Efficient Route Planning and Navigation in Drones Using Pixhawk Autopilot

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***Abstract*—The Pixhawk quadcopter drone is a highly adaptable and customizable drone system utilized globally in various applications, including national security, aerial mapping, surveillance, and exploration. Its open-source nature and community-driven approach enable users to customize the drone according to their own requirements. With its advanced features such as GPS tracking, a sophisticated camera system, and real-time monitoring functions, the Pixhawk drone is well-suited for activities including surveillance, infrastructure inspection, and search and rescue missions. Its capacity to navigate through densely populated metropolitan areas and provide superior aerial video and high-quality footage makes it an ideal solution for a range of users worldwide. The system architecture involves a comprehensive review of existing literature, case studies, and practical examples from leading autonomous Pixhawk drones. A structured framework is proposed for mapping areas, flying to a point, returning to the automatic starting point, and continuous monitoring capabilities. The study highlights the practical implications of implementing Pixhawk quadcopter drones. The drone's system architecture is based on the open-source flight controller, Pixhawk, which supports multiple flying modes and enables precise capturing of human pilot data.**

***Index Terms*—Pixhawk, Autonomous drone, UAV, Mapping, Pixhawk Drone, Agriculture Drone, Navigation, GPS.**

I. Introduction

The Pixhawk quadcopter drone is a major force in many different worldwide applications. Its community-driven approach, open-source nature, and customizability are key strengths. Projects like the construction of Sierra Leone's first drone port, where Aurelia Aerospace customized drones for the transport of medical supplies, utilized Pixhawk quadcopters. Open-source applications such as PX4 or Arduino Pilot are based on the intended use of the drone. The Pixhawk quadcopter's adaptability and customization make it a desirable option for a range of users globally. Pixhawk quadcopters are extensively utilized in national security for various purposes, such as aerial photography, search and rescue operations, and surveillance. The ability of Pixhawk quadcopters to navigate through crowded metropolitan areas and deliver high-quality aerial footage is the most crucial feature of deploying them in Bangladesh. The Pixhawk quadcopter is a cutting-edge drone system, intended for sophisticated aerial mapping, reconnaissance, and exploration. With a GPS tracking system, a sophisticated camera system, and a reliable communication system, the drone can record video in real time, take pictures, and perform real-time monitoring functions. Users may plan and carry out drone missions, watch live video, and retrieve photos using the Pixhawk drone. The user uses the Pixhawk program to plan drone mission regions of interest, establish way-points, and configure the camera settings. Using its sophisticated camera system, the drone flies over the scene, taking pictures and videos. GPS tracking technology is used for drone takeoff and navigation, providing precise position data that enables the user to follow along with its flight route and progress. The drone flies from the designated starting point in the mapping region to the designated ending point and returns. The Pixhawk drone has the option to function in spy mode, which enables it to fly covertly and take pictures. The drone is equipped with a high-resolution camera capable of taking stunning pictures and videos from the air. Mechanisms for controlling flight ensure that Pixhawk quadcopters fly steadily and precisely, even under inclement weather conditions. Advanced sensors found in the system include barometers, gyroscopes, and accelerometers. For various applications, including infrastructure inspection, environmental monitoring, real-time live streaming, and photo capture, Pixhawk quadcopters are an ideal solution. Pixhawk quadcopters are used both domestically and internationally, having a significant impact on many different industries. They can also be used for firefighting purposes, and their design and configuration allow for effective firefighting operations.

II. Literuter Review

Provide a novel hardware and software system for micro air vehicles (MAV) that allows high-speed, low-latency on-board image processing. [1] The MAV navigates based on onboard processed computer vision in GPS-denied in- and outdoor environments. The quad-copter is developed and it is controlled remotely from a ground control station utilizing [2] RASPBERRY PI and GPS is used to trace the location of the drone. A quad-copter, which is fit for payload conveyance, will be planned. A quad-copter is a one of a kind Unmanned Aerial Vehicle (UAV) which has the capacity of vertical take-off and landing. Drone ranges from 500 grms to 1-kg of weight depending upon the number of motors used whereas quad-copter can weigh up to 500 grms. The time and energy consumption will be saved. Drone is the other name of the unmanned aerial vehicles; they are small aircraft that fly by them. Unmanned aerial vehicles (UAVs) are a type of unmanned aircraft. [3] The unmanned aircraft system (UAS) consists of a UAV, a ground-based controller, and a communication system between the two. Drone can fly with various angle with autonomously and also with the help of human under control of remote. The Pixhawk PX-4 autopilot used in unmanned aerial vehicle Skydog, while in the introduction describes motivation and reasons for a research and an analysis. Based on connections to external devices and knowing the principle of communication between processes and applications. [4] The synergy between cutting-edge technology and innovative flight control systems has transformed unmanned aerial vehicles (UAVs). At the core of this revolution is the Pixhawk Flight Controller—an open-source platform redefining drone capabilities across industries. Pixhawk, prized for its precision and adaptability, orchestrates complex manoeuvres and ensures flight stability. It supports Beyond Visual Line of Sight (BVLOS) operations. Unmanned Aerial Vehicle (UAV) quadcopter is a copter with four driving motors. Unmanned Aerial Vehicle (UAV) quadcopter is a copter with four driving motors. The trajectories are predetermined in accordance to the landforms and the quadcopters are expected to follow these trajectories autonomously. [5] While aerial photography continues to play an integral role in forest management. The automatic return-to-home feature on the drone is crucial when operating in a woodland landscape. Photogrammetry and aerial photo interpretation have been used in forest management since aerial photography became available to foresters. A single frame of aerial [6]photo was used for forest type classification and land area estimation, while a pair of aerial photos viewed through a stereoscope added the 3rd dimension for tree height measurement. There are too many technologies involved in today's Agriculture, [7] out of which spraying pesticides using drones is one of the emerging technologies. This paved the way to design a drone mounted with a spraying mechanism having 12 V pump, 6 Litre storage capacity tank,4 nozzles to atomize in fine spray [8] , an octocopter configuration frame ,suitable landing frame, 8 Brushless Direct Current (BLDC) motors. The process of integrating one of the most commonly used laser methane detectors, the Laser Methane mini (LMm), and a multi-rotor unmanned aerial vehicle (UAV) based on the Pixhawk flight controller to create an unmanned aerial system designed to detect methane leakages from the air. The transmission of data from the UAV is carried out in real time. [9] The purpose of this research is to illustrate the potential for simplifying and reducing the cost of using UAS to study methane emissions. A comprehensive survey on anti-drone systems. After drones were released for non-military usages, drone incidents in the unarmed population are gradually increasing. categorized anti-drone technologies into detection, identification, and neutralization, and reviewed numerous studies on each. drone-side safety and security schemes that could nullify current anti-drone methods, and propose future solutions to resolve these challenges. [10]

III. System Architecture

Autonomous drone with Pixhawk quadcopters system architecture is provided here: Due to the flexible, adaptable, and adjustable structure of the Pixhawk system architecture, customers may quickly connect and alter different components to meet their unique requirements. It is necessary to comprehend the system architecture and important interfaces in order to create and integrate systems that utilize Pixhawk drone technology.

A. Component:

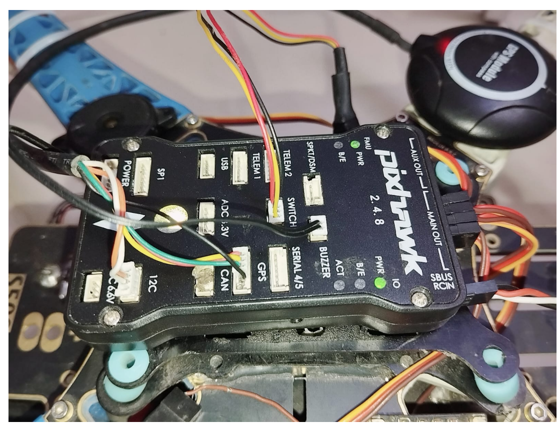

Fig. 1. Pixhawk Quad-copter Model

1) **Pixhawk 2.4.8 Model:** The Pixhawk 2.4.8 is a popular open-source flight controller model designed for autonomous vehicles, including drones, fixed-wing aircraft, and other unmanned aerial vehicles (UAVs).
2) **BLDC Motor:** A brushless DC (BLDC) motor is an electric motor that operates using a direct current power source and is electronically controlled instead of through mechanical commutation. In contrast conventional DC motors that have brushes, BLDC motors utilize permanent magnets in the rotor and electronic control to reg-

ulate the current passing through the stator coils. Compared to brushed motors, this design provides increased efficiency, extended lifespan, and superior control.

3) **ESC:** An ESC (electrical Speed Control) wire is utilized in remote controlled vehicles and drones for the purpose of governing and managing the speed of the electric motor. The ESC links the motor to the battery and receiver, interpreting signals from the receiver to control the speed and direction of the motor. Usually, an Electronic Speed Controller (ESC) involves three sets of wires.
   - The ESC with the battery. Typically, these cords are thicker and come in different colors for easy identification (red for positive, black for negative).
   - The ESC to the motor. Usually, there are three wires, which are commonly colored blue, yellow, and white, or a mix of these colors.
   - Establish a connection between the ESC and the receiver.
4) **Lithium Polymer 12 V battery:** A 12V lithium polymer (LiPo) battery is a rechargeable battery frequently utilized in electronic devices that need high energy density, lightweight design, and flexibility. This type of battery is commonly found in drones, RC vehicles, and portable electronics. Below are the main features and attributes:
   - The standard voltage for one individual LiPo cell is 3.7V. A 12V LiPo battery usually comprises three cells connected in series, resulting in a nominal voltage of 11.1V (3.7V x 3) and a fully charged voltage of approximately 12.6V (4.2V x 3). The capacity of a LiPo battery is determined by the amount of charge it can store, measured in milliampere-hours (mAh) or ampere-hours (AH).
   - The discharge rate of LiPo batteries is determined by their ”C” rating, such as 25C or 50C. This rating indicates the speed at which the battery can be drained.
   - A higher C rating indicates that the battery is capable of delivering a greater amount of current without sustaining any harm. LiPo batteries come in a range of sizes and weights, which makes them ideal for various applications where space and weight are important considerations.
5) **Quad Ground Control (QGC):** The Quad Ground Control system is a complete solution created to oversee the management and operation of unmanned aerial vehicles (UAVs) or drones. It usually consists of software and hardware elements that enable operators to manage flight routes, monitor live data, and guarantee the secure operation of drones. This system is crucial for tasks like monitoring, creating maps, and delivering goods, offering a user-friendly platform for accurate control and analyzing data.
6) **Signals:** Pixhawk is a sophisticated autopilot hardware system that is open-source and utilized in drones and other unmanned vehicles. The LED indicator lights on a Pixhawk autopilot convey crucial information regarding the drone’s condition. Below is a broad overview of the usual meanings associated with the yellow, green, and red signals:
   - Flashing yellow: This is typically a sign of a failure in the pre-arm check process. The drone is unable to arm and take off at the moment due to a problem. For example, it may not have successfully obtained a GPS signal, or there could be errors with other sensors that need to be fixed first.
   - Solid Yellow: This could mean that the system is starting up or in a standby mode, waiting for a GPS signal or other necessary steps to be finished. A flashing red light means there is a serious issue or malfunction. It could indicate a depleted battery, a malfunctioning sensor, or other important problems that require prompt action.
   - Solid Red: This typically signifies a significant issue, and it is recommended not to fly the drone until the problem is fixed. It could also occur during firmware updates or when the system is rebooted. It is advisable to consult the documentation for the particular version and configuration of Pixhawk system being used, as the interpretation of LED signals may differ depending on the firmware and setup employed (such as PX4or ArduPilot).
7) **Memory Card** A memory card is a compact, portable tool for saving information like pictures, videos, paperwork, and various types of files. They are frequently utilized in electronic products such as cameras, smartphones, tablets, and gaming consoles. Some common varieties of memory cards are SD (Secure Digital), microSD, CompactFlash, and Memory Stick. Memory cards are available in different sizes, usually ranging from a few gigabytes to several terabytes, enabling a large amount of data storage in a small and portable format.
8) **GPS:** Pixhawk is a widely used autopilot system in self-navigating drones. It works together with GPS to allow for accurate navigation and positioning features. GPS enables the drone to pinpoint its precise location anywhere in the world by utilizing signals transmitted from satellites. This information is extremely important for autonomous drones because it enables them to effectively navigate, adhere to planned flight routes, and carry out tasks like aerial mapping, surveillance, or delivery with precision and dependability.
9) **Remote Control:** Controlling an autonomous drone with Pixhawk usually requires using a ground control station (GCS) to observe and manage the drone’s flight. Below are some of the main features and functions commonly seen in these types of setups:
   - Telemetry and Communication: The remote control enables two-way communication with the drone

using telemetry connections. This encompasses getting live updates on the aircraft's altitude, speed, GPS coordinates, battery life, and sensor measurements.
- Flight Planning and Mission Management involves using GCS software such as Mission Planner or QGround Control to plan autonomous missions, setting waypoints, altitude, speed, and actions to be performed at each point, such as taking off. Tracking and Management: The remote allows for visual monitoring of the drone's condition and the ability to make real-time adjustments to its flight settings. You are able to alternate between manual control (RC mode) and autonomous mode as required.
- Safety and Emergency Features: This includes safety mechanisms, such as fail-safe modes (like Return-to-Home), that will automatically guide the drone back to its starting point if communication is lost or significant errors occur.
- Data Logging and Analysis: The remote control enables the recording of flight data to be reviewed later to assess performance, identify issues, and enhance mission effectiveness.
- Payload Management:In some cases, may have the capability to remotely control functions of the payload.

10) **BLDC DJI 2212 Model:** The DJI 2212 is a popular brushless Dc (BLDC) motor model used in various application, including drones. Its a high efficiency and reliability.

B. Block Diagram

This block diagram provides a high-level overview of the Pixhawk quad-copter's components and their interactions. provide a brief description of each component of the Pixhawk quadcopters. The figure consists of several rectangular blocks, each of which stands for a distinct system or component:

- GPS stands for Global Positioning System, which offers navigation and positional data.
- Telemetry is the control of data transfer and communication between the Pixhawk and other systems.
- Camera is most likely in the role of capturing visual information.
- Buzzers are typically used for signals or alerts that can be heard.
- Controlled by the ESC (Electronic Speed Controller). The graphs show four different ESCs.
- There are four motors present, which are potentially responsible for any of the system's acceleration or movement.
- The receiver gets signals from other sources, such as external sources or remote controls.
- Pixhawk seems to be the main control unit; it appears to be responsible for organization and handling data from other parts.
- The battery supplies the system with its whole power.

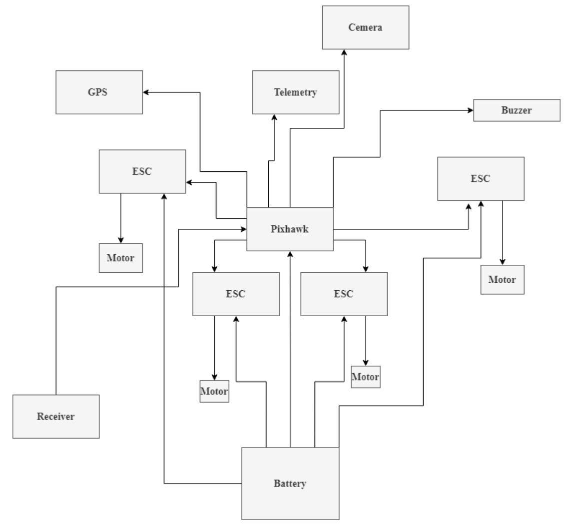

Fig. 2. Block Diagram

C. Flowchart Diagram

The sequential procedure that is illustrated in the figure most likely outlines the operation of an autonomous drone. It begins with the start and moves through a number of phases until arriving at the end. There are a few points of decision-making and concurrent operation:

- Initialization loads the mission and initializes sensors such as the GPS, accelerometer, and camera to set up the system.
- Flight control oversees landing, takeoff, navigation, and avoiding obstacles. Makes use of GPS data to determine location and distance. Uses motor control to drive movements.
- Sensor Processing manages sensor data, possibly performing image processing and sensor fusion.
- Mission control oversees the whole mission, including the taking of pictures and the completion of mission objectives and other elements.
- Pixhawk framework is probably the system's fundamental piece of hardware or software point of guidance.
- Waypoints provides previously specified paths for the vehicle to navigate.
- Altitude and speed are two variables that are managed during flying.
- Distance next way-point navigating information.
- Execution the mission with predetermined objectives, safe landing.
- System termination.

D. Software Tools

The Mission Planner is a software Component of the Pixhawk quad-copter drone system. Responsible for planning

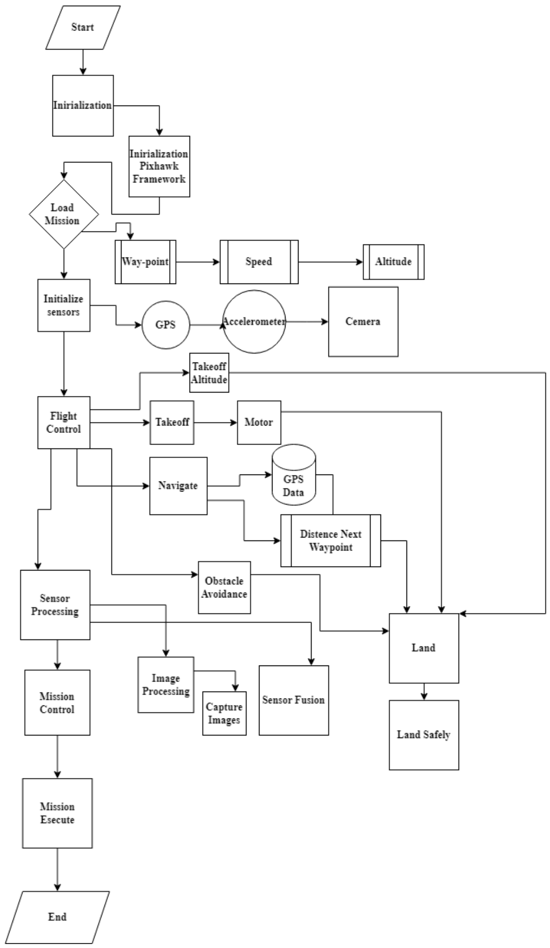

Fig. 3. Flow Chart

and executing drone missions. It is a user-friendly interface that allows operators to design, plan, and monitor missions in real-time.

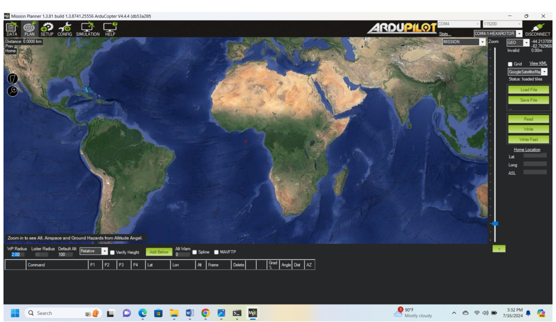

Fig. 4. Mapping View

The image depicts a typical view of the Mission Planner software, likely used for planning and managing drone flights. The map-centric interface and various tools suggest its role in mission setup and execution.

The image depicts a typical view of the Mission Planner software used for planning and managing drone flights. The

Fig. 5. Data View

map-centric interface and various tools suggest its role in mission setup, monitoring, and execution. The ”DISARMED” status indicates that the drone is currently grounded and not ready for flight.

E. Calculation

The overall weight of the drone is calculated by adding the total weights of components and the weight of the payload. Per Motor full Thrust 100 percentage Achieved 1.5kg load 50 percentage Thrust load 800gm. Total capacity of Four Motor 1.5*4= 6kg, Drone Total weight 2.5kg and carry 500 gm water=3kg

IV. RESULT

Total Outcome: Carrying 500g of water, taking pictures, spying, live broadcasting, and waypoint landing. A single drone cannot have all of these features without careful design and system integration. A high-level summary of how to accomplish each of these features is provided below: Parts and Configuration Drone Frame: Select a frame that can hold the additional payload (500g of water) and the combined weight of all the components. Flight Controller: For stability and sophisticated features, use a Pixhawk flight controller. GPS Module: Required for waypoint landing and self-navigation. Camera: A module with a camera for taking pictures and live broadcasting. Make sure it has a stabilizing gimbal. Wireless Transmission Module: Use a wireless transmission solution that is compatible with the camera for live streaming. Payload Delivery Mechanism: Create a system that can hold and release the water payload of 500g. Features Integrate a camera with a live video transmission system to enable live streaming. Utilize a ground station display and receiver that are suitable. Set up the camera to capture crisp, high-definition images. Set up controls to operate the camera remotely or at specific locations. Use the live streaming and photo capture features for surveillance (spying). Ensure the drone can hover steadily for clear footage. Additional Considerations Ensure the drone's structure and motors can support the added weight of the payload. Waypoint Navigation and Landing: Use the GPS module and Pixhawk flight controller to create waypoints. Set up autonomous flight paths and precise landings at predetermined destinations. Use software like Mission Planner or

QGroundControl to configure the Pixhawk.By carefully combining these parts and features, you can build a multipurpose drone capable of live broadcasting, photo taking, surveillance, payload carrying, and self-navigation to destinations. Ensure thorough testing and calibration for optimal results.

A. Drone Flying Graph Chart Accuracy:

Table-1 shows data related to landing accuracy with varying parameters, Distance from the target ending position Actual landing distance from the target position Time taken Payload weight Accuracy of Landing Percentage accuracy with carrying 500 gm water.

Table-1					
SL	Target Ending PositionDistence (m)	Target position landing distance (m)	Time (Sec)	Payload (m)	Accuracy of Landing
1	500	0.21336	60	500	92%
2	500	0.27432	65	500	89%
3	500	0.3048	70	500	85%
4	500	0.4572	75	500	83%
5	500	0.762	80	500	75%
6	500	0.9144	85	500	70%

Fig. 6. Drone Landing position Distance Table

The graph presents data related to landing accuracy, comparing six different series (Series1 to Series6) across various parameters. The x-axis displays the parameters, while the y-axis represents percentage values, likely indicating accuracy levels.

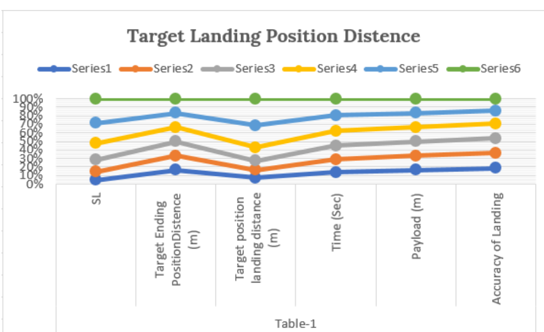

Fig. 7. Drone Landing position Distance Graph

Table-2 shows data related to landing accuracy with varying parameters, Distance from the target ending position Actual landing distance from the target position Time taken Payload weight Accuracy of Landing Percentage accuracy without carrying 500 gm water.

Table-2					
SL	Target Ending PositionDistence (m)	Target position landing distance (m)	Time (Sec)	Payload	Accuracy of Landing
1	500	0.1524	60	0	90%
2	500	0.27432	65	0	89%
3	500	0.3048	70	0	85%
4	500	0.4572	75	0	83%
5	500	0.762	80	0	75%
6	500	0.9144	85	0	70%

Fig. 8. Drone Landing position Distance Table

The graph shows significant variations in performance across the different series and parameters.Series 6 consistently shows the highest values across all parameters. Series 1 and Series 2 generally have lower values compared to the other series. There are noticeable differences in performance between the series for each parameter The graph provides a visual comparison of performance for six different series across various parameters related to landing position distance.

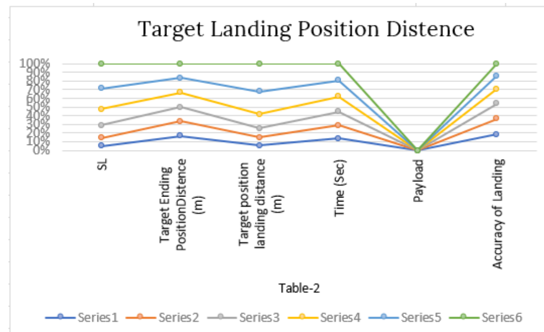

Fig. 9. Drone Landing position Distance Graph

V. Discussion and Conclusion

A Pixhawk quadcopter is an advanced and adaptable drone system that provides a number of benefits for different uses. The following comprehensive conclusions address the features, advantages, and factors to be taken into account when utilizing a quadcopter piloted by a Pixhawk Superior Flight Control Precise control over the drone's motions is made possible by the Pixhawk flight controller, which guarantees steady and seamless flights. It is compatible with waypoint navigation, loiter, and follow-me autonomous flying modes. Adaptable Firmware Due to its compatibility with open-source firmware such as PX4 and ArduPilot, the Pixhawk can be extensively customized to fulfill unique requirements. Through intuitive software interfaces, users can customize mission planning, safety features, and flight characteristics.Integration of Sensor Numerous sensors, like as GPS, IMUs, magnetometers, barometers, and range finders, can be integrated with the Pixhawk to improve situational awareness and navigation accuracy. Versatility of Payload The quad-copter's architecture allows for the integration of many payloads, including cameras, LiDAR, and other sensors, which makes it appropriate for a range of uses, including aerial photography, surveying, and inspections. Instantaneous Communication Pixhawk quadcopters with FPV and telemetry systems can send live video and data streams to a ground station for real-time control and monitoring. Effectiveness and Automation The ability to fly autonomously eliminates the need for human control, allowing for reliable and effective completion of routine duties. Pre-programmed flight paths facilitate accurate and consistent mission performance. Dependability and SafetyFlight safety is improved by sophisticated failsafe mechanisms and obstacle avoidance algorithms. Systems with redundant parts, like dual GPS, are more dependable and less likely to malfunction. Personalization and Adaptability Because the Pixhawk ecosystem is open-source, users can modify it to suit their own needs, whether they be for professional or hobbyist projects. Easy upgrades and the integration of new technologies are made possible by modular architecture. A Pixhawk quadcopter takes technical expertise and experience to set up, calibrate, and maintain. To effectively utilize the capabilities of the system, users must be conversant with the software tools and configuration procedures. Adherence to Regulations When using a Pixhawk quadcopter for business, it's important to follow local aviation laws and secure the required permits. Users are required to ensure responsible data collecting during operations and to be mindful of privacy rules. First Invested Although purchasing a Pixhawk flight controller, suitable sensors, and other parts can be expensive, the long-term advantages in terms of performance and adaptability make it worthwhile. For a variety of aerial applications, Pixhawk quadcopters offer a strong and versatile platform. They may be used for both professional and recreational purposes thanks to their adjustable firmware, sensor integration, and superior flight control. Although the system necessitates a certain degree of technical proficiency and regulatory knowledge, its advantages in automation, safety, and adaptability make it an invaluable resource for anybody wishing to utilize drone technology for a variety of applications.

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