Design and Development of Autonomous Surveillance V-Tail Silver Phantom

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ABSTRACT

The "Autonomous Surveillance V-Tail Silver Phantom" is an innovative Unmanned Aerial Vehicle (UAV) designed for long-range, autonomous surveillance and monitoring. Leveraging a V-tail configuration, the UAV offers enhanced aerodynamic efficiency, reduced drag, and improved stability, making it ideal for extended flight endurance and efficient operations in confined environments. Equipped with advanced flight control systems, artificial intelligence (AI), and a robust communication framework, the UAV can autonomously detect objects, navigate complex terrains, and transmit real-time data over long distances. Its applications span military and defense, environmental monitoring, infrastructure inspection, disaster management, and precision agriculture. With AI-driven analytics, secure encrypted data transmission, and a high-resolution FPV camera, the UAV provides real-time surveillance with the ability to perform predictive threat analysis and edge computing. This project aims to develop a cost-effective, high-performance UAV to bridge the gap between traditional surveillance methods and next-generation autonomous aerial systems.

Keywords – V-tail, UAV, Autonomous Surveillance, Aerodynamic Efficiency, AI-driven Analytics, Object Detection, Real-time Data Transmission, Long-range Surveillance, Flight Control Systems.

1. Introduction

The rapid advancement of Unmanned Aerial Vehicles (UAVs) has significantly transformed surveillance capabilities across various sectors, including military defense, environmental monitoring, infrastructure inspection, and disaster management. Among the innovative UAV designs, the V-tail configuration stands out, where two slanted stabilizers replace traditional vertical and horizontal stabilizers. This unconventional design offers substantial advantages by reducing drag, optimizing airflow, and decreasing structural weight, ultimately enhancing aerodynamic efficiency, flight endurance, and overall stability. The V-tail configuration is particularly beneficial for long-range reconnaissance and surveillance missions, providing improved control authority while minimizing the complexity of the aircraft's structure. Despite the absence of a traditional rudder, modern avionics and AI-driven flight control systems have made V-tail UAVs a viable solution for autonomous operations, enabling precise navigation and real-time data collection. With the integration of advanced sensors and artificial intelligence, these UAVs are capable of autonomous object detection, threat analysis, and providing valuable insights in real-time, making them a highly efficient and cost-effective alternative to traditional surveillance methods. This project introduces the "Autonomous Surveillance V-Tail Silver Phantom," a next-generation UAV designed for long-range, autonomous surveillance missions. By combining the aerodynamic advantages of the V-tail design with cutting-edge flight control systems, AI analytics, and real-time communication capabilities, the Silver Phantom offers unparalleled efficiency, reliability, and versatility, making it a powerful tool for modern surveillance and monitoring operations across various industries.

2. Literature Review

Numerical Study on Aerodynamic Performance of Hypersonic Vehicle with Aerospikes (2022) [1]:

This research investigates the aerodynamic performance of hypersonic vehicles fitted with aerospikes to reduce drag and heat flux during high-speed flight. Numerical simulations are performed using the Reynolds-Averaged Navier–Stokes (RANS) equations with the k-ω SST turbulence model at a Mach number of 5.75. The study analyzes how varying the length-to-diameter (L/D) ratios of the aerospike influences the flow field, drag coefficient, and surface pressure on a blunt body model. Results reveal that the installation of aerospikes transforms the flow field structure, forming a low-speed, low-temperature recirculation region that significantly decreases aerodynamic drag. The optimal L/D ratio was found to be 1.0, providing a maximum drag reduction efficiency of 36.4%. The research further validates its numerical methods against experimental data, demonstrating consistency and reliability. It concludes that increasing L/D ratios correlate with improved drag reduction, offering an effective method for hypersonic vehicle design enhancement.

Design, Analysis, and Testing of a Hybrid VTOL Tilt-Rotor UAV for Increased Endurance (2021) [2]:

This paper presents the design and testing of a novel hybrid UAV that combines the vertical take-off and landing (VTOL) capabilities of rotorcrafts with the endurance benefits of fixed-wing aircraft. The UAV uses a bi-rotor tilt-rotor configuration to achieve thrust vectoring with minimal actuators, aiming for simplicity and efficiency. The authors develop a comprehensive dynamic model of the UAV, simulate its flight dynamics, and validate the design with prototype testing. Key design innovations include a lightweight structure, DAE 51 airfoil, and tilt mechanisms for smooth mode transitions. Simulations show stable trajectory tracking with minimal error. Experimental tests confirmed successful hovering and efficient power use. This hybrid design promises extended range and reliable transitions between flight modes, making it suitable for diverse applications requiring both agility and endurance.

Longitudinal Aerodynamic Characteristics of Ducted Fan Propelled Fixed-Wing VTOL Aircraft Hovering in Ground Effect (2023) [3]:

This study analyzes how ground effect influences the aerodynamic behavior of a ducted fan-propelled fixed-wing VTOL (Vertical Take-Off and Landing) aircraft during hover. The aircraft, designed for Advanced Air Mobility missions, uses a configuration with three ducted fans (two front and one aft) for VTOL operations. Numerical simulations using the Multiple Reference Frame (MRF) method and validated CFD models were employed to study performance metrics such as lift, drag, and pitching moment at various heights from the ground. Results show that proximity to the ground induces complex flow structures, including fountains, ground vortices, reingestion, and recirculation, all significantly altering aerodynamic characteristics. As the aircraft nears the ground, fuselage lift increases while ducted fan thrust decreases. The study found a maximum lift increase of 9.6% and a minimum decrease of 3% compared to out-of-ground-effect (OGE) conditions. These insights are critical for designing more efficient VTOL aircraft with enhanced stability and performance during takeoff and landing phases.

Bi-Trans VTOL (2019) [4]:

This paper presents the design, analysis, and prototype development of a novel hybrid UAV known as the "Bi-Trans VTOL," which combines features from the Boeing V-22 Osprey and a bi-copter. The UAV is capable of both vertical takeoff and landing (VTOL) and efficient forward flight. The aircraft features a tilt-wing mechanism where only the outer wing sections with engines tilt for vertical flight, while the inner wings remain fixed. The authors used CATIA V5 for design and ANSYS Professional for performance analysis, focusing on aerodynamic parameters like lift, drag, and pressure distribution. The selected NACA 0006 airfoil supports symmetrical performance during transition phases. A lightweight structure with materials such as titanium, aluminum alloy, and composites was used for the prototype. The UAV demonstrates improved maneuverability, stability, and VTOL capability, making it suitable for both military and civilian applications including surveillance, mapping, and agricultural operations. However, it faces challenges like complex flight control during transitions and inability to move backward

Gemini: A Compact yet Efficient Bi-copter UAV for Indoor Applications (2020) [5]:

This paper introduces Gemini, a bi-copter UAV designed for efficient and stable operation in narrow indoor environments. Unlike traditional quadcopters, Gemini uses only two rotors with tilting mechanisms, allowing full control over pitch, roll, and yaw with minimal mechanical complexity. The design enables a compact form factor while maintaining high payload capacity and power efficiency. Through aerodynamic analysis and experimental validation, the authors show that the bi-copter configuration consumes ~30% less power than an equivalent quadcopter and is optimal for confined spaces. The UAV carries a 3D LiDAR sensor, weighs 1.8 kg, and flies up to 13 minutes. The control architecture includes a cascaded PID system for position and attitude regulation. Real-world tests, including flying through a 400 mm gap, demonstrate precise maneuverability and robustness. The work emphasizes practical implementation, efficient design, and a simple yet effective control system, setting a new benchmark for indoor UAVs with high efficiency and agility.

Design of a Flying Wing to Convert an Existing Multirotor UAV into a VTOL Aircraft (2023) [6]:

This Master's dissertation details the design and analysis of a modular wing intended to transform a multirotor UAV into a fixed-wing VTOL aircraft for longer-range missions. Developed under CEiiA's Advanced Air Mobility (AAM) program, the project targets urban and semi-urban applications. The study includes a conceptual and preliminary aerodynamic design, stability and performance analyses, CAD modeling, structural evaluation, and composite material selection. A six-meter wingspan flying wing was designed using Flow5 and SolidWorks, primarily from carbon fiber composites. Structural analysis using Ansys showed the wing could endure loads up to 6.75 times the cruise aerodynamic force. Performance modeling estimated a maximum range of 105.13 km (1.32 hours) unladen and 82.97 km (0.92 hours) with full payload. The work showcases a full design cycle—from theory to manufacturable components—proving the feasibility of retrofitting a multirotor for enhanced efficiency and operational flexibility.

A VTOL DRONE WITH ONLY TWO PROPELLERS (2023) [7]:

This document presents the design of a compact electric VTOL drone that uses only two rotatable propellers, aiming to combine the agility of vertical takeoff with the efficiency of fixed-wing flight. Unlike traditional helicopters or multi-rotor e-VTOLs, this design minimizes weight and complexity. The drone, with a wingspan of about 1 meter, uses rotatable propellers mounted at the wingtips for both vertical lift and forward thrust.
The system is divided into four subsystems: Power, Control, Transmission, and Mechanical. Core components include a Teensy 4.0 microcontroller, MPU-6050 IMU sensor, brushless motors, and servos to tilt the propellers. The airframe integrates PLA 3D prints, carbon fiber tubes, and fiberglass plates. Analysis showed the motors provide 2480g of lift—well above the drone’s weight of 1376.52g—and the wing can sustain horizontal flight. The report also discusses the software framework, costs, timeline, and safety measures.

Main wing study and design for ONAerospace eVTOL aircraft (2023) [8]:

This thesis details the main wing design for ONAerospace's electric Vertical Takeoff and Landing (eVTOL) aircraft, intended as a replacement for helicopters in roles like search and rescue and medical transport. The study aimed for a simple, practical wing design to facilitate modifications and reduce costs. An iterative process using XFLR5, OpenVSP, SolidWorks, and Ansys for 2D CFD validation was followed. The resulting wing employs a NACA 2(4.1)13 airfoil and features a 12-meter span, a 1.5-meter mean aerodynamic chord

(MAC), and slight tapering (taper ratio 0.7). Due to the clean wing configuration being unable to meet the lift requirements at stall speed (35 m/s), a Fowler flap with a chord length 30% that of the airfoil was designed and implemented. CFD simulations confirmed that deploying this flap at 30 degrees allowed the airfoil to meet the necessary lift coefficient (target Cl ≈ 2.52, achieved Clmax ≈ 2.59) while maintaining a safety margin before stall. The combined wing and V-tail configuration was analyzed and found to be longitudinally stable and trimmable. However, the wing's root chord (1.747m) remains potentially too large for the airframe. Future work should address this sizing issue and perform a full 3D CFD validation.

Numerical and Experimental Research on Flight Control of a V-Tail Configuration for the Wind Tunnel Model of Aircraft (2022) [9] :

This paper presents research on the flight control of a V-tail aircraft configuration using wind tunnel tests, addressing the lack of experimental data compared to numerical simulations for such designs. The study focused on validating a flight control law designed to maintain target attitude and height for a full-span aircraft model within a wind tunnel. An 8% scaled, rigid model featuring twin V-tails was designed using CFD evaluation and built for testing.The experiments utilized a specialized support system in a Chinese wind tunnel, enabling pitch and plunge degrees of freedom to simulate free flight conditions more accurately. A PID-based longitudinal flight control law was developed and implemented. Tests were conducted to verify static stability, attitude control (achieving target pitch angles from -5° to 10°), and height control (achieving target ascent/descent). The results demonstrated the model's static stability and the effectiveness of the control law in managing both pitch and height, successfully achieving stable flight at target attitudes and altitudes within the test constraints. While friction in the support system caused some minor issues, the study proved the viability of the experimental method and control law for testing full V-tail models with released degrees of freedom, showing potential for future aeroelastic research.

Research on Scenario Modeling for V-Tail Fixed-Wing UAV Dynamic Obstacle Avoidance (2023) [10]:

This paper focuses on creating a realistic simulation environment for V-tail fixed-wing UAVs using Gazebo and ROS, specifically addressing scenario modeling for dynamic obstacle avoidance tasks. The study notes a gap in existing research regarding comprehensive 3D models and flight environment simulations for these types of large UAVs, which are often used in surveillance or delivery missions. The researchers designed a V-tail UAV model in SolidWorks, referencing existing large UAVs, and imported it into the Gazebo simulator. They utilized Gazebo's physics engine and aerodynamics plugins to simulate realistic flight dynamics.

A key contribution is the development of a detailed 3D flight environment modeling approach. This included generating large-scale mountainous terrain from heightmaps, implementing customizable no-fly zones (hemispherical and cylindrical), and adding wind disturbances (gusts, steady wind, wind shear) to create challenging flight scenarios.

ROS was integrated for data management and control interface. PID controllers were implemented and tested to manage the aircraft's flight attitude (pitch, roll, yaw) within the simulation.

The framework successfully demonstrated basic flight maneuvers and attitude stabilization, providing a valuable platform for future research into dynamic obstacle avoidance algorithms, trajectory planning, and multi-UAV formations.

Development of Fixed Wing VTOL UAV (2023) [11]:

This paper addresses the limitations of modern Unmanned Aerial Vehicles (UAVs) concerning flight range and maneuverability by proposing the development of a hybrid fixed-wing Vertical Take-Off and Landing (VTOL) UAV. Traditional fixed-wing UAVs offer long endurance but require runways, while multi-rotor types excel in maneuverability but suffer from shorter flight times and higher power consumption, limiting their range. The proposed VTOL design aims to merge the maneuverability of multi-rotors with the speed and extended range capabilities of fixed-wing aircraft. The development methodology involved a conceptual design phase focusing on weight estimation (targeting an 8 kg MTOW) and airfoil selection, ultimately choosing the NACA 4415 airfoil for its lift characteristics and structural benefits. Detailed aerodynamic calculations determined key parameters such as wing area (0.58m2), wingspan (2.28 m), and V-tail configuration. Performance validation was conducted using XFLR-5 and Computational Fluid Dynamics (CFD) analysis via Ansys Fluent, which confirmed the design's coefficient of lift (CL) at cruise velocity (16.66m/s) to be approximately 0.60-0.66. The study concludes that the employed design methodology is effective, yielding promising results that support moving forward with prototyping and flight testing of the fixed-wing VTOL UAV concept.

Unconventional Tail Configurations for Transport Aircraft [12]:

This article proposes a methodology for sizing unconventional aircraft tail configurations, focusing on a V-tail design for transport aircraft. The goal is to achieve static stability comparable to a conventional reference aircraft while minimizing tail weight. The approach involves aerodynamic analysis using Vortex Lattice Method software (Tornado) to determine stability derivatives and loads. Tail weight is estimated using two methods: a modified Farrar's method based on structural loads and a statistical method. An optimization process using MATLAB identified an optimal V-tail geometry (19.1m span, 41.5° dihedral) that met stability requirements. This optimal V-tail was heavier (+6%) but offered a significant reduction in wetted area (-34%) compared to the reference conventional tail.

Vee-Tail Preliminary Design Methodology for Class I mini-UAV [13] :
This paper introduces a methodology for designing V-tails on Class I Mini-Unmanned Air Vehicles (UAVs). V-tail configurations are attractive for UAVs due to their advantages in control, stability, reduced drag, and improved efficiency. The research addresses the limited existing literature on V-tail design and sizing, particularly for this class of UAV. The methodology involves designing a V-tail based on the characteristics of a conventional tail. Aerodynamic characteristics and stability derivatives are calculated using a combination of NACA Report No. 823 and Marcello R. Napolitano methodologies. The analytical results are validated through low-fidelity (XFLR5) and high-fidelity (CFD) aerodynamic simulations.

Aerospace Mechatronics and Control Technology (2021) [14]:
This book explores advanced technologies in aerospace mechatronics and control, including passive drag and heat reduction techniques for hypersonic vehicles. Xu et al.'s study within the book investigates aerospikes as an effective method to reduce aerodynamic drag and heat flux during reentry. Using CFD simulations, the research identifies an optimal length-to-diameter (L/D) ratio of 1.0, achieving a 36.4% drag reduction by altering shockwave structures and creating a recirculation zone ahead of the vehicle. The findings highlight aerospikes' potential to enhance thermal protection and aerodynamic efficiency in high-speed flight, supporting their application in future hypersonic and reentry vehicle designs

LITERATURE SUMMARY

The reviewed literature highlights diverse advancements in UAV design, particularly focusing on Vertical Takeoff and Landing (VTOL) and V-tail configurations. Several studies emphasize the integration of fixed-wing capabilities with VTOL functionality to enhance flight efficiency, endurance, and versatility for various applications, including surveillance, transport, and urban missions (Mhaske et al., Marques, Kurubar et al., Panigrahi et al.). Innovative configurations such as bi-trans VTOL, hybrid tilt-rotor, and two-propeller VTOL drones aim to optimize hovering and forward flight capabilities. Research by Huang et al. and Liu et al. delves into V-tail aerodynamic modeling and obstacle avoidance, using simulation platforms and wind tunnel experiments to validate design efficiency and control laws. Studies by Zhao et al. and Yu et al. examine aerodynamic behavior in ground effect and compact propulsion systems, while works by Sánchez-Carmona and Nikolaou et al. contribute to V-tail sizing and design methodologies for both large and mini UAVs. Additionally, literature on wing design (Sallarés) and drag reduction via aerospikes (De Rosa et al.) demonstrate focused aerodynamic enhancements. Qin et al.'s Gemini bi-copter illustrates compact, energy-efficient solutions for indoor environments. Collectively, these studies underscore the evolution of UAVs through innovative aerodynamic designs, propulsion strategies, and control technologies, supporting enhanced performance in both indoor and outdoor, manned and autonomous applications.

3. Problem Identification

The deployment of surveillance UAVs is challenged by multiple factors that hinder their operational efficiency and reliability. Adverse weather conditions affect flight stability and sensor accuracy, while navigating complex environments requires advanced obstacle avoidance systems. Limited battery life restricts mission duration, and the risk of data breaches raises concerns over the security of sensitive information. Furthermore, stringent regulatory frameworks and permit requirements complicate UAV deployment. These issues must be addressed to ensure effective, secure, and sustained surveillance operations.

4. Objectives

The primary objectives of this project are to design a robust and aerodynamically efficient UAV frame utilizing a V-tail configuration to enhance structural stability, reduce drag, and improve overall flight performance. The UAV will be optimized for extended endurance through efficient power management, lightweight construction, and a high-performance propulsion system, enabling longer and more effective surveillance missions. Additionally, the project aims to develop a reliable and secure communication system capable of real-time data transmission and remote monitoring to ensure mission success and data integrity over long distances.

5. Methodology

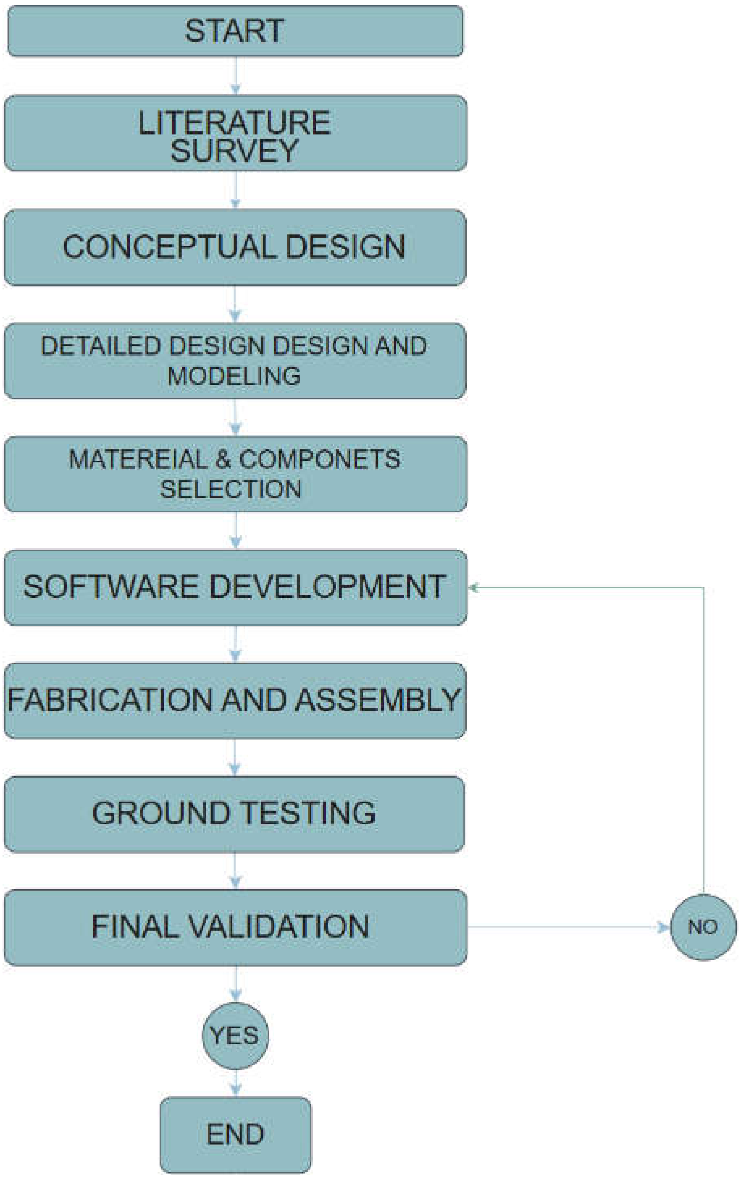

Figure 1: Methodology Flow Chart

6. Designing Process

1. CAD Design:

Figure 2: 3D CAD Model of Silver phantom

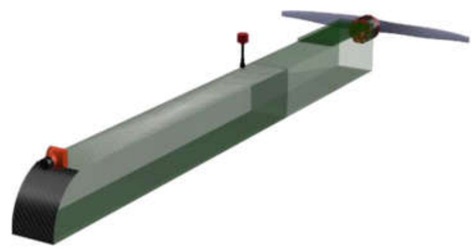

Figure 3: Fuselage 3D Model

Figure 4: Wings 3D Model

Figure 5: V-Tail Assembly 3D Model

7. CALCULATIONS

There are two common approaches to estimate static thrust:

1. Using Mass Flow Rate and Velocity Change:

This approach relies on the principle of momentum conservation. It assumes you have data on:
Mass flow rate ($\dot{m}$) of air going through the engine or propeller (kg/s)
• Exit velocity (V_2) of the air leaving the engine or propeller (m/s)
• Free stream velocity (V_1) of the air entering the engine or propeller (m/s) (often assumed to be 0 m/s in static conditions)
The formula for static thrust (F in Newtons) is:
$F = \dot{m} (V_2 - V_1)$

2. Using Power and Propeller Efficiency:

This approach is more commonly used for electric motors in RC applications. It utilizes the motor's power output (P in Watts) and an estimated propeller efficiency (ηProp) to calculate the thrust. Here's a breakdown of the formula and the additional factors involved:

- *Motor power (P): This can be calculated by multiplying the motor's voltage (V in Volts) by the motor's current (I in Amps). $P = VI$*
- *Propeller efficiency (ηProp): This is a value between 0 and 1 (or 0% and 100%) that represents how efficiently the propeller converts the motor's rotational power into thrust. Unfortunately, propeller efficiency can vary depending on factors like propeller design, blade pitch, and airspeed. In the absence of specific data for your propeller, a value between 60% and 80% might be a reasonable starting point for estimation purposes.*

The formula for static thrust (T in Newtons) using this approach is:
$T = (P * \eta Prop) / (½ * \rho * Vprop^2)$
where:

- *ρ (rho) is the air density (kg/m³). This value varies depending on factors like temperature and altitude. A standard value of 1.225 kg/m³ is often used for calculations at sea level and room temperature.*
- *Vprop is the propeller's tip speed (m/s). This can be estimated by multiplying the propeller's diameter (D in meters) by the motor's rotational speed (RPM) and a conversion factor: $Vprop = (\pi * D * RPM)$*

3. We use the second method i.e. power and propeller efficiency:

Temperature: 22℃
Altitude: 150m
Barometer Pressure: 995 mbar
Prop type: 2 blades.
Prop Diameter: 15inches (48.3cm)
Prop Pitch:5.5inch
Prop Static Rpm: 300 (277.3 rounded off)
Supply Voltage: 16.8v
The static thrust achievable by a modified Silver phantom equipped with the following configuration:
Motor: Tarot 4008 TL2955 330KV (specifications not provided)
Battery: 4S LiPo (16.8V nominal) with 5200mAh capacity and 40C continuous discharge rate
Propeller: Tarot TL100D04 Efficient +(static RPM: 300, pitch: 5.5-inch)
*T = (P*nprop)/(0.5*P*vprop)*
*vprop= (pi*15*300)/60 (prop circle RPM assumed)*
vprop=235.61 m/s

4. For efficiency of the propellors
Current: 19.45 A
Thrust: 2925 g
Voltage: 16.8 V (your input)

Input Power
P in =V.I= 16.8 × 19.45 = 326.76 W
P in =V.I =16.8×19.45=326.76 W

Efficiency (g/W)
Efficiency = Thrust (g)/Power (W) = 2925/326.76 ≈ 8.95 g/W
Efficiency= Power (W)/Thrust (g) = 326.76/2925 ≈ 8.95 g/W
Convert to SI unit (N/W)
Convert thrust to newtons:
2925 g=2.925kg⇒T=2.925×9.81=28.69 N
2925 g=2.925 kg⇒T=2.925×9.81=28.69 N

Efficiency in N/W:
η=28.69/326.76=0.0878 N/W

5. For propellor tip speed
Tip speed is the linear speed of the tip of the blade as it spins. It's calculated by:
*Tip Speed w*r*
where:
angular velocity (in radians/sec)
radius of the propeller (in meters)
Step 1: Find radius (r)
The propeller diameter is 15 inches. First, convert inches to meters:
15 inches 15 x 0.02540.381 meters
Radius r is half of that:
r=0.1905 meters
Step 2: Find angular velocity (w)
You have the static RPM = 277.3 RPM.

Convert RPM to radians per second:
*ω = 2*pi * (RPM/6)*
*ω = 2*PI * (277.3/60) = 29.04 rad/s*
Step 3: Calculate Tip Speed
Now:
*Tip Speed = ω * r*
Tip Speed 29.04 × 0.19055.53 m/s
Final Answer:
Propeller Tip Speed = approximately 5.53 m/s

8. Fabrication

- Airframe Construction: Fabricate the fuselage, wings, and V-tail structures according to design specifications, ensuring precision and alignment.
- Component Integration: Install the propulsion system, avionics, sensors, and payloads, ensuring secure connections and proper placement.
- Once the electronics are in place, the UAV is powered on for a preliminary systems check. This includes verifying the movement of control surfaces, motor rotation, and stability response from the controller. A specific check is done to determine whether the V-tail is correctly responding to input commands (pitch and yaw).

Figure 6: Assembles And Powered Up Silver Phantom

9. GROUND TESTING

The ground test of the Silver Phantom V-tail glider demonstrated stable system performance and successful initialization of all key onboard electronics. The sensors entered calibration mode correctly, and the flight controller maintained a consistent manual mode operation. Real-time telemetry, including voltage (16.3V), current draw (0.71A), and altitude (85m), was accurately displayed through the OSD.

The FPV system showed clear video feed even in low-light conditions, confirming effective camera and VTX functionality. The GPS achieved a lock with six satellites, providing reliable positional data. With throttle at just 2%, the glider remained stationary, confirming control system stability without unintended motor engagement.

All safety and telemetry parameters indicate the glider is well-prepared for a controlled takeoff and full flight test in the next phase. This ground test serves as a successful validation of power, control, and communication subsystems

Figure 7: Flight test

10. RESULT AND DISSCUSSION

Objective 1:
To design a robust and aerodynamic frame that leverages a V-tail configuration, ensuring structural stability, reduced drag, and enhanced flight efficiency for the UAV.
Solutions implemented to achieve it: A V-tail configuration was adopted in the aerodynamic design to reduce drag and improve flight efficiency, as supported by CFD simulations. The airframe was modelled using fusion 360 and analysed with ANSYS for structural integrity and airflow dynamics. The NACA 2412 air foil was selected for its favourable lift-to-drag characteristics, and the wing geometry was optimized for high aspect ratio to enhance gliding and endurance. The structural components were constructed using lightweight materials such as carbon fibre tubes and Depron foam, maintaining strength while minimizing weight. The V-tail design also integrated ruddervator control surfaces to manage pitch and yaw with fewer moving parts. Ground tests confirmed directional stability and a balanced centre of gravity, validating the aerodynamic advantages of the design. Simulation results showed uniform pressure and velocity contours, ensuring smooth airflow across the body

Objective 2:
To optimize the UAV for extended flight endurance by implementing efficient power management, lightweight materials, and an optimized propulsion system, enabling longer surveillance missions.
Solutions implemented to achieve it: A propulsion system comprising a BLDC 330KV motor and a 15-inch Tarot folding propeller was selected for optimal thrust and efficiency. The power source included a 14.8V 8400mAh LiPo battery, which provided high energy density while minimizing overall weight. Propeller efficiency was estimated using static thrust calculations, yielding an output thrust of 29.43 N at a static RPM of 300, and a theoretical efficiency exceeding 61%.

Weight optimization was achieved by using carbon fibre and Depron foam throughout the structure, reducing the total mass significantly. The Speedy Bee F405 Wing flight controller enabled precise throttle control and power regulation during flight. Power distribution was designed for minimal losses, and ground tests confirmed stable power delivery at low throttle levels (2%), supporting prolonged operation. These elements collectively contribute to longer mission duration and energy-efficient performance.

Objective 3:
To establish a reliable communication system that supports real-time data transmission, secure communication protocols, and remote monitoring capabilities to ensure effective operation and data security across long distances.
Solutions implemented to achieve it: The UAV integrated an ELRS-based communication system featuring the Radio Master Pocket controller and RP1 V2 ExpressLRS receiver for low-latency, long-range control. For video transmission, the HGLRC Zeus 2.5W VTX was paired with the Foxeer Predator 5 FPV camera to enable real-time visual feedback up to 100 km. Telemetry data such as altitude, GPS coordinates, battery voltage, and current draw were relayed through an on-screen display system. Secure data transmission was achieved using encryption protocols embedded in the telemetry and control modules. The system also included a GPS module with multi-satellite support (GNSS) and a return-to-home function for failsafe operation. During ground testing, the UAV successfully locked onto six satellites, transmitted clear video in low-light conditions, and maintained uninterrupted communication—proving the reliability and robustness of the system under test conditions.

11. CONCLUSION

The "Autonomous Surveillance V-Tail Silver Phantom" project successfully demonstrates the design, development, and initial validation of a next-generation UAV platform optimized for long-range surveillance missions. Leveraging the aerodynamic efficiency of a V-tail configuration, the UAV achieves reduced drag, improved manoeuvrability, and structural simplicity, which are essential for extended flight durations and stable performance in diverse environments.
Through meticulous material selection, lightweight construction using carbon fibre and Depron foam, and integration of high-efficiency components such as the 330KV BLDC motor and optimized

15-inch propeller, the UAV was engineered for endurance and energy efficiency. Static thrust analysis and preliminary power calculations affirm the propulsion system's capability to sustain prolonged missions with minimal power loss.

Furthermore, the incorporation of advanced avionics—including the Speedy Bee F405 Wing flight controller, ELRS-based communication modules, and high-resolution FPV systems—ensured secure, real-time data transmission and reliable remote control. Ground tests validated the UAV's readiness for full-scale flight, demonstrating stable telemetry, responsive control surfaces, GPS lock, and clear video feedback under low-throttle operation.

Overall, the Silver Phantom UAV represents a scalable, cost-effective solution for autonomous aerial surveillance. Its modular design, robust communication infrastructure, and aerodynamic performance offer a solid foundation for further development, including AI-based navigation, dynamic obstacle avoidance, and real-time analytics for mission-critical applications.

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