GARUDVYU

SAE AEROTHON 2023

PHASE-1 PRESENTATION

Team Name : Team WRise
Team Number :
College Name : UPES, Dehradun
Team Member :

Conceptual Design

- **Airframe (Cross type): S500**
  - Larger diagonal wheelbase
  - Enhanced stability and payload capacity
- Fully electrical propulsion system
- Vertical thrust and balanced performance using motors at rear ends
- **10 inch propeller** used
- **Flight controller: Pixhawk 2.4.8**
- Communication
  - Receiver: **FlySky FS-iA10B**
  - Telemetry Link: **Holybro Sik Telemetry Radio V3**
  - Transmitter: **100mW 433MHz**
- Camera Module: **Arducam 16MP**
- Focusing on area search domain

Preliminary Weight Estimation

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**

Thrust Required Estimation

- Maximum weight of the drone (assumed): 2 Kilogram
- Total thrust required by the drone (estimated): 4 Kilogram
- Thrust per motor must be a minimum of 1 kilogram
- Kv=RPM/Voltage, a range of Kv rating
- This range was 1000Kv-1400Kv producing thrust between a range of 1Kg-1.6Kg.

Final results are shown below:

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

E-calc was used for the calculations and weight estimations.

UAV Sizing (Rotor Arm)

- The **propeller diameter** = ***Dprop*= 10-inch or 25.4 cm**, Minimum arm length can be calculated by,

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

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

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

UAV Sizing (Wheelbase)

- The min radius of the wheelbase by the following relation,

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

where,

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

r_p denotes the radius of propeller.

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

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

UAV Sizing (Propeller Clearance)

- For a propeller with a **10-inch diameter**, the minimum propeller clearance necessary is,

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

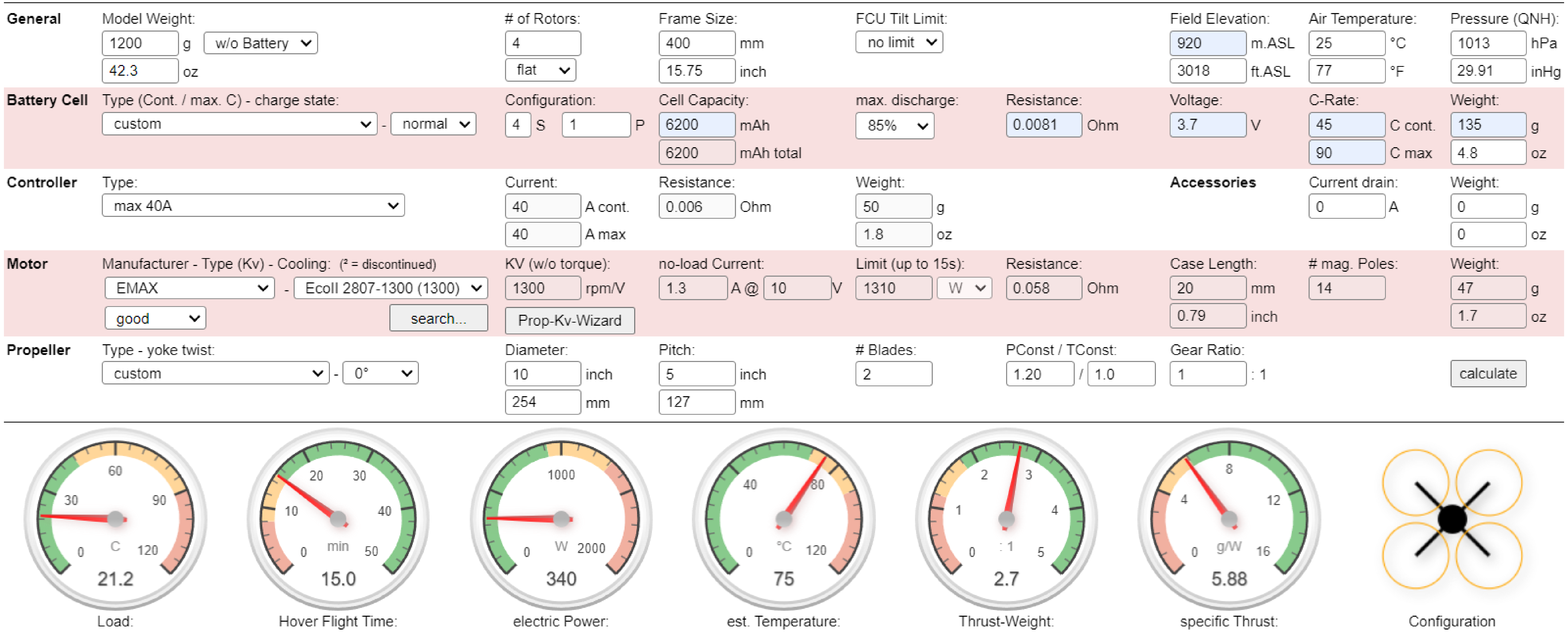
$$PC_{min} = 53.88 - 25.4$$

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

UAV Sizing (Landing Gear)

Positioning / Parameter	Under-Hub	Middle-arm	End-of-Arm
Image			
Camera View	Unobstructed camera view	Obstructed camera view	Unobstructed camera view
Ground clearance	Increased ground clearance	Comparatively low clearance	Ample ground clearance
Stability and Performance	Can toggle	Additional weight and drag	Increased drag
Spacing	Limited space at hub	Efficient use of space	Limited space at ends of arms

UAV Performance (Power required estimation)



Source:eCalc

- The required power from eCalc analysis came out to be 340 Watts.

UAV Performance (Power System Selection)

- The initial battery selection-Orange 3s 4200mAh 35/70C (found to be insufficient)
- Selected the Lemon 4s 6200mAh 45/90C battery to aim for optimal performance and efficiency.
- Thus, the power capacity calculated using P=VI at the battery's total current of 6.2 Amps and voltage of 14.8 V came out to be 367.04 Watts.

UAV Performance (Endurance Estimation)

- The endurance of the drone system increased by examining and optimizing number of elements, such as weight calculations, battery selection, and motor performance characteristics.
- Considerations taken into account-availability, cost, endurance, and weight while evaluating the performance of the EMAX ECOII-2807(1300kV) motor in conjunction with the chosen battery, which provided a flight time of more than 15 minutes at maximum speed.

Material Selection

- Comparison on different pre-manufactured airframes:

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

Motor Specifications

Test item	kV1300
Motor Dimensions	φ33.9*34mm
Bearing Shaft	4mm
Weight	47.6g (W/O Silicone wire)
Idle Current (10V)	1.3A
Internal Resistance	58mΩ
Peak Current (6S)	52A
Max. Power (6S)	1310W

Battery Specifications

Model No.	6200mAh 4S 45C
Nominal Capacity(mAh)	6200mAh @ 0.2C Discharge
Minimum Capacity	5978mAh @ 0.2C Discharge
Nominal Voltage (V)	14.8
Internal Impedance	≤8.1mΩ

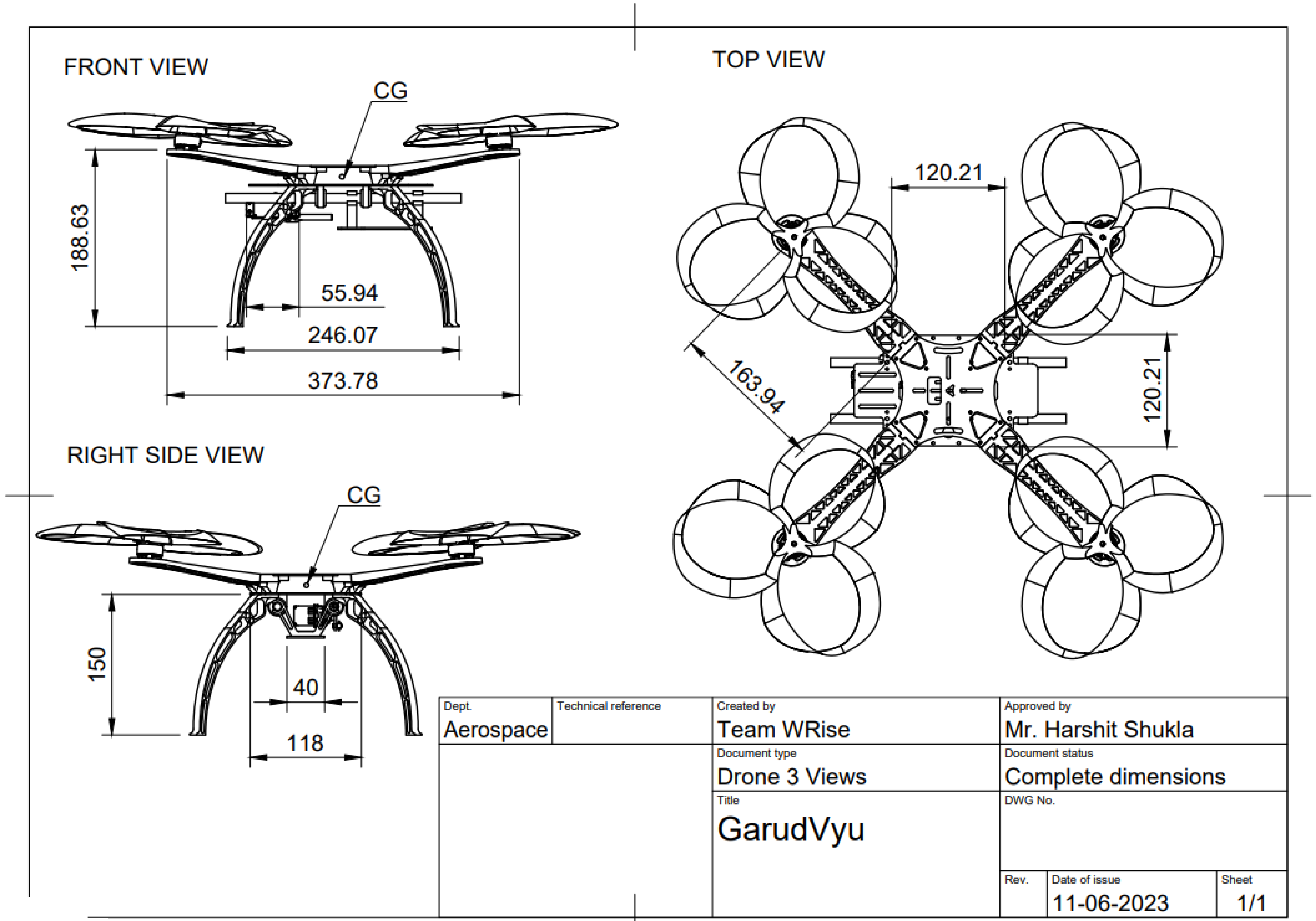
Communication System Control and Navigation System

Components	Options	Selection	Reason
Telemetery Link	Holybro Sik Telemetry Radio V3 Generic Telemetry Radio	Holybro Sik Telemetry Radio V3	• Compatible with Pixhawk 2.4.8 Flight Controller • 433 MHz Frequency • Lightweight Suitable for drone
Transmitter	Radiomaster TX16S Flysky FS-i6	Radiomaster TX16S	• Channels: 16 • Protocols: Supports various RF modules and protocols like FrSky, Flysky, Futaba, and more. • Programming Options: Custom mixes, logical switches, flight modes. • Ergonomics: Comfortable ergonomic design, high-quality gimbals.
Receiver	FlySky FS-iA10 FlySky FS-A8S	FlySky FS-iA10	• Channels: 10 • Transmission Range: Extended range for reliable signal communication. • Compatibility: Supports FlySky AFHDS 2A protocol. • Telemetry: Built-in telemetry for monitoring flight data.

Communication System Control and Navigation System

Components	Selection	Reason
Flight Control	Pixhawk 2.4.8	➢ Cost and Availability: Pixhawk 2.4.8 (affordable, widely available) ➢ Community Support: Pixhawk 2.4.8 (extensive documentation, large user community) ➢ Proven Reliability: Pixhawk 2.4.8 (trusted, reliable track record)
CPU	Raspberry Pi 4B	➢ High Graphical Processing Speed ➢ Optimum for 16MP camera
Camera	Arducam 16 MP	➢ Better quality at Low Cost ➢ Compatible with Raspberry Pi 4B ➢ Autofocus ➢ No Lens Required ➢ Light Weight (3gms)
GPS	Ublox Neo M8N	➢ Compatible with Pixhawk 2.4.8 ➢ Accurate (0.6m) ➢ High Upload Speed (10Hz) ➢ Lightweight

Optimized Final Design (Summary of Design Changes/Optimizations including the Final CAD model and 2D



Detailed Weight Breakdown

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

UAV Performance Recalculation (T/W, Power Required for the mission & Endurance calculation)

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

Battery	
Load:	21.20 C
Voltage:	10.54 V
Rated Voltage:	14.80 V
Energy:	91.76 Wh
Total Capacity:	6200 mAh
Used Capacity:	5270 mAh
min. Flight Time:	2.4 min
Mixed Flight Time:	10.0 min
Hover Flight Time:	15.0 min
Weight:	540 g
	19 oz

Motor @ Optimum Efficiency	
Current:	17.08 A
Voltage:	12.48 V
Revolutions*:	14831 rpm
electric Power:	213.2 W
mech. Power:	177.8 W
Efficiency:	83.4 %

Motor @ Maximum	
Current:	32.87 A
Voltage:	10.34 V
Revolutions*:	10755 rpm
electric Power:	339.9 W
mech. Power:	262.6 W
Power-Weight:	781.5 W/kg
	354.5 W/lb
Efficiency:	77.2 %
est. Temperature:	75 °C
	167 °F

Wattmeter readings	
Current:	131.48 A
Voltage:	10.54 V
Power:	1385.8 W

Motor @ Hover	
Current:	5.26 A
Voltage:	14.08 V
Revolutions*:	5817 rpm
Throttle (log):	35 %
Throttle (linear):	38 %
electric Power:	74.0 W
mech. Power:	58.1 W
Power-Weight:	178.9 W/kg
	81.1 W/lb
Efficiency:	78.5 %
est. Temperature:	35 °C
	95 °F
specific Thrust:	5.88 g/W
	0.21 oz/W

Total Drive	
Drive Weight:	1021 g
	36 oz
Thrust-Weight:	2.7 : 1
Current @ Hover:	21.03 A
P(in) @ Hover:	311.2 W
P(out) @ Hover:	232.4 W
Efficiency @ Hover:	74.7 %
Current @ max:	131.47 A
P(in) @ max:	1945.7 W
P(out) @ max:	1050.4 W
Efficiency @ max:	54.0 %

Multicopter	
All-up Weight:	1740 g
	61.4 oz
add. Payload:	2278 g
	80.4 oz
max Tilt:	64 °
max. Speed:	83 km/h
	51.6 mph
est. Range:	4440 m
	2.76 mi
est. rate of climb:	11.4 m/s
	2244 ft/min
Total Disc Area:	20.27 dm²
	314.19 in²
with Rotor fail:	X

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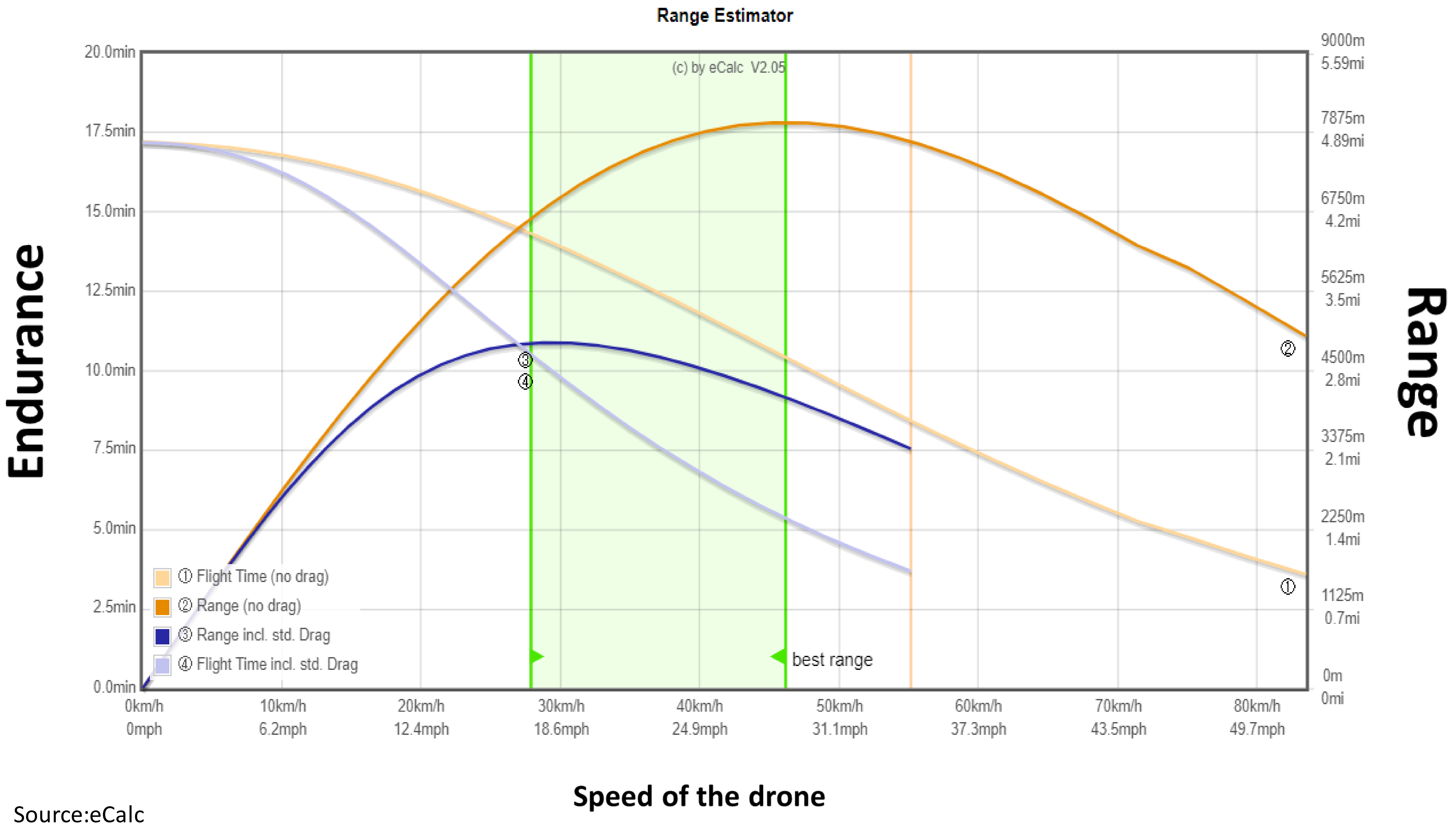
Source:eCalc



Source:eCalc

Final UAV Specification

- Camera Specifications:
  - FPS determines optimal drone speed
  - Higher FPS enables efficient picture-taking
- Relationship between Speed and Endurance:
  - Optimal speed < max. Speed
  - Higher speed leads to increased endurance
- Arducam 16MP Camera:
  - FPS: 0.5 FPS
  - Capture length: 33m
  - Speed for non-overlapping image capture: 16.5 m/s
- Optimal Drone Speed:
  - Optimal calculated speed: 16.5 m/s
  - Optimal operating speed: 10m/s
- Additional Considerations:
  - Thrust-Weight ratio: 2.8
  - Other parameters require physical experimentation for calculation

Bill

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

Sr. No.	Component	Units	Cost
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

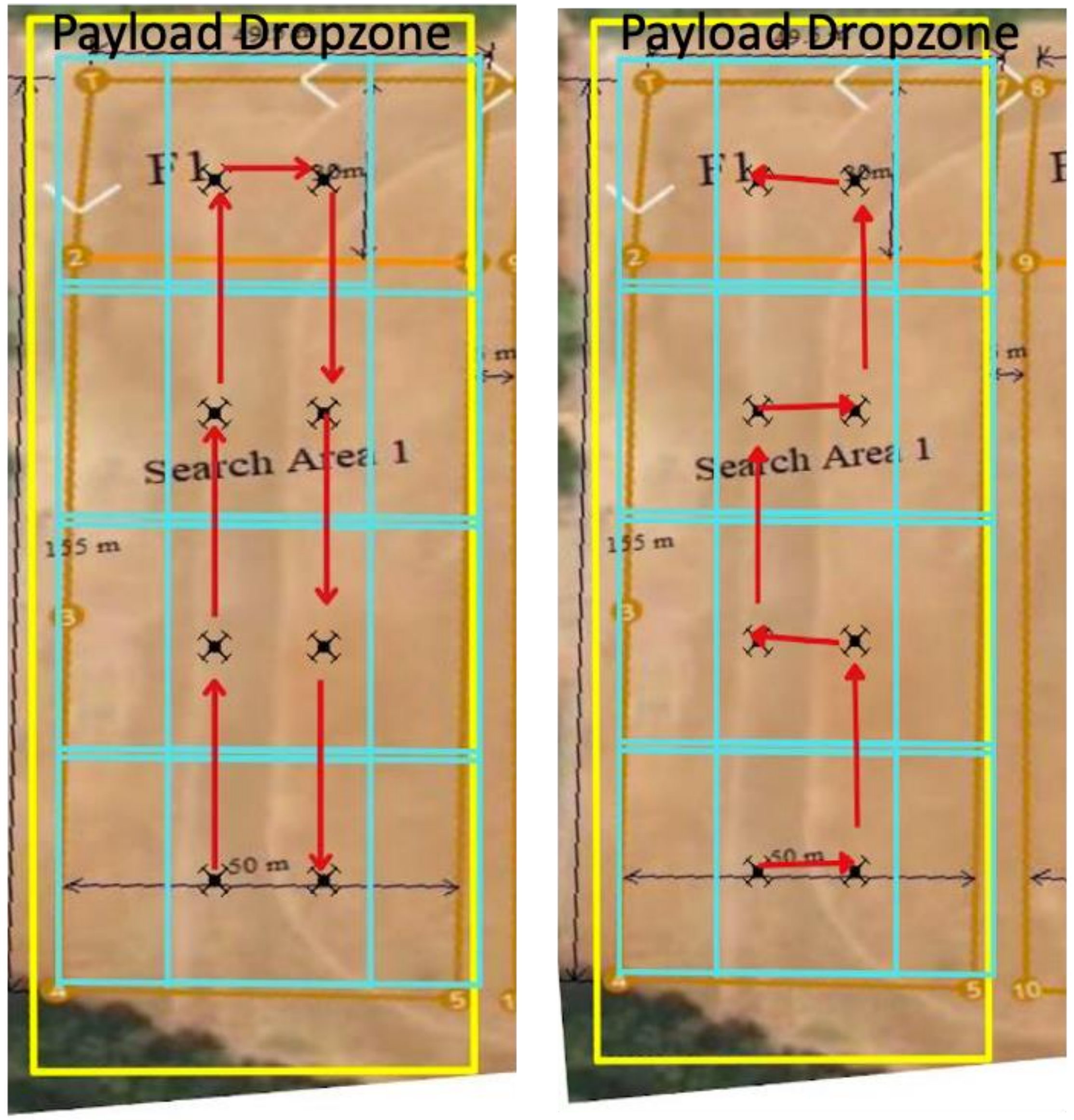
Methodology for Autonomous Operation

Autonomous Flight/Path Strategy

- Blue Triangle Field of View:
  - Field of view from 30m height (Arducam 16MP camera)

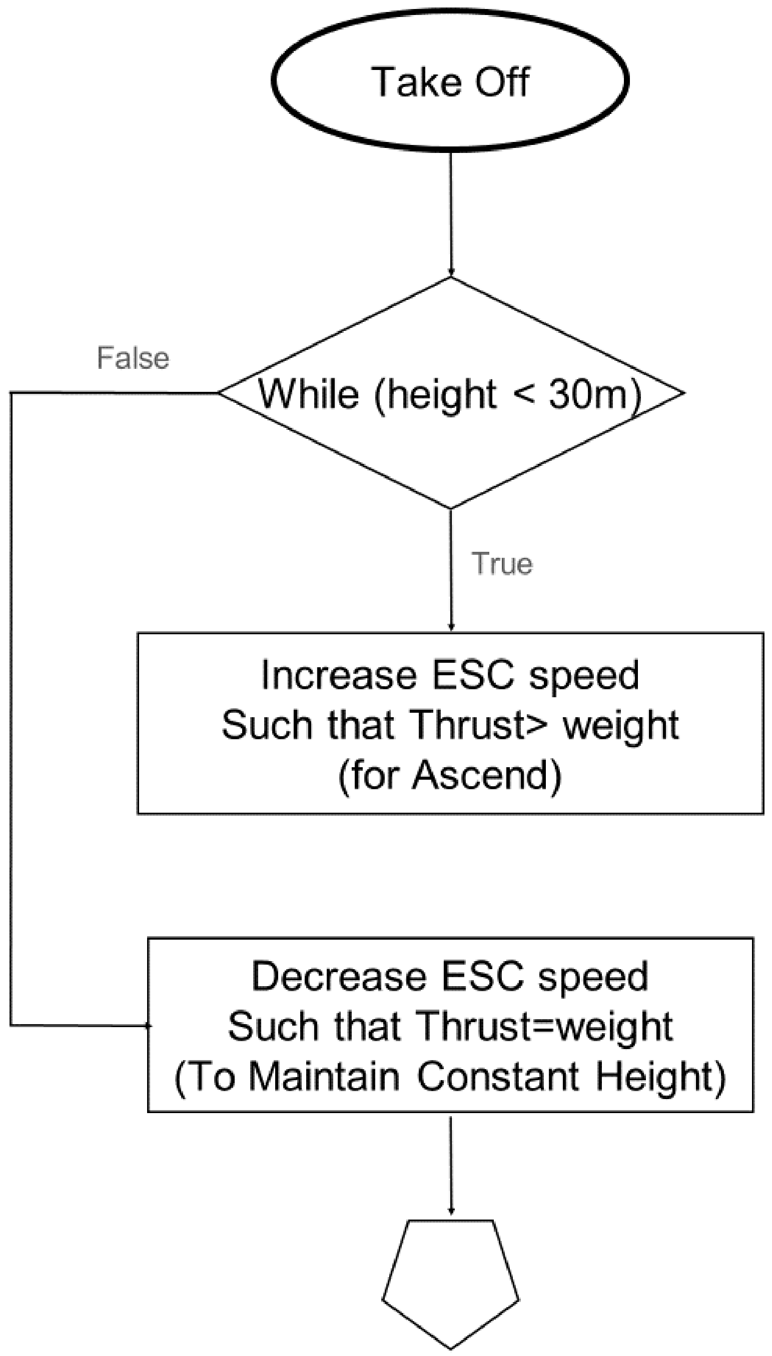
- Path 1 Strategy:
  - Stick to one side and run full length
  - Take a U-turn and return to the other side
  - Suitable if hotspot and payload drop zone are distinguishable
  - Detects all 4 hotspots

- Path 2 Strategy:
  - Better deployment strategy
  - No need to return to drop zone
  - Ideal for indistinguishable hotspot and drop zone images
  - Low risk, drone reaches drop zone during final search stage
  - Detects all 4 hotspots



Path - 1 Path - 2

1. Autonomous Identification of Target
2. Autonomous Payload Drop



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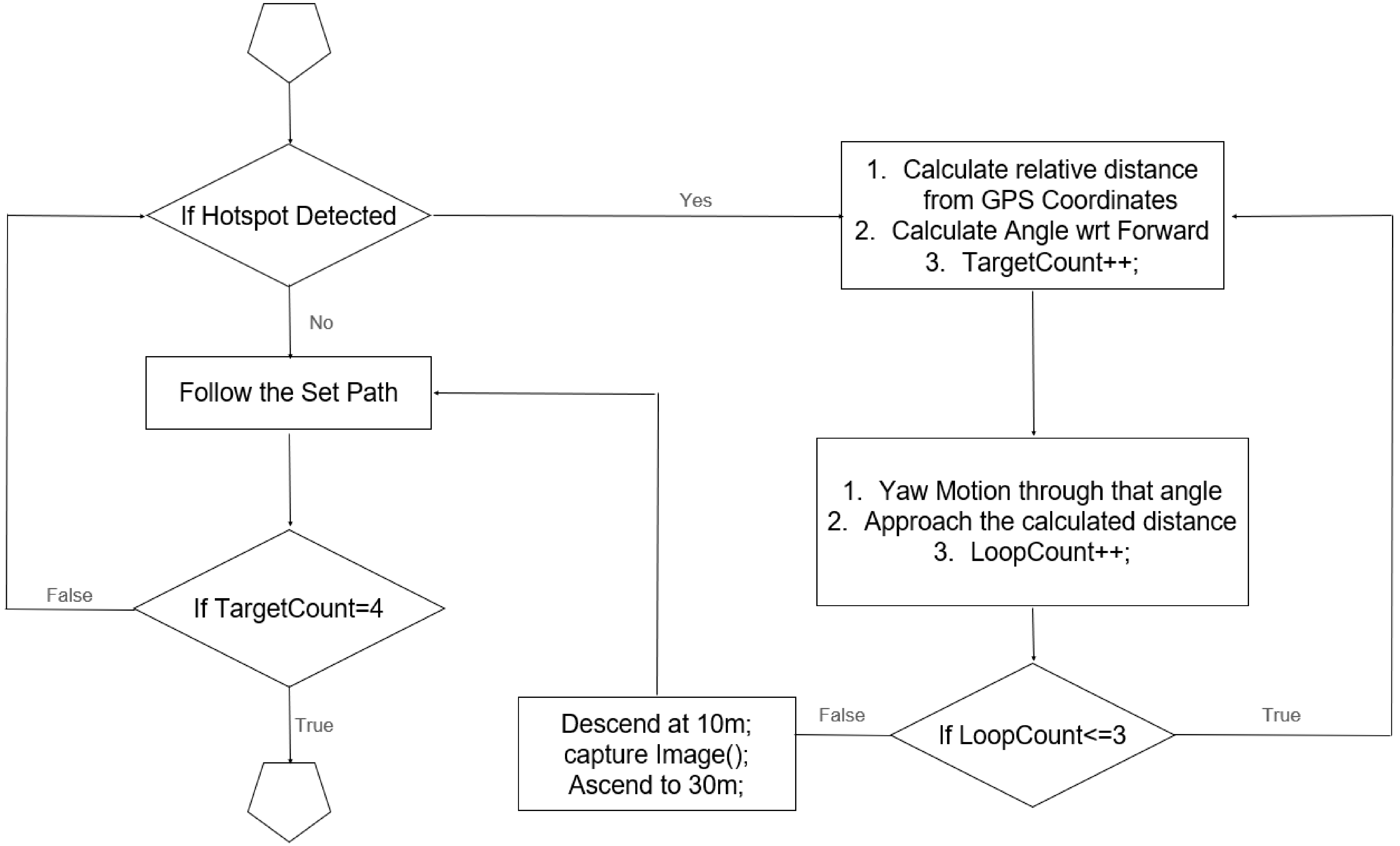

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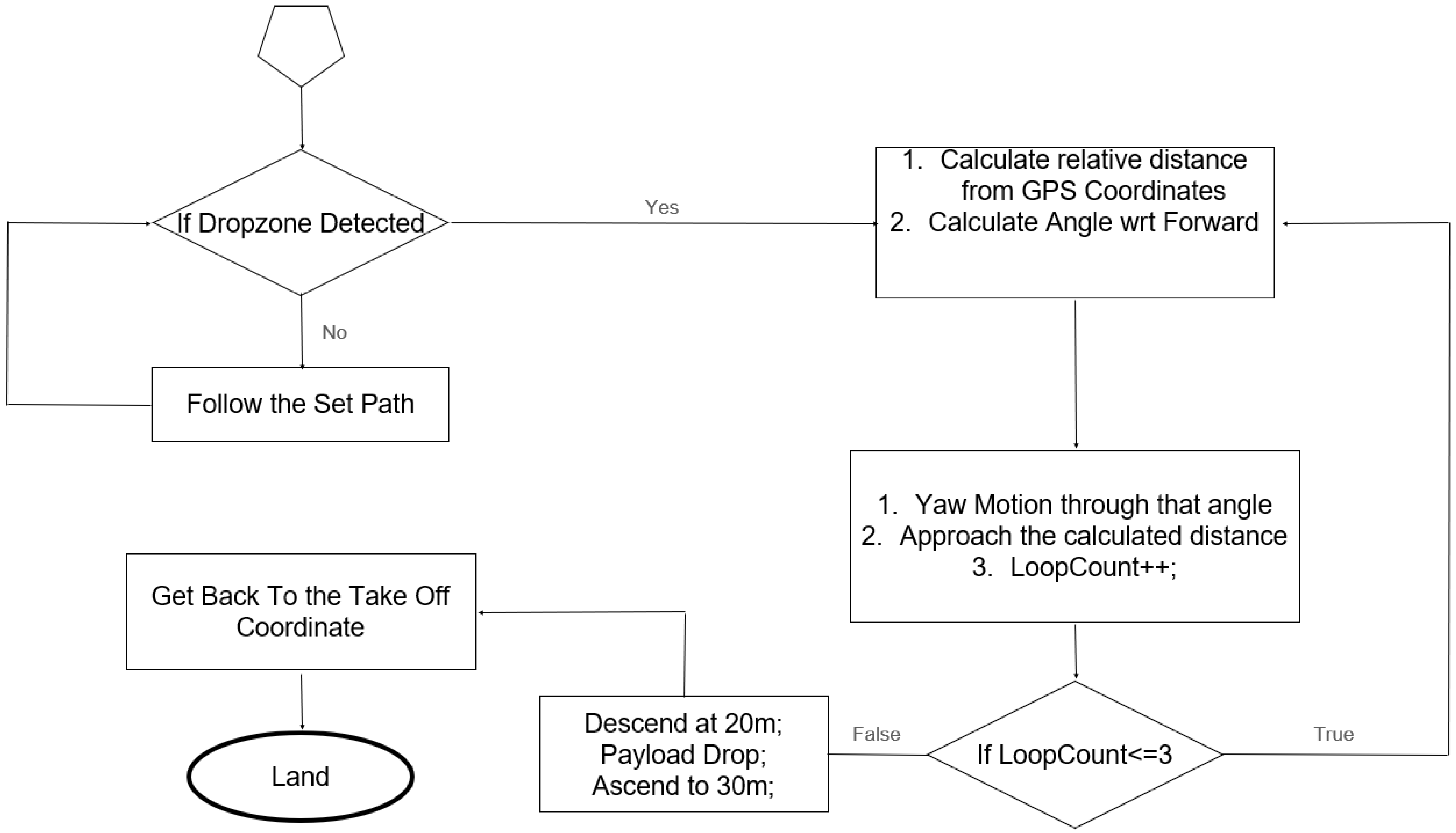
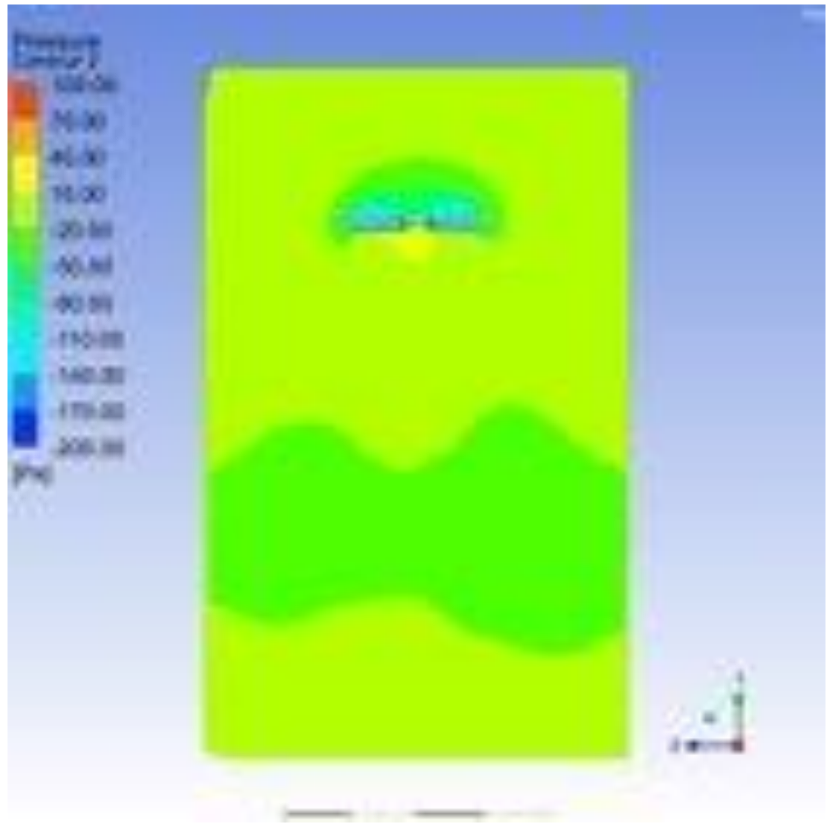
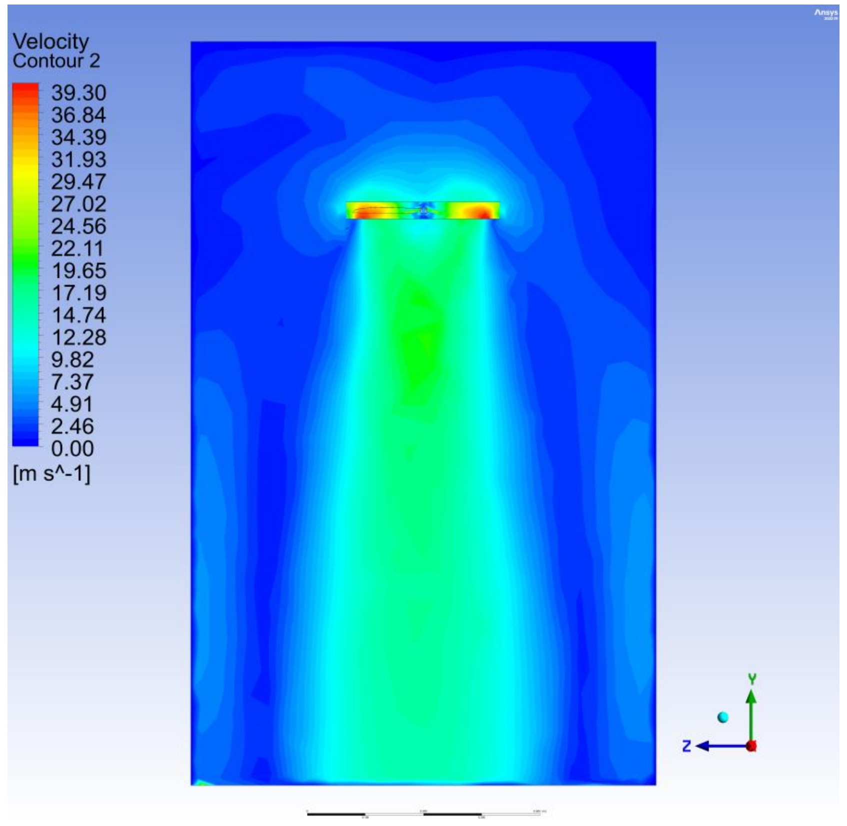


RENDERED VIDEO OF GARUDVYU

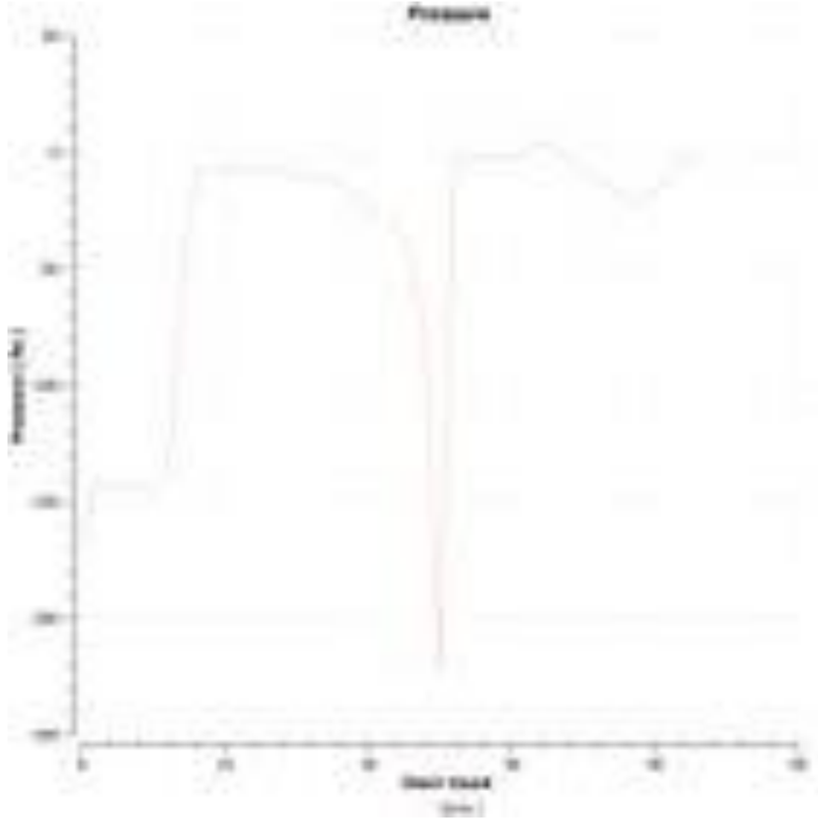
Computational Analysis of 10x4.5in Propeller



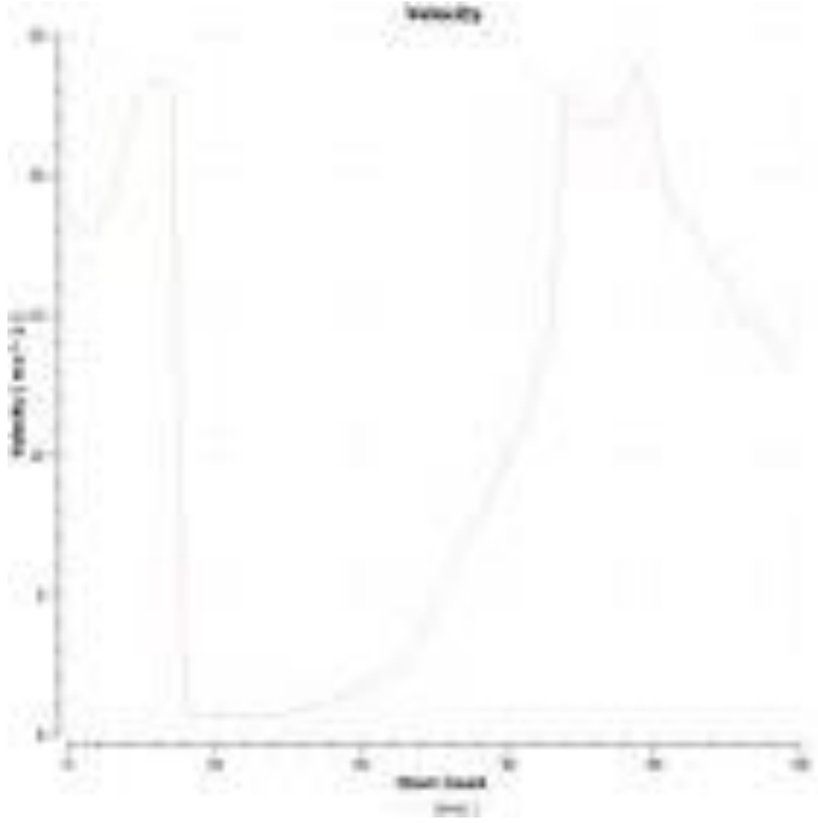
Pressure Contour



Velocity Contour

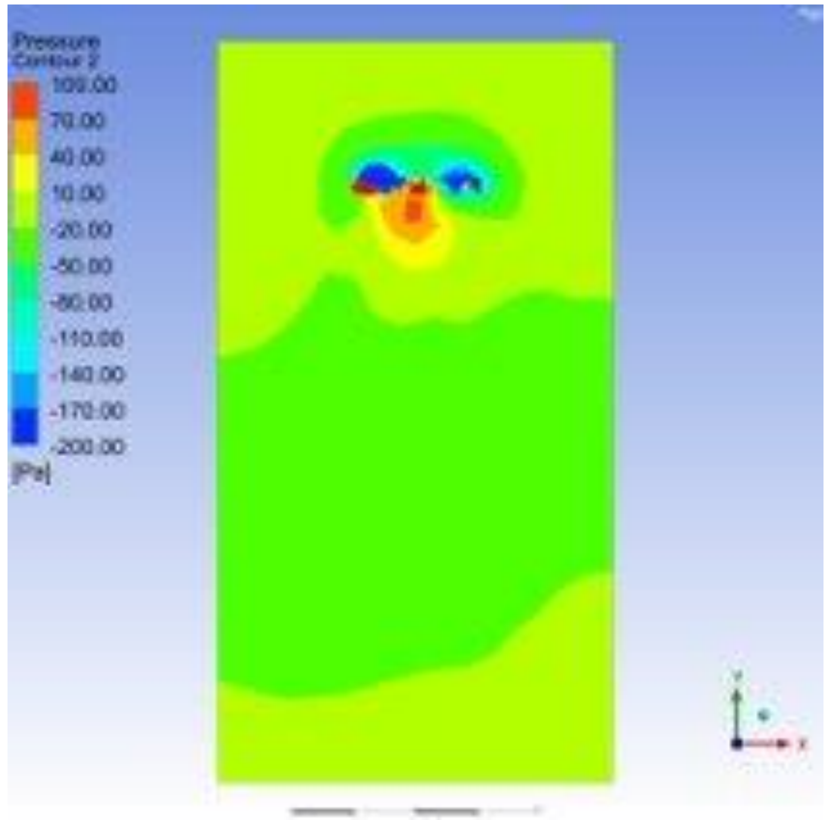


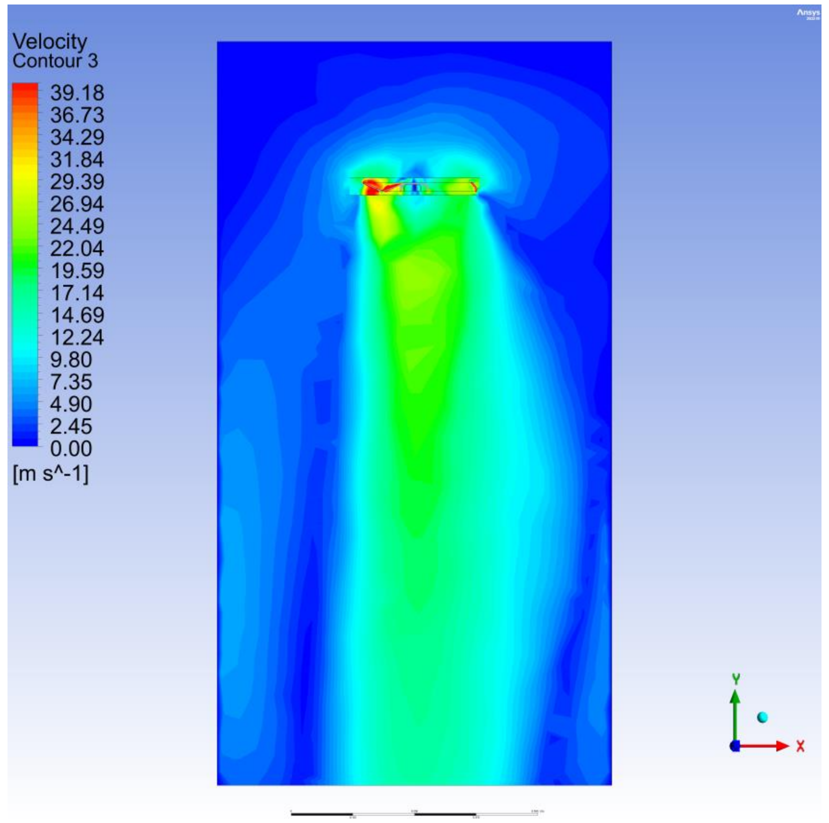
Pressure Chart



Velocity Chart

Computational Analysis of Toroidal Propeller





Pressure Contour

Velocity Contour

Pressure Chart

Velocity Chart