Chapter 5

GUIDED MISSILES

Keywords. Guided missiles, Classification of guided missiles, Subsystems of guided missiles

5.1 INTRODUCTION

Guided missiles have been in the forefront of modern warfare since the second world war. Thanks to the media blitz accompanying the Gulf war they have almost become household words nowadays. Though it is true that guided missiles are mainly used for destructive purposes, one cannot disregard the fact that they are one of the most outstanding examples of the application of scientific techniques to design, control and guide remote vehicles without direct human intervention.

The objective of this chapter would be to understand the major components and the operational principles of guided missiles. We will also define some standard terminology used in the guided missile literature.

A simple definition of a guided missile would be the following:
A guided missile is a space-traversing unmanned vehicle which carries within itself the means for controlling its flight path.

Another definition, based on its operation, could be:

A guided missile is one which is usually fired in a direction approximately towards the target and subsequently receives steering commands from the guidance system to improve its accuracy.

5.2 CLASSIFICATION OF GUIDED MISSILES

A number of different classifications of guided missiles are possible. However, the most usual is the one in which the position of launch and the position of the target are used for classification. This is most widely used as these positions more or less designate the general requirements or specialities of the missiles used. The four general categories of missiles are:

- A Surface-to-Surface Missiles (SSM)
- A Surface-to-Air Missiles (SAM)
- A Air-to-Air Missiles (AAM)
- A Air-to-Surface Missiles (ASM)

Surface-to-Surface Missiles

These missiles are launched from some point on the surface of the earth to another point on the surface of the earth. They could also be launched
from a ship. These missiles are usually employed against large and stationary targets. The range of the missile and the type of warhead it uses depends on the kind of targets. The target could be a small factory or a big city. The range could be as low as a few kilometers to as high as thousands of kilometers. Though the terminal accuracy required of the missile guidance system is usually not much, the accuracy required for targets at long range must be high compared to those required for short ranges. However, many recently designed surface-to-surface missiles demand very high terminal accuracy. The accuracy of such missiles depends to a large extent, on the accuracy of determining the position of the target with reference to some standard frame.

Missiles of this kind, by the very nature of their use, are offensive missiles. Missiles employed for long range targets are also known as strategic missiles. Short Range, Intermediate Range, and Inter-Continental Ballistic Missiles (SRBM,IRBM,and ICBM) are some of the generic names (based on the range performance) of these missiles. Some examples of this type of missiles are: CSS-3 ICBM (Country of origin: China, Maximum range: 7000 km), SS-18 satan ICBM (CIS-formerly USSR, 12000 KM), Minuteman ICBM (USA, 12500 km), Prithvi SRBM (India, 100-250 km), Agni IRBM (India, 600-1000 km).

Surface-to-Air Missiles

Any guided missile launched from a point on the surface of the earth to destroy a target in the air qualifies for this category. The launch point, however, could be either a ship or land. Here the targets are always in motion and quite often have considerable maneuvering capability. The guidance system must be accurate since the targets are usually small in size, move at high speeds, and/or are capable of executing complicated maneuvers (e.g., fighter aircraft, helicopters, SSMs). Thus, these missiles have support equipments which continuously collect information about the current position and veloc-
ity of the target. The time available for the missile to destroy a flying target is usually small and so the guidance system must be able to take appropriate actions in a short period of time.

These missiles are normally used as defensive weapons. Some examples of such missiles are: Gremlin SA-14 (CTS, 6 km), MANPADS (France, 4-6 km), Stringer (USA, 45 km), Akash (India, 27-35 km, under development), Patriot (USA, 160 Km).

**Air-to-Surface Missiles**

These missiles are usually launched from an aircraft to destroy targets on the surface of the earth. The targets could be moving (but not at very high speeds) or stationary. The launch point (aircraft) is in motion. Hence, it is possible to search and seek out targets whose positions or movements are not known beforehand. In other words, the targets for such missiles are seldom predetermined as in the case of SSMs, which means that the missile must have some means of seeking out these targets. This causes the additional problems of avoiding spurious signals from the ground. Since it is possible to come close to the target, accuracy can also be improved. However, the launch point itself moves, and so the velocity and other dynamic properties of the aircraft must be taken into account in the guidance system.

These missiles are primarily offensive weapons but can also be considered as defensive weapon systems depending on their actual use. Some examples are: Gabriel MK-III (Israel, 40 km), HARM AGM-88A (USA, 25 km).

**Air-to-Air Missile**

Here, both the launch platform and the target are aircraft. These missiles are perhaps the most difficult to design and build from a guidance point-of-view. Both aircraft are at motion in high speeds. They are also capable of high maneuverability. Targets are small and difficult to locate. The guidance
system has to take into account all the factors mentioned for SAMs at the target end, and those mentioned for ASMs at the launch end. In addition, the guidance system should be such that it should not prevent the aircraft launching the missile from taking evasive actions for its own survival after the missile has been launched.

These missiles can be used both as offensive and defensive weapon systems. Some examples are: Super 530 (France, 25 km), Ash AA-5 (CIS, 5-20 km), Sidewinder AIM-9 (USA, 5-15 km).

5.3 DESCRIPTION OF THE TACTICAL MISSILE

In these lectures, we will concentrate on surface-to-air and air-to-air missiles only. These missiles fall under the category of tactical missiles. Usually, these missiles comprise of several subsystems like the airframe, flight control section, guidance section, fuze, warhead, propulsion, data link, and radome. Fig. 5.1 illustrates the location of these subsystems within the missile.

The airframe is the framework that carries the missile components. The guidance and fuze sections are located at the forward end of the airframe. The Radome covers the guidance-section seeker head to protect it from aerodynamic forces. The warhead section is located behind the guidance section and in front of the propulsion section. The flight control section is positioned wherever the control surfaces are located. If a data link is required (as in command guided missiles, guided from the ground), the antenna and the receiver are located at the rear end of missile. Some of these subsystems are described below.

Airframe
The airframe is the framework that carries the missile components to an intercept of the target. There are many types of airframes and they are usually categorized by their source of lift and control (that is, the location of control surfaces like wings, tail fins, and canards).

Flight Control

The function of the flight control system is to provide a stable, controlled, and responsive missile. Such a stable and controlled flight is achieved by control-
Figure 5.2: Types of Airframes

Guidance

Guidance is the most important contributor to overall missile performance. This system provides steering commands to the lateral autopilots that will cause the missile to fly to a successful intercept of the target. To
accomplish this task the guidance system needs to perform four functions: (1) Seeker stabilization (2) Target acquisition (3) Tracking, and (4) Steering signal generation. A simplified block diagram is shown in Fig. 5.3.

Figure 5.3: Guidance-section functional block diagram

The sensor that receives the target signal return is normally mounted in some type of gimbal system that is attached to the missile body. In order for the sensor to function properly it must be decoupled from the missile body motions. This is accomplished through the seeker head stabilization loop. Sensor motion is sensed with a rate gyroscope attached to the sensor
platform. Signal from the rate gyroscope is used to generate the feedback which compensates for the body motions.

The output of the sensor is fed into the signal processor which processes the signal and provides the input to the tracking system which does the job of keeping the sensor boresight (or central axis) on the target in order to maintain target track and generate steering signals. The steering commands are generated through guidance laws which use information (available from the signal processor) such as line-of-sight (LOS) rate, closing velocity, etc. These guidance laws will be discussed in detail in the next chapter. The steering commands generated by the guidance system are fed to the lateral autopilots.

**Fuze**

The function of the fuze is to detect the target’s presence in the missile’s vicinity and detonate the warhead. Tactical missiles usually have contact and proximity fuzes. The contact fuze becomes operative when the missile makes physical contact with the target. The proximity fuze is designed to detect the target when the missile passes close to the target without direct contact.

A typical active RF proximity fuze is a small active CW radar system having two transmitting antennas. When the target enters the main lobe, the fuze receives the reflected energy and a fuze pulse is generated which triggers the warhead (see Fig. 5.4).

The fuze is designed to react to signal returns from targets within the lethal range of the warhead. Signal returns from targets beyond a specified range are rejected.

Other kinds of modern proximity fuzes are laser fuzes. This provides very accurate operation and is immune to most conventional electronic counter-
There are two laser beam patterns, one conical and the other circular. When the target hits the conical beam pattern at point A, the fuze system is alerted to the presence of a target and the detonation takes place when the target hits the circular beam pattern at point B. Other strategies to detonate the warhead may also be designed based on the target’s interception of the two beam patterns. The essential idea is to ensure that the warhead detonates at the center of the target.
Propulsion

The propulsion system of the missile provides the required initial thrust to the missile to enable it to fly with sufficient velocity during the subsequent engagement period with the target. There are two phases in missile propulsion: boost and sustain. During boost the propulsion system provides a high level of missile acceleration over a relatively short period of time (1-15 secs). The purpose of sustain propulsion is to maintain the missile at a desired velocity for the majority of the remaining missile flight. Various
combinations of boost and sustain propulsion (like all-boost, boost-sustain, all sustain) may be used in different missile systems. However, in principle, the all-sustain configuration is never used, since it usually requires a very short boost phase. An example is the air-to-air missile which does not have a booster motor but a short boost is provided by the sustainer motor itself.

The booster motor is typically a solid propellant motor while the sustainer motor could either be a solid propellant one or a jet engine. Some modern missiles nowadays use integrated rocket-ramjet propulsion.

Warhead

The warhead is the payload of the missile and consists of a shell, explosives, and a detonator. The weight of the warhead depends on the size of the missile. The fuze pulse activated the detonator which in triggers the explosive. The shell breaks into numerous fragments which are propelled outward in a 60-90 degrees spread and achieves target kill by penetrating target components. Apart from the basic fragmentation type the other kinds of warheads are: continuous-rod warhead, annular blast fragmentation warhead, selectively aimable warhead.