THE PATH PERFORMANCE ANALYSIS OF MISSILE

ALI KHALIFA ALI ELRATAIMI

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University Tun Hussein Onn Malaysia

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ABSTRACT

This thesis presents the flight trajectory analysis for the Missile. It has been known that the missile performance during its flight governed by the flight equation of motions. The present work has presented the flight dynamics analysis for AGM-65 Maverick missiles model. Through this work it can be conclude, in manner how to solve the governing equations are simpler compared to the effort for providing the aerodynamics data or the mass and inertia of the missile. This work presents trajectory of air -to-surface missile attacking a fixed target constraint. The missile must hit the target from above, subject to the missile dynamics and path constraints. The problem is reinterpreted using optimal control theory resulting in the formulation of minimum integrated altitude. The formulation entails nonlinear, three-dimensional missile flight dynamics, boundary conditions and path constraints. The generic shape of optimal trajectory is know how will be the change of the range, altitude and Y-axis deflection with time. The numerical solution of path equations is solved by computer code that can compute the position of missile at any time.

ABSTRAK

Tesis ini membentangkan analisis trajektori penerbangan untuk Peluru Berpandu . Ia telah diketahui bahawa prestasi peluru berpandu semasa penerbangan dikuasai oleh persamaan penerbangan dari usul. Kajian yang telah membentangkan analisis dinamik penerbangan untuk AGM- 65 Maverick peluru berpandu model. Melalui kerja ini ia boleh membuat kesimpulan , dengan cara bagaimana untuk menyelesaikan persamaan yang mengawal adalah lebih mudah berbanding dengan usaha untuk menyediakan data aerodinamik atau jisim dengan inersia peluru berpandu. Kerja ini membentangkan trajektori udara-ke- permukaan peluru berpandu menyerang kekangan sasaran tetap. Peluru berpandu mesti memukul sasaran dari atas , tertakluk kepada dinamik peluru berpandu dan kekangan jalan . Masalah ini ditafsir semula dengan menggunakan teori kawalan optimum menyebabkan penggubalan ketinggian bersepadu minimum. Penggubalan melibatkan tak linear, tiga dimensi dinamik penerbangan peluru berpandu , keadaan sempadan dan kekangan jalan . Bentuk generik trajektori optimum adalah tahu bagaimana akan perubahan lingkungan , ketinggian dan Y- paksi pesongan dengan masa. Penyelesaian berangka persamaan jalan diselesaikan oleh kod komputer yang boleh mengira kedudukan peluru berpandu pada sebarang masa.

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LIST OF SYMBOLS AND ABBREVIATIONS

AG	Acceleration of gravity
ALPH	Angle of attack, $\boldsymbol{\alpha}$
AMASS	Vehicle mass, m
A_T	Thrust direction cosines relative to X
ALT	Altitude
B_T	Thrust direction cosines relative to Y
BW	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 to angle of attack
CMAD	Coefficient of pitching moment due to angle-of-attack rate
C_{mac}	Wing mean aerodynamic chord
CMQ	Coefficient of pitching moment due to 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
Cn	Yaw coefficient
C_T	Thrust direction cosines relative to Z

C_y	Side force coefficient
F	Force
GAM	Flight-path angle
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
SW	Wing or reference area
THR	Thrust
$\dot{U}$	Longitudinal acceleration
U	Velocity along X-body axis
V	Velocity along Y-body axis
VEL	Velocity minus starting
W	Velocity along Z-body axis
WS	Wing area
$\dot{W}$	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

This thesis presents the flight trajectory analysis missile. It has been known that the missile performance during its flight governed by the flight equation of motions. This flight equation of motion consist of 12 first order differential equations which coupling to each other. Those 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. Through solving those 12 equations one can obtain the trajectory of the missile and also possible to define its trim condition for a given flight speed and flight altitude. For this purposes, the analysis missile model, it is namely cruise missile model. The data required for analysis missile performance is involved the aerodynamics data, mass and inertia of the aircraft and also thrust provided by their propulsion system are available. It is therefore time history of their position, aptitude, linear velocity and as well as their angular velocity can be identified. However it had been realized the comparison with actual flight can be done, since such data are not available. [1]

1.2 Back ground

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 vehicle position, aptitude 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 vehicle 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 vehicle designed to be autonomous as result various type of UAV had been developed to fulfill different purposes. [2]

1.3 Problem statements

As unmanned flying vehicle, it is means that the missile has capability to control its flight path over any kind of disturbance may appear during its flight. Flight control system represents computer software which required the aerodynamics data for that missile in order to allow developing flight mechanism for controlling the missile. 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 missile's mass and inertia properties to obtain its trajectory and velocity at any instant time.

1.4 Thesis objective

The flight dynamics equations a consist of a complete system equation which can describe the performance of the missile at different flight condition, so the aim of this thesis is to solving the governing equations of flight motion, to get state space variables. The purpose of this thesis is through developing computer code allowing one to estimate the flight performance of the missile.

1.5 Scope of study

Refer to the objectives of this thesis, the scope of study will be conducted in the present work involves:

i. Coordinate system applied to the missile namely the earth coordinate system, missile body axis coordinate system and the missile stability coordinate system.

ii. Closed loops model in deriving control system for bank angle, angles of attack and sideslip on the missile models.

iii. Development computer code for solving the governing equation of flight motion with imposing the flight control in managing the aerodynamics forces and moments work on the missile.

CHAPTER 2

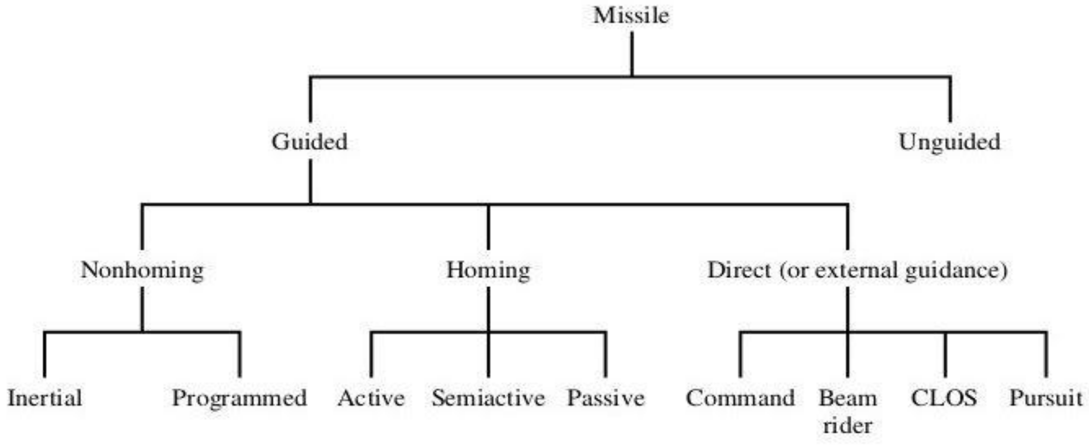
LITERATUR REVIEW

2.1 Mission profile and overview

A MISSILE is any object that can be projected or thrown at a target. This definition includes stones and arrows as well as gun projectiles, bombs, torpedoes, and rockets. But in current military usage, the word MISSILE is gradually becoming synonymous with GUIDED MISSILE. It will be so used in this text; we will use the terms MISSILE and GUIDED MISSILE interchangeably. So a MISSILE is an unmanned vehicle that travels above the earth's surface; it carries an explosive war head or other useful payload; and it contains within itself some means for controlling its own trajectory or flight path. A glide bomb is propelled only by gravity. But it contains a device for controlling its flight path, and is therefore a guided missile. For any aircraft designed without pilot on board called as unmanned aerial vehicle (UAV). The flight control system is a key element that allows the missile to meet its system performance requirements. The objective of the flight control system is to force the missile to achieve the steering commands developed by the guidance system. The types of steering commands vary depending on the phase of flight and the type of interceptor. For example, in the boost phase the flight control system may be designed to force the missile to track a desired flight-path angle or attitude. In the midcourse and terminal phases the system may be designed to track acceleration commands to effect an intercept of the target. This article explores several aspects of the missile flight control system, including its role in the overall missile system, its subsystems, types of flight control systems, design objectives, and design challenges. Also discussed are some of APL's contributions to the field, which have come primarily through our role as Technical Direction Agent on a variety of Navy missile programs.[3]

2.2 Types of missiles.

Guided missiles are classified in a number of different ways; perhaps most often by function, such as air-to-air, surface-to-air, or air-to-surface. A nonballistic missile is propelled during all or the major part of its flight time; the propulsion system of a ballistic missile operates for a relatively short time at the beginning of flight; thereafter, the missile follows a free ballistic trajectory like a bullet (except that this trajectory may be subject to correction, if necessary, by the guidance system). Some missiles are designed to travel beyond the earth's atmosphere, and re-enter as they near the target. Others depend on the presence of air for proper operation of the control surfaces, the propulsion system, or both.



Missile types and classification.

Figure 2.1: Missiles types[4]

Missiles may be further classified by type of propulsion system, such as turbo-jet, ramjet, or rocket; or by type of guidance, such as command, beam-riding, or homing.[4]

Missiles are generally classified on the basis of their type, launch, range, propulsion, warhead and guidance systems.[5]

a. Type **:**
    i. Cruise Missile.
    ii. Ballistic Missile.
b. Launch Mode:
    i. Surface-to-Surface Missile.
    ii. Surface-to-Air Missile.
    iii. Surface (coast)-to-Sea Missile.
    iv. Air-Air Missile.
    v. Air-to-Surface Missile.
    vi. Sea-to-Sea Missile.
    vii. Sea-to-Surface Missile.
    viii. Anti-Tank Missile.
c. Range.
    i. Short range missile
    ii. Medium range missile.
d. Propulsion.
    i. Solid Propulsion.
    ii. Liquid Propulsion.
    iii. Hybrid Propulsion.
    iv. Ramjet.
    v. Scramjet.
    vi. Cryogenic.
e. Warhead.
    i. Conventional.
    ii. Strategic.
f. Guidance System.

i. Wire Guidance.
ii. Command Guidance.
iii. Terrain Comparison Guidance.
iv. Inertial Guidance.
v. Beam rider Guidance.
vi. Laser Guidance.
vii. RF and GPS reference.

2.3 Coordinate Systems.

There are three commonly used methods of expressing the orientation of one three axis coordinate system with respect to another. The three methods are (1) Euler angles, (2), direction cosines and (3) quaternions. The Euler angle method, which is the conventional designation relating a moving-axis system to a fixed-axis system, is used frequently in missile and aircraft mechanizations and/or simulations. The common designations of the Euler angles are roll (φ), pitch (θ), and yaw (ψ). Its strengths lie in a relatively simple mechanization in digital computer simulation of vehicle (i.e., missile or aircraft) dynamics. Another beneficial aspect of this technique is that the Euler angle rates and the Euler angles have an easily interpreted physical significance. The negative attribute to the Euler angle coordinate transformation method is the mathematical singularity that exists when the pitch angle θ approaches 90◦. The direction cosine method yields the direction cosine matrix (*DCM*), which defines the transformation between a fixed frame, say frame *a*, and a rotating frame, say frame *b*,such as the vehicle body axes.[6]

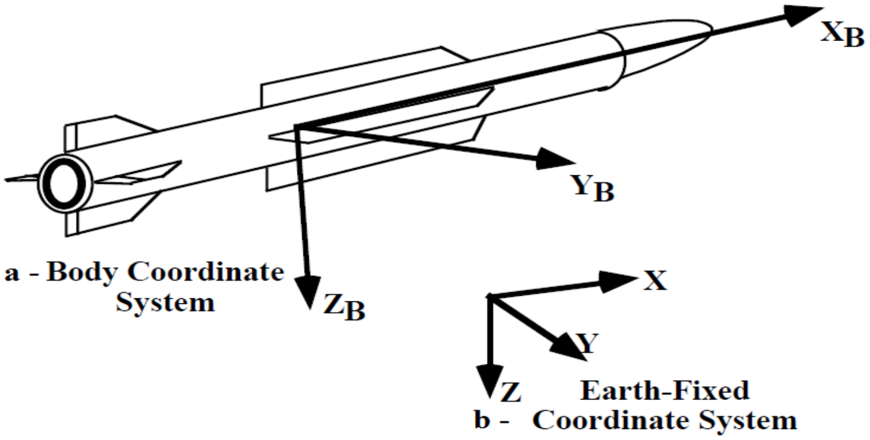


Figure 2.2 Coordinate Systems[6]

2.4 Forces acting on a missile in flight.

Gravity, friction, air resistance, and other factors produce forces that act on all parts of a missile moving through the air. One such force is that which the missile exerts on the air as it moves through it. In opposition to this is the force that the air delivers to the missile. The force of gravity constantly attracts the missile toward the earth, and the missile must exert a corresponding upward force to remain in flight.

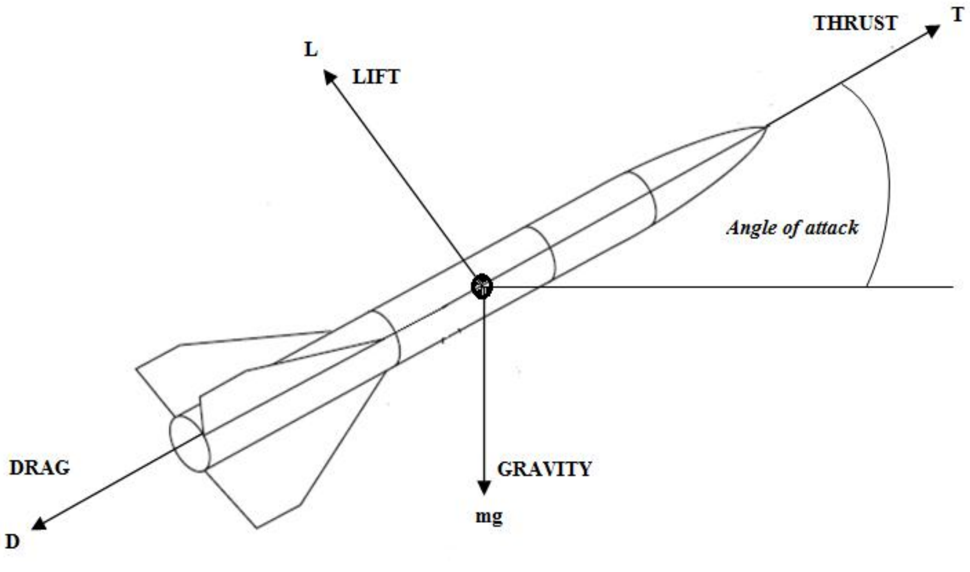


Figure 2.3: forces on a missile[6]

2.4.1 Lift and drag.

Represents a flat surface moving through an airstream. In accordance with the principle of relativity, the forces acting on the surface are the same, regardless of whether we think of the surface as moving to the left, or of the airstream as moving to the right. One of the forces acting on the surface is that produced by friction with the air. This force acts in a direction parallel to the surface, as indicated by the small white arrow at the lower right. As the air strikes the surface, it will be deflected downward. Because the air has mass, this change in its motion will result in a force applied to the surface. This force acts at a right angle to the surface, as indicated by the long black arrow. The resultant of the frictional and deflection forces, indicating the net effect of the two, is represented by the long white arrow. We can resolve this resultant force into its horizontal and vertical components. The horizontal component, operating in a direction opposite to the motion of the surface, is drag. The vertical force, operating upward, is lift. The angle that the moving surface makes with the air stream is the angle of attack. This angle affects both the frictional and the deflection force, and therefore affects both lift and drag.

Bernoulli's theorem states that the total energy in any system remains constant. Air flowing past the fuselage or over the wing of a guided missile forms a system to which this theorem can be applied. The energy in a given air mass is the product of its pressure and its velocity. If the energy is to remain constant, it follows that a decrease in velocity will produce an increase in pressure, and that an increase in velocity will produce a decrease in pressure.

Represents the flow of air over a wing section. Note that the air that passes over the wing must travel a greater distance than air passing under it. Since the two parts of the airstream reach the trailing edge of the wing at the same time, the air that flows over the wing must move faster than the air that flows under. In accordance with Bernoulli's theorem, this results in a lower pressure on the top than on the bottom of the wing. This pressure differential tends to force the wing upward. and gives it lift.

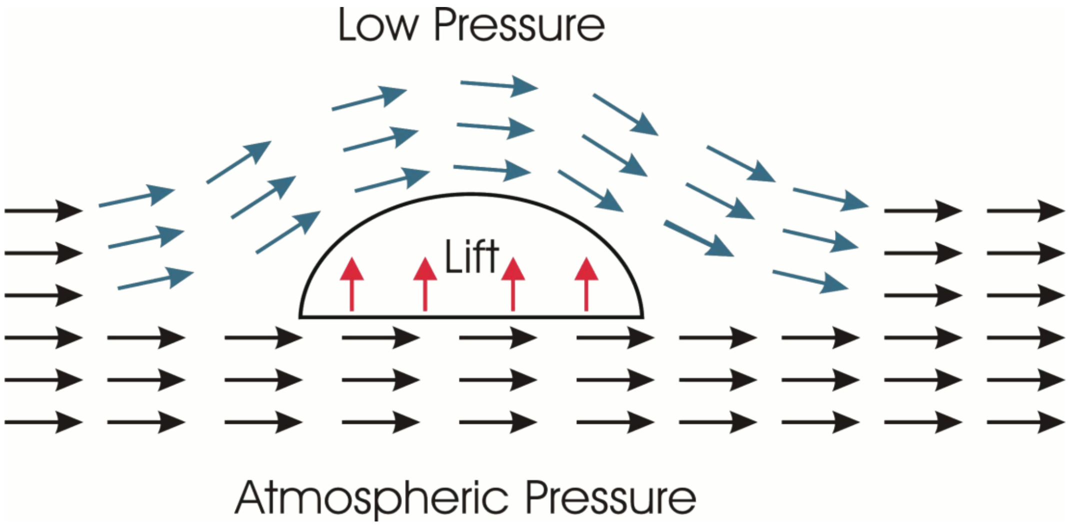


Figure 2.4: Airflow over a Wing[7]

2.4.2 Aerodynamic Forces.

A discussion of the problems of aerodynamic forces involves the use of several flight terms that require explanation. The following definitions are intended to be as simple and basic as possible. They are not necessarily the definitions an aeronautical engineer would use. [7].

AIRFOIL. An airfoil is any structure around which air flows in a manner that is useful in controlling flight. The airfoils of a guided missile are its wings or fins, its tail surfaces, and its fuselage.

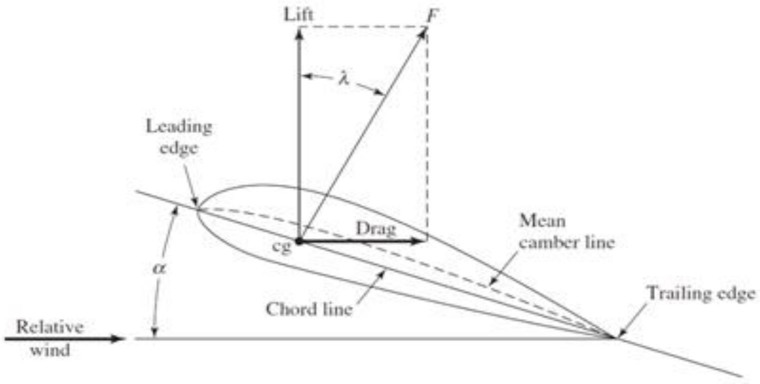


Figure 2.5 Aerodynamic Forces on the airfoil[7]

DRAG is the resistance of an object to the flow of air around it. It is due in part to the boundary layer, and in part to the piling up of air in front of the object. One of the problems of missile design is to reduce drag while maintaining the required lift and stability.

STREAMLINES are lines representing the path of air particles as they flow past an object, as shown in figure 2.5.

WING SPAN is the measured distance from the tip of one wing to the tip of the other.

ATTITUDE. This term refers to the orientation of a missile with respect to a selected reference.

STABILITY. A stable body is one that returns to its initial position after it has been disturbed by some outside force. If outside forces disturb a stable missile from its normal flight attitude, the missile tends to return to its original attitude when the outside forces are removed. If a body, when disturbed from its original position,

2.5 Factors controlled.

Missile course stability is made possible by devices which control the movement of the missile about its three axes. The three flight control axes are shown in figure 2.6. These are the pitch, yaw and roll axes. PITCH. In certain missiles, pitch control is obtained by the use of elevators similar to those used on light airplanes. Other methods will be described in the next section of this chapter. For the present, it is sufficient to say that pitch control means control of the up-and-down movements of the missile, as shown in the illustration. YAW. Missile movement about the yaw axis is controlled by the rudder. Other methods for controlling yaw will be covered in the following section of this chapter. ROLL. Roll deviations are controlled by differential movements of rudders, elevons, or other flight control surfaces.[4]

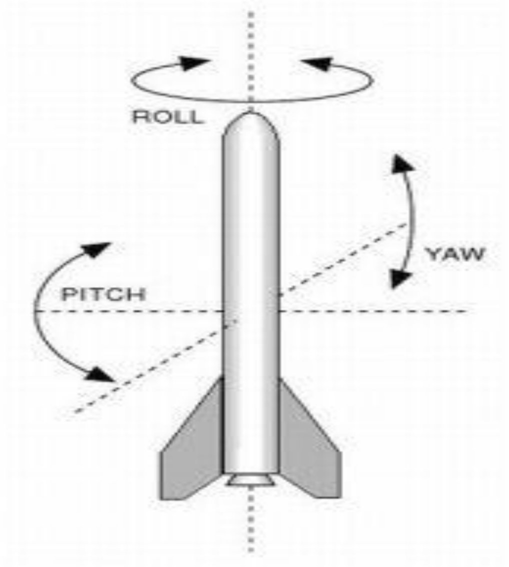


Figure 2.6: Three control axes of a missile[4]

2.6 Missile Control Systems.

The heart of a missile is the body, equivalent to the fuselage of an aircraft. The missile body contains the guidance and control system, warhead, and propulsion system. Some missiles may consist of only the body alone, but most have additional surfaces to generate lift and provide manoeuvrability. Depending on what source you look at, these surfaces can go by many names. In particular, many use the generic term "fin" to refer to any aerodynamic surface on a missile. Missile designers, however, are more precise in their naming methodology and generally consider these surfaces to fall into three major categories: canards, wings, and tail fins.[8]

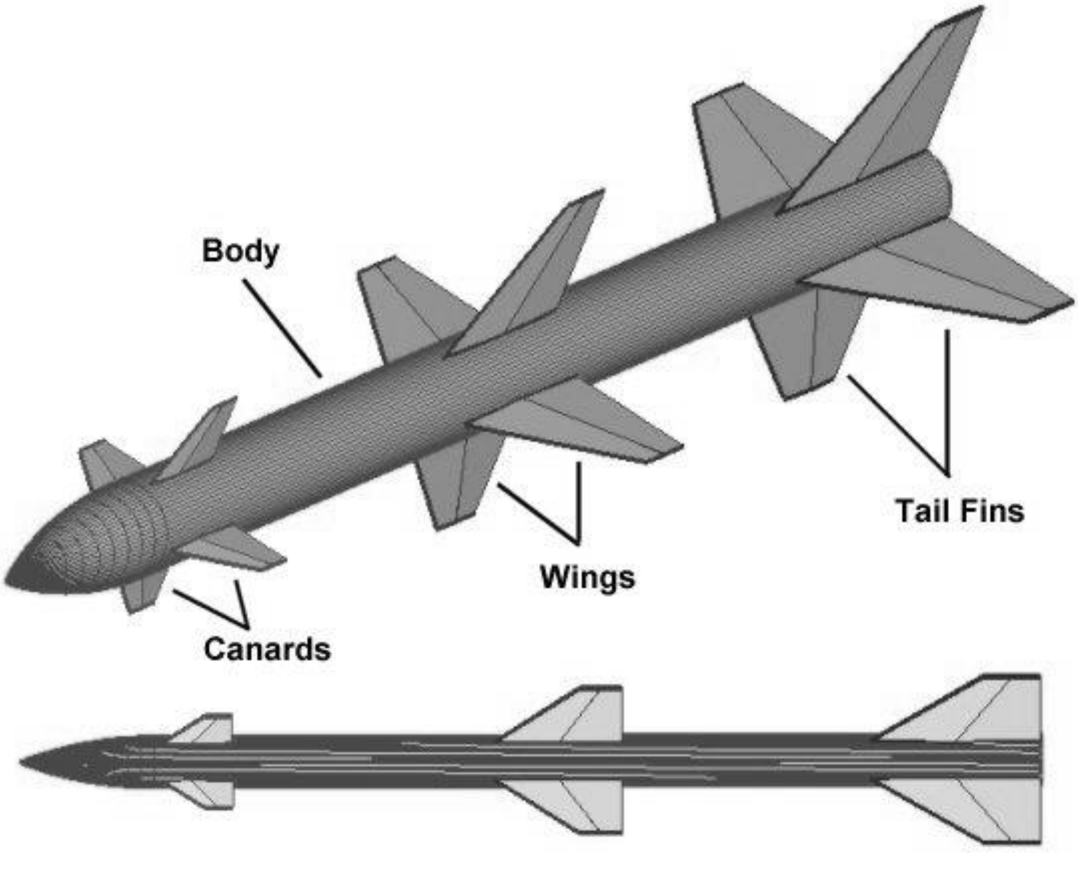


Figure 2.7 **:** Major components of a missile[8]

The example shown in figure 2.6 illustrates a generic missile configuration equipped with all three surfaces. Often times, the terms canard, wing, and fin are used interchangeably, which can get rather confusing. These surfaces behave in fundamentally different ways, however, based upon where they are located with respect to the missile. In general, a wing is a relatively large surface that is located near the center of gravity while a canard is a surface near the missile nose and a tail fin is a surface near the aft end of the missile. Most missiles are equipped with at least one set of aerodynamic surfaces, especially tail fins since these surfaces provide stability in flight. The majority of missiles are also equipped with a second set of surfaces to provide additional lift or improved control. Very few designs are equipped with all three sets of surfaces. We have discussed how aircraft use control surfaces to turn the plane in different directions in a number of previous questions. In order to turn the missile during flight, at least one set of aerodynamic surfaces is designed to rotate about a center pivot point. In so doing, the angle of attack of the fin is changed so that the lift force acting on it changes. The changes in the direction and magnitude of the forces acting on the missile cause it to move in a different direction and allow the vehicle to maneuver along its path and guide itself towards its intended target.

Canards, wings, and tails are often lumped together and referred to as aerodynamic controls. A more recent development in missile maneuvering systems is called unconventional control. Most unconventional control systems involve some form of thrust vector control (TVC) or jet interaction (JI). We have now introduced four major categories of missile flight control systems--tail control, canard control, wing control, and unconventional control--so let's briefly take a closer look at each type .

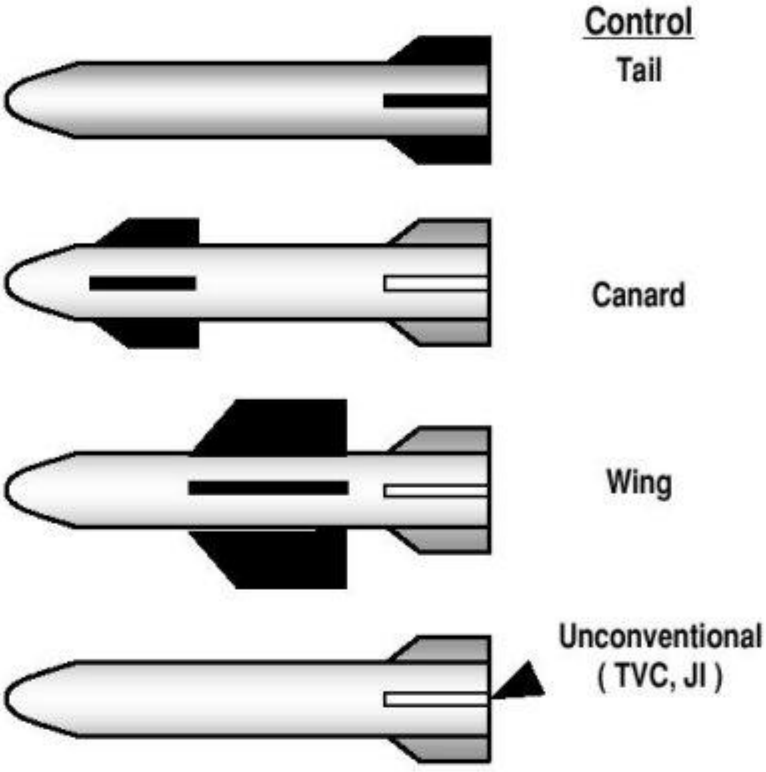


Figure 2.8 : Four main categories of missile flight control[8]

2.6.1 Tail Control.

Tail control is probably the most commonly used form of missile control, particularly for longer range air-to-air missiles like AMRAAM and surface-to-air missiles like Patriot and Roland. The primary reason for this application is because tail control provides excellent maneuverability at the high angles of attack often needed to intercept a highly maneuverable aircraft. Missiles using tail control are also often fitted with a non-movable wing to provide additional lift and improve range. Some good examples of such missiles are air-to-ground weapons like Maverick and AS.30 as well as surface-to-surface missiles like Harpoon and Exocet. Tail control missiles rarely have canards, although one such example is AIM-9X Sidewinder. A selection of 23 representative missiles using tail control is pictured below

Figure 2.9: Missiles with tail control[10]

In addition to missiles, some bombs also use tail control. An example is the JDAM series of GPS-guided bombs [10], [8].

2.6.2 Canard Control.

Canard control is also quite commonly used, especially on short-range air-to-air missiles like AIM-9M Sidewinder. The primary advantage of canard control is better maneuverability at low angles of attack, but canards tend to become ineffective at high angles of attack because of flow separation that causes the surfaces to stall. Since canards are ahead of the center of gravity, they cause a destabilizing effect and require large fixed tails to keep the missile stable. These two sets of fins usually provide sufficient lift to make wings unnecessary. Shown below are twelve examples of canard control missiles.[10].

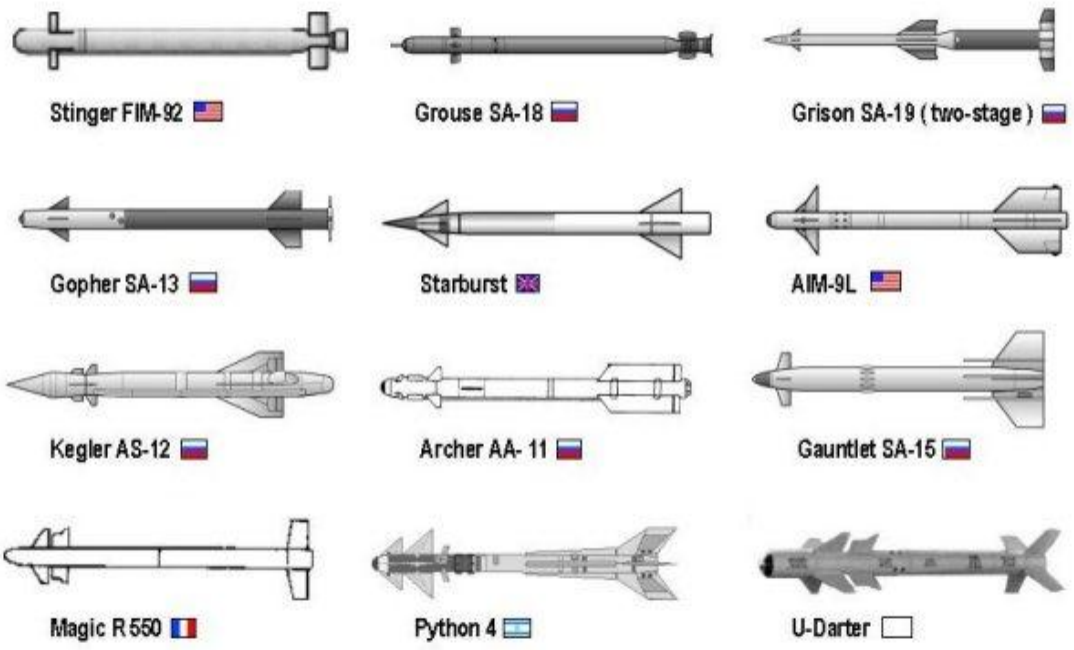


Figure 2.10: Missiles with canard control[10]

A further subset of canard control missiles is the split canard. Split canards are a relatively new development that has found application on the latest generation of short-range air-to-air missiles like Python 4 and the Russian AA-11. The term split canard refers to the fact that the missile has two sets of canards in close proximity, usually one immediately behind the other. The first canard is fixed while the second set is movable. The advantage of this arrangement is that the first set of canards generates strong, energetic vortices that increase the speed of the airflow over the second set of canards making them more effective. In addition, the vortices delay flow separation and allow the canards to reach higher angles of attack before stalling. This high angle of attack performance gives the missile much greater maneuverability compared to a missile with single canard control. Six examples of split canard missiles are shown below.

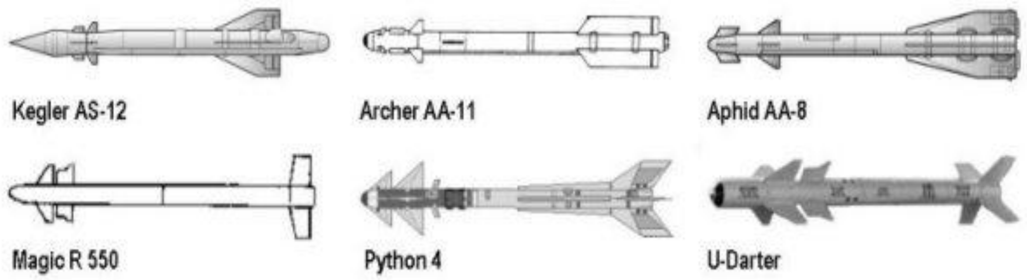


Figure 2.11 : Missiles with split canard control[10]

Many smart bombs also use canard control systems. Most notable of these are laser guided bombs such as the Paveway series.

2.6.3 Wing Control.

Wing control was one of the earliest forms of missile control developed, but it is becoming less commonly used on today's designs. Most missiles using wing control are longer-range missiles like Sparrow, Sea Skua, and HARM. The primary advantage of wing control is that the deflections of the wings produce a very fast response with little motion of the body. This feature results in small seeker tracking error and allows the missile to remain locked on target even during large maneuvers. The major disadvantage is that the wings must usually be quite large in order to generate both sufficient lift and control effectiveness, which makes the missiles rather large overall. In addition, the wings generate strong vortices that may adversely interact with the tails causing the missile to roll. This behavior is known as induced roll, and if the effect is strong enough, the control system may not be able to compensate. A few examples of wing control missiles are shown below.

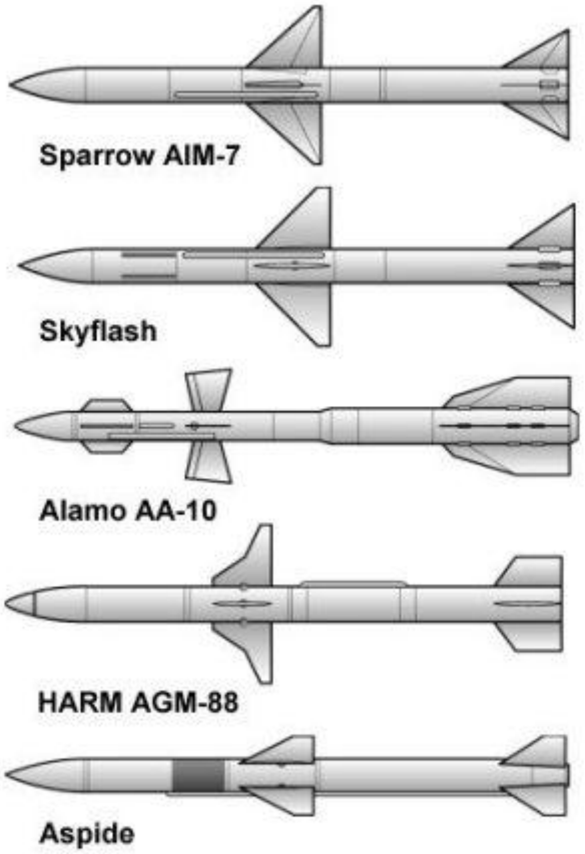


Figure 2.12: Missiles with wing control[10]

2.6.4 Unconventional Control.

Unconventional control systems is a broad category that includes a number of advanced technologies. Most techniques involve some kind of thrust vectoring. Thrust vectoring is defined as a method of deflecting the missile exhaust to generate a component of thrust in a vertical and/or horizontal direction. This additional force points the nose in a new direction causing the missile to turn. Another technique that is just starting to be introduced is called reaction jets. Reaction jets are usually small ports in the surface of a missile that create a jet exhaust perpendicular to the vehicle surface and produce an effect similar to thrust vectoring.

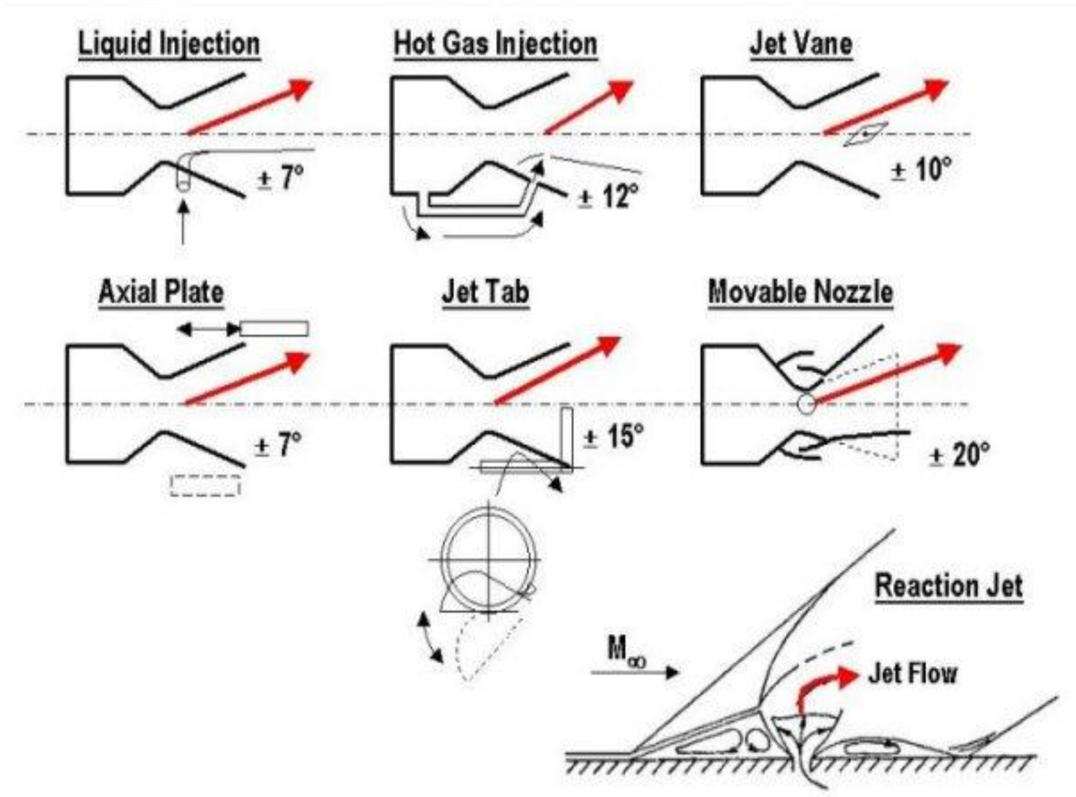


Figure 2.13: Unconventional control technologies[10]

These techniques are most often applied to high off-boresight air-to-air missiles like AIM-9X Sidewinder and IRIS-T to provide exceptional maneuverability. The greatest advantage of such controls is that they can function at very low speeds or in a vacuum where there is little or no airflow to act on conventional fins. The primary drawback, however, is that they will not function once the fuel supply is exhausted.

2.7 Cruise Missile.

A cruise missile is a missile that is guided by a navigation system and is able to sustain flight through aerodynamic lift for most of its path in air. Its main purpose is to place ordnance on a targeted spot. There are different types of cruise missiles, and each differs from its mass to its speed. The different types of cruise missiles include ground-launched, sea-launched, and air-launched cruise missiles. Some have relatively short ranges while some were made to travel long distances and have long ranges. The ranges of cruise missiles vary from 105 km to 3,000 km. The similarity between the missiles is that they fly low and have low radar. This ability allows them to evade detection in defense systems. The average radar cross-section in a cruise missile is 1 square meter.[9]

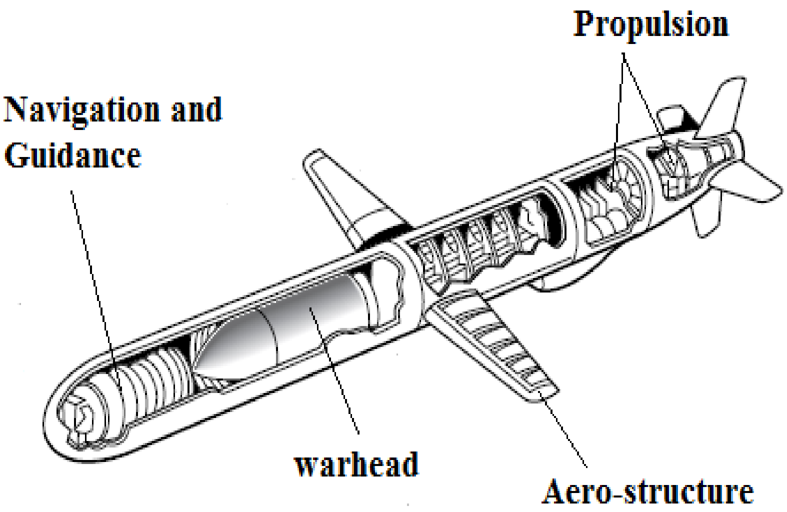


Figure 2.14: Main Cruise Missile Architecture[9]

2.7.1 some examples of cruise missiles.

Cruise missiles exist in three versions: (1) land-based or ground-launched cruise missiles (*GLCM*), (2) sea-based or sea-launched cruise missiles (*SLCM*), and (3) air-launched cruise missiles (*ALCM*). Unlike a ballistic missile, which is powered and hence usually guided for only a brief initial part of its flight, after which it follows a free-fall trajectory governed only by the local gravitational field, a cruise missile requires continuous guidance, since both the velocity and the direction of its flight can be unpredictably altered, for example, by local weather conditions.[4]

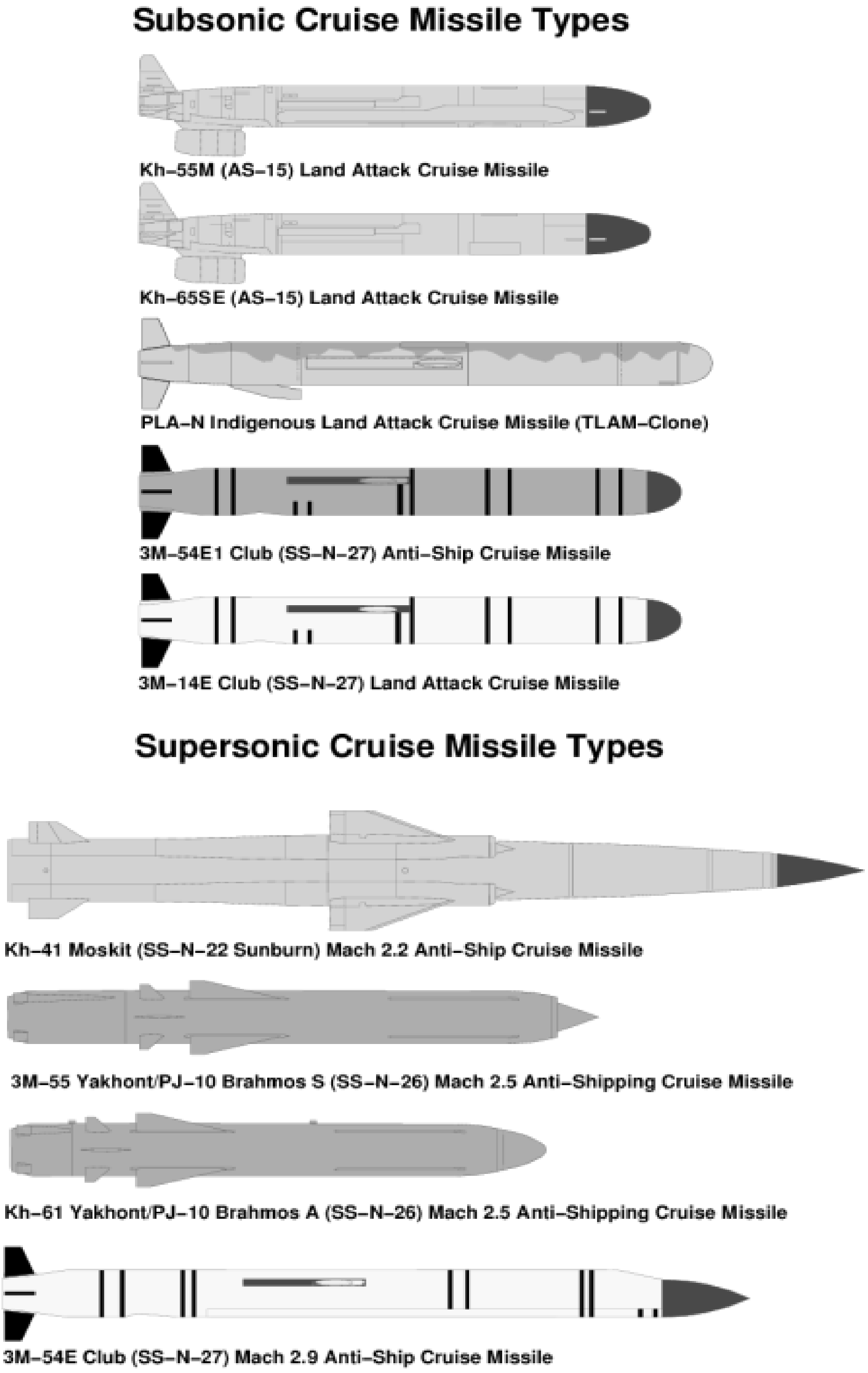


Figure 2.15 : Tepys of cruise Missile[4]

2.7.1.1 3M – 14 TE1 cruise missile.

The 3M – 14 TE1 cruise missile geometry characteristics are shown graphically in Figure 2.15, and its specifications in Table 2.1.

Figure 2.16 : 3M – 14 TE1 cruise missile[11]

Table 2.1: 3M – 14 TE1 missile specifications[11]

Missiles	3M-14TE1(CLUB-N)
Length ,m	6.2
Diameter , m	0.514
Weight , kg	1505
Operational range ,km	Up to 300
Cruise stage flight level , m	20- over the sea 50 – 150- over the land
Target approach flight level ,m	50 - 150
Cruise stage flight speed , mps	180 - 240
Warhead weight , kg	450

2.7.1.2 3M – 54 TE cruise missile

The 3M – 54 TE1 cruise missile geometry characteristics are shown graphically in Figure 2.16, and its specifications in Table 2.2

Figure 2.17 : 3M – 54 TE cruise missile[11]

Table 2.2: 3M – 54 TE missile specifications [11]

Missiles	3M – 54 TE (CLUB-N)
Length ,m	8.22
Weight , kg	1951
Operational range ,km	220
Combat stage cruising range, km	Up to 20
Cruise component flight level, m	20
Warhead weight , kg	200
Target approach flight level ,m	About 5
Cruise component flight speed,mps	180 -240
Maximum combat stage flight speed, mps	Up to 1000

REFERENCES

.

1- R.H._Barnard, D.R. Philpott,_A.C. “Mechanics of Flight” 11th edition

2- John_H._Blakelocka ”Automatic_Control_of_Aircraft” Second Edition .

3- Zak Sarris “Survey of Uav Applications in Civil Markets (june 2001) “, STN ATLAS-3 Sigma AE and Technical University of Crete, Crete, Greece, 2001

4- George_M._Siouris_”Missile_Guidance_and_Control”

5- http://www.brahmos.com/index.php

6- P. K. Menno* and E. J. Ohlmeyer “Integrated Design of Agile Missile Guidance and Control Systems” (science direct) 1999

7- Alex Sullivan “Aerodynamic forces acting on an airfoil” Physics Department; The College of Wooster; Wooster; Ohio; 44691; USA May 6, 2010.

8- http://www.aerospaceweb.org/question/weapons/q0158.shtml

9- “Report to Congressional Committees “ USA April 1995

10- ScottMurman Michael J. Aftosmis “ Cartesian-Grid Simulations of Canard-Controlled Missile with a Spinning Tail” 2003

11- http://trishulgroup.blogspot.com/2009/05/club-family-of-multi-role-cruise.html

12- Liu Yi, Chen Hai-bo” Simulation of Cruise Missile Based on Inertial Navigation Error Model” 2013.

13- Sun-Mee Ryu “Missile Autopilot Design for Agile Turn Control During Boost-phase” Technical Paper 2011.

14- John Douglas, Richard L. Burden “Numerical Analysis” 9th edition.

15- FEDEREATION OF AMERICAN SEICNTISTS JOURNAL.

16- McCormick, Barnes Warnock, “Aerodynamics, Aeronautics, and Fligh Mechanics”, New York: Wiley, (USA) 1979.

17- Roskam, J “Airplane Flight Dynamics and Automatic Flight Controls, Part 1” DARcorporation, 1995.
18- Bandu N. Pamadi, “Performance, Stability, Dynamics and Control of Airplanes”, AIAA 2nd Edition Series, 2004.
19- M. V. Cook “Flight Dynamics Principles” Butterworth-Heinemann, 2007.
20- Roskam, J and Edward L, Chuan-Tau, Airplane Aerodynamics and Performance, Design, Analysis and Research Corporation.
21- MALCOLM J. ABZUG “Computational Flight Dynamics” AIAA Education Series 1998.
22- “Method For 'Predicting The Static Aerodynamic Characteristics Of Typical Missile” Naval Ship Research And Development Center.
23- Weng wai leong “Trade-off study of missile in the boost phase” 2009