PART 4: SECTION 1

CHAPTER 3

GUIDED WEAPONS

Introduction

1. What is a guided weapon and why is it necessary? Probably the best definition is that given by Professor Hermann Oberth: "An unmanned weapon, moving above the earth's surface, whose trajectory or flight path is capable of being altered when in flight".

2. The V.1 and V.2 German weapons were not guided weapons, since after these were launched it was impossible to alter their flight paths (as these had been pre-set before launching).

3. At first sight it would appear that the present armoury of conventional weapons is adequate, but that is debatable. The present fighter armament of guns and unguided rockets have the serious limitations of short range, low lethality, and the tactical disadvantage of requiring the sight to be held on the target long enough for a lethal burst of fire. The fighters themselves cannot get to altitude in time to destroy the bombers before the latter reach their point of bomb release. Free-falling bombs cannot be dropped with sufficient accuracy, particularly under "blind" conditions, and they have the disadvantage of having to be carried right into the enemy defensive zone before they can be released.

4. Details of the accuracy, performance, and effectiveness of individual types of weapons under development are not made public for security reasons, and information is not readily available in the Royal Air Force. However, since guided weapons are to be used, the fundamentals of their design, construction, and performance must be understood.

Fighter Defence

5. It is vital that enemy bombers carrying weapons of mass destruction should be destroyed before they reach a position from which they can attack their targets. If they are jet bombers their speed will be such that defensive forces will have very little time in which to intercept and destroy them. One means of making an earlier interception is to increase the rate of climb of the intercepting fighter. It must not be overlooked that physiological problems are also involved, such as the protection of the body against the effects of large *g* forces, and the limitations of the human brain in contending with the instantaneous reaction and control which are necessary. Complex sighting and computing systems are necessary for successful interception of targets flying at very high speeds and great altitudes. If the fighter is provided with guided weapons, not only do these increase the chances of destroying the bombers without the fighter having to enter the bomber's defensive zone, but they allow greater tactical freedom to the fighter.

Anti-Aircraft Defence

6. The anti-aircraft gun, though much improved since the end of the Second World War, is still limited in effectiveness. Its lethality still depends on the target holding its predicted flight condition during the time of flight of the shell. The effective ceiling of modern A.A. guns is about 45,000 ft., but their accuracy and lethality decreases rapidly above 20,000 ft. Even below this altitude the single-shot lethality rate is extremely small, and the cost of gun-defence for a vital area in initial equipment and expenditure of shells to achieve, say, a 30 per cent. defence is excessive. A guided weapon, however, will home on to its target, automatically making allowance for alterations in the height and track of its target, and in some cases becoming progressively more accurate as it approaches the target. Launched vertically, superior to its target in speed, rate of climb, and manœuvrability, it will be better able to intercept and destroy enemy bombers before they reach bomb release point. Guided weapons have only a limited application against low-flying targets, and there is still a requirement for A.A. fire in this role.

Bombing Offensive

7. **Limitations of Conventional Bombs.** As a general rule the damage caused by the explosion of a conventional type bomb, regardless of its size or the nature of its filling, decreases rapidly with increase of distance from the point of the explosion. Constant research and development is necessary, therefore, to improve the accuracy of bombsights. It may be accepted that the limits of accuracy of erstwhile bombing techniques and

equipment have been reached by experience and application. These techniques depend primarily on the accuracy of the instruments used in bombing, the errors of which are magnified as the speed and height of bomb release increases. It may not be practicable to improve bombsight manufacturing tolerances to restore the balance of accuracy, and this will mean an increase in bombing errors. Other limitations in the use of the conventional bomb include :—

(*a*) The need for the bomber to approach the target closely.

(*b*) The loss of tactical freedom when committed to the bombing run.

(*c*) The difficulties of target identification at high altitude, either visually or with blind aids.

(*d*) The difficulty of avoiding the effects of air-burst bombs in low altitude operations.

One solution of these problems is to guide the trajectory of the bomb during its fall. By guiding the bomb after release it is possible to divorce its accuracy from the speed and height of the bombing aircraft, and from precalculated estimates of conditions during its time of fall ; and instead to use information derived from the target itself. The accuracy of the bomb will then depend on the performance of the guidance and control equipment within the bomb.

8. **Unmanned Expendable Bombers.** The value and accuracy of a bomber force is governed by the limitations imposed by weather, speed, height, cost, and ability to bomb the target. The advantage of the unmanned and expendable bomber is that it is not affected by the errors caused by inaccurate bombing winds, bomb-sight manufacturing errors, and bomb ballistics. In addition, the striking range of the aircraft is improved as it does not have to return from the target. However, at present its use is only economical at the short range within which it can be guided accurately. Its use at a longer range will only be justified if the necessary accuracy of guidance can be extended. Unmanned bombers have a further advantage over manned aircraft in that the maximum potential can be employed in a very short period of time, whereas manned aircraft rely upon repeated sorties for their maximum effect. The use of unmanned bombers is not governed by weather conditions, and their speed and altitude may be increased, thus reducing the chances of interception. In addition, unmanned bombers of aircraft type could be powered by conventional engines built for a short-life expectation, and ballistic trajectory

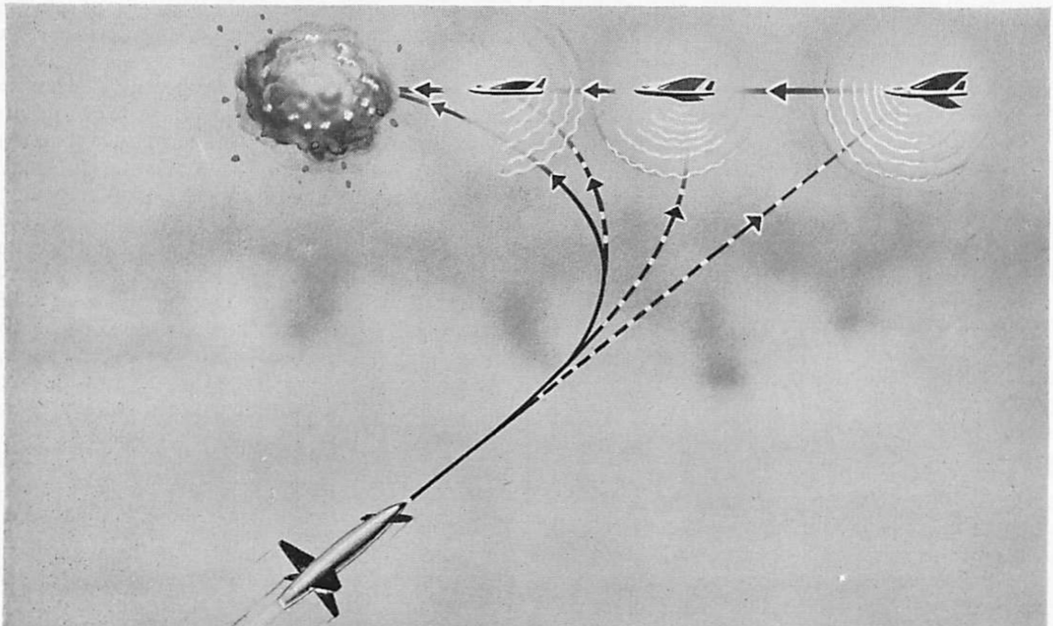

Fig. 1. Active Homing.
The missile carries its own transmitter and receiver.

type weapons could use bi-fuel or solid-fuel rocket motors. The cost of an unmanned expendable bomber force would be large, but under certain conditions this would be justified by the saving in the manpower otherwise needed to run and maintain an expensive airfield which would be unnecessary with a striking force of this nature, and by the prohibitive wastage of trained aircrew which would result against certain targets.

Guided Weapons—Classification

9. Guided weapons fall into four classes :—

(*a*) *Air-to-Air*. Normally the armament of fighter aircraft, but could also be used for defensive armament on bomber aircraft.

(*b*) *Surface-to-Air*. To augment the present gun and fighter systems of air defence, later to replace part of these systems, and eventually to replace all, or nearly all.

(*c*) *Air-to-Surface*. These will replace conventional bombs and torpedoes for certain operations.

(*d*) *Surface-to-Surface*. To augment the use of both tactical and strategical bombers, and possibly P.R. aircraft.

Guided Weapon Components

10. A guided weapon uses all or most of the components in the table below. The various components are discussed in greater detail in subsequent paragraphs.

Booster and Launching System

11. There are several methods of launching a guided missile. These include catapults using compressed air, steam, or cordite ; and launching tubes of the bazooka type. Guide rails, to give initial stability, are sometimes employed in combination with some or all of the other methods. If sufficient initial thrust is available, zero length (very short) launchers can be used for a horizontal launch, or alternative'y the missile can be launched from the vertical position. One or more booster motors are used on some weapons. These are fitted to a :celerate the missile rapidly to a minimum safe speed after which the motors fall away, allowing the missile to continue under the effect of its own propulsive system.

Propulsion Unit

12. A means of propulsion is not always necessary, especially in air-to-ground missiles where the effects of gravity and inertia are sufficient. Some types of propulsion units are listed below :—

(*a*) Propellers driven by piston engines—these can be used for radio-controlled, unmanned, expendable bombers.
(*b*) Gas turbines.
(*c*) Pulse jets (as used in the German V.1).
(*d*) Ram jets.
(*e*) Solid-fuel rockets.
(*f*) Liquid-fuel rockets.
(*g*) Compressed air driving a pneumatic motor—used in torpedoes. The weight in-

Component	*Purpose*	*Implementation*
1. Booster and launching system.	To attain speed.	Rockets, usually solid-fuel.
2. Propulsion unit	To maintain speed and manœuvrability.	Jet or rocket engine.
3. Guidance system for receiving and interpreting intelligence.	Guidance and discrimination.	Preset electronic or similar system.
4. Aerodynamic surfaces and control systems.	Stability, steering, and sometimes lift.	Movable fins, wings, ailerons, and controls.
5. Power system	Provision of the power to transmit command intelligence, and move control systems.	Servo-mechanisms ; hydraulic, pneumatic, or electric power.
6. Airframe	Integration of assembly.	Structure using materials giving high strength-to-weight ratio.
7. Warhead and fuse	Destruction of target.	Explosive, atomic, or chemical, with proximity or other fuse.

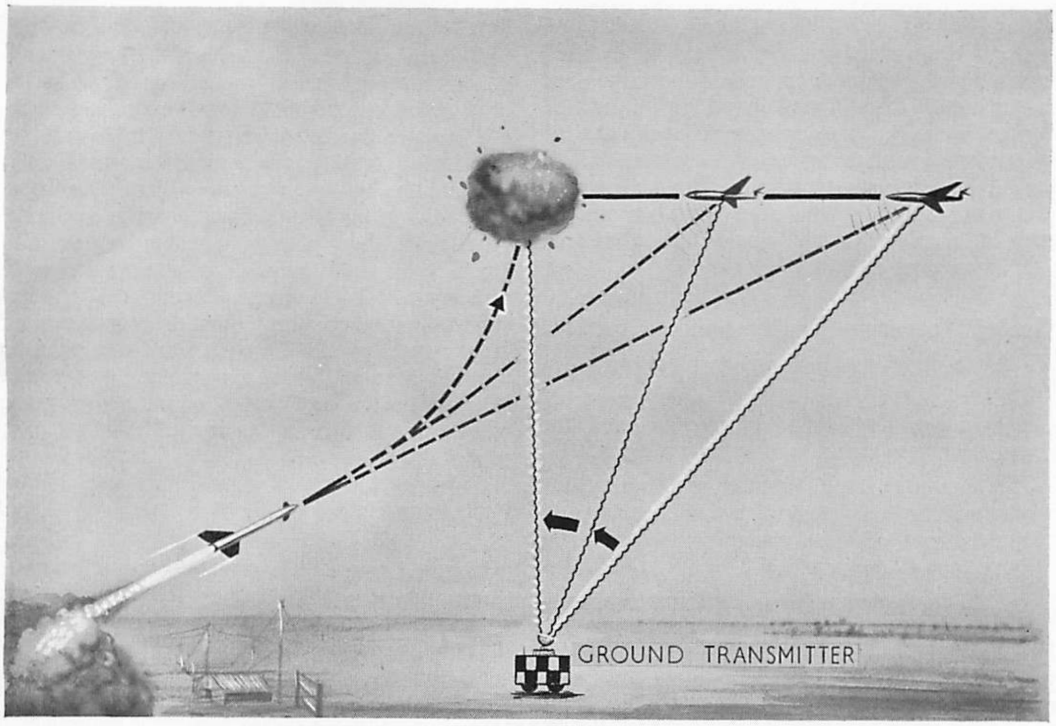

Fig. 2. Semi-Active Homing.
The missile receiver senses radiation from a target which is illuminated by a separate ground or airborne transmitter.

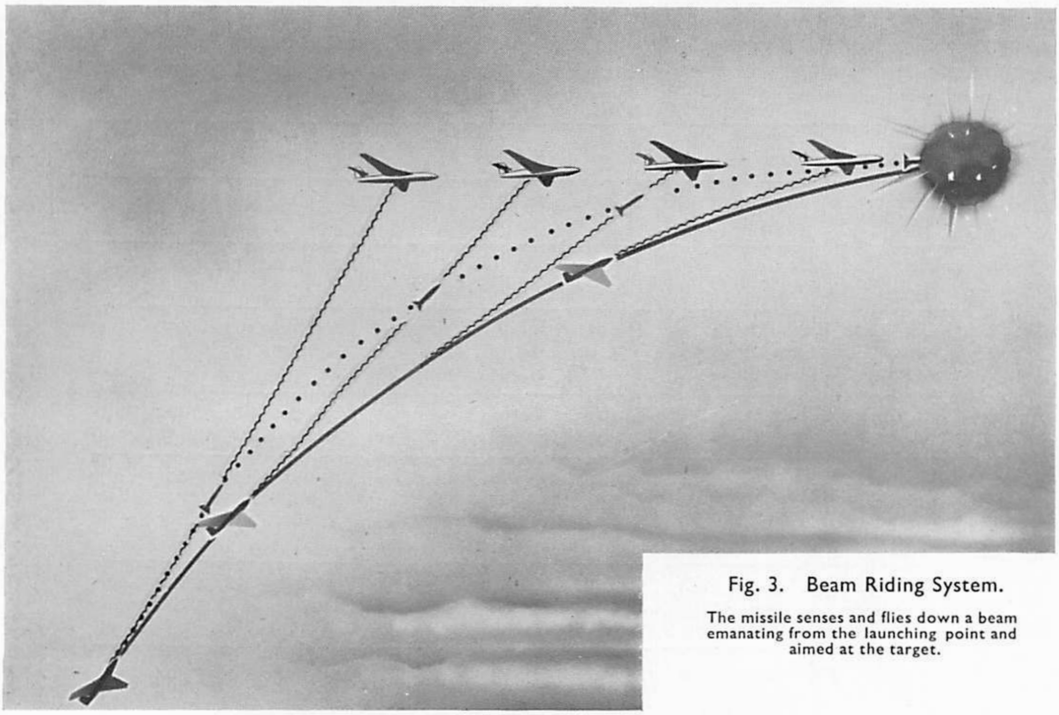

Fig. 3. Beam Riding System.

The missile senses and flies down a beam emanating from the launching point and aimed at the target.

volved in using this method limits its uses to land or water weapons.

Types (*a*) to (*d*) depend on the presence of atmospheric oxygen to enable them to function ; the last three operate independently of atmospheric oxygen. The type of propulsion unit chosen for a particular application will depend mainly on the horizontal and vertical range, speed, and accelerations needed. These considerations determine the size, weight, and cost of the motor, and the fuel needed to give that performance.

Guidance System for Receiving and Interpreting Intelligence

13. There are many different guidance systems, the most common being :—

(*a*) *Homing Guidance*. In this method the missile locates the bearing of the target by sensing an emanation or radiation from it. This may be in the form of light, sound, heat, or radio waves. Homing guidance can be broken down into active, semi-active, and passive homing.

(i) In active homing the missile is the source of the radiation which illuminates and is reflected by the target. For example, a small missile-borne radar transmitter illuminates the target, the subsequent reflections being picked up by the missile-borne receiver. This passes the intelligence to associated equipment which then determines the bearing of the target and moves the controls to steer the missile in the required direction.

(ii) In semi-active homing the target reflects radiation transmitted from a source situated either on the ground or in an aircraft. The missile carries a receiver which picks up only the reflected radiation ; this is usually in the form of radar signals, but light from a searchlight can also be used.

(iii) By passive homing is meant the system by which the missile homes to a target which is itself the source of the radiation. The particular radiation to which the missile is sensitive may be heat or noise from an engine.

(*b*) *Preset Guidance*. Examples of missiles using this type of guidance are the V.2 rocket, the V.1 flying bomb, and the conventional torpedo. In all these weapons the sequence of manœuvres is fed into the mechanism before launching ; thereafter the missile follows the preset manœuvres.

(*c*) *Command Guidance*. This system uses signals which are fed by a controller to the missile, either by radio or through a thin wire link. The controller must be able to determine the relative positions of the missile and the target, either visually or by other means. The principal forms of command guidance are manual and automatic :—

(i) Under manual guidance the controller steers the weapon towards the target, usually by a line-of-sight method. As the weapon moves towards the target the controller keeps it accurately positioned in the line of sight from his eye to the target.

(ii) Under automatic guidance (the beam riding system) the weapon steers itself along the line of sight joining the controller to the target. To do this the controller (who can be either on the ground or in an aircraft) illuminates the target with a radio or radar beam. The weapon is sensitive to the beam and homes along it until it strikes the target.

Aerodynamic Surfaces and Control Systems

14. (*a*) *Aerodynamic Surfaces*. Aerodynamic surfaces are generally used for the control and stability of a guided missile, and are of four types :—

(i) Moving wings.

(ii) Nose control surfaces.

(iii) Rear control surfaces.

(iv) Trailing edge control surfaces.

(*b*) *Control Systems*. The aerodynamic control system of a guided missile is closely interlocked with the guidance system used, and is actuated by, and responds to, signals from the guidance system. There are two systems of controlling the missile ; polar control, and cartesian control.

(i) Missiles using the polar control system have a configuration similar to a conventional aircraft. They have a monoplane wing and two sets of controls, one actuating the elevators and the other the ailerons. In some missiles the elevators are separate surfaces near either the nose or tail. Gyro-stabilization is used. The flight path of the guided missile is monitored through a receiver in the missile. The data received keep the missile tracking towards the target, and also measure range. The missile is rolled towards the target until its wings are at right angles to an imaginary plane joining the missile and target. The elevators are then moved to pull the nose up or down until it is pointing at the target. The weapon is, in effect, first rolled or twisted into the required plane and then steered onto the objective, using the elevators in much the same way as in manœuvring a normal aircraft. Polar control is sometimes referred to as "twist and steer". The mechanism for operating the control surfaces is similar in principle to the automatic pilot but more compact, and is capable of functioning in the presence of very high *g* loads.

(ii) Guidance by the cartesian method entails the use of two identical sets of wings set in a cruciform shape. There are thus four wings in all. Each wing is movable or has a movable control surface. Gyro stabilization is used. Changes of direction to the left or right are accomplished by the vertical surfaces (rudders) and changes up or down are carried out by the horizontal surfaces (elevators). A diving turn is made by using all four controls which have the effect of forcing the missile into a skidding turn while at the same time depressing the nose. Thus there is no rolling motion as in the case of missiles using the polar system.

(*c*) Both these methods of control are very effective aerodynamically. A high degree of manœuvrability is achieved and manœuvres involving lateral accelerations of the order of 20*g* are possible.

Power System

15. The guidance—after reception, interpretation and amplification—will normally be passed as an electrical signal to relays and actuators which move the controls. The actuating power may be electric, pneumatic, or hydraulic. Control may be accomplished through aerodynamic surfaces or through varying the angle of the thrust reaction of a jet or rocket engine. Considerable power may be necessary for the continuous control adjustments needed. As with all servo mechanisms, instability and flutter must be avoided. Methods of measuring the heading, speed, rate of turn, and acceleration are required to co-ordinate the guidance signals into a smooth flight path.

Airframe

16. Since the missiles operate at transonic and supersonic speeds it is important that the frontal area is kept low and that any surfaces are of low aspect ratio and possess the thinnest possible section consistent with rigidity. The slenderness of the body must be a compromise between aerodynamic requirements and the space necessary to carry the mass of miniaturized ultra-lightweight equipment. Thus a monocoque form of construction is necessary, with stiffening formers at intervals down the length. The fuel, which usually forms a considerable part of the total weight, must for stability be reasonably close to the C.G., while for best directional stability the C.G. should be as far forward as possible. This combination is not easy to achieve for if a comparatively heavy liquid-fuel rocket motor is used it must be positioned at the tail, while a light but bulky radar homing aerial might have to be fitted in the nose. Therefore there is no typical layout for the variety of guided weapons. Each is designed and constructed to meet its own particular requirements.

Warhead and Fuse

17. The warhead of a guided weapon may be of fragmentation or blast high-explosive type; it may be atomic, or contain bacteriological or chemical agents, and it will be exploded by a proximity or other fuse. The type and size of warhead depend on the amount of damage required and the distance the missile has to travel. These in turn influence the type and size of the propulsion units, guidance and control systems, and the size and weight of the missile itself.

Conclusion

18. Guided weapons have never before been used on a large scale. Their use is becoming an increasingly important aspect of defence against the high-speed, high-altitude bomber, which is difficult to attack using manned fighters or interceptors. Of paramount importance too is the part that guided weapons will play in increasing the effectiveness of the offensive air war. Because of the different techniques needed to use guided weapons, all aircrew should broaden their knowledge of this new field and adjust their ideas of offence and defence in the light of this knowledge.