

TDP: Skyrats (Brazil), Indoors Category

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ABSTRACT

Namoral is a quadcopter architecture unmanned aerial vehicle (UAV), developed for applications that demand modularity and adequate autonomy and power for diverse indoor missions, with a frame design based on modularity for multiple sensors and actuators. Its electrical system was designed focusing on energy output for multiple components with different power requirements, as well as enough thrust capacity for high take-off weight, useful for heavy stereo cameras and other equipment, developed for precision indoor positioning, spatial awareness and other aerial indoor necessities.

1 INTRODUCTION

This year's novelty from the Skyrats team is focused on creating a new stable platform for indoor applications, addressing the shortcomings of previous projects. Using a new positioning system and more processing power, this drone should be able to locate itself and interact with environments in which GPS is not available, as well as being a standard for Skyrats' future indoor drones, in the same manner the Condor is standard for outdoor applications since its first use at the 2023 IMAV, being upgraded since then. Namoral is designed to fulfill the same role for indoor missions, due to its modularity and capacity to include multiple sensors for different applications.

2 OBJECTIVES

Based on previous competitions, both national and international, the Skyrats team always had some problems surrounding the indoor category. Most of them were caused by a lack of processing power or thrust losses. Therefore, for this edition of IMAV, the team is focused on addressing past difficulties.

Namoral is designed to have a ZED 2i as the primary position system, processed by a Jetson Orin Nano, allowing for extra processing power, with more powerful motors and better arm aerodynamics in relation to past models.

This year's frame is made mainly with carbon fiber due to its stiffness, which helps with the drone's stability, on its

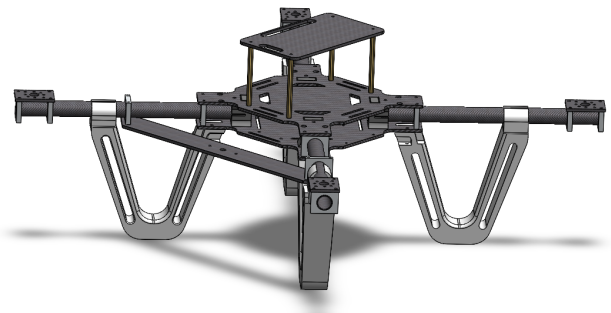


Figure 1: Namoral Frame - CAD

reduced vibration, and on its high strength-weight ratio. The landing gear is 3D printed using TPU filament with low infill density, making the landing process smoother, thus causing less impact on the arms. It has been modeled to be able to dissipate a fraction of the forces upon landing as it can slide along the length of the arms, making the frame more durable.

Considering that this frame has been developed with the intention of being a standard frame for the next indoor competitions, the use of carbon fiber was also based on its durability.

3 METHOD AND COMPONENTS USED

3.1 Mechanical Parts

The UAV frame is composed of several mechanical parts that ensure structural integrity and stability, while supporting embedded systems and providing easy access to them. The project uses components printed and modeled by the team and purchased parts, listed below:

- **Carbon Fiber Tubes:** Used as the arms of the UAV, as well as possible support for mounted equipment.
- **Carbon Fiber Plates:** Modeled and cut by the team into different models, used as the drone's top and bottom plates, as well as motor, camera and flight controller mounts.
- **Aluminum Clamps:** Purchased by the team and used together with screws and nuts as a method of fixing the arms and mounts for different components.
- **TPU Parts:** Developed and printed to be the landing gear of the UAV and also for a case securing NVIDIA's

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Jetson Platform, which is mounted under the inferior plate.

- **PLA Parts:** Connecting piece that unites the tube between the two carbon fiber plates, as well as a possible material for cases and mounts.
- **Brass spacers:** Used to separate the top plate and the flight controller mount.

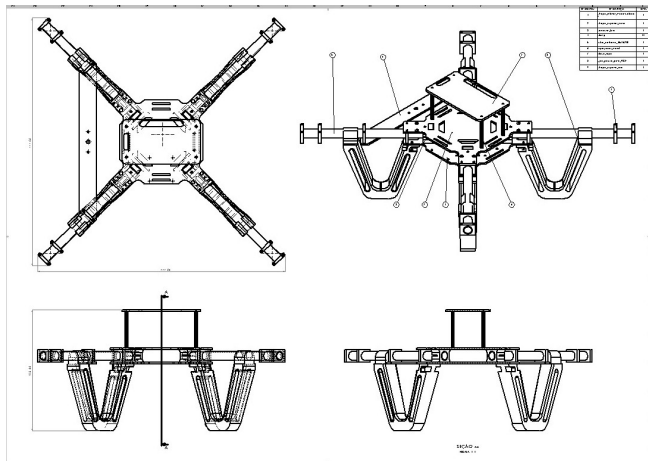


Figure 2: Namoral Frame - Technical Drawing

Therefore, the final result of Namoral's frame is demonstrated in the picture below:



Figure 3: Picture of Namoral's assembled frame

3.2 Component Selection

The components used in Namoral's project were selected based on reliability criteria and compatibility with system necessities. The following list describes the main elements expected to be used ¹, along with their technical references

¹Other components may be used in this frame accordingly to future necessity.

(datasheets):

- **Flight controller:** Pixhawk 6C PRO [1]
- **Motor:** T-Motor V3115-900KV [2]
- **ESC:** ESC Brushless 45 A BLHeli[3]
- **Camera:** ZED 2i [4]

3.3 Electrical System

The electrical system was dimensioned to ensure stability in the voltage and current supplied to all components, ensuring operational safety. DC-DC converters, such as the Step-Down Module and Step-Up Module, allow for the adjustment of supply voltage for the single-board computer and additional components, such as the electromagnet, 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 complementary components - 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;
- Step-Down Module (DC-DC Converter), for the electromagnet.

Other sensors such as cameras and the microphone will be powered directly via USB from the Jetson.

Battery

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

Motor and Propeller System

- Four brushless T-Motor V3115-900KV motors, which are efficient and have an excellent power-to-weight ratio.
- Four carbon fiber T-Motor CF propellers, with a 10-inch diameter and 4.5-inch pitch, set up in pairs: two in clockwise rotation and two in counter-clockwise rotation, installed alternately to ensure aerodynamic stability.

3.4 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 3.5 kg, including the power battery and other embedded components. However, the frame has a nominal weight of 2 kg, without the SBC or any payload.

After a comparative analysis, the **T-Motor V3115-900KV** motor was selected, associated with the **T-Motor CF 10x4.5** propellers ², as illustrated in Figure 4. The main results obtained from the simulation were:

- **Maximum current:** approximately 25 A, with a wide safety margin using 45 A ESCs
- **Hover flight time:** 10.7 minutes
- **Maximum estimated temperature:** under 45 °C
- **Maximum electrical power:** 325.3 W
- **Electrical power in hover flight:** 171.3 W
- **Thrust-to-weight ratio:** 1.5 : 1

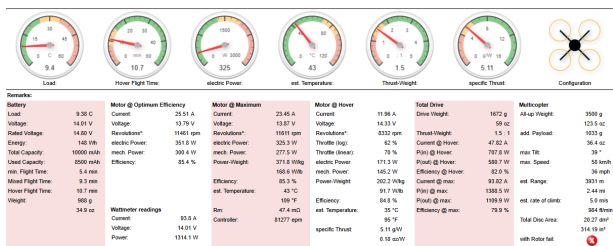


Figure 4: Simulation performed in eCalc XCopter Calc. Source: Own authorship.

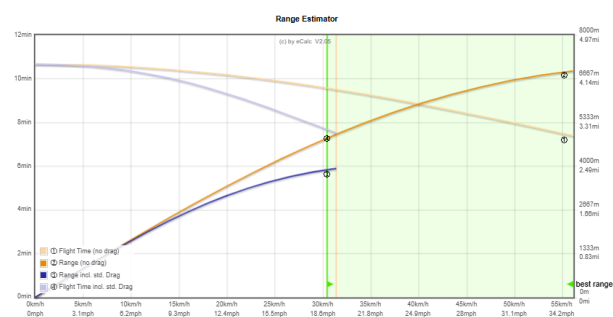


Figure 5: Flight range and duration chart. Source: Own authorship.

²The motor's low usage allow for an increase in propeller pitch if required to compensate for additional weight of the drone

3.5 Flight Components and Avionics

Flight Controller The flight controller used is the **Pix-Hawk 6C PRO**, which integrates the following navigation and altitude sensors:

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

Flight Peripherals

- LR24F Telemetry Radio based on LoRa technology [5]
- FrSky ACCST X8R or FrSky ACCESS R8 PRO receiver for remote control [6][7]
- PWM module for driving motors

4 EMBEDDED SYSTEM

4.1 Single Board Computer (SBC)

Equipped with a GPU for better processing of computer vision algorithms, and a 6 core CPU for multiprocessing, the embedded processing is handled by a **Jetson Orin Nano**[8], for its large processing power and relatively small size and weight. The single-board computer has the following specifications:

- 1024 CUDA and 32 tensor GPU cores
- 6 Core Arm CPU
- 8 GB RAM Memory
- Power consumption: 25 W

This setup is required to allow for the ZED 2i positioning algorithms (required to keep the drone from drifting) to run alongside other computer vision models and mission codes in real time.

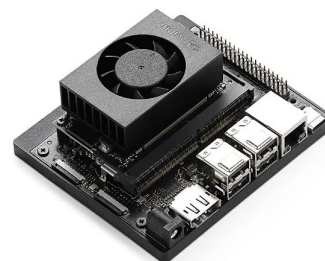


Figure 6: Jetson Orin Nano. Source: Nvidia.

4.2 Visual Odometry

The **ZED 2i Stereo Camera** [4] from StereoLabs will be used for visual odometry. It has a nine degrees of freedom inertial unit, composed of a gyroscope, accelerometer, and magnetometer, in addition to a barometer that allows estimating the drone's altitude. The camera provides pose estimates in six axes (three of translation and three of rotation), already factory calibrated, which guarantees consistency in the measurements. It also delivers high-quality video output in Full HD. Furthermore, it is compatible with the **Jetson Orin Nano**, facilitating the integration between other equipment chosen by our team.



Figure 7: Zed 2i Stereo Camera. Source: StereoLabs.

4.3 Mission Peripherals

These items were chosen as extra components to allow the missions to be possible:

- RunCam 5 Black/Orange (Camera) [9]
- ReSpeaker USB Mic Array v2.0[10]
- Electromagnet 12 V
- Touch sensor developed by the team

Facing Down Vision The camera was chosen because of its ease of setup and automatic camera focus, and various lens aperture settings and ISO configurations allow for great visibility in most situations, as well as reliability, as it was extensively used on past projects.

Med-kit Attachment The electromagnet was chosen for reliability and ease of use, allowing quick release of any package, as long as it has a metal surface.

Sound Detection The microphone needed to be multidirectional and relatively inexpensive, it was acquired for Indoor IMAV 2025; therefore, its effectiveness is yet to be tested.

Sensing the Board For the whiteboard, the team is developing a sensor to detect if the drone is at the right distance from the board.



Figure 8: RunCam 5 Orange. Source: RunCam.

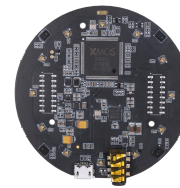


Figure 9: ReSpeaker USB Mic Array v2.0. Source: Sseed Studio.

5 STRUCTURAL ANALYSIS

In this section, the team felt the need to use SolidWorks' simulation mode in order to emulate static load scenarios, with the objective of justifying material choices and confirming the UAV's frame's reliability and stability in the simplest of situations. Since impact situations are difficult to predict and study through the software technologies, the team decided to refrain from this type of analysis, focusing solely on structural static simulations which are described in the next paragraphs.

Carbon Fiber Parts Simulations In this first simulation, regarding the drone's arms, a force of approximately 12 N (the maximum expected during flights) is applied to each arm by the motor on the edge of each carbon fiber tube. This way, the team was able to create simulations, on SolidWorks Simulation software, regarding the scenario in which the motors are on, causing a torque in the drone's arm.

Looking at the result, the maximum deformation caused on the arm is minimal, 0.199 mm, reassuring that using carbon fiber tubes to hold the motors and propellers might be the best option. Combined with the support of the landing gear, there should be practically no deformation on the arms. This can also be said for the ZED 2i support, which is also made entirely of carbon fiber, resulting in a secure platform for this important location system.

In the Outdoor frame, Condor, the piece that connects the arms to the main plates is 3D printed with PLA, and even

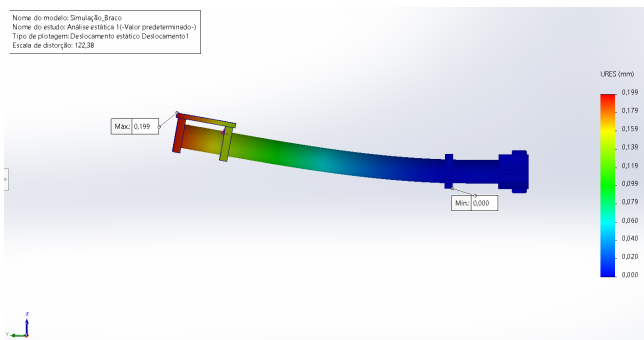


Figure 10: Static analysis of the arm

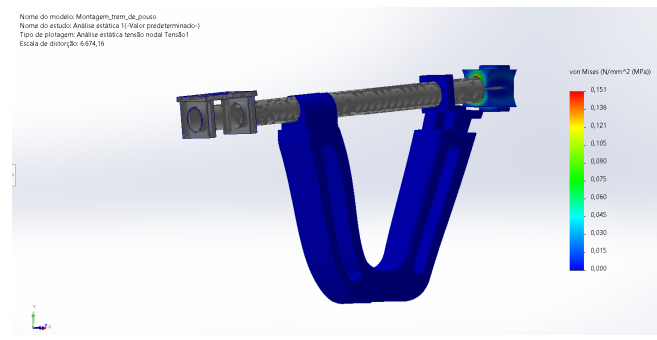


Figure 12: Static analysis of the landing gear

though it is not the best material to make that part with, it has been relatively successful and has not been a major issue, due to its ease of replacement and accessibility. However, for the indoor project, Namoral, the team decided to use a better material. Aluminum offers significantly higher resistance to mechanical forces. By using aluminum instead of PLA, not only is the structural integrity of the drone improved, but it also ensures great durability for the frame.

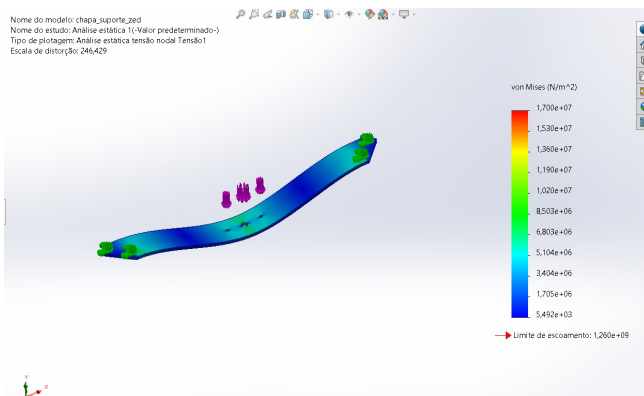


Figure 11: Static analysis of the Zed 2i support plate

Landing Gear Simulation A simulation of the landing gear was made, considering the motors off, with only the weight of the motor and the propeller, rounding about 1.5 N, and considering a frame with an oversized maximum take-off weight of 5 kg, the force of the impact under each of the four corners of the UAV is approximately 12.5 N. Moreover, the motor mount, clamps and carbon fiber tube were considered as rigid bodies [11]. As seen in the results, the 3D printed TPU part is able to absorb impact really well. And the 3D printed PLA piece [12], that connects both the main plates to the arms, suffers a negligible amount of tension and deformation.

6 EMBEDDED SOFTWARE

6.1 Autopilot Tools

The firmware used by the team is ArduPilot. This autopilot stack was selected due to its long-standing development history, which ensures stability and reliability, as well as its 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 the team to seek their expertise and guidance if necessary during any project. For the development of our autonomous missions, the team also makes use of tools such as:

QGround Control This is Skyrats' primary ground station, it is used to change parameters of the flight controller and calibrate sensors. The wireless connection via telemetry allows for real-time assessment of flight and positioning information.

Python Dronekit This Python library is particularly well-suited for autonomous missions with dynamic or mutable paths, such as precision landing tasks. 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.

6.2 Drone Positioning

Stereolabs provides the ZED SDK (Software Development Kit), the main software for developing applications with the ZED camera. Among its features is *Inertial Data Integration*, which estimates the camera's movement by combining data from the stereo camera and the IMU (Inertial Measurement Unit). One of the data provided by Inertial Data Integration is the *pose*, which indicates the camera's estimated position and orientation [4]. One way to access the drone's (camera's) position is through the Sensors API. However, since we will be using ROS 2 (Robot Operating System), it will be necessary to use the ZED ROS2 Wrapper package, also provided by Stereolabs, which publishes this data on ROS 2

topics, allowing ROS 2 to directly receive the camera's position and orientation.

7 COMPUTER VISION SOFTWARE REQUIRED

Make Sense AI Open-source web-based tool to create annotations in images for object detection. It allows exporting the labels in YOLO format [13]. This tool will be used mainly in the moving base mission, where it will be necessary to identify an H.

OpenCV It is an open-source library that brings together several pre-structured functions for computer vision, including edge detection, recognition of geometric figures, ARUCO markers, and manipulation of images and videos in real time. OpenCV is widely used by the team in different operations related to computer vision. [14]

Yolov8 YOLO (You Only Look Once) is an object detection model based on neural networks. Over time, YOLO has gone through several versions and improved its performance. Version 8, in particular, meets our current needs very well, offers ease of use through the Python API, has proven performance, and is capable of handling various types of detection, in addition to having a wide variety of tutorials made available by the community [15].

The graph in Figure 13 shows the relationship between the mean average precision (mAP) and the inference latency of various YOLO versions. Average precision (AP) measures the area under the precision and recall curve for a specific class, while mAP corresponds to the average of the APs calculated across all object classes. Inference latency indicates the time a trained machine learning model takes to process an input and return a prediction [15].

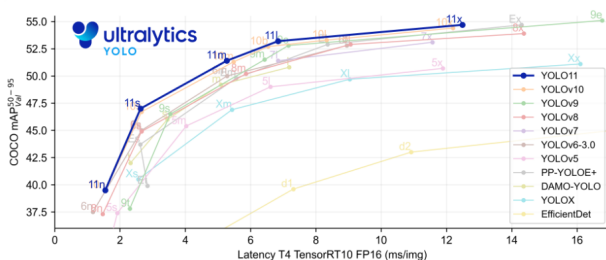


Figure 13: YOLO performance metrics. Source: Ultralytics, 2025

8 ROBOTICS DEVELOPMENT AND SIMULATION TOOLS.

Gazebo Gazebo is a 3D robotics simulator that allows integration with ROS2 and the execution of codes programmed in Python. The simulator enables the construction of custom

maps as well as robotic models [16], such as the drone itself. It is essential to validate the solutions developed by our team before real-world tests.

Blender Blender is a free 3D creation software used for modeling [17]. It will be mainly employed for building the indoor mission map. After modeling, the native .blend file will be converted into the .dae (COLLADA) format, enabling the import and use of the models in the Gazebo simulator.

ROS 2 The Robot Operating System 2 (ROS 2) is a set of libraries and tools [18] that enables communication between the drone and peripheral devices. It will be used mainly for integration with the ZED 2I stereo camera.

9 MISSIONS STRATEGIES

9.1 Square gate

Before passing through the tunnel, it will be necessary to align the center of the camera with the center of the distance between the two lateral rods of the gate. For a higher level of confidence, we will divide the feed from the ZED camera processed by the Jetson into three regions, in order to ensure that each rod is within the correct range. Additionally, a PID (proportional–integral–derivative) controller will be implemented to correct the error of the drone's position relative to the center of the gate. Once centered, the drone will traverse the tunnel composed of five gates.

9.2 Whiteboard touching detection

For this task, the drone will approach the whiteboard slowly until the touch sensing device detects the touch, then move horizontally to draw the line. If the device is no longer triggered, the drone will move closer to the board, (there will be enough margin for the sensor to be disabled while the pen is still touching the board). If the device triggers the secondary connection, meaning the board is too close, the drone will move slightly away from the board. This pattern will be followed until the line is considered done.

9.3 Sound detection

A device called ReSpeaker will be utilized to identify sounds of help requests. The equipment has noise suppression and acoustic simulation algorithms already implemented, which allows for filtering out the drone's motor and propeller making noise. The multiple sound detectors embedded in the device can be used to find out the direction in which the sound is being produced. The drone will follow the cries until the facing down camera detects the black box via OpenCV, a centralization algorithm will be performed, to ensure the drone is directly above the black box, then the med-kit is released.

9.4 Moving base detection and landing

Due to other competitions, including IMAV, our team already has code, using OpenCV and YOLO to detect a static

base and perform a precision landing. For a moving base, it will be necessary to adapt it to estimate the speed and direction of the base's movement, as well as to perform the drone's own dynamic adjustment of speed and position.

10 TESTS AND RESULTS

This is the first version of the Namoral platform, therefore, only preliminary tests have been performed, they show great flight capabilities, although maintenance accessibility is more difficult.

The motors and propellers chosen via the E-Calc calculations have been tested in real situations multiple times and are very reliable, with great and steady thrust.

On SolidWorks, the mechanical team created a model of the frame, as well as simulations of static analysis to ensure that the frame is able to resist all forces that might be applied onto it, and the frame has been deemed flight worthy, both in simulations and in real tests.

Most of the drone's embedded software is reliable and has been extensively tested in other situations, but the audio detection is still untested.

11 CONCLUSION

The Namoral platform consolidates the Skyrats team's efforts in addressing the main limitations faced in previous indoor projects by integrating a robust mechanical structure, a carefully dimensioned electrical system, and reliable, yet heavy embedded software. The use of carbon fiber and aluminum components provided the necessary structural rigidity and durability, while simulations and preliminary tests confirmed the reliability of the design under expected operating conditions. The adoption of the Jetson Orin Nano in conjunction with the ZED 2i camera allows for visual odometry and real-time computer vision, enabling advanced autonomy in GPS-denied environments.

A key aspect of Namoral's design is its modularity, which allows for the integration of diverse sensors, actuators, and mission peripherals without compromising the electrical system, stability or performance. This flexibility, combined with the processing capacity of the embedded system and the versatility of the software stack (ArduPilot, ROS 2, OpenCV, and YOLOv8) ensures that the UAV is inherently prepared to execute the wide range of mission strategies required in this and other competitions. In this way, Namoral is not limited to predefined tasks, but is designed to be a platform capable of adapting to complex indoor challenges.

Although this version of Namoral is still in the early stages of testing, the results so far demonstrate promising flight performance and reliable system integration. As development continues, Namoral is expected to become the reference indoor platform for the Skyrats team, in the same way that Condor has become for outdoor operations, hopefully supporting future competitions and research projects.

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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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