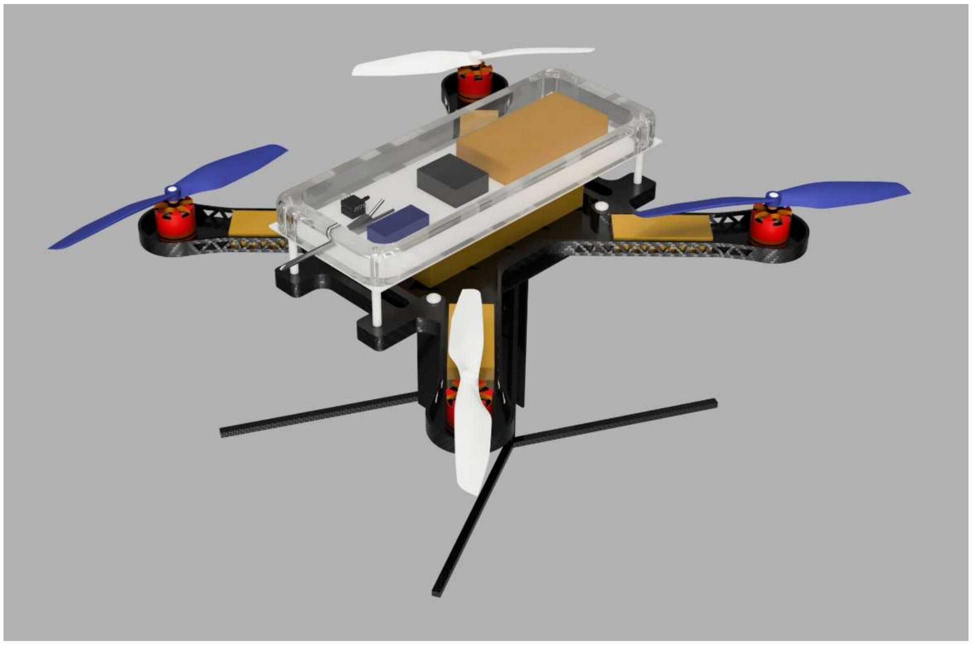
COLLEGE OF ENGINEERING, PUNE

TEAM ALTIUS



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INTRODUCTION

UAVs (Unmanned Aerial Vehicles), also known as Drones, are aircrafts without any pilot on board. They are component of an Unmanned Aircraft Systems (UAS), which includes adding a ground based controller and a system of communications with the UAV.

Drones can be controlled by a controller using Transmitters and Receivers, or using some Automated microcontrollers and making it work completely on its own.

Design aspects of a UAV include various mechanisms and control systems put together to ensure successful flight and completion of its assigned task. These include frame, propulsion system, payload mechanism, motors and batteries, microcontrollers, transmission and signalling, and automation. Along with this, it also includes material selection and simulation analysis at working conditions. Successful software and hardware test results make sure that the proposed design will work safely.

FRAME DESIGN (Part No. 1):

1. We studied various designs including symmetric, asymmetric, pull-type, push-type and many fast moving quadcopters among others. Of these, we found that the basic symmetrical X-type design with pull-type rotors fitted our requirements the best and in feasible conditions.
2. We referred the internet for drone sizing and came across the standard empirical ratios for frame sizing across rotors as per the size of propellers. As we happen to choose the 8" dual blade props to hover our UAV, the standards say that the frame size across rotors should be 400mm.
3. We planned of making a webbed frame body which will serve as a semi-casing for all the components being mounted onto it.
4. The ESCs would be mounted on the rotor arms, thus, the size of ESC was the nominal required size for it, plus some clearance; similarly, the ends of the arms would hold the rotors, thus, motor diameter was the nominal size for rotor-arm ends, plus some clearance for ease of fittings. As the rotor arm is webbed from the sides, it aids a good flow of air through it. We then estimated the total area required to mount all other components. As these would be centred in the structure, we formed a hub platform, the space was not enough. So we added a second deck and covered it with a polymer(plastic) case as a protective cover.

A. As per material selection,

1. Ultimate tensile strength (S_{u_t}) = 4000 MPa
2. Yield strength (S_y) = 2500 MPa
3. Modulus of Elasticity (E) = 500 GPa
4. Factor of safety (FoS) = 2.5

B. Permissible stresses in material:

1. Tensile stress = $\frac{(S_{u_t})}{Fos} = \frac{4000}{2.5}$ = 1600 $\mathrm{N/mm^2}$
2. Compressive stress = $\frac{(S_{u_t})}{Fos} = \frac{4000}{2.5}$ = 1600 $\mathrm{N/mm^2}$ …(assuming $S_{u_t} = S_{u_c}$)
3. Shear stress = $\frac{0.67\ (S_{u_t})}{Fos} = \frac{0.67 * 4000}{2.5}$ = 1072 $\mathrm{N/mm^2}$ …($S_{s_u} = 0.67\ S_{u_t}$)
4. Yield stress = $\frac{(S_y)}{Fos} = \frac{2500}{2.5}$ = 1000 $\mathrm{N/mm^2}$

C. Dimensional specifications as per empirical data and nominal required sizes:-

1. Distance across rotors = 400mm
2. Upper deck of hub: 110 × 280 × 1.5 mm
3. Lower deck of hub: 110 × 194 × 12 mm
4. Support posts: ø6 × 35 mm
5. Extensions of lower deck: 27.57 × 25 × 12 mm
6. Rotor arm: 128.82 × 40 × 12 mm
7. Rotor arm web thickness: 2.5mm

D. Bending in 2nd deck (σ_b) :-

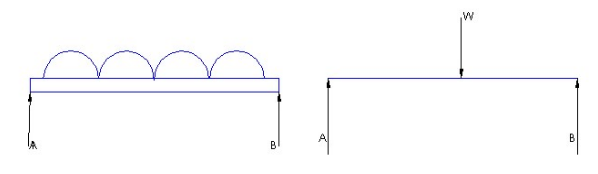


Fig.1 Load Distribution Diagram

1. Bending moment (M) = applied load × length of deck

   = (23×9.81×45) + (70×9.81×75)

   = <u>61655.85 Nmm</u>

2. Inertia of deck (I) = $\frac{bd^3}{12} = \frac{110 \times 280^3}{12}$ = $\underline{21.952 \times 10^6 \text{ mm}^4}$
3. y = 3mm

$$\sigma_b = \frac{\mathrm{M} \times \mathrm{y}}{\mathrm{I}} = \frac{61655.85 \times 3}{21.952 \times 10^6} = \underline{8.4258 \times 10^{-3} \text{ N/mm}^2}$$

E. Assuming the load is uniformly distributed over the 2nd deck,

Total stress at hub intersection

= (Bending stress + direct stress) on complete rotor arm (at support)

= $0.164 \times 10^{-6} + 0.2175$

= $\underline{0.2175 \text{ N/mm}^2}$

F. Buckling in 2nd deck supports using, Euler's formula,

Applied load = (23+51) × 9.81 = <u>0.726N</u>

Max buckling load that can be supported is given by,

$$\mathrm{F} = \frac{n\,\pi^2 EI}{L^2}$$

n = 1 - for fixed ends …(factor accounting for end conditions of poles)

E = 500×10^{3} N/mm^{2} …(Young's modulus of elasticity)

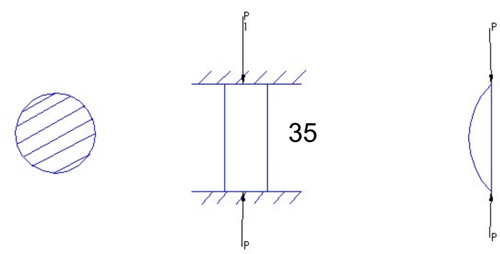
L = 35mm …(effective length of pole)

I = $\frac{\pi\times6^{4}}{64}$ = 63.6172 mm^{4} …(moment of inertia of a pole)

Thus,

F = $\frac{(1)\pi^{2}\times500\times1000\times63.6172}{35^{2}}$

F = <u>256.276 × 10^{3} N</u>



Since, the applied load is very small compared to max sustainable load, the design is safe.

G. Extensions of hub act as cantilevers

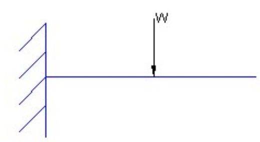
= Bending Stresses + Normal Stresses

$= \frac{FA^{2}(3L-A)}{6EI} + \frac{F}{4A}$

$= \frac{0.726\times12.5^{2}\times(3\times25-12.5)}{6\times5\times10^{5}\times3600} + \frac{0.726}{4\times6^{2}\pi}$

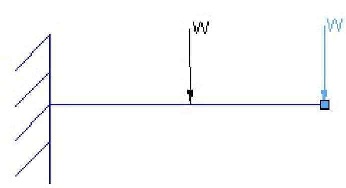
= 0.656 ×10^{-6} + 0.001605

= <u>0.00161N/mm^{2}</u>



H. Shear stress at rotor arm-hub intersection

$= \frac{SF}{Area} = \frac{0.725}{40\times12}$ = <u>0.2175 N/mm^{2}</u>

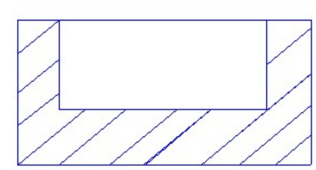


I. Shear in motor mounting portion (name this section)

$= \frac{\text{Wt of the motor}}{\text{Area of hollow arm}}$

$= \frac{70\times9.81}{150}$

= <u>4.578N/mm^{2}</u>



J. Opposite turning moments' couple on drone:

Use of counter-rotors adds to nullify torque produced by individual rotors on the UAV body.

On the basis of empirical relations, nominal sizes, and conclusions, we standardized some figures, formulated our ideas into a 3D model and conducted on it, virtual simulation tests.

From the above analysis, we can conclude that there are no excessive stresses developed in the frame. The maximum Von-Mises stress is found out to be 1.874MPa that too not on the main frame but on the floor where the flight control module and the standard base board are mounted.

From the stress test, the maximum displacement is found out to be 0.5501mm which too is negligible and is acting on the floor.

Hence, from the above results, we can conclude that there is no requirement of making any changes in the design.

Thus, we finalized the dimensions and drafted orthographic views of the frame. (attached in appendix 1.1).

K. Weight Balancing

1. Here,
   a. F1 = Weight of 2 motors = 2 x 70 gm-f = 140gm-f = 1.373N
   b. F2 = Weight of 2 ESCs = 2 x 23 gm-f = 46 gm-f = 0.4513N
   c. F3 = Weight of Battery = 580 gm-f = 5.6898N
   d. F4 = Weight of (Flight Control Module + Standard Base Board) = (23 + 51) gm-f = 0.726N

2. Calculating Moment about Axis O-O (↻ +, ↺ -)

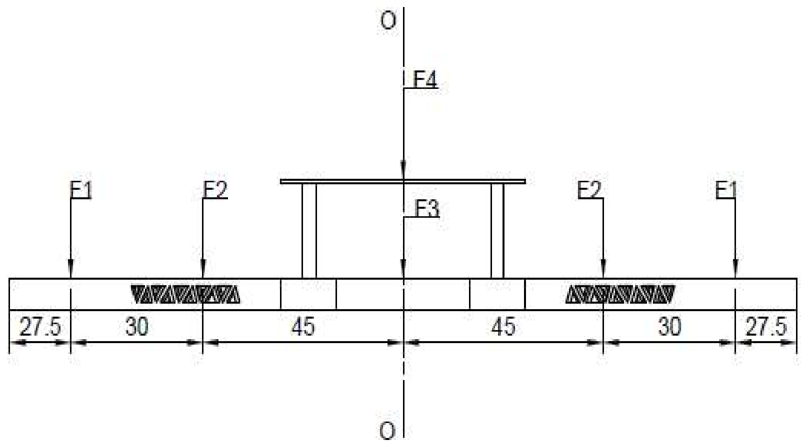
a. From Right Side:
1. $\Sigma M_R = (F1 \times 75) + (F2 \times 45) + (F3 \times 0) + (F4 \times 0)$
2. $= (1.373 \times 75) + (0.4513 \times 45) + (5.6898 \times 0) + (0.726 \times 0) = 123.2835\ Nmm$

b. From Left Side:
1. $\Sigma M_L = (-F1 \times 75) + (-F2 \times 45) + (-F3 \times 0) + (-F4 \times 0)$
2. $= (-1.373 \times 75) + (-0.4513 \times 45) + (-5.6898 \times 0) + (-0.726 \times 0) = -123.2835\ Nmm$

3. $\Sigma M = 123.2835 + (-123.2825) = 0$

4. From the above free body diagram of the assembly and the calculations, it is clear that

5. There is no unresolved moment in the assembly which may lead to an overturning couple
6. The drone's CG will lie on the vertical axis which is at the center of the drone.
7. The drone will not be unstable during its flight due to any unbalanced mass.



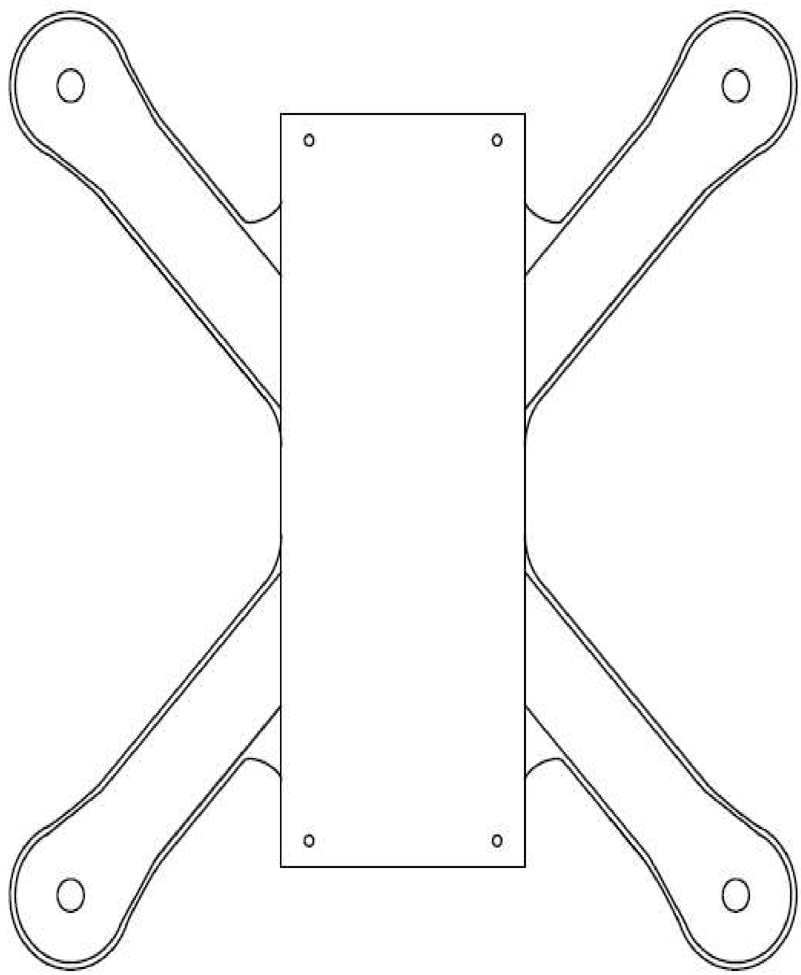


Fig.2 Free Body Diagram

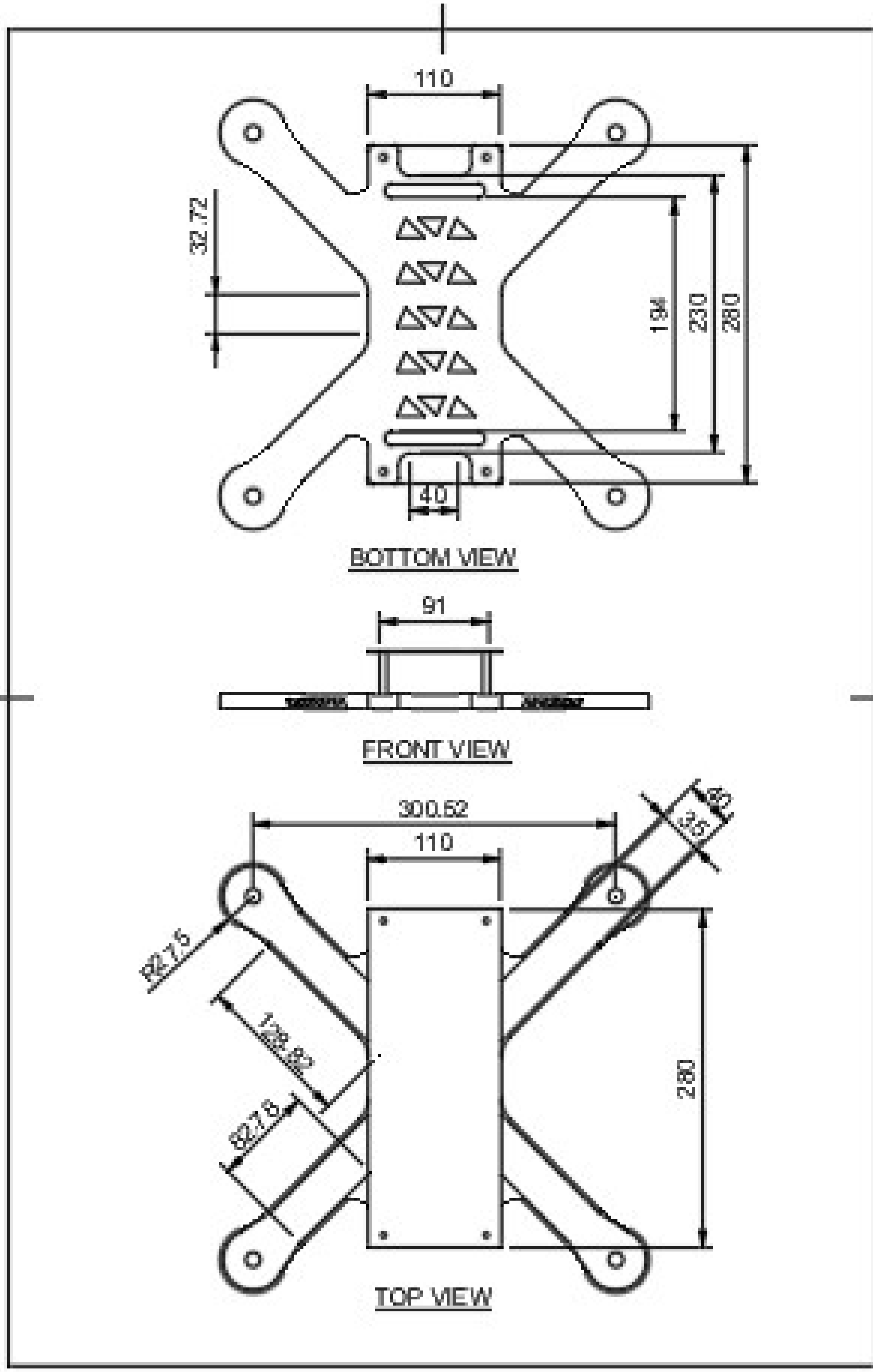


Fig.3 Orthographic View of Frame (Part No. - DR001)

(Orthographic views – all dimensions are in mm)

Computational Analysis Report

1. Stress Test of Frame

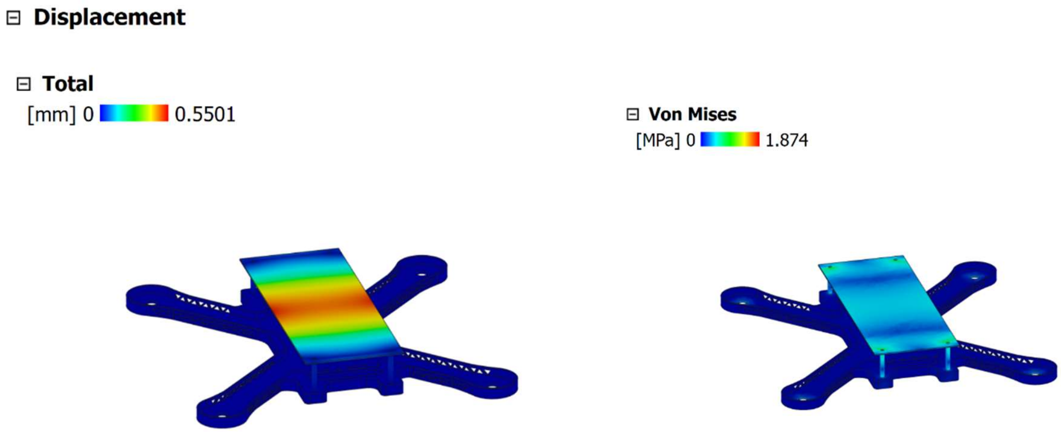


Fig.4 Stress test on Frame

From the above analysis, we can conclude that there are no excessive stresses developed in the frame. The maximum Von-Mises stress is found out to be 1.874MPa that too not on the main frame but on the floor where the flight control module and the standard base board are mounted.

From the stress test, the maximum displacement is found out to be 0.5501mm which too is negligible and is acting on the floor.

Hence from the above results, we can conclude that there is no requirement of making any changes in the design.

Result Summary – Table 1

Name	Minimum	Maximum
Safety Factor		
Safety Factor (Per Body)	15	15
Stress		
Von Mises	6.784E-06 MPa	1.874 MPa
1st Principal	-0.8597 MPa	1.645 MPa
3rd Principal	-2.367 MPa	0.3495 MPa
Normal XX	-1.143 MPa	0.7873 MPa
Normal YY	-2.112 MPa	1.42 MPa
Normal ZZ	-1.453 MPa	1.166 MPa
Shear XY	-0.6038 MPa	0.5565 MPa
Shear YZ	-0.6875 MPa	0.7282 MPa
Shear ZX	-0.3864 MPa	0.335 MPa
Displacement		
Total	0 mm	0.5501 mm
X	-9.618E-04 mm	9.024E-04 mm
Y	-0.5501 mm	0.02215 mm

Z	-0.005003 mm	0.005229 mm
Reaction Force		
Total	0 N	0.9688 N
X	-0.3284 N	0.276 N
Y	-0.9638 N	0.06832 N
Z	-0.2232 N	0.3107 N
Strain		
Equivalent	2.126E-09	5.663E-04
1st Principal	-2.896E-06	5.676E-04
3rd Principal	-6.087E-04	2.989E-06
Normal XX	-9.531E-05	9.927E-05
Normal YY	-3.255E-04	3.315E-04
Normal ZZ	-2.112E-04	2.243E-04
Shear XY	-3.763E-04	3.468E-04
Shear YZ	-4.285E-04	4.538E-04
Shear ZX	-2.408E-04	2.088E-04
Contact Pressure		
Total	0 MPa	2.066 MPa
X	-0.6038 MPa	0.5565 MPa
Y	-1.998 MPa	1.395 MPa
Z	-0.6875 MPa	0.6451 MPa

2. Flow Simulation of the Assembly

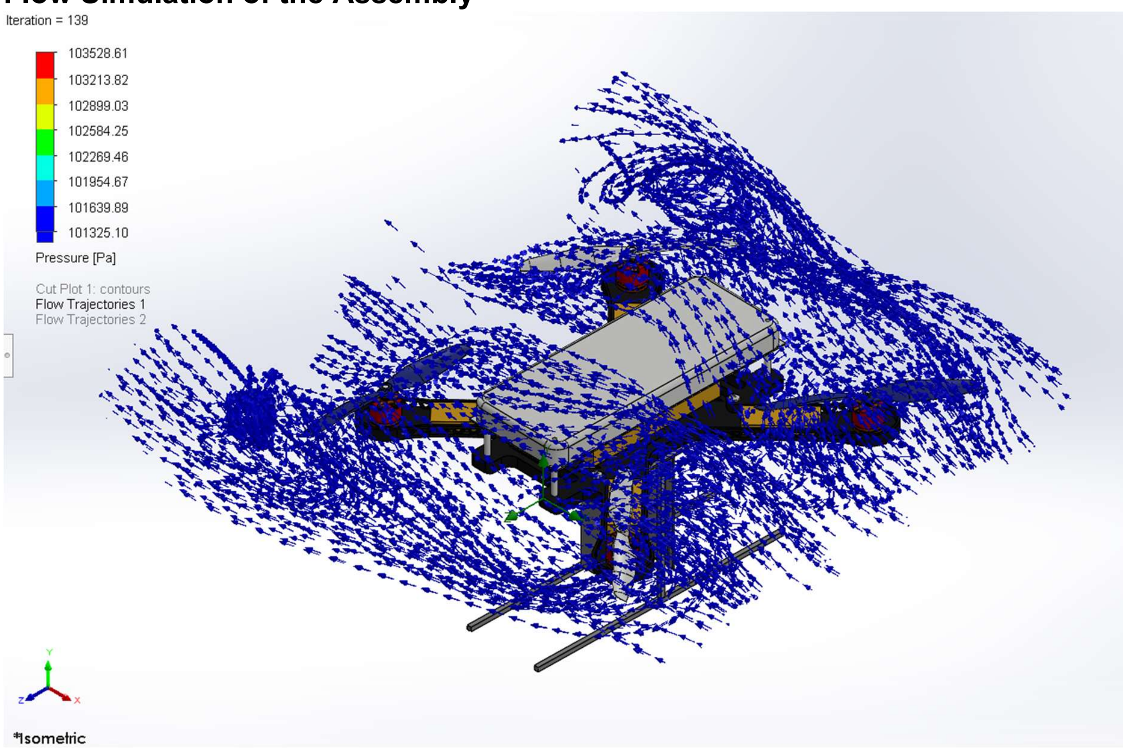


Fig.5.1 Flow Simulation of the Assembly

Figure shows the flow of air particles. This was done to analyse the aerodynamics of the drone to check for any region where air might get trapped/stuck. No such areas were to be found from the analysis and hence no further changes in the design are required.

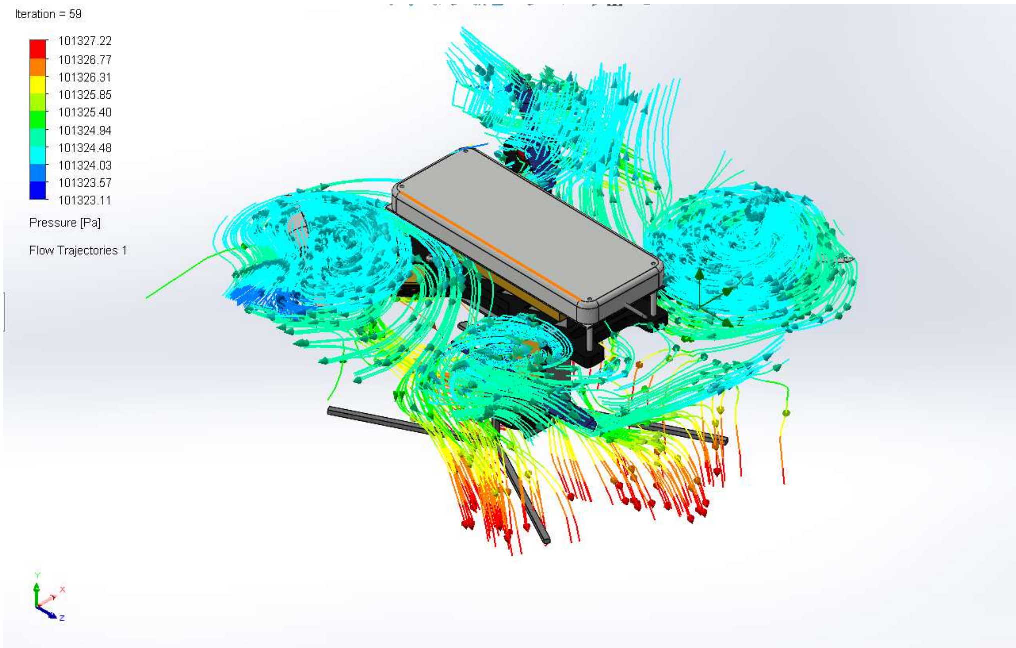


Fig.5.2 Flow Simulation of the Assembly

From the flow trajectory simulation, we can determine the air flow path by the virtue of the streamlines. Here, as shown in the above figure, we can conclude that there is sufficient air flow from top layer of the propeller to the bottom and hence, the pressure difference created will uplift the drone.

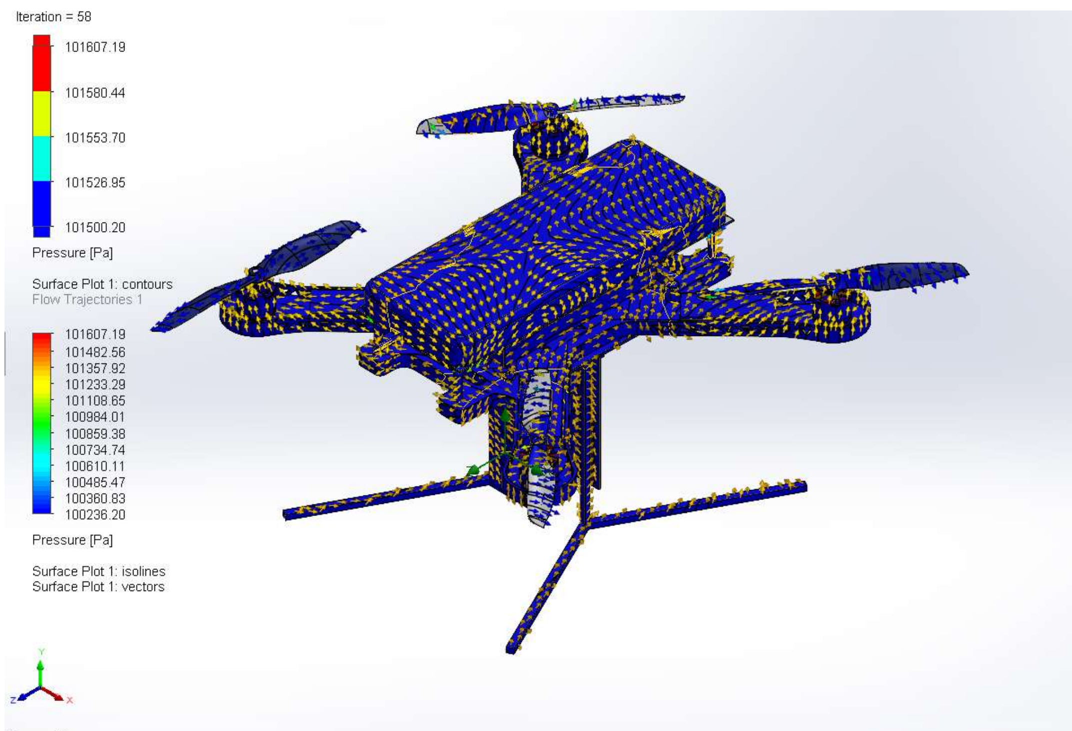


Fig.5.3 Flow Simulation of the Assembly

Figure shows the surface plots of the Contours and Isoline. As there are no areas with pressure exceeding the limits, no further changes were deemed to be required in the design.

PROPULSION SYSTEM (Part No. 10,11)

A. ESTIMATION OF PRELIMINARY WEIGHT – Table 2

Components	**Weight in gm**
Frame	389.9
Payload Lifting Mechanism	@ 220
Payload	@250
Motors	70 * 4
Battery	580
Flight Control Module	23
Standard Base Board	51
GPS	8.1
Camera	173
Distance Sensor	25
Total weight	2000gm = 2kg

B. ESTIMATION OF THRUST REQUIRED.

1. Total weight = 2kg approx.
2. Thrust-to-weight ratio = 2:1
3. No. of motors = 4
4. Required thrust per motor = $\frac{(2 \times 2\ )}{4} + \ 20\%$
   = 1.2kg
   = 11772 N

Fig.6 Propeller

C. SELECTION OF PROPULSION SYSTEM.

1. We have designed a quadcopter with dual blade propellers and its advantages of quadcopter (4 propellers) are :
2. It is preferred that drones have an even number of rotors to balance the forces applied by each rotor. A quadcopter provides four points that offer variable thrust.
3. The even number of propellers allows to balance the craft in several ways. Four points offering variable thrust enable the craft to maintain position in the air and a relatively stable hover.
4. It is the most economical way to produce a drone.
5. Controlled manoeuvrability

D. NO. OF BLADES

1. The main talking points here are thrust and efficiency.
2. Also, 2-blade propellers are
   a. easy to carry
   b. durable in case of collisions due to their flexibility
3. They also have a low price.
4. Highly responsive to changes made to the RPM.

5. A 3 blade will create higher amount of thrust and stability, but is heavier and slower in operation along with increased battery consumption.
6. A 2-blade propeller is more likely to rotate out of the way in case the drone goes down, whereas a 3-blade propeller is prone to damage in any kind of crash.
7. However, the double blade propeller provides enough thrust, and its work efficiency is optimum along with its other salient features and advantages, as per the required design.

E. SPECIFICATION:
1. Material: Carbon Nylon
2. Size: 8 × 4.5"
3. Weight: 14g per pair
4. Diameter of centre bore: 5.0mm
5. Thickness of centre: 9.7mm
6. Hole size: 5mm

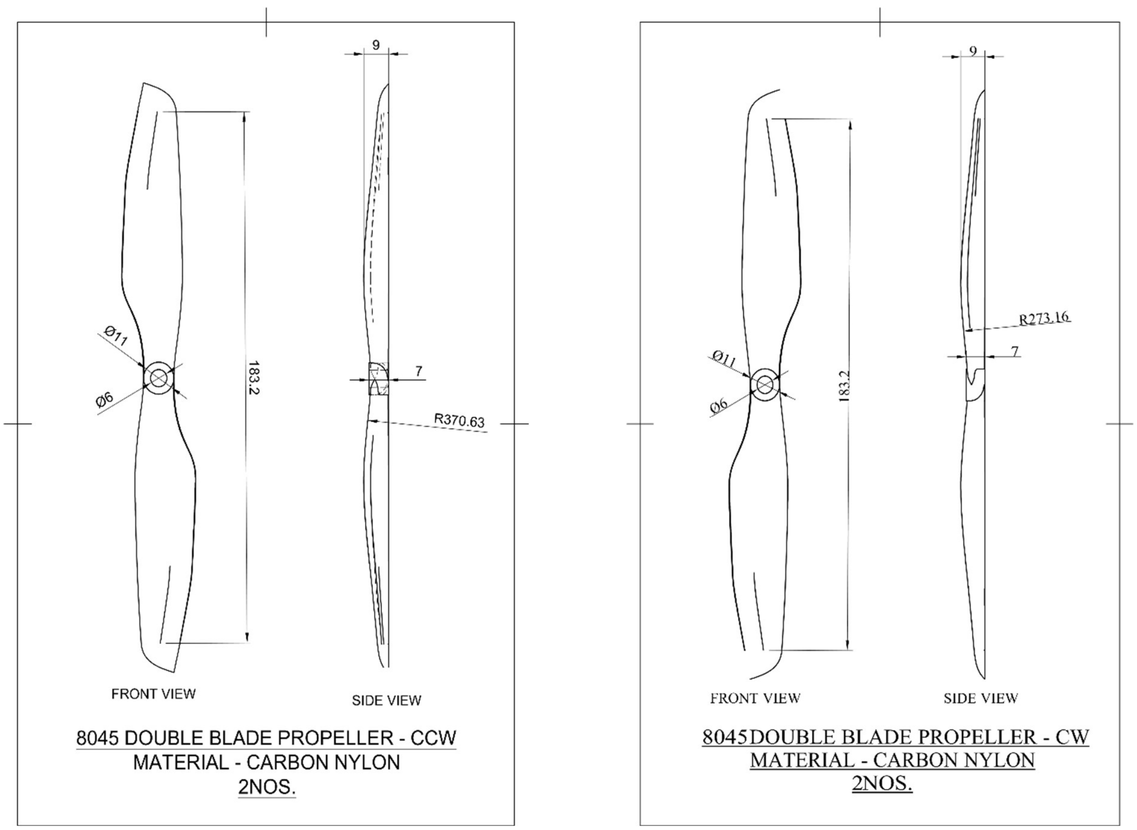


Fig. 6.1 Orthographic views of propellers of size 8”, 4.5 pitch (Part No. - DR003)

PAYLOAD DROPPING MECHANISM (Part No. 12):

UAVs are growing at an accelerating rate in the contemporary world and are used in several industries. One of the applications is delivering payload at a precise location. The payload lifting mechanism is the most important and ingenious part of the drone.

A. CONSTRUCTION:
1. **Stand** (Material- Carbon Fibre): There are 2 stands to support the drone and evenly distribute the drone's overall weight. The base of the stand is V- shaped having angle of 125.84^{o} between 2 arms.

2. **Reciprocating plank** incorporates an attached Rack and Pinion Mechanism, which is actuated by a servo motor for automated payload loading. Additionally, a rubber pad is also fixed and is used to grip the payload.
3. **Fixed plank:** It has a fixed rubber pad to grip the payload. A slot of 10*15 mm is made so that the rack can move through the fixed plank and increase or decrease the distance between 2 planks as required.
4. **Top reference plate:** It features a sliding groove on the plate for the reciprocating plank, and it also helps in joining the Payload Dropping mechanism with the drone with the help of screws .Additional cuboid of dimensions 12*12*6.5 mm weighing 1.79 g is placed whose bottom face is at distance of 82.7 mm above from bottom edge of top reference plate in top view and side face at a distance of 7.88 mm towards left of fixed plank in top view so as to balance the weight of the payload and drone.

   Rubber Pads: They are used for gripping the payload and are attached to the planks using adhesive paste. In addition, the rubber pads feature a projection on the face that will securely grip the payload, creating vacuum action (airtightness).
5. A **Servomotor** is centrally attached to the top reference plate at its centre. It will give rotary motion to the Pinion and rack.
6. **Rack and Pinion:** The rack and pinion mechanism will convert rotary into the reciprocating motion of the reciprocating plank.

Fig. 7 Isometric View of Payload Dropping Mechanism

B. WORKING:

1. The motor's shaft is normal to the plate.
2. A pinion is attached to the motor shaft, which is engaged to the rack of the reciprocating plank. Thus, reciprocating plank slides.
3. When the payload is to be lifted, the lifting mechanism initiates the servo motor, which moves the plank and pushes the payload against the fixed plank. The payload will be securely held in the mechanism since both planks have attached rubber pads.
4. When the drone acquires an appropriate position to drop the payload, the servo motor will be operated, causing the Pinion to move in the reverse direction.
5. The reciprocating plank will move outward, and the payload will be released.

C. SOURCES OF PARTS USED IN THE MECHANISM:

In our mechanism, some parts are to be 3D printed while some are readily available in the market, Following are the sources of each part:

1. Motor: from market
2. Rack and Pinion set: from market
3. Top plate: 3D printed
4. Fixed and moving plank: 3D printed
5. Stand: 3D printed
6. Screws, adhesive paste: from market

D. Free Body Diagram:

1. W is the weight of the drone and payload weight of drone and payload mechanism is equally distributed both of the stands will give equal reaction R.

   Hence,

   R = W/2

   $$R = \frac{(1530+278.89)\times10^{-3}\times9.81}{2}$$

   = 8.872N

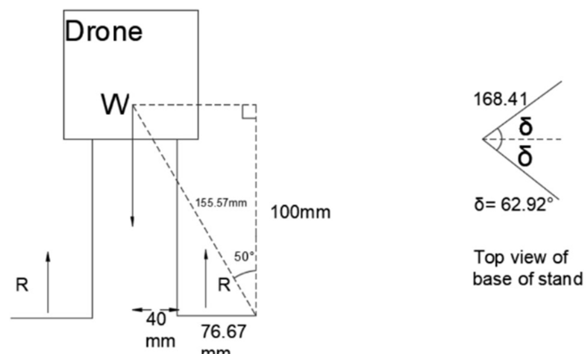


Fig. 7.1 Free Body Payload Dropping Mechanism

2. Point W is the centre of mass of the drone it is positioned 155.57mm and 100 mm above the edge of V shaped base. Thus it allows 50° of rotation about the stand.
3. The V shaped base of stand is 76.67 wide and 300 mm long which provides reactions when drone is inclined at any angle between 0-50°(with respect to horizontal)and these reactions generate moment which are in opposite direction with the moment generated by weight of the drone and thus balances the drone.

E. CALCULATIONS and DIMENSIONS:

- **For Top Plate:-**

1. Top plate dimensions 100 × 200 mm
2. Thickness of top reference plate = 2 mm
3. Groove length of top plate = 60 mm

- **For Planks:-**
  1. Plank dimensions = 150 × 60 mm
  2. The thickness of plank = 2 mm
  3. Thickness of rubber pad = 1 mm
  4. Dimension of rubber pad = 50 × 55 mm

5. Coefficient of friction of rubber with payload = 0.7
6. Gripping force (F_g) = 4.3N
7. Plank to plank distance when moving plank is at the inner side = 52 mm
8. Plank to plank distance when moving plank is at outer side = 105 mm

- **For Stands:-**

1. Stand leg cross-section = 5 × 5 mm
2. Stand height = 165 mm
3. Stand width(minimum) = 78mm
4. Stand base length=2*168.41=336.82 mm
5. Angle between 2 arms of V shape =125.84°
6. Clearance from the ground = 10 mm

- **For Rack and pinion:-**

1. Gear module (pinion) = 2.25
2. Pitch circle diameter (PCD) = 27 mm
3. Volume of the whole mechanism except the servomotor = 118.9 cm^3
4. Number of kinematic links used in mechanism = 8
5. Number of sliding pairs = 2
6. Number of rolling pairs = 3
7. Degree of Freedom= 1
8. Strength of the Carbon fibre selected = 500 ksi or 3.5 GPa
9. Total weight (including weight of motor)= 278.89 gm

The stand must be designed such that it can carry and withstand the weight of the drone and the payload mechanism, which weigh 1530g and 300g(it weighs 278.89 g but for safety 300g is taken as payload weight), respectively,

Considering the safety factor as 1.2, we get the total weight as 2kg, i.e., 19.62N.

- The stress on the base of the stand can be given as

$$\begin{aligned}\text{Stress }(\sigma) &= \frac{\text{Force}}{\text{Area}} \\ &= \frac{19.62}{2 \times \text{base area of each stand}} \\ &= \frac{19.62}{2 \times 5 \times 80} \\ &= 0.024525 \text{ N mm}^{-2} \\ &= 24.525 \text{ kN m}^{-2}\end{aligned}$$

- The material we have selected to make our stand is Carbon fibre which has an ultimate tensile strength of 3.56 GPa or 3.56 × 10^6 kN-m^{-2}.

- From the above calculations, we find that the stress acting on the base of the stand is 24.525 kN-m^{-2} which is within the limits of the ultimate tensile strength that carbon fibre can experience.

F. TORQUE CALCULATIONS:

1. Moment of inertia of Pinion about motor shaft axis(I)= 465.06 g-mm^2
2. Weight of Pinion = 4.55 g
3. Radius of gyration of Pinion about motor shaft axis= 10.11 mm
4. Weight of sliding plank (along with the rack)(M) = 46.1 g
5. Coefficient of friction between the groove and sliding plank=0.74
6. Frictional force between groove and reciprocating shaft (F_s) = 0.334 N
7. Acceleration of the plank while sliding(a)= 0.1m/s^2

   Now while sliding the motor will provide the torque to rotate the pinion as well as slide the reciprocating plank, thus,

$$T_{slide} = \frac{2\times I\times a}{PCD} + \frac{Fs\times PCD}{2} + \frac{M\times a\times PCD}{2}$$

8. Hence, torque (T_{slide}) required for the plank to slide in the groove (No holding pressure applied on payload) = 0.45742 N-cm

   While pressing only torque will be applied to press the rack and no movement of rack or reciprocating plank will take place so,

$$T_{press} = \frac{Fg\times PCD}{2}$$

9. Torque (T_{press}) required to press the payload against the rubber pads and hold it firmly = 5.805 N-cm
10. Time taken by the plank to slide 5 cm in the groove = 1 second

G. COMPONENTS SELECTED:

1. Motor Specifications: A SG90 Continuous Rotation 360^o Servo Motor (Weight=9g) (Operating Voltage= 3.0V ~ 7.2V, Stall Torque=1.2 Kg-Cm @ 4.8V)
2. Since at high elevation, the wind speed is around 10 ms^{-1}, the mechanism might buckle. To avoid such a phenomenon, we have used carbon fibre with a modulus of rigidity of 228 GPa.

H. JOINING PROCESS:

1. The complete payload mechanism is an assembly of parts.
2. Following are the joints present in the mechanism:
3. Top reference plate to frame: 4 Screw of M05 × 18mm
4. Fixed plank to top reference plate: 2 Screw of M05 × 18mm, super adhesive paste
5. Motor to Top reference plate: Super adhesive paste
6. Pinion to motor shaft: We have push fitted it since it is interference fit.
7. Rack to sliding plank: Super adhesive paste
8. Stand to top plate: 4 Screws of M05 × 18mm(2 screws for each stand)
9. Stand Base to Stand leg: Adhesive paste

I. ADVANTAGES OF THIS MECHANISM:

1. This payload lifting mechanism also functions as a stand for the drone.
2. The whole payload mechanism can be mounted to the upper drone frame using screws, providing provision at the top reference plate.
3. This mechanism employs only one servo motor, minimizing power consumption and improving efficiency.
4. The parts of this mechanism are simple to 3D print.
5. The top reference plate has a volume of 40000 mm^3, while the fixed and the moving planks have a total volume of 36018 mm^3. Thus, the amount of carbon fibre material required for the construction will be less, lowering the overall assembly cost.
6. The payload is lifted without dragging the planks against the ground and decreasing wear and tear.
7. In short, this mechanism is low-cost, lightweight, compact, and robust.
8. The drone can stabilize itself when it lands at an angle between (0-50^o with respect to horizontal) degrees since the base support of the drone's stand is shaped like a tetrahedron with an included angle between them.

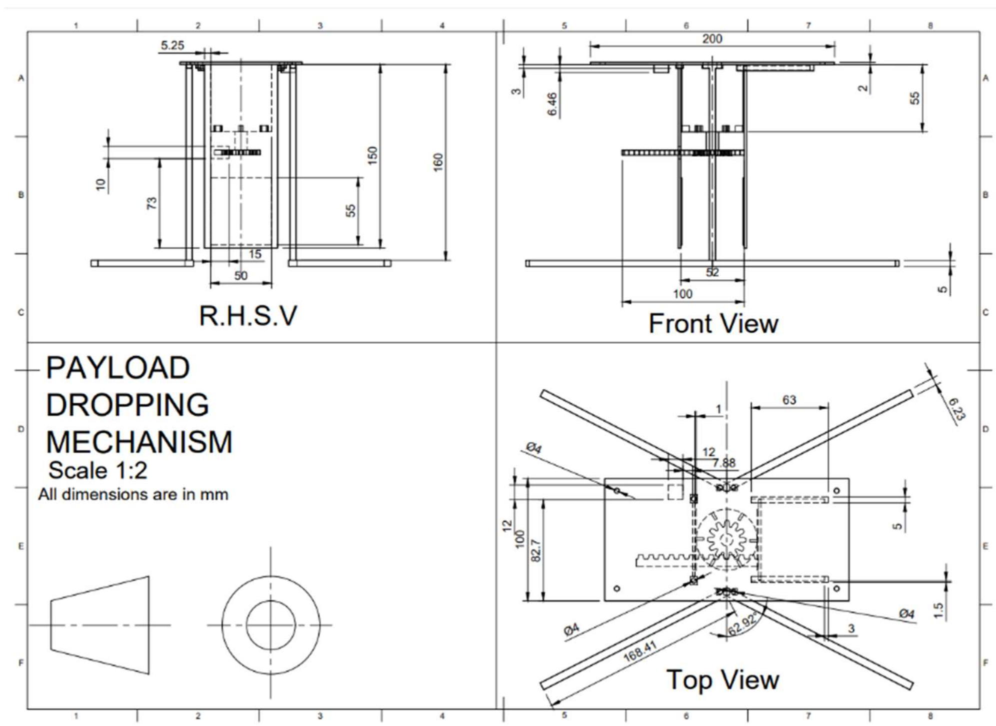
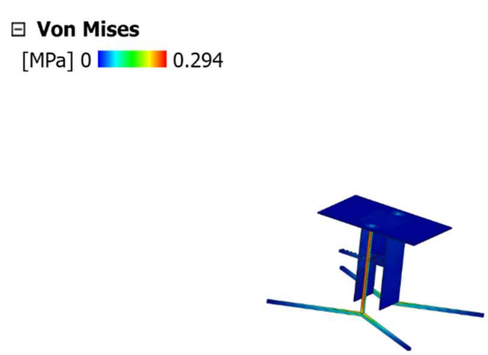


Fig. 7.2 Orthographic View of Payload Dropping Mechanism

3. Stress Test of Payload Mechanism



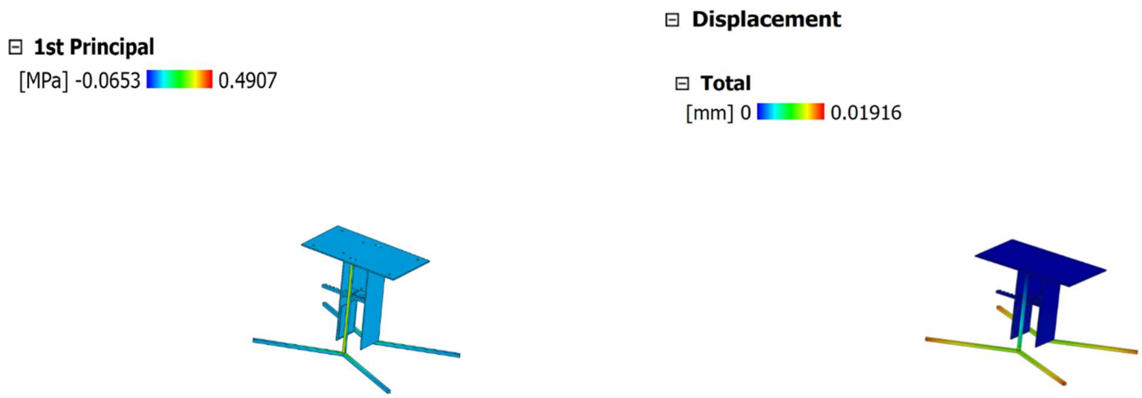


Fig. 7.3 Stress test Result of Payload Dropping Mechanism

MATERIAL SELECTION:

A. INTRODUCTION:

Materials which had revolutionized the aeronautical industry in past few years including alclad sheets, carbon fiber composite, titanium alloys.

For the drone frames we need the material which must have properties like it should be lightweight, stiffer tough durable, strong enough with high tensile strength. According to the requirement, we studied several materials for the drone frame including,

1. Nylon Carbon Fibre Composite
2. Acrylo-Butedyne-Styren
3. Aluminium 7075

B. NYLON CARBON FIBRE:

- **PROPERTIES – Table 3**

Phase at STP	**Solid**
Density	**2000 kg/m3**
Ultimate Tensile Strength	**4000 MPa**
Yield Strength	**2500 MPa**
Young's Modulus of Elasticity	**500 GPa**
Brinell Hardness	**N/A**
Melting Point	**3657 °C**
Thermal Conductivity	**100 W/mK**
Coefficient of thermal expansion	**9×10^{-5}**
Specific Heat	**1.4 j/kmol .**

- **Advantages of Nylon Carbon Fibre:**

1. Printing smoothly, odourless, matte finish.
2. High Strength, High Rigidity, Good Toughness, Wear-Resisting, Fitting to 3D print industrial parts.
3. This material is most widely 3D printed.

- **REASONS FOR SELECTION OF NYLON CARBON FIBRE:-**

1. Properties that creates attraction for the carbon fibre is due to its low density which is only 1.2 g/cc and the high modulus having the statistical value of the range of 4.3 to 19 GPa along with the high tensile strength of the 104 to 230 MPa and the high stiffness.
2. Thermal properties are good enough to sustain for the moderate values of the high temperature application environment having the thermal coefficient of the 9*10^-5 /k along with the specific heat of the 1.4 j/mol k.
3. The carbon fibre material can be made into the intricate shapes with ease and little to no time.
4. We had selected the 3D printing as the manufacturing process to manufacture the drone frame. We are happy to share that all the print setting properties needed are ideally fulfilling the requirement of the machine that we will be using for the manufacturing. The print setting for the typical 3D printing machine data is taken from www.robu.in

C. CONCLUSION

This is the ideal material for our drone frame because it is ideally fulfilling all the requirement others also are good but specifically according to ours need carbon fibre is the only one. From all of the above studied.

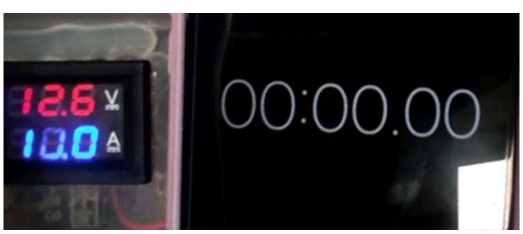
<u>MOTORS (Part No. 2)</u>

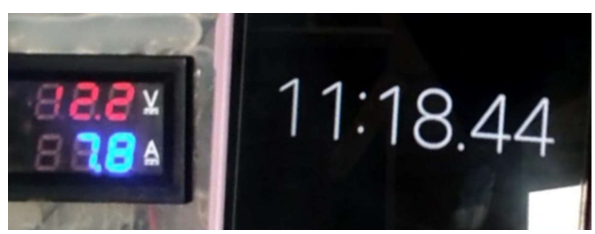
A. THE BENCH TEST:

The This test Is performed to check the motor speed at different current, maximum current drawn by the motor, compatibility of battery and motor and theoretical flight time estimation.

1. Connect one motor to the Esc, Servo motor tester and then to the battery.
2. Clamp the motor to the restrict its displacement.
3. Connect the ammeter to the motor.
4. Record the values (battery consumed by the motor) for the full throttle and for thrust required.
5. Calculate the change in current, time, RPM, and voltage.
6. Calculate the total flight time with the current.

RESULTS OBTAINED FROM BENCH TEST: - Table 4 -





Input Voltage(V)	Current(A)
12.6	10
After 11.18min	
12.2	7.8

1. Motor Rating: 850kV (800 rotations per minute)

2. From this, we can see that the total voltage drop is just 0.4volt.
3. The Maximum RPM (Rotations per minute) achieved in this test is 10,000 rotations per minute.
4. And maximum current drawn from the battery is 20 A when the load is applied even at loading conditions, the temperature rise of the motor is within the permissible limit.
5. During loading, we observed that there is no loss in speed i.e., it runs smooth. We concluded that the selected motor is best for drone design as its working and efficiency are high.
6. The supreme power of a motor is also something to take into consideration. Exceeding the motor's power restriction would result in the motor heating up and thus harshly lowering its efficiency. For the identical KV value, a motor from one brand may perform better than others. That is why we executed the test on our motor before building a drone around it. Manufacturers' data can give you knowledge of which motors and propellers will work in your design, but testing is not standardized, so it is impossible to compare parts across manufacturers.

B. THE RESASONS FOR SELECTION OF GT2215 EMAXMODEL MOTOR:

Fig. 8 Motor

1. The net weight of our quadcopter is 2kg. To get optimum thrust from motor we selected this motor which gives 1000g torque when applying 3s LiPo battery.
2. This motor gives 905 rpm per volt.
3. We have used 3 cells of LiPo battery. Each cell gives 3.7volt so net voltage obtained by thESC 3 pack of cells is11.1 Volt.
4. So each motor gets voltage according to required rpm and thrust requirement.
5. To get practical information about motor we performed bench test.

D. TECHNICAL SPECIFICATION OF BLDC MOTOR: - Table 5 -

Parameter	Value
Brand name	emaxmodel
Type	GT2215
Operating Voltage	12 V
KV rating	905 RPM/V
Max. current	15A
Thrust/motor	1000g/motor
ESC required	40A
Cell Count	3S(Li-po)
Shaft Diameter	5mm
Stator Dimensions	(22×15) mm
weight	70g

Orthographic views of BLDC Motor (Part No. - DR002)

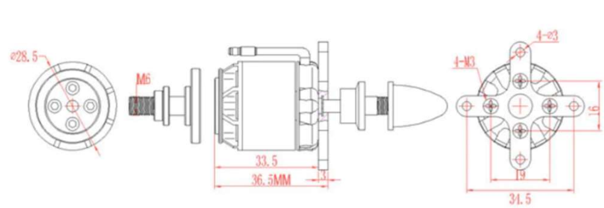


Fig. 8.1 Orthographic views of BLDC Motor

BATTERY (Part No. 3)

A. Selection Process of our battery:

1. LI-ion has more specific energy than Li-po but the problem is it's more volatile, prone to damage when exposed to high temperatures, heavier and loses its charging Capacity, and could burst if the separator is damaged.
2. On comparing Ni-MH and Li-Po battery, Ni-MH was found to have low Power to weight ratio and the cell voltage is just 1.2 V.
3. Hence, we selected Lithium Polymer Battery.

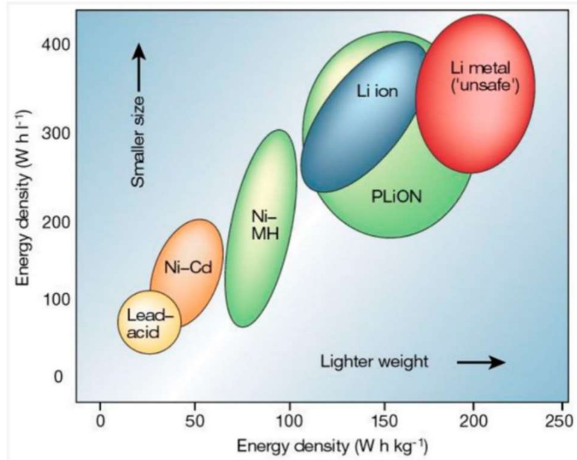


Fig. 9 Comparison Graph of various batteries

B. Calculations:

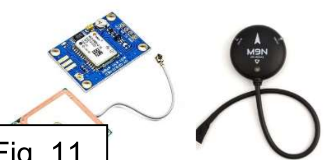
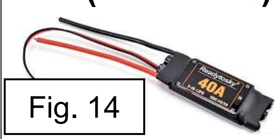
1. Voltage Required for our drone is approximately =11Volts
2. Average value of voltage given by 1 cell of Li-Po=3.7 V
3. no. of cells required=11/3 ~ 3 cells. Hence, 3S battery.
4. Since we are using Li-Po batteries, (it shouldn't be discharged completely the cycle goes from 3.2 v- 4.2 volts. If the voltage goes below 3.2volts the battery, it shortens battery's lifetime.
5. Effective Capacity= $\frac{3.3}{4.2}$ = 0.78
6. Current drawn by other electronics is much less than the current drawn by the motor, hence, we have neglected those value, but added the buffer required while selection
7. Calculating the flight time after using motors at Max:
8. Flight time in minutes = $\frac{(\text{Battery Amp})}{(\text{MotorAmp})} \times \text{Effective Capacity} \times 60$
9. Max. motor Amp = 25.5 A.
10. Battery Amp = 6.2A
11. Flight time in minutes $= \frac{6.2}{25.5} \times 0.78 \times 60$
12. Flight time at full throttle = 11.37 minutes,
13. This value of actual flight time will be more than this since we would not use our motor at maximum capacity.

BATTERY SELECTED: 3S (11.1V), 6200MAH, 40C LI-PO BATTERY

C. Other Specifications of Li-Po:

1. Weight : 460grams (Minimum weight in Class), Dimensions : 155×25×50 mm^2
2. Maximum discharge Rate :50C (310A), Charge Rate 1~3, Discharge connector: HT 60

ELECTRONICS COMPONENTS – Table 6

Sr. No.	Components	Specifications
1	**Pixhawk 5x Flight Controller (Part No. 6)**  Fig. 10	• **Dimensions:** Flight Controller Module: 38.8 × 31.8 × 14.6mm Standard Baseboard: 52.4 × 103.4 × 16.7mm • **Weight:** Flight Controller Module: 23g Standard Baseboard: 51g • **FMU Processor:** STM32F765 • **IO Processor:** STM32F100 • **On-board Sensors**: 1. Accel/Gyro: ICM-20649 2. Accel/Gyro: ICM-42688P 3. Accel/Gyro: ICM-20602 4. Magnetometer: BMM150 5. Barometer: 2x BMP388
2	**GPS (Part No.4)**  Fig. 11	**Neo-M9N-00B (Primary GPS)** • 12.2 × 16.0 mm dimensions • Provides reception for four GNSS, namely GPS, GLONASS, BeiDou, Galileo. • Velocity accuracy - 0.05 m/s • Maximum velocity – 500 m/s • Maximum Altitude – 80,000m
3	**Camera**  Fig. 12	**Raspberry Pi Hi-Quality Camera** • 12.3-megapixel Sony IMX477 sensor • 7.9mm diagonal image size • Output: RAW12/10/8, COMP8 • Interchangeable lens
4	**PDB**  Fig. 13	**Size**: 50 × 50 × 4.5 mm
5	**ESC (Part No.8)**  Fig. 14	**Model:** ReadytoSky 40A **Burst Current:** 60A **Constant Current:** 40A **Suitable Li-Po Batteries:** 2~4S **Weight:** 34 gm
6	**Airspeed Sensor (Part No.15)**  Fig. 15	**MPXV7002DP Air Speed Sensor and Pitot Tube** • Can measure speeds of up to 100m/s • Resolution: 0.84Pa • Measurement Range: 1psi, 100m/s

7.	**Transmitter**  Fig. 16	• Weight : 586g (without including battery) • Size: 191*175*64mm • Maximum communication distance (considering no obstruction): 15 KM • Operating frequency: 2.400-2.483 GHz • Number of channels: 12 physical channels, 16 signal channels • Support battery type: 18650 *2, 2S Lipo battery • Antenna gain: 2dbi • Working current (rated): 210mA

METHODOLOGY FOR AUTONOMOUS OPERATION:

Automation is basically making the UAV fly on its own to a specific location and do a certain task. It will be done by using PIXHAWK 5x and Raspberry Pi. Automating the UAV is necessary because of the task 2 of AEROTHON' 22, in which the UAV is supposed to fly to a location and drop the payload precisely on the location.

A. HARDWARE STACK:

A. Major Operations Required by the Flight Controller:

a. **Sensing:** The sensors connected to the flight controller, give the it information about like its height, orientation, speed, angular speed, acceleration and object detection.

b. **Controlling**: Controlling the motion of the drone. The drone can move forward, backward and left, right as well as rotate and accelerate by creating differences in the speed of its four motors. The flight controller collects the data from the sensors to calculate the desired operation to perform and thus calculated the speed for each of the four motors. The flight controller sends this desired speed to the Electronic Speed Controllers (ESC's), which translates this desired speed into a signal that the motors can understand and act on.

c. **Communicating:** Communication is a key part of a flight controller. To give the pilot information regarding the drone. Example the battery level. In auto-pilot drones, flight controllers need to communicate with other computer systems about its flight destination and path. Communication is mostly done with Wi-Fi and radio frequencies.

B. Raspberry Pi:

Raspberry Pi is a series of single-board computers. They are small and affordable computers.

B. Reasons for use:

Raspberry Pi is competent :-

1. To attach a camera
2. Write an openCV script to track the distance between the drone and the marker
3. Python script to send commands to the flight controller to control the movement of the drone.

Fig. 17 Raspberry Pi

4. Autonomous Mission Scripting with Python: Send flight commands to the flight controller (in our case PIXHAWK 5X) from the raspberry pi.
5. Raspberry pi is comparatively cheap. It provides huge processing power in a compact board. It has many interfaces naming few HDMI, USB Ports, Ethernet, Wi-Fi, Bluetooth and many more. Supports Linux, Python allowing it to build applications easily.

C. PIXHAWK 5X AND RASPBERRY PI AS A SYSTEM

PIXHAWK 5x is a microcontroller and Raspberry pi is a mini computer to which the camera will be connected. Automation will be mainly utilized in TASK 2 of Aerothon 22. Raspberry Pi and PIXHAWK 5x will be connected via Ethernet. Camera connected to the raspberry pi will detect the place using the algorithm which is optimised in such a way that, camera will detect the colour and send the respective co-ordinates to the PIXHAWK 5x via commands and then the UAV will travel to that place. PIXHAWK 5x will work according to the co-ordinates sent by the Raspberry Pi.

D. SOFTWARE STACK:

1. DRONEKIT-PYTHON

In order to control the quadcopter autonomously we needed a way to create applications on a companion computer, in our case the Raspberry Pi, and then send commands to the flight controller to control the quadcopters movements. For this we chose to use DroneKit-Python.

DroneKit-Python allows developers to create apps that run on an on-board companion computer (Raspberry P) and communicate with the Pixhawk flight. The API communicates with vehicles over MAVLink, or Micro Air Vehicle Link. It provides programmatic access to a connected vehicle's telemetry, state, and parameter information, and enables both mission management and direct control over vehicle movement and operations. DroneKit-Python's API provides classes and methods to:

• Connect to a drone from a script.

• Get and set drone state/telemetry and parameter information.

• Receive asynchronous notification of state changes.

• Guide a UAV to specified position.

• Send arbitrary custom messages to control UAV movement and other hardware.

• Create and manage waypoint missions (AUTO mode).

• Override RC channel settings.

2. PX4 AUTOPILOT:

PX4 Autopilot is a professional and open-source autopilot system which powers small scale drones and even autonomous rovers. The free and open source software allows the remotely controlled aircraft to flown to the desired location or marker. Allows modification due to its open source nature.

The autopilot suite consists of the following components:

- QgroundControl software
- MAVLink Micro Air Vehicle Communication protocol
- 2D/3D aerial maps

Using the QgroundControl, the path and the destination of the UAV is planned and set. The communication with the drone takes place using the MAVLink Protocol.

At first, the Basic Configuration of the drone is set including updating the firmware and calibrating the sensors.

Under Flight, flying requirements can be accessed which including drone destination, path, direction, debug on board problems, etc.

3. THE LIBRARY: OpenCV :-

OpenCV is the huge open-source library for the computer vision, machine learning, and image processing and now it plays a major role in real-time operation which is very important in today’s systems. It gives the computer the ability to process images and videos to detect objects, faces, or even handwriting of a human.

It is used for object detection and image processing.

E. COMPUTER VISION AND OBJECT DETECTION:

1. Computer vision is the study of analysing, processing, and understanding images from the real world in a quantifiable manner in order to produce numerical or symbolic information. Operation of the UAV in this case is done by the drone camera detecting objects and recognizing as per the trained model and following them.
2. But there are numerous obstacles in achieving this. Here the most important factor becomes colour. The algorithm searches for a particular colour say red. As soon as the object is acquired, the drone tracks it as long as it is in view.
3. There could be several other methods for object detection and identification but here we use a blob detection technique. The on-board camera captures images at a specified speed in frames per second Every image in converted to grayscale by removing the pixels that do not match the pre-mentioned colour that we intend to track or are not within the threshold value given in the code.
4. This gives us the monochrome image and only the required contour is displayed in white and hence we know exactly what our target is.
5. Tracking the object depends on how big/small it appears in the frame. This can be used to determine relative distance to the object. If the object appears smaller, the UAV is farther away; larger indicates that the UAV is closer.
6. The computer vision heavy lifting is performed by OpenCV, the earlier mentioned open source, widely used computer vision library. It provides C++, Python, and Java APIs on all major desktop and mobile operating systems. Here we have used the python library.

F. DEPTH ANALYSIS:

As soon as the blob of the required colour is in the camera frame, OpenCV detects it. Once detected, we are able to request its apparent area in pixels. This area is stored in real time and serves as a baseline for later comparison. In the upcoming images, the current apparent area of the target is determined. If this area is greater than the baseline, the vehicle is closer to the target than it was initially. If smaller, the vehicle is farther from the target. This determines whether the aircraft is moving towards the target or away from it.

G. PSEUDO CODE:

```
Sixth Sense Arduino Target Detection.


// // Receive Image video from the camera through Arduino serial port and pass it to the program.
// // use colour recognition for TARGET detection.


Code Base:
 loop:
        // //in the program we have a rectangular frame consisting of four smaller frames.
        // //we use the frame to detect colour patterns in the video image to process the video image and locate the target.
        // //to move the drone towards the target.

        create frame
        smoothing of the video image.
        define Region of Interest on the frame for processing.
        threshold the image for colour for the specified colours.
        find contours by passing the threshold image and required parameters.

        // //We detect the position of the target in the video/Image and pass/transmit data to the Arduino
      // //accordingly.

        if there are contour:
                find the index of largest contour and define the pointer on the video accordingly.

                check the position of the target recognized along the x-axis and the y-axis of the frame.

                Conditions:
                if target in upper part of the frame:
                        send the command to controller to move forward - f.

                if target in lower part of the frame:
                        send the command to controller to move backwards - b.
                if target in left part of the frame:
                        send the command to controller to move Left - l.
                if target in right part of the frame:
                        send the command to controller to move Right - r.

release the camera and destroy the frames
```

BILL OF MATERIALS OF THE UAV (UNMANNED AERIAL VEHICLE): - Table 7-

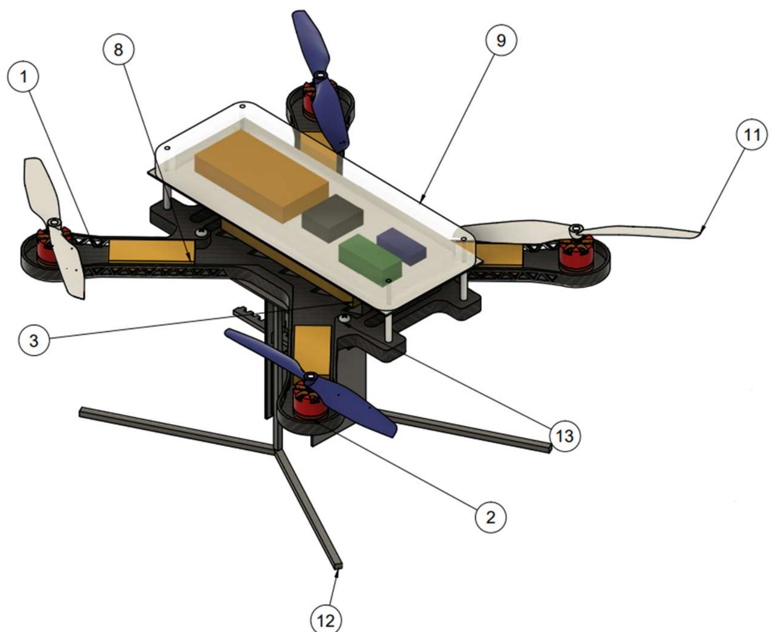


Fig. 18 Assembly of Drone

PART NO.	PART NAME	MATERIAL/SPECS	QUANTITY
1	Frame	CFRP	1
2	Motor	GT2215 BLDC	4
3	Battery	Li-Po	1
4	GPS	Neo-M9N-00B	1
5	Distance Sensor	LiDAR (ST VL53L1X)	1
6	Flight Control Module	Pixhawk 5x	1
7	Standard Base Board	Holybro Power Distribution Board	1
8	Esc	ReadytoSky 40A	4
9	Case	Acrylic	1
10	Propellor CCW	Carbon Nylon	2
11	Propellor CW	Carbon Nylon	2
12	Payload Dropping Mechanism	CFRP	1
13	Screw	MS, M5	4
14	Nut	MS, M5	4
15	Airspeed Sensor	MPXV7002DP	1

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