KLS GOGTE INSTITUTE OF TECHNOLOGY

Belagavi, Karnataka

SAEINDIA AEROTHON 2024

Design Report

Team vayuputras

Faculty Advisor

Prof. Anil Kumar Nakkala

Team Number – AT2024080

Devashish Gojagekar
Aditya Singh
Sameer Kulkarni
Keerthi K R
Koushal S Kedari
Ashma Mardolkar
Amman Raikar
Fiona D’Souza
Ian D’Souza
Chinmayi Hosamani

APPENDIX A

STATEMENT OF COMPLIANCE

Certification of Qualification

Team Name: ________________

University/Institute: ____________

Faculty Advisor: ______________

Faculty Advisor’s Email: _______

Statement of Compliance

As Faculty Advisor, I certify that the registered team members are enrolled in collegiate courses. This team has designed the UAS for the SAE AEROTHON 2024 contest, without direct assistance from professional engineers, R/C model experts or pilots, or related professionals.

_________________________ _________________________

Signature of Faculty Advisor Date

Team Captain Information:

Team Captain’s Name: ____

Team Captain's E-mail: ____

Team Captain’s Phone: ____

Index

List of Figures

1. Introduction

This document presents the final design developed by the Vayuputras Team from KLS Gogte Institute of Technology, Belagavi, for the upcoming SAEINDIA AEROTHON 2024. The purpose of this Unmanned Aerial Vehicle (UAV), named “IRIS (Incident response and imaging surveillance),” is to demonstrate exceptional capabilities in surveying, obstacle avoidance, tracking, navigation, payload drop, object identification and object counting. The main objective of this UAV is to fulfil the mission requirements outlined by SAEINDIA while ensuring safety and reliability in diverse operational environments. The theme guiding the design is surveillance and disaster management, reflecting the team’s commitment to addressing critical challenges through innovative aerial solutions. This report details the methodology, design, analysis, and performance of IRIS, highlighting its potential to redefine UAV capabilities in the field.

1.1 Objective

The main objective of participating in the SAEINDIA AEROTHON is to redefine the limits of drone technology, showcasing our creativity and technical ability to the world. Participating in the SAEINDIA AEROTHON is not just a competition but it is a journey towards innovation and excellence. It is a chance to be part of something bigger to inspire and be inspired by the incredible innovations of our peers. Through this experience, we aim to enhance our skills from design and development to problem solving and teamwork, preparing us for the challenges of future. Networking with industry professionals and like-minded enthusiasts will not only expand our horizons but also open doors to future collaborations and opportunities. We are not just seeking recognition for ourselves, but we want acknowledgment for our commitment to pushing the limits of what we can achieve.

1.2 Problem Statement

The problem statement suggests the development of UAS which can survey a predefined area, navigating an obstacle course, identifying specific objects within the surveyed area and counting tasks. Our UAV need to carry a specified payload and deliver it to a target through both manual and autonomous operations. The payload dimensions are as follows 10 cm x 5 cm x 5 cm.

SI.No.	Parameter	Requirement/Limitation
1	UAS Type	Multirotor
2	UAS Category	Micro UAS (Take-off weight < 2kg)
3	Payload Capacity	200 grams
4	Propulsion Type	Electric
5	Communication System Range	At least 1 km

Table no 1.2.1: UAS Design Requirements

1.3 Mission Profile

The Flight Mission is as follows:

- Take-off manually and climb to 30m altitude. Navigate to search area 300m away avoiding obstacles and maintaining 30m altitude. Identify the target using onboard sensors.

- Descend to 20m, stabilize and drop payload accurately. Ascend back to 30m.Return to take-off point.
- Land safely at designated point.
- Execute system checks and upload mission plan.
- Perform this mission both manually and autonomously.

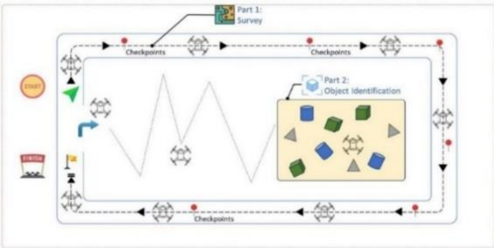


Fig 1.3.1: Mission Profile (Round 1 and 2)

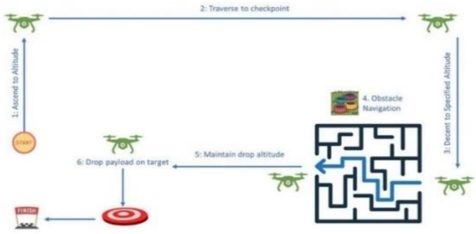


Fig 1.3.2: Mission Profile Round 3 (Manual)

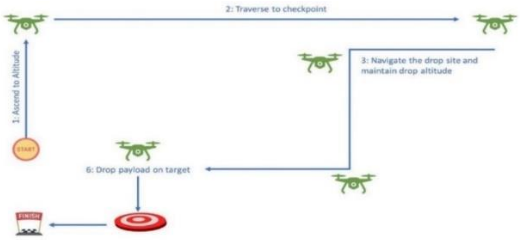


Fig 1.3.3: Mission Profile Round 4 (Autonomous)

2. Technical Design

2.1 Conceptual Design

A comprehensive evaluation of various conceptual designs was conducted, considering factors such as desired features, performance requirements, spatial constraints, and weight limitations. This systematic analysis facilitated the selection of an optimal configuration, culminating in the finalized design of the IRIS Unmanned Aerial System (UAS).

Iteration 1: The design was conceptualized with the intention of maintaining an unchanging centre of gravity position in the x and y planes, both with and without the payload. While this approach offered the advantage of consistent lateral stability, it necessitated the incorporation of longer and more substantial landing gear to accommodate the payload bay situated below the UAS frame. Consequently, a significant portion of the available weight budget was allocated to these bulkier landing gear components, potentially limiting the capacity for a larger battery that could have extended the flight endurance.

Fig 2.1.1: Iteration 1

Iteration 2: The design concept involved a "dead cat" style quadcopter configuration, further augmented with an additional motor arm and propeller mounted perpendicular to the thrust plane of the UAS. The intended function of this fifth rotor was to provide auxiliary thrust during forward flight, theoretically enhancing efficiency in cruise conditions. However, despite the potential efficiency gains, this configuration exceeded the given weight constraints, rendering it unfeasible for implementation within the project's parameters. Consequently, this design iteration was ultimately cancelled due to its excessive weight implications.

Fig 2.1.2: Iteration 2

Iteration 3: The selected design incorporates a true X-configuration for the quadcopter, with the payload bay seamlessly integrated into the frame structure. This approach eliminates the need for additional weight-incurring mechanisms to secure the payload, effectively optimizing the overall weight budget. The consequent weight savings facilitate the accommodation of a larger battery capacity, as well as the incorporation of more advanced and capable sensor suites. These enhancements will contribute to improved functionality, reliability, and overall performance of the Unmanned Aerial System.

Fig 2.1.3: Iteration 3

3. Detailed Design

3.1 Estimation of Preliminary Weight

For an initial weight estimation, a maximum total weight of 2000 grams, including a 200-gram payload, is targeted. The primary components are allocated weight budgets as follows: a lightweight carbon fiber frame with 3D printed arm and motor mounts at approximately 550 grams, electronics (flight controller, ESCs, receiver and other sensors) around 500 grams, and an 5000mAh 6S lithium-polymer battery estimated at 750 grams. This estimation provides a baseline for ensuring the selected components can potentially meet the desired weight requirements while accommodating the intended payload capacity.

Preliminary Weight Estimation	
Component	Estimated weight (g)
Payload	200
Battery	750
Frame	550
Electronics	500
Total Weight (g)	**2000**

Table no 3.1.1: Estimation of Preliminary Weight

3.2 Estimation of Thrust required.

The thrust required will be determined based on the vehicle's weight, desired acceleration and flight conditions. The flight time is computed using the appropriate calculations as indicated below:

Total weight of the UAS:

$$W_{total} = 2000_{grams}$$

This includes the drone's total weight (W_{total}), the weight of the frame $\left(W_{frame}\right)$, the weight of the electronics ($W_{electronics}$), the weight of the batteries($W_{batteries}$) and the weight of the payload $\left(W_{payload}\right)$. All stated in grams.

Minimum thrust-to-weight ratio for hover:

Considering a thrust-to-weight ratio of 1.5 to ensure stable hovering, maneuverability and payload carrying capacity required. This ratio provides resilience against external disturbances, enhances payload capacity, and ensures reliable performance across varying environmental conditions.

Thrust required per motor for hover:

$$T_{\{(per\ motor\})} = \frac{W_{total}}{4} \times \frac{T}{W}$$

$$T_{(per\ motor)} = \frac{2000_{grams}}{4} \times 1.5$$

$$T_{(per\ motor)} = 750_{grams}$$

Thrust required per motor for hovering = 750 grams

3.3 Selection of Propulsion System

The CINE66 2812 KV925 motor has been chosen for several technical reasons. Each motor must provide a hover thrust of 750 grams to achieve stable flight. This motor meets that thrust requirement within its most efficient throttle range, ensuring optimal power usage and extended flight times. Its high torque and power output are crucial for maintaining stable flight with additional payloads in adverse weather conditions. The motor delivers optimal efficiency when paired with 9-inch propellers, which are ideally suited for the aerodynamic design of our frame. Lastly, the motor’s self-cooling design helps prevent overheating, ensuring reliable performance during extended operations.

Fig no 3.3.1: T-motor CINE66 2812 KV925 Fig 3.3.2: T-TYPE CARBON FIBER PROPS

The 9055 carbon fiber propellers have been chosen for their compatibility with the motor and the frame. Its rolled carbon fiber build makes it light weight compared to other APC propellers of similar size while not compromising durability.

Fig 3.3.3: T-MOTOR F55A PRO III 55A 3-8S BLHELI32 4-IN-1 ESC

The T-motor F55A esc has been chosen as its constant current rating of 55A is well above the 50.5A maximum possible current requirement of the motors. The 4 in 1 design makes wire management convenient and is lighter in weight than independent ESCs of similar rating. It runs the BLHeli_32 firmware and thus can be precisely tuned for our drones’ requirements.

Battery Selection: -

Fig 3.3.4: Lithium Polymer (LiPo) Battery

The CNHL Black Series 4000mAh 22.2V 6S 65C LiPo Battery has been chosen as it provides a perfect compromise between flight time and weight. Its 22.2V nominal voltage aligns perfectly with the motor's voltage requirements, ensuring optimal performance and efficiency.

With a C rating of 65C it can sustain a continuous current discharge of 260A which is well above the 205A maximum possible burst current requirement of our drone. The high discharge rate of 65C enables rapid power delivery, crucial for sudden acceleration during payload drops and adverse weather conditions, maintaining stable flight. Overall, the CNHL Black Series 4000mAh 22.2V 6S 65C Lipo Battery - EC5 offers the ideal combination of capacity, voltage, discharge rate, and reliability for our drone's requirements.

3.4 UAV Sizing

Propeller clearance:
For optimal UAV efficiency, the tip-to-tip clearance between adjacent propeller blades should be at least one-third of the full propeller diameter.

Diameter of propeller: $9inch = 228.6mm$
Minimum required propeller clearance $= \frac{1}{3} \times 228.6 = 76.2mm$
Propeller clearance in IRIS $= 80.41mm$

Landing Gear:
The IRIS UAS landing gear serves the critical function of enabling stable landings while maintaining 15mm of ground clearance underneath the unobstructed underbelly. Integrating the payload within the frame allows for low-profile, shock-absorbing, 3D printed TPU pad-style landing gears. This design approach facilitates proper clearance during landings while providing a clean underside configuration.

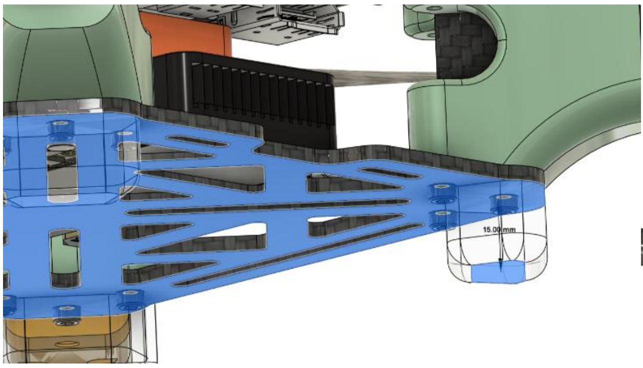


Fig 3.4.2: Landing Gear

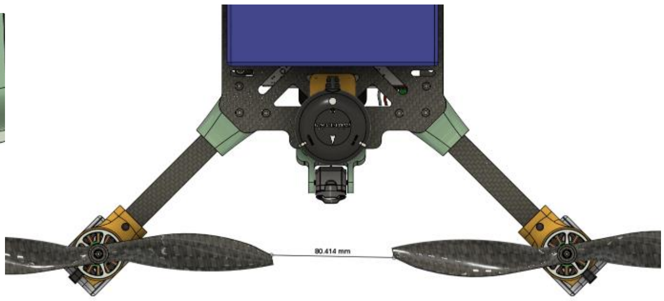


Fig 3.4.1: Propeller clearance

Parameter	Description	Value
Wheelbase	Distance between the motor shafts of diagonal motors	433mm
Rotor Arm	Length of individual Rotor Arm	165mm
Hub	Chassis of the UAV (excluding arms)	220mm*145mm
Propeller Clearance	Shortest distance between propeller tips	66.5mm
Landing gear	Clearance between ground and base of the UAV	15mm

Table no 3.4.1: UAV Sizing

3.5 UAS Performance

Endurance estimation

The flying time will be determined by the connection between available energy and the UAV's energy requirements. The flight time is computed using the appropriate calculations, as indicated below,

$$Flight\ time = \frac{Capacity \times Discharge}{Average\ amp\ draw}$$

This includes the drone's flight duration, which is stated in hours, the battery capacity, which is stated in milliamp hours (mAh) or amp hours (Ah), the amount of battery discharge you permit during flight, and the average amp draw (AAD), which is measured in amperes. Here's how to determine the average amp draw:

$$Average\ amp\ draw = \frac{All - weightup \times Power}{Voltage}$$

The whole weight of your drone, including the battery, is referred to as its "all-up weight" and is typically expressed in kilos. The power, measured in watts per kilogram, needed to raise one kilogram of equipment. The voltage of a battery is stated in volts.

$$AAD = \frac{2 \times 277.11}{25} = 22.16$$

Therefore,

$$Flight\ time = \frac{4 \times 0.95}{22.16} = 0.1714\ hours$$

Flight time = 10.28 minutes

3.6 Material selection

a. **Twill Roll Carbon Fiber Sheet**

It is recommended to utilise carbon fibre because of its excellent impact resistance, which guards against damage to internal electronics, and its lightweight nature, which considerably lowers total weight. Because motors and propellers apply pressures on drone arms, their high tensile strength guarantees that these parts can resist stress without bending. The top and bottom plates that make up the drone's primary structural frame are constructed from twill roll carbon fibre sheets. They are also utilised for the arms that join the central frame to the motors.

b. **Long Strand Carbon Fiber-Infused Nylon PA6 Filament**

Carbon fiber-infused nylon PA6 filament is used in the production of motor mounts. This filament is strengthened to have a high melting point, which keeps it from softening or deforming at high temperatures. This material ensures accurate motor fitting across a range of temperatures by maintaining mechanical qualities and providing high dimensional stability. Moreover, it lessens total thermal stress by enhancing thermal conductivity for efficient heat dissipation.

c. 75A TPU Filament

To protect the motor mount and absorb shocks, landing pads and shock enclosures use 75A TPU filament. Because of its flexibility, it can absorb impact energy during severe landings or crashes, which lessens the strain on the motor mount and other parts. This greatly lowers the possibility of the motor mount being damaged, increasing the drone's overall durability.

d. PLA PRO Filament

PLA PRO filament is used to make arm mounts. Because of its superior adhesion to the print bed and less warping, it is a dependable material for printing complex geometries. It is the best material for drone building because it is environmentally benign and biodegradable, especially in delicate areas. This material's low melting point and excellent flow characteristics also make it simple to print with.

e. M3 Brass Inserts

Drone frames are strengthened and preserved by the incorporation of brass inserts, which also stop loosening and stripping. They lessen wear from repeated assembly by strengthening plastic threads. Motor mounts, frames, and payload attachments all smoothly incorporate brass inserts. When positioned carefully, they aid in distributing weight equally throughout frames, enhancing stability and balance overall, particularly in big, intricate models.

3.7 Subsystem Selection (Communication System, Control & Navigation System & Other Avionics/ Sensors)

Aircraft Components:	**Ground Station Components:**
Pixhawk Orange Cube	Laptop (for ArduPilot)
Power Module for Pixhawk	Telemetry module
HERE 3 GPS	DJI V2 FPV Goggles
RP3 V2 ELRS Receiver	TX16S Mark II RC transmitter
Holybro PMW3901 optical flow sensor	
1 Watt Telemetry Module	
T-Motor F55A Pro III 55A 3-8S BLHeli32 4-in-1 ESC	
5volt UBEC	
CADDX Polar Vista VTX and FPV Camera	
Jetson Nano	
Jetson Nano Camera	
Emax ES08MA II Servo	
iFlight XING X2806.5 FPV Cinelifiter Motor	

Table no 3.7.1: Subsystem Selection

3.7.1 Communication System

The FPV camera and Jetson Nano camera are used in the communication system to provide visual feedback on the aircraft's position while it is in flight, while the RP3 V2 ELRS receiver is used for radio communication between the aircraft and the ground station. With a range of up to 10 kilometres, a one-watt telemetry device is used to transmit data from the aircraft to the ground station, including position, altitude, waypoint location, and many other variables. Its power of one watt allows it to provide a strong signal across great distances, ensuring that the data is correct.

3.7.2 Control and Navigation System

Since they can connect with the Pixhawk Cube Orange, which is utilized for its high processing power, rather reliably, the Telemetry Module and RC Transmitter are employed together for control. During the manual run, the laptop running ArduPilot is used for navigation, and during the autonomous run, the ground station FPV goggles are utilized. The Pixhawk has sensors attached to convey its GPS location, such as a GPS Module. In order to have both forward and downward vision for various jobs during the flight path, we are using two servos: one for the cargo drop mechanism and the other to tilt the FPV camera.

3.7.3 Other Avionics/Sensors

Our primary flying controller, the Pixhawk, communicates directly with our onboard computer, the Jetson Nano, to offer autonomous commands based on computer vision and object recognition. Because of its graphics card and quick processing speed, Jetson is used to process live video feeds. Additionally, a cooling fan installation option for the Jetson is available. The UBEC, which steps down the voltage from the main LiPo battery pack to a lower voltage like 5V or 9V so that all the components may be powered with the necessary voltages, and the Power Module (power distribution board) provide power to the Pixhawk. To precisely regulate the lift created, we combine 4 motors with the 4-in-1 ESC. Since a 4-in-1 ESC is significantly lighter than four separate ESCs and makes wire management easier, it is used in place of regular individual ESCs to save excess weight. An optical flow sensor is utilized to continuously check for drift in the aircraft path so the aircraft may precisely recorrect its position. A GPS module is used to always provide the aircraft's precise location, giving us total control over its course.

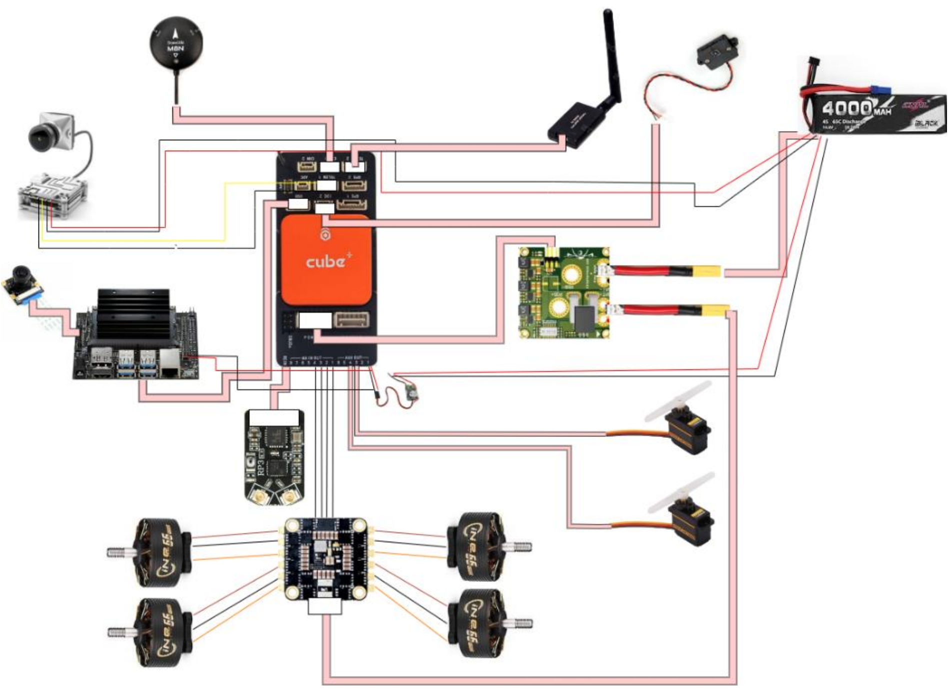


Fig 3.7.2: Circuit diagram

3.9 Preliminary CAD model

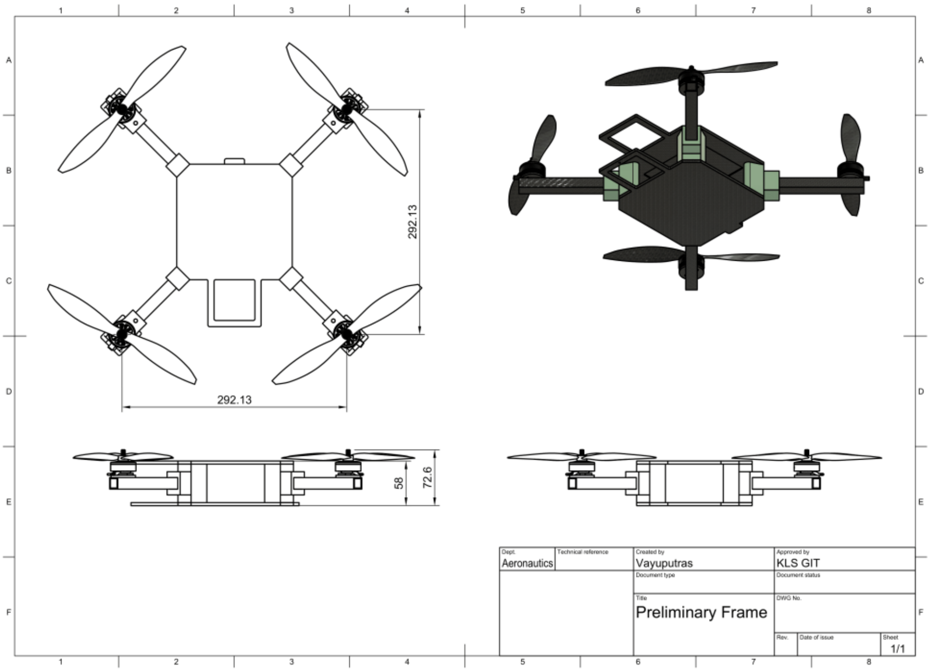


Fig no 3.9.1: Preliminary CAD Drawing

3.10 Computational Analysis

The stress analysis performed on the structural model indicated a minimum Factor of Safety of 4.1 with a maximum displacement of 0.35mm when subjected to a load of 75N applied to each arm, simulating the thrust condition at full throttle with a safety factor of 3. These results demonstrate that the chassis design exhibits sufficient structural robustness to withstand the anticipated load conditions, thereby confirming its suitability for the intended application.

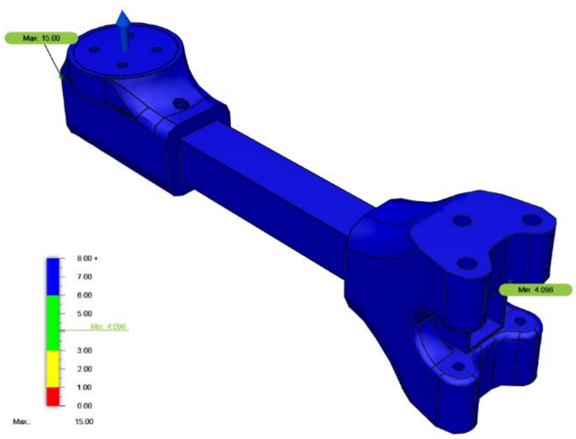


Fig 3.10.1: FOS Analysis of Arm Assembly

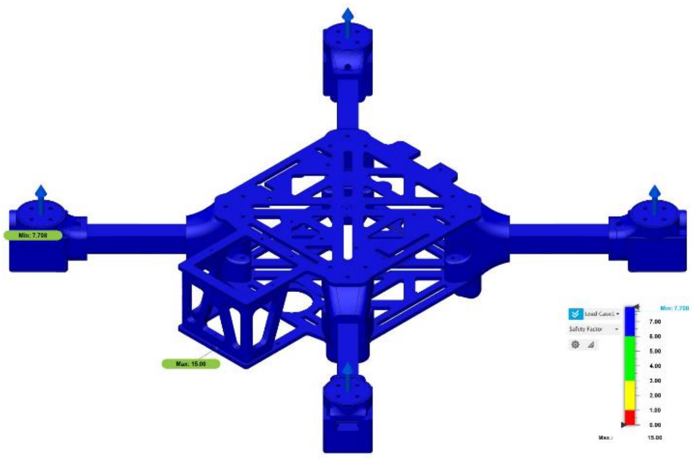


Fig 3.10.2: FOS Analysis of Frame Assembly

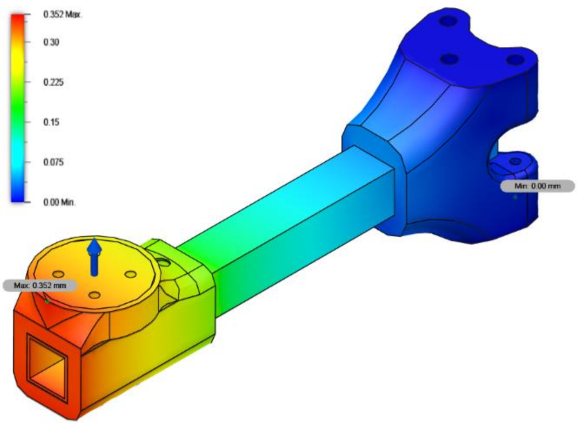


Fig 3.10.3: Displacement of Arm Assembly

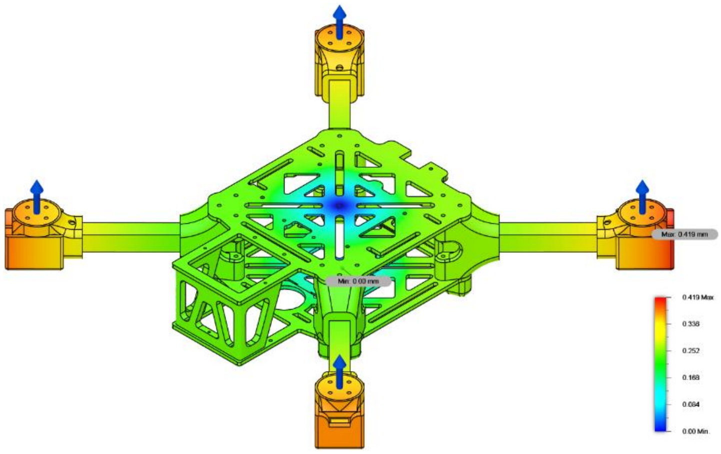


Fig 3.10.4: Displacement of Frame Assembly

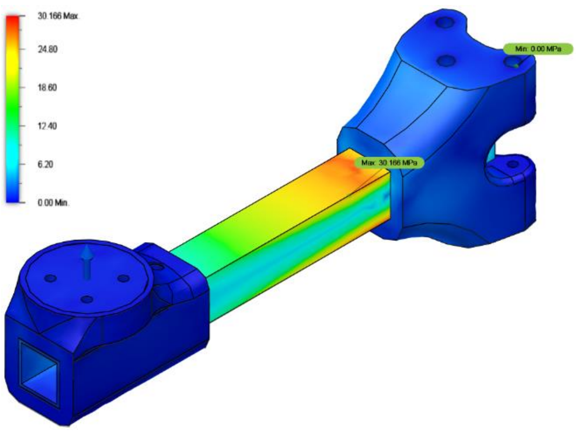


Fig 3.10.5: Stress Analysis of Arm Assembly

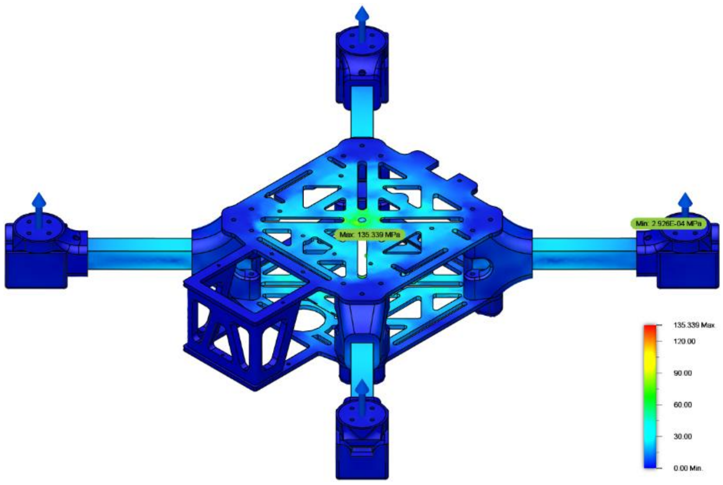


Fig 3.10.6: Stress Analysis of Frame Assembly

3.11 Optimized Final Design

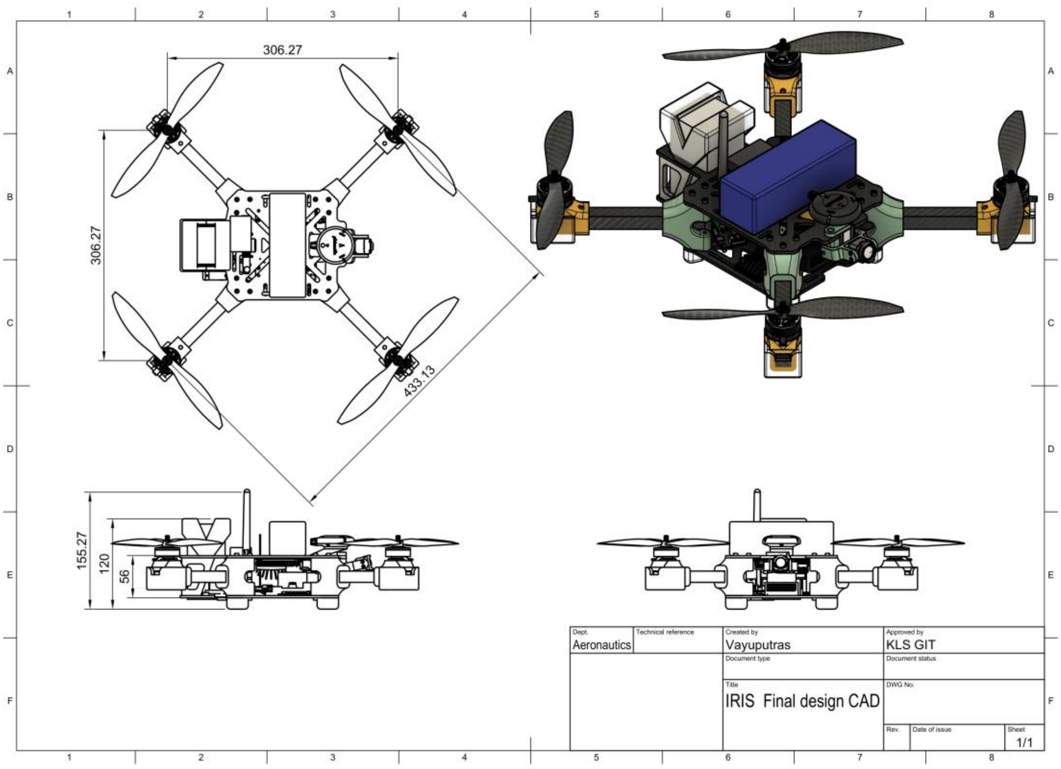


Fig 3.11.1: 2D drawing

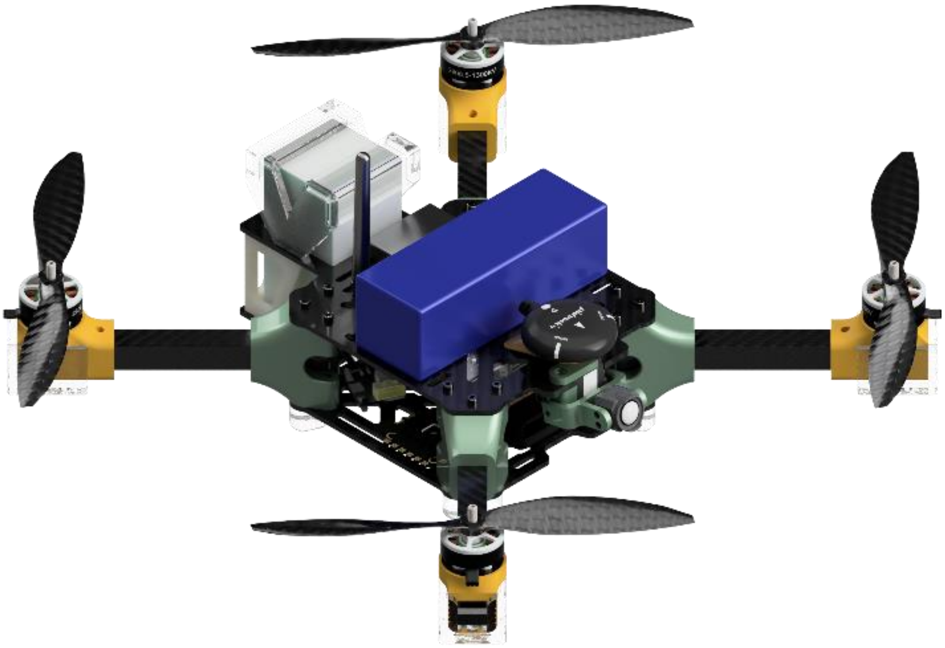


Fig 3.11.2: Isometric view

Exploded Views:

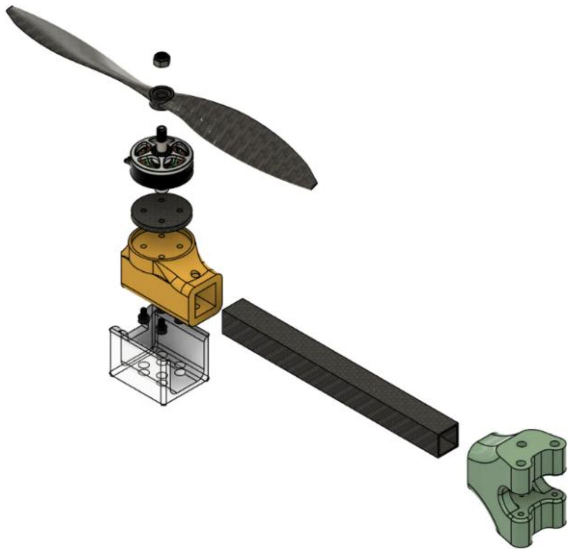


Fig 3.11.3: Exploded view of the arm assembly

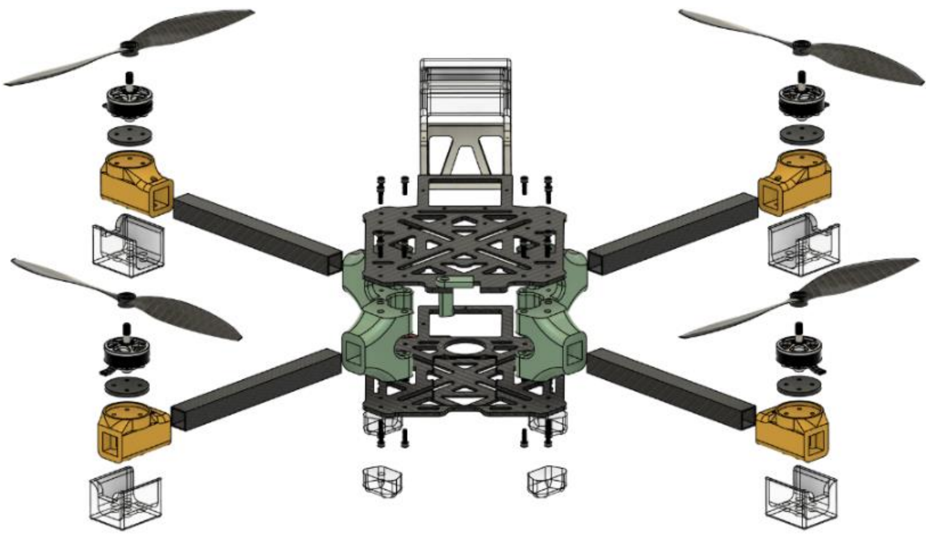


Fig 3.11.4: Exploded view of the frame assembly

3.12 Detailed Weight Breakdown and Centre of Gravity

Component name	Weight per pc (g)	quantity	Total weight (g)
Pixhawk Orange Cube	35	1	35
Holybro M8N	32	1	32
RP3 V2 Receiver	4.6	1	4.6
HOLYBRO PMW3901	0.6	1	0.6
Emax ES08MA II Servo	12	2	24
XT 90 CONNECTOR	15	1	15
1 Watt Telemetry	12	1	12
Caddx Polar Vista Kit starlight	29.5	1	29.5
T-MOTOR CINE66 2812 925kv	76.4	4	305.6
T-Motor F55A Pro III ESC	17.8	1	17.8
Nvidia jetson nano	75	1	75
Jetson camera	40	1	40
Wires and miscellaneous	70	1	70
8045*3 Props	10.5	4	42
Battery	540	1	540
Frame	457	1	457
Payload	200	1	200
Total Weight (g)			1900.1

Fig 3.12.1: Detailed Weight Breakdown

Component name	Weight per pc (g)	quantity	Total weight (g)
Arm Motor mount	14	4	56
TPU sleeve	6	4	24
CF Disk	3.5	4	14
Arm Mount	20	4	80
CF Arms	15	4	60
CF Top plate	65	1	65
CF Bottom plate	61	1	61
M3 Bolts	2	24	48
M3 Brass inserts	1	24	24
FPV camera mount	6	1	6
Servo mount	3	1	3
Landing Gear	4	4	16
Total Weight (g)			457

Fig 3.12.2: Detailed Frame Breakdown

3.12.2 Centre of Gravity

Through analytical calculations, it has been determined that the introduction of the payload will result in a 5.1mm shift in the centre of gravity relative to the configuration without the payload in the direction of the payload.

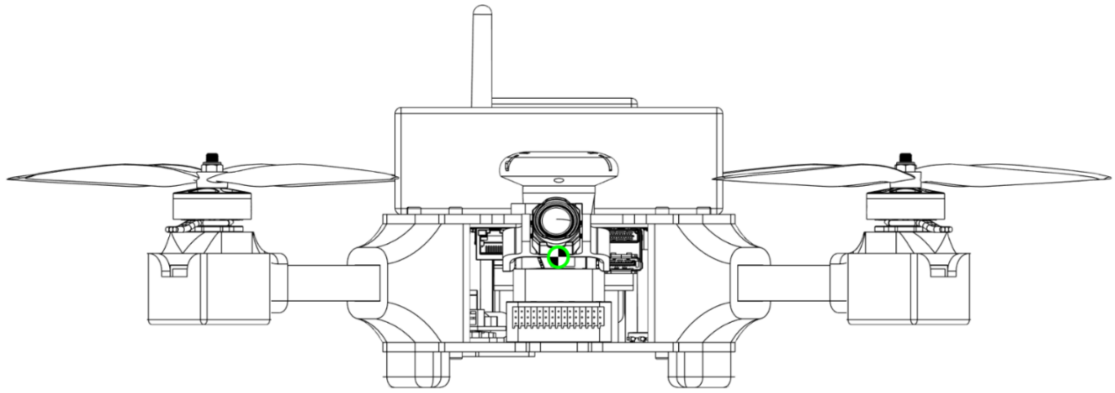


Fig 3.12.2.1: CG Front view

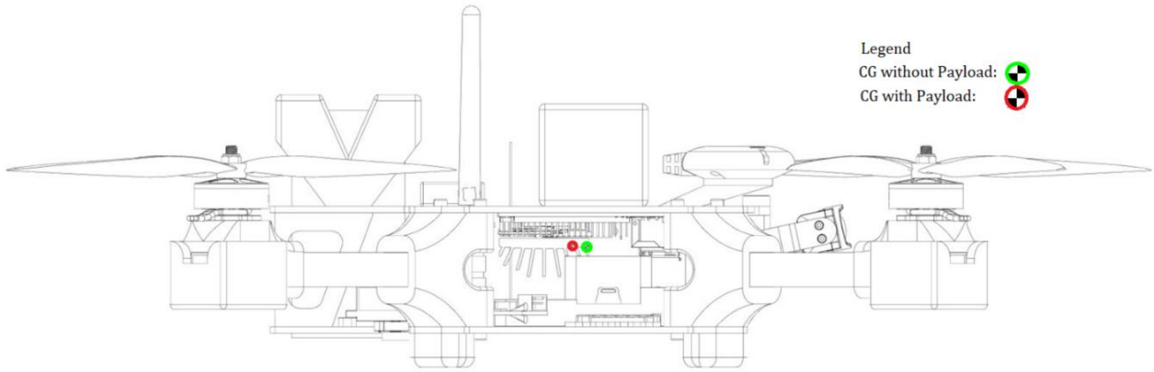


Fig 3.12.2.2: CG Side view

3.13 UAS Performance Recalculation

3.13.1 Thrust/Weight

Maximum take-off weight of the UAV: 1900.1_{grams}

Thrust of 1 motor at 100% power: 2517_{grams}

Total thrust of the UAV at 100% power: 10068_{grams}

Thrust to weight ratio = $\frac{Total\ Thrust}{Maximum\ weight}$

$$T/W = \frac{10068_{grams}}{1900.1_{grams}} = 5.3$$

$$\boldsymbol{Thrust - to - weight \ = 5.3}$$

With a thrust-to-weight ratio of 5.3, the UAV demonstrates that it possesses sufficient power to carry payloads or execute manoeuvres efficiently. This indicates good agility, responsiveness, and potential for carrying additional equipment or payloads while maintaining stable flight characteristics.

3.13.2 Power Required for the mission.

Component name	Quantity	average current(A)	voltage (v)	Total current draw (A)
Motor (Hover)	4	3.8	25	15.2
ESC idle	1	0.05	25	0.05
Flight Controller	1	0.5	25	0.5
GPS	1	0.03	25	0.03
Receiver	1	0.02	25	0.02
Telemetry	1	0.25	25	0.25
Nvidia Jetson	1	0.3	25	0.3
Camera	1	0.002	25	0.002
VTX	1	0.3	25	0.3
Optical sensor	1	0.001	25	0.001
Servo	2	0.048	25	0.096
Internal cooling	1	0.1	25	0.1
Total Power Consumption (total current x voltage)				421.225

Table no 3.13.1: Power Required Estimation

3.13.3 Endurance with payload.

$All - weightup$ = 1900.1_{grams}

$$Average\ amp\ draw = \frac{All{-}weightup{\times}Power}{Voltage} = \frac{1.9{\times}210.61}{25} = 16$$

$$Flight\ time = \frac{Capacity \times Discharge}{Average\ amp\ draw} = \frac{4 \times 0.95}{16} = 0.2375$$

Therefore,

$$\boldsymbol{Flight\ time = 14.25\ minutes.}$$

3.13.4 Endurance without payload.

$All - weightup$ = 1700.1_{grams}

$$Average\ amp\ draw = \frac{All{-}weightup{\times}Power}{Voltage} = \frac{1.7{\times}210.61}{25} = 14.32$$

$$Flight\ time = \frac{Capacity \times Discharge}{Average\ amp\ draw} = \frac{4 \times 0.95}{14.32} = 0.2653$$

Therefore,

$$\boldsymbol{Flight\ time = 15.92\ minutes.}$$

4. Final UAS Specifications and Bill of Material

Parameter	Value
Category	Micro
Empty weight	1700.1g
Max take-off weight	1900.1g
Max thrust	10068g
Maximum endurance with payload	14.25 minutes
Maximum endurance without payload	15.92 minutes
Diagonal wheelbase	433mm
Ground clearance	15 mm
Propeller Clearance	66.5mm
Number of rotors	4
Material	Carbon fiber, PLA and TPU
R/C communication frequency	2.4 GHz
Max Control transmission range	10 km
FPV Video transmission frequency	5 GHz
Max FPV transmission range	2 km
Telemetry frequency	433 MHz
Max Telemetry transmission range	5 km
Battery type	Lithium Polymer
Battery voltage	25.2 volts
Battery capacity	4000 mAh
Failsafe features	Return to home in case of low battery, loss of communication and manual RTH.

Fig 4.1: UAS Specifications

Bill of Materials: -

SR No.	Component Name	Quantity	Single Unit Price	Total Quantity Price	Manufacturer
1	Laptop (for ArduPilot)	1			
2	Telemetry module	1	₹7,999	₹7,999	Generic
3	DJI V2 FPV Goggles	1	₹ 52,999	₹ 52,999	DJI
4	TX16S RC transmitter	1	₹ 18,999.00	₹ 18,999.00	Robu
	Total			**₹79,997.00**	

Fig 4.3: Bill of material for Ground Station Components

SR No.	Component Name	Quantity	Single Unit Price	Total Quantity Price	Manufacturer
1	Pixhawk Orange	1	34,999.00	34999	Cubepilot
2	Power Module	1	529	529	Generic
3	Holybro M8N GPS	1	9609	9609	Holybro
4	RP3 ELRS Receiver	1	2,399.00	2399	Radiomaster
5	HOLYBRO PMW3901	1	3,999.00	3999	HolyBro
6	1 Watt Telemetry	1	7,999	7999	Generic
7	T-Motor F55A Pro III ESC	1	9,749.00	9749	T-Motor
8	5volt UBEC	1	189	189	Generic
9	CADDX Polar Vista	1	13,309.89	13309.89	CADDX
10	Jetson Nano	1	24,999.99	24999.99	NVIDIA
11	Jetson Nano Camera	1	7,740.00	7740	Arducam
12	Emax ES08MA II Servo	1	799	799	Emax
13	T motor cine66 kv925	4	4,499.00	17996	T motor
14	40x40 cooling fan	1	153	153	Generic
15	M3 X6mm brass inserts	28	69	1932	EasyMech
16	Carbon Fibre 300x300x4mm sheets	2	4,379.00	8758	Generic
	Total			**145,159.88**	

Fig 4.2: Bill of Material for Aircraft Components

5. System design for capturing the survey data.

5.1 Introduction

The autonomous drone system designed for this project incorporates the NVIDIA Jetson Nano, equipped with Arducam IMX477 Day Night camera and YOLOv7 algorithms for shape recognition. The system will utilize ROS (Robot Operating System) and Gazebo for simulation and control. The primary tasks of the drone are to identify and count various shapes, record surveillance footage, and, in a subsequent phase, recognize a bullseye and deploy a payload. This section outlines the detailed design for capturing, storing, and retrieving survey data.

5.2 Data Capture and Processing

5.2.1 Camera System

The drone is equipped with a high-resolution Arducam IMX477 Day Night camera capable of capturing video footage and still images at good resolution and in low light, compatible with the companion PC. This camera interfaces with the NVIDIA Jetson Nano, providing real-time video feed for processing.

5.2.2 FPV Data capture

The FPV flight data will be transmitted through FPV Telemetry Polar Vista Starlight using digital transmission. Upon reception, it will be captured by FPV Telemetry N V2 Goggles and stored onto an SD Card. The data will be saved in MP4 format for easy accessibility and playback.

5.2.3 Shape Recognition

The YOLOv7 (You Only Look Once, version 7) algorithm, running on the Jetson Nano, processes the video feed to detect and recognize different shapes. The algorithm identifies shapes in real-time and counts their occurrences.

5.3. Data Storage and Formats

5.3.1 Shape Recognition Data

Upon detecting shapes, the following data will be recorded:

- **Shape Type**: The type of shape detected (e.g., circle, square, triangle).
- **Count**: The total count of each shape type detected during the surveillance period.
- **Timestamp**: The time at which each shape was detected.

This data will be formatted as plain text and stored in a file named **shapes_data.txt** located in the **~/Desktop** directory of the Jetson Nano's operating system. The structure of the text file will be as follows:

```yaml
Timestamp: YYYY-MM-DD HH:MM:SS
Shape: Circle, Count: 5
Shape: Square, Count: 3
Shape: Triangle, Count: 2
```

Fig 5.3.1.1: Shape Recognition Data

5.3.2 Surveillance Video Recording

The entire surveillance operation will be recorded in MP4 format. The video will capture the drone’s viewpoint, providing a comprehensive visual record of the environment and the shapes detected. The recording will be stored in a file named **surveillance.mp4** located in the **~/Desktop** directory.

5.4. Data Transmission and Retrieval

5.4.1 Data Storage Location

All captured data, including the shape recognition text file and the surveillance video, will be stored locally on the Jetson Nano’s filesystem, specifically in the **~/Desktop** directory for easy access.

5.4.2 Data Transmission

In scenarios where remote access to the data is required, several transmission methods can be employed:

- **Wi-Fi Transfer**: Using secure Wi-Fi connections to transfer files from the Jetson Nano to a remote server or PC.
- **USB Transfer**: Physically transferring data using USB storage devices.
- **ROS Communication**: Utilizing ROS topics and services to transmit data to other nodes or systems connected within the ROS network.

5.4.3 Data Retrieval

To retrieve the stored data:

- **Local Access**: Directly accessing the Jetson Nano's desktop directory via an attached monitor, keyboard, and mouse.
- **SSH Access**: Using Secure Shell (SSH) to remotely log in to the Jetson Nano and copy the data files to another computer.
- **ROS Services**: Implementing ROS services that allow requesting and receiving data files via ROS commands.

6. Methodology for Autonomous Operations:

Components used:

Nvidia Jetson Nano: The Nvidia Jetson Nano is a mini pocket computer with high processing power. It is being used as the main brain for our autonomous systems to carry out all the programs for image processing and object detection. The Nvidia Jetson Nano was chosen as the companion PC on board our drone because it is powered by an Nvidia GPU and a programming interface like CUDA, which allows image processing and detection at a much faster rate compared to other companion PCs in the same or lower range, such as the Raspberry Pi, which lacks GPU processing power and is not designed for good image capturing, providing low FPS. These factors are crucial, as time constraints are present while airborne.

Arducam IMX477 CSI camera: The Arducam IMX477 CSI camera is being used for capturing the surrounding images for object detection and recognition. It is powered by the Sony IMX477 sensor, which performs well and includes a daylight sensor, making it reliable even in low light conditions and exceptional weather. Its CSI connection is compatible with our companion mini-PC, and the manufacturer provides drivers for the Jetson Nano, facilitating its use in such projects.

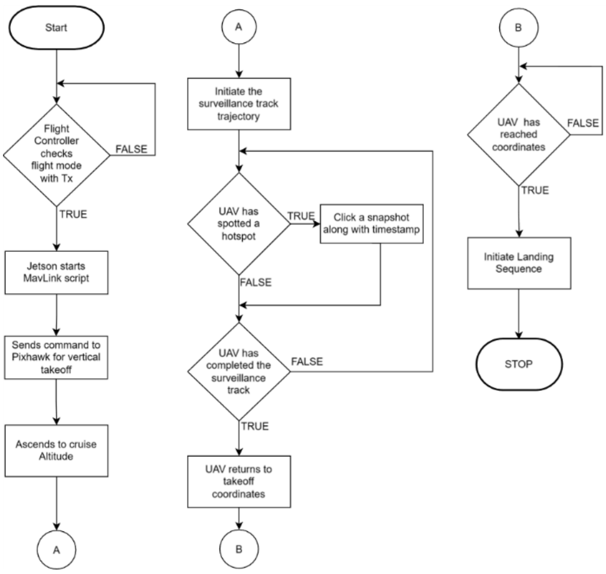
Servo: The Emax ES08MA II servo is considered ideal for a payload drop mechanism on a drone controlled by an NVIDIA Jetson. Sufficient torque (2.5 kg-cm at 4.8V) and speed (0.12 seconds/60 degrees) are offered for effective payload release. Durability is ensured by its metal gears, which are essential for the drone's operational environment. Compatibility with the Jetson platform is achieved through standard voltages and PWM signals managed by GPIO pins or PWM controllers like the PCA9685. The compact (23.0 x 11.5 x 24.0 mm) and lightweight (8.5 grams) design minimizes the impact on flight dynamics. Additionally, it is an affordable and high-quality choice.

Autonomous Algorithms:

Flight Mission 1 - First Leg: Flying Around the Given Track and Over Designated Hotspots An autonomous flight will be conducted using the Mission Planner software, compatible with the Pixhawk Cube Orange and onboard GPS. The given track is divided into 10 waypoints in the mission planner, covering all specified hotspots.

1. **Initialization:** The autonomous flight sequence is initiated.
2. **Take-off Procedure:** Commands are issued through the Mission Planner software for the Pixhawk Cube Orange to execute a vertical take-off.
3. **Altitude Adjustment:** The drone ascends to a predetermined cruise altitude of 15 meters above ground level (AGL) to ensure safe clearance and optimal surveillance coverage.
4. **Surveillance Trajectory Activation:** The prescribed surveillance track trajectory is initiated, encompassing designated hotspots and key areas of interest.
5. **Velocity Configuration:** The flight velocity is set to a consistent 3 meters per second (m/s), ensuring steady progress along the surveillance track while allowing for thorough data collection.
6. **Checkpoint Navigation:** The drone traverses between predefined waypoints along the surveillance track, systematically covering each checkpoint to fulfil surveillance objectives.
7. **Return to Take-off Point:** The drone navigates towards the final checkpoint, which coincides with the initial take-off position, marking the completion of the surveillance mission.
8. **Landing Procedure:** The landing sequence is initiated, guiding the drone to descend safely and autonomously towards the designated landing area.
9. **Mission Conclusion:** The autonomous flight mission is concluded, ensuring all objectives are met and data collection is finalized.
10. **Termination:** The flight operation is completed by halting all autonomous functions and transitioning the drone to a standby or powered-off state as required.

Flowchart:



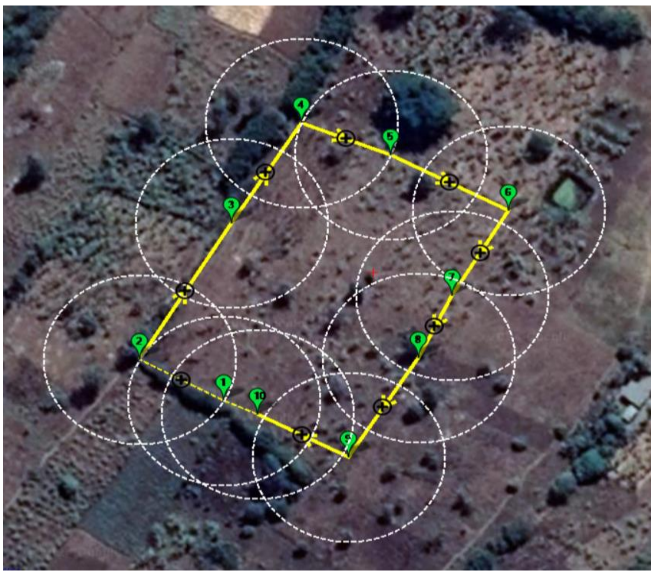


Fig 6.1: Flowchart (Flight Mission 1- First leg)

Fig 6.2: Flight Mission 1- First leg

Flight Mission 1 - Second Leg: Surveillance and Object Recognition in an Open Field The Nvidia Jetson Nano, connected with a camera and the Pixhawk Cube Orange, will be used to complete this mission.

1. **Initialization:** The autonomous flight mission is started.
2. **Take-off Procedure:** Take-off commands are executed via Mission Planner software to initiate the drone's ascent.
3. **Altitude Adjustment:** The drone ascends to a predefined cruise altitude of 15 meters above ground level (AGL) for optimal surveillance coverage.
4. **Surveillance Trajectory Activation:** The designated surveillance track trajectory is initiated to cover targeted areas effectively.
5. **Velocity Configuration:** The drone's velocity is set to a consistent 3 meters per second (m/s) for steady progress along the surveillance path.
6. **Search Pattern Initiation:** The predefined search pattern is activated through Mission Planner to systematically explore the designated area.
7. **Live Feed Capture:** The drone's camera is enabled to capture live footage of the surroundings.
8. **Object Detection Script Execution:** The Jetson Nano onboard the drone runs the object detection script concurrently with live camera feed processing.
9. **Object Recognition and Logging:** Objects resembling predefined shapes are detected and identified, with relevant information logged to a designated text file.
10. **Continuous Data Logging:** The text file is appended with recognized objects after each successful identification.
11. **Checkpoint Navigation:** The drone progresses through checkpoints along the surveillance trajectory, ensuring comprehensive coverage of the designated area.
12. **Return to Initial Position:** The drone navigates back to the starting point, marking the completion of the surveillance mission.
13. **Landing Procedure:** The autonomous landing sequence is initiated to safely bring the drone down to the ground.
14. **Mission Conclusion:** The autonomous flight mission is concluded, ensuring all objectives are achieved and data is logged effectively.
15. **Termination:** All autonomous operations are stopped, and the drone is transitioned to a standby or powered-off state as required.

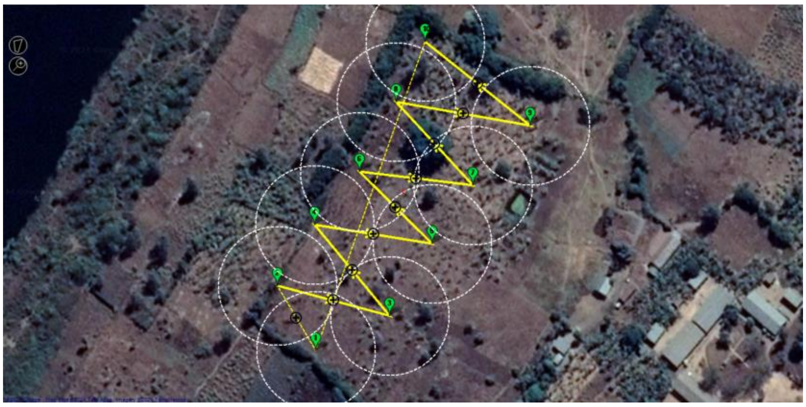


Fig 6.4: Flight Mission 1- Second Leg

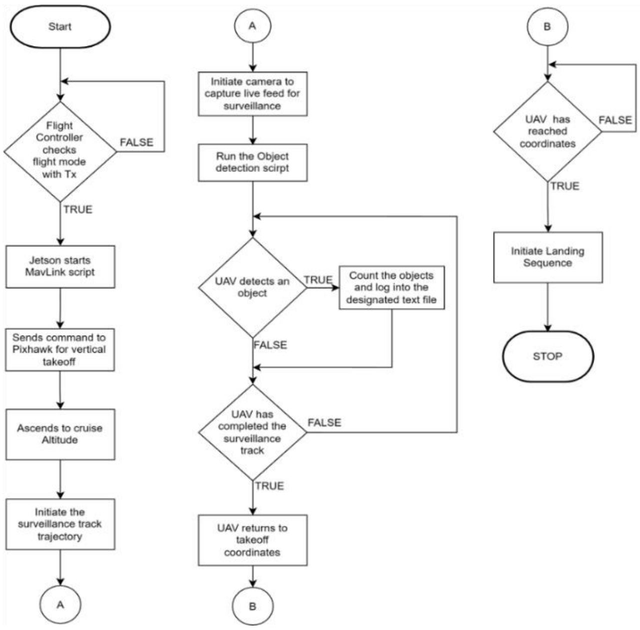


Fig 6.3: Flowchart (Flight Mission 1- Second Leg)

Flight Mission 2- Drone surveillance in each filed and recognizing bullseye and dropping payload over it.

The Pixhawk Cube Orange and companion PC Nvidia Jetson Nano will be used, with both communicating via the MavLink Protocol. ROS simulation integrated with Gazebo will provide the communication interface, using the MAVROS package to convert ROS command protocols into MavLink protocol and send them to the Pixhawk.

1. **Initialization:** The autonomous flight mission is started.
2. **Take-off Procedure:** Take-off commands are executed via Mission Planner software to initiate the drone's ascent.
3. **Live Feed Capture:** The drone's camera is enabled to capture live footage of the surroundings.
4. **Concurrent Script Execution:** The object detection and Mavlink scripts are run on the Jetson Nano alongside the camera feed.
5. **Altitude Adjustment:** The drone ascends to a predefined cruise altitude of 15 meters above ground level (AGL) for optimal surveillance coverage.
6. **Surveillance Trajectory Activation:** The designated surveillance track trajectory is initiated to cover targeted areas effectively.
7. **Velocity Configuration:** The drone's velocity is set to a consistent 3 meters per second (m/s) for steady progress along the surveillance path.
8. **Search Pattern Initiation:** The predefined search pattern is activated through Mission Planner to systematically explore the designated area.
9. **Object Detection Monitoring:** The camera feed is continuously monitored for objects resembling a bullseye. If detected, the Jetson Nano pauses the search pattern via Mavlink.

10. **Centring Procedure:** The Pixhawk is commanded to centre the drone over the detected object.

11. **Verification Process:** A two-step verification process is run on the detected image using the object detection script.

12. **Payload Drop Activation:** If the verification is successful, the payload drop mechanism is activated.

13. **Altitude Adjustment for Drop:** The drone is lowered to 5 meters above ground level (AGL) to prepare for payload release.

14. **Bay Door Operation:** The servo is signalled to open the bay doors for payload release.

15. **Post-Drop Procedure:** After dropping the payload, the drone is commanded via Mavlink to return to the take-off coordinates.

16. **Landing Procedure:** The autonomous landing sequence is executed to safely bring the drone back to its initial position.

17. **Mission Conclusion:** The autonomous flight mission is concluded, ensuring all objectives are achieved and data is logged effectively.

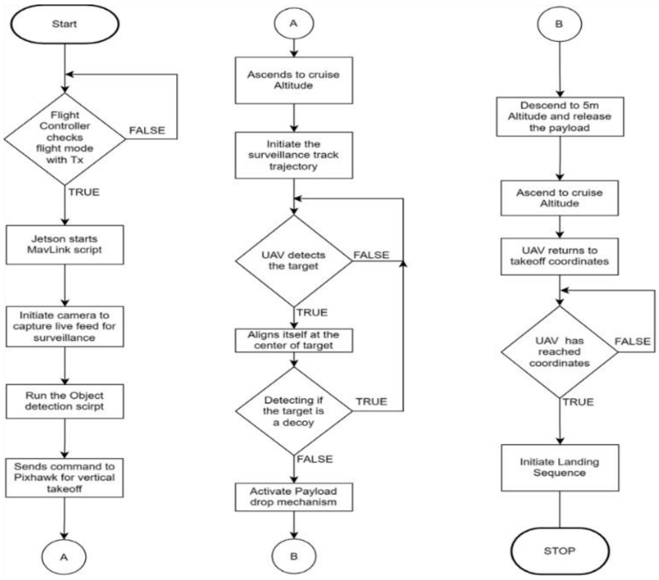


Fig 6.5: Flowchart (Flight Mission 2)

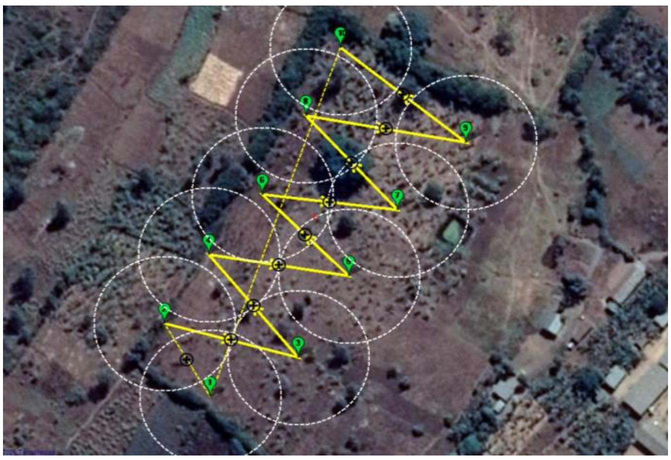


Fig 6.6: Flight Mission 2

Autonomous image recognition program using Machine Learning

The YOLOv7 ML Computer Vision algorithm is used for object detection and training.

Using YOLOv7 for object detection on an NVIDIA Jetson Nano is highly justified due to its optimal balance of speed, accuracy, and efficiency, which are crucial for real-time applications on resource-limited devices like drones. YOLOv7's single-stage architecture ensures rapid object detection with low latency, essential for immediate feedback in drone operations. It maintains high detection accuracy with advanced features like residual connections and feature pyramid networks, making it robust to variations in object size and lighting conditions.

The algorithm is optimized for embedded systems, utilizing the Jetson Nano’s GPU efficiently while minimizing memory and computational overhead, aligning well with the device’s 2GB RAM and power constraints. Integration with PyTorch and TorchVision facilitates easy implementation and deployment, leveraging pre-trained models for quick fine-tuning specific to the application's requirements.

YOLOv7's adaptability allows for customization and scalability, enabling fine-tuning for specific detection tasks and balancing performance with computational demands. This makes it an ideal choice for autonomous image recognition on drones, providing a reliable, efficient, and high-performance solution suitable for dynamic and resource-constrained environments.

Libraries Used: -

- **NumPy:** NumPy is a fundamental library for numerical computing in Python. It provides support for arrays, matrices, and many mathematical functions. In this context: Efficient manipulation of image data (pixels), which are typically represented as arrays, is essential for pre-processing before feeding them into a neural network.
- **Pandas:** Pandas is a data manipulation and analysis library. Though primarily used for structured data, it can be useful for managing metadata associated with images, logging results, and organizing large datasets used for training and evaluation.
- **Pillow:** Pillow is a Python Imaging Library (PIL) fork that adds image processing capabilities. Used for image loading, transformation, and augmentation, which are critical steps in preparing image data for training and inference in deep learning models.
- **PyYAML:** PyYAML is a YAML parser and emitter for Python. Configuration management is crucial for machine learning experiments
- **SciPy:** SciPy is a library used for scientific and technical computing. Provides advanced mathematical functions and algorithms which can be used for optimizing machine learning algorithms and processing image data.
- **PyTorch:** PyTorch is an open-source machine learning library based on the Torch library. It is used for developing and training deep learning models. PyTorch's dynamic computation graph and extensive support for GPU acceleration make it ideal for real-time image recognition tasks on the Jetson Nano.
- **TorchVision:** TorchVision is a package consisting of popular datasets, model architectures, and image transformations for computer vision. Provides pre-trained models (e.g., ResNet, Faster R-CNN) and common image transformations, simplifying the process of building and fine-tuning image recognition models.
- **PyCUDA:** PyCUDA is a Python wrapper for NVIDIA's CUDA API. Directly interfaces with the GPU to leverage its parallel computing capabilities.

7. Summary of innovations in the overall design

- **TPU shock absorbers:** The design incorporates 3D-printed TPU (thermoplastic polyurethane) structures strategically placed to mitigate the impact of shocks that may occur during UAS failures, crashes, or harsh landings. Lightweight yet highly effective 3D-printed TPU landing pads are integrated into the design, providing exceptional shock absorption capabilities. Furthermore, the motor mounts and payload bay are equipped with protective TPU covers, offering an additional layer of safeguarding against potential impact forces. This comprehensive approach to shock mitigation through the judicious use of 3D-printed TPU components enhances the overall durability and resilience of the UAS while minimizing weight penalties.

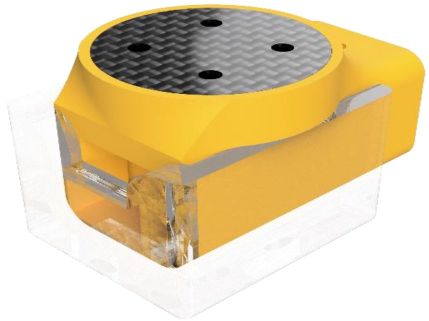


Fig 7.1: TPU shock absorber

- The UAS incorporates a modular design philosophy, featuring easily replaceable components such as arm assemblies, motor mounts, and the FPV camera mount. This modular approach minimizes potential downtime in the event of failures or crashes resulting in component damage. By facilitating swift component replacement, the modular design ensures efficient maintenance and maximizes operational readiness of the UAS.

- **Image recognition algorithms:** The innovation in image detection is undergoing significant advancements, particularly in three key areas. Firstly, there's a focus on custom datasets, leveraging self-learning capabilities to continuously enhance model performance post-deployment as it encounters new data. This approach ensures adaptability and relevance in dynamic environments. Secondly, annotation tools are being upgraded to streamline the labour-intensive process of labelling datasets. By integrating AI-assisted labelling, manual effort is significantly reduced, expediting the training process and improving accuracy. Lastly, the integration of ROS and Gazebo with CUDA algorithms marks a pivotal step forward in image recognition. This combination promises superior performance and efficiency, leveraging parallel processing capabilities for real-time analysis. Overall, these innovations signal a transformative era in image detection, where efficiency, adaptability, and accuracy are paramount.

Appendix

Pixhawk Orange Cube

- PWM I/Os: 14 channels for extensive servo and motor connections.
- Mavlink Serial Interface: 2 ports for communication with ground control stations.

Power Module for Pixhawk

- Max Current Sensing: 200A for monitoring power usage.
- Connector Type: XT60/XT90 for secure and reliable power connections.

Holybro M8N GPS

- Antenna: 25 x 25 x 4 mm ceramic patch for high sensitivity.
- Cold Starts: 26 seconds for quick GPS acquisition.

RP3 V2 ELRS Receiver

- Operating Voltage Range: 3.5V to 10V for flexibility in power supply.
- Dimensions: 26mm x 19mm x 5mm for a compact design.

HOLYBRO PMW3901 OPTICAL FLOW SENSOR

- Sensor: PMW3901 for accurate motion detection.
- Interface: SPI for fast communication with the flight controller.

1 Watt Telemetry Module

- Frequency: 915MHz for long-range communication.
- Transmission Power: 1 Watt for extended range up to 10km.

T-Motor F55A Pro III 55A BLHeli32 4-in-1 ESC

- Continuous Current: 55A per channel for high-power motor control.
- Input Voltage: 3S to 6S LiPo compatibility.

5volt UBEC

- Output Voltage: 5V for powering flight electronics.
- Max Current: 3A to supply ample power.

CADDX Polar Vista VTX and FPV Camera

- Image Sensor: 1/1.8" 2.3Mega starlight sensor for high-quality imaging.
- Latency: 720p 60fps <32ms for real-time video transmission.

Jetson Nano

- CPU: Quad-core ARM A57 @ 1.43 GHz for computational tasks.
- GPU: 128-core Maxwell for processing intensive tasks.

Jetson Nano Camera

- Resolution: 8MP for high-resolution imaging.
- Connectivity: MIPI CSI-2 interface for fast data transfer.

Emax ES08MA II Servo

- Stall Torque @ 4.8V: 2.0 kg-cm for strong actuation.
- Operating Speed @ 4.8V: 0.12 sec/60° for quick response.

T motor cine66 kv925

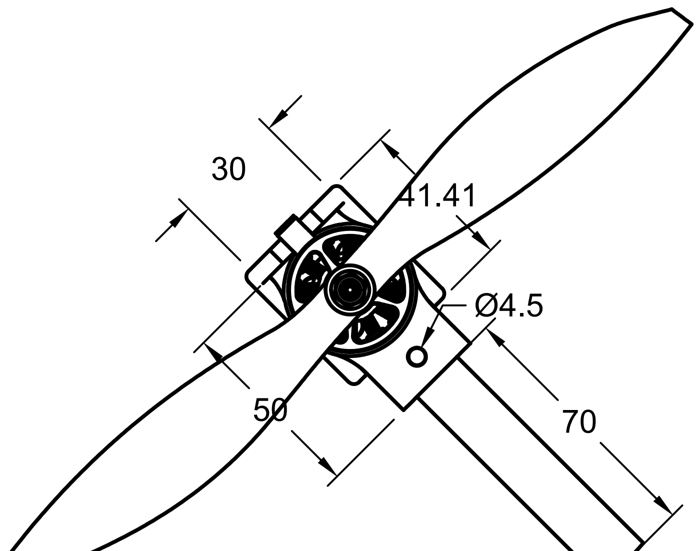
- KV Rating: 925 for efficient motor performance.
- Recommended Voltage**: 6S for optimal power output.

40x40 Cooling Fan

- Dimensions: 40mm x 40mm for compact cooling.
- Voltage: 5V to 12V for versatile power options.

Image recognition: References

- https://www.hackster.io/spehj/deploy-yolov7-to-jetson-nano-for-object-detection-6728c3
- https://medium.com/@jurespeh/yolov7-with-tensorrt-on-jetson-nano-with-python-script-example-63099fa7c8a5
- https://github.com/leggedrobotics/darknet_ros



ARM ASSEMBLY B
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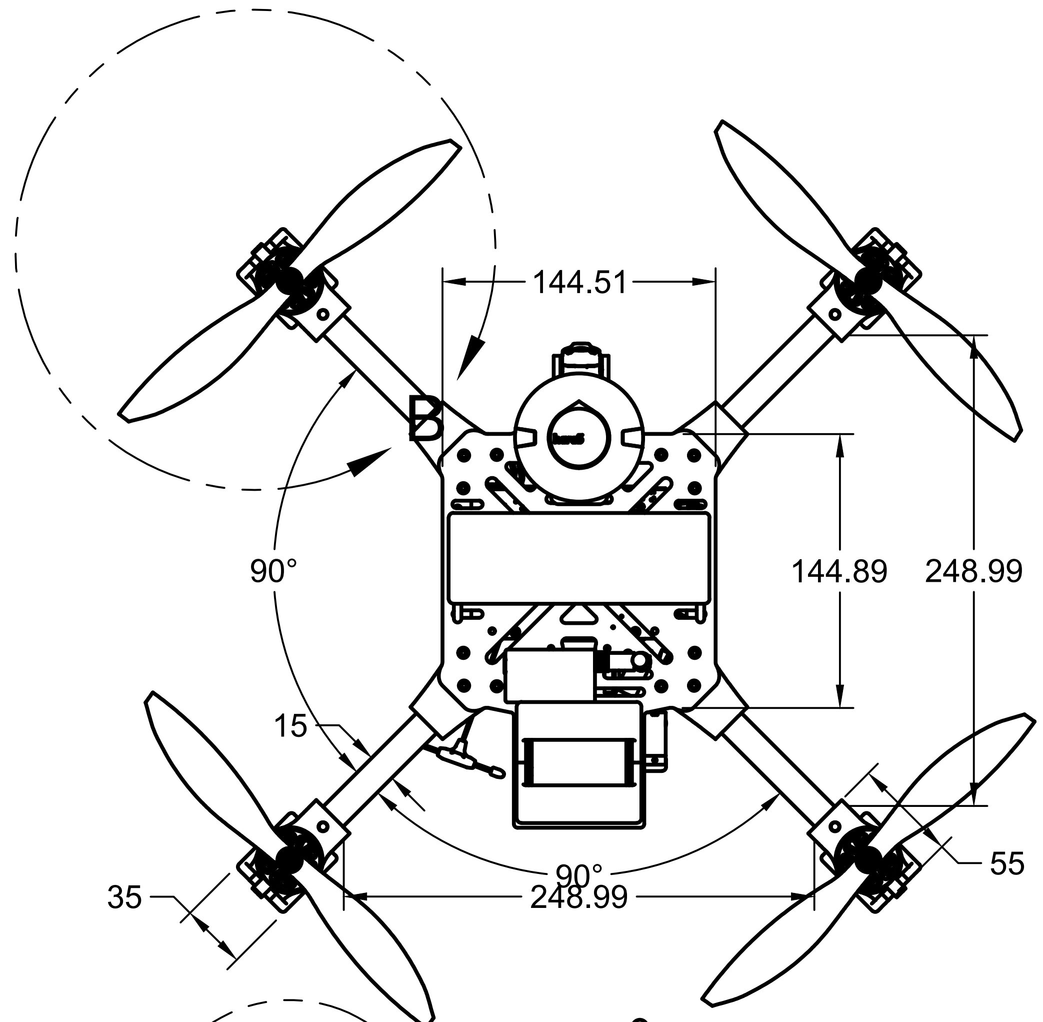

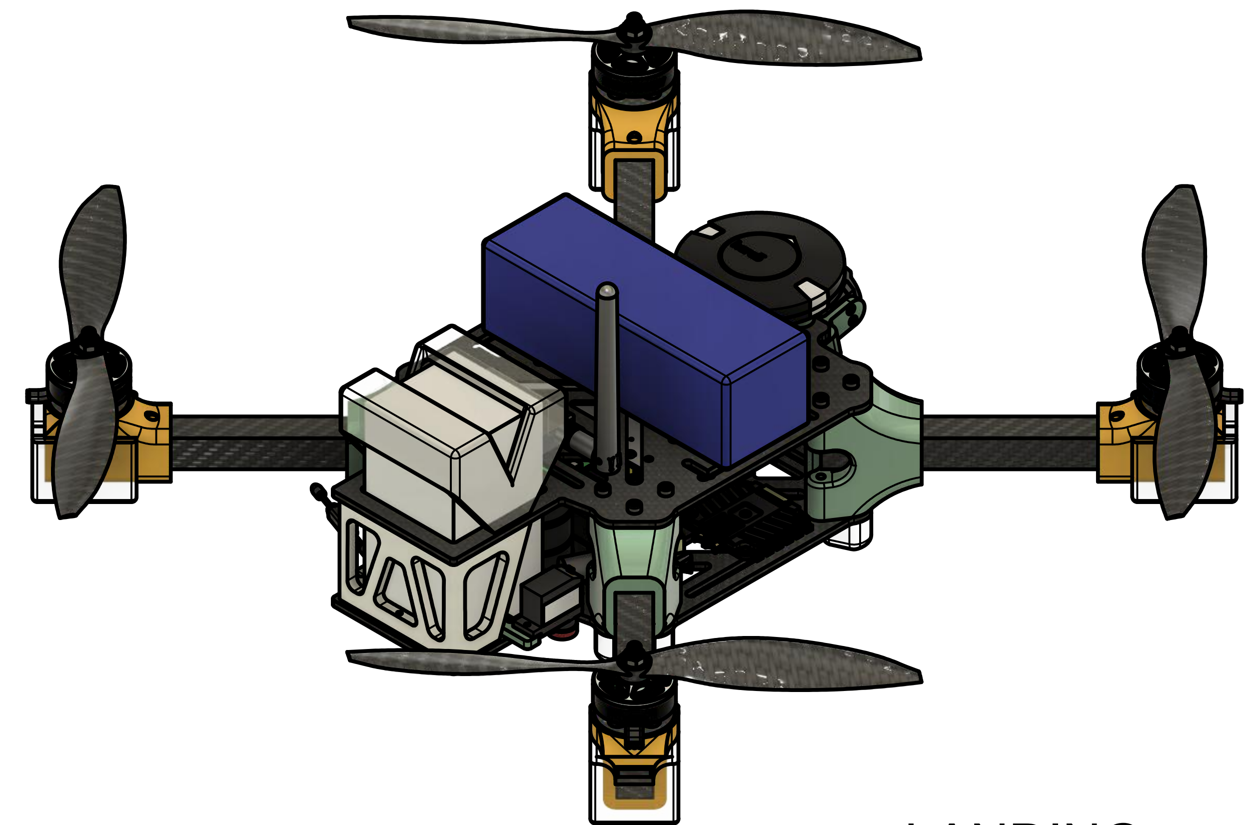

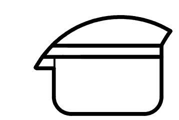

LANDING PADS E
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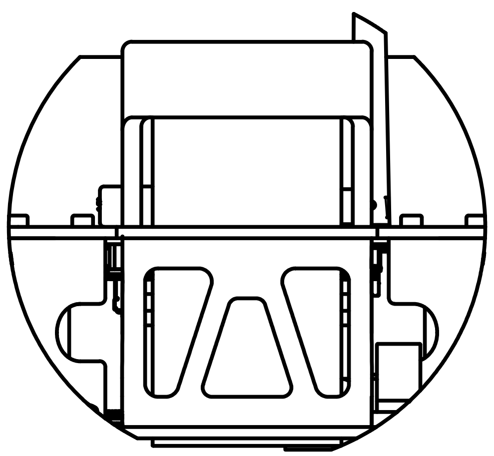

PAYLOAD D
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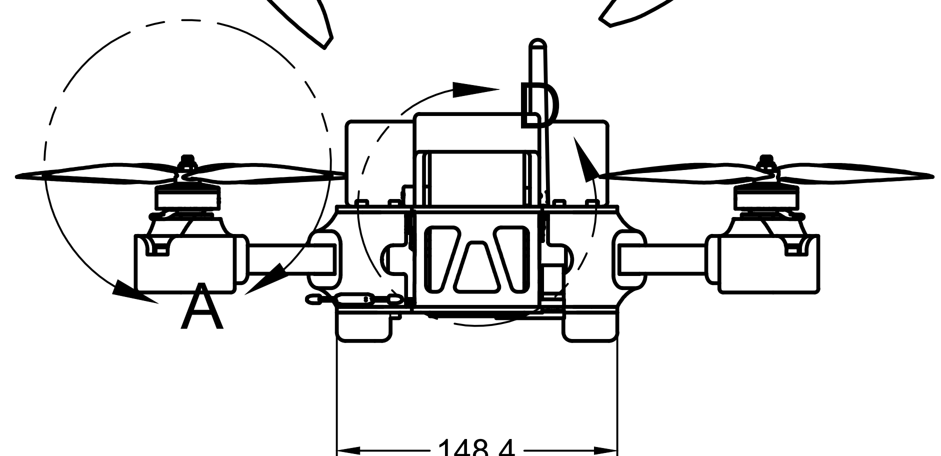
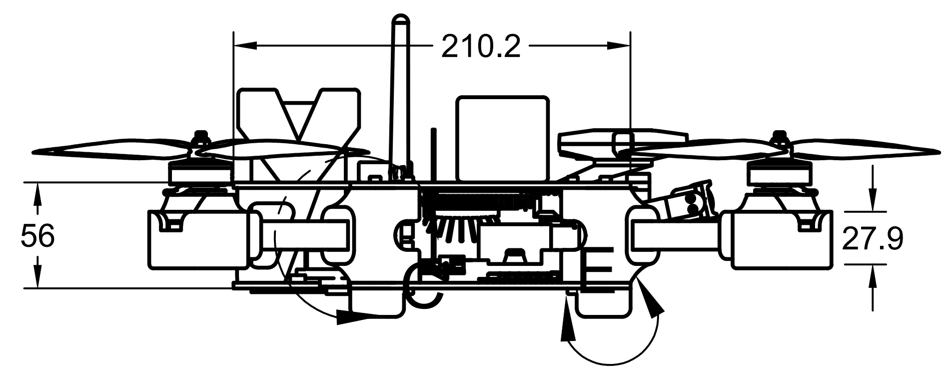
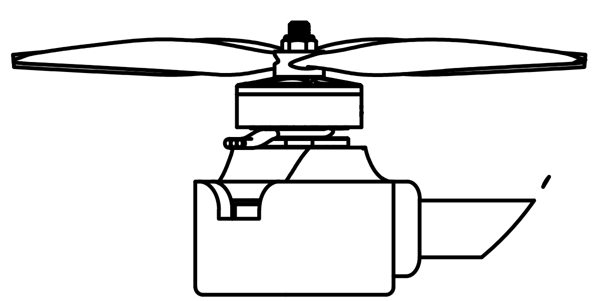
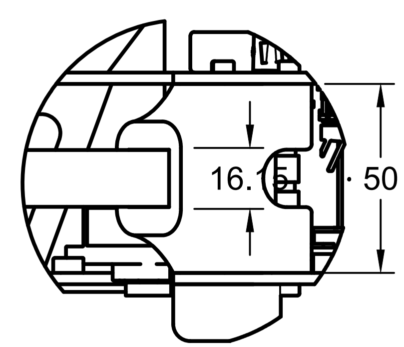






ARM MOTOR MOUNT A
SCALE 1:2



ARM MOUNTS C
SCALE 1:2

Created by **VAYUPUTRAS**

QTY	PART NAME	MATERIAL
1	ARM ASSEMBLY	Carbon Fiber
1	ARM MOTOR MOUNT	CF-NYLON
1	ARM MOUNT	PLA PRO
1	LANDING PADS	TPU

KLS Gogte Institute of Technology