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A prototype of Fixed Wing UAV for delivery of Medical Supplies

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A prototype of Fixed Wing UAV for delivery of Medical Supplies

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Abstract. A prototype Unmanned Aerial Vehicle (UAV) is designed for the purpose of last mile delivery to supply medicines and vaccines. This work aims to ascertain that UAVs can be employed to decrease transportation times, increased power efficiency, and improved safety for transportation of necessary products. The prototype model is design to deliver 700 g maximum payload up to 5 km with an endurance time of 30 minutes. The model is fabricated with a wing span of 1.5 m, Aspect ratio 7, and contains NACA 6 series airfoil shape as its cross section. During the transportation of payload, it has to fly beyond the line of sight which requires an autonomous Pixhawk flight controller installed in the model. Autonomous module aids in the safe flight avoiding the obstacles during the operation. To comply with government regulations for flying the model cruises at an altitude of 350 feet. After reaching the desired GPS destination, the payload is delivered to the target customer via parachute. However, the model requires a runway length of 200 m for its take-off and landing operation.

Keywords: Fixed Wing; UAV; Medical Supply; Pixhawk; Parachute

1. Introduction
The use of drones is proposed for number of domains as it can provides a faster and reliable solution for many transportation issues[1]. Due to an exponential increase in number of road vehicles and the dense traffic pose a challenge for the timely supply of life saving medicines and supply. Hence the use of UAV is proposed mainly for the major task of medical supply transmissions from one point to another. This medical supply generally comprises of blood packets antidotes and even in the transportation of organs which is very difficult in case of road transportation vehicles[2]. To control the spread of diseases and reduce the growing rates of mortality due to lack of adequate health facilities, special attention needs to be given to health care in rural areas. Most people lose their life due to a lack of blood and vaccines. It is difficult to travel inside a rural environment from urban areas because of gridlock as well as some of the rural environments are far away from the city which requires medical supply in a timely manner. Air transportation has many advantages over other means of transportation in the medical supply[3]. An autonomous fixed-wing unmanned aerial system that has higher range capability can travel faster even in rural areas[4] and can carry payloads of crucial components such as blood samples, vaccines, tablets, etc. The fixed wing UAV properly equipped with the autonomous module can fly beyond the line of sight[5]. Once they move beyond the line of sight, with the help of GPS signals it reach the destination and return back using predetermined waypoints. The payload is kept in a bay which is completely enclosed inside the fuselage of the model[6–8].

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2. Design of Fixed Wing UAV

The design and calculation of the medical supply UAV happens in three phase namely conceptual design, preliminary design and detailed design. The conceptual design involves listing a variety of configurations that meet the required mission profile and mission requirements in terms of aerodynamics, propulsion, flight performance, structural and control systems. Further fundamental aspects such as fuselage shape, wing configuration and location, engine size and type are determined during the conceptual design process. In preliminary design process, UAV is further designed to fit the required design parameters of the mission requirements. In this design process component level testing, CFD to estimate wing performance, lift drag estimation, weight estimation, structural design, control surface design, and structural materials are finalized for fabrication. Finally, in the detailed design process, weight of the selected components and electronics is optimized to maximize endurance and ease of operation.

2.1. Mission Profile

The drawing the mission profile (Figure 1) for the proposed application for Fixed Wing UAV provides insight on the actual implementation. From the mission profile the important milestones are highlighted with actual flight envelop (Table 1). From the mission profile the aircraft is outlined to have seven phase in its overall flight. Take-off of the UAV happens on the runway, followed by the climb, the model cruises at an altitude of 350 feet allowed by DGCA regulations, it descend to the altitude of 100 feet to drop the package during using parachute, it again ascents to its cruise altitude during its return flight, it finally descend back to ground followed by ground run before it comes to halt. In the flight envelop, during take-off and landing phase is operated manually the remaining is flight phase is managed by the autonomous flight controller module.

Table 1. Mission Requirements

Criteria	Requirement
Max wingspan	1.5 m
Gross Take-off weight	2.3 kg
Max Endurance	30 minutes
Max Flight speed	12-15 m/s
Payload weight	700 g
Service ceiling (altitude)	150-350 m
Operational range	5 km

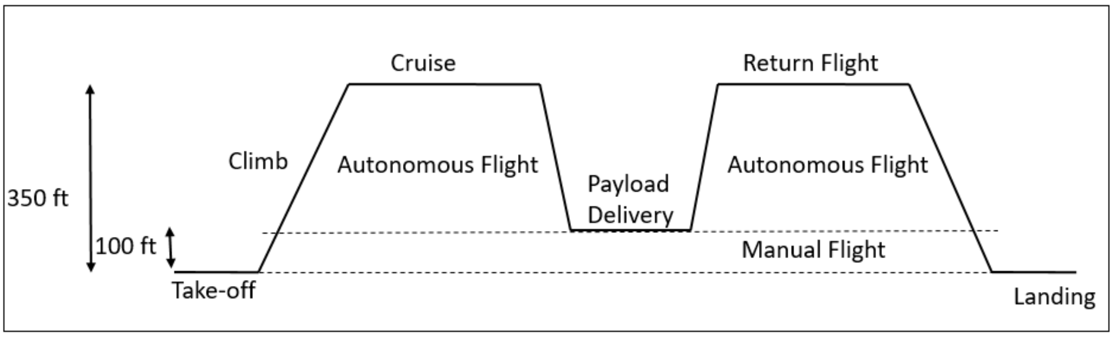

Figure 1: Mission Profile

2.2. Airfoil and Wing Planform

The design of the wing begins with the selection of an airfoil as it is the primary means of generating sufficient lift and minimizing drag effects. The airfoil is selected based on the Reynolds number, coefficient of lift (C_l), coefficient of drag (C_d) and coefficient of moment (C_m) as per the mission requirement. The lift curve slope should be primarily focused while judging the airfoil. Based on above parameters NACA 63-412 was selected as the airfoil for the aircraft. NACA 63-412 has a maximum C_l of 1.2 at an angle of attack 12 degree with a maximum thickness of 12% at 34.9% of chord (Figure 2). This is followed by the selection of an appropriate wing planform. The planform of a wing contributes significantly to its aerodynamic performance, particularly in terms of 3D drag due to wingtip vortex shedding. A detailed analysis led to the involvement of washout and winglets on a combined rectangular tapered planform.

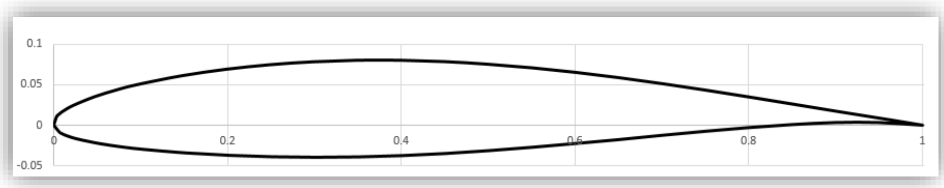

Figure 2: NACA 63-412 Airfoil

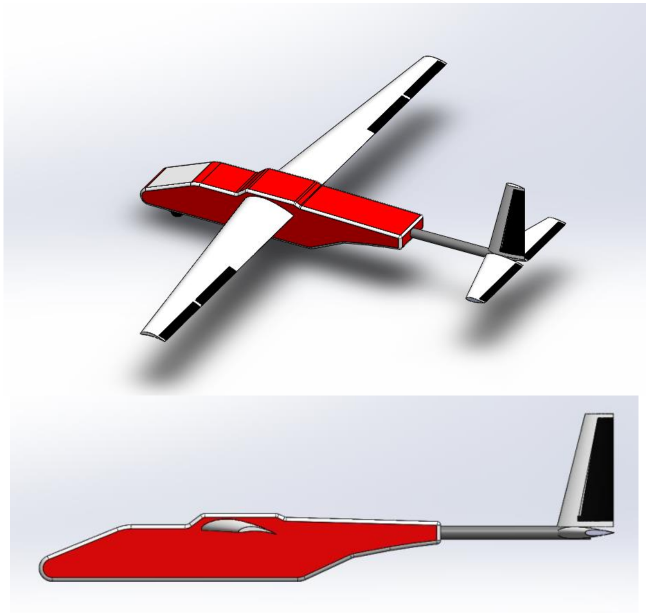

Figure 3: Conceptual Design of Model using CATIA

2.3. Fuselage
The fuselage is the body of the fixed-wing radio controlled plane. It provides space for cargo, controls, accessories, passengers, and other equipment. Fuselage must produce minimum drag and it must have space for all the electronics and propulsion system. From an aerodynamic point of consideration, it is important that the fuselage is streamlined so as to facilitate the airflow with minimum drag. The tail assembly and the propulsion system are attached to fuselage and it bears the all load during the land. Hence the fuselage should have a good structural integrity and it is measured as 1 X 0.12 X 0.10 m^3 (Figure 3). The centre of gravity (CG) of the UAV plays an important role in the flight stability, hence the mass distribution and CG balancing was carried out using the weights of individual components. The electronics, payload and structural components are positioned in the fuselage at different locations and the CG of the model is balanced by altering their locations, so as to locate the CG near the aerodynamic centre.

2.4. Empennage
The empennage for the prototype is located towards the rear end of the model. The empennage contains both horizontal and vertical stabilizers which provides the longitudinal and lateral stability for the plane. It contributes to the overall aircraft stability by controlling the pitch and yaw of the model. Wing position decides the effective location of the empennage. The tail efficiency is reduced when it encounters the wake generated from the wing's trailing edge. Wake creates a reduced pressure region around its centreline for a particular wake width, which depends on the tail moment arm and the minimum drag coefficient of the wing. So the tail has to be positioned outside the wake region for the maximum estimated angle of attack of the flight. The tail configuration was chosen to be of the inverted 'T' type due to its structural strength and the horizontal stabilizer is fixed on the fuselage. Both horizontal and vertical stabilizers are designed to have a cross section of NACA 0012.

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2.5. Electronics

The propulsion system calculations are made with the assumption as a glider model, with thrust to weight ratio as 0.4. Using Static thrust equation propeller dimension is estimated as 11 X 4.5 which provides the necessary thrust for the model. The propeller is driven by an 850 kv brushless DC motor (BLDC) supported by 30 Amp electronic speed controller. The electronic speed controller is positioned such that it is sufficiently air cooled to withstand the heat generated throughout the flight envelop. A 2.4 GHz transmitter is used to assist the model during take-off and landing process while the autonomous flight is supported by a Pixhawk flight controller and 433 MHz telemetry. The power is supplied to all the electronic components using a 6500 mAh Lithium polymer battery (Table 2).

Table 2. Propulsion Specification

Criteria	Requirement
BLDC motor	850 kv
Electronic Speed Controller	30 Amp
Propeller	11 X 4.5
Battery	6500 mAh (4s)
Transmitter/Receiver	2.4 GHz
Autonomous	Pixhawk
Telemetry	433 MHz

2.6. Autonomous Module Installation and Calibration

The autonomous module comprises of a pixhawk flight controller board, Pitot-static tube, GPS module, telemetry, power module and PPM encoder. The entire autonomous module is controlled by the ground control unit which is Mission Planner. The ground control unit transmits the signals to the model using ground and air telemetry. Take-off and landing operations of the model are controlled manually by the pilot. The pixhawk board is placed in the centre of gravity location and it should be free from interference of electromagnetic waves and permanent magnet. The receiver is connected with PPM encoder which converts the PWM (Pulse Width Modulation) signals to digital signals.

Initially the pixhawk is installed in the model for calibration. Through telemetry the flight controller connects with mission planner software. The fixed-wing configuration in chosen manually in the mission planner software and then it uploads the necessary packages to the controller. Once the data is uploaded, the control surfaces in the model are calibrated to ensure proper working for the inbound transmitter signals. The model can be flown in any one of the following three autonomous modes.

- Normal
- Stable
- Fully autonomous

In normal mode, the model is controlled manually. During stability mode, the stability of the model is alone autonomous. In fully autonomous mode the flight controller takes the entire control based on the ground control unit. After completing this process, the model is ready to fly in autonomous mode.

2.7. Parachute design

The parachute is designed to ensure the safe delivery of payload (Figure 4). The parachute is made of nylon fabric to withstand the drag force experienced during the descend phase. The nylon fabric is designed to have a hemispherical surface in its fully extended condition. The strings attaching the payload bay and parachute fabric is arranged and kept together inside fuselage in the manner that they do not tangle during the drop. The surface area of the parachute is designed so that the payload descends at a rate of 3 m/s.

3. Fabrication

To fabricate the fuselage, the bulkheads are made from plywood of thickness 0.3 cm. The remaining structural members are made of duraform sheets of thickness 3 mm and 5 mm. The bulkhead provides the necessary shape to the fuselage. Fuselage is divided into three sections: the first section will contain a propulsion system, the second section is allotted to payload, and the third section contains the autopilot system. The landing gear is attached to the bottom of the fuselage to support ground run during take-off and landing. The prototype has a conventional tail contains horizontal and vertical stabilizers. They are made as separate sections using the duraform sheet and attached to the fuselage.

The wing contains the essential parts such as spar, ribs and stringers. Initially the ribs are cut to the required airfoil sections. A circular aluminium rod of 10 mm diameter is used as spar. The ribs are placed at a distance of 6 inch apart and covered using a 3 mm duraform to complete the wing. The wing screwed to the fuselage and the servos rods are connected to the control surfaces (Figure 5). The entire fuselage and wing structure is covered by vinyl sheets to reduce the skin friction drag and provide a smooth finish.

Figure 4: Parachute attached to payload

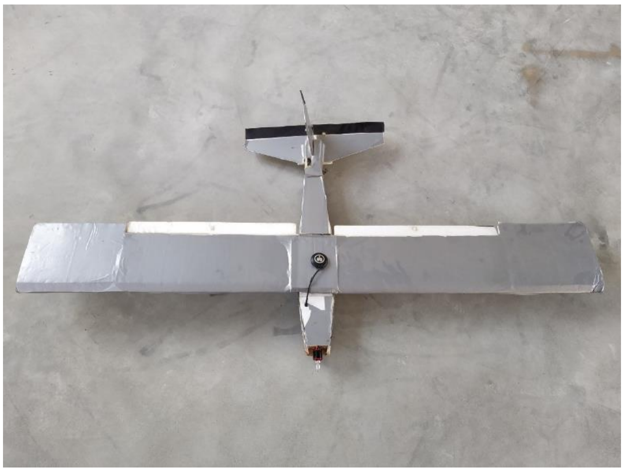

Figure 5: Prototype model with electronics installed

4. Flight Test

The prototype model that need to deliver the medical supply is initially tested for the proper working of control surfaces and propulsion system. The pixhawk module attached with the model is calibrated to the ground control unit to ensure the safe operation during autonomous flight. Payload to be delivered is attached to the parachute system and installed in the payload bay. The payload bay is operated using a servo. The servo opens and closes the payload bay based on the input from the pixhawk. Flight path is instructed to the model through waypoints from the ground control unit to the installed pixhawk using telemetry. Payload drop location is provided to pixhawk as GPS waypoint location.

A fully charged battery is replaced in the model before the flight. The take-off of the model is performed manually until it reaches the altitude of 100 feet and ensured of obstacle free flight. The autonomous module is engaged for the rest of the flight. The model then climbs to 350 and follows the waypoints towards the destination. As soon as the flight close to the drop location it descends to 100 feet altitude and the servo is enabled by the pixhawk to release the payload. Payload using the parachute is descends at 3 m/s and safely landed on the ground (Figure 6). The parachute delivery has to be planned on an open area to avoid the landing on nearby building and trees due to cross wind. The model then ascents to 350 feet and continues its flight using the waypoint for the return flight. Once it reaches the landing spot and acquires the telemetry connection, it will be intimated by the ground control station. The model is then safely landed and prepared for the next flight.

Figure 6: Prototype Test Flight delivering Payload using Parachute

5. Conclusion

The following are concluded from the prototype development

1. Fixed wing UAV is designed and tested for carrying the payload of 700 kg
2. Working of the autonomous module is successful for cruise flight condition
3. Parachute can decent the payload at a rate of 3 m/s to provide safe landing
4. Take-off and landing is to be performed manually by pilot to ensure obstacle free flight
5. Atmospheric wind direction will affect the flight endurance and payload delivery

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