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# Development of Surveillance Quadcopter

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## Abstract

This article presents the design and implementation of a surveillance quadcopter for long-term tracking and surveillance applications. The quadcopter is equipped with a high-definition camera and wireless communication that captures live video and sends it to a remote station in real time. The design includes flight control functions based on custom frames, motors and generators, and open flight controls. The system is capable of flying autonomously and can be controlled using a ground station. Monitoring the quadcopter sends real-time information to the control center in real time, allowing operators to react quickly and efficiently. The performance test results show that the quadcopter has stable flight ability and good video recording ability, which is suitable for monitoring application.

## Keywords

Drone orientation, Quadcopter, Surveillance, Flight

## Introduction

The drone industry is one of the future industries with unlimited future potential. Our group plans to use drone (unmanned aerial vehicle, UAV) technology positively because drone is an aircraft that can operate without a human pilot. The growth of small unmanned aerial vehicles (SUAVs) will present new challenges in airspace [1]. To meet these challenges, SUAV air traffic control will require changes to the existing control system for pilots, including a higher level of automation. With the expectation that communication and flight control equipment will be developed in accordance with various regulations to give clear instructions that can be performed on UAVs, it is expected that many UAV operators and companies will want to have the system, allows systems for different uses [2]. The drone's system simultaneously controls and manages the same service. Create a space where drone operators can get more accurate service. Quadcopter use has become popular because of their ability to access hard-to-reach areas and provide a bird's-eye view of the environment. They can fly at high altitudes, maneuver in tight spaces and provide realistic video footage that can be used in a variety of applications. They are also more effective than traditional surveillance such as drones or ground cameras [3, 4].

This article focuses on the design and application of the observation quadcopter with special frames, engines and propellers and flight controls. The system is capable of autonomous flight and can be controlled using a ground station [5]. The report also presents the performance results of the system, showing that the quadcopter is capable of stable flight and good video recording, making it useful for field monitoring application. Drone technology is an effective and reliable method for continuous and precise monitoring of the urban environment through the use of personal drone navigation and photography with little impact on people [6, 7]. UAV platforms have become a popular and effective way of collecting data for interpretation, surveying, environmental mapping and 3D modelling applications. The compact and agile design of quadcopter allows it to navigate tight spaces and overcome obstacles with ease, making it ideal for use in urban environments. Its high-tech equipment and advanced capabilities make it useful for any organization or individual needing weather monitoring and analysis [8, 9]. Whether you want to improve security measures, monitor critical processes or simply capture world-class footage, a quadcopter surveillance drone offers a unique perspective like no other [10].

The UAVs are aerial robots which are self-propelled [11]. They are easily controlled by speed variation of the four rotors [12]. The front and rear rotors (2, 4) rotate clockwise, while the left and right rotors (1, 3) rotate counter-clockwise. This rotation balances the torque produced by the rotor rotors. The up/down motion is achieved by increasing/decreasing the rotor speed while maintaining the same individual speed. Forward/backward, left/right movement is done by different control strategy of rotor speed. Thanks to this configuration, quadrotors can move in small areas, take off and land, and perform tasks that stationary aircraft cannot.

# Experimentation

## Building a surveillance quadcopter

### Kinematic structure

Analyzing the kinematics of the quadcopter whichrefers to the air and motion that allows the quadcopter to move and operate. A quadcopter is a multi-rotor drone powered by four separate rotors. The rotors are mounted on four arms connected to the main shaft. The frame is usually made of heavy materials such as carbon fiber, which makes quadcopters maneuverable and efficient. Each rotor is controlled by a motor that drives the propeller. Flight controls control the speed and direction of the motors. It is a microcontroller board that receives input from ground sensors and commands from the control centre (Figure 1).

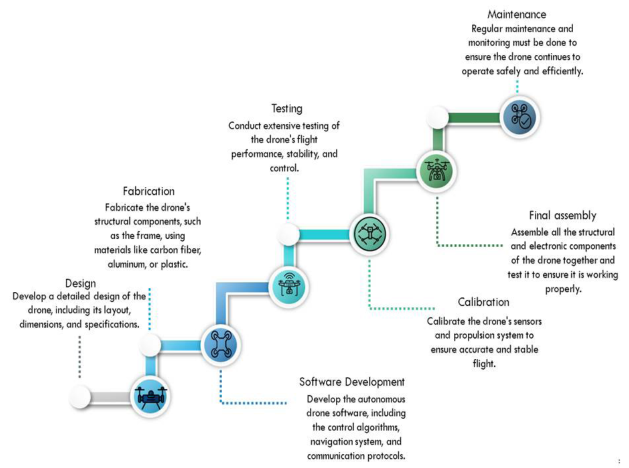


**Figure 1:** Methodology of surveillance quadcopter.

The flight controller is capable of adjusting the speed and direction of the body to maintain stability and control the movement of the quadcopter. Quadcopter's power is obtained by varying the speed and direction of the motors (Figure 2). For example, looking ahead, the motors inside the front of the quadcopter spin quicker than the automobiles within the rear. To rotate, the motors on one facet of the quadcopter spin faster than the automobiles on the other facet. By adjusting the direction and speed of the motors, the quadcopter can move in any direction and rotate around its axis. The model, which follows the movement of a quadcopter, is also equipped with a camera and a wireless system. The camera is mounted on a quadcopter, which is usually stabilized with a gimbal to provide a smooth shot. Wireless communication allows the quadcopter to send video footage to a control centre on the ground, which can be monitored and analysed. Overall, the kinematic design of the observation quadcopter is light, manoeuvrable and efficient, making it possible to perform various observations at different locations.

### Mathematical model of the kinematics

The mathematical model of the kinematics of a surveillance quadcopter is based on the principles of rigid body dynamics and includes equations that describe the quadcopter's motion in terms of its position, orientation, and velocity.

Let's assume that the quadcopter's frame is a rigid body that moves in a 3D space. The position of the quadcopter is described by its Cartesian coordinates (X, Y, and Z) relative to a fixed coordinate system. The orientation of the quadcopter is described by its roll (phi), pitch (theta), and yaw (psi) angles, which determine its attitude with respect to the fixed coordinate system. The quadcopter state variables are listed in under. To manipulate a quadcopter, kingdom area readings are required. For fundamental flight conditions, a kingdom area that completely specifies the six levels of freedom of a quadcopter which is used for following dynamic computations.

The parameters and kinematic equations of the quadcopter: x - inertial position along the axis $x^i$; y - inertial position along the axis $y^i$; z - altitude along the $z^i$ axis; u - body frame velocity along $x^b$; v - body frame velocity along $y^b$; w - body frame velocity along $z^b$; $\phi$ - roll angle; $\theta$ - pitch angle; $\psi$ - yaw angle; p - roll angular velocity ($x^b$ axis); q - pitch angular velocity ($y^b$ axis); and r - yaw angular velocity ($z^b$ axis).

The four motors and propellers are placed in a group m at a distance l from the geometric center of the quadcopter so that all masses (m) are 90° apart from the geometric center

**Figure 2:** Isometric view of the quadcopter.

of the quadcopter. Except for the four motors and propellers, the rest of the quadcopter's fuselage size is MB relative to the quadcopter's geometric area. Suppose the centre of mass m and mass MB is coplanar. The total mass of the quadcopter is thus:

$$M = M_B + 4m$$

Since the dimensions of the quadcopter are negligibly small in compared to the radius of curvature of Earth, it is safe to conclude that the centre of gravity of any part of quadcopter can correspond with the COM of the object.

## Moment of inertia

Using the orthonormal X, Y, and Z axes in figure 3, a symmetric inertia matrix may be defined as follows:

$$J \triangleq ' \begin{matrix} J_{xx} & -J_{xy} & -J_{xz} \\ -J_{yx} & J_{yy} & -J_{yz} \\ -J_{zx} & -J_{zy} & J_{zz} \end{matrix}$$

$$\triangleq ' \begin{matrix} \int(y^2+z^2)dm & -\int(xy)dm & -\int(xz)dm \\ -\int(yx)dm & \int(x^2+z^2)dm & -\int(yz)dm \\ -\int(zx)dm & -\int(zy)dm & \int(x^2+y^2)dm \end{matrix}$$

## Deceleration torque

Due to the wind resistance, the drag vector:

$$\tau_d \triangleq \tau_d^{\,b} = (0, 0, \ \tau_d)$$

Acting on ẑb is added to the model, since the quadcopter will rotate around this axis after losing one or more propellers as used in this project due to windage. This drag vector is modeled experimentally, increasing linearly with the yaw rate.

$$\tau_d = \gamma r$$

Where, $\gamma$ is the drag coefficient. However, this only applies when the angular velocity is very low and there is no turbulence. In this study, it is aimed to try to approximate the force.

$$\tau_d = -\gamma_1 r^2 + \gamma_2 . \text{sgn}(r)$$

Where, "sgn" indicates the signum function. The approximate correlation given by $\gamma_1$ is a particularly supportive hypothesis for angular velocity. Incidentally, if the quadcopter is attached to bearings, $\gamma_2$ is the offset given by the rotational kinetic friction after the static friction of the bearing has been overcome. Without bearings, $\gamma_2$ is simply set to zero.

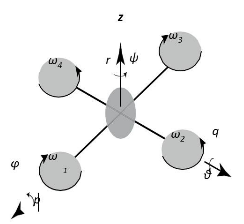

**Figure 3:** Kinematic and dynamic model.

## Hardware and Implementation

A flight controller is a crucial component of a quadcopter that processes sensor data, calculates flight control commands, and communicates with the motors to stabilize and control the drone. The F4 flight controller is a popular model used in quadcopter builds due to its high processing power and advanced features. The F4 flight controller typically consists of a microcontroller unit (MCU) and various sensors, such as an accelerometer, gyroscope, and magnetometer. These sensors provide data on the drone's orientation, position, and velocity, which the MCU uses to calculate the control commands.The MCU of the F4 flight controller is usually a high-performance ARM cortex-M4 processor is clocked at around 168 MHz. This provides the ability to perform complex calculations quickly and process data from multiple sensors in real-time. Overall, the F4 flight controller is a powerful and versatile platform for building high-performance quadcopters with advanced features such as GPS navigation, autonomous flight, and obstacle avoidance.

### Omnibus F4 V3S flight controller board

Omnibus F4 flight controller is a high-performance processor with a 32-bit ARM Cortex-M4 core that runs at 168 MHz (Figure 4). It also has 192 KB of RAM and 1 MB of flash memory, which is plenty of space for storing firmware and flight data. The MPU6000 IMU on the Omnibus F4 is a 6-axis accelerometer and gyro that provides accurate data on the drone's orientation and motion. The BMP280 barometer and HMC5883L compass are also integrated into the flight controller, allowing for altitude hold and navigation capabilities.

### Microcontroller interface with motor

The F4 flight controller interacts with the motors via the Electronic Speed Controller (ESC) connected to the flight control motors. The flight controller sends signals to the ESC, which controls the engine speed and direction. The ESC signal wire is connected to the motor output pin of the flight controller. There are four physical output pins, usually labelled M1, M2, M3, and M4. Connect the power cable from the ESC to the battery or power distribution board (PDB).The ESC takes power from the battery or PDB and supplies it to the motor. Configure motor and ESC settings in flight control firmware. This includes setting the motor output protocol (PWM, Oneshot, DShot), motor idle, and minimum and maximum measurement parameters. Calibrate the ESCs to ensure they are in sync with the flight controls.

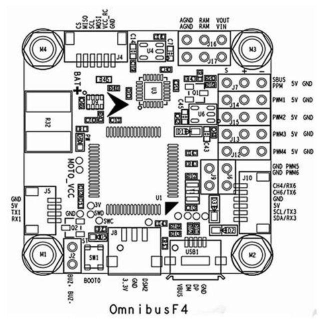

**Figure 4:** Omnibus F4 V3S flight controller board.

The F4 flight control interface performs various calculations to control the movement and stability of the quadcopter. Here are some important calculations performed by the flight controller.

### Orientation estimation

The flight controller uses sensor data from the accelerometer, gyroscope, and magnetometer to calculate orientation of the drone. This includes processing raw data to determine the pitch, yaw and roll angles of the drone used to control the quadcopter during flight.

### PID control

The flight controller uses a proportional-integral-derivative control algorithm to adjust the motor output signal according to the drone's orientation and flight requirements. PID control consistently measures the error in the middle of the current state of the drone and the needed state and adjusts the motor to reduce this error.

### Motor mapping

The flight controller maps the desired motor output to the actual motor output signal based on the motor selection (PWM, Oneshot, DShot). This involves converting the desired motor output value (usually between 1000 and 2000) into a corresponding signal that the ESC can interpret and transfer to the motor and direction.

### Throttle and altitude control

Flight controller uses barometer and GPS data (if available) to maintain constant altitude and throttle control. This includes adjusting the engine output signal to maintain the desired altitude or throttle level based on customer input or flight control algorithms.

### Safety features

The flight controller also includes many safety features such as system failure and disconnection in case of low battery or loss of signal.

These features are designed to ensure that the drone returns to a safe state in the event of an unexpected event. Overall, the F4 flight control interface works hard and keeps the quadcopter stable and functional during flight while still providing good performance and user control.

## Implementation

A quadcopter is a drone that uses four rotors to create lift and control its motion. The motion of the quadcopter is managed with the aid of adjusting the speed and path of the rotors using an ESC related to the flight controller (Figure 5). Here are the steps to use the quadcopter: First step for installing the stepper motor, ESC, flight controller and so on is to choose or build a frame for the quadcopter to mount. The frame must be light and durable and able to support the weight and size of the chosen product. The flight controller is the brain of the quadcopter, which controls the movement and balance of the drone. The flight control system processes sensor data from onboard sensors (accelerometers, gyroscopes, magnetometers, and barometers) and sends signals to the ESC to adjust engine speed and direction. Stability analysis and weather considerations are important when working to monitor a quadcopter and determine flight time.

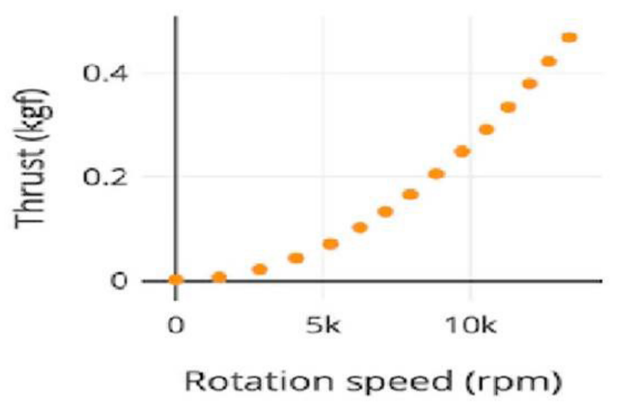

**Figure 5:** Rotation speed vs thrust of quadcopter.

### Stability check

Monitoring the stability of the quadcopter is very important for stable and safe operation. Stability refers to the quadcopter's ability to maintain stable flight and control without being affected by other factors such as wind or wind turbulence. Ensuring stability requires making sure the quadcopter's flight controls, sensors and motors are working properly.

### Safe handling

A stable quadcopter is less prone to movement or collision, reducing the risk of damage to the device itself and injury to neighbours or property.

### Precision surveillance

Stabilization provides smoother and more controllable flight, resulting in clearer video images and more accurate data collection during surveillance missions.

### Long flight time

The stabilized quadcopter uses less energy to maintain stability, providing longer flight times and improved performance.

### Weather considerations

Weather conditions greatly affect the ability to fly a surveillance quadcopter. Factors such as wind speed, precipitation, temperature and visibility affect flight stability, manoeuvrability, and overall safety.

### Flight safety

Bad weather conditions will affect the stability and control of the quadcopter. High winds, rain, fog, or poor visibility can make it difficult to maintain a steady flight or navigation problems, increasing the risk of an accident.

### Equipment protection

Humidity, heat or cold air can damage quadcopter equipment, including electronics and motors. Weather conditions can help protect equipment from damage.

### Good data collection

Certain weather conditions, such as heavy rain or storms, can affect the quality and accuracy of the observation data collected by the quadcopter. Analysis of the weather is necessary to ensure that the data is reliable and valid for the intended purpose.

Flight time = Capacity × Discharge / Average amp draw

The quadcopter requires multiple sensors to provide the flight controller with information about the drone's direction, movement and environment. Sensors include accelerometers, gyroscopes, magnetometers, and barometers. Some quadcopters also include GPS sensors for heading and altitude. Quadcopters requires a power source such as a lithium polymer battery or PDB to power the ESC and motor. The choice of battery or PDB should be based on the power requirement of the engine and the required flight time. They also need a remote control so that the user can access and control the movement of the drone. The remote control usually includes a transmitter, receiver and antenna.

## Operation

Once all parts have been selected and installed, the quadcopter should be tested in a safe, open environment to ensure proper operation and stability. Care must be taken when selecting, installing and testing products to ensure proper performance and safety.

### Initialization

The quadrotor appears to start up by turning on the power and starting the flight control.

### Take-off

The quadcopter will take off and glide in a fixed position, waiting for user input.

### User input

The user provides input from a remote control or other device to control the movement and behavior of the quadcopter.

### Flight control

The flight controller processes user input and sensor data to adjust the quadcopter's movement and stability. This includes adjusting the motor output signals according to the desired flight behavior and direction of the drone.

### Camera and sensors

The quadcopter includes a camera and other sensors that provide information about the drone's surroundings and surroundings. The camera can be controlled by the user to adjust the viewing angle and zoom level.

### Video transmission

Transmission of camera data to a ground station or other equipment for monitoring and real-time monitoring. Videos can be exported or saved for later review.

### Flight plan

A quadcopter can be operated using a flight plan to follow a particular path or direction.This is useful for surveying large areas or following a particular path.

### Return and learning

The quadcopter has a return function, if the signal is lost or the battery is low, the drone can return to the starting point. The quadcopter lands safely and takes off to finish the run.

Nanotechnology-based quadcopters are still in development, but they have the potential to change the way we use drones. Using nanomaterials and nanotechnology, a smaller, lighter, stronger and more efficient drone can be created. Drones are already providing the users with visibility and mobility that would otherwise be impossible, from inspecting wind turbines and construction sites to flying over burning buildings or rain damage from power outages. However, poor movement control reduces their effectiveness.

### Making gyroscopes more accurate

Gyroscopes are an important part of drone technology. Without accurate readings, drones cannot function properly, so the real challenge is measuring the size and accuracy of the gyroscope. The researchers have developed a nanoscale optical gyroscope that uses tiny tubes to eliminate noise and accurately identify tiny patterns. As a result, their devices are 500 times smaller and 30 times more sensitive than standard gyroscopes. Highly visible microscopic changes help drones adapt with minimal impact. This technology allows drones to maintain balance in various situations and perform more efficient and precise manoeuvrability. Drone technology will become more versatile.

### Making small motors

Nanotechnology can improve drone motion control by using smaller motors. While larger motors can provide more power to the rotors, they also increase its weight, making it more difficult to handle the manoeuvrability. Nanotechnology eliminates this problem by delivering comparable energy in smaller packages. Materials differ from the nanoscale in which they are generally stronger, flexible, or better conductors. Engineers can use this knowledge to create machines that are more efficient and lighter than larger machines. For example, they can build an engine that starts and stops in milliseconds, which would not be possible on a larger scale. As nanotechnology advances, drone engines will continue to become smaller without sacrificing power. The device will then be able to operate in many planes of motion without any error.

### Reduce movement

Similarly, nanotechnology can eliminate the movement of many drones. For example, an electric motor company named Nano motion used piezoelectric technology to create an electric motor for a micro drone with no moving parts. The piezoelectric effect creates mechanical stress in the presence of an electric field, resulting in force in the absence of any other movement. Eliminating the gimbal movement can improve drone control in two important ways. First, it reduces the weight of the engine because the machine requires less to do the same job. Secondly, it reduces the risk that the movement of the motor will affect the movement of the rotor. With less movement under the rotor, the drone will hold its position more easily. They can also be faster and more agile, allowing drone operators to control them more.

### Temperature control

Nanotechnology can also solve less visible problems affecting drone control. Although heat does not appear to directly affect movement control, it can have a significant impact on it. Temperature fluctuations can cause thermal drift in mechanical components, resulting in operational errors. Nanotechnology can solve this problem by taking advantage of the different properties of nanometre materials. Some nanomaterials are more heat resistant or retain their properties at different temperatures. Therefore, engineers can use them to design electronic devices and devices that are less prone to thermal drift. Another way to use the piezoelectric effect, piezoelectric controllers reacts to temperature changes and adjusts accordingly, ensuring all components work as they should. Thanks to these systems, drones can move in the airspace without disrupting the operation.

### Fast reaction time

Latency is an important aspect of drone motion control that nanotechnology can improve. The delay between the operator entering a command and the drone executing it affects the drone's results. Nanotechnology can reduce this delay, providing instant feedback for better management. Nanomaterials such as graphene and carbon nanotubes can provide special electromagnetic properties to antennas. This could make them more sensitive to wireless signals, help them process signals faster, or extend their range.

### Increase battery life

Nanotechnology can also improve drone control by affecting drone battery life. Although some drones today can fly as fast as 50 miles per hour, they can only go so far before their batteries run out. As the battery depletes, reaction time will decrease and intense work may drain the battery, causing the flight to end early. Nanomaterials extend battery life, allowing drones to accelerate and rotate quickly without depleting their volume. Graphene can increase the storage capacity of batteries and make them lighter by increasing their size. Although the flight time varies between five minutes, the drone will be more useful for planning or emergency services. Long-life batteries will also reduce concerns about late intervention failures during flight. Drones can fly longer without antennas and power and maintain fast response time.

### Use new controls

Most drones today are operated by remote control, but nanotechnology can open the door to new opportunities. With more ways to control drone movement, operators can control them more accurately. Nanomaterials pave the way for electrodes that can capture signals such as muscle contractions and convert them into commands. Some materials can also create brain-computer connections, allowing operators to control drones with their future thoughts. These new controls could make it easier for drones to do their job. They are also opening up drone operations to a wider audience. For example, people with musculoskeletal disorders that prevent manual labor can control drones with their thoughts.

## Results and Discussion

This article describes the design (Figure 6 and figure 7) and content of the current application. Quadcopters can be used in areas where it is difficult for people to reach and where there are many obstacles (Table 1). They can be used to get drivers and their car licenses, detect ATM thieves, fight flies, dispose of trash and manage waste. Many countries have laws and regulations governing the use of quadcopters. These regulations often contain restrictions on the general scope of the general rule, general aviation is spread all over the world, and compliance with these regulations is important to ensure safety and is the responsibility of monitoring quadcopters. They can quickly and efficiently capture visual information, identify process issues, and monitor maintenance needs without the need for manual inspection. As with any technology, there is the potential for abuse or unauthorized access to surveillance quadcopters. To ensure responsible use of these devices, appropriate security measures should be taken to prevent unauthorized control or disclosure of information.

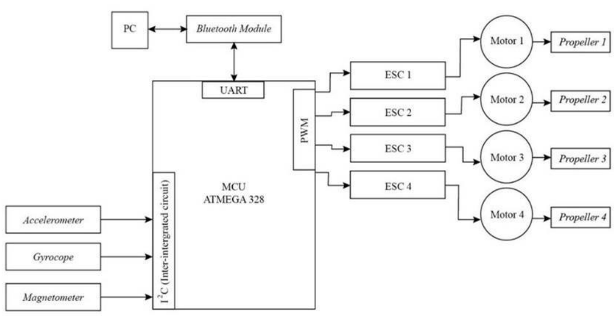


**Figure 6:** Block diagram of quadcopter.

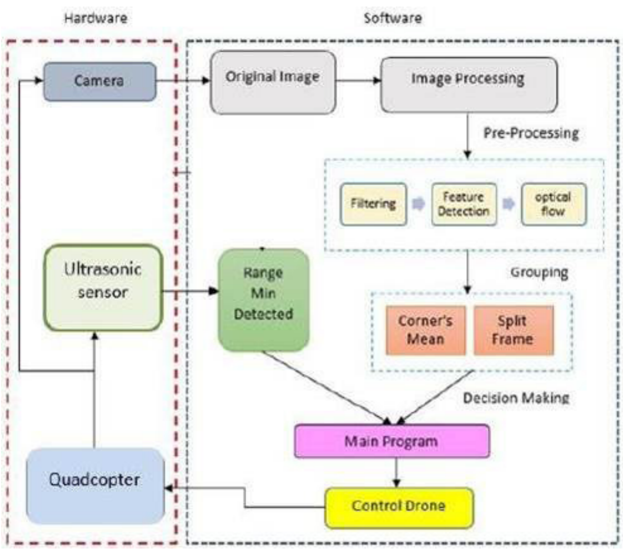


**Figure 7:** Flow chart of quadcopter.

**Table 1:** Quantitative analysis of surveillance quadcopter.

| S. No. | Metric | Value |
|---|---|---|
| 1 | Flight time | 45 min |
| 2 | Maximum speed | 40 mph |
| 3 | Range | 3 miles |
| 4 | Camera resolution | 12 MP |
| 5 | Live video transmission | Yes |
| 6 | Object tracking accuracy | 98% |
| 7 | Noise level | 55 dB |
| 8 | Weight | 1.5 Kg |
| 9 | Dimensions | 30 cm x 30 cm x 15 cm |
| 10 | Battery capacity | 5000 mAh |
| 11 | Battery charging time | 2 h |
| 12 | Control range | 1.5 miles |
| 13 | GPS accuracy | ±2 meters |
| 14 | Max wind resistance | 25 mph |
| 15 | Obstacle avoidance sensors | Yes |
| 16 | Data storage capacity | 64 GB |
| 17 | Video recording resolution | 4K Ultra HD |
| 18 | Gimbal stabilization | 3-axis |
| 19 | Communication frequency | 2.4 GHz/5.8 GHz |
| 20 | Live video transmission range | Up to 1 mile |
| 21 | Real-time telemetry data transmission | Yes |
| 22 | Operating temperature range | 0 °C to 40 °C (32 °F to 104 °F) |
| 23 | Return-to-home function | Yes |

# Conclusion

Surveillance quadcopters are important tools for many applications that provide detailed information and images, reduce the resources and time required for certain missions, and increase security in certain areas. They expand creative possibilities and facilitate access to inaccessible areas. In addition, hobbyists and enthusiasts will enjoy playing drone flight, capturing stunning visuals and exploring new flight perspectives. However, the use of quadcopters must be legal and ensure the safety of people and objects in the vicinity of the drone. Careful attention should be paid to the protection of privacy, security controls, and prevention of abuse. Striking a balance between the benefits and risks associated with maintaining quadcopters is important to keep them responsible and ethical in society. Ongoing discussions, technological advances and changing regulations will play an important role in shaping the future of this rapid revolution.


# Acknowledgements

None.

# Conflict of Interest

None.


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