ON THE DEVELOPMENT COMPUTER CODE FOR DETERMINIG THE ROOT OF EQUATION FOR TRANSIENT FLIGHT ANALYSIS

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Thank you Allah the Almighty for His guidance, for granted me with two amazing people to be my parents. For my beloved mother and father, brothers and sisters, for their generous support at every point in my life. My study would not have been possible without their encouragement.

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ABSTRACT

This thesis presents the governing equation of flight motions which can be used to describe the flight behavior of any type flying vehicles consist of 12 equations described 12 state – space variables involving the aircraft position and aircraft aptitude with respect to the inertial coordinate system and also with respect to their axis body system had been used. These twelve equations are coupling each to others and in the forms highly non linear equation; the numerical approach is required for solving such system equation. The coefficient of system equation can be said as a result of the combination between aircraft's mass and inertia, aircraft geometry properties and also their aircraft aerodynamics derivatives. The present work is focused in the development computer code which allows in manner of determining the root of equation of the 12 equations which described the flight behavior for particular airplane. Through determining the root of equation one will able to carry out a non linear transient analysis such as aircraft at landing approaches gust response and pilot initiated maneuvers.

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ABSTRAK

Tesis ini membentangkan persamaan menakluk gerakan penerbangan yang boleh digunakan untuk menerangkan tingkah laku penerbangan apa-apa jenis kenderaan terbang terdiri daripada 12 persamaan yang dinyatakan 12 negeri - pembolehubah ruang yang melibatkan kedudukan pesawat dan kebolehan pesawat berkenaan dengan sistem koordinat inersia dan juga dengan berkenaan dengan sistem badan paksi mereka telah digunakan. Dua belas persamaan tersebut menggandeng setiap satu kepada orang lain dan dalam bentuk persamaan sangat tidak linear ; pendekatan berangka diperlukan untuk menyelesaikan persamaan sistem itu. Pekali persamaan sistem boleh dikatakan sebagai hasil daripada gabungan antara jisim pesawat itu dan inersia , harta geometri pesawat dan juga derivatif aerodinamik pesawat mereka. Kajian yang memberi tumpuan dalam pembangunan kod komputer yang membolehkan dalam cara menentukan akar persamaan daripada 12 persamaan yang digambarkan kelakuan penerbangan untuk pesawat tertentu. Melalui penentuan akar persamaan satu wasiat dapat menjalankan analisis linear sementara tidak seperti pesawat di pendaratan pendekatan sambutan tiupan dan juruterbang memulakan gerakan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AG	- Acceleration of gravity
ALPH	- Angle of attack, **α**
Amass	- Vehicle mass, m
A_T	- Thrust direction cosines relative to X
B_T	- Thrust direction cosines relative to Y
B_w	- Wing span, or reference length
C_D	- Drag coefficient
C_L	- Lift coefficient
CLB	- Coefficient of rolling moment due to beta
CLP	- Coefficient of rolling moment due to roll rate
CLR	- Coefficient of rolling moment due to yaw rate
C_M	- Pitch moment coefficient
CMA	- Coefficient of pitching moment due t o angle of attack
CMAD	- Coefficient of pitching moment due t o angle-of-attack rate
C_{mac}	- Wing mean aerodynamic chord
CMQ	- Coefficient of pitching moment due t o pitch rate
CMO	- Zero lift Pitching moment coefficient
CNP	- Coefficient of yawing moment due to sideslip
CNDR	- Coefficient of yawing moment due to rudder deflection
CNP	- Coefficient of yawing moment due to roll rate
CNR	- Coefficient of yawing moment due to yaw rate
CYP	- Coefficient of side force due to sideslip
C_n	- Yaw coefficient
C_T	- Thrust direction cosines relative to Z
Cy	- Side force coefficient
F	- Force

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P	- Angular velocity about X
p	- Roll rate
Q	- Angular velocity about Y
$\dot{Q}$	- Pitching acceleration
q	- Pitch rate
$\bar{q}$	- Dynamic pressure
R	- Angular velocity about Z
r	- Yaw rate
S_W	- Wing or reference area
T_{HR}	- Thrust
$\dot{U}$	- Longitudinal acceleration
U	- Velocity along X-body axis
V	- Velocity along Y-body axis
W	- Velocity along Z-body axis
$\dot{W}$	- Vertical acceleration
W_P	- Elevator servo natural frequency
W_R	- Aileron servo natural frequency
W_Y	- Rudder servo natural frequency
X_E	- Distance relative to inertial X axes
Y_E	- Distance relative to inertial Y axes
Z_E	- Distance relative to inertial Z axes
Θ_0	- Steady-state pitch attitude
Φ	- Roll angle
Θ	- Pitch angle
Ψ	- Yaw angle
α	- Angle of attack
β	- Sideslip angle
$\dot{\beta}$	- Derivative of sideslip angle
CFD	- Computational Fluid Dynamic
NASA	- National Aeronautics and Space Administration
UAV	- Unmanned Aerial Vehicle
UTHM	- University Tun Hussein Onn Malaysia

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CHAPTRE 1

INTRODUCTION

1.1 Introduction

The governing equation of flight motions which can be used to describe the flight behavior of any type flying vehicles consist of 12 equations described 12 state – space variables involving the aircraft position and aircraft aptitude with respect to the inertial coordinate system and also with respect to their axis body system had been used. These twelve equations are coupling each to others and in the forms highly non linear equation; the numerical approach is required for solving such system equation. The coefficient of system equation can be said as a result of the combination between aircraft's mass and inertia, aircraft geometry properties and also their aircraft aerodynamics derivatives. Such combination had made each equation which described the behavior of flight has own characteristics.

The present work is focused in the development computer code which allows in manner of determining the root of equation of the 12 equations which described the flight behavior for particular airplane.

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Through determining the root of equation one will able to carry out a non linear transient analysis such as aircraft at landing approaches gust response and pilot initiated maneuvers.

1.2 Background

The flight equation of motion represents the governing equation of flying vehicle which can be used to describe what kind movement of the flying vehicle will be. If one able to control the aerodynamic forces and moments acting on the flying vehicle at any instant time including the capability for controlling the required thrust, it will make such flying vehicle becomes an autonomous flying vehicles. Since through the governing equation of flight motion which normally solved to obtain the aircraft position, altitude and velocity can be inverted to become the problem of prescribing flight trajectory and control mechanism as its solution. Through these experiences of solving the governing equation of flight motion, it can be expected to give a plat form in developing a particular aircraft to become an Unmanned Aerial Vehicles in the future work. However it had been understood, that design flight control mechanism to allow the airplane able to control its movement arbitrary at various flight condition are so complex and difficult task, it is therefore for only particular flight maneuver the aircraft designed to be autonomous as result various type of UAV had been developed to fulfill different purposes.

In parallel of the advancement of computer technology, material, propulsion system and better understanding on the aircraft stability had made the development of autonomous flying vehicle becomes an attracted matter. The applications of UAV are widely had been recognized whether for civilian or military purposed. The military purposes may the UAV can serve for[1]:

Surveillance for peacetime and combat synthetic aperture radar (SAR).
Reconnaissance surveillance and Target acquisition (RSTA).

Maritime operations (Naval fire support, over the horizon targeting, anti-ship missile deference, ship classification).

Meteorology missions.

Electronic warfare (EW) and SIGNT (Signals Intelligence).

Deception operations.

While for civilian applications, the UAV can be used for:

Communications relay. High altitude long endurance UAVs can be used as satellites.

Law enforcement. VTOL UAVs can take the role of police helicopters in a more cost effective way.

Disaster and emergency management. Arial platforms with camera can provide real time surveillance in hazardous situations such as earthquakes.

Research. Scientific research of any nature (environmental, atmospheric, archaeological, pollution etc) can be carried out UAVs equipped with the appropriate payloads.

Industrial applications. Such application can be crops spraying, nuclear factory surveillance, surveillance of pipelines etc.

Considering that there are a lot of application can be served through the use of UAV, it is therefore, the ability to develop the UAV based on own design is necessary in order to limit the foreign dependence in this type of technology.

1.3 Problem statements

As unmanned flying vehicle, it is means that the aircraft has capability to control their flight path over any kind of disturbance may appear during their flight. Such capability only can be obtained through the use of flight control system placed inside the aircraft. Flight control system represents computer software which required the aerodynamics data for that aircraft in order to allow developing flight mechanism for controlling the

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aircraft. Flight control system can be considered as inverse problem of solving the governing equation of flight motion. In the stage of development in developing flight control on board it is necessary to develop a computer code for solving the governing equation of flight motion for a given aerodynamic characteristics, control surfaces movement and aircraft's mass and inertia properties to Obtain the transient flight phenomena if the airplane under small disturbance.

1.4 Thesis objective

The objectives of the research work are to develop computer code which allows one to define the characteristics properties of each equation of the system equation of aircraft's flight motions.

1.5 Scope of study

Refer to the objectives of the research work as mentioned in the previous of paragraph, the scope of study will be conducted in the present work involves:

Understanding coordinate system applied to the airplane namely the earth coordinate system, aircraft body axis coordinate system and the aircraft stability coordinate system.

Understanding how to derive the governing equation of flight motion.

Development computer code for solving root equation of each of equation defining the aircraft motion.

Obtain the transient flight phenomena if the airplane under small disturbance.

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CHAPTER 2

LITERATUR REVIEW

2.1 Type of Aircraft

To fulfill the need of various activities in modern life, the aircraft development was not focused on particular type of aircraft. The aircraft industries around the world had been produced various kinds of aircraft. Hence some manner how to classify is needed. Currently there are various manners to classify the type of aircraft. Basically in manner one in classifying the aircraft defined according to the following groups:

1. Method of Lift Generated
2. Propulsion
3. Design and construction
4. Flight characteristic
5. Impact and use
6. Piloted and Unpiloted Aircraft

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2.2 Mission profile and overview

For any aircraft designed without pilot on board called as unmanned aerial vehicle (UAV). Without pilot on board made the size of vehicle can be reduced significantly but at the same time the ability to maintain their safety flight are highly demanded. In line with the progress of aircraft technology development in respect to the design procedures, material, manufacturing and the rapid progress in electronics, communication system and computing power had made a further effort for UAV's development becomes apparent. The UAV has gained interest for military or civilian users. Military users may look the UAV with a particular design can perform a variety of missions supporting military and intelligence purposes. The list below presents the military applications that UAVs have served up to now [1].

Surveillance for peacetime and combat synthetic aperture radar (SAR).
Maritime operations (Naval fire support, over the horizon targeting, anti-ship missile deference, ship classification).

Adjustment of indirect fire and close air support (CAS).
Meteorology missions.
Ratio and data relay.
Battle damage assessment (BDA).
Reconnaissance surveillance and target acquisition (RSTA).
Deception operations.
Electronic warfare (EW) and SIGNT (Signals Intelligence).
Route and landing reconnaissance support.

While from the point of view, civilian users, the Unmanned Aerial Vehicles may be used for the one of following mission [1]:

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Communications relay. High altitude long endurance UAVs can be used as satellites.

Disaster and emergency management. Arial platforms with camera can provide real time surveillance in hazardous situations such as earthquakes.

Industrial applications. Such application can be crops spraying, nuclear factory surveillance, surveillance of pipelines etc.

Search and rescue. Looking for survivors from shipwrecks, aircraft accidents etc.

Research. Scientific research of any nature (environmental, atmospheric, archaeological, pollution etc) can be carried out UAVs equipped with the appropriate payloads.

Wild fire suppression. UAVs equipped with infrared sensors can detect fire in forests and notify the fire brigade on time.

Border interdiction. Patrol of the borders by aerial platforms.

Law enforcement. VTOL UAVs can take the role of police helicopters in a more cost effective way.

In more specific purposes, where the mission condition in civil application is unsafe mission, the UAV can be used to carry out to conduct such mission the mission for:

Surveillance over nuclear reactors.

Surveillance over Hazardous chemicals.

Fire patrol.

Volcano patrol.

Hurricane observations.

Rescue missions over adverse weather conditions.

Above explanation clearly indicated that there are a numerous missions can be performed by the use of UAV. Each mission may require a specific aircraft configuration, payload and size. For a long endurance UAV may require a sufficient size of UAV to accommodate the required fuel.

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The UAV which designed for law enforcement by authority body may require the UAV in the form of Helicopter rather than fixed wing aircraft in order to provide the ability to take off and landing vertically in crowded area and hovering over particular region may need to be investigated carefully. A good review on UAV mission for military application may be found in[2].

2.3 Some Examples of UAV Model Already Developed

Unmanned Aerial Vehicles, or UAVs, as they have sometimes been referred to, have only been in service for the last 60 years [3]. UAVs are now an important addition to many countries air defenses. Modern UAVs have come a long way since the unmanned drones used by the USAF in the 1940s [4]. These drones were built for spying and reconnaissance, but were not very efficient due to major flaws in their operating systems. Over the years UAVs have been developed into the highly sophisticated machines in use today. Modern UAVs are used for many important applications including coast watch, news broadcasting, and the most common application, defense.

With a growing number of UAVs being developed and flown in recent years there is the problem of classifying these new UAVs. As UAVs are used in a variety of applications it is difficult to develop one classification system that encompasses all UAVs. It has been decided that the UAVs will be classified into the two main aspects of a UAV, their performance specifications and their mission aspects [5].

The specifications of a UAV include weight, payload, endurance and range, speed, wing loading, cost, engine type and power. The most common mission aspects are ISTAR, Combat, Multi-purpose, Vertical Take-off and landing, Radar and communication relay, and Aerial Delivery and Resupply. It is important to have a classification system for UAVs as when a specific UAV is needed for a mission it can be easily chosen from the wide variety of UAVs available for use.

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2.4 Predator [6, 7, 8]

2.4.1 Predator Description

Predator is a Medium-Altitude Endurance (MAE) UAV designed to provide battlefield surveillance with a beyond line of sight communications capability. This aircraft is an evolution from the General Atomics Gnat UAV. The Predator program began in 1994 as an Advanced Concept Technology Demonstrator (ACTD). The program transitioned to operational use very early in development [6].

2.4.2 Geometry Characteristics

The Predator key geometry characteristics are shown graphically in Figure 2.1, and numerically in Table 2.1.

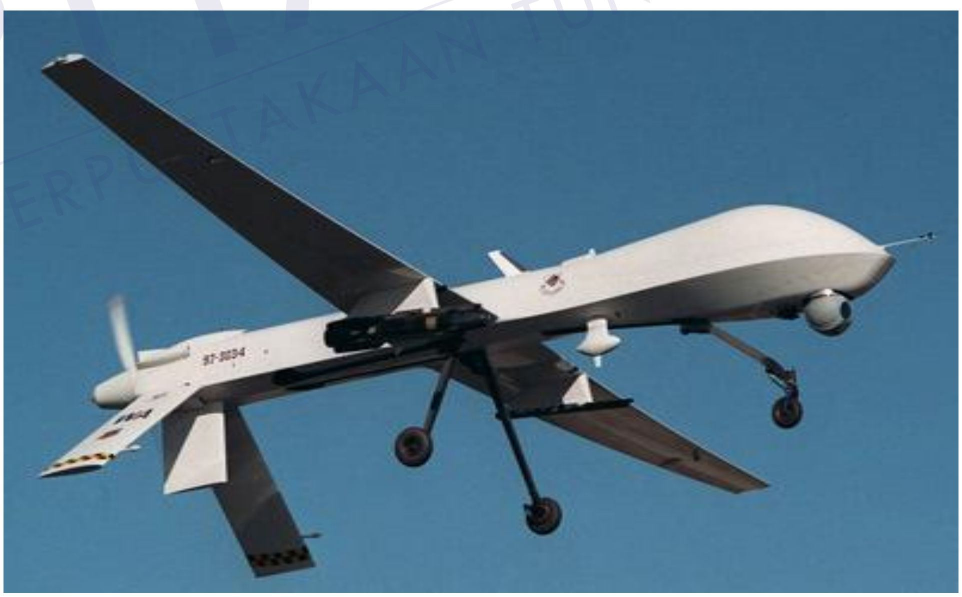

Figure 2.1: Predator UAV [9]

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