Propulsion Requirement and Analysis of a Canard Prandtl - Wing Unmanned Aerial Vehicle Platform for Civilian-Oriented Missions

Cindy May C. Belivestre
Mindanao State University-Iligan Institute of Technology

Jonathan C. Maglasang
Cebu Technological University

https://doi.org/10.5109/7323282

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 10, pp.332-339, 2024-10-17. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

Propulsion Requirement and Analysis of a Canard Prandtl – Wing Unmanned Aerial Vehicle Platform for Civilian-Oriented Missions

Cindy May C. Belivestre[1], Jonathan C. Maglasang[2]
[1]Mindanao State University-Iligan Institute of Technology, [1]Caraga State University, [2]Cebu Technological University.
Corresponding author email: ccbelivestre@carsu.edu.ph

Abstract: *This study evaluated the propulsion performance of a canard Prandtl-wing unmanned aerial vehicle (UAV) using computational methods to assess its compliance with mission requirements. The UAV specifications included a take-off gross weight of 7 kgf, a cruising speed of 20 m/s, and a minimum endurance of 1 hour. Analysis revealed that maximum power consumption occurred during takeoff, requiring 66.48 N of thrust and 200 W power after 2 minutes. During the loiter phase, the system achieved minimum power consumption of 60 W with 51 N of thrust at 16 m/s. Descent commenced at 11.5 minutes, with a descent and landing phase lasting 3.5 minutes. Power consumption decreased during this phase, completing the mission in 15 minutes. The 15-minute sample flight plan, covering 2.5 km, was scaled up to a 1-hour flight at 10 km, proving the electric propulsion system's capability to meet the design specifications for civilian oriented missions.*

Keywords: Computational fluid dynamics, unmanned aerial vehicle, electric propulsion, battery

1. INTRODUCTION

The Philippines' interest in deploying unmanned aerial vehicles (UAV) for various military and civilian operations has increased in the recent years [1]. These activities include surveillance, search and rescue, battle damage assessment, and scientific data collection, among others. UAVs are ideally suited for missions that are deemed too hazardous for human pilots [2]. The possible benefits of UAVs over piloted missions include cost savings, the avoidance of pilot loss, and enhanced maneuverability. It has played an indispensable role but there is still a need to improve the UAV's capabilities to fulfill the growing need for it to undertake additional jobs as its use for a wider variety of missions expands [3]. As the military, emergency, and recreational markets increase their usage of small UAVs, the need for more technologically advanced systems increases [5]. Nowadays, UAV capabilities can be categorized as either in use or in development. Often, they are categorized according to mission requirements [4].

Range, endurance, and payload capacity are three of the most crucial aspects of any unmanned aerial vehicle. Most UAVs are well-balanced in these categories, but their performance lags that of their larger counterparts in all of them. Power, weight, and efficiency are the parameters of range, endurance, and payload [6]. Given that the propulsion system alone consumes up to 90% of the total power generated by the UAV, it is evident that this system's efficiency is a crucial area for optimization [2].

The Philippines is confronted with numerous issues, including food security, resilience, agricultural efficiency, various extreme weather events, multiple geophysical dangers, environmental degradation, and even national security [1]. Innovative solutions and creative applications of currently available technologies would be needed to address the problems and issues the nation is already facing. The vehicle propulsion system of a canard Prandtl - wing unmanned aerial vehicle is to be designed for a subsonic (below Mach 0.2) flow regime.

This vehicle is designed for civilian-oriented tasks including security and incident surveillance, monitoring of the shoreline and sea lanes, search and rescue, monitoring of pollution and the land, and many other similar tasks. The purpose of this study is to determine how the vehicle can perform satisfactorily according to its mission.

The propulsion system of the aircraft was analyzed utilizing computational methods for the UAV to function adequately in accordance with its planned mission and condition.

Specifically, this study aims to conduct computational analysis of the propulsion system of a canard – configured Prandtl - wing unmanned aerial vehicle and validate with experimental data of a hybrid propulsion system with the same aircraft configuration and mission, to establish the propulsion system with appropriate components to achieve the desired mission and conditions and to determine the specifications of the propulsion system components, power, and thrust.

This study will provide an approach for the nation's monitoring operations. The national or local government would be able to use the UAV platform for civilian-focused tasks like security and incident surveillance, coastline and sea-lane monitoring, search and rescue, pollution and land monitoring, search for missing persons, water course and level monitoring, flood and pollution control, fisheries protection, survey, and disaster control [3].

The platform could also be employed in the research community for scientific investigations that call for aerial photography. It can be altered to map atmospheric conditions or topographical features. The significance of the vehicle's propulsion is addressed in relation to how it can function appropriately in accordance with its mission.

In the process of designing an aircraft, several aspects are analyzed. Aerodynamics, structural analysis, stability, control systems, cost, and propulsion are all included in the analysis.

This work primarily focuses on the computational analysis of a canard-Prandtl-wing UAV platform's propulsion system under a controlled environment. The vehicle's computational analysis is carried out through rigorous simulations utilizing computational fluid dynamics.

2. RELATED WORK

An examination of completed studies and subjects pertaining to the propulsion analysis of unmanned aerial vehicles is provided in this section. Propulsion analysis methods were also discussed to support the findings and assess their importance during the design phase.

2.1 Electric propulsion system

Electric propulsion systems encompass various concepts in energy storage and conversion, with fuel cells, batteries, and solar panels being the most prominent. These systems are continually improved due to their use in mobile and automotive applications. This study focuses primarily on battery-powered systems, which directly extract electric power from the stored energy in batteries. The efficiency of these systems is limited by the chemical reactions occurring during charging and discharging. Unlike specific air-breathing cells like Li-O_2, the mass of battery systems generally remains constant. During the operation of lithium-ion batteries, unexpected heat could be generated, which reduces the energy storage capacity as well as the longevity of the batteries. Many researchers conduct simulation analysis of different types of batteries [14]. For small UAVs, key considerations include power density and the weight-to-energy ratio [30].

Doupe [17] outlined the goals, components, performance, and data collection methods for a testing apparatus designed to evaluate a battery-powered aircraft propulsion system intended for commercial use. The primary objective of the apparatus was to identify and measure the characteristics and efficiency of the entire propulsion system. Doupe's [17] findings indicated that at 2200 RPM, the system produced an output power of 3.2 kW, which is 25% of its maximum rated power, with an efficiency of 58.6%. However, the study highlighted the need for improvements in the apparatus, suggesting enhancements such as a more durable and quieter data acquisition (DAQ) system, a reinforced mounting structure, a larger wind tunnel to accommodate the system, and a tool for calculating propeller efficiency.

Le Solliec [19] described a propulsion system for a small unmanned aerial vehicle (UAV) that required a large power plant to enable the UAV to travel quickly, be as light as feasible, and be silent. With the integration of two brushless rolling cage motors, all restrictions were met. On the other hand, the batteries' capacity and number of cells were chosen based on a variety of factors, including motor characteristics, autonomy, power reserve, and life cycle charge/discharge. For these components, a wide variety of technologies were given. Lithium polymer batteries, which perform better than older technologies for stored energy by weight unit, were more suitable in his architecture.

Brandt and Selig [9] stated that much research has been carried out on propellers for full-scale aircraft but not much data exists on propellers applicable to the ever-growing number of UAVs. Many of these UAVs use propellers that must operate in the low Reynolds number range of 50,000 to 100,000 based on the propeller chord at the 75% propeller-blade station. Tests were performed at the University of Illinois at Urbana-Champaign (UIUC) to quantify the propeller efficiency at these conditions. In total, 79 propellers were tested and the majority fit in the 9-14 inches diameter range. During the tests, the propeller speed (RPM) was fixed while changing the wind-tunnel speed to sweep over a range of advance ratios until reaching the windmill state or zero thrust. Propeller efficiencies varied greatly from a peak near 0.65 (for an efficient propeller) to near 0.28 (for an exceptionally poor propeller). Results indicate that the Master Airscrew propellers for UAVs can have a dramatic effect on aircraft performance.

2.2 Aircraft performance

There are many ways to analyze an aircraft's performance, including using Matlab codes, Microsoft Excel codes, computational fluid dynamics (CFD) models, and aircraft applications. With the help of these tools, users can quickly enter information about the aircraft, evaluate the impacts of modifying performance requirements and characteristics, and, if they so choose, modify or adjust the methods used to calculate the aircraft's performance in response to specific circumstances.

Rutkay [13] devised a procedure for the design and fabrication of mission- and aircraft-specific propellers for small UAVs. To build a propeller that satisfies user-defined aircraft performance criteria within the constraints of the material, manufacturing procedures, and motor, he created a computer program using Microsoft Excel. In his investigation, different speeds were computed under the assumptions of steady, level flight, and user-defined normal wind conditions. Moreover, the thrust necessary to reach these speeds under usual operating circumstances, such as while cruising in mild winds or making gentle bends and climbs, is referenced to as the normal required thrust (NRT). The thrust required and measured during testing is displayed in Table I.

Table 1. Thrust required and measured during testing (Rutkay, 2016)

	Speed		**Design thrust [N]**	**Rotational speed [RPM]**	**Delivered thrust @Rotational speed [N]**	**Max delivered in Testing [N]**
	[KTAS]	**[km/h]**				
Maximum endurance	19	35	14.45	4200	10.00	12
Maximum range	23	42	12.73	4000	7.00	8

2.3 Design approach of UAV

When constructing a UAV, several different factors must be considered. The UAV's function must be determined before the design is finalized. Performance is the key consideration, for instance, if the UAV is intended for military attack missions. The length of time a UAV can stay in the air is almost always determined by its propulsion system. The aircraft's construction material is another factor. The geometry of the UAV—specifically, its wing dimensions, length, and wingspan—affects the aircraft's own lift and drag. Finally, developing a UAV is always driven by cost [20].

3. THEORETICAL BACKGROUND

This section focuses on the computational performance of propulsion. As such, the theoretical propulsion concepts presented are merely a summary of how current numerical methods of propulsion were created. The design and methods of propulsion were addressed in the next section. The topics covered in this section can be found in works by Anderson [24], Raymer [23], Roskam [25], and the Federal Aviation Administration [28].

3.1 Forces acting on an aircraft

The precise coordination of four distinct physical forces—lift, drag, weight, and thrust—is required to achieve heavier-than-air flight. An aircraft's lift must equal its weight while its thrust must exceed its drag.

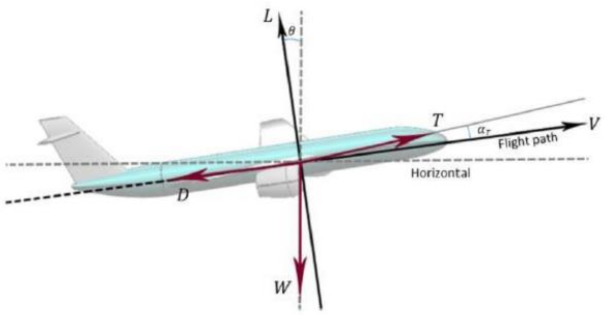

Fig.1. Variables in an aircraft motion (Anderson, 1989).

3.1 Thrust required

The thrust needed to maintain these flight circumstances is adequate to precisely overcome the drag and keep the airplane moving in a constant level flight at a certain velocity and altitude. For a steady level flight, the thrust required is,

$$T_R = \frac{W}{(L/D)} \qquad (1)$$

This indicates that at indicates that T_R reduces as L/D decreases for an aircraft with a fixed weight. When L/D is at its peak, the T_R is minimum.

3.2 Thrust available

The aircraft's power system generates the thrust indicated by T_A, which stands for "thrust available." This study focuses on electrical propulsion systems that can propel an airplane with dependability and efficiency. The thrust available T_A is almost entirely determined by the power plant and less by the airplane's airframe than the thrust required T_R, which is almost entirely determined by the airframe and has little to do with the power plant.

$$T_A = \frac{\eta_{pr} P}{V_\infty} \qquad (2)$$

This demonstrates that T_A drops as V_∞ increases by assuming a variable-pitch propeller with a minimum change of η_{pr} with V_∞.

3.3 Maximum velocity

For steady, level flight, $T_R = T_A$. The available thrust is at its maximum for flight at V_{max}. Hence,

$$T_A = \frac{\eta_{pr} P}{V_\infty} \qquad (3)$$

An analytical technique for determining the maximum velocity directly employs the expression

$$V_{max} = \left\{ \frac{\left[\frac{T_{Amax}}{W}\right]\left(\frac{W}{S}\right) + \left(\frac{W}{S}\right)\sqrt{\left[\frac{T_{Amax}}{W}\right]^2 - 4C_{D,O}K}}{\rho_\infty C_{D,O}} \right\}^{1/2} \qquad (4)$$

Following this equation, maximum velocity is dependent on the maximum wing loading W/S, thrust-to-weight ratio $\frac{T_{Amax}}{W}$, altitude via ρ_∞, and the drag polar via $C_{D,O}$ and K .

3.4 Minimum velocity

Both wing loading and $(C_L)_{max}$ define an aircraft's stall velocity at a given height for steady, level flight

$$V_{stall} = \sqrt{\frac{2}{\rho_\infty}\frac{W}{S}\frac{1}{(C_L)max}} \qquad (5)$$

One of the most essential aspects of an airplane's performance is what is known as its stall velocity. Speeds during takeoff and landing are marginally higher than during V_{stall}.

3.5 Power required

The amount of power needed by an aircraft in a constant, level flight is represented by P_R

$$P_R = T_R V_\infty = \sqrt{\frac{2W^3 C_D^2}{\rho_\infty S C_L^3}} \propto \frac{C_L^{3/2}}{C_D} \qquad (6)$$

Power required varies inversely as $C_L^{3/2}/ C_D$, as opposed to thrust required, which varies inversely as C_L/C_D.

3.6 Power available

The power supplied by the aircraft's powerplant is indicated by PA, or power available. It is given by

$$P_A = T_A V_\infty \qquad (7)$$

3.7 Range and endurance

Range is the total distance an airplane can travel on one tank of fuel, measured in relation to the ground, whereas endurance is the entire amount of time an aircraft can fly on a tank of fuel. The optimization of these variables has long been a crucial component of aircraft design. It was intended to use battery-powered electric components in the aircraft design. Hence, calculations consider the battery's capacity, the circuit's resistance, and the propulsion system's power requirements.

4. METHODOLOGY

The layout and integration of the propulsion system into the overall vehicle design are depicted in this section. The topic of design flow was expounded upon in the book Variational Analysis and Aerospace Engineering: Mathematical Problems for Aerospace Design by Giuseppe Butazzo and Aldo Frediani [26]. Figure 2 illustrates the flow of this design process.

4.1 UAV design requirements

For the desired mission profile, design requirements are often determined by the customer. Calculations of the airplane propulsion performance then start using these needs as the input. Some original requirements are closely adhered to, and some are depending on the calculation findings since the conceptual phase of the aircraft design stage uses an iterative calculation approach. Initial specifications of the UAV for the proposed application in this study are purely based on the literature that are mentioned in section 5.

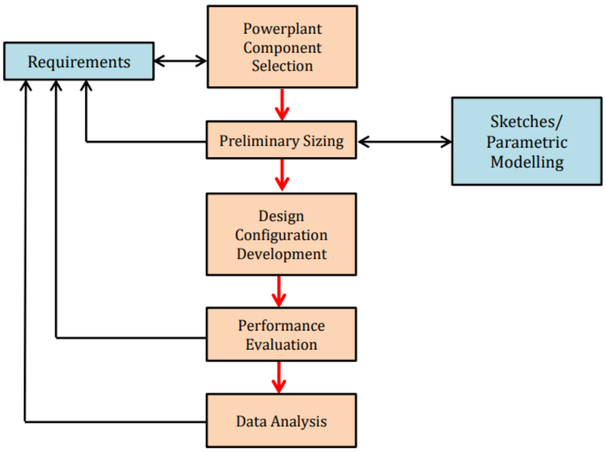

Fig.2. Design process flow.

4.2 Power-plant component selection

The design criteria and mission profile were the main factors in choosing the type of power plant required. A power plant will typically be a fixed-wing aircraft with a way to generate electricity, a way to manage engine temperature, and a way to control engine speed and or power output. The various propulsion technologies taken into consideration for the UAV in this study were compared using systems and trade-off analysis. A basic propulsion conceptualization procedure was then followed once the initial data requirements were determined. For the unique mission requirements of the aircraft, airfoil design and analysis to be employed in the propeller were eliminated. The selection was made from the diverse and dynamic available and published airfoil data. The category for selection was airfoils created for low speed and high gliding performance.

Solidworks and eCalc were utilized to compute flight electronics to ensure optimal effectiveness and flight time. To calculate factors like flight time, amp draw, electronics temperature, propeller size, and thrust produced, eCalc incorporates a sizable brushless motor database in addition to other electronics. Given its high energy density, light weight, scalability, compatibility with brushless motors, and milliamp-hour (mah) measurement, the lithium polymer (LiPo) battery was simulated during trials. Due to weight restrictions and power requirements, LiPo is the best option because it has a better energy density and is lighter than other batteries of such a size. The brushless motor is currently the industry standard and offers sufficient thrust for its small weight [7]. To regulate power output and distribution to all further aircraft systems, an ESC that was wired to the motor was also required.

4.3 Preliminary Sizing

In this study, the propulsion system of the unmanned aerial vehicle was rendered in three dimensions using a CAD-embedded application named SolidWorks. The three-dimensional models of the aircraft's propulsion were drafted once the aircraft loads were established. These models were employed for the CFD study, and each time one of their specifications was not met, it was promptly improved.

4.3 Design Configuration Development

The design configuration involved extensive computational fluid dynamics (CFD) simulations using SolidWorks to optimize the UAV's aerodynamic performance. The canard configuration, characterized by the placement of smaller forewings ahead of the main wing, was selected for its potential to enhance stability and control, as well as to reduce drag. The Prandtl-wing design was incorporated to improve lift distribution and minimize induced drag, further enhancing the UAV's efficiency [1].

Fig.3. Raw UAV configuration used in the study (Remocaldo, 2015).

Key aspects of the propulsion system were tailored to meet the specific needs of civilian-oriented missions, which often require extended flight durations and low noise levels. The study identified the optimal power plant configuration, balancing power output and weight considerations to ensure maximum efficiency. Propulsion system components, including motors and batteries, were carefully selected and integrated based on their performance characteristics and compatibility with the UAV's aerodynamic design.

4.4 Evaluation of UAV’s flight performance

The analysis of the UAV's flying performance is made simple by the drag polar curve produced by the CFD analysis. The term "flight performance" refers to factors like the amount of thrust and power needed, the maximum and stall speeds, the rate of climb, range, endurance, and glide flight. They were all computed using standard equations for the kinematics of flight.

5. RESULTS AND DISCUSSIONS

The output of the aircraft propulsion analysis in this study is presented in this section. The data collected and the changes made at each stage of the process were also discussed

5.1 UAV design requirements

The aircraft's specifications were based on previously published material and were applied to close-range mini-UAVs [21] that could manage extended loiter endurance for civilian oriented missions. Table II and Figure 4 illustrate the design criteria as well as the mission profile, respectively.

Table 2. Close range mini-UAV's design requirements (Austin, 2010)

Gross weight	4 – 7 kg
Wingspan	1.5 – 2.5 m
Cruise speed	20 m/s
Endurance	1 hr
Operating range	10 km
Payload mass	1 – 1.5 kg

The mission profile entailed the following stages: taxi, takeoff, climb, cruise, loiter, cruise, landing, and taxi.

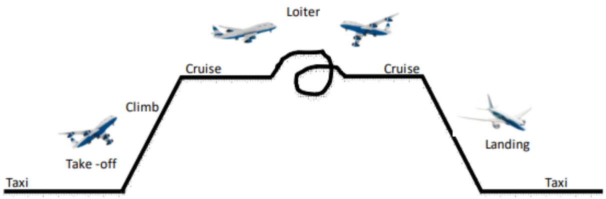

Fig.4. Mission profile

5.2 Power-plant component selection

The selection of suitable power plant for an aircraft depends on its intended function. For the UAV to move quickly, be as light as feasible, and be as silent as possible, the power plant needs to be powerful enough. Normally, the design requirements will make it clear which propulsion technology to use [18].

An electronic speed controller (ESC), a lithium polymer (LiPo) battery, and a brushless motor and propeller were required as a bare minimum for the aircraft's propulsion system in this study and were later incorporated into the simulation. The flight electronics were chosen using Solidworks and eCalc, an online database program, to guarantee maximum effectiveness and flight time. The eCalc uses a vast database of brushless motors as well as other electronics to compute things like flight time, ampere draw, electronics temperature, propeller size, and thrust produced. To ensure that the aircraft can maintain flight, the thrust to weight ratio must be at least 1:1; as a result, setups that return values below this threshold were flagged as not suitable [7].

The key test variables were thrust to weight ratio and flight time, with other variables controlled within appropriate ranges. The UAV's established propulsion system is summarized in Table III. The motor, battery, propeller, and controller used throughout the simulation are listed along with their best fits. To replicate a runtime of more than 60 minutes and maximize the power plant's efficiency, the best and most effective electronics were chosen.

Table 3. Summary of the propulsion system components

Component	Type	Justification
Battery	LiPo (Lithium Polymer)	These batteries are an excellent choice for UAV applications due to their high energy density, high discharge rate, and lightweight. Moreover, LiPos perform well compared to other battery technologies. (Le Solliec, 2013)
Motor	Scorpion SII-4025-330	The use of motors manufactured by the Scorpion brand was chosen upon because of their high strength wire wound that was rated for up to 180℃, and unique CNC cut mate- rial for the best possible fit. (Malhotra & Davis, 2017)
Controller	ESC Max 30A	This controller was created especially for brushless motors. It met the demands for the motor under consideration with a max- imum permissible current draw of 30 amperes. (Based on simulation results)
Propeller	Master Airscrew Elec- tric	Under cambered blades of the Master Airscrew style of propeller allow for excellent speed, thrust, and noise reduction. This is the best way to create an aerial vehicle with excellent performance. (Brandt & Selig, 2011)

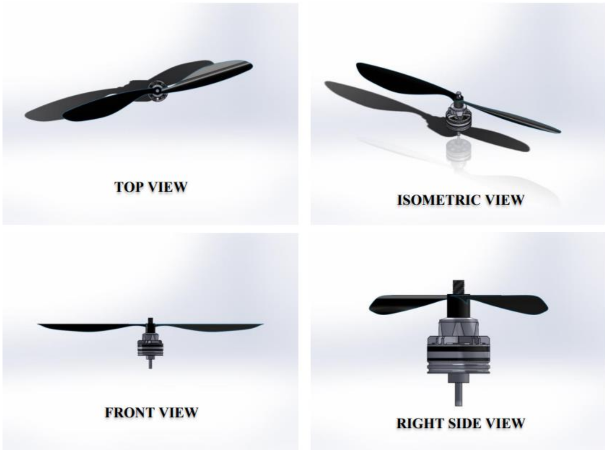

Fig. 5 Motor – propeller assembly rendered thru SolidWorks.

5.3 Performance analysis and evaluation

According to a prior study on the aircraft's aerodynamic analysis, the maximum lift coefficient occurs at 12°, where it is 0.237, and the maximum drag coefficient is 0.054. This is equivalent to a lift force of 127.87 N (13 kgf) on a 190 cm span wing at a 20 m/s airspeed [1]. Figure 6 shows the flow visualization.

The flight missions of the UAV using a hybrid propulsion system (internal combustion engine, solar panel, and electric motor) are depicted in Figures 7 and 8. Utilizing contrasting experimental data from the hybrid propulsion system [2] with computational data from the electric propulsion system.

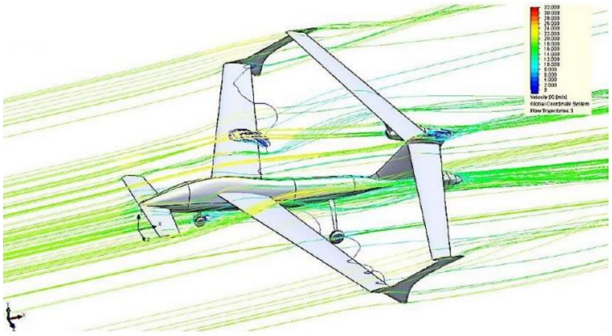

Fig. 6. Flow visualization of the CFD result.

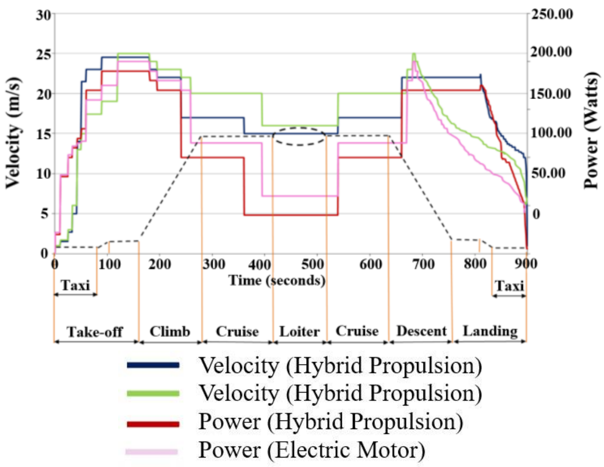

Fig. 7. Flight mission (hybrid propulsion system vs. electric motor)

In both figures, the speed and power as functions of time were depicted. Computational analyses show that the electric motor requires 200 watts more electricity during takeoff than the hybrid propulsion system.

A 3-5% difference is noticeable during the climb. The hybrid propulsion system consumes 100 W while the electric motor requires 115 W when the airplane is cruising.

Table IV compares power usage over time between the hybrid propulsion system and the electric motor for the boxed-wing UAV, using experimental data from the hybrid system [2] and computational data from the electric system. During take-off, both systems increase power, with the electric motor peaking higher (200 W) compared to the hybrid (180 W).

In the climb phase, power starts high and decreases for both, with the electric motor using slightly more power. During cruise, power usage stabilizes, with the hybrid system slightly lower (100 W) than the electric (115 W).

During the loiter phase, the hybrid system uses less power (40 W) compared to the electric motor (60 W). Finally, during landing, both systems increase power slightly, with the electric motor remaining higher.

The thrust curve at a particular flight plan is shown in Figure 9. The aircraft's calculated maximum velocity was 24.5 m/s, while the required thrust and power were 64.52 and 210 W, respectively.

While the maximum thrust of 73.97 N occurs during takeoff at a speed of around 14 m/s, the thrust required to maintain a cruise speed of 20 m/s was 52.72 N. As a result, 74.85 N of thrust was available during takeoff.

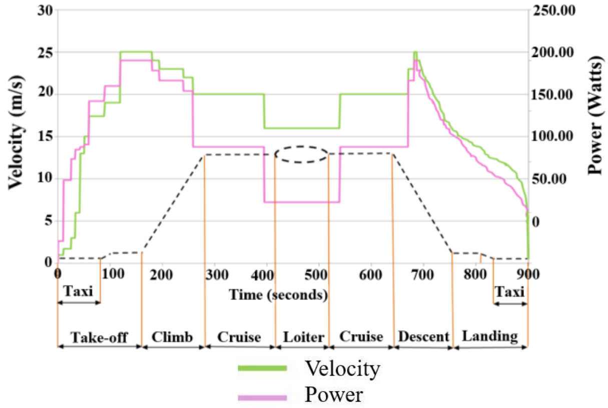

Fig. 8. Flight mission (electric motor)

Table 4. Power usage (hybrid propulsion system vs electric motor)

Flight Plan	**Hybrid propulsion System**		**Electric Motor**	
	Time (s)	**Power (W)**	**Time (s)**	**Power (W)**
Take-off	60 120	170 180	60 120	160 120
Climb	180 240	190 170	180 240	195 180
Cruise	300 360	100 100	300 360	115 115
Loiter	420 480	40 40	420 480	60 60
Cruise	540 600	100 100	540 600	115 115
Landing	660	110	660	115

The key considerations in the conceptual battery design were motor run time and battery weight because the batteries are required to continue operating at a high level for the duration of the targeted mission. Formulas for fuel-burning propulsion systems do not apply to the UAV because it is propelled by an electric motor assembly that is powered by Lipo-batteries. For propulsion systems fueled by batteries, range and endurance are simple concepts. The battery's endurance and range can be thought of as the amount of time before it runs out. This type of usage requires more powerful batteries that can discharge high currents more quickly.

The rate of climb, which is independent of the available thrust, in a steady, unaccelerated, climbing flight along an inclined flight path at angle is predicted to be 17.5 m/s. In contrast, in a power-off glide, the glide's maximum range and smallest equilibrium glide angle of 4.73° are the same. The take-off velocity of 17.40 ms/ was evaluated at 68.6 N (7 kgf) take-off gross weight. The calculated thrust force of the aircraft during take-off at 17.4 m/s is 53.37 N. The take-off distance and velocity for landing approach was calculated to be 54m.and 18.85 m/s, respectively. The landing distance was equal to the distance needed for takeoff.

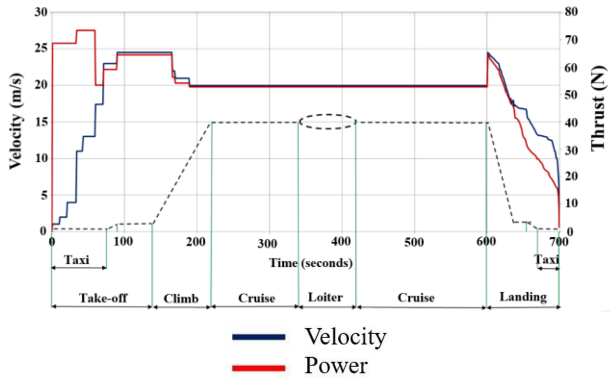

Fig. 9. Thrust curve at specific flight plan

6 CONCLUSIONS AND RECOMMENDATIONS

When constructing a UAV, several critical factors must be considered, with the propulsion system being paramount to its flight endurance and overall performance. The researcher’s literature review and analysis highlight that the propulsion system's performance significantly influences the UAV's size and operational capabilities.

Key findings of the study include:

1. Propulsion System Performance: The computational characterization of the aircraft's power plant showed it could support 7 kgf of weight at 20 m/s cruise conditions. The UAV stalls at 14.5 m/s and has a 4.73-degree power-off glide. Takeoff and landing speeds are 17.4 and 18.85 m/s, respectively, with a minimum runway distance of 54 meters.
2. Propulsion Configuration: Using the Scorpion HKIV-4025-330 model, the propulsion system was simulated with a 21 x 14-inch two-blade propeller, achieving a 1:1 thrust-to-weight ratio. To preserve battery life, the maximum discharge was limited to 85%, and the motor's amp draw was capped at 30 amperes.
3. Power and Thrust Requirements: Maintaining a speed of 19.4 m/s required 192 watts of power. The propulsion system's maximum velocity was 24.5 m/s, with a maximum thrust of 64.52 N. The motor's peak output of 275.6 W supports the UAV's top speed, and a thrust of 74.85 N is sufficient to overcome drag during various flight phases.

The computational analysis demonstrated that the canard Prandtl wing UAV platform for civilian missions is viable for further development. Future studies should focus on building the UAV and conducting experimental tests, such as wind tunnel tests, power measurements, and thrust measurements. Comprehensive testing facilities are crucial for detailed power plant characterization.

Recommendations:

1. Airfoil Exploration: It is recommended to investigate different airfoil types, such as the Selig S3014. This airfoil offers a high lift coefficient, reducing fuel consumption and enhancing efficiency due to its low drag coefficient. Its smooth and well-defined pressure distribution ensures stable and predictable flight characteristics [11].
2. Further Experiments: Conducting thorough experiments to validate the computational findings is strongly advised. This includes separate experiments to assess the performance and efficiency of different airfoils and propulsion configurations.

7. REFERENCES

[1] G.N. Remocaldo, “Conceptual Design and Aerodynamic Performance Analysis of a Canard Box-Wing Unmanned Aerial Vehicle (UAV) Platform for Aerial Photography and Surveillance Applications”, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines (2015).
[2] L. Deiparine, “Design and Development of Energy Management System for Hybrid-Powered Electric Propulsion Fixed-Wing Unmanned Aerial Vehicle”, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines (2018).
[3] M. L. Delos Santos, J. Dasalla, J. Feliciano, and D. Cabatay, ICARUS: An Android-Based Unmanned Aerial Vehicle (UAV) Search and Rescue Eye in the Sky. 2023.
[4] M. Lyu, Y. Zhao, C. Huang, and H. Huang, “Unmanned Aerial Vehicles for Search and Rescue: A Survey,” Remote Sensing, vol. 15, no. 13, Art. no. 13, Jan. 2023, doi: 10.3390/rs15133266.
[5] S. A. H. Mohsan, N. Q. H. Othman, Y. Li, M. H. Alsharif, and M. A. Khan, “Unmanned aerial vehicles (UAVs): practical aspects, applications, open challenges, security issues, and future trends,” Intel Serv Robotics, vol. 16, no. 1, pp. 109–137, Mar. 2023, doi: 10.1007/s11370-022-00452-4.
[6] E. N. Barmpounakis, E. I. Vlahogianni, and J. C. Golias, “Unmanned Aerial Aircraft Systems for transportation engineering: Current practice and future challenges,” International Journal of Transportation Science and Technology, vol. 5, no. 3, pp. 111–122, Oct. 2016, doi: 10.1016/j.ijtst.2017.02.001.
[7] S. Shen and P. Zhou, “Synchronization of the Fractional-Order Brushless DC Motors Chaotic System,” Journal of Control Science and Engineering, vol. 2016, no. 1, p. 1236210, 2016, doi: 10.1155/2016/1236210.
[8] F. Ahmed, J. C. Mohanta, A. Keshari, and P. S. Yadav, “Recent Advances in Unmanned Aerial Vehicles: A Review,” Arab J Sci Eng, vol. 47, no. 7, pp. 7963–7984, Jul. 2022, doi: 10.1007/s13369-022-06738-0.
[9] J. Brandt and M. Selig, “Propeller Performance Data at Low Reynolds Numbers,” Jan. 2011, doi: 10.2514/6.2011-1255.
[10] D. Wall, “Optimum Propeller Design for Electric UAVs,” thesis, 2012. Accessed: Jul. 30, 2024. [Online]. Available: https://etd.auburn.edu//handle/10415/3158
[11] K. Rimi, M. S. Rahman, and T. Sadi, “Optimizing Aerodynamic Performance of Selig S3014 Airfoil through Dimensional Parametric Analysis,” Proceedings of International Exchange and Innovation Conference on Engineering & Sciences

(IEICES), vol. 9, pp. 1–5, Oct. 2023, doi: 10.5109/7157922.
[12] S. Prior and J. Bell, "Empirical Measurements of Small Unmanned Aerial Vehicle Co-Axial Rotor Systems," Journal of Science and Innovation, vol. 1, Jan. 2011.
[13] B. Rutkay and J. Laliberté, "Design and manufacture of propellers for small unmanned aerial vehicles," J. Unmanned Veh. Sys., vol. 4, no. 4, pp. 228–245, Dec. 2016, doi: 10.1139/juvs-2014-0019.
[14] Z. Qasmi et al., "ANSYS simulation of Temperature of Cooling System in Li-ion Battery," presented at the Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), Oct. 2022. doi: 10.5109/5909131.
[15] T. Phillips, "AIAA Design/Build/Fly: Evolution of a Model Aircraft", Accessed: Jul. 30, 2024. [Online]. Available: https://www.academia.edu/60102711/AIAA_Design_Build_Fly_Evolution_of_a_Model_Aircraft
[16] K. AL-Dosari and N. Fetais, "A New Shift in Implementing Unmanned Aerial Vehicles (UAVs) in the Safety and Security of Smart Cities: A Systematic Literature Review," Safety, vol. 9, no. 3, Art. no. 3, Sep. 2023, doi: 10.3390/safety9030064.
[17], A. J. Doupe, Electric Aircraft Propulsion System, California Polytechnic State University, San Luis Obispo, (2012).
[18] A. Gangwar, K. Anurag, & K. Pankaj, Canard Plane, Indian Institute of Technology, Kanpur (2011).
[19] B. Le Solliec, S. Bourgaine, P. Guimbart, & F. Morra, Study of propulsion system for a mini-UAV drone project, National Superior School of Mechanics and Microtechnics, Besançon cedex, France (2004).
[20] R. Turba, Design of a Nuclear Propulsion System for an Unmanned Aerial Vehicle: A system to keep a military UAV airborne for over a year without landing, VDM (2011).
[21] B.W. McCormick, Aerodynamics, Aeronautics, and Flight Mechanics, second ed., Wiley, 1994.
[22] De Havilland, De Havilland DHC-6 Aircraft Components Maintenance Manual, Downsview, Ontario, 1976.
[23] D.P. Raymer, Aircraft Design: A Conceptual Approach, AIAA, USA, 1992.
[24] J. D. Anderson, Aircraft Performance and Design, McGraw-Hill,Companies, Inc., New York, 2010.
[25] J. Roskam, Airplane Design Part I: Preliminary Sizing, Design, Analysis and Research Corporation, Kansas, USA, 2004.
[26] N. Beccasio, M. Tesconi, & A. Frediani, Variational Analysis and Aerospace Engineering II: Mathematical Challenges for Aerospace Design, Springer, 2012 pp. 1-25
[27] R. Austin, Unmanned Aircraft Systems: UAVs Design, Development and Deployment, John Wiley & Sons Ltd., West Sussex, UK, 2010.
[28] Federal Aviation Administration, Airplane Flying Handbook, US Department of Transportation, USA, 2016.
[29] A. Frediani & G. Montanari, Best wing system: an exact solution of the Prandtl's problem. In G. Buttazzo, & A. Frediani, Variational Analysis and Aerospace Engineering. Springer, pp. 181-211.
[30] R. E. M. Nasir, "Mini Class Blended Wing Body Unmanned Aerial Vehicle Aerostructure Design for Fused Deposition Modelling 3D Printing," Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES), vol. 9, pp. 1–3, Oct. 2023, doi: 10.5109/7157931.