

UAV for Real Time Air Pollution Monitoring with Custom Propellers

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Aeronautical Engineering

By

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DEPARTMENT OF AERONAUTICAL ENGINEERING

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of ANIRUDH ASHOK (Reg. No. 38260003) and JOSELINE X (Reg. No. 38260017) who carried out the project entitled **"UAV for Real Time Air Pollution Monitoring with Custom Propellers"** under our supervision from September 2021 to April 2022.

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We ANIRUDH ASHOK (Reg.No. 38260003) and JOSELINE X (Reg. No. 38260017) hereby declare that the Project Report entitled “**UAV for Real Time Air Pollution Monitoring with Custom Propellers**” done by us under the guidance of **Mr. VENKATESH S, M.E.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Aeronautical Engineering.

DATE: 05.05.2022

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ABSTRACT

Air pollution has been one of the most profound and harmful forms of environmental pollution that has plagued humankind ever since the early times of industrial revolution. It is primarily caused by industrial incineration wherein factories producing various goods burn or incinerate certain ingredients and by-products, releasing harmful gases into the atmosphere. With rapid industrialisation, there is an immense growth in the number of emerging industries which either come up in residential or agricultural areas or conversely influence the establishment of residential townships inside industrial zones. This stirs up a conflict between residences and industry in the form of air pollution in the vicinity making it uncomfortable and dangerous for people residing there. Our project aims to develop a product named APM, a quadcopter drone that would offer customers the ability to collect real time air quality data and assess whether the levels of air pollution in the given vicinity are compliant with the prescribed standards set by the respective government of the place and take necessary actions to control it if needed. The novelty of this project lies in its unique propeller design which makes it more efficient than drones operating with stock propellers. The outcome of this project would be a portable, low cost, easy to operate, high efficiency quadcopter drone which is easily maintainable, with scope of additional applications that would offer customers the ability to collect real time air quality data and assess whether the levels of air pollution in the given vicinity are compliant with the prescribed standards set by the respective government of the place and take necessary actions to control and mitigate it if needed. The product is targeted specially for industries and operators working with organisations that are into pollution control and environment protection.

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LIST OF SYMBOLS AND ABBEREVIATIONS

V_c	Cutting speed (mm/sec)
N	Spindle speed (rpm)
V_c	Penetration rate (mm/sec)
F_n	Feed per revolution (mm/rev)
MRR	Metal Removal Rate (Q)
M_c	Torque (N/m)
T_c	Machining Time (sec)
R_a	surface roughness factor
L	length of cut (mm)
D	diameter (mm)
F_x	Tangential Force (N)
F_t	Thrust Force (N)
APM	Air Pollution Monitoring
ESC	Electronic speed controller
FDM	Fused Deposition Modelling
SLA	Stereolithography
UAV	Unmanned Aerial Vehicle
LCD	Liquid Crystal Display
BLDC	Brushless DC

CHAPTER 1

INTRODUCTION

1.1 UAV

An Unmanned Aerial Vehicle or UAV as it is predominantly known is a class of autonomous vehicles that can fly under remote controlled commands or preprogrammed settings input by a user. UAVs are applied and used both in civil and military applications. Military uses include bombing, reconnaissance as well as mapping and patrols. In the civilian domain, UAVs, particularly drones are used for applications like photography, education, leisure, hobby as well as for various industrial applications like wing turbine inspections and forestry and agriculture. UAVs were originally developed through the twentieth century for military missions which were dangerous for mans. by the twenty first century, they have become essential assets to most militaries. As control techs improvised and costs tumbled, their utilisation expanded to various civil uses. Many words are utilised for aircraft which fly without any pilots on aboard. The word drone has been used from the early dawns of aviation, applied to remotely flown aircraft used for practicing, firing of a battleship guns, such as the Fairey Queen de Havilland Queen Bee. Late examples include the Airspeed Queen Wasp and Miles Queen Martinet, before ultimate replacement by GAF-Jindivik. The term remains in common use. An unmanned aerial vehicle (UAV) is defined as a "powered, aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload". UAV is a term that is commonly used to term military cases. For recreational uses, a drone (as opposed to a UAV) is a model aircraft that has first-person video, autonomous capabilities, or both. The emergence of UAVs in urban mobility sector in the form of air taxis is another such emerging trend in the technology space which is going to capture the market very soon. This tells us the significance and widespread scope of the wonderful invention.

UAVs can be classified under the following categories: -

1.1.1 Classification by size:

Classification by size is as follows:

- minuscule UAVs
- Micro or Nano UAVs
- Small UAVs
- Mini UAVs
- Medium UAVs
- Large UAVs

The same way DGCA has also created its own classification of UAVs according to its range:

- low-cost short proximity UAVs
- Close-range UAVs
- Short-range UAVs
- Mid-range UAVs

Table 1: Classification of UAVs

Category	Altitude (ft)	Endurance (hr)	Range (km)	Weight (kg)
Micro UAV	<300	1	<5	<1
Mini UAV	<10,000	1-6	<25	<25
Close Range UAV	<15,000	4-8	<75	<200
Small Range UAV	<25,000	8-24	<200	<750
Medium UAV	<30,000	>24	>1,000	>1000
Large UAV	<40,000	>24	>1,000	>2000
Heavy UAV	>45,000	>24	>1,000	>3000

1.1.2 Classification by type:

Drones can be classified as the following based on their type:

- Multi Rotor Robots
- Fixed Wing Robots
- Single Rotor Helicopter
- Fixed Wing Mixture VT

1.1.2.1 Multi Rotor Drones

These are the most popular class of drones utilized by both Businesses and people alike. They are used in generic applications such as photography/ videography, observation. Other applications include racing, recreation and much more. Multi rotor drones are the least demanding to make and the most effortless to fly. Multi-rotor drones can likewise be grouped dependent on the quantity of rotors on the stage. They are Tricopter, Quadrotor, Hex rotor and Octocopter. Out of these, Quadrotors are the most renowned and limitlessly utilized variation. In spite of the fact that it is easy to fabricate and similarly modest, multi-rotor drones have numerous disadvantages. They have restricted flying time, restricted perseverance and speed. They are not able for enormous scope items like long reach airborne planning or reconnaissance. The numerical issue with the multi rotor is they need to spend a lot of their energy (from a battery) just to battle gravity and settle themselves noticeable all around. right now, a large portion of the multi-rotor drones out in the market are able to do simply a 20 to 30 minutes flying time

1.1.2.2 Fixed Wing Drones

Fixed Wing drones are completely different in design and build to Quad or Hex Rotor type design. They use a 'wing' like the normal aero planes in the market or the real ones. These are not similar to Quad or Hex rotor drones, fixed-wing type models won't consume energy to stay in a single position on-air (fixed-wing types can't hover in the air at one place) fighting gravity. Rather, they just move along the planned path set by the user until they have energy to fly. Most fixed-wing drones have a predominantly mean flying time of a few hours. Gas powered planes can fly more than 15 hours. due

to their higher-flying time and greater fuel efficiency, fixed-wing drones are ideal for long-distance operations (be it mapping or surveillance). But they cannot be used for aerial photography as they need to stand still in the air for a longer time and that can be done only with the help of a multirotor. It's difficult to keep a strong and fast wing drone within the air. A catapult or a runway is needed to launch the drone into air and make it align with the flight path. A runway or a parachute or a net is mandatory to land them back in the ground safely. comparatively multirotor are safe and cheaper than these planes, someone who has good money can buy a quadcopter equipped with a GPS. Flying a quadcopter doesn't require special training. Operators just take them to an open area and fly them. Guiding and flying a quadcopter are often learned on the go.

1.1.2.3 Single Rotor Drones

Single rotor drones are comparative in each viewpoint to genuine helicopters. In contrast to a typical robot, one engine model has just one major estimated engine in addition to a little one on the tail of the robot to control its heading. Single rotor drones are a lot of proficient than quad or hex rotor variants. They have higher flying occasions and may even be fueled by gas motors. In streamlined features, the lower the tally of rotors the lesser will be the twist of the thing. Also, that is the huge motivation behind why quadcopters are steadier than octocopters. With respects, single rotor drones are a lot of effective than Quad or Hexa or Octa drones. Nonetheless, these machines contain a lot higher complexations and operational dangers. Their expenses are likewise on the higher side. The hefty estimated rotor edges regularly have a danger (lethal mishaps are recorded from rc copter mishaps) if the robot is misused or includes in a mishap. Multi-rotor drones, regularly because of their little rotor edges haven't been engaged with lethal mishaps (however a scar on the actual body is likely). They 'Likewise request uncommon preparing to fly them on air appropriately (however they'll not need haven't been involved in fatal accidents (though a scar on the physical on air).

1.2 AIR POLLUTION

1.2.1 Overview of Air Pollution

Air pollution is defined as the pollution caused to air due to contamination via discharge of pollutants which are harmful to both plant and animal health. Air pollution is the profound cause for 7 million deaths of humans worldwide every year as quoted by the world health organization or WHO. 90% of human beings worldwide in the present period are currently breathing air that is exceeding the universal guidelines and limits set by world bodies. People living in middle and low income countries around the planet are the worst affected. In USA an act passed by the house, the clean air act of 1970 empowers an agency named environmental protection agency or EPA to protect public health within the USA by imposing regulations.

1.2.2 Causes of Air Pollution

Air pollution is primarily caused by human activity. This includes but is not limited to energy utilization, generation, transmission. When machines burn fossil fuels such as coal and petroleum, they introduce harmful byproducts and pollutants into the air. These pollutants build up in the atmosphere and severely impact the climate such as ozone causing global warming and climate change. "We have progressed over the last 50 years improving air quality in the United States by the Clean Air Act," says a senior scientist and deputy director of the Science Center. But climate change will make it harder in the future to meet pollution standards, which are designed to protect global health by world leaders. Increased CO₂ and methane levels in the atmosphere raises the earths temperature impacting the lives of not only humans but also of plants and sea creatures.

CHAPTER 2

LITERATURE SURVEY

2.1 Literature Survey for UAV

2.1.1. Rapid Prototyping of a Fixed-Wing VTOL UAV for Design Testing

Yucel Orkut Aktas, Ugur Ozdemir, Yasin Dereli, Ahmed Farabi Tarhan, Aykut Cetin, Aslihan Vuruskan, Burak Yuksek, Hande Cengiz, Serkan Basdemir, Mesut Ucar, Murat Genctav, Adil Yukselen, Ibrahim Ozkol, Metin Orhan Kaya, Gokhan Inalhan

“A UAV named TURAC was designed, a VTOL Tilt Rotor UAV with these capabilities. Mathematical and CFD analyses were performed iteratively so as to optimize the planning, but testing in actual conditions were needed. However, like such an iterative design process, the manufacturing process costs, including different molds for every design, is exorbitant. additionally, once an imperfection within the design is encountered, making design modifications on the complete scale UAV prototype is difficult and expensive. Therefore, a cheap, rapid, and simply reproducible prototyping methodology is important. during this study, the tip results of an iterative design process of TURAC is presented. additionally, a low-cost prototyping methodology is developed and its application is demonstrated very well. the bottom and flight tests are applied on a totally functional prototype and also the results are given.”

2.1.2. Design and performance analyses of a fixed wing battery VTOL UAV

Özgür Dündar, Mesut Bilici, Tarık Ünler

“A clarification of the look steps and performance analyses including energy consumption of a fixed-wing (FW) vertical takeoff landing (VTOL) UAV were done. The vehicle is supposed from the beginning with the goal for low take-off weight and high aerodynamic performance. Aerodynamic design steps and sizing of both wing and control surfaces are demonstrated and static stability is fulfilled by evaluating the center of gravity location with relevance neutral point. additionally, power requirements and energy consumptions for take-off, climbing, cruise and landing are evaluated in perspective of flight performances to go looking out Azur the required endurance for each flight condition. so, on attempt to try this selected battery is modelled in Simulink

and results are represented. In take-off and landing flight conditions, momentum theory is implemented for vertical flight while the cruise flight is utilized to look out so, the foremost endurance. Drag calculations in level flight are performed well to experience the drawbacks of multi-rotor system including propellers providing vertical flight. Finally, VTOL-FW concept having multi-rotor system with four extra propellers and only fixed wing (FW) concept are compared in terms of endurance. It's found that FW concept without multi-rotor system with four propellers have rather more endurance compared to VTOL-FW concept. Manufacturing with three-dimensional printers and flight tests of VTOL-FW UAV are performed as a future work."

2.1.3. Design and Structural Analyses of a Reciprocating S1223 High-Lift Wing for an RA-Driven VTOL UAV

Johnson O. Imumbhon , Mohammad D. Alam and Yiding Cao

"During aircraft design, analysis is done to check the aircraft components to demonstrate the structural element's ability to resist what they're designed for, as well as predict any potential failure of the components/parts. The study focused on the structural design and analysis of a high-lift, low Reynolds number airfoil profile, the Selig S1223, under reciprocating inertial force loading, to work out the ability of its use in a very new reciprocating airfoil-driven VTOL UAV. The fabric selected for the wing structures including ribs, spars, and skin, was high-strength carbon fiber. The wing was designed in SolidWorks software, while finite analysis was performed with ANSYS mechanical workbench in conjunction with the inertia forces because of the reciprocating motion of the wing and also the lift and drag forces that were derived from the aerodynamic wing analysis. The structural stress and strain determined under the loading conditions were found to be satisfactory for the study and therefore the craftily designed wing could sustain the high reciprocating inertia forces within the RA-driven VTOL UAV system. The results of this study indicate that the Selig S1223 airfoil profile, because of its superior performance at low Reynolds numbers, high lift, reduced noise characteristics at low angles of attack, combined with the use of high strength CFRP, proves to be a good choice for this RA-driven aircraft application."

2.1.4. Conceptual Design and Multi-Disciplinary Computational Investigations of Multirotor Unmanned Aerial Vehicle for Environmental Applications

Vijayanandh Raja , Senthil Kumar Solaiappan, Parvathy Rajendran, Senthil Kumar Madasamy and Sunghun Jung

“Establishing of a conceptual design for a multirotor unmanned aerial vehicle (UAV) was done in this paper. The objectives of this octocopter are to cut back the quantity of flight cancelations and car accidents thanks to low-visibility issues and to enhance abnormal environmental conditions thanks to the presence of smoke. The proposed octocopter contains a convergent–divergent [CD] duct-based tank, which provides a platform to store saltwater and allows it to fly in foggy zones. Fine saltwater is sprayed from the octocopter and dispersed into the low clouds, thereby altering the vapor’s microphysical processes to interrupt it up and improve visibility. the character of the seawater and its enhanced fluid properties, because of the involvement of octocopter, creates the fluid flow mixing between atmospheric fluids and spraying particles, which increases the settling of foggy and smokey content groundward. For deployment, the conceptual design of the octocopter was initially constructed through analytical approaches. Additionally, three unique historical relationships were created. the quality engineering approaches involved during this work were stability analysis through MATLAB and fluid-property analysis through computational fluid dynamics (CFD) cum multiple reference system (MRF) tools. The systematic model of this octocopter was developed by CATIA, and thereafter CFD and fluid–structure-interaction (FSI) analyses were computed, in ANSYS Workbench, on the octocopter for various environmental conditions. The aerodynamic forces on the drone, the enhancement of dynamic pressure by the presence of high amounts of rotors and nozzle sprayer, suitable material to resist aerodynamic loadings, and tests on the efficiency of the controller and its electronic components were investigated thoroughly. Finally, the proposed octocopter-based dynamic system was conceptually constructed.”

2.1.5. Stability Analysis and Augmentation Design of a Bionic Multi-Section Variable-Sweep-Wing UAV Based on the Centroid Self-Trim Compensation Morphing

Hang Ma, Yuxue Ge, Bifeng Song and Yang Pei

“In this study, a design scheme for a high-aspect-ratio bionic multi-section variable-sweep wing unmanned aerial vehicle (UAV) that utilizes the reverse coordinated change within the sweep angle of the inner and outer wing sections is proposed, which improves the aerodynamic performance and realizes the self-trim compensation of the wing's centroid. In keeping with the layout characteristics of this kind of UAV, an affordable distribution design of the wingspan ratio of the inner and outer sections is explored, to scale back the impact of aerodynamic centre movement and moment of inertia change. The calculation and analysis results show that the coordinated variable-sweep scheme can significantly improve the influence of sweep angle change on the longitudinal static stability margin of UAVs with a high ratio. The coordinated sweep angle change within the inner and outer wing sections cannot only reduce the drag during high-speed flight, but also play a big role in improving the performance of the aircraft at different stages within the mission profile. Appropriately increasing the wingspan proportion of the inner section can reduce the trim resistance of the V-tail, reduce the thrust of the engine, and increase the range and duration of the UAV. From the attitude of stability change, the multi-section variable-sweep wing UAV with a wingspan ratio of the inner and outer sections that's between 1.41 and 1.78 has better dynamic stability performance. Among them, the UAV with a wingspan ratio of the inner and outer sections that's adequate 1.41 has better longitudinal stability performance, while the UAV with a wingspan ratio of the inner and outer sections that's up to 1.78 has better lateral/directional stability performance.”

2.1.6. Modeling, Control System Design and Preliminary Experimental Verification of a Hybrid Power Unit Suitable for Multirotor UAVs

Matija Krznar, Petar Piljek, Denis Kotarski, and Danijel Pavković

“A key drawback of multirotor unmanned aerial vehicles (UAVs) with energy sources based solely on electrochemical batteries is said to be the available on-board energy. Flight autonomy is often limited to 15–30 min, with a flight duration upper limit of 90 min currently being achieved by high-performance battery-powered multirotor UAVs. Therefore, propulsion systems that utilize two or more different energy sources (hybrid power systems) could also be considered as another so as to extend the flight duration

while retaining key performance benefits of battery energy storage use. The research presented during this work considers a multirotor UAV electromagnetic unit, supported the interior combustion engine (ICE) powering an electricity generator (EG) connected to the common DC (DC) bus in parallel with the lithium-polymer (LiPo) battery, and also the respective modelling and identification of individual emu subsystem, together with the dedicated system design. Experimental verification of the proposed hybrid electromagnetic unit system has been administrated on the custom-build emu prototype. The results show that the proposed system combines the 2 power sources in a very straightforward and effective way, with subsequent analysis showing that a two-fold energy density increase will be achieved with a hybrid energy source, consequently making it possible to attain higher flight autonomy of the potential multirotor (hover load around 1000–1400 W) equipped with such a hybrid system.”

2.1.7. Design, Analysis, and Testing of a Hybrid VTOL Tilt-Rotor UAV for Increased Endurance

Siddhant Panigrahi, Yenugu Siva Sai Krishna and Asokan Thondiyath

“Unmanned Aerial Vehicles (UAVs) have slowly but steadily emerged as a search and commercial hotspot thanks to their widespread applications. thanks to their agility, compact size, and skill to integrate multiple sensors, they're mostly probe for applications that need supplementing human effort in risky and monotonous missions. Despite all of those advantages, rotorcrafts, in general, are limited by their endurance and power-intensive flight requirements, which consequently affect the time of flight and operational range. On the opposite hand, fixed-wing aircrafts have an extended range, because the entire thrust force is along the direction of motion and are inherently more stable but are limited by their take-off and landing field requirements. one amongst the potential solutions to extend the endurance of VTOL rotorcrafts (Vertical Take-Off and Landing Vehicles) was to take advantage of the thrust vectoring ability of the individual actuators in multi-rotors, which might enable take-off and hovering as a VTOL vehicle and flight as a fixed-wing aircraft. the first aim of this paper is to put out the general design process of a Hybrid VTOL tilt-rotor UAV from the initial conceptual sketch to the ultimate fabricated prototype. The novelty of the look lies during achieving thrust vectoring capabilities in a fixed-wing platform with minimum actuation and no additional control complexity. This paper presents novel bi-copter

that has been designed to perform as a hybrid configuration in both VTOL and stuck wing conditions with minimum actuators compared to existing designs. The unified dynamic modelling together with the approximation of multiple aerodynamic coefficients by numerical simulations is additionally presented. the general conceptual design, dynamic modelling, computational simulation, and experimental analysis of the novel hybrid fixed-wing bi-copter with thrust vectoring capabilities planning to substantially increase the flight range and endurance compared to the standard aircraft rotorcraft configurations are presented.”

2.1.8. Project On UAV Design for Flight Competition in SAE Aero Design West-2013

M. Fazlay Rabbey, E. Arafat Papon, H.M. Monerujjaman, F. Hasan Nuri, A.

Mahmood Rumi, S. Akter Jahan

“This paper has demonstrated the design and simulation of an UAV for the SAE Aero Design West 2013 Competition which was sponsored and managed by NASA's Aeronautics Research Mission Directorate in partnership with SAE International. Each year, SAE International hosts a competition to design, construct and fly three types of remote controlled aircraft. The MIST students made an endeavor to design a micro class aircraft to compete in this Competition. The project was started from September 2012 and continues through competition in April 2013. During this period the team faced many obstacles with design process, overall management, schedule meetings, team dynamics, resolving communication issues and budget. Considering availability of technology, material and skilled workmanship, this is the best design of a unique innovation to be proud of a developing nation like Bangladesh.”

2.1.9. Design, Manufacturing, and Flight Testing of an Experimental Flying Wing UAV

Pei-Hsiang Chung, Der-Ming Ma and Jaw-Kuen Shiau

“This paper presents the look, manufacturing, and flight testing of an electric-powered experimental flying wing unmanned aerial vehicle (UAV). the look process starts with

defining the performance requirements including the stall speed, maximal speed, cruise altitude, ceiling, and switch radius and speed. The loading and associated loading are obtained supported the defined performance requirements. The wing area, UAV mass, and power requirements are determined from the endurance and payload requirements. the facility requirement determines the motor size. Aerodynamics and stability designs are obtained supported the chosen airfoil and obtained wing area. After completing the planning, the UAV is manufactured using composite materials. The UAV is supplied with an AXi 4130/20 kv305 brushless motor and a Pixhawk control board. Its total weight is 8.6 kg. Flight tests were conducted to guage the UAV's performance and dynamic characteristics and to demonstrate the success of the look."

2.2 Literature Survey for Air Pollution Monitoring UAVs

2.2.1. Development and Validation of a UAV Based System for Air Pollution Measurements

Tommaso Francesco Villa, Farhad Salimi, Kye Morton, Lidia Morawska and Felipe Gonzalez

"Air quality data collection near pollution sources is difficult, particularly when sites are complex, have physical barriers, or are themselves moving. Small Unmanned Aerial Vehicles (UAVs) offer new approaches to pollution and atmospheric studies. However, there are variety of critical design decisions which require to be made to enable representative data collection, specifically the placement of the air sampler or air sensor intake. The aim of this research was to ascertain the simplest mounting point for four gas sensors and a Particle Number Concentration (PNC) monitor, onboard a hex copter, so to develop a UAV system capable of measuring root emissions. The research included two different tests: (1) evaluate the air flow behaviour of a hex copter, its downwash and upwash effect, by measuring air speed along three axes to see the placement where the sensors should be mounted; (2) evaluate the utilization of gas sensors for CO₂, CO, NO₂ and NO, and therefore the PNC monitor (Discman) to assess the efficiency and performance of the UAV based system by measuring emissions from a diesel. The air speed behaviour map produced by test 1 shows the most effective mounting point for the sensors to be alongside the UAV. This position is a smaller amount suffering from the propeller downwash effect. Test 2 results

demonstrated that the UAV propellers cause a dispersion effect shown by the decrease of gas and PN concentration measured in real time. A rectilinear regression model was used to estimate how the sensor position, relative to the UAV centre, affects pollutant concentration measurements when the propellers are turned on. This research establishes guidelines on the way to develop a UAV system to live route emissions. Such research should be undertaken before any UAV system is developed for global data collection.”

2.2.2. A Methodology to Monitor Airborne PM₁₀ Dust Particles Using a Small Unmanned Aerial Vehicle

Miguel Alvarado, Felipe Gonzalez, Peter Erskine, David Cliff and Darlene Heuff

“This paper expands upon previous research undertaken to develop a relative methodology to observe PM₁₀ dust particles produced by mining activities making use of small unmanned aerial vehicles (UAVs). A module sensor employing a laser particle counter (OPC-N2 from Alpha sense, Great Notley, Essex, UK) was tested. An aerodynamic flow experiment was undertaken to work out the position and length of a sampling probe of the sensing module. Flight tests were conducted so as to demonstrate that the sensor provided data which might be accustomed calculate the emission rate of a source. Emission rates are a critical variable for further predictive dispersion estimates. First, data collected by the airborne module was verified employing a 5.0 m tower during which a TSI DRX 8533 (reference dust display, TSI, Shoreview, MN, USA) and a reproduction of the module sensor were installed. Second, concentration values collected by the monitoring module attached to the UAV (airborne module) obtaining a percentage error of 1.1%. Finally, emission rates from the source were calculated, with airborne data, obtaining errors as low as 1.2%. These errors are low and indicate that the readings collected with the airborne module are cherish the TSI DRX and will be accustomed obtain specific emission factors from fugitive emissions for industrial activities.”

2.2.3. Developing a Modular Unmanned Aerial Vehicle (UAV) Platform for Air Pollution Profiling

Qijun Gu, Drew R. Michanowicz and Chunrong Jia

“The target of this study is to style and develop a modular UAV-based platform capable of real-time monitoring of multiple air pollutants. The system comprises five modules: the UAV, the bottom station, the sensors, the information acquisition (DA) module, and therefore the data fusion (DF) module. The hardware was constructed with off-the-shelf consumer parts and therefore the open-source software Arduino was used for control and data fusion. The prototype UAV system was tested in representative settings. Results show that this UAV platform can wing pre-determined pathways with adequate flight time for various data collection missions. The system simultaneously collects air quality and high precision X-Y-Z data and integrates and visualizes them in a very real-time manner. While the system can accommodate multiple gas sensors, UAV operations may electronically interfere with the performance of chemical-resistant sensors. Our prototype and experiments prove the feasibility of the system and show that it features a stable and high precision spatial-temporal platform for air sample collection. Future work should be focused on gas sensor development, plug-and-play interfaces, impacts of rotor wash, and all-weather designs.”

2.2.4. The Characteristics and Contributing Factors of Air Pollution in Nanjing: A Case Study Based on an Unmanned Aerial Vehicle Experiment and Multiple Datasets

Shudao Zhou, Shuling Peng, Min Wang, Ao Shen and Zhanhua Liu

“Unmanned aerial vehicle (UAV) experiments, multiple datasets from ground-based stations and satellite remote sensing platforms, and backward trajectory models were combined to analyse the characteristics and influential mechanisms of the pollution episode that occurred in Nanjing during 3–4 December 2017. Before the experiments, the position of the detector mounted on a UAV that was minimally disturbed by the rotation of the rotors was analysed supported computational fluid dynamics (CFD) simulations. The combined analysis indicated that the surface meteorological conditions—high ratio, low wind speed, and low temperature—were conducive to the build-up of PM_{2.5}. Strongly intense temperature inversion layers and also the low thickness of the atmospheric mixed layer could have resulted in elevated PM_{2.5} mass concentrations. within the early stage, pollution was full of the synoptic circulation of the homogenous pressure field and low wind speeds, and therefore the pollutants mainly originated from emissions from surrounding areas. The aggravated pollution

was mainly attributed to the front and powerful north westerly winds above 850 hPa, and also the pollutants mostly originated from the long-distance transport of emissions with north westerly winds, mainly from the Beijing–Tianjin–Hebei (BTH) region and its surrounding areas. This long-distance transport predominated during this event. The pollution level and aerosol optical depth (AOD) were positively correlated with relevancy their spatial distributions; they might reflect shifts in areas of significant pollution. Pollution was concentrated in Anhui Province when it absolutely was alleviated in Nanjing. Polluted dust, polluted continental and smoke aerosols were primarily observed during this process. particularly, polluted dust aerosols accounted for a significant a part of the transport stage, and existed between the surface and 4 km. Moreover, the common extinction coefficient at lower altitudes (<1 km) was higher for aerosol deposition.”

2.2.5. Autonomous monitoring, analysis, and countering of air pollution using environmental drones

Godall Rohi, O'tega Ejofodomi, Godswill Ofualagba

“This paper investigates large scale pollution elimination to get rid of pollutants that are already breathing within the environment. This method involves the utilization of Environmental Drones (E-drones) to autonomously monitor the air quality at a particular location. The E-drone flies up to a predetermined height (Altitude) every hour, measures the air pollutants at that location, implements on-board pollution abatement solutions for pollutants above the recommended threshold, and so flies backtrack to its location on the bottom. the benefits of this method are its ability to live pollution concentration of CO₂, CO, NH₃, SO₂, PM, O₃ and NO₂, detect after they are too high, and implement on-board pollution abatement solutions pro re nata. This system's novelty lies within the undeniable fact that it not only detects when there's excessive pollution, but it also automatically deals with and abates the detected pollution above earth. When multiple E-drones are employed in different locations, a custom software generates an Air Quality Health Index (AQHI) map of the region that may be used for present and long-term environmental analysis.”

2.2.6. Use of Multi-Rotor Unmanned Aerial Vehicles for Fine-Grained Roadside Air Pollution Monitoring

Bai Li, Rong Cao, Zhanyong Wang, Rui-Feng Song,

“At present, most research on vehicle exhaust directly measures the whole emissions from the pipe or monitors the time variation of air pollutants at the roadside by setting roadside monitoring stations. The spatial resolution of those two methods is incredibly low, however, and it's impossible to explain accurately the diffusion patterns of exhaust gas within the atmosphere after discharge. Some scholars have conducted research on the standard of roadside air by hand-held portable devices, but these are limited by the speed of travel, and also the spatial and temporal resolution of the acquired data is additionally very low. By using multi-rotor unmanned aerial vehicles (UAVs) and portable equipment, this study demonstrates an atmospheric environment monitoring system supported multi-rotor UAV by designing corresponding hardware circuits and software programs. With flexible requirements for take-off or landing sites and high manoeuvrability of multi-rotor UAVs, the system increases the potential for prime resolution spatial and temporal monitoring of the diffusion of traffic-emitted pollutants. The system can conduct fixed-point measurement by hovering, and might also measure air pollutants in complex urban terrain, providing an innovation within the study of auto exhaust gas diffusion.”

2.2.7. Development of Drone Real-time Air Pollution Monitoring for Mobile Smart Sensing in Areas with Poor Accessibility

Sarun Duangsuwan and Punyawit Jamjareekulgarn

“The topic of pollution, especially in terms of stuff (PM), could be a very significant issue in current society. This problem is caused by such factors as forest fires, construction, industrialization, and therefore the ever-increasing number of cars. Thus, PM2.5 has become a crucial risk factor for citizens in Thailand additionally as globally, not only in terms of the issues related to health risks, but also the negative impact on the image of the country. Measuring pollution for air quality monitoring could be a challenging task, especially when considering areas that have poor accessibility. The aim of this work is to develop a drone equipped with sensors to observe and collect air quality data in real time from such areas of potential pollution. The proposed drone is termed the drone for real-time pollution monitoring (Dr-TAPM) and is supplied with the flexibility to live the concentration of monoxide (CO), ozone (O₃), dioxide (NO₂),

PM, and sulphur dioxide (SO₂). Additionally, the collected data is transmitted to a cloud server every second over a wireless internet connection. during this study, the measurement was conducted within the experiment area, which is taken into account to be within the pollutant model scenario. The experimental results are shown as graphs of quantitative pollutant levels and air quality index (AQI) values obtained from real-time monitoring on a mobile application.”

2.2.8. Using UAV-Based Systems to Monitor Air Pollution in Areas with Poor Accessibility

Oscar Alvear, Nicola Roberto Zema, Enrico Natalizio, and Carlos T. Calafate

“Air pollution monitoring has recently become a problem of utmost importance in our society. Despite the very fact that crowdsensing approaches may be an adequate solution for urban areas, they can not be implemented in rural environments. Instead, deploying a fleet of UAVs may be considered a suitable alternative. Embracing this approach, this paper proposes the utilization of UAVs equipped with off-the-shelf sensors to perform pollution monitoring tasks. These UAVs are guided by our proposed Pollution-driven UAV Control (PdUC) algorithm, which relies on a chemotaxis metaheuristic and a neighbourhood particle swarm optimization strategy. Together, they permit automatically performing the monitoring of a specified area using UAVs. Experimental results show that, when using PdUC, an implicit priority guides the development of pollution maps by that specialize in areas where the pollutants’ concentration is higher. This way, accurate maps are often constructed during a faster manner in comparison to other strategies. The PdUC scheme is compared against various standard mobility models through simulation, showing that it achieves better performance. specifically, it’s able to find the foremost polluted areas with more accuracy and provides the next coverage within the time bounds defined by the UAV flight time.”

2.2.9. Optimization of air pollution measurements with unmanned aerial vehicle low-cost sensor based on an inductive knowledge management method

Sławomir Pochwała, Stanisław Anweiler, Adam Deptuła

“The article presents the study of material pollution with PM1, PM2,5 and PM10 by means of a low-cost sensor mounted on Unmanned Aerial Vehicles. The article is split into two parts. In first part pollution measurement system is described. In second part expert system for optimization of flight parameters is described. The research was conducted over a municipal cemetery area in Poland. The obtained results were analyzed through an inductive knowledge management system (decision tree method) for classification analysis of pollution. the choice tree mechanism would be accustomed optimize flight parameters taking into consideration the pollution parameters. The analysis was made of the influence of PM concentration point of view, looking on the altitude. the choice tree method was used, which allowed to see, among other aspects, which PM indicator should be measured and which altitude plays a greater role within the optimization of pollution measurements by means of cheap sensors mounted on drones. As a results of the analysis, the optimum flight altitude of the measurement drone within the specified area decided.”

2.3 Literature Survey for Propellers

2.3.1. Aerodynamic Analysis of a Quadcopter Drone Propeller with the Use of Computational Fluid Dynamics

Konstantinos Christodoulou, Michail Vozinidis, Asterios Karanatsios, Efstathios Karipidis, Fotios Katsanevakis, Zinon Vlahostergios

“In the current work, an analysis for the initial aerodynamic assessment of a tiny low sized quadcopter drone propeller is presented, specializing in the drone aerodynamic characteristics optimization. the target of the work is to style and construct from scratch a quadcopter drone, so as to participate to the UAS Challenge 2020 student competition. The study of the quadcopter design and construction is applied by the Democritus Aeronautical Rescue Team (DART), a team that consists of scholars of the Democritus University of Thrace School of Engineering. The performance analysis which is presented is especially supported the aerodynamic characterization of an initial selected propeller design, which is able to be used for the examined quadcopter, with the employment of Computational Fluid Dynamics (CFD). Three turbulence models were selected for the computations each supported a special modelling approach. The computations are assessed and conclusions regarding the propeller

design are derived. supported the computations, the optimal propeller shape is going to be designed, and also the results will further help to the refinement of the general quadcopter aerodynamic layout within the final detailed design stages for the UAS Challenge competition.”

2.3.2. Virtual Modelling and Testing of the Single and contra-Rotating Co-Axial Propeller

Balram Panjwani, Cecile Quinsard, Dominik Gacia Przemysław and Jostein Furseth

“Propellers are an important component to realize successful and reliable operation of drones. However, the drone developer faces many challenges while selecting a propeller and a standard approach is to perform static thrust measurement. However, the choice of a propeller employing a static thrust measurement system is time-consuming. to beat a requirement for the static thrust system a virtual model has been developed for measuring both the static and dynamic thrust of one and coaxial propeller. The virtual model is reliable enough to reduce the necessity for full-scale tests. The virtual model has been built using two open-source software Qblade and OpenFoam. Qblade is used to get the lift and drag coefficients of the propeller’s airfoil section. OpenFoam is used to perform the flow simulations of propellers and for obtaining the thrust and torque data of the propeller. The developed virtual model is validated with experimental data and also the experimental data are obtained by developing a multi-force balance system for measuring thrusts and torques of one and a pair of coaxial contra-rotating propellers. the information obtained from the propeller virtual model are compared with the measurement data. For one propeller, the virtual model shows that the estimated forces are near the experiment at lower rotational speeds. For coaxial propellers, there are some deviations at the rear propeller because of the turbulence and flow disturbance caused by the front propeller. However, the computed thrust data are still accurate enough to be employed in selecting the propeller. The studies indicate that within the future, these virtual models will minimize a necessity for experimental testing.”

2.3.3. Variable Pitch Propeller for UAV-Experimental Tests

Maciej Podsedkowski, Rafał Konopiński, Damian Obidowski and Katarzyna Koter

“Growth in application fields of unmanned aerial vehicles (UAVs) and a rise in their total number are followed by higher and better expectations imposed on improvements in UAV propulsion and energy management systems. Most commercial vertical takeoff and landing (VTOL) UAVs employ a continuing pitch propeller that forces a mission execution tradeoff within the majority of cases. another solution, presented here, consists of the utilization of a variable pitch propeller. The paper summarizes experimental measurements of the system equipped with an innovative variable pitch rotor. The investigations incorporated characteristics of the rotor for no wind conditions and a replacement approach to optimize pitch settings in hover flight as a function of UAV weight and energy consumption. As UAV battery capacity is usually limited, efficient energy management is that the only thanks to increase UAV mission performance. The study shows that use of a variable pitch propeller can increase the maximal takeoff weight of the aircraft and improve power efficiency in hover, especially if load varies for various missions. The maximal thrust measured was 31% higher with reference to the initial blade settings. The coefficient of thrust during hover showed a rise of two.6% up to 7.5% for various pitch angles with reference to the first fixed propeller.”

2.3.4. Computational Study of the Wake of a Quadcopter Propeller in Hover

Andres M. Pérez G., Omar D. López.

“Quadcopter is that the main platform for Unmanned Aerial Vehicle (UAV), the employment of this technology is growing fast in numerous industries like agriculture, mining and oil and gas. Computational Fluid Dynamics (CFD) plays a crucial role in understanding the aerodynamics of UAVs. within the present paper, the Stalwart Almaraz and k- ω turbulence models were accustomed simulate a propeller employed in a quadcopter in hover. Both models predict the wake generated by the propeller, further as thrust and moment coefficients. For validation, numerical results of thrust and torque were compared to experimental measurements supported flying test. The wake, forces, torque, pressure and velocities fields predicted by the 2 turbulence models are similar; the most difference found was within the turbulent viscosity field within the far wake. The models overestimate thrust and torque around 18%, this difference may well be due the interaction of the wakes and with the fuselage that's not included within the present study.”

2.3.5. High altitude propeller design and analysis

J. Morgado, M. Abdollahzadeh, M.A.R. Silvestre, J.C. Páscoa

“This paper presents the planning and optimization of a replacement propeller to use on the MAAT cruiser airship. The inverse design methodology relies on minimum induced losses and was implemented in JBLADE software so as to get optimized geometries. additionally, the planning procedure and therefore the optimization steps of a replacement propeller to use at high altitudes also are described. The results of propellers designed with JBLADE are then analyzed and compared with conventional CFD results, since there's no experimental data for these particular geometries. Two different approaches were went to obtain the ultimate geometries of the propellers. rather than using the standard lift coefficient prescription along the blade, the airfoil best and best were went to produce different geometries. it's shown that this new design approach allows the minimization of the chord along the blade, while the thrust is maximized.”

2.3.6. A B-spline design model for propeller blades

F. Pérez-Arribas, R. Pérez-Fernández

“This work presents a brand-new design methodology for modelling the blades of propellers using B-spline surfaces. Propeller blades are good samples of free morpheme surfaces, designed specifically considering several parameters that control their performance. Traditional tools for surface design in CAD, like control point manipulation, don't seem to be appropriated for blade design, and also the designers choose to work with design parameters that possess a transparent aerodynamic / hydrodynamic meaning. This method uses common design parameters for the geometry of propellers and produces a final B-spline surface for the geometry of the blades that may be used for the visualization, calculations, and construction of the propeller. the strategy starts with the definition of a 3D grid of points that form the propeller blades supported the 2D definition of a series of cross-sectional profiles at several radial locations. Propeller blades are very thin objects with great changes of curvature, and if standard B-spline techniques are used, they can not be modelled well under a tolerance unless an oversized number of control points is employed,

producing very complex surfaces. The inclination and twist of the blades are given by rake and pitch angles, quite common within the design procedures. the strategy stresses the fitting of the blade's forefront which has great effect on the propeller behavior and geometrically includes a small curvature radius as compared with the remainder of the blades.”

2.3.7. Design Analysis of Ducted Propeller for Bicopter Drone Propulsion

M R Priatmoko and W Nirbito

“Drones nowadays became a crucial a part of people's lives. Drones for transporting people or goods are considered to turn into reality. To be effective and efficient, the drone should be light but have big propulsion for giant lift and thrust forces. This paper presents a way to boost the performances by designing usage of only 2 propulsion motors with ducted and special fan blades. The special designed fan blades theoretically will produce more thrust with smaller propeller size and lower RPM since combine the lift blade and momentum thrust effects. the specified propulsion force to fly the drone with its payload is analyzed and determined. Then the torque, rpm, airfoil type, Thrust Coefficient, and blade twist angles will be determined based on that propulsion force. Afterward, an evaluation is performed with fluid dynamics simulation tools to predict the forces working on the propeller.”

CHAPTER 3

AIM AND SCOPE OF THIS PROJECT

Our project aims to develop a product named APM, a quadcopter drone that would offer customers the ability to collect real time air quality data and assess whether the levels of air pollution in the given vicinity are compliant with the prescribed standards set by the respective government of the place and take necessary actions to control it if needed. The novelty of this project lies in its unique propeller design which makes it more efficient than drones operating with stock propellers. The project would develop a custom propeller using 3D printing technique which would improve the aerodynamic efficiency of the drone, hence improving the flight time of the drone hardware and providing the ability to survey an extensive range as compared to similar products in the market. The monitoring would be done by a wireless Wi-Fi module consisting of a microcontroller and sensors which would collect and transmit real time air quality data to a ground station. The outcome of this project would be a portable, low cost, easy to operate, high efficiency quadcopter drone which is easily maintainable, with scope of additional applications that would offer customers the ability to collect real time air quality data and assess whether the levels of air pollution in the given vicinity are compliant with the prescribed standards set by the respective government of the place and take necessary actions to control and mitigate it if needed. The product is targeted specially for industries and operators working with organizations that are into pollution control.

CHAPTER 4

4.1 COMPONENTS USED

4.1.1 FRAME

The DJI F450 Flame Wheel Quadcopter Frame Kit is a readily available frame kit in the market which comprises of 4 heavily reinforced lightweight and strong arms made from plastic with provisions for mounting the bottom and top center plates as well as the landing gear. The provisions for mounting the motor and ESCs is also present. It comprises of 2 White arms and 2 Red arms which are to be mounted adjacent to each other in such a way that one set of 2 identical arms represents the direction of flight for the drone.

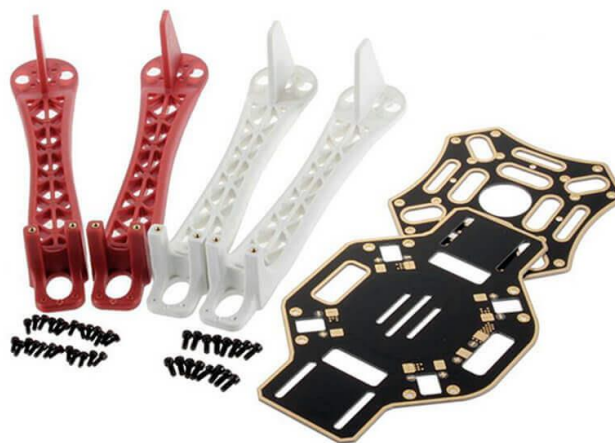


Fig 4.1 arms, plates

4.1.2 LANDING GEAR

The DJI F450 Flame Wheel Quadcopter Frame Kit also comes with a set of 4 Landing Gears which are plastic legs designed to absorb the impact of hard and crash landings

as well as to provide the quadcopter with a significant ground clearance. The landing gear is mounted at the lower part of the bottom center plate with screws at provisions provided in the lower plate. The landing gear also ensures that the quadcopter stays level and balanced on ground.



Fig 4.2 Landing Gear

4.1.3 MOUNTS AND SCREWS

The DJI F450 Flame Wheel Quadcopter Frame Kit has specifically designed holes, threads and brass provisions on all the frame and landing gear components where the plates and all other devices and systems are to be mounted. The screws are provided in the frame kit. Other methods for mounting components such as boards, ESP32 module, sensors, ESCs, etc. includes the use of double-sided-tape, electric/duct tape as well as tags.



Fig 4.3 Screws, 2-sided tape, Insulation tape, tag

4.1.4 FLIGHT CONTROL BOARD

The model of the flight control board utilized for this project is a kk 2.1.5 flight control board which is suitable for RC planes, drones, hovercrafts etc. It is capable of powering up to 8 motors i.e., octocopter. It controls and provides flight to the aircraft during operation. It uses a 6050 mpu gyro and accelerometer for this purpose. The central processor of this board is the Atmega 644 PA IC. It processes the signals from gyro and acc and the users commands and passes output control signals to the ESC units. These output signals then control the ESCs to command the motors rotation hence controlling the aircraft remotely. The board receives signals from the receiver and processes them in the IC via different channels. The IC sends output signals to the ESCs which act as inputs for motor control. The KK board is the most preferred board for beginners and hobbyists.

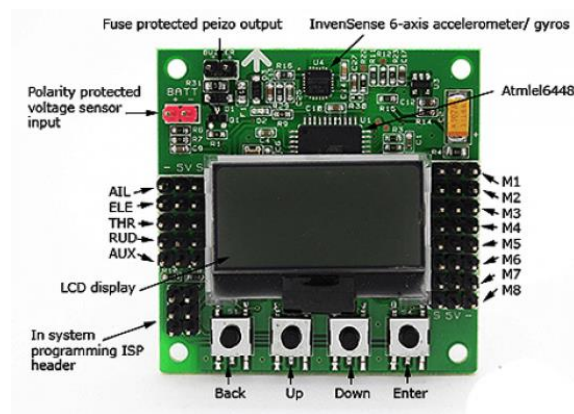


Fig 4.4 KK 2.1.5 Board

Table 2: Features of KK2 1.5 Flight Controller Board

Specification	Description
Model	KK2.1.5 Flight Controller
IC	Atmega644 PA
Input Voltage	4.8V-6.0V
AVR Interface	6 Pin
Dimensions	13 x 10 x 4.9 cm
Weight	20 grams

4.1.5 TRANSMITTER/RECIEVER

The transmitter utilized is a fly sky fsi6 which is a popular transmitter/receiver used by student projects. It consists of a digitally proportionality radio frequency system operating across the 2.4 gigahertz or global ism radio band (2.4ghz). This makes it suitable for usage across the world. The unit is built in AFHDS 2A technology which stands for Automatic Frequency Hopping Digital System Second Generation. The specifications of the transmitter is shown in the figure below:

Specification	Description
Channels	6
RF range	2.4055 – 2.475 GHz
Bandwidth	500KHz
Band	140
RF Power	Less than 20dBm
2.4G system	AFHDS 2A and AFHDS
Sensitivity	1024
Low voltage warning	Less than 4.2V
DSC Port	PS2
Output	PPM
Charger Point	No
ANT length	26mm*2 (dual antenna)
Weight	392gm
Power	6V 1.5AA*4
Display mode	Transflective STN positive type 128*64 dot matrix
Size	174*89*190 mm
On-line update	Yes
Certificate	CE0678, FCC

Fig 4.5 Specifications of FSi6 Transmitter

This model of the transmitter does not need a PC for initial setup. It consists of an LCD display unit, which displays information needed to configure the tx. The buttons can be used to operate various menu items to setup the tx for user specific needs. It has an operating range of 1500 meters. The LCD screen and the buttons make up the “user interface of this transmitter”. We configure the transmitter settings by using the menu buttons and viewing the LCD display. The battery indication, mode indication, etc. can be viewed by the user on the LCD display unit. The battery status indicates status of both the transmitter as well as the receiver onboard. The rx's battery status

will be unable to be visually displayed if it's not connected to the tx set. The transmitter unit consists two sticks - one on the left side and the other on the right. By making Use of these gimbals/sticks, we can utilize four channels: Channel 1 which consists of aileron/roll control, Channel 2 which comprises elevator/pitch control, Channel 3 making up the throttle/ speed, and Channel 4 for rudder or yaw control. these channels subscribe to mode 2 configuration. there are 2 gimbals shown in the image given below, one is on the right side and the other is on the left. Use these trims for stabilizing the aircraft. Adjust the trims when the aircraft is unstable in flight. 4 trims are associated with four channels of the tx. By holding the trim in the desired direction, we can carry out adjustments of the trims. The transmitter starts beeping a higher tone when the trim position reaches the middle point.

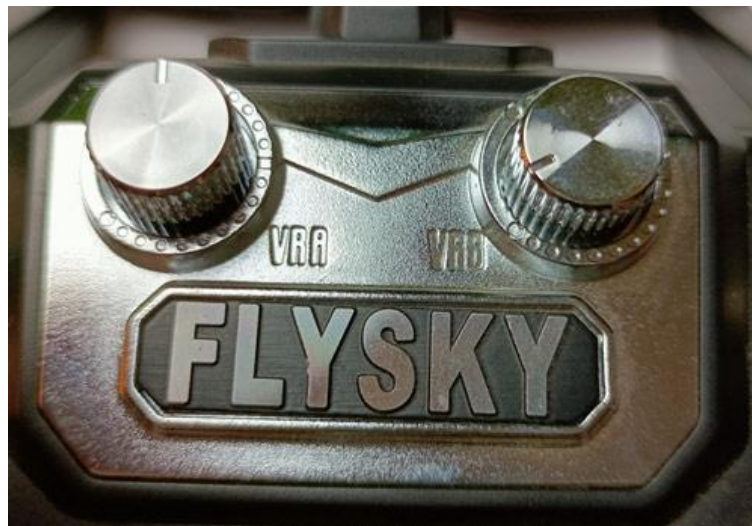


Fig 4.6 VRA VRB Knobs

There are 2 knobs located on the top of the transmitter unit. These are called auxiliary channels or aux channels that are used to accommodate additional provisions and extra channels to control extra parts of the model like camera, ldg or nozzle. In the figure below, we can see the 2 knobs of the tx. The knob on the left is VRA and the knob on the right is VRB.



Fig 4.7 Switches

4 switches are given on top of the transmitter unit. These are SWA, SWB, SWC, and SWD with SW referring to switch. Of these, switch A, B, D are two mode switches and switch SWC is a 3 mode switch. We can allot the function of channel 5 and 6 in any one of the 2 mode switches. We make use of SWC when we use GPS module in drone models.



Fig 4.8 Receiver Bind button

A bind key is used to bind the transmitter and receiver belonging to the user. The black key is shown below in figure 4.7. The rx bind button is located at the bottom of the left side of the transmitter.



Fig 4.9 Receiver

The receiver unit consists of 2 antennas and 6 channels in its assembly. For strong signal reception, the receiver unit should be mounted in a position such that its placed away from the magnetic components of the motors or other metallic parts in the model. The ESC signal wires are connected to the receiver via channels 1 to 6. The receiver bind key is also connected via the B/Vcc port.

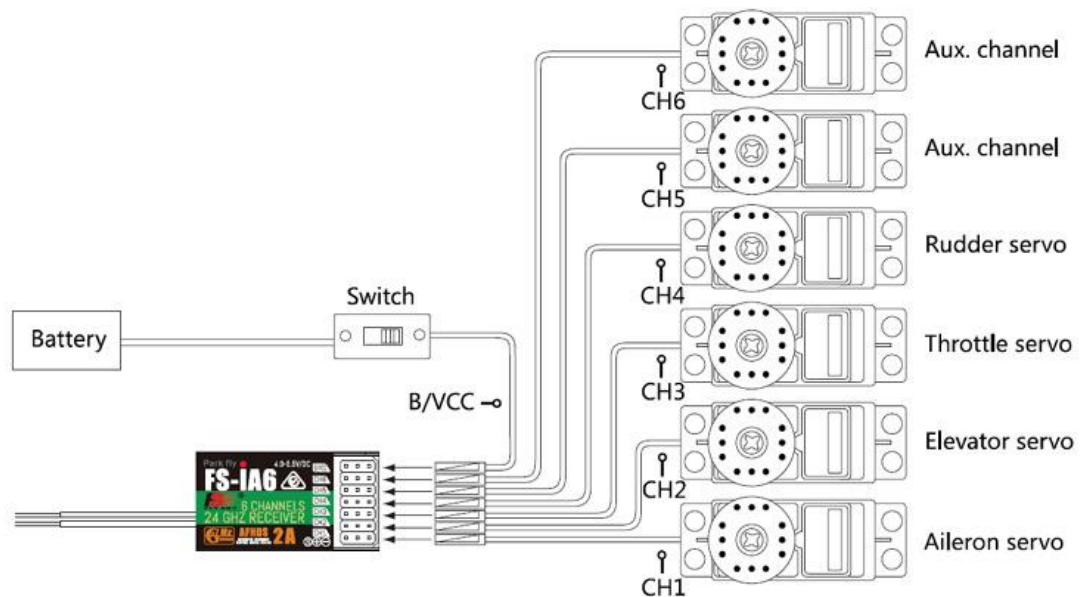


Fig 4.10 Receiver Channels

We can connect the receiver and motor sets through selected ESCs (electronic speed controllers) units. The specifications of the given receiver is shown in the figure below.

Channels	6
RF range	2.4055 – 2.475 Hz
Band	140
RF Power	Less than 20dBm
2.4G system	AFHDS 2A
ANT length	26mm*2(dual antenna)
weight	16.4g
Power	4.0-6.5V
Size	42.6*26.1*15.1mm
RX Sensitivity	-105dBm
Certificate	CE0678, FCC
i-Bus port	Yes
Data acquisition port	Yes

Fig 4.11 Specifications of FSi6 Receiver

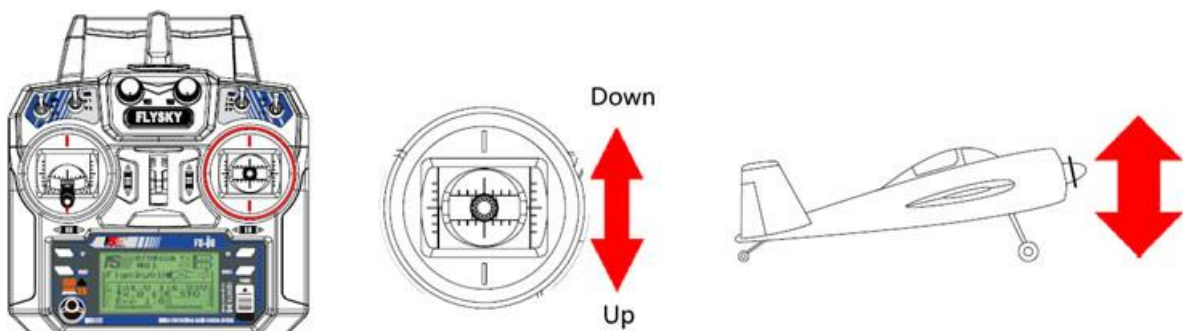


Fig 4.12 Pitch control

Roll (Right Stick Left/Right)

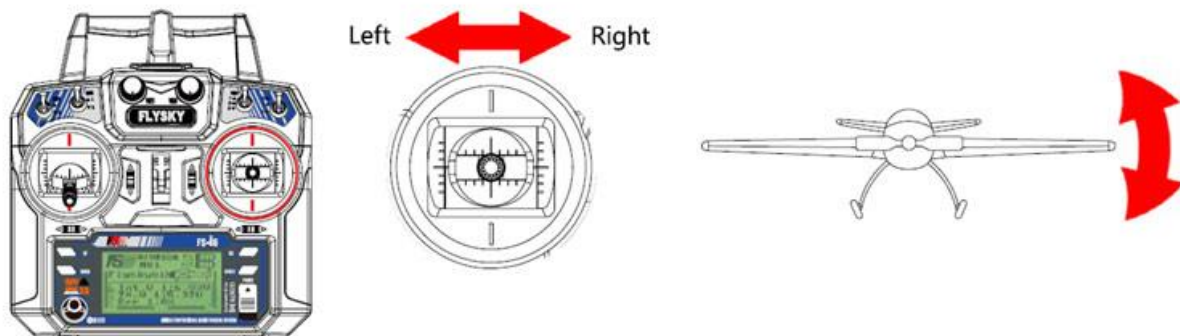


Fig 4.13 Roll control

Yaw (Left Stick Left/Right)

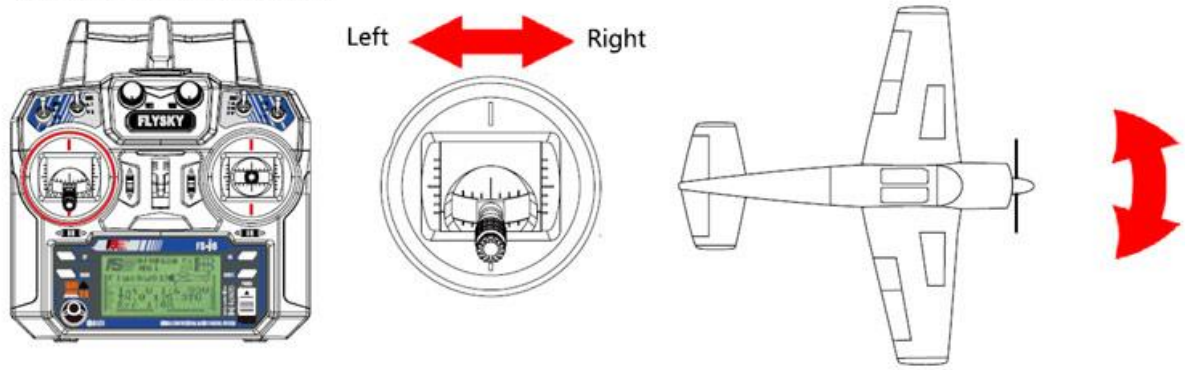


Fig 4.14 Yaw control

Throttle (Left Stick Up/Down)

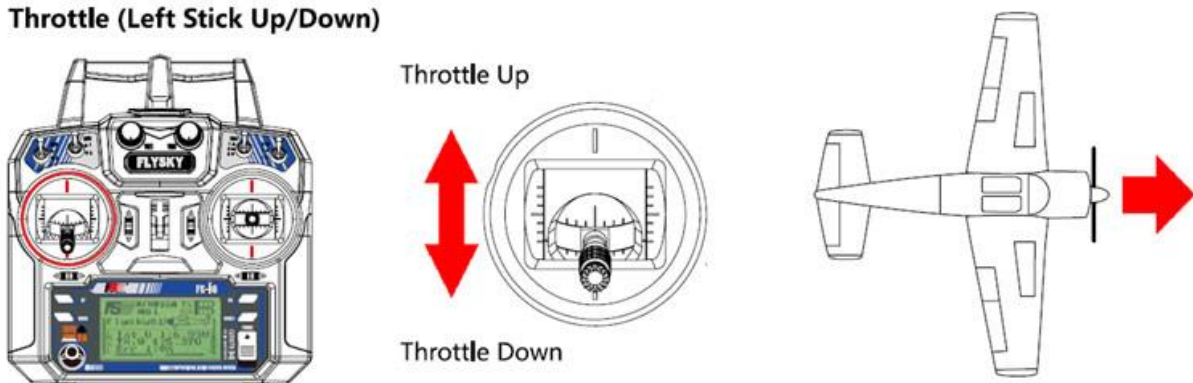


Fig 4.15 Throttle control

There are sticks which control the model motion which can be either a drone, rc or hovercraft etc., with each stick having 2 functions. The right stick is the one which controls the pitching and rolling moment, while the left stick controls throttle power and yaw quantity. It is also called designated elevator function. For mode 2, control of pitch for the model in Channel no 2 takes place at the right-side given stick. Roll Control motion is also called aileron function. For mode 2 operation, we control roll component in Channel no 1 at the right position given stick. Yaw Control is called rudder function. For mode 2, we can control yaw motion in Channel no 4 at the left side stick. For mode 2, we can control throttle power in channel no 3 at the left side stick.

4.1.6 ELECTRONIC SPEED CONTROLLER

An electronic speed controller, popularly known as ESC is an electronic circuit that is used to control the rotation direction speed of a BLDC motor according to user preference or program control. The circuitry consists of a set of mosfet transistors which are activated by the signal inputs which creates a RMF or rotational magnetic

field which provides the motor rotation. The speed of the motor connected is decided by the frequency of switching or the speed of going through 6 intervals. To determine the current position of the rotor, hall effect sensors are embedded in the circuitry of the BLDC motor which is present in the stator. The sensors detect the EMF of the rotor magnets and transmit signals to the ESC unit using which it sequences the activation/deactivation of the stator coils. Another popular method used by ESCs is by back EMF generated by the motor. The back electromotive force is generated when the magnets of the rotor pass through inactive stator coils which is routed back to the ESC circuit. The ESC keeps a track of the coil position by capturing these back EMF signals.

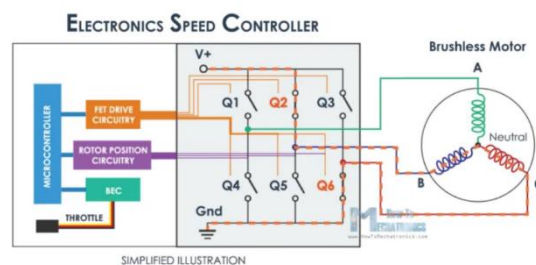


Fig 4.16 ESC

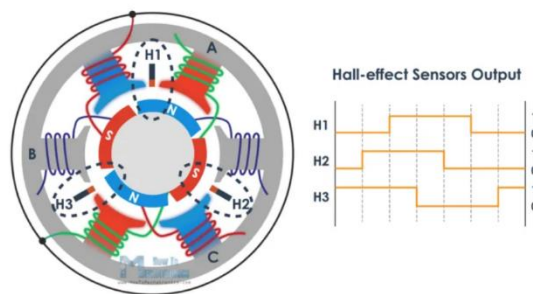


Fig 4.17 ESC control



Fig 4.18 ESC Used

4.1.7 BLDC MOTOR

A BLDC motor or brushless Dc motor as it is commonly known is a class of motors (DC motors) which consist of independently mobile rotors/stators. The most notable way to recognize a BLDC from a DC motor is by the missing brushes. This helps in longevity and higher speeds as there are no brushes present to wear off and replace. There is no friction between the stator and the rotor. BLDC motors are operated with the help of an electronic speed controller. This controller stimulates the stator coil sets of the motor in an organized order of pulses. This class of motors is known for producing a large amount of torque at a varied range of rotational speed. There are 2 types of BLDC motors: Inrunner and outrunner. In outrunner motors the outer casing of the motor comprising the rotor magnets rotates while the hub consisting of the stator unit is fixed. In inrunner motors the case is vice versa. This motor type has great flexibility and operational capability. Brushless motors are grouped into specs by a 4 digit number such as 1234, where the 12 numbers indicate the stator width and 34 indicates the stator set height. Essentially, the wider and taller the motor is, the larger the numbers are and the more torque it will produce. KV is another specification which is an essential parameter of BLDC motors. It denotes the increase of motor rpm (rotation per minute) when the voltage goes up by 1 volt under unloaded condition. For example, when we are running a 2300KV motors with a 3S LiPo battery (12.6V), the motor will turn at around 28980 rpm. ($2300 \times 12.6V = 28980$). We are utilising an A2212 1000KV BLDC motor for this project.



Fig 4.19 BLDC Motor

4.1.8 PROPELLER

We have designed a custom 10-inch propeller and fabricated it by 3D printing which gives more lift per unit rpm hence improving the efficiency and flight time of the drone.



Fig 4.20 Propeller Final Version

4.1.9 ESP32

The ESP32 development board is manufactured by a company named Espressif Systems. It is based in Shanghai, China. The brand name ESP stands for espressif. This board is a microcontroller board similar to Arduino with the only difference between the 2 being its capability to function as a wifi module. It is also integrated with Bluetooth as an additional mode of communication. The board uses a tensilica xtensa lx 6 microprocessor in both dual-core and single-core variations, Xtensa LX7 dual-core microprocessor or a single-core RISC-V microprocessor and includes built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power-management modules. It is a successor to the ESP8266 microcontroller.

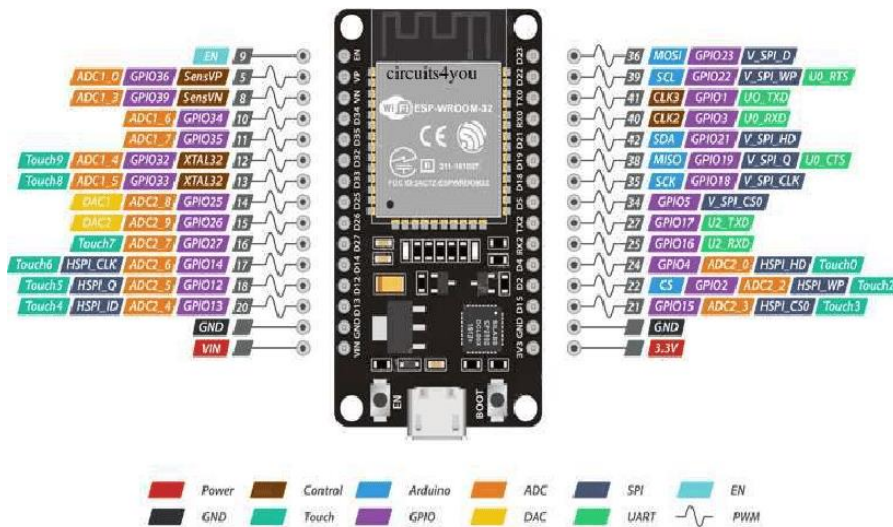


Fig 4.21 ESP 32

“Features of the ESP32 include the following:

- Processors:
 - CPU: Xtensa dual-core (or single-core) 32-bit LX6 microprocessor, operating at 160 or 240 MHz and performing at up to 600 DMIPS
 - Ultra-low power (ULP) co-processor
- Memory: 320 KiB RAM, 448 KiB ROM
- Wireless connectivity:
 - Wi-Fi: 802.11 b/g/n
 - Bluetooth: v4.2 BR/EDR and BLE (shares the radio with Wi-Fi)
- Peripheral interfaces:
 - 34 × programmable GPIOs
 - 12-bit SAR ADC up to 18 channels
 - 2 × 8-bit DACs
 - 10 × touch sensors (capacitive sensing GPIOs)
 - 4 × SPI
 - 2 × I²S interfaces
 - 2 × I²C interfaces
 - 3 × UART
 - SD/SDIO/CE-ATA/MMC/eMMC host controller
 - SDIO/SPI slave controller

- Ethernet MAC interface with dedicated DMA and planned IEEE 1588 Precision Time Protocol support^[4]
- CAN bus 2.0
- Infrared remote controller (TX/RX, up to 8 channels)
- Motor PWM
- LED PWM (up to 16 channels)
- Hall effect sensor
- Ultra-low power analog pre-amplifier
- Security:
 - IEEE 802.11 standard security features all supported, including WPA, WPA2, WPA3 (depending on version)^[5] and WAPI
 - Secure boot
 - Flash encryption
 - 1024-bit OTP, up to 768-bit for customers
 - Cryptographic hardware acceleration: AES, SHA-2, RSA, elliptic curve cryptography (ECC), random number generator (RNG)
- Power management:
 - Internal low-dropout regulator
 - Individual power domain for RTC
 - 5 μ A deep sleep current
 - Wake up from GPIO interrupt, timer, ADC measurements, capacitive touch sensor interrupt”



4.1.10.2. GP2Y1010AU0F Dust Sensor

GP2Y1010AU0F is a dust sensor by optical sensing system. An infrared emitting diode (IRED) and a phototransistor are diagonally arranged into this device. It detects the reflected light of dust in air. Especially, it is effective to detect very fine particle like the cigarette smoke. In addition, it can distinguish smoke from house dust by pulse pattern of output voltage.

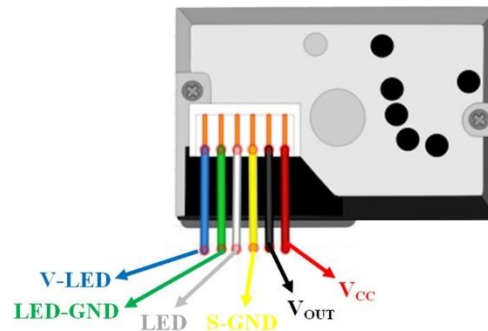


Fig 4.24 GP2Y Dust Sensor

4.1.10.3. MQ135

The MQ-135 Gas sensor can detect gases like Ammonia (NH₃), sulphur (S), Benzene (C₆H₆), CO₂, and other harmful gases and smoke. Similar to other MQ series gas sensor, this sensor also has a digital and analog output pin. When the level of these gases goes beyond a threshold limit in the air the digital pin goes high. This threshold value can be set by using the on-board potentiometer. The analog output pin, outputs an analog voltage which can be used to approximate the level of these gases in the atmosphere. The MQ135 is one of the popular gas sensors from the MQ series of sensors that are commonly used in air quality control equipment. It operates from 2.5V to 5.0V and can provide both digital and analog output. The pinouts and important components on an MQ135 Module are marked below

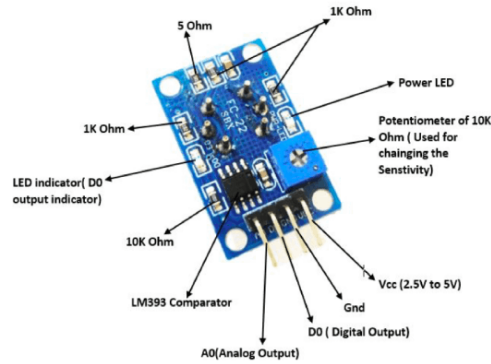


Fig 4.25 MQ135 Pinout

4.2 THE PROPELLER

4.2.1 FIRST ATTEMPT

Our first attempt to start off with the propeller began with the exploration of a suitable airfoil that would generate maximum lift at a minimum angle of attack. The airfoil we chose was NACA 4412 which had the maximum Cl vs Cd at 15 degrees angle of attack. We proceeded with the design process in Autodesk Fusion 360, by selecting a canvass of a foldable propeller for template and designed the propeller and hub with the initial dimensions. We later proceeded to fabricate the first propeller design by 3D printing with SLA technique.



Fig 4.26 First Version of Propeller

However, on mounting the propeller on the hardware and running it, the propellers, which we later found out to be way thinner and smaller in scale than required for the drone of the actual size and payload that had been fabricated, snapped at the roots due to the unbearable lift force that they were unable to endure to lift the now much heavier drone. Thus, we went back to the drawing board to work on a much stronger and bigger design.

4.2.2 SECOND ATTEMPT

Now that we had learnt from our mistakes in the first attempt, it was time to go for a re-attempt. This time we studied a readily available stock 10*45 propeller, particularly its root and tip dimensions such as length, span and thickness. We later designed a completely new set of propellers which this time are of non-folding single piece type. We utilised Autodesk Fusion 360 for the same and obtained a bigger and thicker design reinforced in the root. We fabricated it using the same SLA 3D printing technique and proceeded to test it out on our platform. But unfortunately, this too came crashing down, snapping at the roots during full throttle.

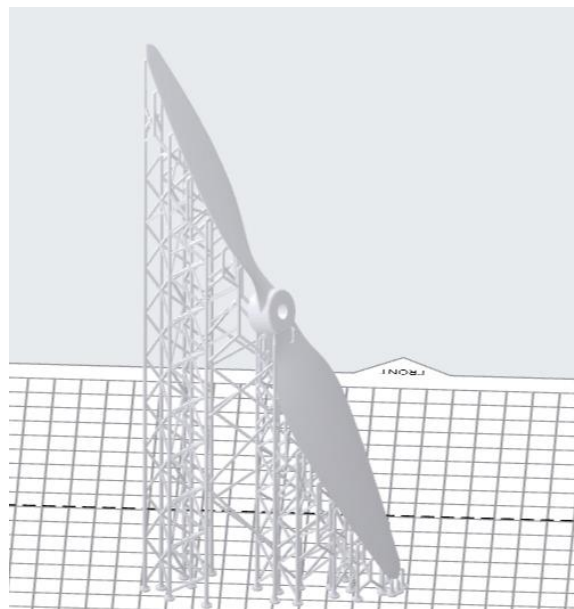


Fig 4.27 Second Version of Propeller



Fig 4.28 Second Version of Propeller after printing

4.2.3 FINAL ATTEMPT

We finally found out by consultation with our guide that the design was up to mark and there was no dimensional flaw in it. We relooked into the material properties of the material that makes up the SLA resin. We later inferred that the materials thermoplastic nature made it very brittle as compared to thermosetting plastics used in various common applications. We later also learnt about a unique property of propellers. And that is its tendency to feather to a straight orientation away from its twisted contour during high-speed flight which put a lot of stress on its roots and cause materials with a low strength to fatigue. We thus froze our design as the final one and opted this time for carbon-nylon material and fabricated the final version of the propeller using the FDM 3D Printing technique. This propeller was finally successful in our static and flight test and was chosen as the final product for the drone.



Fig 4.29 Final Version of Propeller

4.3 MANUFACTURING METHODS USED (FOR PROPELLER)

4.3.1 3D PRINTING

There are 2 main methods of 3D printing: FDM or fused deposition moulding and SLA or Stereolithography. Out of these 2 techniques we opted to utilize the SLA technique for the quality of finish and the precision of detailing.

4.3.1.1 Overview about FDM 3D Printing

Fused deposition modelling, or FDM 3D Printing, is a method of additive manufacturing where layers of materials are fused together in a pattern to create an object. The material is usually melted just past its glass transition temperature, and then extruded in a pattern next to or on top of previous extrusions, creating an object layer by layer. In layman's terms, a typical FDM 3D printer takes a plastic filament and squeezes it through a hot end, melting it and then depositing it in layers on the print bed. These layers are fused together, building up throughout the print, and eventually they will form the finished part. FDM is the same as fused filament fabrication (FFF), but the term "fused deposition modelling" and the abbreviated "FDM" were trademarked by Stratasys in 1991, creating the need for a second name. Many types of materials can be used with FDM techniques, including the most common thermoplastics, chocolate, pastes, and even "exotic" materials like metal- or wood-infused thermoplastic. Widely accepted as the simplest way to achieve 3D printing, FDM is cheap and fairly efficient. FDM 3D printers dominate the 3D printing market, almost drowning out more expensive methods.

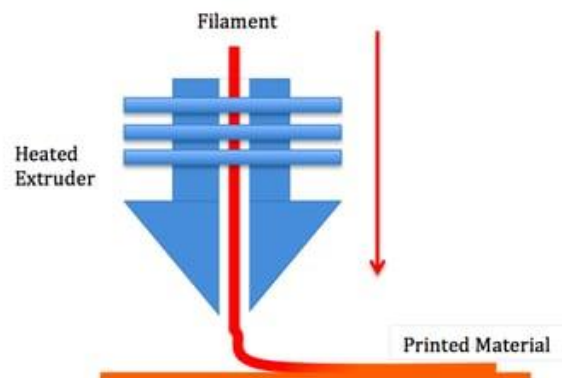


Fig 4.30 FDM Printing



Fig 4.31 FDM Machine

4.3.1.2 Overview about SLA 3D Printing

Stereolithography (SLA) is an additive manufacturing process that belongs to the Vat Photopolymerization family. In SLA, an object is created by selectively curing a polymer resin layer-by-layer using an ultraviolet (UV) laser beam. The materials used in SLA are photosensitive thermoset polymers that come in a liquid form. SLA has many common characteristics with Direct Light Processing (DLP), another Vat Photopolymerization 3D printing technology. For simplicity, the two technologies can be treated as equals. A laser beam is directed in the X-Y axes across the surface of the resin according to the 3D data supplied to the machine (the .stl file), whereby the resin hardens precisely where the laser hits the surface. Once the layer is completed, the platform within the vat drops down by a fraction (in the Z axis) and the subsequent layer is traced out by the laser. The resin that is not touched by the laser remains in the vat and can be reused. This continues until the entire object is completed and the platform can be raised out of the vat for removal.

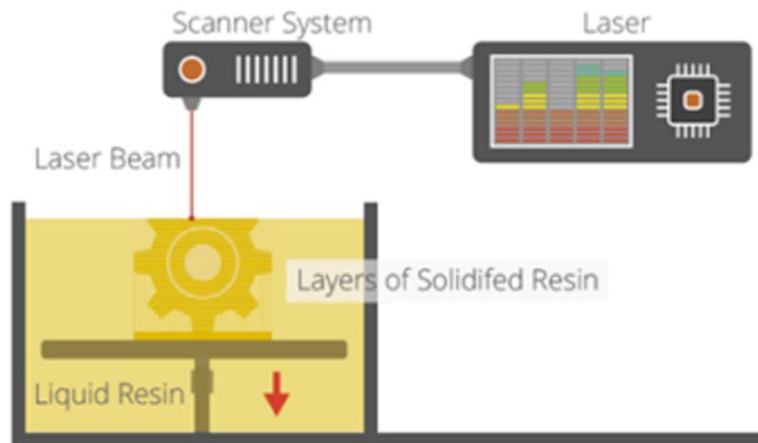


Fig 4.32 SLA Technique

Support structure is always required in SLA. Support structures are printed in the same material as the part and must be manually removed after printing. The orientation of the part determines the location and amount of support. It is recommended that the part is oriented so that so visually critical surfaces do not come in contact with the support structures.



Fig 4.33 SLA Machine

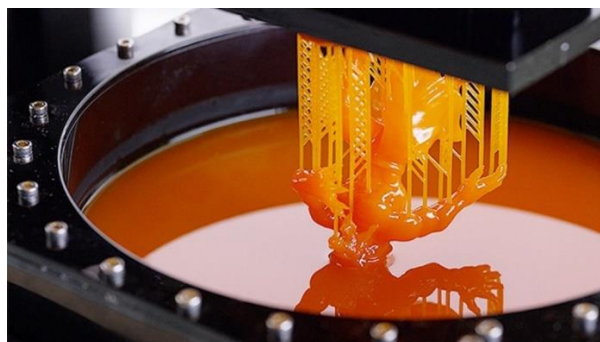


Fig 4.34 SLA Output

4.4 DESIGN PROCESS

The design process was mainly concentrated upon the custom propeller which naturally takes up more time and effort than the rest of the components. Designing the propeller is a very precarious process which demands high amount of precision and knowledge of concepts pertaining to both mechanical (Strength of Materials) and aeronautical (aerodynamics) engineering. The propeller is required to be strong enough to withstand the full load of the drone with its payload as well as be aerodynamically efficient in order to improve upon previously attempted models and increase the flight time of the drone. Taking all of these factors in account we proceeded to start with our first design attempt by exploring a suitable airfoil for the propeller structure. After studying the characteristics of various 4- and 5-digit airfoils we zeroed in on NACA 4412 which had a sleek shape and an impressive C_l vs C_d characteristic. This airfoil generates its maximum lift at an angle of attack of 15 degrees as derived from its C_l vs C_d graph.

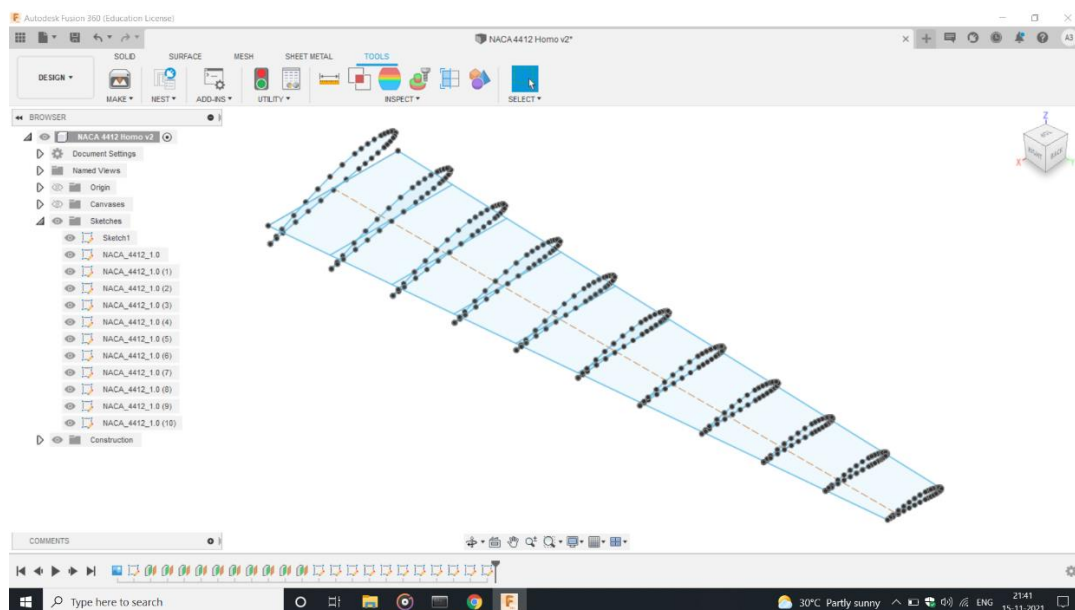


Fig 4.35 Airfoil Mounting first design version

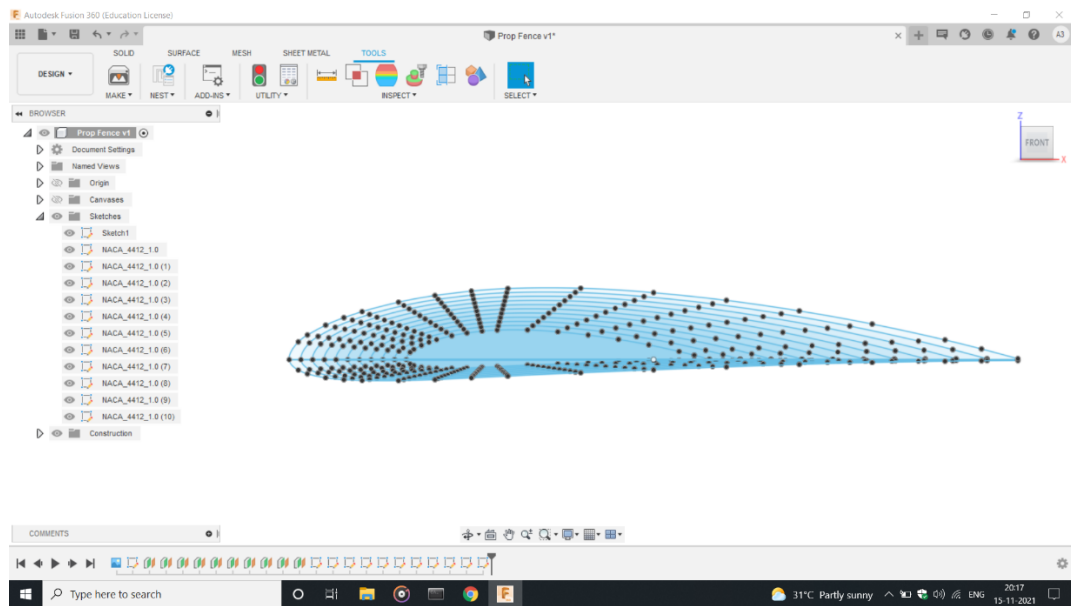


Fig 4.36 Side View of first design version

2/28/22, 9:47 PM

NACA 4412 (naca4412-il)

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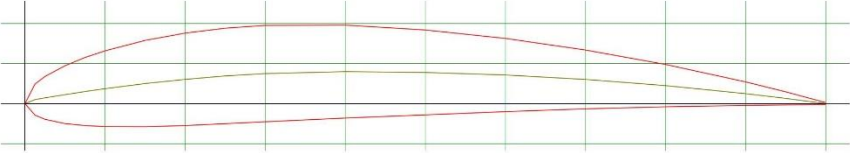
Like 1.3K

You have 0 airfoils loaded.
Your Reynold number range is 50,000 to 1,000,000. [set](#)

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NACA 4412 (naca4412-il)

NACA 4412 - NACA 4412 airfoil



Details

(naca4412-il) NACA 4412
NACA 4412 airfoil
Max thickness 12% at 30% chord.
Max camber 4% at 40% chord
Source [UIUC Airfoil Coordinates Database](#)
[Source dat file](#)
The dat file is in Selig format

Dat file

NACA 4412
1.0000 0.8013
0.9500 0.8147
0.9000 0.8271
0.8000 0.8489
0.7000 0.8669
0.6000 0.8814
0.5000 0.8919

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Polars for NACA 4412 (naca4412-il)

Plot	Airfoil	Reynolds #	Ncrit	Max Cl/Cd	Description	Source
☒	naca4412-il	50,000	9	33.4 at $\alpha=9.75^\circ$	Mach=0 Ncrit=9	Xfoil prediction Details
☐	naca4412-il	50,000	5	36.1 at $\alpha=8.5^\circ$	Mach=0 Ncrit=5	Xfoil prediction Details
☒	naca4412-il	100,000	9	56.1 at $\alpha=8.5^\circ$	Mach=0 Ncrit=9	Xfoil prediction Details
☐	naca4412-il	100,000	5	57.4 at $\alpha=6.75^\circ$	Mach=0 Ncrit=5	Xfoil prediction Details
☒	naca4412-il	200,000	9	78.1 at $\alpha=7^\circ$	Mach=0 Ncrit=9	Xfoil prediction Details
☐	naca4412-il	200,000	5	76.6 at $\alpha=6^\circ$	Mach=0 Ncrit=5	Xfoil prediction Details
☒	naca4412-il	500,000	9	107.5 at $\alpha=6^\circ$	Mach=0 Ncrit=9	Xfoil prediction Details
☐	naca4412-il	500,000	5	101.1 at $\alpha=5^\circ$	Mach=0 Ncrit=5	Xfoil prediction Details
☒	naca4412-il	1,000,000	9	129.4 at $\alpha=5.25^\circ$	Mach=0 Ncrit=9	Xfoil prediction Details
☐	naca4412-il	1,000,000	5	119.2 at $\alpha=4.25^\circ$	Mach=0 Ncrit=5	Xfoil prediction Details

Update plots

[Reynolds number calculator](#)

Set Reynolds number and Ncrit range

Update Range

Reynolds Number

Ncrit

Low

High

50,000

1,000,000

7

9

airfoiltools.com/airfoil/details?airfoil=naca4412-il

1/2

Fig 4.37 NACA 4412 Characteristics

48

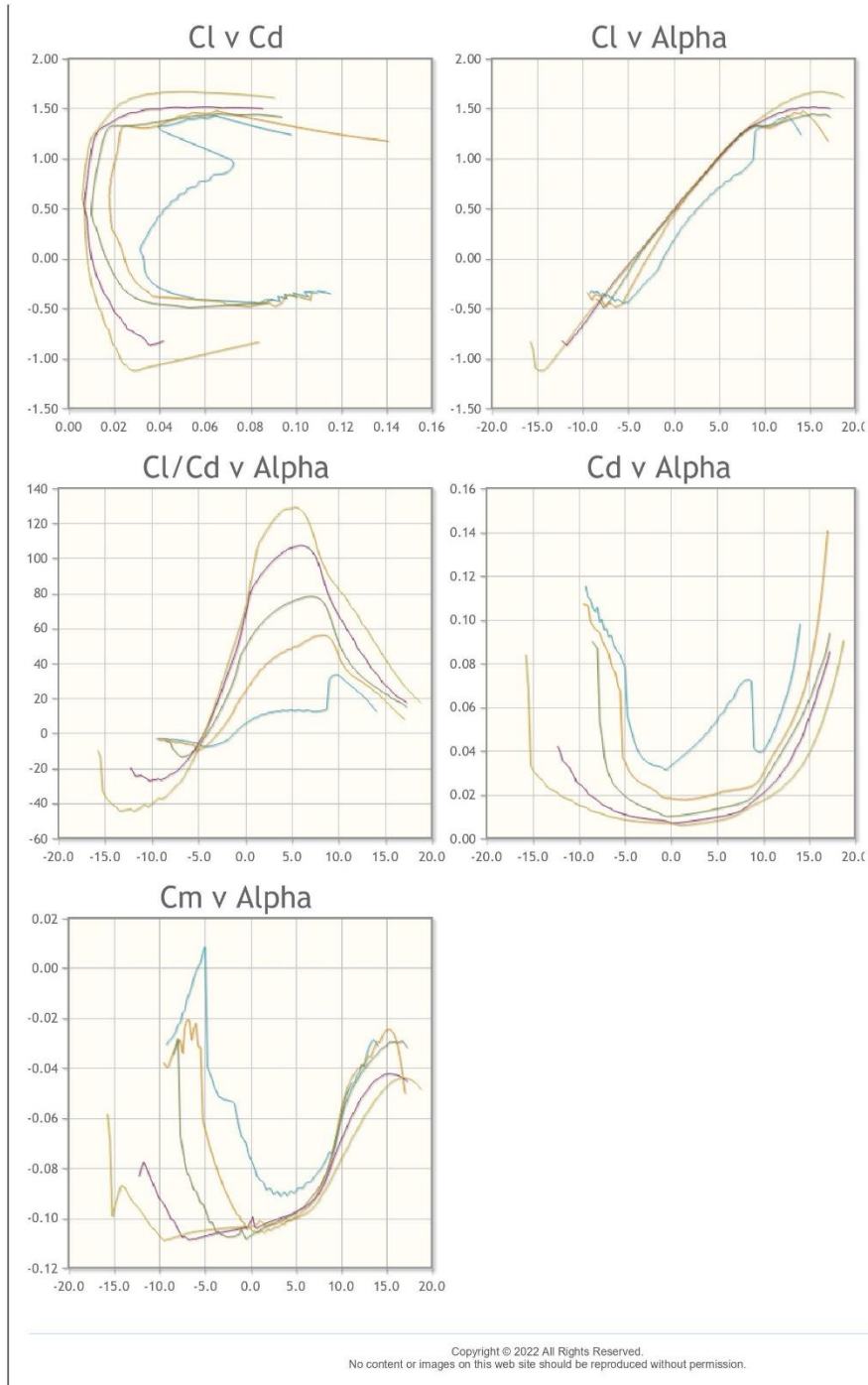


Fig 4.38 NACA 4412 Characteristics

We split the part into 2 components: the propeller and the hub. The hub was designed such that it had provisions to mount 2 propeller halves on the outer edge and get itself mounted on the motor shaft using a 6mm hole made along the centre. There would be a set of fasteners which included a screw, a washer and a nylock nut which would hold the propeller halves in such a way that they would be free to rotate/split open when they were in flight and fold inwards when they were to be stored.



Fig 4.39 First Version of custom Propeller

However, after testing it on the hardware it was found that the initial design was too thin and dimensionally half scale of the actual propeller design that would withstand the lift force generated by the drone in order for it to fly. Thus, this foldable design had to be abandoned and we had to work on a new design.



Fig 4.40 Failure of first version



Fig 4.41 Point of Failure of first version

We went back to the drawing room this time with a readily available propeller and studied it with thorough observation of its dimensions mainly its thickness at various regions including root, tip, mid-section etc. After getting an idea of the minimum dimensions required for the propeller in order for it to be strong enough to fly the drone, we designed a completely new single piece propeller with reinforced root and thicker sections. After fabricating our design, we put it to the ultimate test. But unfortunately, this too came crashing down, snapping at the roots during full throttle.



Fig 4.42 Second version



Fig 4.43 Failure of Second version



Fig 4.44 Point of failure

This time we took a deep dive into the material side of things as we found out by consultation with our guide that the design was up to mark and there was no dimensional flaw in it. We relooked into the material properties of the material that makes up the SLA resin. We later inferred that the materials thermoplastic nature made it very brittle as compared to thermosetting plastics used in various common applications. We later also learnt about a unique property of propellers. And that is its tendency to feather to a straight orientation away from its twisted contour during high-speed flight. When this happens, the propeller tends to bend straight causing a huge stress on the propeller root. Thus, materials with low strength can easily fail under such enormous loads. Now that we finally concluded the root cause of our failure, which was material fatigue, we searched for a material with a good elastic strength capable of being lightweight and withstand huge loads without fatigue. Our eyes were on nylon which is a common material used for FDM 3D Printing. Nylon in its raw form has a hygroscopic nature, which is its tendency to absorb moisture. This would result in warping of the Propeller print. We thus went in for carbon-fibre reinforced nylon,

more commonly known as carbon-nylon which imparts moisture and fatigue resistance through its carbon fibre reinforcements. And finally, this material holder good and our flight test was successful and our project hence concludes.



Fig 4.45 Final Version of Propeller

We had initially created a rough representation of our drone using the initially designed propellers. Once it was confirmed that we would use a readily available platform, we updated the final design with the final version of our propeller.

The drone platform is a commonly available DJI F450 Flame Wheel Quadcopter Frame Kit. We created a near replica of the F450 Frame Kit including the plates, landing gears and screws and integrated it into an assembly using Fusion 360. We also integrated all the systems including Flight Control Board, APM Module, Receiver, Motors with the propellers mounted on them, ESCs, hence completing us design process.

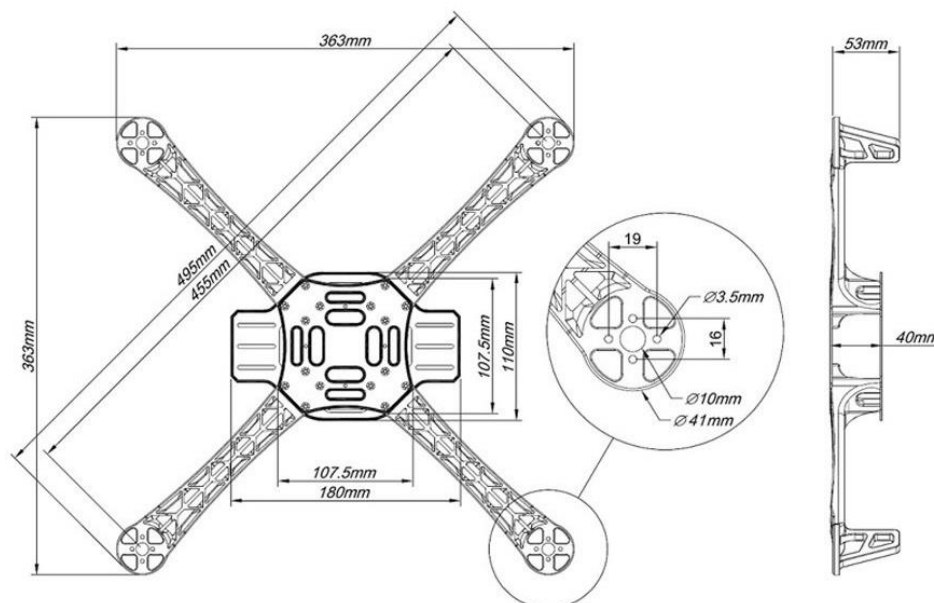


Fig 4.46 F450 Frame Dimensions

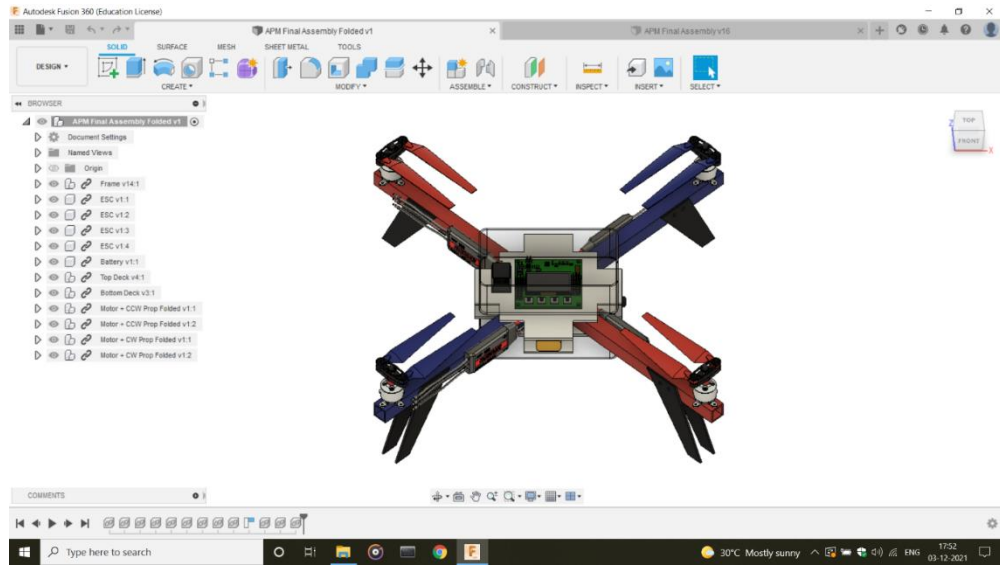


Fig 4.47 First version of design in Autodesk Fusion 360

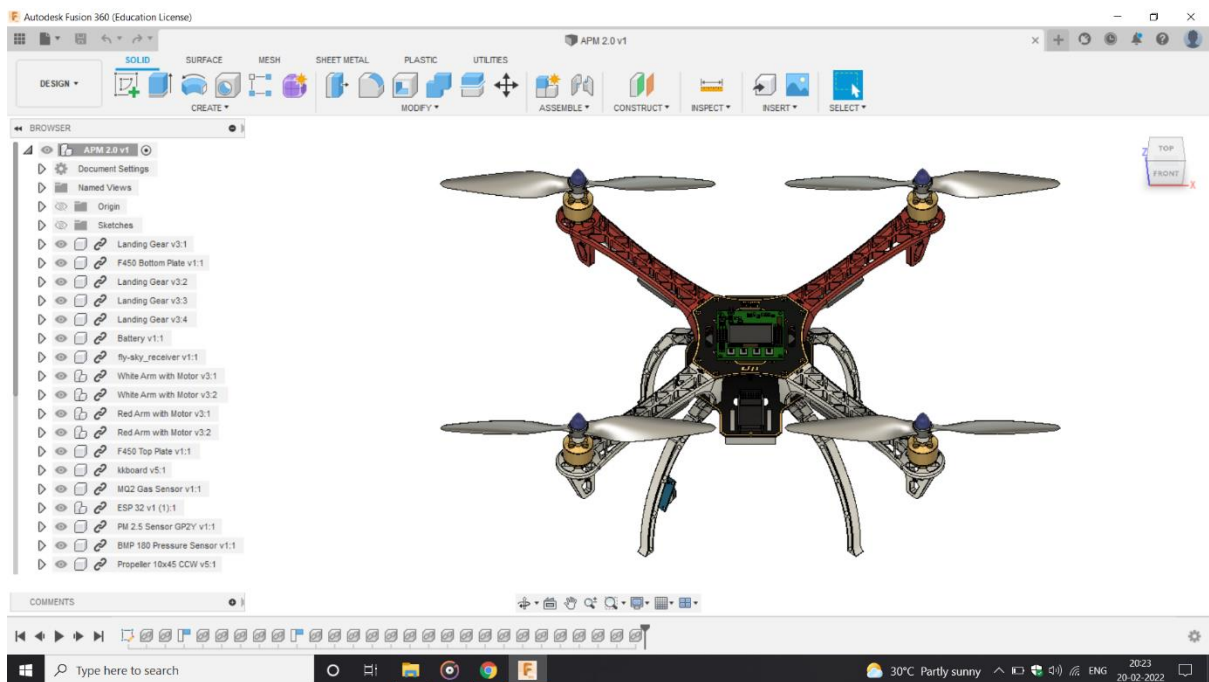


Fig 4.48 Final Version of design

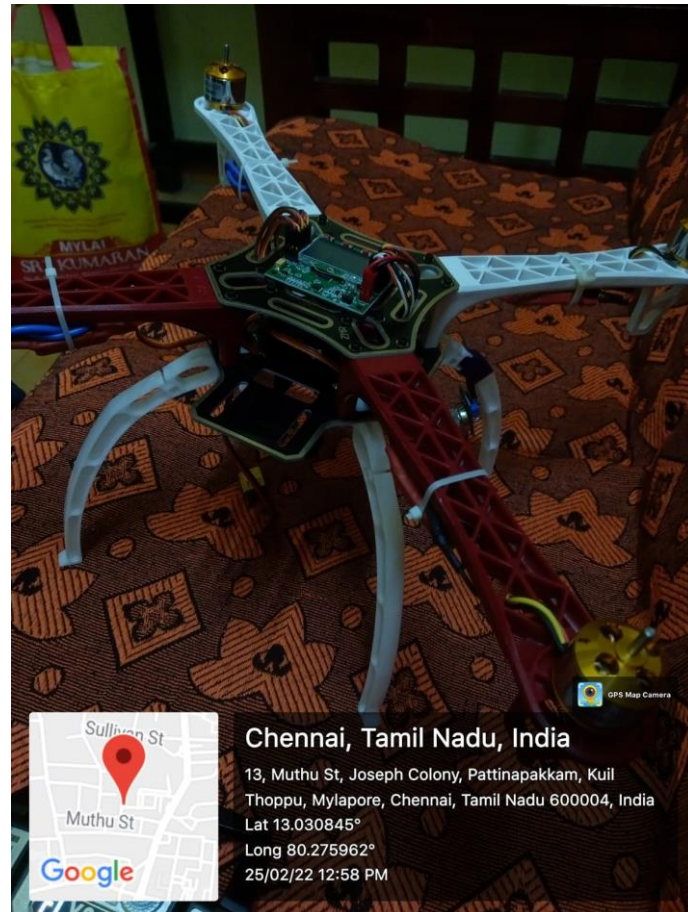


Fig 4.49 Fabricated Drone

4.5 AIR POLLUTION MODULE

4.5.1 COMPONENTS AND SETUP

The APM Module or the Air Pollution Module has been customly setup by us using a set of 3 sensors and interfacing them to the ESP32 WiFi module in order to carry out the environment air quality parameters in the vicinity using the quadcopter. The ESP32 board gets its power from the receiver of the drone which it in turn gives to the individual sensors from its VCC and GND pins.

There are 3 sensors:

1. MQ135 to monitor the air quality and output in PPM
2. GP2Y1010AU0F to monitor the dust density and output in
3. BMP 180 to monitor the pressure and altitude

The algorithm is coded so as to make these sensors take input values and display them in Blynk, which is our ground station. If there is any error or loose connection in any of the sensors the ground station receives an error message from the particular sensor using which we can monitor the status of the sensors. The module is powered up along with the drone and the code can be uploaded via the USB cable once alone. The code remains in the modules memory until there is a new code uploaded by connecting the USB cable again which in this case is only necessary when there is a significant loss of function that we didn't experience at any point during the various rounds of flight tests. Blynk is an IoT interface that utilises the Arduino IDE for coding using a special set of functions dedicated to it. The blynk app which is installed in a smartphone function as the serial monitor and the ground station. The app is interfaced with the ESP32 module by connecting it with the mobile hotspot using the ssid and password coded in the Module code. A unique auth token ensures that the correct blynk device is connected to the ESP32 module.

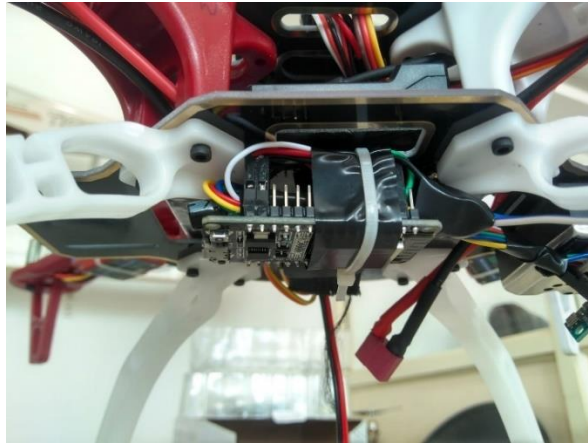


Fig 4.50 APM Module

4.5.2 ALGORITHM

A very simplistic algorithm was coded to run a self-test on each sensor, indicate errors if any and then start collecting values and displaying them onto the blynk monitor using dedicated virtual pins for each type of value at an interval of 1000 or 1 second.

The code is as follows: -

```
#include <SimpleTimer.h>

#define BLYNK_PRINT Serial

#include <SPI.h>

#include <WiFi.h>

#include <WiFiClient.h>

#include <BlynkSimpleEsp32.h>

SimpleTimer timer;

#include <SFE_BMP180.h>

#include <Wire.h>

SFE_BMP180 pressure;
```

```

#define ALTITUDE 114

int measurePin = 39;

int ledPower = 32;

int sensorValue;

unsigned int samplingTime = 280;

unsigned int deltaTime = 40;

unsigned int sleepTime = 9680;

float voMeasured = 0;

float calcVoltage = 0;

float dustDensity = 0;

char auth[] = "yG5Coc-efGy_wravxdygP-sE_u3P7TY5";

char ssid[] = "3LA";

char pass[] = "TATA1616";

void sendSensor(){

    char status;

    double T, P, p0, a;

    status = pressure.startTemperature();

    if (status != 0)

    {

        delay(status);
    }

```

```
status = pressure.getTemperature(T);
```

```
if (status != 0)
```

```
{
```

```
    Serial.print("temperature: ");
```

```
    Serial.print(T, 2);
```

```
    Serial.println(" deg C ");
```

```
    Blynk.virtualWrite(V1, T);
```

```
status = pressure.startPressure(3);
```

```
if (status != 0)
```

```
{
```

```
    delay(status);
```

```
    status = pressure.getPressure(P, T);
```

```
    if (status != 0)
```

```
    {
```

```
        Serial.print("absolute pressure: ");
```

```
        Serial.print(P, 2);
```

```
        Serial.print(" hpa = ");
```

```
        Blynk.virtualWrite(V2, P);
```

```

double pa = P * 100;

Serial.print(pa);

Serial.print(" pa = ");

Blynk.virtualWrite(V3, pa);

double atm = P * 0.000986923;

Serial.print(atm, 2);

Serial.print(" atm = ");

Blynk.virtualWrite(V4, atm);

double mmHg = P * 0.750063755;

Serial.print(mmHg, 2);

Serial.print(" mmHg = ");

Blynk.virtualWrite(V5, mmHg);

double torr = P * 0.750061683;

Serial.print(P * 0.750061683, 2);

Serial.print(" torr = ");

Blynk.virtualWrite(V6, torr);

double psi = P * 0.014503774;

Serial.print(psi, 2);

Serial.println(" psi");

Blynk.virtualWrite(V7, psi);

p0 = pressure.sealevel(P, ALTITUDE); // we're at 943.7 meters

```

```

    Serial.print("Relative (sea-level) pressure: ");

    Serial.print(p0, 2);

    Serial.println(" hpa ");

    Blynk.virtualWrite(V8, p0);

    a = pressure.altitude(P, p0);

    Serial.print("your altitude: ");

    Serial.print(a, 0);

    Serial.println(" meters ");

    Blynk.virtualWrite(V9, a);

}

else Serial.println("error retrieving pressure measurement\n");

}

else Serial.println("error starting pressure measurement\n");

}

else Serial.println("error retrieving temperature measurement\n");

}

else Serial.println("error starting temperature measurement\n");

Serial.println("=====
=====");

pinMode(ledPower,OUTPUT);

digitalWrite(ledPower,LOW);

delayMicroseconds(samplingTime);

```

```

voMeasured = analogRead(measurePin);

delayMicroseconds(deltaTime);

digitalWrite(ledPower,HIGH);

delayMicroseconds(sleepTime);

calcVoltage = voMeasured*(5.0/1024);

dustDensity = 0.17*calcVoltage-0.1;

if ( dustDensity < 0)

{

    dustDensity = 0.00;

}

Serial.println("Raw Signal Value (0-1023):");

Serial.println(voMeasured);

Serial.println("Voltage:");

Serial.println(calcVoltage);

Serial.println("Dust Density:");

Serial.println(dustDensity);

delay(1000);

Blynk.virtualWrite(V10,voMeasured);

Blynk.virtualWrite(V11,calcVoltage);

Blynk.virtualWrite(V12,dustDensity);

sensorValue = analogRead(36);    // read analog input pin 0

```

```

Serial.print("AirQuality=");

Serial.print(sensorValue, DEC);           // prints the value read

Serial.println(" PPM");

Serial.println();

Blynk.virtualWrite(V13,sensorValue);

}

void setup() {

Serial.begin(115200);

delay(10);

Serial.print("Connecting to ");

Serial.println(ssid);

WiFi.begin(ssid, pass);

int wifi_ctr = 0;

while (WiFi.status() != WL_CONNECTED) {

delay(500);

Serial.print(".");

}

Serial.println("WiFi connected");

timer.setInterval(1000L, sendSensor);

Blynk.begin(auth, ssid, pass);

if (pressure.begin())

```

```

    Serial.println("BMP180 init success");

else

{

    Serial.println("BMP180 init fail\n\n");

    Serial.println("Check connection");

    while (1);

}

}

void loop(){

Blynk.run();

timer.run();}

```

4.5.3 EXPERIMENTATION

The APM test is setup such that the drone equipped with the APM module traces a rectangular flight path ABCD where A is the starting point. The drone gains an altitude of 10 ft across AB and 20 ft across BC where it takes a left. The drone takes another left and traces the path CD at an altitude of 10 ft and then returns to the starting point A tracing the path AD.

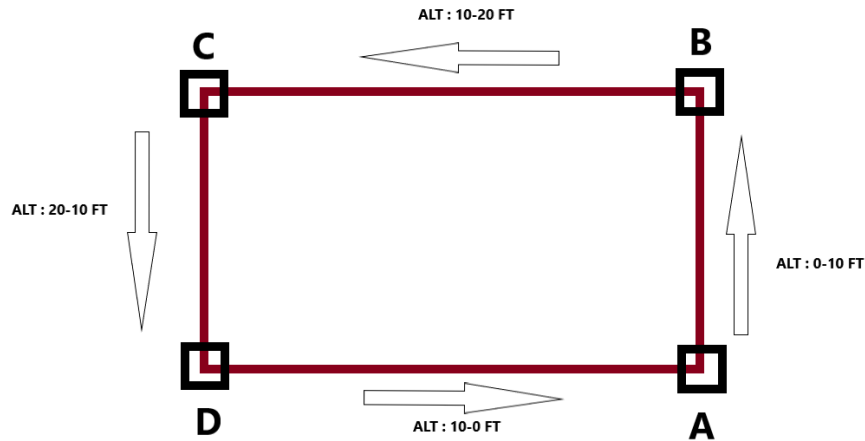


Fig 4.51 Flight Path

The APM or Air Pollution Monitoring is carried out as follows:

STEP 1: The drone platform along with the module mounted on it is placed at the starting point of the site.

STEP 2: The ground station (Blynk) is connected to the platform using the mobile hotspot and the pollution monitoring system is initialised and monitoring begins.

STEP 3: The drone is flown across the planned flight path with the module providing real time readings.

STEP 4: After the drone returns to base/starting point the module is disconnected after the drone is powered off by disconnecting its battery. The readings are later interpreted and appropriate actions taken to protect the vicinity from air pollution by taking requisite steps.



Fig 4.52 Step 1

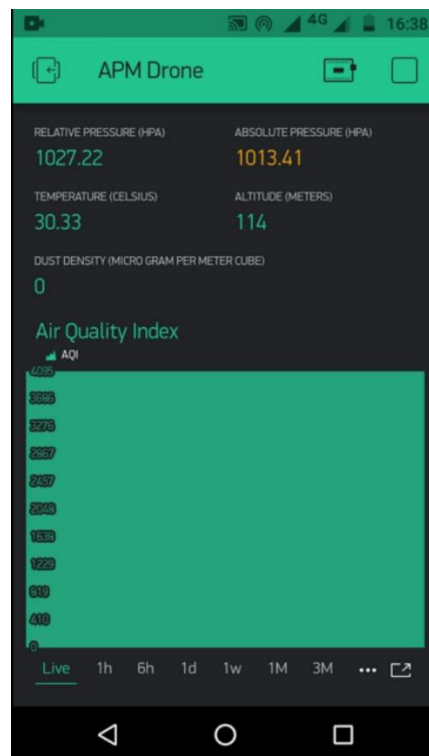


Fig 4.53 Blynk (Ground Station)



Fig 4.54 Step 3 Drone beginning to fly



Fig 4.55 Drone after returning to base

CHAPTER 5

RESULTS AND DISCUSSION

5.1 AIR POLLUTION MONITORING

The air pollution monitoring exercise was successfully tested out by carrying out the experimentation in the campus vicinity with sufficient range and altitude. The readings collected were of relative pressure in HPA, absolute pressure in HPA, Temperature in Celsius, dust density in mg per meter cube and air quality index in PPM. One point to be noted here is that when the drone flies from a sandy terrain the initial take-off and landing thrust kicks up some dust and the air quality readings fall and later restore to normal as the dust settles. At high altitudes pressure changes can be observed. We have compiled the readings of the Blynk ground station by plotting them from viewing screen recordings and compiled the following results.

5.1.1 Relative Pressure

Relative pressure is defined as the atmospheric pressure corrected to sea-level conditions. The fluctuation in readings can be explained by the quick ascents and descents made by the drone during its flight. These values can be verified by the whether station readings collected during the test. The values are tabulated below.

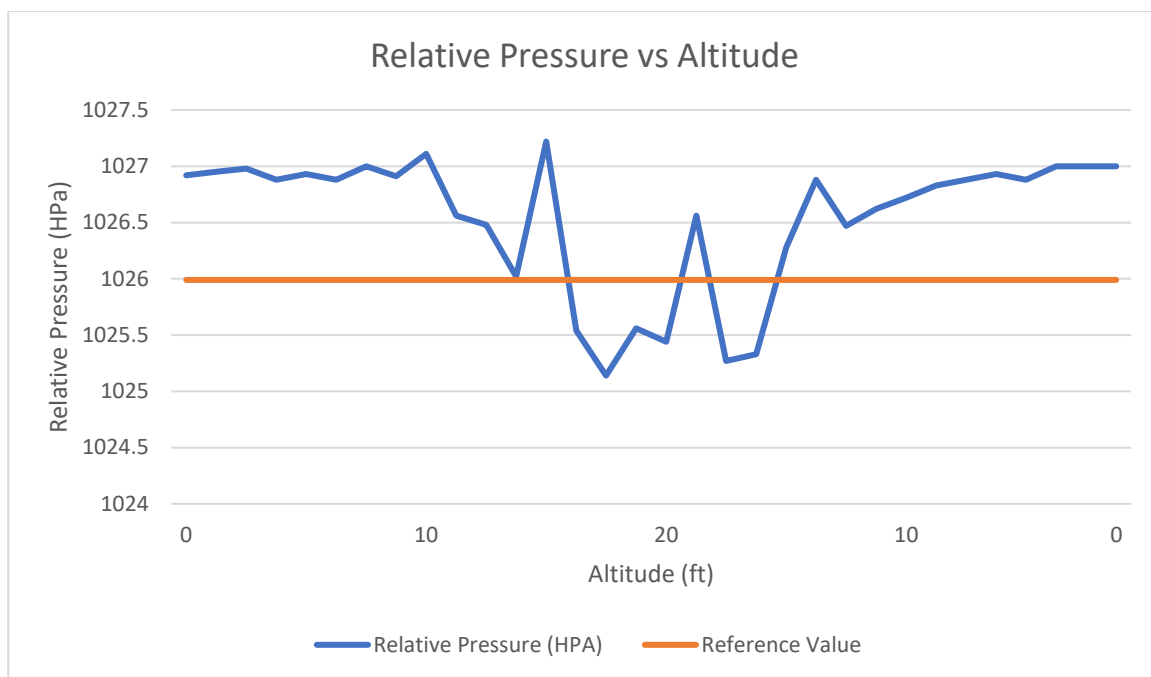


FIG 5.1 Relative Pressure Readings

Table 3: Relative Pressure Readings

Reference Value: 1025.99

Altitude (ft)	Relative Pressure (hPa)
0	1026.92
	1026.95
	1026.98
	1026.88
	1026.93
	1026.88
	1027
	1026.91
10	1027.11
	1026.56
	1026.48
	1026.02

	1027.22
	1025.54
	1025.14
	1025.56
20	1025.44
	1026.56
	1025.27
	1025.33
	1026.28
	1026.88
	1026.47
	1026.62
10	1026.72
	1026.83
	1026.88
	1026.93
	1026.88
	1027
	1027
0	1027

5.1.2 Absolute Pressure

Absolute Pressure is defined as the pressure that is relative to zero pressure in empty space. The fluctuation in readings can be explained by the quick ascents and descents made by the drone during its flight. These values can be verified by the whether station readings collected during the test. The values are tabulated below.

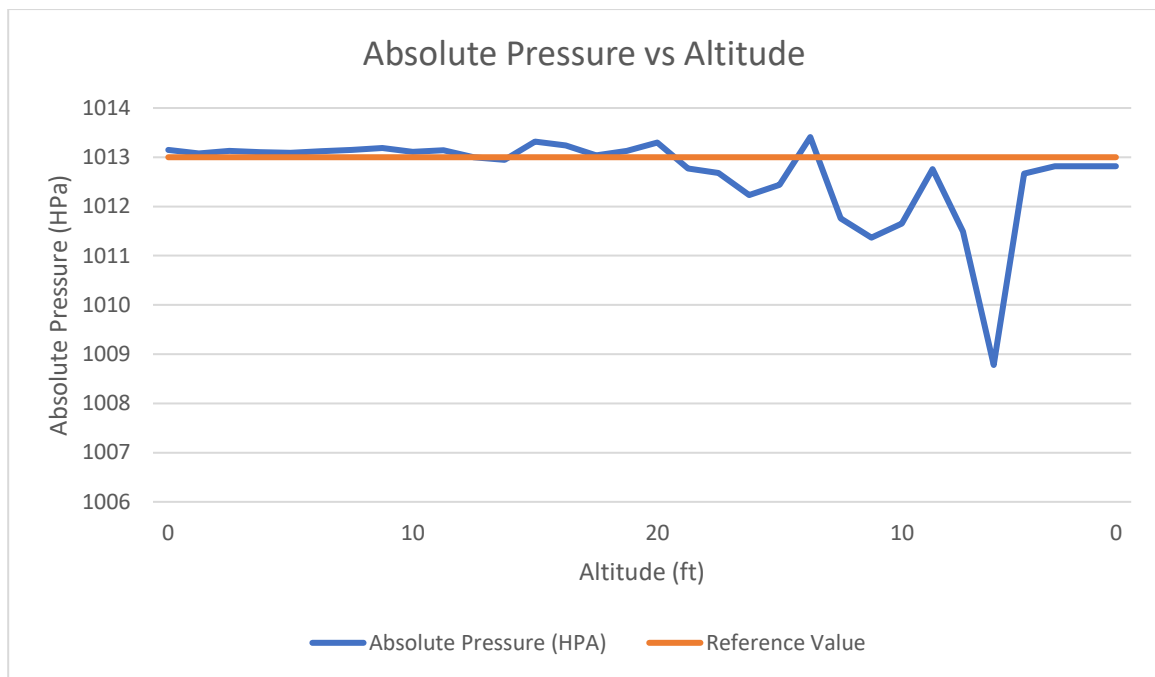


FIG 5.2 Absolute Pressure Readings

Table 4: Absolute Pressure Readings

Reference Value: 1013 HPa

Altitude (ft)	Absolute Pressure (HPa)
0	1013.15
	1013.08
	1013.13
	1013.1
	1013.09
	1013.12
	1013.15
	1013.19
10	1013.11
	1013.14
	1013
	1012.95
	1013.32
	1013.24

	1013.04
	1013.13
20	1013.3
	1012.77
	1012.68
	1012.23
	1012.44
	1013.41
	1011.76
	1011.37
10	1011.65
	1012.76
	1011.49
	1008.78
	1012.67
	1012.82
	1012.82
0	1012.82

5.1.3 Temperature

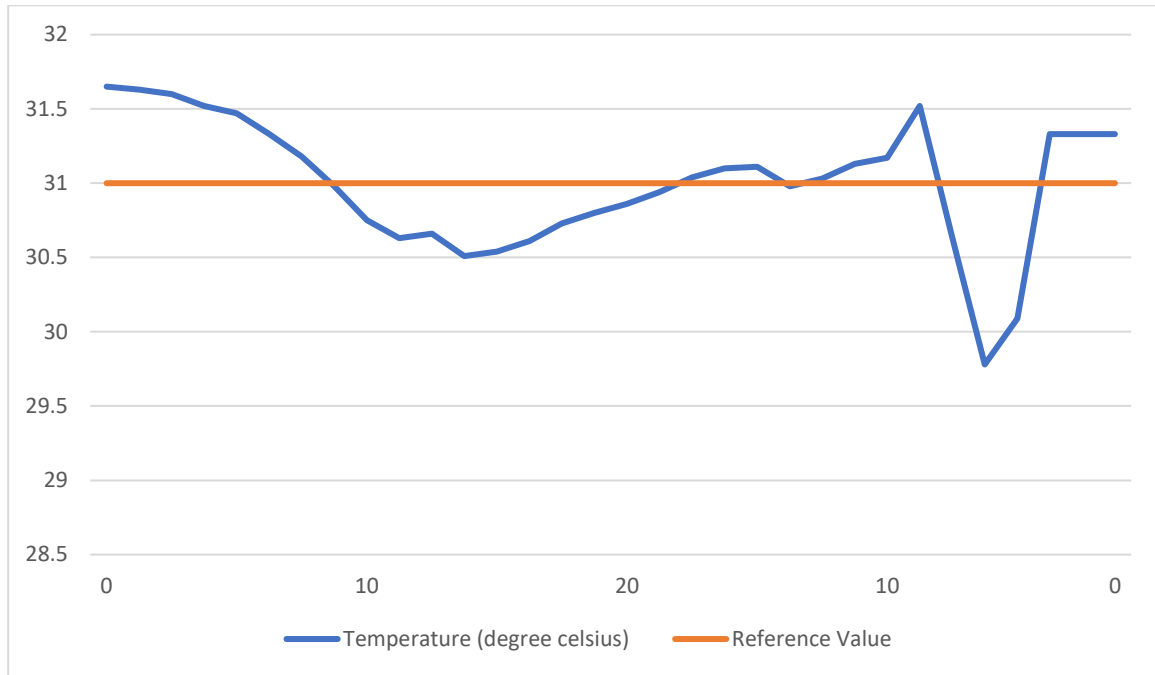


FIG 5.3 Temperature Readings

Reference Value: 31 degree celsius

Table 5: Temperature Readings

Altitude (ft)	Temperature (degree celsius)
0	31.65
	31.63
	31.6
	31.52
	31.47
	31.33
	31.18
	30.98
10	30.75
	30.63
	30.66
	30.51
	30.54
	30.61
	30.73
	30.8
20	30.86

	30.94
	31.04
	31.1
	31.11
	30.98
	31.03
	31.13
10	31.17
	31.52
	30.63
	29.78
	30.09
	31.33
	31.33
0	31.33

5.1.4 Dust Density

For clean air the dust density value should ideally be zero. But as the drone kicks up dust while taking off and landing a deflection can be noted in the readings thus indicating a properly functional hardware.

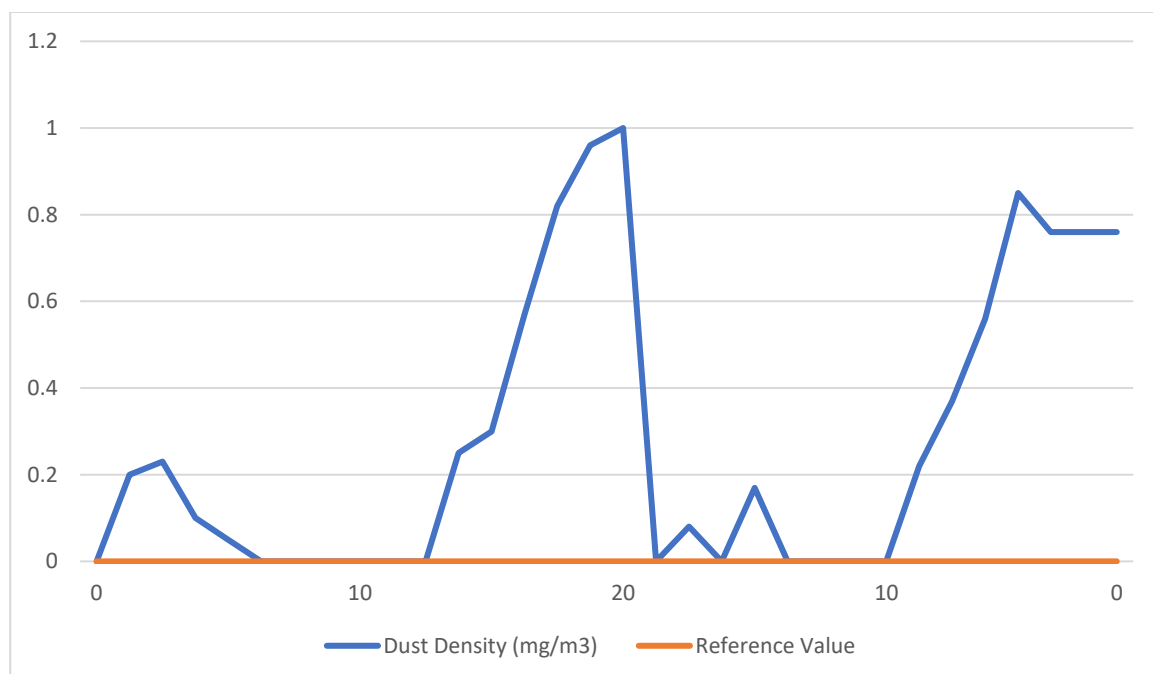


FIG 5.4 Dust Density Readings

Reference Value: 0 mg/m³

Table 6: Dust Density Readings

Altitude (ft)	Dust Density (mg/m ³)
0	0
	0.2
	0.23
	0.1
	0.05
	0
	0
	0
10	0
	0
	0
	0.25
	0.3
	0.57
	0.82
	0.96
20	1
	0
	0.08
	0
	0.17
	0
	0
	0
10	0
	0.22
	0.37
	0.56

	0.85
	0.76
	0.76
0	0.76

5.1.5 Air Quality

Air quality is indicated in PPM which stands for parts per million. In this experimentation it is to be noted that the value indicated is of the scale of air quality and not the actual air quality index of the vicinity. This scale can be used to determine the variation in air quality across the vicinity and take note of drastic changes. The values are tabulated as follows

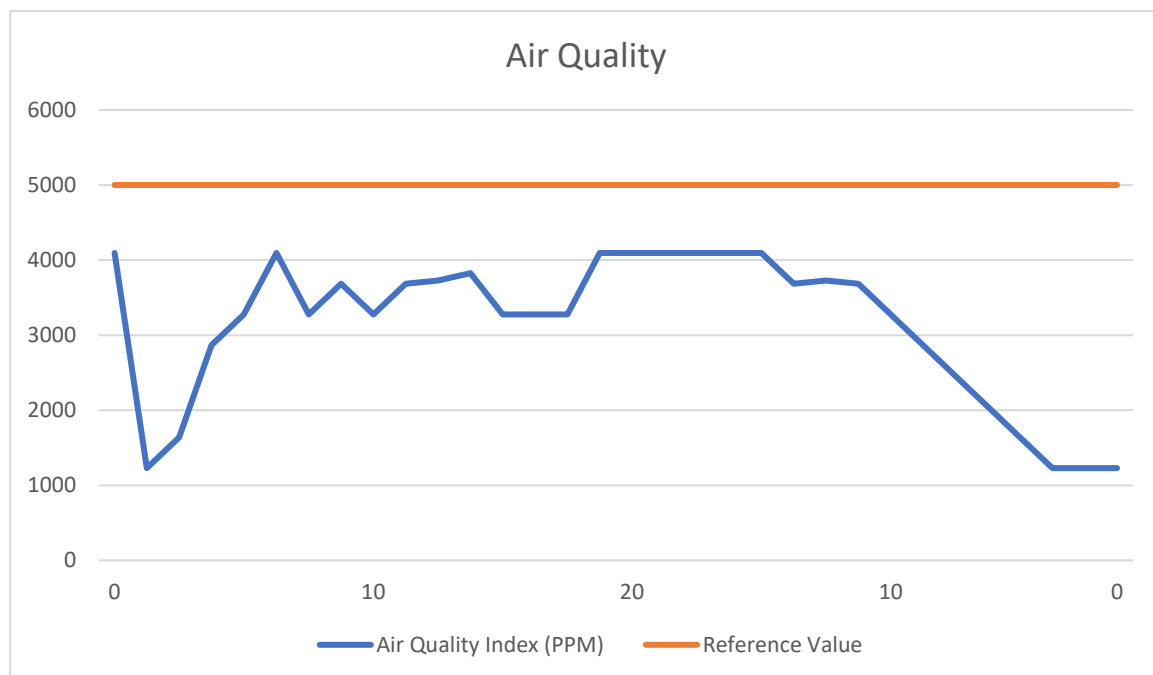


FIG 5.5 Air Quality Readings

Reference value :5000

Table 7: Air Quality readings

Altitude (ft)	Air Quality
0	4095

	1229
	1638
	2867
	3276
	4095
	3276
	3686
10	3276
	3686
	3726
	3826
	3276
	3276
	3276
	4095
20	4095
	4095
	4095
	4095
	4095
	3686
	3726
	3686
10	3276
	2867
	2457
	2048
	1638
	1229
	1229
0	1229

CHAPTER 6

SUMMARY & CONCLUSION

Thus, an affordable accessible and repetitive methodology to monitor real time air quality parameters in the environment by anyone with a drone platform has been tested out and formulated successfully. There has been an improvement in the design of the conventionally available propellers and a strong and reliable material has been identified in the form of nylon-carbon which can be used to materialise and fabricate any custom propeller intended for RC airplanes, RC boats, Drones and any other high thrust platform. The aerodynamically efficient and bigger propeller will help increase the flight time of the APM drone due to lower power consumption of the motors, hence providing a way to add additional accessories for other purposes as well as providing the capability to monitor a greater vicinity than conventional propeller equipped platforms. This platform can be utilised by drone operators working with government pollution control agencies or industries and even Non -Governmental Organisations working towards fighting air pollution.



FIG 6.1 Completed Product

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