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Background Radiation Surveillance Using An Autonomous UAV

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Abstract: Background radiation is an important aspect of environmental monitoring, as it can have significant impacts on human health and safety. In recent years, advances in technology have made it possible to measure background radiation more accurately and efficiently. One promising approach involves the use of drones, which can cover large areas quickly and provide high-resolution data. The key challenge in this approach is to develop a reliable method for collecting and analysing the data.

To address this challenge, this paper presents a novel method for measuring background radiation using drones equipped with wireless transfer capabilities and custom software. The drones are flown at predetermined altitudes and collect data using radiation sensors. The data is then transmitted wirelessly to a ground station, where it is processed and analysed using custom software. The results of our experiments show that this method is highly effective in measuring background radiation over large areas. The data collected by the drones is accurate and reliable, and the custom software provides a powerful tool for analysing and visualizing the data. This approach makes it easier and more efficient to gather data and identify potential health risks.

Keywords: Background Radiation, ESP8266, GPS, Geiger Counter, UAV, IoT

I. INTRODUCTION

Background radiation is the ionizing radiation that is constantly present in the environment from natural and manmade sources. Natural sources include cosmic rays, radioactive isotopes in rocks, and soil, whereas man-made sources include nuclear power plants, medical facilities, and industrial processes. Exposure to high levels of radiation can pose serious health risks to humans, including an increased risk of cancer, genetic damage, and other health effects. One of the most concerning health effects of radiation exposure is childhood skin cancer. Children are more vulnerable to radiation exposure than adults, and prolonged exposure to radiation during childhood can lead to an increased risk of skin cancer later in life. This risk is especially high for children who live near nuclear power plants or other sources of radiation. Kendall [1] showed a relation between early development of skin cancer in children living in areas of higher background radiation. Traditional methods of measuring radiation levels involve the use of handheld detectors or stationary sensors. These methods are often time-consuming, expensive, and limited in scope. In recent years, unmanned aerial vehicles (UAVs) have emerged as a promising platform for radiation monitoring due to their ability to cover large areas of terrain quickly and easily.

In response to the need for more efficient and effective radiation monitoring methods, we wish to develop an airborne UAV hardware-software device capable of measuring radiation levels in the air and transmitting those values to a computer running custom software. Our device provides an efficient and cost-effective solution for radiation monitoring, with the potential to significantly improve our understanding and management of radiation in the environment. The UAV hardware component of our device includes a radiation detector mounted on the UAV, which measures the amount of ionizing radiation present in the air as the UAV flies over a particular area. The UAV hardware also includes a GPS module and a wireless communication system that allows the UAV to transmit the radiation readings to a ground station. The software component of our device includes a custom-built application that runs on a computer. The application is designed to receive and display the radiation readings transmitted by the UAV. The readings are transmitted to the software when a mission (flight covering a certain area) is complete. The application can also store the readings in a database, allowing users to analyse the data over time and identify any trends or patterns.

In conclusion, our UAV hardware-software device provides a more efficient and effective solution for monitoring radiation levels in the environment. This has important implications for public health and safety, especially for children who are more vulnerable to the harmful effects of radiation. We hope that our work will inspire further research and development in this area, leading to even more effective radiation monitoring solutions in the future.

II. OBJECTIVE

The objective of this paper is to design and develop a system of hardware and software units to aid in effective measurement of background radiation present in the atmosphere. This goal will be achieved by successfully implementing the aforementioned system and testing it as per the literature.

III. LITERATURE SURVEY

There are three principal methods available with which to carry out the monitoring of radioactive material: static ground based, mobile ground-based, and airborne surveys. Of these, airborne surveys are our concern as they are the most effective way to quickly gather data over a large area. Previous studies have explored a variety of UAV designs like: Fixed-wing [2].[3], single-rotor style [4] and multi-rotors [5] (the focus of this paper).

Kurvinen et al. 2005 [2] and Pollanen et al. [3] 2009 used ¨ a fixed-wing aircraft to survey an area. This had great area coverage due to the nature of the vehicle used but suffered from lack of resolution of data. The aircraft achieved a top speed of 240 and 120 km hour–1 and cruising velocity of 90 and 60 km hour–1 respectively. At this high speed, they were able to cover 250m and 17m per measurement.

Martin et al. 2014 [6] achieved flight times of 30-40 minutes using a battery-powered UAV. Similarly, MacFarlane et al. 2014 [7] achieved a flight time of 12 minutes.

Ghose et al. 2022 [5] used a stock UAV affixed with a GM Counter to measure radiation. This project achieved measurement heights of as low as 10m above ground resulting in better spatial resolution of measurements.

IV. METHODOLOGY

A. Overview

The principal components of our hw/sw system are the Software (The Ground Control Software), the hardware (Geiger Counter) and the method of communication between them. Once readings have been communicated, they are analyzed using techniques mentioned above.

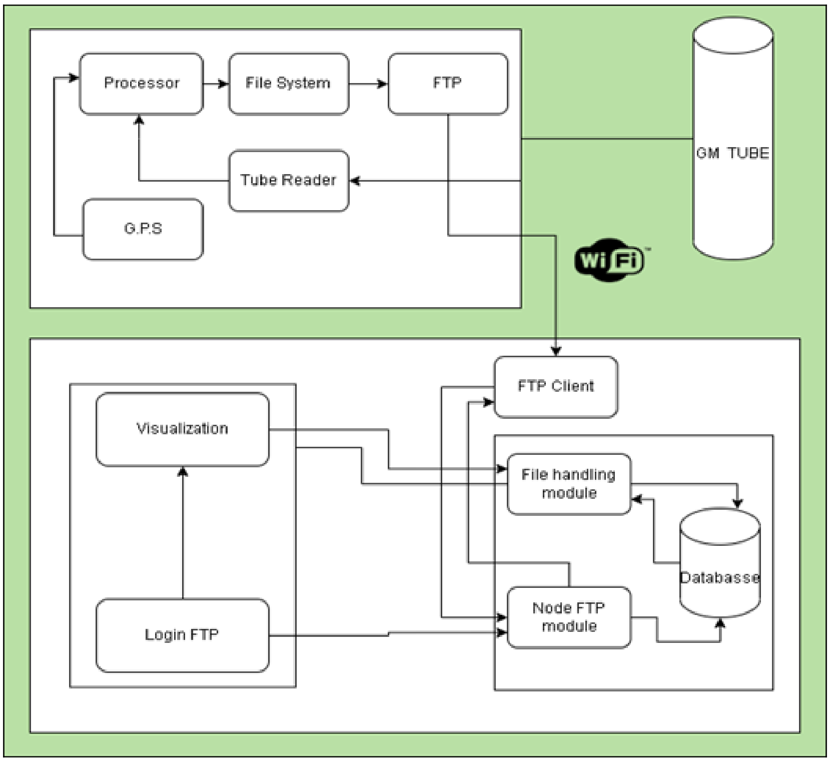

Fig. 1 Block Diagram

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Briefly, these are the hardware components:

1.Sensor: For sensing/reading radiation present in the atmosphere, a Geiger counter is designed. This counter uses an esp8266 Micro-controller. This controller has been chosen as it has a Wi-Fi modem attached to it, is widely available and is easy to program.

2.Geiger Tube: The tube is the component that registers counts of radiation and sends it into the circuit. We've used the SI-3BG class of Geiger tube.

3.GPS: Location of the UAV is recorded in the form of (latitude, longitude) pair and are sent to the GCS.

B. Ground Control Software

Username: gm_counter

Password: ••••••••••

File downloaded successfully, timestamp: 4/16/2023, 10:26:03 PM

Fig. 2 Readings are fetched on correct login details.

Fig. 3 Show all Readings.

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Fig. 4 Show only area of high radiation .

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The software, or as we shall refer it, the Ground Control Software (GCS) is the component that will receive data from the Counter and perform analysis and visualization on it.

1) Server: The server is the backend system that manages file handling, FTP server connection, data processing and client requests. It runs on node, which is an opensource JavaScript runtime. The server has several node module dependencies that provide features like file handling and interactions with the FTP server. The node server is supported by Express which is a node module that provides framework for hosting web applications.

The server further contains three modules within itself. The file handling makes use of the node fs module, which is a prebuilt node module that allows the user to work with the file system on the computer and manage local databases. It takes request from the client and provides appropriate data regarding the information about the directory or the data within the requested file. It uses the fs.readdir() function to read the directory of provided path and it returns with a list of files that it contains.

2) Client: The client side is the interface of the web application. It allows the user to interact with the system by logging-in to the FTP sever and selecting which file recording is to be visualized. The client side also provides visualization in form of heatmap which represents the radiological data. It contains two pages, one for the purpose of FTP login and the other one for visualization.

C. GEIGER COUNTER MODULE

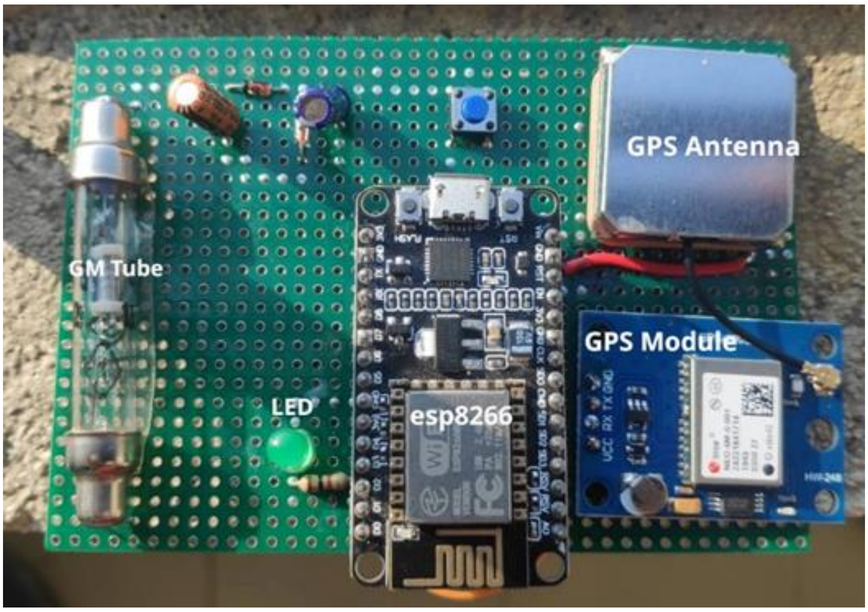

Fig. 5 Circuit Board. .

Fig 6 is the Geiger-Counter Designed and Implemented. The Geiger Counter is a multi-sensor microcontroller module. Its main job is to collect data during flights, store it and then transmit it when queried.

These are the modules present on the Geiger Counter:
1) Geiger Tube
2) GPS Module
3) ESP8266 Microcontroller

1) Geiger Tube: A Geiger Tube is a vacuum-sealed glass tube usually enclosed in a cylindrical enclosure that is filled usually with Noble gases like Argon and Neon at low pressure.

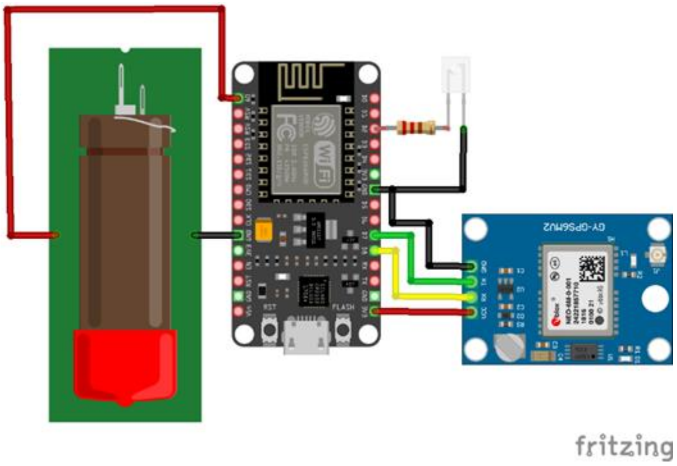

Fig. 6 Connection Diagram of the Geiger Counter

The working principle of a Geiger Tube is called the Townsend Effect. When ionized radioactive particles pass through the glass tube, they ionize some electrons present inside it. This causes an increase in its total energy which causes it to jump from its orbit. This leads to an effect where there is an increase in the charge in the circuit. This is what is detected in the circuit. If the terminals of the tube are connected to a sampler that samples its inputs every n second and reports its output, we've essentially measured the pulse count emitted by the Tube. In our setup, the outputs of the Geiger tube are connected to the Analog Pin (A0) of the ESP8266 Microcontroller Unit (MCU).

In ordinary settings, Analog signals from Analog devices such as the Geiger tube need a Analog-To-Digital converter (ADC) for it to be read by the MCU that it is connected to, as MCU are purely digital devices. In our case, the ESP8266 already carries a ADC built inside it. The interface to this ADC has been exposed via pin A0 of the MCU.

The capacity of an ADC is measured in terms of its 'resolution'. Since, analog signals are continuous and digital signals are discrete, the job of an ADC simply becomes sampling an changing signal and assigning it a discrete value in some range. The range that the discrete values fall in is called its resolution. An ADC of 12-bit resolution can produce values in the range of (0,212) or (0, 4096). The higher the resolution, the more precise will the reading of a signal be. The ADC in ESP8266 has a 10-bit resolution, therefore it can return values in the range of (0, 210) or (0, 1024).

2) GPS Module: The NEO-6M GPS module is a compact and low-power device that can be easily integrated into a wide range of projects. It uses the GPS system to determine its location and then communicates that information to a host device via a serial interface. The module is powered by a single voltage source and has a built-in antenna.

Global Positioning System (GPS) modules like the NEO-6M use a complex system of satellites, receivers, and algorithms to determine an accurate location on the Earth's surface. GPS modules are used in a variety of applications, including. Navigation, surveying, tracking, and timing. The NEO-6M module also uses an onboard microcontroller to perform various tasks such as signal processing, data filtering, and error correction. The module also includes a Real-Time Clock (RTC), which is used to provide accurate timing information.

To use the NEO-6M module, the host device must send commands to the module using the serial interface. To utilize the GPS data generated by a module like NEO-6M, the module typically outputs data in the NMEA format, which stands for National Marine Electronics Association. The NMEA standard defines a set of ASCII messages that contain information about the location, speed, heading, and time of the GPS module. These messages are transmitted over a serial interface and can be received by a host device such as an Arduino or Raspberry Pi.

To parse the NMEA string and extract meaningful data, a library like TinyGPS can be used. TinyGPS is a lightweight C++ library that can be easily integrated into a project and used to extract GPS data from NMEA messages. It is capable of handling different types of NMEA messages and can extract latitude, longitude, altitude, speed, and other relevant information from the messages The library includes a set of functions that can be used to retrieve specific GPS data, such as getLatitude(), getLongitude(), and getSpeed(). These functions take the NMEA string as input and return the relevant data as a float or double value. The library also includes functions for handling time and date information, making it a comprehensive solution for GPS data parsing.

3) ESP8266: The ESP8266 is a low-cost, high-performance system-on-a-chip (SoC) that is widely used in Internet of Things (IoT) applications. It is designed for Wi-Fi applications and includes a built-in Wi-Fi module that allows it to connect to Wi-Fi networks and communicate over the Internet. NodeMCU is a development board that is based on the ESP8266 SoC. It features a compact form factor, easy-to-use development tools, and a built-in USB-to-serial converter. The NodeMCU board includes a set of GPIO pins that can be used to connect to external sensors, actuators, and other devices. It is also compatible with a range of programming languages, including Lua and MicroPython.

The Wi-Fi capabilities present on the ESP8266 allow it to connect to Wi-Fi networks and communicate over the Internet. It supports a range of Wi-Fi protocols, including 802.11b/g/n, and can operate in various modes such as station mode and soft access point (AP) mode.

In station mode, the ESP8266 can connect to an existing Wi-Fi network and communicate with other devices on that network. This mode is useful for IoT applications that require the ESP8266 to communicate with other devices over a network. In soft AP mode, the ESP8266 can create its own Wi-Fi network and allow other devices to connect to it. This mode is useful for applications that require the ESP8266 to act as an access point, such as in a wireless sensor network.

Overall, the ESP8266 and NodeMCU provide a powerful and cost-effective platform for developing IoT applications. The Wi-Fi capabilities present on the ESP8266 allow it to connect to Wi-Fi networks and communicate over the Internet, making it a versatile platform for a wide range of applications. The NodeMCU board provides an easy-to-use development environment that simplifies the process of building IoT applications using the ESP8266 SoC

D. Communication Between Hardware and Software

The micro-controller on the hardware is a Wi-Fi capable chip and this fact has been taken advantage of. Communication between the hardware and software takes place through Wi-Fi, using the FTP application layer protocol in a pre-established Local Area Network. Here, the controller is the FTP server, and the GCS is the FTP client. After recording a fixed number of data, the controller enters the serving mode. It waits for a client to establish a connection. The client will initiate a connection when the UAV has landed. Both the client and the server are required to be on LAN.

1)Device Discovery: In order to discover a device on a network, another device, which we shall call the client, needs to uniquely identify the device it needs to communicate with. This unique ID in Internet networks is called the” IP address” of the device, where IP stands for” Internet Protocol” (The other part of the underlying TCP/IP stack on which the Internet stands). An IP is usually statically assigned to devices on a network or can be dynamically configured by server traditionally using a protocol like Dynamic Host Configuration Protocol or DHCP.

In order to make discovery reliable and work every time, we need some sort of mechanism that translates a ascii string dynamically into an IP address of our server. DNS is an application layer service that translates ascii strings (called” Domain Names”) to IP addresses by communicating with a server that has a translation table of domain names to their respective IP addresses for all devices that fall under the DNS server.

The version of DNS that we use for our purposes is called mDNS or mobile DNS. How it works is by using multicasting IP packets to every device in the network. Each device that supports mDNS will match the received string with one that they identify with. The right server then sends an its IP address as acknowledgement to the transmitting client. Now, the client has the IP address it needs.

2)Transfer of Readings: The readings recorded by esp8266 are stored natively on the 4MB device flash present on the it. This part of the flash To make discovery easy, the server registers itself with a preknown mDNS domain name. This allows the client to query the server without knowing its IP address. Now, to transfer data, the client initiates a ’RETR’ request on the latest function file. Once this file has been received, the GCS can proceed to process the data.

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Fig. 7. Drone along with the Geiger Counter

E. Unmanned Aerial Vehicle

A UAV, or Unmanned Aerial Vehicle, is a type of aircraft that is operated without a human pilot onboard. Instead, UAVs are controlled remotely or operate autonomously using pre-programmed flight plans and onboard sensors. There are various types of UAVs available today, each designed for specific purposes and applications, such as: Fixed-Wing UAVs, Rotary-Wing UAVs, Hybrid UAVs etc. We have chosen a **Rotary-Wing Quadcopter**, see figure 7.

To build a drone, there are several requirements in terms of the parts that are needed. Firstly, a frame is required, which provides the structure for the drone and houses all the components. The frame should be lightweight and sturdy enough to withstand flight conditions. Next, a flight controller is needed, which is the brain of the drone and controls the motors based on input from the pilot or autopilot system.

Another essential component is the power system, which includes a battery and an electronic speed controller (ESC). The battery provides power to the drone, and the ESC regulates the speed and direction of the motors. Propellers are also required to generate lift and propel the drone forward.

Additionally, a radio transmitter and receiver are required for remote control of the drone, and a camera can be added for aerial photography and videography.

1) Flight Controller: The Flight Controller (FC) is essentially the brains of a quadcopter drone. The FC of our choice is the KK2.1.5 board. The KK2.1.5 is a popular flight controller for drones and multirotor. It is a compact and lightweight circuit board that serves as the brain of the drone, controlling its flight characteristics and ensuring stability in the air. The KK2.1.5 flight controller is designed to integrate with the various sensors and components of the drone, including the receiver, electronic speed controllers (ESCs), and motors. It processes data from these components to stabilize the drone during flight, adjust motor speeds, and respond to user input. One of the key features of the KK2.1.5 is its user-friendly interface, which allows pilots to easily adjust settings and fine-tune the drone’s flight characteristics. The controller has a built-in LCD screen and button interface, which displays important flight information such as battery voltage, altitude, and motor speed. The KK2.1.5 also has a number of advanced features, such as the ability to support multiple flight modes and adjustable stabilization settings. It can also support automatic leveling and return-to-home capabilities with the addition of GPS and other sensors.

2) Rest of the Drone: The construction of a drone using a glass fiber frame, 4 brushless DC motors of 1000KV each, and 4 propellers each 10 inches wide is a relatively simple process. The glass fiber frame is assembled according to the manufacturer’s instructions, and the four brushless DC motors are mounted onto the frame using screws and bolts. The motors’

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KV rating refers to the motor’s rotational speed per volt applied, and in this case, a 1000KV motor will spin at 1000 revolutions per minute for every volt applied to it. The four propellers are then attached to the motors, each measuring 10 inches in width.

To calculate the thrust of the drone, we need to convert the weight of the drone from kilograms to Newtons:

$$\text{Weight} = 2\text{kg} * 9.81\text{m}/\text{s}^2 = 19.62\text{N} \tag{1}$$

Next, we need to plug in the values for the drone:

$$\text{MotorKV} = 1000 \tag{2}$$

$$\text{Voltage} = 11.1\text{V} \tag{3}$$

$$\text{Propeller Diameter} = 10\text{inches} = 0.254 \text{ meters} \tag{4}$$

$$\text{Propeller Pitch} = 4.5\text{inches} = 0.1143 \text{ meters} \tag{5}$$

(6)

Using these values, we can calculate the thrust for each motor:

$$\text{Thrust} = (1000 * 11.1 * 0.2542 * 0.1143)/(29.7 * 1000) \tag{7}$$

$$= 0.668\text{N} \tag{8}$$

Since there are four motors, the total thrust produced by the drone is:

$$\text{Total thrust} = 4 * 0.668\text{N} = 2.672\text{N} \tag{9}$$

Therefore, the drone will generate a total thrust of 2.672 Newtons.

To determine the weight that can be lifted by the 2.672 Newtons of thrust generated by the drone, we can use the following formula:

$$\text{Weight} = \text{Thrust}/\ (\text{acceleration due to gravity}) \tag{10}$$

Assuming a standard acceleration due to gravity of 9.81 m/s^2, we can calculate the weight that can be lifted:

$$\text{Weight} = 2.672\text{N}/9.81\text{m}/\text{s}^2 = 0.272\text{kg} \tag{11}$$

Therefore, the drone can lift a weight of approximately 0.272 kg or 272 grams with the given thrust. Our payload, which is the Geiger Counter, weighs 89 grams, which our drone should be able to handle easily.

V. ANALYSIS

”Amount of radiation” is an accumulative unit. As a result, the levels of radiation absorbed by a person in a region is measured over time. Usually, this metric is expressed in mSv/yr (mili Sieverts/year). Our counter, measures counts in uSv/hr (micro Sieverts/hour), therefore there is a need for a conversion factor. Conversion from uSv/hr to mSv/yr can be expressed with the following formula:

Let x be mSv/yr and y be uSv/hr.

$$x = (y) * (10^3\ ) * (365 * 24) \tag{12}$$

According to a study conducted by [8] the levels of total radiation measured in the cities of Nagpur, Mumbai and Bangalore were found to be 2.8, 1.4 and 1.7 respectively. According to [9] the average annual dosage of radiation is around 2.4 mSv/yr. So, the readings hover around normal except in Nagpur, where it is a tad greater than average.

Our analysis shall keep this number in mind. However, crossing this threshold can’t simply be categorized as being dangerous. [10] established that a 100 mSv/yr dose of radiation is the minimum to be considered dangerous.

Our representation of data therefore will be on a scale of 0-100 where readings near 0 are ’Green’ or ’Safe’ and as we ascend this scale, it becomes progressively ’Dangerous’.

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VI. CONCLUSION

In conclusion, our project successfully combined the design and construction of a drone with the use of a Geiger counter to measure background radiation. By mounting the Geiger counter on the drone, we were able to collect radiation data from various locations and altitudes. The recorded data was then transmitted to a software program for analysis, which allowed us to identify trends and patterns in the radiation levels.

We were able to design and construct a drone with a Geiger counter that was able to collect and transmit data effectively through wireless medium.

Furthermore, we gained a deeper understanding of the complexities involved in software and hardware design, particularly in the context of integrating different components to achieve a specific goal. We encountered challenges along the way, but we were able to overcome them through collaboration and creative problem-solving.

Overall, the project was successful in achieving its objectives and demonstrated the potential of using drones for adiation monitoring and analysis. We believe that this technology has great potential for use in environmental monitoring and disaster response efforts, and we look forward to further developing and refining our methods in the future.

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