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

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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.

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

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

LIST OF APPENDICES

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.

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 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.

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

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]:

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.

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.

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]

Table 2.1: Predator Geometry [6]

Description	Value	Source
Wing span	48.7 ft	Jane's [1999]
Aspect ratio	19.25	Jane's [1999]
Sweep (quarter chord)	0^o	Jane's [1999]
Fuselage Length	26.7 ft	Jane's [1999]
Length	27 ft	Jane's [1999]
Height	6.9 ft	Jane's [1999]
Weight	1,130 lbs (empty)	Jane's [1999]
Runway (ISA)	Improved,3000 ft * 100 ft	Jane's [1999]
Max Gross Take-off Weight	2250 lbs	Jane's [1999]
Fuel	Type: 110 LL avgas ; capacity: 110 lits	Jane's [1999]

2.4.3 Propulsion

Predator uses the Rotax 914 reciprocating engine to drive a pusher propeller. Major engine characteristics are presented in Table 2.2.

Table 2.2: Predator Propulsion Characteristics [6]

Item	Value	Source
Maximum Power (S/L)	105 HP	Jane's [1999]
BSFC	0.5 lbm/HP-hr	Assumed
Weight	150.4 lbs	Jane's [1999]

2.4.4 Avionics

Predator has a relatively simple avionics suite compared to Global Hawk. Predator is largely a single-sting system with little redundancy. A summary of the Predator avionics weights is presented in Figure 2.2.

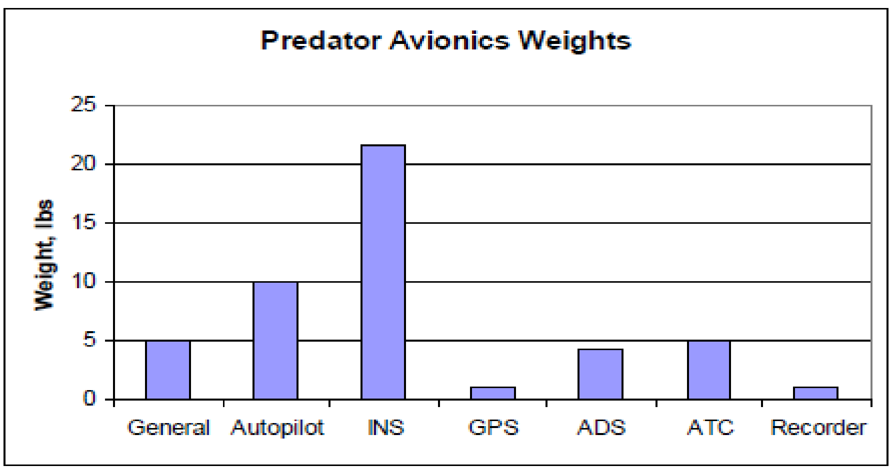

Figure 2.2: Predator Avionics Weights Summary [6]

2.4.5 Subsystems

A summary of the Predator subsystems weights is presented in Figure 2.3.

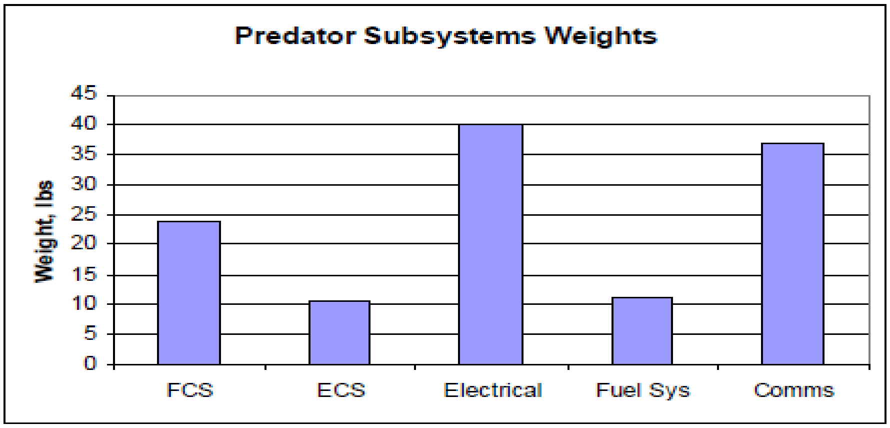

Figure 2.3: Predator Subsystems Weights Summary [6]

2.4.6 Structures

The structure is largely made of carbon/epoxy composites [Jane's 1999]. The smaller Gnat UAV in the Predator family is stressed for 6 G maneuvers at an unspecified weight. Absent of further information, the 6 G loading was applied to the Predator. A summary of the Predator structural weights is presented in Figure 2.4.

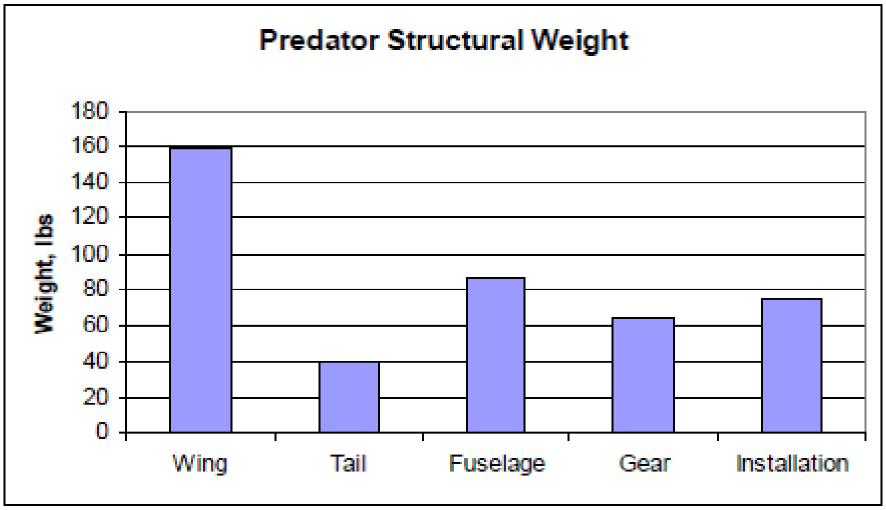

Figure 2.4: Predator Structural Weight Summary [6]

2.4.7 Performance

The mission profile for Predator is 24 hours time on station at a 500 nautical mile radius, according to Jane's [1999]. The 2003 General Atomics Predator brochure indicates that the performance is 24 hours time on station at a 400 nautical mile radius. The Jane's [1999] mission profile was used here. The EO/IR-SAR payload combined weight of 181 pounds was used, not the maximum payload capacity. An additional one-hour loiter at sea level is added to account for recovery operations. A ceiling of 25,000 feet was imposed on the mission performance calculation. A climb from sea level to 20,000 feet was included in the ingress segment. The descent from the final loiter point to sea level was included in the egress segment. The Predator altitude and velocity performance is shown in Figure 2.5 and Figure 2.6.

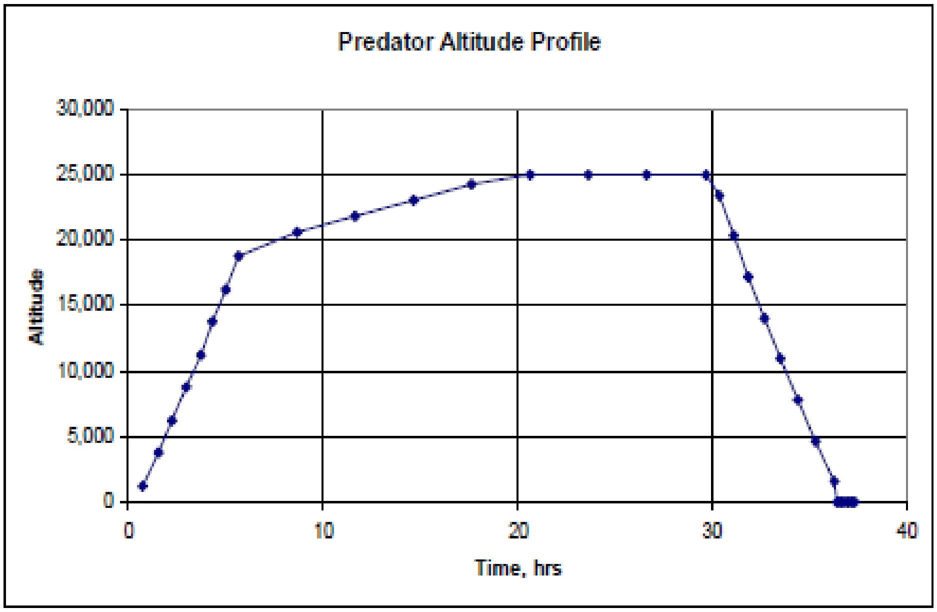

Figure 2.5: Predator Altitude Profile [6]

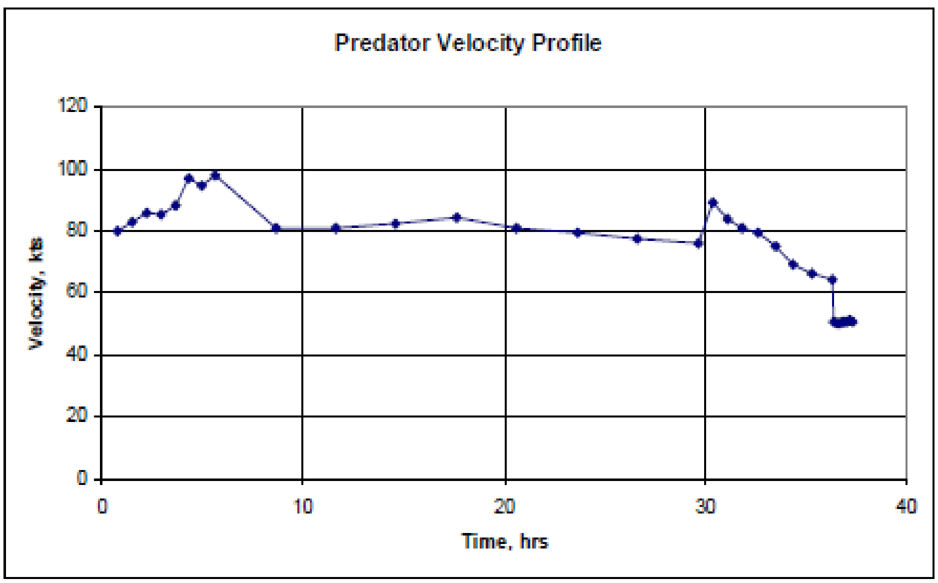

Figure 2.6: Predator Velocity Profile [6]

2.4.8 Predator's Design Technology

The weights and performance calibration process resulted design technology levels shown in Table 2.3.

Table 2.3: Predator Design Technology Level [6]

Design Item	Tech Level (0-1)
Volume Efficiency	0.5
Induced Drag	0.4
Interference Drag	1.0
Wave Drag	1.0 (No compressibility impacts)
Laminar Flow	0.4
Factor Of Safety	1.0
Weight Growth	0.75
Installation Weight	1.0

2.5 **Global Hawk** [6, 10, 11, 12]

2.5.1 Global Hawk Description

The Global Hawk is the first and only operational strategic high altitude UAV. This system began development in 1994 [6]. Global Hawk started as an Advanced Concept Technology Demonstrator (ACTD) with many goals, but the only firm requirements was a fixed Unit Fly-away Price (UFP). Many modifications have occurred to improve the system, and it has experienced operational use in wartime. Therefore, the available performance numbers represent the estimated performance of the vehicle as built, not necessarily as designed. As with nearly any aircraft program, the performance changes over time due to weight growth, system modifications, and other considerations. An attempt is made to calibrate the code against a representative Global Hawk [6].

2.5.2 Geometry Characteristics

A rendering of Global Hawk is shown in Figure 2.7 and some important geometrical, weight and other Global Hawk characteristics are shown in Tables 2.4.

Figure 2.7: Global Hawk UAV [13

Table 2.4: Global Hawk Geometry [6, 14]

Item	Value	Source
Wing span	35.42 m	Jane's [1999]
Length	13.52 m	Jane's [1999]
Height	4.60 m	Jane's [1999]
Wing area	50.2 m²	Jane's [1999]
Weight MTOW	12111 kg	Jane's [1999]
Aspect ratio	25.09	Jane's

		[1999]
Equipped empty weight	4177 kg	Jane's [1999]
Take-off weight	11622 kg	Jane's [1999]
Fuel weight	6583 kg	Jane's [1999]
Mission equipment weight	900 - 1000 kg	Jane's [1999]

Detailed geometry characteristics were found through scaling of 3-view drawings. The results were integrated into the detailed geometry input files [6].

2.5.3 Propulsion

The Global Hawk engine is the Rolls-Royce 3007H. Major engine characteristics are shown in Table 2.5.

Table 2.5: Global Hawk Propulsion [6]

Item	Value	Source
Thrust (T-O S/L)	8,290 lbs	Jane's [1999]
TSFC	0.33 lbm/lb-h	Jane's [1999]
Weight (Dry)	1,581 lbs	Jane's [1999]
Length	8.88 ft	Jane's [1999]
Diameter	3.63 ft	Jane's [1999]

In addition to the engine, an additional 50 pounds of propulsion weight was added to account for the engine control electronics and actuators, as an assumption [6].

2.5.4 Avionics

Global Hawk is known to have an extensive electronics suite. Weights for all of the components are not available. Details of some avionics components, such as INS and data recorders, are found in Global Hawk literature and vendor data sheets. The assumed avionics weights use a fragmentary Master Equipment List (MEL), developed from information generated from Altmann [2002] and Janes [1999], as guidance. Figure 2.8 shows the avionics weights determined for the calibration case.

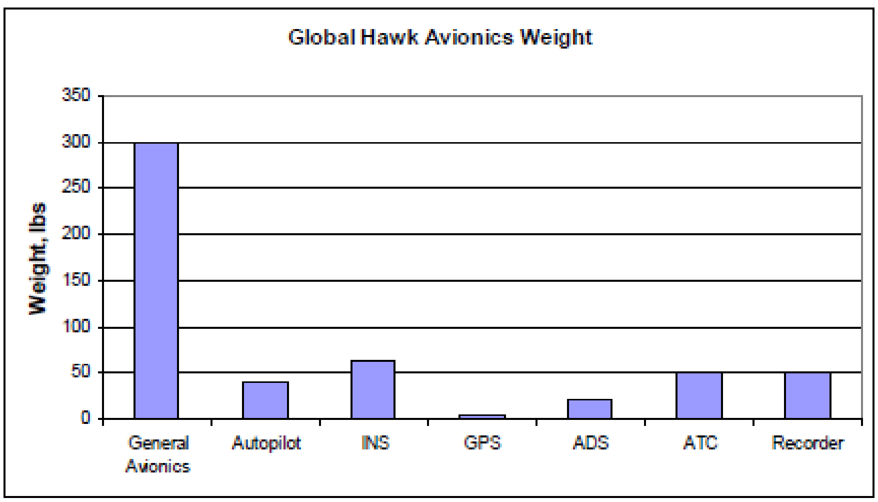

Figure 2.8: Global Hawk Avionics Weights Summary [6]

2.5.5 Subsystems

Global Hawk has a complex set of subsystems. A list of known subsystems identified by Altmann and Janes is captured in the simple MEL. Unfortunately, no weights data is available for the subsystems. Therefore, no actual weights were used, only assumed subsystem weights and parametric methods. The resulting subsystems weights are shown in Figure 2.9.

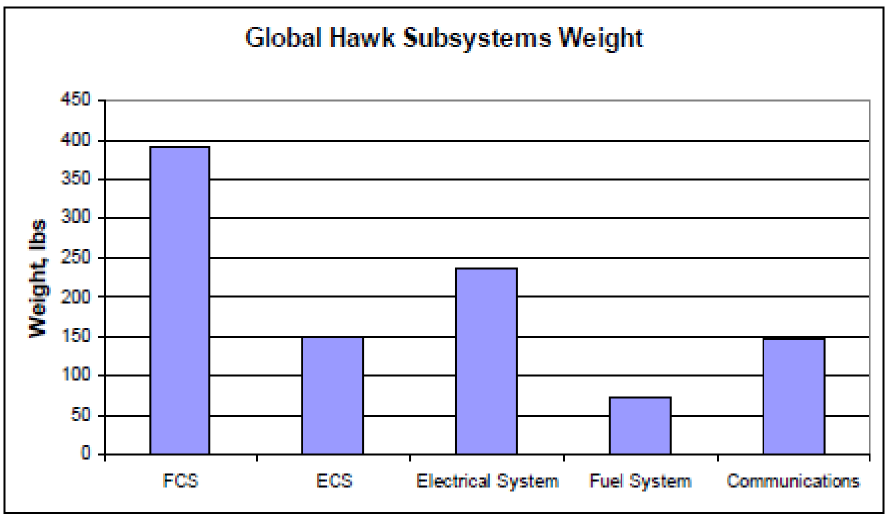

Figure 2.9: Global Hawk Subsystems Weights Summary [6]

2.5.6 Structures

The Global Hawk structure consists of the main wing, tails, fuselage, nacelle, landing gear and installation weight. No direct weights data is available for the structure. However, Altmann [2002] provides useful information to describe the structural design drivers and philosophy. The factor of safety for the structure is 1.25. Altmann provides a V-N diagram that indicates that the light weight vertical load is approximately 3.6 G, and the heavy weight vertical load is approximately 2 G. Because the wing weight is calculated at gross weight, the vertical load is assumed to be 2 G. The Global Hawk structural weight is presented in Figure 2.10.

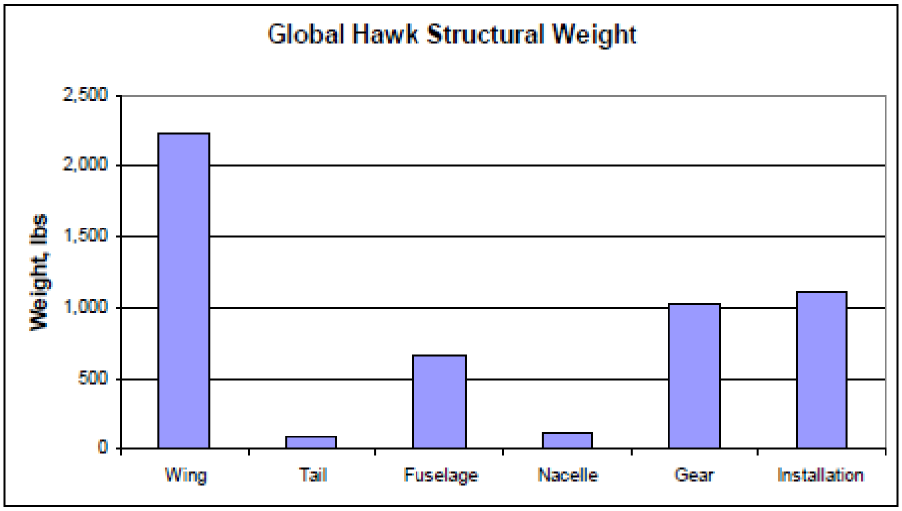

Figure 2.10: Global Hawk Structural Weight Summary [6]

2.5.7 Payloads

Global Hawk payloads consist of a Synthetic Aperture Radar (SAR), an Electro-Optical/ Infrared (EO/IR) payload, and the supporting electronics. The supporting electronics include an integrated sensor processor, a receiver/exciter/controller unit, transmitter (for SAR, presumably), and a sensor electronics unit. It is unclear if the elements of the communications architecture, INS, or structure are included in the advertised payload weight of 1,900 pounds [Jane's 1999]. The summation of the listed components comes to 797 pounds [Jane's 1999]. There is no available source that clarified this discrepancy. To satisfy the sizing mission profile, 1,900 pounds was assumed for the total payload weight, with an even weight division between SAR and EO/IR.

2.5.8 Performance

Altmann [2002] provides useful information on the Global Hawk performance and flight envelope limitations. The maximum equivalent airspeed is 175 Keas, and the maximum Mach is approximately Mach 0.7 and the characteristics are shown in Table 2.6.

Northrop Grumman advertises the Global Hawk Performance as 24 hours time on station at 1,200 nautical miles radius [Northrop 2003]. This performance estimate was adopted for sizing. Range credit was assumed to be 100 nautical miles for the initial climb to 50,000 feet, and 200 nautical miles from the end of cruise to the final loiter altitude. A half-hour loiter at 5,000 feet was assumed for airfield operations. Altitude and Mach characteristics are shown in Figure 2.11 and Figure 2.12.

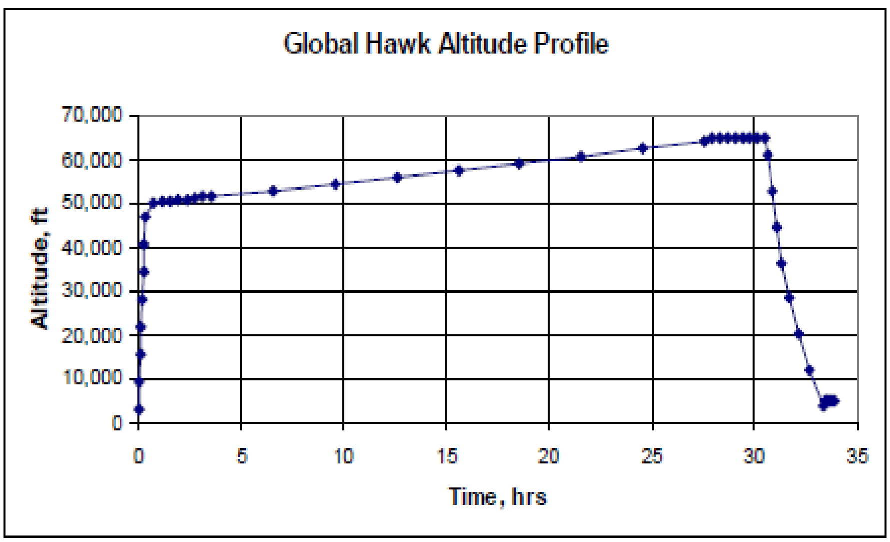

Figure 2.11: Global Hawk Altitude Profile [6]

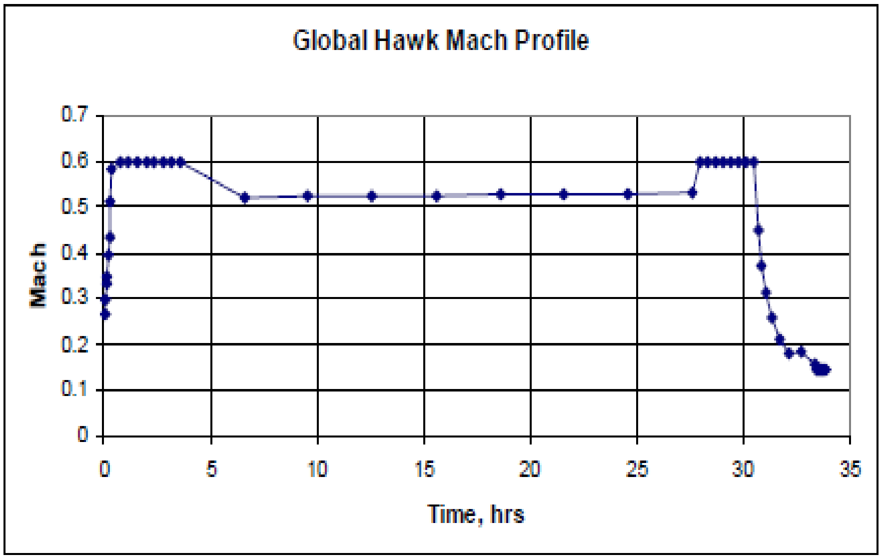

Figure 2.12: Global Hawk Mach Profile [6]

Table 2.6: Global Hawk– selected performances [6, 14]

Item	Value	Source
Stall speed	170 km/h	Jane's [1999]
Loiter speed	650 km/h	Jane's [1999]
Max speed	670 km/h	Jane's [1999]
Ceiling	19.80 km	Jane's [1999]
Rate of climb	17.3 m/s	Jane's [1999]
Endurance	38 - 42 h	Jane's [1999]
Range	17 000 km	Jane's [1999]
Runway length	1500 m	Jane's [1999]
Take-off thrust	3.13 kN	Jane's [1999]
Wing loading	231.52 kg/m²	Jane's [1999]
Thrust loading	37.1 kg/N	Jane's [1999]
Max Altitude	65 000 ft	Jane's [1999]

2.5.9 Design Technology

The weights and performance calibration process resulted design technology levels are shown in Table 2.7.

Table 2.**7**: Global Hawk Design Technology Levels [6]

Design Item	Tech Level (0-1)
Volume Efficiency	0.5
Induced Drag	0.31
Interference Drag	1.0
Wave Drag	0.31
Laminar Flow	0.31
Factor Of Safety	1.0
Weight Growth	0.35
Installation Weight	0.5

2.6 Shadow 200 [6, 15, 16, 17]

2.6.1 Shadow 200 Description

Shadow 200 is a small tactical UAV designed to support line-of-sight battlefield surveillance missions. Initial development began in 1990. However, the technology year was assumed to be 2000 due to the extended development time, significant design evolution, requirements changes, and incorporation of more advanced technologies. Palumbo [2000] is assumed to be the most authoritative source of Shadow 200 data.

Palumbo describes an evolutionary design history beginning in 1990 that has not ended. For example, the wing configuration is driven by a constraint to re-use Pioneer program wing tooling [6].

2.6.2 Geometry Characteristics

The Shadow 200 geometry characteristics are shown graphically in Figure 2.13, and numerically in Table 2.8.

Figure 2.13: Shadow 200 UAV [18]

Table 2.8: Shadow 200 Geometry Characteristics [6, 15]

Item	Value	Source
Wing span	12.75 ft	Office of the Secretary of Defence, Unmanned Aircraft Systems Roadmap 2005-2030.
Weight	165 lbs. empty; 328 lbs. loaded	
Length	11.2 ft	
Height	3.0 ft	
Aspect ratio	7.07	
Fuel Capacity	51 lb	
Sweep (quarter chord)	0 º	
Payload Capacity	60 lb	
Ceiling	14,000 ft	

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