

TDP: Skyrats (Brazil), Outdoors Category

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ABSTRACT

Condor Wide is a quadcopter architecture unmanned aerial vehicle (UAV), developed for applications that demand energetic efficiency and adequate autonomy for both short and long-term missions duration, with a frame design biased towards mapping and package delivery tasks. Its electrical system was designed focusing on energy efficiency - appropriate for monitoring, mapping operations, and other aerial outdoor applications. The sizing methodology, based on simulation software, and the integrated control and processing systems are key to its reliable performance.

1 INTRODUCTION

This project, developed by the Skyrats team, is focused on the improvements and applications for the Condor Wide MAV, an unmanned aerial vehicle engaged in outdoor operations. The use of MAVs in aerial mapping for precision agriculture, environment monitoring, and infrastructure inspection areas, have been proved as a successful case, and now its operations are being expanded for new contexts, such as fire extinguish, whether in rural or urban areas. As the imminent use of drones in such extreme situations grows, it becomes essential the improvements of MAVs in bigger flight autonomy, higher stability and wider territorial coverage capacity. In this context, Condor Wide was designed to fulfill the demand for large-scale mappings and higher precision detection and usage in various situations, offering superior performance in flight time and operational efficiency. The present document describes the platform's goals, development, and application, highlighting its strategic importance in the Skyrats team's advance of autonomous aerial solutions.

2 OBJECTIVES

Considering our previous experience in competitions, especially IMAV 2023 and 2024, the Skyrats team was used to use the Condor. A UAV frame designed for speed and energy efficiency - considering it's unusual shape, quite different than a typical frame X type.

Although, in the same previous competitions the team had the opportunity to observe that the frame's shape was not that

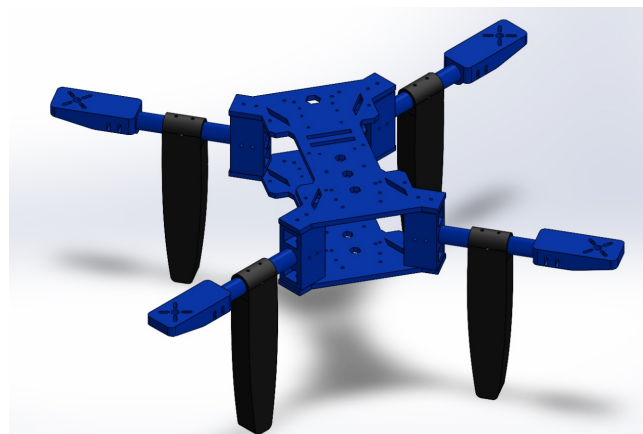


Figure 1: Condor Frame - 2024 version (CAD)

relevant for energy efficiency as the propellers and, at the same time, it could make difficult to control the UAV, especially to find the appropriate PID parameters.

Considering that, the next Skyrats' outdoor frame was designed to have assemble patterns similar to our previous frame (Condor)1, but using new motors and propellers - and, as a consequence, bigger arms.

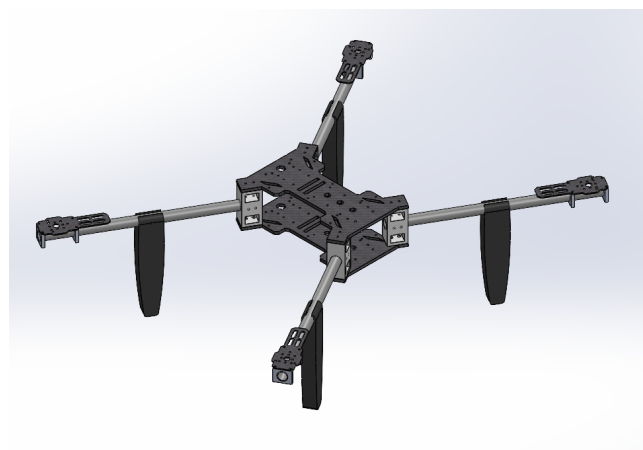


Figure 2: Condor Frame - 2025 version (CAD)

Thus, with a similar vessel, the team was able to improve its performance in similar missions with the previous version. The main plates of the 2024 version were 3D printed PLA parts reinforced with layers of fiberglass fabric, but on this new model, due to greater momentum caused by bigger arms, better resistance to mechanical stress is required. And carbon

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fiber plates grant enough resistance to ensure great durability.

We also developed a project in which the piece connecting both plates to the arms, the spacer, is fixed with four screws, improving its stability by reducing its momentum.

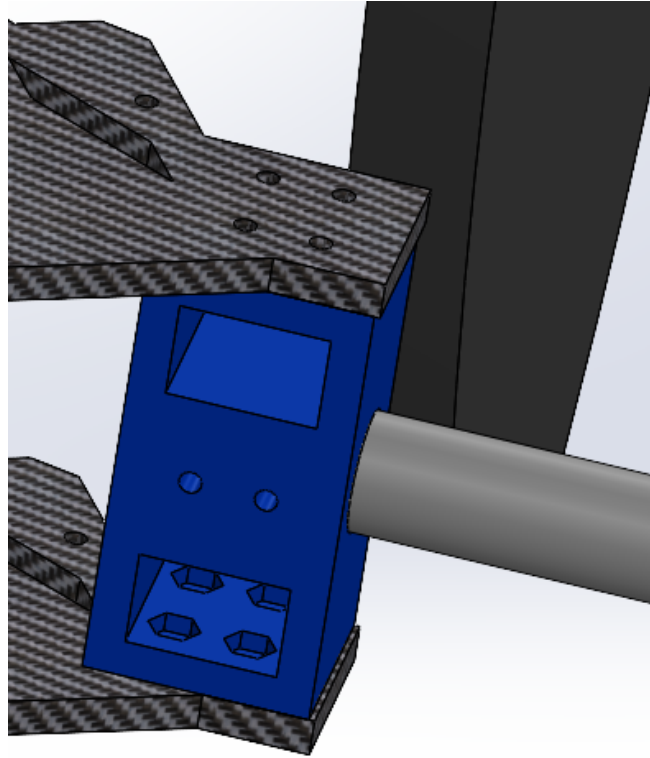


Figure 3: Spacer with four screws (CAD)

3 METHOD AND COMPONENTS USED

3.1 Component Selection

The components used in Condor Wide's development were selected based on reliability criteria, energy efficiency, and compatibility with system necessities. The following list describes the main elements used¹, along with their technical references (datasheets):

- **Flight controller:** Pixhawk 6C [1]
- **Motor:** T-Motor MN3508-700KV [2]
- **GNSS:** Holybro H-RTK F9P [3]
- **Telemetry:** RFD900 915 MHz 1W [4]
- **ESC:** ESC Brushless 80A with UBEC 5A ²

¹other components will be used in this frame accordingly to the mission requirement

²An alternative ESC model of 45A might be used in this UAV

- **UBEC:** Hobbywing UBEC 5V 3A [5]

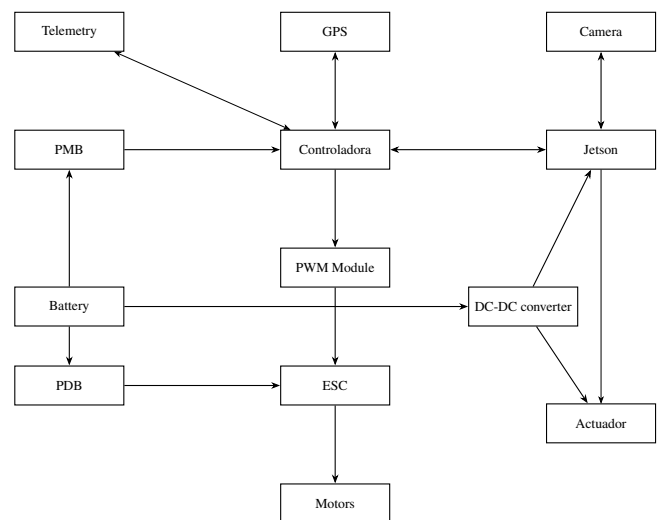


Figure 4: Block Diagram of Condor Wide Electrical System

3.2 Electrical System

The electrical system was dimensioned to ensure stability in the voltage and current supplied to all components, guaranteeing operational safety. DC-DC converters, such as the Step-Down Module and UBEC, allow for the adjustment of supply voltage for the single-board computer and the flight controller, while the energy distribution board distributes power to the four ESCs and motors.

Energy Distribution

- Power Module, for power supply to the flight controller and auxiliary modules - and for measuring current and voltage.
- Power Distribution Board (PDB), for ESC connections.
- Step-Up Module (DC-DC Converter), for powering the single-board computer(SBC) Jetson.
- UBEC 5V 3A, for a stable voltage supply to the raspberry Pi ³.

Battery

- A LiPo 4S 10000 mAh 25/35C Battery provides the necessary energy capacity to support the motors and embedded systems.

³This SCB will not be used simultaneously with Jetson



Figure 5: RunCam 5 Orange

Motor and Propeller System

- Four brushless T-Motor MN3508-700KV motors, which are efficient and have an excellent power-to-weight ratio.
- Four carbon fiber T-Motor CF propellers, with a 13-inch diameter and 6.5-inch pitch, set up in pairs: two in clockwise rotation and two in counter-clockwise rotation, installed alternately to ensure aerodynamic stability.

3.3 Motor and Propeller Sizing

The motor/propeller set was chosen based on simulations performed with the *eCalc XCopter Calc* software, which is widely adopted by the aeronautic industry. The simulations considered a significant weight error margin of approximately 3 kg, including the power battery and other embedded components. However, the frame has a nominal weight of 2Kg, without the SBC or any payload.

After a comparative analysis, the **T-Motor MN3508-700KV** motor was selected, associated with the **T-Motor CF 13x6.5** propellers, as illustrated in Figure 6. The main results obtained from the simulation were:

- **Maximum current:** approximately 30A, with a wide safety margin using 80A ESCs.
- **Hover flight time:** 13.5 minutes at an average speed of 10 km/h.
- **Maximum estimated temperature:** under 69°C, well within safe limits.
- **Maximum electrical power:** 447W.

- **Electrical power in hover flight:** 115.9W.
- **Thrust-to-weight ratio:** 2.4 : 1, above the minimum recommended of 1.8 : 1.

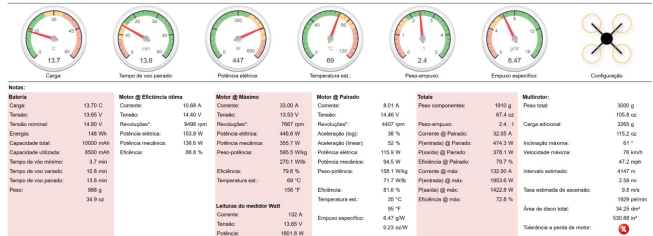


Figure 6: Simulation performed in eCalc Xcopter Calc. Source: Own authorship.

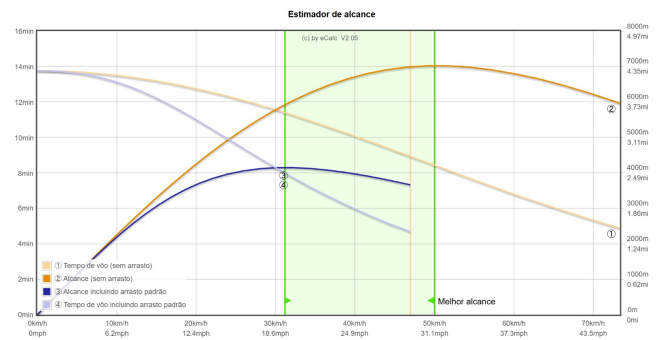


Figure 7: Flight range and duration chart. Source: Own authorship.

3.4 Embedded Components and Avionics

Flight Controller: Pixhawk 6C The flight controller used is the **PixHawk 6C**, which integrates the following navigation and altitude sensors:

- Accelerometer/Gyrometer (IMU): ICM-42688-P
- Accelerometer/Gyrometer (IMU): BMI055
- Magnetometer: IST8310
- Barometer: MS5611

Flight Peripherals

- PWM module for driving actuators.
- RFD900 915MHz 1W telemetry for long-range communication.
- FrSky ACCST X8R receiver for remote control.

Single Board Computer (SBC) Despite the absence of GPU for better processing of computer vision algorithm, the embedded processing is handled by a **Raspberry Pi 4**, for its practical use and extensive documentation. As Raspberry Pi 4 has only CPU, we had to adapt our algorithms for optimized performance in a limited hardware. The single board computer has the following specifications:

- 8GB/4GB RAM Memory.
- Power consumption: 15 W.

Mission Peripherals The camera below was chosen because of its very low weight, minimizing the impact on the drone's aerodynamics and efficiency, and ease of setup, bringing automatic camera focus and various lens aperture settings and ISO configurations. Setting up different shutter options, we could test how light exposure impacts on mapping photos and its quality definition, and working on ISO configurations we were able to define which one was the best for different weather and environments.

- RunCam5 Black/Orange for capturing images and videos.

4 TESTS AND RESULTS

4.1 Structural analysis

4.1.1 Mechanical Parts

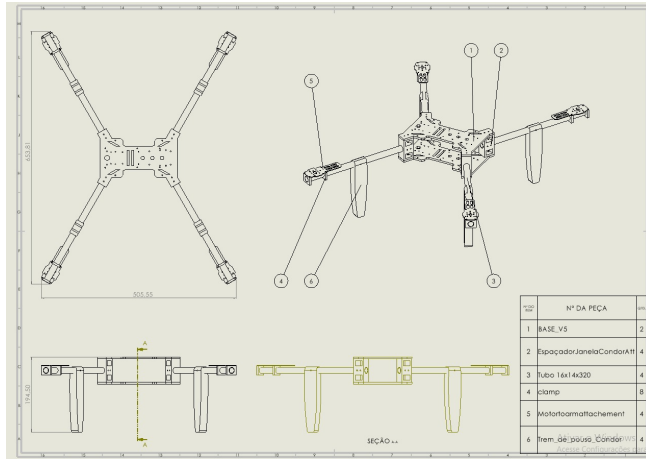


Figure 8: Technical assembly drawing

4.1.2 Calculating the forces on the spacer

Considering a trust-weight ratio of approximately 2.4 : 1 and a drone with 3Kg of takeoff weight, we can calculate the motors (rover state) force applied by each arm as:

$$F_{arm} = \phi * \frac{M}{4} * g \quad (1)$$

Table 1: List of Drone Components

Part	Material / Specification	Quantity
Base	Carbon fiber	2
Tube	Carbon fiber, 16 × 320 mm	4
Motor attachment	Carbon fiber	4
Spacer	PLA	4
Clamp	Aluminum, 6061-T6	8
Landing Gear	TPU	4

Thus, we have the following:

$$F_{arm} \approx 2.4 * \frac{3}{4} kg * 10 \frac{m}{s^2} = 18N \quad (2)$$



Figure 9: Damaged PLA parts

And, the momentum:

$$M_{arm} = F_{arm} * L \quad (3)$$

And, numerically:

$$M_{arm} = 18N * 0.28m = 5.04Nm \quad (4)$$

4.1.3 Simulation

The fracture pattern illustrated in Figure 9 indicates a brittle failure, which is associated with the intrinsic characteristics of the thermoplastic material.

To further investigate the failure mechanism in the spacer, static structural simulations (SOLIDWORKS) were conducted considering the previously calculated force (F_{arm}). The drone arm was modeled as a cantilever beam, with one end fully constrained. The horizontal bases of the spacer were fixed in accordance with the boundary conditions of the problem (green) and the force is applied on motor attachment, in

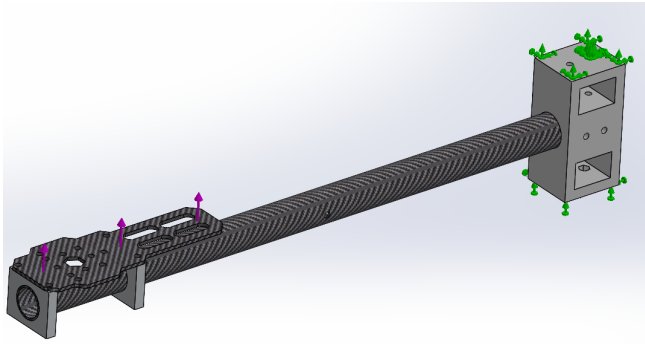


Figure 10: Problem Definition

purple (Figure 10). All analyses were performed using units from the International System of Units (SI).

The carbon components (tube and motor attachment) and the clamp (aluminum) were modeled as rigid bodies [6], since their mechanical strength is significantly higher (approximately two orders of magnitude) than that of the spacer material.

Property	Value	Units
Elastic Modulus	69000.00067	N/mm ²
Poisson's Ratio	0.33	N/A
Shear Modulus	26000.00013	N/mm ²
Density	2700	kg/m ³
Yield Strength	275.0000009	N/mm ²

Table 2: Mechanical properties of Aluminum 6061-T6 (source: simulation software database).

Property	Value	Units
Elastic Modulus	101000	N/mm ²
Poisson's Ratio	0.286	N/A
Shear Modulus	4020	N/mm ²
Density	2250	kg/m ³
Yield Strength	1260	N/mm ²

Table 3: Mechanical properties of Carbon Fiber (source: MatWeb).

Nevertheless, PLA (Polylactic Acid) was selected due to its suitability for rapid prototyping and its capacity to enable more adaptable geometries [7], which are inherent characteristics of additive manufacturing. Moreover, the spacer functions as a mechanical sacrificial element, as it is intentionally designed to fail before higher-value components, thereby protecting the overall structure [8].

The results indicate that the region near the tube connection is subjected to the highest stress levels. Deflections induced by the motor thrust force lead to potential stress values that may exceed the material's strength, although the magni-

Property	Value	Units
Elastic Modulus	1896	N/mm ²
Poisson's Ratio	0.4	N/A
Shear Modulus	677.14	N/mm ²
Density	1240	kg/m ³
Tensile Strength	50	N/mm ²
Yield Strength	24.8	N/mm ²

Table 4: Mechanical properties of PLA (sources: F3DB, 3D Lab).

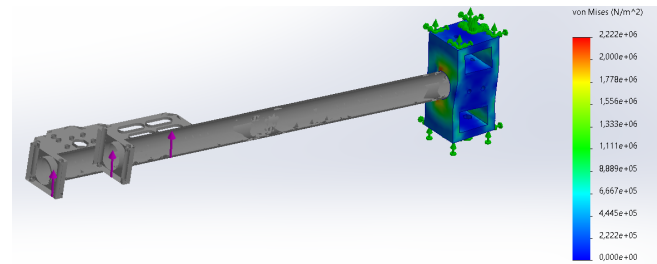


Figure 11: Simulation: Stress in takeoff

tude of displacement remains small (on the order of tenths of a millimeter).

Considering the forces applied in each PLA piece that separates the carbon fiber plates and sustains the carbon fiber tube (arm). Using PLA might be suboptimal for long periods. The frame test showed that, over time, the PLA piece is clearly damaged - as shown in the figure 9 - and must be replaced. However, these cracks are extremely visible and, considering the accessibility of 3D printing, using PLA 3D printed parts has not compromised the project and mission tests.

4.2 Stability and Efficiency

The frame tests were, in general, very successful. The frame was, compared to its previous version 1, extremely stable and efficient. With its minimal weight and a 16Ah LiPo, it was able to fly for over 19 minutes. It was also extremely stable and has not presented any risk of fall in the tests that occurred under various conditions. - such as strong winds, partial rain and various temperatures.

The use of a RTK base was extremely successful and, for applications such as a swarm, extremely helpful. The team was able to set the GPS accuracy as small as 18cm. Such high accuracy allowed us to test swarm applications, smaller landing sites and more reliable missions.

5 EMBEDDED SOFTWARE

5.1 Autopilot Tools

The firmware used by our team is ArduPilot. This autopilot stack was selected due to its long-standing development history, which ensures stability and reliability, as well as its



Figure 12: Test flight

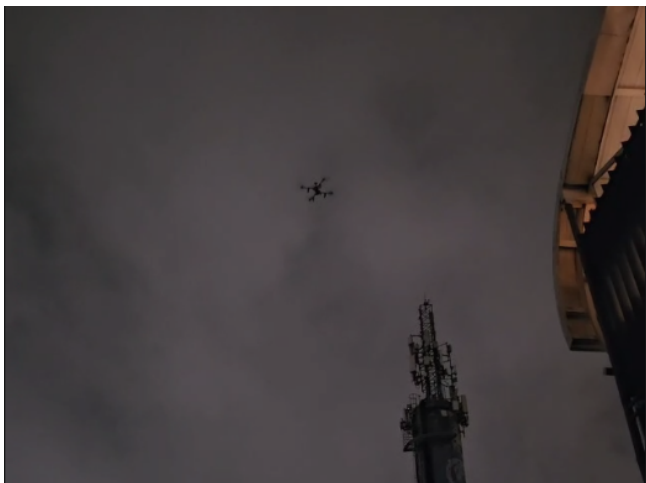


Figure 13: test using rtk base

extensive feature set and versatility, making it suitable for a wide range of UAV applications. In addition, some former team members contributed to the development of this platform, which allows us to seek their expertise and guidance if necessary during our project. For the development of our autonomous missions, we also take advantage of tool such as:

Qground Control Apart from Ardupilot configurations on the flight controller, compass calibration, etc; this tool customary use is for simple mapping missions or perhaps prototyping and testing the drone reliability in autonomous mis-

sions. We use the **Survey** mode for easily implementing a lawnmower pattern for the drone to follow. Simple way points are also used when necessary.

Mission Planner This tool and Qground present many overlapping functionalities. However, native support for the Ardupilot swarm was key in incorporating this application into our stack.

Python Dronekit This Python library is particularly well suited for autonomous missions with dynamic or mutable paths. It is a recently incorporated tool in our team, and we were impressed by its versatility and operating system independence, which allow it to function seamlessly across different platforms.

5.2 Drone Mapping

Onboard Image Capture and Geotagging The images are obtained during a Qground Search flight. Yet, we have only performed tests in a low altitude using the new Condor Wide platform. We have developed a code using Dronekit to obtain GPS and altitude information. After that, the code stores the geolocation info for later use.

From Geotagged Images to Orthophotos and Textured Meshes After obtaining the geotagged images from the drone's SBC we process them using WebODM, an open source software for aerial imagery processing. Specific configurations depend on the output map we want to acquire, but in general we are interested in orthophotos, 3D models and point clouds. In **APPENDIX A** you can observe a 2D map and in **APPENDIX B** a textured 3D model is shown.

5.3 Object Detection Via Text Description

One of the challenges proposed by IMAV consists in finding a specific person described by a textual prompt and then landing 2m radius nearby the person that best fits the description. This section will expose methods used to solve this problem.

Computer Vision and YOLO11 Ultralytics has provided to all computer vision and machine learning community a powerful object detection and image segmentation model. This model is known as YOLO (You Only Look Once) [9]; it is capable of detect 80 different objects classes and it is easy of use, allowing anyone with basic programming knowledge to train a model and use it for diverse purposes. YOLO11 is the core of our computer vision algorithms, mainly because of its prediction accuracy, adaptability and good performance in different hardware platforms, even the ones with less processing power.

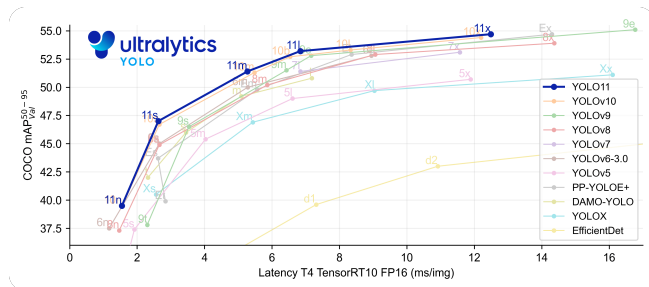


Figure 14: YOLO performance comparison

Detection process While the MAV is hovering over search location, it takes photos of the ground with a camera placed 90 degrees regarded to the floor. When a photo is taken, we apply YOLO11 model trained in it, and we try to detect the objects we are searching for.

The detection process is divided in 5 steps. First photo will be taken in a predetermined altitude, then we detect a person that fits the textual description. Next step is to estimate the person detected position in real world, go closer to detected person using the found coordinates and lower the MAV altitude by half. For preventing false positives caused by low resolution images or high distances between the MAV and the searched object, we repeat the detection process one more time. In total, there is no need more than 2 process detection cycles, so is expected that after the second cycle the MAV has total sure about the right detected person and land 2m radius nearby them.

The camera's wide 145-degree field of view allows the MAV to cover the entire search area with just a few photos, enabling a faster detection process.

5.4 Swarming Capability

This year's missions required our team to research and implement drone swarming. Some tasks involved the creation of a 2D surface, which requires at least three lifting drones, while others demanded high payload capacities. Both challenges can be addressed more effectively through swarm operations.

Swarm Organization Although ArduPilot supports a wide range of vehicles, it currently lacks native drone-to-drone communication. Research has been conducted on this topic, such as the 2023 Google Summer of Code project [10], in which contributors implemented a Wi-Fi-based communication network using ESP8266/ESP32 modules.

The Use of Mission Planner Due to the absence of built-in swarm communication in the firmware used by our team, we explored an alternative solution through a different Ground Control Station (GCS). Mission Planner, as previously noted, is a GCS that enables the creation of waypoint missions. A

particularly useful feature is its ability to send unique commands to each drone, allowing for a leader-follower swarm configuration.

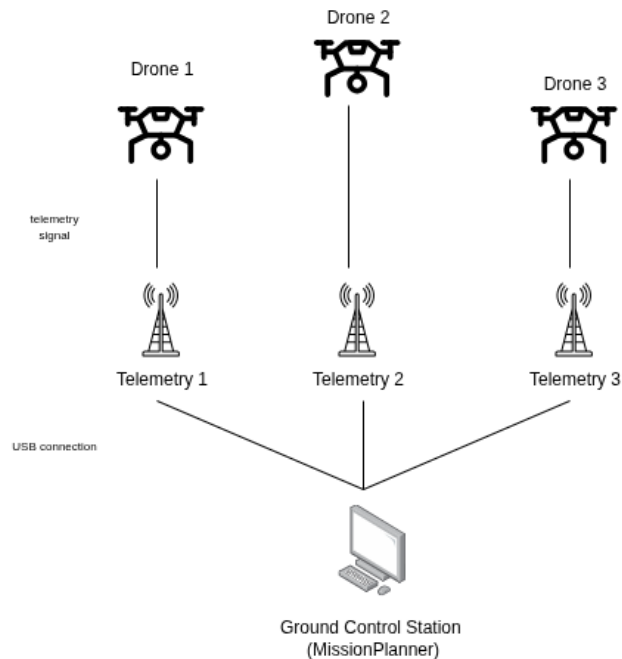


Figure 15: Swarm organization using multiple telemetry connections

Overcoming the Lack of Intercommunication While issuing commands from the GCS without inter-drone communication provided an acceptable solution for the required tasks, it does not offer the highest level of precision. To address this limitation, we employed Real-Time Kinematic (RTK) GPS. The high positional accuracy of RTK was essential to maintain the relative distances between drones within the required tolerances.

6 CONCLUSION

The Condor Wide project successfully met its primary design objectives, transitioning from the team's previous unconventional airframe to a more stable and efficient quadcopter architecture. This transition directly addressed control stability and PID tuning challenges identified during prior competitions, while retaining key assembly methodologies developed by the Skyrats team.

The rigorous component selection process, guided by simulation software, was validated through extensive flight testing. The results confirmed significant improvements in performance, including enhanced flight stability under adverse weather conditions and extended endurance, achieving flight times exceeding 19 minutes. A critical advancement was the successful integration of the RTK GPS system, which

delivered high-precision navigation capabilities essential for complex autonomous tasks. This high accuracy facilitated the development of advanced software functions, including effective mapping workflows and preliminary swarm control configurations using a GCS-based leader-follower model.

Structural analysis identified the intended role of the PLA spacers as sacrificial components, though their limited durability under sustained operational stress presents a clear area for future material refinement. It is further concluded that the printing orientation should align the filament transversely, as this arrangement acts as a barrier to crack propagation within the material.

Nonetheless, the Condor Wide has proven to be a robust and reliable platform. It provides a solid foundation for the team's ongoing development in autonomous aerial solutions, particularly for applications in mapping, precision landing, and multi-vehicle operations.

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It should be noted that the team is composed entirely of undergraduate students, working without any aid or salary. In the spirit of collaboration, all data published and obtained by us is made freely available to the drone community.

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APPENDIX A: MAPPING

Figure 16: 2D map

APPENDIX B: 3D MAPPING

Figure 17: 3D mapping