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AUTONOMOUS AERIAL MINEFIELD RECONNAISSANCE AND EXPLOSIVE ORDNANCE DETECTION SYSTEM

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ABSTRACT

The goal of the article "Autonomous Aerial Minefield Reconnaissance and Explosive Ordnance Detection System" is to offer a secure, dependable, and effective way to find landmines and unexploded explosive ordnance in dangerous areas. The system conducts airborne surveillance and reconnaissance activities using an unmanned aerial vehicle (UAV) outfitted with sophisticated sensors, GPS navigation, wireless communication modules, cameras, and metal detecting technologies. In order to scan vast regions and spot potentially dangerous metallic items or explosive materials concealed beneath the earth, the drone autonomously follows a predetermined flight route. Real-time transmission of the sensor data and photographs is made to a ground monitoring station for observation and analysis. The system helps reduce human involvement in dangerous minefield inspection activities, thereby improving the safety of military personnel and civilians. The integration of thermal sensing, obstacle avoidance, and automated navigation improves detection accuracy and operational efficiency in difficult terrains and remote locations. The proposed system can be effectively used in border security, military surveillance, disaster-affected regions, and humanitarian demining operations. The project offers a modern and cost-effective approach for reconnaissance and explosive detection while minimizing operational risks and reducing mission time.

***Keywords* -** Autonomous UAV, Minefield Reconnaissance, Explosive Ordnance Detection, Landmine Detection, Thermal Sensing, GPS Navigation, Metal Detector, Wireless Communication, Obstacle Avoidance, Aerial Surveillance, Embedded System, Humanitarian Demining.

I. INTRODUCTION

An sophisticated unmanned aircraft system called the "Autonomous Aerial Minefield Reconnaissance and Explosive Ordnance Detection System" was created to find landmines, unexploded ordnance (UXO), and improvised explosive devices (IEDs) in dangerous areas. For precise threat detection, the system employs a UAV equipped with sensors including metal detectors, thermal imaging cameras, hyperspectral sensors, and ground-penetrating radar. By using GPS, IMU, and obstacle avoidance techniques, autonomous navigation is made possible, allowing the drone to function in challenging environments without constant human supervision. Remote monitoring and danger visualization on digital maps are made possible by real-time data transmission and geospatial mapping. The method enhances operating safety, speed, and efficiency while lowering human exposure to hazardous minefields. detection efficiency. Lightweight construction, energy-efficient battery management, and modular sensor integration enhance flight endurance and adaptability. The proposed system can be used in military operations, border security, humanitarian demining, disaster management, and search-and-rescue missions, contributing to safer and more efficient explosive detection operations.

II. OBJECTIVES

• To Find Explosive Ordnance and Landmines
• Lower Human Risk in Dangerous Areas
• Offer autonomous aerial surveillance
• Include GPS-Based Location Monitoring

III. SYSTEM OVERVIEW

An innovative UAV-based platform called the Aerial Minefield Reconnaissance and Explosive Ordnance Detection System was created to safely and effectively identify explosive threats and landmines in dangerous areas. To lower human danger during reconnaissance missions, the system combines drone technology, thermal imaging, sensor fusion, wireless connection, and cognitive processing. Survey routes and waypoints are created and uploaded to the UAV flight controller during mission planning, which is the first step in the operation. During operation, autonomous navigation, steady flying, and precise location are provided by the GPS, IMU sensors, and flight controller.

A thermal camera, an ESP32 camera module, and a metal detector magnetometer are among the sensors carried by the UAV platform. Abnormal heat signatures from buried explosives are detected by the thermal camera. objects, while the ESP32 camera captures real-time visual images and video streams for surveillance. The magnetometer identifies metallic anomalies caused by underground mines or unexploded ordnance. All sensor data is combined in the sensor fusion unit to improve detection accuracy and reduce false alarms. The processing module analyzes thermal patterns, visual data, and magnetic signals to identify suspicious objects and hazardous zones. The communication system wirelessly transmits live images, GPS coordinates, and alerts to the ground station or mobile device. The system provides real-time threat mapping, remote monitoring, and reconnaissance reports, making it highly effective for military, border security, and humanitarian demining applications.

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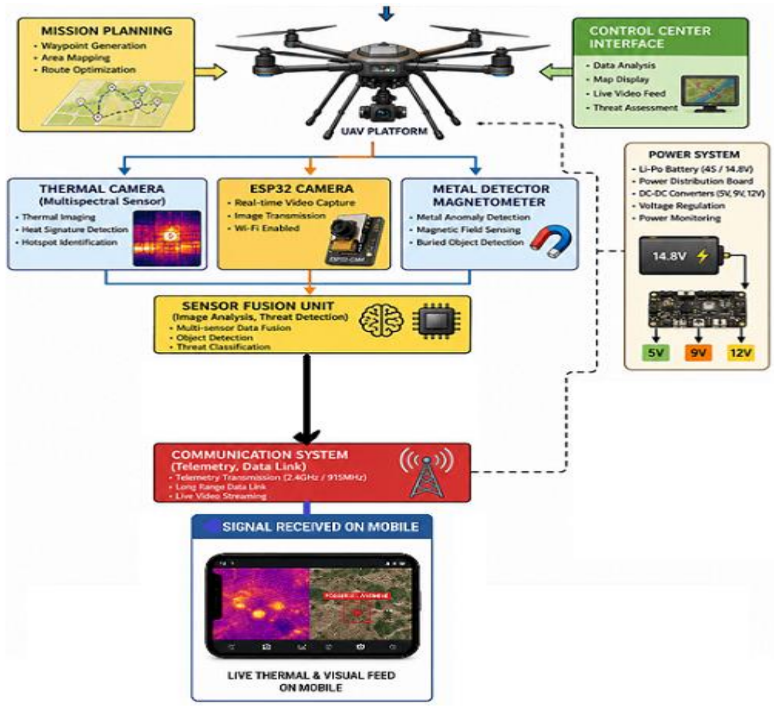

Fig.1- Proposed System

IV. HARDWARE COMPONENTS

F450 Quadcopter Drone Frame

Fig.2- ESP 8266 Nodemcu

The F450 quadcopter drone frame is a widely used structural platform in autonomous aerial systems, including an Autonomous Aerial Minefield Reconnaissance and Explosive Ordnance Detection System. It serves as the mechanical backbone that supports all electronic and sensing components while ensuring stable flight. The F450 frame operates on a quadcopter configuration, consisting of four arms arranged in an “X” shape. Each arm holds a brushless DC motor connected to a propeller. Two propellers rotate clockwise and the other two counterclockwise to maintain

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balance and eliminate torque. The flight controller continuously adjusts motor speeds based on sensor inputs (GPS, IMU), enabling stable hovering, navigation, and autonomous path tracking.

1000KV BLDC Motor for Drones

Fig.3- 1000KV BLDC Motor for Drones

The 1000KV BLDC motor (A2212/13T) shown in the image is a commonly used propulsion unit in quadcopters designed for applications such as an Autonomous Aerial Minefield Reconnaissance and Explosive Ordnance Detection System. This motor operates on the principle of electronic commutation, where the Electronic Speed Controller (ESC) rapidly switches current through the stator windings to generate a rotating magnetic field. This field interacts with permanent magnets in the rotor, producing smooth and efficient rotation. The motor speed is controlled by varying the input signal from the flight controller, enabling precise thrust adjustment for lift, hovering, and navigation.

Simonk 30 A speed controller

Fig.4- Simonk 30 A speed controller

The ESC acts as an interface between the flight controller and the brushless DC motor. It receives PWM (Pulse Width Modulation) signals from the flight controller and converts them into high-frequency switching signals using MOSFETs. These signals energize the motor windings in sequence, creating a rotating magnetic field that drives the motor. The SimonK firmware enables a fast response rate (~490 Hz), ensuring quick throttle changes and smooth maneuvering, which is essential for obstacle avoidance and precise navigation in minefield detection missions

Ardupilot Flight Controller

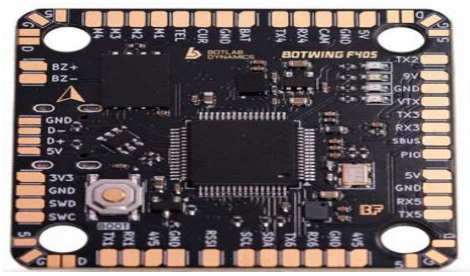

Fig.5- Ardupilot flight controller

Onboard sensors such the GPS module, barometer, compass, and IMU (accelerometer and gyroscope) provide real-time data to ArduPilot. It continually modifies motor speeds through the ESCs using sophisticated control algorithms (PID control) to maintain steady flying. The drone may follow pre-programmed routes for methodical minefield scanning thanks to the system's capability for autonomous waypoint navigation. Additionally, it incorporates payload sensors (such as magnetometers, GPR, and thermal cameras) and uses sensor fusion to increase accuracy. For monitoring and decision-making, telemetry modules allow for real-time connection with the ground control station.

Transmitter FS-i6

The FS-i6 operates on 2.4 GHz AFHDS 2A (Automatic Frequency Hopping Digital System) technology, which minimizes interference and ensures stable signal transmission. The transmitter sends control commands (throttle, pitch, roll, yaw) to the receiver connected to the flight controller. These commands are converted into PWM or PPM signals, allowing precise control of the drone's motors via the flight controller and ESCs. In autonomous missions, the transmitter acts as a manual override system, enabling the operator to take control during emergencies or unexpected obstacles in minefield environments. This transmitter provides stable communication, low latency, and reliable manual control, ensuring safety and flexibility in hazardous reconnaissance operations.

Fig.6- Transmitter FS-i6

Battery 5500 mAh

Fig.7- Battery 5500 mAh

A Li-Po battery operates based on the movement of lithium ions between the anode and cathode through an electrolyte. During discharge, lithium ions flow from the anode to the cathode, generating electrical energy that powers the drone’s motors via ESCs, as well as the flight controller, sensors, and communication modules. The high energy density and lightweight nature of Li-Po batteries make them ideal for aerial applications. A higher capacity (5500 mAh) allows longer flight time, which is crucial for scanning large minefield areas and performing continuous surveillance.

Thermal Camera

Fig.8- Thermal Camera

A thermal camera operates on the principle of infrared (IR) radiation detection. All objects emit heat energy in the form of infrared radiation. The camera captures this radiation using a microbolometer sensor, which converts temperature differences into electrical signals. These signals are processed to generate a thermal image, where different temperatures are represented by varying colors or grayscale intensities. In minefield detection, buried mines often cause slight temperature differences compared to surrounding soil due to differences in material and heat retention. The drone captures thermal data in real time and transmits it to the ground station for analysis and decision-making.

Metal Detector

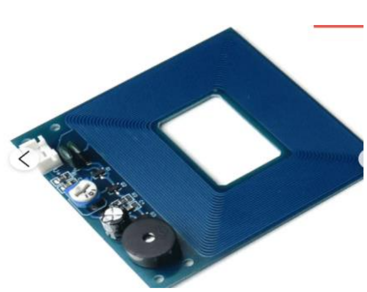

Fig.9- Metal Detector

A metal detector works on the principle of electromagnetic induction. It consists of a transmitting coil that generates an alternating magnetic field when current flows through it. When this field encounters a metallic object underground, it induces eddy currents in the object. These eddy currents create a secondary magnetic field, which is detected by the receiving coil. The system processes this change in the magnetic field and produces a signal indicating the presence of metal. In drone applications, the sensor is mounted beneath the UAV and scans the ground while flying at low altitude. The detected signals are transmitted to the onboard controller and ground station for real-time analysis.

V. SYSTEM DESIGN

The Autonomous Aerial Minefield Reconnaissance and Explosive Ordnance Detection System circuit diagram illustrates a UAV-based platform intended for the secure detection of explosive threats and landmines. A 14.8V 4S Li-Po battery powers the system, which is linked to a power distribution board that provides various electrical modules with regulated voltages like 5V, 9V, and 12V. Stable power transmission to delicate parts, including as the Pixhawk flight controller, ESP32-CAM, GPS module, telemetry module, and thermal camera, is ensured by voltage regulators and DC-DC converters. As the primary control device, the Pixhawk flight controller generates PWM signals for the ESCs that operate the brushless DC motors while processing sensor and navigation data. For autonomous aircraft operation, the GPS module offers waypoint navigation and real-time position. thermal camera detects abnormal heat signatures from buried explosive objects, while the ESP32-CAM captures live visual images and video for surveillance. A Raspberry Pi or Jetson Nano performs advanced image processing, object recognition, and threat analysis. Additional modules such as a micro SD card, buzzer, and HC-SR04 ultrasonic sensor support data storage, alert generation, and obstacle avoidance. The processed information is transmitted wirelessly to a mobile device or monitoring station for real-time minefield reconnaissance and explosive detection.

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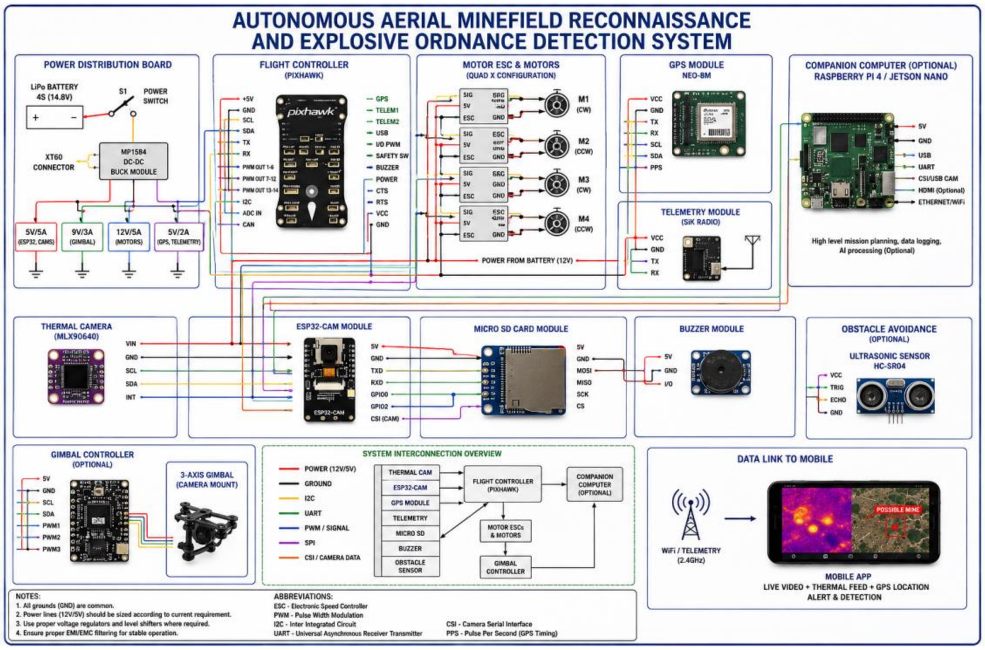

Fig.10- System Design Overview

EXPERIMNTAL SETUP

VI. RESULT AND DISCUSSION

Combined Detection Test IR and Metal Detector

S.No	**Scenario**	**IR Alert**	**Metal Alert**	**Combined Result**	**Alert Output**
1	Landmine	Yes	Yes	Both	Dual Siren plus Vibration

				Triggered	
2	Dark box with iron pipe	Yes	Yes	Both Triggered	Dual Siren plus Vibration
3	White bag with metal inside	No	Yes	Metal Only	Beep Siren
4	Landmine without metal	Yes	No	IR Only	Sweep Siren
5	Normal ground no object	No	No	Safe	No Alert

Table. Result Analysis

The test findings show how well the Autonomous Aerial Minefield Reconnaissance and Explosive Ordnance Detection System uses a mix of infrared sensing and metal detection to identify various explosive hazards. Accurate detection of objects with both thermal and metallic signatures, such as landmines and hidden explosive devices, resulted in dual alarms by vibration and sound. While non-metallic landmines were successfully detected using infrared, metal-only devices produced a beep sound. sensing with a sweep siren alert. The absence of alerts in normal ground conditions confirms reliable discrimination, reducing false alarms and enhancing operational safety and reconnaissance efficiency.

VII. CONCLUSION

A significant development in contemporary defense, surveillance, and safety technology is the Autonomous Aerial Minefield Reconnaissance and Explosive Ordnance Detection System. The research effectively detects explosive threats and buried landmines by combining unmanned aerial vehicle (UAV) technology with sophisticated sensor and intelligent processing algorithms. The system offers a dependable and extremely precise solution for reconnaissance in dangerous areas by combining technologies including thermal imaging sensors, metal detector magnetometers, GPS navigation systems, ESP32 cameras, and artificial intelligence-based processing modules. By analyzing data from several sensors simultaneously, sensor fusion systems reduce false alarms and increase detection accuracy. Because of this, the system is extremely reliable even in difficult combat situations or areas ravaged by natural disasters. control center or mobile device. This enables quick decision-making and effective mission planning. In conclusion, the project demonstrates an effective combination of automation, advanced sensing, wireless communication, and intelligent processing for safe and efficient explosive ordnance detection. Beyond military applications, the system has great potential in humanitarian demining, border security, disaster management, and search-and-rescue operations. By reducing human risk and improving detection efficiency, the project contributes significantly toward creating safer environments and protecting countless lives.

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