MODELLING AND CONTROL LAW DESIGN OF UNMANNED AERIAL VEHICLE

A MAJOR PROJECT REPORT

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THESIS CERTIFICATE

We hereby certify that the work which is being presented in the project report entitled **"Modelling and Control Law Design of Unmanned Aerial Vehicle"** in partial fulfillment of the requirements for the satisfactory performance for B.Tech Avionics Engineering, Major Project submitted in the Department of Aerospace Engineering, University of Petroleum and Energy Studies, Dehradun is an authentic record of our own work carried out during a period from July 2012 to April 2013.

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Prof. A.J.Arun Jeya Prakash

Guide

Date: 17 April' 2013

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ABSTRACT

KEYWORDS: UAV, Simulation flight model, Trim determination, Flight dynamics analysis, designing the control laws, Gain scheduling development, Simulation of control laws

Modeling and control law design of an Unmanned Aerial Vehicle is a complex multidisciplinary problem involving many disciplines e.g. aerodynamics, propulsion and flight control. Such design problem often has large dimensional design parameter spaces and consists of non continuous functions, making it extremely hard to solve. The purpose of this project is to design a control law of fixed wing unmanned air vehicle (UAV) using multidisciplinary aspects. This project seeks to optimize dimensions and performance parameters of the aircraft based on the desired flight characteristic. The model prepared for the design incorporates dimensional variables and flight performance parameters and is capable of being maneuvered by parallax propeller generating different performance metrics. The success of the flight eventually aid in the design and rapid prototyping of the aircraft. The design, implementation and feasibility analysis of this optimization program will be presented in the following report.

Prior to the development of the prototype model, conceptual model using solid work, flight performance equations, objective and constraints functions will be discussed, derived and implemented. The modeling of the aircraft consisting of various sensors implemented subsequently and demonstrate its ability to flight controlling the three axis gyros. The initial feasibility analysis of the prototype model involves the generated design and operational UAVs and remote controlled aircraft.

Some discrepancies are observed between theoretical, simulation and flight tests results and be discussed, analyzed and accounted for. Finally, the modeling and control law design has proven capable of flight with acceptable flight performance. Thus, this project has proven to be a feasible tool in designing of fixed wing UAVs.

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ABBREVIATIONS

AIS	Automatic Identification System
COG	Course over Ground
CEOS	Committee of Earth Observation Satellite
CFAR	Constant False Alarm Rate
DLR	German Aerospace Agency
DR	Dead-reckoning
DSTO	Department of Science & Technology Organization
ECS	Electronic Chart Display
GPS	Global Positioning System
GHz	Giga Hertz
GTC	General Test Committee
IEICE	Institute of Electronics, Information and Communication Engineers
IJUAV	International Journal of Unmanned Aerial Vehicle
KHz	Kilo Hertz
UAV	Unmanned Aerial Vehicle

NOTATIONS

English Symbols

AR	aspect ratio of the wing of the aircraft
b	wing span of the aircraft
c	wing chord of the aircraft
C_L	lift coefficient of the aircraft
C_{Lw}	lift coefficient of the wing of the aircraft
$C_{L\alpha t}$	lift coefficient slope of the tail of the aircraft
C_{Lt}	lift coefficient of the tail of the aircraft
$C_{L\alpha w}$	lift coefficient slope of the wing of the aircraft
CD	drag coefficient of the aircraft x
C_{De}	parasitic drag coefficient of the aircraft
C_{Di}	induced drag coefficient of the aircraft
C_{mcg}	pitching moment coefficient of the aircraft about the CG
C_{mo}	pitching moment coefficient of the aircraft at zero
C_{mow}	pitching moment coefficient of the wing at zero degree
C_{mof}	pitching moment coefficient of the fuselage at zero degree
$C_{m\alpha}$	pitching moment coefficient slope of the aircraft
$C_{m\alpha f}$	pitching moment coefficient slope of the fuselage
S_t	horizontal tail area
S	wing area
V_H	horizontal tail volume ratio
X_{cg}	CG position of the aircraft from the leading edge of the wing
X_{ac}	aerodynamic center of the aircraft from the leading edge of the wing
X_{NP}	neutral point position of the aircraft from the leading edge of the wing
V	velocity of the aircraft
W	weight of the aircraft
α	angle of attack of the wing of the aircraft
θ	Incidence angle
θ_a	Along-track angular position of target

CHAPTER 1

INTRODUCTION AND BACKGROUND

Currently most aircraft are designed for a single mission such as reconnaissance or flak. The geometry of an aircraft is dictated by the vehicles primary mission and is non optimal for other mission segments and roles. This results in reduced range, loiter, and the inability to operate from some airfields. The ability to change wing shape and vehicle geometry substantially while in light would allow a single vehicle to perform missions that are beyond current capabilities or to perform multiple tasks, including those done by separate aircraft operating as a large system. The ability to change wing shape or morph combines optimal performance into a single system. Performance benefits may include a low turning radius, long endurance, increased payload, and high speed tasks that cannot be efficiently combined into a single vehicle. These new vehicles over the potential of radically different light regimes. Unmanned aerial vehicles or UAVs" are the ideal platform to examine this new technology as pilot safety is not a concern.

1.1 Background and Overview

The interest in Unmanned Air Vehicles has increased tremendously over the past decade and a rise in its employment has been predicted for the next twenty years to come. Studies have been carried out on overall aspects of UAV design, such as cost-effectiveness and multidisciplinary optimization. Currently, in the area of design studies, majority of the work are dedicated the assessment of novel concepts such as inflatable and retractable wings. This report focuses on the development of autonomous prototype model of MQ-9 Reaper. The entire process will be covered, from the design and analysis to fabrication using a microcontroller system. Finally, a flight evaluation was conducted to verify the design. Hence, this project encompasses a larger intent, which is to assemble an actual UAV with mission capabilities. Collaboration with three other team members is required, each handling an aspect of the UAV. The diagram below depicts an overview.

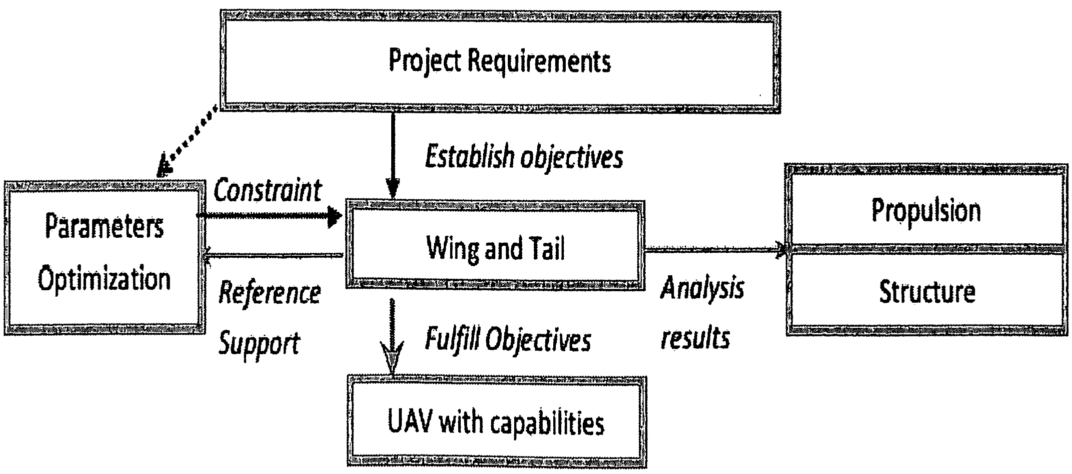
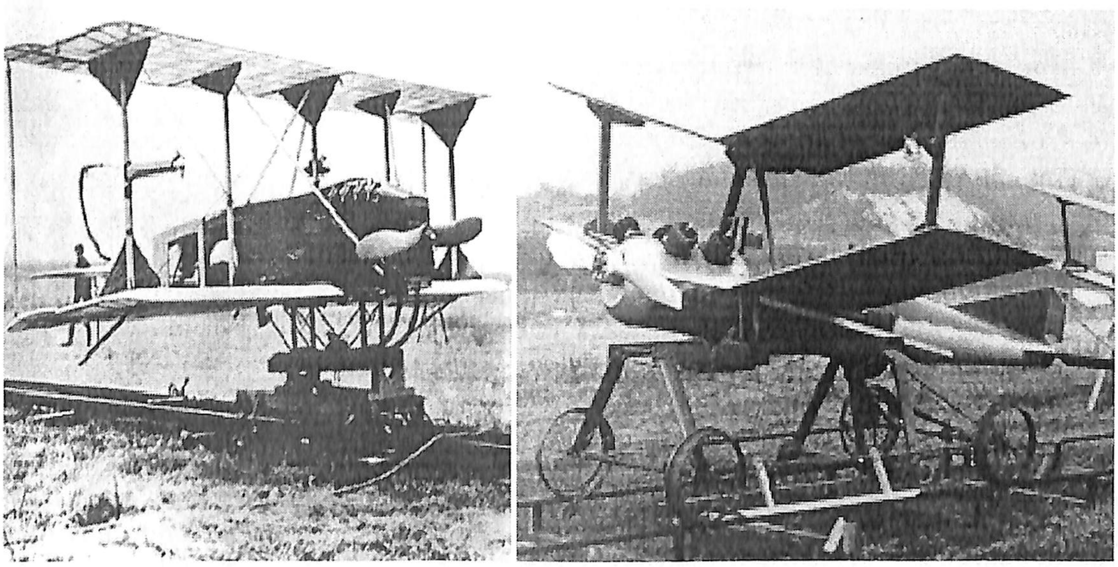


Figure 1.1: Project Overview

Unmanned aircraft have been under development since the beginning of flight. The Wright brothers tested heavier than air unmanned gliders over the dunes of Kitty Hawk, North Carolina, preceding the first powered fight. On May 6, 1896, Samuel Langley's Aerodrome made the first successful light of an un-piloted, engine-driven, heavier-than-aircraft. The aircraft was launched from a spring-actuated catapult mounted on top of a houseboat on the Potomac River in Virginia. Two fights were made, one of 1,005 m (3,300ft) and a second of 700 m (2,300 ft), at a speed of approximately 25 miles per hour. On November 28, another successful flight was made with a similar model. It flew a distance of approximately 1,460 m (4,790 ft). These aircraft were structurally weak and had minimal control systems.

Further UAV developments were made during World War I. The Curtiss/Sperry Aerial Torpedo, seen in Fig. 2.1a, made its first successful flight on 6 March 1918 at Copi-ague, Long Island, NY. The 431 kg (950 lb) UAV flew 914 m (1000 yards) after being launched by a falling-weight catapult; it then dived at a preset distance from the launch site into the water. The UAV was then recovered and re-own. A total of six Torpedos were built and several made repeated fights. The vehicle had a wingspan 6.7 m (22 ft), an empty weight of 680 kg (1500 lb), a range of 80 km (50 miles), a top speed of 113 km/h (70 mph), and it was designed to carry a payload of 450 kg (1000 lb) of high-explosives. Inspired by the successes of the Aerial Torpedo, the 530 lb Wright Liberty Eagle (a.k.a .Kettering Bug), seen in Fig. 2.1b, and made its first successful fight in October 1918. The vehicle was half the size of the Curtiss Sperry Aerial Torpedo. The vehicle had a range of 50 miles, after which the ignition was cut and the vehicle entered a steep dive, delivering its 200 lb payload to the target. Orville Wright acted as the Kettering Bug's technical consultant and added dihedral to the vehicle's wings to improve its gust response. Forty were built; however, production was cut short by the end of World War I. Both these vehicles were forerunners of today's cruise missiles.



(a) Curtiss/Sperry –"Aerial Torpedo". (b) Wright Liberty Eagle – "Kettering Bug".

Figure 1.2: Early UAVs

The British RAE 1921 Target made the world's first successful radio controlled flight without a pilot on board on 3 September 1924. A subsequent fight was made and had duration of 39 minutes during which 43 separate fight commands were executed. This was followed just 12 days later on 15 September by a modified U.S. Navy N-9. This flight lasted for 40 minutes, during which it executed 50 commands, and then landed successfully. Target drones were introduced in the 1930s in both the U.S. and in Britain as a spin-off of these early cruise missile efforts. By the end of the decade, hundreds were regularly being own in both countries to train anti-aircraft gunners. However, these UAVs were little more than full-sized remote controlled airplanes.

Reconnaissance drones burst on to the military scene in the 1950s. Cameras were added to target drones and the drones were used as the first tactical reconnaissance UAVs. Between 1959 and 1966, the United States Army operated 1,455 of these UAVs and spread the vehicle to other NATO countries. The US Marine Corps tested a two-man Bikini UAV for small units in the 1960s. This is a forerunner of the Pointer and later Dragon Eye mini-UAVs. By the time of the Cuban Missile Crisis, the Air Force had modified a number of target drones to carry cameras, a capability which was used extensively during the Vietnam convict. The 1950s also saw the maturation of inertial navigation systems, the key technology in the development of unmanned flight.

In the last two decades, interest in UAVs has increased substantially. UAVs are currecently being used in various roles, including reconnaissance and intelligence-gathering, and in more challenging roles, combat missions. Currently, 32 nations are developing or manufacturing more than 250 models of UAVs, and 41 countries operate 80 types of UAVs, primarily for reconnaissance. UAVs hold allure because they over cheaper, capable vehicles that do not place air-crews at risk. Among the advantages of UAVs is their suitability to perform missions considered dull, dirty, dark, or dangerous." These missions include orbiting a point for communications relay or jamming, collecting air samples to measure pollution, and wing reconnaissance over hostile air defenses. Repetitive, long duration and high- risk missions are the most suitable for UAVs.

1.2 Vehicle Terminology

For the purposes of this dissertation research, the term "Unmanned Aerial Vehicle" or UAV" will be used to describe the aircraft designed, built and tested for this research. The term UAV is used to describe all aircraft without a pilot on-board. The UAV is a powered aircraft that does not carry a human operator. The vehicle uses aerodynamic forces to provide lift and can y autonomously or be piloted by remote control. Additionally, unlike missiles or other projectiles, UAVs can be recovered for repeated flights. Thus, expendable autonomous projectiles like cruise missiles are not considered UAVs. Many terms have been used to describe aircraft without a pilot on-board. The term "drone" (Dictionary.com: "a remote control mechanism, such as a radio-controlled airplane or boat") was used in the 1940s and 1950s when describing vehicles used predominantly as an aerial target. This gave way to \Remotely Piloted Vehicle" (RPV) in the Vietnam era to distinguish the vehicles' new role as a reconnaissance asset due to the on-board equipment. The RPV then evolved to "Unmanned Aerial Vehicle" (UAV) in the 1980s, the name change was used to distinguish the vehicles (due to their new technology) from the Vietnam era vehicles. With efforts to develop rules integrating UAVs into the National Airspace System (NAS), and realizing that Federal Aviation Administration (FAA) rule-making authority applied only to aircraft. The term "Remotely Operated Aircraft" (ROA) was coined in 1997.To further complicate things, the U.S. Air Force refers to its UAV aircraft as Remotely Piloted Aircraft" (RPA) because they are unique in having a pilot with a stick and rudder ying them from a ground station. The FAA (and Department of Defense (DoD)) adopted the more inclusive term "Unmanned Aircraft System"(UAS) in 2004.The terminology stated "Micro Aerial Vehicle or UAVs" has also become prevalent over the last few decade. The term UAVs, describes a class of aircraft whose size is of the order of magnitude of small birds. These vehicles have a maximum dimension of less than 15 cm (6 in) in any direction. The length scales of UAVs pose challenging problems for engineers. The smaller vehicle sizes create aerodynamic concerns not encountered in larger vehicles. Designers are investigating new vehicle control and drag reduction techniques in morphing aircraft. The aerodynamics and aero elasticity of these vehicles is of primary interest.

1.3 Aerodynamics

Aerodynamics is the study of the motion of gas moving around objects and the forces created in this interaction. The shape of the object and the speed at which gas flows over it determine the magnitude of the forces created. The principle non-dimensional relation of concern is the "Reynolds Number" (Re), seen in equation 1.1.

$$\mathrm{Re} = \frac{\rho U\mathrm{c}}{\mu} = \frac{Uc}{\nu} \tag{1.1}$$

In which □ denotes density, c denotes a length scale (normally chord length), U denotes velocity, μ denotes dynamic viscosity, and ν denotes the fluid's kinematic viscosity. The aerodynamic characteristics of low Re airfoils are fundamentally different from those seen in typical aviation applications. Subsonic aerodynamics, not a major area of study until the recent past, promises tremendous potential in the development of small, robust and high performance UAVs. For a given wing, we are principally interested in maximizing the airfoil lift L and minimizing the drag D, or alternatively, maximizing the lift-to-drag ratio, $L = D$ (also written as the ratio of lift coefficient C_L to drag coefficientC_D , or $C_L = C_D$, demanded below). This is taken as a measure of the wings overall efficiency. This ratio is dependent upon the wing geometry and the flow conditions in which the wing is immersed. These flow conditions are typically expressed as dimensionless parameters such as the Re and Mach number (M). A given airfoil profile will have vastly different lift and drag characteristics over the possible ranges of Re and M. Thus, airfoils are typically designed for a narrow range of flight conditions for optimum performance, as seen in Fig.1.3.1.This figure depicts several classes of air vehicles that fit into this Re and M number space. Note that each class of vehicle has a fairly narrow bandwidth in both Re and M space. The sole exceptions in this graph are UAVs and Lighter-Than-Air" vehicles (LTAs), both of which cover a large category of aircraft built for a variety of purposes. An alternative is to design an airfoil that adequately operates over a wide range of flow conditions but does not perform well in any.

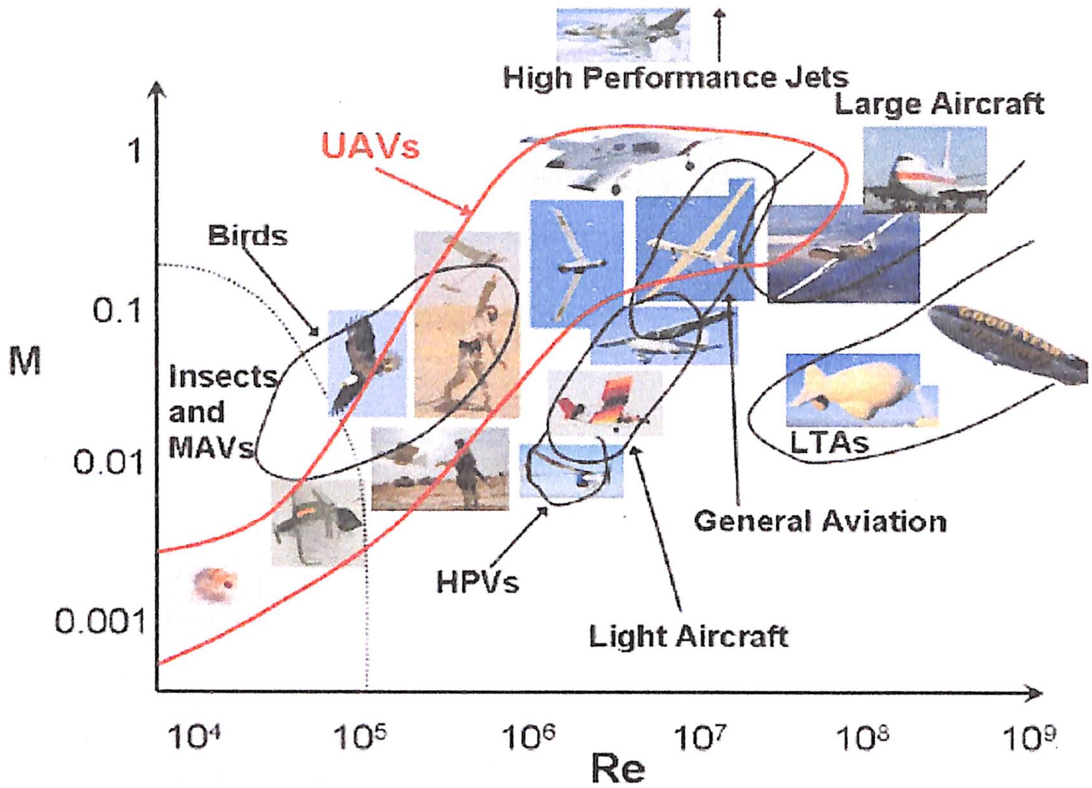


Figure 1.3: M versus Re for a wide range of airborne object

1.4 MQ-9 Reaper

In the general terminology MQ-9 reaper is an unmanned aerial vehicle (UAV), capable of capable of remote controlled or autonomous flight operations. The MQ-9 and other UAVs are referred to as Remotely Piloted Vehicles or Remote Piloted Aircraft (RPV/RPA) to indicate their human ground controllers. The MQ-9 is the first hunter-killer UAV designed for long-endurance, high-altitude surveillance.

The MQ-9 is quiet larger, heavier and more capable aircraft than the earlier MQ-1 Predator; it can be controlled by the same ground systems used to control MQ-1s. The Reaper has a 950-shaft-horsepower (712 kW) turboprop engine. The power allows the Reaper to carry 15 times the ordnance payload and cruise at almost three times the speed of the MQ-1. The aircraft is monitored and controlled by aircrew in the Ground Control Station (GCS), including weapons employment. The aircraft can also fly pre-programmed routes autonomously.

MQ-9 Reapers become the first fighter squadron conversion to an all–unmanned combat air vehicle (UCAV) attack squadron. Then Chief of Staff of the United States Air Force General T. Michael Moseley said, We have moved from using UAVs primarily in intelligence, surveillance, and reconnaissance roles before Operation, to a true hunter-killer role with the Reaper.

Figure 1.4: MQ-9 Reaper

The general MQ-9 system is composed of multiple aircraft, ground-control stations, satellite and flight and maintenance crew. The aircraft is powered by a 950 horsepower turboprop, with a maximum speed of about 260 knots (300 miles per hour or 483 km per hour) and a cruising speed of 150-170 knots (278 to 315 km/hour). With a 66 foot/20.1168 meter wingspan and maximum payloads of 1723.65 kilograms, the MQ-9 Reaper can be armed with a variety of weaponry, including Hellfire missiles and 500 lb laser guided bomb units. The Reaper has a varied range of 3,682 miles or 5925.6 kilometers and an operational altitude of 50,000 ft, which make it especially useful for long-term loitering operations, both for surveillance and support of ground troops.

1.5 Unmanned aerial Vehicle

An unmanned aerial vehicle (UAV), commonly known as a drone is an aircraft without a human pilot on board. Its flight is either controlled autonomously by computers in the vehicle, or under the remote control of a pilot on the ground or in another vehicle. There are a wide variety of drone shapes, sizes, configurations, and characteristics. Historically, UAVs were simple remotely piloted aircraft, but autonomous control is increasingly being employed. They are predominantly deployed for military applications, but also used in a small but growing number of civil applications, such as firefighting and nonmilitary security work, such as surveillance of pipelines. UAVs are often preferred for missions that are too 'dull, dirty, or dangerous' for manned aircraft.

The UAV is a low attitude and short range UAV having following the technical specifications:

- Cruise Speed: 50 km/h
- Cruise Altitude: 100 m
- Endurance: 2-10 Minutes
- Takeoff weight: 1.5 kg
- Stall Speed: 10 km/h. and its configuration are given by the Figure 2.

The design and development process of autonomous control laws for this UAV begins with the definition of mission to be fulfilled by the UAV, which imposes requirements upon the shape of the flight path and the velocity along this flight path.

For the UAV the mission requirements are formulated as follows:

- UAV should have autonomous flight capability for surveillance & reconnaissance within the defined flight area bounded from the altitude 100 m to 1000 m at the speed of 75 km/h to 150 km/h.

- UAV should fly through any flight coordinates accurately with required flight characteristics.

- The consequence of the requirement stated above is UAV should have following autonomous control laws (or control modes):

1. Pitch and Yaw Damper–mode to augment the stability/damping characteristics.

2. Attitude hold/select-mode to keep and select the desired attitude and improve the response and dynamics characteristics of UAV.

3. Altitude hold/select mode to maintain the desired altitude & to flight through the different altitude level.

4. Speed Hold – mode to keep the given speed of UAV.

5. Coordinated Turn –mode to perform smoothly turning flight and maintain the altitude during turn flight.

6. Waypoints based Navigation through GPS (waypoints following).

The resulting control law in producing the autonomous control modes is therefore to generate appropriate deflections of aerodynamic control surfaces or modification done in engine power or thrust, necessary to accomplish the mission of UAV. The approach to solve this control problem is summarized in Figure 2. It illustrates a complete design & development process of autonomous control law for UAV and the division in different design stages starting from stability and control derivative determination, setting up the non-linear equation of motion simulation flight model, flight dynamics analysis, designing the control laws, until the simulation of control laws.

1.6 Autopilot

An autopilot is a mechanical, electrical, or hydraulic system used in an aircraft to relieve the human pilot. The original use of an autopilot was to provide pilot relief during cruise modes. Autopilots perform functions more rapidly and with greater precision than the human pilot. In addition to controlling various types of aircraft and spacecraft, autopilots are used to control ships or sea-based vehicles. An autopilot is unique pilot. It must provide smooth control and avoid sudden and erratic behaviour. The intelligence for control must come from sensors such as gyroscopes, accelerometers, altimeters, airspeed indicators, automatic navigators, and various types of radio-controlled data links. The autopilot supplies the necessary scale factors, dynamics (timing), and power to convert the sensor signals into control surface commands. These commands operate the normal aerodynamic controls of the aircraft.

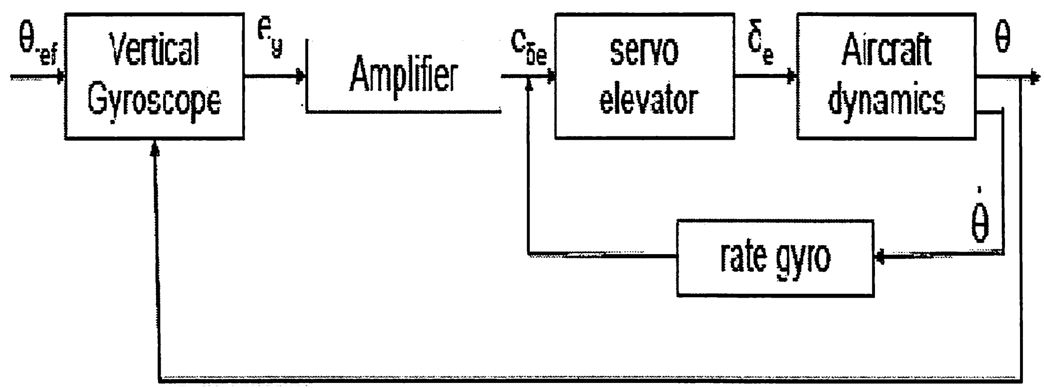


Figure 1.5: Autopilot

1.6.1 Replacement of Human Pilot

In the aircraft control systems, human pilots play a very important role as they have certain advantages. Human pilots are highly adaptable to unplanned situations, means they can react according to the desired conditions. Also they have broad-based intelligence and can communicate well with other humans. But still autopilots have advantages over the human pilot which forced it to replace human pilot . There characteristics are described as:

1. Autopilots have high reaction speed as comparison to human pilot.

2. They can communicate well with computers, which is difficult for human.

3. They can execute multiple events and tasks at the same time.

4. Autopilot relieves human pilot from fatigue.

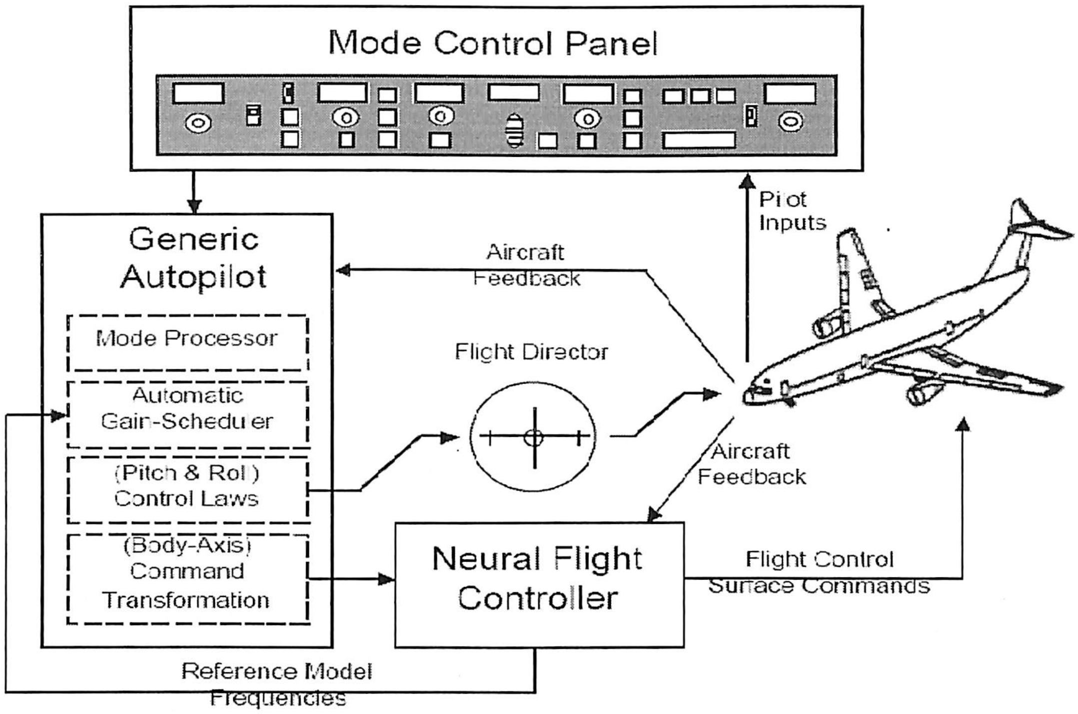


Figure 1.6: Generic Autopilot Concept

1.6.2 Flight Control System

A flight control system is either a primary or secondary system. Primary flight controls provide longitudinal (pitch), directional (yaw), and lateral (roll) control of the aircraft. Secondary flight controls provide additional lift during takeoff and landing, and decrease aircraft speed during flight, as well as assisting primary flight controls in the movement of the aircraft about its axis. Some manufacturers call secondary flight controls auxiliary flight controls. All systems consist of the flight control surfaces, the respective cockpit controls, connecting linkage, and necessary operating mechanisms. Basically there are three type of flight control systems as discussed below.

1.6.3 Flight management system

FMS is a fundamental part of a modern airliner's avionics. An FMS is a specialized computer system that automates a wide variety of in-flight tasks, reducing the workload on the flight crew to the point that modern aircraft no longer carry flight engineers or navigators. A primary function is in-flight management of the flight plan. Using various sensors such as GPS and INS often backed up by radio navigation to determine the aircraft's position, the FMS can guide the aircraft along the flight plan. From the cockpit, the FMS is normally controlled through a Control Display Unit (CDU) which incorporates a small screen and keyboard or touch screen. The FMS sends the flight plan for display on the EFIS, Navigation Display (ND) or Multifunction Display (MFD).

1.6.4 Flight Director Functions

A Flight Director is an extremely useful aid that displays cues to guide pilot or autopilot control inputs along a selected and computed flight path. The flight director usually receives input from an ADC and a flight data computer. The ADC supplies altitude, airspeed and temperature data, heading data from magnetic sources such as flux valves, heading selected on the HSI (or PFD/multi-function display (MFD)/ electronic horizontal situation indicator (EHSI)), navigation data from FMS, very high frequency omni directional range (VOR)/distance measuring equipment (DME), and RNAV sources. The flight data computer integrates all of the data such as speed, position, closure, drift, track, desired course, and altitude into a command signal.

1.6.5 Principle of Operation

Autopilot aim is to make the aircraft evolve from a static equilibrium position to another.

1st principle: Separate the small movements of the aircraft around an equilibrium point in longitudinal and lateral planes

- Longitudinal modes affect the aircraft in its vertical plane
- Lateral modes affect the aircraft in its horizontal plane modes off.

A lot of couplings exist between longitudinal and lateral movements of the aircraft (ex.: turning), within longitudinal mode (maintaining a constant descent rate and decreasing speed) and within lateral modes (stabilized turn)

→ Command laws should include these couplings either with more correcting terms with more correcting terms or with introduction of limitation to ensure only small movements.

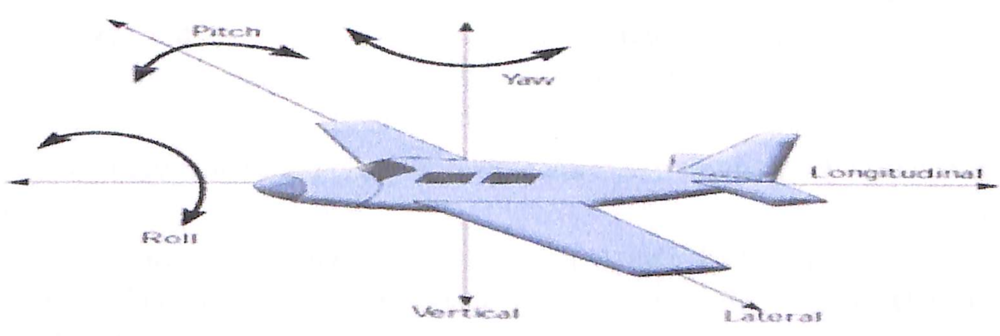


Figure 1.7: Control surfaces of an aircraft

2nd principle: in automatics system signals are classified in principle: in automatics, system signals are classified in function of their speed or frequency (their bandwidth).

Aircraft's basic modes:

- Longitudinal — Attitude command
  Speed control

- Lateral — Bank angle control
  Yaw control

• Example: input: elevator deflection

Output: variation of attitude, pitch velocity, attack angle, climbing angle, vertical speed, altitude.

1.6.6 Construction and Working

The basic aim of an autopilot is to track the desired goal. Autopilot can be displacement type or pitch type. There are different techniques available to design an autopilot like model-following control, sliding mode control, model predictive control, robust control, lyapunov based control, adaptive control and dynamic inversion control.

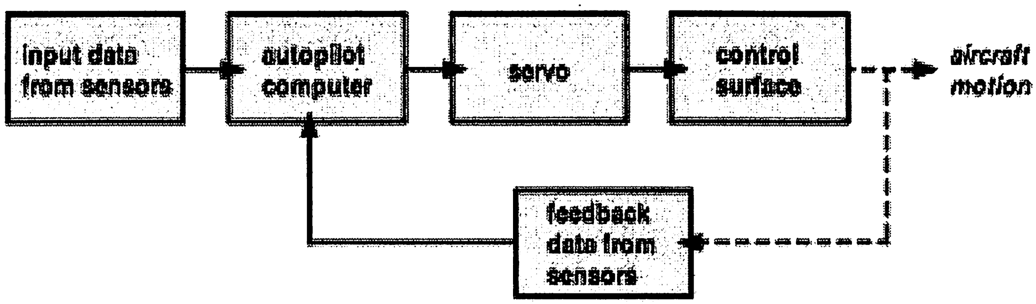


Figure 1.8: Autopilot control system

An autopilot is an example of a control system. Control systems apply an action based on a measurement and almost always have an impact on the value they are measuring. A classic example of a control system is the negative feedback loop that controls the thermostat in your home. Such a loop works like this:

- The thermostat measures the air temperature and compares it to the present value.
- Over time, the hot air outside the house will elevate the temperature inside the house. When the temperature inside exceeds 78°F, the thermostat sends a signal to the air conditioning unit.
- The air conditioning unit clicks on and cools the room.
- When the temperature in the room returns to 78°F, another signal is sent to the air conditioner, which shuts off.

It's called a negative feedback loop because the result of a certain action (the air conditioning unit clicking on) inhibits further performance of that action. All negative feedback loops require a receptor, a control center and effectors.

1.6.7 Applications

1. Autopilot is an application performance management (APM) solution used to monitor the availability and performance of applications. Its strength is in the ease of use in monitoring complex, multi-tier, composite applications.

2. Autopilot is a single platform for management of both distributed and nframe applications that span from Java and .NET to middleware messaging. It provides its users with deep visibility, end-to-end and it does it in real-time.

3. Autopilot is built on an internally developed Complex Event Processing (CEP) engine, optimized for APM with pre-built rules and business views. This enables it to scale to handle very large volumes of events, constantly determine what is business normal application behavior and deliver early-warning alerts to its users when behavior veers from normal.

1.6.8 Advantages

1. Smoother flight for passengers, allows you to concentrate on other issues such as communications and keeping an eye on your planes systems because you don't have to concentrate completely on keeping the plane level. Flying the CRJ-200 with auto pilot sure makes the job easier, moving up to bigger planes im sure ill appreciate it more and more.

2. Plane will take a better flight for saving fuel and faster flight.

3. Having an automatic pilot engaged can reduce the workload and permit attention to other things.

4. On the C130, the autopilot is very advantageous to lengthen the crew duty day, due to the fatigue factor

1.6.9 Disadvantages

1. Its only as good as the programmer makes it, Remember, the pilot is the one typing in the commands; so as AP is engaged, pilot is constantly checking to make sure they are in the right place.

2. If the automatic pilot is not understood, or if it is programmed wrong by the pilot then the aircraft will obediently do things the pilot doesn't want. If a clearance or procedure calls for tight maneuvering the autopilot is not as good as hand flying.

CHAPTER 2
LITERATURE REVIEW

2.1 J. Bals, H.-D. Joos, G.Looye, and A.Varga Literature review on Tools for Design and Simulation of UAV flight Control, *Deutsches Zentrum fur Luft- und Raumfahrt (DLR), Institute of Robotics and Mechatronics*, D-82234 Wessling, Germany.

High performance and robustness requirement for autonomous UAV flight control system and stringent requirements for short and cost effective design cycles increase the necessity for an efficient computer aided control law design process using process using advanced control design method and tools. This paper describes a model and optimization based flight control law design process, which can be applied to a wide range of vehicle classes. The design process is based on multi-physical, object oriented flight dynamics modeling using the modeling language Modelica and on a multi-objective parameter optimization environment. A generic Modelica flight dynamics library allows modular composition of new parameterized vehicle model and efficient simulation code generation for specific use cases. Multi-objective optimization is used for tuning the free parameters in linear and non linear flight control laws. Therby, given requirements for stability, trading structural loads and other physical limitations are formulated as computational design criteria. Robustness to uncertain parameters can be addressed via robustness measures, via a multi-model and multi-case approach based criteria. In the assessment step of the design process worst-case optimization w.r.t. uncertain parameters is applied for systematically detecting weakness of the control law design. The successful application of the design process to civil transport and high performance military aircraft is demonstrated and the applicability for UAV flight control design is discussed.

2.2 Chong Shao Ming Literature review on Unmanned Air Vehicle (UAV) Wing Design and Manufacture, *National University of Singapore (NUS),* Singapore.

This paper documents the development of a UAV wing, encompassing the entire process from design to manufacture, and finally its implementation on an aircraft. Beginning with wing design and analysis, requirements are first identified and related concepts are formulated. A literature survey is then conducted to establish focus for analysis.

Aerodynamic data is then generated for four different planforms with different combinations of rectangular and tapered section. Their drag coefficients were found to be lower than the baseline. However, they are not convincingly significant to justify their selection over the rectangular baseline, which yields practical and aerodynamic benefits. For dihedral and the sizing of control surfaces, practical data on stability and control derivatives are derived from literature. Computations are subsequently carried out to determine the design parameters.

To fabricate the wings, a computer numerical controlled system was developed. It involves three sections. The mechanical parts were fabricated from scratch, while the electronic components and the software were obtained from credible sources. To optimize the performance of the system, mechanical calibrations were first carried out. The selection of wire heat and cutting speed has significant implications on the dimensional accuracy, hence, empirical tests are conducted to derive the optimum values. Finally, the accuracy and precision of the system is put the test through a detailed inspection of fabricated airfoils cross section. The coordinates were registered and analyzed using Xfoil to yield aerodynamic data. Differences were deemed acceptable. With the established fabrication process, prototype aircrafts were assembled subsequently.

2.3 **Scott D. Hanford, Lyle N. Long and Joseph F. Horn** Literature review on A Small Semi-Autonomous Rotary-Wing Unmanned air Vehicle (UAV).the Pennsylvania State University, University park, PA, 16802.

Small radio controlled (R/C) rotary-wing UAVs have many potential military and civilian applications, but can be very difficult to fly. Small and lightweight sensors and computers can be used to implement a control system to make these vehicles easier to fly. To develop a control system for a small UAV, an 8-bit microcontroller has been interfaced with MEMS (Micro-Electro-Mechanical Systems) gyroscopes, an R/C transmitter and receiver, and motor drivers. A single angular degree of freedom test bed has been developed to test these electronics and successful pilot-in-the-loop PI control has been achieved for this test system. A UAV with a stability augmentation system that uses these electronics to control the vehicle has also been developed. The future goals of this research are to incorporate more sensors to increase the level of autonomy for UAV operation.

CHAPTER 3
OBJECTIVE AND SCOPE

3.1 Objectives

The project can be divided into three main components namely (1) Design and Analysis, (2) Fabrication and (3) Flight Test. Each component comprises of designated objectives to be fulfilled to complete the assignment.

The objective for the project is to model and control law of the unmanned aerial vehicle that will be designed to incorporate multiple disciplines such as aerodynamics, structures and flight control parameters to achieve required performance metrics for the aircraft. The flight test will be validated the fabrication of the generated design. Feasibility of the prototype design will be analysis by means of aircraft designs, computation and flight data.

Components	Designated Objective
(1) Design and Analysis	Designing solutions (i.e. selection of appropriate parameters) to meet mission requirements Justification using computational analysis
(2) Fabrication	Development of a prototype model to enable rapid and precise production of 3D design Verification of equipment reliability and worthiness
(3) Flight Test	Demonstration of airworthiness Evaluation of actual flight data

Table3.1: Designated Objectives

The initially an aircraft is to be fabricated and a scaled controlled system was developed. It comprises of three sections. The mechanical parts were fabricated from scratch, while the electronic components are obtained from credible sources. To optimize the performance of the system, mechanical calibrations are first carried out. The other portion of the report will involve the feasibility analysis of the optimization programming of various sensors which are to be performed based on the flight requirement. The first analysis will be carried out for the autonomous UAV designs. The sensitivity of the flight performance metrics with respect to design parameters will also be analyzed. Subsequent analysis will involve the microcontroller programming of the aircraft model. Upon fabrication of the aircraft, flight tests will be carried out and flight data can be collected and a conclusion will be drawn regarding the feasibility of the optimization of the unmanned aerial vehicle.

3.2 SCOPE

UAVs typically capitulate into six functional categories that are as listed below:

- Target and decoy – providing ground and aerial gunnery a target that simulates an enemy aircraft or missile
- Reconnaissance – providing battlefield intelligence
- Combat – providing attack capability for high-risk missions Logistics – UAVs specifically designed for cargo and logistics operation
- Research and development – used to further develop UAV technologies to be integrated into field deployed UAV aircraft
- Civil and Commercial UAVs – UAVs specifically designed for civil and commercial applications

They can also be categorized in terms of range or altitude and the following has been encouraged by such industry events as Unmanned Systems. An unmanned aircraft system includes ground stations and other elements besides the actual aircraft. The inclusion of the term aircraft stresses that regardless of the location of the flight crew, the operations must comply with the same regulations and procedures with their flight crew on board. UAVs perform wide variety of functions and possess various advantages. The majority of these functions are as elaborated.

1. Remote sensing

UAV remote sensing functions comprises of electromagnetic spectrum sensor, gamma rays sensor, biological sensor and chemical sensors. A UAV's electromagnetic sensor typically include visual spectrum, infrared, or near infrared cameras as well as radar systems. Other electromagnetic wave detectors such as microwave and ultraviolet spectrum sensors may also be used, but are uncommon. Biological sensors are sensors capable of detecting the airborne presence of various microorganisms and other biological factors. Chemical sensors use laser spectroscopy to analyze the concentration of each element in the air.

2. Commercial aerial surveillance

Aerial surveillance of large areas is made possible with low cost UAV systems. Surveillance applications include: livestock monitoring, wildfire mapping, pipeline security, home security, road patrol and anti-piracy. The trend for use of UAV technology in commercial aerial surveillance is expanding rapidly with increased development of automated object detection approaches.

3. Domestic policing

Drones are increasingly used for domestic police work in Canada and the United States. Texas politician and commentator Jim Hightower has warned about potential privacy abuses from aerial surveillance.

4. Oil, gas and mineral exploration and production

UAVs can be used to perform geophysical surveys, in particular geomagnetic surveys where the processed measurements of the differential Earth's magnetic field strength are used to calculate the nature of the underlying magnetic rock structure. Knowledge of the underlying rock structure helps trained geophysicists to predict the location of mineral deposits. The production side of oil and gas exploration and production entails the monitoring of the integrity of oil and gas pipelines and related installations. For above-ground pipelines, this monitoring activity could be performed using digital cameras mounted on one, or more, UAVs. The In View Unmanned Aircraft System is an example of a UAV developed for use in oil, gas and mineral exploration and production activities.

5. Transport

UAVs can transport goods using various means based on the configuration of the UAV itself. Most payloads are stored in an internal payload bay somewhere in the airframe. For many helicopter configurations, external payloads can be tethered to the bottom of the airframe. With fixed-wing UAVs, payloads can also be attached to the airframe, but aerodynamics of the aircraft with the payload must be assessed. For such situations, payloads are often enclosed in aerodynamic pods for transport.

6. Scientific research

Unmanned aircraft are uniquely capable of penetrating areas which may be too dangerous for piloted aircraft. The National Oceanic and Atmospheric Administration began utilizing the Aerosonde unmanned aircraft system in 2006 as a hurricane hunter. Corporation subsidiary Aerosonde Pvt. Ltd. Of Victoria, Australia, designs and manufactures the 35-pound system, which can fly into a hurricane and communicate near-real-time data directly to the National Hurricane Center in Florida. Beyond the standard barometric pressure and temperature data typically culled from manned hurricane hunters, the Aerosonde system provides measurements far closer to the water's surface than previously captured. Further applications for unmanned aircraft can be explored once solutions have been developed for their accommodation within national airspace, an issue currently under discussion by the Federal Aviation Administration. UAVSI, the UK manufacturer also produce a variant of their vigilant light UAS (20 kg) designed specifically for scientific research in severe climates such as the Antarctic.

7. Armed attacks

MQ-1 Predator UAVs armed with Hellfire missiles are increasingly used by the U.S. as platforms for hitting ground targets. Armed Predators were first used in late 2001 from bases in Pakistan and Uzbekistan, mostly aimed at assassinating high profile individuals (terrorist leaders etc.) inside Afghanistan. Since then, there have been many reported cases of such attacks taking place in Afghanistan, Pakistan, Yemen and Somalia. The advantage of using an unmanned vehicle, rather than a manned aircraft, in such cases is to avoid a diplomatic embarrassment should the aircraft be shot down and the pilots captured, since the bombings take place in countries deemed friendly and without the official permission of those countries.

8. Search and rescue

UAVs will likely play an increased role in search and rescue in the United States. This was demonstrated by the use of UAVs during the 2008 hurricanes that struck Louisiana and Texas. Micro UAVs, such as the Aeryon Scout have been used to perform Search and Rescue activities on a smaller scale, such as the search for missing persons.

For example, Predators, operating between 18,000–29,000 feet above sea level, performed search and rescue and damage assessment. Payloads carried were an optical sensor which is a daytime and infra red camera and synthetic aperture radar. The Predator's SAR is a sophisticated all-weather sensor capable of providing photographic-like images through clouds, rain or fog, and in daytime or nighttime conditions; all in real-time. A concept of coherent change detection in SAR images allows for exceptional search and rescue ability: photos taken before and after the storm hits are compared and a computer highlights areas of damage.

9. Forest fire detection

Another application of civil UAVs is prevention and early detection of forest fires. The chief exponent of this type of is the FT-ALTEA, developed by Flightech Systems. The possibility of constant flight, both day and night, makes the methods used until now (helicopters, watchtowers ...) becoming obsolete. Its payload is provided by numerous cameras (HD, thermal, hyperspectral ...) and multiple sensors that provide real-time emergency services not only information about the location of the outbreak of fire, to many data (wind speed temperature, humidity ...) that are helpful for fire crews to conduct fire suppression.

For the development of UAV, autonomy technology is considered to descend under the following categories:

- Sensor fusion: Combining information from different sensors for use on board the vehicle
- Communications: Handling communication and coordination between multiple agents in the presence of incomplete and imperfect information
- Path planning: Determining an optimal path for vehicle to go while meeting certain objectives and mission constraints, such as obstacles or fuel requirements
- Trajectory Generation: It is also called as Motion planning. It is for determining an optimal control maneuver to take to follow a given path or to go from one location to another.
- Trajectory Regulation: The specific control strategies required to constrain a vehicle within some tolerance to a trajectory
- Task Allocation and Scheduling: Determining the optimal distribution of tasks amongst a group of agents, with time and equipment constraint.

CHAPTER 4
UAV DESIGN

4.1 METHODOLOGY

This report documented the development and control law design of a UAV, encompassing the process from design to fabricating and finally its implementation on an aircraft. Beginning with design and analysis, requirements are first identified and related concepts are formulated. A literature survey is then conducted to establish focus for analysis. Analysis is conducted for the main design parameters.

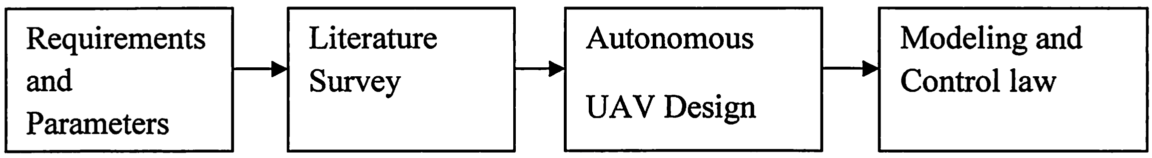


Figure 4.1: Methodology

Initially, we scaled our model which is well suitable in aspects of structure and aerodynamics. Grading is done by evaluating its results. Aerodynamic data is then generated for planforms with combinations of rectangular section. For the sizing of control surfaces, practical data on stability and control derivatives are derived from literature. Computations are subsequently carried out to determine the design parameters.

To fabricate the aircraft, a computer controlled programming system is developed. It comprises of three sections. The mechanical parts are fabricated from scratch, while the electronic components and the microprocessor are obtained from credible sources. To optimize the performance of the system, mechanical calibrations were first carried out. The selection of wire heat and cutting speed has significant implications on the dimensional accuracy hence empirical tests are conducted to derive the optimum performance of flight. Lastly, the controlled programming syntax for control surfaces is fed to the parallax propeller microcontroller for the autonomous working of the aircraft.

With the established fabrication process, prototype aircrafts were assembled subsequently. To achieve this, flight instruments and a data storage device are mounted on the aircraft and flight data were collected. Finally, by demonstrating air worthiness and flight test we are able to demonstrate the most practical way to verify the results from computational analysis.

4.2 Parameters

To initiate the design process, the physical parameters are first identified. There are two types of parameters, dimensional and design. Dimensional parameters basically refer to sizes of the wing and tail and other parameters involving the required specifications. They are resolved in the optimization process, leaving the design parameters to be worked out.

4.3 CAD Design in Solid works

Unmanned Aerial vehicle is designed on the CAD software Solid Works Premium 2010 that is a 3D Design & Modeling Software that is based on parametric based modeling technology.

An attempt was made to use most of the features in Solid Works. The main features used extensively were

- Extrude feature
- Loft feature
- Reference Plane feature

The model has been created around the z-axis with sketches drawn in the xy-plane. The "Reference Plane" feature was used extensively to create the different features at different distances from the reference (front) plane.

4.3.1 Construction

The whole aircraft assembly is designed in one part.

- Main Fuselage
- Swept Wing
- Ruddervators
- Flaps
- Ailerons

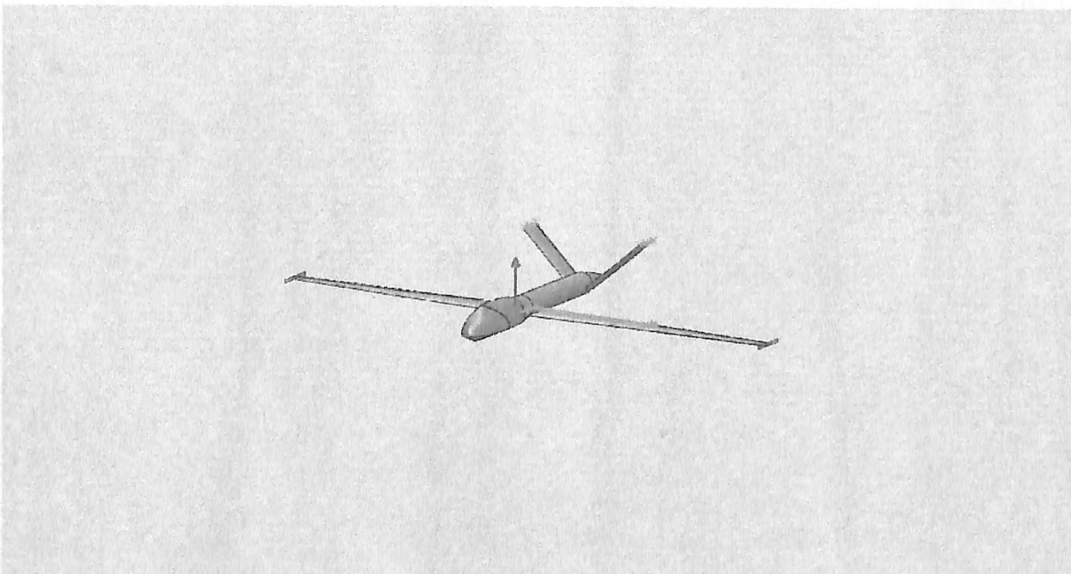


Figure 4.2: Exploded View of Entire UAV

4.3.2 Main Fuselage

- The main fuselage was created by extruding a circle in the xy-plane.
- First the main fuselage assembly was created by extruding a circle in the right plane for 500 mm.

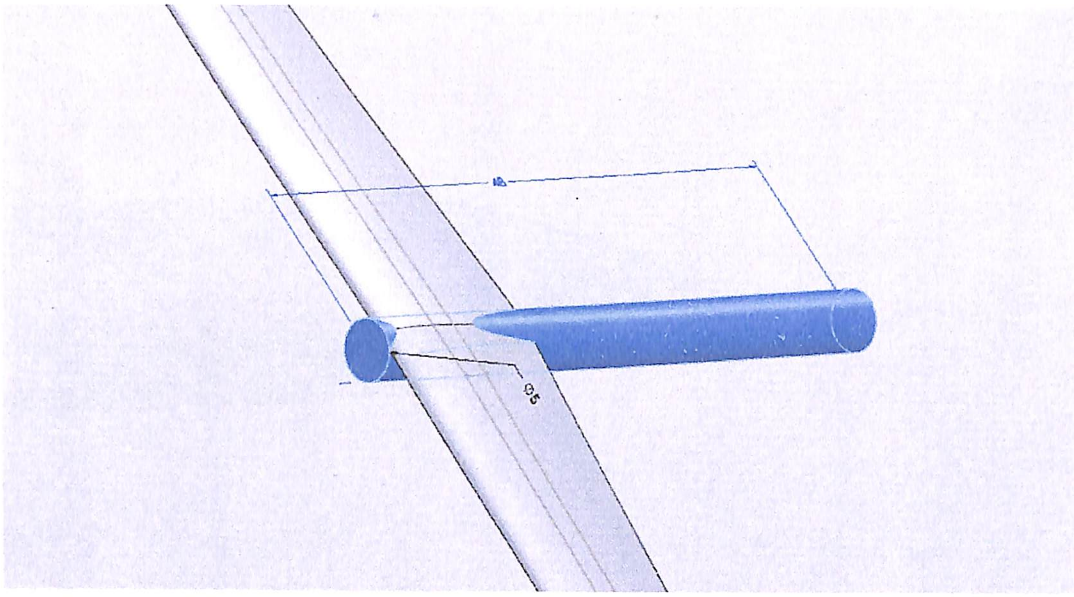


Figure 4.3: Extrusion of main fuselage

Next, the front structure was created by lofting ellipse of 400 mm length and width of 120 mm and by lofting it to the point created in right plane at coordinates(-330,120) and for the lower section similarly point was created in the right plane at coordinates (-380,-34) and point was lofted with the ellipse .

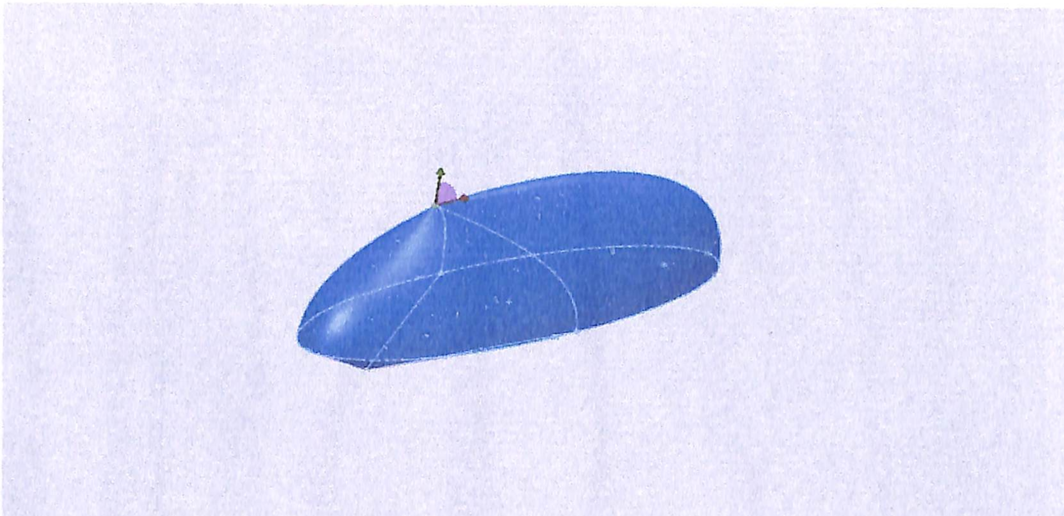


Figure 4.4: Extruded (with draft) Forward Cabin Structure

For the aft cabin structure, a reference plane was created at some distance behind the sketch plane. A circle was sketched on this reference plane and a loft feature created between the end of the cylinder and the circle.

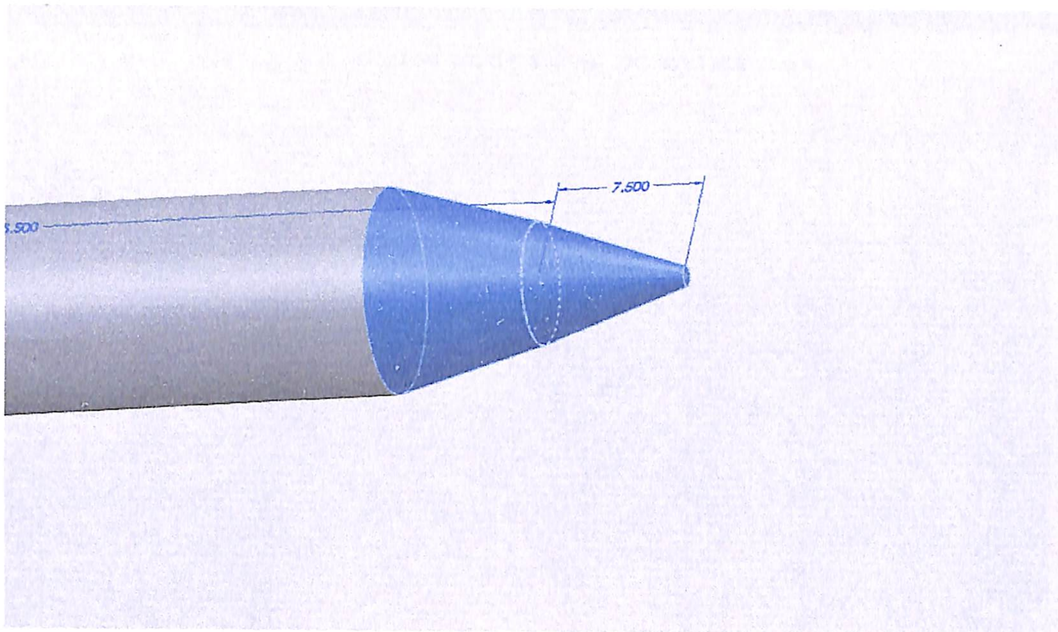


Figure 4.5: Aft Cabin Structure: Loft feature

4.3.3 Swept Wing

For creating the swept wing of a UAV, first the NACA 0010 airfoil coordinates were imported onto the front plane .

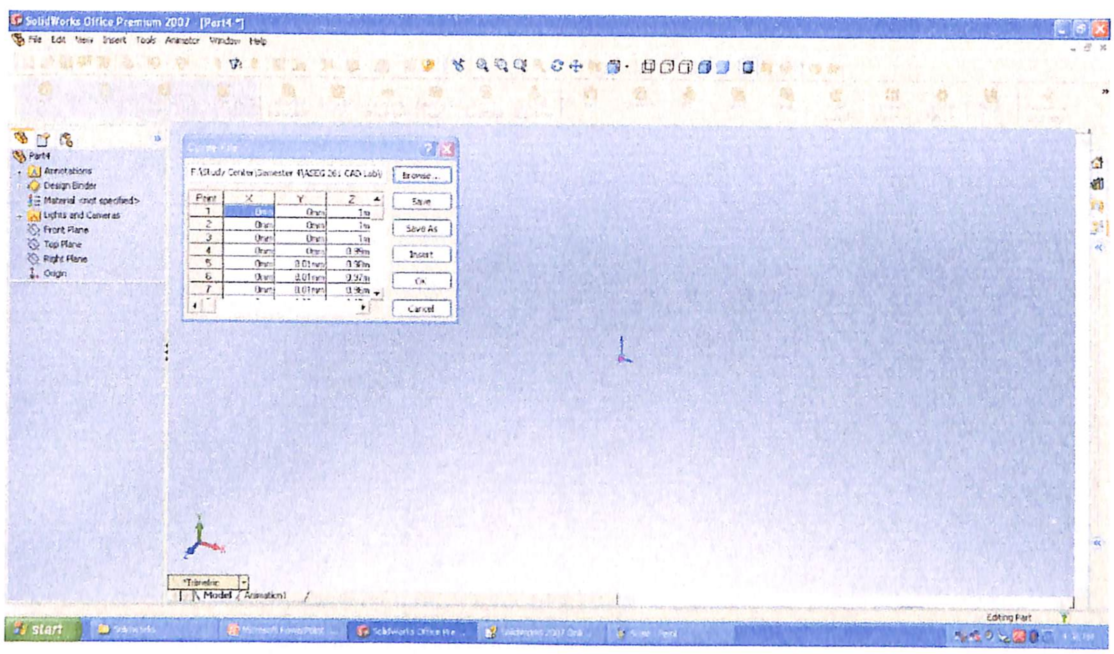


Figure 4.6: Importing airfoil coordinates

After using Convert Entities to fully define the curve, the curve was scaled to 0.3 times the original size. Copying the scale model entity.

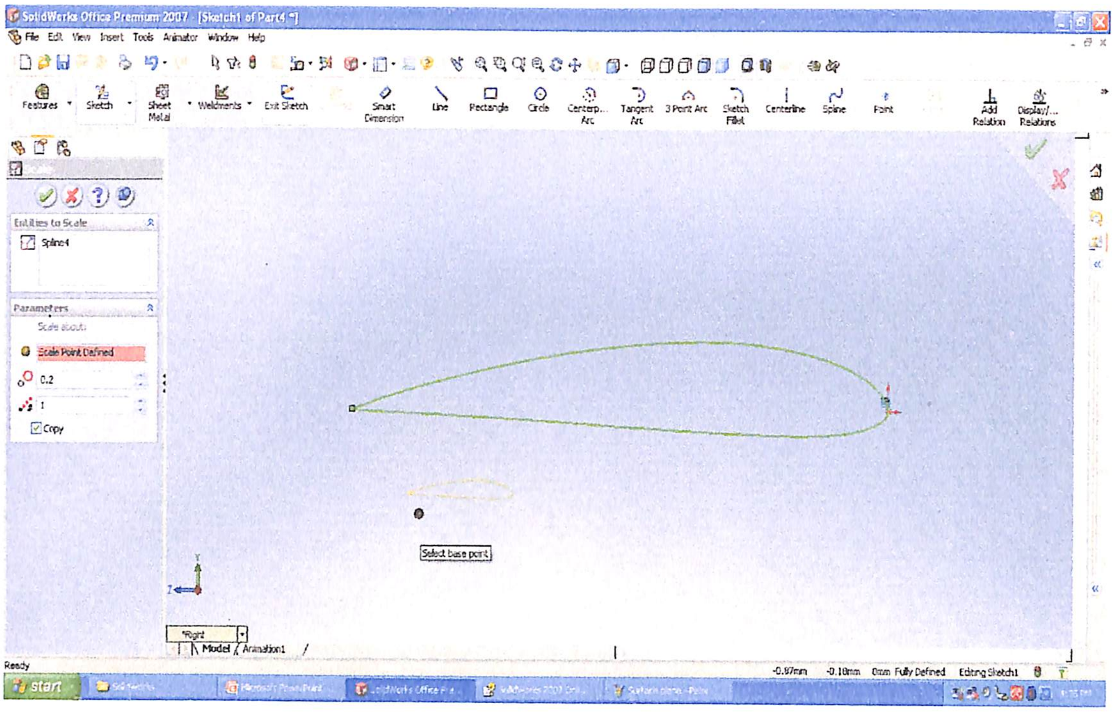


Figure 4.7: Scaling down the curve

Creating a reference plane at some distance, the scaled curve was placed as shown.

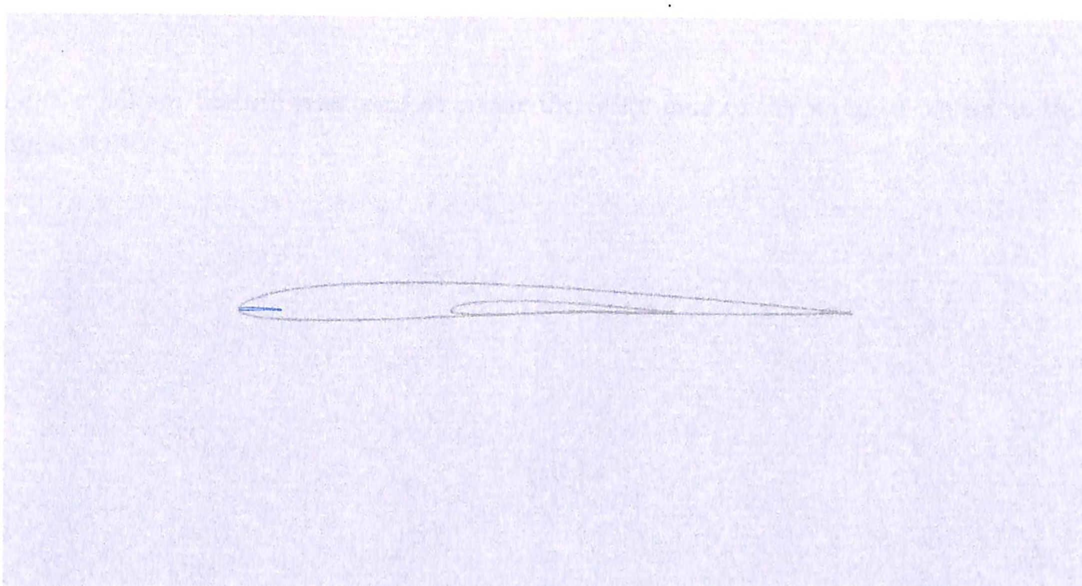


Figure 4.8: Placing the scaled down curve

Now, the loft feature was added between the two airfoils to create the solid wing body.

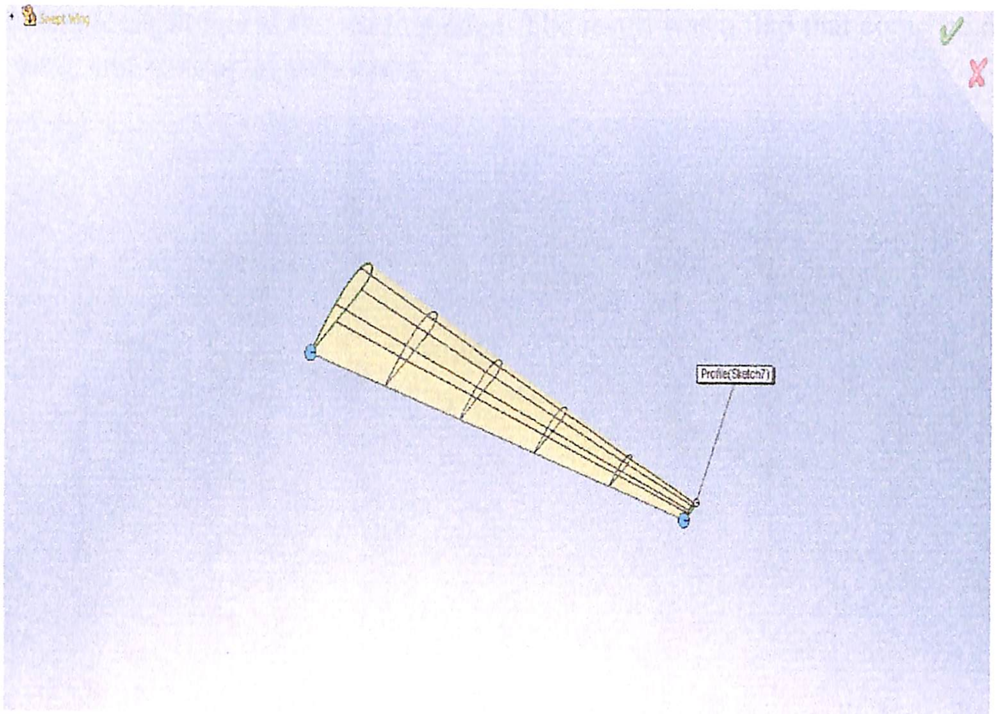


Figure 4.9: Swept Wing: Loft feature

Last, the Mirror feature was used to create the other side of the wing to complete the wing assembly.

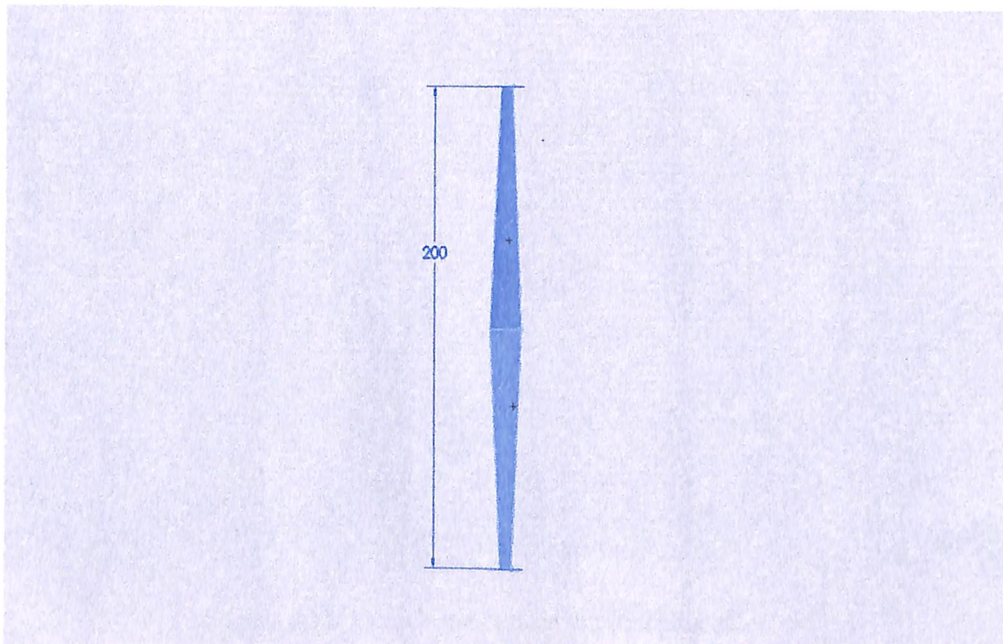


Figure 4.10: Left Side Wing: Mirror Feature

4.3.4 Flap & Ailerons

To create a flap, NACA 0010 airfoil coordinates were imported and the curve edited to include a straight line at the leading edge .The result was a flap that could be mated to the wing and horizontal stabilizers.

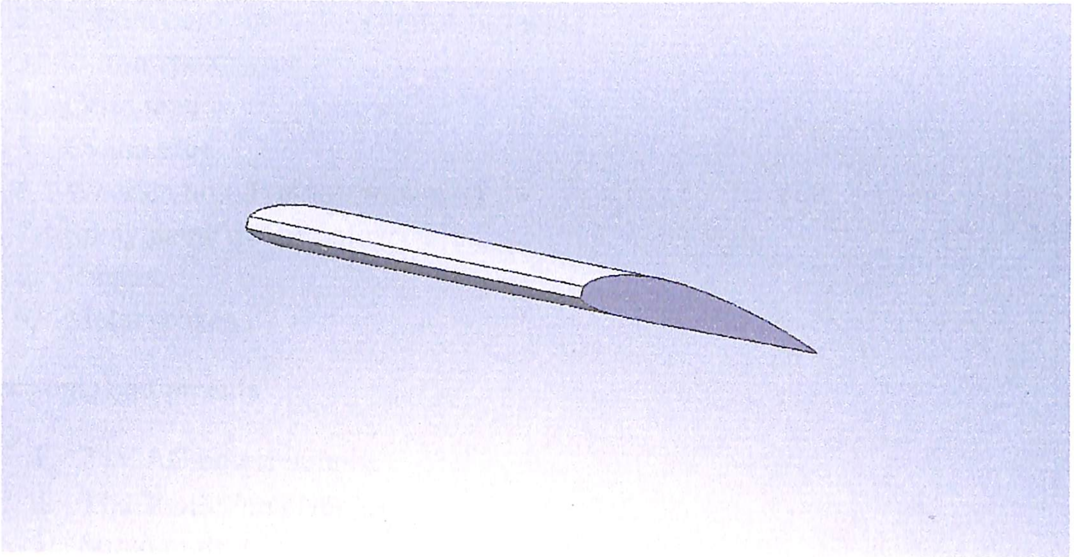


Figure 4.11: Extruded from edited airfoil

Next, using the Extruded-Cut feature cut a rectangular portion of the wing to create space for attaching the flaps and Ailerons.

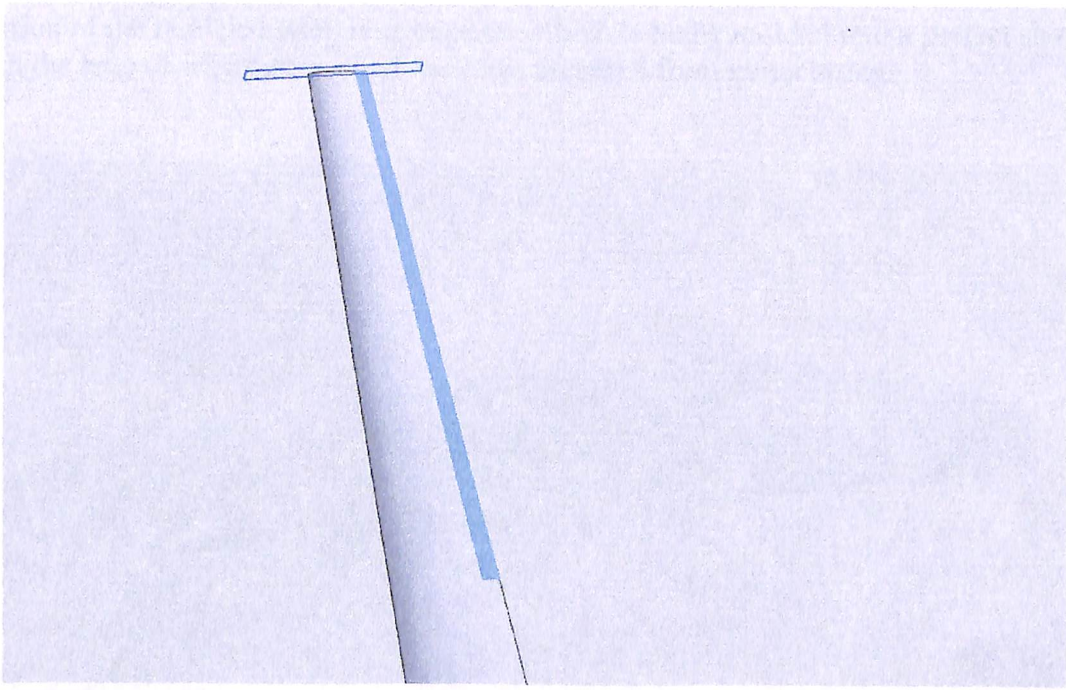


Figure 4.12: Extrude cut feature for attaching Ailerons

4.4 Fabrication of the model

Materials used in fabrication of UAV

1. 5 sheets of 2 mm Industrial or High Density Thermacoal (for fuselage and wing)
2. 1 4mm coro sheet.(for control surfaces)
3. 5 min epoxy glue
4. Cello tape
5. Cyano glue
6. Wooden board (motor mounter)
7. Spray paint(for designing)
8. Hinges
9. Metal spokes

Electronic equipments

1. 24V AC power supply.
2. Transmitter/receiver kit
3. Servo motors
4. Brushless dc motor
5. Parallex propeller microcontroller
6. Battery
7. Motor speed controller

Portion of the modeled wing is as depicted which is being molded into a perfect shape with the help of wire cutter which we have prepared from guitar strings.

Figure 4.13: Fabrication of the wing

Figure 4.14: Fuselage and wing

The above figure shows the fuselage and wing of the UAV, later which are supposed to be fixed.

Figure 4.15: Controller assembly of UAV

The above figure shows the nose section of the UAV on which controller is installed.

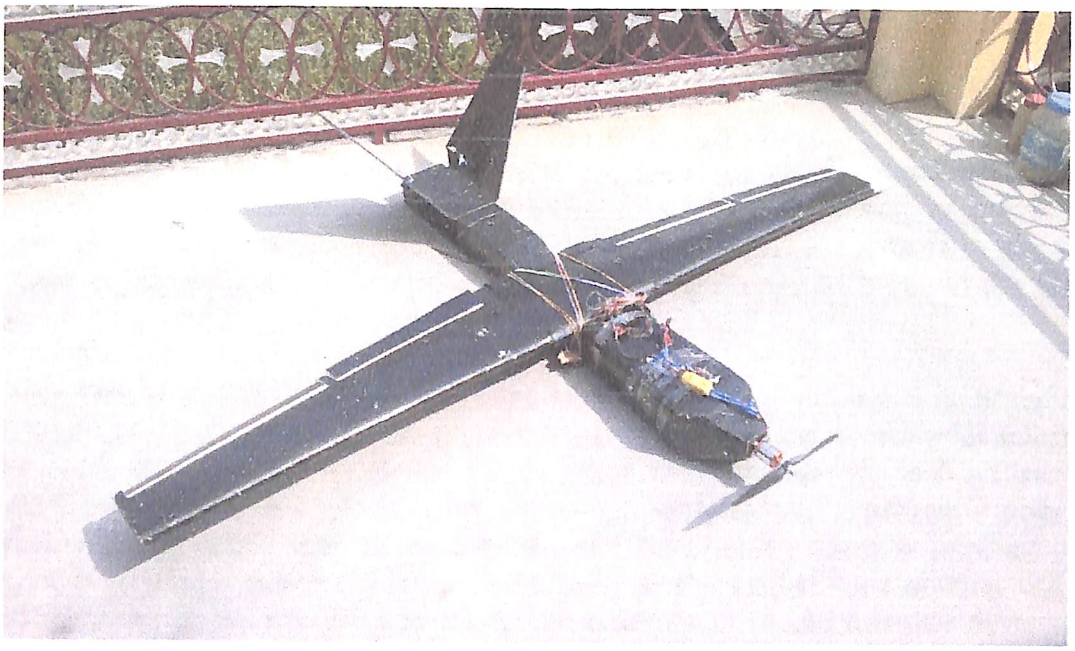


Figure 4.16: Complete prototype model of UAV

The above figure shows the complete model of UAV which is ready to undergo a test flight.

4.5 Electronic Component/System Involved

4.5.1 MQ-9 Reaper:-

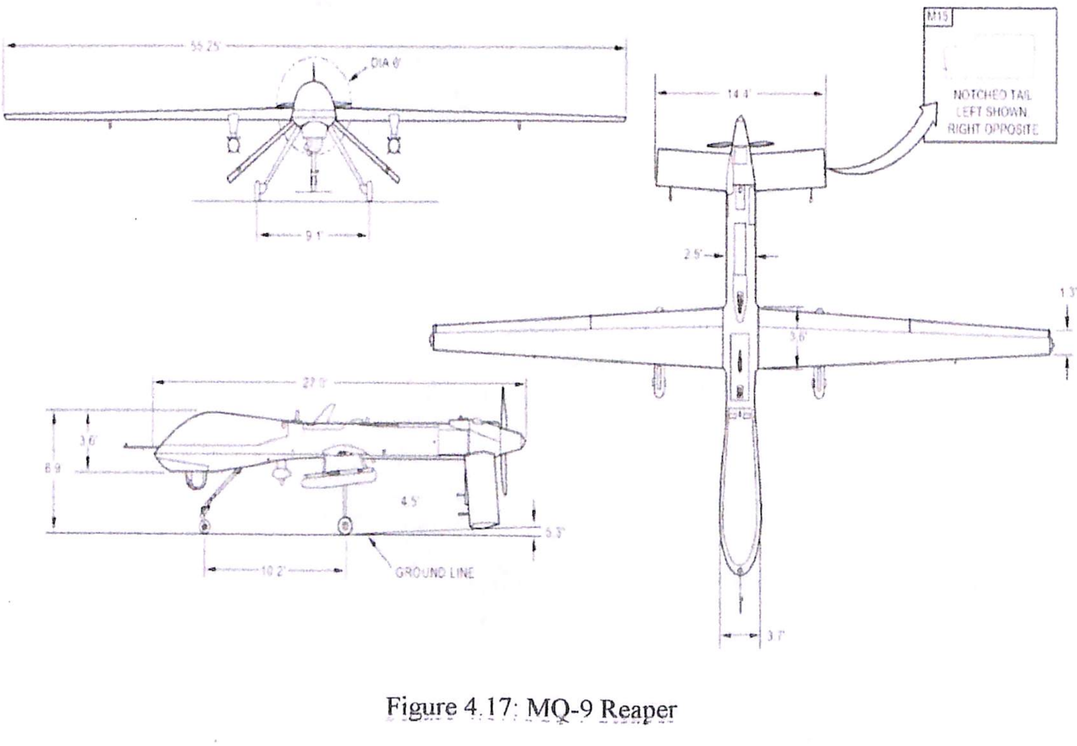
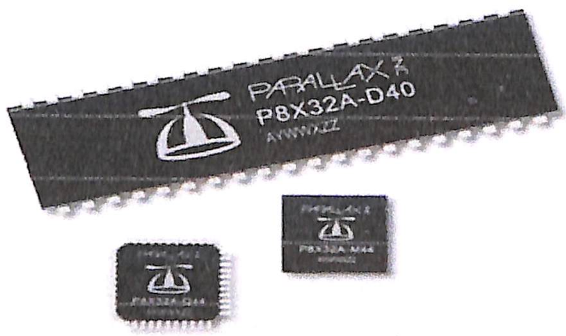


Figure 4.17: MQ-9 Reaper

4.5.2 Parallax Propeller (P8X32A-D40)

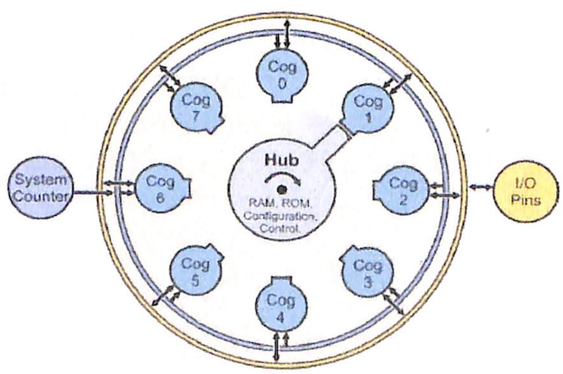
The propeller Microcontroller is a single chip with eight integral 32-bit processors, known as cogs. Cogs may be programmed to operate at the same instance, each on an individual basis and hand in glove with extra cogs. In other words, cogs will all operate all at once, however whether or not they operate severally or hand in glove is outlined by the program. Teams of cogs may be programmed to figure at the same time, whereas others work on freelance tasks.

All cogs are provided with a eighty mega hertz clock signal through a configurable clock system. Figure shows however every cog takes turns at the selection for selected read/write access of the propeller chip's main memory via the Hub. There is Exclusive read/write tool which is very important with its help it prevent 2 cogs to aim at switch a similar item in memory at a similar case. It conjointly prevents one cog from reading a selected address in memory at the similar time another cog is writing there to. So, exclusive access ensures that there square measure never any access conflicts that would corrupt information. thirty two kilobyte of the propeller chip's main memory is RAM used for program and information storage, and an extra thirty two kilobyte is read-only memory, and stores valuable tables like log, antilog, sine, and graphic character tables.



P8X32A-D40

Figure 4.18: Propeller Microcontroller Packages and Hub and Cog Interaction



Hub and Cog Interaction

Figure 4.19: Hub and Cog interaction

The read-only storage conjointly has boot loader code that cog zero uses at startup and interpreter code that any cog will build use of to get and execute application code from main memory. Each cog conjointly has the flexibility to scan the states of whichever or all of the propeller chip's thirty two I/O pins at any time, also as set their pointers and output states at any instance time.

Introducing Parallax's own all-custom silicon, designed at the transistor level by schematic. The Propeller module is a multi-processing chip, with shared memory and a built-in interpreter for programming in a high-level object-oriented language, called Spin, and low-level (assembly) language. With the set of pre-built Parallax "objects" for video, mice, keyboards, NTSC/VGA displays, LCDs, stepper motors and sensors your application is a matter of high-level integration with Propeller chips. The Propeller chips are designed for high-speed embedded processing, while maintaining low power, low current consumption and a small physical footprint.

The P8X32A-D40 is most useful for prototyping in its 40-pin DIP package. Connecting the Propeller module to your computer's serial or USB port using our Prop Plug for programming is quite simple. The Propeller chip can run on its own with a power supply, internal clock and using RAM for code storage. Add an external EEPROM for non-volatile code storage.

Features:

- Model Number: P8X32A-D40
- Processors (cogs): Eight
- Architecture: 32-bits
- System Clock Speed: DC to 80 MHz
- Global RAM/ROM: 64 K bytes; 32 K RAM / 32 K ROM
- Cog RAM: 512 x 32 bits each
- I/O Pins: 32 (simultaneously addressable by all eight cogs)
- Current Source/Sink per I/O: 40mA
- Clock Modes: (a) External crystal 4 -8 MHz (16 x PLL) (b) Internal oscillator ~12 MHz or ~20 kHz (c) Direct drive
- Package Type: 40-pin DIP

Key Specifications:

- Power requirements: 2.7 to 3.3 VDC
- Communication: Serial for programming
- Dimensions: 0.48 x 2.0 x 0.13 in (12.3 x 51 x 3.41 mm)
- Operating temp range: -67 to +257 °F (-55 to +125 °C)

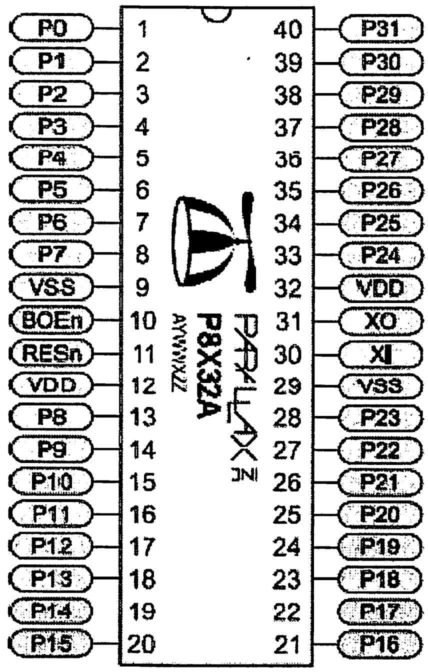


Figure 4.20: Parallax Microcontroller P8X32A-D40 40-pin DIP

Pin Name	Direction	Description
P0-P31	I/O	General purpose I/O Port A. can source/sink 40mA each at 3.3 VDC.
VDD	-	3.3 volt power (2.7-3.3VDC).
VSS	-	Ground.
BOEn	I	Brown Out Enable (active low). Must be connected to either VDD or VSS if low.
RESn	I/O	Reset (active low). When low, resets the Propeller chip: all cogs disabled and I/O pins floating.
XI	I	Crystal input. Can be connected to output/oscillator pack, or to one leg of crystal.
XO	O	Crystal Output. Provides feedback for an external crystal, or may be left disconnected depending on clock.

Table 4.1: Specifications of Parallax microcontroller

4.5.3 Motors

The motors are cobalt, brushless, DC motors rated for 12 V, 25 amps. The DC, brushless motor configuration was desired for ease of control (ability to control via PWM). The cobalt rotors use strong rare earth magnets and provide the best power to weight ratio of the hobby motors available for model aircraft. We were limited to these hobby motors by our design budget. As a result, the rest of our structural design revolves around the selection of these motors and the allowable weight of the craft based on the lift provided by these motors (approximately 950g of lift from each motor).

Figure 4.21: BLDC motor

4.5.4 Electronic speed controller

Electronic speed controller is a device used to control the rotations of BLDC motor. It has power input wires (red & black) and another set of wires for PWM signals. The esc we are using is a 30amp esc which is suggested by motor manufacturer.

Figure 4.22: Electronic speed controller

4.5.5 Propellers

Propellers are the propulsive plant of quad rotor. In quad rotor pair of counter clock wise and a pair of clock wise propeller is used to fly. We have chosen 10*4.5 inch propellers where 10 is the diameter of propeller and 4.5 is the pitch.

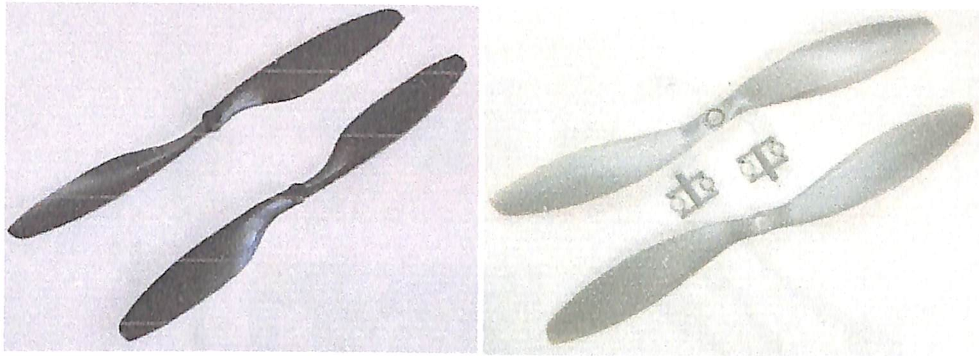


Figure 4.23: Propeller set

4.5.6 Battery & Charger

The battery was selected on the basis of power requirements for the selected Motor and esc combination. We opted for a battery of the lithium-polymer variety, despite the fact that it was considerably more expensive than other batteries providing the same power, because this battery provided the best power-to-weight ratio. Our battery choice was a 2200mah 12.0V 25-30C Li-polymer battery. A balancer charger is recommended for li-poly batteries for longer life of battery.

Figure 4.24: Battery & Balancer charger

4.5.7 Control Unit

Control unit is the brain of the UAV which takes the input from the user and according to the input values it gives instructions to the motors and hence stabilises the UAV. The control board (APM 1.0) is a 32 bit based microcontroller unit.

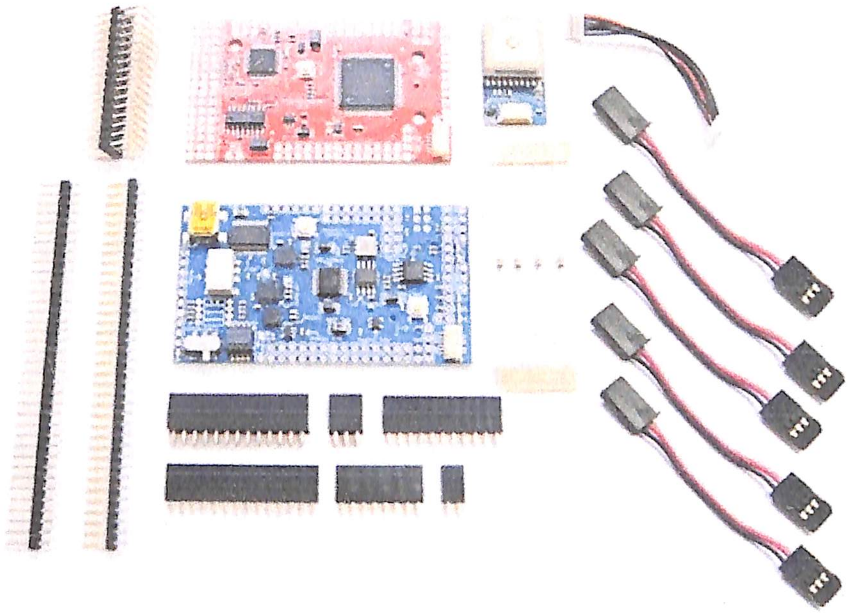


Figure 4.25: Ardu Pilot Mega (APM)

4.5.8 Tools

Soldering iron, screw driver set, soldering wire etc.

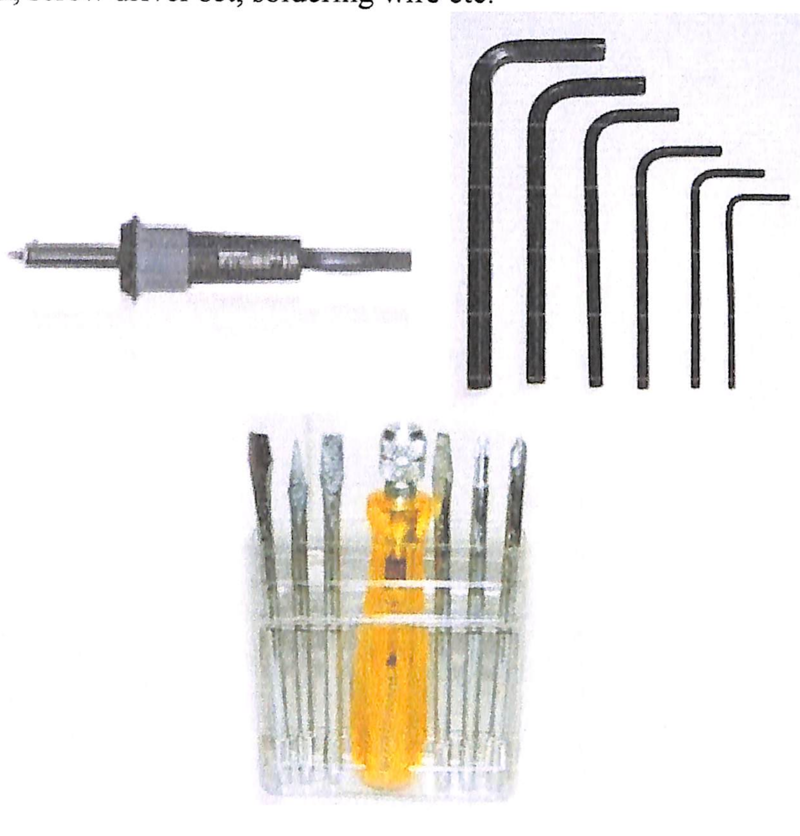


Figure 4.26: Tools

Applications:-

UAS (Uninhabited Aerial Systems) have received increasing attention in the last decade as are placement for expensive human-piloted systems. They have become a widely used platform for many applications for which human operation are considered unnecessary, repetitive, or too dangerous. UAS have extremely varying application domains that include both indoor and outdoor applications. Possible UAS applications are enumerated in the list below:

- Aerial Surveillance and Intelligence for Law Enforcement
- Hobbyist and Professional Aerial Photography and Video
- Property Assessment and Real Estate promotion
- Traffic monitoring and Traffic pattern Analysis
- Weed identification in Agriculture
- Educational learning Platforms
- Search and rescue operations
- Significant role during disasters

The listed application domains require different levels of control and maneuverability. Some applications may need high precision, while others may have a larger tolerance.

CHAPTER 5
MODELLING AND CONTROL LAW DESIGN

A control law is a set of pattern that predominates that are used to determine the commands to be sent to a system based on the desired state of the system. Control laws are used to prescribe the moves of an aircraft within its environment, by sending commands to an actuator(s). The goal is usually to follow a pre-defined trajectory which is given as the robot's position or velocity profile as a function of time.

The flight control system is the system which controls the plane. This system consists of mechanical and electronic part, and the pilot. It has to improve safety by means of a high degree of fault tolerance, and by remedying the task of the pilot:

- Reduce the pilot's workload by providing an intuitive user interface and by performing some functions automatically.
- Prevent the crew from inadvertently exceeding the aircraft's controllability limits.
- Act to maintain the aircraft within its normal range of operation.
- Prevent the pilot from inadvertently entering a stall condition.

5.1 Functional Analysis and System Definition

From top-level point of view the flight control system consist of the following parts:

- Electronic Flight Control System (EFCS)
- Actuator control
- Flight control surfaces
- Sensors
- Interface
- Pilot

The relations between these parts are depicted below

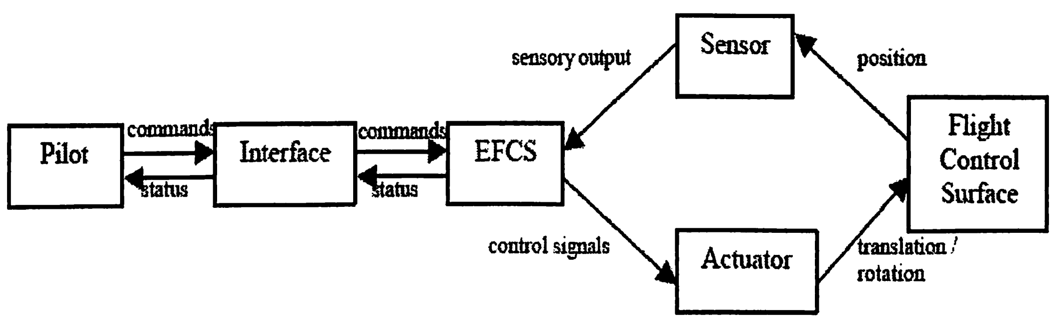


Figure 5.1: System top-level functions of the Flight Control System

5.2 Maintenance Concept

To assert the flight control system various necessary things are required:

- Modularity so spare parts can be swapped in easily.
- Self testing system (and parts) that will indicate faults in an early stage.
- Automatic performance logging (so engineers can trace odd behavior in the past).
- Periodic replacement of parts that are subject to wear-out.
- Service engineers, training.
- Service documentation, storage and access.
- Test and support equipment

Fault tolerance can be implemented by making the entire control system redundant. An example can be seen in figure 4, where there is a mechanical as well as an electronic link to the control surface. The actuators can be mechanical and hydraulic. This kind of redundancy has to be applied in every subsystem. Suggested is to use multiple pilots, interfaces, computers and algorithms, sensors and actuators preferably in an arrangement that are designed to provide a high degree of protection against a wide variety of system faults. Triple redundancy will serve in emergent cases and will be required for the control system.

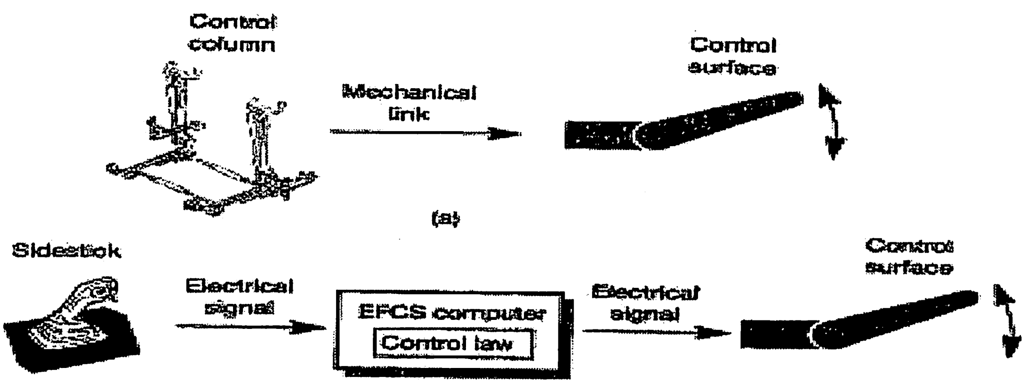


Figure5.2: Mechanical and Electrical control

Each flight control surface must be driven by multiple independent actuators, which are in turn controlled by different computers. This guarantees that failure of a single actuator or computer will not result in a loss of control of that surface. As movement of the control surfaces is achieved using hydraulic actuators, the hydraulic supply represents a key component within the control system. In common with other commercial aircraft, three separate hydraulic supplies should be used.

5.3 Allocation of Requirements

The requirements set for the top-level system have to be applied to all subsystems. So if it is required to have three fold redundancies each part comprising of EFCS computers, actuators, sensors, power supplies etc. have to implement threefold redundancy.

EFCS computers have to interpret pilot commands, combine it with all kinds of sensory input and use it for actuator control and interface display. They also have to monitor (and eventually reconfigure) the entire system, including itself. EFCS computers should operate independently. If one of these computers malfunctions, its tasks should be taken over by the other computers.

Actuators are driven by the EFCS computers and have to position the flight control surfaces. They must be very accurate and show no hysteresis so position is always known. Sensors are to be used for all flight control surfaces besides for flight status measurements invokes airspeed, attitude, altitude, horizon, vertical speed, GPS information. The sensors have to be used in high quantities. They must be very accurate and work independently, and stay robust in all weather conditions. They have to be protected against shocks, extreme pressures and temperatures, moisture etc.
The interface has to show sensory measurements, flight status, but also feedback to recent signal commands. The controller should be able to request all kinds of information, like system status, air traffic status and weather status. Furthermore it has to show all kinds of calculations e.g. errors, deviations and also warnings. It should be very reliable and should also be very ergonomically in use.

5.4 Test and Support Equipment

The testing has been done by experiencing a flight of the prototype model of unmanned aerial vehicle by the ground crew periodically. The circuit involving all the electronics equipments have been tested which is capable to test all sensors is responding correctly and keeps track of power consumption of all parts. If a part is consuming more power than its estimated amount, a fault could be present. The team members also tested all essential parts before every take-off. All other parts should be tested every flights.
We have also taken the videos of all the flight that has all the necessary actions and are therefore captured for future purposes and evidence.

5.5 Design and Development of Control laws

The design of flight control laws (FCLs) for automatic and manual (augmented) control of aircraft is a complicated task. Large amounts of performance criteria and must work reliably in all flight conditions have to be fulfilled by the flight control laws, for all aircraft configurations and in adverse weather conditions. Consequently, a large part of the FCL design process involves extensive simulation analyses, hardware-in-the-loop testing and flight testing. Multi-disciplinary aspects here play an important role. For example, control laws heavily influence loads on the airframe during maneuvering and in turbulence, as well as flutter stability of the structure. These aspects are extensively addressed, after the actual design phase. As a consequence, problems that arise with other disciplines usually give rise to re-design of control law functions. This thesis proposes a Flight control law design process that allows multi-disciplinary aspects to be addressed from the beginning. In the first place, this requires multi-disciplinary aspects to be present in the aircraft dynamics models used for FCL design. Lastly, the use of object-oriented modeling techniques is proposed which in contrast to contemporary techniques, inherently supports the development of models consisting of components from various engineering areas. In the second place, multi-disciplinary FCL design requires a means to automate tuning of design parameters and functioning of the control surfaces, since consideration of the many additional criteria make manual parameter synthesis are well refined. This technique allows certain parameters to be optimized with respect to the possible conflicting design criteria via so called min-max approach.

5.5.1 Controller Design

The following schematic depicts our controls system. The diagram represents how the control system interacts with the physical system for controlled quad-rotor flight.

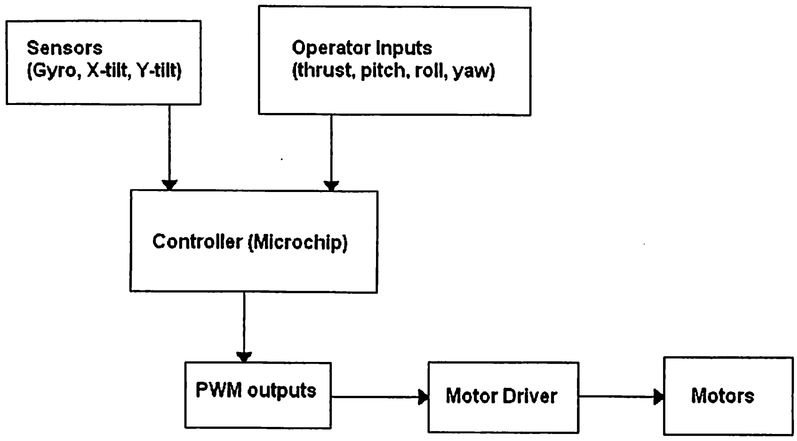


Figure 5.3: Control system schematic

PWM Encoder Driver- Once everything has been computed, the PWM Encoder takes the control values and generates a pulse width modulated (PWM) output for each motor. This is the exact opposite process of the PWM Decoder.

The proposed design process allows the analyses to be directly addressed in the synthesis of control law parameters, so that analyses for documentation can be passed in one shot. The proposed multi-disciplinary design process further allows the control design in aircraft preliminary design, by providing a means for rapid control law modeling. This methodology allows nonlinear control laws for a specific aircraft design status to be automatically generated from an object oriented implementation of a current flight dynamics model, using the technique of feedback linearization and the possibility of automatic model inversion from object oriented programming implementations. For the control, rapid prototyping allows for quick experimentation with controller structures, the selection of command variables, etc. For other engineering departments, the methodology results in early availability of representative control laws to analyze dynamic flight characteristics of the current aircraft design.

In this report, we design a distributed UAV formation flight control law in the framework of nonlinear master program control and feed it to microcontroller. A virtual reference point control strategy is used to determine the formation configuration. Vehicle crashing avoidance is guaranteed by cost function combined with a priority strategy, using the effective material for structure purposes.

CHAPTER 6
RESULT AND CONCLUSION

6.1 Result

The process starts with calculating-estimating data of the UAV needed for non linear flight model. It consist of the aerodynamic data, the stability and control derivatives as well as geometrical data of aircraft, like the moment inertial, wing span and the wing surface. Figure 6.1 shows the final fabricated UAV model. The design and development process of autonomous control laws (control algorithm) for this UAV starts with the definition of the mission that it will follow, which impose the requirement upon the shape and velocity.

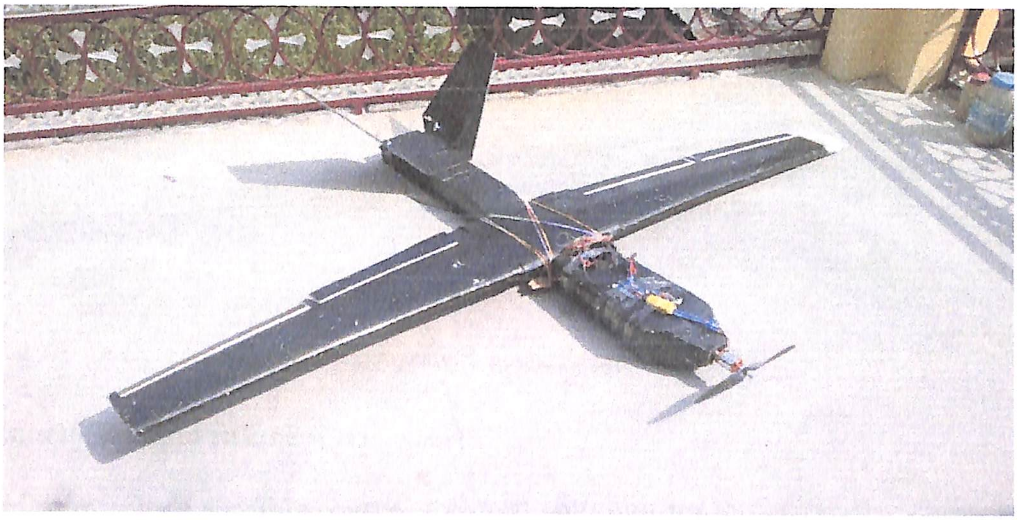


Figure 6.1: Prototype scaled model of UAV

Our project starts with various sketches by hand that was transferred to the drawing table in solid works. Then we have chosen the MQ-Reaper UAV for our study, model and analysis. We have first design the original model in solid works using the required dimensions.

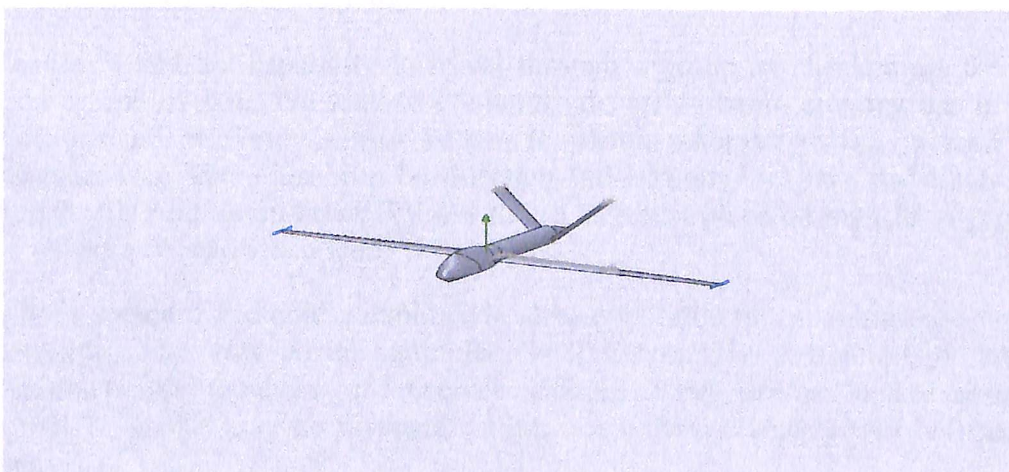


Figure 6.2: Solid work model of MQ-9 Reaper

The following model is the well scaled model of the prototype model which we first designed in solid works as our preliminary work which results in a relatively innovative design, having a straight base line aircraft.

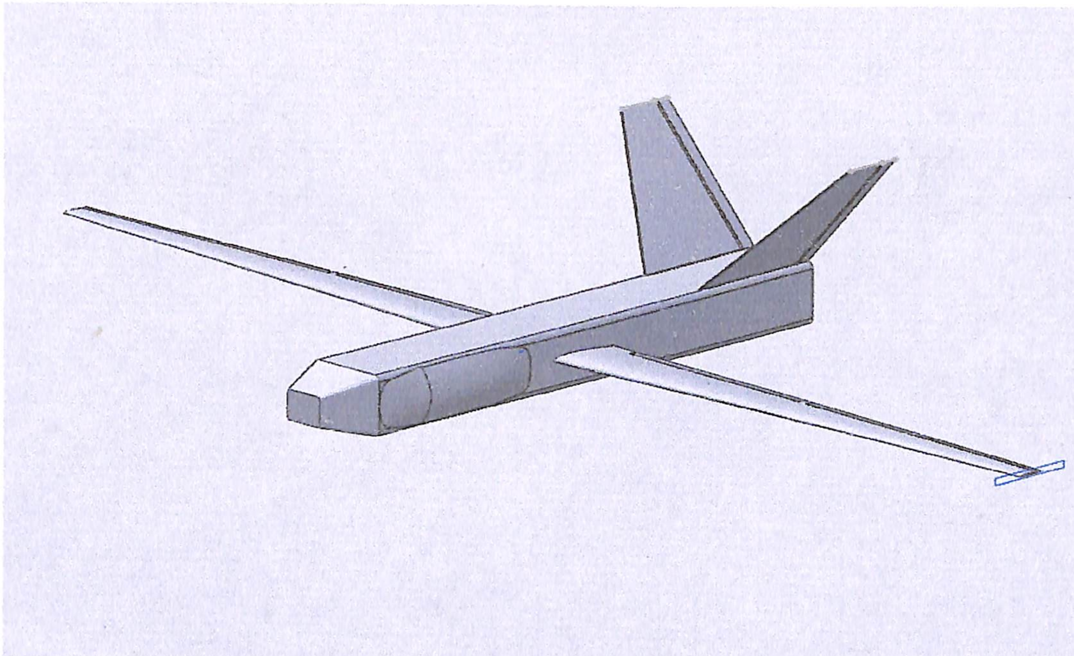


Figure 6.3: Solid work model of fabricated UAV

6.2 Conclusion and future work

Autopilot may be a sensible source, standard autopilot for RC- aircrafts. They can be enabled/disabled with the assistance of an additional channel/switch located on your transmitter device, and once switched on and off, stabilizes the aircraft in the direction in which it is directed without losing its altitude and flight path.

In future this plane can be used to navigate its path and return back to the originating position, where it'll circle around in case autopilot mode is left turned on. It also can optionally trigger different peripheral actions, like taking a snap or for dropping things, once it reaches a checkpoint.

We decide to add the capability to travel through a group of checkpoints for it to navigate to one by one. We tend to conjointly decide to begin creating use of data from the ground proximity sensor system to permit autopilot to land a craft at a selected location. There also can be different fun add-ons too, like stabilization of inverted flight, And an on-board TV-out to use as a text place on high for a primary person purpose of read video feed.

Autopilot's standard and configurable style already permits for an enormous quantity of flexibility. Therefore as an example, you'll use simply navigation, or simply stabilization. The numbers of receiver channels and servos square measure configurable. Servos may be reversed. Either one or two channels will be used for ailerons.

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