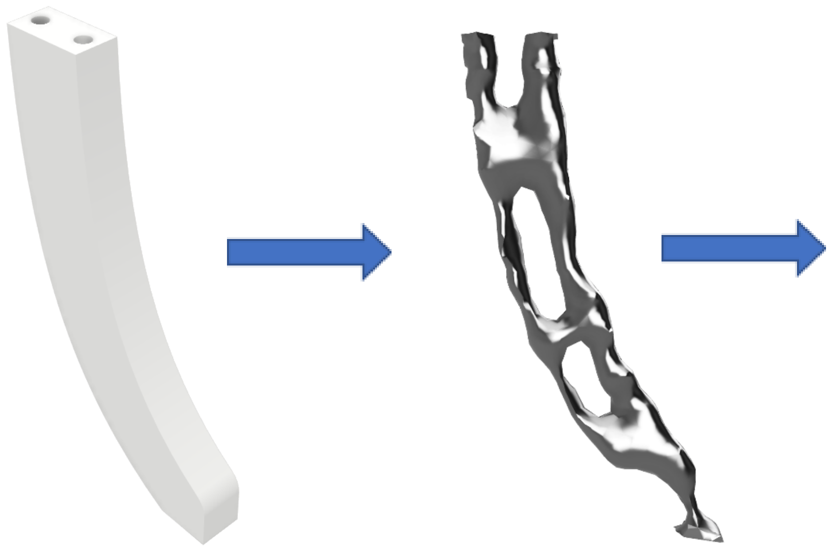
Mass of Coarse Leg



Mass of Final Leg

So, we can see that factor of safety is nearly equal and the mass is slightly changed. However, we gained a wide and strong connection area.

3) Topology Optimization



Topology analysis has done on the coarse leg design and the mass of the leg is decreased by trimming the unnecessary mass from the 3D model. By this way we gained the ability of improving connection edge of the leg to the arm by adding extra mass on the structure.

4) Mass Estimation

Component	Number of Pieces	Unit Mass (g)	Total Mass of the Component (g)
Arm	4	46	184
Leg	4	14	56
Bottom Chassis	1	53	53
Upper Chassis	1	34	34
Battery Protection	1	69	69
FC Protection	1	33	33
Brushless DC Motor	4	56	224
Battery	1	379	379
ESC	4	28	112
FC	1	80	80
GPS Antenna	1	30	30
PDB	1	11	11
Propeller	4	18	72

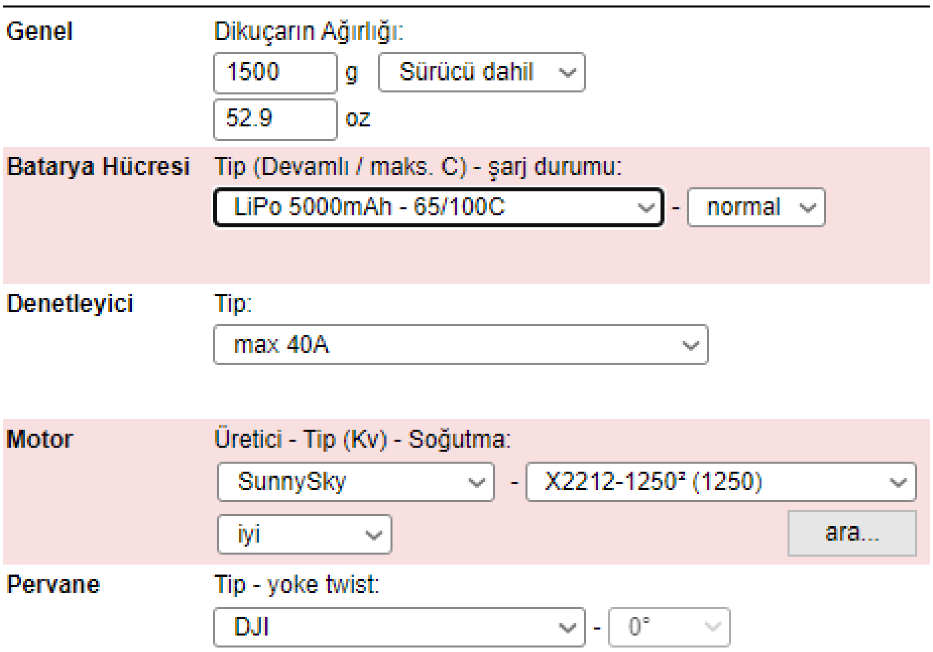
Total Mass of Drone (g)
1337

We are calculating the total mass of known components as 1337g. With a margin of 163g because of the uncertainties and unknown masses of some components. We are estimating the total mass of the drone around 1.5kg.

5) Thrust System Design

According to mass estimated and components selected, thrust calculations are done in the web site: https://www.ecalc.ch/xcoptercalc.php.

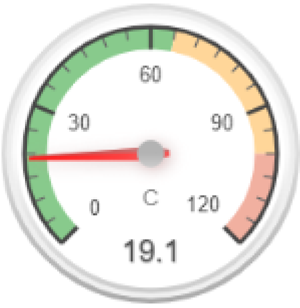
Inputs:



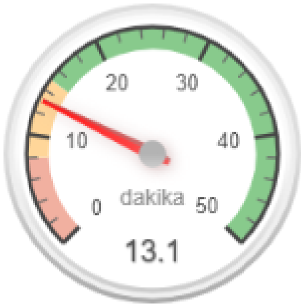
# Motor Sayısı: 4 düz	Çerçeve Ölçüsü: 500 mm 19.69 inç	Uçuş Denetleyicisi Yatış Sınırı: sınır yok
Yapı: 3 S 1 P	Batarya Kapasitesi: 5000 mAh 5000 mAh toplam	Maks. deşarj: 85%
Akım: 40 A Sürekli 40 A Maks.	Direç: 0.006 Ohm	Ağırlık: 50 g 1.8 oz
KV (Tork hariç): 1250 dev/dak/V Pervane-Kv-Ara	Yüksüz akım: 0.6 A @ 10 V	Sınır (15s'ye kadar): 390 W
Çap: 10 inç 254 mm	Hatve (Pitch): 4.7 inç 119 mm	# Kanatlar: 2

	Rakım:	Hava Sıcaklığı:	Pasınç (QNH):
	938 m ASL	25 °C	1013 hPa
	3077 ft ASL	77 °F	29.91 inHg
Direnç:	Gerilim:	C-Oranı:	Ağırlık:
0.0027 Ohm	3.7 V	65 C Sürekli	141 g
		100 C Maks.	5 oz
	Aksesuarlar	Çekilen Akım:	Ağırlık:
		0 A	0 g
			0 oz
Direnç:	Gövde Uzunluğu:	# Manyetik Kutup:	Ağırlık:
0.079 Ohm	30 mm	14	57 g
	1.18 inç		2 oz
PSabiti / TSabiti:	Dişli Oranı:		
1.10 / 1.0	1 : 1		hesapla

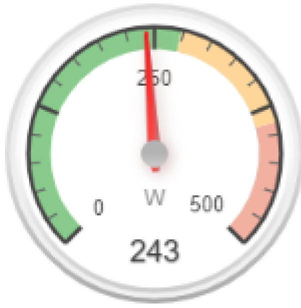
Outputs:



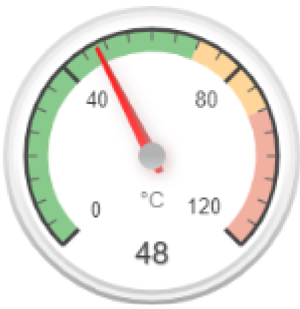
Battery Discharge



Flight Time (min)

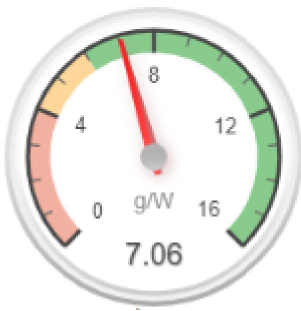


Electrical Power (W)



Estimated Temperature

Thrust Weight Ratio



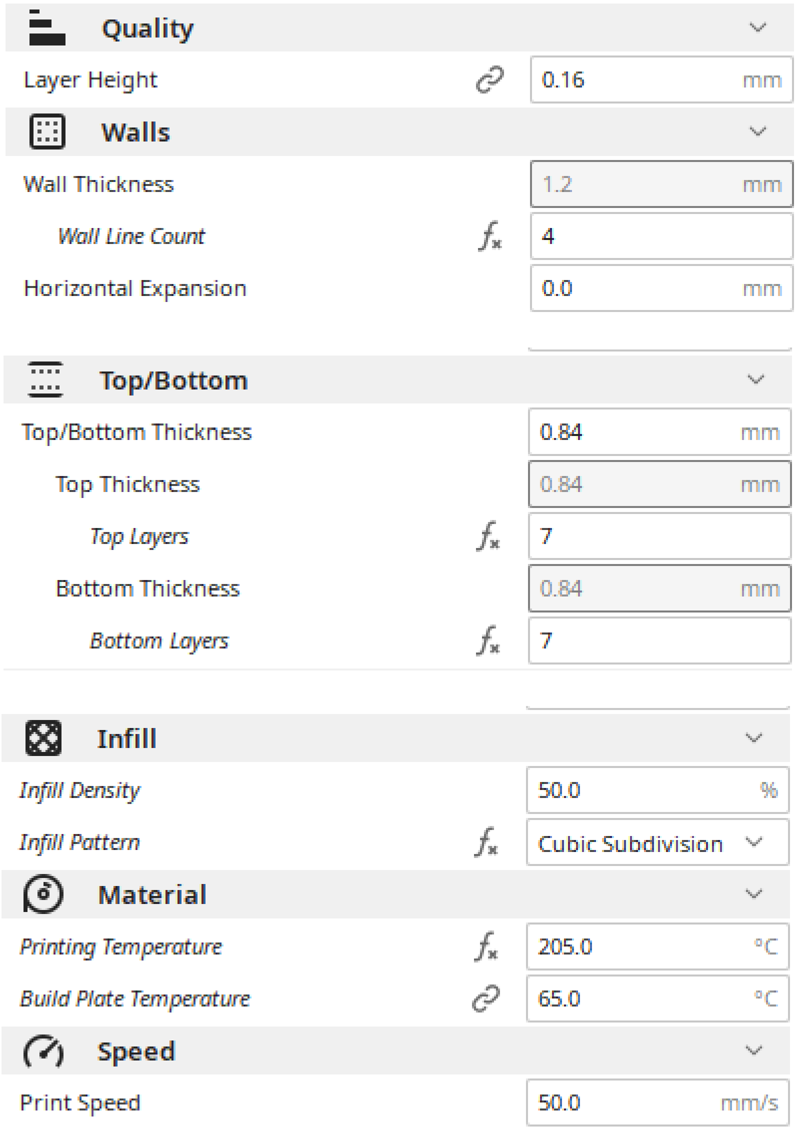
Thrust Power Ratio (g/W)

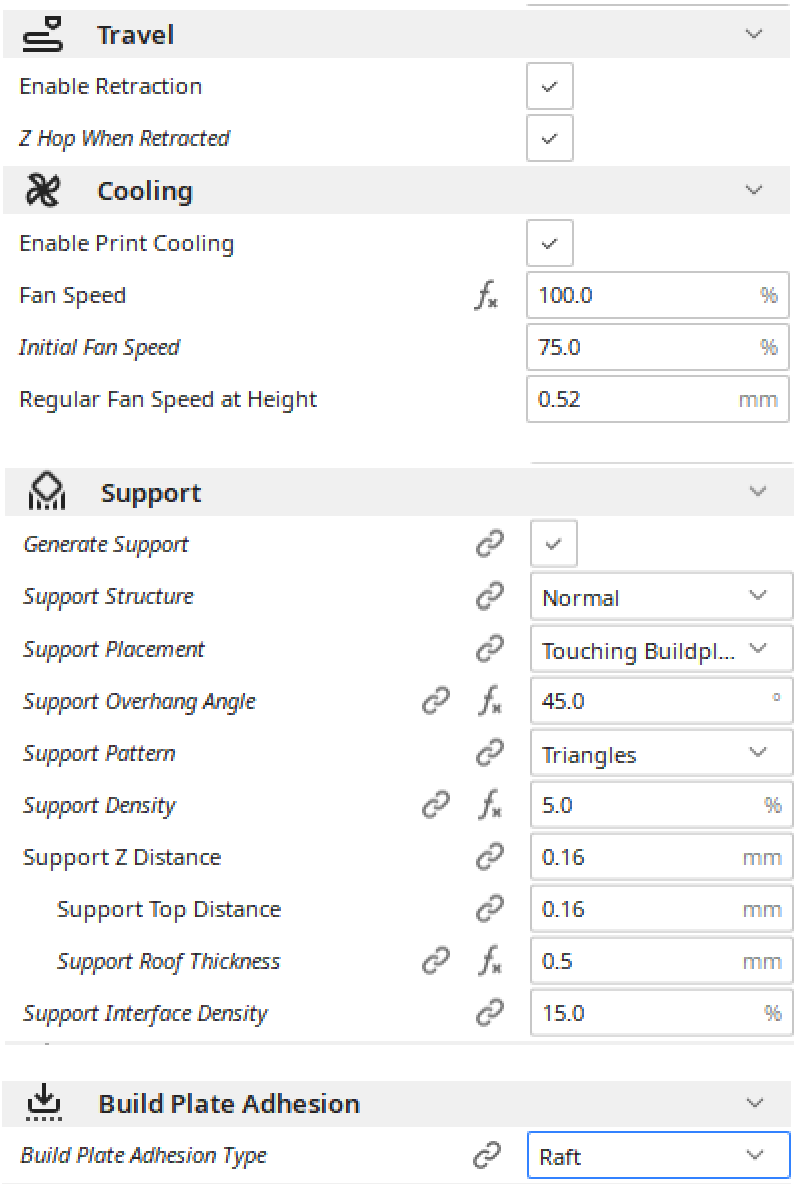
We can see that all the parameters which are important for a drone design are in the green areas except flight time but also flight time is close enough to the green area and 13.1 minute is enough to complete a mission in the competition of TEKNOFEST.

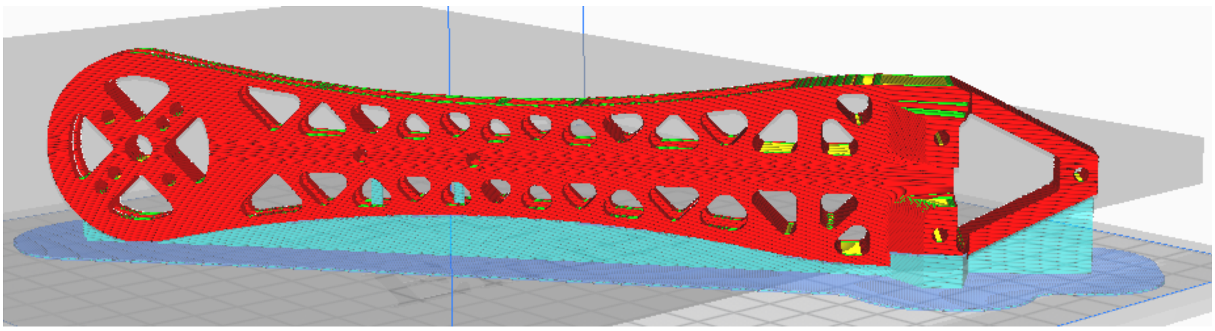
6) Prototype Production

Arm Production

As a result of many attempts on 3D Printing Arm and Leg components of the drone, optimum 3D Printing settings are found as shown.



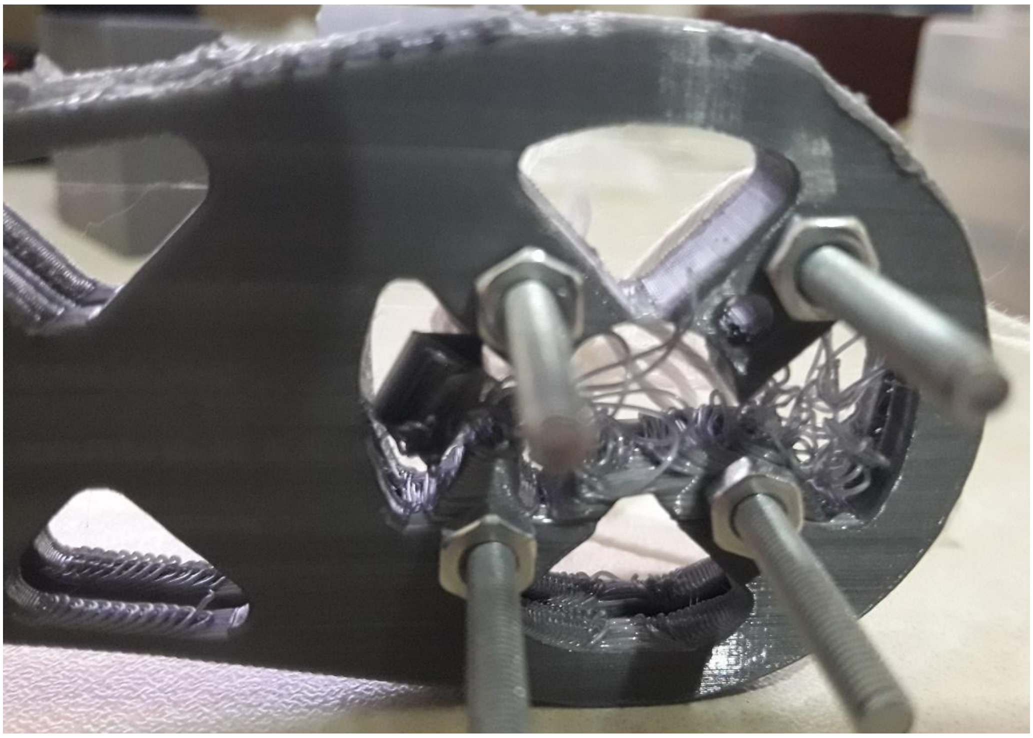




The arm is printed in this orientation because other orientations caused difficult support cleaning and low surface quality. In this orientation there are places where the printer is printing to the space but the distances between walls of the structure are not too much in this orientation. So the printer is capable to print the model nearly perfect.

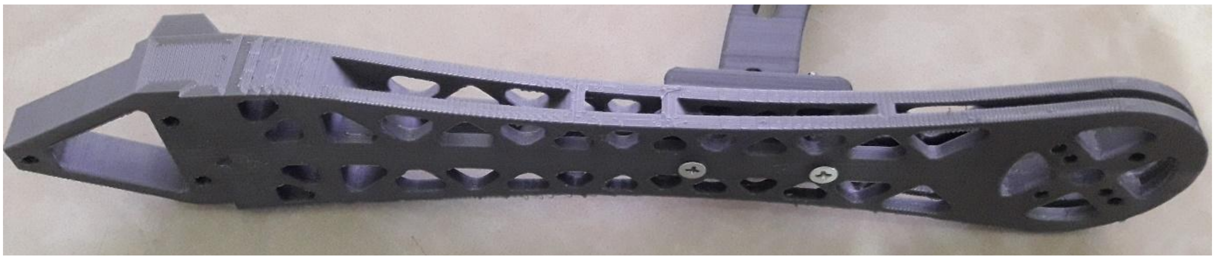
Fail Printings Because of the Wrong Orientation and Setting:

Support cleaning was a big problem because the arm is printed as top surface at the bottom. Also, cleaning support from inside cavities was so difficult. As a result, surface quality is degraded.



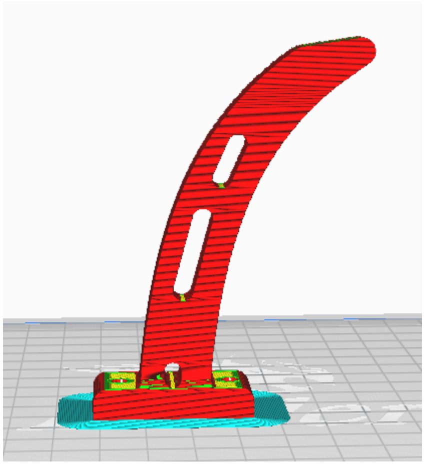
In this error, inside holes' wall was so thin, so printer couldn't accomplish the mission.

Successful Printing:



The surface quality is satisfaction. Only the one side of the arm has support residue, but it can be cleaned easily by using emery. Also, there is no support residue inside the cavities.

Leg Production:



Printed Leg *Printing Orientation*

Leg production was simpler than the arm production because of simpler geometry and not needing supports. Printer settings are same with arm, only difference was support setting was closed. Surface quality is satisfaction.

Propeller Balancer Production:

Since the propeller balancers in the market are expensive and the mechanism can be modeled and printed easily. We did our own propeller balancer.

Reference Propeller Balancer *Our Propeller Balancer*

ELECTRICAL & ELECTRONICS DESIGN DOCUMENT

1. Connecting, Soldering and Installing Electronic Components

Required components are prepared for connection, soldering and installing to the mother board.

a. Connecting Motors To The Arm

b. Soldering Motors to the ESC

c. Soldering ESCs to the PDB

d. Connecting ESC's Signal Cable to the Flight Control

e. Installing Battery

f. Connecting Power Module with Battery & Connecting Signal Cable to the Flight Control Card

g. Connecting GPS Module, Telemetry and Receiver to the Flight Control Card

2. Electrical Specification of All Components

a. 3-Phase motor is coupled mechanically to the propellers.

b. ESCs have output of 5V/3A and power the 3-Phase motors.

c. PDB is connected to the Power Module's 5.3 pinouts and Power module's signal cable is connected to the Flight Control Card.

d. Battery have output of 11.1V and connected to the Power Module.

e. All ESCs are connected to the Flight Control Card's 5V pinouts.

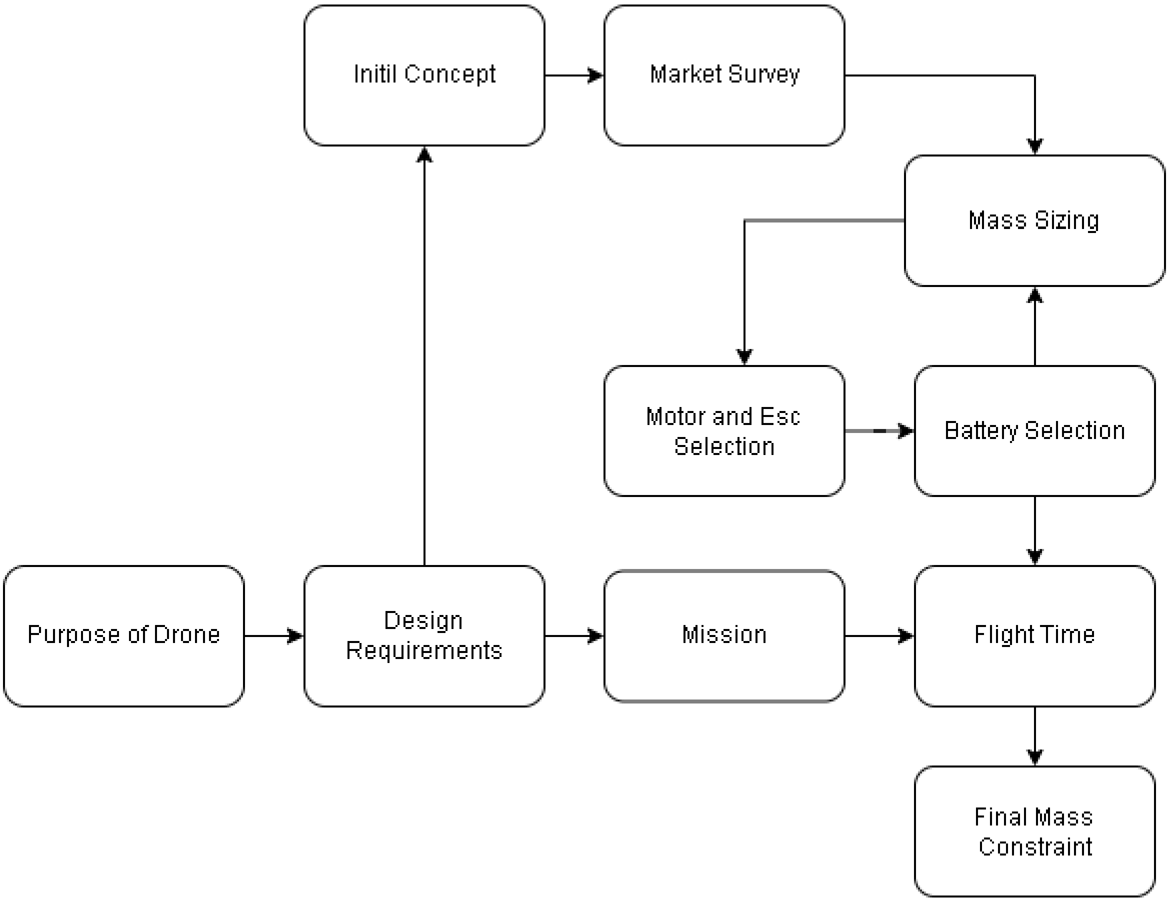
f. 2.4 GHz / 12 Channel Receiver is connected to the Flight Control Card.

g. All additional external components are connected to the 5V pinouts.

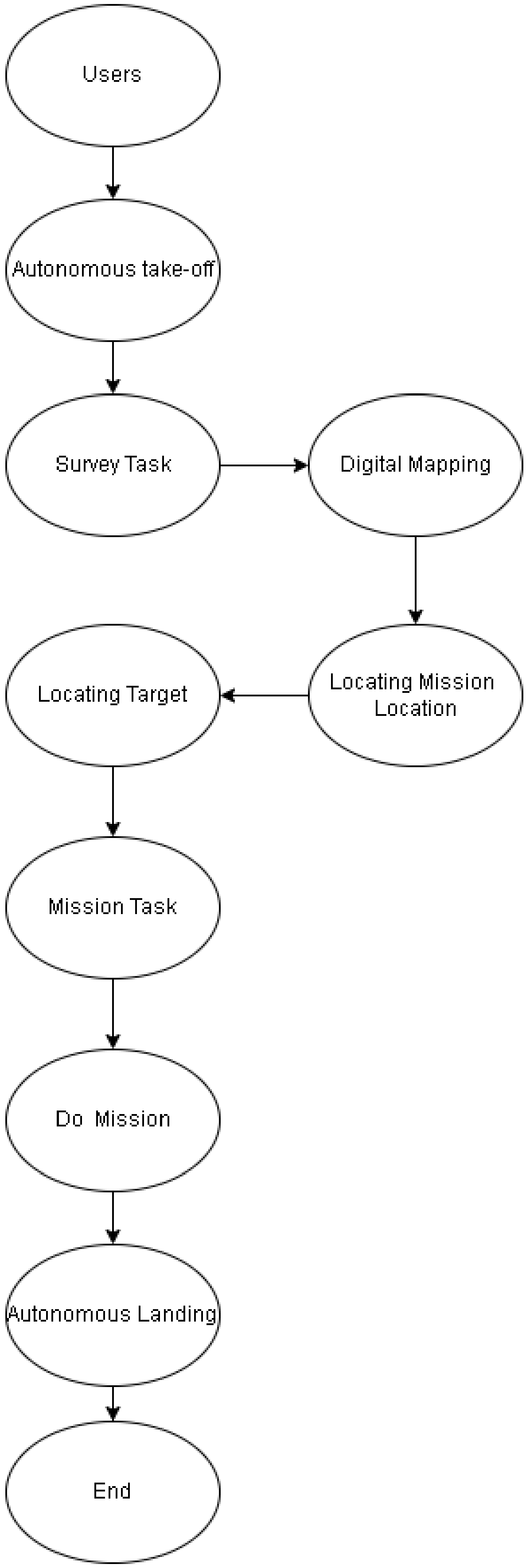
Figure 1 UAV Electronics Block Diagram

DESIGN DOCUMENT

Firstly we desing our desing life cycle and it is as below

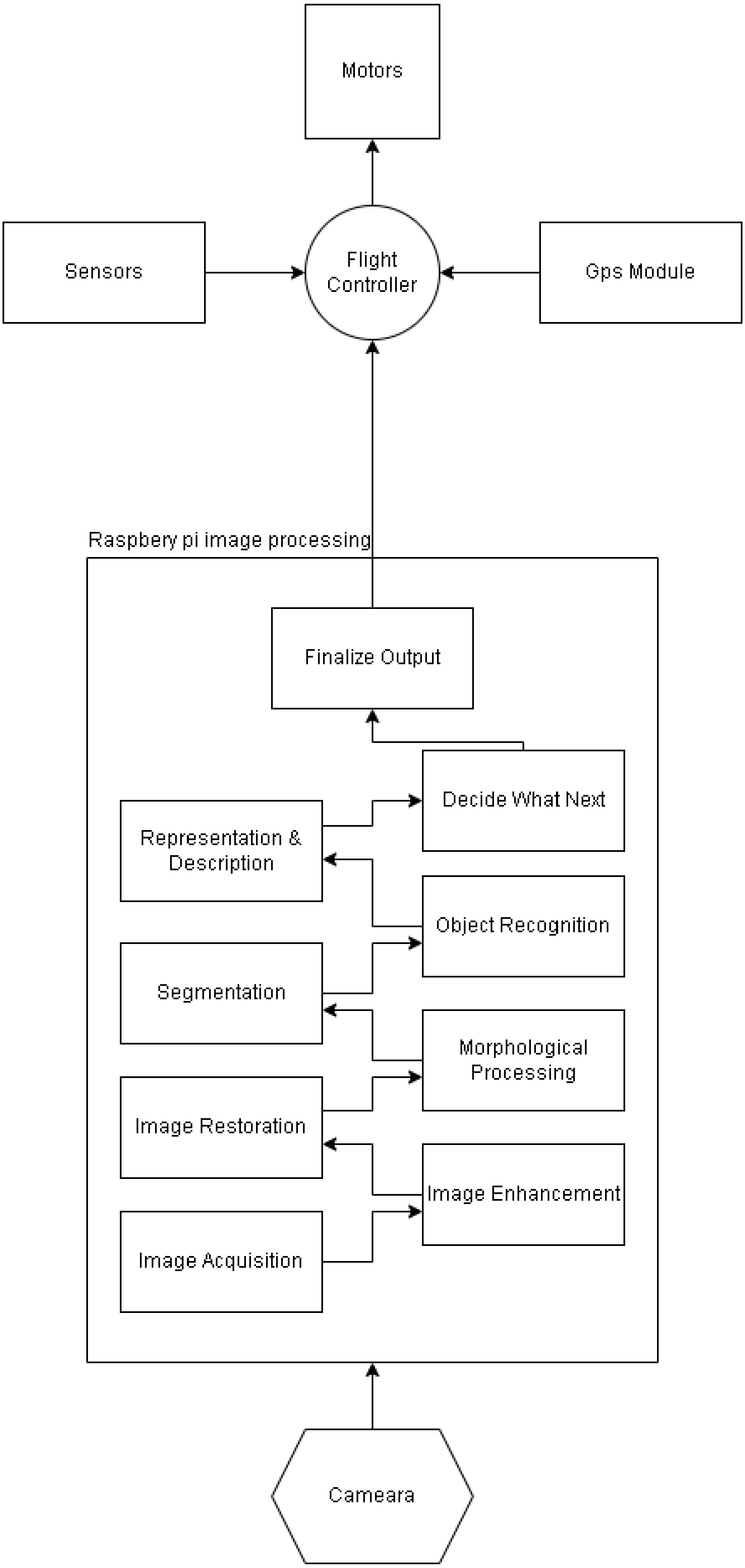


Our mission design as below chart.


Users
Autonomous take-off
Survey Task
Digital Mapping
Locating Target
Locating Mission Location
Mission Task
Do Mission
Autonomous Landing
End

SOFTWARE DESIGN DOCUMENT

Firstly Pi-Camera gathers images while the drone flies, and they are transported to raspberry pie to process. Image processing software searches for mission elements such as targets and tools. If it founds it stores their locations. And after the mapping process drone will go to their locations and perform tasks expectedly. Raspberry pi is the brain of a drone and makes decisions according to the image process and gives orders to the flight computer. The flight controller takes variables from sensors and adjusts motors accordingly.


Motors
Sensors
Flight Controller
Gps Module
Raspbery pi image processing
Finalize Output
Decide What Next
Representation & Description
Object Recognition
Segmentation
Morphological Processing
Image Restoration
Image Enhancement
Image Acquisition
Cameara