DEVELOPMENT AND IMPLEMENTATION OF AVIONICS IN FIXED WING UAV

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report titled "***Development and Implementation of Avionics in Fixed Wing UAV***" is the bonafide work of "**LAKSHAY GOPALKA (RA1511018010176)**, who carried out the project work under my supervision. Certified further, that to the best of my knowledge the work reported here in does not form any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

The Unmanned Aerial vehicles have been in use for various applications for over a decade. In the past years, the need for optimum control, stability and autonomous control have prevailed. Thus, the Scorpio Mark-III is a fixed-wing UAV which is capable of autonomous control and eliminates the need for continuous monitoring by RC pilot. Pixhawk module is used which is autopilot hardware and used as an interface to connect servos, transmitter and GPS. The controller design is made in Simulink using 2 axis stabilization of roll and pitch by using Pixhawk library components and control theory basics. The waypoints for navigation are given by Mission planner software for autonomous mission. The autonomous controller and way point navigation are tested in Software and in Hardware-in-Loop by various tests in X-Plane, Ground test and flight test. The avionics and communication elements are all electronics components installed in the aircraft which help in flying, data transmission, interface telemetry data from the plane to ground station. The ground and air telemetry module along with transmitter help to obtain flight parameters like speed, altitude, latitude, longitude. The OSD and camera are used to display plane position to the display device at the ground station. Various tests are carried out to test the working of all the electronics and their functionality.

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LAKSHAY GOPALKA

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ABBREVIATIONS

UAV	Unmanned Aerial vehicle
PID	Proportional Integral derivative
PI	Proportional Integral
MTOW	Maximum Takeoff Weight
CNC	Computerized Numerical Control
RC	Radio Control
HIL	Hardware in loop
SIL	Software in loop
PX	Pixhawk
OSD	On Screen Display
GPS	Global Positioning System
SLAM	Simultaneous Localization and Mapping
IMU	Inertial Measurement Unit
PWM	Pulse Width Modulation
DC	Direct Current
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal serial Bus
AAT	Automatic Antenna Tracker
LED	Light Emitting Diode
FPV	First Person View
TV	Television
CMOS	Complementary Metal Oxide Semiconductor
RGB	Red Green Blue
ADC	Analog to Digital Converter

CHAPTER- 1 INTRODUCTION

1.1 Background of the Project

The UAVs have been widely used in many different applications over the years, its applications have only widened including its use in military, agriculture, rescue, surveying etc. There are major difficulties building such systems and in technological era, we thrive for optimum output that includes efficient control and positioning, delivery time, speed, stability, ability to work in different environments and much more. There are many aerial systems prevalent today and fixed wing aerial systems are among being preferred. Fixed wing UAV which uses wings that are stationary and are used to generate lift as and when the aircraft move forward. These aircraft have some advantages over the rotary wing aircraft. The fixed wing aircraft are comparatively faster and requires a simpler mechanism, the cost of production and maintenance is less and can fly for longer duration of time. This is also a major reason why all commercial aircrafts used for passengers commute employ fixed wing aircrafts.

In the Tamkang University, Taiwan, the aerospace department students are in-charge of modelling, fabricating, testing and to integrate a new compelling technological advancement to their aircraft every academic year to be inherited with advancements along with the hands on experience. The fixed aircraft is Scorpio Mark- III compared to last year Scorpio Mark-II with major changes in its design like wings and tail allowing better stability and to run the flight by autonomous control. The UAV lab is reserved for building such UAVs every year and is instilled with fabrication work bench, computer systems and all the essential tools, machines, instruments required to build a UAV from scratch.

The process of building an UAV starts from designing the structure of the aircraft which is done via CAD software CATIA and various simulation tests are carried by software like ANSYS. The aircraft is designed in a way that is robust, high grade, lightweight, stable, resist to deformity etc. The design is manufactured using CNC to get the best accuracy. The various considerations include seeking highly repeatable results, flexible payload system, adaptable to design changes. The structure division ensures the components are within the tolerable limit and have smooth edges after the wire cut CNC operation on the manufacturing material.

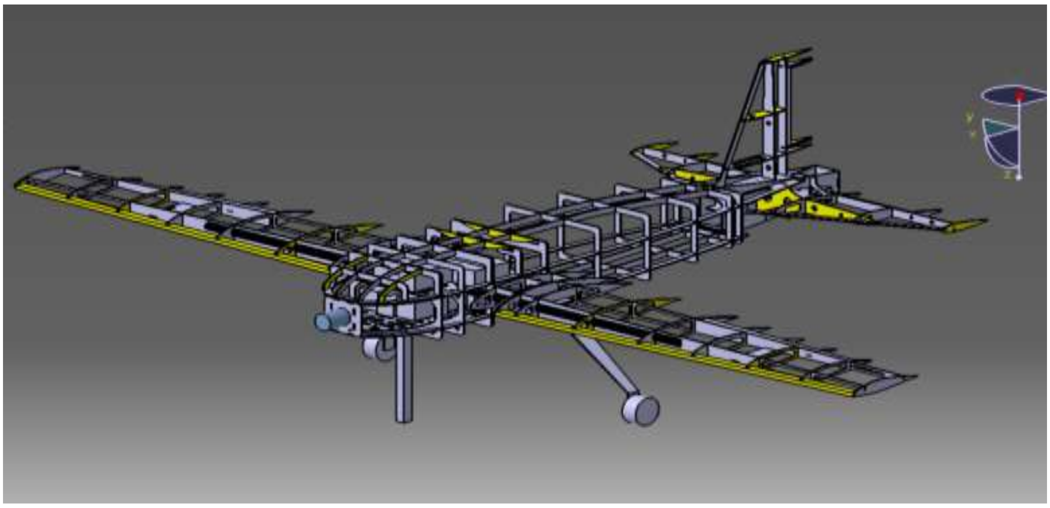


Figure 1.1: Design of MK-III on CAD software

Similarly, for the various tasks, there are divisions assigned namely: aircraft design, structure, avionics, communication, engine, pilot and computer vision. The results in this report primarily are for the communication and avionics division. The avionics in simpler words is aircraft electronics systems which consist of installing, wiring, designing control system, collecting data. The communication system is the set of components used by aircraft to transmit and receive signals using ground station, radio transmitter and receiver with RC controller.

1.1.1 Aircraft Specifications

The taxonomy is given by following main parameters [2]-

A. Size- MTOW is used to classify different types of UAV. MK-III is a medium type as its load carrying capacity is between 20-150 kg.
B. Capability- The performance and ability of UAV measured by speed, payload mass, cruising altitude.
C. Degree of autonomy- It describes the control parameters of the aircraft and is used to differentiate fully autonomous pilot with remotely controlled vehicle.
D. Mission- Various missions to be accomplished during the flight operation-communication, survey, support.

The major MK-III specifications are summarized in the Table 1.1. It displays general, performance parameters as well as of wing and tail.

Table 1.1 General Specifications of MK-III aircraft

Aircraft Specifications	Value (Units)
MTOW	8 Kg
Total Length	1.5 mts
Cruising Speed	14mt/sec
Cruising Altitude	100 mts
Wing span	2.41 mts
Wing area	40.6 mts
Air foil NACA	4412
Capability	Autonomous
Horizontal tail area	0.17 m2
Vertical tail area	0.85 m2
Endurance limit	40 min

1.1.2 Objectives

The project was done in the UAV lab of Tamkang University Taiwan with the main objective to work in Avionics division and assist the team members in accomplishing the task of fabricating the fixed wing aircraft. The objectives are required to meet the desired specifications and are listed below-

- Accomplish the installation of all electronics components in the aircraft;
- Perform the necessary tests and checks to ensure the working of each hardware component;
- Assist Communication division to install the necessary components involved for communication;
- Design a controller using Simulink for autonomous flight control;
- Run the SIL tests using Mission Planner, X-Plane and MATLAB to check the Pixhawk controller;

- Run the Controller using test flight for HIL;
- Obtain the flight test parameters using ground station and tune the controller.

Hence, the above objectives were met in MK-III and the controller worked and performed as simulated in the software environments.

1.1.3 UAV Structure

The MK-III UAV contains many components and parts like the control surface, lifting surface, fuselage, propulsion system, landing gear, pilot, computer vision, communication and avionics systems. The lifting surface includes elevators, rudder and ailerons which are blended with aircraft and controlled by servo command to give direction and control. The propeller or fan is used to drive aircraft along with use of batteries. Pilot division is responsible for running the RC controller in manual mode and collect required parameters while computer vision is used to obtain the images while aircraft is flying in the sky. The communication systems involve antenna, transmitter, and receiver with ground station and simultaneously with the pilot. The avionics systems deals with servo control, wiring, batteries, controller design and integrating Pixhawk in the aircraft. These constitute the basic components to lay out an aircraft.

1.1.4 Control Theory

Control theory deals with analysis of various components that work as a system to provide the control. A control system uses an open or closed loop feedback, but in order to get a subsequent and accurate description, we use a closed loop approach in which the feedback is established. Developing a control system involves assessing various flight mechanics parameters. Nowadays, UAVs are becoming more and more complex with a robust control system. The use of auto pilot in UAVs is to fly an aircraft from one place to another by using GPS while maintaining altitude and speed. The aircraft should have a fail-safe mechanism that it is able to reach a safe position in extreme cases. The auto pilots should be able to direct telemetry data via radio. The specific points is given by waypoints. This is obtained by Mission Planner software and uploading the program in the PX hardware.

1.2 Challenges in Existing Systems

UAVs are an aerial aircraft with no pilot on-board and rather controlled by a pilot with RC controller. Since, there is a flourish in such aviation systems; there are a few setbacks to such aircrafts. Primarily, most of the UAVs available today in the market are manual operated, hence without the knowledge of RC controller, it is impossible to fly them and auto-pilot is still in development. Auto-pilot or autonomous control is being tested on various platforms and is used to guide the aircraft to accurate locations without the continuous user input. The major challenges in existing systems include the inability of the aircraft to fly without the manual input and lack the desired accuracy. The existing systems lack the safeguard mechanisms and are unable to provide consistent flight operating conditions and performance.

The aerial systems primarily the fixed wing have limited flight performance. These include the low payload capacity and endurance. Most of the systems run out of the power obtained via battery or cannot carry a significant load. To overcome this, MK-III can run over 40 minutes and carry at least 8kg of payload.

The UAVs have limited range and are restricted in terms of speed, altitude. The MK-III despite its size is able to fly with a good speed while maintaining the autonomous control, as the signals needs to be sent synchronously to the ground station channel. Therefore, the major challenge overcome by this UAV is to improve the structural stability parameters, this has been done by introducing change in wing, fuselage and tail design.

Another major concern is lack in development of auto-control, therefore my objective for the aircraft is able to navigate itself without the pilot control, this has lacked in major UAVs available. To solve this issue, the various SIL and HIL tests have been performed with the flight controller. The goal is reached through navigating the waypoints in the Mission Planner and using PX hardware to run the program. Further, this has been implemented using tests in X-Plane and test flight. The challenge of manual control is resolved by designing a controller in Simulink which can provide stability and control logic signals.

1.3 Applications

Aerial aircrafts have been prevalent in the market for a long time. The different types of UAVs have been used in many different applications. The structure, design and other components can be added or modified in an aerial system depending on the need and requirement.

Todays, UAVs are used by military, aviation industries, students etc for specific applications. The wide applications include use of UAV for monitoring, surveying and assessing a particular region by defence or security reasons. These applications extend to fixed wing aircraft as it is the backbone of , for all major aircraft industries for passenger and carriage transport like Etihad, British Airlines, Emirates and so on.

The applications include Inspection like for PV panels or construction site, transporting materials and good which are widely employed by Amazon in USA. The UAVs are used in agriculture for precise cropping, surveying; used for fun by entertainment industry; used for obtaining images of places cannot be reached by humans and for photography; in computer vision and image processing.

UAVs are used in complex flight dynamics, swarming and SLAM. These are incorporated with auto-pilot or autonomous control which can influence its use in many fields. The precise position, accuracy and control will enable them to employ them for various mission plans, detection of objects, to transport objects to remote places. Using auto-pilot, we can easily obtain maps of unknown environment as the UAV is continuously mapping the images using an algorithm and without the need of continuous manual input. The recent UAVs including MK-III is used for object recognition and obtaining flight data parameters.

Hence, autonomous control develops the UAV to guide them without human inputs. These ensure safety and introduce repeatability into the aircraft control. This is most significant in aviation industries when pilot is unable to determine the position and interpret the plane position. Together with autopilot, the UAVs application broadens in several fields and results in, obtaining the better outcome in terms of control, stability, and accuracy.

1.4 Need of the Project

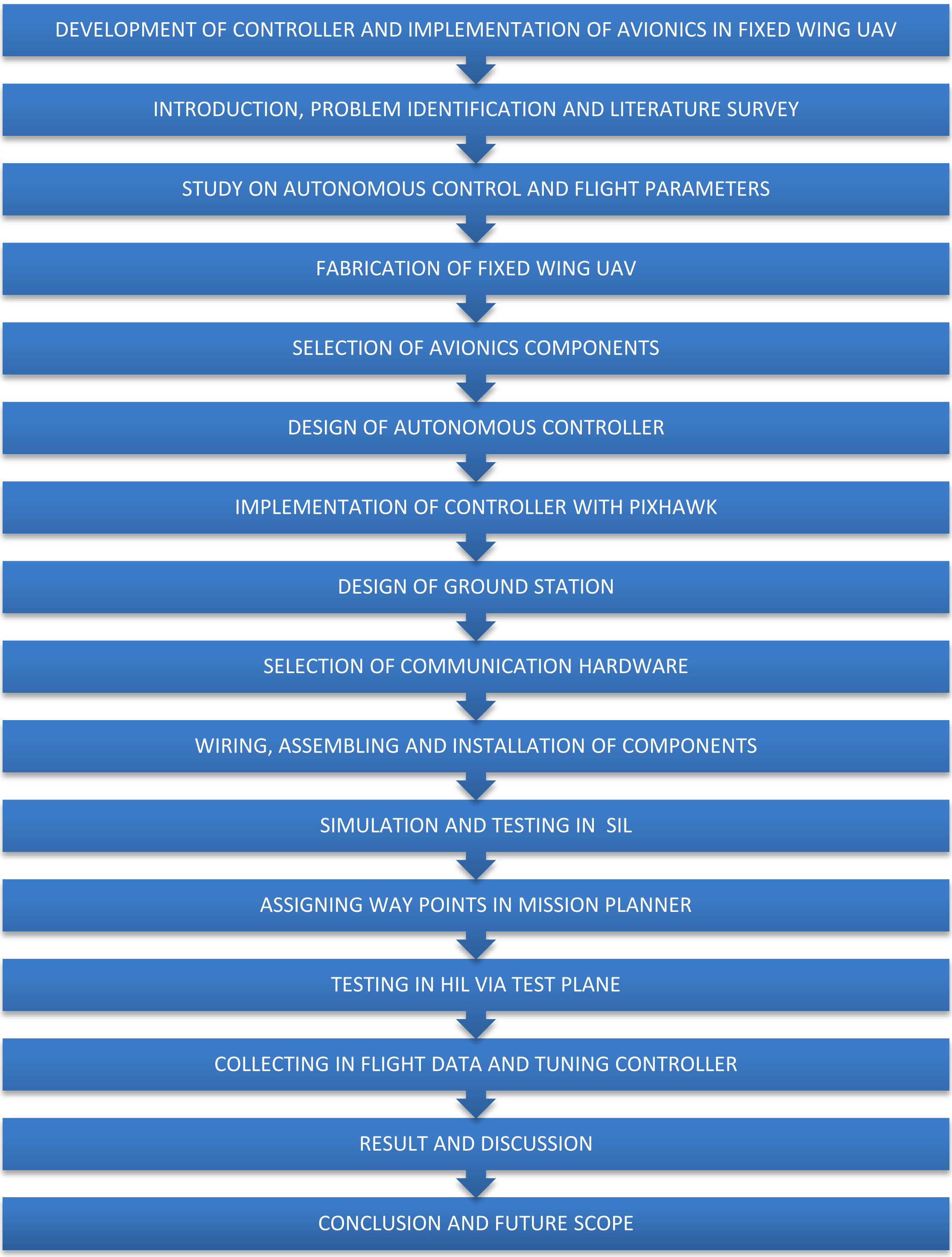
The autonomous control has been popular topic among the technologists and engineers. Introducing autonomous control has various advantages and can improve the quality of the life. The major reasons of the accidents are due to lack of control or attention by humans, leading to fatal injuries, death and destruction. The number of such mishaps is continuously increasing, hence, introduction of auto-pilot and use of high tech sensors system like in flights, can help to curb this issue. Having a good avionics and control system will highly influence the aerial aircrafts enabling them with better transit journeys.

The autonomous control can resolve this issue by automatically controlling itself with help of controller namely, autopilot and on board sensors all integrated with the hardware platform. Implementing this will also increase safety, efficiency and accuracy of all vehicles including fixed wing UAVs.

The UAVs with on board computer vision will be able to gather essential information as captured by the camera. The computer vision algorithm can be used to determine objects and other things on the planer surface. Additionally, using the Pixhawk, the flight parameters can be recorded and monitored continuously without the hassle of writing or storing them separately.

Therefore, the integration of autonomous control to UAVs will help them move to various position or waypoints in a better manner including greater accuracy, optimum control, enhanced safety, and ensure the proper collection of flight data (telemetry data).

1.5 Methodology



1.6 Organization of the Report

The results of the project work have been combined in a report. The outline of the report is summarized as below-

Chapter 1 provides an overview of the internship project, and introduces the background information of the UAV, autonomous control and avionics. It explains the objectives, control theory, need of the project, and challenges in the existing system, methodology, applications and organisation of the report.

Chapter 2 describes about the work and progress in the autonomous control and UAV by other researchers. It explains and mentions about the literature review from different journals in the same study.

Chapter 3 presents the controller design procedure followed in order to design the autonomous controller and ground station using MATLAB- SIMULINK with the use of Pixhawk components. It also illustrates the simulation and test of controller on various platforms.

Chapter 4 describes about the avionics and communication components and hardware used in the MK-III. It describes the need and description of the product along with its fabrication methodology employed in the aircraft.

Chapter 5 draws the conclusion of the project and focuses on the main contribution points along with the possible areas for future research work for further enhancement of the project.

CHAPTER- 2 LITERATURE SURVEY

Hamzeh Alzu'bi, Belal Sababha and Basim Alkhatib (AAIA Infotech Aerospace Conference, Model –Based Control of a Fully Autonomous Quadrotor UAV, 2013, MA, Boston) in the paper have presented the control model to control an autonomous quadrotor UAV. The controller is developed in Simulink and consists of roll, pitch and yaw control. The microcontroller and two telemetry make up the avionics which are capable of transmitting data. The ultrasonic range finder is employed for altitude feedback. The control system is composed of motor and commands from GPS and sensor feedback. The IMU is used to find the various roll, pitch and yaw angle. The simulation is carried out in Real Time Workshop which is further used to generate code, later executed on the controller. The PID controllers are used for roll and pitch and used to rectify any error signals by correction to obtain the appropriate PWM signals for left and right motors. The altitude controller command obtained from ground station and pilot is added to signals to drive the DC motor while the GPS is responsible for exact waypoint position. It is done by lateral and longitudinal coordinates which are given by ground station for successive waypoint to control the position of the UAV. The difference between command and output is fed to the PID to make appropriate corrections to produce desired angles every 250 ms. Thus, the results imply the perfect hovering of the quadrotor and also, follows the waypoint which apparently forms a circular path. The model based control system using avionics has been able to fully control autonomous UAV and the results are stable and repetitive.

Jeonghoon Kwak and Yunsick Sung (Institute of Electrical and Electronics Engineers (IEEE) Access, Autonomous UAV Flight Control for GPS Based Navigation, Seoul, South Korea,2018) in the research paper developed a flight control method using A* algorithm which is dependent on the multiple surveillance points. The method uses an UAV to collect flight data and this is used to generate flight paths. Then, the path is processed by using A* algorithm. The final flight is the result of search algorithm and the collaboration of all the points. The autonomous control process is reached by training which involves the process like record, graph generation and path planning phase. The results have been verified multiple times by taking various flight intermediate positions. The experiments were conducted in the university and the data were collected by a smartphone which was in connection with the controller. The pilot was successfully able to collect data and analyse it to form a path for flight and which was executed by the UAV in autonomous manner. Hence, the UAV was able to connect to waypoints and form the trajectory using the algorithm for 6 flight paths.

Lorenz Meier, Petri Tanskanen, Friedrich Fraundorfer and Marc Pollefeys (IEEE International conference on Robotics and Automation, Pixhawk: A System for Autonmous Flight using Onboard Computer Vision, Shanghai, China) in their paper have used a software and novel hardware system for aerial vehicles. These vehicles are able to use autonomous flight with the application of vision system. These vehicles do not use radio or any external device, just camera mounted on 4 sides. The stereo cameras are required to estimate the distance, and Pixhawk is used simultaneously. The communication protocol is given by middleware architectural layers namely, application, middleware, communication and hardware layer which significantly reduces the system complexity. The autopilot unit is responsible to provide parameters like acceleration and velocity. The avionics components are secured in shock absorber case which protects the camera and other hardware systems. The Pixhawk is able to provide precise time and control for autonomous flight. This is incorporated with robotics technology- Discrete kalman filter for better quadrotor dynamics, roll, pitch and yaw. This is used to estimate velocity and states of the aerial vehicle by localization algorithm. This all is implemented using PID controller for attitude stabalization. The results reveal precise localization which enumerates the trajectory, takeoff, landing, obstacle avoidance by making a map.

Yaqub Aris Prabowo, Bambang Riyanto Trilaksono and Fadjar Rahino Triputra (The 5th International Conference on Electrical and Informatics 2015, Hardware in the loop Simulation for Visual Servoing of Fixed Wing UAV, Bali, Indonesia) in their paper titled, ‘Hardware in the loop Simulation for Visual Servoing of Fixed Wing UAV’ worked on autonomous flight control using imaging basis. The camera is used to identify obstacles and objects and further, implemented by using visual servoing algorithm. This algorithm enables the servo motors to drive and control the surface like elevators etc. Pixhawk is used to provide autonomous control base which is assisted with Image processing module and flight gear. HILS is used for testing the controller hardware. The system has been implemented in real time based on autopilot implemented by Pixhawk hardware. C language is chosen as the flight dynamics computations are faster than MATLAB. The model is converted in C language and uploaded in PX hardware. Various mathematical calculations and expressions have been derived by authors to find force, moment, velocity and position parameters. The UART and UDP communication modules are used to transmit information. During the implementation of the controller in HILS, UAV flies at an altitude of 1000m and the program runs successfully without any crash. However, there was some latency and error observed which was equal to 0.54%.

Shuo Wang, Ziyang Zhen, Fengying Zheng and Xinhua Wang (Proceedings of 2014 IEEE Chinese Guidance, Navigation and Control Conference, Design of Autonomous Flight Control for small scale UAV, Yantai, China) in their paper, titled, 'Design of Autonomous Flight Control for small scale UAV' developed an autonomous controller for small scale UAV. The hardware system consists of ATmega and laser sensors which are used in landing and determining distance. The laser sensor incorporation against barometer is to achieve greater accuracy during flight operations of take-off and landing. The ground station is responsible to communicate with microprocessor to send signals for the auto pilot task. The controller is built on cascade approach in which inner loop is for attitude control while the outer loop is for trajectory control. These are used to eliminate errors and to make sure the UAV follows the desires path in a safe range. The controller consists of roll and yaw to make controlled tilts. Hence, the results conclude that aircraft follows a rectangular path and works well to give significant results.

CHAPTER- 3 CONTROLLER DESIGN AND TESTING

The UAVs control and ability to fly beyond human controls and eyesight has led researchers and people to work on autonomous control, autopilot, developing models and hardware's which can replicate and perform what a human wants to do without giving impromptu commands every time. This had led to significant developments with control algorithm which can now be used to achieve stable control, maintain hovering and performing navigation for unknown environments. The same task is being executed in this controller design but the objective to fly the MK-III autonomously and implement a new control algorithm with new hardware system to implement learning.

The model based approach uses a system development using MATLAB Simulink with the aid of Pixhawk components [9]. This chapter illustrates on how different objectives have met to control the UAVs stability, heading, waypoint and attitude stabilization. During the auto mode, the UAV has to stabilize itself and also navigate through waypoints while maintaining a close connection with ground station and simultaneously transmit and receive telemetry data. The main components of this system are described in chapter 4 while this chapter focuses on the design of thee controller, methodology employed, description of software and testing procedure to obtain the controller using the system selection.

The aerial vehicles control can be described by maneuvering parameters [3] like poll, pitch and yaw which are basically controlling the direction and movement. If these parameters can be effectively controlled then autonomous control can be achieved, hence, I made up a controller design in Simulink in which we have used Pixhawk hardware components and basic control system applications. The attitude control is the method used to vary aircraft orientation by implementing changes. Figure 3.1 depicts the basic process, communication and framework for MK-III, in which, the communication and data transfer work is done by transmitter and receiver. The Pixhawk is the main modality which acts as a system to control and implement signals, control surface, throttle etc to the aircraft MK-III. The UAV can be controlled by manual operations and can be used to give commands to controller and to give waypoint navigation, Mission planner software is used. The insights on each blocks and subsequent testing have been described in further sub-sections of this chapter.

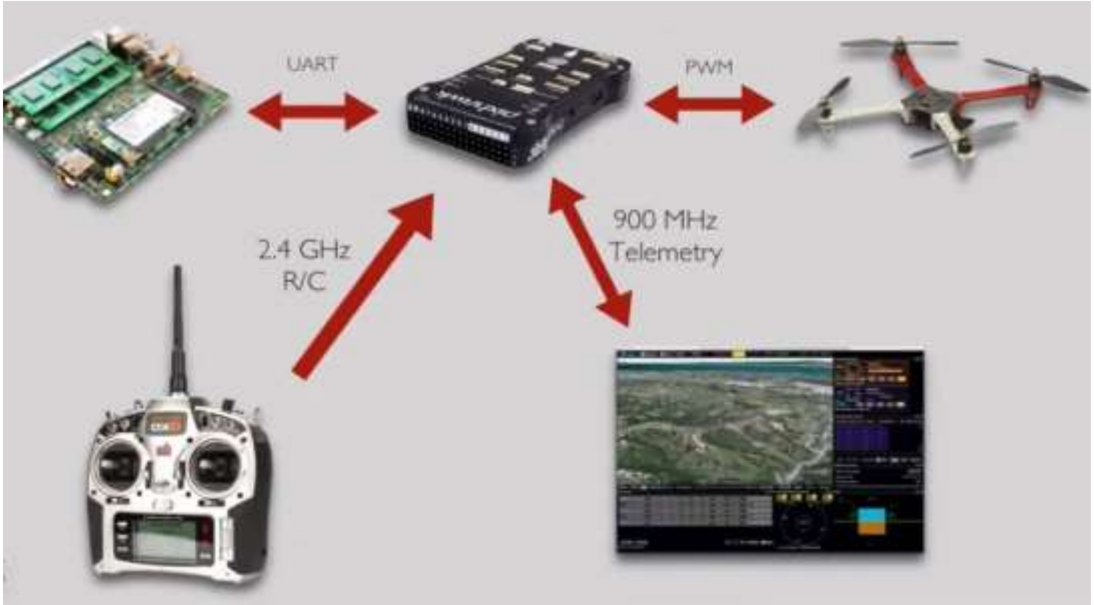


Figure 3.1: Communication process

3.1 Mission Planner

ArduPilot Mission Planner [1] is autopilot software which is used to control vehicles like drones, UAV, rover, boats etc. It can be used to perform various multitudes functions like waypoint selection using GPS, configure and select various mission commands. Analyse mission, control vehicles and simulate a flight controller. For my purpose, I used Mission Planner software to connect to Pixhawk and then, transfer the route or path for UAV set using the ArduPilot software platform. The steps and the modes used in Mission planner the figure for the software are illustrated below.

Figure 3.2: Mission Planner window

The Mission Planner is a control utility in which the plan, setup and loading of multiple way points are done by loading the firmware to PX with MK-III. After the installation, the controller hardware is connected to PX by a USB and connected with AUTO/ COMP port. In the window, select plane. The ground telemetry module is also attached to the system.

The software supports many mission planning methods like take off, waypoint, hover, fly via, land etc. For autonomous missions, Auto mode is used. It enables the aircraft to follow a pre-defined path made using various commands. There are several steps to set a mission; it involves first checking of the connection. In the planner, setting the speed and distance units according to the desired users preference. Following it, in flight plan screen, adjust the home point which will be the Arm point for the airplane mission. In the waypoint menu, set the radius in which the plane can travel while moving to and from the waypoint, loiter radius is when the airplane is free and can be set to roam around in the proximity while the default altitude is at which the airplane can fly above the ground level according to GPS position. Using the mouse, the waypoints can be created in succession to create a path for travel. In the command, the first waypoint is set as take off and the last waypoint is set as return to launch which helps in airplane set off and return. The specific delays and other functions can be given for a particular waypoint, but it is not desired in any of our case. Hence, the file is saved and loaded in the Pixhawk and can be used according to our convenience any time. The simulation screen is capable to show flight telemetry data like speed, angle, battery, altitude, waypoint number, distance etc. therefore, the Mission planner aids the aircraft to fly on a set mission without the user giving significant data for the location and thus, solves the basic navigation purpose to create autonomous flight control.

3.2 Controller Design

The controller is built primarily on MATLAB Simulink which allows development of algorithms and program models using the blocks from the Simulink library and by using the traditional way of writing codes. For the design, we have used graphical way for designing program and also using blocks from Pixhawk Simulink components. The Pixhawk Pilot Package allows the use of components for Pixhawk flight management. The model can be simulated for control system and is useful to obtain sensor data and other parameters.

For controller development, the various testing approaches are used. I used and thoroughly supervised the controller in SIL and HIL platforms before it could be run on main airplane. Software-in-loop (SIL) is the simulations for the controller and run on the computer on a software platform. It helps to determine the performance of the model and its execution and therefore, to resolve any issues. Hardware-in-loop is testing of the controller model with the actual hardware system, which is in addition to the main aircraft. It helps to cater any physical errors and show a detailed results of their functioning and results. For SIL, the MATLAB platform, Mission Planner and X-Plane are used while for HIL, a real separate plane is used which is discussed in flight test sections of this chapter. It therefore, gives the user a chance to reduce risks and in exercising the controller in the aircraft after successful testing.

Attitude control system [8] consists of multitude subsections which are used to control, vary the plane orientation in the space coordinates during any inflight operation for stability. It requires various sensors and a optimum controller to apply the changes and maintain its position while navigating to other waypoints. The aircraft orientation in space is its attitude and it must be stabilized via any of controller. In our system, I use roll and pitch to control the position which is further discussed in next section.

3.2.1 Pixhawk Simulink Block Library

Simulink blocks are used to interface directly with the Pixhawk hardware. The Simulink toolbox and drivers are installed. C-Make is additional software which is used to convert the controller in C code which the recognizable format. There are several interface blocks and are found under Pixhawk target blocks in library. These blocks include: battery measure, input RC, PWM output, RGB LED, sensor combines, speaker tune, vehicle attitude and vehicle GPS [11]. These components are very intrigate and have several configurations and internal parameter settings which is used, varied to obtain the desired performance from the control system. These individual descriptions of these components are given below:

Input RC is used to interface the RC controller and its signals to the control system. For this control system, 6 channels are used to control roll, pitch, yaw, throttle and ARM control. It has other few configurations like channel count, failsafe, lost connection.

PWM output is the output from the control system and sends the data to the Pixhawk hardware. It is used to control the speed of motor in quad rotor, propellers in UAV. The frequency can be selected and can turn the output as true according to Boolean.

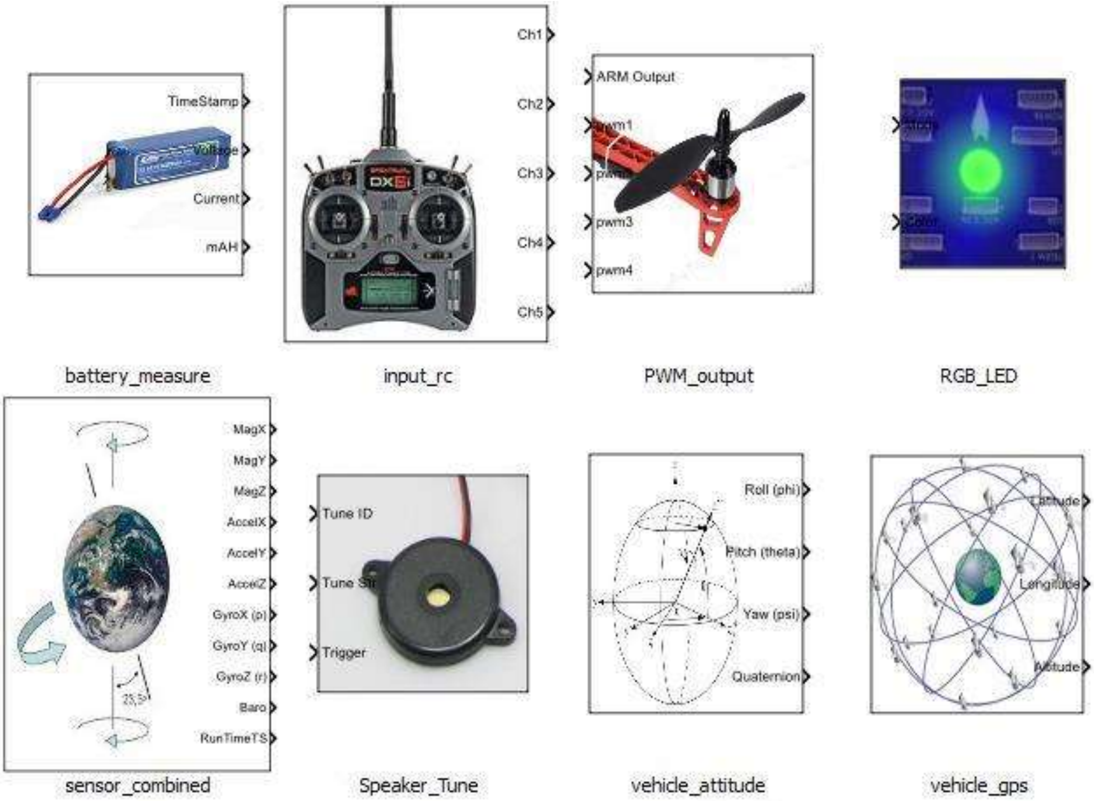


Figure 3.3: Pixhawk Target Block

Speaker Tune is used to control the tunes from the Pixhawk. It has 3 options tune ID for inbuilt tunes, str for custom tunes and trigger for any change in values which acts as an indicator.

RGB LED allows the user to observe and see various lights on Pixhawk. It accepts mode and colour commands. The colour option can vary the light on hardware while the block in the control system can vary modes.

Sensors combined displays all the sensors used in the airplane. These include gyroscope, barometer, accelerometer etc. In my aircraft, barometer is used since it is available inside the Pixhawk and calculates the altitude based on pressure difference.

Vehicle attitude gives the current attitude based on sensor data and switching state estimators. It uses roll, pitch and yaw angle values at current position. Battery measure gives the status and various measurements of the battery like voltage, mAH, current, timestamp of measurement.

Vehicle GPS gives the latitude, longitudes, position, velocity, fix type etc signal values. Although in my control system, only the latitude and longitude are used which are measure of global coordinates and employed for navigation purpose. Apart from these blocks, there are blocks like binary blogger, print function, read ADC.

3.2.2 Control System Description

The UAV requires a robust control system [5] which can control and stabilize the aircraft. The controller is designed in Simulink and contains dynamic algorithm designed by assessment of flight parameters and by Pixhawk demo guide. The controller contains various parts for manual and autonomous control using control theory fundamentals. To obtain the optimal stability in aircraft, all bank angles must be correct so drag ratio is optimum so the altitude would be even. It is known that the roll angle is non-proportional to radius and proportional speed. The controller uses roll pitch for controlled flight. The servo control is also essential to control heading and attitude of the airplane.

The controller system in the figure 3.4 depicts the basic input and output of the system. The control system inputs and output contains the elements from Simulink component library which are described in previous section. The vehicle attitude contains the roll, pitch and yaw of the aircraft which are the angles for attitude control. These are pre-defined in degrees so to change degree to radian, I used gain with 180/pi along with data conversion block which converts the input and scales up the element via output form. The RC six channels are control from futaba controller for elevators, rudder, ailerons which are control surface. The GPS is the module which shows the position of the plane in form of global coordinates- latitudes and longitudes. The sensors are the sensor placed on board which is barometer which is incorporated inside the Pixhawk module. These all are attached to control block and data conversion block. The outputs from the system are for motor and servo control given by PWM output and ARM output. The speaker and LED acts as an indicator of Pixhawk for various mode and connected with tune mode and RGB mode subsystem in order to access the signal and represent it to the user. All the inputs and ARM output are connected to data converter which is connected to multiplexor, which acts as a function of converting many signals to one. The rate transition element allows the system to transfer data at different rate and with deterministic delay time to UART.

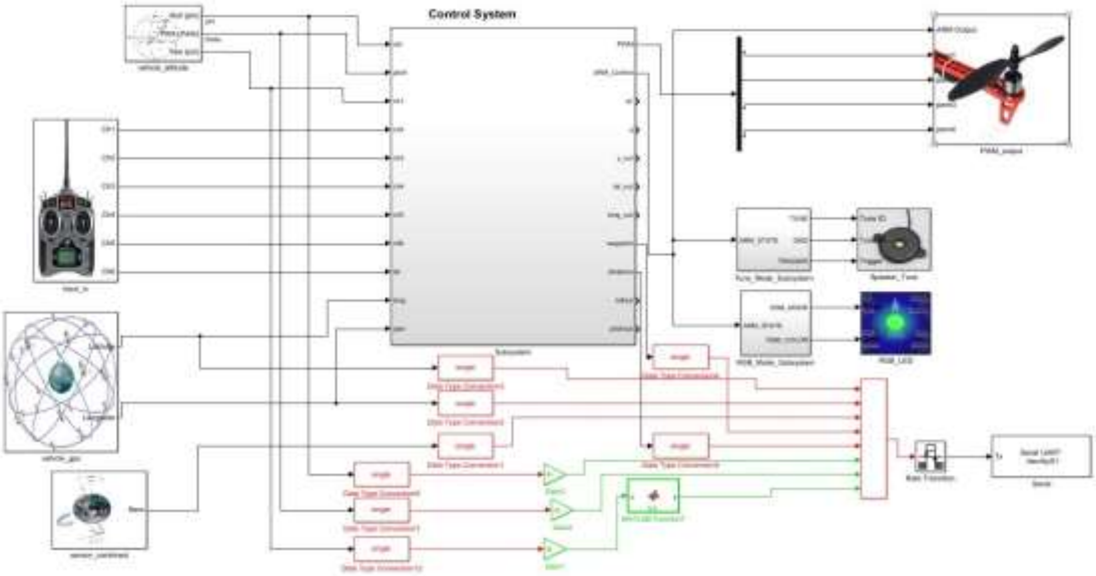


Figure 3.4: Controller input/output

The sub-system of the control system is shown in figure 3.5. The switch in RC is from SA-SH for different use. However, the pilot sets up only couple of switches which are implemented in the control system too which acts as model control and to activate various flight modes/ features. The switch has lever for binary 0 and 1 in which 0 is for implantation of controller from Pixhawk while 1 is manual operation. The outputs are connected to another system which contains the roll, pitch, yaw angles along with the plane angles at the respective position which are phi, theta and psi. The GPS coordinates are also given to the altitude control.

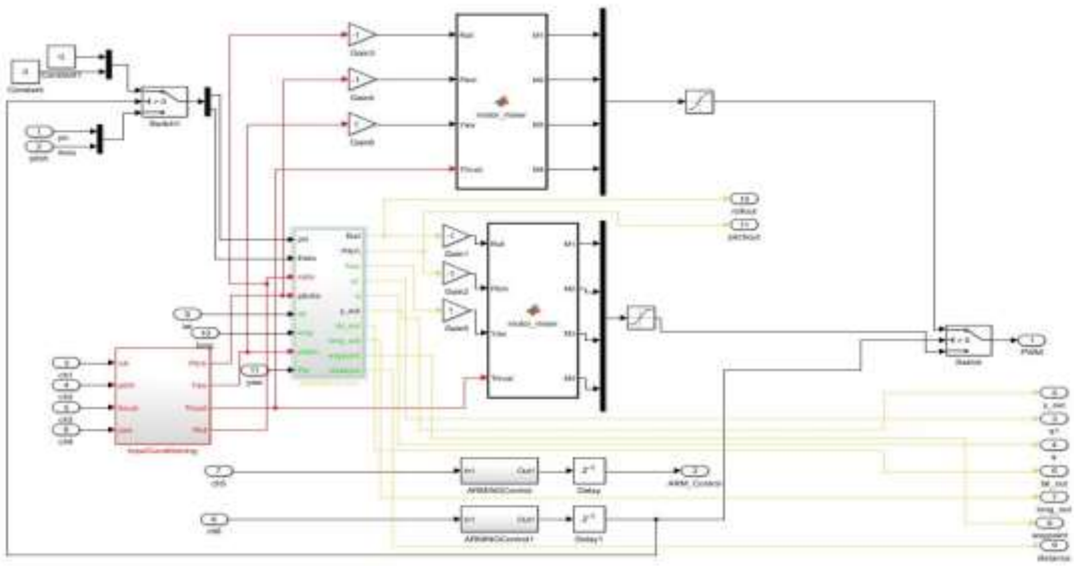


Figure 3.5: Controller subsystem elements

In the RC controller, the gimbal range is from 1100 to 1900, hence to make it to even system; conversion of signals is done which is represented in figure 3.6. It converts the 1100 to 1900 in range of -1 to 1, in which 1 represents the positive or up control while 0 is negative or down control. The saturation signal is used to limit input values and to get a stronger response.

Figure 3.6: Conversion of system range to binary values

The channel 5 and 6 are for Arming control which allows the motor, propeller to start moving along with control servos. It is connected with delay and to switch for changeover function. There are 2 motor commands for roll, pitch, yaw and thrust: one for autonomous controller or implementation of control system and other for manual operation. The gains are used to make the servo move in upward direction and their outputs are connected to various ports. The arm control is connected to another switch for safety and manual output. These are the same output which are in basic plant model of the control system. The attitude control block is further represented in figure 3.7 along with its functioning.

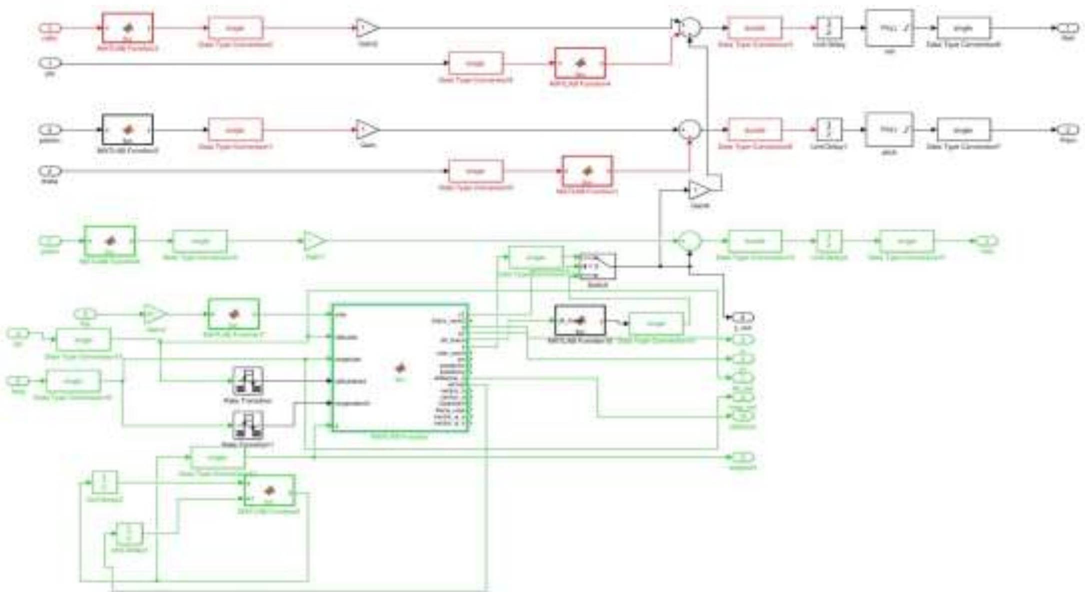


Figure 3.7: Attitude control system

The attitude control system should have exactly same parameters as it controls the flight control model. The three-axis autopilot approach is adopted in which the primary goal is to control and stabilize roll and yaw axes which is then processed by yaw control. The controller implements the autopilot for stability, navigation and servos. The roll and pitch stabilization works on tilt axis which measures the angles and continuously monitors with roll/pitch. It gives roll and sense of turning.

The controller uses two signals from controller and aircraft which are compared using a comparator and then PI controller. The PI is used instead of PID as it takes fewer times and is suitable for small measure of time. This is adopted for roll/phi and pitch/theta, while the yaw is controlled using the function block. The yaw angle is not employed for control purpose as 2 axis stabilization is used. The latitude and longitude position are updated continuously to the aircraft and its heading direction is given by function block in small increments.

The final positions are given to the function for y and u1 which ultimately gives waypoint direction. Hence, using the controller, it helps to stabilize the roll and pitch using the PI controller using the feedback command and updating it to the Pixhawk system on board. Following the attitude control, the signals are sent to the motor control for M1-M4 which helps in optimal control. The output command is saturated and given as PWM output to propeller and servo control.

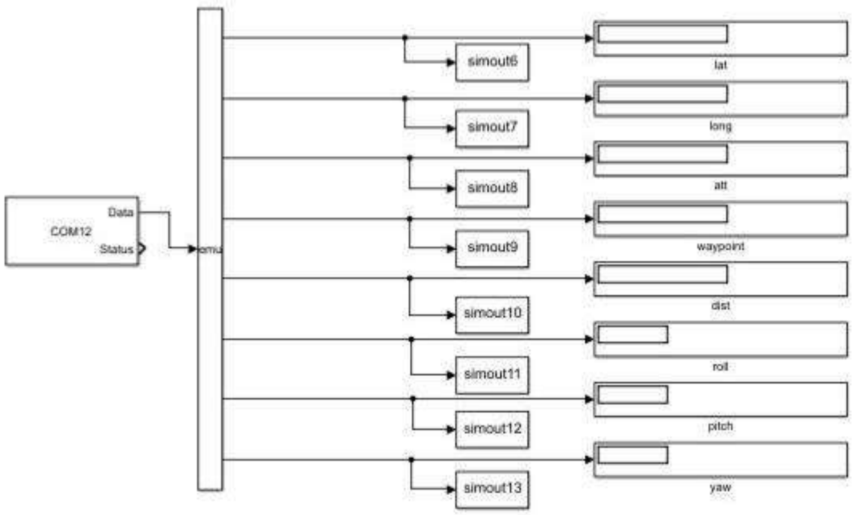


Figure 3.8: Ground control module

The ground control gives the flight control parameters data while the aircraft is flying with ArduPilot and Pixhawk configuration. It displays various data, mission planning for the aerial vehicles. It is implemented on the Simulink platform. The COM12 is the transmitter installed on the aircraft and data is sent via fly telemetry module to the ground control module configured with the laptop. It gives real time data of aircraft using on board hardware and shows current latitude, longitude, attitude, waypoint, distance, roll, pitch and yaw components, which is shown in figure 3.8.

3.3 Pixhawk Module

Pixhawk [4] is an auto-pilot hardware which is used by users for developing and running their projects for aerial aircrafts using various options for on-board components. The Pixhawk is able to incorporate a memory card with MATLAB functions converted using C-Make for all their operations. The Pixhawk is one stop hardware for control as it can control all the surfaces, obtain and transmit data. There are various Pixhawk available and for this aircraft, HKPILOT32 is used.

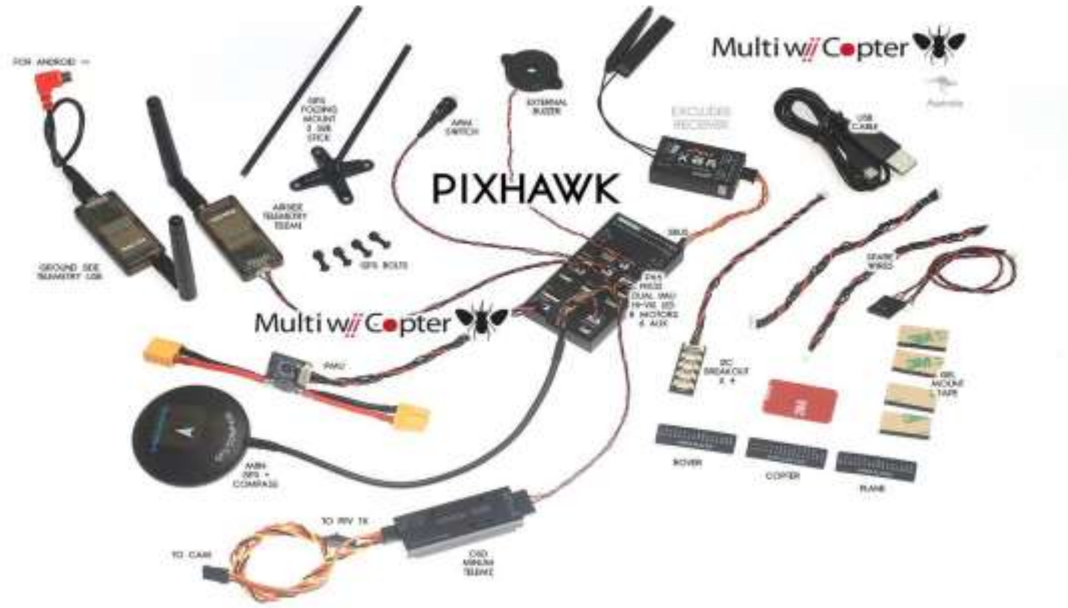


Figure 3.9: Pixhawk module connections

The Pixhawk has 168 MHz/256 kb memory with in-built sensors like gyroscope, accelerometer, barometer. It is extremely light weight with 33.1 gm and size of 81*44*15 mm and is secured in place by Velcro and double sided tape. The Pixhawk connections samples are illustrated by figure 3.9. The servos, GPS, telemetry transmitter, receiver are all connected by the module. The Pixhawk is tested various time using RC controller and by inserting the C code program to check its functionality and determine its working. The flight test of the program and controller is implemented by test plane.

3.4 Flight Testing

The testing for flight to observe its performance and functionality under a given situation help to get more detail about plane, analyse its characteristics. It helps to check the system, validate the performance and also, about safety requirements. There are various tests for flight test done to check but in this section, the testing is done in software-in-loop and in hardware-in-loop using software and real flying test. This helps to find and fix any flaw in controller and assess its working and if it meets our desired criteria.

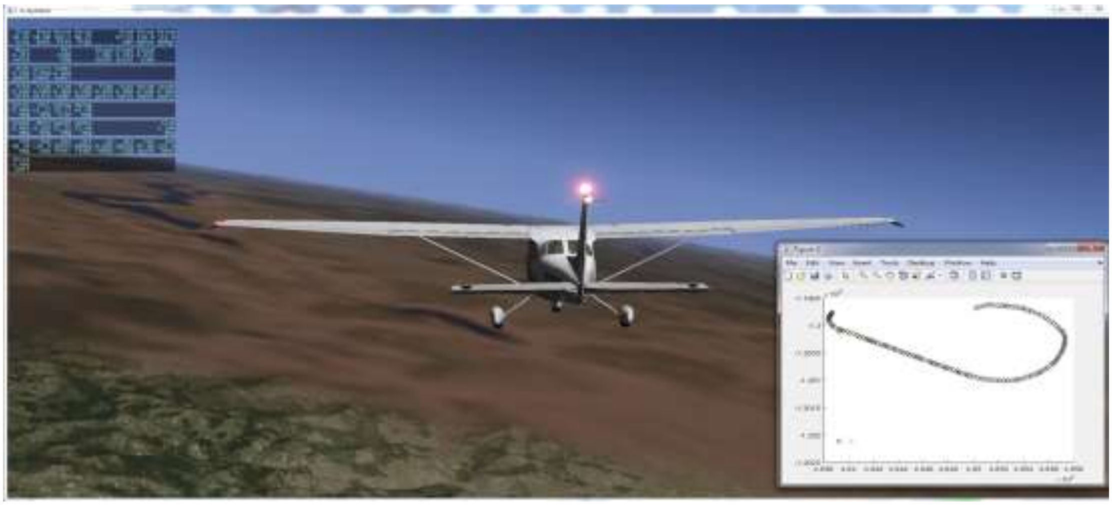


Figure 3.10: Simulation in X-Plane

X-Plane is software which uses Simulink model to run the controller and simulates its performance on the software. It is powerful software which can control dynamics, noise, sensors and plane orientation. The plane data can be seen real time on the software and various missions can be set using waypoint, to navigate the plane from staring position to target location.

Figure 3.11: Flight test

It helps to visualize the controller performance and to validate if the controller will stabilize itself along roll and pitch axis. The X-Plane settings are adjusted and configured according to the plane. The model is used for guidance and control while the airplane dynamics and navigation are done by X-Plane from the sender to the plane receiver. The simulation of 4 waypoints is done and the results displayed plane is able to align itself in presence of disturbances too [7].

The controller was also tested using a model plane to simulate the controller performance. The figure 3.11 shows image of plane flying and navigating itself to waypoints without the RC input. The test showed the implementation and expected data as it was achieved in the SIL. The data for the plane path was taken and monitored using ground station control. Therefore, the plane is able to stabilize itself while flying using the attitude and auto controller and also, navigate to waypoints from one location to another using Mission Planner path. The plane is successfully able to transmit and receive data at a fixed channel without any disturbances. In the next chapter, the description and methodology along with testing of all the avionics and communication elements are mentioned.

CHAPTER- 4 FABRICATION AND IMPLEMENTATION OF AVIONICS

The aircraft fabrication is a major step towards reaching the desired objectives to fly the UAV in autonomous manner. The aircraft design is made by structure and design members and its testing is done for force, load, vibration, damping etc. The avionics division is an essential part which caters the need for the entire functional requirement like direction, control, navigation, flight data etc. In this chapter, I will discuss about the work done by me in the fabrication of aircraft, employing avionics component and its installation accompanied by the test process, if any [6].

4.1 Airframe Material

The aircraft material forms the foundation of the UAV. The objectives of selecting a material depends on its strength, load carrying capacity, flexibility, weight etc. The aircraft frame is made up for Base wood while the auxiliary structures like wings, fuselage is made up of Balsa wood. The wooden structure is light weight, and inexpensive which makes it ideal and to cover up for aesthetics, it is later covered up in films. The wooden structure can be easily carved; cut and repaired allowing ease of fabrication as compared to aluminium or composites.

The Balsa wood is superlight, durable, sturdy and easily shaped wood which is used to make the cover of aircraft main body, elevators, rudder, and fuselage. Though it takes a lot of time to carve and special care is required so the individual doesn’t damage or break the wood. Base wood is comparatively harder, thicker and has more tensile strength and it is used in making the body and frame of the aircraft. It is easily cut by application of CNC wire cut machines. It can be easily enforced by use of various adhesives as discussed in section 4.1.1.

4.1.1 Adhesives

The adhesives are used to bind and interlock the two surfaces. The selection of adhesives is crucial as it determines the strength and bond between the two surfaces. Foe the MK-III, the use of AB glue, super glue and resin based glass fibre (composting) has been used. The images in figure 4.1, 4.2 and 4.3 illustrates the use of several adhesives used in the fabrication process along with the kind of material used in making the airplane structure and body.

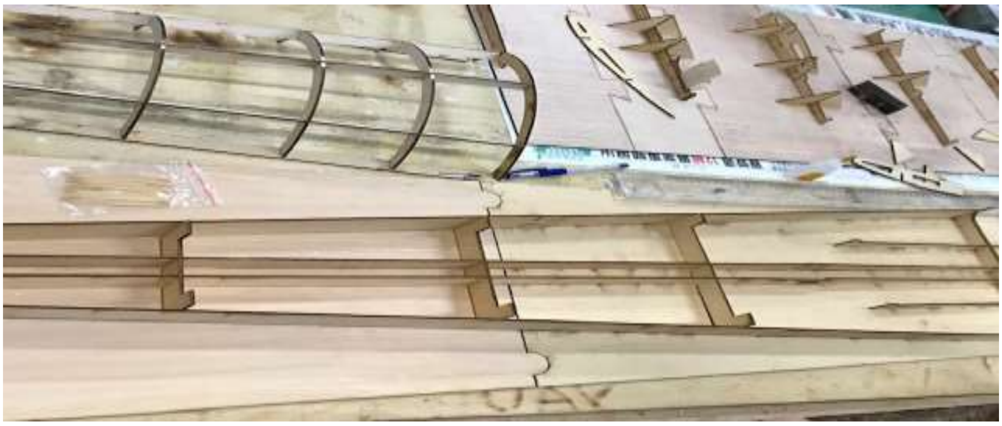


Figure 4.1: Aircraft frame made with base wood

Figure 4.2, 4.3: Super glue and AB Glue

The AB glue is used in 1:1 ratio and mixed to form a even texture which is further used on base wood and other connections. The glue takes around 5-7 minutes to harden up. The bond has high mechanical properties like strength, toughness and hardness. The super glue is very fast to cure, (3 sec to 3 minutes) and has high bond strength. It is used to secure connections with less space and connections with light materials like balsa wood. The epoxy based glass resin is used to secure the high load bearing members in the frame like the connections in the base wood. After placing a weight over-night, the bonds become very durable and hard, which fulfils the needs.

4.2 Avionics and Communication Systems

The avionics system constitutes all the electronics component used in an aircraft and is correlated with communication division. This system must be precisely placed and should be monitored continuously as all the plane performance and safety depends on the avionics.

A typical avionics system constitutes of communication, control system, navigation and monitoring. The goal of avionics is to reach autonomous control, collect flight data and optimize power by considering size and weight of the individual components. Navigation and communication system enables an UAV to transmit data at a particular frequency. The transmitter range depends on the power or gain so inorder to maximize the distance, one of those parameters should be increased. In the following sections, I will enumerate on avionics hardware used in the MK-III.

4.3 Lifting and Control Surface

The lifting surface involves wings, elevators etc with the aim to ease flying and to make aerodynamics better for turns and movements. To fabricate the lifting surface, the main structure and stress bearing members are made up of base wood and the cover, outer body is covered with balsa wood, enabling them the proper shape and fit. Then, the surface is covered with Mylar film. Mylar films are thin plastic sheet made from a resin called as Polyethylene Terephthalate. This film enhances the strength, durability, and aesthetics. It protects the UAV from damage and gives more resistance from oil, dirt and dust. These films are covered using a sealing iron and air blower to shrink and to cover the plane body securely, allowing no gaps or cavity.

Figure 4.4: Fabrication of main wing with balsa.

The control surfaces are the movable surface on aircraft lifting surface. These create a pressure difference to facilitate the movement of aircraft in the desired direction. The main control surface includes rudder, ailerons and elevators. The ailerons are used to control roll and mounted near the end of main wings, typically moves in opposite direction to control lift.

Rudder is mounted on the fail in the vertical direction and controls yaw movement that is vertical axis movement. Elevators are the movable horizontal part attached on the aircraft tail and move in the same direction; it causes the plane movement in up and down way.

Figure 4.5: Main wings with ailerons covered in Mylar film

4.4 Servos

The servos are used extensively for roll, pitch and yaw controls which are used on the control and lifting surfaces. The servo gives an impeccable control and able to perform many tasks pertaining to flight performance. There are various types of servos available, for the MK-III, Savox servos are used and of 2 sizes according to their specifications as listed in table 4.1 for 2 models SH-0256 and SA1230SG.

Figure 4.6: Savox SH-0256 with composite gear set

The servo system used tend to vary on specifications like size, length, torque, performance, hence, the Savox have shown incredible results without much fatigue or damage though they cost more than general servo brands like Hitec, Futaba, MKS etc. These servo have aluminium outer casing with ball bearded mechanism allowing fine resolution, accurate and quick response. These employ use of 3-Pole Brushed motor.

Table 4.1 Servo properties

Specifications	SH-0256	SA1230SG
Input Voltage	4.8-6 V	4.8-6 V
Length (mm)	22.4	40.3
Height (mm)	12	20.2
Width (mm)	29.4	45
Weight (g)	15.8	79
Torque (Kg/cm)	4.6	36
Speed (60/s)	0.16 sec/60	0.20 sec/60
Gear Spline (Teeth)	21	25

The servos are used on the lifting surface to control the surface like ailerons, elevators, rudder and tail wheel. The 2 servo used on ailerons and for tail wheel are SA1230SG while 2+1 servo used in elevators and rudder control are comparatively smaller, SH-0256.

The installation of servo to the lifting surface is an intriguing task and care must be taken to ensure that two servo on the same wing are aligned properly. To avoid this, the rubber attachment to the metal extension is placed to absorb shocks and unnecessary twists. The fixing of servo is almost the same for two kings of model used in the aircraft. The end of servos are mounted with the cushion layer of basewood and balsa wood which acts as the leverage to fix and screw them on the structure. The screws are drilled on the wood and then using AB glue, it is placed in the wing. To ensure sealed ends, powered wood is reinforced to the surface touching the plane with super glue; it gives additional stability and strength. The composite gear attachments are then mounted with the lever set and screw is inserted which acts as the clamp. The washer and screw are then firmly attached in the gear set cavity. These servos are used in moving the surface and during flying, it holds up a lot of wing force, so the mounting and bolting should be very firm and several tests are taken to ensure this. The linking mechanism is called as servo horn which acts an arm and moves so the control surface is able to move in up or down direction. The servo resemble a four bar mechanism.

Figure 4.7: Installed servo on the left wing

After the installation, it is important to check its neutral position and it should align with the resting wing surface else it could led to crash, burning of servo and overheating. To check this, we use a secondary power supply and multi-function tester. The knob is used to change the servo angle manually, using the set value with help of Align multi-function tester using RCE-MT9. This helps to establish the control and servo performance mimicking to the situation when the total in-wirings are completed. It works in auto mode after giving the value, for our purpose we use 1520u and by using the actual battery so incorporate the same voltage.

Figure 4.8: Align RCE-MT9 multifunction tester for servo

4.5 Ground Station

The ground station is the system of hardware that is used to monitor the flight performance, to receive and transmit commands and to obtain all kinds of data. Ground station is an essential component for the UAVs avionics system and through inspection, mounting, installation should be done to check its control and performance. The telemetry data is the data which is used to send and receive data from the ground station and to UAV. It includes data like altitude, speed, angles, battery status etc.

Telemetry modules which are connected to the ground station are the main system which transmit and interpret any signal and it is essential to pair and synchronise them to communicate efficiently. For the MK-III, the ground station includes several components, namely: MyflyDream Automatic Antenna Tracker, Telefly Pro OSD, AAT Driver, Tracker, USB programmer cable and connecting cables with a tripod stand. Other things which are required for the communication division includes sensors, Pixhawk module, power management module, connector pins, transmitter, receiver, radio control, screen display system and battery.

The AAT [13] are the tracking system that are useful in tracking the location of UAVs, it determines the position of the UAV by transmitter signals and orient itself. The use of these systems is that they enhance the range of signals for transmitting any kind of telemetry data for communications. To obtain high quality video signal, a high gain antennas are used thus, the hardware used in MK-III keeps the antenna pointed at the plane throughout the flight. It works by reading data from GPS, then encodes the plane position and determines altitude which is fed to video transmitter to be sent to ground station, and finally to the display module. The AAT driver is secondary attachment with tracker system which helps in demodulating and decoding the signal to ger plane orientation and other information. After the processing, it sends back the information to AAT which is synchronised by internal servo to keep up with plane direction. The driver is mounted along with tracker system on the stand. It consumes 12V power and weighs 66 gms with current consumption of 80mA. The connection of driver to AAT is done by using DC barrel plug cable to output connector. The installation and subsequent images shows the connection of AAT System with driver, Radio link as in figure 4.8.

The radio link is also called as point to point connection which is wireless and is connected with AAT system. These systems are mounted on top which allows transferring at high rates. The black rectangular box in the below figure is the radio link and connected with antenna.

Figure 4.9: Ground station system

The mounting includes the antenna and its locker which are secured firmly by screws on the wooden platform to provide structural support. The 3 cables are connected for power, video and audio signal to the tracker. The power requirement is 12V which is given by battery and connected by 5.5mm plug.The ground station is paired and is a part of communication system and the other hardware system are listed below which are finally tested in the next segment. To check just the ground station, it is powered using a secondary battery and for correct connections, the LED of the driver blinks very fast which means that the driver is successfully able to do the demodulation task of tracking data to video signal. The beep sound is also an indication of power on and the antenna sets itself to a fixed determined angle of 30 degree. This test is done every time to check the connections and overall system to avoid any damage.

4.5.1 OSD

On-Screen Display or OSD is useful to display flight information parameters and video link of camera to the FPV screen feed. In the UAV, this is connected in the avionics with the other hardware necessities. It is integrated with camera which allows the user to get the real time status during the flying operation. It is used to display levels of altitude, heading, speed, battery level, voltage, current etc. It is an addition to the UAV as it helps in better monitoring and surveying of plane performance and situation.

MFD Telyflypro OSD helps to modulate the data to video feed which is done by video transmitter- receiver module which can be used to track the plane and record the data for better control, and many applications. This model employs the barometer for altitude detection which is more precise than GPS, and additionally 100Amp current sensor can be used to measure current or voltage.

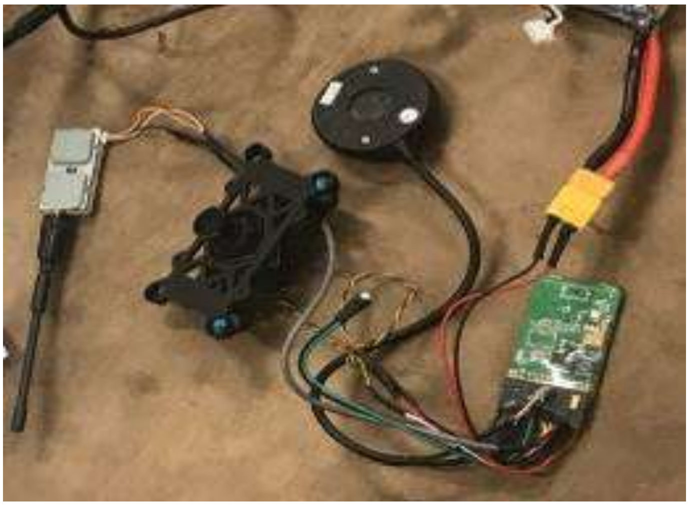


Figure 4.10: OSD connections

The connections for OSD are represented in figure 4.9. The OSD helps to sends live video feed using camera and transmitter via Channel 1 to the receiver which is attached to display monitor. The pin 1 and 14 are used to give power which is connected to battery and 3,4,5 to camera. The GPS is connected to pin 23-26 and video TX is connected to pin 16-19. This system is attached to the plane and is tested several times prior to final installation.

4.5.2 Transmitter/ Receiver

The transmitter and receiver are 2 elements that make up the radio control system for UAV communication. It uses the radio signals at a particular frequency to send signals to a receiver. For the RC control, the Futaba T14SG has been used as gives frequency control and allows viewing telemetry data adequately at 2.4GHz with 14 channel system. The products are well built, extremely robust with good communication systems with an effective range of 1000 metres. The receivers and transmitters are set to the same channel to bind the signals properly and is tested which is illustrated in further sub-sections. For each control, a specific channel is need by the controller, for instance, the two gimbals can make 4 channels comprising of roll, pitch, yaw and throttle. The remaining channels are used for controls such as flight mode change, alarm; state arm etc and these can be configured in 4 modes. The mode differs in the control settings like in mode 1 elevator is controlled on left side but on right side in mode 2 [14].

Figure 4.11: Operation of RC Controller

The receiver also termed as RX is the hardware system that allows the device to receive signals and commands which is then sent to controller. The radio transmitter, TX works with a system protocol and is given by the brand. The flight information data which is telemetry data is received or transmitted by two separate module- FPV Radio Telemetry Ground module and Air Module. These depict information like current, altitude, heading, speed and so on. MK-III uses multiple receivers which gives the advantage to switch over if the signal is weak or if any issue arises in any form of transmission.

4.5.3 GPS

GPS is used for navigation, tracking waypoints and determining the location of the aircraft. The position is received by the ground station via on board receivers and then the subsequent position or directions can be given manually or via autonomous control by setting of waypoints. It is imperative to get a precise and a very accurate location for all the control implication and to avoid any damage. With the Pixhawk module, the GPS hardware is available which is used in this plane. The rate of transmission that is baud rate is 38400 5HZ and has features like; navigation sensitivity, ceramic antenna, noise regulator and indicators LEDs. The autopilot hardware employs uses its own GPS that gives centimetre precision.

4.5.4 Payload Systems

The autopilot or autonomous systems use additional payload system, consisting of a downlink for camera systems. The camera is an accessory in MK-II which is installed on the bottom middle section of the aircraft, which can be used to gather the video output of the plane. This is connected to the OSD systems and tested its operation in the total ground station test.

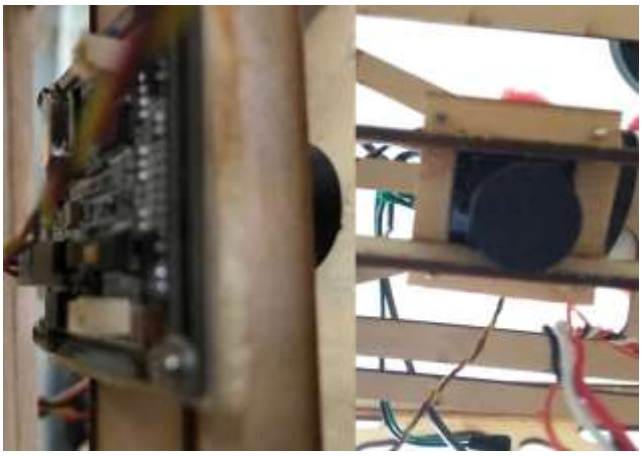


Figure 4.12: On-board camera mounting in side and top view

The camera acts as FPV with wide viewing angle with 2.5mm lens. Its dimension extend to 25 mm square and has 3 channels; red for DC 5V, black for ground and yellow for video transmission. The camera is 1000 TV line camera which is a measure of camera fineness and resolution. It uses a CMOS sensor and gives sufficient output when operating and has a 45 degrees adjustable tilt angle. To provide safety, it is protected by Flight control damping plate which acts a shock absorber.

4.6 Power requirements

The power is the source through which all the electronics part in the aircraft works therefore, having adequate amount of power to run servo, Pixhawk, OSD, transmitter , receiver and other electronics component is important. Since, there are many components, the airplane uses multiple battery packs to it is easy to give power and monitor the requirements according to different power consumptions. The current drawn by different servos are checked prior. The power supply is very essential to the aircraft performance and safety so multiple battery system is used and still periodically checked like from 100% to 50%. The LEDs are also used as an indicator along with buzzer but those become very hard to detect while flying at high altitudes in different visibility.

For the UAV, we use LiPo batteries [12] which are Lithium Polymer batteries which are very different to ordinary batteries as they have large energy density which is capable of storing more energy. These are not particularly heavy. The various mAh of batteries used are of 2200,2800, 4800 and 5200 mAh. Total of more than 20000 mAh batteries are employed which can run plane for over one hour without any issue.

The batteries are secured with velcro in the aircraft which enables a strong traction force and doesn't displace itself or disconnect during the operation. The ends of wires needs to be connected with battery connectors, we use XT60 male/female for this purpose. The wires are clipped of their shells and heat shrink is added before the soldering operation between the wires and the connector and the flux is melted on the surface. This allows pretty tight and secure connections for long term applications.

Figure 4.13: LiPo batteries with secured XT60 connector

4.7 Ground Station Testing

Inorder to check the functioning and data transmission capabilities, we run a demo test for ground station and its entire component. This can be compared to actual working with the difference being that the aircraft is not flying. The hardware elements, GPS, RC, OSD, camera, transmitter, receiver, antenna tracker and batteries are all connected with proper wiring. The OSD is the link between the other elements and to transmit data, a particular frequency is required, therefore, RC frequency and transmitter frequency shouldn’t match so it is kept as 1000GHz, else due to mixing of frequency signals, the commands may be lost and result in plane crash, which was the case in last flight test. The setup is connected with power supply and ground station is also powered which ultimately gives output on display device. The radio link and transmitter has 8 channels for communication, I check the transmission capabilities of each channel and the output is verified by the display device as it shows the video output. The ground station operation is indicated by red light on driver.

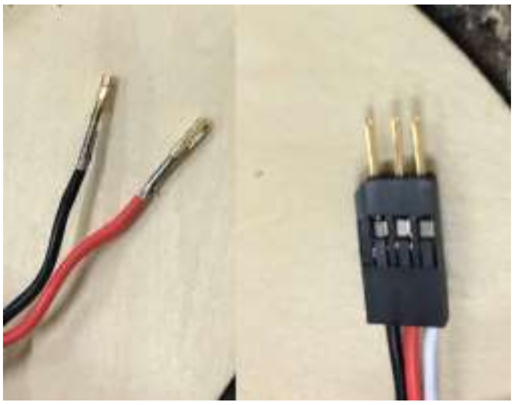
Furthermore, the servo capabilities are also checked using RC control by placing a test servo to see if it responds to gimbal control on the controller by moving its arm. Following images show the ground station test with avionics component for the UAV. The testing was successful for all the channels transmission and the avionics system is implemented on the aircraft.

Figure 4.14 (a) & (b): Ground station testing with avionics component

4.8 Wirings and additional connections

The wiring provides the framework for the electronics components. The wiring is done to connect the entire component in the aircraft like servos, controller, transmitter, OSD, etc. The wires are laid on the base wood and are also secured so they function without any loose connection or any cuts. We use the heat shrink and plastic cap insulation for all the wires so provide secure and tight connection and utmost safety.

The wiring connections depend on the plugs used to power the components. We tend to use three part wire connector which depends on the connector type like for battery, XT60 is used, for the servos, JST connector plug pins and male, female RCY connector are used. This when secured in 3 way plastic case, increase the standard and are self-locking so this approach consumes time and requires steady effort but provides the best connection required for moving aircraft.



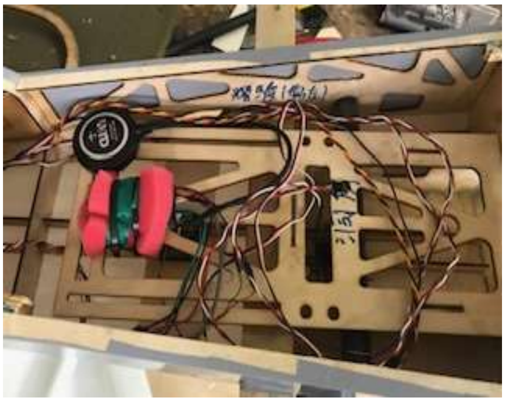


Figure 4.15: JST RCY connector pins

Figure 4.16: Wiring of avionics component

4.8.1 Propeller

The propulsion system is used for UAVs for long endurance and to support flying, the system should be light weight, vibration free and should not consume much power. The two blade propeller is used as gives better efficiency. For the MK-III, electric system is used and avionics division is concerned with its assembly and operation only. The main goal of my division is to install and operate propeller to the front of the plane structure. The system is mounted suing screws and drill securely while the connections for propeller are done by 3 channels wire. These wires are connected to the futaba receiver R6208SB which is done by provide throttle control.

Futaba R6208SB is a receiver and is compatible with all forms of conventional systems; it is very light and requires 3.7-7.4 V. It has 8 channel of operation and the propeller command is assigned to channel 3. The figure below shows the propeller with wiring connections.

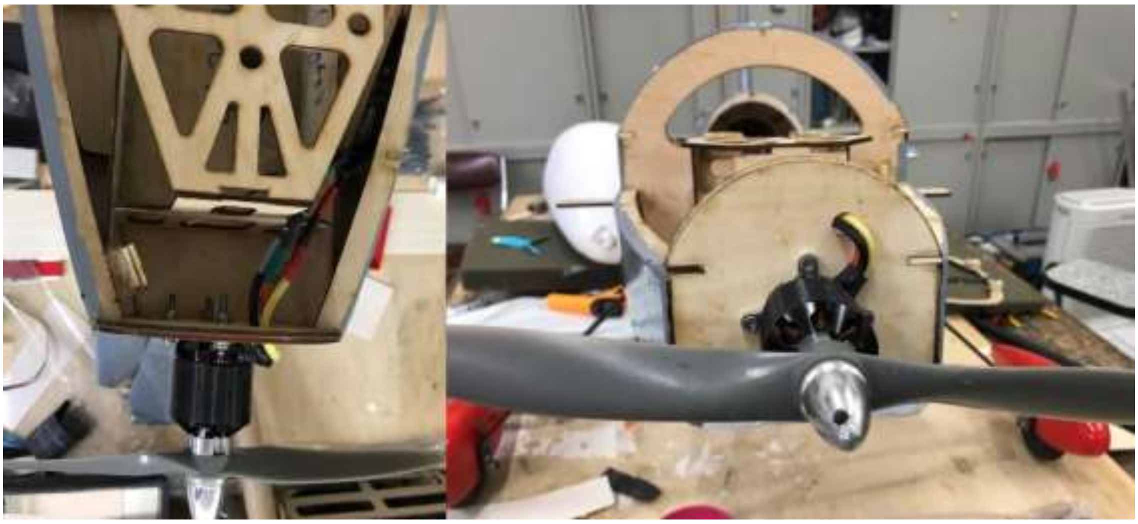


Figure 4.17: Propulsion system

The avionics components and its installation are dealt with and the control system/ which supports the various autonomous capabilities is all finished on the aircraft. T/here is however some work to be implemented by structure division on the MK-III// before it is assembled completely. All the essential examination for components, functional testing and operation has been completed several times. The image below is the final image of the project.

Figure 4.18: Scorpio Mark-III plane

CHAPTER- 5 CONCLUSIONS AND FUTURE SCOPE

5.1 Conclusions

In this project, my work focused on collaborating with the UAV team to fabricate, design and test their new airplane Scorpio Mark-III. My work begun with fabricating the design and structure of aircraft using the CNC wire cut machine and assembling the parts to the body of the aircraft. My primary work focused on working with avionics and communication division. As there are a lot of intricate part and is crucial for the plane efficient working, so a control approach was adopted.

The main controller was built in MATLAB Simulink software which employed the use of Pixhawk PX32 library components and using model control operation from futaba RC controller for manual and autonomous control. The controller used roll, pitch and yaw angles from user and plane and using PI controller to provide stability, heading and optimal control. The various soft wares which compliment this controller uses Simulink 2018B, C Make, X-plane and Mission Planner. Mission planner is used to give waypoints for auto control while the ground station is built in Simulink 18b. C-Make is used to change the model from MATLAB to readable C code.

The hardware implementation used various components from servos, transmitter, receiver, ground station module, batteries, Pixhawk module, GPS, RC controller, OSD, camera, control surface, propeller, various connectors like XT-60, JST for secure connections.

The testing was done various times for all the steps and upon successful results in SIL and HIL; they were adopted on the system. The controller uses 2 axis stabilization and attitude controller which show satisfying and desired results. The various simulations demonstrates the efficient control system which can use controller model to fly in autonomous mode while using the plane's avionics and communication system are used to interact and send telemetry data to the ground station hardware and program on MATLAB.

5.2 Future scope

In the future, the autonomous controller can be built on more sophisticated aircraft like rotary wing aircraft. The 3 axis control can be used which can do more complex task. The introduction of fail-safe or collision avoidance between aerial vehicles is important for proper coordination and safety. The on-board sensors can include IMU and lightweight MAVLink too with the avionics system. The system approach can be researched for autonomous quad rotor which can navigate and do path planning without using waypoints by building maps and using a series of sensors to maintain position and orientation. These types of technologies and research methodology will be very useful for some applications and vastly, increase quality of life.

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