 

# Development of a Spray System for A Drone System in Nigeria

[1]Aigbe O. Sunday [2] Suleiman I. Abubakar [3]Isah O. Oshiobugie

[1,3]Department of Electrical & Electronics Engineering Technology, School of Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria

[2]Department of Agricultural and Bioenvironmental Engineering Technology, School of Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria

Correspondence: suleiman_ibrahim@auchipoly.edu.ng

**ABSTRACT.**
The application of crop production and protection materials is a crucial component in the high productivity of American agriculture. Agricultural chemical application is frequently needed at specific times and locations for accurate site-specific management of crop pests. Piloted agricultural aircraft are typically used to treat large, unobstructed, continuous acreage crops and are not as efficient when working over small or obstructed plots. An Unmanned Aerial Vehicle (UAV), which can be remotely controlled or fly autonomously based on preprogrammed flight plans, may be used to make timely and efficient applications over these small area plots. This research developed a low volume spray system on a fully autonomous UAV to apply crop protection products to specified crop areas. This article discusses the development of the spray system and its integration with the flight control system of a fully autonomous, unmanned vertical take-off and landing helicopter. Sprayer actuation can be triggered by preset positional coordinates as monitored by the equipped Global Positioning System (GPS). The developed spray system has the potential to provide accurate, site-specific crop management when coupled with UAV systems. It also has great potential for vector control in areas not easily accessible by personnel or equipment.
***Keywords.*** *Unmanned Aerial Vehicle, Autonomous flight, Spray system, GPS.*
**DOI:** 10.7176/JNSR/13-10-05
**Publication date:**May 31st 2022

## 1. INTRODUCTION

Agriculture remains the foundation of most economies. Agriculture includes soil cultivation, crop processing, and animal farming. Any crop requires ploughing, harvesting, seeding, and irrigation. Fertiliser and pesticide applications are challenging in agriculture. In modern agriculture, drones may spray insecticides. Manual spraying of pesticides allows the workers involved in the spraying process to experience several damaging side effects. The consequences of exposure can vary from mild skin irritation to congenital disabilities and cancers. It has become increasingly necessary to utilise drone technology in spraying our farmlands. The Drone is a unique type of Unmanned Aerial Vehicle (UAV) which has Vertical Take-Off and Landing (VTOL) ability. Frequent application of fertilisers and pesticides at precise times and locations is required for accurate, site-specific management of crop pests. Typically, ground sprayers, chemigation, or aerial application equipment are used. Although these techniques are well-suited for large-acreage cropping systems, they may become inefficient or onerous for small-plot production systems. This demand may be met by Unmanned Aerial Vehicles (UAVs), which are more manoeuvrable, less expensive to operate and require fewer capital costs(Huang et al., 2014).

Widespread military and civilian use of unmanned aerial vehicles (UAVs) has been and continues to be widespread (Blyenburgh, 1999). Applications include archaeological prospecting (Eisenbeiss, 2004), rangeland management (Hardin and Jackson, 2005), evaluation of grain crop features (Jensen et al., 2003; Hunt et al., 2005), and vineyard management (Jensen et al., 2003; Hunt et al., 2005). (Johnson et al., 2001). UAVs have been utilised in agriculture for pest control and remote sensing. The Yamaha model helicopter (Yamaha Motor Co., Ltd., Shizuokaken, Japan) was designed and mainly used for agricultural applications, such as insect pest control in rice fields, soybeans, and wheat. In 1997, the world saw the introduction of the RMAX model, which was later outfitted with azimuth and differential Global Positioning System (GPS) sensor systems (Yamaha, 2004). Miller (2005) presented an experiment to test the efficacy of employing an unmanned aerial vehicle (UAV) to disperse insecticides to reduce human sickness caused by insects. Using a commercially available Yamaha RMAX UAV equipped with both liquid and granular pesticide dispersal devices, he conducted a series of tests to determine the efficacy of the UAV for airborne pesticide delivery. Overall, the results demonstrated that the

UAV pesticide-dispersal system operated dependably.

The aerial spray helps control arthropod vectors, especially mosquitoes. UAVs make vector spraying possible. Fully autonomous UAVs for agricultural or vector control spraying aren't published. The UAV spray system creates a moving space spray. These sprays target flying mosquitoes. The vector control spray defends against disease-carrying arthropods. The study aims to design and optimise spray application systems from a Nigerian UAV.

Numerous studies have been done to determine the best droplet size for vector control (Himel, 1969; Lofgren et al., 1973; Curtis and Beidler, 1996; Crockett et al., 2002). As determined by the studies, the vector control spray application maximises non-chemical or least hazardous chemical techniques to manage pests and disease vectors. Distance between the measuring device and the sprayer can affect droplet size measurements. Aerosol droplets more significant than 50 m tend to "settle out" or deposit on the ground (Matthews, 1988). Hoffmann et al. (2007) observed that far-away samplers measure smaller droplets when huge droplets settle out.

This project aims to create a low-volume spray system for a completely autonomous UAV to protect crops and control pests. This preparation is for vector control.

## 2. METHODOLOGY

The UAV developed (see figures 1-2) will ultimately serve as the platform for the developed spray application system. The hardware system will comprise the following components: the KK 2.1 Multi-Rotor controller manages the flight of (mostly) multi-rotor Aircraft (Tricopters, Quadcopters, Hex copters etc.). Its purpose is to stabilise the aircraft during flight, and to do this; it takes signals from onboard gyroscopes (roll, pitch and yaw). It passes these signals to the Atmega324PA processor, which processes signals according to the user's selected firmware (e.g. Quadcopter) and gives the control signals to the installed Electronic Speed Controllers (ESCs). The combination of these signals instructs the ESCs to make fine adjustments to the motor's rotational speeds, which stabilises the craft. CT6B RC Transmitter and Receiver; Radio Control (RC) communication typically involves a hand-held (hobby) RC transmitter and RC receiver. Propellers for multi-rotor aircraft are adapted from propellers used in RC airplanes. UAV (Drone) Size UAVs come in various sizes, from "nano", which are smaller than the palm of your hand, to mega, which can only be transported in the bed of a truck. Our constructed drone body parts are built using a 3D Printer and other fibre materials. The Drone has a primary rotor diameter of 1 and a maximum payload of 3.15 kg.

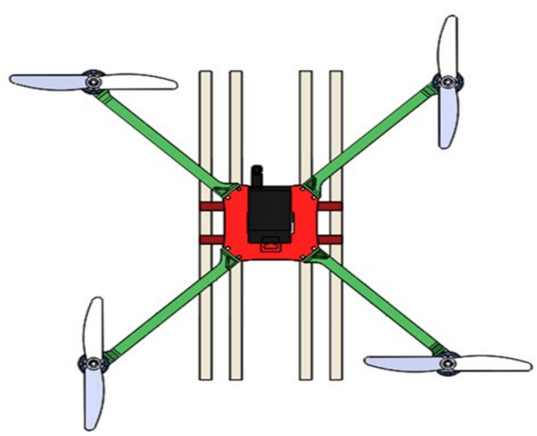

Figure 1: Top View of the Designed Drone

 

Figure 2: Constructional Phase of the Drone

### 2.1 FLIGHT CONTROL SYSTEM AND TELEMETRY

A Drone's AFCS is an integrated module. The AFCS has a 3axis, 6degrees-of-freedom Inertial Measurement Unit (IMU), a 3axis magnetometer, a GPS, and a proprietary radio receiver with servo interface and safety pilot override. The AFCS controls the Drone using signals from a ground transmitter. A C++ API allowed the AFCS to communicate commands to the transmitter and ground station. Using software and shell commands pushed from the ground control system using unique Internet Protocol (IP) addresses for each UAV, command routines such as Ground, GCS, RunSim, and Flyto can be used to control UAV flight operations.

### 2.2 ONBOARD SPRAYER

A spray system was conceived and constructed for simple installation on the Drone. The spray system interfaced directly with the UAV's electronic control systems to trigger spray release depending on preprogrammed GPS coordinates and spray locations. The spray system comprised four essential components: a boom arm with attached spray nozzles, a tank to store the spray material, a liquid gear pump, and a control mechanism for spray activation. These components have to weigh less than the Drone's maximum payload of 3 kg. A procedure has been created to assist component selection and maximise available mission payload capacities for optimal spray mission effectiveness.

### 2.3 SPRAYER COMPONENT SELECTION AND PAYLOAD CONFIGURATION

The sprayer on the UAV was required to spray 0.1 ha (1000 sqm) of land on the double load at a low volume spray rate of 0.001 L/ha. With a 1.25-kg standard undercarriage, the net useable payload was 3.15 kg. Given this payload, the high-performance telemetry was deducted. The 1.9 kg payload was left for mechanical and electronic components of the sprayer, such as the spray pump, pump speed controller, chemical, chemical tank, tubing, and nozzles. Table 1 lists the weights of the UAV attachments and sprayer components. The boom tubing with nozzles weighed 0.2 kg. The spray pump weighed 0.1 kg. The spray tank weighed 0.2 kg plus 0.2 kg (0.2 litres) of chemicals.

**Table 1. Weights of UAV attachments and sprayer components.**

| | | Weight (kg/litres) |
|---|---|---|
| UAV attachments | Standard undercarriage | 1.25 |
| | Motors | 0.45 |
| | Telemetry unit | 0.45 |
| | Tank tubing and nozzles | 0.2 |
| Sprayer components | Spray pump | 0.1 |
| | Control box | 0.3 |
| | Spray tank | 0.2 |
| | Chemical | 0.2 |
| | Total | 3.15 |

### 2.4 NOZZLES, SPRAY MATERIAL TANK, PUMP AND MOTOR ASSEMBLY

Micronair UltraLowVolume (ULV) –A+ nozzles (Micron Sprayers Ltd, Bromyard, Herefordshire, UK), ASABE standard 250067 nozzles (Spraying Systems Co., Wheaton, Illinois), and two misting nozzles were assessed for droplet size and flow rate (Orbit Irrigation Products, Inc., Bountiful, Utah, and Ecologic Technologies, Inc., Pasadena, Md.). A 0.3 kg spray tank was designed and built out of 3D Printer to a finished size of 1.4 × 1.8 × 1.4 cm. The bottom of the tank was sloped to the centre to form a 0.5-cm deep channel into which a pipe fitting was fitted to feed the spray mixture to the pump assembly. The voltage delivered to the DC pump motor was in pulses, with the pump speed determined by the modulated pulse width. Two internal baffle plates (1.4 × 1.8 cm) reduced the spray material load sloshing during flight. The tank weighed 0.2 kg plus 0.2 kilograms of chemicals. An all-plastic, low-volume, variable speed DC gear pump was used to pump the liquid from the tank to the nozzles. The
electrical components of the sprayer are weather-proof and electrically shielded (fig. 3).

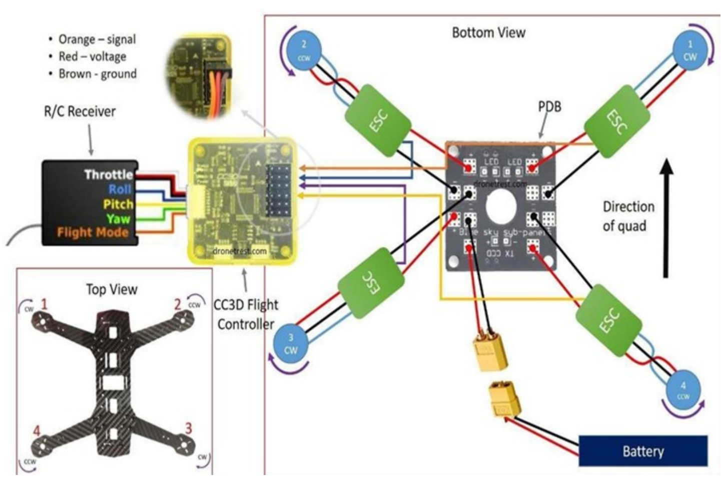


**Figure 3: The Block Diagram for The Circuit Connection of The Drone**

### 3. RESULTS AND DISCUSSION

The nozzle droplet sizing and flow rate testing and the integration and testing of the developed spray system are detailed below.

### 3.1 NOZZLE STUDY

The droplet spectra of the four nozzles operating with water are presented in table 2. The droplet size spectra was then measured with a chemical as the spray solution. The results indicate that the misting nozzles produced the minimum droplet size. However, when spraying fine chemicals and higher altitudes, the Micro nozzles had a much better plume pattern of spray atomisation. For vector control, the flow rate through the nozzle was higher than desired, so the orifice into the nozzle was modified by closing the original orifice and drilling a 220-µm orifice in the metering insert for the nozzle.

### 3.2 SPRAY SYSTEM INTEGRATION WITH UAV AND FLIGHT CONTROL SYSTEM

Based on preliminary field testing, the UAV was anticipated to have a 10 m effective spray swath when spraying at 3 m. With an expected 30m swath width and a speed of 2.2 m/s, the system will be able to spray 0.1 ha/min. Using the nozzle selected for vector control applications, the flow rate of herbicide oil under varied pump pressures was measured. Using the measured flow rates, the number of nozzles needed on the spray system was determined for a 10m swath width, an airspeed of 1.2 m/s and a spray rate of 0.1 L/ha. The results indicate that two, three, or four nozzles are needed for the targeted spray rate, depending on the applied pump voltage.

**Table 2. Flow rate measurement and number of nozzles needed.**

| Pump Voltage (V) | Flow Rate (mL/min) | No. of Nozzles Needed |
|---|---|---|
| 10 | 30 | 4 |
| 8 | 36 | 3 |
| 6 | 40 | 3 |
| 4 | 44 | 3 |
| 2 | 48 | 2 |

## 4. CONCLUSIONS

This research has shown that a spray system was successfully developed for a UAV application platform. The integration of the spray system with the UAV results in an autonomous spray system that can be used for pest management and vector control. This spray system on the UAV is especially good at spraying for vector control (<50µ-m droplet size) with several nozzles (2, 3, and 4) in the PWM control range of spray pump speed. The development of the UAV system with the sprayer has a great potential to enhance pest management over small crop plots or spots within a large crop field to realise the highly accurate site-specific application in Nigeria.

**ACKNOWLEDGEMENTS**: This research was supported by the Tertiary Education Trust Fund (TETFUND), Nigeria, and the authors wish to express their gratitude to TETFUND for their kind approval.

## REFERENCES

Blyenburgh, P. V. 1999. UAVs: An overview. Air & Space Eur. 1(5): 43-47.

Crockett, R. J., J. A. Dennett, C. M. Ham, R. D. Nunez, and M. V. Meisch. 2002. Efficacy of Biomist 30:30® and Aqua Reslin® against Anopheles quadrimaculatus in Arkansas. J. American Mosq. Control Assoc. 18(1): 68-69.

Curtis, G. A., and E. J. Beidler. 1996. Influence of ground ULV droplet spectra on adulticide efficacy for Aedes taeniorhynchus. J. American Mosq. Control Assoc. 12(2): 368-371.

Eisenbeiss, H. 2004. A mini unmanned aerial vehicle (UAV): System overview and image acquisition. In Proc. Intl. Workshop on Processing and Visualisation using High-Resolution Imagery. Pitsanulok, Thailand: International Society for Photogrammetry and Remote Sensing, Beijing, China.

Hardin, P. J., and M. W. Jackson. 2005. An unmanned aerial vehicle for rangeland photography. Range. Ecol. Mgmt. 58(4): 439-442. Himel, C. M. 1969. The optimum size for insecticide spray droplets.
J. Econ. Entomol. 62(4): 919-926.

Hoffmann, W. C., T. W. Walker, D. E. Martin, J. A. B. Barber, T. Gwinn, V. L. Smith, D. Szumlas, Y. Lan, and B. K. Fritz. 2007. Characterisation of truck-mounted atomisation equipment typically used in vector control. J.

American Mosq. Control Assoc. 23(3): 321-329.

Huang, Y., Hoffman, W. C., Lan, Y., Fritz, B. K., & Thomson, S. J. (2014). Development of a Low-Volume Sprayer for an Unmanned Helicopter. Journal of Agricultural Science, 7(1). https://doi.org/10.5539/jas.v7n1p148

Hunt, E. R., C. L. Walthall, and C. S. T. Daughtry. 2005. High-resolution multispectral digital photography using unmanned airborne vehicles. In Proc. of the 20th Biennial Workshop on Aerial Photography, Videography, and High Resolution Digital Imagery for Resource Assessment . Weslaco, Tex.: American Society for Photogrammetry and Remote Sensing, Bethesda, Md.

Jensen, T., A. Apan, F. R. Young, L. Zeller, and K. Cleminson. 2003. Assessing grain crop attributes using digital imagery acquired from a low-altitude remote controlled aircraft. In Proc. Spatial Sci. 2003 Conf. Canberra, Australia: Spatial Sciences Institute, Deakin ACT, Australia.
Johnson, L. F., D. F. Bosch, D. C. Williams, and B. M. Lobitz. 2001. Remote sensing of vineyard management zones: Implications for wine quality. Appl. Eng. in Agric. 17(4): 557-560.

Lofgren, C. S., D. W. Anthony, and G. A. Mount. 1973. Size of aerosol droplets impinging on mosquitoes as determined with a scanning electron microscope. J. Econ. Entomol. 66(5): 1085-1088.

Matthews, G. A. 1988. Pesticide Application Methods, 3rd ed.
Singapore: Longman Singapore Publishers.

Miller, J. W. 2005. Report on the development and operation of an UAV for an experiment on unmanned application of pesticides. Youngstown, Ohio: AFRL, USAF.

Yamaha. 2004. Available at: www.yamaha-motor.co.jp/ global/business/sky/solution/index.html. Accessed 8 October 2004.