Mid-Semester Report

IC202P - AUTONOMOUS DRONE BASED SURVEILLANCE SYSTEM FOR DISASTER MANAGEMENT

Report

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1. INTRODUCTION

1.1 Problem Statement and Motivation

The initial hours after a natural disaster are the most important for locating and rescuing the survivors. However, these environments can't be accessed easily. An example of such a situation are the 2023 Sikkim floods, where washed out roads and tough terrain made it nearly impossible for the rescue teams to fully understand the scope of the damage and locate isolated survivors quickly, therefore leading to loss of many savable lives.

In such scenarios, the rescue teams face immediate and life threatening risks as they have to navigate through unstable structures with potential landslides with incomplete information of what lies ahead. Covering vast, difficult areas on foot is slow and also exposes these teams to unnecessary danger.

This project addresses these challenges and is motivated by the critical need for a rapidly deployable, low-cost autonomous aerial surveillance system. While sophisticated surveillance drones exist, their high cost makes them not feasible for widespread use. Our primary motivation is to come up with an effective solution with a budget of approximately 50,000, making the solution feasible and low cost.

1.2 Project Objectives and Scope

The main objective of this project is to create an autonomous drone that can properly survey a designated disaster area, identify potential signs of human life, and revert that information back to a ground control station in real-time so that the concerned teams can dispatch the required help to the GPS coordinates provided.

The primary objectives of this project are:

1. To design a stable and robust platform (the chassis or basis of our drone) capable of carrying the required payload of sensors and the onboard computing unit like Jetson Nano.
2. To develop and integrate an onboard AI computer vision system, powered by a Jetson Nano, that is capable of real-time detection and geotagging of humans from the drone's video feed.

This is the most important task of this project.

3. To establish a reliable communication link between the drone and a ground control station for smooth transmission of critical data, including live video telemetry and survivor detection alerts and respective GPS coordinates.

2. CHALLENGES FACED

Developing an autonomous drone based surveillance system with a budget of 50k poses a lot of challenges and limitations.

2.1 Hardware and Budget Constraints

Our budget of approx. 50k is the main constraint that directly impacts every hardware decision.

- Limited Payload Capacity: The drone frame and motor configuration must be carefully selected to support the combined weight of the components like Jetson Nano, sensors (camera, thermal, GPS etc.) and battery.
- Component Selection: The budget limitation forces us to use less efficient components than what are commercially available in high-end systems. We must carefully choose parts that offer the best possible performance for their cost, avoiding low-quality clones that could negatively affect the drone's reliability.
- Power Limitations: Supplying adequate and stable power to both the high demand Jetson Nano and the flight control systems (motors, flight controller) from a single battery source is another challenge. Every component adds to the power draw from the battery, which in turn reduces the overall flight time of the drone, which is also a major factor we need to focus on.

2.2 Software and Algorithmic Hurdles

The core of this project lies in its onboard intelligence, which presents significant software challenges:

- Accuracy vs. FPS Trade-off: This is a major challenge for us. The algorithms which are more accurate are unable to run smooth on systems like Jetson Nano 4GB kit, and therefore they provide less FPS. The algorithms which provide more FPS and are less heavy are not that accurate. So we need to come up best possible algorithm that is accurate and also provides a decent FPS.
- Lack of Specialized Training Data: The effectiveness of our detection model is entirely dependent on the data it is trained on. There is a severe lack of publicly available, large

datasets depicting humans in disaster scenarios as viewed from an aerial perspective. To ensure that our model is reliable and can recognize individuals who may be partially covered or stuck in unusual positions, we will need to undertake the significant task of creating our own training dataset.

2.3 System Integration

Another challenge lies in the smooth communication between the hardware and software components. The flight control system managed by the Pixhawk and the AI processing system (human detection) managed by the Jetson Nano must communicate effectively.

3. SYSTEM DESIGN & ARCHITECTURE

3.1 High-Level System Architecture

The system is sch designed that there is a distributed on board computing system that separates real-time flight control from AI-based data processing. The pixhawk flight controller ensures stable flight and executes navigation comands, while the jetson processes sensor data to find survivors.

Key Data and Control Flows:

- Flight Control Loop: The Ground Control Station or GCS sends mission objectives to pixhawk. Pixhawk then uses the data from the GPS module to control the motors and navigate the drone to the desired location, while side by side sending flight telemetry back to the GCS.
- Onboard Processing Loop: The camera sends its video feed to jetson, which then runs the AI Human Detection Model. Upon a detection, it requests the current GPS coordinates from pixhawk.
- Data Downlink: The Jetson Nano transmits a detection alert, containing an image snippet and the precise GPS tag i.e. geotagging, to the GCS for review by the operator at the ground station.

3.2 Hardware Design and Components

The hardware was selected keeping in mind our budget of 50k, performance, cost-effectiveness and availability.

3.2.1 Frame

We received a F450 Quadcopter Frame from previous year's project and we will be using this as our base for our project.

3.2.2 Flight Control and Navigation System

- Flight Controller : We have used Pixhawk 2.4.8 which acts as the main flight controller. Pixhawk is known for its reliability, provides extensive features for autonomous missions, and broad community support.
- GPS Module: Holybro M9N GPS is the model that we have used for grabbing co-ordinates becuase of its accuracy and cost. This module provides precise and reliable satellite data, which is critical for accurate waypoint navigation and for geotagging detections made by the AI system.

3.2.3 Propulsion System

- Motors and electronic speed conotrolers: The propulsion is provided by 1000kV Brushless DC Motors paired with 30A Electronic Speed Controllers. This combination, standard for an F450 frame, offer a good balance of thrust and efficiency for a 20-25 minute target flight time.
- Propellers: 10-inch propellers are used to provide the necessary lift for the drone's estimated take-off weight.

3.2.4 AI and Vision System

- Onboard Computer: An NVIDIA Jetson Nano 4GB Developer Kit functions as the AI brain. Its integrated GPU is essential for accelerating the deep learning model, allowing for real-time video analysis directly on the drone.
- Camera: A raspbery pi camera module V2 is used as the main visual sensor. This camera is chosen for its direct compatibility with the Jetson Nano's CSI interface, its low latency, and its sufficient resolution for the human detection task.

3.2.5 Power System

- Battery: We have used a Turnigy 4S 5000mAh Lithium Polymer (LiPo) Battery. This battery provides the necessary voltage and capacity to power the motors and all onboard electronics required for the project objectives.
- Power Distribution: A power module included with the Pixhawk distributes the power to the flight controller and electronic speed controlers. A separate 5V Buck Converter is used to step down the battery voltage to safely power the Jetson Nano without damaging it.

3.2.6 Communication and Control

- Remote Control: A Flysky FS-i6S 10-channel transmitter and receiver pair is used for manual flight control and for switching between autonomous and manual flight modes.

- Telemetry: A 915MHz Telemetry Radio module provides a long range communication link between the drones Pixhawk and the Ground Control Station, allowing for real-time monitoring of flight data and mission parameters.

3.3 Software Architecture

The software is logically divided between the two main onboard processors.

- Pixhawk Software: It is responsible for all real-time flight stabilization, sensor fusion (IMU, GPS), and executing the pre-programmed GPS waypoint navigation mission loaded from the GCS.
- Jetson Nano Software: The Jetson runs a custom software stack written in Python. This stack utilizes the OpenCV library for camera interfacing and a deep learning framework to run the YOLOv8n object detection model.
- Ground Control Station (GCS) Software: A standard open-source GCS application like Mission Planner or QGroundControl will be used for mission planning, live telemetry monitoring, and recieving the custom detection alerts sent from the Jetson Nano.

4. PROPOSED SOLUTIONS

This chapter lists the various technologies that could be applied to disaster management. It details the ten most viable solutions that were considered.

4.1 List of Potential Solutions

1. AI-Powered ”Signs of Life” Detection System
   Description: An AI/ML model deployed on a on board computer like NVIDIA Jetson to analyze the drone’s camera feed in real-time. The model detects human figures or movement, automatically flagging their GPS coordinates for rescuers.
   Analysis: This solution’s primary advantage is its direct approach to locating survivors, providing actionable GPS data. It offers a technical challenge across hardware and software. However, its feasibility is dependent on the AI model’s accuracy, and it requires a powerful onboard computer, creating a high risk of false positives and negatives.
2. Unified Real-Time Disaster Map Platform
   Description: A cloud-based software platform that takes live video feed from the drone and stitches it into a high-resolution map accessible to response teams.
   Analysis: This solution provides immense situational awareness for command and control and is highly scalable. Its main drawback is that it is primarily a cloud software project with less focus on mechatronics. It also requires a stable connection and does not actively locate the survivors itself.
3. Automated Damage Assessment & Prioritization
   Description: This solution uses computer vision to analyze drone’s feed and classify building damage levels, therefore generating a report to help the responders prioritize resource allocation.
   Analysis: This strategic value in organizing a large scale rescue effort is a major advantage, and the computer vision task is relatively straightforward. Although, the solution is a bit less focused on the immediate search and rescue phase and only indirectly helps the survivors by improving resource management.
4. Flying Cell Tower Drone for Comms Relay
   Description: A tethered drone with a cellular or Wi-Fi relay that provides a communication

bubble for first responders and survivors.

Analysis: This solution addresses the critical and common problem of communication failure in disaster zones. The main limitations are its severely restricted mobility due to the tether and the fact that the drone becomes a single point of failure for the entire network.

5. Modular Multi-Sensor Payload System

   Description: A drone with a versatile payload bay and a standardized connector, allowing for rapid swapping of sensor modules, e.g., RGB camera, thermal imager.

   Analysis: The main benefit of this solution is a versatile and future proof platform that can be reconfigured for multiple roles. The downside is that the project's focus shifts to the mechanical and electronic design of the payload bay itself, rather than a specific application, increasing overall complexity and cost.

6. Augmented Reality (AR) Overlay for First Responders

   Description: A system that streams the drone's video to a tablet, overlaying critical data like street names, building numbers, and hazard locations.

   Analysis: This is a highly innovative solution that would massively improve ground team safety and awareness. The primary challenges are the high software development complexity and the reliance on specialized, expensive AR hardware for ground teams and a very stable, low-latency video link.

7. Autonomous Interior Mapping Drone (SLAM)

   Description: A small, ducted fan drone using LiDAR (or stereo cameras) and SLAM algorithms to navigate through and create 3D maps of the damaged building's interior without GPS which is crucial for rescuing humans stuck inside buildings.

   Analysis: This idea addresses the critical challenge of searching inside unsafe structures. However, it was declared too high-risk due to the extreme technical complexity of SLAM algorithms, the need for expensive sensors like LiDAR, and the high probability of the drone being lost during operation.

8. AI-Powered Predictive Disaster Modeling

   Description: The drone collects real-time data and feeds it to an AI model on a ground server, which then predicts the disaster's progression, e.g., fire spread.

   Analysis: The potential for proactive resource allocation is a significant advantage. The concept was sidelined as it is more of a data science and simulation project, requiring immense computational power on the ground, and the accuracy of such predictions can be unreliable.

9. Drone-Based Ad-Hoc Mesh Network

   Description: A system where two or more drones communicate with each other to form a resilient mesh network, extending communication and operational range.

   Analysis: This approach effectively solves the range and line-of-sight limitations of standard radio links. The main drawbacks are the high cost and logistical overhead of purchasing, deploying, and managing a fleet of multiple drones.

10. Chemical/Gas Detection "Sniffer" Drone
    Description: A drone carrying specialized sensors to detect dangerous gases after industrial accidents, creating a real-time gas map for rescue team's safety.
    Analysis: This system provides critical safety information that is otherwise very difficult to acquire. Its main disadvantage is its limited utility, it is only useful in specific disaster scenarios involving chemical leaks and is less universally applicable than a visual surveillance system therefore making it less general and a bit case specific.

5. STATISTICAL ANALYSIS OF SOLUTIONS

5.1 Evaluation Methodology

To select from a list of potential solutions, we perform a systematic and objective evaluation based on certain decided parameters. Each solution is rated on a scale of 1 to 10 for ten different criterias, which help in reflecting the project's technical, financial, and practical constraints.

5.2 Description of Evaluation Criteria

The following ten criteria were used to score each proposed solution:

1. Cost of the Idea: A measure of the estimated cost of the final project. A higher score i.e. closer to 10 indicates a more budget-friendly cost solution, therefore aligning with our project's budget constraints.
2. Availability of Parts: This assesses the ease of availability of the necessary components, especially within the domestic market. A higher score indicates that parts are readily available from trusted vendors.
3. Ease of Manufacturing or Assembly: This criteria evaluates the complexity of constructing and assembling the system. A higher score indicates that the solution is simpler, more straightforward assembly process.
4. Ergonomics / Aesthetics: This considers the usability and physical design of the final product. A higher score reflects a well-designed, user-friendly, and field-ready system. Basically this refers to how simple and good looking the final product is.
5. Integration of Power Source: This evaluates the complexity of designing and implementing the power delivery system for all onboard components. A higher score indicates a more straightforward power integration.
6. Integration of Electronics: This assesses the difficulty of interfacing all electronic components (sensors, controllers, computers). A higher score is given for solutions with simpler electronic integration.
7. Timebound Manufacturing Feasibility: This evaluates the likelihood of successfully building a functional prototype within the academic semester's timeline. A higher score indicates

greater confidence in timely completion.

8. Maintenance or Servicing Cost: This considers the long-term cost and effort required to maintain the system. A higher score is awarded to more robust solutions with lower expected maintenance needs.
9. Overall Feel/Confidence in the Solution: A subjective but important measure of the team's collective confidence in their ability to successfully execute the idea and its potential for real-world impact.
10. Fulfilment of Purpose: This is a critical measure of how effectively the solution addresses the core problem statement of aiding disaster management. A higher score means the solution has a more direct and significant impact.

Table 5.1: Solution scoring across the ten criteria.

Sol. No.	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	Total
1	7	8	7	7	8	7	8	8	8	9	77
2	8	9	8	8	9	8	9	9	9	8	85
3	7	8	8	7	8	8	8	8	8	9	79
4	4	6	5	5	4	5	5	5	7	9	55
5	6	7	7	8	8	7	7	7	7	8	72
6	6	7	6	8	7	6	6	7	7	8	68
7	3	4	3	6	6	3	3	4	5	10	47
8	6	8	7	7	8	7	7	8	7	8	73
9	5	6	5	6	7	5	5	6	6	8	59
10	5	5	6	6	7	6	6	6	6	7	60

6. BENCHMARKING

To position our project within the current technological landscape, a thorough market survey was conducted on existing drones used for disaster management and adjacent industries. The analysis focused on commercially available solutions to identify their capabilities, limitations, and price points. This helps establish a benchmark against which our proposed system's performance and cost-effectiveness can be measured.

6.1 Market Survey of Disaster Management Drones

The survey of drones specifically marketed for disaster response was segmented by DGCA weight class.

6.1.1 Nano Drones (¡ 250g)

In the nano category, the DJI Mini 4 Pro stands out as a market leader. Priced around 1 Lakh, it offers a 34-minute flight time, a high-quality 4K camera with omnidirectional obstacle avoidance, and a 20 km transmission range. However, its primary limitation for our application is its complete lack of payload capacity. It is a closed ecosystem designed purely for aerial photography and cannot be integrated with custom hardware like a Jetson Nano or additional sensors, making it unsuitable for our "signs of life" detection mission.

6.1.2 Micro Drones (250g - 2kg)

The micro category features tactical drones like the ideaForge SWITCH UAV. This military-grade system, with a high price point (over 10 Lakhs), boasts a 2-hour flight time and advanced features like thermal imaging and a 15 km range. While highly capable, its cost is far beyond our project's budget, and its feature set is designed for military reconnaissance rather than the specific needs of civilian disaster response.

6.1.3 Small Drones (2kg - 25kg)

This category represents the high-end professional standard drones. The DJI Matrice 350 RTK (approx. 12 Lakhs) and the Quantum-Systems Trinity F90+ (approx. 25 Lakhs) are major examples. These offer larger flight times (55-90 minutes) and significantly higher payload capacities (2.7-7 kg), allowing them to carry multiple sensors, including thermal imagers, LiDAR, and high zoom cameras. However, their extremely high cost makes them inaccessible for widespread deployment by many response organizations.

6.2 Survey of Adjacent Markets

To gain a broader perspective, drones from the agricultural and defense sectors were also analysed.

6.2.1 Agricultural Drones

Agricultural drones, such as the DJI Agras T30 or the Garuda Kisan Drone, are engineered for a fundamentally different purpose. Their design is optimized for carrying heavy liquid payloads (10L to 30L) for spraying crops. While they possess robust GPS navigation, their flight characteristics are focused on stable, low-altitude grid patterns, not the dynamic search patterns required for surveillance. Their sensor suites are specialized for crop monitoring, not human detection, making them unsuitable for our application despite their impressive payload capacities.

6.2.2 Defense Drones

Defense drones like the DRDO Netra V4+ or the imported IAI Heron are the pinnacle of surveillance technology. They are built with military grade components and feature encrypted communication links (necessary for defense drones), and carry sophisticated sensors for long-range communication. While their capabilities are extensive, they come with very high price tags and are subject to strict regulatory and export controls, therefore placing them entirely outside the scope of civilian-led disaster management.

6.3 Conclusion of Benchmarking

The market survey reveals a distinct and critical gap. The drone market is polarized: on one end are affordable, consumer-grade nano drones that lack the payload capacity and customizability for AI hardware. On the other end are highly capable but prohibitively expensive professional systems for disaster, agriculture, and defense. Therefore there is a clear need for a low-cost, adaptable, and powerful drone system specifically for autonomous search and rescue. Our project, with a target budget of around 50,000, aims to fulfil this need. By using open-source hardware like Pixhawk and software, we can develop a tool that provides critical, AI-driven capabilities currently only available in drones costing over 20 times as much.

7. CAD MODEL

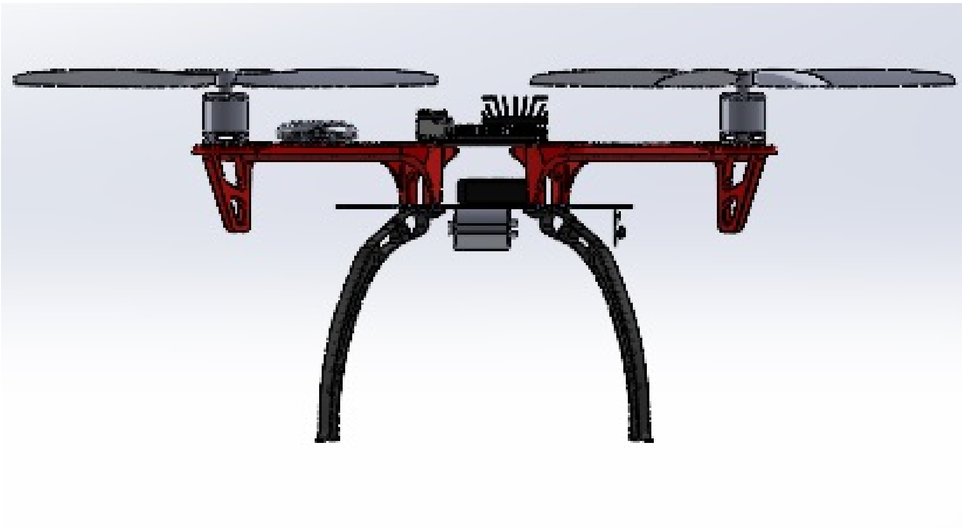

Figure 7.1: Front view of the drone assembly.

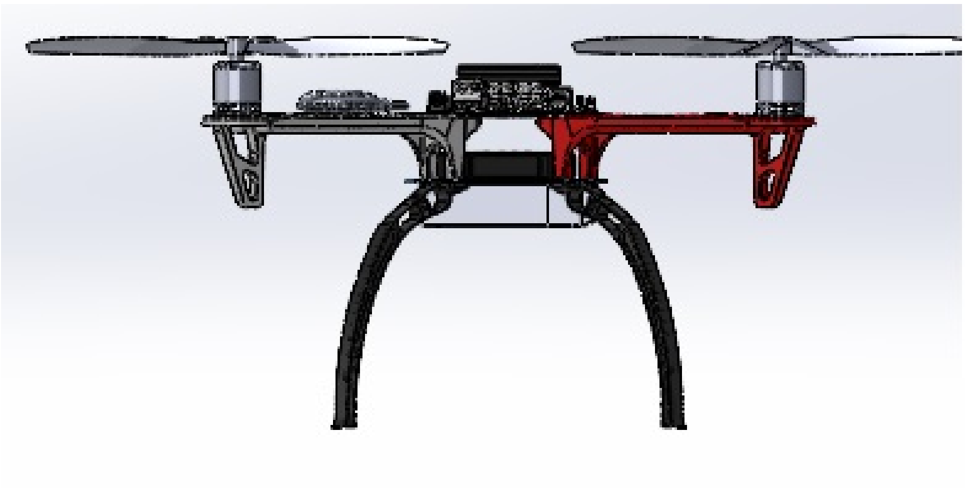

Figure 7.2: Side view of the drone assembly.

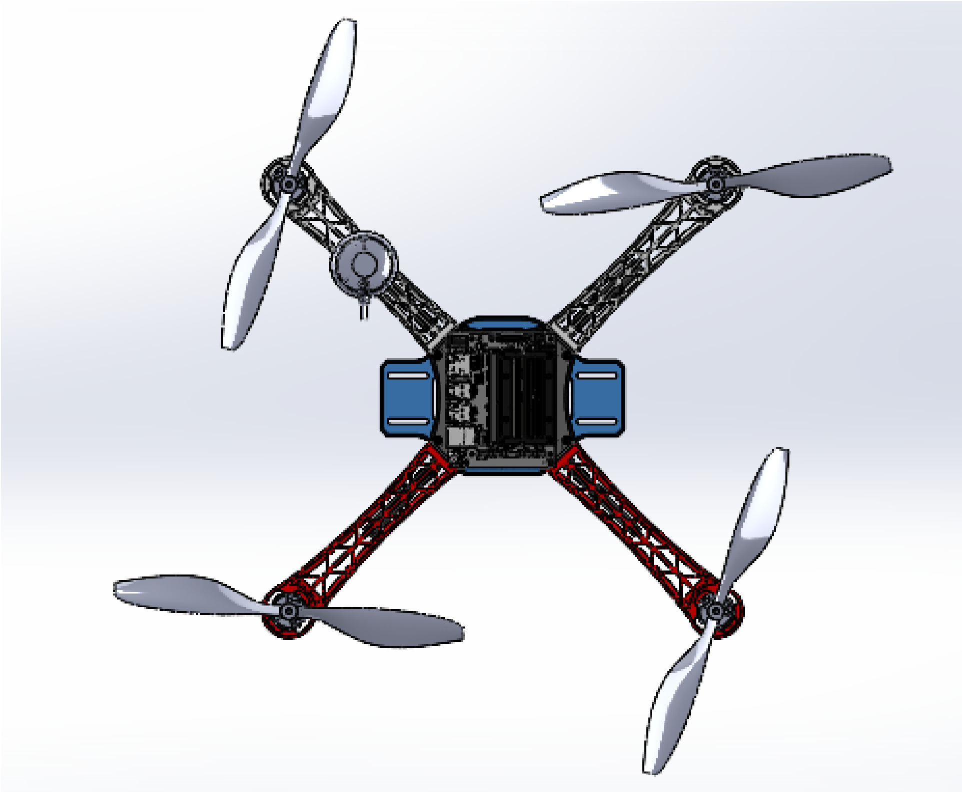

Figure 7.3: Top view of the drone assembly.

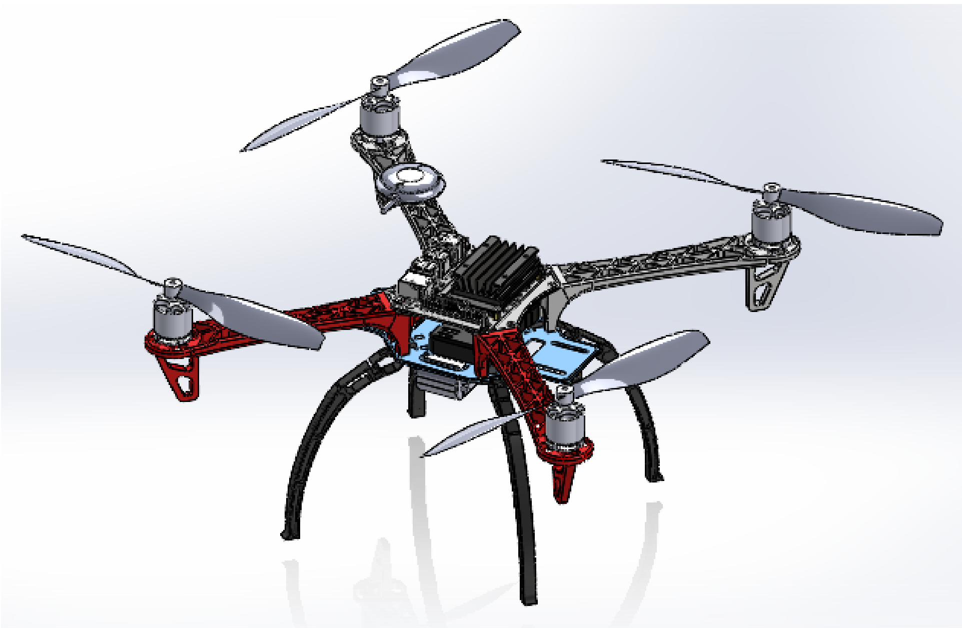

Figure 7.4: Trimetric view of the drone assembly.

8. BUDGET

Table 8.1: Estimated bill of materials.

Component	Model/Description	Price (INR)
Flight Controller	Pixhawk 2.4.8 (with power module)	8,776
AI Computer	NVIDIA Jetson Nano 4GB Dev Kit	18,807
GPS Module	Holybro M9N GPS (Multi-GNSS + Compass)	8,317
Camera	Raspberry Pi Camera Module V2 (IMX219)	1,500
Battery	Turnigy 4S 5000mAh 35C XT60 (14.8V)	4,200
Battery Charger	iMAX B6 AC/DC Balance Charger	1,700
Telemetry Radio	915MHz Telemetry Module	4,400
Buck Converter	5V 3A Step-down for Jetson	600
SD Card	High-speed 64GB UHS-I for Jetson	550
Cables & Connectors	CSI cable, power cables, misc	1,500
Transmitter	Flysky FS-i6S 2.4GHz 10CH AFHDS 2A RC Transmitter With FS-iA10B 10CH Receiver	5,500
	Total	57,043

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