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To Design an Aircraft Control System

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Abstract: *This paper going to design the two important stages of aircraft – takeoff and landing. In physical form it is to difficult the study of takeoff and landing stages of aircraft. In this paper we will include a new way to analysis the takeoff and landing of aircraft by Simulink which is the branch of Matlab. On matlab simulator we can see the takeoff and landing position of aircraft and analysis the graphs on different parameters. The take-off and landing of an aircraft is often the most critical and accident prone portion. This paper describes the design of an aircraft take-off and landing algorithm implemented on an existing low-cost flight control system. This paper also describes the takeoff and landing algorithm development and gives validation results from matlab in the loop simulation.The scope of the paper is reaches to the best situation to the design of aircraft control systems in most common high risk phases at important two stages with use simulink programme and development it and transfer design from conventional and classical design into advanced design with low cost, high performance in short runway and how change the classical design used control system from mechanical to hydromachanical into electrical control system as used in modren aircraft with Fly-By-Wire but in the future design technology Fly-By-Light may be used. The takeoff and landing control system is designed under constraints as degree of freedom and equation of motion to improvement in many situations. The research is achieved by MATLAB/Simulink. The simulation results show that the control system performs well. We get the information of attitude and altitude by using aircraft model and various indicators shows the actual reading in aircraft model. The three classes of models and simulations are virtual, constructive, and live.*

Objectives

The objective of this paper is as follows:

i. To analyze the control system of the aircraft during takeoff and landing stage.
ii. To design the control system of aircraft for takeoff and landing.
iii. To simulate the control system design and evaluate the system developed.

I. Introduction

1.1. Principle of Flight Control

The four basic forces acting upon an aircraft during flight are lift, weight, drag and thrust as shown in Figure 1.1.

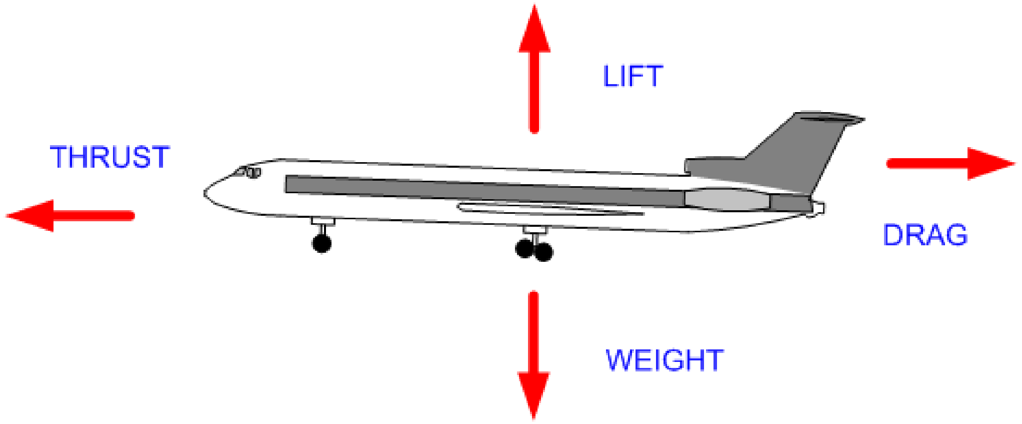


Figure 1.1. Forces acting on an aircraft

1.1.1. Lift

Lift is caused by the flow around the aircraft. Lift is the upward force created by the wings, which sustains the airplane in flight. The force required to lift the plane through a stream of air depends upon the wing profile. When the lift is greater than the weight then the plane raises.

1.1.2. Weight

Weight is the downward force created by the weight of the airplane and its load; it is directly proportional to lift. If the weight is greater than lift then the plane descends. 8

1.1.3. Drag

"The resistance of the airplane to forward motion directly opposed to thrust". The drag of the air makes it hard for the plane to move quickly. Another name for drag is air resistance. It is created or caused by all the parts.

1.1.4. Thrust

The force exerted by the engine which pushes air backward with the object of causing a reaction, or thrust, of the airplane in the forward direction.

1.2. Flight Control Surfaces

An aircraft requires control surfaces to fly and move in different directions. They make it possible for the aircraft to roll, pitch and yaw. Figure 1.2 shows the three sets of control surfaces and the axes along which they tilt.

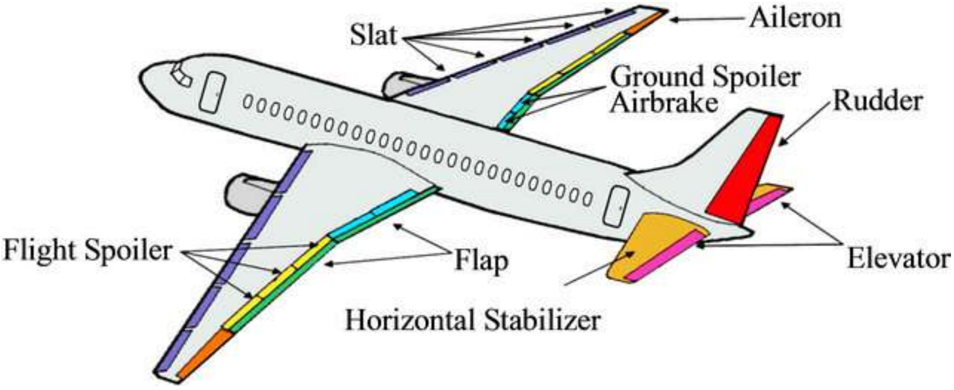


Figure 1.2. Control Surface

axes. The ailerons, operated by turning the control column [Figure 1.3], cause it to roll. The elevators are operated by moving the control column forward or back causes the aircraft to pitch. The rudder is operated by rudder pedals that make the aircraft yaw. Depending on the kind of aircraft, the requirements for flight control surfaces vary greatly, as specific roles, ranges and needed agilities. Primary control surfaces are incorporated into the wings and empennage for almost every kind of aircraft as shown in the . Those surfaces are typically: the elevators included on the horizontal tail to control pitch; the rudder on the vertical tail for yaw control; and the ailerons outboard on the wings to control roll.

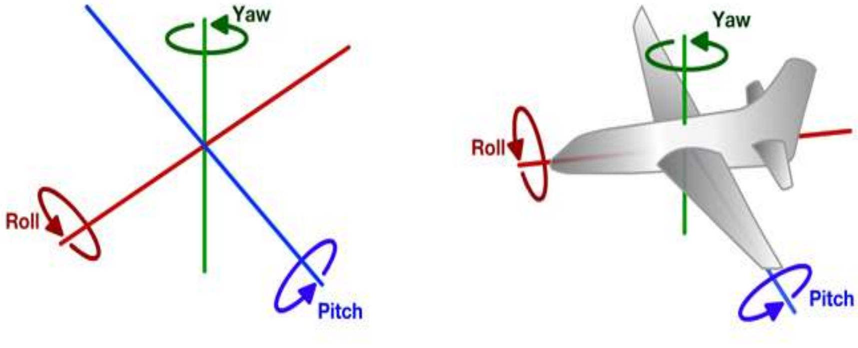


Figure 1.3. Axes of Aircraft

These surfaces are continuously checked to maintain safe vehicle control and they are normally trailing edge types.

1.3. Aircraft Actuation System

Actuation systems are a vital link in the flight control system, providing the motive force necessary to move flight control surfaces. Whether it is a primary flight control, such as an elevator, rudder, aileron, spoiler or fore plane, or a secondary flight control, such as a leading edge slat, trailing edge flap, air intake or airbrake, some means of moving the surface is necessary. Performance of the actuator can have a significant influence on overall aircraft performance and the implications of actuator performance on aircraft control at all operating conditions must be considered during flight-control system design and development programmes.

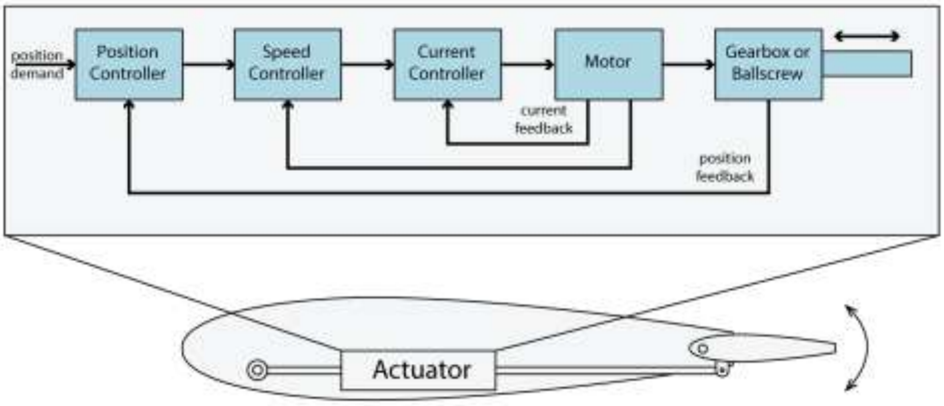


Figure 1.4. Actuation System

Overall aircraft performance requirements will dictate actuator performance requirements, which can lead to difficult design, control and manufacturing problems in their own right. An overview of current actuation system technologies as applied to modern combat aircraft is presented, and their performance and control requirements are discussed. The implications for aircraft control are considered and an overview of selected modeling and analysis methods is presented.

1.4 Introduction of Aircraft Flight Instruments

1.4.1. Airspeed Indicator

This device measures the difference between STATIC pressure (usually from a sensor not in the air-stream) and IMPACT or stagnation pressure from an aircraft's PITOT TUBE which is in the air-stream. During flight greater pressure will be indicated by PITOT TUBE and this difference in pressure from the static sensor can be used to calculate the airspeed.

$V = \sqrt{(pstg - pstat) / \rho}$

Air Speed Indicator by fritzthefox Zazzle

Figure 1.5 Airspeed Indicator

Primary Flight Group Instruments:

Airspeed Indicator , Rate of Climb , Altimeter Linkages and Gears are designed to multiply the movement of the Diaphragm & provide indication on the dial of the Instrument. Instrument measures differential pressure between inside of diaphragm and instrument case.

True Airspeed

adjusts the IAS for the given temperature and pressure. The F-15E receives TAS from the Air Data Computer which measures the outside temperature & pressure. True airspeed is calculated incorporating pressure and temperature corrections corresponding to flight altitude.

$VT = Vi \sqrt{(Pstd\ Tactual / Tstd\ Pactual)}$

VT= True airspeed, V= Indicated airspeed, p & T are pressure and temperature with subscripts std and actual indicating standard and actual (altitude / ambient) conditions True Air Speed and Ground Speed will be the same in a perfectly still air.

Ground Speed

It is another important airspeed to pilots. Ground-speed is the aircraft's actual speed across the earth. It equals the TAS plus or minus the wind factor. For example, if your TAS is 500 MPH and you have a direct (180 degrees from your heading) tail-wind of 100 MPH, your ground-speed is 600 MPH. Ground-peed can be measured by onboard Inertial Navigation Systems (INS) or by Global Positioning Satellite (GPS) receivers. One "old-fashion" method is to record the time it takes to fly between two known points. Then divide this time by the distance. For example, if the distance is 18 miles, and it took an aircrew in an F-15E 2 minutes to fly between the points, then their ground-speed is:

18 miles / 2 minutes = 9 miles per minute.

1.4.2. Altimeter

It is one of the most important instruments especially while flying in conditions of poor visibility. Altitude must be known for calculating other key parameters such as engine power, airspeed etc. Altimeter works on the principle of barometer. In a sensitive altimeter there are three diaphragm capsule with two or three different dials each indicating different slab of altitude. Altimeter should be compensated for atmosphere pressure change.

Figure 1.6 Altitude Indicator

Altimeter senses normal decrease in air pressure that accompanies an increase in altitude. The airtight instrument case is vented to the static port. With an increase in altitude, the air pressure within the case decreases and a sealed aneroid barometer (bellows) within the case expands. The barometer movement is transferred to the indicator, calibrated in feet and displayed with two or three pointers. Different types of indicators display indicated altitude in a variety of ways,

Altitude Definitions

1. Indicated altitude is read directly from the altimeter when set to current barometric pressure.
2. Pressure altitude is read from the altimeter when set to the standard barometric pressure of 29.92 in. Hg.
3. Density altitude is the pressure altitude corrected for non- standard temperature.
4. True altitude is the exact height above mean sea level.
5. Absolute altitude is the actual height above the earth’s surface.

1.4.3. Rate of Climb Meter

This is also called vertical speed indicator which is again useful in blind flights.

Level flights could be indicated by keeping the pointer on zero and subsequent changes are indicated in terms of ft/minute.

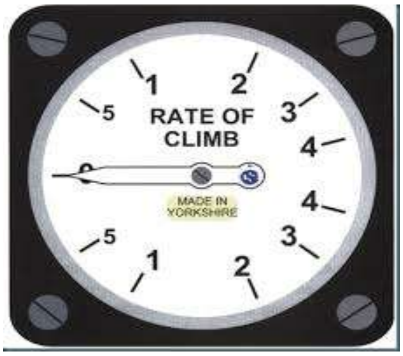


Figure 1.7 Climb Rate Indicator

This is also differential-pressure instrument -atmosphere and chamber pressure which is vented through a small capillary. Response of VSI is rather sluggish and is also sensitive to temperature changes. Mechanical stops prevent damage due to steep dives or maneuvers.

1.4.4. Vertical Speed Indicator

Vertical Speed Indicator (VSI) displays vertical component of an aircraft's flight path. It measures the rate of change of static pressure in terms of feet per minute of climb or descent. VSI compensates for changes in atmospheric density. VSI is in a sealed case connected to the static line through a calibrated leak (restricted diffuser).

Figure 1.8 Vertical Speed Indicator

Diaphragm attached to the pointer by a system of linkages is vented to the static line without restrictions. With climb, the diaphragm contracts and the pressure drops faster than case pressure can escape through restructure, resulting in climb indications.

1.5. Take-off of an aircraft

The take-off segment of an aircraft trajectory is shown in Fig.1.11. The aircraft is accelerated at constant power setting and at a constant angle of attack (all wheels on the ground) from rest to the rotation speed VR. For safety purposes, the rotation speed is required to be somewhat greater than the stall speed, and it is taken here to be

$$V_R = 1.2 V_{stall}$$

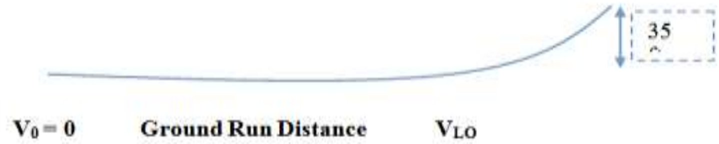


Figure 1.11. Take off of an aircraft

When the rotation speed is reached, the aircraft is rotated over a short time to an angle of attack which enables it to leave the ground at the lift-off speed VLO and begin to climb. The transition is also flown at constant angle of attack and power setting. The take-off segment ends when the aircraft reaches an altitude of h = 35 ft. Because airplanes are designed essentially for efficient cruise, they are designed aerodynamically for high lift-to-drag ratio. A trade- off is that the maximum lift coefficient decreases as the lift-to-drag ratio increases. This in turn increases the stall speed, increases the rotation speed, and increases the take-off distance. Keeping the take-off distance within the bounds of existing runway lengths is a prime consideration in selecting the size (maximum thrust) of the engines. The same problem occurs on landing but is addressed by using flaps. A low flap deflection can be used on take-off to reduce the take-off distance.

1.6. Landing of an aircraft

The landing segment of an aircraft trajectory is shown in Fig. 1.12. Landing begins with the aircraft in a reduced power setting descent at an altitude of h = 50 ft with gear and flaps down. As the aircraft nears the ground, it is flared to rotate the velocity vector parallel to the ground. The aircraft touches down on the main gear and is rotated downward to put the nose gear on the ground. Then, brakes and sometimes reverse thrust, spoilers, and a drag chute are used to stop the airplane. The landing ends when the aircraft comes to rest. For safety purposes, the touch down speed is required to be somewhat greater than the stall speed and is taken here to be

VTD = 1.2Vstall.

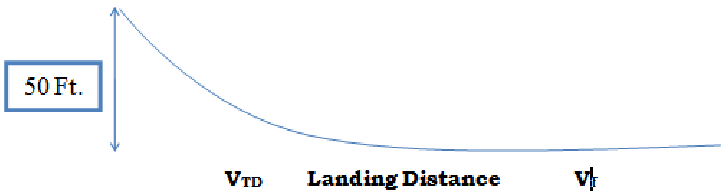


Figure 1.12. Landing of an aircraft

1.7. Equations of Motion

The term flight mechanics refers to the analysis of airplane motion using Newton’s laws. While most aircraft structures are flexible to some extent, the airplane is assumed here to be a rigid body. When fuel is being consumed, the airplane is a variable-mass rigid body. Newton’s laws are valid when written relative to an inertial reference frame, that is, a reference frame which is not accelerating or rotating. If the equations of motion are derived relative to an inertial reference frame and if approximations characteristic of airplane motion are introduced into these equations, the resulting equations are those for flight over a nonrotating flat earth. Hence, for airplane motion, the earth is an approximate inertial reference frame, and this model is called the flat earth model. The use of this physical model leads to a small error in most analyses.

A general derivation of the equations of motion involves the use of a material system involving both solid and fluid particles. The end result is a set of equations giving the motion of the solid part of the airplane subject to aerodynamic, propulsive and gravitational forces. Introduction to Airplane Flight Mechanics for the forces are assumed to be known. Then, the equations describing the motion of the solid part of the airplane are derived. The airplane is assumed to have a right-left plane of symmetry with the forces acting at the center of gravity and the moments acting about the center of gravity. Actually, the forces acting on an airplane in fight are due to distributed surface forces and body forces. The surface forces come from the air moving over the airplane and through the propulsion system, while the body forces are due to gravitational effects. Any distributed force can be replaced by concentrated force acting along a specific line of action. Then, to have all forces acting through the same point, the concentrated force can be replaced by the same force acting at the point of interest plus a moment about that point to offset the effect of moving the force. The point usually chosen for this purpose is the center of mass, or equivalently for airplanes the center of gravity, because the equations of motion are the simplest. The equations governing the translational and rotational motion of an airplane are the following:

a. Kinematic equations giving the translational position and rotational position relative to the earth reference frame.

b. Dynamic equations relating forces to translational acceleration and moments to rotational acceleration.

c. Equations defining the variable-mass characteristics of the airplane (center of gravity, mass and moments of inertia) versus time.

d. Equations giving the positions of control surfaces and other movable parts of the airplane (landing gear, flaps, wing sweep, etc.) versus time.

These equations are referred to as the six degree of freedom (6DOF) equations of motion. The use of these equations depends on the particular area of flight mechanics being investigated.

1.8. 6DOF Model: Wind Axes

The translational equations have been uncoupled from the rotational equations by assuming that the aircraft is not rotating and that control surface deflections do not affect the aerodynamic forces. The scalar equations of motion for flight in a vertical plane have been derived in the wind axes system. These equations have been used to study aircraft trajectories (performance). If desired, the elevator deflection history required by the airplane to fly a particular trajectory can be obtained by using the rotational equation.

In this chapter, the six-degree-of-freedom (6DOF) model for non-steady flight in a vertical plane is presented in the wind axes system. Formulas are derived for calculating the forces and moments. Because it is possible to do so, the effect of elevator deflection on the lift is included. These results will be used in the next chapter to compute the elevator deflection required for a given flight condition. Finally, since the equations for the aerodynamic pitching moment are now available, the formula for the drag polar can be improved by using the trimmed polar.

II. Review Of Literature

Thomas Carnes (2014) Presented The take-off and landing of an Unmanned Aerial Vehicle (UAV) is often the most critical and accident prone portion of its mission. This potential hazard coupled with the time and resources necessary to train a remote UAV pilot makes it desirable to have autonomous take-off and landing capabilities for UAVs. However, a robust, reliable, and accurate autonomous takeoff and landing capability for fixed-wing aircraft is not an available feature in many low-cost UAV flight control systems. This thesis describes the design of an autonomous take-off and landing algorithm implemented on an existing low-cost flight control system for a small fixed wing UAV. This thesis also describes the autonomous takeoff and landing algorithm development and gives validation results from hardware in the loop simulation.Much effort is currently spent on the research and production of unmanned vehicles, particularly those related to Unmanned Aerial Vehicles (UAV). The obvious advantage UAVs have over their conventional, manned aircraft counterparts is that UAVs do not need a pilot or crew to be physically present in the vehicle during operation. This fact keeps the pilot and crew out of harm’s way during potentially dangerous missions while also allowing the aircraft to be made smaller and exempt from all the hardware necessary to sustain life support. UAVs can also host a variety of sensors and payloads that can be tailored for a given situation or need. Due to the advantages listed above, UAVs have become very popular in military applications and more recently in civilian areas.

Abdulhamitbilal, E. (2014) In this paper, an aircraft robust flight control system design is studied via high order sliding mode techniques with parameter uncertainties in flight speed, altitude, aerodynamic coefficients without any reconfiguration of control parameters. Complete nonlinear six degree of freedom flight dynamics model is built for a conventional aircraft in state space. Control commands are assumed to be aileron deflection of wings, elevator deflections of horizontal stabilizers, rudder deflection of vertical fin, trust input of jet-engine/propeller. Twisting and super-twisting algorithms are considered and compared to illustrate effectiveness of each control system on nonlinear aircraft dynamics for different flight conditions.

Wang Zhaoning (2014) In this paper, a control simulation of the autonomous landing process of a Vertical Take-Off and Landing (VTVL) Reusable Launch Vehicle (RLV) is proposed and we consider the effects of the inner liquid propellant sloshing, elastic vibration, disturbance force, disturbance torque and other complex conditions in the virtual RLV model. On the basis of dynamics modeling of the RLV, we analyzed RLV's landing process. The landing control system was designed under certain conditions. Co-simulation Research was achieved by ADAMS and MATLAB/Simulink. The simulation results show that the control system performs well.

Aditya Intwala (2015) Presented Vertical Take Off and Landing Vehicles (VTOL) are the ones which can take off and land from the same place without need of long runway. This paper gives the brief idea about numerous types of VTOLs and their advantages over traditional aircrafts. They can either be of manned type or unmanned type and can be in various sizes and scales. The paper gives insight to various types of multicopter and evaluates their configurations. Vertical takeoff and landing vehicles came into existence due to experiments carried out during the years 1950 – 1970 and almost all came out to be failures. Sometimes it used to have short run before the take off hence they were also called STOL, Short run Take Off and Landing vehicle. The flight control and stability of VTOL/STOL is very difficult and is of prime area of research presently in this field. This paper focuses on how the VTOL emerged gradually over the years and depicts the current advancement in the field of aerospace. VTOL has basically three configurations up till current development in this field, wing type configuration, helicopter type configuration and ducted type configuration. Wing type has fixed wings with vector thrust engine or moving wings with engine, ducted type has ducted rotor which helps to provide lift, helicopter type has rotor mounted above it to provide lift. Initially the VTOL developed were of wing type configuration, primarily for military purposes and were man operated but later their importance was know and more and more advanced designs of it came into existence.

III. Material And Methods

3.1 Critical situations in takeoff and landing flight phases

Figure 3.1 Takeoff and Landing Phase of Aircraft

A critical situation during the takeoff phase or a landing phase could be an engine out condition. In this case, the operative engine will create a force moment that has to be balanced by a side aerodynamic force created by the rudder deflection. In a normal airplane landing the vertical speed towards the ground is about 2 to 4 m/s. If the vertical speed is between 6 m/s and 8 m/s, we have a hard landing, and the problem just a matter of a control maintenance of the landing gear. If the landing vertical speed is higher than 8m/s, we have a crash problem occur. This situation can happen because pilot error in landing procedures (vertical speed too high or not the correct position of the plane with rapport to the ground), special meteorological phenomena, as turbulence (vertical speed towards the ground) or wind shear (wind velocities parallel to the ground, that decrease suddenly the relative on the speed of the airplane wind reference to the air). Some times its occur due to incorrect reading of the control instruments. Flight control problems include gross weight and center-of-gravity problems, jammed or locked controls, aircraft stall, instrument error or false indications (like airspeed indicator). Airspeed Indicator Problems when stop working. Basically at taxiing and taking off the speed indicator works fine. When aircraft in the air it sometime stop working. This situation is very critical for a pilot.

A review of some of the general aviation reports seems to indicate that pilot error in responding to the situation caused more of a problem than the electrical problem. Because many of the reports had little or no damage reported, the narrative of the reports were very brief without a lot of details. For example, one report about a Cessna 182 stated, Electrical problem, Alternator field wire loose. The following incident is even more common. The air taxi "departed alternators off. Drained batteries. Used manual gear. Not locked down. Folded landing." Another report said, "Alternator failed en route. Diverted. In confusion landed gear up." Again, minor damage was done to the aircraft. Another pilot while descending from altitude did a "long cruise descent with the engines at a very low power output. the aircraft had generators instead of alternators, and that the engine speed was using for the descent was below the speed required to keep the battery charged." After landing the commercial pilot and flight instructor discovered the aircraft's battery was too low to start the aircraft.

3.2 Accidents of aircraft during the takeoff and landing phases

Data is collected from aircraft accident in different phases of aircraft during takeoff and landing.

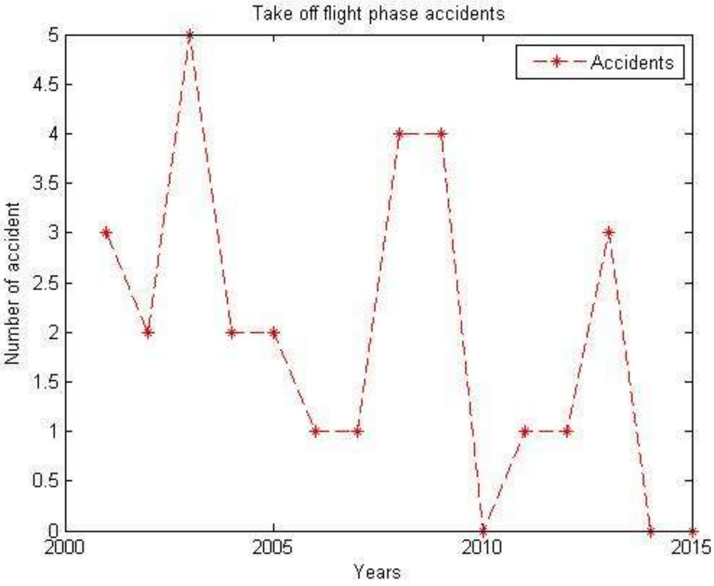
3.2.1 Statistical information regarding the Takeoff flight phase

The number of fatal hull-loss accidents and fatalities per year is given from 2001 - 2015. The table include corporate jet and military transport accidents.

Figure 3.2 Airfrance Accident during Takeoff

Table 3.1 Accidents and Casualties during Takeoff

Year	**Accidents**	**Casualties**
2015	0	0
2014	0	0
2013	3	33
2012	1	4
2011	1	1
2010	0	0
2009	4	10
2008	4	162
2007	1	1
2006	1	49
2005	2	8
2004	2	13
2003	5	169
2002	2	17
2001	3	131



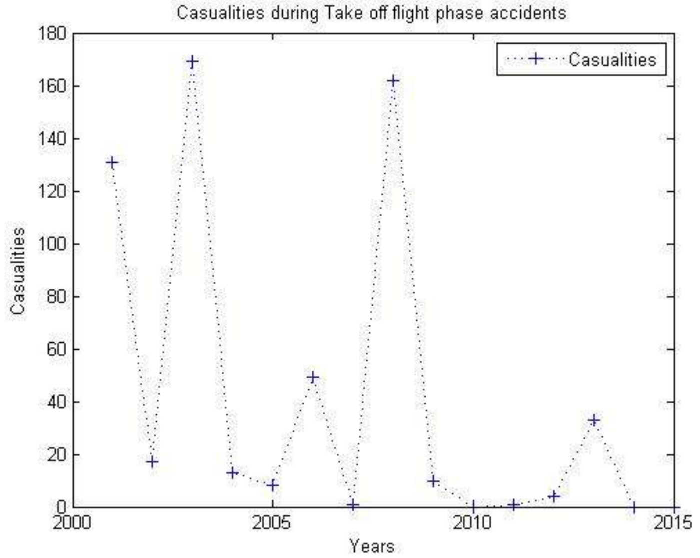


Figure 3.3 Graphs between Year of Accidents and Casualties during Takeoff

3.2.2 Statistical information regarding the Landing flight phase

The number of fatal hull-loss accidents and fatalities per year is given. The table include corporate jet and military transport accidents.

Figure 3.4 Crash of a Fokker F27 in Sligo

Table 3.2 Accidents and Casualties during Landing

Year	**Accidents**	**Casualties**
2015	0	0
2014	2	3
2013	4	18
2012	3	7
2011	3	115
2010	5	212
2009	4	20
2008	4	64
2007	7	318
2006	5	160
2005	4	114
2004	3	64
2003	0	0
2002	2	6
2001	1	1

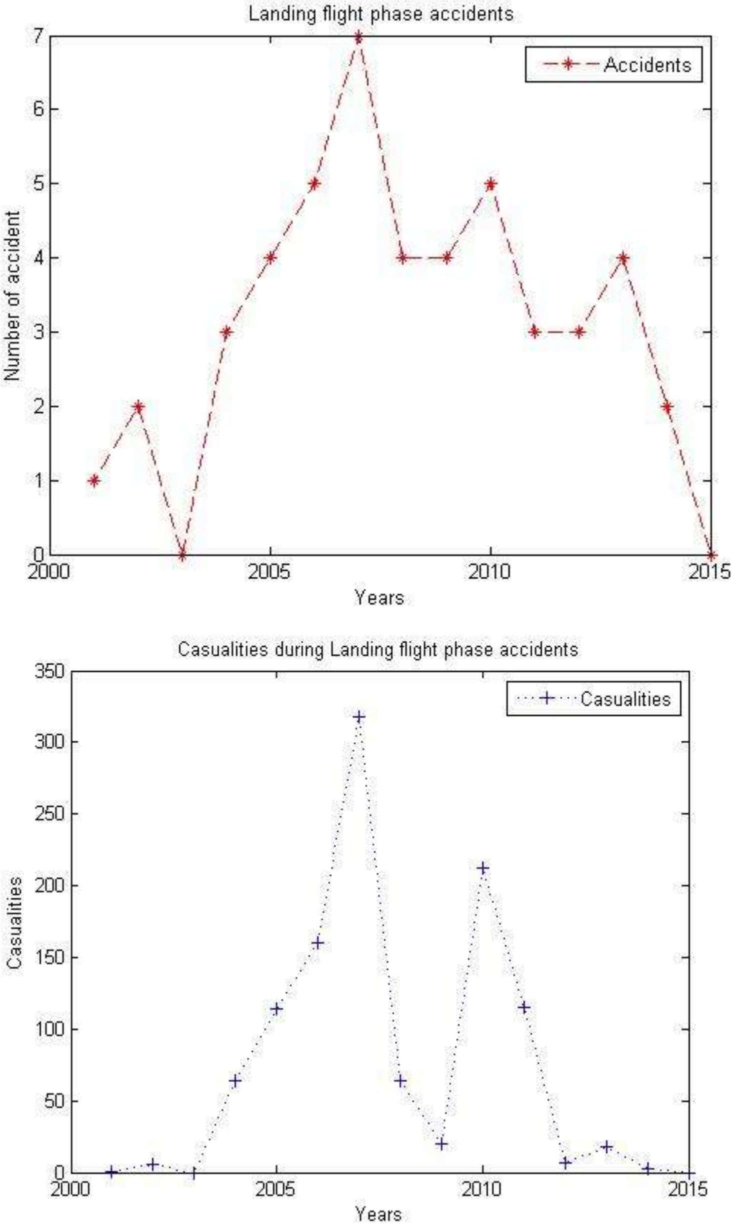


Figure 3.5 Graphs between Year of Accidents and Casualties during Landing

3.2.5 10 worst accidents in Asia

List of the 10 worst aviation occurrences excluding ground fatalities, including collision fatalities.

Table 3.5 : 10 worst accidents in Asia

Fatalities	Date	Type	Registration	Operator	location
520	12-AUG-1985	Boeing 747SR-46	JA8119	JAL	Japan
349	12-NOV-1996	Boeing 747-168B	HZ-AIH	Saudi Arabian	India
349	12-NOV-1996	Ilyushin 76TD	UN-76435	Kazakhstan Airlines	India
301	19-AUG-1980	Lockheed L-1011 TriStar 200	HZ-AHK	Saudi Arabian	Saudi Arabia
275	19-FEB-2003	Ilyushin 76MD	15-2280	IranianRevolutionary Guard	Iran
264	26-APR-1994	Airbus A300B4-622R	B-1816	China Airlines	Japan
261	11-JUL-1991	DC-8-61	C-GMXQ	Nationair, opf. Nigeria Airways	Saudi Arabia
234	26-SEP-1997	Airbus A300B4-220	PK-GAI	Garuda	Indonesia
223	26-MAY-1991	Boeing 767-3Z9ER	OE-LAV	Lauda Air	Thailand
213	01-JAN-1978	Boeing 747-237B	VT-EBD	Air-India	India

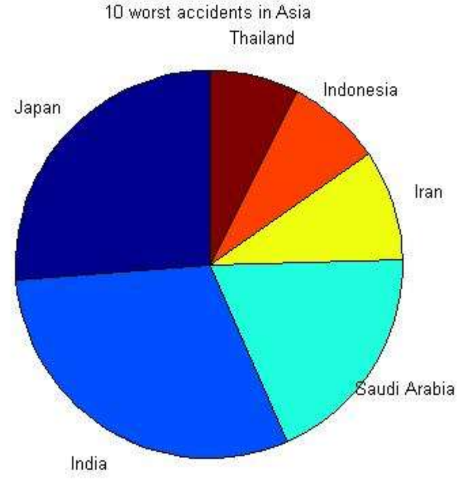


Figure 3.6 10 worst accidents in Asia

3.3 Analysis of Phases of Aircraft

3.3.1 Analysis of Takeoff phase

The evaluation of takeoff performance can be examined in two phases, the ground and air phase. The ground phase begins at brake release, includes rotation, and terminates when the aircraft becomes airborne. The air phase is the portion of flight from leaving the ground until reaching an altitude of 50 ft. In the case where stabilizing at a constant climb speed before reaching 50 ft is possible, the air phase is divided into a transition phase and a steady state climb phase. From table 3.1 and fig 3.3, we have observed that the more accident during takeoff phase in year 2003 and more casualties in this year.

3.3.2 Analysis of Landing Phase

The evaluation of landing performance can be examined in two phases, the air phase and the ground phase. The air phase starts at 50 ft above ground level and ends on touchdown. The ground phase begins at touchdown and terminates when the aircraft is stopped. From the table 3.2 and Fig. 3.4. Shows that in 2007 more accidents held during landing phase and more casualties.

3.4 Shortcoming in older system

In takeoff and landing phases, two controller are discussed in older methods. H_∞ and LQG method are used to improve the safe takeoff and landing but these methods have not sufficient to ensure safe takeoff and landing. The aim of these controllers is to achieve robust stability margins and good performance in step response of the system. LQG method is a systematic design approach based on shaping and recovering open-loop singular values while mixed-sensitivity H_∞ method is established by defining appropriate weighting functions to achieve good performance and robustness. Comparison of the two controllers show that LQG method requires rate feedback to increase damping of closed-loop system, while H_∞ controller by only proper choose the weighting functions, meets the same performance for step response. Output robustness of both controllers is good but H_∞ controller has poor input stability margin. The net controller order of H_∞ is higher than the LQG method and the control effort of them is not in suitable range.

3.5 New Approach to improvement for takeoff and landing

To eliminate the accidents during takeoff and landing of aircraft, we should improve the tools of treatments of degree of freedom and equation of motion. By use advanced methods to obtain high performance and low cost in short time and in short runway. In older method longitudinal and lateral motion have discussed separately to improve. In this paper we have discuss new concept to treat these problem by using simulink in matlab to find the optimum solution form using multi methods. In the model of aircraft give the virtual reading near the actual reading. We have overcome the problem of the lose of control during takeoff and landing. Autopilot has ensure the takeoff and landing advanced airport but in many county they dont have advance airport. when aircraft instruments reading is correct then no need of autopilot to safe takeoff and landing. Our research are going on to improve the passive safety of the aircraft, both in takeoff and landing by experimental methods (Simulink).

3.6 Pitch Control System(Classical Method)

We have give to brief description on the modelling of pitch control longitudinal equation of aircraft, as a basis of a simulation environment for development and performance evaluation of the proposed controller techniques. The system of longitudinal dynamics is considered in this investigation and derived in the transfer function and state space forms. The pitch control system considered in this work is shown in Figure 3.10 where X_b, Y_b and Z_b represent the aerodynamics force components. θ, ϕ and δ represent the orientation of aircraft (pitch angle) in the earth-axis system and elevator deflection angle.The equations governing the motion of an aircraft are a very complicated set of six nonlinear coupled differential equations. Although, under certain assumptions, they can be decoupled and linearized into longitudinal and lateral equations. Aircraft pitch is governed by the longitudinal dynamics. In this example we will design an autopilot that controls the pitch of an aircraft. The basic coordinate axes and forces acting on an aircraft are shown in the figure given below

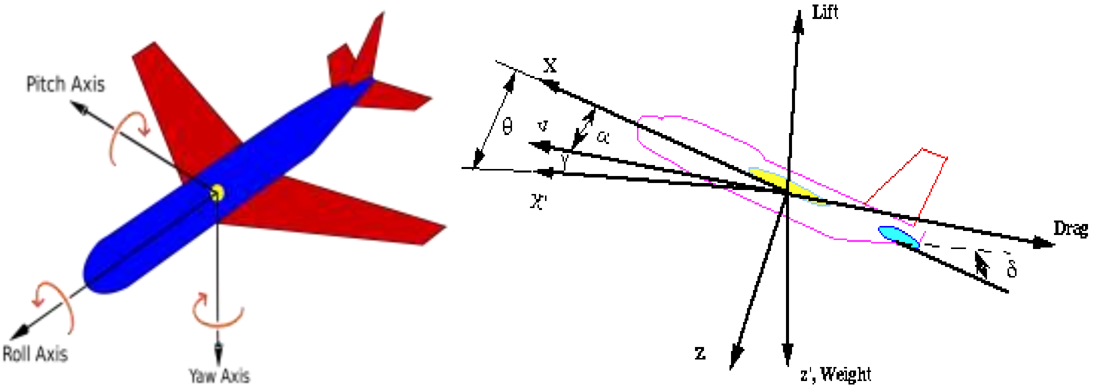


Figure 3.7 Pitch Control Systems

Figure 3.10 shows the forces, moments and velocity components in the body fixed coordinate of aircraft system. The aerodynamics moment components for roll, pitch and yaw axis are represent as L, M and N. The term p, q, r represent the angular rates about roll, pitch and yaw axis while term u, v, w represent the velocity components of roll, pitch and yaw axis. α and β are represents as the angle of attack and side slip.

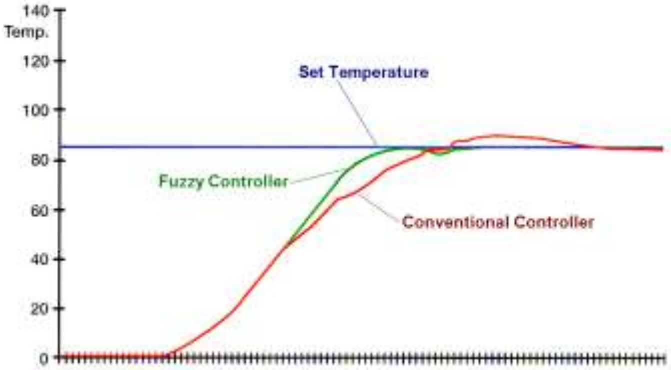


Figure 3.8. Fuzzy Application

A few assumption need to be considered before continuing with the modeling process. First, the aircraft is steady state cruise at constant altitude and velocity, thus the thrust and drag are cancel out and the lift and weight balance out each other. Second, the change in pitch angle does not change the speed of an aircraft under any circumstance.

3.7 Simulink Blockset for takeoff and landing of aircraft (New Model)

The aircraft control toolbox, used in matlab, provides all of the tools needed to design and test control system for aircraft. The toolbox is used worldwide by leading research and industrial organization. The latest version brings many new features including Newtonian aerodynamics, airship modeling function, new aircraft models and new aircraft performance tools. A paper to upgrade the aircraft model with enhanced controls and an aero-brake was initiated, and while the scope of the project was small enough to be undertaken by individuals without a rigorous configuration management system, it was decided that this project should leverage recent work done to provide a reference implementation of a Simulink based CM system.The aircraft model consists of an integrated six-degrees-of-freedom (6-DOF) vehicle model, avionics and sensor models as well as an environment model, and an interface to the third-party, open source software FlightGear for visualization of simulation results. The vehicle model contains the vehicle airframe dynamics, including landing gear and control surface components. The avionics model provides a guidance control system distributed on three redundant processors. All of the components within the model are built up from more than 11,000 blocks. The model, shown in Figure 3.28, is configured to provide a simulation of the final 60 seconds of approach and landing of the aircraft.The model has the full 6-DOF dynamics of the plant as well as the guidance controls implemented within it. We use this collection of files as an executable specification, working with it to understand the behavior of the system. This, in turn, helps us analyze, design and implement the controls system with Model-Based Design.

3.8 Simulink Model for Takeoff of an aircraft

Visualize airplane takeoff and chase airplane with the virtual reality animation object. Virtual Reality Animation object to set up a virtual reality animation based on the asttkoff.wrl file. The scene simulates an airplane takeoff.

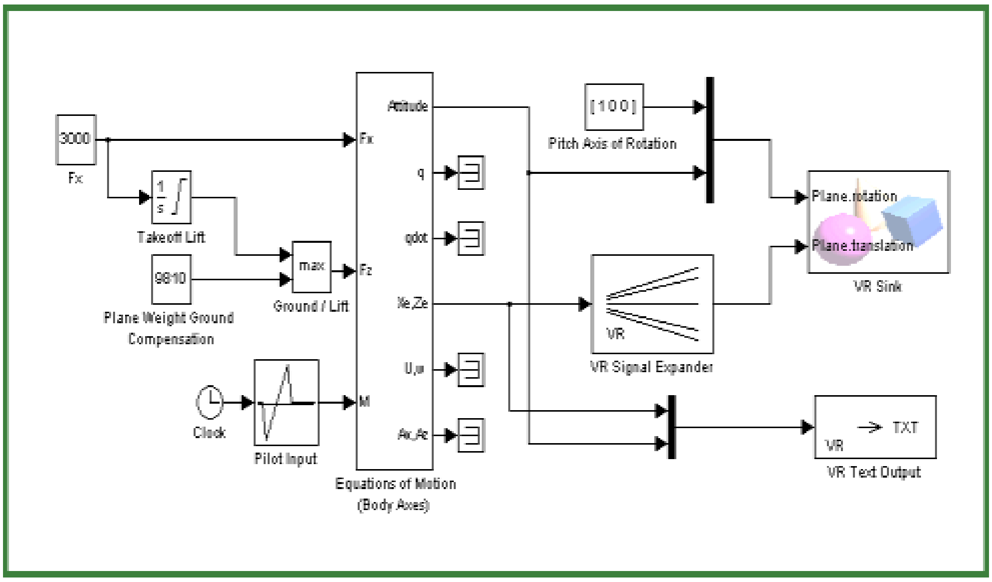


Figure 3.9. Simulink Model of Takeoff of an aircraft

3.8.1 Initialize the Virtual Reality Animation Object

The initialize method loads the animation world described in the 'VRWorldFilename' field of the animation object. When parsing the world, node objects are created for existing nodes with DEF names. The initialize method also opens the Simulink 3D Animation viewer. h.initialize();

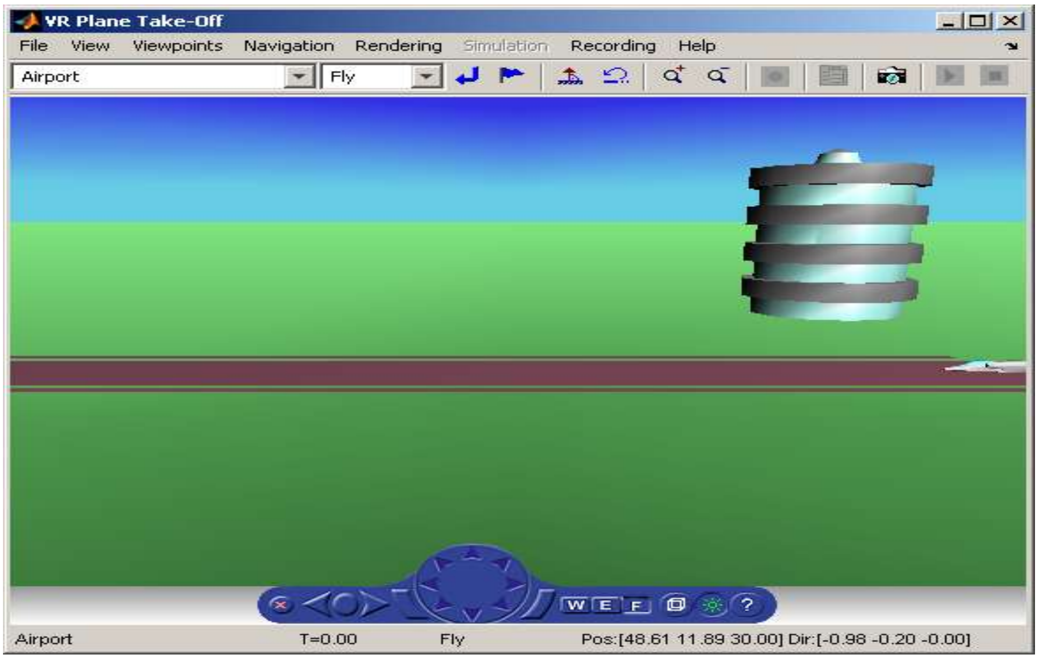


Figure 3.10. Virtual Reality Animation Object-1

3.8.2 Set Coordinate Transform Function

The virtual reality animation object expects positions and rotations in aerospace body coordinates. If the input data is different, we must create a coordinate transformation function in order to correctly line up the position and rotation data with the surrounding objects in the virtual world. This code sets the coordinate transformation function for the virtual reality animation. In this particular case, if the input translation coordinates are [x1, y1, z1], they must be adjusted as follows: [X, Y, Z] = - [y1, x1, z1].

Table 3.1 Node Information

Node	**Information**
1	_v1
2	Lighthouse
3	_v3
4	Terminal
5	Block
6	_V2
7	Plane
8	Camera1

3.8.3 Play Animation From Airplane

This code sets the orientation of the viewpoint via the virtual reality node object associated with the node object for the viewpoint. In this case, it will change the viewpoint to look out the right side of the airplane at the plane.

```
h.Nodes{1}.VRNode.orientation = [0 1 0 convang(160,'deg','rad')];
set(h.VRFigure,'Viewpoint','View From Aircraft');
```

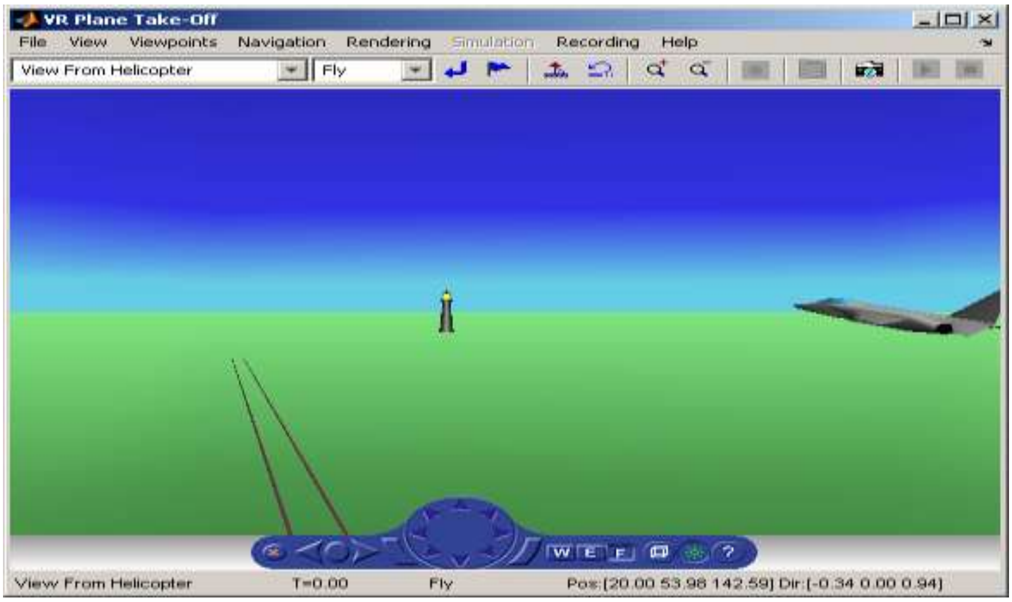


Figure 3.11. Animations from Airplane-1

3.8.4 Close and Delete World

To close and delete h.delete();

3.9 Simulink Model for Landing of an Aircraft

This section gives an introduction to aircraft modeling for landing. The equations of motion are linearized using perturbation theory and the results are state-space models for the longitudinal and lateral motions. The models can be used for aircraft simulation and design of flight control systems. In this model we have to use blockset for degree of freedom and equation of motion but in classical way which is discussion earlier they were using the program to write equation of motion. But in modern way matlab provide us build-in program in the form of blockset which is more accurate than previous work.

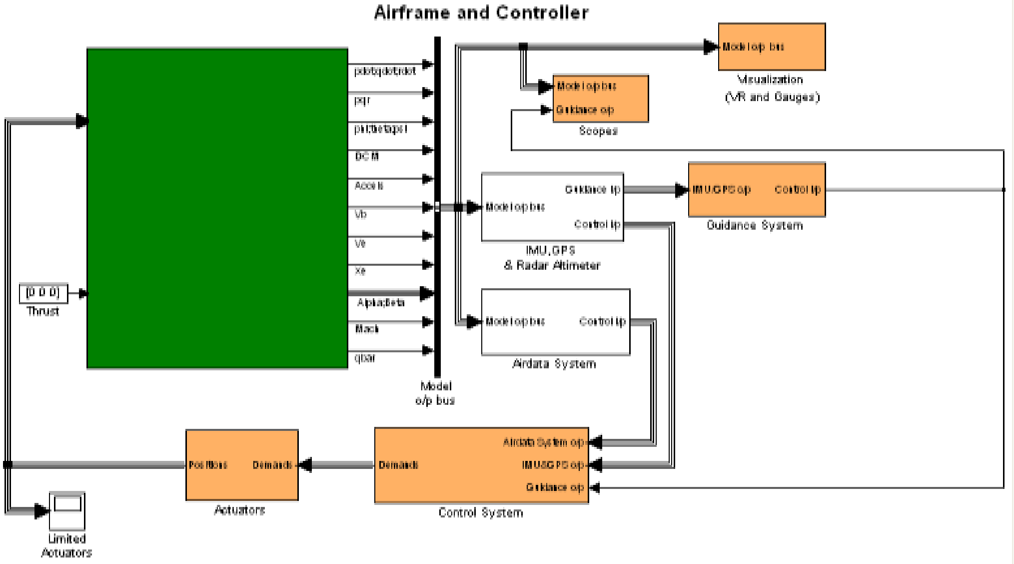


Figure 3.12. Simulink Model of Landing of an Aircraft

6DoF (Euler Angles) Subsystem

The 6DoF (Euler Angles) subsystem contains the six-degrees-of-freedom equations of motion for the airframe. In the 6DoF (Euler Angles) subsystem, the body attitude is propagated in time using an Euler angle representation. This subsystem is one of the equations of motion blocks from the Aerospace Blockset library.

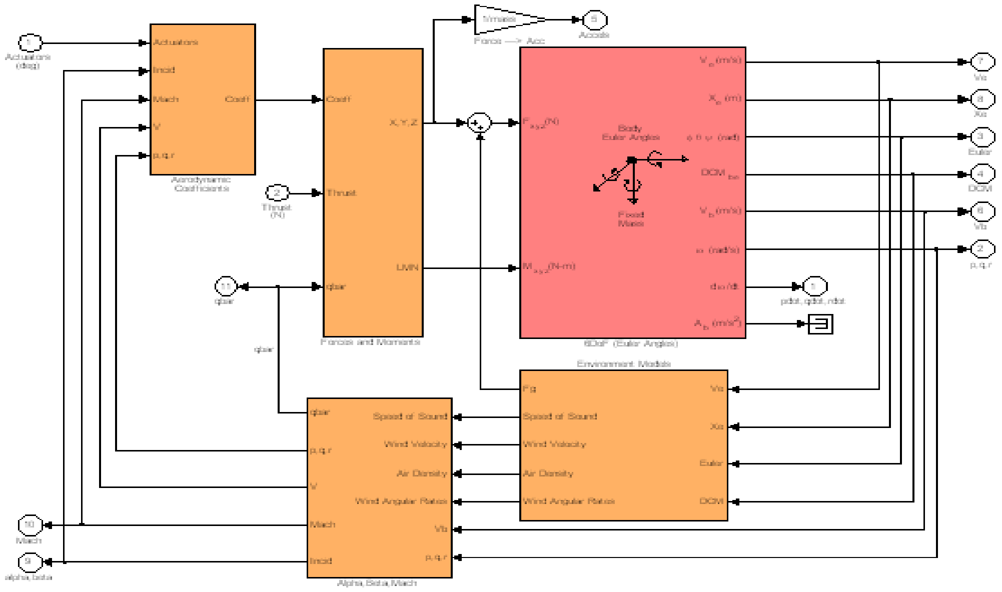


Figure 3.13. 6DoF (Euler Angles) Subsystem

3.10 Aircraft Control and Instruments

This model simulates approach and landing flight phases using an auto-landing controller. Simulink model for landing of aircraft is sub divided into subsystems. Here we have discussed the subsystems of the model and furthers discussion of its block and parameters required inside the block of the subsystem.

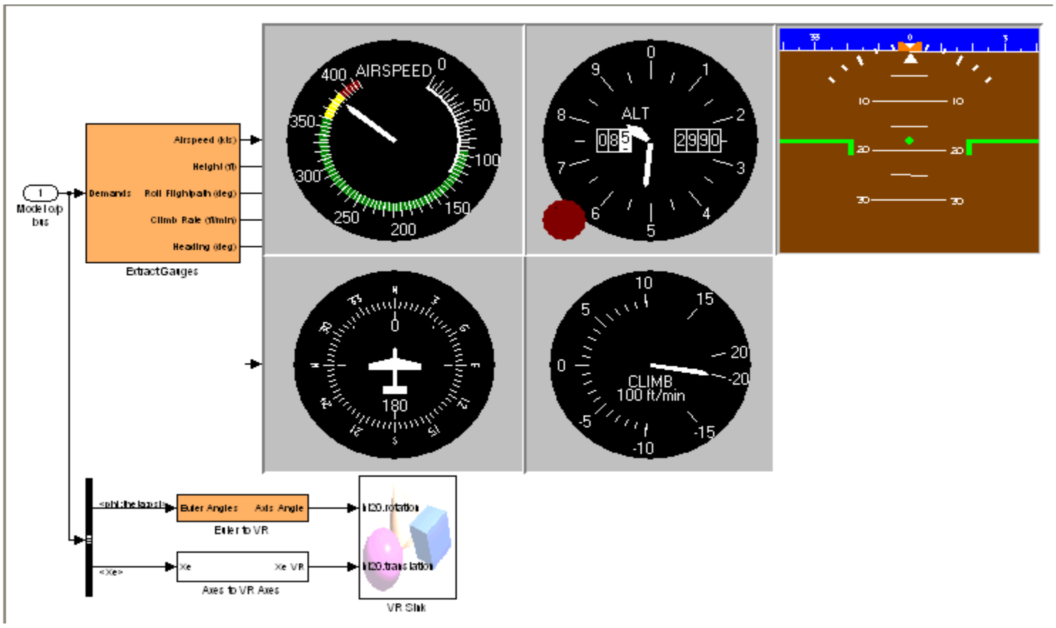


Figure 3.14 Aircraft Control Instruments

3.11. Extract Gauges

Path: CONTROL_AND_INSTRUMENTS/Visualization/Extract Gauges

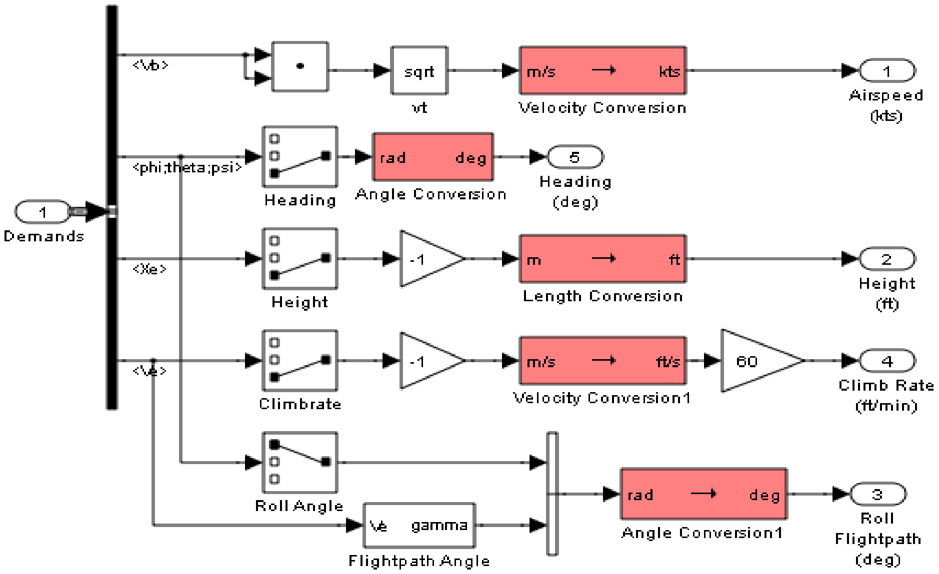


Figure 3.15 Subsystem of Extract Gauges

Blocks Parameters

3.11.1. "Airspeed (kts)" (Outport)

Airspeed is an output port which we can see on the right top of this subsystem and it will be further pass to the next section. In this section we can calculate the airspeed and pass it to next section of the model. The following parameters are required.

Table 3.2. "Airspeed (kts)" Parameters

Parameter	Value
Port number	1
Icon display	Port number
Specify properties via bus object	off
Bus object for validating input bus	BusObject
Output as nonvirtualbus in parent model	off
Port dimensions (-1 for inherited)	-1
Variable-size signal InheritSample time (-1 for inherited)	-1
Minimum	[]
Maximum	[]
Data type Inherit	auto
Source of initial output Value	Dialog
Output when disabled	held
Initial output	[]

3.11.2. "Bus Selector" (BusSelector)

Bus Selector block is used to separate the modulated signal which have done by bus creator. The following parameters are required.

Table 3.3. "Bus Selector" Parameters

Parameter	Value
Output signals	Vb,phi;theta;psi,Xe,Ve
Output as bus	off

3.11.3. "Climb Rate (ft/min)" (Outport)

This is an output port. In this section we have to calculate climb rate of aircraft in ft/min. The number of port used to measure it is 4 and the following parameters are required.

Table 3.4. "Climb Rate (ft/min)" Parameters

Parameter	Value
Port number	4
Icon display	Port number

Specify properties via bus object	off
Bus object for validating input bus	BusObject
Output as nonvirtual bus in parent model	off
Port dimensions (-1 for inherited)	-1
Variable-size signal Inherit Sample time (-1 for inherited)	-1
Minimum	[]
Maximum	[]
Data type Inherit	auto
Source of initial output Value	Dialog
Output when disabled	held
Initial output	[]

3.11.4. "Climbrate" (Selector)

This is a selector block of Simulink library. Number of input dimension is 1 and the following parameters are required.

Table 3.5. "Climbrate" Parameters

Parameter	**Value**
Number of input dimensions	1
Index mode	One-based
Index Option	Index vector (dialog)
Index	[3]
Output Size	1
Input port size	3
Sample time (-1 for inherited)	-1
Index Option Index	vector (dialog)
Index	[3]
Output Size	1

3.12. Aerospace Coordinate Systems

3.12.1 Coordinate Systems for Modeling

Modeling aircraft is simplest if we use a coordinate system fixed in the body itself. In the case of aircraft, the forward direction is modified by the presence of wind, and the craft's motion through the air is not the same as its motion relative to the ground.

3.12.2 Aircraft Body Coordinates

The noninertial body coordinate system is fixed in both origin and orientation to the moving craft. The craft is assumed to be rigid. The orientation of the body coordinate axes is fixed in the shape of body.

- The x-axis points through the nose of the aircraft.
- The y-axis points to the right of the x-axis (facing in the pilot's direction of view), perpendicular to the x-axis.
- The z-axis points down through the bottom the craft, perpendicular to the xy plane and satisfying the RH rule.

3.12.3 Translational Degrees of Freedom. Translations are defined by moving along these axes by distances x, y, and z from the origin.

3.12.4 Rotational Degrees of Freedom. Rotations are defined by the Euler angles P, Q, R or Φ, Θ, Ψ. They are: P or Φ: Roll about the x-axis, Q or Θ: Pitch about the y-axis, R or Ψ: Yaw about the z-axis

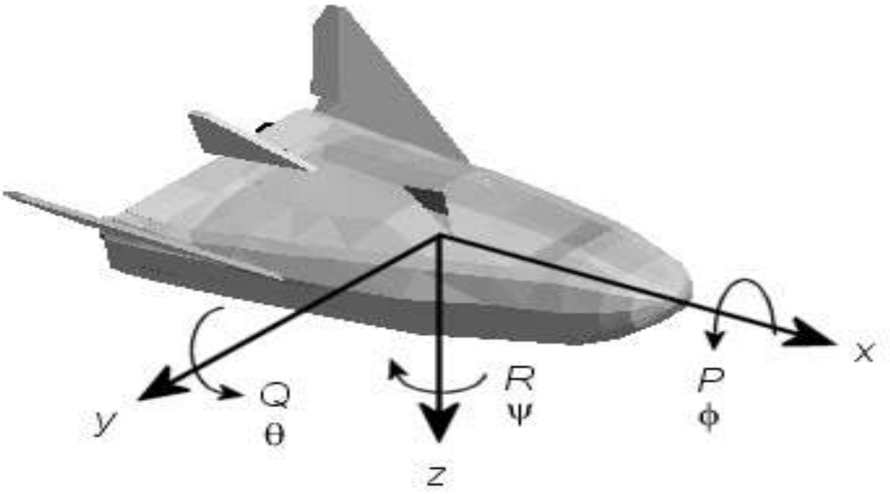


Figure 3.16 Rotational Degrees of Freedom

3.12.5 MATLAB Graphics Coordinates

MATLAB Graphics uses this default coordinate axis orientation:

- The *x*-axis points out of the screen.
- The *y*-axis points to the right.
- The *z*-axis points up.

3.12.6 Flight Gear Coordinates

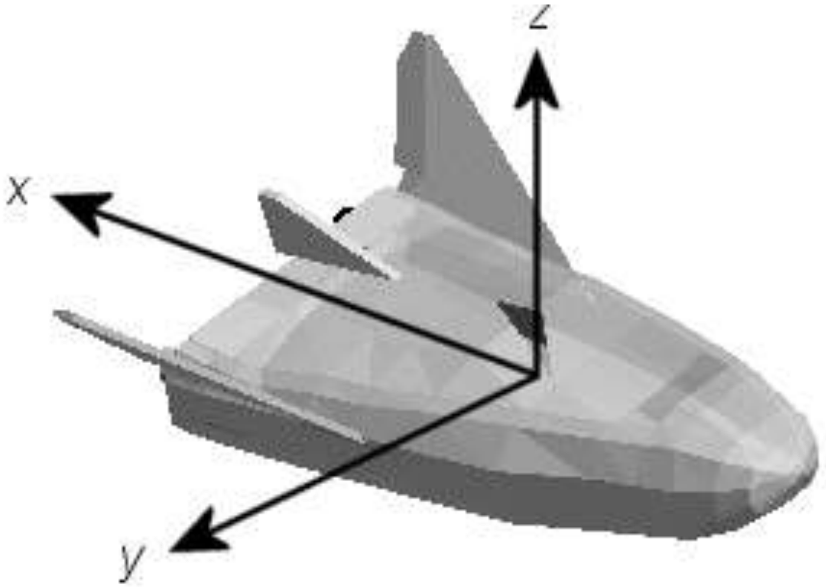


Figure 3.47 Flight Gear Coordinates

Flight Gear is an open-source, third-party flight simulator with an interface supported by the blockset.The Flight Gear coordinates form a special body-fixed system, rotated from the standard body coordinate system about the *y*-axis by -180 degrees:

- The *x*-axis is positive toward the back of the vehicle.
- The *y*-axis is positive toward the right of the vehicle.
- The *z*-axis is positive upward, e.g., wheels typically have the lowest *z* values.

IV. Result And Discussion

4.1 Simulink Result of Takeoff of the aircraft

We have discussed in chapter 3 about the design of takeoff of the aircraft simulation model. In this model different view of the aircraft takeoff are discussed. This model of simulink is more important for low cost and perfomance and planning to optimum design of modern aircraft. We have divided takeoff stage into three stage in our model.

4.1.1 First stage for takeoff of an aircraft

Simulink model for takeoff of the aircraft show the different position of the aircraft in a figure window of the matlab and we have the value of height, altitude, airspeed and vertical airspeed at different positions. This is the initial stage of takeoff of the aircraft.In this stage, speed of aircraft increase rapidally and reach to where aircraft is going to leave the ground.In this part of simulation aircraft is nearly 15 m from the start point and aircraft is on the ground. The attitude measure is -0.03 rad.

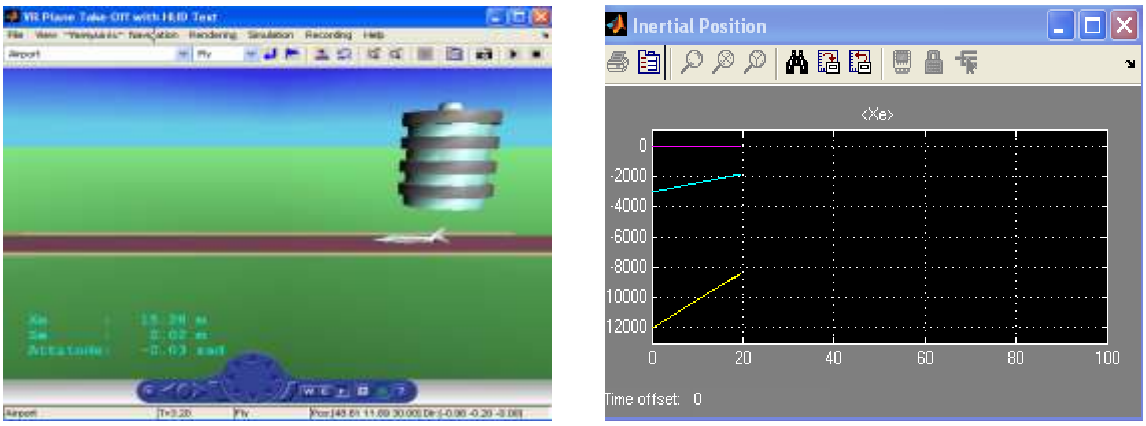


Figure 4.1 First stage for takeoff of an aircraft in model

4.1.2 Second stage for takeoff of an aircraft

When aircraft reach the suitable speed (for small aircraft near 260 km/h, for large aircraft near 300 km/h) all extra power will be disconnected and aircraft going to leave the ground. This is the critical time of the aircraft. In this model aircraft nearly 35 m from start point and height is nealy 1.5 m from the ground. The attitude at this stage is -0.09 rad which show the least stability of the aircraft. On this stage all power is used by the aircraft to leave the ground.

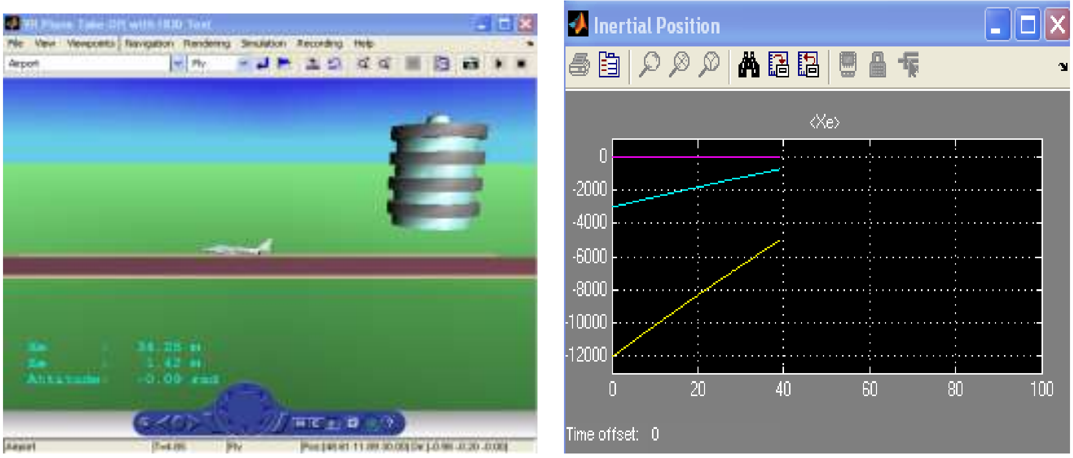


Figure 4.2 Second stage for takeoff of an aircraft in model

4.1.3 Third stage for takeoff of an aircraft

In this stage aircraft reach to steady level flight and in this model distance from initial stage of the aircraft is near 78m and height of aircraft is near 12m and attitude is near to 0.

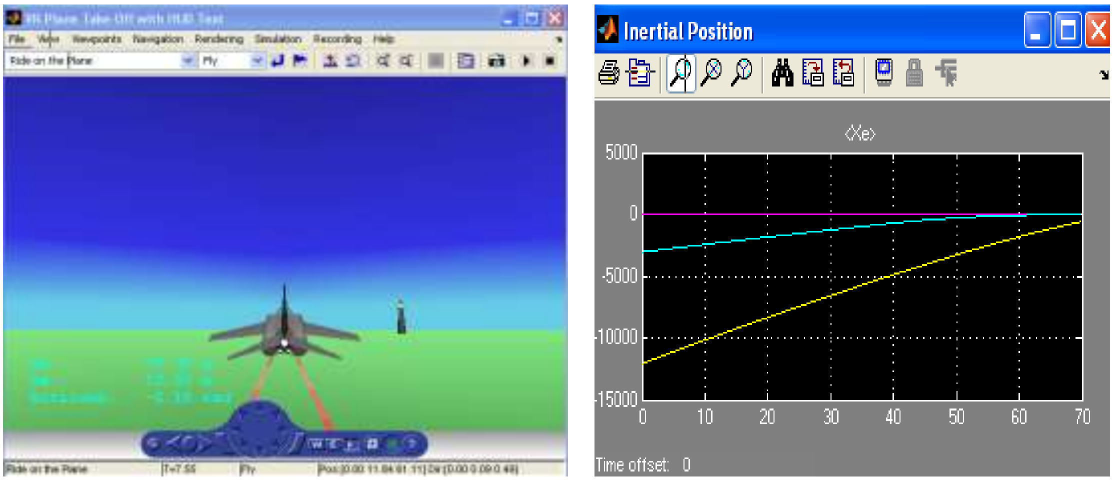


Figure 4.3 Third stage for takeoff of an aircraft in model

4.2 Simulation Result for Landing of an aircraft

The landing process is always consider a complex phase, because the accidents of aircraft sometime occurs within this stage. So the insure flight safety and comfort is very more important. In this model we will analysis the landing stage of an aircraft to form different view point to improve the landing stage. We have divided landing of an aircraft into three stages.

4.2.1 First stage for landing of an aircraft

The descent portion of flight is simply the aircraft lowering its altitude in the preparation to land at an airport or runway of some sort. Most the airports today one equipped with an instrument landing system (ILS).

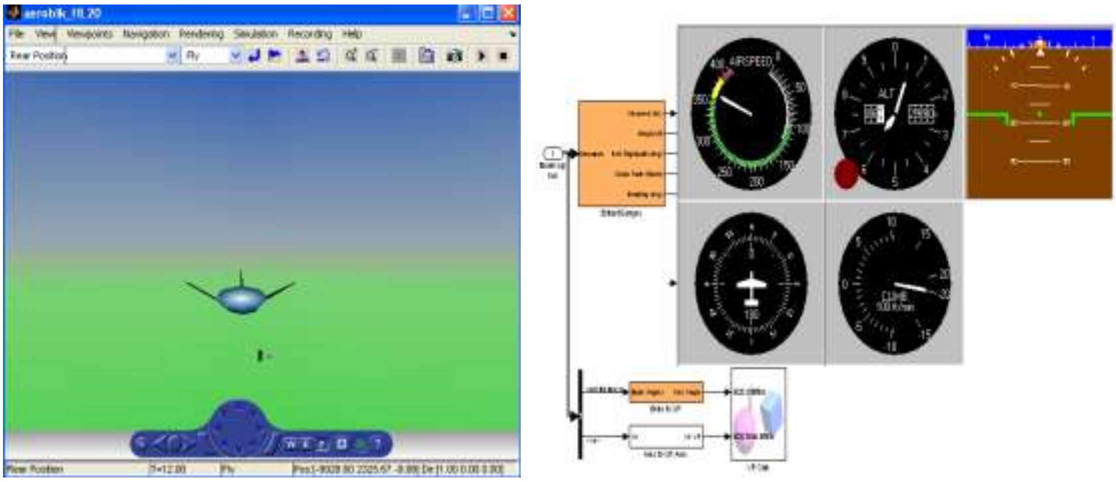


Figure 4.4 First stage for landing of an aircraft in model

From the following indicator when aircraft near about 6000 ft form the ground, we can observe that the airspeed is more than 350 m/s and altitude indicator read near about 6000 ft, climb rate of the aircraft is nearly -20 ft/min. Attitude indicator shows that aircraft is in stable position because it is near 0 deg.

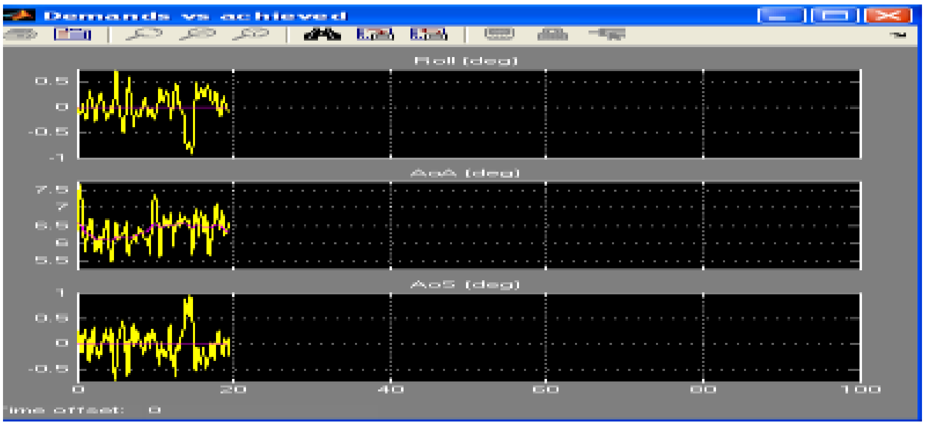


Figure 4.5 Roll, AoA, AoS in first stage of landing

Stability and control are much more complex for an airplane.Imagine three lines running through an airplane and intersecting at right angles at the airplane’s center of gravity. Rotation around the front-to-back axis is called roll. On the outer rear edge of each wing, the two ailerons move in opposite directions, up and down, decreasing lift on one wing while increasing it on the other. This causes the airplane to roll to the left or right. To turn the airplane, the pilot uses the ailerons to tilt the wings in the desired direction. At this situation the graph shows the roll angle between the -1 to 0.5 degree.

An angle-of-attack indication system, on the other hand, provides an instantaneous readout of stalling margin regardless of how heavily loaded we are, what spot of bank we've got dialed in or what the wind is doing. In this way, we should change the old maxim to “angle of attack equals life.”

For those of us who fly without an AOA indicator, at least for now, the key is to unload the wing, which is easy enough to do in the pattern. Hint: point the nose down. we lose a little altitude in the process, but greatly reduce AOA, even if there isn't a gauge there to tell we as much. If there's no altitude to lose and sense we'll need to pull some Gs to make that turn, keep it wide, overfly the airport and live to get it right on the next circuit. From the Graph of AoA it varies for 5.5 to 7.5 degree and AoS angle varies form -0.5 to 1 degree.

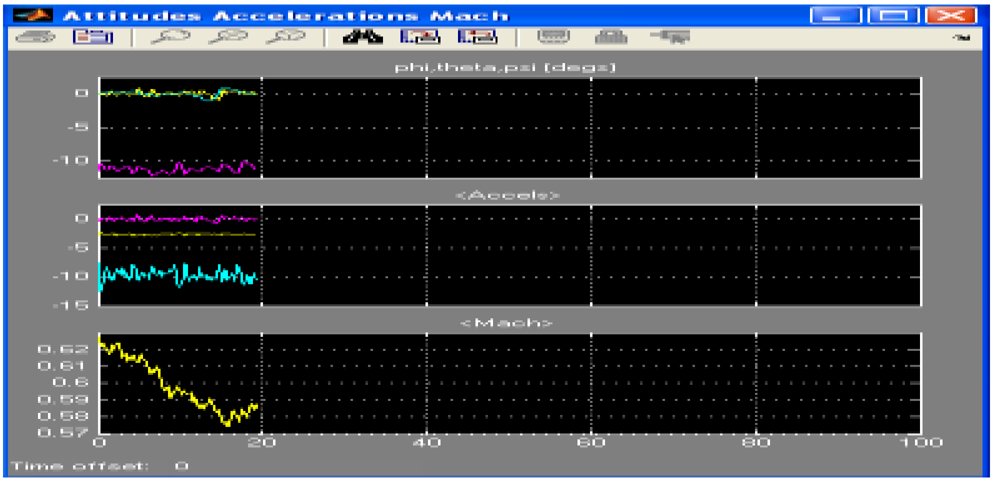


Figure 4.6 Attitude,Acceleration, Mach first stage of landing

The ratio of the speed of the aircraft to the speed of sound in the gas determines the magnitude of many of the compressibility effects. Because of the importance of this speed ratio, aerodynamicists have designated it with a special parameter called the Mach number. Subsonic conditions occur for Mach numbers less than one, $M < 1$. For the lowest subsonic conditions, compressibility can be ignored. In aircraft simulation the mach number between .57 to .62. That’s mean aircraft in this simulation is subsonic.

Mach Number = Object Speed / Speed of Sound

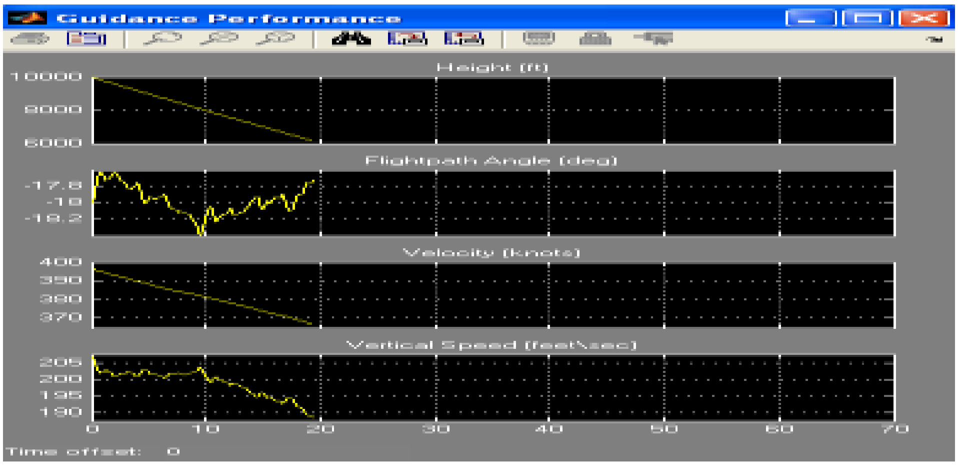


Figure 4.7 Height, Flightpath Angle, Velocity, VS in first stage of landing

At this stage of aircraft height become nearly 6000ft from the ground, the flight path angle varies from -17.8 to -18.2 degree and velocity of aircraft decreases from 400 knots to 360 knots. At the same time vertical speed decreases from 205 ft/sec to 190 ft/sec. In this simulation work of landing of aircraft we can analyses all the result at the different inputs. We can change the parameters of the block which is discussed in the table of chapter 3.

4.2.2 Second stage for landing of an aircraft

In second stage of landing the when aircraft reach near the ground, we have observe the actual reading from the indicator of the model. In this stage the airspeed of aircraft decreased up to 270 km/h and altitude indicator shows near about 3km from the ground, climb rate indicator shows the result -20 ft/min.

From the graph we have observed that acceleration is continuously decreased and roll angle lies between optimum level (-0.5 to 0.5). The angle of attack of the aircraft will increase while velocity, vertical speed, height will continuously decrease. This is the more critical stage of aircraft but by optimum condition of this model, its shows that the safe landing with high performance.

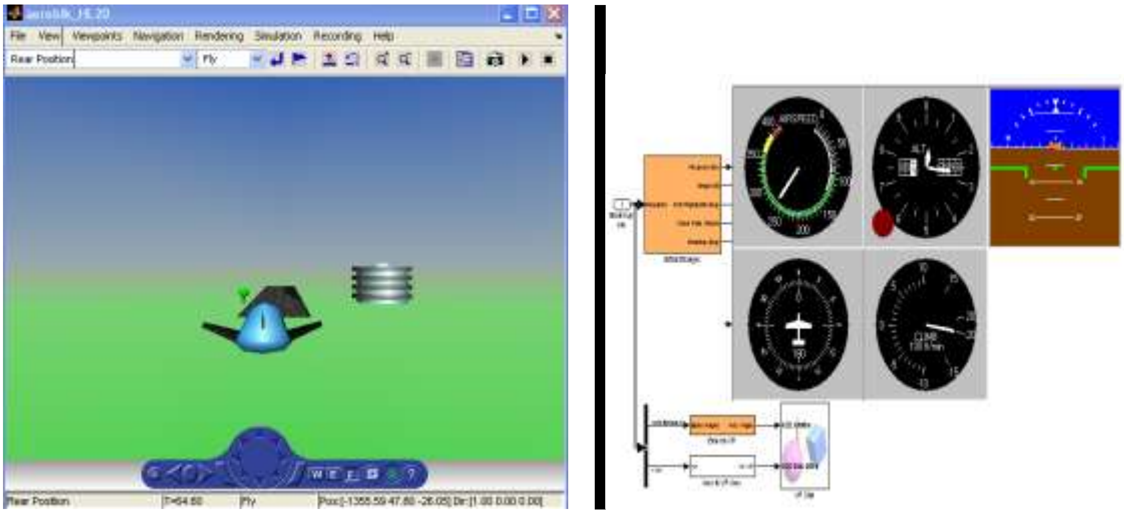


Figure 4.8 First stage for landing of an aircraft in model

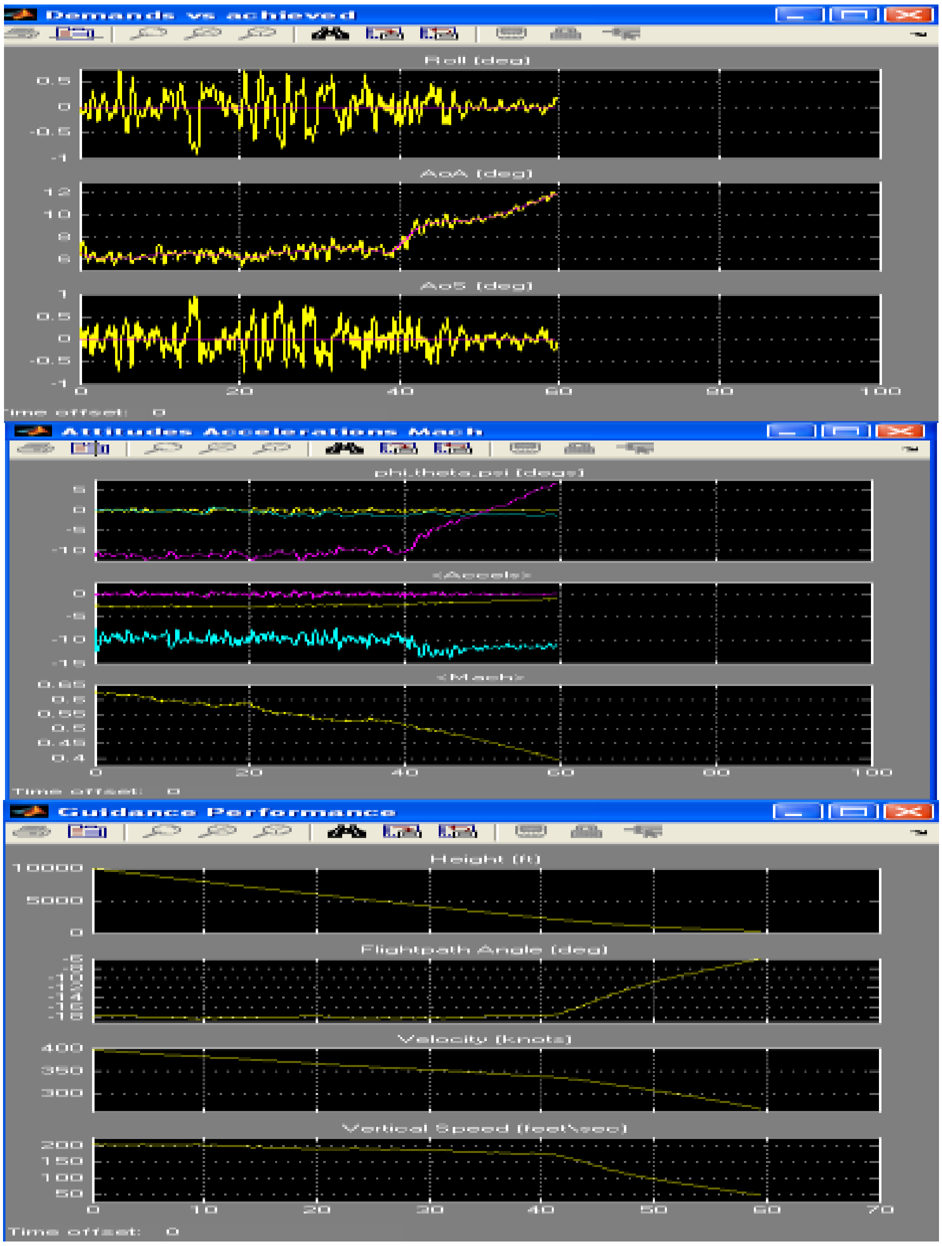


Figure 4.9 Results in second stage of landing

4.2.3 Third stage for landing of an aircraft

In this stage aircraft will touch the runway with the speed 200km/h. All indicators shows the optimum result. We have observed from the following graph height and flight path angle is decreased to 0. Climb rate of the aircraft is nearly -9 ft/min.

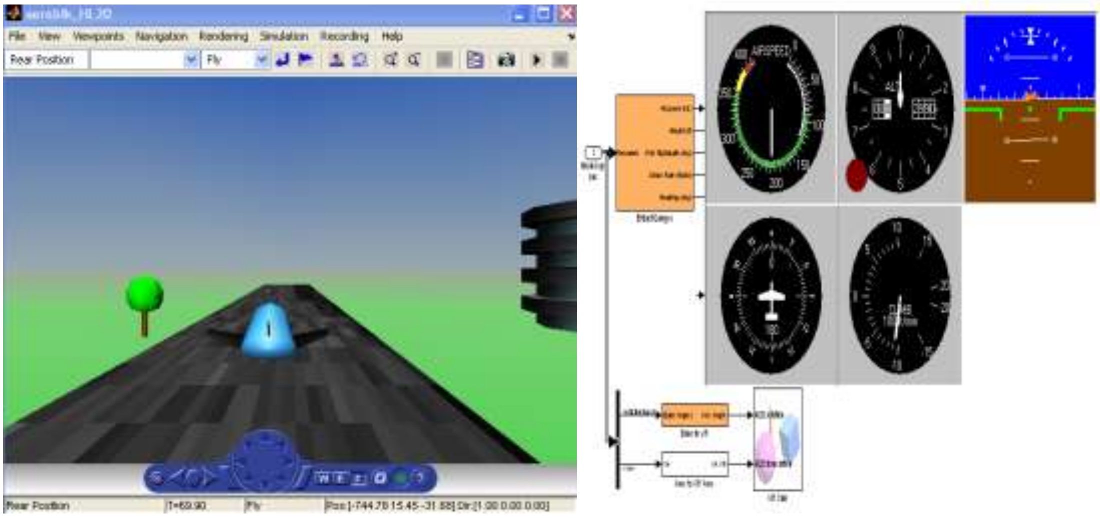
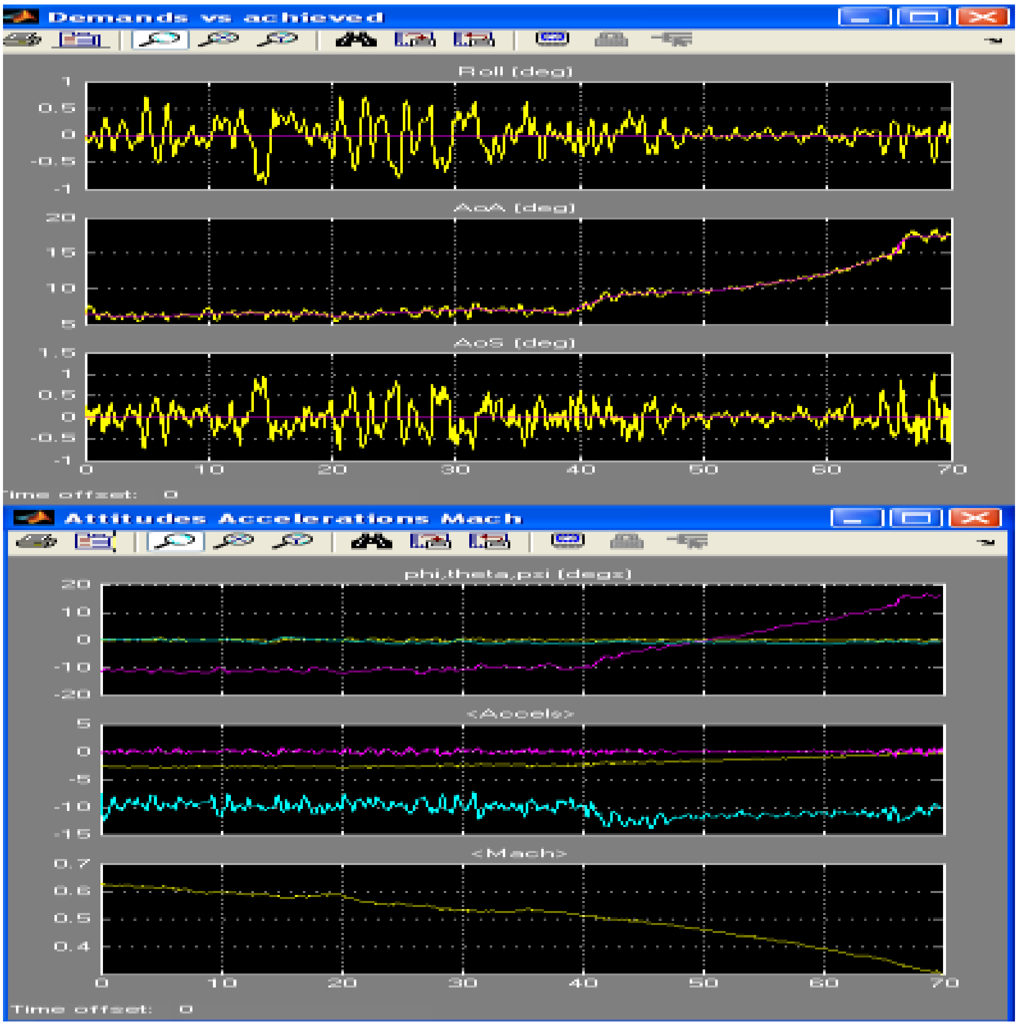


Figure 4.10 Third stage for landing of an aircraft in model



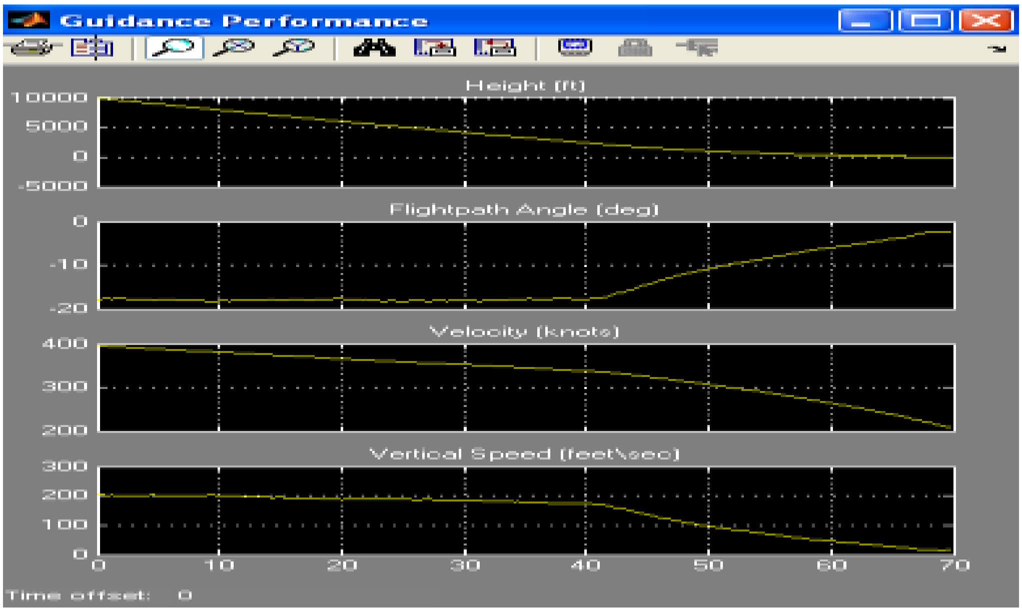


Figure 4.11 Results in third stage of landing

V. Summary And Conclusion

The present work provides a background to the matlab simulink model used in the anlysis and design of flight control system, reviewing instrument systems, altitude equipments, air speed indicator and vertical speed.

Research has also shown that new technologies can be both cost effective and providing additional safety margins. Such technical improvements, when mature, are incorporated in aircraft design.

The aim of a flight control system of an aircraft is to maintain a safe and economic operation. Thus, the desired flight missions can be accomplished even under unexpected events. In the early days of flight, safety was the main concern of a flight control system. Since the number of flights and number of people using planes for travel has increased, safety is even more important.

Aircraft dynamics are in general nonlinear, time varying, and uncertain. Generally, the dynamics are linearized at some flight conditions and flight control systems are designed by using this linearized mathematical model of the aircraft. However, some aerodynamic effects are very difficult to model resulting to uncertainties in the aircraft dynamics and the dynamic behavior of an aircraft may change in a short period of time as a result of internal and/or external disturbances.

The developed system described here is intended to be used as test platform to aircraft controllers. The system is made of two different blocks executing different tasks: one block implements the controllers necessary to the desired movement and the other block implements the model of the aircraft when performing the desired movement. Traditionally, the aircraft movements are classified as longitudinal and lateral movement and under specific flight conditions these movements are considered uncoupled, which makes possible to study them separately. The structure of the developed system should be used for both movements in an aircraft, changing the controllers and the aircraft model depending on the case in study. Here it will be described the development of a digital control system for the longitudinal movement of an aircraft. The dynamic model to represent the target aircraft is a 6 degrees of freedom model, describing the ascending and descending movement, the velocity variation in the vertical movement and the altitude change as a function of the aircraft climbing or descent. The longitudinal dynamic model is characterized by the pitch angle. The reference value of the pitch angle depend on the desired values of the aircraft altitude and velocity. The aircraft dynamic equations were implemented in MATLAB/SIMULINK. Longitudinal controllers were designed with the objective of maintaining the aircraft stability through the specified operations conditions.

References

[1] FM(AG08), Robust Flight Control Design Challenge Problem Formulation and Manual: the Research Civil Aircraft Model (RCAM), Technical Report GARTEUR/TP-088-3, GARTEUR, 1997.

[2] L. J. N. Jones and R. Akmeliawati and C. P. Tan, "Roll and Yaw Stabilisation using Nonlinear Energy Method", in Proceedings of the 9th International Conference on Control, Automation, Robotics and Vision, 2006, pp. 803-806.

[3] L. J. N. Jones and R. Akmeliawati and C. P. Tan, "Aircraft Automatic Maneouvering System Using Energy-based Control Technique", in Proceedings of the 17th World Congress of The International Federation of Automatic Control, 2008, pp. 1200-1205.

[4] R Kristiansen and P. J. Nicklasson and J. T. Gravdahl, Spacecraft coordination control in 6DOF: Integrator backstepping vs passivitybased control, Automatica, vol. 44, 2008, pp. 2896-2901.

[5] Y. J. Huang, T. C. Kuo, and H. K. Way, "Robust vertical takeoff and landing aircraft control via integral sliding mode", IEE Procedings Control Theory Application, vol. 150, (4), pp. 383-388, 2003.

[6] V. I. Utkin, Sliding Modes in Control and Optimization. Springer, Berlin, 1992.

[7] C. W. Tao, J. S. Taur, Y. H. Chang, and C. W. Chang, "A novel fuzzysliding and fuzzy-integral-sliding controller for the twin-rotor multiinput multi-output system", IEEE Transactions on Fuzzy Systems, vol. 18, (5), pp. 893-905, 2010.

[8] K.-K. Shyu, Y.-W. Tsai, and C.-K. Lai, "Sliding mode control for mismatched uncertain systems", Electronics Letters, vol. 34, (24), pp. 2359-2360, 1998.

Bibliography

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