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REVIEW OF DEVELOPMENT OF IR GUIDANCE TECHNIQUES
PART II

by

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REVIEW OF DEVELOPMENT OF IR GUIDANCE TECHNIQUES
PART II

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III. Development of Antitank Missiles

As indicated in the mideast wars and the Gulf War, new combat craft, principal warships, as well as tanks and armored vehicles with offensive and defensive capabilities will still be the most important weapon systems in the three branches of the armed services in future wars. Therefore, it is unavoidable to develop precision-guided weapons against air, against ships, and against tanks. In particular, since the unprecedented progress of fire-control systems, mobility, and defense capability (especially the emergence and applications of reactive armor and composite ceramic armor) of tanks, for a long period into the future tanks will certainly still assume the main role in ground combat. Therefore, the development of various types of antitank missiles to cope with tanks, armor, and tank clusters at different distances, as well as attacks on in-depth targets, naturally antitank missiles receive greater attention. Up to now, three generations of antitank missiles have been developed. In the following, a brief description is given.

1. First-generation antitank missiles were deployed with troops in the late fifties and the early sixties. Wires to transmit commands, manually-controlled guidance, visual optical aiming, and visual optical tracking were used for the older type of antitank missiles. The typical models are the Sagger of the Soviet Union, the SS-11 of France, the Aboula of the FRG, the Alert Widimeter of the U.K, the Malcala of Austria, the Mosquito of Switzerland, and the Bantam of Sweden. The Red Arrow-73 of China was also a product of this generation. Today, the vast majority of missiles applying this guidance method have been retired.

2. Beginning from the TOW missiles first deployed in U.S. forces in 1970, antitank missiles gradually developed from first generation to second generation. Products of this generation were represented by the TOW and the Dragon and their improved models in the U.S., an improved version of Sagger in the Soviet Union, the Arbon of France, the HOT and MILAN as well as their improved versions in France and West Germany, the Swinfi of the U.K., the Bill of Sweden, and the heavier-version Matt of Japan. Typical second-generation antitank missiles used optical aiming, infrared tracking, wire transmission of commands, and semiautomatic guidance. Relative to the first generation, the major improvements include adding an infrared goniometer to the

guidance system to form an infrared semiautomatic tracking. By using such semiautomatic guidance, the operator only consistently aligns his aiming lens on the target, and the missile will automatically hit the target. The Red Arrow-73B and C of China are products with improvements over the previous models of Red Arrow-73. Thus Red Arrow-8 is a typical second-generation product. Up to now, the various improved versions of the second generation antitank missiles are still deployed. Moreover, while various improvements are made to the second-generation products with the above-mentioned infrared semiautomatic tracking abroad, some new model antitank missiles with semiactive laser guidance system were developed, such as the Hellfire of the U.S., Trigat (jointly developed by NATO countries, including the U.K. and France), and Copperhead (U.S.) terminal-guidance artillery round. Nevertheless, laser designators are inconvenient in real combat, but are also not suitable to cope with in-depth enemy targets.

3. Third-generation antitank missiles developed since the eighties are missiles employing millimeter wave or infrared guidance, terminal guidance dispenser and bomblets, sensitive terrain-following missiles, and terminal-guidance artillery rounds. These are multiple novel precision guidance weapons with fire-and-forget capability. In addition, due to complex and variable meteorological conditions and combat environments, with the existence of complex infrared backgrounds on the ground and a variety of jamming, it is required that the newer-generation antitank missiles should have capabilities of counterjamming,

discrimination between real and false targets, coping with multiple targets, and all-weather operating capabilities, therefore the development direction of antitank missiles is the following: a) development from point detection to infrared imaging guidance. Besides the foregoing-mentioned Maverick AGM-65D and F as well as the AAWS-M systems, the U.S. prepared to make vast investments to develop missiles to replace the TOW missile by using graphic guidance with the 128x128 IRFPA device in the heavy-version advanced-missile system (AMS-H). This will be another new milestone. b) Development from semiactive laser guidance to infrared imaging guidance. For example, in the Hellfire air-to-ground antitank missiles deployed with U.S. forces, the guidance head (with code number AGM-114A) of infrared imaging guidance has been proposed for use. In the three European countries (the U.K., France, and Germany), the developing long-range antitank missile Trigat also makes use of infrared imaging guidance to replace the laser semiactive guidance. c) To cope with the requirements of different distances in attacking in-depth and cluster tanks, the development of sensitive terrain-following missiles of infrared or millimeter wave guidance, as well as terminal-guidance artillery rounds of combined guidance, will be described later in this article.

IV. Development of Sensitive Terrain-Following Missiles and Terminal-Guidance Artillery Rounds

As is well known, artillery and munitions are the most active factors in wars. In modern warfare, besides the requirement that the ground artillery units accomplish traditional firepower suppression and support tasks, they are also required to have the capability of long-range indirect firing on tanks, armor, and other hard targets. In recent years, developments were emphasized in China and abroad on the sensitive terrain following dispenser and bomblets (with infrared or millimeter wave guidance) fired by howitzers, mortars, or multibarrel rocket launchers. By using this method to cope with the far-away cluster tanks and firing base of an enemy, this is a very effective method of annihilating them. This is because conventional artillery rounds have unique properties of fast firing rate, high muzzle velocity, flexible handling, capability of continuous firing, as well as simple logistics and defense; however, missiles are high in power and high in hitting precision. By combining the sensitive terrain-following missiles or the terminal-guidance artillery rounds, the firing capability of artillery will be greatly upgraded. In the following, brief presentation is given first on the sensitive terrain-following missiles and typical terminal guidance dispenser and bomblets, then a more detailed description is given of terminal-guidance artillery rounds.

4.1. Sensitive terrain-following missiles

This kind of missile is a new munition that applies advanced sensor technology and explosion-forming round technology in new munitions of dispenser and bomblets so that the area-killing properties of dispenser and bomblets are developed for attacking point targets. To exploit the features of high firing precision of conventional artillery, the sensitive terrain-following missile generally is in the form of bomblets to be transported in the dispenser (artillery round or other carrier) to arrive over the target area. With a time fuze point ignition casting powder, the sensitive bomblets are ejected. The optical axis and the drop direction of the sensor form a certain angle (about 30 degrees). The ejected bomblets descend and rotate (the axis of rotation is the line of descent), by using a brake parachute to reduce the velocity and spin, to finally reach the appropriate altitude over the desired target. Thus, the rounds can scan and search the target area by controlling the drop and rotation situation. Generally, the scanning locus is an archimedean spiral. When the sensor senses the target, the warhead of the explosion-forming round is ignited, attacking a tank or armored target. Mostly, 155-mm artillery is used to fire the sensitive terrain-following rounds, but they can also be fired in multibarrel rocket launchers. At present, the well-known sensitive terrain-following rounds known abroad include Sadan of the United States and Hobich of Germany. The Sadan round can be fired from a 155-mm or 203-mm artillery, or by a 227-mm multibarrel rocket launcher. In a dispenser for a 155-mm round, two bomblets are contained, each weighing 13.6kg and 160mm long. Fired in a multibarrel rocket launcher, each Sadan dispenser can be packed with six bomblets.

Under general conditions, after velocity and spin reduction of the ejected rounds, stabilization can be attained at a height of 100 to 150m above the ground. The rate of descent during scanning and search is about 10m/s, and the spin rate is about four revolutions per second. The coverage in scanning is about 20,000m^2. The explosion-forming round rushes toward the target at a velocity of approximately 2000m/s.

4.2. Terminal-guidance dispenses and bomblets

Among the dispensers and bomblets with terminal-guidance made abroad, the more typical is the Assault Breaker system (of the United States), which can use model T-16 dispensers (made by Marietta Corporation), or model T-22 dispensers (made by the Ward Corporation). One of the two following bomblet models can be packed inside the dispenser. One is the terminal-guidance bomblet TGSM (made by General Dynamics, about OD100mm, length 640mm, and overall weight 11kg). The second is the SKEET (OD 95mm and weight 2.7kg; four bomblets are packed per dispenser), made by the Bhoko Corporation. In both cases, infrared terminal-homing guidance is used. The model T-16 dispenser carrier can carry 14 TGSM or 88 SKEET (that is, 22 dispensers). A model T-25 dispenser carrier can carry 24 TGSM or 96 SKEET. It was reported that between March 1981 and December 1982, U.S. forces conducted multiple flight tests of this missile system. As indicated in the results, the weapon system is certainly feasible to deal with tank clusters at long range. Additionally there are JTACMS and ERAM projects in the United States. The former is the application of the technical accomplishments of the Assault Breaker. The latter is antitank mines by using SKEET carried and dispensed in order to extend the firing range.

4.3. Terminal-guidance artillery rounds

In the early eighties, Copperhead rounds (code number XM712, CLGP) fired in 155-mm artillery pieces with laser semiactive terminal guidance were successfully developed in the United States. The main tactical technical indicators are as follows: length 1.372m, weight 63.5kg, firing range 3 to 20km (16km is the typical range), hit probability 90%, hit accuracy (CIP) between 0.4 and 0.9m, and maximum axial direction impact at 9000g. The laser indicators attached are of three types (light, vehicle-borne, and airborne). Concentrated energy armor-piercing warhead is 22.5kg in weight, packed with type B molten high-energy explosive, 6.4kg. This is the world's first and up-to-now the only terminal-guidance artillery round. It was reported that the statistical destruction probability of a Copperhead round against a tank corresponds to 2000 to 2500 conventional artillery rounds. However, Copperheads have a fatal weak point: a laser designator has to be used. This not only is inconvenient in combat, but is also not suitable in dealing with in-depth enemy targets. Therefore, although the first Copperheads were developed and built as the conventional terminal-guidance rounds for 155-mm artillery of NATO countries, yet interest in these countries was not aroused. Even so, some development projects using laser guidance or single format terminal guidance artillery rounds were discontinued. However, there was not an abandonment of such weapon systems of terminal guidance artillery rounds, but a stressing of improvements of the guidance system and other aspects to develop in the fire-and-forget direction. Today, there are more than ten types of terminal-guidance artillery rounds under development abroad. It is estimated that these will be gradually deployed in the mid- and late-nineties. A presentation and description of key points are given below:

1. In 1986, the U.S. proposed to use rotating stabilized guidance artillery rounds with dual-color infrared guidance head, developed by Raytheon Corporation, or ejecting current-controlled artillery rounds with millimeter-wave guidance head, developed by Honeywell Corporation to replace the Copperhead, so that it has the fire-and-forget capability. The project code is CGSP. In 1987, an improvement proposal was made on using infrared imaging and laser semiactive guidance for the Copperhead.

2. In 1987, a development code APGM generalized-type 155-mm terminal-guidance artillery round with active hitting of hard targets was proposed by eight NATO countries (U.S., France, Germany, Italy, Canada, The Netherlands, Spain, and Turkey). The ADCO scheme with millimeter-wave guidance was proposed. At that time, 22-months of feasibility clarification was planned to be pursued. Somewhat later, a scheme of ASP smart rounds of dual-

mode infrared/millimeter wave guidance was proposed with rounds 0.9m long, 45kg in weight, and with a range of 24km. It was claimed that the round was able to hit and destroy, as well as being able to engage in all-weather combat. According to plans, engineering developments will begin in 1993.

3. There are two schemes for 155-mm terminal-guidance artillery rounds in development by Germany, EAP and EPHRAM. Both employ millimeter-wave guidance, with a range between 4 and 24km. In a further step, dual-mode infrared/millimeter-wave guidance is also being prepared for use.

4. Under development by Bofors Corporation in Sweden, BOSS 155-mm artillery terminal-guidance round used millimeter wave guidance. Four rudder fins are stowed in the nose compartment to execute commands from the guidance head to update the trajectory until 200m from the target. A feasibility study was completed in late 1986.

The above-mentioned are terminal-guidance artillery rounds fired by 155-mm artillery. In the following, several types of typical terminal-guidance mortar rounds are presented.

1. Under development by the BAE Corporation in the U.K., the Merlin terminal-guidance mortar rounds fired in an 81-mm L16 mortar employ active-millimeter wave guidance. The round is 900mm long, 6kg in weight, and has a 6-km range, capable of attacking main battle tanks, infantry armored carriers, and armored personnel carriers from their top. The round project was begun in 1980. The project was formally accepted in 1984. In

1985, the first firing experiment was carried out. It is scheduled to be deployed in 1990.

2. Developed by the FFV Corporation in Sweden, Strix terminal-guidance mortar rounds are to be fired by a 120-mm smooth-bore mortar. The round (1.34-m long and 24.2kg in weight) employs infrared guidance of focal plane array, and has a range between 0.6 and 8.5km. The rounds are used to deal with tanks and armored vehicles. The project was proposed in 1980. A feasibility study was completed in 1982. Development was completed between 1984 and 1989. Production began in 1990.

3. Developed by the TBA Corporation in France, 120-mm antitank terminal-guidance mortar rounds PMGT applies millimeter-wave radar guidance and hollow-core explosive-packed warhead.

4. Jointly developed by the U.K., France, Switzerland, and Italy, the 120-mm terminal-guidance mortar rounds employ 94GHz millimeter radar guidance. The rounds are 1m long, 20kg in weight, with a range between 1.5 and 8km. Development began in 1987. The feasibility study was completed in 1989. It is planned to deploy the rounds in 1993. The U.K. Spaceflight Corporation provides guidance head and electronic equipment; the guidance head is an improvement of Merlin.

Besides, to distinguish real from false targets and to cope with infrared jamming, the dual-color infrared sensing scheme has also been emphasized abroad. For example, the dual-color infrared guided artillery round developed by Teradyne Corporation for the U.S. Army, the PbSe detector with sensing range between 1 and 4micrometers (peak value approaching 4micrometers) and the PbS detector with sensing range between 2 and 3micrometers (peak value approaching 2micrometers), due to higher irradiation by false targets, by sunlight and flames, and higher irradiation of ground tanks and other targets at 4micrometers, if the PbS detector receives a strong signal, these are false targets. In other words, with processing and comparison of signals received by two types of sensor, signals from tanks and other targets can be extracted by discriminating between real and false targets. To extract the orientation signals from targets, this dual-color detector applies a multielement cruciform structure composed of four PbS and four PbSe elements. Now, dual-color infrared detectors can perform better and operate at wavelength intervals between 3 and 5micrometers, as well as between 5 and 14micrometers, such as the CMT detectors, to extract orientation signals from the targets. Thus, this is a more effective scheme of a multilobe rose-curve or reciprocating spiral for scanning and positioning.

Up to now, the more advanced and practical as well as feasible system for antitank terminal-guidance artillery rounds is to apply the combined guidance of dual-mode three-wavelength-intervals with millimeter waves and dual-color infrared. The receiving of irradiation signals employs a shared antenna that is compatible with the dual-mode phase, as well as the corresponding structure. To search and track the targets, conical-shaped scanning is employed in the millimeter wave system, and the multi-lobe rose curve or the reciprocating spiral scanning is employed by the infrared system. The dual-color infrared system is good in resolution, high in positioning precision, small in guidance blind zone, and high in antijamming functions, in addition to the capabilities of background suppression and discriminating between real and false targets. The millimeter wave system has the capability of acquiring the information on target distance, orientation, and velocity. Moreover, the system can better penetrate rain, snow, clouds, fog, and battlefield smoke and dust, thus being beneficial to all-weather combat. Moreover, the adoption of active millimeter waves and entirely-passive infrared guidance can carry out the tactical application requirements in fire-and-forget. However, since the millimeter wave has a wide frequency band and the combined system operates in three wavebands, it is very difficult for the enemy to jam. Even camouflaging and stealth techniques are hard to be effective. Therefore, the combination of these two modes can supplement each other in operations. It was reported that the U.K. Royal Academy of Aircraft Research proposed developing guidance heads (MIRTH, 3mm, 3 to 5 as well as 8 to 14micrometers), with a combination of millimeter waves and dual-color infrared phase. In their view, the adoption of the dual-mode guidance can greatly simplify the capacity of data processing and can lower the requirements on each type of single-mode system, therefore it is expected to replace the complicated guidance head with a single frequency. However, the structure of dual-mode terminal guidance and the electronic signal processing are still relatively complex, with more difficulties in technology. In particular, when using artillery to fire missile, problems of endurance against high g-loads and miniaturization should be solved, in addition to the capability of the dual-mode approach. These problems should receive adequate emphasis in design and development.

Finally, we must give the following explanation. Although artillery can fire terminal-guidance rounds and sensitive terrain-following missiles, in addition to the fire-and-forget property, yet their operating principle and application methods are still different. Terminal-guidance artillery rounds have a large field of view with its search area as large as $2x10^5 m^2$. Their control system and rudder apparatus are installed in the round. At the terminal-guidance segment, the round can automatically search for and track targets with higher hit accuracy. Therefore these rounds are effective weapons in dealing with tanks, armor, or other hard targets. However, the structure of these rounds are complex, with heavy weight (about 60kg), as well as high cost. The sensitive terrain-following missile does not have a control system, so the missile can only search for targets while in free-fall and is not able to change direction in flight; the search area is about $2x10^4 m^2$ and the hit probability is also lower than the terminal-guidance artillery rounds. However, the sensitive terrain-following missile is simpler in structure, smaller in size, lighter in weight (about

15kg), and lower in cost. Frequently, the form of the dispenser and bomblets is applied therefore it is very suitable in attacking target clusters.

With respect to the references, since there are quite a number of sources, the author is unable to detail them. Therefore, they are not included. However, if readers have interests in problems of some areas, they are welcome to contact the author.

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