DESIGN & DEVELOPMENT OF PLC/MCU BASED FULL FLIGHT SIMULATOR COCKPIT OF CESSNA-172 AIRCRAFT

B.E. SENIOR DESIGN PROJECT REPORT
Electronics Specialization

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SDP COMPLETION DECLARATION

ELECTRICAL ENGINEERING DEPARTMENT

We the students of Electrical Engineering department (College of Engineering), with batch **Spring 2019** hereby declare that we have completed our final year project titled **Design & Development of PLC/MCU Based Full Flight Simulator Cockpit of Cessna-172 Aircraft** and have achieved all targets set forth in the project proposal.

It is requested that we may be examined.

	NAME	REGISTRATION ID	SIGNATURE
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Confirmation by Project Supervisor:

I **Dr. Safi-ud-Din Qadri**, as project supervisor for the above-mentioned group confirm that they have fulfilled all the necessary requirements of the final year project including the number of minimum visits for supervision, submission of all deliverables etc.

They may now be allowed to present and defend their work.

____

Signature with date

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				Remarks (If any)
1.	Report submitted	☐ Yes	☐ No	________________
2.	Project hardware & software fully functional	☐ Yes	☐ No	________________
3.	All other deliverables received	☐ Yes	☐ No	________________
4.	Presentation Date & Time	________________		

Approved by Project Committee ☐ Yes ☐ No

		SIGNATURE
1. Chairperson	**Dr. Syed Safi Uddin Qadri**	________________
2. Member	**Dr. Sameer Hashmat Qazi**	________________
3. Member	**Miss Noor ul Ain**	________________

Approved by the Dean/Director:

I certify, to the best of my knowledge, that the required procedures have been followed and the preparation criteria have been met for this project work.

Dated: ________________

____

(Dean/Director CoE)

Karachi Institute of Economics & Technology

Korangi Creek, Karachi-75190, Pakistan

SDP CERTIFICATE OF COMPLETION

This is to certify that the following students of College of Engineering have completed their Senior Design Project under the title ***"Design & Development of PLC/MCU Based Full Flight Simulator Cockpit of Cessna-172 Aircraft"*** in partial fulfillment of the requirement of the **Bachelor of Engineering in Electrical Engineering.**

GROUP MEMBERS:	REGISTRATION ID
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(Name & *Signature)*

Senior Design Project Committee:

Dr. Syed Safi Uddin Qadri	**Dr. Sameer Hashmat Qazi**	**Miss Noor ul Ain**
(Chairperson)	**(Member)**	**(Member)**

Assoc. Prof. Dr. Sameer Hashmat Qazi
Head of Department (HoD)
Electrical Engineering Department

Gp Capt (R) S. Najeeb Haider Jafri
Director, College of Engineering
KIET

FINANCIAL SPONSORSHIP

The project is selected for financial assistance and got "Proposal Acceptance Certificate" by Pakistan Engineering Council (PEC) under the umbrella of FYDP funds. We are thankful to the PEC team for shortlisting our project after a competitive analysis of projects.

Ref No: PEC/PPDC/22/261

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PLC/MCU Based Full flight Simulator cockpit of cessna-172 Aircraft.

(Electrical Department, PAF-KIET, Karachi)

of your university has been approved for financial assistance by PEC

CONGRATULATIONS

It is required to complete this Design Project in accordance with the PEC standards so it can be included in the Capstone Expo-2023 and have it uploaded to the PEC E-library.

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SUSTAINABLE DEVELOPMENT GOALS (SDGs) TABLE

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06	Clean Water and Sanitation	
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15	Life on Land	
16	Peace, Justice and Strong Institutions	
17	Partnerships for the goals	

PLO RUBRICS

PLOs	Mapping	Page No.
PLO1	Knowledge of the math, science, and engineering specialization have been applied to foresee the main challenges in project and their possible solutions	9, 10
PLO2	Principles of engineering are thoroughly applied to identify the problems, followed by analysis and literature review to address the actual scope of project	19, 20
PLO3	Transformation of idea(scope) into design that complies with existing standards of respective field and fulfills all requirements including safety, conservation and economics within realistic constraints.	16-18
PLO4	Designed problem and its solutions were properly investigated in a methodical way resulting in synthesis of information. Further valid conclusions have been derived after testing multiple case studies, through experiments and simulations.	29-33
PLO5	Employed techniques, resources, and modern engineering and IT tools, including prediction and modeling, in the feasibility or the development phases for designing, testing, debugging, and optimization of the project.	35-42
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PLO7	Highlight the societal and environmental impact of the engineering project solutions and justify the sustainability of designs.	59
PLO8	Provide a proof that you have followed ethical principles, commit to professional commit to professional ethics and responsibilities, and norms of engineering practice and haven't forged or exaggerating the actual contribution, result in violation of research ethics. (plagiarism report)	ii-v
PLO9	Exhibit soft skills needed to actuate teamwork. Demonstrate roles of each project member from the team lead to a supporting role depending upon the nature of tasks and milestones achieved. (Resource allocation in Gantt Chart)	11-12
PLO10	Effectively explain their work in the form of oral presentations and (written) technical report using charts, graphs, figures etc.	29-34
PLO11	Demonstrated management skills through effective project planning, resource and budget utilization, task scheduling and meeting deadlines. (Gantt Chart)	11
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ACKNOWLEDGMENT

In the beginning, all praise to the almighty Allah, who provided us strength by which we have completed this project, it was no doubt is the blessing from Allah. During the project completion till the last day and the span this report was compiled and written, a number of people give us immense support and encouragement.

The research project titled "**DESIGN & DEVELOPMENT OF PLC/MCU BASED FULL FLIGHT SIMULATOR COCKPIT OF CESSNA-172 AIRCRAFT**" was successfully completed in the Avionics Systems Design Lab of the **Karachi Institute of Economics & Technology (KIET)** under the Pakistan Engineering Council (PEC) Annual Award of Final Year Design Projects (FYDP's) for the year 2022-2023. The project was supervised by "Dr. Syed Safi Uddin Qadri".

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ABSTRACT

In this era, aviation becomes an essential part of human life. In the first decade of 1900 CE, when aviation was in the initial stage of aviation, first successful flight was made. It was dec 17, 1903 when famous wright brothers remarked this achievement. Before achieving this milestone hundreds of unsuccessful attempts were made and resulted in the loss of human lives and capital. Although invention is not an easy target to achieve without loss of anything, but it could be done in a more convenient way which can reduce risk of human life. Because this asset is non-replenishable and unreplaceable so can’t take risk of it.

Unlike driving a car, flying an airplane requires a pre-defined set of skills and sound knowledge and training of aerodynamics, flight controls, aviation safety rules and regulations, communication with ATC, reading flight data, taking feedback from instruments and managing all these things at the same time along with controlling aircraft and follow the given flight path. A small mistake in this can be fatal or at least may result in serious injuries. It is much clear from the above discussion that its not an easy task to manage all the things in parallel so there is a need of ground training and proper learning before starting flying. If talking about conventional flying training, it is all about classroom lectures, flying lessons, audio-visual sessions and all these with a little bit practical flying. This is because onboard flying training requires a lot of resources and is much expensive due to higher cost of unleaded hi-octane fuel, aircraft routine maintenance cost, instructor salary etc. Besides this, taking flying permit from concerned CAA and aviation safety agency is another big factor. Similarly, weather conditions can also affect your plan so there are a large number of factors which reduce the number of practical flying sessions.

With the passage of time, research techniques, as well as teaching and training methodologies are totally changed and now you just have to spend time and money to achieve anything and not need to take risk of your life. Same applies to aviation, there is no need to take risk of human life just to learn flying but it can be done on ground with similar conditions and the environment, and it is made possible only by the development of an amazing and outstanding device known as “flight simulator”.

Our project is about the development of a Full flight simulator cockpit having all the control columns, flight instruments and switches like an aircraft. It also includes complete modeling and simulation of the various displays of the aircraft as well so that the trainee pilot can see in and outside views of the aircraft on different display panels.

KEYWORDS

AFCS:	Automatic Flight Control System
ATC:	Air Traffic Control
ADC:	Air Data Computer
EASA:	European Aviation Safety Agency
FCS:	Flight Control System
FCC:	Flight Control Computer
FDCVR:	Flight Data & Cockpit Voice Recorder
PCCA:	Pakistan Civil Aviation Authority
PIA:	Pakistan International Airline
PAC:	Pakistan Aeronautical Complex
PAF:	Pakistan Air Force
TX:	Transmitter
RX:	Receiver
ADC:	Analog to Digital Convertor
DAC:	Digital to Analog Convertor
SDA:	Serial Data
SCL:	Serial Clock
I/O:	Input output
UDP:	User Datagram Protocol
MCU:	Microcontroller Unit
SPI:	Serial Peripheral Interface

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PROJECT OBJECTIVES

Motivation

Flight simulator cockpit is basically a device which consists of all the displays and controls to mimic the actual environment of the aircraft. Displays involve external displays which shows the actual surrounding of the aircraft like weather, airport tower, ground, runway etc as well as internal displays and dials which gives info about flight data and physical parameters of the aircraft like engine speed and status, static and dynamic pressure, temperature, altitude, heading etc

Problem Discussion

There is a small number of multinational companies and industrial manufacturers who make flight simulators. TRC simulators is one of them whose designs are outstanding. Their simulators are available in the abroad market so anyone who need it in Pakistan is required to order it online and wait for shipment. According to our custom and merchant navy rules, these products considered as luxury products so 100% duty will be charged on the shipment of these products. These simulators are expensive and addition of custom duty make them costly which is not possible for everyone to buy them, so there is a very small number of organizations and institutions who order and afford them.

If these simulators are purchased with all duties and taxes even after this they can't fulfil the requirements of a research organization or educational institutions as when it comes to testing an algorithm like autopilot or VTOL etc which requires modification in code and programming or sometimes change of controller, it doesn't allow you to do so as the product has limited access to "use only" not to modify programming or code so after spending a lot they are restricted to operate only.

On the other hand, they have maintenance issues because of unavailability of devices or due to communication gaps between foreign companies and our maintenance providers.

Aim

We aim to design a cost-effective solution for this. Our design involves complete physical modelling of the aircraft cockpit, as well as the simulation of the head up and head down displays of the aircraft by means of PC based flight simulation software and electrical and electronic control system to model switches, pots and other physical inputs and controls.

Objective

The main objective is to design a full flight simulator cockpit of Cessna-172R which is a famous trainer aircraft. Although its cockpit is designed like that of Cessna but can be used for flight simulation of other aircrafts which are available in the software. The reason behind selection of this aircraft among others is that it is used worldwide for flying training. Its simulation is available in all the famous flight simulation softwares e.g. X-plane, Microsoft Flight Simulator.

- A Full flight simulator whose cockpit is a replication of Cessna-172R aircraft
- It should have all the important control columns, switches and displays which play a vital role in a complete flight
- It should have the feasibility to switch over from one flight simulation software to other and will not limited to one flight simulation software
- With slight modification or addition of hardware, it can be used as test bench to test avionics algorithms like autopilot
- It is equally beneficial for student pilots and instructor pilots

Methodology

Our flight simulator is divided into four major parts:

1) Front Panel
2) Elevation Angles
3) Pilot Seat
4) Base

Front Panel

The soul of our entire project is front panel which is further divided into two major sections:

1) Displays

   They are further classified as:

   a) Head-up Display (32’’ LED Monitor)
   b) Head-down Display (22’’ LED Monitor)

2) Controls

They include switches, control columns, knobs etc which are mounted on front panel. Few of them are in form of modules and are as follows:

1) Ignition & Switch Panel
2) Throttle & Mixer Quadrant
3) Flap Switch
4) Trim Wheel
5) Fuel Selector
6) Parking Brake
7) Flight Yoke

Market or Industry adaptability/applications:

Our project is not just an integration of few devices and displays but an effective solution to a huge problem of aviation industry so has a great industry adaptability and application. There is a huge market for flight simulators and its variants. This is because keeping an aircraft is not as easy as anyone think of there are are a large number of customers who need this product, they include flying schools, airlines, flying clubs, airforce, aeronautical institutions etc and last but not least student pilots, hobbyist pilots and aeronautical Engineers can purchase them for personal use and learning purposes.

Gantt Chart

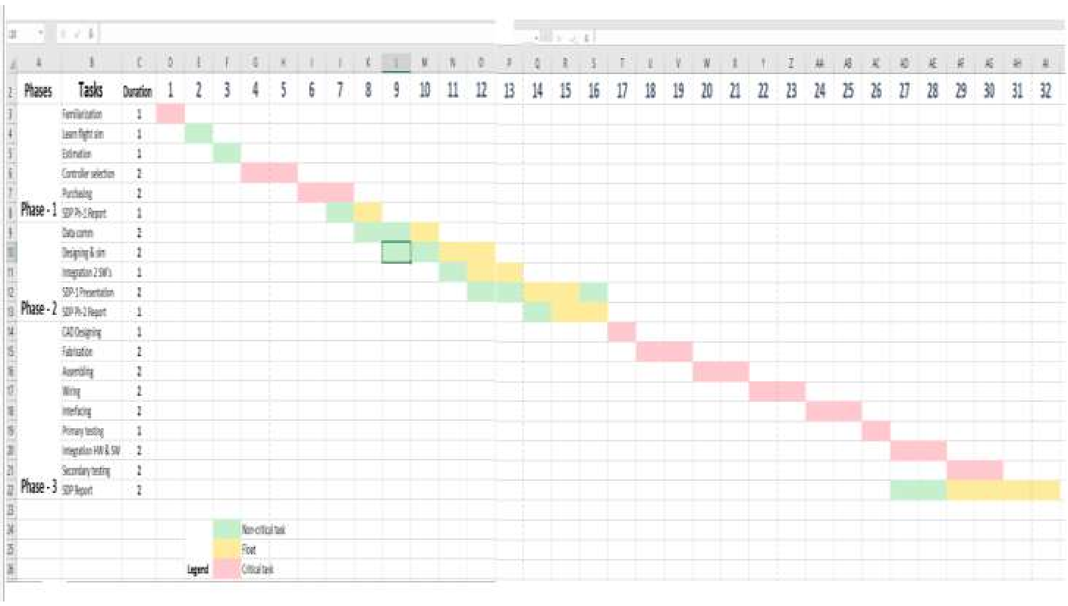

Fig 1-1: Gantt Chart

At the very initial stage, in SDP0 we did planning for SDP working till completion. For which we divided the entire work into 3 major phases as shown in the gantt chart. Each phase has assigned tasks which are further divided in weeks with period as shown:

Phase	**Task**	**Duration**
Phase-I	Familiarize with the aircraft & flight simulator, Do estimation & market survey	Jan - Mar
Phase-II	Data gathering & Designing of Electronics (Avionics)	Mar - May
Phase-III	Designing, Fabrication & Integration of all the devices	May - Nov

Table 1-1: Task Distribution Table

CHAPTER 1

1 INTRODUCTION

Flight simulator cockpit is basically a device which consists of all the displays and controls to mimic the actual environment of the aircraft. Displays involve external displays which shows the actual surrounding of the aircraft like weather, airport tower, ground, runway etc as well as internal displays and dials which tells us about physical parameters of the aircraft like engine speed and status, static and dynamic pressure, temperature, altitude, heading etc Different companies make flight simulators which are available in the market but are very expensive and have maintenance issues because of unavailability of devices or due to communication gap between foreign companies and our maintenance providers.

The typical users of today's flight simulators are commercial airlines, and they are designed to emulate specific production aircraft. The expense of these full-flight simulators (FFSs), which can be in the tens of millions of dollars, has, however, typically prevented their adoption for pilot training at the entry level. A flight training device (FTD), which is considerably less expensive and has poorer fidelity, is being examined as a more cost-effective option. Although FTDs can be useful for pilot training, unlike FFSs, regulatory bodies do not view the time spent using them as being equivalent to time spent in the actual aircraft. FTDs' introduction of immersive simulation into flying schools, like the nearby Ottawa Aviation Services (OAS) Flight Centre, is a highly welcome development. FTDs have the disadvantage that their aircraft simulators are constrained by the fact that they are not typically aircraft specific, do not offer motion cueing, have a more constrained field of view, and have poorer visual fidelity than what is ideally needed for efficient pilot training.

1.1 Project scope

Aviation industry is a billion-dollar industry. Any institution or organization related to aviation charges a lot in exchange of services which they offer it may be in terms of air ticketing, pilot training and educational services. Besides this those research organizations which are related to avionics or aerospace mostly face difficulties when it comes to test a device or algorithm like autopilot or VTOL etc because of the fact that they can't test an algorithm directly on aircraft without knowing their after effects as it would result in loss of human lives. On the other hand, they are bounded by aviation rules and regulations made by safety agencies like EASA, SAARI and aircraft manufacturing companies like Cessna, Boeing, Airbus etc. In a nutshell, they can't test anything directly on aircraft without undergoing a lengthy legal process. The only solution for these problems is to buy a flight simulator. But the story wouldn't end here even if they manage to buy expensive company made flight simulators, they are restricted to use or operate them but can't test algorithms on it due to limited access which companies provide to them in exchange of huge amount so there a huge market whose problem is solved by our design. Its scope can be classified as follows:

- It may solve a huge problem of the unavailability of modern aircrafts in the flying schools and training institutions as it can replace them not entirely but partially.
- It can be used for initial flying training
- It can be used to evaluate the aptitude of a person for flying (flying aptitude test) which generally conducted in Air force and Flying schools for selection of commercial and fighter pilots.

1.2 Key Objectives

- Easy to use and operate
- Wide variety of software support
- Can be modified when required
- Artificial feel system like a real aircraft
- Adjustable seating arrangement

1.3 Functionality

Seat There are many ways to design hand gestures vocalizer, some designs are based on digital image processing but our main focus is to achieve efficiency and remoteness and time to speak. In our design we use flex sensors which changes its resistance on bending we use it with fixed resistance ,followed by voltage divider .

The signal went to the ADC of microcontroller then the program executes send the signal to send the microcontroller using I2C protocol, the second microcontroller has send the signal to DF mini mp3 player ,which play the voices. The flex sensors is implemented on gloves, which make it wearable electronics. We use clustering algorithm, it is grouping of objects in sets in such a way that objects in the different groups are more different to each other to than those in other groups. Main task of clustering algorithm is exploratory, data mining and for data analysis in many different fields like machine learning, image processing, bio informatics and computer graphics. It is the simplest unsupervised learning algorithms.I2C communication protocol is serial, half-duplex ,two wired communication interface protocol. It is used to connect low-speed devices such as A/D and D/A convertors, I/O interfaces, microcontrollers, EPROMS in embedded systems. Data is send by bit by bit along a single line, one is SDA which is data line and other SCA which is serial Clock line.

CHAPTER 2

2 DESIGN OBJECTIVES, ISSUES AND THEIR ANALYSIS

2.1 Design objective:

The main objective of making this project is to design an efficient and effective solution for flying schools, flying clubs, aeronautical research organizations. It may also fulfil the requirements of Aeronautical Engineers in terms of research and educational purposes as well as the hobbyist pilots for entertainment purpose.

Before coming towards design objective, I would say that we are not the first who’re working on it. There is a large number of people who have done some work and achieved milestones, even a group from our senior batch made flight simulator in their final year. But we planned to do it in a different way and do some innovations in the design. First and foremost, unlike others, we planned to design own control columns i.e. flight yoke, rudder pedals, throttle quadrant, parking brake etc so that we can modify them in future. We made separate module for each control column so it will be replaceable and can be taken to the workbench for maintenance, testing, modification etc. Secondly, we made flexible design so that modifications can be made when desired. Like for using simulator as test bench some addition of hardware is required. If talking about autopilot testing, an essential requirement of autopilot is that there should be a servo mechanism (a servo motor or a pair of stepper and encoder) for moving the control column automatically in autopilot mode. Let us take an example of flight yoke, it controls 2 DOF’s of aircraft, pitch and roll. In manual mode, rolling moment is done by turning yoke CW or CCW while pitching is done by push pull motion of the yoke and each moment is sensed by means of encoder or pot by measuring angular displacement in terms of voltages or pulses. In autopilot mode these moments should be done automatically which requires a motor having certain amount of torque enough to drive the yoke. We made it using encoder and pots but not servo or stepper as our design is manual, so for autopilot testing a servo/stepper motor could be added to achieve the desired results.

Initially we decided to use LabVIEW for designing our control algorithm and programming. For which we need to do these four tasks in series:

1) Reading flight data from X-plane and display it in LabVIEW using anyone UDP reading port (49001-05)
2) Reading IO’s from physical world and display their status in the LabVIEW VI. These IO’s including switches, encoders, pots etc.
3) Writing flight data from LabVIEW to X-plane using UDP writing port (49000)
4) Writing flight data which is gathered in LabVIEW from real world IO’s

When it comes to task1 which is reading flight data from X-plane, we did it using different UDP ports like 49001, 49002, 49004 etc

2.2 Issues:

As our project is a complete system and related to aviation which has specific application so there are a number of issues which we encountered during this project. We divided these issue in four categories:

1) Hardware Related Issues
2) Software Related Issues
3) Issues in Structure

2.2.1 Hardware Related Issues

Our hardware is not limited to electronics but rather it involves ruggedized Electromechanical systems in which sensing of moments is done in a way that each moment is associated with another one so sensing them separately and collectively is not an easy task. Therefore, we face a number of issues while designing it few of them are discussed here:

Here are few hardware related issues which we faced during our project:

1) Limited Span of Pot’s Motion

Initially we decided to employ pots for sensing angular moments of yoke or rudder pedals. The thing which restricts ourselves is the span of the motion of potentiometer. Generally, conventional pots have around 270 degrees of full motion while our requirement is about more or less 360 degrees. so we look for another solution which may be multiturn or precision pot. But the problem is its resolution which is around 10 turns for full motion which is more than enough for us as our need is 360 degrees or 1 revolution so if employ this we'll get very less resolution due to division factor which comes due to large number of turns, For instance a 10kΩ precision pot has a resistance of about 1kΩ / turn which in terms of voltage change will be around 0.5V if applied voltage is 5V so this can't work well too.

The main issue which we encountered during this project was not able to send data to X-plane. This issue took a lot of our time due to many unsuccessful attempts which are made to rectify and resolve it. Initially we were trying to send data without reading it We've make another VI and trace each and every logic block of block diagram of VI but not succeeded in tracing any fault in it. After that due to

2.3 Analysis

To resolve this issue of sending data we find another way which is to use flight data extracting tool. There are a number of tools available for it we employed dataref toolkit which not initially worked but after hit and trials it worked perfectly.

CHAPTER 3

3 DESIGN SPECIFICATIONS

3.1 Literature review

3.1.1 Flight Simulators

In general, flight simulators are available in two fashions:

1) Static Flight Simulator
2) Motion Flight Simulator

Static Flight Simulator

Fig 3-1: TRC300 Simulator Courtesy of TRC Simulators

The simulators belong to this class have static platform including head up and head down displays and seating arrangement. This seating may either be in a fixed manner or adjustable system so that person can move it forward or backward according to his/her ease of sitting. This type of simulator is available in two classes:

1) Single Seat (For Trainee Pilot)
2) Dual Seat (For Trainee Pilot and co-pilot/instructor)

Motion Flight Simulator

Fig 3-2: Full Motion Flight Simulator for Boing Aircraft

To better understand about motion flight simulators, knowledge of aircraft moments is essential. So first we've to put some light on moments of an aircraft. As aircraft has to perform some certain kinds actions and movements to gain or loss altitude and speed to achieve desired values for take-off, landing, turning, heading hold, altitude hold, attitude hold etc. These actions based on aircraft moments also called as "degrees of freedom". In total, there are six types of moments which an aircraft made during flight. They are also referred to as six DOF's or degrees of freedom of an aircraft.

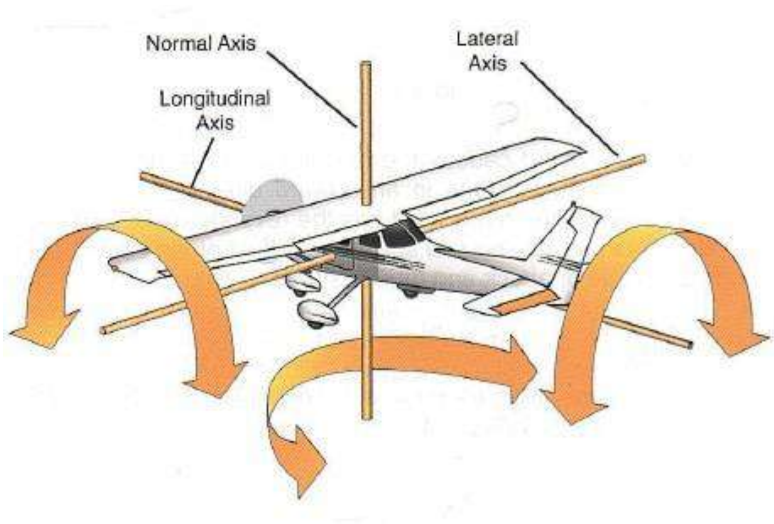

Fig 3-3: Aircraft Axes System

These moments are classified into two groups, one group is of linear moments and the other for angular moments and interesting thing is that angular moments are of much importance than that of linear. So angular moments are described first which are as follows:

1) Roll (about longitudinal axis of the aircraft)
2) Pitch (about lateral axis of the aircraft)
3) Yaw (about normal axis of the aircraft)
4) Heave (up-down motion along normal axis)
5) Surge (forward-backward motion along longitudinal axis)
6) Sway (right-left motion along lateral axis)

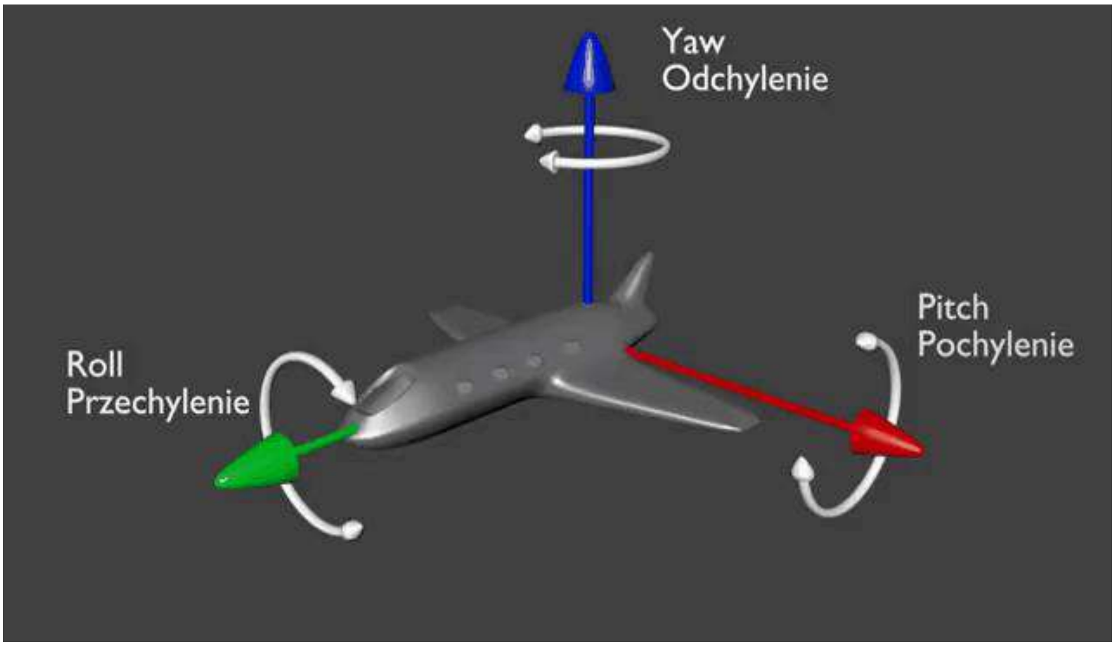

Fig 3-4: 6 DOF of Aircraft

So coming back towards the discussion of motion simulators, these kinds of simulators are equipped with a motion platform to model above moments of aircraft. They have few or all kinds of moments so they are further classified on the basis of the number of moments which it can model as degrees of freedom. These classes are as follows:

1) 2 DOF (Pitch-Roll)
2) 3 DOF (Pitch-Roll-Yaw)
3) 4 DOF (Pitch-Roll-Yaw-Heave)

4) 5 DOF (Pitch-Roll-Yaw-Heave-Sway)
5) 6 DOF (Pitch-Roll-Yaw-Heave-Sway-Surge)

The main objective of these simulators is to replicate the physical environment of aircraft on ground either with static or motion platform. The very first choice is static simulator as the beginner has to learn about flight controls and primary and secondary flight instruments first then about moments and maneuvering which is a secondary part so our design solely focused on static simulator with static platform whose design approach and specifications will be covered later in this chapter. Now we put some light on flight instruments which is soul and blood of flight simulators.

3.1.2 Flight Instruments

There are around 15 gauges or dials on the instrument panel of the aircraft of which six are basic flight instrument also referred to as “6 packs of avionics” as shown in figure. These instruments are as follows:

Fig 3-5: 6 Packs of Avionics

1) Altimeter
2) Air Speed Indicator (ASI)
3) Heading Indicator (HI)
4) Attitude Director Indicator & Artificial Horizon (ADI)
5) Turn Coordinator & Slip Indicator
6) Vertical Speed Indicator (VSI)
7) Tachometer
8) Digital Clock
9) Oil Pressure & Temperature Gauge
10) Instrument Landing System
11) VHF Omnidirectional Range
12) Auto Direction Finder

13) Voltmeter
14) Ammeter
15) Air Pressure Gauge

Altimeter

An altimeter is an instrument that describes the aircraft's altitude above sea level by measuring the atmospheric pressure. It works on a measured height above sea level because the air's pressure decreases at a more or less regular rate as you ascend. Inside the altimeter is a sealed disc called an aneroid, or bellows. We can set the setting of the altimeter and check the value of the atmospheric pressure used to adjust the sub-scale of a pressure altimeter so that it indicates the height of an aircraft above a known reference surface.

Air Speed Indicator (ASI)

An Air Speed Indicator (ASI), is a device for measuring the speeds of an Aircraft. This device tells us how far the Aircraft Ascend and descends in Air. The ASI uses the pressure differential in the pitot-static system to measure and display the aircraft’s speed. In most aircraft the ASI displays speed in knots or miles per hour. A needle points to the aircraft’s current indicated air speed (IAS). Standard color-coded markings provide various critical speed information for that model of aircraft, including stall, flap setting, normal operating, caution, and never exceed speeds.

Heading Indicator (HI)

Heading Indicator (HI), is a flight instrument used in an aircraft to inform the pilot of the aircraft's heading. The pilot uses a Heading Indicator to determine the plane’s current heading, or direction of flight, based on 360 degrees about magnetic north. The Heading Indicator (HI), also known as a directional gyro (DG) or direction indicator (DI).

Attitude Director Indicator & Artificial Horizon (ADI)

The Attitude Indicator (AI), is a flight instrument that informs the pilot of an aircraft’s orientation relative to Earth's horizon, and gives an immediate indication of the smallest orientation change. The attitude Indicator tells us the direction of the pitch and bank. Basically, it tells the pilot whether the wings are level or tilted to one side (the roll or bank of the plane). It also tells the pilot whether the nose of the plane is pointing above or below the horizon (the pitch of the plane). It is also called as Artificial Horizon.

Turn Coordinator & Slip Indicator

The Turn Coordinator (TC) variants are essentially two aircraft flight instruments in one device. One indicates the rate of turn or the rate of change in the aircraft's heading while the other part indicates whether the aircraft is in coordinated flight, showing the slip or skid of the turn. The slip indicator is actually an inclinometer that at rest displays the angle of the aircraft's transverse axis with respect to horizontal, and in motion displays this angle as modified by the acceleration of the aircraft. The most commonly used units are degrees per second or minutes per turn. It is also called as Slip Indicator.

Vertical Speed Indicator (VSI)

A Vertical Speed Indicator (VSI), The Vertical Speed Indicator (VSI) is an instrument that displays the rate of climb and descent to the pilot by measuring rate-of-pressure changes. It is also known as a Rate of Climb and Descent Indicator (RCDI).

Fig 3-6: Cessna-172 Cockpit View

Digital Clock

The digital clock is a clock that simply shows numbers to denote the time. Digital clocks have many different functions like normal operation, setting universal time, setting local time, control /selecting disable, setting flight time alarm, setting timer Flight time reset, Elapsed time count up or down, etc.

ILS Receiver

The ILS stands for Instruments Landing System. An ILS consists of two or three marker beacons, a localizer, and a glide slope to provide vertical and horizontal guidance information. The localizer operates in the 108–112MHzband andisnormallylocated1000 feet beyond the stop end of the runway. Instrument Landing System (ILS) is a precision runway approach aid based on two radio beams which together provide pilots with both vertical and horizontal guidance during an approach to land.

Fig 3-7: Cessna-172 Instrument Panel

VOR Receiver

A Very high-frequency Omni-directional range (VOR) is a type of short-range radio navigation system for aircraft, enabling aircraft with a receiving unit to determine its position and stay on course by receiving radio signals transmitted by a network of fixed ground radio beacons. It is also called as COM Receiver.

Voltmeter

A Voltmeter is an instrument used for measuring the potential difference, or voltage, between two points in an electrical or electronic circuit. The voltmeter gauge shows the voltages of the battery or the alternator.

Ammeter

An ammeter is an instrument used for measuring either direct (DC) or alternating (AC) electric current, in ampere. Ammeter gauge shows the amperage or current drawn from the battery by the lights, avionics and other appliances in the cockpit.

Oil Temperature Gauge

The oil temperature gauge measures the temperature of oil. A green area shows the normal operating range and the red line indicates the maximum allowable temperature. Unlike oil pressure, changes in oil temperature occur more slowly.

Air Pressure Gauge

When an Aircraft fly than its pressure decreases according to its height. So, the oil pressure gauge provides a direct indication of the oil system operation. It ensures the pressure in pounds per square inch (psi) of the oil supplied to the engine. Green indicates the normal operating range or a safe range, while yellow indicates the precautionary range or minimum and maximum pressures range and in last the red indicates the operating limits or a danger range.

Besides dials or gauges, there are few other displays and avionics from which pilot get updates of flight data. They are as follows:

NDB Receiver

The Non-Directional Radio Beacon (NDB). It is a low or medium-frequency radio beacon that transmits non-directional signals in a given operating range. A non-directional beacon or non-directional radio beacon is a radio beacon which does not include inherent directional information. Radio beacons are radio transmitters at a known location, used as an aviation or marine navigational aid. And NDBs are also most commonly used as "locators" for an instrument landing system (ILS) approach and, standard approaches.

Transponder

A transponder is shortened from "transmitter" and "responder". It's a wireless communications, monitoring, or control device that picks up and automatically responds to an incoming signal. A transponder is an avionic system located on board the aircraft that provides information about the aircraft identification and barometric altitude to the ATC system on the ground and to TCAS on other aircraft. A radio transmitter in the cockpit that receives a signal from "secondary" radar and returns a squawk code with the aircraft's position, its altitude and, its call sign. Air traffic control units use the term "squawk" when they are assigning an aircraft a transponder code.

Autopilot

An autopilot is a device used to guide an aircraft without direct assistance from the pilot. An autopilot is a software or tool that can only manage the aircraft under certain conditions using the vehicle's hydraulic, mechanical and electronic systems. This system, which can follow the flight plan, can stabilize speed and height as well as the location of the front of the aircraft heading.

GNSS Receiver

The Global Navigation Satellite Systems, GNSS receivers work by receiving signals sent from the relevant satellites in orbit. The signals that are used depend on the type of receiver. It gives the direction from location to location at one point. Global Navigation Satellite Systems (GNSS) form akey technology in the communications, navigation, and infrastructure. GNSS are used in all forms of transportation: space stations, aviation, maritime, rail, and roads. Positioning, navigation and timing (PNT) play a critical role in telecommunications, land surveying, law enforcement, emergency response, mining, finance, scientific research and so on. It is also called as positioning system.

Tachometer

A tachometer is a device for counting. It is used to show the number of revolutions per minute (RPM) of the aircraft engine. An airplane needs one tachometer for each of its engines. It's used as a measure of how fast any Aircraft engine is operating at a given time. It is also called an Engine RPM Indicator.

ADF

An Automatic Direction Finder (ADF), is an aircraft navigation product that automatically calculates the relative bearing of the aircraft to the radio station. ADF is a basic instrument that transmits location information on the AM band. To use, tune it to a non-directional beacon (or NDB).

Typically, in flight simulators construction, dedicated modules are employed for control columns which are available as plug-and-play. We planned to design them by ourselves. For which we have decided to design their CAD models first and then go towards their physical design.

3.1.3 Software Tools Requirement

Our project is based on various kind of simulations and interfacing as well as data communication which requires a number of software packages. Some brief description of them are as follows:

X-plane: This software is the soul of our system as it provide us the environment for flight simulation of the aircrafts, to read and write flight data.

Air Manager: This software is used to make 2D instrument panel. It works with X-plane or any other flight simulator.

Proteus: It is employed for simulation and design of Electrical & Electronic circuits of the project.

Mobiflight: It is used to take data input from physical world by means of switches, pots and encoders which are connected to the controller which in our case is Arduino. It’s a software package which is used to interface Arduino with flight simulation software (Xplane or Microsoft flight simulator). It is widely used in flight simulators building and designing. The purpose of which is to interface hardware with the PC on which flight simulation software is running. It is done in such a way that by means of controller i.e. Arduino mega, pro micro etc. It allows us to configure various types of IO devices which are taking data from physical world including switches, encoders, potentiometers etc and sending back to the real world in form of light indication or sound etc. Its user interface consists of two sections

3.2 Designing of Control Columns

3.2.1 CAD Designing on Solidworks

Base modelling

We started our modelling from the base of the structure by first making a sketch of a rectangular shape whose two sides of 32 inches and the sides of 48 inches than by using the feature of Solidworks (extrude boss) 1 in thickness as shown in the picture:

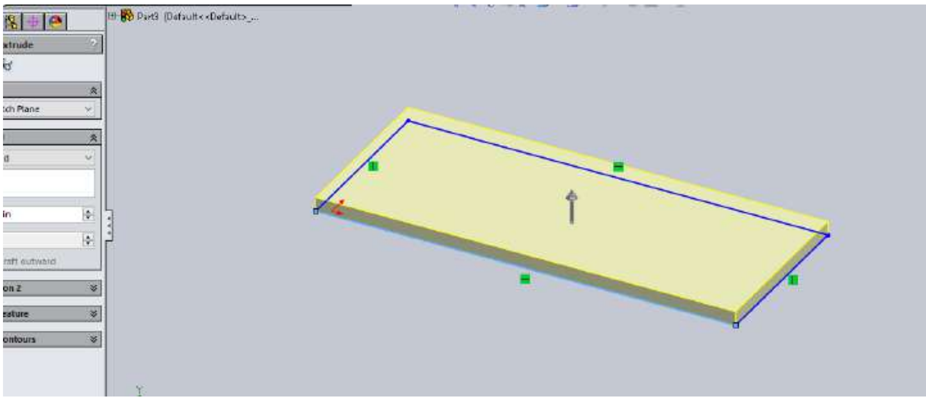

Fig 3-8: Base Structure1

Then we make the base (base angle) for the angles in which we will fix the angles and its dimensions are 3 x 5 in then extrude boss as shown in the picture:

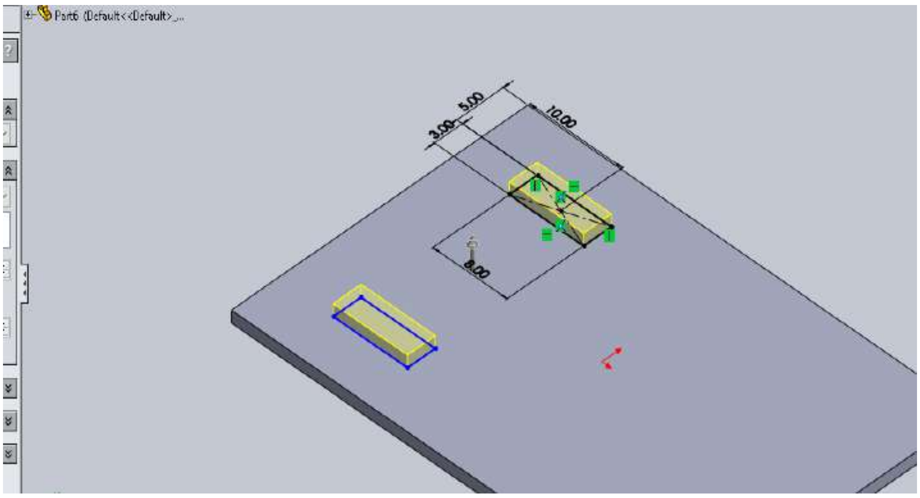

Fig 3-9: Base Structure2

Then we make the holes in the base angle first in one base we made the two sketches for holes in one base angle and using the mirror feature of the Solidworks it makes the same sketch on the other base angle and the sed the extrude cut feature to made the holes for angle as shown in picture:

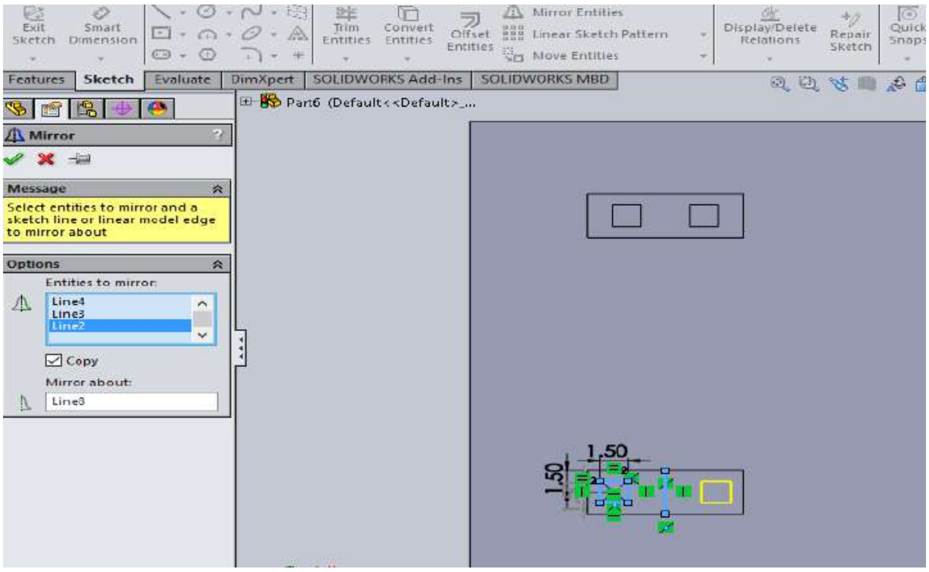

Fig 3-10: Base (Top View)

Angles modelling:

The second part is the angle we make the sketch of the angle whose dimension is 1 x 1 inches then extrude the boss to make the solid angle as shown in the picture:

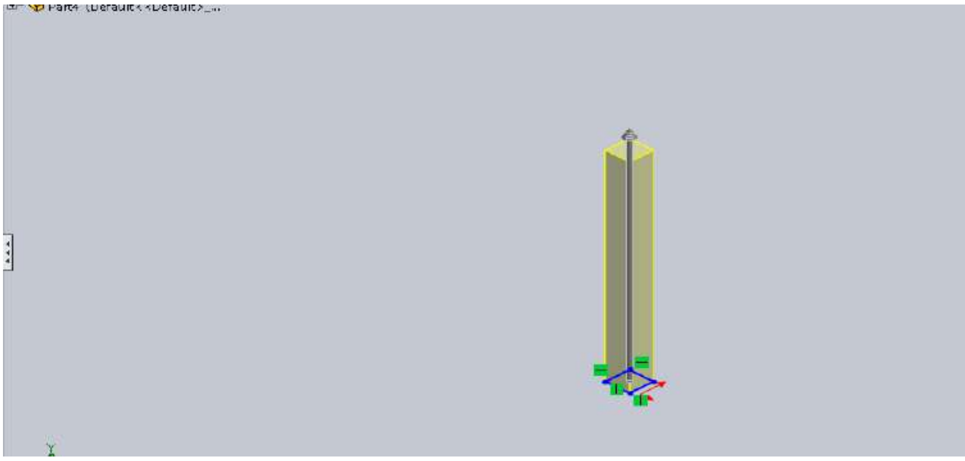

Fig 3-11: Base Angle Modelling

Front panel modelling:

The third part we made the front panel. First we made the sketch of 24 x 30 inches the top of the front panel is rounded shape so we use the arc feature of Solidworks so then, we extrude boss the sketch to made the solid front panel as shown in picture:

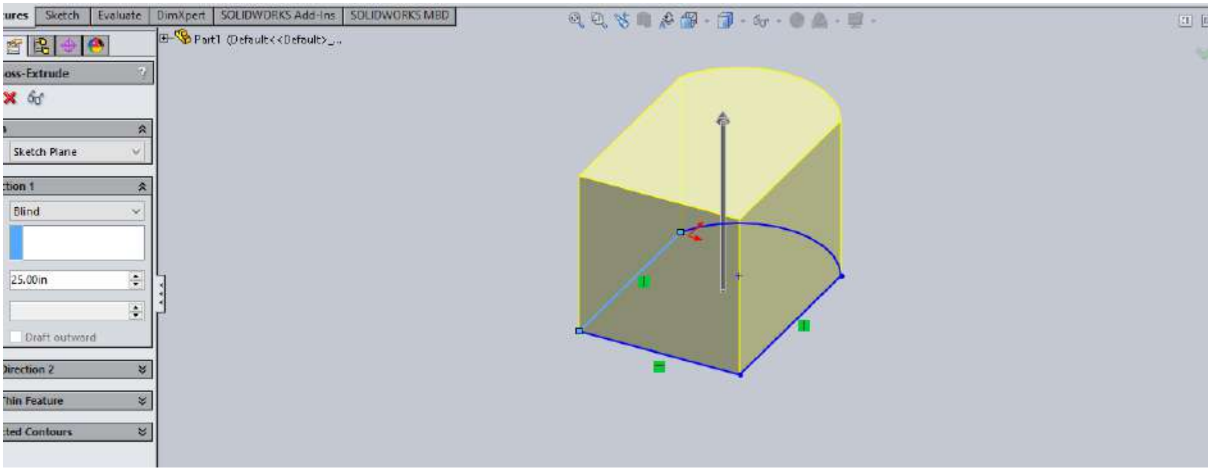

Fig 3-12: Front Panel Extrude

After this we used the extrude cut feature to made the cut in the front panel as shown in picture:

Then we made the last part of the front panel that is

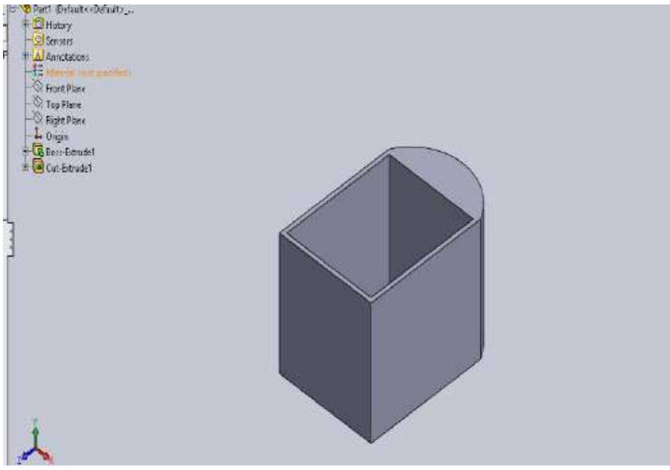

Fig 3-13: Front Panel 2

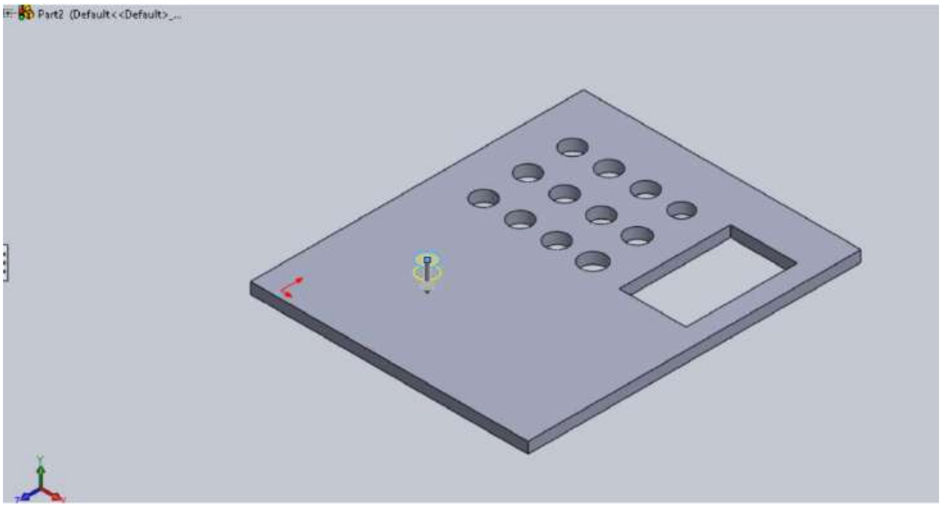

Fig 3-14: Instrument Panel

Steps:

1) Make the sketch then extrude cut of 0.8 mm thickness.
2) Make a circle and use the linear pattern feature of the Solidworks and made 12 holes then used the extrude cut feature to made cut.
3) Made the rectangular extrude cut

Assembly:

Finally we made the assembly of our senior design project in the solidworks as shown in pictures

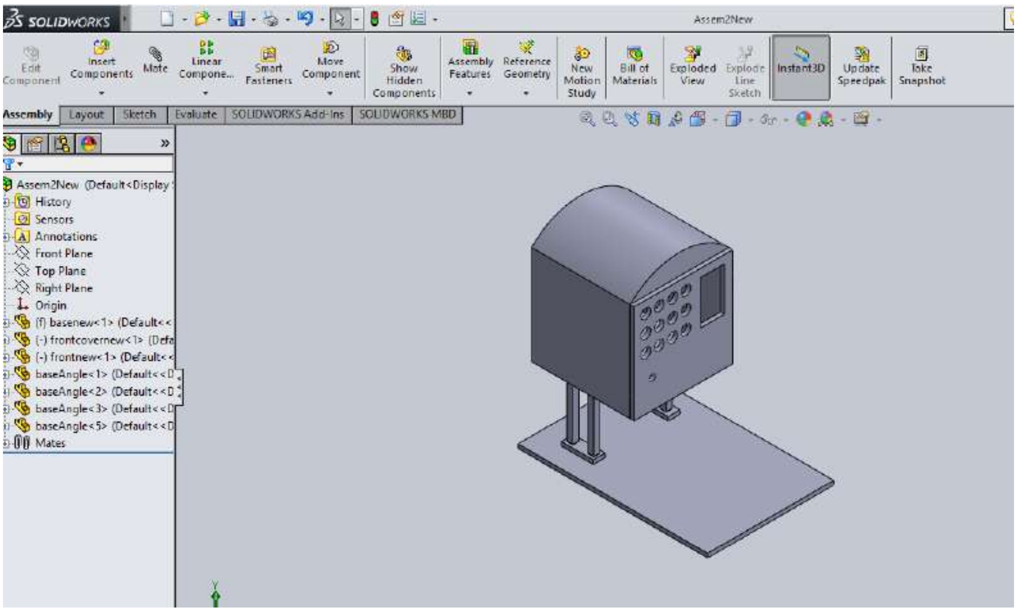

Fig 3-15: Completed Structure (Isometric View)

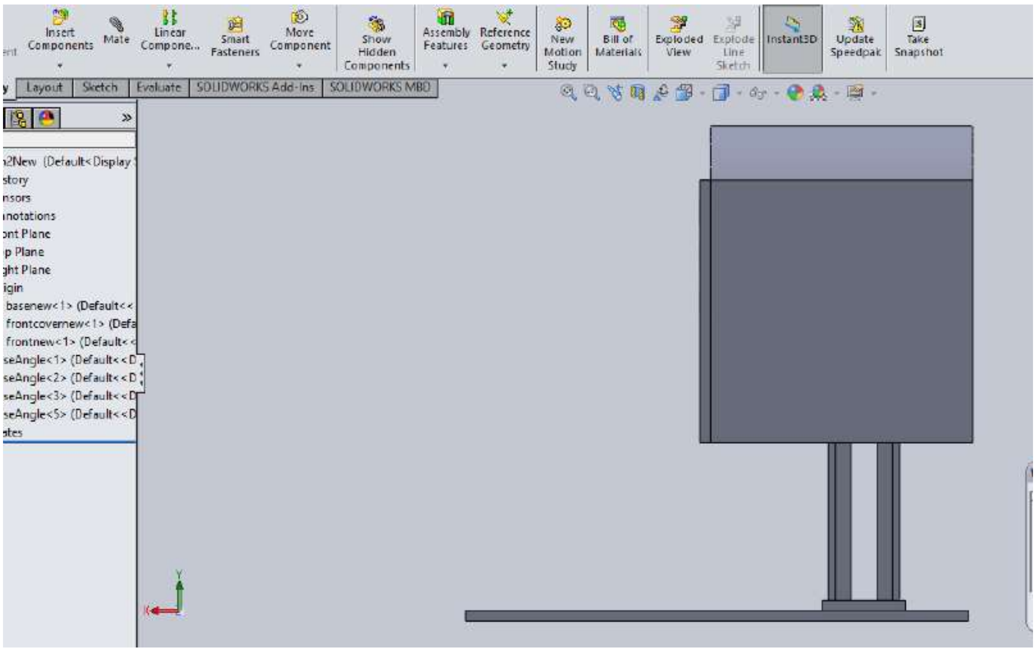

Fig 3-16: Completed Structure (RSV)

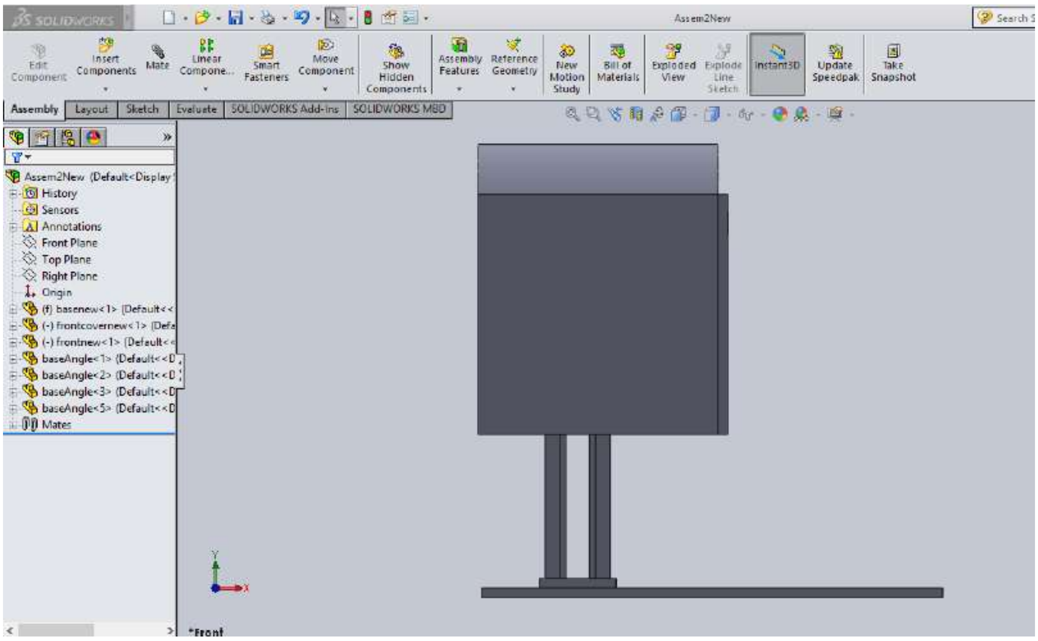

Fig 3-17: Completed Structure (LSV)

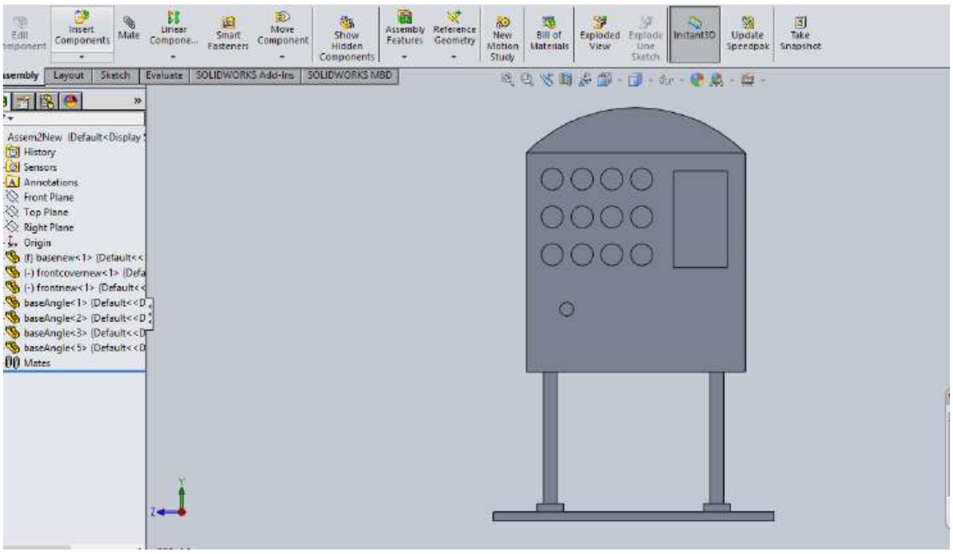

Fig 3-18: Completed Structure (FV)

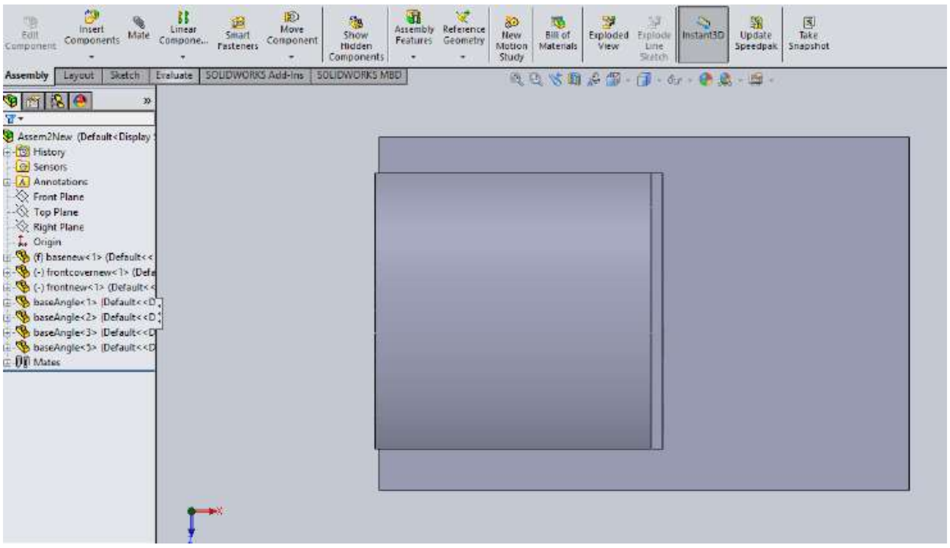

Fig 3-19: Completed Structure (TV)

3.2.2 Flight Yoke

The flight yoke is one of the most essential control columns in the cockpit, and we can say that almost 50–60% of the control of the aircraft is based on this control column. As we know, an aircraft has 6 DOFs, or degrees of freedom, in total, of which 3 are linear and the rest are angular. The angular movements of the aircraft are as follows:

- Rolling (rotational movement about the longitudinal axis)
- Pitching (rotational movement about the lateral axis)
- Yawing (rotational movement about a normal axis)

Each of the above movements is achieved by a pair of control surfaces, which are as follows:

- Rolling is done by the help of ailerons
- Pitching is done by the help of elevators
- Yawing is done by the help of rudder

Two of the above (rolling & pitching) are done with the help of a flight yoke in such a way that elevators are controlled by the push-pull motion of the yoke while ailerons are by CW-CCW rotation of the yoke. Here it must be noted that the movement of elevators is synchronized means they both move upward or downward simultaneously while that of ailerons is differential to create a difference in pressure and drag on both wings to turn left or right. We decide to design the flight yoke on our own due to two reasons, one is that company-made flight yoke systems are much more expensive, and the other is that there would be an absence of design work if we employed a company-made yoke.

Designing of Flight Yoke

Fig 3-20A: Mechanical Structure of Flight Yoke

The whole design scope of the flight yoke assembly consists of two major parts i.e. Mechanical Design and Electrical Design.

Mechanical Design

If talking about the mechanical design we first have to consider the number of DoF's or degrees of freedom of the yoke assembly. The yoke has two kinds of motions one is linear (push-pull for pitch control) and the other is angular (CW-CCW for roll control) so we've to deal with 2 DoF's system. In mechanics, designing rotary systems is pretty much easier than a linear one because of the fact that there is a huge variety of parts available for rotary systems like ball bearings, wheels, pulleys, motors, actuators etc in various shapes and sizes so our bigger challenge is to design pitch control system.

1) Roll Control System

First, we put some light on Our Roll Control System which consists of a circular pipe, UC ball bearings, bearing brackets, springs, hooks, jubilee clip etc. These things are mounted on a wooden plank in a way that the first bearing is mounted on the front edge of the plank and the other one on the rear edge so that the pipe is allowed to rotate freely. To equip the system with restoring capability we make it spring loaded by mounting between pipe and hooks.

2) Pitch Control System

For achieving pitch moment, it is required to move back and forth the roll control assembly. This could be achieved by a drawer sliding channel which is mounted between the two planks unlike that in drawers.

Electrical Design

Electrical design of the flight yoke deals with the sensing of the pitching and rolling moments and a sudden change with reference to their mean positions. At this point a problem arises that how these moments could be sensed electrically? There is a number of instruments available for sensing physical moments like encoders, pots, ultrasonic, RADAR etc. But we've to opt a precise, accurate and economical instrument so that our system responds efficiently on small changes. Before selecting anything for design of the yoke, we went through the working principle of the real flight yoke used in aircraft, which is that it employs RVDT for rotational moment sensing and LVDT for linear moment sensing, and the sensed values are further processed (scaled or normalized) and then given to the FCC. We decided to modify this approach according to the needs of our system. At this point and will use LVDT and RVDT and interface them with MCU or PLC analog inputs, but the problem arises when we tried to find out if there were any dealers or suppliers for LVDT and RVDT. There are at least a few suppliers who deal in Pakistan, but the problem is we've to order it online and have to wait for a month or more because it delivers from shipping service, so we change our minds to replace it with its substitute, which could be a sliding potentiometer but we don’t get our desired size so we prefer rotary encoder over pots. We design a mechanical structure that converts the to-and-fro motion of the yoke (push-pull movement) into angular motion to rotate the pot, and from its CW or CCW rotation we sense the movement and its magnitude by varying the voltage applied to the analog input of the MCU/PLC

1) Sensing Rolling Moment

For sensing of rolling moment, we employ conventional rotary encoder so that each and every change in angle can be sensed by number of pulses as well as the direction of rotation by leading and lagging pulses of the encoder.

2) Sensing Pitching Moment

There are two ways to do this one is to sense it either by employing sliding pot or by converting this motion into angular and then sense by encoder. We opt the later one due to precision and accuracy. This is achieved by famous mechanical arrangement known as “Rack & Pinion”. This arrangement is generally employed in vehicles steering systems. It consists of a pair of gear sets in which one is linear known as ‘Rack’ and the other is circular known as ‘Pinion’ as shown in the figure. This arrangement converts linear motion into angular motion or vice versa. We are doing the earlier one here. This results in simplification of electrical design as we just have to sense two angular moments.

Fig 3-20B: Rack & Pinion Arrangement

Mathematical Modelling

The permitted value for all the analog controls in the flight simulator has a range of ($-1 \leq 0 \leq 1$) which is a closed interval from both sides means that the value can reach one or negative one including all the values in between. So we've to convert our angular motion in degrees into numerical values in the above given range this could be achieved by scaling

Rudder Pedals

Rudder Pedal is one the important control columns in an aircraft. It plays a vital role in controlling of a control surface known as "rudder" which is responsible for yawing or heading variation of an aircraft. It also provides braking facility for rear landing gears. If talking about its working principle, it has 2 Degrees of freedom in which one is linear for controlling rudder motion and the other is angular for applying left or right brakes to stand still or to achieve differential motion of the aircraft by braking single wheel. During taxiing rudder pedal act as control column for nose gear variation to change the direction of taxiing on taxi ways to reach runway.

Designing & Assembly of Rudder Pedal

Our design has two major sections to discuss which are as follows:

1) Mechanical Design
2) Electrical Design

Firstly, we put some light on mechanical design because of the fact that electrical design is dependent upon mechanical system. For mechanical designing we've employed exercise machine pedals which is mounted on the wooden block by means of hinges and spring to provide braking facility. The wooden block further mounted on drawer channel strip which ensures linear motion of the pedals.

Fig 3-21: Parts & Components of Rudder Pedal

In general, rudder pedals have differential motion which means that when left rudder pedal moves forward the right one moves backward or vice versa we achieve this differential motion by means of clutch wire which is generally used in motor bikes. It is done in such a way that both the pedals are connected to the ends of the coil which passes over pulley wheels to provide required tension and stability in motion. This entire system provides desired 2 DOF mechanical system.

Fig 3-22: Mechanical Structure of Rudder Pedals

Now coming towards electrical design, we employed potentiometers for detecting linear and angular motion. For sensing linear motion of the pedals we've employed conventional angular pot which is widely used in volume controls. The pot is mounted under a pulley and the wire passes over it so that when right rudder pedal moves forward the left one moves backward and the pulley moves in the CW direction so the resistance increases so voltage at variable pin decreases which is sensed by analog input of the MCU. Similarly, when left pedal moves forward and right moves backward so in this case pot's pulley rotates CCW so that the resistance decreases and the voltage at variable pin increases which is further sensed by the same analog pin of the MCU and this data is written in Xplane dataref and results in the motion of the rudder pedals in simulation. If talking about toe brakes, it is spring loaded so when we push down the pedal it automatically returns to neutral position when released. The motion of brakes is sensed by sliding pot which is mounted on the wooden block and connected by the pedal by means of spring or hard core wire so when pushed it slides the pot proportional to the motion of the pedal this change in resistance results in change of voltage at the analog pin of the MCU which sends data to Xplane. Same applies for other pedal but one thing should be noted that each pedal has separate sliding pot as sometimes one brake is applied to achieve differential motion and sometimes both are applied to stop the airplane at runway or taxiway so in short we employed 3 pots in total for our rudder pedal design in which one is angular pot and the other two are sliding pots.

Fig 3-23: Final Assembly of Rudder Pedals

Parking brake

Fig 3-24: Mechanical Structure of the Parking Brake

The function of parking brake is to keep the aircraft stand still either in hanger or on runway. After starting the engine, the pilot releases the parking brake so that the aircraft start moving in accordance with the acceleration provided by throttle. If coming towards the construction of parking brake, it consists of a lever which is made up of handle and shaft which is spring loaded and to apply the brake the pilot has to hold the handle and to pull it towards him and then rotate it in the CW direction for about 90 degrees and then leave it so it remains in this position until releases again. In this condition it presses a limit switch which tells the controller about the status of the brake. In contrast, releasing procedure is somehow easier than applying as you just have to hold the handle and rotate it in CCW direction and then leave it, it returns to its position by spring mechanism and depress the limit switch as well so status is updated in the controller.

In our project we've designed it by using hydraulic chair's lever which is pretty much similar in shape to that of real parking brake of Cessna 172. First of all we took its measurement which is about 8’’ so we’ve done further designing and fabrication accordingly.

Fig 3-25: Final Assembly of Parking Brake

Process Flow:

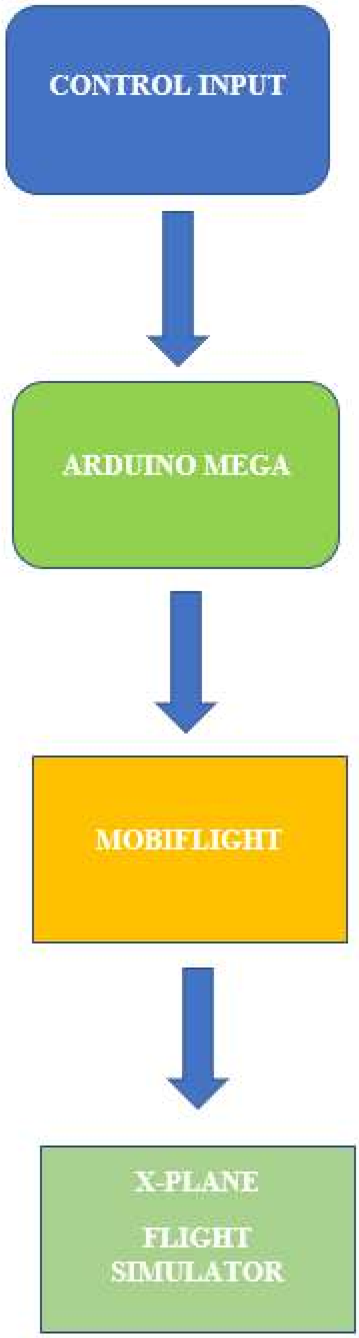

Fig 3-26: Process Flow Diagram of Flight Simulator

It can be seen from the flow diagram that when a switch or sensor (pot or encoder) changes state or value, it is sensed by the Arduino mega which send this information to the mobiflight software. This software has the access to flight data of xplane by means of dataref toolkit which allows it to read or write any flight data. It allows to control any switch or control column of the cockpit.

3.3 Schematics:

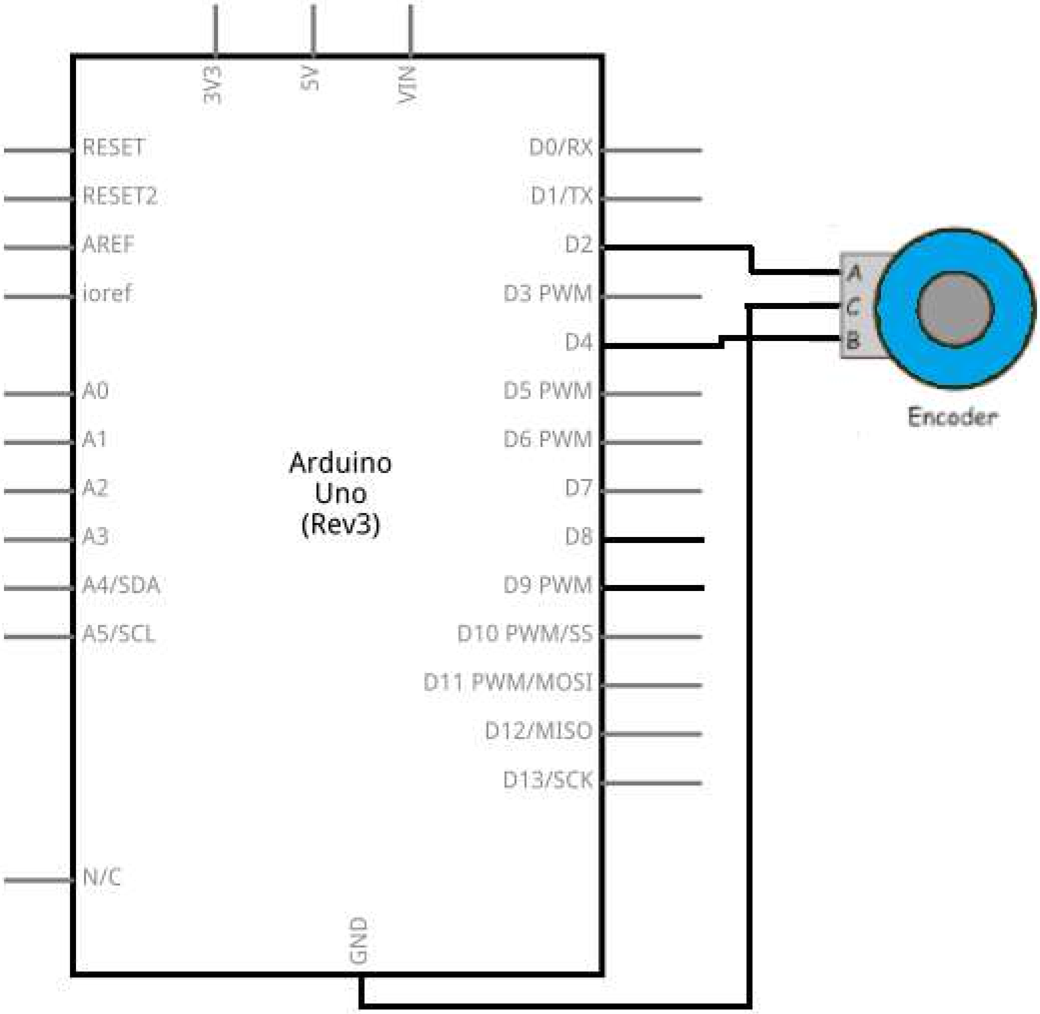

Fig 3-27: Schematic Diagram of Encoder & Arduino

3.4 Simulations

3.4.1 Flight Simulations

For flight simulation purposes we employed X-plane 11 software. As our cockpit design is a replication of the cockpit of Cessna-172 so we're using Cessna-172 skyhawk for designing and testing purposes. Here is a cockpit view of the Cessna-172 in X-plane environment.

Fig 3-28: C172 Flight Simulation in X-plane Environment

Reading/Writing Flight data using Dataref Tool & Mobiflight

Xplane is a product of laminar research and designed to use with USB P-n-P devices like rudder pedals, flight yoke, throttle quadrants. But we are using it in a slightly different way. We are controlling flight controls and modifying flight parameters by data gathered form real world by means of switches, encoders and pots. So in short Xplane itself doesn't have any such capability to support such kind of design and reverse engineering tasks so we've to use a plugin for it. Which is known as for "Dataref". It is a toolkit used to get-out the flight data from X-plane for design and analysis. For flight simulator design this data is of much importance for us. Here is a list of flight data parameters along with their types and states.

List of Flight Data Parameters in Dataref tool

Flight Data / Control Column	Parameter Name / Dataref Name	States

Rudder Pedals	sim/cockpit2/controls/yoke_heading_ratio	3 (-1, 0, 1)
Yoke (Pitch)	sim/cockpit2/controls/yoke_pitch_ratio	3 (-1, 0, 1)
Yoke (Roll)	sim/cockpit2/controls/yoke_roll_ratio	3 (-1, 0, 1)
Throttle	sim/cockpit2/engine/actuators/throttle_ratio_all	2 (0, 1)
Mixer	sim/cockpit2/engine/actuators/mixture_ratio_all	2 (0, 1)
Parking brake	sim/cockpit2/controls/parking_brake_ratio	2 (0, 1)
Trim Wheel Elev	sim/flightmodel2/controls/elevator_trim	3 (-1, 0, 1)
Ignition Sw	sim/cockpit2/engine/actuators/ignition_key	5 (0, 1, 2, 3, 4)
Avionics Bus1	sim/cockpit2/switches/avionics_power_on	
Avionics Bus2		
Master Power ALT		
Master Power BAT		
Taxi Light Toggle Sw	sim/cockpit/electrical/taxi_light_on	2 (0, 1)
Beacon Light Toggle Sw	sim/cockpit/electrical/beacon_lights_on	2 (0, 1)
Landing Lights Toggle Sw	sim/cockpit/electrical/landing_lights_on	2 (0, 1)
Nav Lights Toggle Sw	sim/cockpit2/switches/navigation_lights_on	2 (0, 1)
Strobe Lights Toggle Sw	sim/cockpit/electrical/strobe_lights_on	2 (0, 1)
Pitot Heat Toggle Sw	sim/cockpit/switches/pitot_heat_on	2 (0, 1)

Table 3-1: List of Flight Data Parameters in Dataref tool

An example of reading or writing flight data in X-plane with the help of dataref tool.

Turning On/Off Landing Light Switch

Fig 3-29: Controlling Landing Light Switch States using dataref

3.4.2 Proteus Simulations

We're taking both analog and digital data from real world, digital data which shows status of the switches on the front panel while analog data which tell us the current position or value of the control column i.e., flight yoke, rudder pedals etc. For this purpose, we employed physical switches for getting digital data while pots and encoders for analog data. Here one thing should be noted that in general pots are considered as analog devices while encoders are as digital but in our case both are used for reading analog data which is basically the control input of a control column which may be in the range or (0-100%). As most of our IO's are based on switches, pots and encoders. We did three major simulations of control columns in which all the IO's are covered. The list of proteus simulations are as follows:

1. Switch Panel Simulation
2. Rudder Pedal Simulation
3. Flight Yoke Simulation

Switch Panel Simulation

Our project has a front panel on which a number of switches are mounted for different purposes, one ignition switch for self-starting engine and controlling alternators of the aircraft, few of them are for aircraft lighting, for instruments, controls and other internal and external Electronics or avionics. We made proteus simulation for this in a same manner as they are mounted on the panel and further connected to the Arduino mega. The simulation is as follows:

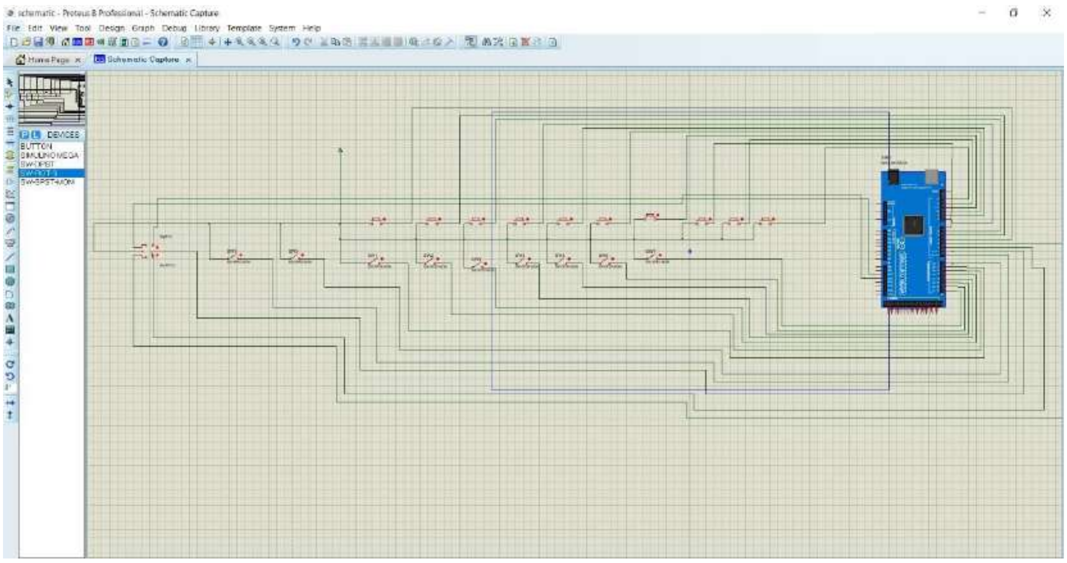

Fig 3-30: Proteus Simulation of Ignition & Switch Panel Circuit

Rudder Pedal Simulation

Our rudder pedal consists of two pots each one for left and right brake sensing and one encoder for sensing differential motion of the pedals. They are connected to Arduino Mega in a way that pots are connected to analog inputs (A0, A1) while encoder is to digital pins (2, 3). The pulse train of the encoder is displayed on the oscilloscope.

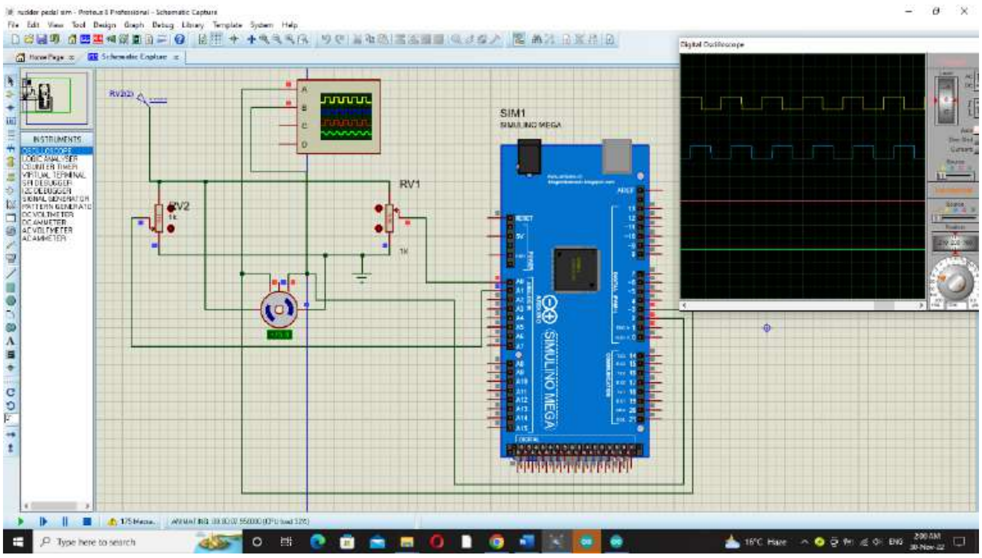

Fig 3-31: Proteus Simulation of Rudder Pedal Circuit

Flight Yoke Simulation

Our flight yoke design consists of one pot and one encoder, encoder is for sensing pitching moment while potentiometer for sensing rolling or banking moment. They are connected to Arduino Mega in a way that pot is connected to analog input (A0) while encoder is to digital pins (2, 3). The simulation is as follows:

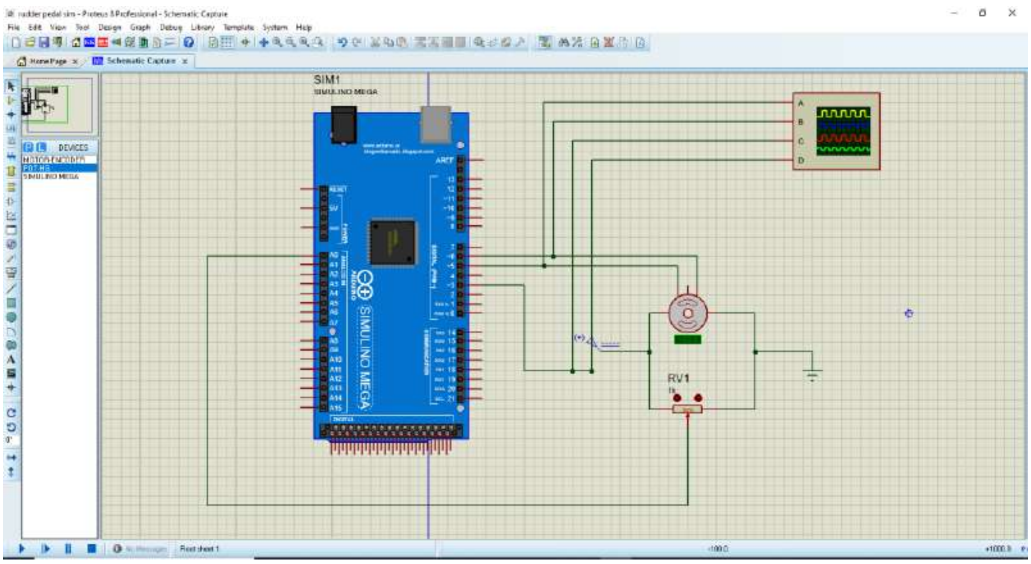

Fig 3-32: Proteus Simulation of Flight Yoke Circuit

3.4.3 LabVIEW Simulations

UDP Reading data

First of all, data enters in UDP port in form of data sentence or string which is read as it is by UDP read block and then converted into sub string by string subset block. Here sub string refers to a part of string which is important for us, for instance if data has 41 bytes as in case of x-plane then first 5 bytes are prologue or header which is for the system not for user so we filter this portion of data by setting offset of 5 so remaining 36 bytes will be transferred to unflatten from string block which converts it into the type which is wired at type terminal in case of our program it is cluster so it is then supplied to cluster to array block which converts it into array of elements so that each data element at n index can be extracted form array by using index array block and can be further displayed using any indicator (i.e. graph, bar, gauge etc)

String => sub string => cluster => array => single element

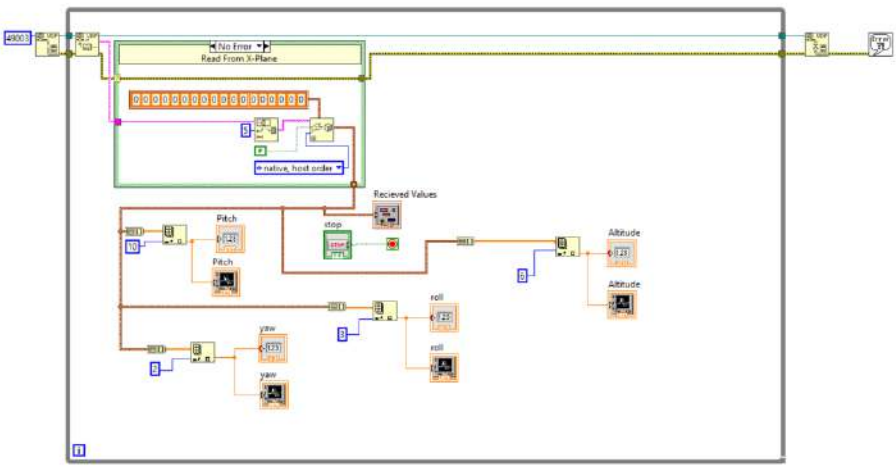

Fig 3-33: LabVIEW VI for Reading data from Xplane

Reading Flight Control Data during Flight using LabVIEW

Fig 3-34: Reading Banking Angle of the Aircraft

Fig 3-35: Reading Ptiching Angle of the Aircraft

UDP Writing data

As the name implies writing process is inverse to that of reading process so we've to follow some rules for writing which are as follows:

- X-plane only receives data at UDP port 49000
- X-plane accepts data only in the same format it sends
- 5th byte of prologue or header must be zero
- For those elements you don't wish to change data, send -999

Before going into description of writing process we've to put in mind that in LabVIEW if we wish to write a data element in an array we've to read that element first and then overwrite our data parameter and send the packet again to update the flight data. For this purpose we've to use reading program blocks with some additional blocks to achieve writing operation.

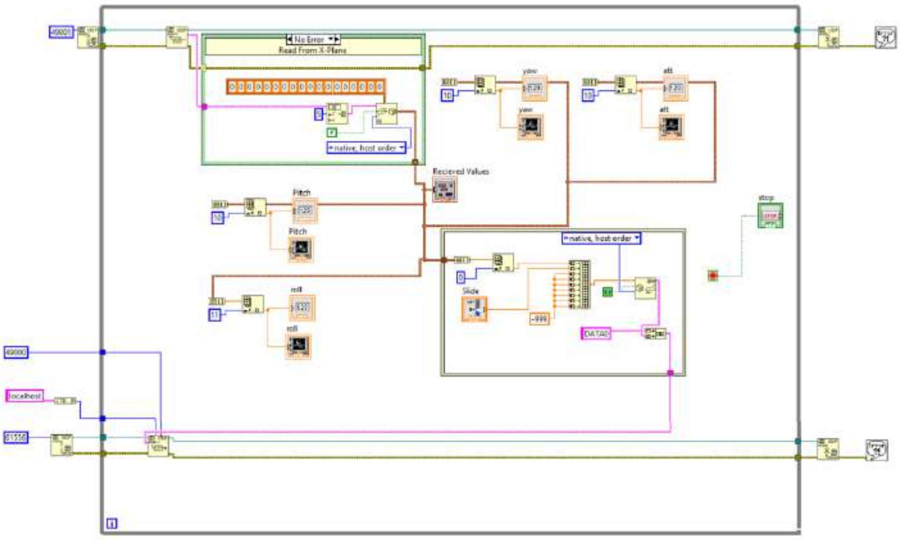

Fig 3-36: LabVIEW VI for Writing data from Xplane

As stated earlier that the writing process is mirror image of reading process so here we start with taking data string from reading block and passes it from string-to-array block which converts it into data array. To extract specific data element from array we've to give index of that data element which we wish to overwrite. In this example 0 is given as index so first data element will be taken. Then this data element is overwritten with new parameter which in this case is given by slider, we can use numeric constant, knob or anything instead. As we don't wish to modify other data elements so -999 is provided to all other inputs as shown. Then this data cluster is converted back to array and then fed to array-to-string block to convert into string of data. This string is finally given to UDP write block which send it to xplane via UDP port 49000.

Interfacing Pot with Arduino and LabVIEW

As we've a number of analog inputs in our project which are interfaced firstly using Arduino mega and labview. This is done by LIFA which is a toolkit to interface Arduino with LabVIEW aka "LabVIEW interface for Arduino".

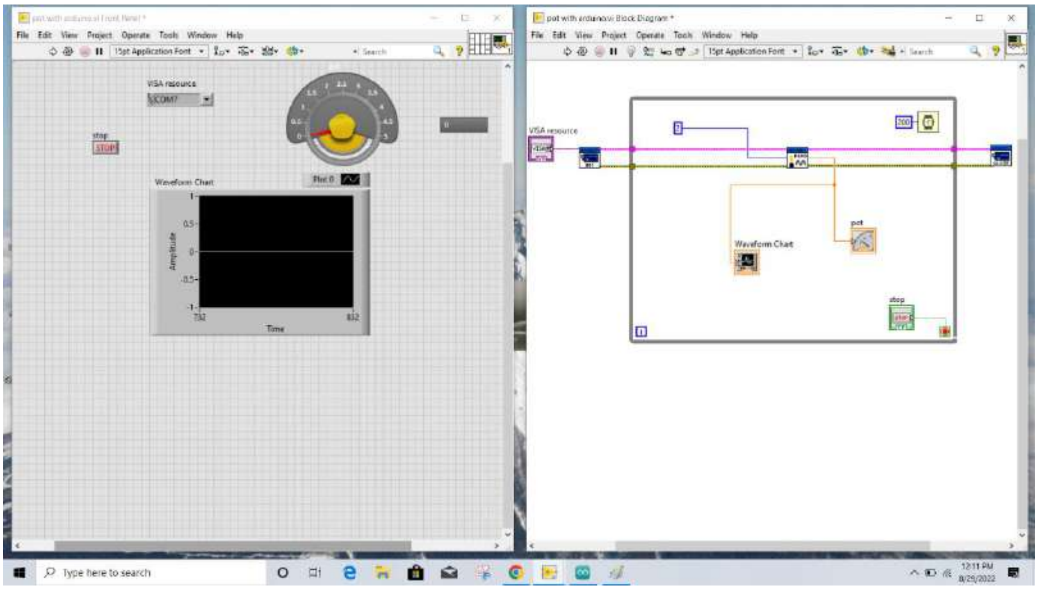

Fig 3-37: LabVIEW Simulation for Pot Interfacing with Arduino

As clearly depicted in the block diagram of LabVIEW firstly INIT block is used to initialize Arduino with LabVIEW then this program enters into while loop where analog read block is used to read analog data of pin A2 and the output of data is fed to gauge and waveform chart for analysis. This loop iterates for 200ms time interval. We can modify it to change resolution. Then program closes the VISA resource which is opened via com port at which the Arduino is connected.

3.4.4 Air Manager Simulation

Real Time Simulation of Flight Instruments

The use of air manager software is essential for us as we've to display all the primary flight instruments of Cessna 172 on an LED monitor which can be done in two ways: by displaying the instrument panel from Xplane or by employing another software like air manager or air player. The latter one is much more suitable for us as the display quality is much better than the way of displaying a fraction of the xplane's view. The thing is air manager is not freeware so we've to purchase its license.

Fig 3-38: Air Manager Full Screen View of Our Customized Panel

CHAPTER 4

4 TEST RESULTS AND THEIR ANALYSIS

After mounting all the IO devices i.e. switches, encoders, pots, levers, actuators etc our front panel of the cockpit looks as shown.

Fig 4-1: Flight Instrument & Controls Panel

Displaying Flight Instruments in Panel

As we're employing air manager for displaying customized flight instrument so here is a view of air manager displaying flight instruments (i.e. Altimeter, ASI, ADI, HSI, CDI, RMI & HI, Clock, Oil & Temperature gauge, Volt-ammeter etc) & GPS**.**

Fig 4-2: Flight Instruments Display on Instrument Panel

Integration of IO's with Software(s)

After a number of independent as well as combined simulations on various software packages i.e. proteus, LabVIEW, Arduino IDE, Xplane, Air Manager etc we finally got a perfect solution for our prototype which is combination of mobiflight, Xplane and air manager. In which mobiflight is used for IO configuration, Xplane for flight simulation and air manager for displaying customized flight instruments. This method make use of dataref toolkit to extract flight data from Xplane and modify this data in accordance with the states of the IO devices configured in mobiflight software. All these IO devices are physically connected to Arduino mega whose configuration is done in mobiflight environment according to their pin configuration as shown.

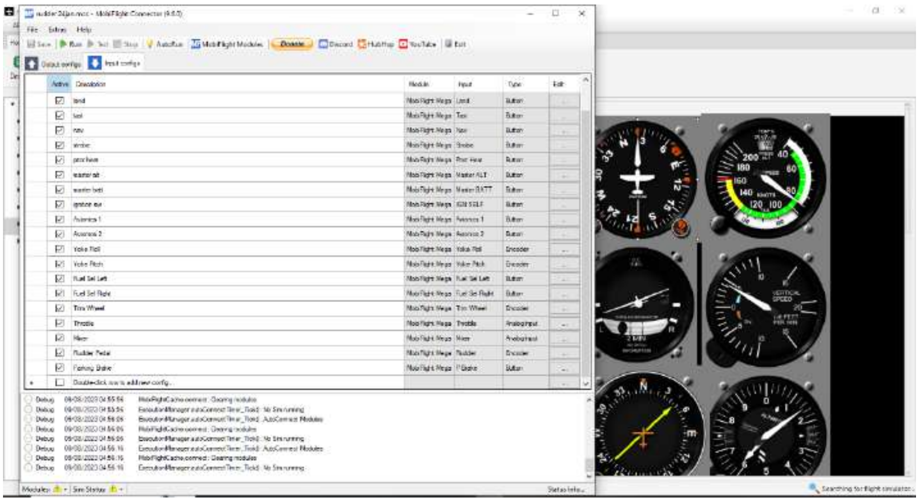

Fig 4-3: Configured IO's in MFC Environment

After configuration in mobiflight connector we did hw interfacing accordingly and then connect all the hardware with the relevant softwares. After that testing our physical hardware to control the aircraft in simulation environment. Here are the results:

Flight Control Columns Actuation Testing On Board

Fig 4-4: Roll-right Control with by Turning Yoke to the Right

Fig 4-5: Roll-left Control by Turning Yoke to the Left

Fig 4-6: Pitch-up Control by Pulling Yoke Towards

Fig 4-7: Pitch-down Control by Pushing Yoke Away

Fig 4-8: Yawing Control by Moving Rudder Pedals

Fig 4-9: Parking Brake Hold & Release Mechanism

CHAPTER 5

5 ECONOMIC ANALYSIS

5.1 Cost Table for Electronics

Sr. #	**ITEM: Specification / Description**	**Rate**	**Amount**
1	Multimeter	3000	3,000.00
2	Soldering Iron	500	500.00
3	Sucker	1500	1,500.00
4	Solder paste	100	100.00
5	Solder wire	300	300.00
6	Encoders	100	1,000.00
7	Arduino Mega	4500	1,600.00
8	Potentiometers	150	1500.00
9	Limit Switch	100	12,00.00
10	Push Button	40	800.00
11	Rocker Switch (Dual)	150	1,500.00
12	Knob	100	1000.00
13	Change Over	1000	1,000.00
14	Vero Board	50	500.00
15	Bread Board	125	250.00
16	Power Supply	3500	3,500.00
17	Jumper Wires	1000	1000.00
18	Connectors	15	150.00
19	Servo Motor SG90	500	1,500.00
20	LED Monitor 22’’	10,000	10,000.00
21	LED Monitor 32’’	20,000	20,000.00

Table 5-1: Component Cost Electronics

5.2 Cost Table for Wood & Metal Goods

22	Lasani Lamination 0.75’	3,000.00	9,000.00
23	Lasani Lamination 4mm	2,000.00	4,000.00

24	Lasani Lamination 6mm	1,500.00	3,000.00
25	Ply Wood Sheet 4mm	1,500.00	3,000.00
26	Ply Wood Sheet 10mm	2,800.00	2,800.00
	Wheels, Nails, Screws, Clips, Bolts, Washers etc	5,000.00	5,000.00

Table 5-2: Component Cost General Engineering

5.3 Market analysis

We did most of the market survey and analysis online as there is no physical market in Pakistan which deals in flight simulators although there are few companies and manufacturers which supplies flight simulators in the international market. TRC simulators is one of them but the thing is that their prices are more than enough and anyone who want to purchase in Pakistan need to pay 100% duty on single purchase as it lies in the category of luxury product.

If talking about commercialization of this product we’ve to modify the design and make it more presentable and attractive to the customers. Besides this we did some cost estimation and computations to take it to the industrial level. The details are as follows:

Expenditures	Cost per piece in Rupees	Cost per 100 pieces in Rupees
Structure	50,000	50,000,00
Switches / Sensors	20,000	20,00,000
Labor	20,000	20,00,000
Maintenance	6000	600,000
Wiring, Painting etc	4000	4,00,000
TOTAL	100,000	100,00,000

Table 5-3: Marketing Analysis

Profit Percentage:

Profit %= (production price/sell price*100)-100

=((100,000/150,000)*100)-100 =50%

Profit on 100 pieces will be Rs. 5,00,0000/=

CHAPTER 6

6 CONCLUSION

We’ve achieved the desired results from our designed Flight Simulator cockpit although it took a lot of our time but we learned a lot during this project which includes avionics, flight controls, aerodynamics, mechanics, stability analysis etc

It is not limited to a project but rather it can be implemented after modification in the design and make it more user friendly so that it can be a solution for flying schools and pilot training institutions.

Wherever possible, actual aircraft parts were utilised to keep costs down while retaining a high level of physical fidelity. The prototype had the original flying controls installed and was constructed around a fuselage. To gather pilot control input values, data acquisition components were added into the system. The system was then interfaced to the virtual simulation environment using proprietary software.

It was deemed impractical to employ original components for a number of the simulator's parts, including the flying instruments and circuit breakers. In these situations, it was determined which commercially available components would most closely resemble the original components, and those were purchased and incorporated.

The virtual environment for the simulator was chosen through a survey of commercially available flight simulation software, and it is called X-Plane 93 94 by Laminar Research.

The software development kit included with X-Plane enables the creation of applications for interacting with the simulator's physical parts. The custom-built Katana flight model's precise aerodynamic calculations as well as the excellent scenery included with X-Plane further contribute to the simulator's high level of practical accuracy.

Despite earlier plans for an externally designed projection system to create a fully immersive visual environment, a more constrained temporary single-projection system onto a flat screen was used to give visual cueing for the Project.

The six-degree-of-freedom Gough-Stewart motion platform from Moog was used to implement motion cueing for the Project in the Applied Dynamics Laboratory. A washout algorithm was adjusted to give the Project with appropriate motion cueing by combining the performance data from the Katana flight tests with the motion base's constrained motion.

A review of the prototype simulator revealed that it is possible to create type-specific, high-fidelity full-flight simulators for ab-initio flight instruction. Although the current prototype showed various shortcomings that would likely restrict the amount of training for which the simulator would be employed, ways to address these shortcomings have been provided in this thesis.

CHAPTER 7

7 FUTURE RECOMMENDATION

Our project flight simulator cockpit is a major solution to a huge problem of the unavailability or deficiency of aircrafts in the training and educational institutions. We've planned to take it to the industrial level by making some design modifications into it. For this purpose we did a market survey and realized that there are a very few but big fish customers of this product. There are a lot of challenges which we've to face while taking it to the industrial level, the very first challenge would be PCAA approval. In aviation there is a standard which must be followed while designing such products which aimed to use for training of pilots and Engineers. These set of rules are set by aviation safety agencies like EASA, SAARI, FAA etc Each country's civil aviation is bounded by them as they are international so there is a set of tests for evaluation of flight simulators which should be passed before making it a product. We hopefully pass this test after design modifications.

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