Surveillance Drone With Landmine Detection And Robotic Arm

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Abstract: Unmanned Aerial Vehicles (UAVs) have gained significant importance in defence, disaster management, and security applications due to their versatility and ability to operate in hazardous environments. This research presents the design and development of a multifunctional surveillance drone integrated with landmine detection capabilities and a robotic arm for remote handling tasks. The system is intended to enhance safety for military personnel by reducing direct human exposure to life-threatening conditions.

This project is about a special drone that can move both in the air and on the ground as it work like rover. The proposed drone is built on a quadcopter platform equipped with gear motor and wheels to work like rover, a high-resolution camera for real-time aerial surveillance. For landmine detection, the system uses a metal detection module, enabling the identification of explosive threats from a safe distance. A robotic arm mounted on the drone provides additional functionality, allowing for object manipulation such as picking up suspicious materials, collecting samples. The drone is remotely operated through a wireless communication link, with an onboard flight controller managing navigation.

The project demonstrates a hybrid approach that combines aerial mobility with ground-focused sensing, offering a cost-effective and scalable solution for security forces. Field testing showed promising results in detecting metallic landmine simulants, maintaining flight stability during arm operation, and providing continuous live feed for surveillance.

This work contributes to the growing field of UAV-based defence applications by proposing a multipurpose platform that improves operational safety, and supports in reducing demining human efforts. Future developments will focus on improving detection accuracy and extending flight endurance.

Index Terms - Aerial Surveillance, Ground Surveillance, Operational safety, Landmine detection, Material manipulation, GPS Tracking, Wireless Telemetry

I. INTRODUCTION

In some areas, especially those affected by past conflicts, there may still be landmines hidden underground. These places are unsafe and can't be used by normal people for farming, building, or daily activities. Sending humans to check these areas is dangerous and takes a lot of time. Morden defence System uses multiple unmanned vehicles like drones and rovers. Handheld devices like metal detectors are also been used to detect hidden landmines. In such areas finding landmines with handheld metal detectors can cause landmines to explode and occurs big accident. In such situation the life of military personal is also at high risk, to reduce that risk drones can be also used for Survey but drone are limited to flying only because of which they are not able to detect hidden landmines on the ground. landmine detecting rovers can also be use but they are unable to cover larger distance as they can walk only. This major problem requires a smart solution, the solution we

are introducing is an unmanned vehicle which can (1) able to fly as a drone this will help to travel large distance in less time, also flaying ability makes the route shorter and efficient they can also access hazardous terrains. This project uses a APM 2.8 flight controller because of its multiple Capabilities like good stability, GPS support, Mission planning ability for autonomous flight, supports telemetry, Open-source platform, etc. The project is developed on a quadcopter frame which uses 4 BLDC motors along with 10-inch Propeller and 30 Ampere ESC (electronic speed controller). This combination gives better flight stability, less power consumption, and enough thrust to fly the system and even carry small objects like soil samples. In flying mode the project include multiple features like multiple flight modes like altitude hold in which the system hold its altitude without any input given from transmitter, loiter which is GPS dependent flight mode which hold the position of system in air with help of GPS, RTL or return to launch flight mode is also available in the system in which the vehicle will return to its launch location when command is given or it will also return if any failure occurs like low battery or communication loss. All the flight modes are customizable as per requirement. (2) The proposed project has a capability to work as rover this capability makes him different form existing drones. The rover is work with the help of DC gear motors and wheels, 4 wheels are attached with 4 DC gear motors which provides enough torque to operate the vehicle in rough terrains because of 4 wheel drive the vehicle can turn in any direction. This ground movement system gets signal from radio receiver, the receiver gives the output in the form of PWM (Pulse width Modulation) signals which can not directly given to the motor that's why Arduino and motor driver is used. The selected microcontroller is Arduino nano because of its simplicity and compact size, the motor driver we select is L298n which has two channels and it can be able to provide 2 ampere currant which is sufficient for our 4 gear motors. PWM signal output of radio receiver is connected to Arduino nano, Arduino reads the PWM signals and gives 5v logic output on its 4 different pin which are connected with motor driver. This 4 pins decides the direction of motors, for PWM signal of width 1500 micro second the microcontroller does not give any output because it is center position of transmitter buttons. For PWM signal of width 1000 micro second microcontroller gives the output such as motor rotates backwards and for PWM signal width of 2000 micro second microcontroller gives the output such as motor rotates forward. Using microcontroller and motor driver is more precise and customizable than simple PWM switch. (3) when the vehicle working as rover it is a lot closer to ground than drone then we take the advantage of it and fix a metal detector module to detect buried landmines. The metal detector module is attached with SG90 micro servo motor because of which we can be able to change height of the metal detector module, which helps to get closer to ground and lift upward if there is any obstacles like rocks. Used metal detector module is an DIY metal detector kit which has PCB mounted coil to detect change in electromagnetic fields. Landmine detection with this method is a lot more safe than handheld metal detectors. (4) The project also includes an analog FPV camera which performs multiple operations like when the metal detected it shows red LED indicator on the camera, it is also used for ground and air Surveillance as it can transmit live video and audio feed wirelessly on the base station. We use 1000TVL CMOS camera sensor along with 5.8GHz audio video transmitter, because of which we are able to see live video feed from base station with the help of 5.8GHz OTG receiver. Camera plays an important role in Surveillance as well as in navigation during long flights. The audio video transmitter has 5 frequency bands and 8 channels in total which gives 40 different frequences any one of those we can use for transmission. As we attached a mechanical arm with the system with help of camera we can see the working of mechanical arm and it is also helpful for watching a object live while picking it. (5) Mechanical arm or robotic arm is an mechanism which opens and closes with the help of MG995 servo motor, MG995 servo is an 180 degree rotation high torque servo motor which gives high torque to the robotic arm. This servo motor operates on 6v and gets PWM signal from receiver. Robotic arm it self is build of aluminum metal which is strong and light weight. Use of robotic arm is essential to collect samples or even move small Suspicious objects. Even during survival situations it will help to transfer various life saving objects like medical kit or food packets. The whole system work together as a hybrid vehicle which can fly, walk, detect landmines and also pick and place small objects.

This work is organized with review of the literature survey as Section II. Methodology described in Section III, Section IV discusses the results and discussions. Lastly, Section V concludes with the main suggestions and findings.

II. LITERATURE SURVEY

Over the past few years, the design of hybrid aerial–ground vehicles has gained particular interest from the robotics and unmanned systems communities. Our project revolves around a drone that not only can fly like a conventional quadcopter but can also move on the ground like a rover. To justify the scope of this work, it is important to review past research and existing technologies related to hybrid locomotion, UAV-based landmine detection, aerial manipulation, and the use of onboard cameras for surveillance.

The concept of combining flight and ground mobility has been explored in different ways by researchers seeking to overcome the limitations of purely aerial or terrestrial robots. For instance, the HyTAQ robot showed how covering a quadrotor with a protective rolling cage enables the same propulsion system to be employed for flying and rolling on the ground. This design enhanced endurance considerably since ground movement required less energy than hovering. Along the same lines, the DALER project created a winged robot that could fly and fold its wings into "whegs" that enabled it to walk, mimicking biological mobility. These experiments demonstrated that hybrid platforms are able to access complex terrain, respond to obstacles, and link the ground efficiency of travel with the flexibility of flight. On an industrial scale, the European HUUVER project has suggested a professional UAV–UGV hybrid platform with flight, and driving capability, which verifies that this technology has uses beyond university prototype level and can be integrated into real-world missions.

In parallel with developments in hybrid locomotion, drones have come under growing research for detecting landmines. Conventional landmine clearing is time-consuming and expensive, thus unmanned systems can enhance safety and efficiency. UAVs are able to scan large areas quickly and travel into hazardous areas without losing human lives. A number of reviews have highlighted the promise of UAVs in mine clearance, but they also recognize the difficulty of achieving the very high reliability levels demanded by the application. Metal detection is still one of the most elementary and effective ways of finding landmines buried in the ground, and researchers have been finding into equipping metal detector modules on aerial vehicles. But the effectiveness of airborne metal detection largely depends on flight height, sensor sensitivity, and environmental conditions like soil mineral composition and electromagnetic interference. Research has indicated that operating in low and stable altitudes is essential for enhancing signal quality. Some projects, such as the Mine Kafon system, suggested a division of labor whereby one UAV is for mapping and another to sweep the ground with a detector along planned routes. These examples emphasize the utility of UAVs for detection but also show that most systems either do aerial mapping only or use multiple platforms instead of bringing all capabilities to bear in one.

Another area that is appropriate to our project is aerial manipulation. Mounting robotic arms on drones has been researched under the term of "flying manipulators." Researchers have designed low-power and light-weight arms enabling multirotors to pick up, carry, and deposit small objects. In the research in this direction, challenges like ensuring flight stability as the arm translates, reducing payload weight, and counterbalance shifts in the center of gravity are highlighted. Certain experimental designs, such as FlyCroTugs, have demonstrated that tiny drones can apply forces many orders of magnitude larger than their own body weight through anchoring, although they lack a conventional arm. For our project, a small mechanical arm is included in the function to pick and place light samples or tag suspected landmine sites. Because our system can operate on the ground, the task of manipulation is easier, as the arm may operate while the drone remains on the ground and not while hovering, reducing complexity and adding stability.

Onboard imaging is another heavily documented topic in the literature. Drone-mounted cameras are routinely employed in reconnaissance, mapping, and navigation. For landmine detection, aerial imagery assists in creating geographical maps as well as pinpointing areas to visit at closer range. Some researchers have combined GIS-based mapping with UAV imagery to organize systematic sweeps using detection payloads. The integration of vision and detection sensors enables the operators not only to identify potential danger but also to record and geo-tag it for subsequent clearance activity. On platforms like Mine Kafon, the camera is used as the major mapping tool and the detector module ascertains the presence of mines. This two-pronged strategy reflects the significance of vision in assisting landmine detection operations.

From the published work, we see that, although hybrid aerial–ground drones, UAV-based mine detection, aerial manipulators, and onboard imaging have been researched, they tend to be dealt with individually or applied in incomplete combinations. Most of the current systems are based on aerial flight alone, which has the limitation of precision in metal detection due to changes in altitude. Others emphasize hybrid locomotion but without landmine detection. Likewise, research on aerial manipulation has mostly emphasized hovering drones, which imposes limitations on stability. Our project is an attempt to bridge all these limitations by combining all of these into one hybrid platform. Through the ability to both travel by air and on the ground, our drone is able to map vast regions from above before descending to conduct accurate sweeps at close proximity with the metal detector module. With the inclusion of a mechanical arm, easy pick-and-place operations such as soil sampling or tagging suspected spots are possible, while the camera's role is mapping and visual identification. This combined method presents a fuller and more applicable solution than currently

available systems, and it may play an important role in the continued efforts to create safe, secure, and affordable technologies for landmine detection.

III. METHODOLOGY

This project adopts a design-and-implementation methodology to develop a hybrid drone capable of operating as both an aerial vehicle and a ground rover. The system integrates multiple subsystems including flight, ground mobility, landmine detection, object manipulation, and surveillance. The methodology explains the systematic process followed from system design and testing.

3.1 System Design and Architecture

The hybrid drone design is a multirole aerial and ground platform with dual mobility modes. The aerial mode is based on a quadcopter configuration, while the ground mode uses conveyor belt tracks for surface navigation. Additional modules such as a metal detector, robotic arm, and camera were included to enhance functionality. The system architecture was divided into five subsystems.

1. Flight subsystem
2. Ground movement subsystem
3. Detection subsystem
4. Manipulation subsystem
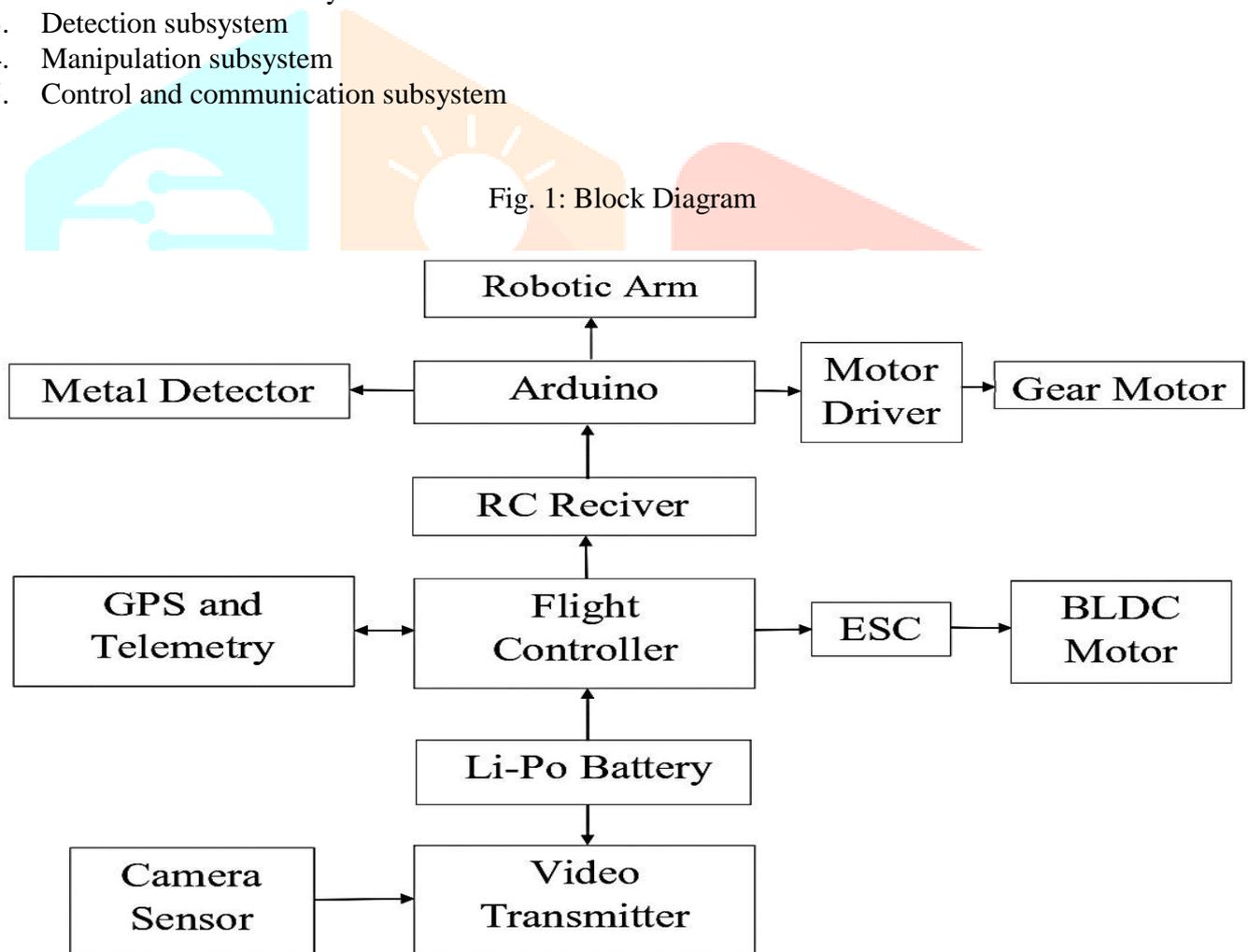5. Control and communication subsystem

Fig. 1: Block Diagram

Fig. 2: Actual Project Image

3.2 Hardware Methodology

3.2.1 Frame and Propulsion

A 450 mm quadcopter frame was chosen for its lightweight structure and ability to support multiple modules. Brushless DC motors (2212 series, 1000 KV) were used along with 30A electronic speed controllers and 1045 propellers to provide thrust for aerial flight. For ground movement, wheels were attached to the base of the frame to enable rover-like mobility.

3.2.2 Control Unit

An Arduino nano microcontroller was used as the central control unit for ground movement. It coordinates inputs and outputs across subsystems, and executed programmed control algorithms.

3.2.3 Detection Module

A metal detector module was mounted on the underside of the frame. It was directly interfaced with the LED, which mounted in front of camera sensor, LED emits lights as module detects the change in electromagnetic signals for metallic objects that could represent buried landmines.

3.2.4 Manipulation Module

A lightweight robotic arm driven by servo motors was installed below the frame. The arm allowed pick-and-place operations of small objects or soil samples.

3.2.5 Camera Module

A downward-facing camera was mounted for live video capture, track the movement of robotic arm and verify the presence of landmine. The camera provided surveillance capability and assisted the operator in navigation.

3.2.6 Power Supply

The drone was powered by a two 3-cell 2200 mAh Li-Po battery. A power distribution board supplied power to ESC, flight controller, camera system, metal detector module and robotic arm.

3.3 Software Methodology

3.3.1 Programming Environment

The Arduino nano was programmed using the Arduino IDE software. Control codes were written for Ground movement subsystem.

3.3.2 Flight Control

Used flight controller is APM 2.8 and its belong to ArduPilot Mega family of flight controller. This flight controller is setup from mission planner software which is open source platform. This software is also used to see live data of project like speed, altitude, battery voltage, etc.

Fig. 3: Mission Planner interface
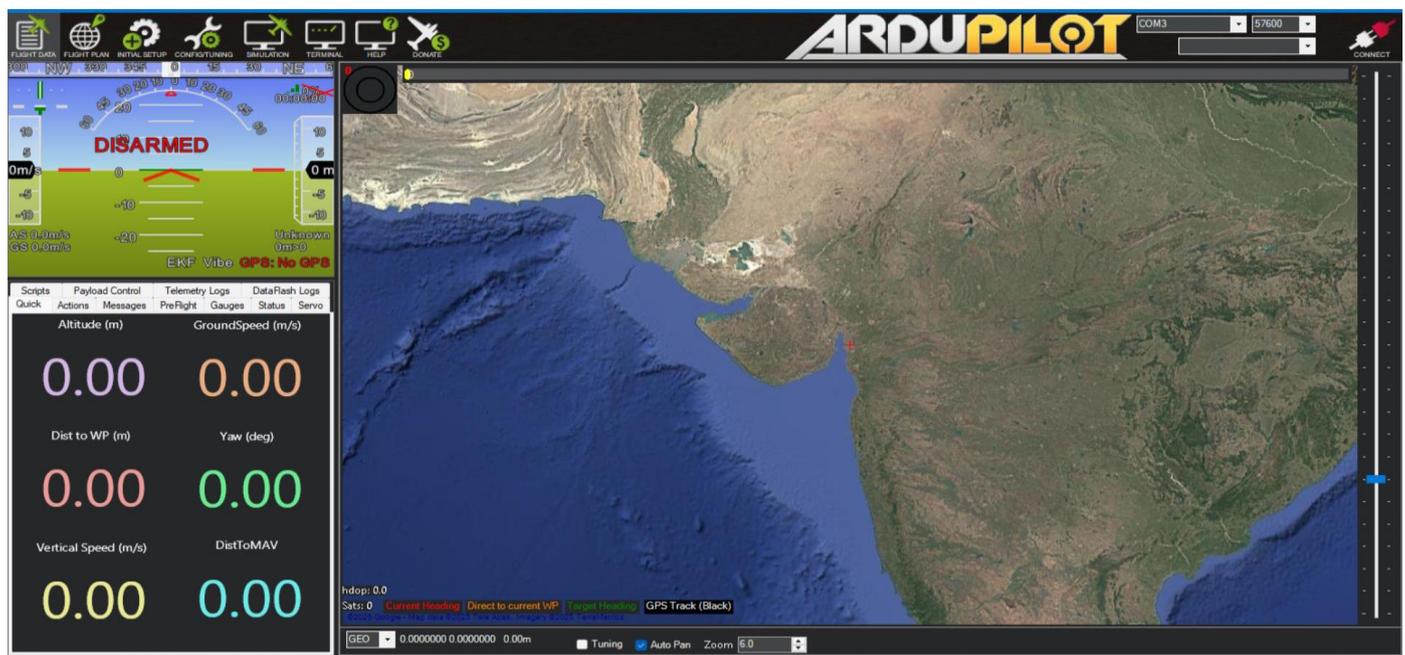
3.3.3 Ground Navigation

The wheels attached to the motors were controlled using signals generated by the Arduino nano. Functions for forward, reverse, and turning movements were programmed for flexible navigation.

3.3.4 Detection Algorithm

The metal detector continuously transmit electromagnetic signals with the help of coil inbuilt on PCB. On detecting metallic interference, the module generated a warning signal and glows the LED.

3.3.5 Robotic Arm Control

Servo motors of the robotic arm were programmed with predefined angular movements to perform lifting and placing actions. The arm is controlled manually.

3.3.6 Communication

Serial communication was used for telemetry which is used for watching live status of the project while working. Communication between camera and ground station is done at 5.8GHz frequency with the help of 5.8GHz audio video transmitter. The project is controlled manually with the help 2.4GHz RC transmitter and receiver.

3.4 Implementation Procedure

The development procedure was carried out in sequential stages

1. Requirement analysis and conceptual design.
2. Selection of components based on performance and weight constraints.
3. Mechanical assembly of the aerial and ground modules.
4. Integration of power distribution, control circuits, and subsystems.
5. Setup of flight controller for flight, programming of Arduino nano for rover movement.
6. Independent subsystem testing for verification of each module.
7. Full system integration and calibration of axis, compass, GPS, radio controller, ESC parameters.

3.5 Testing and Validation

Testing was divided into three stages

3.5.1 Ground Mode Testing: Evaluation of rover movement on different surfaces, detection of metallic samples, and operation of the robotic arm.

3.5.2 Flight Mode Testing: Assessment of lift, flight stability and endurance.

3.5.3 Integrated Testing: Combined operation of aerial and ground mobility, metal detection, robotic arm handling, and live video streaming to confirm proper system integration.

3.6 Assumptions and Limitations

The system design assumes that landmines contain metallic elements, making them detectable by a metal detector. Payload capacity was limited by frame size and battery capacity. Flight duration was constrained by the additional weight of modules. All tests were conducted in controlled environments using metallic samples as substitutes for live landmines.

IV. RESULTS AND DISCUSSION

The hybrid drone was successfully created and tested in aerial and ground modes. Each subsystem was tested individually and then collectively in integrated operation.

4.1 Ground Mode Testing

The gear motor and wheel system provided smooth movement on concrete and ground surfaces. The system did not deviate from stable traction and reacted well to control signals. The metal detector successfully detected metal objects set at shallow depths of 0.02-0.05 Meter. The detection sensitivity was poor at deeper depths. The robotic arm could lift and deposit small loads of up to 700 gram, but heavy loads compromised stability while operating.

4.2 Flight Mode Testing

The drone performed stable flight with a top tested altitude of around 30 meters. The PID control was smooth to stabilize, and user input from the transmitter reflected rapid response. Average flight time was 720–900 seconds without payload. Payload weight had a direct influence on endurance, with decreased flight time when both the robotic arm and metal detector were in use.

4.3 Integrated Testing

In hybrid mode, the unmanned aerial vehicle successfully work with air and ground mobility. Live video from the onboard camera enhanced situational awareness and navigation during testing. Concurrent metal detector and robotic arm operation were possible, although power management was required to prevent power drops.

In general, the system proved that integration of UAV and UGV capabilities in one platform increases operational flexibility.
The hybrid solution makes it possible for the drone to conduct operations in terrain inappropriate for prolonged flight but capable of carrying out aerial surveillance when needed. The primary restrictions found were payload capacity, short flight time, and diminished detection accuracy at deeper soil depths.

Table 1: Results Obtained

Range of operation	1km
Flight Time	900 Seconds
Weight carrying capacity	700 gram
GPS Accuracy	2 Meter
Metal detection depth	0.02-0.05 Meter
Camera Resolution	1280×720
Total Weight	1700 gram

V. CONCLUSION

This study was able to design and develop a hybrid drone that can perform aerial flight, ground travel, landmine sensing, robotic arm manipulation, and real-time video monitoring. The approach provided tough integration of hardware and software subsystems, and the findings validated the practicability of such a multi-functional platform.

The system was found to be effective in the detection of metallic objects simulating landmines and showed consistent performance in ground as well as air modes. The robotic arm extended the functionality by enabling object handling, while the onboard camera offered visual feedback for monitoring and navigation.

Restrictions in the form of low payload, short flight time, and detection depth limitations were noted. Not with standing these limitations, the hybrid drone provides an affordable option for use in unsafe environments and search-and-rescue missions. Future developments might include increasing battery life, decreasing weight via optimized design, and implementing sophisticated sensors for enhanced landmine detection accuracy.

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DOI:10.1088/1757-899X/1012/1/012023
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