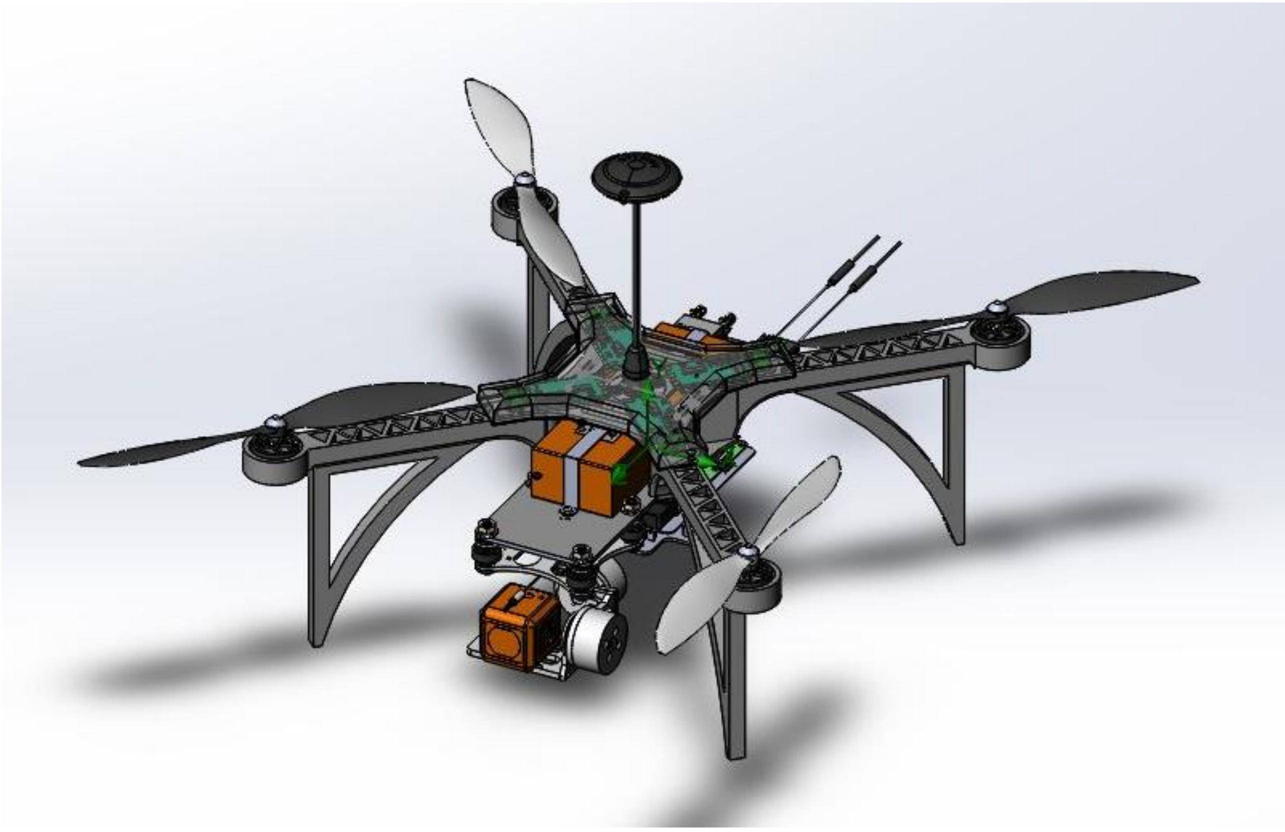
Design report
SAE Aerothon-2023



Team 12
National Institute of Technology, Srinagar

Aviato

Statement of compliance

APPENDIX A

STATEMENT OF COMPLIANCE

Certification of Qualification

Team Name: AVIATO	
University/Institute: National Institute of Technology, SRINAGAR	
Faculty Advisor: Dr. H.S. Pali	
Faculty Advisor's Email: hspali@nitsri.net	

Statement of Compliance

As Faculty Advisor, I certify that the registered team members are enrolled in collegiate courses. This team has designed the UAV for the SAE AEROTHON 2023 contest, without direct assistance from professional engineers, R/C model experts or pilots, or related professionals.

Signature of Faculty Advisor

Date 10. 06. 2023

Dr. Harveer Singh Pali
Assistant Professor
Department of Mechanical Engineering
NIT Srinagar, J&K, (India)

Team Captain Information:

Team Captain's Name: Gowtham Narayanasetty

Team Captain's E-mail: gowthamnarayanasetty2003@gmail.com

Team Captain's Phone: 9666771732

Note:
A copy of this statement needs to be included in your Design Report as page 2

SAEINDIA AEROTHON - UNMANNED AIRCRAFT SYTEM (UAS) DESIGN, BUILD AND FLY CONTEST 2023 PAGE | 32

Introduction:

The term UAV, which stands for Unmanned Aerial Vehicle, refers to an aircraft that operates without a human pilot on board. The main purpose of these unmanned aerial vehicles is to perform ISTAR (Information, Surveillance, Target Acquisition, and Reconnaissance) activities. The continuous advancements in drone autonomy have led to their increased utilisation in time-sensitive applications such as disaster monitoring, defence and border patrols, agriculture, and various other fields. Drones are also employed in telecom, geospatial mapping, agriculture and farming, media and entertainment, law enforcement, as well as oil and gas industries for tasks such as surveillance, land surveying, progress monitoring, and condition assessment using aerial photography and thermal imaging. Moreover, during the COVID-19 pandemic, numerous countries have utilised drones to spray disinfectants in public outdoor areas.

Problem Statement and Executive Summary:

Our team, known as Team Aviato, undertook the challenge of designing an autonomous unmanned aerial vehicle capable of delivering a specific payload with given mass and dimensions to a designated location. The UAV needed to have multi rotor capabilities for autonomous and manual delivery of the payload. Additionally, we had to design a reliable dropping mechanism to ensure the safe delivery of the payload to the target point.

After multiple rounds of design iterations and concept generation, we arrived at the final design of our drone. One notable feature of the design is the incorporation of a simple servo motor and a hook in the dropping mechanism. This design choice provides significant advantages making the design simple and leaving no chance for the payload to be dropped in between the mission effectively securing the payload during flight.our design team is proficient enough that they have designed a perfect, simple dropping mechanism

To power our drone, we carefully determined the electronic components required and calculated their power draw. Based on this analysis, we selected an appropriate battery that offers an approximate runtime of 11-12 minutes, which is suitable for our mission. Furthermore, we conducted computational analysis to validate that our design can withstand the mission requirements and complete it successfully without any failures.

Considering the autonomous operation of our drone, Our autonomous algorithm addresses this issue and ensures that the payload is dropped as close as possible to the target point while minimising the effects of drag.

For seamless communication, we carefully selected compatible transmitter and receiver systems based on the control distance required, as well as their stability and compatibility with other components. Our drone also incorporates an onboard gyro sensor and three axial angular velocity detection, which contribute to stability control. To enable wireless data acquisition, we chose telemetry modules based on their transmission speed and range, tailored to meet the mission's requirements.

It is worth highlighting that our team, consisting of expert designers and passionate engineers, developed this drone from scratch, investing significant effort and expertise into every aspect of its design and functionality.

A) ConceptualDesign:

I. High level physical law:

Upon careful analysis of the requirements and thorough comprehension of the problem statement, our team, Team Aviato, has made the decision to develop a quadcopter. This quadcopter will feature a unique and custom-designed drone frame exclusively crafted by our team. Additionally, it will be equipped with propellers, motors, ESCs (Electronic Speed Controllers), a flight controller, an RC (Radio Control) receiver, a power distribution board, sensors, a GPS module, an r-pi (Raspberry Pi) board, an HD camera, and various other components. The specific arrangement and comprehensive details of these parts will be elaborated in the subsequent text.

Physical Elements:

- Brushless Motors: These motors generate the necessary thrust for the UAV's flight. To counteract the rotational force produced by the propellers, quadcopters (drones) employ two clockwise motors and two counterclockwise motors. Our design incorporates brushless electric motors, which offer superior efficiency, reliability, and quieter operation compared to brushed motors.

- Propellers: Similar to the motors, our UAV will utilize two different types of propellers, each designed for a specific motor direction. As the propellers rotate, they create downward airflow over the airfoil surface, resulting in a pressure differential that enables the drone to take flight.

- FC (Flight Controller): The flight controller plays a crucial role by receiving inputs from the GPS module, various sensors, and the remote controller. It processes this data and generates output information for the ESCs (Electronic Speed Controllers) to regulate the motor functions accordingly.

- ESC (Electronic Speed Controller): These ESCs connect to the power distribution board (battery) and the flight controller. They receive signals from the flight controller and adjust the power distribution to the motors accordingly.

- PDB (Power Distribution Board): The power distribution board serves as the central hub that connects all the electrical components of the drone and draws power from the battery.

- Camera: Our drone incorporates a camera that captures real-time video feed, enabling FPV (First Person View) flight.

- Gimbal: The gimbal system allows for camera movement and stabilization, ensuring smooth and steady footage.

- LiPo Battery: LiPo, short for lithium-ion polymer battery, is a rechargeable battery that utilizes a polymer electrolyte instead of the more common liquid electrolyte. It is selected as the power source for our drone.

- Frame: The frame serves as the primary structural framework of the drone, housing and supporting all the components.

- GPS Module: This module combines a GPS receiver and magnetometer, providing essential data such as latitude, longitude, elevation, and compass heading from a single device.

- R/C receiver (RX): The R/C receiver is responsible for receiving signals from the remote controller, establishing the communication link between the user and the drone.

- Remote controller (TX): The remote controller serves as the user interface, allowing the operator to control the drone's movements and functions.

- FPV: FPV goggles or screens are used to observe the live video feed transmitted from the quadcopter, providing a first-person perspective during flight.

- Landing Gear: The landing gear is an essential component designed to facilitate safe landings of the drone on the ground.

- Holding Mechanism: This mechanism is specifically designed to securely hold the payload throughout the duration of the flight.

Physical element’s arrangement:

The following steps outline the arrangement of the physical elements involved in constructing our quadcopter:

1. Begin by trimming and soldering the positive and ground wires from the Electronic Speed Controller to their respective terminal points on the Power Distribution Board (PDB).

2. In this step, mount the brushless motors to each arm using screws. Attach the ESC to each arm and connect it to the corresponding motor to supply power for motor rotation. Then, mount the Lithium-ion battery and connect it to the Power Distribution Board.

3. Proceed by adding the receiver and flight controller, and wiring them together. Mount the receiver to one of the side panels, while the flight controller board is mounted to the frame.
4.Configure the model on the transmitter using a standard airplane profile and bind the receiver to the transmitter. Additionally, connect the ESCs to the appropriate side of the Flight Controller Board.

5. Before attaching the propellers, ensure that each motor is rotating in the correct direction. It is crucial for effective yaw control that diagonally opposite motors spin in the same direction.

6. To spin the motors, arm the flight controller by using the left joystick on the transmitter. Move the left joystick down (to zero throttle) and to the right. Holding it in this position for a few seconds will arm the flight controller, and increasing the throttle stick will cause the motors to spin. Verify the direction of rotation for each motor, which can be easily reversed by switching two of the wires between the ESC and the motor. At this stage, the quadcopter is ready for propeller attachment and flight controller tuning.

7. Next, mount the FPV Camera and GPS module on the frame, ensuring they are connected to the flight controller.
8.Connect the Raspberry Pi 4 to the camera module so that the installed machine learning algorithm made by Aviato can detect the desired payload drop location using image processing and GPS.

9. For the payload drop mechanism designed by Aviato , connect a Raspberry Pi 4 Model B to the flight controller.
10.connect the servo motor to the Raspberry Pi to receive the release signal from it.

B) Detailed design

I. Estimation of preliminary weight.

motors*4	20-100 grams
propeller*4	5 - 20 grams
esc*4	5-20 grams
Power distribution board	20 grams
chasis	200-500 grams
Flight controller	80 grams
Telemetry sensor	10-50grams
Rasberry pi 4	46 grams
Ultra sonic sensor	5-20 grams
Gps module	20 grams
Video transmission kit	50-200 grams

gyroscope	10 grams
First person view camera	5-30 grams
Payload grabbing mechanism	100-150 grams

Maximum weight of drone = **2.166kg**

Minimum weight of drone = **1.061 kg**

Excluding Payload of **200g**

II. Estimation of thrust required

Given an estimated weight of approximately 2000 grams for our quadcopter, it is prudent to maintain a 1.5:1 thrust-to-weight ratio. Therefore, we have determined that generating a total thrust of 3200 grams will be sufficient, considering additional flight operations such as hovering. To distribute this thrust evenly among the four motors, we aim for approximately 800 grams of thrust per motor. This calculation takes into account the customized chassis and serves as a precautionary measure to ensure safe and stable flight operations.

Motor used is 1000kV BLDC

Hence, thrust provided by each motor = 800 g approx.

Therefore , total thrust provided by all motors = 800*(no. Of motors)

= 800*4

Total thrust provided to drone = 3200 g approx.

III.Selection of propulsion system.

Justification for Choosing Motor and Propeller as the Propelling System for UAV

When designing a UAV (Unmanned Aerial Vehicle), selecting the propelling system is a critical decision that directly impacts flight performance, efficiency, and maneuverability. Among the various propelling systems available, the choice of motor and propeller offers several advantages over alternative systems like jet engines, rocket engines, and rotor systems. This justification provides data-driven reasons for selecting motor and propeller as the propelling system for our drone.

1. Efficiency:

Motor and propeller systems are known for their high efficiency, especially in the context of small to medium-sized UAVs. They convert electrical energy from the drone's battery directly into rotational motion, driving the propeller to generate thrust. Electric motors offer good power-to-weight ratios and can efficiently convert energy, resulting in effective propulsion. This efficiency translates into longer flight times, increased range, and improved battery utilization compared to alternative systems.

2. Weight-to-Thrust Ratio:

Motor and propeller systems provide excellent weight-to-thrust ratios, particularly when considering the lightweight nature of electric motors and propellers. Electric motors are compact, lightweight, and offer high power output relative to their size. Similarly, propellers are lightweight and generate significant thrust efficiently. This favorable weight-to-thrust ratio allows for increased payload capacity, improved maneuverability, and enhanced overall performance of the UAV.

3. Control and Maneuverability:

Motor and propeller systems offer precise control and maneuverability, making them suitable for a wide range of UAV applications. Electric motors can rapidly adjust their rotational speed, allowing for responsive control of thrust. This enables the UAV to perform precise maneuvers, maintain stability, and hover at specific altitudes or positions. The ability to control thrust and rotational speed provides versatility in flight operations, such as takeoff, landing, altitude adjustments, and agile movements.

4. Noise Levels:

Compared to alternative propelling systems like jet engines or rotor systems, motor and propeller systems produce relatively lower noise levels. Electric motors operate silently, minimizing the acoustic signature of the drone. This characteristic is especially crucial for applications that require stealth operations, noise-sensitive environments, or compliance with noise regulations. Reduced noise levels also contribute to better user experience and make the UAV less intrusive in residential or public areas.

5. Scalability and Customization:

Motor and propeller systems offer scalability and customization options to accommodate different UAV designs and requirements. Electric motors are available in various sizes and power ratings, allowing for selection based on the desired thrust and performance characteristics. Propellers come in different diameters, pitches, and blade configurations, providing flexibility in optimizing the UAV's efficiency, thrust output, and flight characteristics. This scalability and customization enable the propelling system to be tailored to specific mission objectives and payload requirements.

6. Safety:

Motor and propeller systems present relatively lower safety risks compared to alternative propelling systems like jet engines or rocket engines. Electric motors are self-contained units with fewer hazardous components and fuel sources. The absence of combustion processes reduces the risk of fuel-related accidents or fires. Additionally, propellers are typically enclosed within a protective housing or frame, mitigating the likelihood of accidental contact and reducing potential injury risks.

Conclusion:

Considering the efficiency, weight-to-thrust ratio, control and maneuverability, noise levels, scalability and customization options, and safety aspects, motor and propeller systems emerge as a justified choice for the propelling system in UAV design. The high efficiency and favorable weight-to-thrust ratio of electric motors and propellers contribute to increased flight performance, longer flight times, and improved payload capacity. Their precise control allows for agile maneuverability, while lower noise levels enhance operational versatility. Furthermore, scalability and customization options provide flexibility in meeting specific design requirements. Finally, the safety .Advantages of motor and propeller systems make them a reliable choice for UAV applications.

IV. UAV Sizing.

Team Aviato has dedicated significant effort to designing the UAV with a focus on maximizing strength while minimizing material usage and taking into consideration the aerodynamics of the aircraft.

In order to achieve an optimal design, the weight of the UAV and its components, including the Hub, propellers, and brushless motor thrust, were carefully considered. Through thorough analysis, our team determined the ideal length for the wheelbase, ensuring a balanced distribution of weight and optimal performance. To ensure structural integrity and handle the generated thrust during flight, the Rotor Arm length was aligned with the wheelbase length and the dimensions of the Hub.

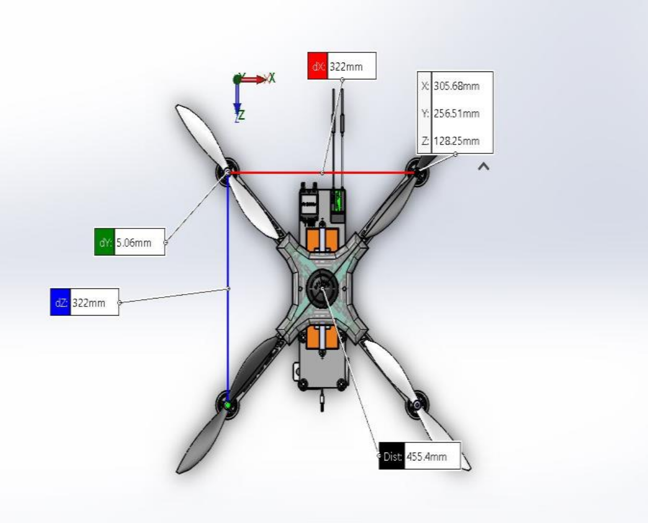
The Hub, serving as the central component housing all UAV elements, was meticulously designed to accommodate the arrangement of various components and provide ample space for the connecting wires. This careful consideration ensures efficient organization and easy maintenance.

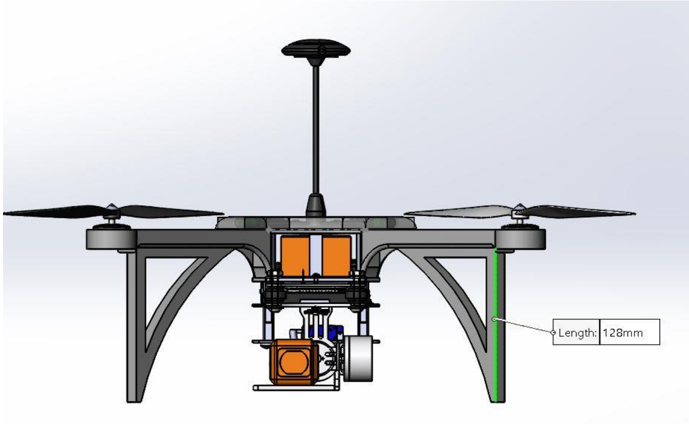
A critical aspect for achieving a high-quality UAV is the Propeller Clearance. Our team paid close attention to this factor, taking measurements that would result in the best possible aerodynamic conditions for improved stability and speed of the UAV. By carefully addressing Propeller Clearance, we enhance the overall flight characteristics and performance of the aircraft.

Considering the weight of the UAV, Team Aviato ingeniously integrated the landing gear and wings mechanism into a single, cohesive assembly. This integration not only optimizes space utilization but also ensures seamless functionality and operational efficiency.

Through these meticulous design choices and considerations, Team Aviato has strived to create a UAV that exhibits maximum strength, efficient material usage, and excellent aerodynamics. This comprehensive approach enhances the overall performance, stability, and functionality of our UAV, setting it apart as a remarkable achievement.

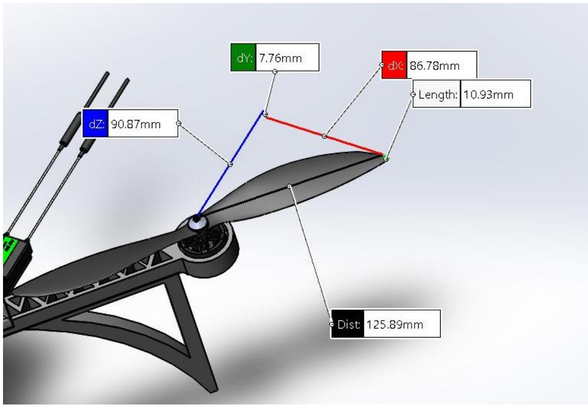
Rotor Arm = 177.81mm
Wheelbase = 455.42mm
Propeller Clearance = 203.22 mm
Landing gear =128 mm
hub = 155.15 x 155.15 mm

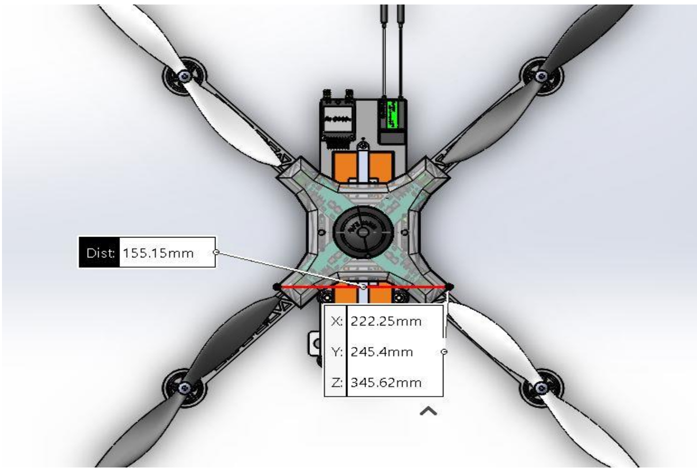




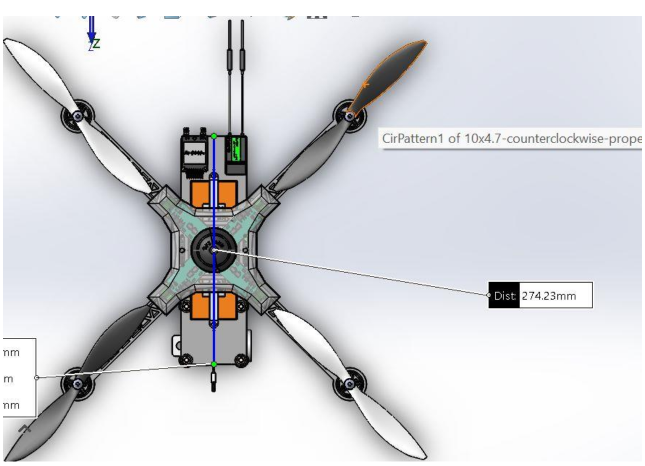
Landing gear=127.04mm

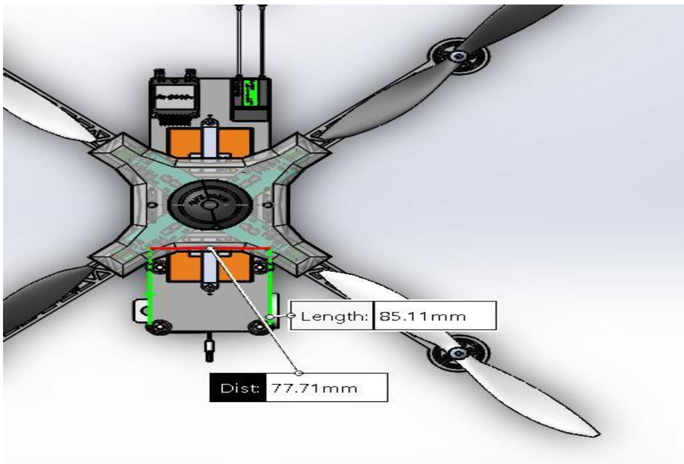
Wheelbase=455.42





Propeller clearance = Wheelbase- (2*propeller radius)
= 455.4 - (2* 125.89)
= 203.22





HUB dimensions

V.UAV Performance.

Required Thrust by one motor for the drone to fly = 850 grams
Required Thrust by 4 motors for the drone to fly = 850*4 = 3400 grams
We will look for motors which can provide thrust higher than this value of 3400 grams to be on the safer side.
Motor discovered: DYS D3536-8 1000 KV BLDC Motor
We are going to use a motor of maximum thrust 1270 grams giving a maximum power of 496 Watt.

So the power required for 4 motors = 496 * 4 = 1984 Watt
Power required by other components = 50 Watt
Efficiency of the motor to fly the drone = 0.5
Total power required by motor = 1984 * 0.5 = 992 Watt
Total power required in a drone = 992 + 50 = 1042 Watt

BATTERY SELECTION:
Flight time required = 11 minutes
Energy of battery required = (11*1042)/60 = 191.033-Watt h
We will now look for such a kind of battery.
BATTERY : Orange 22.2V 8000mAh 25C 6S Lithium Polymer Battery Pack
LINK: https://robu.in/product/orange-8000mah-6s-25c-50c-lithium-polymer-battery-pack-lipo/

VI.Material selection.

When it comes to choosing a material for the drone chassis, there are several options to consider, including plastic, carbon fiber, and glass fiber. In the case of Team Aviato, we have carefully evaluated these options and decided to justify our choice of plastic as the primary material over carbon fiber and glass fiber. This justification is based on various factors, such as cost-effectiveness, ease of manufacturing, impact resistance, flexibility, and weight reduction.

1. Cost-effectiveness:

One of the significant advantages of using plastic is its cost-effectiveness. While carbon fiber is known for its high-performance characteristics, it also comes with a considerably higher price tag. Glass fiber, although more affordable than carbon fiber, is still relatively more expensive than plastic. Considering the importance of cost in our decision-making process, plastic provides a more budget-friendly option without compromising on essential properties.

2. Ease of Manufacturing:

Plastic materials, such as carbon fiber-reinforced polymer (CFRP) or glass fiber-reinforced polymer (GFRP), are easier to manufacture compared to carbon fiber and glass fiber. Manufacturing processes for carbon fiber involve specialized techniques like layup and curing in controlled environments, which can be complex and time-consuming. Glass fiber composites also require specific manufacturing methods. In contrast, plastic components can be easily fabricated through injection molding or 3D printing, making them more accessible, scalable, and cost-effective to produce.

3. Impact Resistance:

While carbon fiber is known for its exceptional strength-to-weight ratio and high impact resistance, plastic materials can also provide sufficient impact resistance for drone chassis. CFRP and GFRP composites offer good impact resistance due to the reinforcement fibers, allowing them to withstand minor collisions or shocks during drone operations. Plastic materials can absorb and distribute impact forces, protecting internal components and maintaining the structural integrity of the drone.

4. Flexibility and Customization:

Plastic materials offer greater design flexibility and customization options compared to carbon fiber and glass fiber. Carbon fiber is relatively rigid and challenging to shape into complex designs, limiting the possibilities for customization. Glass fiber composites are more flexible but still not as versatile as plastic. Plastic materials can be easily molded or 3D printed, enabling the creation of intricate shapes, aerodynamic designs, and tailored features specific to the drone's requirements. This flexibility allows for optimized drone designs and the integration of additional components or sensors.

5. Weight Reduction:

Although carbon fiber is renowned for its lightweight properties, plastic materials, especially CFRP and GFRP composites, can provide a similar weight reduction advantage at a lower cost. Plastic composites offer a favorable strength-to-weight ratio, effectively reducing the overall weight of the drone. This weight reduction translates into increased flight time, improved maneuverability, and better energy efficiency. Plastic materials strike a balance between weight reduction and cost-effectiveness, making them suitable for a wide range of drone applications.

6. Availability and Accessibility:

Plastic materials are readily available and accessible in various forms, making them easier to source compared to carbon fiber and glass fiber. Carbon fiber and glass fiber may have limited availability in certain regions, requiring specialized suppliers or longer lead times for procurement. Plastic materials, on the other hand, are widely available and can be obtained from numerous suppliers, reducing logistical challenges and ensuring a more streamlined manufacturing process.

In conclusion, considering factors such as cost-effectiveness, ease of manufacturing, impact resistance, flexibility, and weight reduction, plastic materials emerge as a justifiable choice over carbon fiber and glass fiber for drone chassis. By selecting plastic as the primary material, Team Aviato can achieve a cost-efficient, reliable, and customizable solution that meets our specific requirements while still delivering high-performance drones.

VII. Sub system selection.

Subsystems for Communication unit:

1. **RC Receiver: Radio link R12DS**
   Reasons for selection: 4 km control distance, 12 channels, compatibility with Pixhawk flight controller.
2. **Data Telemetry: ZOONv1**
   Reasons for selection: Global frequency coverage, range from 6 km to 21 km (depending on data bandwidth configuration), hassle-free mesh functionality for MAVLINK packets, Cha-cha 20 encryption.
3. **Video Telemetry: TS832**
   Reasons for selection: Transfers videos in NTSC/PAL format, lightweight and small size, operates at high temperatures, suitable voltage range.
4. **RC Controller: Radiolink AT10**
   Reasons for selection: Operates on 2.4 GHz frequency, eliminates interference and glitching from other electronic components on the drone.

Subsystem for control and navigation unit:

1. **Flight Controller (Pixhawk 4):**
   It has various onboard sensors like a magnetometer, barometer, accelerometer, gyroscope, and temperature sensor for smooth control of the motion. We decided to use Pixhawk 4 over other flight controllers as it features more computing power and 2X the RAM than the previous versions. It also has additional ports for better integration and expansion, new sensors, and integrated vibration isolation. Also on comparing its weight to usability ratio is more than those of its competitors.

2. **GPS Module(GPS Module GPS NEO-M8N BDS Compass Module(3 in 1))**
   This GPS Module can measure with a time accuracy of 60 ns. Also, it can work with good consistency in the temperature range of -40 to 85 degrees celsius as it comes up with the main chip U-B-LOX M8030 KT and Built-in TCXO. Also, it has a wide range of use for APM flight controller; PIX flight controller; PX4 flight controller; the outlet terminal is directly compatible with the APM serial port and I2C port. Plug and play other flight controllers are also available in it.

VIII. CG Estimation and Stability Analysis.

1.CG Estimation

We have designed the chassis to be symmetric when viewed from top. This means that the center of gravity of our quadcopter can only shift in y direction. Here we will neglect the lighter components and consider only those components that can change the Centre of gravity significantly. We will take the center of chassis as our origin.

Component	Weight (m)	Distance from centre (Z- direction) (r)
Battery	500 g	17.5 mm
Gimbel and camera mount	100 g	76.2mm
Flight controller	40 g	72.2 mm
Motor	**80 *4= 320g**	**23.2 mm**

NOTE : We did not consider the weight of the chassis as we are taking the origin at the geometric Centre of chassis and we have assumed that the geometric Centre of chassis and Centre of gravity of chassis are at same position.

Position of COG from origin = (8750 + 7620 + 2888 + 7424) / (500 +100 + 40 + 320)
= 26682 / 960 = 27.79 mm

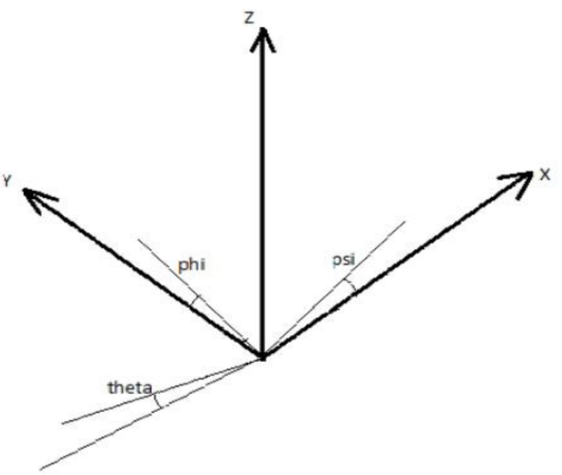
Thus our Centre of gravity of Quadcopter is 27.79 mm below the geometric Centre of the chassis.

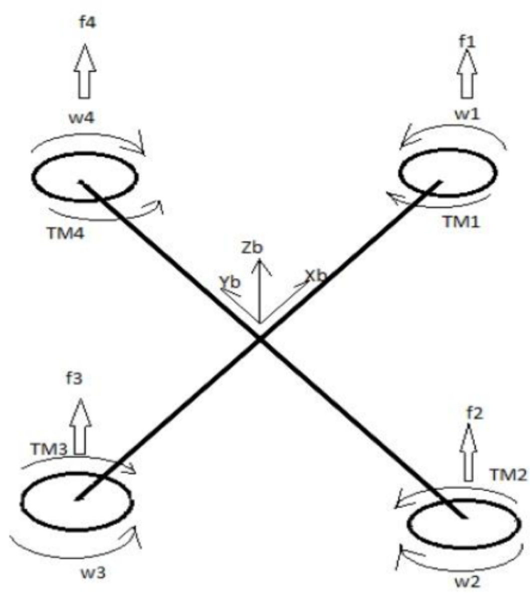
2.Stability analysis.

Quad copter is a flying robot, that has four propellers, two rotates clockwise and two counter clock wise. Two opposite rotation of propellers cancel out the rotation in z axis. For flight dynamics we need to discuss moments and forces acting on body. Product of force and distance defines torque. Quad copter arm acts as a lever arm and the propulsion from the each propeller acting as force. From the help of vector force diagrams, in the same plane two forces are positive, and two are negative y addition of these net force would be zero and spinning doesn't occur in hovering.

Body of quad copter is supposed as a rigid body and following assumptions are considered:
(a) Mass distribution is assumed constant.
(b) Structure is rigid and symmetrical.
(c) Origin of centre of gravity and fixed body frame coincides.

The structure of the quadcopter and its angular velocities, and torques are represented in the figure individually for 4 rotors. (W indicates angular velocity TM indicates torque f indicates force.)





Kinematics and dynamics of the quad rotor describes how the transformation is carried out between coordinate systems.it is essential to state coordinate systems and frames of reference. The usage of coordinate frames is needed to identify the attitude and location of the quad rotor in six degrees of freedom (6 DOF). For modelling of quad copter's dynamics two frames of references are considered, one is earth frame other is inertial frame. Earth frame is fixed and orthogonal axis (x y z) with unit vectors. Both frames are oriented at centre of mass of quadcopter that is angular velocity of quadcopter. Dynamics of quadcopter includes subsystems of motion which are translational and rotational and both frames are references for equation of motions and dynamics.

For stability analysis, we used the following dynamic equations:

Position vector: ξ=[xyz]

η=[$\emptyset\theta\varphi$]

Euler Angles: The orientation of the drone is described by Euler angles.

1. Rotation with respect to x - roll angle.
2. Rotation with respect to y - pitch angle.
3. Rotation with respect to z - yaw angle

ROTATION MATRICES FOR ANGLES:

$$R_{\emptyset} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & C_{\emptyset} & -S_{\emptyset} \\ 0 & S_{\emptyset} & C_{\emptyset} \end{bmatrix};$$

$$R_{\theta} = \begin{bmatrix} C_{\theta} & 0 & S_{\theta} \\ 0 & 1 & 0 \\ -S_{\theta} & 0 & C_{\theta} \end{bmatrix};$$

$$R_{\varphi} = \begin{bmatrix} C_{\varphi} & -S_{\varphi} & 0 \\ S_{\varphi} & C_{\varphi} & 0 \\ 0 & 0 & 1 \end{bmatrix};$$

The global rotation matrix is 'R':

$$R = R_\varphi R_\theta R_\emptyset = \begin{bmatrix} C_\varphi C_\theta & C_\varphi S_\theta S_\emptyset - S_\varphi C_\emptyset & C_\varphi S_\theta C_\emptyset + S_\varphi S_\emptyset \\ S_\varphi C_\theta & S_\varphi S_\theta S_\emptyset + C_\varphi C_\emptyset & S_\varphi S_\theta C_\emptyset - C_\varphi S_\emptyset \\ -S_\theta & C_\theta S_\emptyset & C_\theta C_\emptyset \end{bmatrix};$$

$$S_x = \sin x;$$

$$C_x = \cos x;$$

$$f_i = k\omega_i^2;$$

$$\tau_{Mi} = b\omega_i^2 + I_m \omega_i;$$

$$T = \sum_{i=1}^{4} f_i = K \sum_{i=1}^{4} \omega_i^2,$$

$$T_B = \begin{bmatrix} 0 \\ 0 \\ T \end{bmatrix};$$

$$\tau_B = \begin{bmatrix} \tau_\emptyset \\ \tau_\theta \\ \tau_\varphi \end{bmatrix} = \begin{bmatrix} lk(\omega_4^2 - \omega_2^2) \\ lk(\omega_3^2 - \omega_1^2) \\ \sum_{i-1}^{4} \tau_{Mi} \end{bmatrix};$$

$$m\ddot{\xi} = G + RT_B;$$

$$\begin{bmatrix} \ddot{x} \\ \ddot{y} \\ \ddot{z} \end{bmatrix} = -g \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} + \frac{T}{m} \begin{bmatrix} C_\varphi S_\theta C_{\emptyset +} S_\varphi S_\emptyset \\ S_\varphi S_\theta C_\emptyset - C_\varphi S_\emptyset \\ C_\theta C_\emptyset \end{bmatrix};$$

Euler-Lagrange Equations:

$$\mathcal{L}(q, \dot{q}) = E_{trans} + E_{rot} - E_{pot};$$

$$\mathcal{L}(q, \dot{q}) = \left(\frac{m}{2}\right) \dot{\xi}^T \dot{\xi} + \left(\frac{1}{2}\right) v^T I v - mgz;$$

Linear Euler-Lagrange equations:

$$f = RT_B = m\ddot{\xi} + mg \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix};$$

$J(\eta)$is Jacobian matrix

$$J(\eta) = J = W_\eta^T I W_\eta;$$

$$J = \begin{bmatrix} I_{xx} & 0 & I_{xx} S_\theta \\ 0 & I_{yy} C_\emptyset^2 + I_{zz} S_\emptyset^2 & (I_{yy} - I_{zz}) C_\emptyset S_\emptyset C_\theta \\ I_{xx} S_\theta & (I_{yy} - I_{zz}) C_\emptyset S_\emptyset C_\theta & I_{xx} S_\theta^2 + I_{yy} S_\emptyset^2 C_\theta^2 + I_{zz} C_\emptyset^2 C_\theta^2 \end{bmatrix};$$

Rotational energy $Erot$:

$$E_{rot} = (\tfrac{1}{2}) v^T I v;$$

$$E_{rot} = (\tfrac{1}{2}) \ddot{\eta}^T J \ddot{\eta};$$

$$\tau = \tau_B J \ddot{\eta} + \frac{d}{dt}(J)\dot{\eta} - \frac{1}{2}\frac{\partial}{\partial \eta}(\dot{\eta}^T J \dot{\eta}) = J\ddot{\eta} + C(\eta, \dot{\eta})\dot{\eta};$$

C(η, η) is the Coriolis term which contains gyroscopic and centripetal terms:

$$C(\eta, \dot{\eta}) = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix};$$

$$C_{11} = 0;$$

$$C_{12} = (I_{yy} - I_{zz})(\dot{\theta} C_\emptyset S_\emptyset + \dot{\varphi} S_\emptyset^2 C_\theta) + (I_{zz} - I_{yy})\dot{\varphi} C_\emptyset^2 C_\theta - I_{xx}\dot{\varphi} C_\theta.$$

$$C_{13} = (I_{zz} - I_{yy})\dot{\varphi} C_\emptyset S_\emptyset C_\theta^2.$$

$$C_{21} = (I_{zz} - I_{yy})(\dot{\theta} C_\emptyset S_\emptyset + \dot{\varphi} S_\emptyset C_\theta) + (I_{yy} - I_{zz})\dot{\varphi} C_\emptyset^2 C_\theta + I_{xx}\dot{\varphi} C_\theta.$$

$$C_{22} = (I_{zz} - I_{yy})\dot{\emptyset} C_\emptyset S_\emptyset.$$

$$C_{23} = I_{yy}\dot{\varphi} S_\emptyset^2 S_\theta C_\theta - I_{xx}\dot{\varphi} S_\theta C_\theta + I_{zz}\dot{\varphi} C_\emptyset^2 S_\theta C_\theta.$$

$$C_{31} = (I_{yy} - I_{zz})\dot{\varphi} C_\theta^2 S_\emptyset C_\emptyset - I_{xx}\dot{\theta} C_\theta.$$

$$C_{32} = (I_{zz} - I_{yy})(\dot{\theta} C_\emptyset S_\emptyset S_\theta + \dot{\emptyset} S_\emptyset^2 C_\theta) + (I_{yy} - I_{zz})\dot{\emptyset} C_\emptyset^2 C_\theta + I_{xx}\dot{\varphi} S_\theta C_\theta - I_{yy}\dot{\varphi} S_\emptyset^2 S_\theta C_\theta - I_{zz}\dot{\varphi} C_\emptyset^2 S_\theta C_\theta.$$

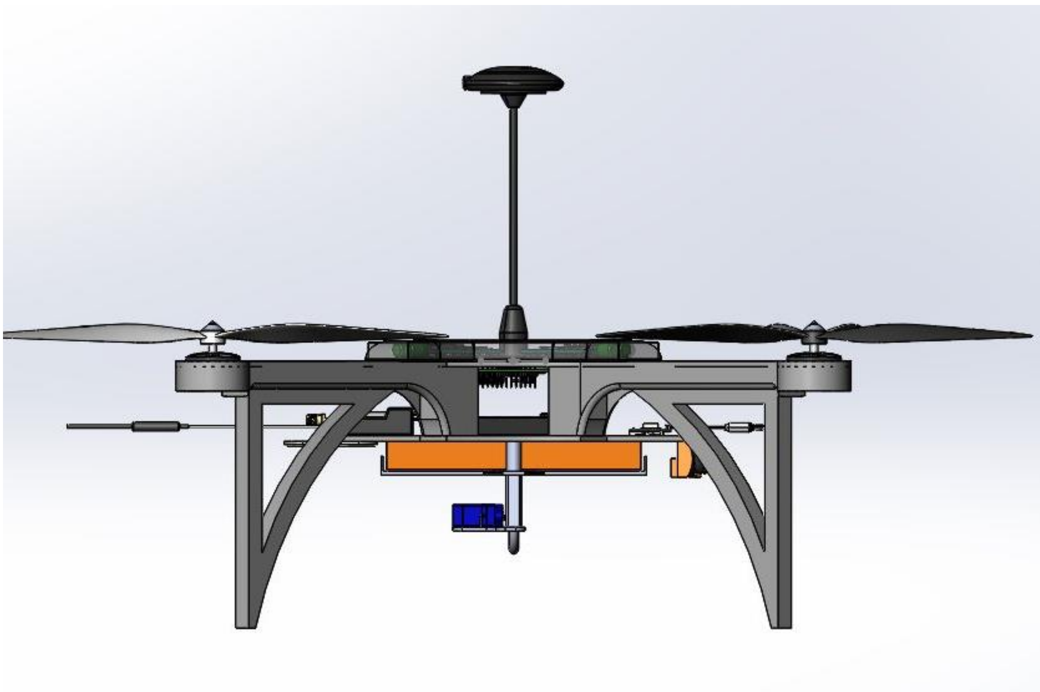
$$C_{33} = (I_{yy} - I_{zz})\dot{\emptyset} C_\emptyset S_\emptyset C_\theta^2 - I_{yy}\dot{\theta} S_\emptyset^2 C_\theta S_\theta - I_{zz}\dot{\theta} C_\emptyset^2 C_\theta S_\theta + I_{xx}\dot{\theta} C_\theta S_\theta.$$

By simplifying equation for η we get the following equation:

$$\ddot{\eta} = J^{-1}(\tau_B - C(\eta, \dot{\eta})\dot{\eta}).$$

IX. Preliminary CAD model.

Trimetric View



Side View

Top View

Front View

Computational analysis :

Team Aviato has successfully conducted a comprehensive computational analysis of our drone design using Autodesk Fusion 360. Through diligent effort and iterative design changes, we have achieved remarkable improvements in the structural integrity and safety of our drone.
By considering a thrust load of 9.8 Newtons per motor, a decentralized load of 1 kg, and accounting for the gravitational forces acting on the chassis, we conducted a simulation on chasis that yielded impressive results. Our initial design had a safety factor of 0.38, indicating a relatively low level of structural reliability. However, with careful adjustments and enhancements, we have significantly raised the safety factor to an outstanding value of 10.06.

During the simulation, we monitored several critical parameters to assess the performance of our drone design. The maximum stress experienced in the structure was measured at 2.754 MPa, which demonstrates the robustness of our design under load. We also observed a maximum displacement of 0.2364 mm, indicating minimal deformation and excellent structural stability.
Furthermore, the maximum reaction force encountered was 8.53 Newtons, which indicates our drone can withstand substantial external forces without compromising its integrity. The maximum strain recorded was 0.00194, highlighting the efficiency of our design in maintaining its shape and resisting deformation. In terms of contact pressure, we observed a maximum value of 3.065, further assuring the durability of our drone.

Finally, the maximum contact force reached 6.326 Newtons, indicating that our drone's components can withstand contact forces and maintain their functionality without failure. The team's diligent efforts in analyzing and refining the design have yielded remarkable results. By increasing the safety factor from 0.38 to 10.06, we have significantly enhanced the structural reliability and safety margin of our drone. These achievements reflect the team's dedication, expertise, and commitment to delivering a high-performing and secure drone design.

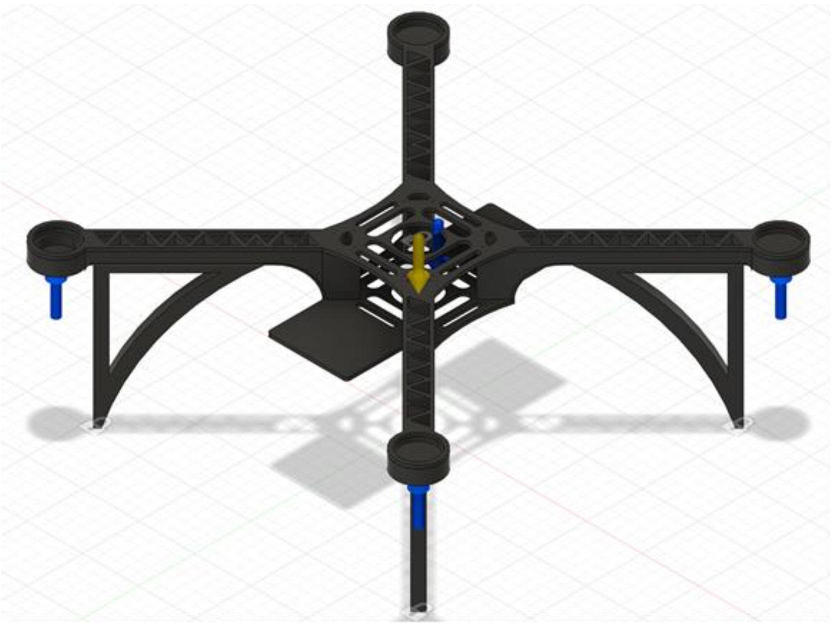


Fig 10.1 Drone overview

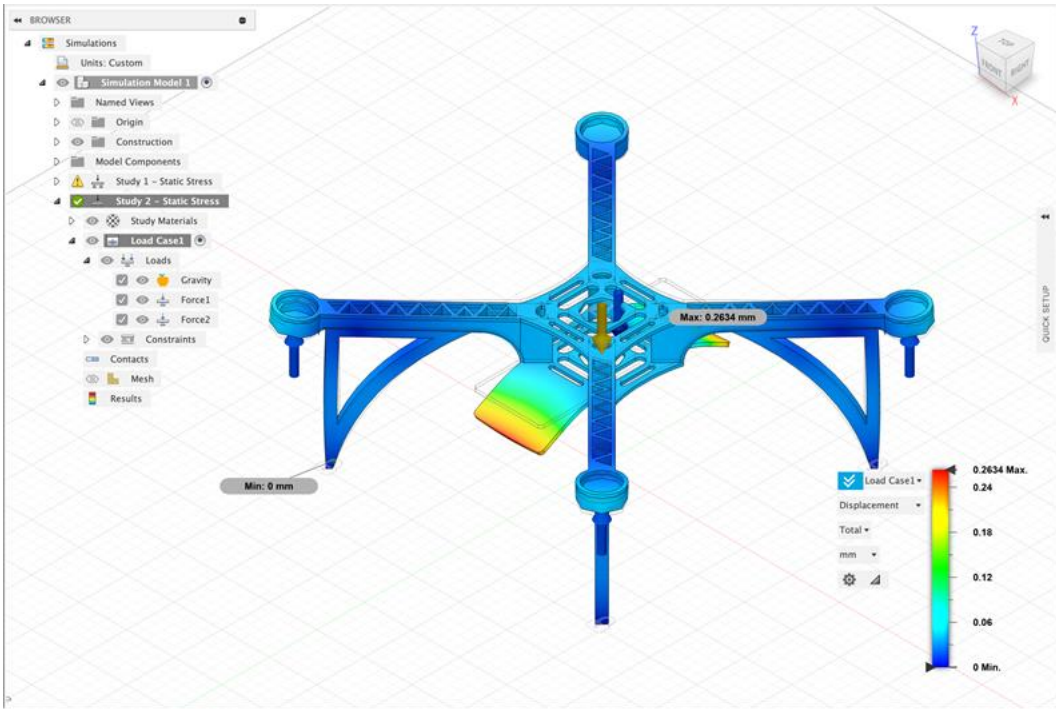


Fig 10.6 Displacement

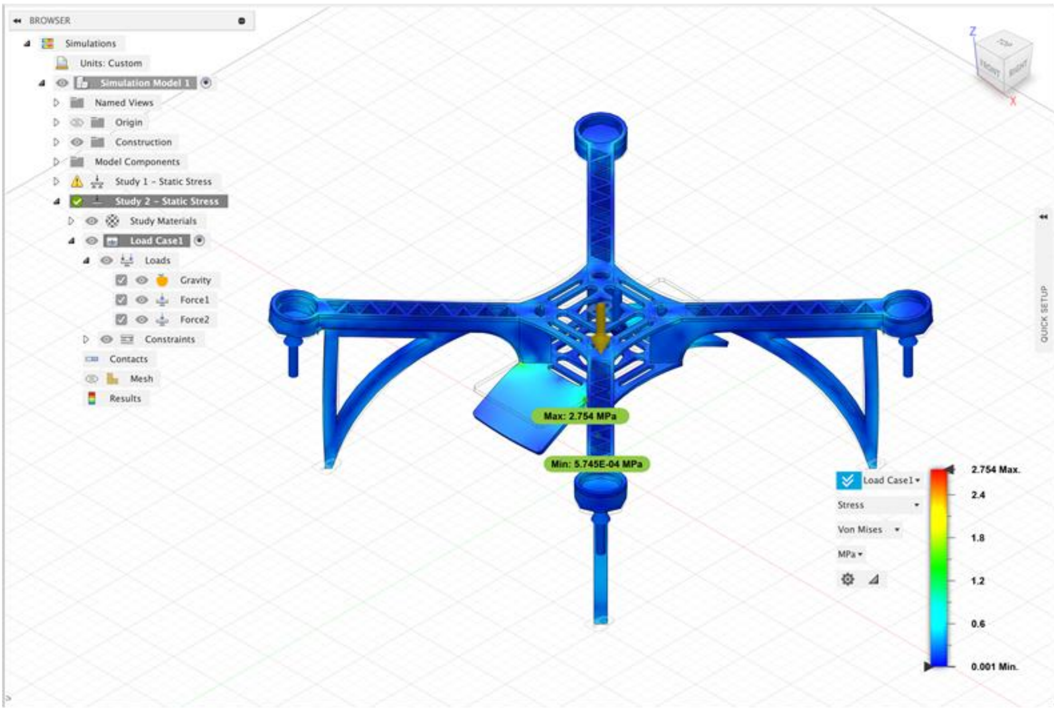


Fig 10.7 Stress

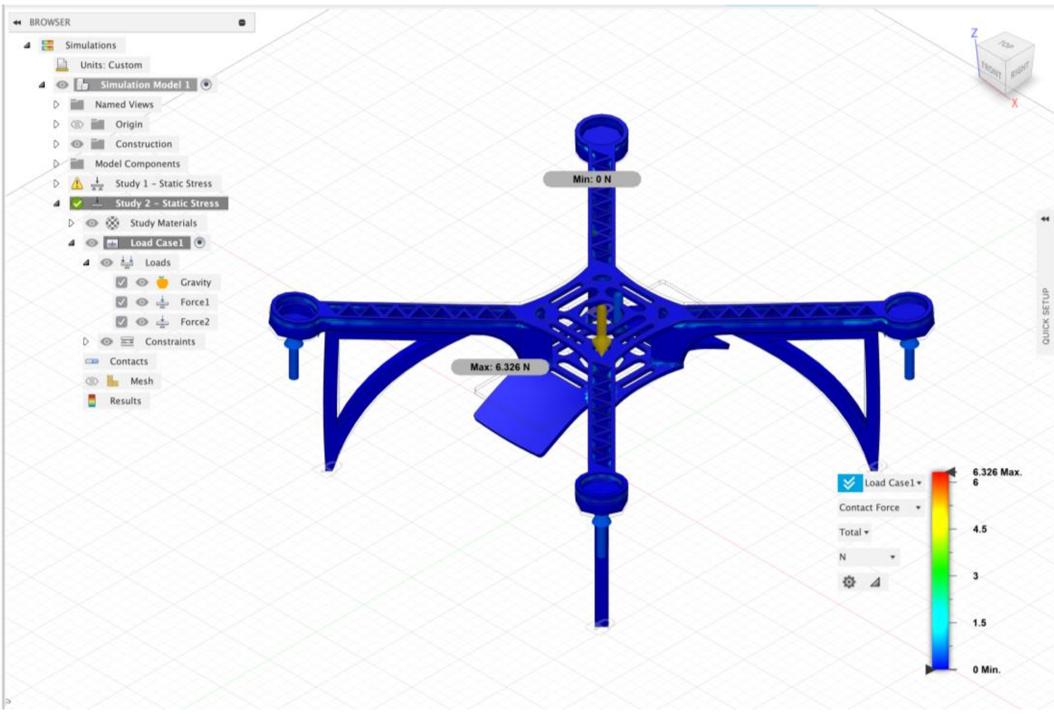


Fig 10.2 Contact Force

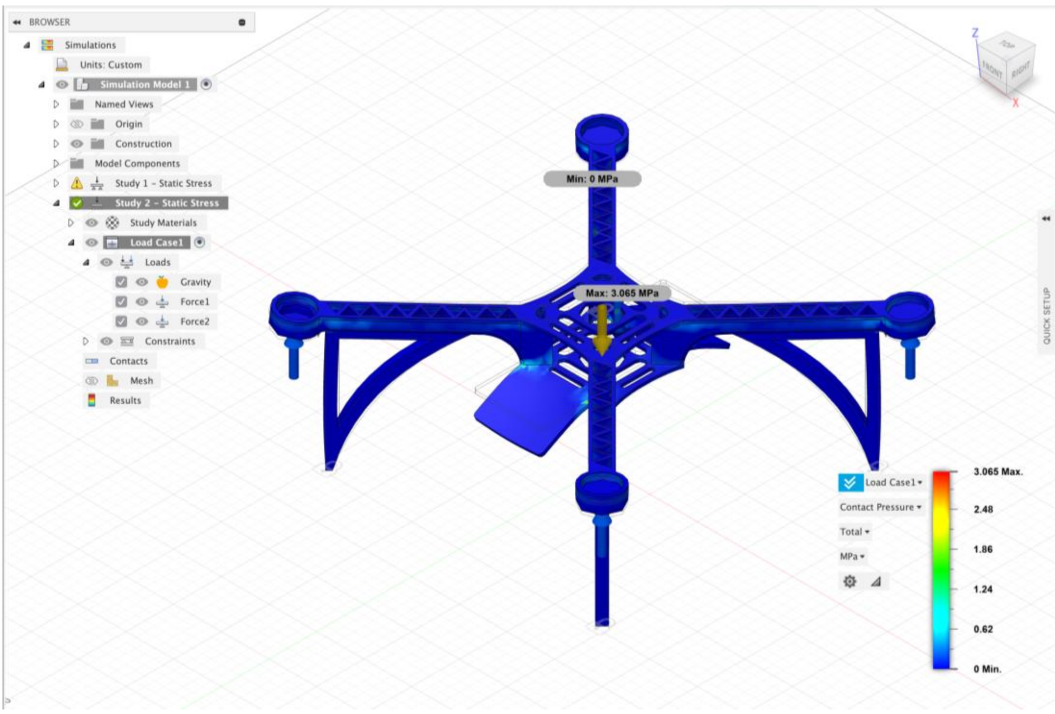


Fig 10.3 Contact pressure

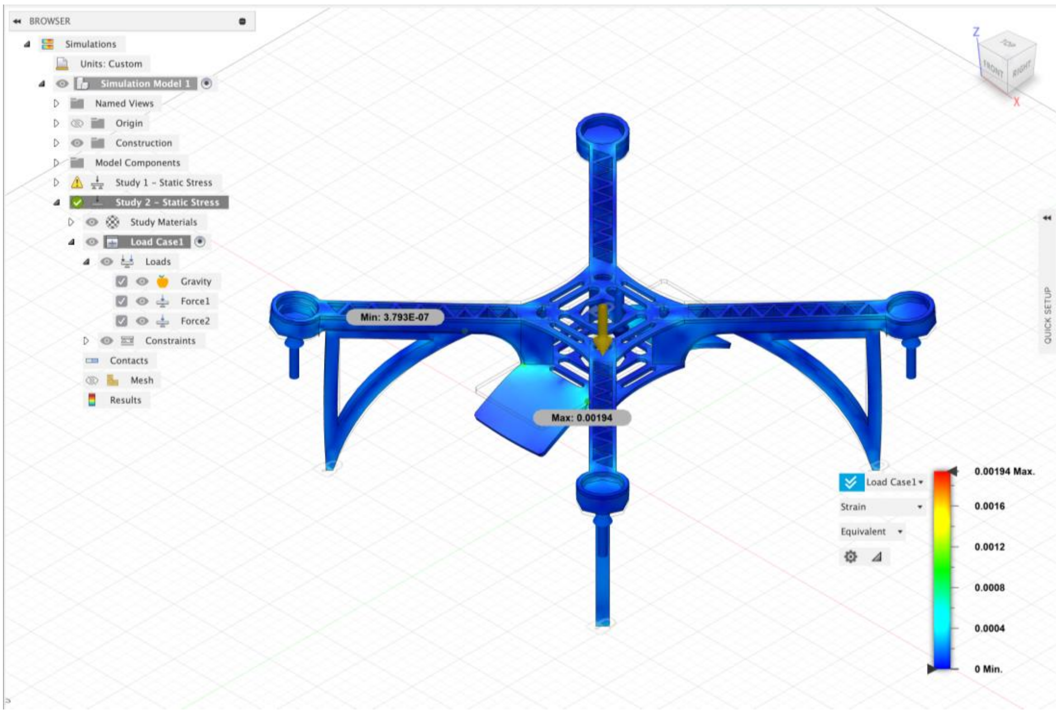


Fig 10.4 Strain

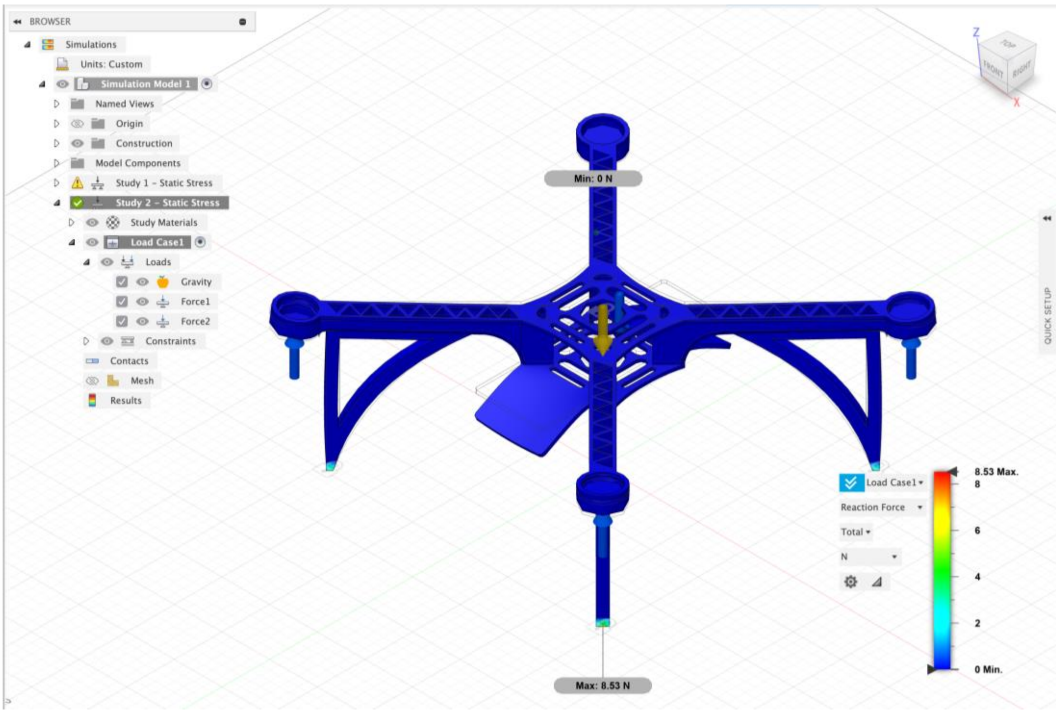


Fig 10.5 Reaction Force

▪

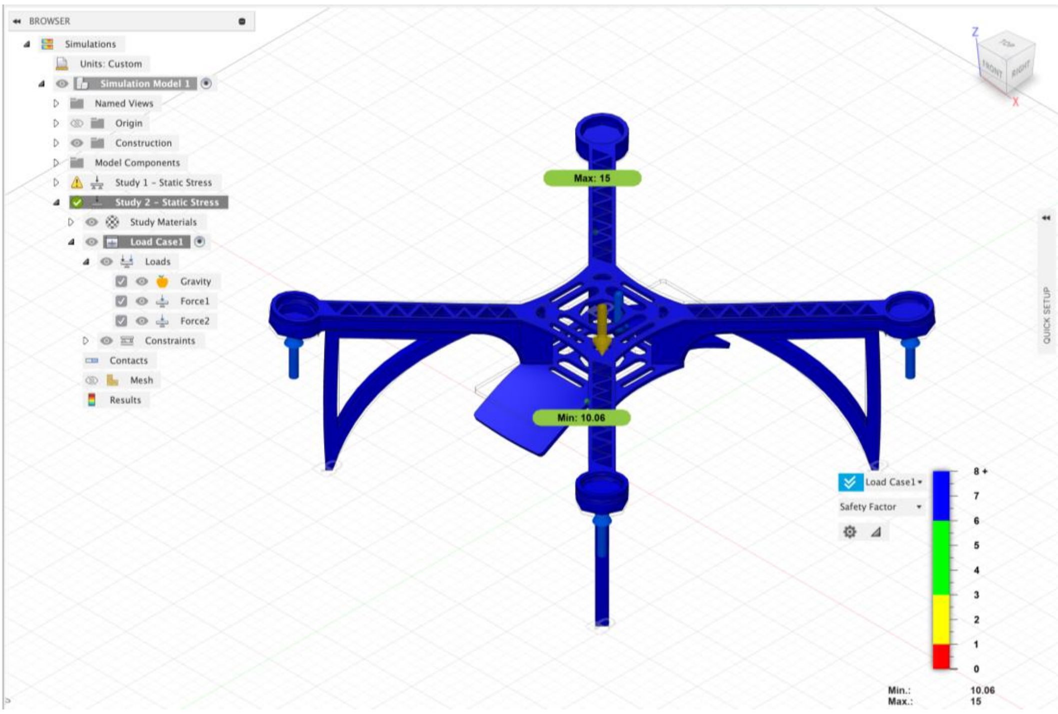
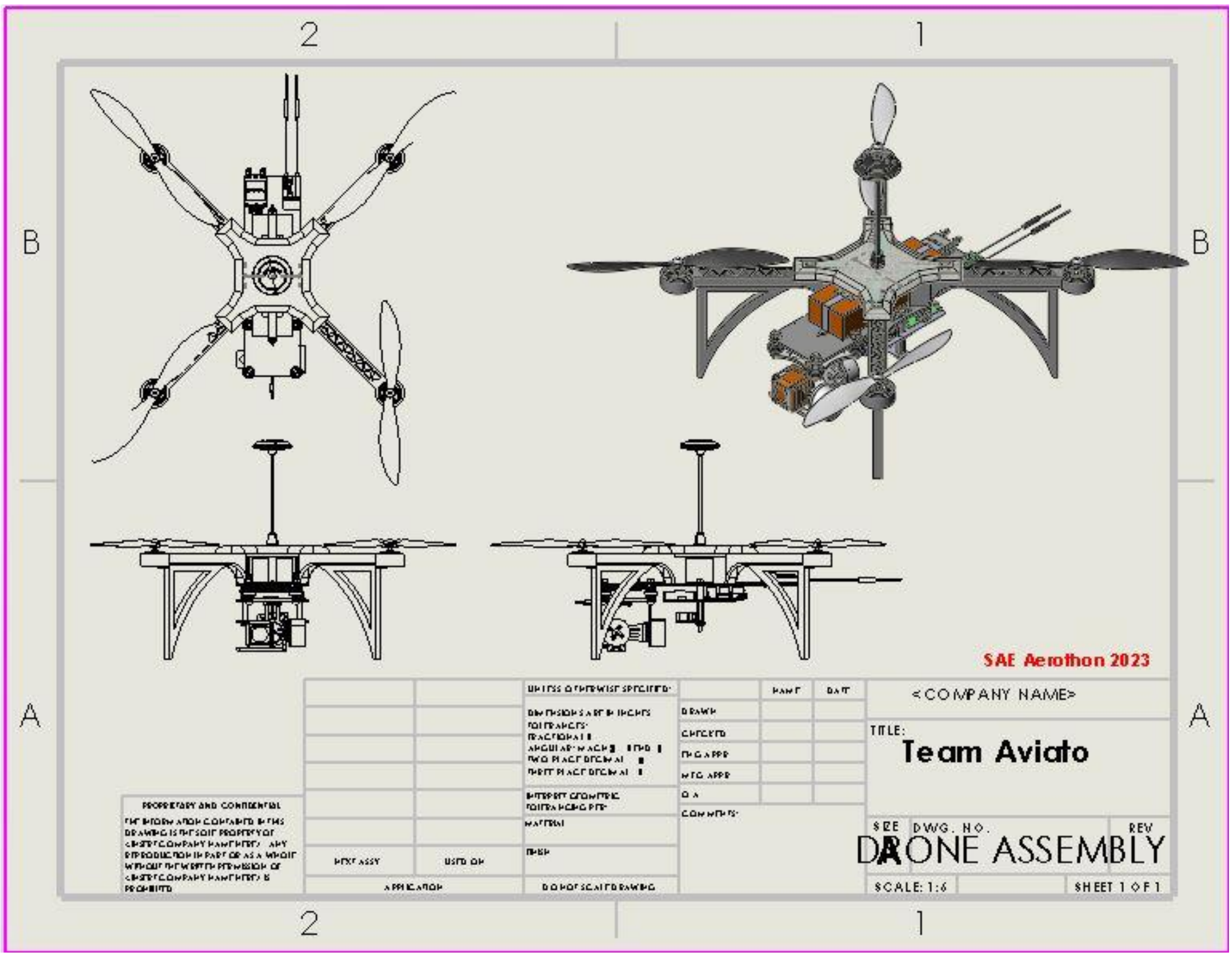
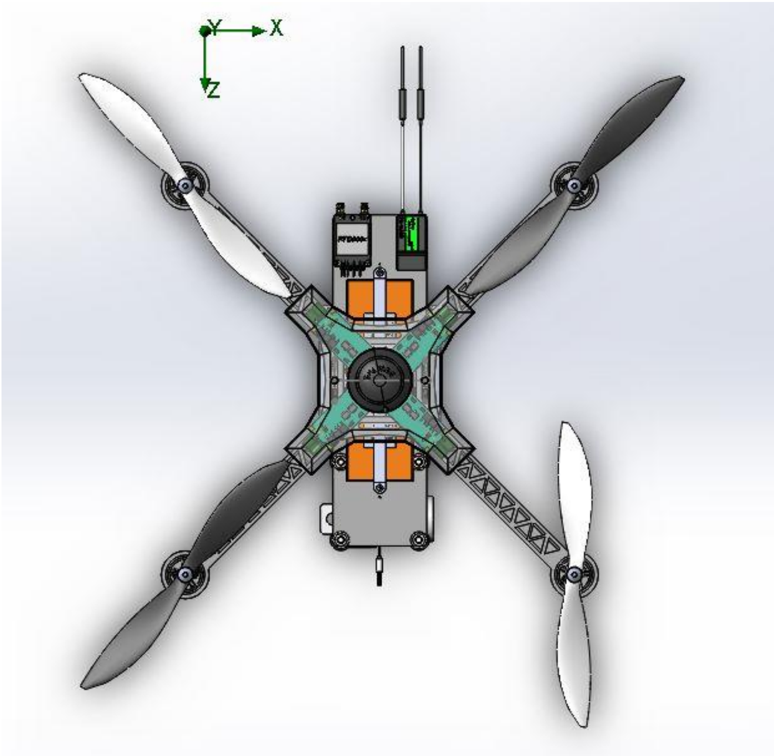


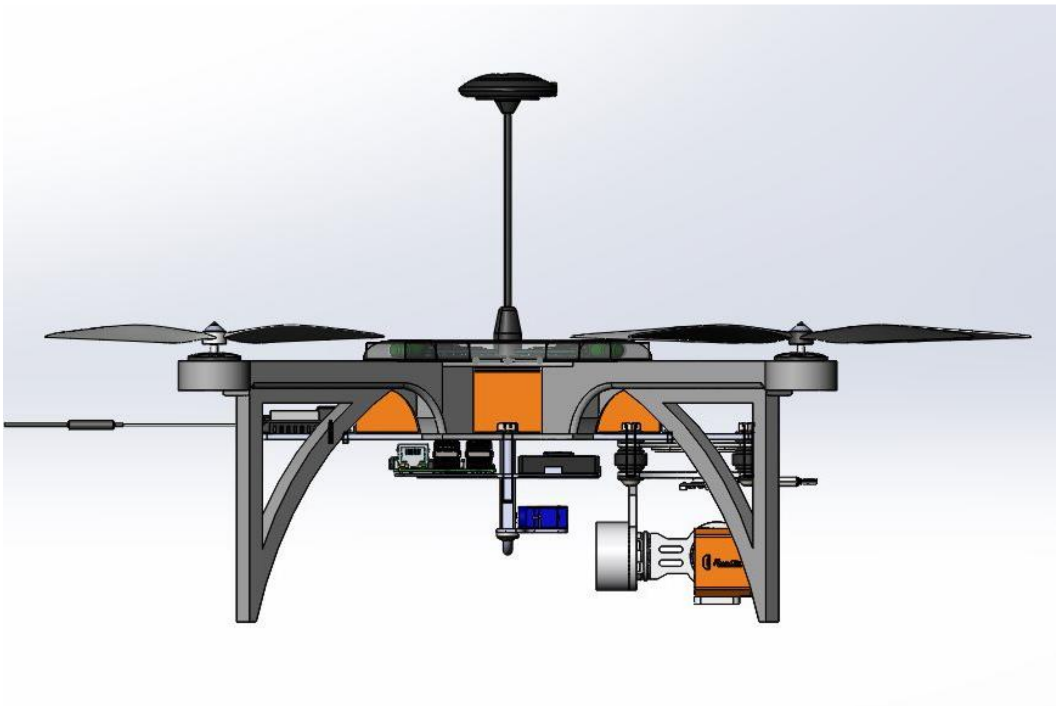
Fig 10.8 Safety Factor

OPTIMIZED FINAL DESIGN:



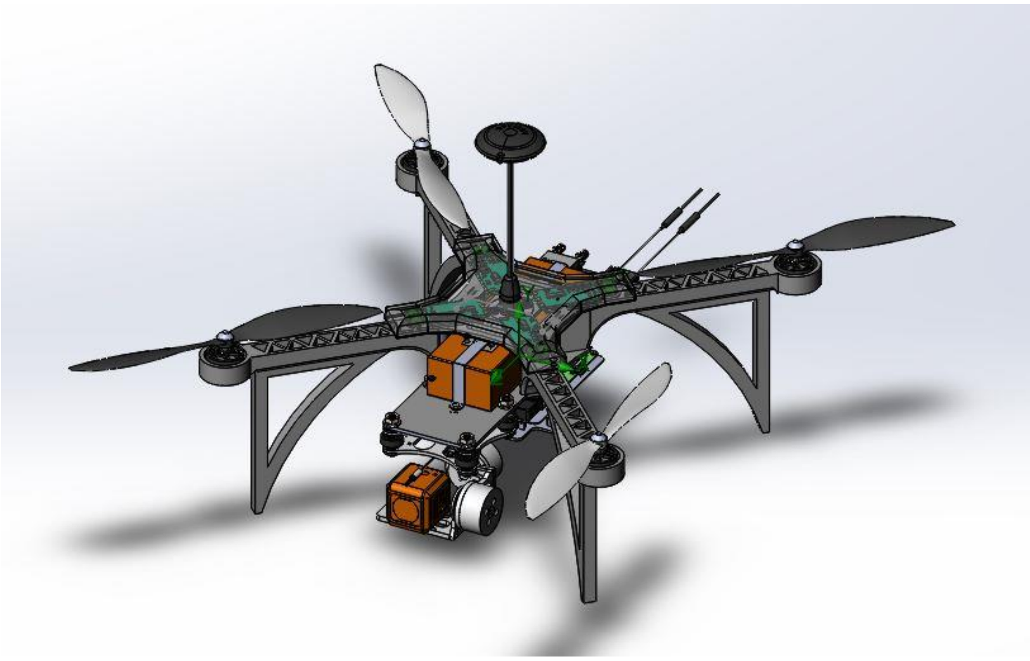


TOP VIEW



Side view

Front view



Trimetric view

Summary of design changes :

S.no	Design changes	Reason
1	shifted the position of battery to the centre section of drone	To ensure that CG is at centre of drone.
2	Changing the battery capacity from 3000 mah to 8000mah	To get required time of flight
3	Installed a Gimble for FPV camera	For getting dual axis rotation to detect target better
4	Changed the position of power distribution board	For optimum space utilisation and making the drone more compact

XII.Detailed Weight Breakdown

Understanding the weight distribution of drone components is crucial for optimizing flight performance, ensuring stability, and maintaining safety. Below is the detailed weight breakdown and dimensions of the key components of the drone and their respective weights.

COMPONENT NAME	WEIGHTS (grams)	Dimensions
Drone Battery (LiPo)	260 g	140 x 43 x 20(mm)
BLDC (1000kV)	99g	Motor size(mm): Φ35*36 Shaft size(mm): Φ5mm
ESC	26g	12 × 9 × 2 cm
Customised flight chassis	400g (w/out electronics)	Width: 450mm Height: 55mm
FLIGHT CONTROLLER	0.163 kg	20 × 11 × 6 cm
GPS M8N	23 gm	54 x 22 (Dia x W)
Propellers (10x4.5 inch)	15g	Diameter: 10" (25.4 cm) Pitch: 4.5" (11.43 cm)
CAMERA & GIMBAL	100 to 300g (estimated)	8x8x5cm (estimated)

1. Frame:
The frame serves as the main structural component of the drone, providing support and housing for all other components. The weight of the frame can vary significantly depending on the material used. Common materials include carbon fiber, aluminum, and plastic. The weight of the frame typically ranges from 200 grams (for smaller drones) to 600 grams (for larger, professional-grade drones). Team Aviato's customised plastic frame weighs around **400 grams.**

2. Motors and Propellers:
The weight of these components depends on the motor type (brushed or brushless) and the propeller size. On average, a motor can weigh between 20 to 40 grams, while a propeller weighs around 5 to 10 grams. Therefore, for a quadcopter (4 motors), the total weight of motors and propellers can range from 100 to 200 grams. From the table above the total weight of motor and propellers sums up around
114 grams using BLDC 1000kV & Propellers (10x4.5 inch).

3. Battery:
The battery is a crucial component that powers the drone's motors and electronics. The weight of the battery is determined by its capacity (measured in milliampere-hours, mAh) and chemistry (typically lithium-polymer or LiPo). Battery weights can range from 50 grams for smaller drones to over 500 grams for high-capacity batteries used in professional applications. Using a 3300 Mah 30c Drone Battery LiPo Battery the weight of the battery is **260 grams**

4. Flight Controller: The flight controller is the "brain" of the drone, responsible for receiving input from sensors and transmitting commands to the motors. The weight of a flight controller can vary depending on its features and complexity, ranging from 10 to 50 grams. The exact weight of the flight controller used is **163 grams.**

5. Camera and Gimbal:
If the drone is equipped with a camera for aerial photography or videography, the weight of the camera and gimbal assembly should be considered. Camera weights can range from a few grams for lightweight action cameras to several hundred grams for professional-grade cameras. Gimbals, which provide stabilization, generally weigh between 100 to 300 grams. (**Actual weight ?**)

6. Transmitter and Receiver:
For remote control, drones require a transmitter (remote controller) and a receiver. The weight of these components depends on the technology used (such as 2.4 GHz or 5.8 GHz) and the number of channels supported. The weight of a transmitter typically ranges from 200 to 500 grams. Team Aviato is using transmitter which weighs **410 grams** and receiver of **15 grams.**

7. Other Components:

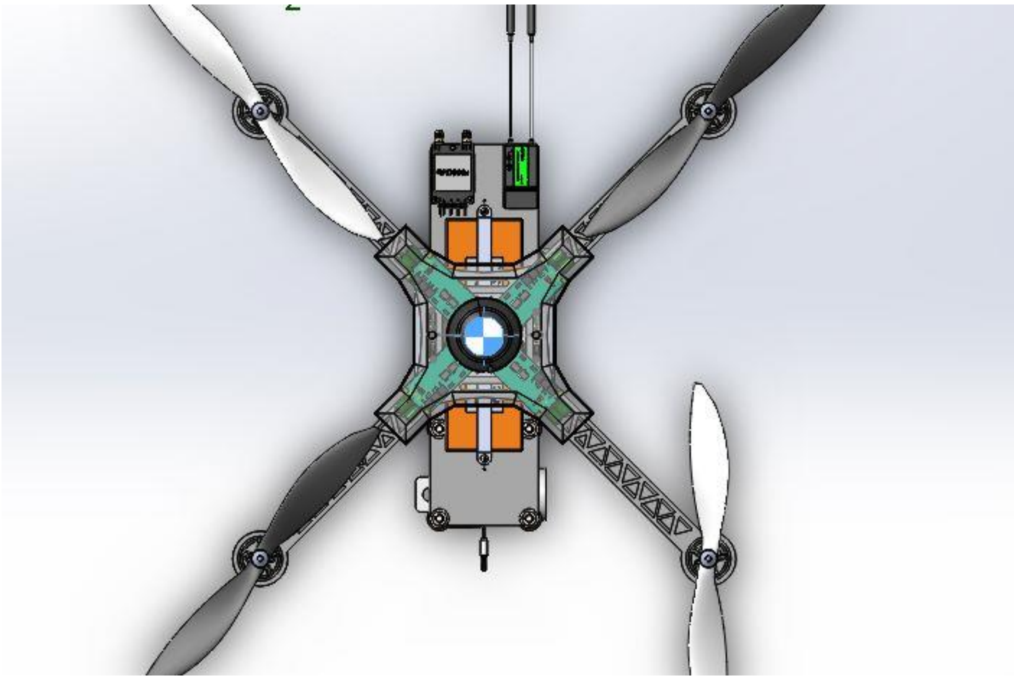
Additional components, such as GPS modules, sensors (e.g., altimeter, compass), LED lights, and landing gear, electronic speed controller also known as ESCs can contribute to the overall weight of the drone. These weights vary based on the specific requirements and features of the drone. Summing up the weights of these components the figures equals **319 grams.** Refer the table above for the same.

Conclusion:

Understanding the weight distribution of drone components is essential for optimizing flight performance, flight time, and payload capacity. It is important to state that the weights provided here are general estimates taken from the specification provided by the component manufacturers, and actual weights may vary.

CG of final optimized design

Front



TOP

13.UAV performance recalculation.

Required Thrust by one motor for the drone to fly = 850 grams
Required Thrust by 4 motors for the drone to fly = 850*4 = 3400 grams
We will look for motors which can provide thrust higher than this value of 3400 grams to be on the safer side.

Motor discovered : DYS D3536-8 1000 KV BLDC Motor
We are going to use a motor of maximum thrust 1270 grams giving a maximum power of 496 Watt.

So the power required for 4 motors = 496 * 4 = 1984 Watt
Power required by other components = 50 Watt
Efficiency of the motor to fly the drone = 0.5
Total power required by motor = 1984 * 0.5 = 992 Watt
Total power required in a drone = 992 + 50 = 1042 Watt

BATTERY SELECTION :

Flight time required = 11 minutes
Energy of battery required = (11*1042)/60 = 191.033-Watt h

We will now look for such a kind of battery.

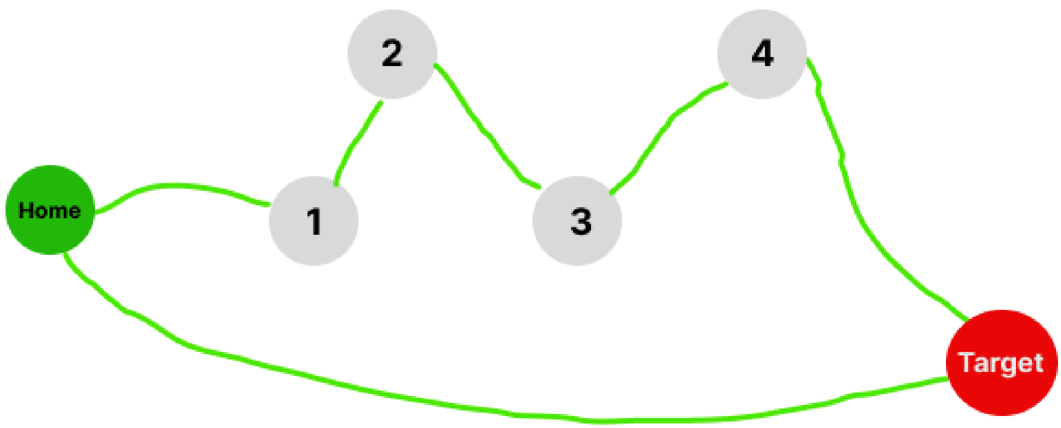
BATTERY : Orange 22.2V 8000mAh 25C 6S Lithium Polymer Battery Pack
LINK: https://robu.in/product/orange-8000mah-6s-25c-50c-lithium-polymer-battery-pack-lipo/

C) Final UAV specifications and bill of materials.

Parts	Weight	Price	QTY.	
DRONE CHASIS	446.86	5500/-	1	5500/-
BLDC motor	60g	1405/-	4	5620/-
ESC 40 amp	82.96g	1050/-	4	4200/-
Pixhawk4	40g	16905/-	1	16905/-
Battery Lipo 8000mAh	720g	11799/-	1	11799/-
GPS_MN8	26.73g	810/-	1	810/-
video reciever	22g	3349/-	1	3349/-
Servo Motor	9g	106/-	1	106/-
RFD900X Data telemetry	11g	33000/-	1	33000/-

10x4.7-clockwise-propeller	10g	650/-	2	1300/-
10x4.7-counterclockwise-propeller	10g	650/-	2	1300/-
RaspberryPi 4	37g	8499/-	1	8499/-
screw	20g	20/-	10	200/-
Gimbal 2 axis	61.84g	3765/-	1	3765/-
RC Module	14.37g	4975/-	1	4975/-
Power distribution board	9.92g	329/-	1	329/-
FPV camera	56g	10000/-	1	10000/-
TOTAL				1,10,357/-

D) Methodology for autonomus operations.



The methodology for autonomous operations outlined in the provided text involves several steps and algorithms to enable the drone to perform specific tasks autonomously.

1. Initial Setup:

To facilitate autonomous operations, the drone is equipped with a Raspberry Pi and a Pixhawk flight controller. The Raspberry Pi serves as the onboard computer, while the Pixhawk controls the flight dynamics and communication with the drone's subsystems. The precise geolocation coordinates for the target location and hotspots are determined and stored.

2. Waypoint Setup:

Waypoints are defined using Mission Planner, a ground control software. For each hotspot and the target location, specific coordinates are configured to guide the drone's navigation. These waypoints create a predefined flight path for the drone to follow autonomously.

3. Home to Hotspot:

The drone takes off from the home location and maintains a constant altitude of 30 meters. As the drone approaches a hotspot, it uses the barometer sensor to initiate a controlled descent. The barometer provides accurate altitude readings, allowing the drone to gradually lower itself to a predetermined height, typically 20 meters above the hotspot.

To ensure precise alignment, advanced computer vision technology is employed. The drone's camera is positioned directly below the drone, achieving a 0-degree angle alignment with respect to the hotspot. This alignment is crucial for capturing high-quality images using the Raspberry Pi camera module.

The captured image plays a vital role in the hotspot detection process. It contains valuable visual data that can be processed and analyzed using computer vision algorithms. By leveraging image classification and pattern recognition techniques, the captured image can be examined to identify specific features, analyze patterns, or detect anomalies relevant to the hotspot.

To transfer the captured image from the Raspberry Pi to the Pixhawk flight controller, the Mavlink protocol is utilized. Mavlink establishes a seamless communication link between the onboard computer and the flight controller, enabling the transmission of data, including images, for real-time monitoring and analysis.

Telemetry is employed to share the captured image with the ground station or connected devices. This allows stakeholders to access visual information from the hotspot in real-time, enabling them to make informed decisions or take appropriate actions based on the detected data.

4. Hotspot to Target:

After completing the hotspot analysis, the drone proceeds to the next hotspot using the predefined waypoints. The same process of controlled descent, camera alignment, image capture, and telemetry transmission is repeated for each subsequent hotspot.

Once the drone reaches the final target location, it descends by a specified distance, typically 10 meters, using the barometer sensor. Object detection techniques in computer vision are employed to identify and align the drone precisely with the target.

To initiate the payload drop, the Raspberry Pi communicates with the Pixhawk flight controller via Mavlink. The flight controller triggers the servomotor responsible for releasing the payload. This integrated process showcases the potential of drones as efficient delivery systems, combining intelligent algorithms, computer vision, and meticulous flight controls to enable safe and precise transportation.

5. Target to Home:

After successfully delivering the payload, the drone ascends to a height of 30 meters, once again utilizing the barometric sensor for accurate altitude measurement. It then follows a pre-determined path set by the mission planner, which guides the drone back to the home location.

During the return journey, the drone maintains a safe altitude and navigates along the predefined flight path, adhering to the established waypoints. The barometric sensor assists in initiating a gradual descent as the drone approaches the landing spot at the home location. With careful descent control, the drone slowly approaches the ground, and upon touchdown, the propellers automatically cease their operation, ensuring a safe and controlled landing.

By implementing this detailed and comprehensive methodology, the drone can autonomously perform a range of operations, including hotspot detection, payload delivery, and safe return to the home location. The integration of hardware components, software algorithms, and computer vision capabilities allows for efficient and precise autonomous operations.

Throughout the entire operation, the flight controller continuously monitors and adjusts the drone's flight parameters, such as altitude, speed, and heading, to ensure safe and stable flight. The flight controller also handles communication with the various sensors and systems onboard the drone, orchestrating the coordinated actions required for autonomous operations.

The use of computer vision technologies, such as image classification, pattern recognition, and object detection, enables the drone to analyze visual data captured by its onboard camera. These algorithms extract valuable information from the images, aiding in hotspot identification, payload alignment, and target detection. The processed data assists in decision-making, allowing the drone to execute tasks accurately and efficiently.

The Mavlink protocol serves as a crucial communication link between the Raspberry Pi and the Pixhawk flight controller. It facilitates the transfer of data, including captured images, telemetry, and control commands, ensuring seamless integration and coordination between the various components of the autonomous system.

E) Summary of innovations in the overall design.

Team Aviato has achieved a significant innovation by developing a quadcopter with a self-made 3D printable chassis. The quadcopter possesses an impressive factor of safety, measured at an outstanding value of 10.06. This indicates that the design has been carefully engineered to ensure optimal stability and structural integrity.

Furthermore, the team has successfully designed a payload dropping mechanism integrated into the quadcopter. This mechanism utilizes a simple servo motor connected to a hook, which can be activated by a basic electrical signal. By incorporating this feature, the quadcopter gains the ability to drop payloads accurately and efficiently.

Overall, the innovative quadcopter with its self-made chassis, high factor of safety, and well-designed payload dropping mechanism demonstrates Team Aviato's commitment to pushing the boundaries of drone technology while maintaining a focus on safety, precision, and design excellence.

Optimization in Payload Dropping Algorithm

The technique of optimization combines the act of adapting control with real-time feedback to enhance the way in which payloads are dropped. The process involves integrating sensors and utilizing a feedback loop alongside the flight control system, actively monitoring the drone's position, altitude, and orientation. This data is then utilized through the use of an adaptive control algorithm to dynamically modify the drone's flight parameters during the dropping stage. This can entail altering heading, altitude, and release timing to ensure the drone follows the desired trajectory, even if faced with unforeseen obstacles or environmental factors.

The adaptive control algorithm can be boosted by utilizing machine learning and AI techniques to learn from large datasets of payload drops and perfect its control strategy. Real-world testing and refinement are vital to establish the efficiency of the adaptive control technique and guarantee consistent and precise delivery of payloads.