AEROTHON 2025

**UNCREWED AIRCRAFT SYSTEM (UAS)
DESIGN, BUILD
AND FLY CONTEST**

PHASE 1: DESIGN REPORT

TEAM NAME: UDSAV
TEAM NUMBER: AT2025043

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APPENDIX A

STATEMENT OF COMPLIANCE
8.1.1.1.1 Certification of Qualification

Team Name: _U D S A V_

University/Institute: _Gati Shakti Vishwavidyalaya_

Faculty Advisor: _Asifa Yasmin_

Faculty Advisor's Email: _asifayasmin@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 UAS for the SAE AEROTHON 2025 contest, without direct assistance from professional engineers, R/C model experts or pilots, or related professionals.

_12/05/25_

Signature of Faculty Advisor

_12/05/25_

Date

8.1.1.1.2 Team Captain Information:

Team Captain's Name: _Shashank Shekhar_

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Team Captain's Phone: _8340326449_

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Introduction

1.1 Overview

In the face of natural and man-made disasters, rapid response and situational awareness are critical. Drones have emerged as powerful tools in disaster management, offering real-time aerial insights, access to hard-to-reach areas, and faster deployment compared to traditional methods. Whether locating survivors, assessing damage, or delivering essential supplies, drone technology enhances the efficiency and safety of relief operations. As disasters grow more complex and unpredictable, integrating drones into emergency response systems is no longer a luxury—it's a necessity.

Through Aerothon, Team UDSAV (*Uncrewed Disaster Surveillance Aerial Vehicle*) is not just competing—we are contributing to the evolution of drone-assisted disaster response, pushing the boundaries of what UAVs can achieve in life-saving missions.

1.2 Problem Statement and Mission Requirements

This year's AEROTHON is themed on **Surveillance and Disaster Management.** The problem statement is to build an **Uncrewed Aircraft System (UAS)** to be able to perform the mission requirements as per the rulebook. The mission requirements at a glance are as follows:

Mission - 1: *Advanced Obstacle Navigation* & *Fragile Payload Delivery with Precision Placement – Manual Operation*

Mission - 2: *Autonomous Object Classification, Disaster Situation Identification* & *Payload Drop – Autonomous Operation*

1.3 Scope of Report

The scope of this report is to provide a comprehensive understanding of the design rationale we have used while building this project. We have tried to provide the relevant calculations, figures, and analysis models to justify the materials/design/framework we've chosen to work with for our structural and system architectures.

Apart from that, this report is intended to also serve as an accessible guide catering to neophytes in UAV/UAS systems. We have tried our best to aim at providing clear context and insight that sort of demystifies drone development.

1.4 System Requirements & Design Objectives

1.4.1 Mission Profile

1. **Mission 1:** *Advanced Obstacle Navigation* & *Fragile Payload Delivery with Precision Placement*
   This is a **Manual Operation.** In this mission, the drone must transport a fragile payload through a challenging course filled with static obstacles such as walls, barriers, and narrow passages. The primary objective is to navigate these obstacles with high precision while

ensuring the payload remains undamaged.

Upon reaching the target zone, the drone must land carefully and place the fragile payload on the ground without causing any damage. After the successful placement, the drone must then return to the takeoff point or designated home base, ensuring safe and efficient navigation back through the course. The mission is complete once the payload is placed securely, and the drone successfully returns to the home base.

2. **Mission 2:** *Autonomous Object Classification, Disaster Situation Identification & Payload Drop*
This is an **Autonomous Operation.** In this mission, the drone will autonomously scan, classify, and assess objects within a predefined area using onboard sensors and algorithms. The objects will vary in shape, size, color, and structure, and may be partially obscured, presenting challenges for detection and classification. Once the objects are classified, the drone will identify potential disaster scenarios, such as flooding, fire, or damaged infrastructure, within the same area.

1.4.2 Key Performance Indicators & Constraints

According to the above defined mission profiles, we have a few KPIs (*Key Performance Index*) to keep in mind.

1. Flight Endurance and Range

2. Payload Handling

3. Autonomous Capabilites

4. System Reliability

5. Design and Innovation

The design and development of the UAV is subjected to several constraints as per the guidelines mentioned in the rulebook AEROTHON 2025. These include dimensional constraints, payload restrictions and strict autonomy requirements. The drone must perform all missions bound by these constraints and we have taken great time and care to articulate them down to ensure nothing is amiss.

1. **Dimensional Constraints**

   - Maximum Wingspan: **1.5 metres** - the UAV must fit inside a **1.5m x 1.5m x 1.5m bounding box** in assembled condition.
   - Maximum Takeoff Weight: $< 2kg$ including battery and payload.

2. **Payload Constraints**

   - Payload: One fragile payload cube of **12cm x 7cm x 7cm** weighing **200g**.
   - Payload must be released within a **3m x 3m** target zone.

3. **Flight Environment Constraints**

   - Missions are conducted in **open outdoor airspace**.
   - Expect wind speeds upto **5m/s**

4. **Autonomy and Mission Constraints**

   - **Mission 1:** Manual flight only (no GPS or autopilot usage).

- **Mission 2:** Fully autonomous flight (no pilot intervention or RC use).
- All autonomous missions must avoid obstacles and make decisions based on ***onboard computation.***

5. **Power and Communication Constraints**

   - Must operate on battery only
   - No cellular or internet-based comms allowed
   - Only 2.4 GHz or 5.8 GHz RF modules permitted

6. **Safety and Compliance**

   - Must have a failsafe mode (e.g., return-to-home or emergency land)
   - Must pass technical inspection before flying
   - Compliance with DGCA drone guidelines (if relevant in test zones)

7. **Operational Constraints**

   - The team must complete the flight within a ***15-minute slot.***
   - Payload must be dropped in an area of ***3m x 3m.***

Conceptual Design Approach

2.1 Design Methodology

2.2 Product Benchmark & Trade-off Analysis

Detailed Design Breakdown

3.1 Preliminary Weight Estimation

Table 3.1: Detailed Weight Breakdown

Parameter	Weight *(gms)*
NVIDIA Jetson Orin Nano	176
Pixhawk 2.4.8	39
Camera (*x2*)	20
SpeedyBee BL32 50A 4-in-1 ESC	90
DYS D2836-7 1120KV BLDC (*x4*)	280
Battery (Orange 5200mAh 11.1V 3S)	360
GPS – Neo M8N	23
Transmitter (SkyDroid)	525
Receiver	17
Payload	200
Additional Wiring	50
Servo Motor	10
Propellor (9")	40
Estimated Frame Weight	500
Total:	**2330**

Note: The transmitter is not a part of the UAS itself, so effective drone weight is **1805gms**.

3.2 Thrust Requirement & Propulsion System Selection

3.2.1 Thrust Requirement
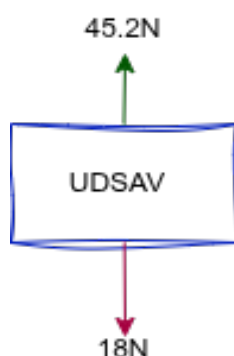
Figure 3.1: Thrust-to-Weight Diagram

To ensure stable and controlled flight, a multirotor drone must generate sufficient thrust to overcome its total weight. The drone in this design has a total takeoff weight of **1805 grams** (1.805 kg). For stable hovering, the combined thrust of all motors should ideally be at least equal to the total weight. However, to allow for effective maneuverability, rapid ascent, and compensation for wind or payload imbalance, a common design guideline is to target a thrust-to-weight ratio of at least **2:1**. This implies a minimum total thrust of approximately $2 \times 1.805 = 3.61$ kg. The selected propulsion system comprises four DYS D2836-7 1120KV brushless DC motors. According to manufacturer test data, when paired with a suitable 10×4.7 propeller and a 3S (11.1V) LiPo battery, each motor can

produce up to approximately **1130 grams** of thrust. Therefore, the total available thrust from all four motors is approximately **4.52 kg**, yielding a thrust-to-weight ratio of $4.52/1.805 \approx 2.5$. This satisfies the performance margin and confirms that the chosen motor-propeller combination is adequate for the drone's operational requirements.

3.2.2 Motor, ESC & Propellor

Motor: DYS D2836-7 1120KV Brushless Motor

The DYS D2836-7 1120KV Brushless Motor is our go-to motor for this project because of the following leverages it offers:

• *KV Rating: 1120KV* - KV generally means RPM per volt. In layman terms, in one volt, how many rotations does it make per minute = KV. In this case, 1120KV is mid-range, which means good thrust at moderate RPMs, and it works decently with larger propellors (*9" - 11"*) which improves lift and efficiency, *especially* at low speeds. This is perfect for surveillance drones that require loitering and stability. A lower KV would force us to use bulky propellors, and a higher KV would drain the battery faster. 1120KV is a sweet spot between the two.

Figure 3.2: DYS D2836-7 1120kV BLDC

• *Power & Efficiency:* - With a 3S or 4S LiPo, this motor produces 800g to 1100g of thrust, depending on the propeller used. It can pull 20–25A max, so it's efficient for mid-weight UAVs (*in our case, it is around **1.5 2kg AUW** (All Up Weight.)*), so it's ideal for our choice.

Table 3.2: Motor Datasheet (DYS D2836-7 1120kV BLDC)

Parameter	Value
Motor KV (RPM/V)	1120
Motor Type	Brushless Motor
Compatible LiPO Batteries	2S to 4S
Weight (g)	70
Shaft Diameter (mm)	Φ4.0×49mm
Max. Power (W)	336
Maximum Thrust (gm)	1130
Compatible Propeller (inch)	9×5
Required ESC (A)	40

ESC: SpeedyBee BL32 50A 4-in-1 ESC

The SpeedyBee BL32 50A 4-in-1 ESC is a good choice for surveillance drones, and our use case for the following reasons:

Figure 3.3: SpeedyBee BL32 50A 4-in-1 ESC

- *High Current Rating (50A per motor):* Supports high-thrust motors and larger propellers. Useful for longer flight times, heavy payloads (cameras, sensors, gimbals), and stable cruising. Provides headroom — motors drawing 20–30A will run cooler and more reliably under a 50A ESC.

- *BLHeli_32 Firmware:* Smoother motor response, more efficient power delivery, and better low-end throttle control, which helps in steady hovering and slow maneuvering — perfect for surveillance.

- *4-in-1 Design:* Combines 4 ESCs into one board, and reduces weight and wiring complexity. Makes the stack cleaner, ideal for modular or compact drone frames. Fewer potential failure points (vs. 4 individual ESCs).

- *Telemetry & Monitoring:* Supports ESC telemetry (RPM, current, temperature) via BLHeli_32. This is important for diagnostics, health monitoring, and autonomous missions — ensuring no motor overheats or fails mid-flight.

- *Built for 3–6S LiPo:* Offers flexibility across drone designs. For surveillance, a 4S or 6S setup is common due to higher efficiency and flight duration. This ESC handles both without issue.

- *Built-in TVS Protection:* Has **Transient Voltage Suppression diodes** that protect against voltage spikes — vital for drone safety, especially in critical missions.

Table 3.3: ESC Datasheet (SpeedyBee BL32 50A 4-in-1 ESC)

Parameter	Value
Continuous Current (A)	50
PWM Frequency Range (KHz)	16 to 128
Input Power (W)	3-6S LiPo
Current Sensor Input	Support (Scale=490 Offset=0)
Mounting Hole Diameter (mm)	30.5 x 30.5mm(4mm hole diameter)
Length (mm)	45.6
Width (mm)	40
Height (mm)	8.8
Weight (g)	19.2g with heat sink

Propellor: HQProp Thin Electric Prop 9×5 (2CCW) Propeller

This propeller is perfect for our use case for the following reasons:

Figure 3.4: HQProp Thin Electric Prop 9×5 (2CCW) Propeller

- ***High Efficiency for Long Endurance Flights:*** It is Thin electric profile = low drag → reduces current draw. Designed for cruise efficiency over brute force thrust, it serves perfect for surveillance missions where hovering and slow, steady forward flight dominate.

- ***Optimized for Mid-Sized Motors (like D2836-7):*** The 9-inch diameter is a good disc area for smooth lift, and 5-inch pitch gives moderate speed per RPM (good forward motion without excess current). These features allows it to pair well with 1000–1200KV motors on 3S LiPo → ideal thrust-to-efficiency balance.

- ***Smooth Throttle Response:*** Thin blades create less turbulence and vibration. This is crucial for gimbal-mounted cameras or FPV systems, reducing jello and image blur.

- ***Expected Performance on 3S + DYS D2836-7:***

  1. Static Thrust $\qquad$ 850–1000g
  2. Current @ full throttle $\qquad$ 15–18A
  3. Thrust Efficiency $\qquad$ ≈ 60–65 g/W

Table 3.4: Propeller Datasheet (HQProp Thin Electric Prop 9×5 (2CCW) Propeller)

Parameter	Value
Material	Carbon Fiber Composite
Rotation Direction	CCW
Pitch(inch)	5
No. of Blades	2
Hub Diameter (mm)	18
Hub Thickness (mm)	7
Shaft Size (mm)	9.5/8/6
Adapter Rings (mm)	6/5/4/3
Weight (g)	9, (each)

3.2.3 Propulsion Powertrain Efficiency

The total powertrain involves all the individual components that draw power from the battery, this includes things like the flight controller and flight computer. Here we are interested only in the propulsion powertrain. The propulsion powertrain typically includes:

$$\text{Battery} \quad \rightarrow \quad \text{ESC} \quad \rightarrow \quad \text{Motors}$$

The battery and ESC are suppliers, they supply on demand, and since all 4 motors won't derive the same amount of current (and hence power) at the same point of time– the real-life parameters will vary in time. Here we assume that all motors demand the same power at all times.

To quantify the overall efficiency of the UAV's propulsion system, we analyze losses in each powertrain component. That is mathematically given by,

$$\eta_{total} = \eta_{battery} \times \eta_{esc} \times \eta_{motor}$$

Note: There are other components in the powertrain which we have not discussed here, and which we have discussed later in this report. Here we are only interested in Propulsion powertrain.

In order to calculate each of these components, we would need to calculate the power input and output at each stage. Since we don't currently have access to each component at the moment, we're going to use the parameters provided by the manufacturers for this calculation.

Battery Efficiency Derivation:

Given are the following from datasheets:

- Voltage (V):   11.1V

- Max Discharge Current: 208.0A (40C)

- Max Power Output ($P_{battery}$):   V x I = 11.1 x 208 = **2308.8 W**

This output power from the battery shall be used as input to the ESC. Now, to calculate the efficiency of battery, we can define it as,

$$\eta_{battery} = \frac{P_{out}}{P_{stored}}$$

But in-flight, it's more feasible to model this using internal resistance. So,

$$\text{Power lost in battery} = I^2 R_{int}$$

$$\eta_{battery} = \frac{VI - I^2 R_{int}}{VI} \;\; = \;\; 1 - \frac{IR_{int}}{V}$$

Typically, for our battery, the internal resistance is $R_{int} = 0.015\Omega$

$$\text{Power loss} = (208)^2 \times 0.015 = 648.96\,\text{W}$$

$$P_{out} = 11.1 \times 208 = 2308.8\,\text{W}$$

$$P_{stored} = 2308.8 + 648.96 = 2957.76\,\text{W}$$

$$\boldsymbol{\eta_{battery}} = \frac{2308.8}{2957.76} \;\; \approx \;\; 78.07\,\% \;\; = \mathbf{0.78}$$

ESC Efficiency Calculations:

The following data from the datasheets:

- Max Continuous Current: 50A (per channel)

- Voltage Range: 3–6S LiPo (up to 25.2V)

- Estimated Losses: 5–10% (heat dissipation)

Since this is a 4-in-1 ESC, it shares a single power input from the battery and distributes it internally to all 4 ESC channels. The output power is given by,

$$P_{out} = P_{in} - P_{loss}$$
$$\Rightarrow P_{out} = 2308.8 - \frac{5}{100} \times 2308.8$$
$$\therefore P_{out} \approx 2193.36\,W$$

$$\Rightarrow \boldsymbol{P_{in} = 2308.8W} \qquad \boldsymbol{P_{out} = 2193.36W}$$
$$\boldsymbol{\eta_{esc}} = \frac{P_{out}}{P_{in}} = \frac{2193.36}{2308.8} \quad \approx \quad \boldsymbol{0.95}$$

The total power output shared by all 4-channels of the ESC is **2193.36W**. A single channel is capable of supplying,

$$\mathrm{P_{in\_motor}} = \mathrm{P_{out\_ESC}} = \frac{2193.36}{4} = \boldsymbol{548.34}\text{ W}$$

Motor Efficiency Derivation:

The following data is given in the official datasheet:

- KV Rating: 1120 RPM/V

- Max Power: 336 W

- Max Current: 23.2 A

- Voltage Range: 2–4S LiPo (7.4–14.8 V)

- Internal Resistance: 0.070 Ω

- Propeller: 9×5

The algorithm to derive the motor losses goes as follows: the efficiency is given as,

$$\eta = \frac{\boldsymbol{P_{out}}}{\boldsymbol{P_{in}}}$$

Electrical input power: $\boldsymbol{P_{in} = V \times I}$

Mechanical output power: $\boldsymbol{P_{out} = T \times \omega}$

where **V** is voltage at which thrust is rated, **I** is current drawn at that voltage; **T** is torque generated by the motor (in newton-meters), and ω is angular velocity given by,

$$\omega = \frac{2\pi \times \mathrm{RPM}}{60}$$

The RPM without any load will be $1120 \times 11.1V = 12432.0\,rpm$. But when we attach the propellers, some load will be acting agaisnt them, causing the RPM to drop by an amount. Let us assume the new RPM under load is $\boldsymbol{RPM_{load} = 12000\,rpm}$, then the angular velocity is

$$\omega = \frac{2\pi \times 12000}{60} \approx 1256.63\,rad/s$$

The theoretical torque can be calculated from the formula

$$\tau = K_t \,.\, I$$

$$\text{where} \quad K_t = \frac{60}{2\pi \, K_v} \quad and \quad I \rightarrow \text{current in amps} \;=\; 23.2\text{A}$$

$$\text{now,} \qquad K_t = \frac{60}{2\pi \times 1120} \quad \approx \quad 0.00852$$

$$\therefore \tau = 0.00852 \times 23.2 \;=\; 0.19780\,\text{Nm}$$

$$\Rightarrow P_{out} \quad = \tau \times \omega = \quad \mathbf{248.57}\,\text{W}$$

Therefore, the motor efficiency is

$$\eta_{motor} = \frac{P_{out}}{P_{in}} = \frac{248.57}{336} = 0.73979 \quad \approx \quad \mathbf{0.74}$$

which is a pretty reasonable efficiency in real world BLDC motors. Finally, the total propulsion powertrain efficiency is given as,

$$\eta_{total} = \eta_{battery} \times \eta_{esc} \times \eta_{motor}$$
$$\Rightarrow \boldsymbol{\eta_{total}} = 0.78 \times 0.95 \times 0.74 \quad = \quad \mathbf{0.55}$$

The final propulsion powertrain efficiency sums upto around 55%, which is a reasonable value considering that some of the parameters we're assumed. Real world values will obviously vary from this.

3.3 Aircraft Sizing

Rotor Arm

Hub

Wheelbase

Propeller Clearance

Landing Gear

3.4 Aircraft Performance

3.4.1 Battery Selection and Endurance

Battery: Orange Pro-Range 11.1V 5200mAh (3S)

The Orange Pro-Range 11.1V 5200mAh battery is the best for our use case for the following reasons:

The 3S variant provides 11.1V, and has a **discharge-rate** of 40C. According to the official rated specifications, the maximum continuous discharge current is **208.0A** (*40C*). It also has a max. burst discharge of **416.0A** (*80C*). Let us assume that each motor draws 24A current at full-throttle, total current draw would be $24 \times 4 = 96A$ then

Figure 3.5: Orange 11.1V 5200mAh 3S

$$\text{Theoretical Flight Time (hrs)} = \frac{\text{Capacity (Ah)}}{\text{Current Draw (A)}} = \frac{5.2}{96} \approx 0.0542 hrs = 3.25 mins$$

But in real world applications, we dont use 100% of the battery, we use about 60%, so that would make the flight time around 5.2mins.

Table 3.5: Battery and Flight Datasheet Summary (Orange 11.1V 5200mAh 3S)

Parameter	Value
Voltage	11.1V (3S)
Capacity	5.2Ah
C-Rating (Continuous)	35C
Theoretical Max Discharge Current	$35 \times 5.2 = \mathbf{182A}$
Stated Max Discharge Current (datasheet)	156A
System Current Draw (4 motors @ 24A)	$4 \times 24 = \mathbf{96A}$
Flight Time @ Full Throttle (96A)	$\frac{5.2}{96} = \mathbf{3.25}$ minutes
Flight Time @ Moderate Throttle (60A)	$\frac{5.2}{60} = \mathbf{5.2}$ minutes
Energy Capacity	$11.1 \times 5.2 = \mathbf{57.72\,Wh}$

3.4.2   Total Power Budget Summary

This sub-section summarizes the total electrical power budget of the UAS, highlighting how power from the battery is allocated to propulsion and non-propulsion (avionics and payload) subsystems.

Table 3.6: Power Distribution Summary

Subsystem	Included Components	Power Demand (W)	% of Total Power
Propulsion	4 x Motors + ESC	1344 W	58.2%
Avionics	Flight Controller, GPS Module, Sensors (IMU, barometer)	–	
Communication	RC Receiver, Wifi Modules	–	
Cameras	–	–	
Onboard Computer	NVIDIA Jetson Orin Nano 8GB Module	–	

Propulsion Demand

Avionics Demand

Margins, Safety Factors

3.5 Material Selection

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Avionics Power Demand

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6.3   Autonomous Payload Drop Mechanism (Gripper)

Innovations and Future Scope

Bill of Materials

Table 8.1: Battery and Flight Datasheet Summary (Orange 11.1V 5200mAh 3S)

Component Name	Quantity	Unit Price INR
NVIDIA Jetson Orin Nano 8GB	1	36,499
Pixhawk 2.4.8 Flight Controller	1	11,179
Cameras	2	1,000
SpeedyBee BL32 50A 4-in-1 ESC	1	7139
DYS D2836-7 1120KV Brushless Motor	4	1,228
Orange Pro-Range 5200mah 11.1V	1	3,653
GPS – Neo M8N	1	1,500
SkyDroid Transmitter	1	12,075
Servo	1	500
Frame	1	3,000
9-inch Propellers	4	200
Total	–	83,257