# AR enhanced video streaming with object detection capabilities designed for a versatile UAV platform

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**Abstract**

*The project aimed at developing a versatile UAV platform equipped with a remote transport and launch system, object detection, and augmented reality projection on goggles. The outcome consists of a drone capable of executing independently planned missions via GPS, transmitting real-time images, and deploying payloads. With an operational range of up to 1.5 km and a flight autonomy of up to 30 minutes, it can carry payloads of up to 1.2 kg, including electronic devices and communication equipment for various purposes. This platform provides robust and adaptable solutions for different application domains. Additionally, three live image transmission pathways were identified and implemented, each with distinct advantages, contributing to the versatility and efficiency of the entire solution.*

*The images captured by the drone were interpreted by a pre-trained machine learning model for image detection and saving relevant data for subsequent analysis of key information.*

**Keywords:** *UAV Platform, Versatility, Independent Missions, Live Transmission, Payload Transport and Deployment, Extended Operating Distance, High Autonomy, Electronic Devices, Perspectives*

## Introduction

In the modern era of technology, the temporal pressure exerted stimulates progress and innovation in addressing the complexity of the contemporary world. The use of drones in various research and monitoring domains represents a striking example of adaptation to current requirements. Drones have become a vital component in the contemporary technological arsenal, being employed in a variety of civilian and military applications [1].

From environmental monitoring [2] and agriculture [3] to border surveillance [4] and military operations [5], these unmanned aerial vehicles have redefined the ways of exploring and interacting with the surrounding environment.

Drones equipped with video streaming capabilities have significant applications in a variety of fields. Firstly, they are used in the domain of monitoring and security, enabling law enforcement agencies and emergency services to obtain a rapid and detailed aerial perspective of critical situations, such as traffic accidents, natural disasters, or ongoing crimes [6].

Regarding the industrial and construction sectors, drones with video streaming are used for aerial inspections of structures and equipment, reducing costs and time required for routine assessments or defect detection [6]. They are also valuable in agriculture for crop monitoring, defect or disease detection, and land management optimization.

In the media and entertainment industry, drones with video streaming allow the capture of spectacular aerial images used in film production, sports events, or special reports. They offer directors and producers extended creative options and the ability to create captivating and impressive content.

The main objective of this work is the design and implementation of an agile UAV (Unmanned Aerial Vehicle) platform through the integration of several electronic solutions. The project was implemented through the construction of the flight platform and the implementation of the following capabilities: performing independent missions planned via the GPS positioning system; real-time image transmission; implementation of an object detection algorithm on the transmitted image; fixed-point payload release. The originality of our project lies in the selection and customized integration of electronic parts in order to construct the UAV platform and implement the envisioned capabilities. The materials and methods used in the project, the main results obtained, and the conclusions drawn will be presented in the next sections.

*Fig. 1. Designed UAV platform with video streaming capabilities*

## Materials and methods

This project involves the integration of selected technologies into an electronic system operable through the UAV platform, aiming to improve its functionality and prove its versatility. The integration process involved the following key components and methodologies, including the construction of the drone platform and the integration of electronic systems.

A customized drone platform was constructed using components such as the APM2.8 flight controller, ESC30A electronic speed controllers, brushless motors, a power distribution board, 1045 propellers, and a 4S LiPo battery. This selection was made based on the adaptability and suitability of the platform for the intended purposes. These specific components were chosen to ensure optimal stability, adequate maneuverability, and increased payload capacity, thus providing a solid foundation for the seamless integration of additional electronic systems. For further functionalities, other components were integrated, such as ESP32, FPV camera, Raspberry Pi 4, Raspberry Pi HQ cam, and GoPro Hero7.

APM 2.8 is a robust flight controller designed for unmanned aerial vehicles (UAVs). Equipped with an ATmega2560 microcontroller running at 16MHz, it integrates various sensors, including gyroscope, accelerometer, barometer, and GPS for precise navigation and stabilization. Through channels 1-4, it communicates with the receiver, receiving commands from the operator's remote control. Additionally, channel 5 allows setting certain flight modes such as full control, altitude hold, position hold, landing, etc. Although its processing speed is relatively slower compared to modern microcontrollers, APM 2.8 remains a popular choice due to its open-source nature.

ESP32 is a microcontroller with a dual-core Xtensa LX6 architecture, operating at frequencies of up to 240 MHz, providing excellent processing power for IoT and embedded applications. It supports a wide range of communication protocols, including Wi-Fi 802.11 and Bluetooth. ESP32 operates in the 2.4 GHz frequency bands and can be used to implement complex wireless communication and IoT control applications.

ESC 30A, or Electronic Speed Controller 30A, is a vital component in drone systems and RC vehicles, regulating the speed of brushless motors. It can handle currents of up to 30 amperes, making it suitable for a wide range of applications, from small drones to larger multirotors. ESC interprets signals from the flight controller and adjusts the power supplied to the motor accordingly, controlling its speed and direction. With its compact size and efficient design, ESC 30A provides reliable performance and precise motor control. Typically, it includes features such as built-in Battery Eliminator Circuit (BEC) for powering the flight controller and other onboard electronics, as well as over-current and overheat protection mechanisms.

The FPV (First Person View) camera is an essential component of the drone's real-time viewing system. The CMOS camera provides high resolution of 1200TVL, ensuring clear and detailed images during flight. Connected to a 600mW transmitter, the camera transmits the video signal to a 5.8 GHz receiver, using a series of channels with their frequencies. This technology allows pilots to see in real-time what the drones see, providing them with immediate control and feedback during flight. Through an OTG cable, the receiver can be connected to various devices, such as mobile phones or tablets, to view and record the video stream in real-time. This advanced FPV system offers pilots an immersive and accurate experience during flight, allowing them to explore and navigate with confidence in diverse environments.

The GoPro HERO 7 is a compact action camera equipped with a 1220 mAh lithium-ion battery, providing variable autonomy depending on the recording settings. It has the capability to live stream at 720p, 60 frames per second, using advanced video compression. It employs digital encryption and Wi-Fi security protocols for protection against interception. The transmission range can reach up to 100 meters, on either the 2.4 GHz or 5 GHz band. Waterproof up to 10 meters without additional housing, with advanced image stabilization and voice control.

Raspberry Pi 4 is equipped with a Broadcom BCM2711 processor, which contains four ARM Cortex-A72 cores running at a frequency of 1.5 GHz. This processor provides significant processing power, facilitating intensive tasks. The HQ camera for Raspberry Pi 4 offers a maximum resolution of 4056 x 3040 pixels and is compatible with a wide range of interchangeable lenses. Live streaming is possible through

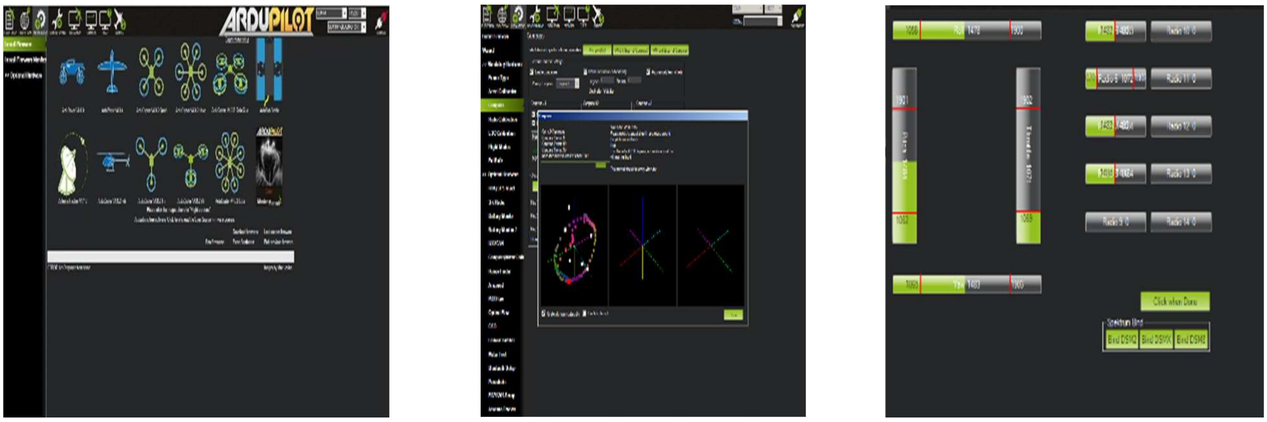

*Figure 2. a) Setting parameters b) Motion sensors calibration c) Radio calibration*

various protocols such as RTSP and HTTP, and connectivity is ensured through USB 3.0 ports, HDMI, Ethernet, and Wi-Fi.

After completing the basic assembly, adjustments to the project were made, including the calibration of motion sensors, GPS, and radio as shown in Figure 2. The calibration of the APM was conducted through the Mission Planner software interface, constituting a pivotal stage in ensuring precise flight of the drone (Figure 2a). Mission Planner provides an intuitive interface for performing this calibration and other APM settings, enabling users to customize and optimize the drone's behavior according to their specific requirements. Consequently, we calibrated the embedded sensors, such as the gyroscope and compass (Figure 2b), within Mission Planner. Additionally, we established the connection of the joystick channels for flight modes and UAV platform directions (Figure 2c). This entails the assignment and correct configuration of joystick control channels, contingent upon desired flight modes and drone movement directions.

The integration of control channels is imperative to ensure precise and accurate control of the drone during flight.

Subsequently, new functionalities were added, including the payload release system, which is controlled by remote control and processed by ESP32. Additionally, three distinct live image transmission systems were implemented: using the GoPro camera, the Raspberry Pi HQ camera, and an analog camera. These live transmission systems ensure high-quality surveillance in both analog and digital domains.

By using these three live transmission systems, increased resistance to interference, noise, and other technical factors is guaranteed, providing a robust and reliable solution to avoid loss of connection in varied environmental and usage conditions.

Laboratory equipment, namely oscilloscopes and spectrum analyzers were used to check and validate communication protocols between the electronics parts.

## Results and discussions

### 3.1 Circuit analysis and functionality validation

PWM signals are modulated by APM 2.8 to encode information such as the acceleration level, which determines the motor speed, and other control parameters. By adjusting the pulse duration of the PWM signals, APM 2.8 regulates the power sent to each motor through the ESCs, thereby controlling the movement and stability of the drone during flight.

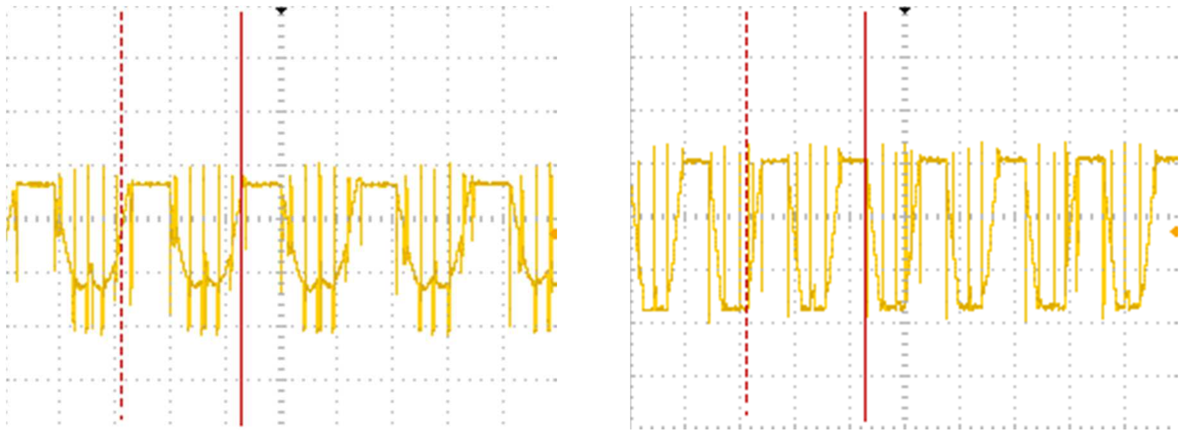

*Fig. 3. Signal measured with the oscilloscope for minimum (left) and maximum (right) speed control from the remote controller.*

Figure 3 depicts the signals measured with the oscilloscope for minimum and maximum speed control from the remote controller. These measurements indicate the same duration of time visible between the read cursors, while differences in frequency and pulse duration are evident.

The Fly Sky remote control communicates with the FS-iA6 receiver through radio signals. The remote control emits these signals, which are received by the receiver's antenna. It operates in the 2408 MHz to 2475 MHz frequency band with 500 kHz wide channels and provides a stable connection. Inside the receiver, a circuit processes these signals, extracting control commands from them. These commands correspond to user inputs on the remote control, such as joystick movements or button presses. The remote control generates Pulse Position Modulation (PPM) signals for each control channel, representing them as electrical pulses with variable durations depending on the inputs from the remote control. These PPM signals are combined into a single signal, which contains information for all control channels, and wirelessly transmitted to the receiver. The receiver decodes the combined PPM signal, extracting individual signals for each control channel. These signals control the drone's functions based on the user's commands. Overall, the PPM protocol simplifies communication from the remote control to the receiver, reducing cable clutter and facilitating installation and use. Figure 4 presents a spectrogram of a portion of the electromagnetic spectrum with the visible remote-control channels of 500 kHz bandwidth.

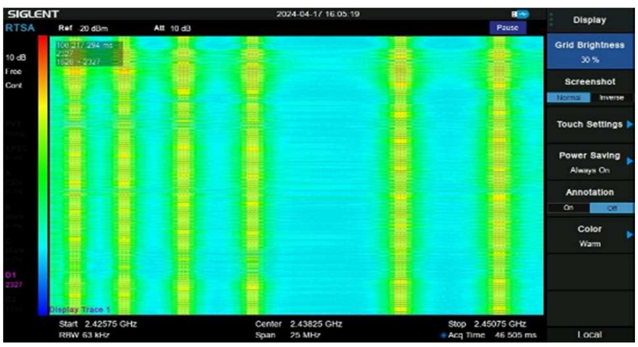


*Fig. 4. Spectrogram type visualization of the channels on the spectrum analyzer*

The fact that these pathways are visible in the electromagnetic spectrum indicates that it is not a secure communication method for military applications, being a solution in the civilian domain.

In the communication between the FS-iA6 receiver and APM 2.8, pulse width modulation (PWM) signals like the one in Figure 5a are used. These signals are generated by the receiver and transmit information about the position of the sticks on the remote control or other user commands. Each channel of the receiver generates a separate PWM signal, and the pulse duration of this signal varies depending on the position of the stick or the command given by the operator.

APM 2.8 interprets these PWM signals and uses the received information to control the motors, servos, and other components of the drone according to the commands received from the human operator via the remote control.

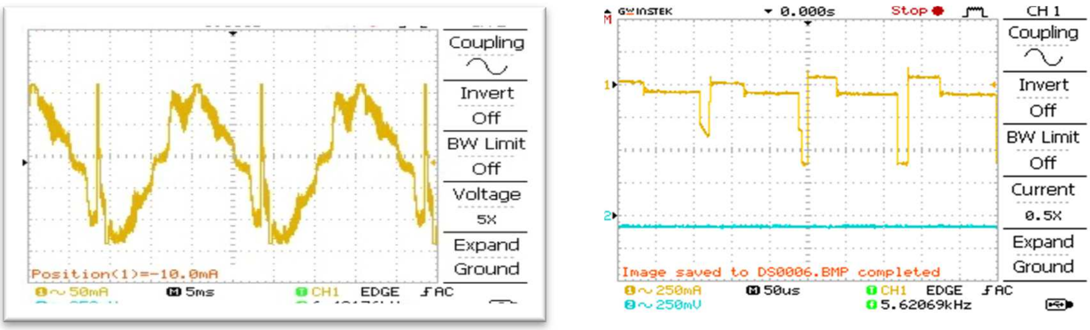


*Figure 5. a) Signal between APM2.8 and ESC30A* *b) Signal between ESC30A and motors*

Thus, PWM signals serve as an intermediary between the remote control and APM 2.8, allowing precise control of the drone during flight.

It doesn't show up perfectly rectangular, an effect of noise on the channels.

After the processes in APM 2.8, where the information from the remote control and motion sensors is correlated, communication with the Electronic Speed Controllers (ESCs) is achieved using pulse width modulation (PWM) signals. These PWM signals carry commands generated by APM 2.8 based on the input from the remote control and data from the motion sensors. Each ESC receives a separate PWM signal from APM 2.8, which controls the speed and direction of the corresponding motor on the drone.

Electronic Speed Controllers (ESCs) regulate the amount of electric current supplied to brushless motors to control their speed and direction of rotation. This regulation is achieved by modulating the pulse width modulation (PWM) signals by the ESCs.

In simple terms, ESCs receive commands from the flight controller (FC) or remote control and adjust the voltage and frequency of the PWM signals sent to the motors accordingly. These PWM signals efficiently control the amount of electric current delivered to the motors, which directly influences their speed and direction of rotation.

Therefore, while ESCs modulate the voltage and frequency of the PWM signals, the practical effect is the regulation of the amount of current supplied to the motors, thereby influencing their speed and direction of rotation.

## Power consumption and autonomy

The current consumption of the drone was analyzed by powering the drone from a power source, with the evaluation conducted at a voltage of 12.7 V. In the initial phase, a current of 0.39 A was obtained when all motors were stopped, indicating the consumption of the electrical circuit. When a single motor was started without a propeller, the consumption increased to 0.72 A, meaning that a single motor running at maximum capacity without a propeller consumes 0.32 A. However, adding the propeller would increase the current consumption to over 5 A, but the power supply is limited to 5 A, suggesting the need for a high-capacity battery, such as a 4S LiPo battery, tailored to the high demands of the circuit, especially in processes such as takeoff and ascent.

At the beginning of the experiment, the voltage level of the battery composed of 4 cells was measured, recording a value of 14.9 V. After 3 minutes of drone operation in the test room, a new measurement was taken, showing a decrease to 14.8 V. Thus, it was deduced that 0.1 V is consumed in a 3-minute interval when the drone operates without additional weights and under favorable indoor conditions. Given the optimal operating range of the battery between 14.8 and 15.2 V and the previously mentioned current consumption, an estimated flight autonomy of approximately 12 minutes is anticipated under ideal environmental conditions and without additional payload. Extending this autonomy can be achieved by employing a 5000mAh battery, which introduces a surplus weight and thus additional energy consumption. Consequently, the autonomy can be extended to approximately 33 minutes. However, considering real weather conditions and a payload of 0.5 kg, the guaranteed flight time is estimated to be 22 minutes.

Although the recommended voltage range for the battery is between 14.8 and 15.2 V, it may be exceeded in exceptional circumstances to ensure the safe landing of the drone.

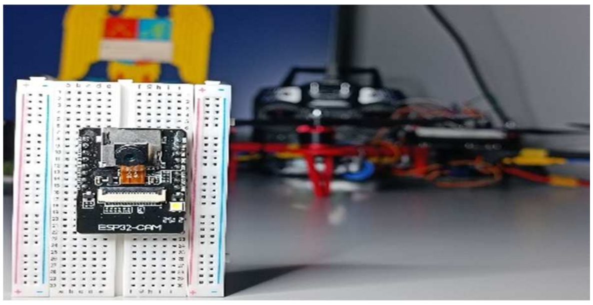


*Fig. 6. a) ESP32CAM*

*b) Hololens AR glasses*

## Live image transmission

The live image transmission capability was implemented using the following approaches:
a) by ESP32cam, b) using a Raspberry PI 4, c) with a GOPRO camera d) using a FPV camera.

a) Live image transmission using ESP32

The ESP32 camera was programmed to create a web server, through which it projects the captured images. These images can be accessed by any device connected to the network. Thus, we connected the augmented reality glasses to this server, enabling the transmission and projection of images onto augmented reality.

This system is powered by the APM2.8, which is powered in turn by the ESC30A. The performance of image transmission was assessed by analyzing the packet rate data transmitted over the network. Ping and tracer commands were used to evaluate connectivity to the camera's IP address. A latency of 1120 milliseconds was obtained, with this performance being dependent on network traffic at the time of evaluation. The test was conducted at a moment when the network was subject to other processes.

The obtained images were projected onto Hololens2 augmented reality glasses – figure 7b.

Through a Python script, periodic screenshots are taken with images obtained from the drone on any of the live streams and saved in a dedicated folder. Then, the same script runs a MATLAB program that retrieves these images and subjects them to an object detection algorithm. This algorithm, based on the pre-trained Alex Net model, provides real-time results, framing the detected objects in a frame and indicating the object's name. It records relevant information about the detected objects in a text file.

*Fig. 8. a) HQ raspberry pi CAM setup b) Raspberry Pi 4 HQ camera image*

b) Live transmission using Raspberry PI 4

On the Raspberry Pi, powered similarly from the APM2.8, we connected a high-quality camera configured to transmit a live image stream over the network. This stream can be viewed using the VLC media player, under the network section, and projected onto the augmented reality glasses.

The camera was connected to the dedicated port of the Raspberry Pi 4, and subsequently, the microcomputer's firmware was modified to execute a command upon booting. This command initiates streaming of images over the network with each Raspberry Pi startup. Additionally, it automatically connects to the local wireless network upon booting.

The command used for raspberry pi is ‘rasped -o - -t 0 -hf -w 1280 -h 720 -fps 30 | nc -l -p 5000’, and the URL needed for VLC media is ‘http://adresa_ip_rpi:5000’.

To automatically run the command for opening the camera and streaming on startup, you can add the command to the 'collocal' file. This file is automatically executed upon system boot. By using the command ‘sudo nano /etc./collocal’ and adding the command ‘rasped -o - -t 0 -hf - w 1280 -h 720 -fps 30 | NC -l -p 5000 &’, the stream is played along with the boot.

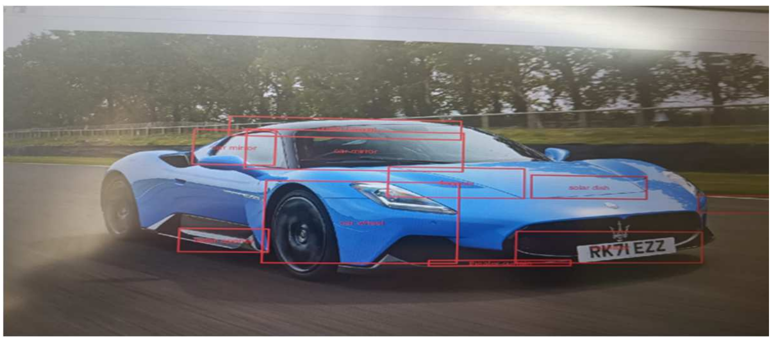


*Fig 7. Alexnet performed object detection*

c) Live image transmission with a GOPRO camera

To ensure an independent transmission from the local network, a GoPro HERO7 camera with independent power supply was used. It streams to platforms such as Twitch, Facebook, or YouTube. It can also be projected onto the augmented reality glasses. The camera provides ultra-high-quality images with image stabilization and extended autonomy, being resistant to extreme weather conditions and shocks. Additionally, the images can be saved to the camera's memory card.

d) using a FPV camera

To avoid dependency on the local network or internet, an analog FPV camera was integrated, capable of transmitting and receiving signals up to distances of 2000 meters. However, it is important to mention that the receiver generates significant heat, so it needs to be mounted away from the propellers for better ventilation. The captured image can be viewed on any smartphone via a micro-USB connector.

## Payload launch and transport system

To achieve the payload transport and release functionality, we utilized a servo motor for which we designed a support structure. Here, we integrated an ESP32, which was employed to control the servo motor from the remote control, based on the commands received through the receiver connected to the ESP32. Figure 11a presents the used servomotor model and figure 11 b) presents the UAV assembly with the mounted payload launch and transport system capable of transporting and a payload of up to 1 kg.

*Fig 9. a) GOPRO setup* *b) GOPRO retrieved images*


*Fig 10. a) FPV setup* *b) FPV image*

## Autonomous flight

The APM 2.8 is equipped with the ability to execute autonomous flights, with the capability to follow planned routes where parameters such as altitude, speed, starting, and stopping points can be set. This functionality is highly valuable in various applications such as mapping, monitoring, or delivery, where precise and autonomous navigation is required. Figure 12 present the integration of this feature and a scenario involving autonomous flight planning for a GPS coordinates defined route.

## Conclusion

Our project successfully integrates multiple electronic elements to create a functional quadcopter equipped with advanced technologies and essential functionalities for contemporary needs. By utilizing components such as APM 2.8, Raspberry Pi 4, ESP32, and GoPro Hero7, we achieved a versatile and efficient

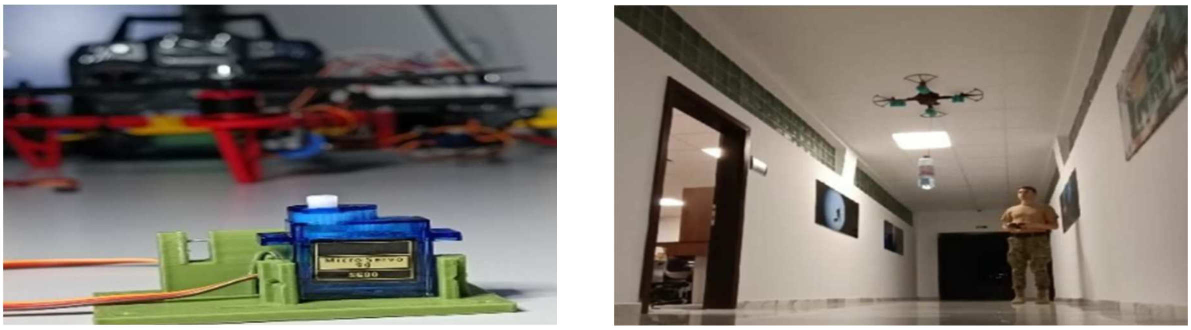

*Fig. 11. a) Servomotor* *b) 1kg payload test*

*Fig. 12. Autonomous flight planning*

system capable of live transmissions, object detection, augmented reality projection, and autonomous flight, bringing the drone to current standards of technology and performance. These functionalities not only add value to the project but also place it at the forefront of technological innovation in the drone field.

The integration of these electronic systems demonstrate the platform versatility and also underscores the potential for broader applications in various industries. The capabilities implemented in our versatile UAV platform have promising implications for fields such as search and rescue operations or environmental monitoring, addressing real-world challenges and marking a step forward in the usage of this technology.

**Aknoledgement**: scientific supervisor: Assoc. Prof. Dr. Annamaria Sarbu

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