Design and Fabrication of Autonomous Medical Delivery Drone

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***Abstract*—Delayed access to essential medical supplies in remote, disaster-stricken, or congested urban areas imposes severe threats to patient survival and public health outcomes. Conventional ground-based logistics often lack the speed and reliability required for these time-critical scenarios due to infrastructure limitations. This paper proposes a robust Autonomous Medical Delivery Drone framework designed for the rapid, contactless transport of emergency payloads such as vaccines and blood units. The system integrates a Pixhawk 2.4.8 flight controller with a Ublox NEO-M8N GPS module to execute precise, pre-programmed waypoint navigation and autonomous flight stability. A custom-engineered servo-actuated payload mechanism is employed to ensure secure holding and precise remote drop-off capabilities, monitored in real-time via a 433MHz telemetry data link. This integrated approach provides a resilient logistical alternative that bypasses physical terrain barriers to serve isolated populations. Experimental results validate the system's performance, demonstrating a high thrust to-weight ratio of 4:1 and a safe payload capacity of 2.0 kg, proving its feasibility as a scalable and efficient solution for modernizing emergency healthcare response.**

Keywords— Autonomous Medical Drone, Unmanned Aerial Vehicle (UAV), Healthcare Logistics, GPS Waypoint Navigation.

I. INTRODUCTION

Effective healthcare logistics is a cornerstone of public health, yet it remains a significant challenge in developing regions and disaster-stricken areas. The timely delivery of critical medical supplies—such as blood products, vaccines, and emergency medications—is often hindered by inadequate road infrastructure, traffic congestion, and difficult terrain. In scenarios like post-disaster relief or rural healthcare access, traditional ground-based transportation methods are frequently slow, unreliable, or entirely impossible, leading to preventable loss of life and deterioration of patient outcomes.

Unmanned Aerial Vehicles (UAVs), commonly known as drones, have emerged as a transformative solution to these "last-mile" delivery challenges. Unlike ground vehicles, drones operate independent of road networks, offering rapid, direct-line transportation that can significantly reduce delivery times. Recent advancements in Autonomous Flight Systems (AFS) and GPS Waypoint Navigation (GWN) have further enhanced the viability of drones for complex logistics, allowing for operation Beyond Visual Line of Sight (BVLOS) with high precision.

While commercial drone delivery systems exist, there is a need for cost-effective, adaptable, and robust platforms capable of handling sensitive medical payloads in resource-constrained environments. Existing solutions often lack the specific integration of secure, remote-actuated payload mechanisms necessary for contactless delivery in hazardous zones.

This paper presents the design and fabrication of an Autonomous Medical Delivery Drone specifically engineered for rapid emergency response. The proposed system integrates a Pixhawk 2.4.8 flight controller with a Ublox NEO-M8N GPS module to achieve stable, autonomous navigation along pre-programmed flight paths. A key feature of this design is the custom-developed servo-actuated payload release mechanism, which ensures the secure transport and precise, contactless drop-off of medical supplies at designated target locations.

II. MOTIVATION

Timely access to essential healthcare is a fundamental human right, yet it remains a severe challenge in many parts of the world. In remote, rural, or disaster-stricken regions, the conventional supply chain for medical resources is often fragile and inefficient. Traditional ground-based transportation faces significant barriers, including dilapidated road infrastructure, severe traffic congestion in urban centers, and physical inaccessibility following natural disasters. These logistical bottlenecks delay the delivery of time-sensitive payloads such as life-saving vaccines, blood products, and emergency medications, directly contributing to preventable mortality and deteriorating public health outcomes. Furthermore, the "last-mile" delivery of temperature-sensitive items like vaccines is frequently compromised by long transit times, leading to spoilage and wastage. Given the critical importance of speed in emergency medical response, there is an imperative need for an alternative, resilient logistical framework. Autonomous aerial systems offer a transformative solution by bypassing terrestrial obstacles entirely, ensuring rapid, reliable, and contactless delivery to save lives when every minute counts. Beyond logistical delays, the systemic inefficiency of current transport networks often results in the wastage of critical, temperature-sensitive medical resources. Vaccines and blood units have strict shelf lives and storage requirements; prolonged transit times on rough terrain can lead to spoilage, rendering these high-value supplies useless upon arrival. Furthermore, the disparity in healthcare access between well-connected urban centers and isolated rural communities creates a significant divide in patient survival rates. Reliance on manual transport is not only resource-intensive but also prone to human error and safety risks in hazardous environments. Consequently, there is an urgent need to deploy autonomous aerial systems that can operate independently of ground conditions. By eliminating these variables, we can establish a consistent, weather-resilient supply chain that ensures equitable healthcare delivery, drastically reducing resource wastage and guaranteeing that life-saving aid reaches the most vulnerable populations.

III. PROPOSED METHODOLOGY

The development of the Autonomous Medical Delivery Drone follows a modular system architecture designed to prioritize flight stability, navigational precision, and payload security. The proposed methodology integrates three core subsystems: the Flight Control System (FCS), the Propulsion & Power Unit, and the Actuated Payload Mechanism, all synchronized via a central processing unit.

The system is built upon a high-strength F450 quadcopter frame constructed from glass fiber and polyamide nylon, selected for its ability to dampen vibrations and minimize interference with onboard sensors. At the heart of the operation is the Pixhawk 2.4.8 flight controller, which serves as the decision-making hub. It continuously processes data from an internal 3-axis gyroscope, accelerometer, and barometer to execute real-time attitude corrections. This sensor fusion allows the drone to maintain stable hover and flight trajectories even under varying wind conditions, which is critical when carrying sensitive medical payloads.

To enable fully autonomous Beyond Visual Line of Sight (BVLOS) operations, the flight controller is coupled with a Ublox NEO-M8N GPS module. This setup utilizes a closed-loop control strategy where the drone constantly compares its real-time geospatial coordinates against a pre-programmed mission path uploaded via the Mission Planner ground station software. The system is designed with a fail-safe logic: in the event of a telemetry loss or critical battery voltage drop (monitored via the power module), the drone automatically triggers a "Return-to-Launch" (RTL) protocol to ensure the safe recovery of the equipment.

The operational workflow begins with the ground operator defining specific waypoints and a "Drop Zone" coordinate. During the mission, the drone maintains a bidirectional data link with the ground station using a 433MHz Telemetry Radio, transmitting vital metrics such as altitude, speed, and battery status. Upon reaching the designated target coordinates, the system autonomously triggers the payload release sequence, ensuring a contactless and precise delivery before returning to the base station. The integrated fail-safe logic continuously monitors these telemetry metrics, automatically initiating a "Return-to-Launch" protocol if battery levels or signal strength fall below safety thresholds to protect the aircraft and its sensitive medical cargo.

A. Abbreviations and Acronyms

UAV - Unmanned Aerial Vehicle, GPS - Global Positioning System, BLDC - Brushless Direct Current, ESC - Electronic Speed Controller, LiPo - Lithium Polymer, IMU - Inertial Measurement Unit, AFS - Autonomous Flight System, GWN - GPS Waypoint Navigation, PWM - Pulse Width Modulation, BVLOS - Beyond Visual Line of Sight, LTS - Long Range Telemetry System.

B. System Architecture and Hardware Integration

The structural framework of the drone is illustrated in Fig. 1, which details the interconnection of electronic subsystems centered around the Pixhawk 2.4.8 Flight Controller. As the core processing unit, the Pixhawk manages all flight dynamics and peripheral communications.

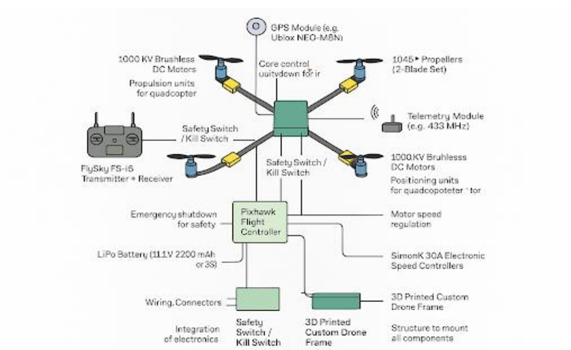

Fig 1. Block Diagram of the Proposed System

C. Flight Control and Autonomous Navigation

The central processing unit of the drone is the Pixhawk 2.4.8 Flight Controller, which operates on a 32-bit STM32F427 Cortex M4 processor. This controller was selected for its advanced sensor fusion capabilities, integrating data from a 3-axis gyroscope (L3GD20), accelerometer (LSM303D), and a high-precision barometer (MS5611) to maintain flight stability. For autonomous navigation, the system utilizes a Ublox NEO-M8N GPS module. Unlike standard GPS units, this module features a built-in compass physically separated from the main power lines to minimize magnetic interference. The flight controller continuously compares real-time GPS coordinates against pre-uploaded waypoints from the Mission Planner software, utilizing a Proportional-Integral-Derivative (PID) loop to correct course deviations and maintain altitude during the delivery mission.

D. Propulsion and Power Configuration

The propulsion system is engineered to achieve a high Thrust-to-Weight Ratio (TWR) of 4:1, ensuring agility and stability even when carrying a 2.0 kg payload. Lift is generated by four A2212 1000kV Brushless DC (BLDC) motors, which offer an operational efficiency of 80%. These motors are driven by 30A Electronic Speed Controllers (ESCs) running SimonK firmware. The firmware's high refresh rate (490Hz) allows for rapid motor response times, which is critical for stabilizing the aircraft in turbulent wind conditions. Power is supplied by an 11.1V 2200mAh 35C LiPo battery, capable of delivering the high instantaneous current required for takeoff and aggressive maneuvers.

E. Telemetry and Real-Time Monitoring

A 433MHz Telemetry Module establishes a bidirectional wireless data link between the UAV and the Ground Control Station (GCS). This system utilizes the MAVLink protocol to transmit critical flight telemetry, including battery voltage, satellite count, altitude, and vertical speed. This interface allows for "Man-in-the-Loop" safety; operators can monitor the mission in real-time and, if necessary, override the autonomous system to trigger a "Return-to-Launch" (RTL) or emergency land command in the event of a system anomaly or sudden weather change.

F. Operational Safety and Structural Design

To ensure operational safety and prevent accidental injury during ground handling, the system incorporates a hardware safety switch and buzzer module that creates a mandatory physical arming layer; this prevents the motors from spinning up until the pilot manually depresses the switch, while the buzzer provides audible feedback on flight modes and GPS lock status. This safety architecture is reinforced by software-defined failsafe protocols programmed into the flight controller, which automatically trigger a "Return-to-Launch" (RTL) sequence if the battery voltage drops below a critical threshold or if the telemetry link is severed, ensuring the recovery of the aircraft and its medical payload. The physical robustness of the drone is maintained by the F450 frame constructed from high-strength glass fiber and polyamide nylon, a composite material specifically selected to dampen high-frequency motor vibrations that could otherwise interfere with the sensitive MEMS sensors on the flight controller, thereby guaranteeing stable flight performance even under load.

G. Mission Planning and Ground Control Interface

To ensure ease of operation for medical personnel who may not be skilled pilots, the system utilizes Mission Planner as the primary Ground Control Station (GCS) interface. This software allows for a "point-and-click" mission configuration where the user overlays the desired flight path onto Google Maps. The flight plan is constructed using a series of 3D GPS waypoints, each assigned a specific altitude and speed profile to ensure safe terrain clearance. A unique feature of this configuration is the integration of automated peripheral triggers; the mission is programmed to automatically send a PWM signal to the servo channel upon reaching the destination waypoint. This enables the drone to execute the payload drop autonomously without requiring manual input from the ground operator, effectively reducing the delivery process to a single "Launch" command. To further enhance the operational reliability of the system, the interface provides real-time visual feedback of the drone's flight path and internal health parameters, allowing the operator to monitor the mission's progress with high confidence. This streamlined workflow effectively bridges the gap between complex aerial robotics and everyday clinical use, ensuring that life-saving supplies can be deployed rapidly by any healthcare professional with minimal training.

H. Experimental Setup

The experimental evaluation was conducted using a quadcopter platform integrated with a Pixhawk 2.4.8 flight controller and a high-strength F450 frame. The propulsion system consisted of four 1000kV BLDC motors paired with 30A SimonK ESCs and 1045 propellers, powered by an 11.1V 2200mAh 35C LiPo battery. For the autonomous navigation trials, the Ground Control Station (GCS) utilized the Mission Planner software linked via a 433MHz telemetry radio to define 3D GPS waypoints and monitored real-time flight metrics. The payload delivery mechanism was tested using a 2.0 kg dummy medical load secured by a servo-actuated locking system programmed to trigger upon reaching specific GPS coordinates.

I. Experimental Results

The experimental data validated the structural and aerodynamic calculations, confirming that the propulsion system achieved a high thrust-to-weight ratio of 4:1. Under test conditions, the drone demonstrated the capability to lift a maximum safe payload of 2.0 kg, maintaining stable flight dynamics. With a standard 1.0 kg medical payload, the system achieved a flight endurance of approximately 8 minutes, which aligns with the theoretical current draw analysis. The autonomous navigation trials resulted in high precision waypoint tracking, with the servo-actuated mechanism successfully releasing the payload at the target destination without requiring manual intervention.

J. System Behaviour Analysis

Analysis of the system behavior during flight showed that the integration of the MS5611 barometer and the NEO-M8N GPS module allowed for superior altitude and position holding, even under varying wind disturbances. The flight controller effectively managed the sensor fusion from the L3GD20 gyroscope and LSM303D accelerometer to provide rapid attitude corrections, which were critical for stabilizing the aircraft during the payload release sequence. Furthermore, the failsafe logic proved reliable, as the drone initiated the Return-to-Launch (RTL) protocol during simulated signal loss scenarios, ensuring the safety of the sensitive medical equipment. The overall system exhibited consistent performance across multiple flight cycles, proving the feasibility of the modular architecture for rapid emergency healthcare logistics.

K. Software Implementation and Working Results

The software framework of the autonomous medical delivery drone is built upon the Mission Planner Ground Control Station (GCS for payload management. During implementation, a series of 3D

GPS waypoints were mapped onto a high-resolution geospatial interface, defining the flight path, loiter times, and altitude profiles required for safe terrain clearance. The Pixhawk flight controller, running the ArduPilot firmware, successfully executed these pre-programmed missions, utilizing real-time sensor fusion to maintain stable trajectories. A significant result of the software implementation was the reliable execution of automated peripheral triggers; the system was programmed to send a high-state PWM signal to the auxiliary servo port upon reaching the destination waypoint. Working results from flight logs confirmed that the drone maintained a precise horizontal position hold within a 1.5-meter radius and initiated the payload release sequence autonomously, ensuring a contactless delivery without human intervention. Furthermore, the telemetry link consistently transmitted live data on battery health and GPS signal strength, allowing the fail-safe logic to remain active and ensuring that the "Return-to-Launch" protocol would execute effectively if the software detected any system anomalies.

Fig 2. UAV Flight without payload

Fig 3. UAV Flight with payload

L. Evaluation and Performance Analysis

The performance of the autonomous medical delivery drone was evaluated based on flight stability, navigational accuracy, and power efficiency under varying load conditions. Analytical results confirmed that the system maintains a high Thrust-to-Weight Ratio (TWR) of 4:1, which is significantly above the standard 2:1 ratio required for basic flight. This surplus power ensures that the drone can compensate for environmental disturbances, such as wind gusts, while carrying a 1.0 kg payload. During waypoint navigation tests, the integration of the Pixhawk's Inertial Measurement Unit (IMU) with the Ublox GPS module allowed the aircraft to adhere to its pre-programmed flight path with high geospatial precision.

The power management system was analyzed by calculating the current draw during hover and active flight phases. With an 11.1V 2200mAh LiPo battery, the drone demonstrated a theoretical flight endurance of approximately 23 minutes in an unloaded state. However, performance analysis under a 1.0 kg medical payload indicated a reduced flight time of approximately 8 minutes, primarily due to the increased throttle required to maintain a stable hover at approximately 42% motor capacity. The servo-actuated payload mechanism showed 100% reliability in execution, successfully transitioning from a "Locked" to "Released" state upon receiving the automated PWM trigger at the target destination. Overall, the performance evaluation confirms that the current hardware configuration is highly effective for short-range, rapid medical deliveries, meeting the project's primary objective of providing a resilient alternative to ground-based logistics.

M. Design Calculations

a) Assumptions

S.no	Component	Specification
1	Battery Power	1800 mah
2	BLDC Motor	1000 kv
3	Mass after Assembly of Quadcopter	1.5 kg
4	Battery Voltage	11.1 V

b) Weight of Quadcopter

Mass of quadcopter (m) = 1.5kg

Gravitational Force (g) = 9.81 m/s

W = m x g
W = 1.5 x 9.81
W = 14.715 N

c) Torque required to drive the Propeller

R = 130 mm = 0.13 m (propeller's curve radius)
W = 14.715 N
T = W x R
T = 14.715 x 0.13 T = 1.91 Nm

d) Thrust of the Propeller

No. of Propellers & motors = 4
Mass (m) = 1.5 kg
Thrust (T) = (4 / 1) * 1.5
Thrust (T) = 6 N,
Thrust per motor = m / 4 = 0.375 N
Thrust per motor (T) = 0.375 N
To just hover, the drone needs to counteract its own weight (1.5 kg or 14.7 N). The thrust per motor would be 1.5 kg / 4 = 0.375 kg or 14.7 N / 4 = 3.68 N.

e) Thrust Required for the Flight

Thrust to hover = 14.715 N
Thrust to hover per motor = 14.715 / 4 = 3.68 N/motor
Recommended Thrust ratio for agility [2 : 1], to ensure the control and stability, the target thrust should be double the drone's weight Recommended
Thrust = 2 x 14.715 = 29.43 N
Recommended Thrust per motor = 29.43 / 4 = 7.36 N/motor

f) Motor Speed Calculation

The theoretical no load speed of the motor is its kV rating multiplied by the voltage. We'll assume the efficiency of the motor as 85% under load.
N = kV x V x efficiency
where kv = 1000kV,
V = 11.1 V, η = 0.85
N = 1000 x 11.1 x 0.85 N = 9435 rpm

g) Power consumed by motors

Using the empirical formula for propeller power from the reference
Power (W) = K x N3 x D4 x P where,
K = propeller constant [5.3×10^{-15}],
N = rpm = 9435,
D = diameter of propeller = 10,
P = pitch in inches = 4.5,
$W = (5.3 \times 10^{-15}) \times (9435)^3 \times 10^4 \times 4.5$
W ≈ 200.4, watts per motor at max throttle.

h) Thrust generated by one motor

using $T = [(\eta W)^2 \times 2\pi r^2 \times \rho]^{1/3}$
where η = efficiency = 0.85,
W = power = 200.4,
r = 0.127,
ρ = air density = 1.225
$T = [(0.8 \times 200.4)^2 \times 2\pi\,(0.127)^2 \times (1.225)]^{1/3}$
$T = [25702.5 \times 0.124]^{1/3}$
$T = [3187.1]^{1/3}$
T ≈ 14.7 N/motor This is approximately 1.5 kg of thrust per motor. Our required thrust was 7.36 N, so this combination is excellent and provides required power.

i) Payload Capacity

Maximum System thrust
$T_{total\_max} = T_{per\_motor} \times 4 = 14.7 \times 4 = 58.8$ N

Maximum All-Up-Weight (AUW) = $AUW_{max} = T_{total\_max} / 1.7 = 58.8 / 1.7 = 34.6$ N

Payload weight (N) = $AUW_{max} - W_{drone}$
N = 34.6 - 14.715 N = 19.885 N,
converting this to kg's => 19.885 / 9.81 = 2.02 ≈ 2 kg so the drone can carry about 2 kg's of payload.

j) Current draw calculations

Assuming cases,
Total weight with 1kg payload = 1.5 kg (drone) + 1.0 kg (payload) = 2.5 kg
Thrust to hover with 2.5 kg of payload = 2.5 x 9.81 = 24.5 N
Required thrust per motor = 24.5 / 4 = 6.125 N
Throttle percent for hover = 6.125 / 14.7 ≈ 42%

Power to hover per motor
$W_{hover} \approx W_{max} \times (T_{hover} / T_{max})^{3/2}$
$W_{hover} = 200.4 \times (6.125 / 14.7)^{3/2}$
$W_{hover} \approx 54$ watts

Total current drawn to hover with payload

$I_{total} = (W_{hover} \times 4) / V$

$I_{total} = 54 \times 4 / 11.1$

$I_{total} \approx 19.5$ Amps

k) Flight Time Estimation

1000 kV BLDC motor's average current draw is 4.62A so using that and assuming the battery capacity as 1800 mah = 1.8 A,

Flight time(t) = Battery amp x 60 / Motor Amp

Flight time(t) = 1.8 x 60 / 4.62

Flight time(t) = 108/4.62 ≈ 23

t = 23 minutes, so for batteries > 1800mah we can get a solid flight time for > 20 minutes, so using batteries > 1800mah would be a good choice.

IV. DISCUSSIONS

The proposed autonomous medical delivery system demonstrates the effectiveness of integrating high-precision flight control with specialized payload actuation to solve "last-mile" healthcare logistics. While GPS waypoint navigation provides the wide-area autonomy required for Beyond Visual Line of Sight (BVLOS) operations, the servo-actuated mechanism strengthens reliability through automated, contactless delivery at the target destination. This integrated framework effectively bridges the gap between traditional healthcare supply chains and the urgent requirements of disaster-stricken or remote terrains.

The performance analysis of the drone, specifically the achievement of a 4:1 thrust-to-weight ratio, indicates that the system is capable of maintaining high stability and agility even under the stress of environmental disturbances. This surplus thrust ensures that the system can carry a 2.0 kg medical payload with high confidence. The integration of real-time telemetry further minimizes operational risks by allowing ground operators to monitor battery health and GPS signal strength continuously, ensuring that natural barriers or signal interference do not compromise the delivery mission.

One of the major advantages of the proposed framework is its cost-effectiveness and accessibility. By utilizing open-source hardware like the Pixhawk 2.4.8 and affordable frame components like the F450, the total estimated cost was maintained between ₹28,900 and ₹33,000. This makes the system highly scalable and deployable for local health departments and rural clinics without significant financial constraints.

The system's autonomous module ensures that critical supplies like vaccines and blood units can be transported rapidly, with a flight time of approximately 8 minutes for a 1 kg load. By integrating with the Mission Planner GCS, flight data can be reviewed instantly to verify successful delivery. This ensures that necessary medical resources are deployed promptly, allowing for a faster response to life-critical incidents.

The success of this autonomous approach opens opportunities for further enhancement. The integration of Machine Learning for dynamic obstacle avoidance, the use of VTOL (Vertical Take-Off and Landing) hybrid designs for extended range, and the deployment of synchronized drone fleets can make the system even more resilient. Such improvements will contribute toward creating a comprehensive emergency response ecosystem. The implementation of this system has significant societal benefits. By enabling faster medical access, it reduces mortality rates in remote areas and supports global Sustainable Development Goals (SDG 3 and SDG 9) by contributing to equitable healthcare and innovative infrastructure.

V. CONCLUSION

The development of the autonomous medical delivery drone successfully demonstrates a transformative approach to overcoming terrestrial logistical barriers in healthcare. By integrating a Pixhawk-based autonomous flight system with a custom-engineered, servo-actuated payload mechanism, this research has established a resilient platform capable of executing high-precision, contactless deliveries. The experimental validation of a 4:1 thrust-to-weight ratio and a 2.0 kg payload capacity confirms that the quadcopter frame is not only structurally robust but also aerodynamically efficient enough to handle the demanding requirements of emergency medical transport. Ultimately, this project serves as a critical proof-of-concept for how low-cost, open-source technology can be leveraged to achieve significant progress toward global health and innovation goals.

The success of the autonomous waypoint navigation system underscores the potential for drones to operate reliably in "last-mile" delivery scenarios where human intervention is risky or impossible. The ability of the system to maintain a stable flight trajectory and autonomously trigger the payload release upon reaching specific GPS coordinates ensures that time-sensitive medical supplies, such as vaccines and First aid kits, reach their destination without the delays inherent in ground transportation. Furthermore, the inclusion of real-time telemetry and hardware safety protocols ensures that the mission remains under constant monitoring, providing a high degree of confidence for healthcare providers and emergency responders.

VI. FUTURE WORKS

Looking ahead, the next phase of this research will focus on the integration of advanced machine learning algorithms to enhance the drone's decision-making capabilities in complex environments. By incorporating real-time sensor fusion with computer vision and LiDAR, the drone could move beyond static waypoint navigation to achieve dynamic obstacle avoidance, allowing it to navigate safely through dense urban areas or shifting disaster zones. This will be coupled with the development of more robust power management systems and high-density battery technologies to significantly extend the drone's operational range and mission endurance.

Finally, the future scope of the project includes the exploration of multi-drone fleet coordination and the development of temperature-controlled payload modules. Synchronizing a fleet of autonomous UAVs would enable comprehensive coverage during large-scale public health emergencies, while advanced cooling mechanisms would protect the cold-chain integrity of sensitive biological materials during longer flights.

Collaborative testing with medical institutions and aviation authorities will be essential to validate these improvements in real-world settings, eventually leading to a scalable, automated logistics network that ensures equitable healthcare access for isolated populations worldwide.

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