KLS GOGTE INSTITUTE OF TECHNOLOGY

Belagavi, Karnataka

SAEINDIA AEROTHON 2022

Design Report

Team vayuputras

Faculty Advisor

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Team number 006

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APPENDIX A

STATEMENT OF COMPLIANCE

Certification of Qualification

Team Name: Vayuputras Team Number: 06

University/Institute: KLS Gogte Institue of Technology, Belagavi

Faculty Advisor: Prof. Adarsh Krishnamurthy

Faculty Advisor's Email: adarsh.uav@gmail.com

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 2022 contest, without direct assistance from professional engineers, R/C model experts or pilots, or related professionals.

Signature of Faculty Advisor

10-June-2022

Date

Team Captain Information:

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Team Captain's Phone: 9420224581

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List of Figures

1. Introduction

This document details the final design made by the Vayuputras Team from KLS Gogte Institute of Technology, Belagavi, with the purpose of participating in SAEINDIA AeroTHON 2022. The report explains the methodology, overall design, analysis, performance, used to build this Unmanned aerial vehicle, “**Kestrel**”. Kestrel is famously known for its incredible ability to keep their heads perfectly still while hovering in place during flight. The main objective is to design an unmanned aerial vehicle capable of. Manual as well as Autonomous dropping of payload. In addition, it fulfills its mission by following the SAEINDIA design requirements and is an aircraft safe enough to operate under different mission profiles.

1.1 Objective

The main objective of participating in the SAEINDIA AEROTHON is to be able to contribute towards an *AtmaNirbhar Bharat* and help the sector of unmanned space technology reach newer heights with our innovative contributions. It will soon be a thing of the past when India will have looked towards other countries to develop and procure UAV systems. Events like SAEINDIA AEROTHON help boost our creativity as well as challenge our thinking. All this coupled with passion and patriotism will play a huge role in endowing our nation with ground breaking new technologies. Through this competition we can improve our communication and interpersonal skills which are vital for working together in multidisciplinary teams.This along with research and implementation of our innovations will open up new opportunities and career paths. Furthermore, we will also be able to unleash and recognise our full potential as future engineers by working on different aspects that go towards the successful building and completion of a project.

1.2 Problem Statement

The objective for this year’s contest is to design, build and fly a multirotor UAV that can deliver cargo to a specified location. The teams shall design a UAV that can carry a specified payload and deliver it to a target area by manual as well as autonomous operations.

Sl. No.	Parameters	Requirement/Limitations
1	UAV Type	Multirotor
2	UAV Category	Micro UAS (Take off Weight < 2kg)
3	Payload Capacity	200 grams
4	Propulsion Type	Electric
5	Communication System Frequency	Data Telemetry - 2.4 GHz Video Telemetry - 2.4GHz or 5.8 GHz
6	Communication System Range	At least 1 km

Fig no 1.2.1: Required Parameters

1.3 Mission Profile

The Flight mission is as follows:

- Take-off and reach an altitude of 30 m.
- The UAV must be flown at 30 m altitude to reach the search area which is 300 m away from the take-off point and identify the target .
- After identifying the target, the UAV must descend down to 20 m and drop the payload.
- After the payload is dropped, the UAV must again climb to an altitude of 30 m and fly back to the take-off point.
- After reaching the take-off point the UAV must be landed

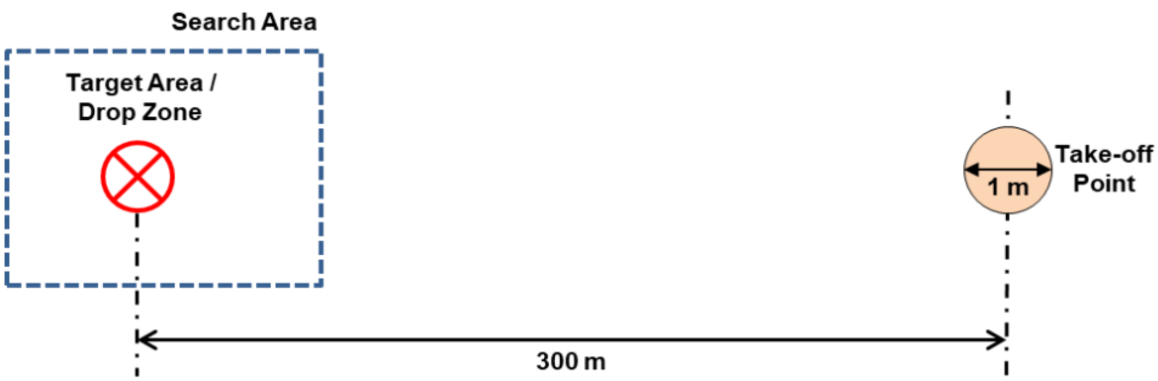


Fig no 1.3.1 Mission Profile

2. Technical Design

2.1 Conceptual Design

Different iterations were examined to determine optimum weight and spacing parameters which led to the conception of the final design, the Kestrel.

First Iteration: Octa-rotor extruding-arm design

This design was initially designed having 8 arms with extruding arms. This was discarded due to weight constraints.

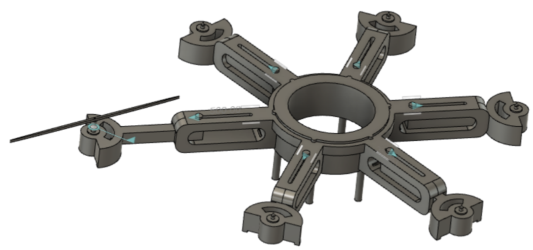


Fig no 2.1.1 Octa-rotor extruding-arm design

Second Iteration: Unibody Design

This design was discarded as the effective propeller area decreased due to components and the hull which were placed right below the propeller position.

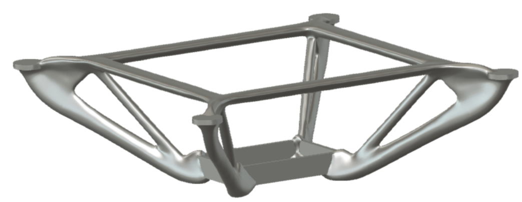


Fig no 2.1.2 Unibody Design

Third Iteration: Staggered Thrust Plane X Quad Rotor

Upon brainstorming, it was decided that an **X- Configuration Quadcopter** would fulfill the objective of the problem statement. This was decided to incorporate a stable and agile UAV which would ensure its safe operation and hence the safety of the payload as well. A quadcopter also was determined to be the most compatible for the given weight limitations. The diagonal motors would rotate in the same direction.

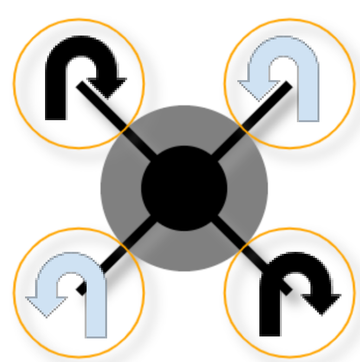


Fig no 2.1.3 X configuration Design

2.2 Estimation of Preliminary Weight

Drone		
Sr. No.	**Components**	**Total Weight(Grams)**
1	Motors	280(4 motors)
2	Electronics	215
3	Image Processing	200
4	Propeller	60(4 Props)
5	Battery	600(3 batteries)
6	Body	400
7	Payload	200
Total weight(Grams)		**1955**

Fig no 2.2.1 Estimation of Preliminary weight

Initially, weights were decided for specific components based on previously built models. These were used as a reference for further selection of specific components.

2.3 Estimation of Thrust (Required and Available)

It was determined that the weight of the drone would be 2 kilograms. Drones used for payload drop require a thrust to weight ratio of 2:1. To fulfill this condition, it was required to have a thrust of 4 kilograms. This means that each combination of a motor and propeller should produce about 1 kilogram of thrust at full throttle. This is true for half of the mission profile. For the second half, upon dropping the payload, the weight of the drone will reduce to 1.8 kilograms. The same thrust of 4 kilograms will then give a Thrust to Weight ratio of 2.2 : 1.

Thrust Variation throughout the mission profile:

Parameter	**Before Payload Drop**	**After Payload Drop**
Weight	2 kg	1.8 kg
Thrust Available	4 kg-f	4kg-f
Thrust to Weight Ratio	**2:1**	**2.2:1**

Fig no 2.3.1 Thrust Variation throughout the mission profile

2.4 Selection of Propulsion System

Fig no 2.4.1 Motor

Fig no 2.4.2 Propellers

Model Name: 1) T- Motor Navigator Series MN2212 920kV V2.0
2)T- Motor 9545-B Polymer Propellers

With the navigator design concept, T-Motor Navigator Series is mostly used in Aerial photos as a multirotor power system the motor is high quality smooth running, durable brushless motor built for multirotor UAV application, the custom assembly methods and components unique to the Navigator series help to provide the reliability required for a dependable aerial platform.

T-motor MN2xxx series motors come with a bearing twice as large as the same size motor. Qualified big ball bearing, which suits low-speed smooth running and allows for a stable frame against pressure is put into application precision.

The motors come with a higher level EZO bearing which improves the life of bearing. The office test indicates that the motor can complete its flight time up to 60-80 hours.

Justification: 4 of T Motor Navigator MN2212 V2.0 920 KV have been used for their excellent thrust to weight ratio.

Load Testing Data									
Ambient Temperature			/		Voltage			DC Power Supplier	
Item No.	Voltage (V)	Prop	Throttle	Current (A)	Power (W)	Thrust (G)	RPM	Efficiency (G/W)	Operating Temperature (℃)
MN2212 KV920 V2.0	14.8	T-MOTOR 9545	50%	2.1	31.08	293	4260	9.43	/
			65%	4	59.2	476	5300	8.04	
			75%	5.6	82.88	605	5960	7.30	
			85%	7.4	109.52	742	6000	6.78	
			100%	10.3	152.44	918	7350	6.02	

Fig no:2.4.3 Official Load Testing data of selected motor and propeller combination

The above chart gives a clear idea of the Thrust force that the selected Propeller and Motor combination will produce when connected to a 4S battery. It produced a Max thrust of **918 grams** at 100% throttle. This gives a total thrust of **3.672 kilograms** of thrust.

2.5 UAV Sizing

The dimensions of the final model is as follows:

Parameter	Description	Value
Wheelbase	Distance between diagonal motor shaft	551.8 mm
Rotor Arm Length	Length of individual Rotor Arm	161.4 mm
Propeller Clearance	Shortest distance between propeller tips	130 mm
Landing gear	Distance between base and ground	15 mm

Fig no 2.5.1 UAV sizing

2.6 UAV Performance

2.6.1 LithiumPolymer(LiPo) Battery

A lithium polymer battery or more correctly lithium-ion polymer battery is a rechargeable battery of lithium-ion technology using a polymer electrolyte instead of a liquid electrolyte. High conductivity semisolid (gel) polymers form this electrolyte. These batteries provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature, such as mobile devices, radio-controlled aircraft and some electric vehicles.

Fig no:2.6.1 Lithium Polymer(LiPo)Battery

Model Name: Tattu R-line Version 3.0 2000mah 4s 120c

Justification: 3 of Tattu R-line Version 3.0 2000mah 4s 120c LiPo Batteries in Parallel have been used instead of a single large battery for its high current output capacity and as the 3 batteries can be strategically placed to balance center of gravity(CG)

The Endurance of Kestrel is later determined, which is mentioned in section 2.14..

2.6.2 Power Distribution Board(PDB)

A distribution board (also known as panelboard, breaker panel, electric panel, DB board or DB box) is a component of an electricity supply system that divides an electrical power feed into subsidiary circuits while providing a protective fuse or circuit breaker for each circuit in a common enclosure.

Model Name: Matek Systems PDB-XT60

Fig no 2.6.2 Power Distribution Board(PDB)

Justification: The Matek Systems PDB-XT60 has been used for cleaner wire management and power distribution of different voltages for all the components.

2.6.3 Ideal Diode Circuit

Ideal diodes are a great simple solution for combining battery packs. “Ideal diodes” in terms of this application do not refer to a diode, but instead to an “ideal diode circuit”. The main component of an ideal diode circuit is a MOSFET which is how they achieve such low on resistance and mimic the theoretical “ideal diode”.

Model name: DG7512 75V 12A High Current Ideal Diode

Justification: 3 * DG7512 75V 12A High Current Ideal Diodes have been used to prevent back flow of current during hot swapping of batteries.

Fig no 2.6.3 High Current Ideal Diodes

2.7 Material selection

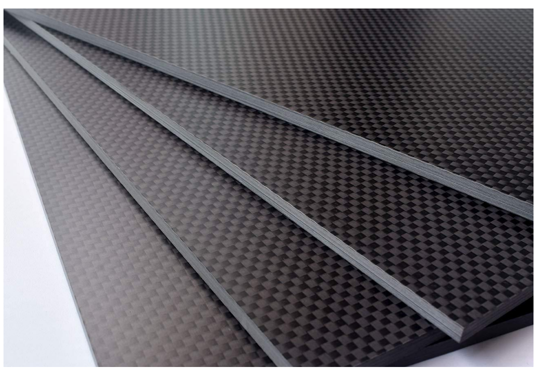
1. **PLA (PolyLactic Acid)**

Properties
Tensile Strength:35.9 MPa
Young modulus:4.107GPa
Shear modulus:4.8GPa
Density:1.00 - 2.47 g/cc

Application
To manufacture the coupling which holds the motors to the carbon fiber arm and the arm to the body of the drone, PLA is used.

Fig no 2.7.1 PLA Filament

2.Carbon Fiber Sheet



Properties
Tensile Strength: 3.5 Gpa
Young's Modulus: 5 Gpa
Shear Modulus: 22.43 Mpa
Density: 1.75 g/cm^3

Application
The arms are made using carbon fiber round tubes (OD-20mm ,ID-16mm) and the top and bottom plates are made of 3mm thick 3K carbon fiber plates and the mid plate is 4mm thick 3K carbon fiber plates

Fig no 2.7.2 Carbon Fiber Sheet

3. Aluminum

Properties
Tensile Strength:90 MPa
Young modulus:68 GPa
Shear modulus:25 GPa
Density:2.7 g/cm³

Application
Aluminum stand-offs are used to connect all the three plates together and to provide structural regidity.

Fig no 2.7.3 Aluminum stand-offs

2.8 Subsystem Selection

2.8.1 Control & Navigation System

2.8.1.1.Flight Controller:

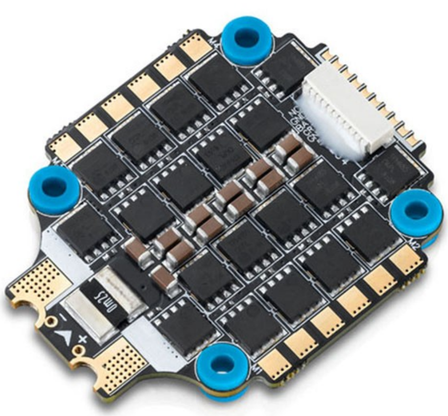
The Pixhawk autopilot system is a complete solution for multi-platform autonomous vehicles, based on the open-source Pixhawk autopilot. The Pixhawk kit includes a power module, I2C splitter, mounting foam, micro-SD card, buzzer, safety button, and required cables for connecting the Pixhawk system.

Model Name: Pixhawk 2.4.8 Flight Controller

Fig no:2.8.1.1 PixHawk Flight Controller

Justification: The Pixhawk 2.4.8 Flight Controller has been used for its open source nature, excellent Compatibility with Raspberry pi as a companion Board for autonomous flight.

2.8.1.2. ESC(Electronic speed controller)



Electronic speed controllers (ESCs) are devices that allow drone flight controllers to control and adjust the speed of the aircraft's electric motors. A signal from the flight controller causes the ESC to raise or lower the voltage to the motor as required, thus changing the speed of the propeller.

Model Name: Hobbywing Xrotor Micro 60 amp 4 in 1 BLHeli 32

Justification: The Hobbywing Xrotor Micro 60 amp 4 in 1 BLHeli 32 esc has been used for its compatibility with BLHeli 32. A 4 in 1 ESC has been used to save the weight of 4 individual ecs.

Fig no 2.8.1.2 ESC(Electronic speed controller)

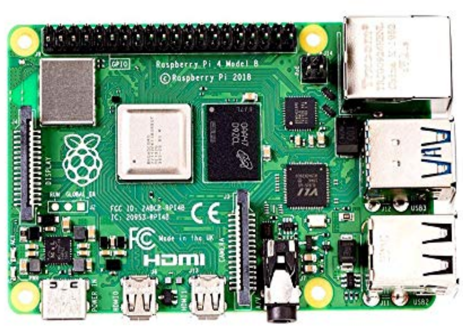
2.8.1.3. GPS(Global Positioning System) Module

A GPS module provides in-flight positioning data for full autonomy. The GPS with Compass module adds high-performance GPS with improved accuracy over Pixhawk's internal compass. The GPS ports are connected with Fig no 2.8.1.3. six-position DF13 cable, and the MAG port is connected to the I2C port with the four-position DF13 cable.

Model Name: NEO-M8N
Justification: The NEO-M8N has been used for its compatibility with Pixhawk 2.4.8.

Fig. No.:2.8.1.3 GPS Module

2.8.1.4. Raspberry Pi



The Raspberry Pi 4 Model B is the latest version of the low-cost Raspberry Pi computer. The Pi isn't like your typical device; in its cheapest form it doesn't have a case, and is simply a credit-card sized electronic board -- of the type you might find inside a PC or laptop, but much smaller.

Model Name: Raspberry Pi 4, 8 Gb ram

Justification: The Raspberry Pi 4,8 Gb ram has been used to provide enough computing power for seamless image recognition during autonomous flight.

Fig no:2.8.1.4 Raspberry Pi 4

2.8.2. <u>Communication system</u>

2.8.2.1. Receiver

The receiver on a drone is an electronic device that uses built-in antennas to receive radio signals from the drone controller. But the receiver doesn't just receive signals from the drone controller. It also interprets the signals and converts them into alternating current pulses.

Model Name: FrSky X8R 8/16ch Full Duplex Telemetry Receiver
Fig no:2.8.2.1 Receiver

Justification: The FrSky X8R 8/16ch Full Duplex Telemetry Receiver has been used for its reliability and compatibility with the selected transmitter.

2.8.2.2. FPV Camera

To meet the video transmission requirements, a digital FPV system will be used. It will be powered via the PDB. This air unit will directly provide digital video feed to the FPV goggles on the ground

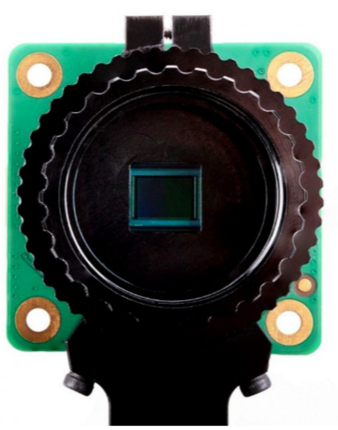
Model Name: Caddx FPV Air Unit.

Justification: The Caddx Air Unit has been used for its full HD video transmission to provide for excellent visibility during manual flight.

Fig no:2.8.2.2 FPV Camera

2.8.3. Image Processing System

2.8.3.1.Camera Module



Pi Camera module is a camera which can be used to take pictures and high definition video. Raspberry Pi Board has CSI (Camera Serial Interface) interface to which we can attach the Pi Camera module directly. This Pi Camera module can attach to the Raspberry Pi's CSI port using a 15-pin ribbon cable.

Model Name: Raspberry Pi High Quality Camera with Interchangeable Lens Base

Justification: The Raspberry Pi camera has been used for its excellent image quality, low light performance and 1st party compatibility with Raspberry pi boards..

Fig no:2.8.3.1 Camera sensor Module

2.8.3.2. Telephoto Lens

Fig no:2.8.3.2 Telephoto Lens

A telephoto lens has a long reach—traditionally this means a focal length of 60mm or more—but it does not necessarily need to slide through a range of focal lengths.

Model Name: Raspberry Pi 16mm Telephoto Lens

Justification: The Raspberry Pi camera by itself cannot clearly photograph the target circle of 3 meters diameter from the required altitude of 30 meters. For this, a telephoto zoom lens has been used for better image detection.

2.8.4. <u>Ground Station Unit</u>

2.8.4.1.Transmitter

Fig no:2.8.4.1 Transmitter

The RadioMaster TX16S Mark II Radio Transmitter is the latest in radio transmitter technology. This radio features Hall Gimbals V4.0, an Multiprotocol 4-in1 Internal Module, OpenTX and EdgeTX compatibility, and 2.4GHz radio frequency with 16 Channels.

Model Name: RadioMaster TX16S MKII 2.4GHz 16CH

Justification: The RadioMaster TX16S MKII 2.4GHz 16CH has been used for its Open TX compatibility and customizability.

2.8.4.2. FPV Goggles

The DJI FPV Goggles V2 with DJI O3 image transmission features high definition, low latency, long-distance transmission, and strong anti-interference capabilities. The DJI FPV Goggles Battery in the box supports up to 110 minutes of flight time.

Model Name: DJI V2 FPV Goggles

Justification: A digital FPV system has been used over an analog system as during manual flight it provides better quality video feed. According to the problem statement, the pilot has to locate a circle of 3 meters diameter from an altitude of 30 meters. It was experimentally determined that the circle was not clearly visible in an analog system.

Fig. No.: 2.8.4.2 FPV Goggles

2.9 C.G. Estimation & Stability

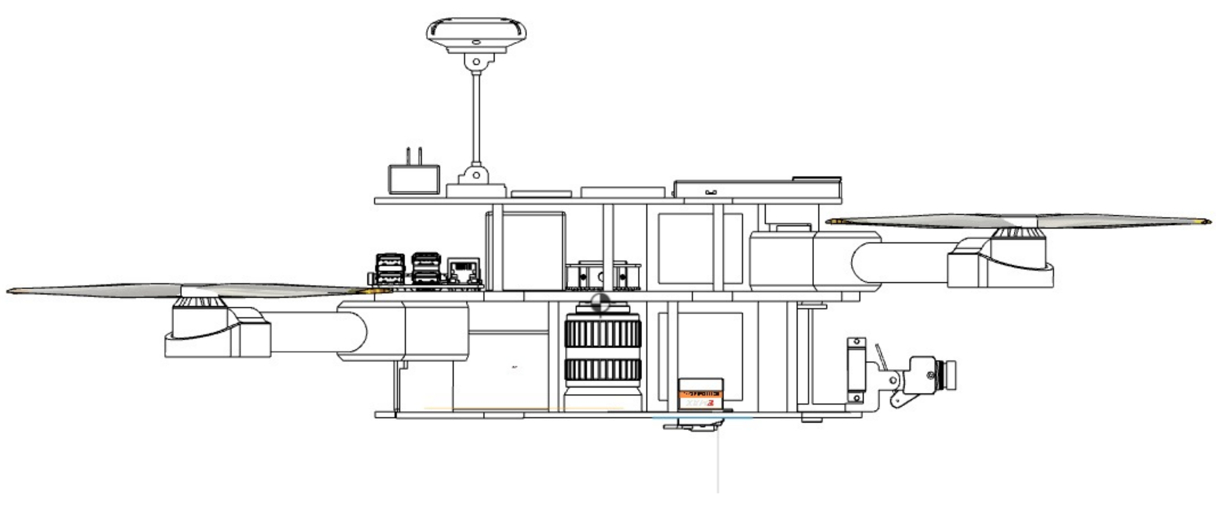


Fig. No: 2.9.1. CG location

The CG was expected to be exactly at the center of the drone. For a drone to be stable, it is required to have the CG below the thrust plane. To ensure that, a staggered thrust plane is decided, so that at all times, the CG may lie below the Thrust Plane. The above image shows the exact location of CG of the finalized model. This was determined using CAD software, by providing mass to every component that was used.

2.10. Preliminary CAD model

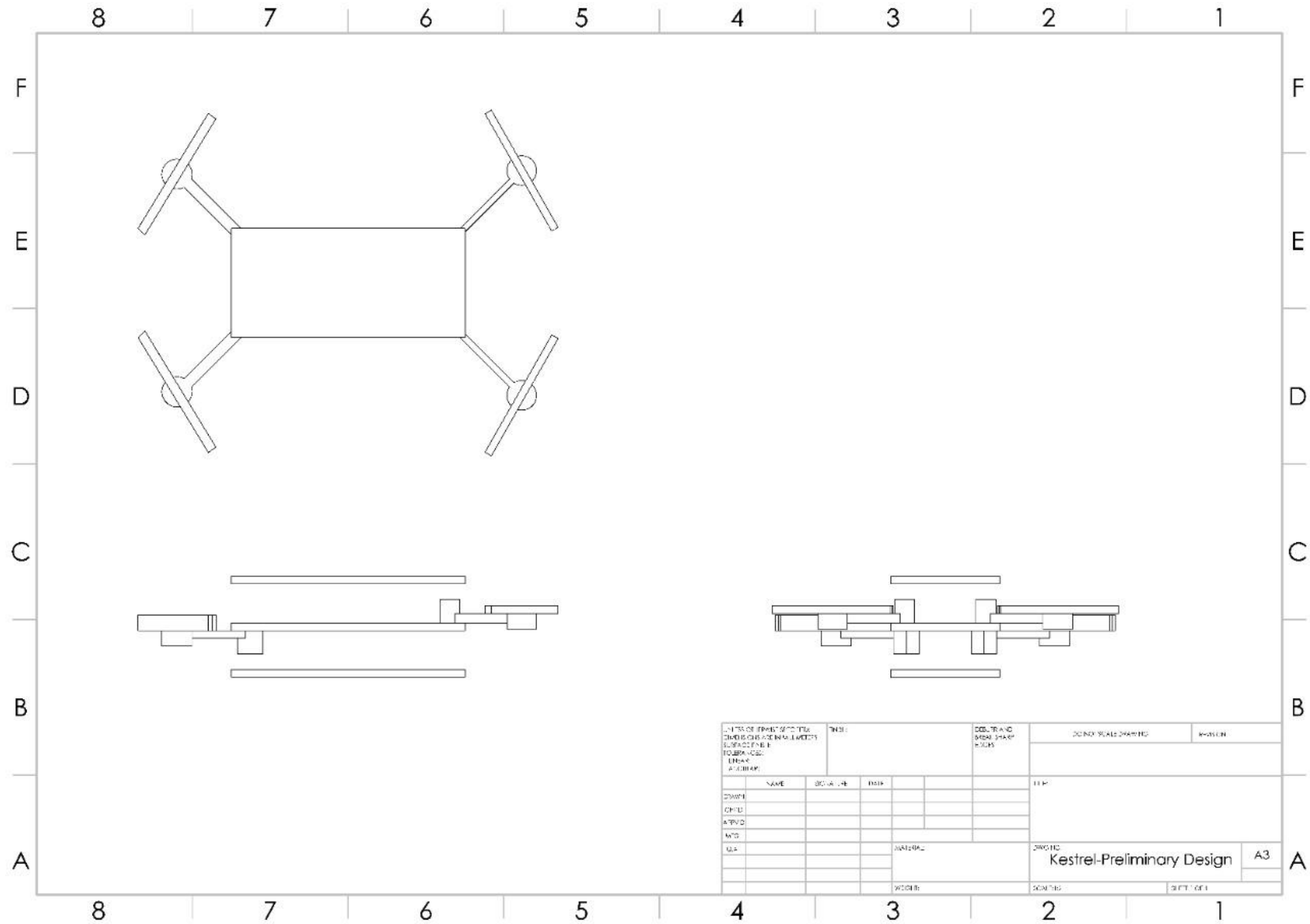
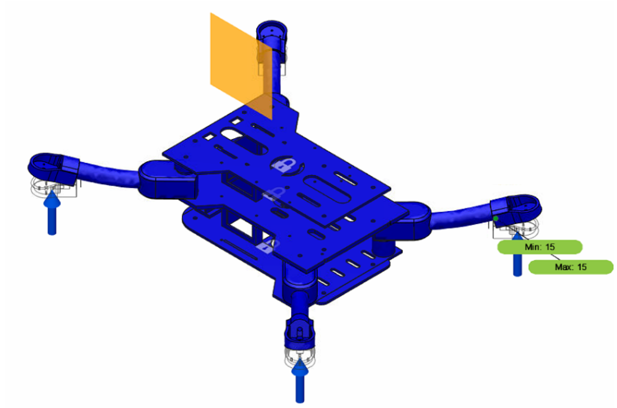


Fig. No. 2.10.1. : Preliminary CAD Drawing

The ideology was to make it portable and hence the design was finalized with a staggered thrust plane with foldable arms.The design consists of 3 plates mounted or stacked in a vertical manner with the standoff supports made of aluminum. The arms being used are made up of carbon fiber to compensate for the weight limits and make it efficient for the mission objective prescribed. The joints would be made of PLA using additive manufacturing. The plates used for stacking are also made up of carbon fiber to house the electronics, and the design also incorporates housing for the payload which gives it a clean look as it is housed inside the panels.

2.11. Computational Analysis

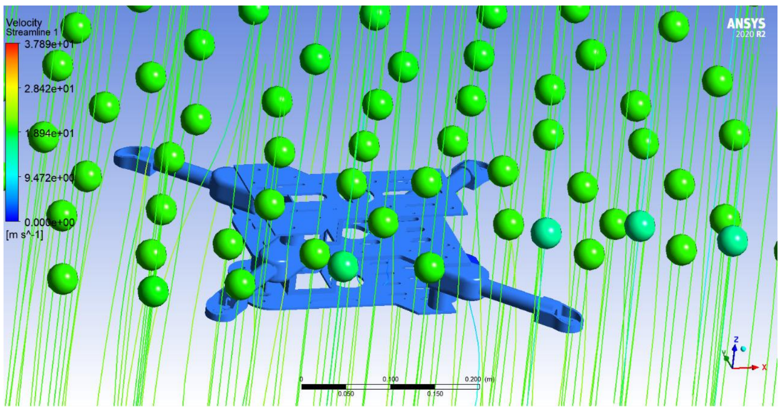
Stress Analysis



The stress analysis performed on the model denoted that, The Factor of Safety is **15** for a load of 1 kg applied on each arm, ie. the thrust condition at full throttle. This indicates that the chassis meets the required load conditions and is structurally sound.

Fig no 2.11.1: Stress Analysis of UAV Chassis

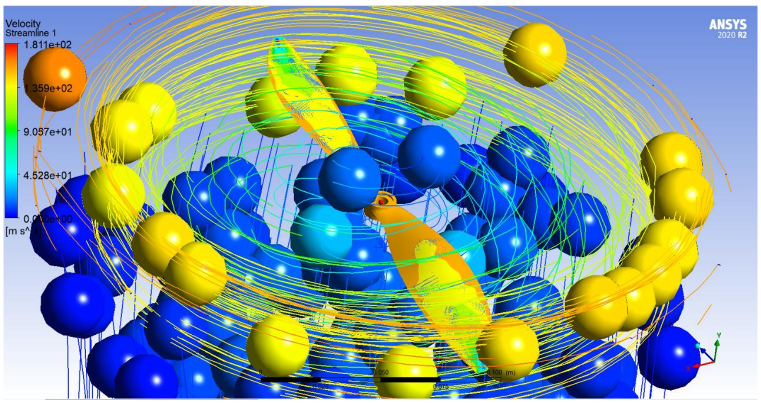
Computational Fluid Analysis of Chassis



This figure represents the velocity profile of the chassis computed at a velocity of 20 m/s of climb speed. The maximum pressure that will act on the chassis is 276.973 Pa while the minimum pressure determined is -764.17 Pa.

Fig. No. 2.11.2.: CFD Analysis of Chassis

Computational Fluid Analysis of Propeller



This represents the CFD analysis conducted on the 9545 Propeller that was chosen. It was made to rotate at an RPM of 7350 RPM which was derived from Fig. No.: 2.4.3.

The analysis stated that the thrust produced by each Propeller motor combination is **1.017 kg**.

Fig. No. 2.11.3.: CFD Analysis of Propeller

2.12 Optimized Final Design

Final Renders of Kestrel

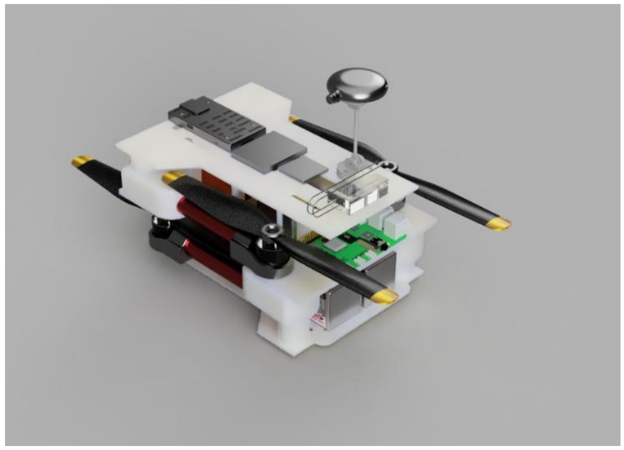


Fig no 2.12.1: Kestrel Collapsed View

Fig no 2.12.2: Kestrel Isometric View

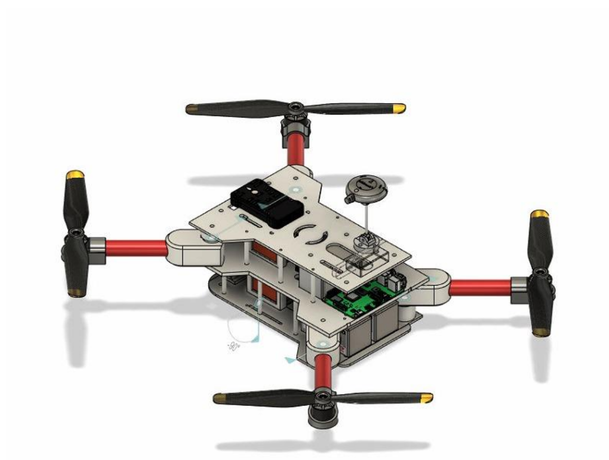


Fig. No. 2.12.3; Kestrel Isometric view

Circuit Diagram

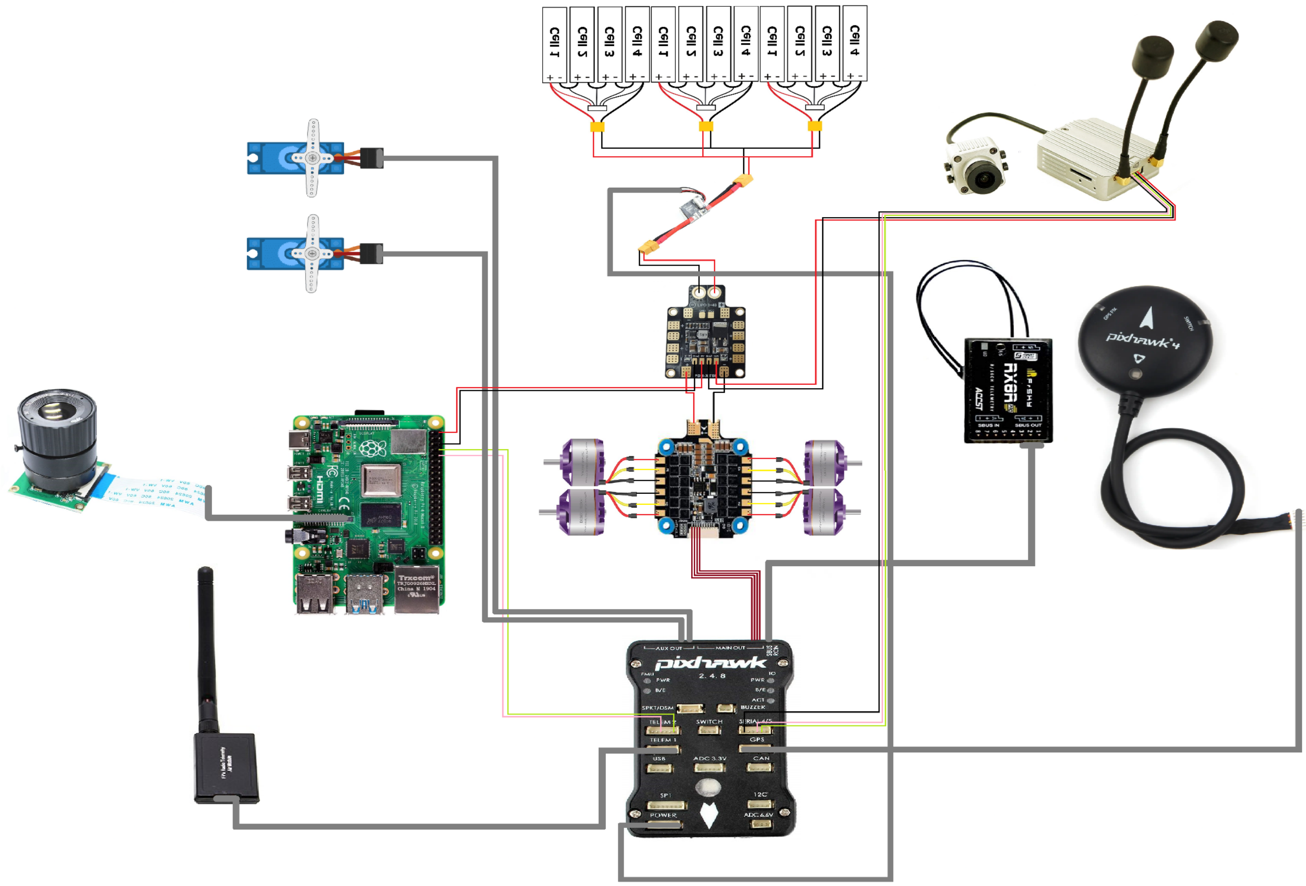
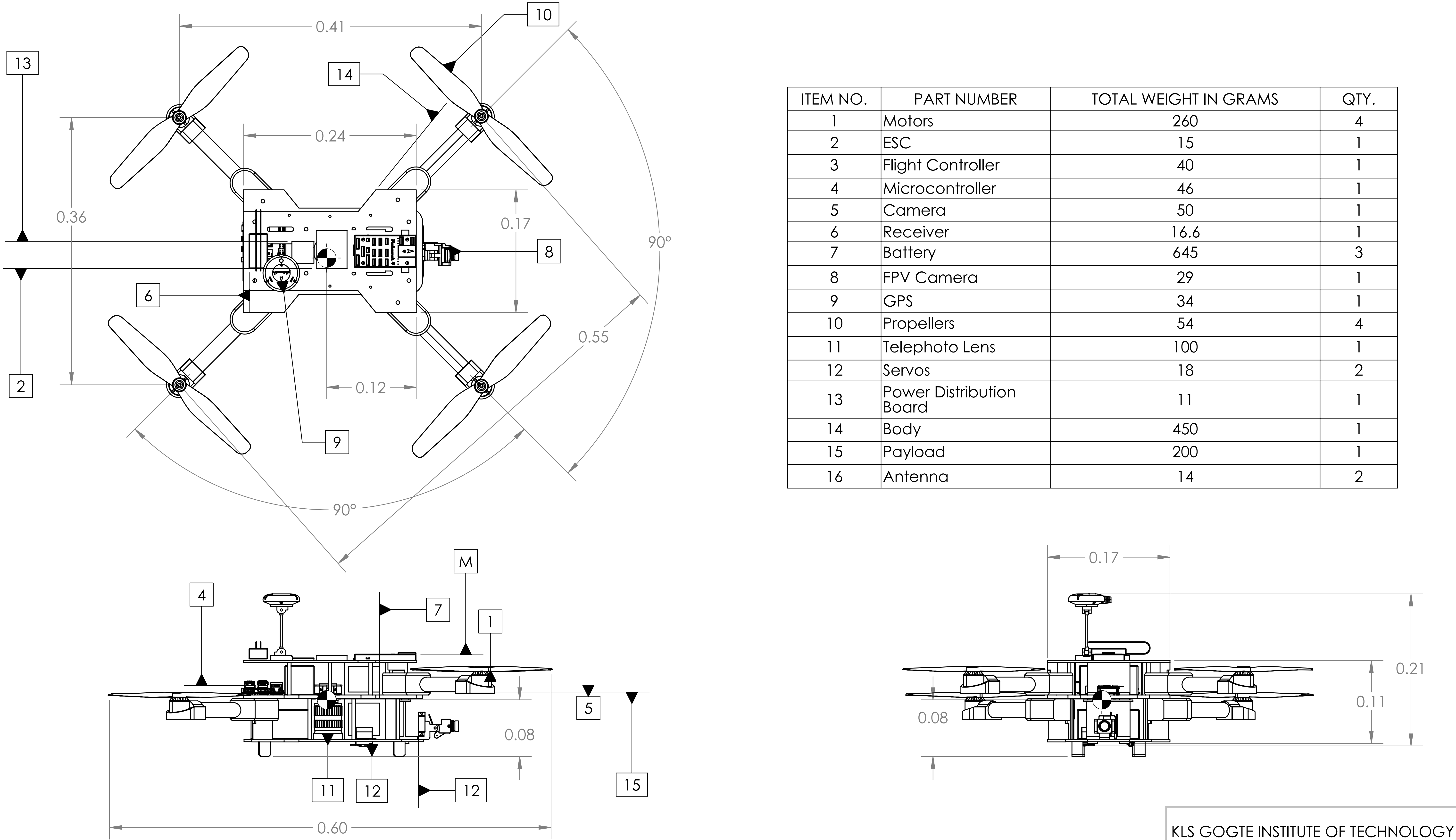


Fig no:2.12.4 Circuit Diagram

Above is the finalized detailed placement of electronics along with the wiring that is implemented in the Kestrel.



ITEM NO.	PART NUMBER	TOTAL WEIGHT IN GRAMS	QTY.
1	Motors	260	4
2	ESC	15	1
3	Flight Controller	40	1
4	Microcontroller	46	1
5	Camera	50	1
6	Receiver	16.6	1
7	Battery	645	3
8	FPV Camera	29	1
9	GPS	34	1
10	Propellers	54	4
11	Telephoto Lens	100	1
12	Servos	18	2
13	Power Distribution Board	11	1
14	Body	450	1
15	Payload	200	1
16	Antenna	14	2

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TEAM VAYUPUTRAS

Kestrel: Final Design

A3

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

2.13 Detailed weight breakdown & C.G. of Final UAV Design

Drone				
Sr	**Components**	**Unit Weight(Grams)**	**Quantity**	**Total Weight(Grams)**
1	**Motors**	65	4	260
2	**ESC**	15	1	15
3	**Flight controller**	40	1	40
4	**Micro-Controller**	46	1	46
5	**Camera**	50	1	50
6	**Receiver**	16.6	1	16.6
7	**Battery**	215	3	645
8	**FPV Cam**	29	1	29
9	**GPS + Holder**	34	1	34
10	**Propeller**	13.5	4	54
11	**Antenna**	7	2	14
12	**Telephoto Lens**	100	1	100
13	**Servo**	9	2	18
14	**PDB**	11	1	11
15	**Body**	450	1	450
16	**Payload**	200	1	200
	Total Weight(Grams)			**1982.6**

Fig no 2.13.1 Table for Detailed weight breakdown

The weight estimation was done on the basis of charts and particulars mentioned by the product retailers. Every product estimation is done with references available online and may occur to change in real world analysis. All the components are selected with respect to the mission objective and weight limitations provided. The Weight estimation given above is based on the average readouts, these might change in the physical application during the actual build of the drone with all the components combined together.

The CG lies exactly in the center of the UAV and below the thrust plane. This ensures the stability of the drone.

2.14 UAV Performance Recalculation

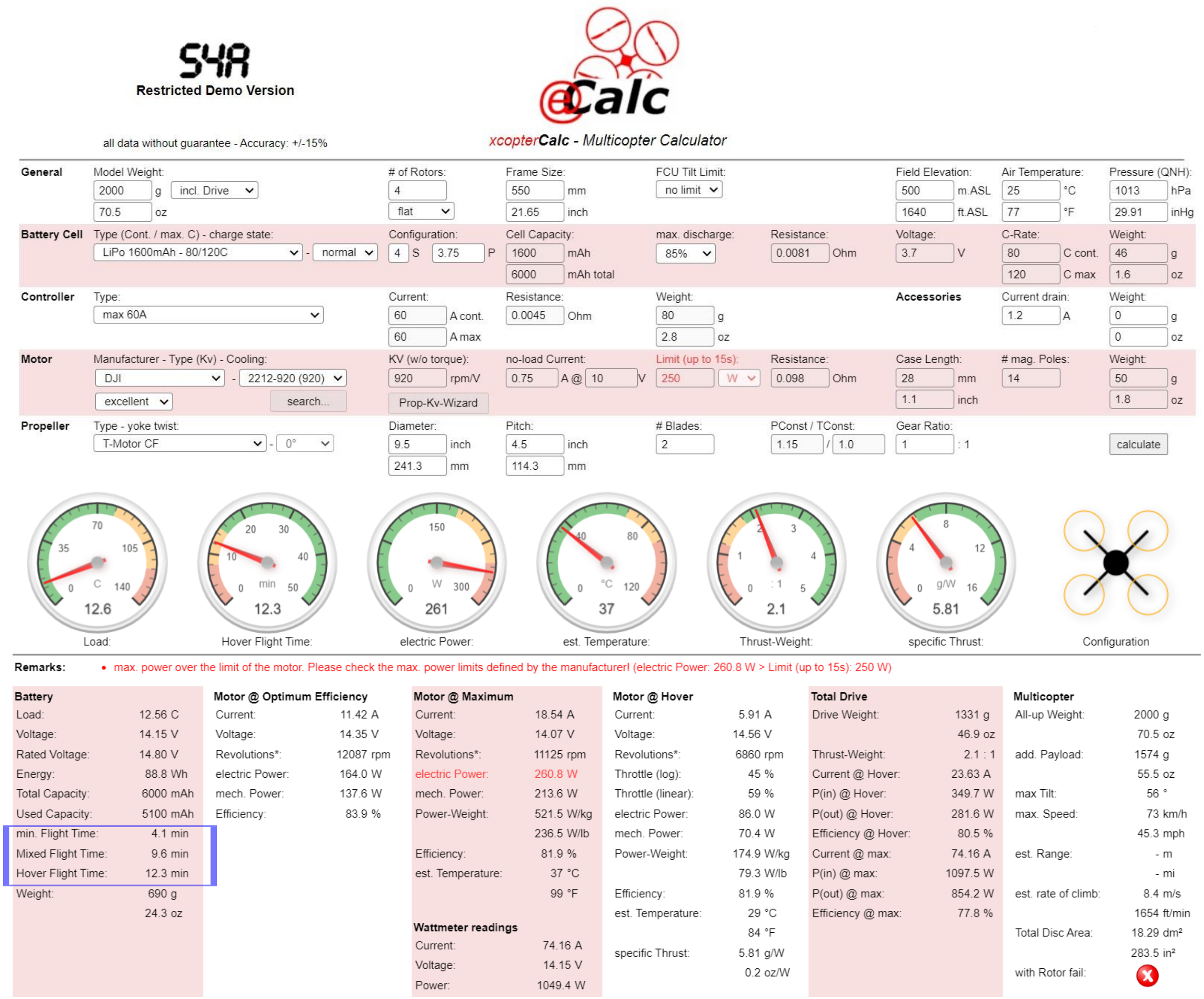


Fig no 2.14.1 Calculations

Upon Calculations, made using **ecalc**, it was found that the endurance Kestrel will achieve is **12.3** mins upon hovering with full take-off weight condition. This endurance will further increase upon dropping of payload as the weight will reduce.

NOTE:As the exact motor chosen was not available, A different motor with the exact same specifications was used to perform the calculations.

2.15 Final UAV Specifications and Bill of Materials

UAV Specifications	
Parameters	**Value**
Max Flight Time	12.6 mins
Empty Weight	1.75 kg
Wheel Base	551.8 mm
Ground Clearance	15 mm
Video Transmission Type	Digital

Fig. No. 2.15.1.UAV Specifications

Component list					
Sl. No.	Components	Description	Price	Quantity	Total Price
1	Flight Controller	Pixhawk 2.4.8 with telemetry kit	26,000/-	1	26,000/-
2	Power Distribution Board	Matek Systems PDB XT-60	375/-	1	375/-
3	Receiver	FrSky X8R 8/16 inch	4,000/-	1	4,000/-
4	Lipo Battery	2000 mah 4s 120c	2,200/-	3	6,600/-
5	Electronic Speed Controller	Micro 60amp 4 in 1 BLHeli 32	4,200/-	1	4,200/-
6	FPV Camera	CADDX Vista Digital System	15,000/-	1	15,000/-
7	Raspberry Pi	Version 4,8GB RAM	9,000/-	1	9,000/-
8	Camera Module	Raspberry Pi Interchangeable Lens Base	4,949/-	1	4,949/-
9	Lens	16mm Telephoto lens	5,000/-	1	5,000/-
10	Body	Frame	10,000/-	1	10,000/-
11	Motor	Navigator MN2212 V2.0 920KV	4,299/-	4	17,196/-
12	Ideal Diode Circuit	DG7512 75V 12A High Current Ideal Diode	492/-	3	1,476/-
Total			1,03,796/-		

Fig no 2.15.2 Bill of Material for Kestrel

Ground Station					
Sl. No.	Components	Description	Price	Quantity	Total Price
1	Transmitter	RadioMaster TX16S MKII	20,000/-	1	20,000/-
2	FPV Goggles	DJI FPV Goggles	40,000/-	1	40,000/-
Total				60,000/-	

Fig no 2.15.3 Bill of Material for Ground Station

3. Methodology for Manual Operation

During manual flight, the pilot has used the DJI digital FPV system for live HD video feed along with the Radiomaster transmitter to manually fly the drone. The servo that operates the bay door has been controlled via an AUX switch on the transmitter. The live feed from the DJI FPV system has been streamed on a laptop for the team to view. The live telemetry from Pixhawk will be streamed on another laptop to assist the flight.

4. Methodology for Autonomous Operations

4.1.1 Algorithm

Below is the algorithm for ‘How Autonomous Flight Works’

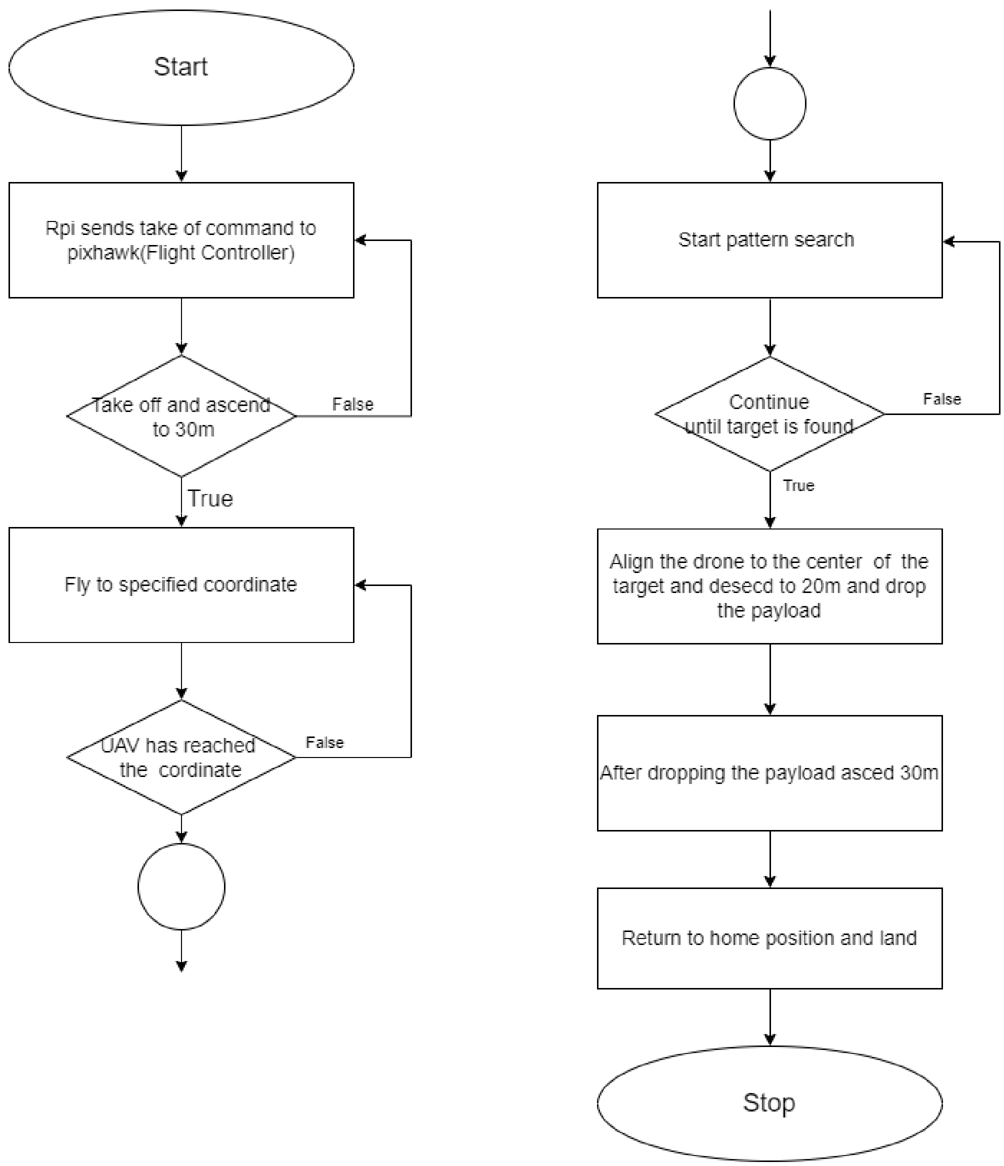


Fig no 4.1.1 Algorithm

4.2 Autonomous Flight

A raspberry pi 4 8gb(Henceforth referred to as 'Rpi' till the end of this segment) will be used as a companion board alongside Pixhawk to implement autonomous flight. The 'tx' and 'rx' (UART)pins of the Rpi will be connected to the 'rx' and 'tx' pins of the Pixhawk through the TELEM2 port. The Rpi will be flashed with an ardupilot image to communicate with the pixhawk through MAVlink protocol. A 'Raspberry Pi camera along with a 'Raspberry Pi 16mm Telephoto Lens' will be connected to the CAM port on the Rpi to feed live data for autonomous operations.

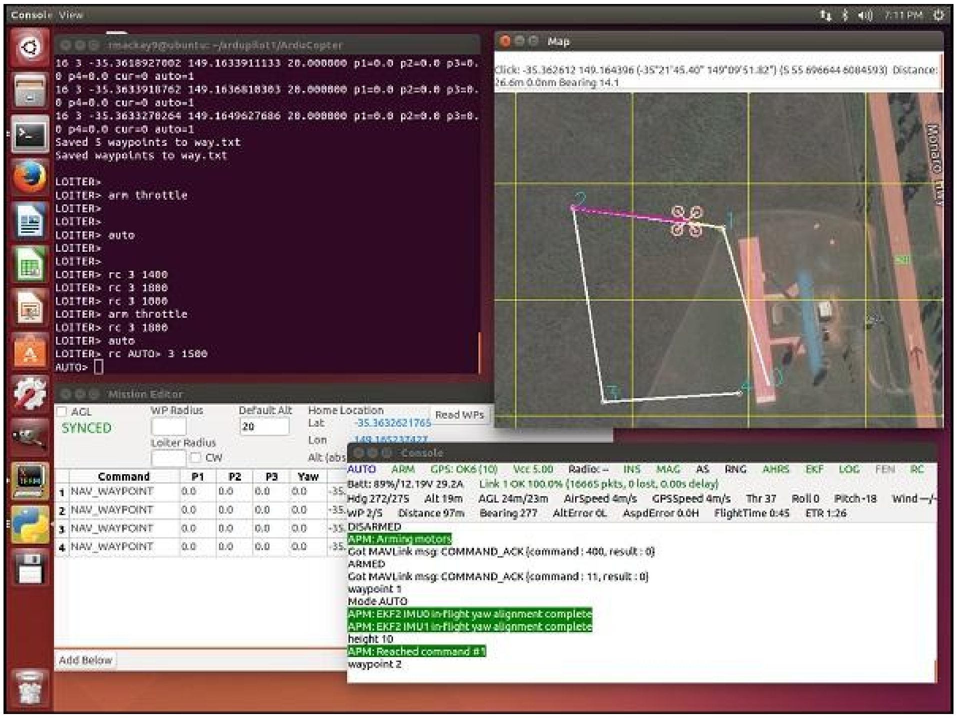


Fig no 4.2.1 MAVlink software

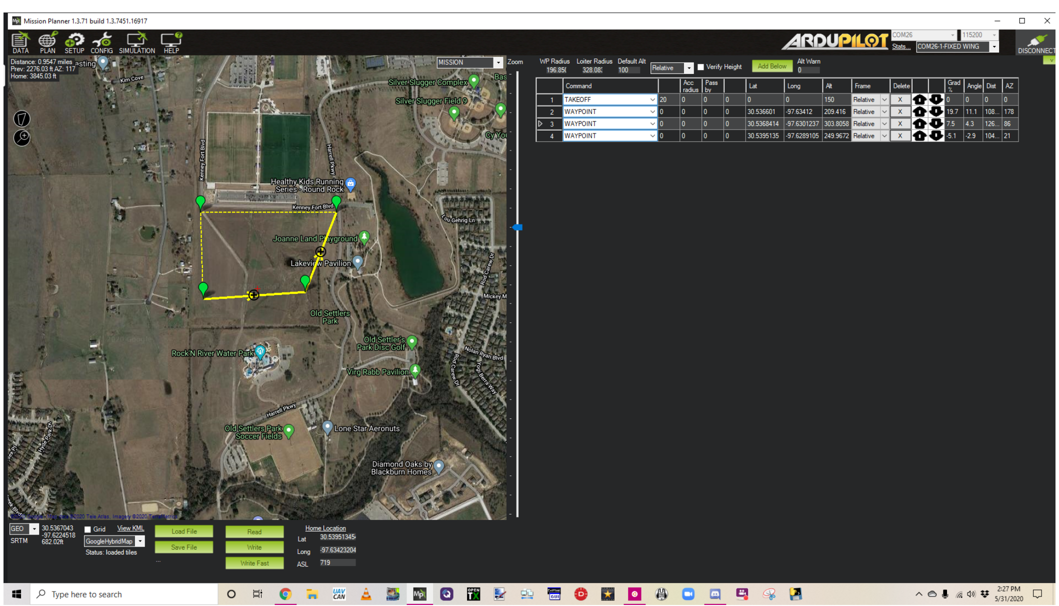


Fig no 4.2.2 Mission Planner

4.3 Autonomous Identification of Target:

The Rpi will command the pixhawk to arm the motors, take off and ascend to 30 meters, It will then command the pixhawk to go to the specified coordinates and start a pattern search in the area encircled by the given coordinates. The image detection model will be trained to identify the circular target consisting of concentric circles as given in the problem statement. As the Rpi detects the target, it will command the pixhawk to go into ‘Position hold’. The Rpi will then define an arbitrary center point on the target by averaging the pixels present in the circle and then command the pixhawk to move the aircraft to align the center point of the circle to the center to the center most pixel of the camera adjusted along the Y axis to compensate for the distance between the center of the camera and the center of the payload. The Rpi will then command the pixhawk to descend to 20 meters and release the payload by actuating the servo which will open the trap door. Once the payload is released, the Rpi will command the pixhawk to ascend back to 30 meters and return to the home point and land.

4.4 Autonomous Payload Drop:

The payload has been held inside the aircraft by bay doors. Once the aircraft descends to 20 meters after aligning itself with the target circle, The Rpi commands the pixhawk to open the bay doors by actuating the servo connected to it, Thus dropping the payload. Once the doors are opened, a pre-set delay is triggered, after the set delay, the Rpi commands the pixhawk to close the bay doors, ascend back to 30 meters, return to the home point and land.

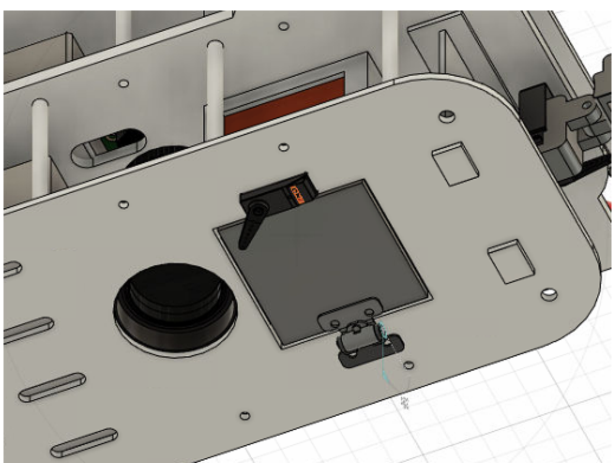


Fig no 4.4.1 Closed bay doors

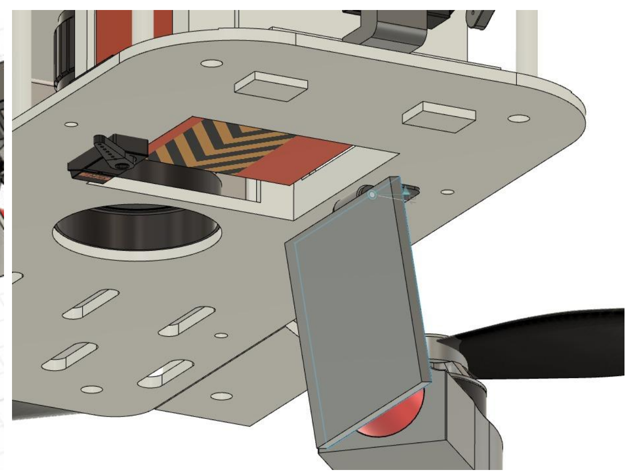


Fig no 4.4.2 Opened bay doors

5. Innovation

Whilst developing the **Kestrel**, innovation was taken as a key objective and subsequently the following systems were conceptualized:

5.1. Summary of innovations in the overall design

1. **Compact:** The concept was made in such a way that it was designed from scratch to have folding arms which makes it portable and compact hence easy to carry around.

2. **Multipurpose:** The drone is built in such a way equipped with sensors, cameras and Image Processing such that it can be used for multiple purposes like Geological Survey and Imaging(Vegetation Mapping), Surveillance, Search and Rescue.

3. **Hot-Swappable Batteries:** The power delivery system is designed in such a way including a Ideal Diode Circuit that the battery can be hot-swappable, so as to change the battery one after the other such that the UAV never turns off.

4. **Easy to Replace Parts:** The UAV was designed in such a way that connectors were used at every possible joint. This ensures that in case of failure of parts, the joints can be replaced with ease.

5. **Payload Protection:** The payload carried by the UAV is safely encapsulated in the center of the UAV and protected from all environmental factors.

6. **Payload Ejection:** The payload is injected out of the UAV using a small spring attached to the top of the Payload Bay. It is also held within the body such that when the payload is released, the design acts as a guideway for the payload to drop in a guided manner.

6. Appendix

Specifications of the selected components.

1. **Pixhawk 2.4.8 Flight Controller:**
    - ➢ Processor: 32-bit ARM Cortex M4 core with FPU
      168 Mhz/256 KB RAM/2 MB Flash
      32-bit failsafe co-processor
    - ➢ Sensors: MPU6000 as main accelerometer and gyroscope
      ST Micro 16-bit gyroscope
      ST Micro 14-bit accelerometer/compass (magnetometer)
      MEAS(measure pressure/force, position, vibration, temperature, humidity, and fluid properties) barometer
    - ➢ Power: Ideal diode controller with automatic failover
      Servo rail high-power (7 V) and high-current ready
      All peripheral outputs over-current protected, all inputs ESD protected
    - ➢ Interfaces: 5x UART serial ports, 1 high-power capable, 2 with HW flow control
      Spektrum DSM/DSM2/DSM-X Satellite input
      Futaba S.BUS input
      PPM sum signal
      RSSI (PWM or voltage) input
      I2C, SPI, 2x CAN, USB
      3.3V and 6.6V ADC inputs
    - ➢ Dimensions: Weight 38 g (1.3 oz)
      Width 50 mm (2.0")
      Height 15.5 mm (.6")
      Length 81.5 mm (3.2")

2. **Matek Systems PDB-XT60:**
    - ➢ 4-layers and 1.6mm PCB
    - ➢ Built-in XT60 Socket
    - ➢ Total 6 pairs ESC solder tabs are fit for H or X type frame
    - ➢ 5V and 12V Output LED indicators
    - ➢ Regulated 5V and 12V outputs
    - ➢ BEC 5V output:5V/2A (Max.2.5A 10s/minute)
    - ➢ Output Ripple:40mV (VIn= 16V, VOut= 5V@2A load)
    - ➢ Short-circuit tolerant:5 seconds/minute
    - ➢ BEC 12V output (4S LiPoly, 13~18V DC):12V/500mA (Max.0.8A 5s/minute)
    - ➢ BEC 12V output (3S LiPoly):=3S LiPoly voltage 1V

3. **FrSky X8R 8/16ch Full Duplex Telemetry Receive**
   - ➢ Number of Channel 16
   - ➢ RSSI Output(DC Analog) 0~3.3V
   - ➢ Servo Frame Rate 9ms/18ms
   - ➢ Operating Voltage(VDC) 3.5~10V
   - ➢ Max Operating Current(mA) 100mA@5V
   - ➢ Operating Range Full Range (>1.5km)
   - ➢ Length (mm) 46.25
   - ➢ Width (mm) 26.6
   - ➢ Height (mm) 14.2
   - ➢ Weight (gm) 15

4. **NEO-M8N:**
   - ➢ GPS/QZSS L1 C/A, GLONASS L10F, BeiDou B1.
   - ➢ SBAS L1 C/A: WAAS, EGNOS, MSAS.
   - ➢ Galileo-ready E1B/C (NEO-M8N).
   - ➢ Nav. update rate1 Single GNSS: up to 18 HZ.
   - ➢ Assistance AssistNow GNSS Online.
   - ➢ Assist Now GNSS Offline (up to 35 days)3.
   - ➢ Assist Now Autonomous (up to 6 days).
   - ➢ OMA SUPL & 3GPP compliant
   - ➢ Oscillator TCXO (NEO-M8N/Q).
   - ➢ Crystal (NEO-M8M).
   - ➢ RTC crystal Built-In.
   - ➢ Noise figure On-chip LNA (NEO-M8M). Extra LNA for.
   - ➢ lowest noise figure (NEO-M8N/Q).
   - ➢ Anti-jamming Active CW detection and removal.
   - ➢ Extra onboard SAW bandpass filter (NEO-M8N/Q).
   - ➢ Memory ROM (NEO-M8M/Q) or Flash (NEO-M8N).
   - ➢ Supported antennas Active and passive.
   - ➢ Odometer Traveled distance.
   - ➢ Data-logger For position, velocity, and time (NEO-M8N).

5. **Tattu R-line Version 3.0 2000mah 4s 120c:**
   - ➢ Minimum Capacity: 2000mAh
   - ➢ Configuration: 4S1P / 14.8V / 4Cells
   - ➢ Discharge Rate: 120C
   - ➢ Max Burst Discharge Rate: 240C
   - ➢ Net Weight(±20g): 215g
   - ➢ Dimensions: 78mm x 39mm x 41mm (L x W x H)
   - ➢ Charge Plug: JST-XHR
   - ➢ Discharge Plug: XT60

6. **Hobbywing Xrotor Micro 60 amp 4 in 1 BLHeli 32:**
    - ➢ LiPo Power input: 3S-6S
    - ➢ Cont.Current: 60Ax4
    - ➢ Burst Current: 80Ax4
    - ➢ BEC Output: 5V@ 1.5A
    - ➢ Input wires: 12AWG-130mm* (Red/Black)
    - ➢ Output Wire: No wires but solder tabs
    - ➢ Connectors: (In/Out) XT60 (w/ Wires Soldered on) /no
    - ➢ Weight / Size: 15.0g / 32.7x18.4x6.2mm
    - ➢ Mounting holes: 30.5x30.5mm
    - ➢ Throttle Calibration: Supported
    - ➢ ESC Programming: BLHeliSuite32

7. **Caddx Air Unit:**
    - ➢ Operating Temperature: 32 to 104 F (0 to 40 C)Input Power: 7.4-17.6V
    - ➢ Transmitter Power: FCC/SRRC: <30dBm CE: <14dBm
    - ➢ I/O Interface: USB-C, MMCX, 3-in1 Port, MicroSD
    - ➢ Output Power: 25mW/3200mW/500mW/700mW
    - ➢ Video Transmission: 28ms Low Latency
    - ➢ Flight Control System: BetaFlight
    - ➢ Max Transmission Range: 4km
    - ➢ Coaxial Cable Length: 100mm
    - ➢ FOV: 150(D); 122(H); 93(V)
    - ➢ Goggle Compatibility: DJI
    - ➢ Video: 1080p/60fps
    - ➢ Lens: 2.1mm, F/21

8. **Raspberry Pi 4,8 Gb ram:**

➢ Model-Raspberry Pi 4 Model-B
➢ Processor- Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @1.5GHz
➢ RAM Memory - 4 GB LPDDR4 SDRAM

<u>Connectivity:-</u>

➢ 2 × USB 2.0 Ports
➢ 2 × USB 3.0 Ports
➢ 2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless LAN, BLE Gigabit Ethernet Bluetooth 5.0

<u>Operating Power:-</u>

➢ 5 Volt 3 Ampere DC via GPIO Header
➢ 5 Volt 3 Ampere DC via USB Type-C Connector
➢ Power Over Ethernet (PoE)–Enabled (requires separate PoE HAT)
➢ GPIO- (Fully backward compatible with previous boards)

<u>Multimedia:-</u>

- ➢ H.264 (1080p60 decode, 1080p30 encode);
- ➢ H.265 (4Kp60 decode);
- ➢ OpenGL ES, 3.0 Graphics

Video and Sound:-

- ➢ 2 × micro HDMI ports (up to 4Kp60 supported)
- ➢ 2-Lane MIPI CSI Camera Port
- ➢ 2-Lane MIPI DSI Display Port
- ➢ 4-Pole Stereo Audio and Composite Video Port
- ➢ Clock Speed- 1.5 GHz
- ➢ Micro-SD Card Slot- Yes (FAT32 format), support maximum 32G Micro SD Card Memory Features
- ➢ Operating Temperature Range- 0ºC to 50ºC

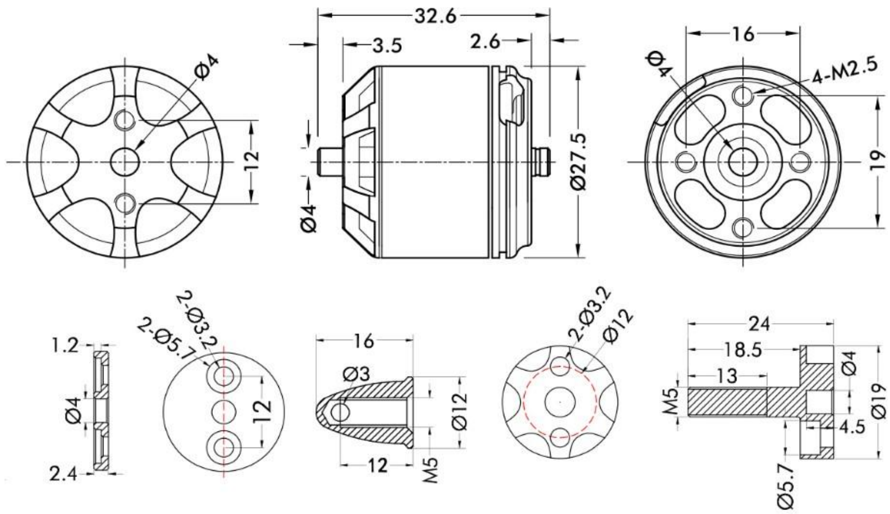
9. Raspberry Pi High Quality Camera with Interchangeable Lens Base:

- ➢ Sony IMX477R stacked, back-illuminated sensor.
- ➢ Resolution: 12.3 megapixels.
- ➢ Output: RAW 12/10/8, COMP8
- ➢ Compatible with Raspberry Pi 1/2/3/4 boards
- ➢ Back focus: Adjustable (12.5 mm–22.4 mm)
- ➢ Lens standards: C-mount, CS-mount (C-CS adapter included)
- ➢ IR cut filter: Integrated
- ➢ Ribbon cable length: 200 mm
- ➢ Tripod mount: 1/4”-20

10. Raspberry Pi 16mm Telephoto Lens:

- ➢ Focal length: 16mm
- ➢ Resolution: 10 Megapixel
- ➢ Aperture: F1.4 to F16
- ➢ Mount: C
- ➢ Field Angle: 1" 44.6°× 33.6°
2/3" 30.0°× 23.2°
1/1.8” 24.7°× 18.6°
1/2" 21.8°× 16.4°
- ➢ Distortion: 1" (-0.7%)
1/2" (-0.5%)
1/3" (-0.15%)
- ➢ M.O.D: 0.2m
- ➢ Back focal length: 17.53mm
- ➢ Optical length: 67.53mm
- ➢ Dimensions: 39x50mm
- ➢ Weight: 133.7g

11. T Motor Navigator MN2212 V2.0 920 KV:



Specifications			
Internal Resistance	173mΩ	Configuration	9N12P
Shaft Diameter	4mm	Motor Dimensions	Φ27.5×26.5mm
Stator Diameter	22mm	Stator Height	13mm
AWG	20#	Cable Length	400mm
Weight Including Cables	65g	Weight Excluding Cables	55g
No.of Cells(Lipo)	2-4S	Idle Current@10v	0.4A
Max Continuous Power 180S	200W	Max Continuous Current 180S	13A

12. RadioMaster TX16S MKII 2.4GHz 16CH:

➢ Display: 4.3-inch TFT full-color touch display with a resolution of 480 * 272
➢ Upgrade method: Supports USB-C online / SD card offline upgrade
➢ Antenna gain: 2db (transmit power adjustable)
➢ Transmitter module: (CC2500 CYRF6936 A7105 NRF2401)
➢ Option 1: Internal 4-in-1 multi-protocol module
➢ Transmitting power: (protocol dependent)
➢ Internal 4-in-1 multi-protocol module : Max 100mw
➢ Channels: Up to 16 channels (depending on the receiver)
➢ Gimbal: V4.0 Hall sensor with Aluminum fascia
➢ Module Firmware: Multiprotocol Module (41N1)
➢ Transmission frequency: 2.400GHz-2.480GHz
➢ Remote control distance:> 2 km @ 22 dbm
➢ Module Bay: JR compatible module bay
➢ Weight: 750g (without battery)
➢ Working voltage: 6.6-8.4V DC
➢ Radio firmware: EdgeTX
➢ Working current: 400mA
➢ Size: 287x129x184mm

13. **DJI V2 FPV Goggles:**

- Weight: Approx. 420 g (headband and antennas included)
- Dimensions: 184×122×110 mm (antennas excluded)
- 202×126×110 mm (antennas included)
- Screen Size: 2-inches (×2)
- Screen Refresh Rate: 144 Hz
- Communication Frequency: 2.400-2.4835 GHz / 5.725-5.850 GHz
- Transmitter Power (EIRP): 2.400-2.4835 GHz
- FCC: ≤ 28.5 dBm
- CE: ≤ 20 dBm
- SRRC: ≤ 20 dBm
- MIC: ≤ 20 dBm