Shri Vile Parle Kelavani Mandal's
DWARKADAS J. SANGHVI COLLEGE OF ENGINEERING
(Autonomous College Affiliated to the University of Mumbai)

DESIGN AND FABRICATION OF BIOMIMETIC INSPIRED VTOL UAV

Submitted in partial fulfillment of the requirement
of the degree of

**Bachelor of Technology in
Mechanical Engineering**

By

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A.Y. 2022 – 2023

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CERTIFICATE

This is to certify that the project entitled, **"Design and Fabrication of Biomimetic Inspired VTOL UAV"** is a bonafide work of **Shubham Mehta (60005190107), Tanmay Pagariya (60005190116), Tatsat Baldaniya (60005190117)** and **Tejas Srinivas (60005190118)** submitted in the partial fulfillment of the requirement for the award of the Bachelor of Technology in Mechanical Engineering.

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DECLARATION

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that, we have adhered to all the principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources, which have thus not been properly cited or from whom proper permission has not been taken, when needed.

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APPROVAL SHEET

Project entitled, **"Design and Fabrication of Biomimetic Inspired VTOL UAV"**, submitted by **Shubham Mehta (60005190107), Tanmay Pagariya (60005190116), Tatsat Baldaniya (60005190117)** and **Tejas Srinivas (60005190118)** is approved for the award of the Bachelor of Technology in Mechanical Engineering.

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ABSTRACT

This project is a basic and small-scale prototype of a bicopter. The idea arises from the concept of drones being used for surveillance. Surveillance is of essential importance for any organization. Thus, in order to facilitate this idea, we have built a bicopter which revolves around the same.

A bicopter is a two-armed drone powered by a battery. This drone is mostly used for taking aerial photo shoots. Apart from surveillance it can also be used for other purposes like transportation of small goods, sprinkling pesticides, search and rescue, construction, entertainment, etc.

As stated earlier, this project focuses on surveillance. So, a bicopter was made for aiding the process. The scope of this project includes improvements and modifications that can be made in this design along with better mechanisms, which will increase the efficiency of the bicopter in the desired task.

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CHAPTER 1

INTRODUCTION AND SYNOPSIS

1.1 AIM

The aim of our project is to design and fabricate a Bicopter equipped with a GPS and camera system that will help in reconnaissance and surveillance. It has the potential to be used in combat situations to keep a bird's-eye view. This project is just a prototype and can be used on a larger scale as per the requirements. The utility of the bicopter can be expanded as per the application.

1.2 PROJECT DEVELOPMENT

In the initial phase of the project, various electronic components and materials for the prototype building were shortlisted. After initial shortlisting, appropriate components are then studied further, and their advantages and disadvantages are considered. This helped in selecting the material and other components for the bicopter based on different parameters, the most important being cost and suitability. After factoring in the average weight of the motors, ESC, propeller, and other components, a static thrust test was done for the selection of suitable motor-propeller combinations. Moving further, we started conceptualising the design and performed various iterations of the same. After successive iterations and persistent efforts, we finally made a proper prototype that was able to take flight with a payload of one half of a kilogram.

1.3 APPLICATIONS

Bicopter are a versatile type of aircraft that can be used for a variety of purposes. They are becoming increasingly popular as technology improves and the cost of ownership decreases. Here are some of the uses of bicopters in each of the categories:

- <u>Aerial photography and videography</u>: Bicopters are often used for aerial photography and videography because they are relatively easy to fly and can be equipped with high-quality cameras.

- Search and rescue: Bicopters can be used for search and rescue missions because they can fly quickly and easily over difficult terrain.
- Agriculture: Bicopters can be used to spray crops, pollinate flowers, and monitor crops for pests and diseases.
- Construction: Bicopters can be used to inspect bridges, buildings, and other structures.
- Military: Bicopters can be used for surveillance, reconnaissance, and attack missions.
- Entertainment: Bicopters can be used for racing, stunts, and other forms of entertainment.

1.4 TYPE OF PROJECT

This project aims to develop a prototype that can then be scaled, modified, and probably commercialised to develop a low-cost solution for the beneficiaries. The problems that our bicopter can solve range from reconnaissance to sprinkling pesticides on farmland. With this project, we would like to contribute our bit to finding solutions to the prevailing problems in our world.

1.5 INTRODUCTION

Drones are more formally known as UAVs. Essentially, a drone is a flying robot. The aircraft may be remotely controlled or can fly autonomously through software-controlled flight plans in their embedded systems working in conjunction with GPS.

A bicopter is a type of UAV that belongs to the family of drones. A Bicopter is a helicopter with two rotors. The rotors are directed upwards, and they are placed on either side of the frame at an equal distance from the centre of mass of the quadcopter. The quadcopter is controlled by adjusting the angular velocities of the wings, which are spun by servo motors.

Bicopters are used in firefighting, surveillance, search and rescue, construction inspections, and several other applications.

A lot of new modifications have been and can be made in the typical design of Bi-copters to make them more and more efficient.

This project presents the "Design and Fabrication of a Biomimetic-Inspired VTOL UAV." A box-shaped design of the frame is used to house the electronic components of the frame. The bi-copter built in this project is controlled by a transmitter and receiver control system.

The major challenge in the execution of this project is the weight-lifting capacity of the Bicopter. Along with this, another challenge that is faced is ensuring a low overall weight of the quad with all the components installed on it. Using the right electric components is necessary for the proper functioning of the prototype.

The weight-carrying capacity depends on the selection of motor and propeller. Static thrust analysis of three different motor-propeller combinations led to the selection of propellers that could lift the desired weight. Light weight is ensured by using light materials for the frame. Carbon fibre is one of the top recommended choices. However, due to cost constraints, acrylic was used.

1.6 OBJECTIVES

This project aims to provide surveillance by using a bicopter. The objective of this project is to suggest ways to reduce human dependencies in many areas by employing drones in those areas. A basic prototype has been made to achieve the objectives given below. Many modifications can be made in the future to improve and increase the functionality of this idea. There is still a lot of scope for advancement in this field. This project aims at presenting one basic idea of an ocean-wide concept.

1. **Flight stability**: Achieving flight stability is crucial for any aerial vehicle, and it is especially important for a bicopter, which relies on two rotors for lift and thrust. The bicopter must be designed in a way that prevents it from tilting or wobbling during flight, which could lead to instability or even a crash. Flight stability can be achieved through the careful design of the bicopter's frame and control system.
2. **Maneuverability**: Maneuverability is another important objective for a bicopter project, as it allows the vehicle to move in different directions and perform a variety of tasks. A well-designed bicopter should be able to fly forward and backward, turn left and right, and hover in place, among other maneuvers.
3. **Payload capacity**: Payload capacity refers to the maximum weight that the bicopter can carry, and it is an important consideration for many applications, such as aerial

photography or surveying. The bicopter must be designed in a way that allows it to carry a payload of a certain weight without compromising its stability or flight time.

4. **Flight time**: Flight time refers to the maximum amount of time that the bicopter can fly before it needs to be recharged or refuelled. Flight time is a key consideration for many applications, as it determines how long the bicopter can operate before it needs to be grounded.
5. **Control system**: The control system is a critical component of any bicopter project, as it allows the pilot to control the vehicle's movement and behavior. The control system must be designed in a way that allows the pilot to make precise adjustments to the vehicle's movement while also providing feedback on the bicopter's status and performance.
6. **Safety**: Safety is a key objective for any bicopter project, as it ensures that the vehicle operates in a way that minimises the risk of accidents or damage to people and property. Safety considerations can include the use of redundant systems and fail-safe mechanisms, as well as the implementation of emergency procedures in the event of a malfunction or other unexpected event.
7. **Cost-effectiveness**: Cost-effectiveness is an important consideration for any bicopter project, as it determines how much resources and effort are required to design, build, and operate the vehicle. Cost-effectiveness can be achieved through careful selection of materials and components, as well as through efficient design and manufacturing processes. The overall cost-effectiveness of the project should be weighed against the desired performance and capabilities of the bicopter, as well as the intended use and application of the vehicle.

CHAPTER 2

LITERATURE REVIEW

2.1 RESEARCH ARTICLES

There is a fair amount of published research with regards to bicopter aircraft.
The following are some of the research papers that we went through:

[1] E. Apriaskar, F. Fahmizal, N. A. Salim, and D. Prastiyanto, "Performance Evaluation of Balancing Bicopter using P, PI, and PID Controller," *Jurnal Teknik Elektro*, vol. 11, no. 2, pp. 44–49, Dec. 2019, doi: https://doi.org/10.15294/jte.v11i2.23032.

The above-mentioned paper [1] states the potential control mechanisms involved in controlling bicopters. The paper talks about the uses of PID (proportional, integral, and derivative). The main issue that crops up when flying a bicopter is maintaining an acceptable response time and overcoming oscillations, if any. In most cases, PID comes to the rescue. Proportional terms have a role in improving the response time of bicopter performance, while derivative terms can provide a damping effect for unwanted overshoots. In order to assure a bicopter performs the desired movement, an integral term may eliminate steady-state error.

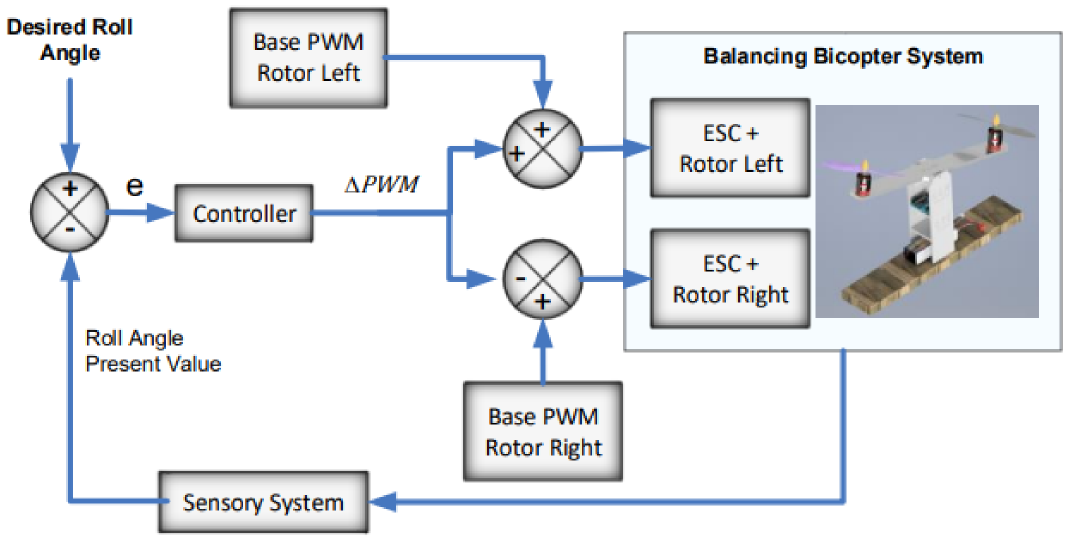


Figure 1: Control System Block Diagram Representation

In this paper, the Ziegler-Nichols tuning method is used to determine the control parameter based on PID components. This work also aims to evaluate which controller types are better at performing attitude control on balancing bicopter systems. The performance of the method is tested using a balancing bicopter on roll movement. In the balancing bicopter system, the input and output variables have to be determined first before controlling the system. The balancing bicopter system used in this work considers roll angle (φ) as the output and the actuating signal for two rotors as the input.

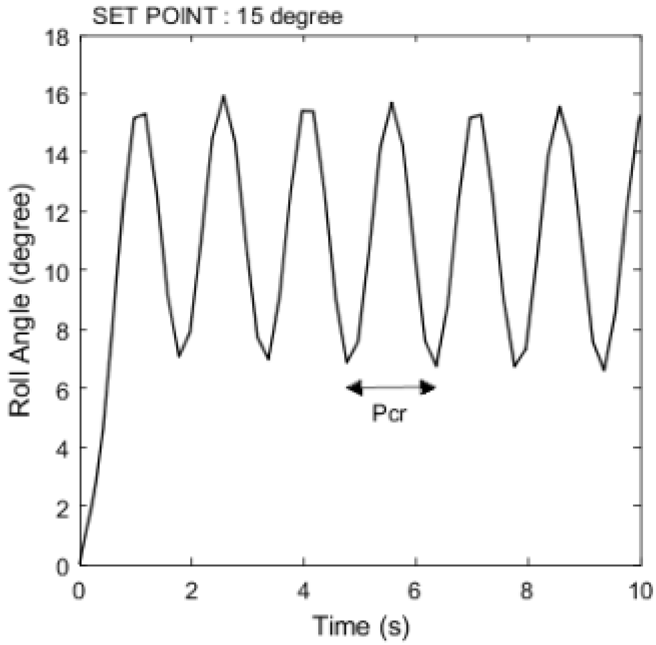


Figure 2: Ziegler-Nichols Tunig Method

The above image was obtained by performing the Ziegler-Nichols tuning method, where time was the independent variable. Here, PCR is known as the ultimate period or time period between two pulses. Here, the authors employed a closed-loop structure with one integrator while calculating the roll angle values. The Ziegler-Nichols tuning method was applied to PID, PI, and P controllers, and their concerned parameters were compared.

[2] O. B. Albayrak, Y. Ersan, A. S. Bagbasi, A. Turgut Basaranoglu, and K. B. Arikan, "Design of a Robotic Bicopter," *2019 7th International Conference on Control, Mechatronics and Automation (ICCMA)*, Nov. 2019, doi: https://doi.org/10.1109/iccma46720.2019.8988694.

The research paper titled "Design of a Robotic Bicopter" presents the design and control of a Bicopter, a type of flying robot with two rotary-wing units. The paper discusses the advantages of the Bicopter design, such as reduced cost, vibration, and power demand compared to other multicopter configurations.

The authors describe the mechanical design of the Bicopter, including the frame made of aluminium beam, landing gear made of aluminium sheet, and 3D printed parts for the tilt mechanism. Carbon fibre plates are used to mount the system components. The paper also explains the mathematical modelling of the Bicopter's dynamics, including the forces, moments, and equations of motion.

The control system of the Bicopter is based on cascaded PID (proportional-integral-derivative) controllers, which are designed for attitude and altitude dynamics. Simulations are performed to ensure stable flight, and the control system is implemented and tuned on a Naze32 flight controller connected to a Raspberry Pi for real-time applications.

The paper provides details about the physical components of the Bicopter, including brushless motors, propellers, ESCs, a LiPo battery, servo motors, and additional hardware for autonomous control and target detection. Flight time calculations are also discussed, considering propeller characteristics and battery capacity.

Overall, the paper provides a comprehensive overview of the design, control, and implementation of a Bicopter. The presented information and mathematical models can be valuable for researchers and engineers working on flying robot systems, particularly for indoor robotic applications.

[3] G. R. Gress, "Natural Pitch Stabilization of Bicopters in Hover Using Lift-Propeller Gyroscopics," *Journal of Guidance, Control, and Dynamics*, vol. 41, no. 2, pp. 476–487, Feb. 2018, doi: https://doi.org/10.2514/1.g002468.

The above paper refers to the stabilisation of a bicopter using lift propellers as a means to balance the whole body. The paper discusses the ways in which one can achieve stability in a bicopter when subjected to disturbances. For studying this phenomenon, disturbances were applied in the yaw, pitch, and roll directions, respectively. Since the prop rotors were free to rotate, they will try to adjust accordingly by aligning themselves in the opposite direction of the applied disturbances. Various other parameters were also calculated.

[4] Y. Qin, W. Xu, A. Lee, and F. Zhang, "Gemini: A Compact yet Efficient Bi-copter UAV for Indoor Applications," *IEEE Robotics and Automation Letters*, pp. 1–1, 2020, doi:

https://doi.org/10.1109/lra.2020.2974718.

In the following paper, the authors address the issue of flying through tight spaces through an adapted, optimised bi-copter UAV design. Unlike the existing work, which focuses more on the control of such a bi-copter UAV, they focused on the overall aircraft design and implementation to increase its usability, i.e., payload capacity, size, and power efficiency. More specifically, their contributions are threefold:In the following paper, the authors address the issue of flying through tight spaces through an adapted, optimised bi-copter UAV design. Unlike the existing work, which focuses more on the control of such a bi-copter UAV, they focused on the overall aircraft design and implementation to increase its usability, i.e., payload capacity, size, and power efficiency. More specifically, their contributions are threefold:

(1) They conducted a comprehensive aerodynamic analysis and showed that the bi-copter UAV is the most power-efficient drone among all the common practical configurations for indoor applications;

(2) They implemented the concept of the UAV by systematically selecting its components (e.g., propellers, motors) to design a simple yet effective control system that was composed of cascaded PID controllers with accurate control mixing.

[5] "Stability and control of VTOL tilt-rotor bi-copter UAVs," *reports.ias.ac.in*. http://reports.ias.ac.in/report/21006/stability-and-control-of-vtol-tilt-rotor-bi-copter-uavs

The research paper discusses the stability and control techniques for tilt-rotor bi-copter vertical take-off and landing (VTOL) unmanned aerial vehicles (UAVs). It highlights the limitations of quadcopters and fixed-wing aircraft and explores the potential of bi-copters in terms of improved horizontal speed, endurance, and VTOL capabilities. The paper focuses on two design models: Forward-Aft Active Tilting (FAAT) and the newly proposed Oblique Active Tilting (OAT) for bi-copters.

The paper addresses several research questions, including the differences between bi-copters and other designs, the challenges in stabilizing bi-copters, methods for achieving control, and the merits and demerits of FAAT and OAT bi-copters. The study aims to improve the stability and control responses of bi-copters by analyzing and comparing these two design models.

The importance of the research lies in the need for an aircraft that can vertically take off, hover stably, and achieve high-speed horizontal flight. This type of VTOL design is currently lacking in the aerospace industry and could have significant applications in military and civilian sectors. However, there is a gap in knowledge regarding the design and stability analysis of bi-copters, as well as the lack of stable firmware support for bi-copter flight controllers.

To address these issues, the research project aims to experimentally explore and compare stability and control techniques for bi-copters. The study involves constructing functional bi-copter UAVs based on each methodology and analyzing their stability and control responses using software analysis.

The scope of the research is limited to tilt-rotor bi-copter stability using FAAT and OAT concepts. The study primarily focuses on pitch stability while briefly discussing roll and yaw stability. The research uses Pixhawk flight controllers with Ardupilot firmware, although stable firmware builds for bi-copters on Pixhawk are currently unavailable. The study assumes constant parameters such as gravity and air density for the low-altitude, low-subsonic operating conditions of the UAVs.

The objectives of the research include understanding the design and operation of VTOL bi-copters, studying their stability and control, comparing FAAT and OAT models, proposing solutions for stability improvement, and determining the best technique for the design process of VTOL bi-copters.

The literature review section provides information on VTOL vehicle classification, including type 1, type 2, and type 3 vehicles, while introducing a new classification called Type 4 VTOL UAVs. These Type 4 vehicles are bi-copters with tiltable prop-rotors but no wings or other control surfaces. The stability and control of bi-copters are discussed, including differential thrust vectoring for yaw control and differential thrust control for roll control. The paper introduces the FAAT and OAT design models, with OAT utilizing gyroscopic precession for stabilization in addition to differential control.

In conclusion, the research paper aims to address the stability and control challenges of bi-copters by comparing the FAAT and OAT design models. The study contributes to the knowledge gap in bi-copter design and stability analysis, with the goal of improving the control and stability of bi-copter VTOL UAVs.

2.2 BRIEF HISTORY

Etienne Oehmichen was the first scientist to experiment with rotorcraft designs in the 1920s. Among the six designs he tried, his second multicopter had four rotors and eight propellers, all driven by a single engine. The Oehmichen used a steel-tube frame with two-bladed rotors at the ends of the four arms. The angle of these blades could be varied by warping. Five of the propellers, spinning in the horizontal plane, stabilized the machine laterally. Another propeller was mounted at the nose for steering. The remaining pair of propellers were for forward propulsion.

In 1922, Dr. George de Bothezat and Ivan Jerome developed this aircraft with six bladed rotors at the end of an X-shaped structure. Two small propellers with variable pitch were used for thrusting and yaw control. The vehicle used collective pitch control. It made its first flight in October 1922. About 100 flights were made by the end of 1923. The highest it ever reached was about 5 m (16 ft 5 in). Although demonstrating feasibility, it was underpowered, unresponsive, mechanically complex, and susceptible to reliability problems. The pilot's workload was too high during hover to attempt lateral motion.

Convert Wings Model "A" Quadrotor: In 1955, this unique helicopter was intended to be the prototype for a line of much larger civil and military quadrotor helicopters. The design featured two engines driving four rotors, with wings added for additional lift in forward flight. No tail rotor was needed, and control was obtained by varying the thrust between rotors. Flown successfully many times in the mid-1950s, this helicopter proved the quadrotor design.

Figure 3: Quadrotor

In the world of higher education, there are a few members of academia who have published research on quad-rotor UAVs. Among them are Joseph F. Horn and Wei Guo of Pennsylvania State University ("Modeling and Simulation for the Development of a Quad-Rotor UAV Capable of Indoor Flight"), Ming Chen and Mihai Huzmezan of the University of British Columbia ("A Simulation Model and H8 Loop Shaping Control of a Quad Rotor: An Autonomous Quadrotor Flying Robot 9 Unmanned Air Vehicle"), and Eryk Brian Nice of Cornell University ("Design of a Four Rotor Hovering Vehicle").

An attempt to search for similar projects on the market did not yield many results. Aside from a few overachieving hobbyists, there are only a few commercially available products that take advantage of similar quad-rotor flight: The SilverLight X-UFO, the Draganflyer V Ti, and the MicroDrones GmbH MD4-200 All three of these products use four rotors in conjunction with a control system that consists of three gyroscopes for feedback. The Microdrones GmbH MD4-200 and a model of the Draganflyer V Ti additionally have an onboard camera for reconnaissance purposes. However, as these crafts are designed as high-end hobbyist crafts, they also come with a fairly steep price tag, as the Dragon Flyer and the Microdrones products are upwards of $1500 or more. On a much larger industrial scale, there is currently a project in development named the Bell Boeing Quad Tiltrotor.

2.3 CONCLUSION

The purpose of this review was to view the trends in bicopter use within the recent past and see how the use of bicopters will evolve over time. Also, we gained insight about various control mechanisms involved in a bicopter, such as PID, P, and PD. We also studied the various designs available on the market and the aerodynamics of the bicopter. Apart from design and control, we also studied the payload capacity and efficiency of the bicopter.

CHAPTER 3

ASSEMBLY

3.1 ELECTRONICS

3.1.1 COMPONENTS

1. Flight Controller-

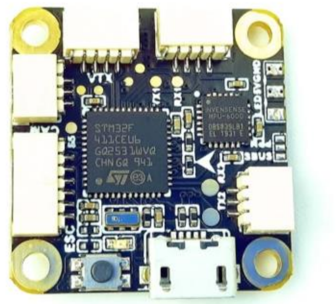


Figure 4: Darwin F3 Flight Controller

Darwin F3 FC - The flight controller is the brain of the drone. It is a type of electronic circuit board that receives input from various sensors on the drone (such as the gyroscope and accelerometer) and uses that information to calculate the drone's orientation and position. Based on this information, the flight controller can then adjust the speed of the drone's motors to achieve the desired flight path. The Darwin F3 FC is a specific brand and model of flight controller that is designed for small drones.

2. 35A 4-in-1 ESC –

Figure 5: Electronic Speed Contoller 35A

An Electronic Speed Controller (ESC) is an electronic circuit that controls the speed and direction of the drone's motors. The 4-in-1 ESC is a type of ESC that combines four separate ESCs into a single board for easy installation and improved reliability. The "35A" designation means that the ESC is capable of supplying a maximum current of 35 amps to each of the four motors.

3. RCINPOWER GTS 1202.5 11500KV motor –

Figure 6: RCINPOWER 11500kV BLDC Motor

This is a brushless motor that provides the power necessary to lift the drone off the ground and fly it through the air. Brushless motors are preferred over brushed motors for drones because they are more efficient, have a longer lifespan, and generate less heat. The Rcinpower GTS 1202.5 motor is a specific brand and model of motor that has a high KV rating of 11500, which means it can spin at a high RPM and is suitable for small, lightweight drones.

4. SG90 servo motors –

Figure 7: SG90 Servo Motor

Servo motors are small motors that can rotate to a specific angle. They are often used for controlling the orientation of the camera on a drone or for controlling the drone's landing gear. The SG90 servo motor is a specific brand and model of servo motor that is commonly used on small drones because of its compact size and low power consumption.

5. SONY 18650 4S Li-ion cells –

Figure 8: Sony 18650 Li-ion Cells

These are rechargeable lithium-ion batteries that provide power to the drone. The "18650" designation refers to the size and shape of the battery, which is cylindrical and measures 18mm in diameter and 65mm in length. The "4S" designation means that the batteries are arranged in a series configuration, which provides a total voltage of around 14.8V. Lithium-ion batteries are preferred over other types of batteries for drones because they are lightweight and have a high energy density, which means they can store a lot of energy in a small space.

6. Cyclone XF5804 Pro VTX –

Figure 9: XF5804 Video Transmitter

The XF5804 Pro is a 5.8GHz VTX that is designed for use on small drones. It features a compact size and a low weight, which makes it ideal for use on lightweight drones. The VTX is connected to the drone's flight controller and is powered by the drone's battery. It can transmit video signals over a range of several hundred meters, depending on the power output and the quality of the receiver on the ground. The XF5804 Pro also features adjustable power output levels, allowing the user to choose between different power settings to optimize transmission range and battery life. It is important to note that the use of a VTX requires compliance with local laws and regulations regarding radio transmission.

7. TBS M8.2 GPS –

Figure 10: GPS

This is a Global Positioning System (GPS) receiver that provides accurate location data for the drone. It is often used for navigation and for ensuring that the drone stays within a specific area. The TBS M8.2 GPS is a specific brand and model of GPS receiver that is designed for use on drones. It is connected to the drone's flight controller and is powered by the drone's battery.

8. X6B receiver –

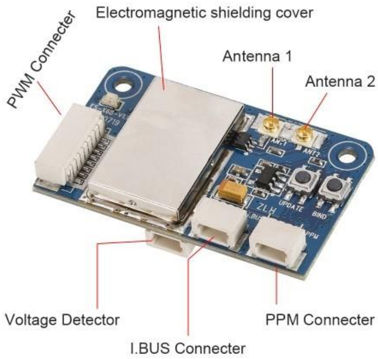


Figure 11: X6B Receiver

The X6B receiver is a type of radio receiver that is used to control the drone. It receives signals from the remote-control transmitter and sends them to the drone's flight controller, which uses the information to adjust the drone's speed, altitude, and direction. The X6B receiver is a specific brand and model of receiver that is designed for use with small drones. It uses the FrSky protocol, which is a popular protocol for radio control systems. The X6B receiver is typically connected to the flight controller via a set of wires and is powered by the drone's battery. It is also important to note that the X6B receiver should be installed in a location on the drone that provides a clear line of sight to the remote-control transmitter in order to ensure reliable communication.

3.1.2 TRANSMITTER AND RECEIVER (FS-ia6b)

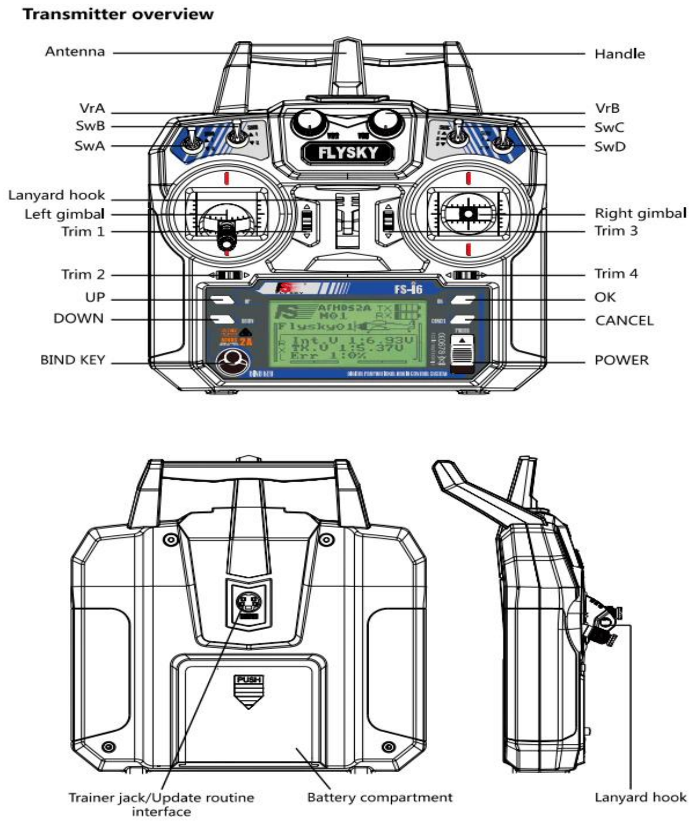


Figure 12: FlySky FS-iA6B

The FS-iA6B is a popular transmitter and receiver system manufactured by Flysky, a well-known brand in the field of radio control systems for model aircraft and drones. Here's a brief overview of the FS-iA6B transmitter and receiver:

- **Transmitter (FS-iA6B)**:

The FS-iA6B transmitter is a 6-channel radio control system that operates on the 2.4 GHz frequency. It features a compact and ergonomic design, making it comfortable to hold and use for extended periods. The transmitter incorporates digital frequency hopping spread spectrum (FHSS) technology, which ensures stable and interference-free signal transmission. It offers a wide control range and reliable signal reception, allowing for precise control of your model aircraft or drone. The FS-iA6B transmitter is compatible with a variety of receiver options, including the FS-iA6B receiver.

- **Receiver (FS-iA6B):**

The FS-iA6B receiver is a 6-channel receiver designed to work seamlessly with the FS-iA6B transmitter. It features a lightweight and compact design, making it suitable for small to medium-sized model aircraft and drones. The receiver supports PWM (Pulse Width Modulation) signal output, providing compatibility with a wide range of flight controllers and electronic speed controllers (ESCs). It has a dual antenna system, which enhances signal reception and reduces the chances of signal loss or interference. The FS-iA6B receiver has a high sensitivity receiver chip, allowing for reliable and responsive control of your aircraft or drone.

Overall, the FS-iA6B transmitter and receiver system provides a reliable and cost-effective solution for radio control applications. It offers good signal stability, a comfortable user experience, and compatibility with various aircraft and drone configurations. It is a popular choice among hobbyists and enthusiasts in the radio control community.

3.1.3 CIRCUIT DIAGRAM:

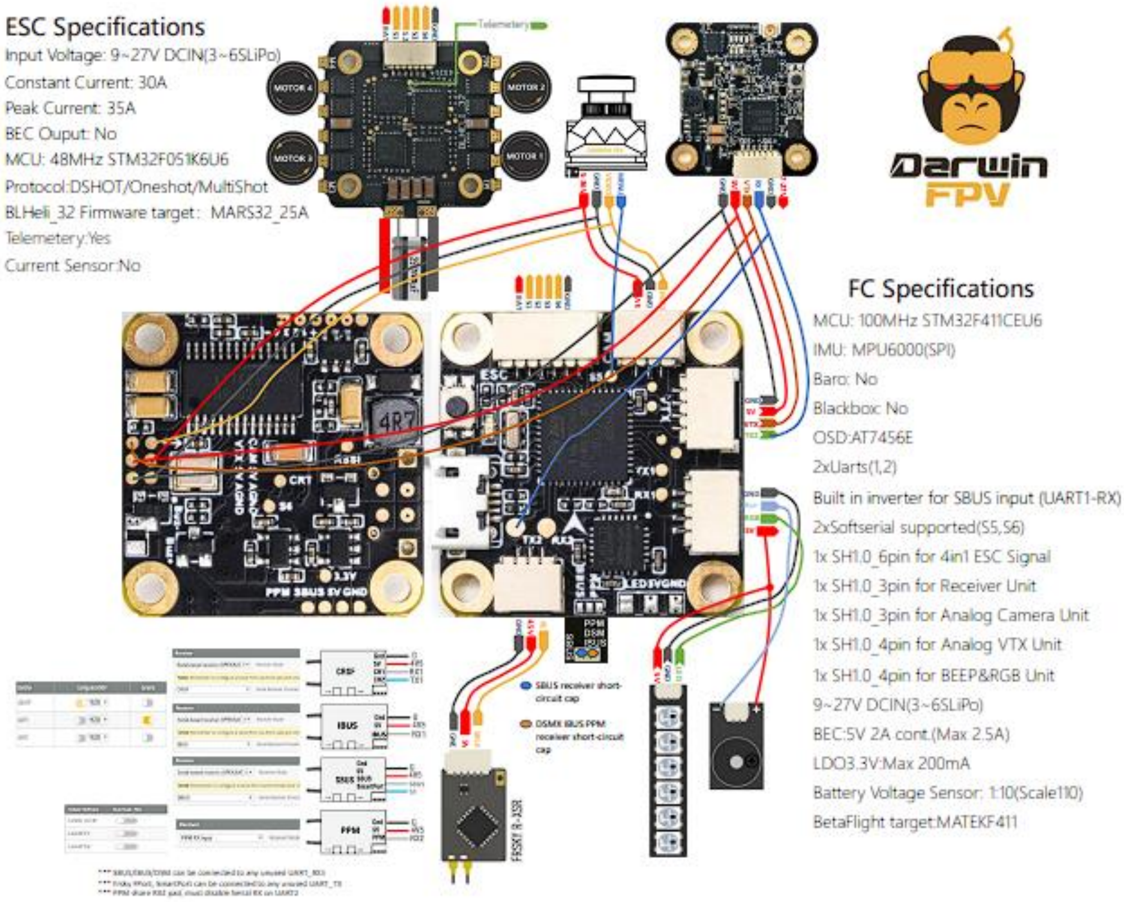


Figure 13: Circuit Diagram

3.1.4 WORKING:

The 18650 4S Li-ion battery is connected to the power distribution board, which is connected to the 4-in-1 ESC through a set of wires. The ESC controls the power supplied to the motors and is also connected to the flight controller.

The Rcinpower GTS 1202.5 11500KV motors are connected to the ESC through wires or solder connections. The motors convert electrical power into mechanical energy, which drives the propellers and produces lift to make the drone fly.

The flight controller, in this case the Darwin F3 FC, receives information from the X6B receiver through a set of wires or connections. The flight controller sends commands to the ESC, which in turn adjusts the speed of each motor based on the input received from the X6B receiver.

The SG90 servo motors, which are used to control the drone's camera gimbal or other accessories, are also connected to the flight controller through wires or connections. The flight controller sends commands to the servo motors to adjust the position of the camera or other device.

The TBS M8.2 GPS is connected to the flight controller through a set of wires or connections. The GPS provides location data to the flight controller, which uses this information to control the drone's flight behaviour.

The XF5804 Pro VTX is connected to the drone's camera and the flight controller through a set of wires or connections. The VTX transmits the video signal from the camera to the ground and is powered by the drone's battery.

The X6B receiver is connected to the remote-control transmitter, which sends signals to the receiver. The receiver sends these signals to the flight controller, which adjusts the drone's speed, altitude, and direction based on the input received. The program was flashed into the FC via the Betaflight Configurator.

3.1.5 CLI (Command-line Interface) CODE and BETA FLIGHT CONFIGURATOR:

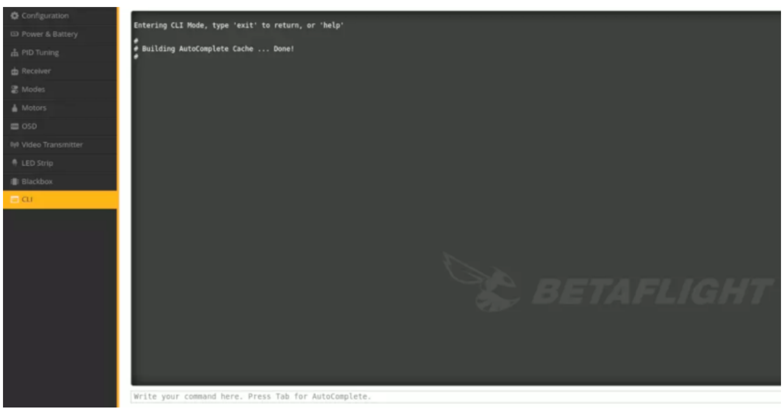


Figure 14: Command Line Interface

```
resource
resource BEEPER 1 B02
resource MOTOR 1 B06
resource MOTOR 2 B07
resource SERVO 1 B04
resource SERVO 2 B05
resource PPM 1 A03
resource LED_STRIP 1 A08
resource SERIAL_TX 1 A09
resource SERIAL_TX 2 A02
resource SERIAL_TX 11 B03
resource SERIAL_RX 1 A10
resource SERIAL_RX 2 A03
resource I2C_SCL 1 B08
resource I2C_SDA 1 B09
resource LED 1 C13
resource LED 2 C14
resource SPI_SCK 1 A05
resource SPI_SCK 2 B13
resource SPI_MISO 1 A06
resource SPI_MISO 2 B14
resource SPI_MOSI 1 A07
resource SPI_MOSI 2 B15
resource ADC_BATT 1 B00
resource ADC_CURR 1 B01
resource OSD_CS 1 B12
resource GYRO_EXTI 1 A01
resource GYRO_CS 1 A04
resource USB_DETECT 1 C15
# feature
feature RX_SERIAL
feature SOFTSERIAL
feature TELEMETRY
feature LED_STRIP
feature ANTI_GRAVITY

# master
set acc_trim_pitch = -14
set acc_trim_roll = 0
set rc_smoothing_type = FILTER
set rc_smoothing_input_hz = 0
set rc_smoothing_derivative_hz = 0
set rc_smoothing_debug_axis = ROLL
set rc_smoothing_input_type = BIQUAD
set rc_smoothing_derivative_type = BIQUAD
set min_throttle = 1070
set max_throttle = 2000
set min_command = 1000
set dshot_idle_value = 300
set dshot_burst = OFF
set use_unsynced_pwm = OFF
set motor_pwm_protocol = DSHOT600
set motor_pwm_rate = 480

# profile
profile 0

set dterm_lowpass_type = BIQUAD
set dterm_lowpass_hz = 100
set dterm_lowpass2_hz = 200
set dterm_notch_hz = 260
set dterm_notch_cutoff = 160
set vbat_pid_gain = OFF
set pid_at_min_throttle = ON
set anti_gravity_mode = SMOOTH
set anti_gravity_threshold = 250
set anti_gravity_gain = 4000
set feedforward_transition = 10
set acc_limit_yaw = 100
set acc_limit = 0
set crash_dthreshold = 50
set crash_gthreshold = 400
set crash_setpoint_threshold = 350
set crash_time = 500
set crash_delay = 0
set crash_recovery_angle = 10
set crash_recovery_rate = 100
set crash_limit_yaw = 200
set crash_recovery = OFF
set iterm_rotation = ON
set smart_feedforward = OFF
set iterm_relax = RP
set iterm_relax_type = GYRO
set iterm_relax_cutoff = 11
set iterm_windup = 50
set iterm_limit = 150
set pidsum_limit = 500
set pidsum_limit_yaw = 400
set yaw_lowpass_hz = 50
set throttle_boost = 5
set throttle_boost_cutoff = 15
set p_pitch = 48
set i_pitch = 37
set d_pitch = 29
set f_pitch = 60
set p_roll = 45
set i_roll = 35
set d_roll = 27
set f_roll = 60
set p_yaw = 38
set i_yaw = 14
set d_yaw = 0
set f_yaw = 60
set p_level = 50
```

```
set i_level = 50
set d_level = 75
set level_limit = 55
set horizon_tilt_effect = 75
set horizon_tilt_expert_mode = OFF
set abs_control_gain = 0
set abs_control_limit = 90
set abs_control_error_limit = 20

# rateprofile
rateprofile 0

set thr_mid = 50
set thr_expo = 0
set rates_type = BETAFLIGHT
set roll_rc_rate = 100
set pitch_rc_rate = 100
set yaw_rc_rate = 110
set roll_expo = 0
set pitch_expo = 0
set yaw_expo = 0
set roll_srate = 63
set pitch_srate = 63
set yaw_srate = 63
set tpa_rate = 10
set tpa_breakpoint = 1650
set throttle_limit_type = OFF
set throttle_limit_percent = 100
```

3.1.6 WHY WE SELECTED XING CAMO 1408 MOTORS?

Figure 15: Xing 2800 kV BLDC Motor

After testing and prototyping, it was determined that the RCINPOWER motors were not powerful enough to meet the performance requirements of the drone, particularly due to the increase in weight of the overall Bicopter resulting from the structural design changes. As a result, the decision was made to switch to Xing Camo 1408 2800 kV motors, which are more powerful and better suited to handle the increased weight of the drone.

The Xing Camo 1408 2800 kV motors offer several advantages over the RCINPOWER motors, including a higher power output, improved efficiency, and better durability. These motors are designed to handle high loads and provide reliable performance, making them an excellent choice for use in the Bicopter drone.

In addition to the motor upgrade, other changes may also need to be made to the drone's components and systems in order to accommodate the increased weight and power requirements. This may include changes to the ESC, flight controller, and battery, as well as adjustments to the overall design and structure of the drone.

Overall, the decision to switch to the Xing Camo 1408 2800 kV motors represents an important step in the development of the Bicopter drone, as it will allow for improved performance and greater stability in flight. Further testing and refinement will be necessary to ensure that the drone is fully optimized for its intended purpose and meets all performance requirements.

3.2 MECHANICAL DESIGN

3.2.1 INITIAL DESIGNS

The initial designs related to the building of the Bi-copter frames consisted of the following projects:

- **V22 Osprey**

The Osprey, a tiltrotor aircraft produced by Bell Boeing, is a significant achievement in aviation technology. This unique aircraft features a three-bladed proprotor, turboprop engine, and transmission nacelle mounted on each wingtip, allowing it to function as both a helicopter and a fixed-wing aircraft. The Federal Aviation Administration classifies the Osprey as a powered lift aircraft, due to its ability to take off and land like a helicopter, and transition to horizontal flight like a traditional airplane. The nacelles of the Osprey are capable of rotating forward in as little as 12 seconds, enabling a conversion to a more fuel-efficient, higher speed turboprop aircraft during horizontal flight. Additionally, the Osprey has the capability to achieve STOL (short takeoff and landing) through forward tilting of the nacelles up to 45 degrees, which allows it to operate in a variety of environments and conditions. Overall, the innovative design and capabilities of the Osprey represent a significant achievement in aviation technology, and have opened up new possibilities for future aircraft development.

Figure 16: V22 Osprey

- **Other Bicopter Designs**

Unmanned aerial vehicles (UAVs) have become increasingly popular in recent years, and researchers and drone makers alike have explored various designs for these devices, including the bicopter. Despite the widespread interest in bicopters, many designs suffer from issues related to weight and stability. Specifically, many bicopters feature a tilting mechanism located at the end of the wings, which requires the use of higher density materials to support the added weight. As a result, bicopters with this design have been prone to bending and vibrations, which can affect their performance and durability. Despite these challenges, however, researchers and drone makers continue to explore new approaches to bicopter design that address these issues and push the boundaries of what is possible with UAV technology.

In response to the limitations of previous bicopter designs, a new approach was developed that involved a central core structure to support the various components of the aircraft. This design would allow for the use of lightweight materials, simplifying the building process and improving overall performance. To enable this design, various mechanisms were needed to transfer the rotation of the servos from the central core to the end of the wings. In order to create this new bicopter design, a set of objectives was defined to guide the design process from inception to completion. By establishing clear goals and objectives, the design team was able to develop a bicopter that addressed the shortcomings of previous designs, resulting in a more efficient and effective aircraft. This new approach to bicopter design holds promise for future advances in UAV technology, and demonstrates the importance of clear objectives in the design and development process.

3.2.2 DESIGN OBJECTIVES

Following points were considered in the design and development process of the bicopter.

- **Reduced Size and Weight**

The primary objective of the design and development process for the bicopter was to reduce its overall size and weight. By implementing a central core structure and incorporating all necessary mechanisms into this core, the design team was able to eliminate unnecessary bulk and reduce the overall weight of the aircraft.

- **Reduced Cost**

It's important to consider that cost-effectiveness depends on specific use cases, requirements, and operational context. Conducting a comprehensive cost analysis, including factors such as initial investment, maintenance, operational expenses, and overall efficiency, would provide a more accurate assessment of the cost-effectiveness of a bicopter compared to other drone configurations. As the components used in a bi-copter are less when compared to a quadcopter, the manufacturing cost eventually spent is less. Thus making it cost effective too.

- **Simplified Control Mechanisms**

To make the bicopter easier to control and operate, the design team aimed to implement a simple mechanism for control of the yaw, pitch, and roll (YPR) axes. This would allow for greater precision and responsiveness in flight, while minimizing the complexity of the control system.

- **Balanced Mass Distribution**

In order to achieve stable and controlled flight, it was important to create a balanced mass distribution throughout the body structure of the bicopter. This would help to prevent the aircraft from becoming top-heavy or unbalanced during flight, leading to improved performance and maneuverability.

- **Centralized Mechanisms**

To minimize the stress and fatigue on the wings of the bicopter, all necessary mechanisms were incorporated into the central core of the body structure. This helped to distribute weight more evenly and reduce the strain on individual components, resulting in a more durable and reliable aircraft.

- **Biomimetic Body Design**

Inspired by nature, the design team aimed to create a biomimetic body shape for the bicopter. This involved studying the form and function of various animals and incorporating these principles into the design process. The resulting body shape would help to improve aerodynamics and overall performance.

- **Internal Core Support**

Finally, to provide adequate support for all the electronic components of the bicopter, a strong internal core was designed and implemented. This core would serve as a stable and secure platform for the installation of all necessary electronics, ensuring that they remained in place during flight and reducing the risk of damage or malfunction.

- **Improved Stability and Maneuverability**

The design team aimed to create a bicopter that was both stable and maneuverable. To achieve this, they incorporated a range of features such as a balanced mass distribution, simplified control mechanisms, and a biomimetic body shape. These elements helped to improve the stability of the aircraft in flight, while also making it more responsive and agile.

- **Enhanced Durability and Longevity**

To ensure that the bicopter could withstand the rigors of flight and operate reliably over time, the design team aimed to create a robust and durable aircraft. This involved selecting high-quality materials and components and implementing design features such as a centralized mechanism structure and internal core support.

- **Increased Efficiency and Flight Time**

In order to improve the efficiency of the bicopter and increase its flight time, the design team aimed to reduce its weight and optimize its aerodynamic performance. This involved designing a streamlined body shape, selecting lightweight materials, and implementing efficient propulsion and control systems.

- **Modular Design for Customization and Maintenance**

Finally, the design team aimed to create a modular bicopter design that could be easily customized and maintained. This involved designing components and systems that could be easily replaced or upgraded, and implementing a design that was easy to disassemble and reassemble for maintenance purposes.

3.2.3 DESIGN APPROACH

To create the bicopter, the design team followed a structured approach that involved several key stages:

- **Analysis of Previous Designs**

The team conducted a thorough analysis of previous bicopter designs to understand their strengths and weaknesses. This analysis helped inform the design requirements and identify areas for improvement.

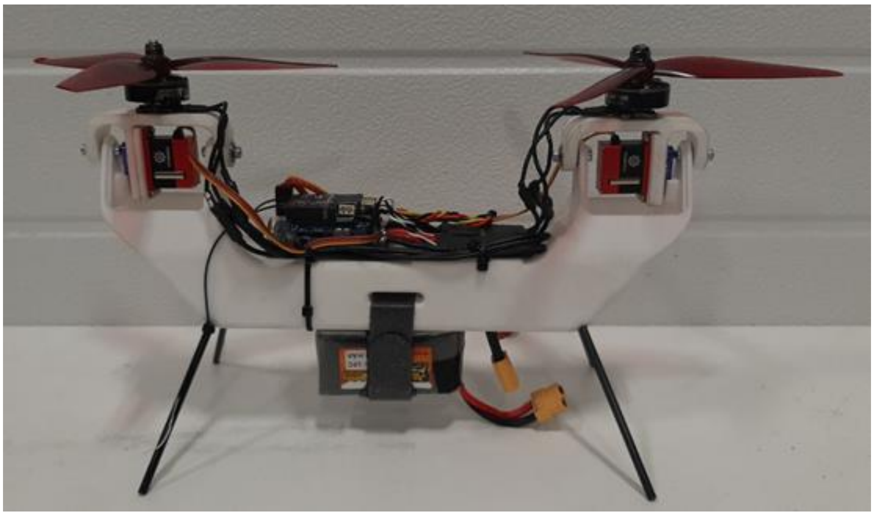


Figure 17: Previous Design of Bicopter

- **Component Selection and Dimensioning**

Based on the design requirements, the team selected the necessary electronic components and determined their initial dimensions and parameters such as thickness. This was done by referring to the component data sheets and other relevant technical information.

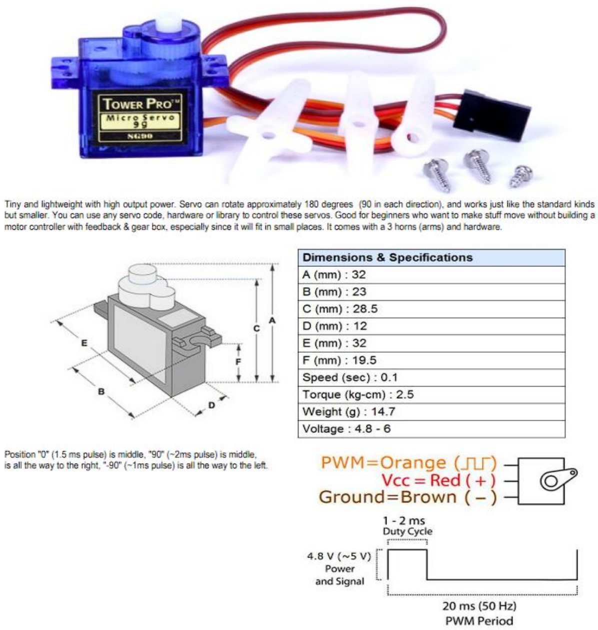
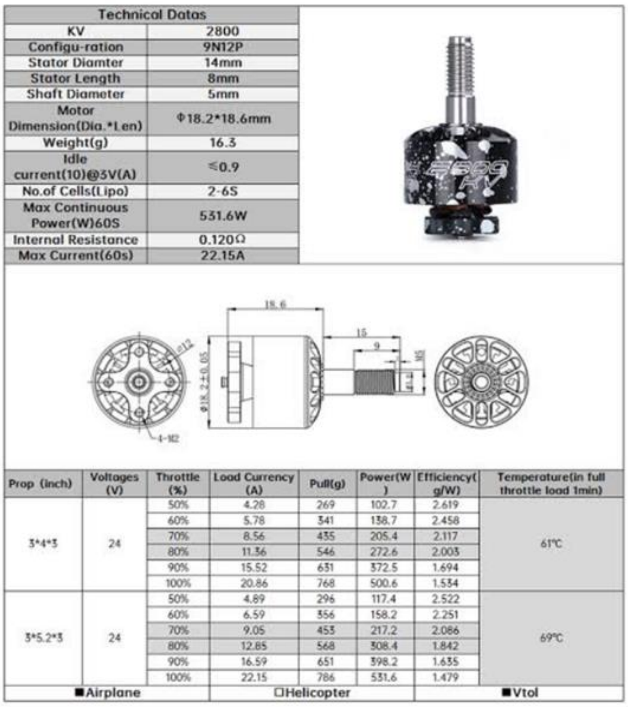


Figure 18: SG90 Servo Motor Datasheet

Technical Datas	
KV	22000
Configu-ration	9N12P
Stator Diamter	10mm
Stator Length	2mm
Shaft Diameter	1.5mm
Motor Dimension(Dia.*Len)	Φ 13.5*7.75mm
Weight(g)	2.5(5cm wire)
Idle current(5)@5V(A)	1.5
No.of Cells(Lipo)	1S
Max Continuous Power(W)3S	52
Internal Resistance	75mΩ
Max Current(3S)	14A
Max.Effciency Current	(2-4A)>84%

Prop (inch)	Voltages (V)	Throttle (%)	Load Currency (A)	Pull(g)	Power(W)	Efficiency(g/W)	Temperature(in full throttle load 3's)
GF1610R*2	3.7	50%	2.2	31	8.1	3.808	61℃
		100%	7.9	72	29.2	2.463	
GF1635R*3	3.7	50%	2.7	33	10.0	3.303	66℃
		100%	9.4	75	34.8	2.156	
GF1635R*4	3.7	50%	3	36	11.1	3.243	67℃
		100%	10.4	79	38.5	2.053	
GF2015R*2	3.7	50%	3.5	44	13.0	3.398	71℃
		100%	10.9	93	40.3	2.306	
GF2023R*3	3.7	50%	4.4	42	16.3	2.580	84℃ (Hot)
		100%	14	76	51.8	1.467	
■Airplane			□Helicopter			■Vtol	

Figure 19: RCINPOWER 11500kV Datasheet



Technical Datas	
KV	2800
Configu-ration	9N12P
Stator Diamter	14mm
Stator Length	8mm
Shaft Diameter	5mm
Motor Dimension(Dia.*Len)	Φ18.2*18.6mm
Weight(g)	16.3
Idle current(10)@3V(A)	≤0.9
No.of Cells(Lipo)	2-6S
Max Continuous Power(W)60S	531.6W
Internal Resistance	0.120Ω
Max Current(60s)	22.15A

Prop (inch)	Voltages (V)	Throttle (%)	Load Currency (A)	Pull(g)	Power(W)	Efficiency(g/W)	Temperature(in full throttle load 1min)
3*4*3	24	50%	4.28	269	102.7	2.619	61℃
		60%	5.78	341	138.7	2.458	
		70%	8.56	435	205.4	2.117	
		80%	11.36	546	272.6	2.003	
		90%	15.52	631	372.5	1.694	
		100%	20.86	768	500.6	1.534	
3*5.2*3	24	50%	4.89	296	117.4	2.522	69℃
		60%	6.59	356	158.2	2.251	
		70%	9.05	453	217.2	2.086	
		80%	12.85	568	308.4	1.842	
		90%	16.59	651	398.2	1.635	
		100%	22.15	786	531.6	1.479	
■Airplane			□Helicopter			■Vtol	

Figure 20: Xing CAMO 2800kV Datasheet

Comes without battery, charger, receiver or remote control.

116mm Racing Frame Kit	Wheel base: 116mm Frame arm thickness: 2.5mm Frame kit material: 3K carbon fiber
1104 8600KV 3 S **Brushless Motor**	KV: 8600KV Lipo cell: 3S Weight: 4.5g Maximum pull: 171g Maximum power: 144W Mounting holes distance: 9mm Mounting holes: φM2 Bearing: NSK N52 Strong NdFeB Magnet Recommend propeller: 3 inch
4 IN 1 30A BLHeli_S ESC	Continuous current: 30A Pe ak current: 35A (10S) BEC output: no Input voltage: Main control chip: EFM8BB21 Firmware upgrade: Supports Dshot600/BLHeli_S/Oneshot125 MOS: 3*3
F4 Flight Controller	Main control chip: STM32F411 Sensor: MPU6000 Integrated OSD PPM/DSM/IBUS/UAR share: UART1-RX Mounting holes distance: 20*20mm Weight: 3.6g Supports Betaflight/cleanflight/inav firmware
Camera	Case size: 12mm*12mm Weight: 3.5g Resolution ratio(horizontal center): 700TVL Total pixels:1280*960
5.8G 40CH 25mwVTX	Supports TBS SmartAudio Transmitting power: 25mW Channel: 40CH Full video format: NTSC/PAL Input voltage: 5V Size: 15*14mm Weight: 0.8g (except antenna) With copper pipe mini antenna (ipex antenna)
3016 3-blade propeller	Material: PC Mounting hole: 1.5mm Center thickness: 5.5mm Quantity: 2 pairs Weight: 1.6g
Lipo Battery	Not included Recommend 3S

Figure 21: Component Specifications

- **Modelling and Simulation**

The use of Solidworks software was a key aspect of the design process for the bicopter. With this software, the team was able to create highly detailed 3D models of the bicopter, allowing for the visualization of the different components and their interactions. Through this software, the team was able to iterate the design multiple times, improving upon it with each iteration.

To ensure that the design was suitable for flight, the team also performed static structural simulation on the CAD model of the bicopter. This simulation allowed the team to test the bicopter in various flight scenarios, analyzing the impact of forces and stresses on the different components. This enabled the team to refine the design further, addressing any potential issues and ensuring that the bicopter would be able to withstand the forces experienced during flight.

By utilizing Solidworks software and conducting structural simulations, the team was able to refine the design of the bicopter and ensure that it was optimized for flight performance. These steps were crucial in the development process, as they allowed the team to identify and address any potential issues early on, before moving on to physical prototypes.

- **Iteration and Testing**

In order to ensure that the final design of the bicopter was optimal, the design team adopted an iterative approach to the development process. This involved creating several prototypes using various manufacturing techniques, including laser cutting, CNC router machining, and 3D printing. Each prototype was designed to incorporate the latest refinements to the design, allowing the team to test the bicopter in controlled environments and assess its performance.

Through this iterative approach, the team was able to identify and address any issues that arose during the testing process, refining the design of the bicopter with each iteration. This approach allowed the team to optimize the design for flight performance, while also ensuring that the final product would be reliable and durable.

The use of various manufacturing techniques also allowed the team to explore different materials and fabrication methods, enabling them to select the most suitable approach for each component of the bicopter. By testing multiple prototypes, the team was able to ensure that the final product would be both functional and efficient, meeting the design objectives established at the outset of the project.

- **Final Product Creation**

Once the design had been refined and tested to meet the design objectives, the final product was created. This involved manufacturing the necessary components and assembling them into the final bicopter design.

- **Flight Testing**

After the final product was created, it was subjected to flight testing to evaluate its performance in real-world conditions. This involved testing various flight parameters, such as speed, stability, and maneuverability, and analyzing the data to identify areas for further improvement.

- **Evaluation and Feedback**

After flight testing was complete, the design team evaluated the performance data and solicited feedback from users and other stakeholders. This feedback was used to identify areas for further improvement and inform future design iterations.

- **Documentation and Reporting**

Throughout the design process, the team maintained detailed documentation and reporting to track progress and ensure that all design requirements were met. This documentation was used to create technical reports and other materials that could be shared with stakeholders and used for future reference.

3.2.4 ITERATION AND TESTING:

- **Prototype v1:**

In this iteration, the team tested the suitability of the components that were selected for the bicopter. To do this, an old carbon fibre frame of a mini drone was used to mount the flight controller (FC), electronic speed controllers (ESC), and motors. The team also tested the range and frequency of the remote control to ensure that it was suitable for the bicopter. By testing these components, the team was able to identify any potential issues and make necessary adjustments before moving on to finalising the selected components.

Figure 22: Prototype v1

- **Prototype v2:**

In this iteration, the design team focused on creating an internal structure that could hold all the necessary components in one place. They arranged the servo motors horizontally with their shafts facing outwards and opposite to each other. The mountings for the flight controller (FC), electronic speed controller (ESC), and receiver were placed at the top and bottom of the servo motors, based on the dimensions provided in the datasheet of the respective components. The mountings were made using acrylic material and a laser cutting machine. The goal of this iteration was to ensure that the components could be properly placed in a central core and to try different possible configurations.

The team also manufactured the arms that would be connected to the servo motors using servo hubs. These arms were used to hold the brushless DC (BLDC) motors at a distance from the center. By keeping the motors at a distance from the center, the bicopter could have better stability during flight.

The following were the design flaws we faced during the testing phase:

1. Bending of the arms: The servo motors were not able to handle the weight of the BLDC motors at the end of the arms properly, resulting in bending of the arms. This issue affected the stability and flight performance of the bicopter.

2. Dimensional tolerances: Some components did not fit properly due to dimensional errors, leading to issues with the overall structure and stability of the bicopter.

3. Difficulty in assembly: As there were no definite guide marks to assemble the core, it was difficult to assemble the structure properly. This caused delays in the manufacturing process and affected the overall timeline for the project.

These design flaws were addressed in subsequent iterations to improve the performance and stability of the bicopter.

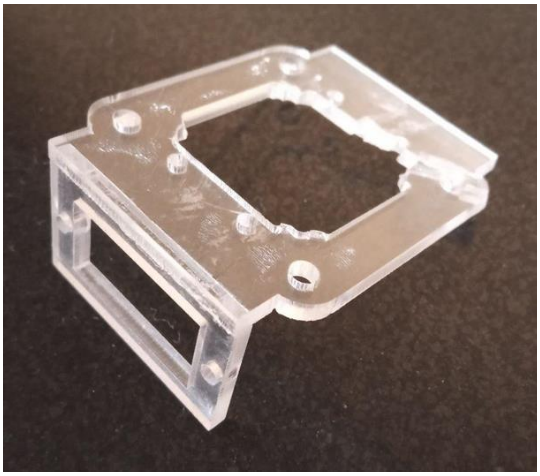


Figure 23: Prototype v2

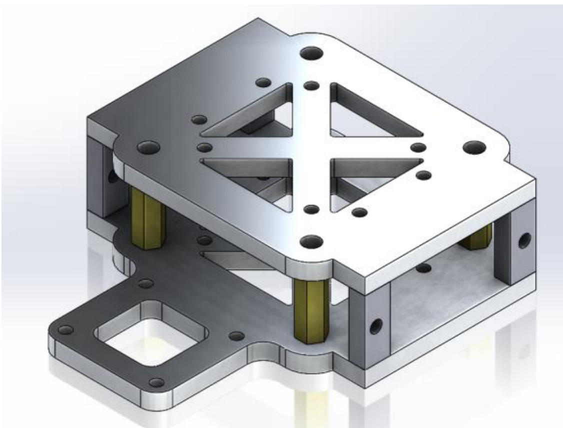


Figure 24: Prototype v2 CAD Model

- **Prototype v3:**

During this iteration, we addressed the previous design flaws and made significant improvements to the design, particularly in terms of ease of assembly and weight reduction. We introduced guide mark extrusions to assist with alignment during assembly and made adjustments to dimensional tolerances to ensure proper component support. Additionally, we incorporated pockets into the model to reduce the overall weight of the structure, resulting in a weight reduction of nearly 40%. However, we still encountered issues with arm bending, despite our efforts to address this problem. As a result, we continued to explore alternative solutions during this phase of development.

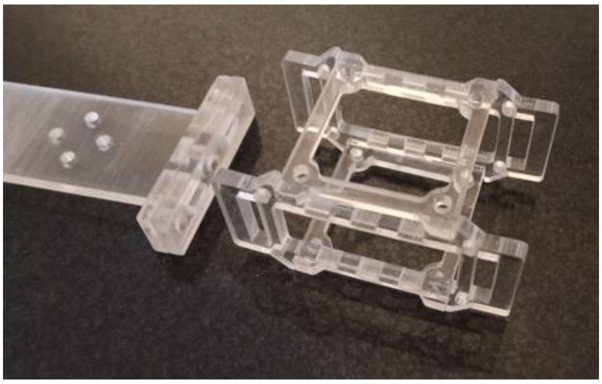


Figure 25: Prototype v3

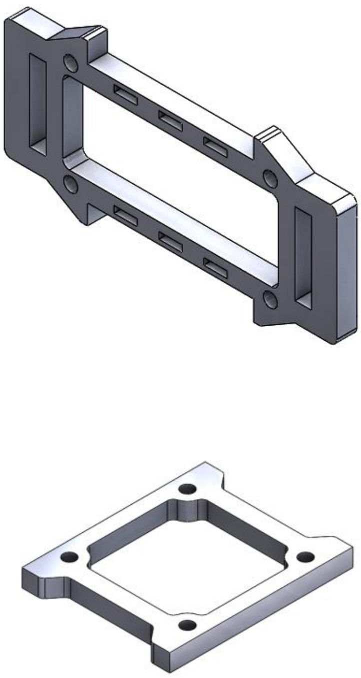


Figure 26: Prototype v3 CAD Model

- **Prototype v4:**

In the previous iteration, the team faced an issue of bending arms due to the weight of the BLDC motors at the end of these arms. In this iteration, the team decided to solve this issue by introducing a gear mechanism. The team re-designed the core structure and made arrangements for the gears. The servo motors were now connected to the gears, which in turn transferred the rotation to the arms holding the BLDC motors. The gears increased the mechanical advantage of the servo motors, which solved the issue of bending of arms to a considerable amount.

Apart from introducing the gear mechanism, the team also made other changes to the design. They gave mounting holes for shafts and introduced snap fit assembly to further ease the assembly process. This made the design more user-friendly, and also helped in reducing assembly time. Overall, the team was successful in resolving the issue of bending arms, and the new design was able to handle the weight of the BLDC motors without any issues.

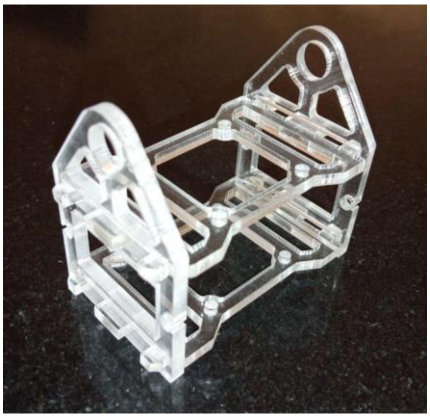


Figure 27: Prototype v4

Figure 28: Prototype v4 CAD Model

- **Prototype v5:**

In this final prototype, we made some minor changes to the design based on the results of previous testing and feedback from our team members. We increased the thickness of certain components to make the body more robust and resistant to damage during flight. Additionally, we made some small adjustments to the placement of components and the overall design to optimize performance.

To further enhance usability, we also designed and manufactured a stand for the bicopter. This stand provides a stable base for the bicopter to rest on when not in use, making it easier to perform maintenance and adjustments. The stand was designed to be lightweight and portable, so it can be easily transported along with the bicopter to different locations for testing and demonstrations.

Overall, this final prototype represents the culmination of our design and testing process. We are confident that it meets all of our design objectives and will perform well in a variety of flight scenarios.

- **Final Product:**

  The final product was manufactured using PLA Material. This material was printed on Voron V2 350 Industrial Grade 3D Printer.

  The printer specifications are listed below:

- **Style:** CoreXY Cartesian
- **Frame:** Aluminum extrusions with 3D printed parts
- **Build volume:** 250 x 250 x 250 mm, 300 x 300 x 300 mm, or 350 x 350 x 350 mm
- **Extruder configuration:** Direct
- **Extruder:** Bondtech BMG extruder (3:1 gear ratio)
- **Hot end:** V6, Revo, Phaetus Rapido, Phaetus Dragon, or Mosquito
- **Motion system:** Belts and linear rails for all axes

- **Bed leveling:** Automatic leveling using inductive probe or mods such as Klicky and Tap
- **Stepper motors:** 7x NEMA 17s (4 for the Z-axis, 2 for the X- and Y-axes, 1 for the extruder)
- **Voltage:** 24 V (with Meanwell PSU)
- **Mainboard:** BigTreeTech Octopus V1.1 with TMC2209 stepper motor drivers
- **Bed:** Cast aluminum bed with magnetic PEI sheet
- **Enclosure:** Detachable clear acrylic panels with a hinged door
- **Firmware:** Klipper
- **Computer:** Raspberry Pi 4 (to work with Klipper firmware)

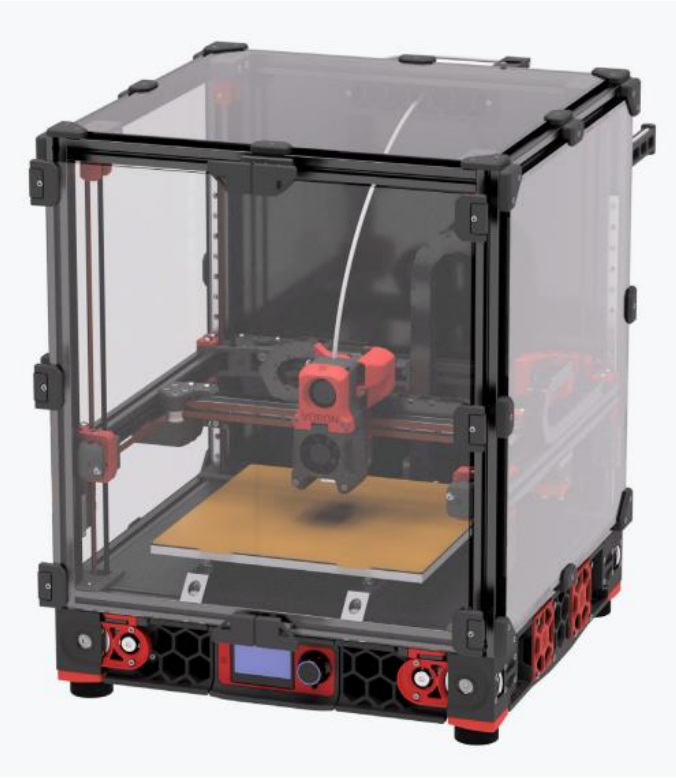


Figure 29: Voron v2 350

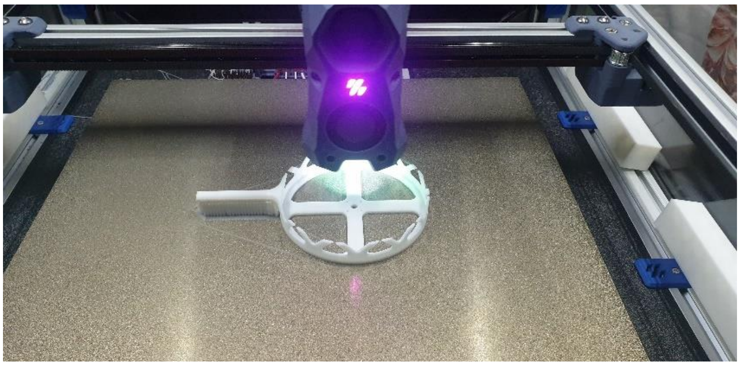


Figure 30: 3D Printing the Hoop

Figure 31: 3D Printed Hoop

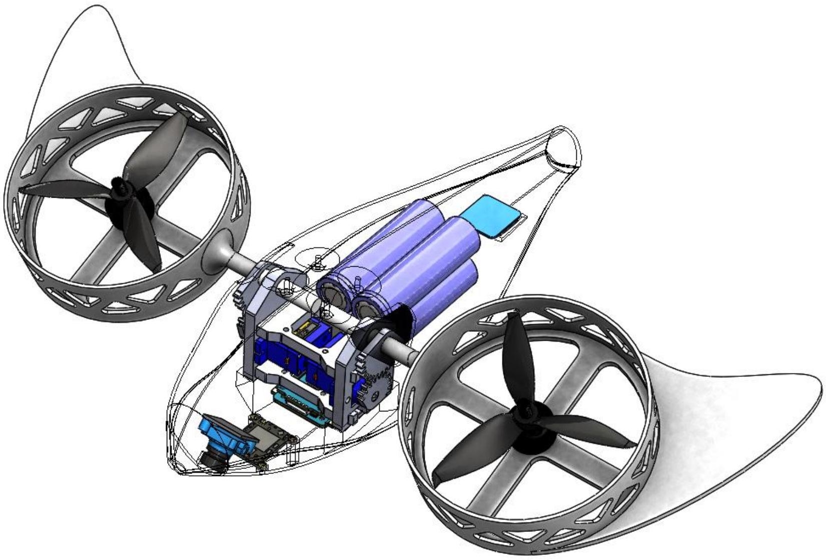


Figure 32: Final Bicopter Design CAD Model

3.2.5 MECHANISM OF WINGS

The mechanism to tilt the wings relies on the servo motor and the pair of gears attached to it. The servo motor gives rotation to the driving gear, which in turn rotates the driven gear. The driven gear then rotates the shaft attached to it. The shaft rotates the hoop so that the bicopter can perform the required movements of pitch, yaw, and roll. The driven gear has teeth only on one side, as we only needed the hoop to rotate 180 degrees. The gears were made of acrylic. The respective diameters of the gears are 22 mm and 32 mm. On either of the hoops, there was one motor that provided the required thrust to lift the bicopter. The selection of the thrust motor was based on the weight of the bicopter. The use of the gears was to minimise the torsional effect on the shaft and also to give adequate torque to tilt the hoop as and when required. Also, before coming up with the idea of gears, we had inserted the shaft directly through a common piece that connected both the servo motor and the shaft, but the results weren't satisfactory as the issue of bending was quite prevalent. The hoop and the shaft were 3D printed so that they became one entity. The material used in this case is ABS.

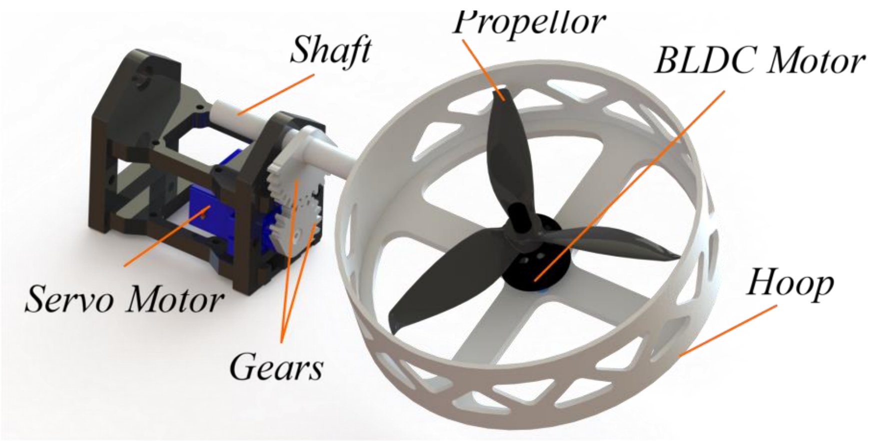


Figure 33: Wing Mechanism

3.2.6 CAD MODELS

Rendered CAD Model of Bicopter:

Figure 34: Rendered Image of Bicopter

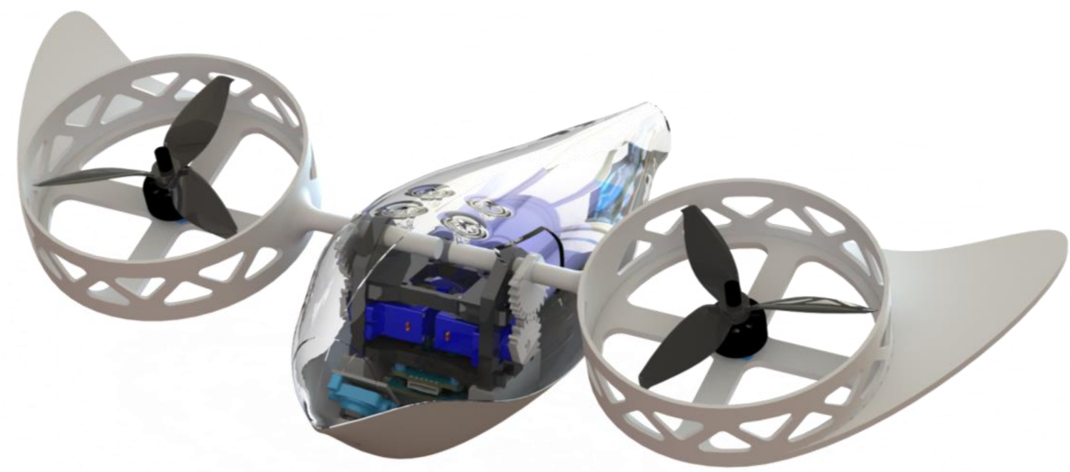


Figure 35: Transparent view

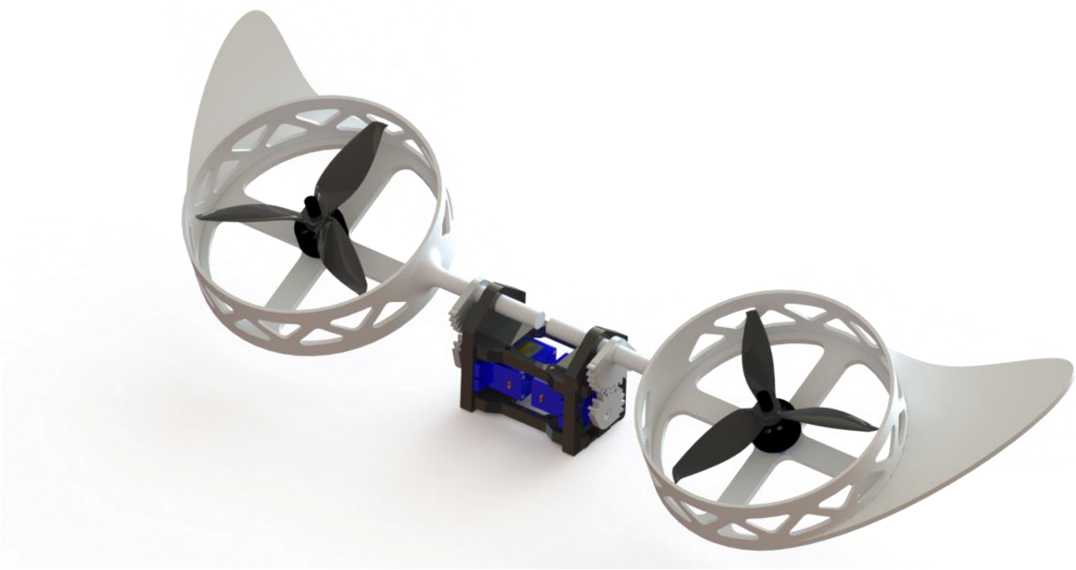


Figure 36: Internal Core Structure

Exploded View

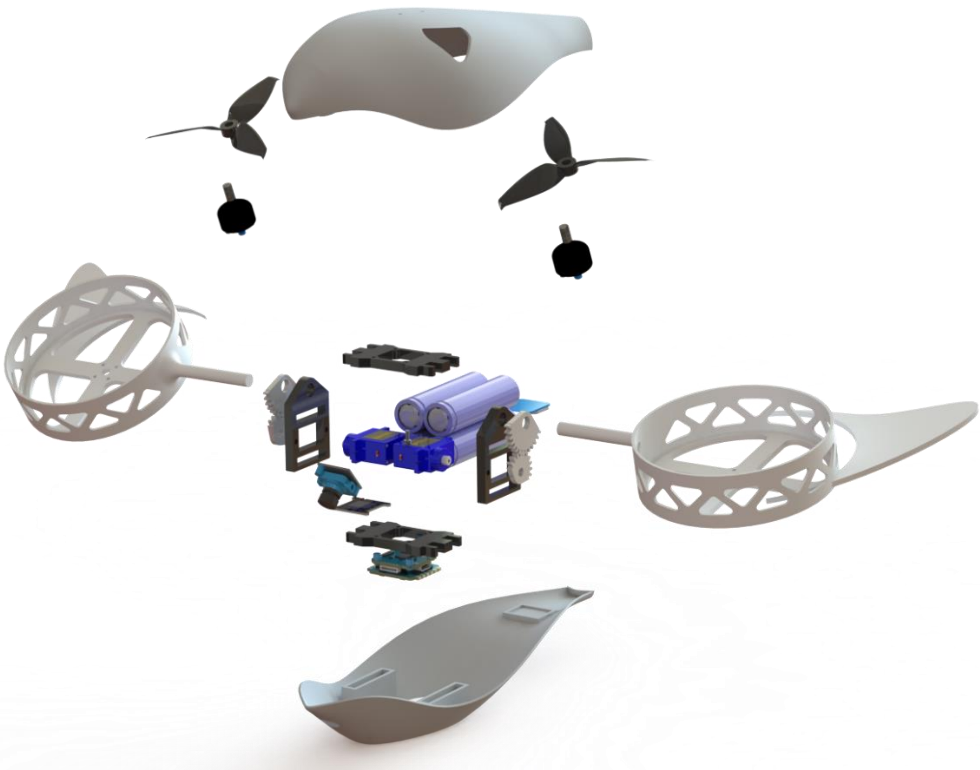


Figure 37: Exploded View of Bicopter

CHAPTER 4

CASE STUDY

4.1 MOTOR SELECTION

Bicopter and multirotors usually use brushless outrunner motors as their power plants. When selecting the motor and propeller for a bicopter, it is important to know what application the bicopter is expected to complete. Is it planned for racing, casual flying, acrobatics, or aerial videos and carries a heavy payload? If the desired application is speed and acrobatics, then a very fast-turning motor with small propellers (under eight inches) is the most suitable option. If the bicopter is planned to carry a payload such as a video camera and gimbals, then a slower-turning motor with a large propeller (eight to 12+ inches) is to be selected. Unfortunately, it's not possible to have both, and some basic knowledge of motors and propellers is an important prerequisite to picking the right motor-propeller combination for the bicopter. So we considered the datasheets of the motor, where the maximum thrust gained in grammes can be determined and a perfect pair of motor and prop can be selected.

4.1.1 Determining Thrust

One of the first things to consider when choosing a motor is the weight that it must be able to comfortably lift. A point to be remembered is that the bicopter is literally hanging in the air totally dependent that everything works the way that it is supposed to. **The basic rule of thumb is that the combined motor-propeller combinations should be able to generate 1.5-2 times the flying weight of the craft in thrust, which will provide more than enough thrust and a nice safety margin**. **So, then the basic equation is this: required thrust per motor equals (total weightx2)/2 motors.** If the bicopter maker already knows the total weight of the craft, he's off to a great start! But if the aircraft is yet to be built, then the only way of selecting the motor is by estimating the weight of the bicopter. The approximate weight of our bicopter is as follows-

Table 1: Weight of Bicopter

Component	Weight (g)
Bicopter Frame	63
Motor	110
Propeller	15
Battery	100
Electronics	82
Gear Mechanism	10
Total	378 g

Using the above equation for selecting a bicopter motor, a total of 0.3kg or 300gms of thrust per motor-propeller combination is required.

4.1.2 Motor Ratings

Brushless out runner motors are rated in kV per RPM (K=RPM, v=per volt) which is usually specified as just kV. For racing and acrobatics, a good starting point in motor selection is to consider motors that are rated over 1200kV and for heavy payloads motors that are rated under 1200kV. Actually, it is possible to break this down a little more accurately and say for a unit that weighs less than 1kg use a motor in the range of 1200-3000kV and for craft below 500 grams motors around 1300-2200kV. Granted there is often a bit of overlap to this basic rule of thumb, especially when propeller variations are considered.

Motors also have a different number of poles. Some motors have only two poles while others can have as many as fourteen poles. Smaller, faster motors for racing and acrobatics have fewer poles than the bigger heavier motors used for carrying video equipment. Another specification that needs careful consideration while motor selection is the working current and the maximum current that the motor can function with. These are rated in amps and need to be known in order to choose the right electronic speed controller which is also rated in amps. For example, if a motor is rated at a working current of 19 amps and a maximum current of 23 amps then the ESCs that are rated at a maximum of 25 amps are used. Now onto the shaft size, the diameter of the shaft needs to be known so that the propeller fits properly. Fitting a propeller on a shaft that is too small (without inserts/bushings) can be dangerous and can result in unstable flight.

Finally, one last point to consider is the motor mounts and mounting screw pattern. Some motors come with motor mounts, others do not. In choosing the motor mounts, one should be sure to consider the mounting hole patterns on both the motor and boom of the frame.

The estimated weight of the bicopter with the payload is 300 grams as calculated above. Also by the thrust generation thumb rule, the motor-propeller combination should be able to generate twice the flying weight; and as there are two motors in a bicopter, the thrust generated should be equal to half the flying weight. Hence the motor-prop combination should generate 1000gms. By using the static test result, the motor of **2800 kV rating** is selected as this motor along with 3.5x2 prop gives precisely the required thrust.

4.2 PROPELLER SELECTION

A bicopter uses two CW and two CCW propellers. Propellers are classified by length and pitch. For example, 3.5×2 propellers are 3.5-inch-long and have a pitch of 2.

When deciding on the diameter and pitch of a propeller, first consider what the craft has to do and then find the balance between the diameter and the pitch. Generally, a lower pitch will generate more torque (and less turbulence) for lifting and the motors don't have to work as hard to carry heavier loads. As a result, a motor that doesn't have to work as hard will draw less current from the battery which results in increased flight time. One simple way to increase flight time on a heavier unit is to use a lower pitch propeller on the aircraft! A propeller with a higher pitch can move a greater amount of air but creates more turbulence and less torque.

For stable flight an equal number of clockwise and counterclockwise propellers is needed. The motors don’t need to work as hard so it pulls less current with this type of prop. In acrobatics, torque propellers which provide more acceleration are needed; it puts less pressure on the power system. Lower pitch propellers will also improve stability. A higher pitch propeller moves a greater amount of air, which could create turbulence and cause the aircraft to wobble during hovering. When it comes to the length, propeller efficiency is closely related to the contact area of a prop with air, so a small increase in prop length will increase the propeller efficiency.

A smaller prop is easier to stop or speed up while a larger prop takes longer to change speeds (inertia of movement). Smaller prop also means it draws less current, that is why hexacopters and octocopters tend to use smaller props than bicopter of similar size.

Large propellers and low-KV motors are often the most effective combination for bigger bicopters that are designed to transport payloads. These have a greater rotational momentum, and as a result, they will make it easier to keep the aeroplane stable.Large propellers and low-KV motors are often the most effective combination for bigger bicopters that are designed to transport payloads. These have a greater rotational momentum, and as a result, they will make it easier to keep the aeroplane stable.

4.3 WORKING

Working of a bicopter is basically the working of the components and its movements during flight. Another term for movements is maneuvering. Maneuvering involves movements like rolling and yawing. Take-off and landing are also among the quad movements. Working of a bicopter is in short, information about the different flight characteristics of the quad that helps it fly and stabilize in mid-air.

4.3.1 Bicopter Movements

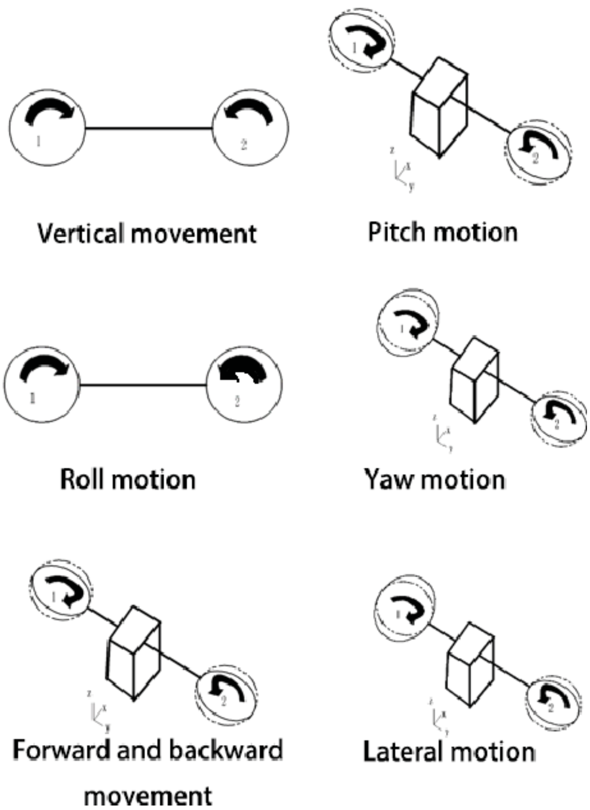


Figure 38: Bicopter Movements

A bicopter is a type of unmanned aerial vehicle (UAV) or drone that features two rotors for lift and control. Unlike traditional quadcopters with four rotors, a bicopter relies on the differential thrust between its two rotors to achieve stability and maneuverability. The movement of a bicopter is determined by adjusting the speeds of its two rotors in various combinations. Here are the basic movements that a bicopter can perform:

1. **Hovering**: By maintaining equal thrust on both rotors, the bicopter can hover in a stable position, maintaining its altitude and position in the air.
2. **Roll**: To perform a roll movement, the bicopter adjusts the speed difference between its two rotors. Increasing the speed of one rotor while decreasing the speed of the other causes a tilting motion, resulting in a roll.
3. **Pitch**: Similar to a roll, the bicopter can adjust the speed difference between its rotors to achieve a pitching motion. By increasing the speed of one rotor while decreasing the speed of the other, the bicopter tilts forward or backward, resulting in a pitch movement.
4. **Yaw**: Yaw movement is achieved by adjusting the speed of the rotors in opposite directions. By increasing the speed of one rotor while decreasing the speed of the other, the bicopter generates a torque that causes it to rotate around its vertical axis, resulting in a yaw motion.
5. **Forward/Backward Flight**: To move forward, the bicopter increases the speed of the rear rotor while decreasing the speed of the front rotor. This creates a forward thrust and allows the bicopter to move in the desired direction. Similarly, to move backward, the speed of the front rotor is increased while decreasing the speed of the rear rotor.
6. **Sideways Flight**: The bicopter can achieve sideways flight by adjusting the speed difference between the rotors on the left and right sides. Increasing the speed of the rotor on one side while decreasing the speed of the other side allows the bicopter to move laterally in the desired direction.

By combining these movements, a bicopter can perform a wide range of flight maneuvers, enabling it to navigate through various environments and accomplish different tasks.

CHAPTER 5

ANALYSIS

5.1 ANALYSIS OF BICOPTER FRAME

We conducted an analysis of two components of the bicopter. One was done to check the allowable stresses in the frame, and the other was about the bending stress and displacement of the gear.

5.1.1 Stresses in frame

We conducted an analysis of two frames of different thicknesses. One was for 3 mm, and the other was for 5 mm thickness. We went with the analysis so that we could assess which one would be better.

CASE 1: Considering a frame of 3mm thickness

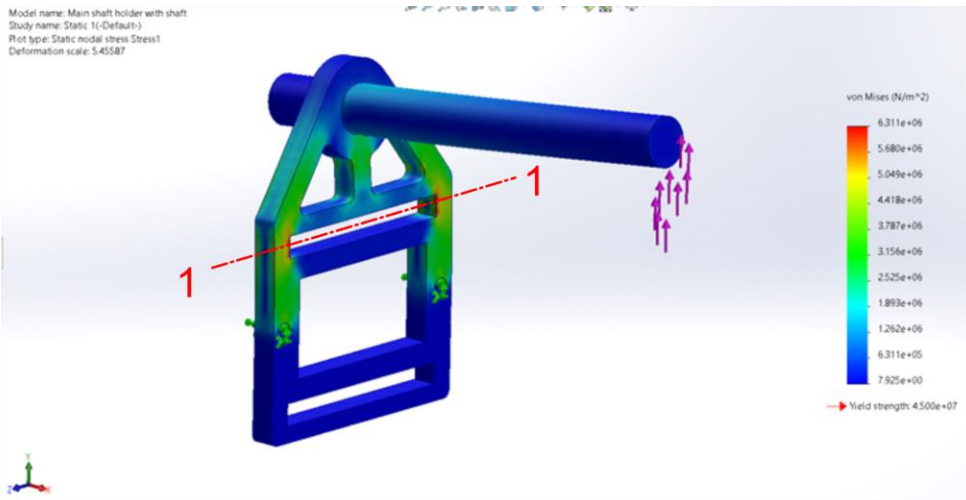


Figure 39: Static Stress Analysis of 3mm Shaft Holder

So for conducting the analysis, we first applied a force of 0.296 N (from the datasheet of the motor) at one end of the shaft. The value of the force was obtained from the datasheet of the Iflight Xing Camo motor. The following results were obtained:

Equivalent stresses	Value
Maximum	6.31Mpa
FOS	1.5

The maximum stress generated is indicated in the component by section line 1-1. The stresses primarily arise due to the bending of the shaft and the load (frame) being eccentric to the load applied. Also, since the thickness of Section 1-1 was not much, it bore a significant amount of stress. Also, the yield strength for the material of the frame was 45 MPa, which is well above the calculated value of 6.31 MPa.

CASE 2: Considering a frame of 5mm thickness

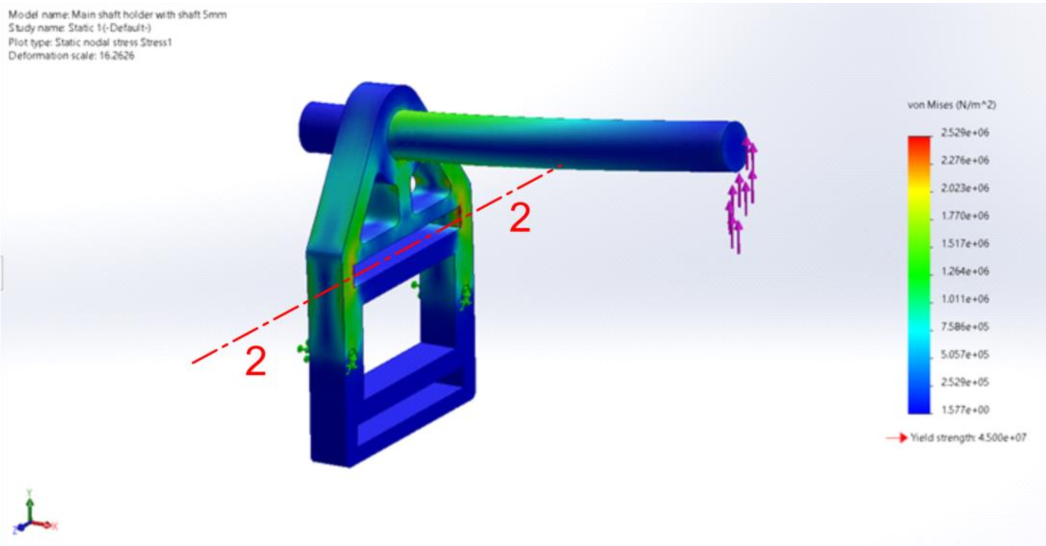


Figure 40: Static Stress Analysis of 5mm Shaft Holder

In this case too, we applied a load of 0.296 N at one end of the shaft, and the following results were obtained: Section 2-2 refers to the section of maximum stress.

Equivalent stresses	Value
Maximum	2.54 Mpa
FOS	1.5

As one can see from the difference between maximum stress values in cases 1 and 2, we went with case 2, i.e., a 5 mm mount for our design and manufacturing. The primary reason for the variation in stress levels in both cases was the difference in thickness values. So we chose to go with the 5 mm mount.

5.2 ANALYSIS OF GEAR MECHANISM

5.2.1 Static stress analysis of gear

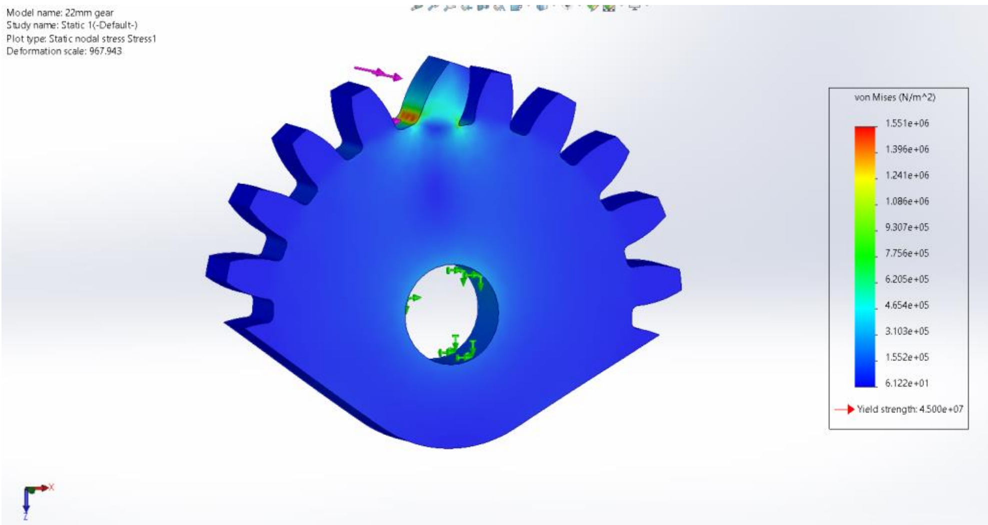


Figure 41: Static Stress Analysis of gear

Equivalent stresses	**Value**
Maximum	1.55 Mpa

The following analysis was conducted on the interaction between the pair of gears mounted on the servo and the shaft, respectively. The static stresses generated in the gear were primarily due to the engagement between the gears. So the contact forces that were generated were responsible for the stresses in the gear. A force of 11 N was applied in the tangential direction of the gear. The force caused the bending of the tooth and is shown in the figure. We arrived at the figure of 11N by considering the torque of the servo motor and the diameter of the gear used. Note that for the analysis, we used a gear of 22 mm.

5.2.2 Force calculations

From servo data sheet, we get torque(T)=2.5kg cm

diameter of the gear attached to servo(D)=22mm

therefore,

Force(F) = T/D

= 2.5*10/22 = 1.1kg = 11N

5.2.3 Displacement analysis of gear

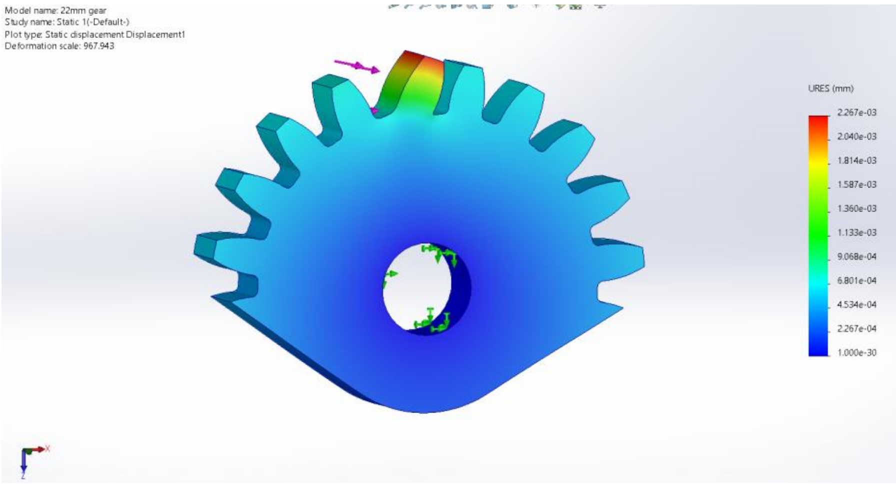


Figure 42: Displacement Analysis of gear

Displacement	**Value**
Maximum	2.2 Micron

CHAPTER 6

FIRST FLIGHT

After the selection process of all the components was successfully completed it was time to test our work till now. The bicopter components were assembled and we were ready for our flight test. The first flight of our bicopter took place in mid-February.

6.1 PROBLEM

- **Initial Flight Control and Design Challenges**

In the first few iterations of the bicopter it was able to take flight but wasn't able to adjust to the surroundings smoothly. One of the primary reasons for this was the instability in the controls. Moreover, the design and manufacturing of the bicopter was not up to the mark and had many inaccuracies. Due to which the forces required to generate lift were not precisely guiding the bicopter to take a flight.

- **Motor Arm Bending Issue**

Another issue was the bending of motor arms. The initial design was such that the motors arms were directly connected to the shaft of the servo motor. This created a cantilever effect and thus the motor arm was bending due to the weight of the motors. There was a dire need to solve this bending issue and this could only be solved by design upgradation.

- **Compatibility Issues with Battery and ESC**

Initially we planned to use a 2S LiPo battery which would have helped us in keeping the bicopter light weight. However, the ESC that we selected was not able to perform well with the 2S battery. The motors were not working at full throttle and became a hindrance in the take-off action.

- **Programming Challenges with Flight Controller**

Also, there was a problem with the programming part of the bicopter in initial stages. The FC (Flight Controller) was unable to detect the datum position of the bicopter. The datum position was quite important as it was the only way through which FC would be able to judge the position of the bicopter with respect to the surroundings. For programming the FC, we used the beta flight controller which is a standard tool in drone programming.

6.2 SOLUTION

- **Leveraging Advanced Manufacturing for Stability Enhancement**

The problem of instability in the bicopter was effectively addressed by leveraging advanced manufacturing technologies such as Laser cutting and 3D printing. These cutting-edge techniques allowed for precise manufacturing, eliminating the inaccuracies that may have existed in previous manufacturing methods. As a result, a highly accurate physical model of the bicopter was achieved, closely matching the digital model.

- **Design Modification for Bending Issue Resolution**

To tackle bending issues in the bicopter, a new design approach was implemented. Instead of directly connecting the motor arm with the hub of the servo motor, a gear mechanism was introduced. This transformation replaced the cantilever beam effect with a simply supported beam configuration. A shaft holder was incorporated at one end, and the radial reaction of the gear pairs served as support on the other end. This design modification not only resolved the bending issues but also provided a mechanical advantage by utilizing a gear with a higher number of teeth on one end and a smaller number of teeth on the servo.

- **Resolving Battery-ESC Compatibility**

The compatibility issue between the battery and Electronic Speed Controller (ESC) was resolved by opting for a higher variant of the battery, specifically a 3S LiPo Battery. By choosing a battery with a higher specification, the motors could operate at their maximum power and speed, ensuring optimal performance of the bicopter.

- **Overcoming Configuration Challenges in Betaflight Configurator**

The configuration process in the betaflight configurator posed challenges due to the sensitivity and the multitude of parameters involved. Initially, setting the datum of the bicopter proved difficult due to errors in the gyroscopic parameters. However, through persistent trial and error, the right set of gyroscopic parameters were eventually identified, allowing for the accurate establishment of the datum in the bicopter's flight control system.

CHAPTER 7

COST ESTIMATION

Table 2: Cost Estimation Table

SR. NO.	COMPONENTS	SPECIFICATIONS	RATE	QUANTITY	PRICE
1.	Frame	3D Print PLA and Acrylic	100	1	1000
2.	Electric Motor	XING 1408 2800kv	2100	2	4200
3.	Battery	4S 18650 Li-ion, 14.8V, 3300mAh	1100	4	4400
4.	Propellor	HQ T65mm x 3	200	1	200
5.	ESC	35 A	4500	1	4500
6.	Flight Controller	Darwin F3	8000	1	8000
7.	Transmitter and Receiver	Fly-Sky FS - ia6B	4000	1	4000
8.	Servo Motor	SG90	150	2	300
9.	GPS	TBS M8.2 GLONASS	1000	1	1000
10.	Camera	RUN CAM 800 TVL	1020	1	1020
11.	VTX	Cyclone XF		1	
12.	Miscellaneous	Fasteners and Adhesives		1	
Total					**28620**

CHAPTER 8

FUTURE SCOPE

This project is one the most basic and miniature versions of a bird bi-copter. There can be a lot of modifications that can be made in this model and used for a better way of surveillance. There are many changes and improvements that can be done to make this bicopter a more efficient and multifunctional model.

The concept of using drones for surveillance is a very new concept. With further research and tests a lot more efficient and complex ideas can be applied and used. Drones can aid and also if possible, in the future, replace humans in this task thereby increasing the safety of human beings.

Some of the future modifications that may be done with more research about this idea are:

1) Aerial Photography and Videography: Bicopters can be used for capturing high-quality aerial images and videos in industries such as filmmaking, real estate, surveying, and tourism.
2) Precision Agriculture: Bicopters equipped with specialized sensors and cameras can be utilized in agriculture for crop monitoring, crop spraying, and precision agriculture techniques to optimize farming practices and improve crop yield.
3) Industrial Inspections: Bicopters can conduct inspections of infrastructure such as buildings, bridges, pipelines, and power lines, providing visual data and detecting structural issues or maintenance needs.
4) Search and Rescue Operations: Bicopters with thermal cameras and real-time video transmission capabilities can assist in search and rescue missions, locating missing persons or surveying disaster-stricken areas.
5) Environmental Monitoring: Bicopter can be deployed to monitor environmental factors like air quality, water quality, wildlife tracking, and vegetation analysis, aiding in ecological research and conservation efforts.
6) Package Delivery: With advancements in payload capacity and autonomous flight capabilities, bicopter can serve as delivery drones for transporting small packages or medical supplies to remote or hard-to-reach areas.

7) Traffic Monitoring: Bicopter can help monitor traffic congestion, provide real-time traffic updates, and assist in accident investigations and traffic management.
8) Entertainment and Sports Events: Bicopter can enhance the spectator experience in sports events, concerts, and outdoor gatherings by capturing unique aerial footage and providing immersive perspectives.

These are just a few potential applications, and the future scope for bicopters may expand as technology progresses and new opportunities arise.With more research in this field, there can be many more additions made and there might come a time when the process of security will be completely automated. The scope of this field is very wide, and it might take a long time before the above-mentioned ideas come into existence.But all in all, there’s still a long way to go.

CHAPTER 9

CONCLUSION

This project aimed to introduce the concept of bicopter drones as a means of surveillance and monitoring, with a specific focus on minimizing risks to human lives. By employing bicopter, it becomes possible to monitor critical sections of high towers and other challenging environments without exposing personnel to potentially dangerous situations.

The study concluded that utilizing bicopter drones in surveillance and monitoring operations offers notable advantages in terms of efficiency, time savings, and resource optimization. Traditional methods of surveillance often involve significant human involvement and potential risks, whereas deploying drones allows for remote assessment of situations, eliminating the need for human presence in hazardous areas. This not only enhances safety but also increases operational efficiency by minimizing the time required to gather information and make informed decisions.

One of the key findings of this study was the importance of addressing the weight carrying capacity limitations of drones. In many applications, drones face constraints in terms of the payload they can carry, which can limit their effectiveness in certain scenarios. However, through proper material planning and fabrication techniques, these limitations can be overcome. By utilizing lightweight and sturdy materials, and employing advanced manufacturing technologies such as 3D printing and laser cutting, it becomes possible to design and construct bicopter drones with improved weight carrying capabilities. This opens up opportunities for using drones in a wider range of applications, including carrying additional sensors, equipment, or payloads for specific surveillance and monitoring needs.

Bicopter drones may be improved in the future. The future scope shows that continued research and development might produce ever more advanced and efficient drones. Improve flying stability, battery life, manoeuvrability, and data collecting and analysis by adding modern imaging and sensor technology.

In conclusion, bicopter drones can revolutionise surveillance and monitoring. Drones' remote operation, safety, and data collection may reduce human danger and optimise resource use. Bicopter drones may soon improve situational awareness and decision-making in surveillance and monitoring applications.

NOMENCLATURE

Short Form	Full Form	Page
UAV	Unmanned Aerial Vehicles	2
GPS	Global Positioning System	2
RC	Remote Controlled	3
Config	Configuration	7
CW	Clockwise	7
CCW	Counterclockwise	7
FPV	First Person View	8
Li-Po	Lithium Polymer	18
Li-ion	Lithium Ion	18
ESC	Electronic Speed Controller	18
PCB	Printed Circuit Board	20
BLDC	Brushless Direct Current	22
ECM	Electronically Commutated Motors	22
FC	Flight Controller	30
LCD	Liquid Crystal Display	30
BEC	Battery Eliminator Circuit	31
AUX	Auxiliary	32
mS	milliseconds	33
PWM	Pulse Width Modulation	34
mAh	Mili-Ampere Hour	38
EMF	Electromotive Force	40
PDB	Power Distribution Board	44
RF	Radio Frequency	46
AM	Amplitude Modulation	46
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REFERENCES

Research Papers

1. E. Apriaskar, F. Fahmizal, N. A. Salim, and D. Prastiyanto, “Performance Evaluation of Balancing Bicopter using P, PI, and PID Controller,” *Jurnal Teknik Elektro*, vol. 11, no. 2, pp. 44–49, Dec. 2019, doi: https://doi.org/10.15294/jte.v11i2.23032.

2. J. M. Bustamante, C. A. Herrera, E. S. Espinoza, C. A. Escalante, S. Salazar, and R. Lozano, “Design and Construction of a UAV VTOL in Ducted-Fan and Tilt-Rotor Configuration,” in 2019 16th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE), 2019, pp. 1–6.

3. M. Reyad, M. Arafa, and E. A. Sallam, “An optimal PID controller for a qaudrotor system based on DE algorithm,” in 2016 11th International Conference on Computer Engineering & Systems (ICCES), 2016, pp. 444–451.

4. O. B. Albayrak, Y. Ersan, A. S. Bagbasi, A. Turgut Basaranoglu, and K. B. Arikan, “Design of a Robotic Bicopter,” *2019 7th International Conference on Control, Mechatronics and Automation (ICCMA)*, Nov. 2019, doi: https://doi.org/10.1109/iccma46720.2019.8988694.

5. G. M. Hoffmann, H. Huang, S. L. Waslander, and C. J. Tomlin, “Quadrotor helicopter flight dynamics and control: Theory and experiment,” Proceedings of the AIAA Guidance, Navigation and Control Conference and Exhibit, Aug. 2007.

6. Ø. Magnussen, “Multirotor Design Optimization: The Mechatronic Approach,” University of Agder. Unpublished Doctoral Thesis, May 2015.

7. G. R. Gress, “Natural Pitch Stabilization of Bicopters in Hover Using Lift-Propeller Gyroscopics,” *Journal of Guidance, Control, and Dynamics*, vol. 41, no. 2, pp. 476–487, Feb. 2018, doi: https://doi.org/10.2514/1.g002468.

8. Y. Qin, W. Xu, A. Lee, and F. Zhang, “Gemini: A Compact yet Efficient Bi-copter UAV for Indoor Applications,” *IEEE Robotics and Automation Letters*, pp. 1–1, 2020, doi: https://doi.org/10.1109/lra.2020.2974718.

9. "Stability and control of VTOL tilt-rotor bi-copter UAVs," *reports.ias.ac.in*. http://reports.ias.ac.in/report/21006/stability-and-control-of-vtol-tilt-rotor-bi-copter-uavs

10. J. Lin, L. Wang, F. Gao, S. Shen, and F. Zhang, "Flying through a narrow gap using neural network: An end-to-end planning and control approach," 2019, arXiv:1903.09088.

Books

1. DIY RC Airplanes from Scratch: The Brooklyn Aerodrome Bible for Hacking the Skies by Baldwin and published by McGraw Hill Professional, 1 July 2013.
2. Getting Started with Hobby Bicopters and Drones eBook by Craig Issod, (ASIN-B00DBJQKD8) 10 June 2013.

Others

1. http://oddcopter.com/2012/02/21/bicopter-escs-electronic-speed-controllers/
2. http://www.electroschematics.com/8712/rf-based-wireless-remote-control-system/
3. http://learnrobotix.com/uavs/bicopter-basics/bicopters-multirotors-motors-propellers-basics.html
4. http://blog.oscarliang.net/how-to-choose-motor-and-propeller-for-bicopter/
5. http://batteryuniversity.com/learn/article/
6. http://www.rogershobbycenter.com/lipoguide/
7. http://www.edn.com/design/sensors/4406682/1/Brushless-DC-Motors---Part-I-- Construction-and-Operating-Principles
8. http://www.electrical4u.com/working-or-operating-principle-of-dc-motor/
9. http://www.learnengineering.org/2014/10/Brushless-DC-motor.html
10. http://blog.oscarliang.net/types-of-multicopter/
11. http://ijiset.com/v1s4/IJISET_V1_I4_13.pdf
12. http://www.dronetrest.com/t/power-distribution-boards-how-to-choose-the-right-one/1259
13. http://propeller.org.uk/
14. http://blog.oscarliang.net/how-to-choose-motor-and-propeller-for-bicopter/
15. http://oddcopter.com/2012/06/10/dji-flame-wheel-f450-bicopter-frame-and-clones/
16. https://www.quora.com/Bicopters/Why-is-x-configuration-preferred-over-+-config-of-bicopter