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An Efficient Design And Development Approach For A Fixed-Wing VTOL UAV

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Abstract
This paper presents a comprehensive exploration into the design and development of a Fixed-Wing VTOL UAV, aiming to address the complex engineering challenges inherent in achieving complex trade-offs between stability and maneuverability. The development and analysis methods and tools proposed not only ensure an efficient and seamless design process, but also help in achieving highly accurate preliminary design studies and analysis. By combining insights from aerodynamics, propulsion, stability, and control, obtained from software like XFLR5, OpenVSP and Simulink, this study endeavours to contribute to the advancement of VTOL UAV technology and pave the way for its widespread adoption in practical scenarios. It successfully addresses the challenges faced to balance stability and maneuverability. The fully electric propulsion system also contributes to reducing the carbon footprint in the environment.

Keywords Fixed wing, Stability, Maneuverability, UAV, VTOL.

1. Introduction

Unmanned Aerial Vehicles (UAVs) have emerged as one of the most transformative technologies in modern aerospace engineering, finding widespread applications in military surveillance, environmental monitoring, precision agriculture, infrastructure inspection, disaster management, logistics, and smart city development. Their ability to operate autonomously in hazardous and inaccessible environments has significantly enhanced operational efficiency while reducing human intervention. Among the various UAV configurations, fixed-wing platforms are preferred for long-endurance missions because of their superior aerodynamic efficiency, higher cruising speeds, and extended flight range. However, their dependence on conventional runways for take-off and landing restricts deployment in confined or remote environments.

To overcome these operational limitations, Fixed-Wing Vertical Take-Off and Landing (VTOL) UAVs have been developed by integrating the endurance and energy efficiency of fixed-wing aircraft with the operational flexibility of multirotor systems. Such hybrid platforms eliminate the need for dedicated runways while maintaining efficient forward flight, making them highly suitable for applications including emergency response, infrastructure inspection, surveillance, precision agriculture, cargo transportation, and environmental monitoring. Despite these advantages, designing a fixed-wing VTOL UAV remains a challenging multidisciplinary problem requiring careful optimization of aerodynamics, propulsion, structural configuration, stability, controllability, and avionics integration.

The proposed methodology provides a practical engineering framework for the rapid development of fixed-wing VTOL UAVs and may assist researchers and designers in reducing development time while improving overall aircraft performance.

2. Literature Review

The increasing demand for Unmanned Aerial Vehicles (UAVs) across military, civil, industrial, and commercial sectors has motivated extensive research in aircraft design, autonomous navigation, propulsion systems, and flight control. Designing a fixed-wing Vertical Take-Off and Landing (VTOL) UAV is particularly challenging because it requires combining the aerodynamic efficiency of fixed-wing aircraft with the operational flexibility of multirotor systems while ensuring stability, manoeuvrability, and energy efficiency. Abid and Parveez [1] presented a comprehensive review of UAV design methodologies for different applications and identified several research gaps related to application-specific aircraft design and system integration. Their work emphasized the importance of defining mission requirements before selecting the aircraft configuration. Gursul et al. [2] reviewed leading-edge vortex flow mechanisms and vortex control techniques for delta-wing aircraft, providing valuable insights into aerodynamic performance enhancement and aircraft stability. Anton and Inman [3] investigated vibration energy harvesting techniques for UAVs to improve endurance by utilizing motor-propeller vibrations as an auxiliary energy source. Dundar and Belici [4] proposed a systematic methodology for designing a battery-powered fixed-wing VTOL UAV, including preliminary sizing, aerodynamic analysis, stability calculations, and propulsion system selection, demonstrating the feasibility of hybrid aircraft configurations.

Beyond aircraft design, UAV applications have expanded considerably in recent years. Jensen [5] discussed the role of drones in smart city development and urban mobility, highlighting their potential for infrastructure monitoring, environmental observation, and municipal services. A comprehensive survey on anti-drone technologies reviewed detection, tracking, identification, and mitigation techniques using radar, radio-frequency sensing, computer vision, and image processing methods [6]. Studies on UAV-enabled wireless communication have further demonstrated the advantages of deploying aerial base stations for disaster management and emergency communication networks [7]. These developments illustrate the growing significance of UAV technologies beyond conventional aerial surveillance.

Several researchers have focused on improving UAV flight dynamics and control. Experimental investigations on reconnaissance UAVs validated aerodynamic performance and stability derivatives through both theoretical modelling and flight testing [8]. Universal modular UAV architectures have been proposed to improve adaptability and simplify trajectory control for different mission requirements [9]. The development of integrated onboard data acquisition systems has enabled real-time monitoring of flight parameters, thereby facilitating rapid design iterations and improving overall aircraft performance [10]. Similarly, nonlinear mathematical models for tilt-rotor UAV transition flight have been developed to improve flight control during hover-to-cruise and cruise-to-hover transitions, demonstrating the importance of accurate dynamic modelling for hybrid UAV configurations [11]. Advanced neural-network-based flight controllers have also been investigated to enhance trajectory tracking and flight stability under uncertain operating conditions [12].

Recent studies have further expanded the application domain of UAVs. Çiçek [13] investigated the role of UAVs in smart city ecosystems, emphasizing their applications in environmental monitoring, emergency response, traffic management, and public infrastructure inspection. Alhajahmad [14] developed a smart VTOL UAV equipped with real-time visual intelligence for critical missions, integrating autonomous navigation with onboard image processing to improve operational efficiency in complex environments. Koç et al. [15] presented a comprehensive modelling and simulation framework for UAVs, demonstrating the importance of dynamic simulation and system-level validation during aircraft development.

Several recent studies published in the Turkish Journal of Engineering have also contributed significantly to UAV research. Akay et al. [16] investigated the influence of flight altitude on the spatial accuracy of UAV-derived photogrammetric products and demonstrated that mission planning parameters considerably affect mapping accuracy. Özben et al. [17] proposed a digital twin framework for multimodal drone detection by integrating radio-frequency sensing and computer vision within the AirSim simulation environment, highlighting the importance of intelligent UAV monitoring systems. Şasi and Yakar [18] demonstrated the effectiveness of UAV-based photogrammetric modelling for generating accurate three-dimensional reconstructions of engineering structures, illustrating the versatility of UAV platforms in surveying and mapping applications.

Although substantial research has been conducted on aerodynamic design, propulsion systems, autonomous navigation, photogrammetry, UAV applications, and intelligent control, most existing studies focus on individual aspects of UAV development. Limited work has presented a unified engineering framework that integrates preliminary aircraft sizing, aerodynamic optimisation, stability and control analysis, propulsion system design, avionics implementation, and simulation-based validation for a fixed-wing VTOL UAV. Furthermore, few studies have demonstrated the complete design workflow using widely available engineering software tools suitable for rapid prototyping and practical implementation.

The present work addresses this research gap by proposing a comprehensive and systematic design methodology for a fixed-wing VTOL UAV. The proposed approach combines preliminary weight estimation, aerodynamic analysis using XFLR5 and OpenVSP, stability and control validation through MATLAB/Simulink, propulsion system optimisation, avionics integration, and performance evaluation within a unified development framework. The methodology enables efficient aircraft development while achieving an appropriate balance between stability, maneuverability, payload capability, and flight endurance for practical engineering applications.

3. Method

The development of the fixed-wing Vertical Take-Off and Landing (VTOL) Unmanned Aerial Vehicle (UAV) followed a systematic multidisciplinary design methodology that integrates conceptual aircraft design, aerodynamic analysis, stability evaluation, propulsion system optimization, avionics integration, and flight dynamics validation.

3.1 Overall Design Methodology

The proposed methodology aims to reduce design iterations while achieving an optimal balance between aerodynamic efficiency, stability, maneuverability, payload capacity, and energy consumption. The complete design workflow is illustrated in Figure 1.

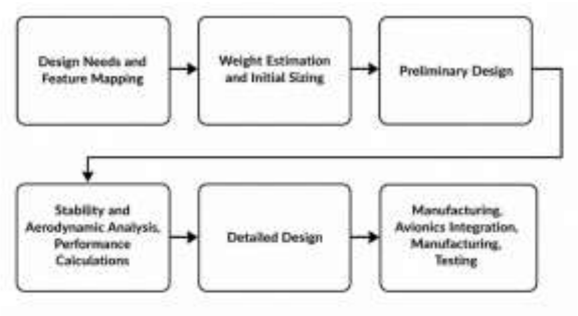

Figure 1. Design Workflow

Initially, mission requirements such as payload capacity, endurance, cruising speed, flight ceiling, and VTOL capability were established. Based on these requirements, preliminary weight estimation and aircraft sizing were performed to determine the principal geometric dimensions of the UAV. The aerodynamic configuration was subsequently developed using OpenVSP, while XFLR5 was employed to evaluate lift, drag, stability derivatives, and aerodynamic characteristics. The propulsion system was designed separately for forward flight and hovering conditions to satisfy the thrust and power requirements of both flight modes. Stability and control analyses were performed using XFLR5 and MATLAB/Simulink, followed by avionics integration using an STM32-based F405 Flight Controller. Finally, the complete aircraft configuration was validated through simulation before prototype fabrication.

3.2 Mission Requirements and Aircraft Configuration

The primary objective of the proposed UAV is to provide a highly efficient fixed-wing VTOL platform capable of autonomous take-off, transition, cruise flight, and vertical landing. The aircraft is designed for surveillance, infrastructure inspection, environmental monitoring, and disaster response missions where conventional runway operations are not feasible.

The principal design requirements include Vertical take-off and landing capability, Cruise endurance of approximately 60 minutes, Maximum operating altitude of 25,000 ft, Payload capacity suitable for imaging and sensing applications, High aerodynamic efficiency during cruise, Stable flight during hover, transition, and forward flight, Fully electric propulsion system. Considering these operational requirements, a hybrid fixed-wing VTOL configuration with four vertical lift motors and one forward propulsion motor was selected. This configuration combines the endurance advantages of conventional fixed-wing aircraft with the operational flexibility of multirotor systems.

3.3 Preliminary Weight Estimation and Aircraft Sizing

Aircraft sizing was performed using empirical aircraft design relationships derived from previously developed composite UAVs. The total gross weight was estimated as given in eq. 1.

$$W_0=W_{af}+W_{pow}+W_{pay} \qquad (1)$$

where

W0= Gross weight
Waf = Airframe weight
Wpow = Propulsion system weight
Wpay = Payload weight

The relationship between empty weight and gross weight was further used to estimate the structural weight of the aircraft. Based on the estimated gross weight, the required wing loading, wing area, aspect ratio, and wing span were determined. An aspect ratio of seven was selected to achieve an appropriate compromise between lift generation, aerodynamic efficiency, structural weight, and glide performance. The horizontal and vertical stabilizers were designed using conventional tail-volume coefficients to provide adequate longitudinal and directional stability. An H-tail configuration was adopted owing to its improved pitch stability and control effectiveness. Here, the weights of the powerplant and payload are known. The relation between the empty airframe weight and the gross weight is given by eq. 2.

$$W_o = A.W_{af}\,C \qquad (2)$$

The values of A and C obtained from pre-existing data, for home-built composite airplanes, is observed to be 1.11 and 0.09 respectively. By substituting the values, we get a value of W_o = 2.65kg and W_{af} = 1.01kg. For intial sizing, the target wing aspect ratio was taken to be 7, to ensure good glide performance and good stability, without affecting the amount of lift produced. The required wing area is calculated from the estimated weight, which is equal to 26N. The lift required is calculated by eq. 3.

$$L=(1/2)\,\rho v^2 A C_L \qquad (3)$$

Where ρ is the air density, CL is the lift coefficient, A is the wing area and v is the indicated airspeed The required wing area for safe operation at sea level is 0.196 m^2. However, since a higher flight ceiling is required, the altitude assumed during initial calculations is 23000ft. above MSL. Hence, the required area at this altitude is 0.345 m^2. These values were then added into XFLR5, which generated the preliminary geometry.

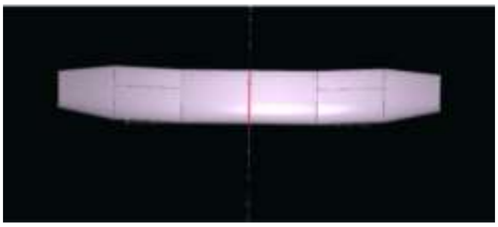

Figure 2: Wing Design

Table 1: Stability Derivatives

Wingspan	Root Chord	Aspect Ratio	Dihedral Angle
1.55m	0.233m	7	7

For the empennage, based on empirical values and pre-existing data, the aspect ratio was taken to be 2/3rd of that of the wing. An H-Tail configuration was selected over other configurations, due to its high effectiveness and better longitudinal stability.

Table 2: Horizontal Stabilizer Design

Horizontal Stabilizer Span	Horizontal Stabilizer Chord	Aspect Ratio	Tail Moment Arm
0.5m	0.15m	3.7	0.61m

Table 3: Vertical Stabilizer Design

Vertical Stabilizer Span	Vertical Stabilizer Chord	Aspect Ratio	Tail Moment Arm
0.28m	0.12m	2.8	0.61m

3.4 Aerodynamic Performance Analysis:

To verify the aerodynamic performance of the aircraft, an analysis was run, which uses the Vortex Lattice Method to compute aerodynamic forces. This analysis verified whether the performance achieved by the aircraft was according to the design needs. The results of the analysis are as follows.

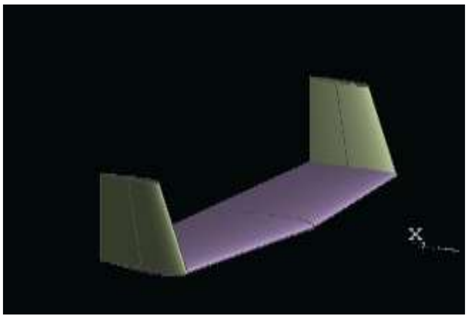

Figure 3: Empennage Design

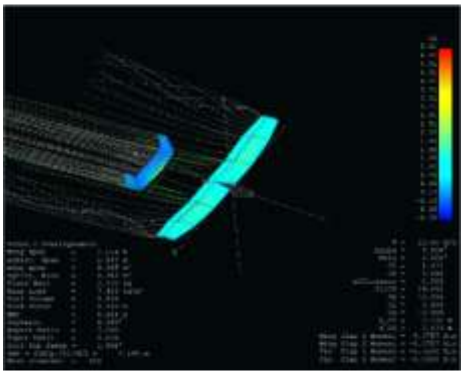

Figure 4: CFD Analysis

Table 4: Design validation case

Lift Force	Drag Force	Pitching Moment	Ostwald Efficiency Factor	Center of Pressure
42N	3N	2.8N-m	0.875	0.139m

From the results obtained as given in Table 4, it is evident that the preliminary design has passed all the necessary requirements and meets the required design needs.

3.5 Stability and Control Analysis:

The aircraft motion, the underlying inter-relations between the various different moments, the effects of the control surfaces have been thoroughly analysed in XFLR5 and Simulink. The dynamics of the aircraft are defined by its stability derivatives, which give an idea on the aircraft's inherent stability characteristics, and its behaviour in response to external disturbances. These stability derivatives, coupled with control derivatives, give an idea of the moment of the aircraft in the three axes. They represent the variation in one parameter, with respect to another parameter. Stability and control derivatives were obtained by conducting a comprehensive stability analysis in XFLR5, and validating these results in Simulink. The values obtained from XFLR% as as follows. The stability derivatives are given by table 5. These values help in understanding the dynamic response of the aircraft due to external disturbances, and the ability to recover level flight without any control inputs.

Table 5: Stability Derivatives

Derivative	Value
C_L (Lift Coefficient due to angle of attack)	5.795
C_m (Pitching moment due to angle of attack)	-3.501
C_{Lq} (Lift coefficient due to pitch rate)	9.443
C_{mq} (Pitching moment due to pitch rate)	-15.763
C_{Yb} (Side Force due to sideslip)	-0.260
C_{lb} (Rolling Moment due to Sideslip)	-0.097
C_{nb} (Yawing moment due to sideslip)	0.097
C_{Yp} (Side force due to roll rate)	-0.17
C_{lp} (Rolling moment due to roll rate)	-0.503
C_{np} (Yawing moment due to roll rate)	-0.03
C_{Yr} (Side force due to yaw rate)	0.223
C_{lr} (Rolling moment due to yaw rate)	0.115
C_{nr} (Yawing Moment due to Yaw rate)	-0.087

The control derivatives are given by Table 6. These values indicate the dynamic response of the aircraft due to the effect of control inputs. The control surface actuation results in secondary aerodynamic effects, which lead to additional moments in different axes. The control derivatives help in understanding these very moments.

Table 6: Control Derivatives

Derivative	Value
C_{la} (Rolling moment due to aileron deflection)	0.288
C_{lr} (Rolling moment due to rudder deflection)	0.027
C_{nr} (Yawing moment due to rudder deflection)	0.076
C_{na} (Yawing moment due to aileron deflection)	-0.088
C_{me} (Pitching moment due to elevator deflection)	-2.26

From the above stability and control derivatives, the body rates have been calculated as given in eq. 4, 5 and 6.

$$p = \frac{2V\left(Cl - Cl\beta.\beta - Cl\delta a.\delta a - Cl\delta r.\delta r - \left(Clr.\frac{rb}{2V}\right)\right)}{Clp.b} \quad (4)$$

$$q = \frac{2V\left(Cm - Cm\alpha.\alpha - Cm\delta e.\delta e - \left(Cm\alpha.\frac{\alpha c}{2V}\right)\right)}{Cmq.c} \quad (5)$$

$$r = \frac{2V\left(Cn - Cn\beta.\beta - Cn\delta r.\delta r - Cn\delta a.\delta a - \left(Cnp.\frac{pb}{2V}\right)\right)}{Cnr.b} \quad (6)$$

where p,q, and r are the roll, pitch and yaw rates respectively, b is the span of the surface and is the chord. The control derivatives have been calculated at a 10 degree deflection of the control surfaces. From these mathematical equations, we get the values of the body rates as given in Table 7.

Table 7: Body Rates (Mathematical)

Roll Rate (Aileron)	Roll Rate (Rudder)	Pitch Rate (Elevator)	Yaw Rate (Rudder)	Yaw Rate (Aileron)
1.250 rad/s	0.872 rad/s	0.381 rad/s	0.431 rad/s	0.227 rad/s

These calculated body rates were then verified in Simulink, which validates the maneuverability of the aircraft. Analysis for the short-period and phugoid modes in the longitudinal axis and the dutch roll mode in the lateral axes was conducted in XFLR5. The dutch roll modes helps understand the effects of adverse yaw on the UAV.

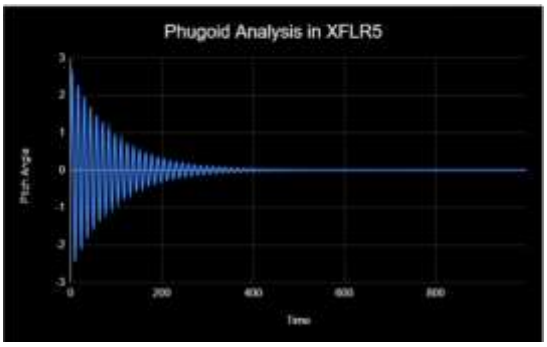

Figure 5: Phugoid Analysis in XFLR5

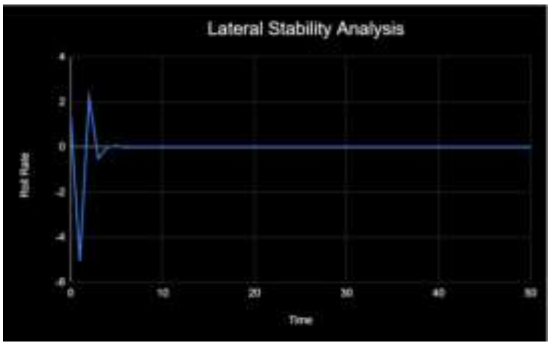

Figure 6: Lateral Stability Analysis in XFLR5

From the Phugoid analysis, it is observed that post a disturbance in steady-state flight path, the aircraft returns to a normal steady state flight path in around 400 ms, with a maximum pitch angle of 3deg. From the dutch roll analysis, it is evident that the aircraft is extremely stable, due to the dihedral added to the end-section of the wing. The aircraft returns back to its steady state in 10ms, with a maximum roll rate of 2 rad/s. A static stability analysis was also conducted, to ensure static aerodynamic stability. To achieve static stability, the neutral point of the aircraft must be located significantly aft of the centre of gravity of the aircraft. The neutral point is defined as the value of CG, wherein the pitching moment does not vary with alpha, i.e. $dCm/d\alpha = 0$. The neutral point can be computed as given in eq. 7.

$$\frac{l_{np}}{c} = \frac{a_t}{a}\left(1 - \frac{d\varepsilon}{d\alpha} \cdot V_h\right) \quad (7)$$

Here, l_{np} is the distance between the neutral point and the centre of gravity of the UAV, c is the mean aerodynamic chord, at and a are the lift coefficient gradients of the wing and the empennage respectively, and ⅆⅆ is the rate of change in downwash angle with respect to angle of attack. The neutral point is obtained at a distance of 28.1cm from the nose. The static stability margin is computed as given in eq. 7.

$$\frac{X_{np}-X_{cg}}{c} \qquad (8)$$

Where, Xnp is the distance of neutral point and the nose, Xcg is the distance between the nose and center of gravity, and c is the mean aerodynamic chord. The stability in the roll axis has been enhanced by introducing a dihedral angle towards the tip of the wing.

From all the above analyses, it is conclusive that the UAV design is aerodynamically efficient and can carry the required payload, while being inherently and aerodynamically stable, both in static and dynamic modes. This is conclusively proved by the phugoid mode analysis and the static stability calculations.

3.6 Propulsion System Design:
The aircraft is powered by a fully electric propulsion system, containing a brushless DC motor, a 3-cell Lithium polymer battery and an electronic speed controller. The thrust and power required are calculated as follows:

a. Forward Flight Modes -

$$T_{req} = W/(L/D) \qquad (9)$$

$$P_{req} = T_{req}.V_{cruise} \qquad (10)$$

From eq. 9 and 10, the required thrust comes to be 3N, to sustain flight in the air, and a power requirement is of 26W. To select an appropriate motor-propeller combination, a rotating-blade analysis was done in OpenVSP, with propellers of different diameters rotating at different RPMs, to arrive at an appropriate value.

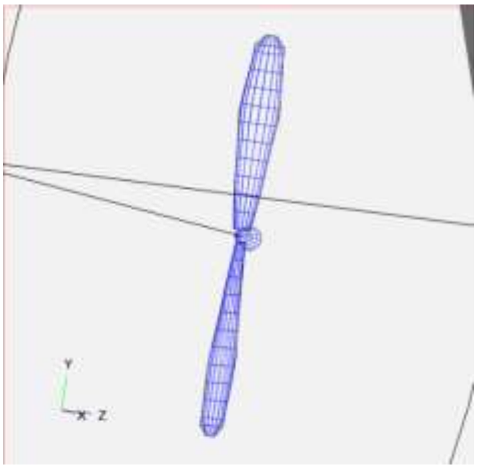

Figure 7: Propeller Design for Forward Flight

Table 6: Propeller Analysis Results

RPM	Thrust	Power
2000	5N	14W
2500	8N	23W
3000	14N	33W

From the analysis results in Table 6, a 920Kv motor was shortlisted, to ensure that the required RPM and torque can be provided, with a 13-inch propeller.

b. Hovering Flight Modes -
To successfully achieve hovering flight, the thrust produced by the four-motor configuration together must be equal to the weight as given in eq. 11.

T=W

For a single motor,

$$(T/4)=W \qquad (11)$$

From the weight estimations, we get the required thrust to be 25.97N. Therefore, for each motor, the required thrust is 6.49N.

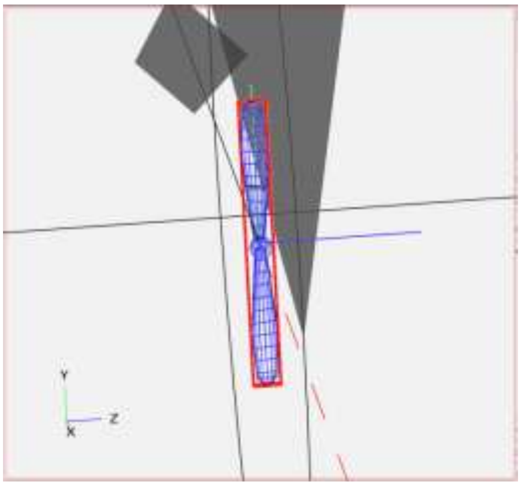

Figure 8: Propeller Design for Hovering Flight

Table 7: Propeller Analysis Results

RPM	Thrust	Power
4000	6N	12W
4500	8N	26W
5000	11N	34W

As per the analysis results in Table 7, a 1000Kv motor and a 10-inch propeller was selected.

3.7 Avionics Interfacing and Calibration:

The on-board computer is the F405 Flight Control Unit, an STM32-based control processor unit. It controls the rotation or RPM of the engine during take-off, landing or horizontal movement of the VTOL-UAV.

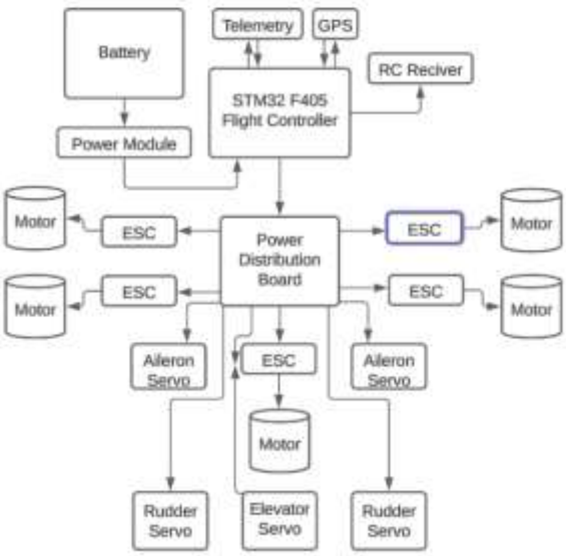

Figure 9: Flight Computer Connections and Interfacing

Data is transmitted from the RC transmitter on the ground for remote control of the VTOL-UAV using a microwave signal operating at 2.4 GHz (ISM unlicensed band for commercial applications). Another transmitter of data from the ground is the control/navigation information for the aircraft. The range is determined by the transmitted power of the RC on the ground and the receiver sensitivity of the RC receiver on board the UAV. It must be in line of sight, meaning any obstruction such as rain, cloud, trees will impair the achievable range of the remote control. Beyond the achievable RC range or due to stalling, the VTOL-UAV will fly under control and the risk of crash/landing will be unavoidable. On board the VTOL-UAV is a GPS and telemetry unit. GPS devices read the position, speed and altitude of the UAV. This GPS data, along with battery and sensor (such as camera) health information, is sent back to a ground-based telemetry transmission centre operating at 915 MHz. A key element to ensure the VTOL capability of the four engines with the stability of the rotary blade for lifting the load. All four rotating blades will have the same RPM and acceleration rate. An increase in RPM would mean an increase in take-off height or slope. A decrease in speed or RPM means a decrease in altitude. Equal RPM for all vertical blades and weight balance are key to ensure stability during take off, landing and horizontal movement. Propeller speed and stability is achieved using PID stability control techniques. Position and stability control is achieved by adjusting the control surface accordingly and tuning the gain of the PID control. Manual speed/rpm adjustments of all engines/propellers are done remotely via radio remote control, while during autopilot missions the UAV will follow a designated speed as programmed in the software.

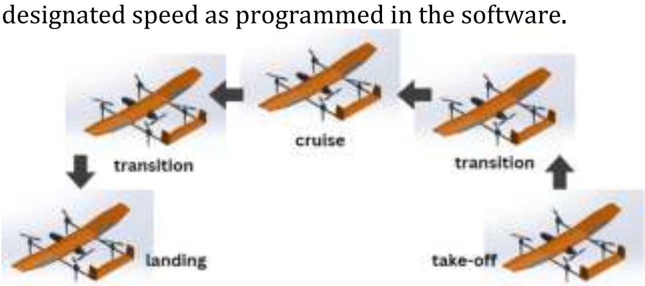

Figure 10: Flight Mission Profile

Proportional, integral and derivative (PID) control is one of the most attractive techniques used to stabilize and optimize UAV control. During flight, stable flight is preferred where the aircraft effortlessly maintains the desired attitude without external inputs from the user. In cases where wind or other external disturbances are detected, the FCU as a processing unit calculates the errors between the current and desired position and makes the necessary corrections. PID control tries to balance this interference by providing more motor and servo outputs accordingly.

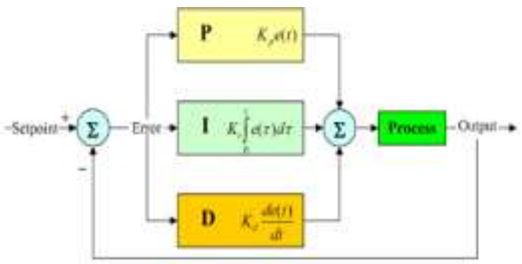

Figure 11: PID Control

The steps for PID control are: First, the desired state is determined and the previously measured state is presented at the beginning of the loop to calculate the state error e(t) = desired state – measured state. The proportional, integral and derivative terms are calculated as KP*e(t), KI*($\int_0^t e(t)\,dt$) and KD*($de(t)/dt$). These 3 terms add up to give the motor/servo output, u(t) = P + I + D. In reality, it would be difficult to obtain a stable system by simultaneously tuning the control gains (KP, KI and KD). PID controller controls movement on all three axes. Therefore, the more critical axes, which are pitch and roll, are first stabilized separately before the yaw axis. The PID control method will provide the desired stability characteristics on all axes when the control gains are properly tuned. PID control is the most widely used method in theoretical approach and engineering applications partly because exhaustive dynamic models are not required to implement this method. Obtaining the best control gain parameters can be done by adjusting the live gain during flight tests according to the control effect of the UAV until the desired response is achieved. Many researchers who have resorted to the development of UAVs based on PID control have achieved stable flights on their experimental platforms in various modes. Therefore, PID control is adopted in this study due to its reliability.

3.8 Aerodynamic Design and Performance Analysis

The complete aircraft geometry was developed using OpenVSP and subsequently analysed using XFLR5 based on the Vortex Lattice Method (VLM). The aerodynamic analysis estimated lift coefficient, drag coefficient, pitching moment, centre of pressure, and Oswald efficiency factor over the operational flight envelope.

The aerodynamic model was iteratively refined until the required lift generation and stability characteristics were achieved. The design was optimized to minimize aerodynamic drag while maintaining sufficient lift for cruise flight and ensuring acceptable stall characteristics. The obtained aerodynamic parameters served as inputs for subsequent stability and control analyses.

4. Results

To evaluate the compliance of the designed aircraft with the design requirements, the major performance characteristics such as flight ceiling, stall speed, maneuvering speed, etc. were computed. The aircraft shows full compliance with all the required design parameters, constraints and needs. The values of body rates for the longitudinal and lateral trim conditions were obtained using the Model Linearizer in Simulink. The trim conditions were obtained at altitudes of 2000ft, the optimum operating altitude and the maximum operating altitude of 25000ft. The longitudinal phugoid stability and lateral stability were verified in Simulink. The body rates were also verified, resulting in highly accurate results. The wave illustration of the rates is given in

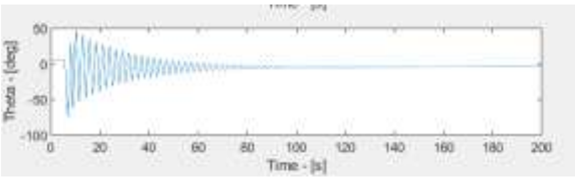

Figure 12: Phugoid Mode Verification in Simulink

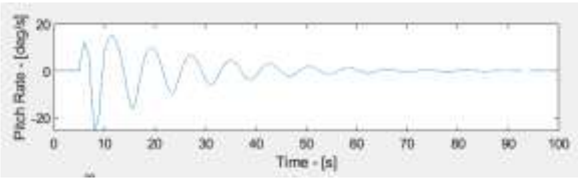

Figure 13: Pitch Rate due to Elevator deflection in Simulink

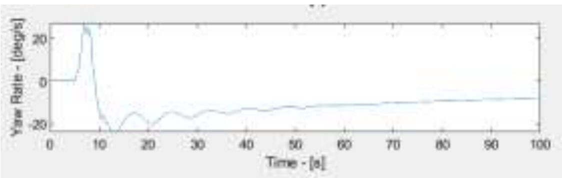

Figure 11: Yaw Rate due to Aileron deflection in Simulink

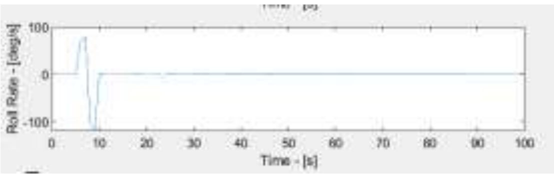

Figure 12: Roll Rate due to Aileron deflection in Simulink

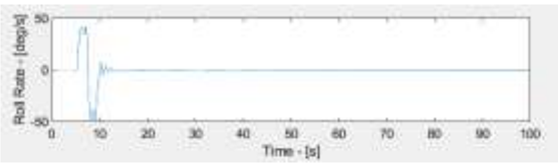

Figure 13: Roll Rate due to Rudder deflection in Simulink

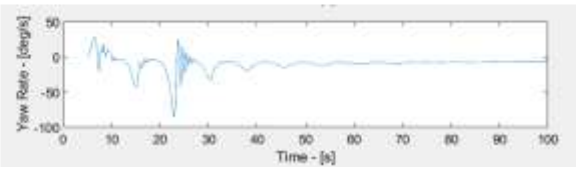

Figure 14: Yaw Rate due to Rudder deflection in Simulink

Table 8: Performance Characteristics

Max Altitude	Enduran-ce	Cruise Speed	Maneuvering Speed	Stall Speed	Top Speed
25000ft	60min	15.89 m/s	19.76m/s	5.92 m/s	23.04m/s

A static stability margin of 14% has been achieved, making the UAV inherently stable in forward flight, and according to the roll, pitch and yaw rates calculated and verified from Simulink, the desired maneuverability has also been achieved, without compromising on stability.

5. Conclusion

In conclusion, this research paper has presented a comprehensive approach to the design and development of a Fixed-Wing VTOL UAV, addressing the challenges associated with seamless transitions between vertical and horizontal flight modes. Through amalgamating insights from aerodynamics, propulsion, stability, and control, significant progress has been made in enhancing the operational capabilities of UAV technology. The methodology outlined in this paper, including feature mapping, weight estimation, aerodynamic performance analysis, stability and control analysis, detailed design, and powerplant selection, provides a structured framework for efficient UAV design and development. By systematically addressing key aspects of UAV engineering, such as aerodynamic efficiency, stability, and control, the proposed approach ensures the creation of a robust and capable aircraft. There are several avenues for further research and development in the field of Fixed-Wing VTOL UAVs. Firstly, continued advancements in propulsion systems, including electric propulsion and energy harvesting technologies, can further improve the efficiency and endurance of UAVs, enabling extended mission durations and increased payload capacities.

Additionally, research into advanced control systems, including adaptive control algorithms and autonomous navigation capabilities, can enhance the autonomy and reliability of UAV operations, enabling greater autonomy in complex environments. Furthermore, exploring novel materials and manufacturing techniques can lead to lighter and more durable airframes, reducing weight and improving overall performance. Integration of advanced sensing and communication technologies can enhance situational awareness and enable seamless integration into existing airspace systems. Overall, the future of Fixed-Wing VTOL UAVs holds immense potential for revolutionizing aerial operations across various domains, from military reconnaissance and surveillance to civilian applications such as infrastructure inspection and disaster management. By continuing to innovate and refine design and development methodologies, UAV technology will continue to advance, unlocking new possibilities and driving the adoption of unmanned aerial systems in diverse fields.

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Conflicts of interest
The authors declare no conflicts of interest.

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