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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AEROTHON 2025

SAEINDIA AEROSPACE

APPENDIX A

STATEMENT OF COMPLIANCE

8.1.1.1.1 Certification of Qualification

Team Name: UDSAV

University/Institute: Gati Shakti Vishwavidyalaya

Faculty Advisor: Dr. 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:

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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

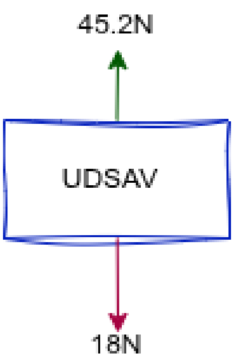

Figure 3.1: Thrust-to-Weight Diagram

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$\times$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.
- ***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.

Figure 3.2: DYS D2836-7 1120kV BLDC

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:

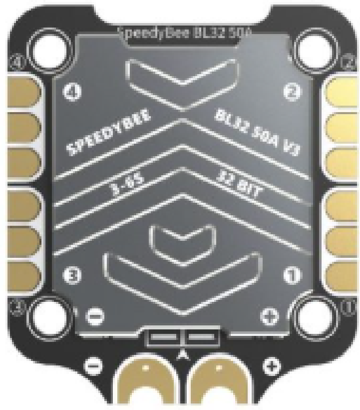

Figure 3.3: SpeedyBee BL32 50A 4-in-1 ESC

- ***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:

- ***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.

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

- ***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 850–1000g
  2. Current @ full throttle 15–18A
  3. Thrust Efficiency ≈ 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,

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

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 $\boldsymbol{R_{int} = 0.015\Omega}$

$$\text{Power loss} = (208)^2 \times 0.015 = 648.96\,\text{W}$$
$$P_{out} = 11.1 \times 208 = 2308.8\,\text{W}$$
$$P_{stored} = 2308.8 + 648.96 = 2957.76\,\text{W}$$

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

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,

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

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

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

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

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,

$$\eta = \frac{\boldsymbol{P_{out}}}{\boldsymbol{P_{in}}}$$
$$\text{Electrical input power:} \quad \boldsymbol{P_{in} = V \times I}$$
$$\text{Mechanical output power:} \quad \boldsymbol{P_{out} = T \times \omega}$$

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 $\boldsymbol{\omega}$ is angular velocity given by,

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

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

$$\boldsymbol{\tau = K_t \, . \, I}$$

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

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

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

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

Therefore, the motor efficiency is

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

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 $\mathbf{24 \times 4 = 96}\boldsymbol{A}$ then

Figure 3.5: Orange 11.1V 5200mAh 3S

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

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 Datasheet (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	1344 W	58.2%
Avionics	Flight Controller, GPS Module, Sensors (IMU, barometer)	6.9486 W	0.3009 %
Communication	RC Receiver, Wifi Modules	20.41 W	0.884 %
Payload	2 x Cameras	3.879 W	0.168 %
Onboard Computer	NVIDIA Jetson Orin Nano 8GB Module	6.997 W	0.303 %

Propulsion Demand

Based on the datasheet specification and text results, the propulsion subsystems (***4xMotors***) demands **1344W** during peak operation. This forms the largest share of the total Power requirement ($\sim$ 58.2 %).

Avionics Demand

The avionics system forms the central nervous system of any unmanned aerial vehicle (UAV), including those designed for **Aerothon-class missions**. Its architecture and power requirements play a decisive role in shaping the overall energy distribution and electrical resilience of the aircraft. The avionics suite typically comprises a flight controller (e.g., Pixhawk), GPS module, telemetry and communication transceivers, RC receiver, and sensor systems such as IMUs and barometers.

In advanced UAV configurations—such as ours—it is further augmented by an onboard companion computer, namely the NVIDIA Jetson Orin Nano 8GB, which performs real-time perception and decision-making tasks.

Based on our subsystem-level analysis, the avionics block—comprising flight control, communication, and onboard computing—demands a cumulative peak power of approximately **34.36 W**. This includes:

- **6.948 W** for the flight controller and embedded sensor suite
- **20.41 W** for communication subsystems including RC receivers and WiFi modules,
- **6.997 W** for the Jetson Orin Nano, which manages AI workloads and perception.

While this represents only **1.49 %** of the total system power draw, the avionics demand is non-negotiable and continuous, requiring high uptime and precision. Power is supplied via a regulated DC bus derived from the main propulsion battery, with dedicated buck converters providing clean and stable 5V and 3.3V rails to sensitive electronics.

Margins, Safety Factors

Power Budget Margin:

1. **Purpose:** To ensure that the chosen power source (battery) and propulsion system can consistently provide sufficient power, even under demanding conditions or if components don't perform exactly to spec.
2. **Typical Range:** 15% - 30% of the calculated total power demand.
3. **Application:** After calculating the power required for propulsion (hover, cruise, max thrust) and avionics, an additional percentage is added.

   Total Required Power = (Propulsion Power + Avionics Power) * (1 + Power Margin)

4. **Considerations:**
   - Battery degradation over time.
   - Variation in motor/propeller efficiency.
   - Ambient temperature effects on battery performance.
   - Increased power draw due to wind or aggressive maneuvers.

Weight/Payload Margin:

1. **Purpose:** To allow for small increases in component weight during design evolution, manufacturing variations, or for potential future upgrades/additional payloads.
2. **Typical Range:** 10% - 20% of the estimated total weight (Empty Weight + Max Payload).
3. **Application:** When defining the Maximum Take-Off Weight (MTOW), a buffer is included. This also impacts thrust-to-weight ratio calculations.

   Max All-Up Weight (MAUW) = (Estimated Empty Weight + Max Payload) * (1 + Weight Margin)

4. **Considerations:**
    - Small design changes or additions.
    - Manufacturing tolerances.
    - Unforeseen weight of cabling, fasteners, etc.

Battery-Capacity/Flight-Time Margin:

1. **Purpose:** To ensure sufficient energy is available for the planned mission duration, plus a reserve for unexpected events (e.g., strong headwind, holding pattern, emergency landing).
2. **Typical Range:** 15% - 25% of the total mission energy requirement.
3. **Application:** After calculating the energy needed for the mission profile, additional capacity is added. Also, a "return to home" or "emergency landing" battery percentage is typically set (e.g., 20-30% remaining).

    Total Battery Capacity Needed = (Mission Energy Requirement / Battery Discharge Efficiency) * (1

4. **Considerations:**
    - Battery performance degradation over cycles and temperature.
    - Unexpected mission deviations.
    - Wind conditions requiring higher power.
    - Maintaining a safe reserve for landing.

Structural/Safety Margin:

1. **Purpose:** To ensure that the drone's airframe and structural components can withstand expected and unexpected loads without failure.
2. **Ultimate Factor of Safety (FoS):** 1.5 - 2.0 (or higher for critical components). This is the ratio of ultimate load capacity to the maximum expected operating load.
3. **Yield Factor of Safety:** 1.1 - 1.25. This is the ratio of yield strength to the maximum expected operating load, ensuring no permanent deformation.
4. **Application:** Applied to material strength calculations for frame arms, motor mounts, landing gear, etc.

    Required Strength = Maximum Expected Load * Factor of Safety

5. **Considerations:**
    - Dynamic loads during flight (acceleration, turns).
    - Impact loads during hard landings or minor crashes.
    - Vibration fatigue.
    - Material imperfections and manufacturing variability.

3.5 Material Selection

3.5.1 Structural Frame, Airframe Components

3.6 Avionics Subsystems Selection

3.6.1 Detailed Component Breakdown

Flight Controller (Pixhawk 2.4.8)

Pixhawk is widely egarded as one of the best flight controllers for drone and autonomous aircraft projects — especially in academic and research-grade prototypes — for several compelling reasons:

Figure 3.6: Pixhawk 2.4.8

- ***Open-Source and Flexible:*** It is built on open hardware and supported by powerful open-source firmware like PX4 or ArduPilot. This enables deep customization, ideal for research and control system testing. And for this reason also, we have **ample documentation backed by a strong collaborative community, forums, and tutorials**.
- ***Rich I/O capabilities:*** Multiple UART, I2C, CAN, and PWM ports for connecting sensors (GPS, IMU, barometer, etc.) and actuators (ESCs, servos). Ideal for integration with multiple onboard systems including companion computers (e.g., Jetson Nano).
- ***Compatible with autonomous and GPS-guided missions:*** Supports autonomous navigation, geofencing, waypoints, and RTL (Return to Launch).
- ***Built-in failsafes and safety features:*** Battery failsafes, signal loss handling, and software watchdogs protect the aircraft during unexpected conditions.
- ***Excellent simulation support:*** Compatible with **HITL (Hardware-in-the-loop)** and **SITL (Software-in-the-loop)** for control testing and simulation.

Flight Computer (NVIDIA Jetson Orin Nano 8GB)

The NVIDIA Jetson Orin Nano 8GB is a powerful, compact AI computing module designed for edge AI applications that demand both high performance and energy efficiency. In the context of our Aerothon UAV project, the Orin Nano plays a pivotal role in enabling advanced onboard computation, particularly for tasks such as **real-time image processing, autonomous navigation, and object detection.**

Table 3.7: Flight Controller Datasheet (Pixhawk 2.4.8)

Parameter	Value
Input Voltage (V)	7V
Firmware	Mission Planner
Sensor	3-Axis Gyrometer, Accelerometer, High-performance Barometer, Magnetometer
Processor	32bit STM32F427 Cortex M4 core with FPU, The 32-bit STM32F103 failsafe Co-processor
Micro SD Card Slot (Y/N)	Yes
Dimensions (L x W x H) mm	82 x 50 x 16
Weight (g)	40

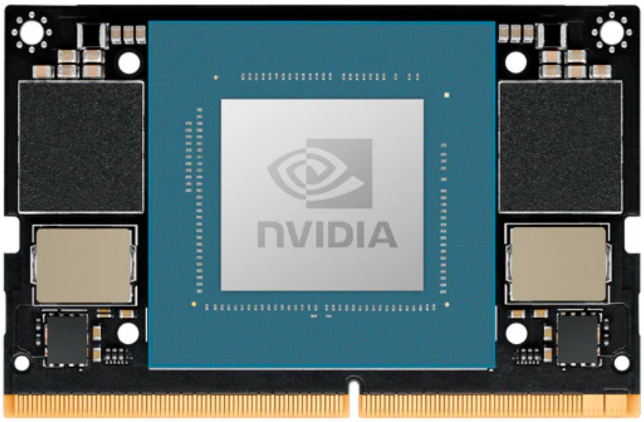

Figure 3.7: NVIDIA Jetson Orin Nano 8GB Module

We selected this module not only for its impressive up to **40 TOPS** of AI performance but also for its **low power footprint**, which makes it ideal for flight-based applications where every gram and watt matter. The 8GB RAM ensures sufficient memory for running heavy models, such as convolutional neural networks for visual recognition or SLAM algorithms for path planning.

The Jetson Orin Nano interfaces seamlessly with the Pixhawk flight controller via UART or serial USB connections, enabling a tight coupling between autonomous decision-making and low-level control. For example, live video feed from an **ESP32-CAM** or other camera modules is processed onboard the Jetson, where the output — such as target coordinates or navigation commands — is relayed to the Pixhawk for actuation.

This configuration allows the aircraft to function **autonomously even without constant ground station communication**, which is critical in GPS-denied or communication-constrained environments. By offloading high-level intelligence to the Jetson module, we achieve a modular and scalable architecture that separates perception and decision-making from flight stabilization, thereby improving system robustness and flexibility.

In essence, the NVIDIA Jetson Orin Nano 8GB empowers our drone with a true edge-AI brain — transforming it from a remotely controlled vehicle into a **fully autonomous aerial system** capable of intelligent flight and mission execution.

Camera

Transmitter: (SKYDROID T10 2.4Ghz 10CH)

Reasons why this transmitter is good for our mission:

- ***10-Channel Support:*** Enables simultaneous control of multiple subsystems—throttle, yaw, pitch, roll, camera gimbal, payload, etc.—with high precision.
- ***Long-Range Communication (upto 10-20 kms):*** Essential for long-distance BVLOS (Beyond Visual Line of Sight) flights, ideal for mapping, surveying, or package delivery missions.
- ***Low Latency, High Reliability:*** Ensures stable control inputs with low delay (¡200 ms), which is critical for real-time maneuvering and emergency responses.
- ***Telemetry Integration:*** Supports two-way telemetry for critical in-flight data monitoring such as battery voltage, GPS, altitude, and more.
- ***Open Protocol Compatibility:*** Works seamlessly with systems like ArduPilot and PX4, making it a perfect match for autopilots like Pixhawk.

Figure 3.8: Skydriod T10 2.4Ghz

Table 3.8: Transmitter Datasheet (Skydroid T10 2.4Ghz)

Parameter	**Value**
Frequency (GHz):	2.4
Operating Voltage (V):	4.2V
Working Current (mA)	100mA
Dimensions (L x W x H) mm	150*130*20
Weight (g):	525g

The T10-R10 combo is designed for mission-critical UAV applications. They reduce system complexity by combining control, video, and telemetry into a single ground control unit. Ideal for mapping, surveillance, agricultural spraying, or delivery drones—as in Aerothon. Seamlessly integrates with Pixhawk flight controllers, NVIDIA Jetson modules, and other onboard avionics.

Receiver: Skydriod R10

- ***10 PWM Channels or SBUS/PPM Support:*** Can directly interface with flight controllers (like Pixhawk) and handle multiple channels via a single signal wire (SBUS).
- ***High-Speed, Low-Latency Link:*** Matches the T10's low-latency protocol for precise motor response and stability.
- ***Secure Signal Handling:*** Supports frequency-hopping and error correction to minimize interference and signal loss, even in high-noise RF environments.
- ***Long-Range Capability:*** Complements the T10's range, enabling safe long-range flight and robust signal quality even at maximum distance.

- ***Powerful Telemetry Interface:*** Allows downlink of data to the transmitter (e.g., battery status, GPS info), helping pilots make informed decisions mid-flight.

3.6.2 Avionics Powertrain Efficiency

3.7 Autonomous Navigation System

3.7.1 Hardware Setup

3.7.2 Software Architechture

3.8 C.G. Calculation & Stability Analysis

3.8.1 Lift, Drag and Stability Considerations

3.8.2 Center of Gravity Position & Trim

Computational Analysis

4.1 CFD / FEM / MATLAB Simulations

4.2 CAD Model and Performance Validation

Safety & SORA Assessment

5.1 Risk Analysis and Mitigation Strategies

Methodology for Autonomous Operations

6.1 Flight Control Algorithm

6.2 Object Detection & Counting

6.3 Autonomous Payload Drop Mechanism (Gripper)

Innovations and Future Scope

Bill of Materials

Table 8.1: Bill of Materials

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 /-**