AEROTHON 2023 – UNCREWED AIRCRAFT SYSTEM (UAS) DESIGN, BUILD AND FLY CONTEST

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES, DEHRADUN - 248007

DESIGN REPORT

TEAM NO. - AT2023-030
TEAM NAME : WRise
DRONE NAME : GarudVyu

APPENDIX A

STATEMENT OF COMPLIANCE

Certification of Qualification

Team Name: Team WRise

University/Institute: University of Petroleum and Energy Studies

Faculty Advisor: Mr. Harshit Shukla

Faculty Advisor's Email: hshukla21@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 2023 contest, without direct assistance from professional engineers, R/C model experts or pilots, or related professionals.

Signature of Faculty Advisor

11/06/2023

Date

Team Captain Information:

Team Captain's Name: Ms. Amisha Singh

Team Captain's E-mail: amishasingh134@gmail.com

Team Captain's Phone: +917999354244

A. Conceptual Design

I. The UAV's airframe selection is the S500, specifically configured as a 'cross' type. This configuration prioritizes a larger diagonal wheelbase, ensuring enhanced stability and increased payload capacity. We opted for this frame to align with our mission statement of delivering payloads, necessitating a frame capable of effectively accommodating the required payload capacity.

The UAV employs a fully electrical propulsion system, utilizing four motors positioned at the rear ends of the frame. This placement enables vertical thrust generation and ensures balanced performance. Each motor is equipped with a 10-inch propeller to facilitate efficient propulsion.

The UAV is equipped with a ‘Pixhawk 2.4.8’ flight controller, For the communication system, the team is utilizing the FlySky FS-iA10B receiver and to link between drone and ground control we have Holybro Sik Telemetry Radio V3-100mW 433MHz transmitter. For Image Processing a Camera Module Arducam 16MP is used.

While we are confident in our UAV's ability to perform various maneuvres and ensure the safe delivery of payloads, we acknowledge that we are currently focusing on improving its capabilities in the area search domain. This aspect of the UAV’s functionality is still under development as we strive to enhance its effectiveness in conducting comprehensive area searches.

B. Detailed Design

I. Estimation of Preliminary Weight:

Sr. No.	Components	Weight (g)
1.	Battery	650
2.	Motor (x4)	(55x4) = 220
3.	Airframe	500
4.	Raspberry Pi	80
5.	Raspberry HQ camera	53
6.	Propeller (x4)	(20x4) = 80
	Total	1583

Table 1: Preliminary weight estimation

II. Estimation of Thrust required:

For a drone to perform simple manoeuvres and drop a payload, the thrust-weight ratio of that drone must be 2:1. The maximum weight of the drone is assumed to be 2 Kilograms, and by simple calculation, the total thrust required by the drone is estimated to be 4 Kilograms. Thus, thrust per motor must be a minimum of 1 Kilogram.

By using a simple thrust calculator, Kv rating was varied which varied the RPM by the simple relation:

$$Kv = \frac{RPM}{Voltage}$$

The relation also varied thrust produced by a motor having that specific Kv rating. This helped in finding a range of Kv rating motors that will provide good thrust for the drone.

This range was 1000Kv-1400Kv producing thrust between a range of 1 Kg- 1.6 Kg.

III. Selection of Propulsion System:

A comprehensive analysis for selecting the most suitable motors for drone's propulsion setup was conducted in which several key factors were considered. The aim was to identify the most suitable motors that would deliver optimal performance, efficiency, and safety for the drone.

The weight of the drone was estimated to be 2 kilograms and the motor analysis was conducted. The E-calc software was used to assess the available options. The comparison was primarily based on multiple criteria.

To meet specific operational requirements, the main emphasis was on the thrust-weight ratio of the motors. It was crucial to maintain a minimum thrust-weight ratio of 2. This ensured that the drone could perform these tasks effectively and safely.

Weight was another pivotal factor in the evaluation. The aim was to remain within the weight limit therefore the motors' weight specifications were carefully assessed.

To align with the desired flight duration of at least 15 minutes, the motors' flight time capabilities were evaluated. It was crucial to select motors that could operate within acceptable temperature limits, ensuring the longevity and reliability of the entire propulsion system.

Based on this, the first analysis was done, and the results are shown below:

Motor	Power (W)	Weight per motor (g)	Temperature (℃)	Thrust-Weight ratio	Specific thrust	Flight Time (min)	Kv ratings
DYS BE2208	165	44	43	1.3	4.5	5.1	1400
DYS BE2814	220	100	35	1.56	4.93	5.6	1400
DYS 2808	196	75	37	2	4.88	5.5	1400
T-motor F90	276	47	72	2	5.4	6.2	1300
iFlight XING2	272	61	61	1.5	5.57	6.4	1250

Table 2: Motor performance after 1st analysis

The analysis revealed that the initially selected battery did not possess sufficient power capacity to meet the desired flight time requirements. Recognizing this limitation, a search for alternative batteries with higher milliampere-hour (mAh) ratings was conducted.

As a result, the previous battery was replaced with the Lemon 3s 5500mAh 45C/90C. This new battery boasted a significantly increased power output compared to the previously considered options.

With this upgraded battery in place, a refined analysis focusing on motors that were readily available in India and aligned with our specified criteria for Kv ratings falling between 900 and 1600 was done

The results of those analyses were: -

Motor	Power (W)	Weight per motor (g)	Temperature (℃)	Thrust-Weight ratio	Specific thrust	Flight Time (min)	Kv ratings
EMAX ECO II-2807	241	50	62	1.8	5.46	7.8	1500
EMAX ECO II-2004	180	17	101	1	3.41	4.6	1600
DYS BE2814	250	100	36	2	6.14	8.9	1400
EMAX XA2212	218	39	48	1.6	5.3	7.5	1400
EMAX ECOII2807	209	47	54	1.7	5.58	8	1300
EMAX GT2812	191	105	37	1.6	5.84	8.4	1180
iFlight XING X2806.5	246	50	48	1.8	5.82	8.3	1300

Table 3: Motor performance after 2nd analysis

To address the issue of flight time failing to meet the requirements, it became evident that a more powerful battery was necessary. This comprehensive evaluation allowed us to make informed decisions based on factors such as

Kv ratings, power consumption, thrust-weight ratio, specific thrust, flight time, and temperature considerations.

As part of the overall optimization process, a new battery was selected. This battery had an enhanced **mAh rating of 6200** and operated on a **4s configuration with a discharge rating of 45C/90C**.

- These battery specifications aimed to provide a higher power capacity and sustained performance during drone operations.
- With these modifications and the inclusion of the new battery, a subsequent analysis using E-calc software was conducted which allowed us to assess and compare the performance outcomes for different motor options based on the refined weight calculations and updated battery configuration.

Motor	Power (W)	Weight per motor (g)	Temperature (℃)	Thrust-Weight ratio	Specific thrust	Flight Time (min)	Kv ratings
DYS BE2814	382	100	44	3.5	6.74	19.7	1400
EMAX XA2212	344	39	65	2.5	5.55	13.8	1400
EMAX ECO II-2807	343	50	65	2.8	6.11	15.7	1300
EMAX GTII-2212	345	52	56	2.7	5.75	14.7	1400
T-motor F90	322	47	81	2.7	5.91	16.1	1300
T-motor F100	288	67	55	2.4	6	14.8	1100

Based on availability, cost, endurance and weight the motor selected was EMAX ECOII-2807(1300Kv).

For the propellers, new research was taken into consideration that suggested the use of toroidal propellers or propellers with loop-like blades.

i. The toroidal propeller provides an advantage over other propellers that have been used in a small multirotor unpiloted aircraft, or drone, since the beginning of aviation which is being quieter. This can increase the efficiency of the drone, which is now quieter, by as much as 36%.
ii. The closed structure minimizes the drag effects of air swirls (i.e., tip vortices) created at the blade tips which also strengthens the overall stiffness of the propeller. These features diminish the propeller's acoustic signature.
iii. Prototype toroidal propellers that have been tested on commercial quadcopters demonstrated thrust levels comparable to those of traditional propellers at equivalent power levels. Reduced sound levels allowed the drones to operate without tiring human ears at a distance half that of a typical operation.

IV. Design:

For this mission we have designed a toroidal propeller of our own while considering the aerodynamic properties it will have.

- The propeller is tri-bladed (i.e., contains three blades).
- NACA 4412 airfoil is equipped at the root of every blade with an angle of 60° with the horizontal.
- CLARK Y airfoil is present at the edges and the tip of the blades with angles 30° and 10° with the horizontal respectively.
- The propeller is a counter clockwise version with an overall diameter of approximately 10 inches.
- The hub diameter is 45 mm and the hole for the motor shaft has a diameter of 4.9 mm.

Fig. Toroid Propeller

V. UAV Sizing:

Rotor arm:

The performance of the drones, including their manoeuvrability and stability, is greatly influenced by the length of the rotor arm. Although less stable, a small rotor arm offers good manoeuvrability. The drone becomes more steady but less swift as the arm length increases.

As a result, a range was considered to estimate the arm length. The chosen propeller was used to determine the minimum arm length. After accommodating all necessary parts while figuring out the hub's size, the arm's maximum value was measured.
The propeller diameter = D_{prop}= 10-inch or 25.4 cm,

Minimum arm length can be calculated by,

$$L_{arm} \geq \frac{\frac{D_{prop}}{2}}{\sin \sin \left(\frac{\pi}{n_{arm}}\right)}$$

Hence,

$$L_{arm} \geq \frac{\frac{10}{2}}{\sin \sin \left(\frac{180}{4}\right)}$$

or $L_{arm} \geq 7.07\ inch = 17.96\ cm$

Wheelbase:

The size of the propeller being employed determines the minimum wheelbase, or the distance between the motors, for the typical multirotor, which is also known as the diagonal wheelbase.

It is an important measurement as it affects the stability, manoeuvrability, and payload capacity of the drone.

The minimum radius of the wheelbase can be determined by the following relation,

$$R \geq \frac{\sigma}{\sin \sin \left(\frac{\alpha}{2}\right)} \times r_p$$

where,

σ denotes the safety factor. For Aerospace application, we assume σ=1.5.

r_p denotes the radius of the propeller.

α denotes the angle with adjacent rotor arms, given by $\alpha = \frac{2\pi}{n_{arm}}$.

Hence,

$$R \geq \frac{1.5}{\sin \sin \left(\frac{180}{4}\right)} \times 5\ or\ R\ \geq 10.60 inch\ =\ 26.94 cm$$

Therefore, Wheelbase dimension, W= 53.88 cm = 538.8 mm.

Propeller Clearance:

- To prevent collisions and the development of tip vortices owing to airflow interference, which can impair the UAVs performance in terms of flight time and power consumption, a minimum propeller clearance is needed between the axis of the propellers.
- For a propeller with a 10-inch diameter, the minimum propeller clearance necessary is,

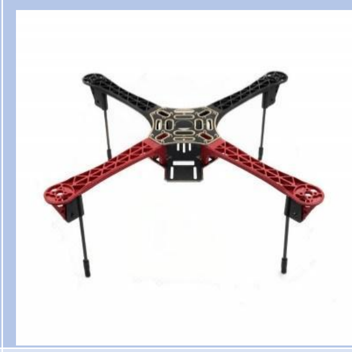
$$PC_{min} = R - D_{prop}$$

$$PC_{min} = 53.88 - 25.4$$

$$PC_{min} = 28.48\ cm$$

Landing Gear:

- The drone's landing gear can be either fixed or retractable, although the fixed selection is preferable for this application because retractable gear requires more electrical equipment and structural complexity, which increases drone weight.
- Additionally, if the retractable gear system malfunctions for any unanticipated reason, the drone may sustain harm during landing.
- The segment needs 10-15 cm of ground clearance because the payload is located below the hub.

Positioning Parameter	Under-Hub	Middle arm	End-of-Arm
Image			
Camera View	Unobstructed camera view and wider range of camera angles.	Can obstruct the camera's field of view or limit the range of camera angles.	Offers unobstructed camera view and maximum range of camera angles.
Ground clearance	Increased ground clearance for safer landings on uneven surfaces	Provides good ground clearance for landing in rough terrain.	Provides ample ground clearance and stability during landings.

Stability and Performance	Can toggle during landing	May add additional weight and drag to the drone.	May affect flight performance due to increased drag, but stable flight operations.
Spacing	Limited space for larger payloads or accessories under the hub.	Allows for efficient use of space on the main frame.	Allows for efficient use of space on the main frame. Limited space for larger payloads or accessories at the end of the arms.

- From the above comparison, it was concluded that Landing gear positioning at the end-of-arms is much more beneficial than other arrangements.
- This configuration provides maximum stability during landing and is easier to access during any failures and even for attachment purposes.

VI. UAV Performance

The motor which we had selected is EMAX ECOII-2807(1300Kv). The flight performance calculated at max speed of 82 km/h (22.7m/s) are:

- Max. current- 32.73A
- Max. RPM- 10791
- Max. electric power- 339W
- Max. efficiency- 77.3%
- Max. estimated temperature- 75^{o} C
- Total weight - 1818g
- Estimated rate of climb-11.5m/s
- Specific thrust- 6.30g/W
- Used capacity of battery- 5270 mAh
- Estimated range- 4747m
- Flight time- 15.7 min

At hover speed, the motor performance is:

- Current- 4.48A
- RPM- 5552
- Electric power- 63.5W
- Efficiency- 78.6%
- Estimated temperature- 34^{o} C

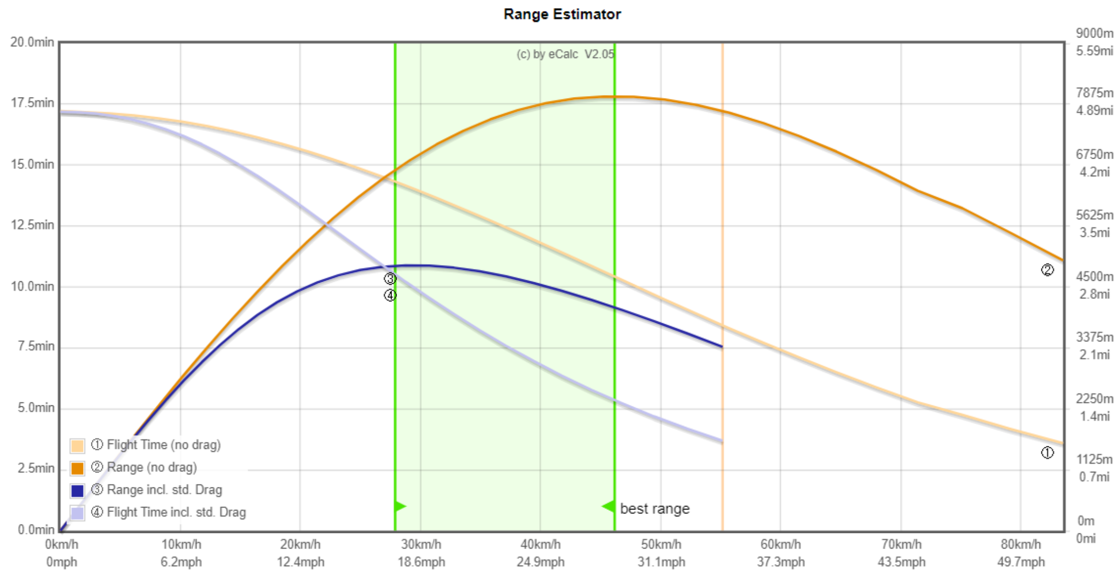


Fig: Range Estimator

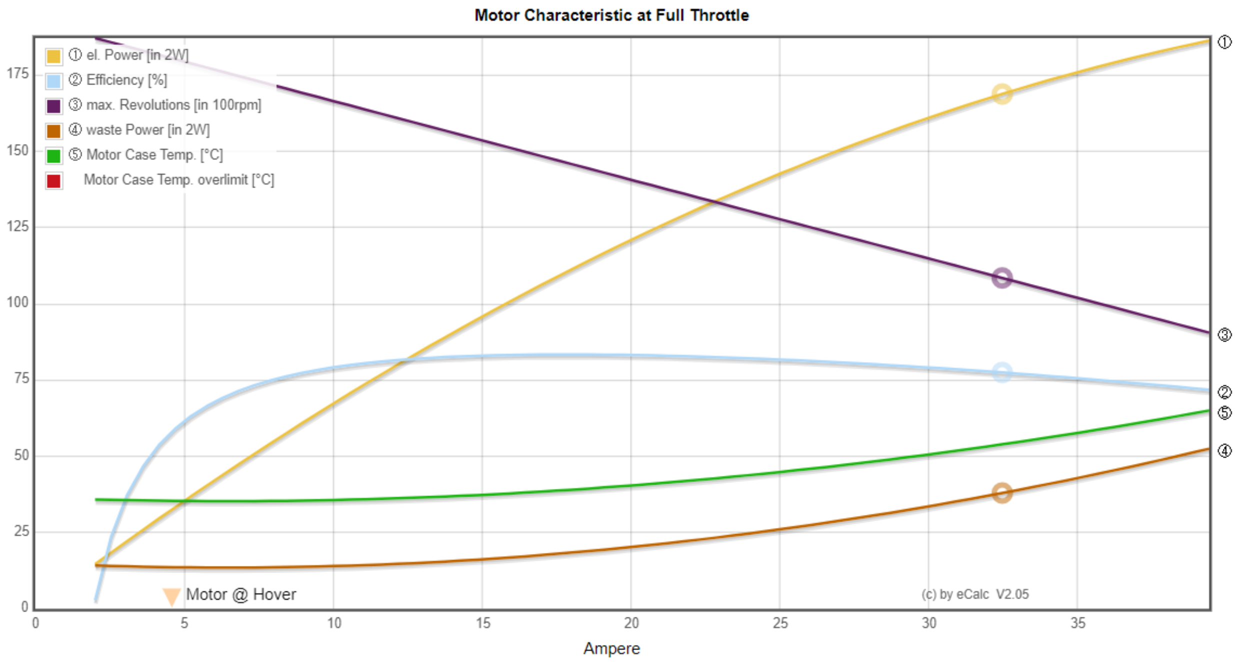


Fig: Motor characteristics at full throttle

VII. Material selection:

The team chose pre-manufactured airframes. The frames were compared on the following parameters:

Model/ Parameter	F450 Quadcopter Frame	S500 Multirotor PCB Airframe	F330 Mini Quadcopter Frame

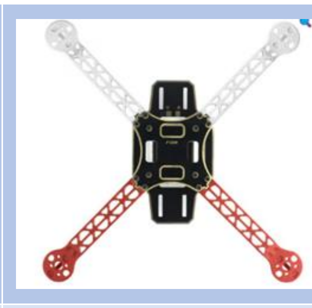
Image			
Material	Glass Fiber + Polyamide Nylon	Glass Fiber + Polyamide Nylon	Glass Fiber + Polyamide Nylon
Wheelbase (mm)	450	500	330
Weight (gm)	330	405	160
Arm Size (mm)	220 x 40	220 x 40	155 x 34
Motor Mounting Hole Dia. (mm)	3	3	3

Fig: Comparison on different Pre-manufactured Airframes

VIII. Subsystem Selection:

Communication System:

For the communication system, the team is utilizing the **FlySky FS-iA10B** receiver and **Radiomaster TX16S** transmitter, as they are compatible and integrated, and have excellent range and signal stability for dependable communication on long-distance flights on a 2.4GHz frequency channel. It supports several channels for precise control of various flight functions.

Safety features such as failsafe operation, low voltage warning, and interference detection have been improved.

- Control arrangement is adaptable to individual flying styles and competition requirements.
- The FlySky FS-iA10B receiver has a proven track record of dependability and robust performance.
- The receiver and transmitter communicate in real-time.
- Ensure constant and accurate control of inputs throughout the competition.
- Risk reduction and effective response to crucial situations
- During the competition, promote safe operation and the prevention of accidents or problems.

The team will be utilizing the 433MHz 100mW Radio Telemetry Kit in the mission strategy, which can be justified by its long-range communication capabilities, immunity to interference, power output efficiency, robustness, dependability, and regulatory compliance. This telemetry package will provide a dependable and efficient communication link between the drone and the

GCS to conduct seamless mission operations, real-time monitoring, and exact control over the drone's flying characteristics. For this, ***Holybro Sik Telemetry Radio V3-100mW 433MHz*** was finalized, which will be utilized as a telemetry link, as it is a dependable and efficient communication link between the drone and the GCS.

Parameters	Specifications
Connector	RP-SMA connector
Communication	2-way full-duplex communication through adaptive TDM UART interface
Input Voltage (V)	5V DC (from USB or JST-GH)
Transmitting current	100 mA at 20dBm
Receiving current	25 mA
Communication Protocol	MAVLink protocol framing
Weight	0.127 kg

Control & Navigation System:

In the team's study of commercially available open-source flight controllers, the autopilot system was identified as a crucial component for accomplishing tasks in the competition. Considering this, three flight controllers were evaluated: Pixhawk 2.4.8, Pixhawk 4 Holybro, and Pixhawk Cube. The primary advantage of selecting an open-source flight controller lies in the flexibility to modify its settings according to specific requirements.

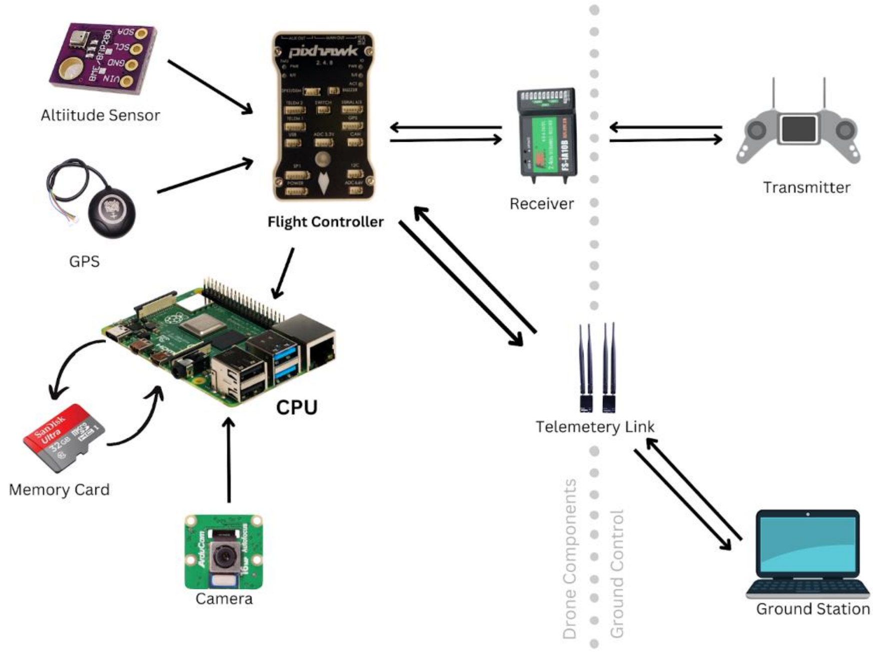


Fig: System Architecture

Among the options analyzed, Pixhawk 2.4.8 emerged as a compelling choice. It offers several advantages over the Pixhawk 4 Holybro and Pixhawk Cube like Open-source and customizable, Cost-effectiveness. In the comparative study, Pixhawk 2.4.8 demonstrated a cost-effective solution without compromising essential functionality. It offers a robust set of features and capabilities at a relatively lower price point compared to the Pixhawk 4 Holybro and Pixhawk Cube.

Considering the significance of the autopilot system and the team's evaluation, the Pixhawk 2.4.8 is recommended as the preferred choice due to its open-source nature, established track record, and cost-effectiveness.

Parameters	Pixhawk 2.4.8	Pixhawk 4	Pixhawk 2.1
Frequency	168 MHz	216 MHz	168 MHz/252 MIPS
RAM	256 KB	512 KB	256 KB
Flash memory	2 MB	2 MB	2 MB
CPU	32 Bit STM32F427	32 Bit STM32F765 Arm® Cortex®-	32 Bit STM32F427 Cortex-

	Cortex-M4 core with FPU	M7	M4F core with FPU
Failsafe CPU	32 Bit STM32 F100	32 Bit STM32F100	32 Bit STM32F103
CAN	2	2	2
I2C	2	2	2
Telemetry	2	2	2
GPS	1	1	2
Power i/o	2	3	2
UARTS	5	5	8
Sensors	IMU -1	IMU–1	IMU–3
	Barometer -1	Barometer -1	Barometer - 3

GPS System:

Ardupilot's Mission Planner will be used to program the drone and define the appropriate route. To accomplish this, a GPS module will be incorporated into the drone to determine its position and establish target paths using coordinates.

In addition, for image processing purposes, the relative positions of hotspots and other relevant targets in relation to our drone's camera will be calculated. This will enable us to determine the drone's direction of movement accurately. To achieve this, it is crucial to have an accurate GPS system.

The Ublox Neo M8N GPS module was selected, which is compatible with the flight controller Pixhawk 2.4.8. This module is known for its low power consumption and high precision, with an ultimate accuracy of 0.6 meters. It provides updates at a speed of 10Hz, meaning it refreshes its coordinates ten times per second.

Using RTK (Real Time Kinematic) GPS module was considered, which offer extremely high accuracy in the centimetre range, they are expensive, and their availability is not guaranteed.

Fig: GPS

Camera Module:

The Camera Module that is selected is ***Arducam 16MP***. A moderately high-resolution camera is needed that can recognize images while flying from 30m Height and differentiate real targets from dummy targets. Also, the camera should be lightweight so that the drone overall does not exceed the 1800g limit. Auto Focus is also an essential criterion, as it is not possible to manually adjust the focus of the lens once the drone takes off because it must vary its height and process images accordingly.

Using a very high-resolution camera like *Arducam 64MP will* be avoided because it will make the image processing slow, as the system must process more details in a short time, it will create overloading in GPU (Graphical Processing Unit) leading to system lag. Also, for our drone to capture images from *30m height*, a 16MP camera is more than enough. This 64-camera will just increase the cost of manufacturing.

Sensors & IP System

Altimeter:

The most important parameter for the mission is the Altitude of the drone. It is a key factor that will determine how much more the drone must go up, when it has achieved the required height of 30m, how much it must descend and what is its current altitude. This information will be given by a sensor that determines Altitude, i.e.,

Fig: BME280 Sensor

Several sensors can be used to measure altitude accurately: Barometric **Pressure Sensor (BME280), GPS Module, LiDAR Sensor, Ultrasonic Sensor, Inertial Measurement Unit (IMU). Out** of these available options, the range of Ultrasonic Sensors and Lidar sensors is around 5m-6m and not suitable for the operation where the height from 30m must be determined. The calculation of inertial measurement is difficult and can be inaccurate. So, we decided to go with the *Barometric Pressure Sensor*, which determines the altitude by measuring static Pressure. It can determine height with an accuracy of +/- 1 meter.

Image Processing System:

When selecting an operating system for drone usage for this mission statement, the team considered several factors that should be considered to ensure optimal performance, stability, and compatibility with the mission requirements such Compatibility with Drone Hardware, Real-time Capabilities, Performance and Efficiency, Security and Stability, Customization and Flexibility, Long-term Support.

By utilizing the ROS framework in conjunction with the Ubuntu operating system. Ubuntu's stability, coupled with ROS's comprehensive toolset and community support, ensures a solid foundation for developing and executing complex drone missions. The collaboration between ROS and Ubuntu allows for faster development, reduced time-to-market, and increased efficiency in implementing advanced functionalities.

The team selected ROS *Noetic Ninjemys,* for operation as it supports Python 3. For Ubuntu,2 options there were: 32bit and 64bit. A 64-bit version was considered, enclosing the Raspberry aspects to be of at least 4GB or better for optimum usage. Thus, we will be requiring Raspberry Pi 4 *(4GB or better versions).*

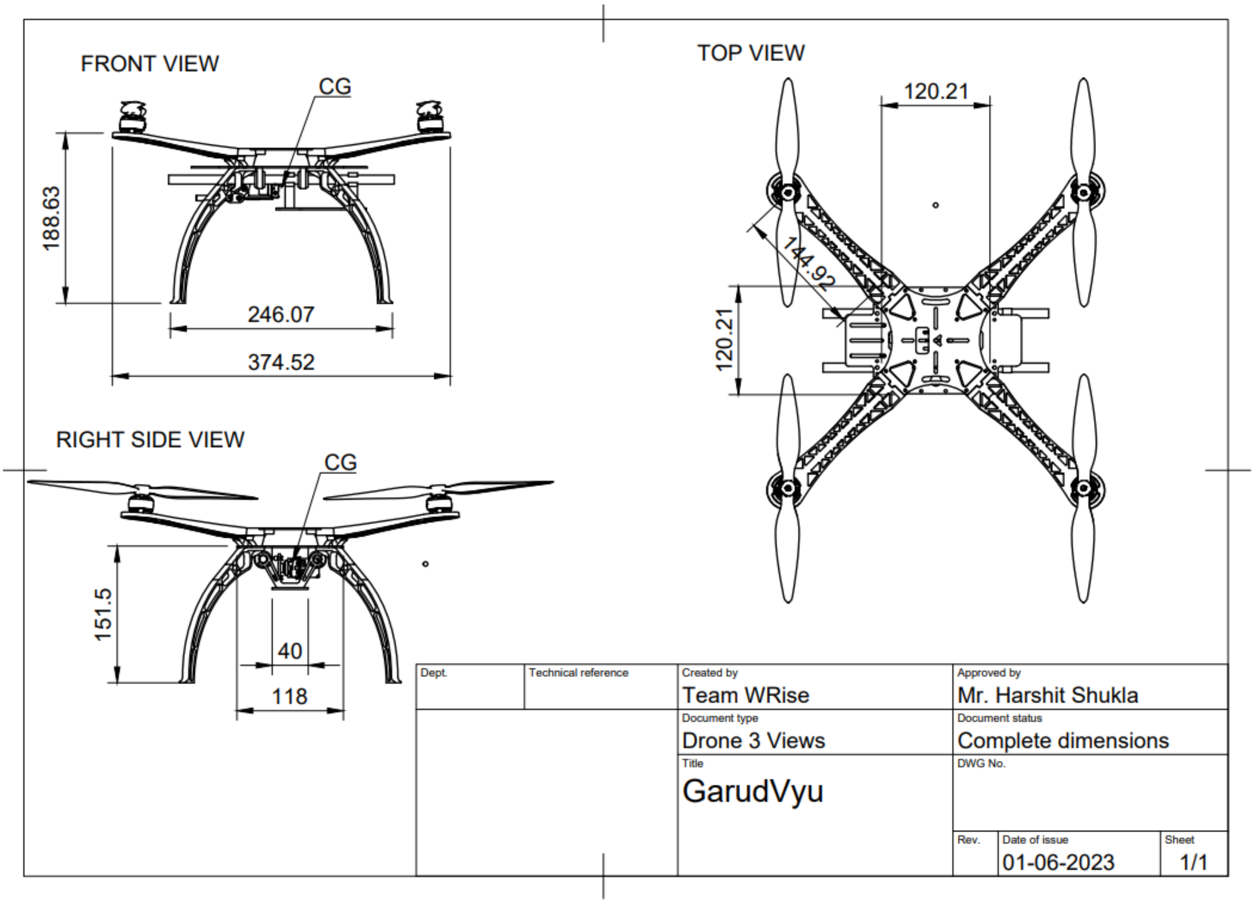
The team has finalized **Ubuntu Server 20.04.3 LTS {64-bit version},** which operates best with **Raspberry Pi 4 {4GB}.** OpenCV Library will be added and necessary libraries to use **ROS** (Robot Operating System) in the codes to control the Drone Path and Movements.

Flight Termination System:

- The integration of a Flight Termination System (FTS) during a drone competition, utilizing ROS, MAVLink, and Ubuntu, provides a critical safety mechanism to prevent potential hazards. The combined capabilities of **ROS** for software development, **MAVLink** for communication, and **Ubuntu** for a stable operating system offer a robust foundation for implementing the FTS.
- Following the outlined procedure, including hardware setup, software integration, FTS logic development, and thorough testing, we can ensure the FTS operates effectively and enhances safety during the drone competition.
- Implementing a Flight Termination System shows our commitment to prioritizing safety and mitigating risks, fostering a secure and controlled environment for participants and spectators during the competition. This failsafe action will activate under the following parametric conditions:

Fail-Safe Condition	Specification
Battery Loss	In case the battery indicates to be insufficient for mission operation.
Transmission Loss	If the transmission signal is lost, for a moment.
Geofence Breach	If the drone has exited the designated fenced area.
Telemetry Loss	If in autonomous mode, the connection between the drone and the GCS (Ground Control Station) is severed.

IX. Preliminary CAD model (2D Drafting Front view, Top view and Side View, 3D Model)



X. Optimized Final Design

Flight Controller:

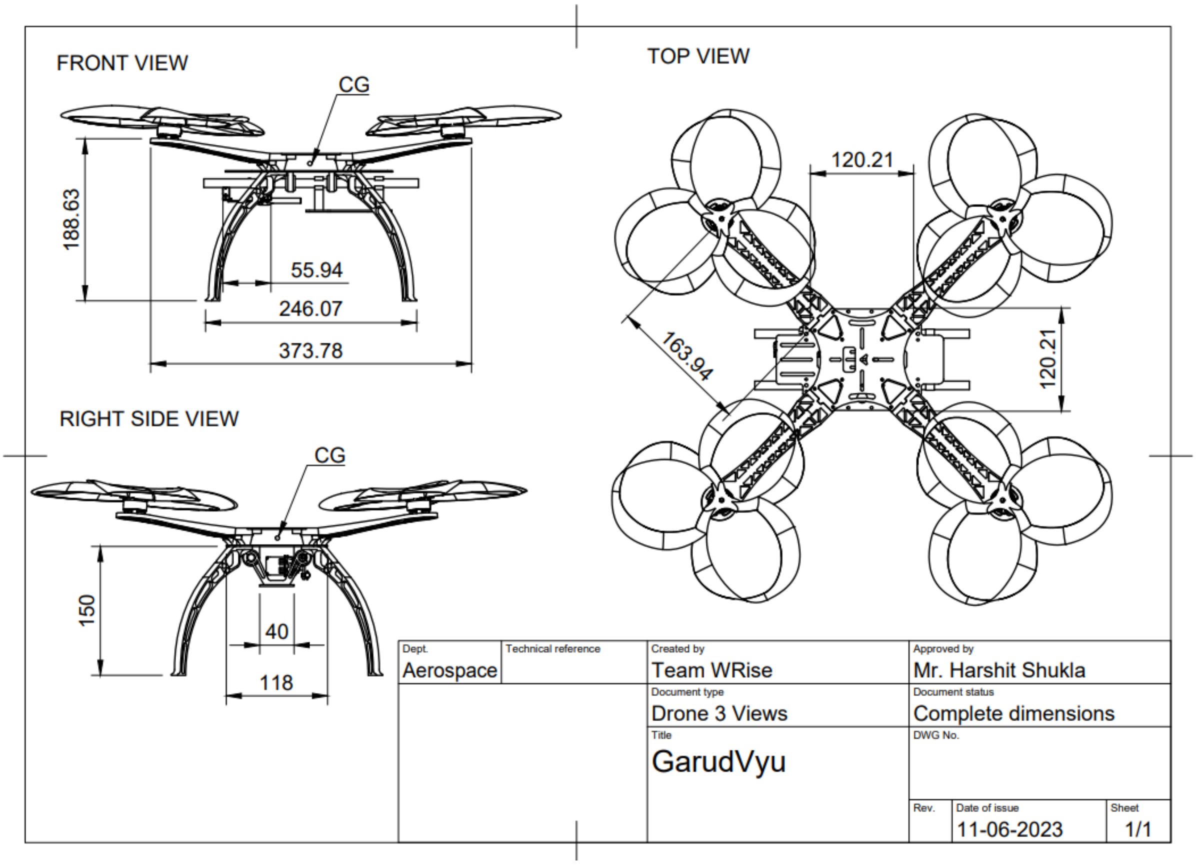
- ***Flight Controller:*** Pixhawk 2.4.8

Communication:

- ***Receiver:*** FlySky FS-iA10B
- ***Transmitter:*** Radiomaster TX16S
- ***Telemetry Link:*** Holybro Sik Telemetry Radio V3-100mW 433MHz

Image Processing:

- ***Camera:*** Arducam 16MP
- ***Central Processing Unit:*** Raspberry Pi 4 {4GB}
- ***Memory Card:*** SanDisk 32GB Micro SD Class 10 Memory Card



CG: -0.93 mm z direction ,0 mm y direction,0mm z direction

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

Sr. No.	Component	Units	Weight	Total weight
1	Battery	1	540g	540g
2	Motors	4	50g	200g
3	ESC	4	34g	136g
4	GPS module	1	23g	23g
5	Camera	1	3g	3g
6	Altimeter	1	3g	3g
7	Receiver	1	15g	15g
8	Raspberry Pi4	1	46g	46g
9	Pixhawk 2.4.8	1	40g	40g
10	Memory card	1	2g	2g
11	Telemetry antenna	1	127g	127g
12	S500 frame	1	405g	405g

13	Payload	1	200g	200g
14	Wires	1	75g	75g
15	Payload dropping mechanism	1	30g	30g
Total weight				1845g

XII. UAV Performance Recalculation

Final flight performance

- The final speed of the drone depends on the camera specifications. The Frame Rate per Second (FPS) decides the optimal speed of the drone which enables the drone to take pictures and support good efficiency. Since, the optimal speed will be less than the max. Speed, thus the endurance would increase.
- The FPS of the selected Arducam 16MP camera is 0.5 FPS and the camera can capture 33m of length thus the speed of the drone to capture images without overlapping comes out to be 16.5 m/s.
- Therefore, the optimal speed of the drone is 16.5 m/s

C. Final UAV Specifications and Bill of Materials.

Sr. No.	Component	Units	Cost
1	Battery: Lemon 6200mAh 4S 45C/90C Lithium Polymer Battery Pack	1	₹ 7,999.00
2	Motors: EMAX ECO II-2807	4	₹ 7,360
3	ESC: ReadytoSky 40A 2-4S ESC	4	₹2,980
4	GPS module: Ublox Neo M8N GPS module	1	₹2,299
5	Camera: Arducam 16MP	1	₹3,199
6	Altimeter: BME280	1	₹453
7	Receiver: FlySky FS-iA10B	1	₹1,325
8	Raspberry Pi4	1	₹5,049
9	Pixhawk 2.4.8	1	₹11,559
10	Memory card: SanDisk Ultra 32GB Class 10 SDHC UHS	1	₹419

11	Telemetry antenna: Holybro Sik Telemetry radio V3-100 mW 433 Mhz	1	₹6,500
12	S500 frame	1	₹1,699
13	Radiomaster TX16S transmitter with battery	1	₹26,000
Total cost			₹76,841

D. Methodology for Autonomous Operations.

Pseudo Code for Autonomous mode:

1. Set up the necessary ROS nodes, including the MAVLink communication node and image processing node.

    (a) Initialize the ROS node for communication with the flight controller using pymavros.
    (b) Initialize the image processing node to process images from the drone's camera.

2. Start the mission loop:

    (a) Check if the drone is within the geofenced area. If not, start the return-to-home procedure using MAVLink commands.
    (b) Get an image from the drone's camera using the image processing node.

3. Process the image to detect the presence of hotspots using image processing techniques within the image processing node.

4. If all four hotspots have been visited, go ahead to the final target.

    (a) Continuously check the drone's camera feed for the presence of the final target using the image processing node.

5. If there are remaining hotspots:

    (a) Determine the next hotspot to visit based on the drone's current location and the hotspots' positions.
    (b) Calculate the required flight path and altitude changes to reach the next hotspot using MAVLink commands.
    (c) Command the drone to ascend to 30 meters using MAVLink commands.
    (d) Command the drone to move toward the next hotspot using MAVLink commands.
    (e) Command the drone to descend to 10 meters using MAVLink commands.
    (f) Capture an image of the hotspot using the image processing node.
    (g) Store the image or process it further if needed.
    (h) *Command t*he drone to ascend back to 30 meters using MAVLink commands.

6. Once all hotspots have been visited, proceed toward the final target.

(a) *Continuously monitor the drone's camera feed for the presence of the final target using the image processing node.*

7. Once the final target is confirmed:

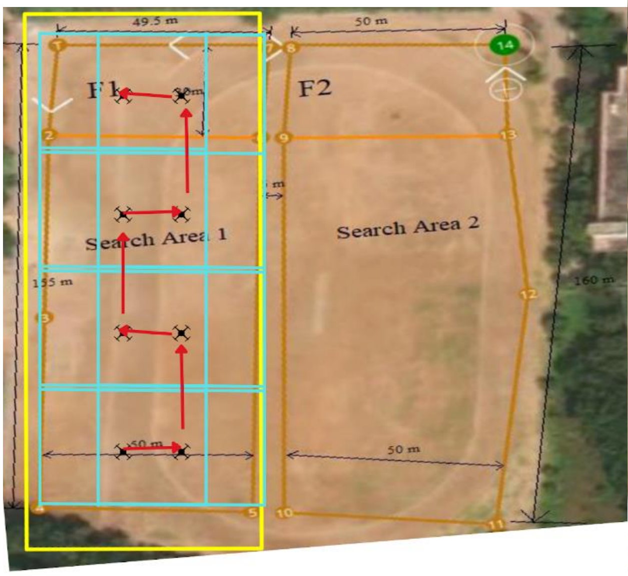
    (a) *Command the drone to descend to a height of 20 meters using MAVLink commands.*
    (b) *Activate the payload drop mechanism using MAVLink commands.*
    (c) *Ascend back to the original altitude of 30 meters using MAVLink commands.*

8. Initiate the return-to-home procedure using MAVLink commands.

9. Perform necessary error handling and cleanup procedures.

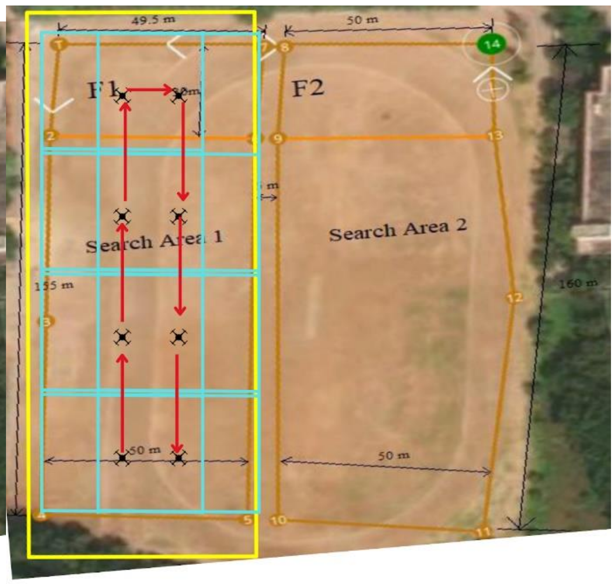
10. End the pseudo-code.

Image Processing Approach



Path 1:

All the Hotspots would get recognized first, image will be captured and then after the Hotspots counts = 4, then payload will be dropped on the Dropzone (which looks like a shooting target board).



Path 2:

Risk in this path is that if Hotspot and Dropzone Looks same, dropzone might be recognized as Hotspot. And the drone would capture its image instead of Dropping the payload after all hotspot detection process.

<u>***Fig:** Strategy for Searching Hotspots from Drone. Red Arrow is the Path followed*</u>

The blue rectangle depicted in the provided image represents an approximate calculation of the field of view captured by our camera, specifically the 16MP Arducam. With a diagonal field of view of 80 degrees, we have utilized trigonometry to determine the rectangular area covered from a height of 30 meters, while also considering the camera's aspect ratio.

Based on these calculations, the resulting rectangular area measures approximately 38.6 meters in width and 32.3 meters in height. Considering our search area has a width of 50 meters, two overlapping areas of 38.6 meters each can cover the entire width. Similarly, the length of a single image from a 30-meter height is 32.3 meters, while our search area spans 155 meters (Search Area 1) and 160 meters (Search Area 2). Consequently, utilizing 5-6 non-overlapping rectangles, each with a length of 32.3 meters, will cover the entire field effectively.

Two possible paths have been outlined in the image, namely Strategy 1 (Left Image) and Strategy 2 (Right Image). If we employ Strategy 1, the drone will systematically search the entire field before reaching the designated Dropzone at the conclusion of its search. Thus, if the images of the hotspots and the Dropzone appear similar, it is likely that the drone would have already identified four hotspots, enabling it to recognize the fifth image as the Payload Dropzone. However, if we opt for Strategy 2, the drone will approach the Payload Dropzone midway through its search, potentially causing confusion regarding whether to treat the object as a hotspot or proceed with an autonomous payload drop. Strategy 2 is preferred in instances where the images of the hotspots and Dropzone differ, thereby eliminating any potential confusion. Path 2 would be the appropriate strategy for hotspot detection.

Strategy for Hotspot Detection

- The drone will ascend to a height of 30 meters and capture images at a rate of 1FPS or faster.
- The Arducam 16MP camera will transmit the images to the Raspberry Pi (CPU).
- If possible, the same image will be transmitted to the Ground Control System through a telemetry link connected to the Flight Controller (Pixhawk 2.4.8).
- The images will be processed using a Python code with the OpenCV library imported.
- OpenCV commands will be utilized to determine the presence of hotspots in the images.
- In case of a hotspot being detected, the code will calculate the hotspot's coordinates relative to the drone's camera. The GPS module will provide input on the position of the hotspot and the drone.
- The Python code will then use ROS commands (Dronekit can also be used) to instruct the Flight Controller to orient the drone toward the target and move towards it.
- To ensure accuracy, the code for determining the relative distance between the drone and the target will be executed multiple times (e.g., 3 times).

- Once the drone is directly above the target, ROS commands will be employed to reduce the propeller's rotation speed, facilitating a descent of 20 meters. The altimeter BME280 will be utilized to confirm the height.

- The image will be captured and saved to the memory card inserted in the Raspberry Pi board.

E. Summary of innovations in the overall design

The team is utilising Toroidal Propeller for the drone. The toroidal propeller provides an advantage over other propellers that have been used in a small multirotor unpiloted aircraft, or drone, unchanged since the beginning of aviation which is being quieter. This can increase the efficiency of the drone, which is now quieter, by as much as 36%. The closed structure minimizes the drag effects of air swirls (i.e., tip vortices) created at the blade tips which also strengthens the overall stiffness of the propeller. These features diminish the propeller’s acoustic signature. Prototype toroidal propellers that have been tested on commercial quadcopters showed thrust levels comparable to those of traditional propellers at equivalent power levels. Reduced sound levels allowed the drones to work without tiring human ears at a distance half that of a typical operation.

The biggest drawback is the complex design that is hard to produce/manufacture as compared to a conventional propeller. While 3D printing, surface finish issues can occur on the model that if not treated properly will hinder the propeller performance vastly.

For the mission the team has designed a toroidal propeller of our own while considering the aerodynamic properties. The propeller is tri-bladed. NACA 4412 airfoil is equipped at the root of every blade with an angle of 60^0 with the horizontal. CLARK Y airfoil is present at the edges and the tip of the blades with angles 30^0 and 10^0 with the horizontal respectively. The propeller is a counter clockwise version with an overall diameter of approximately 10 inches. The hub diameter is 45 mm and the hole for the motor shaft has a diameter of 4.9 mm.

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