Bull's Eye with Precision Guidance

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Introduction

Employment of artillery guns started with aiming directly at the target but as the gun range increased, firing had to be indirect, with observers deployed forward to observe the target and direct fire on it. Many techniques were developed to make the fire accurate and fast. The process of 'ranging' on to the target wasted ammunition and was time consuming. The effects of weather, gravity and natural dispersal of the ammunition were taken into account while correcting fire onto the target. Engaging a moving target by indirect fire was almost impossible. Efforts have been on since World War 1 to make the engagement of targets from land, sea and air as accurate as possible but technology has been lagging behind. Every weapon, apart from having mobility, destructive power and range, should be able to engage the target with precision. The evolution of Precision Guided Munitions (PGMs) started with the attempt to combine all these attributes in a single weapon. The current family of PGMs for land, sea and aerial platforms has all this and a lot more. The normal dispersion of artillery can be around 175 m at 20 km and 273 m at 30 km which has been brought down to within 50 m or less. Such accuracy saves ammunition, reduces collateral damage and is more destructive, with a very short reaction time.

During the Cold War, there was great reliance on nuclear warheads but in 1984 (the Cold War ended only in 1991), Mshl Ogarkov of the erstwhile Soviet Union was of the view that developments in non-nuclear means of destruction, which

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included everything from precision munitions to fuel-air explosives, would "make it possible to sharply increase the destructive potential of conventional weapons, bringing them closer to weapons of mass destruction in terms of effectiveness." In 1993, the US Office of Net Assessment also felt that low-intensity or unconventional warfare would continue to be the "most prevalent form of conflict". The erstwhile Soviet Union always believed in developing conventional forces along with nuclear weapon capability. The US pioneered the long range precision reconnaissance strike and also realised the importance of short-range precision strike with Guided Rockets, Artillery, Mortars, and Missiles (G-RAMM). The accuracy of these weapons is dependent both on the accuracy of the measurement system used for locating the target and the precision with which the coordinates of the target can be fed into the system. Precision strike with G-RAMM does not need very elaborate support systems for target selection and guidance but can be very effective against high value static targets. There are guidance technologies like laser, infrared, millimetre wave radar, LADAR (light detection and ranging), etc. The guidance can also be provided by inertial guided systems supported by satellites having Positioning, Navigation and Timing (PNT) capabilities like the Global Positioning System(GPS) of the US. Russia has the GLONASS satellite navigation system, China is working on the second generation of a third PNT system, the Beidou; the Europeans plan to have a fourth PNT constellation, the Galileo, which will be fully operational by 2019 and India is developing the Indian Regional Navigational Satellite System (IRNSS). All this will make some of the G-RAMM systems really 'ubique' (everywhere) which is also part of the motto of the Royal Artillery and its Sanskrit translation '*Sarvatra*' of the Indian Artillery. Precision guidance implies that there is no limitation of engaging every possible target.

Guidance Technologies

The Germans were the first to introduce PGMs when they attacked the Italian battleship *Roma* in 1943 with a 1,400-kg Fritz X. The Germans used radio control or wire guidance. The closest the Allies developed such a system was the 454 kg AZON (AZimuth ONly). The US also tested the rocket-propelled Gargoyle which never entered service. It also tried various guidance systems based on TV, semi-active radar and infrared. The Japanese PGMs were not used in combat except for the air-launched, rocket-powered, human-piloted Ohka suicide flying bomb.

Radio-Controlled Weapons

The British tried radio-controlled remotely guided planes laden with explosive, such as the Larynx. The US used similar techniques with Operation Aphrodite with little success. During the Korean War, the US again started trying out the electro-optical bomb (or camera bomb) which was equipped with TV and flare sights. The camera gave the location of the target with the help of which the bomb could be steered by the sighting system onto the target. The control signals to guide the bomb were sent from the aircraft to the steerable fins of the bomb. The camera bombs were also used in Vietnam. The Tigercat Surface-to-Air-Missile (SAM) was guided onto the target through a radio. The Tube-launched, Optically tracked, Wire-guided (TOW) missile system is another example of using the wire to transmit signals to guide the missile onto the target. Milan and Malyutka anti-tank missiles are two such examples. The wire was used to transmit the signals as the radio could be jammed but the wire limited the range. Raytheon's Maverick AGM-65A anti-tank missile also uses the electro-optical guidance system.

Infrared Guided Weapons

Infrared (IR) light is electromagnetic radiation with longer wavelengths than those of visible light and includes most of the thermal radiation emitted by objects at near room temperature. Objects like people, vehicle engines and aircraft generate and retain heat which is visible in the infrared wavelengths of light when compared to objects in the background. Emission of this IR is used to track a target which is called IR guidance and is used for passive guidance of missiles. Such missiles are also called heat seeking missiles. Smaller missiles, especially man-portable air-defence systems normally use the IR homing guidance system which has the advantage of being "fire-and-forget". The US Stinger and Maverick(AGM-65D), the Russian SA-18 Igla and the Chinese FN-6, are some examples of IR guidance.

Laser-Guided Weapons

Laser guidance was first applied to aerial bombs to achieve greater accuracy as they were cheaper than employing a guided missile. Laser-guided weapons were first developed in the US and UK in the early 1960s. Some laser guided systems utilise beam riding guidance, but most operate on semi-active laser homing. In this technique, the target has to be illuminated with a laser which then assists the bomb to accurately hit the target. The US Air Force gave the first development contracts in 1964 which resulted in the development of the Paveway Laser Guided Bomb(LGB) which were used effectively in Vietnam. The Paveway series continued to be developed, adding new features for their effectiveness and accuracy. Later versions were used in the Gulf War. The Raytheon Paveway IV LGB is a dual mode GPS/INS(Inertial Navigation System) which entered service with the Royal Air Force (RAF) during 2008. The latest in the series is the GBU-59 Enhanced Paveway II. Other examples are the LAHAT (Laser Homing Attack or Laser Homing Anti-Tank) of Israel, the Maverick AGM-65E anti-tank missile and the AGM-114 Hellfire of the US. BAE Systems' Advanced Precision Kill Weapon System (APKWS) laser-guided rocket which is under development, is another example of laser guidance. APKWS completed another major milestone when it was fired for the first time from an AH-64D Apache helicopter during flight testing. The APKWS laser-guided rocket bridges the gap between unguided rockets and larger guided anti-tank munitions.

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In beam riding guidance, a laser beam is used by the missile to ride on it for guidance towards the target. Beam riding guidance was introduced during the 1990s with the introduction of low-cost portable laser designators. Laser beam riding is generally used for short-range anti-tank and anti-air missiles like the British SAM Starstreak, Swedish SAM RBS 70, Brazilian anti-tank MSS-1.2 and Russian anti-tank 9M119 Svir.

Millimetre-Wave Radar

Active radar guidance technology was earlier used for anti-ship and surface attack weapons. It has now also been integrated into the land attack missiles. Radar seekers can be augmented by other elements such as electro-optical GPS, LADAR, etc. Another application of millimetre wave radars is to detect and identify and engage armoured vehicles and other high value targets as it provides a very high resolution, all weather capability and is difficult to jam. In the third generation of Anti-Tank Guided Missiles (ATGM), it provides lock-on-before-launch capability. The Indian ATGM Nag also uses a millimetre wave radar seeker which is under development. Lockheed Martin's AGM-114 Hellfire is an air-to-surface ATGM which also uses a millimetre radar as its seeker.

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Satellite-Guided Weapons

The Gulf War brought out the importance of PGMs but their employment was degraded by poor visibility. This problem was overcome by satellite-guided weapons which employ GPS and are all weather systems. As the GPS can be jammed, these weapons have inertial navigation as back-up. There are many examples of satellite-guided weapons. HOPE and HOSBO are a new family of precision-guided munitions used by the German Air Force that use GPS/INS and electro-optical video feedback for guidance. Satellite-guided weapons are likely to be more effective in adverse conditions than any other PGM, provided the target coordinates are accurate. The Joint Direct Attack Munition (JDAM) kit has been developed by the US to convert unguided bombs into all-weather guided bombs. JDAM-equipped bombs are guided by INS guidance, coupled to a GPS. The AGM-154A joint standoff weapon is a fire and forget system which employs a coupled GPS/ INS for terminal guidance.

PGMs for the Artillery

M712 Copperhead: The M712 Copperhead is a 155 mm calibre projectile which is fin-stabilised and has laser guidance for terminal homing. It can be fired from M114, M109 and M198 howitzers and is very effective against tanks and artillery guns. It is longer and heavier than conventional ammunition. The problem is that it requires the target to be laser illuminated to guide the projectile. The Copperhead was used in a limited way during Operation Desert Storm and Operation Iraqi Freedom.

XM1156 Precision Guidance Kit: This is a US Army programme to develop a PG guidance kit(PGK) for 155 mm artillery shells. The PGK is screwed into the nose of the projectile, similar to a fuse. PGK will function like a fuse, provide GPS guidance and control surfaces to correct the flight of the shell. It is similar to the JDAM tail-kit which converts a dumb bomb to a smart bomb. Its Circular Error Probable (CEP) is less than 30 to 50 m which is an improvement over the 260 m CEP of an unguided 155-mm round at a range of 30 km. PGK is a cheaper option as compared to other systems.

XM395 Precision Guided Mortar Munition (PGMM): PGMM is a 120 mm guided mortar round which is guided by the Distributed Aperture Semi-Active Laser Seeker technology. The system consists of a GPS-guided kit which includes a nose and tail sub-system for manoeuvring the bomb. Its CEP is one metre and it is being used in Afghanistan as mortars are particularly effective in the mountains.

30F39 Krasnopol: The Krasnopol is a Russian 152/155 mm calibre projectile which is fin-stabilised and has semi-automatic laser-guidance. The target has to be laser illuminated to be guided. It is very effective against tanks, artillery guns or any small hard targets. India also has this system.

M982 Excalibur: The Excalibur is a 155 mm calibre PGM with extended-range and GPS guidance which is capable of providing accurate, first round, fire-for-effect capability. It has been developed by Raytheon Missile Systems and BAE Systems Bofors. It can be fired from two US Army howitzers, the Paladin and LW 155 and also from the Swedish Archer 52-calibre weapon system. The Excalibur has a range of approximately 40 to 57 km depending on configuration, with a CEP of around 5 m to 20 m. It is claimed that one round of the Excalibur can be equal to 10-50 rounds of conventional ammunition in effectiveness. The Excalibur was very effective in Iraq. An improved version of the Excalibur 1b is being developed by Raytheon which will provide greater range, increased accuracy and less collateral damage. During testing, the Excalibur 1b achieved exceptional accuracy, with the majority of the rounds landing within 2 m of the target.

GMLRS (Guided Multiple Launch Rocket System): Lockheed Martin has developed a new extended-range GMLRS with a range of more than 70 km which is in service with many countries. The GMLRS XM30 rocket has a combination of GPS and inertial guidance system for guidance, with small canards on the rocket nose to enhance accuracy. The US Army began using GMLRS rockets in Iraq in September 2005. The 200-pound warhead proved small enough for the weapon to be employed in urban areas against individual buildings without appreciable collateral damage. Statistics up to 2008 indicate that about 670 GMLRS-U rockets had been fired with 98.6 percent reliability.

Some Future Trends

The US has been leading in PGMs and the Defence Advanced Research Projects Agenc*y (*DARPA) has been progressing many PGM development programmes through its many offices. The US defence forces have also been developing precision technology. A few examples are given below:

Adaptable Navigation Systems (ANS): GPS is a very important for PNT for the military but GPS can be easily blocked by jamming, inside buildings, under dense foliage, underwater or underground. ANS attempts to provide GPS-quality PNT to military users even in a difficult operational environment through the Precision

Inertial Navigation Systems (PINS) and All Source Positioning and Navigation (ASPN). PINS and ASPN provide better Inertial Measurement Units (IMUs) that require fewer external position fixes, alternate sources to GPS for those external position fixes and new algorithms and architectures for rapidly reconfiguring a navigation system for a particular mission. PINS is developing an IMU that uses cold atom interferometry for high-precision navigation without dependence on external fixes for long periods of time. However, since long-duration IMUs also require an eventual position fix, the ASPN effort is developing sensors that use signals from sources like television, radio, cell towers, satellites and lightning. At present the system is in Phase 2 of development and demonstration of GPS-independent PNT is being planned for 2015.

Extreme Accuracy Tasked Ordnance (EXACTO) and Counter-Sniper Program (C-Sniper): EXACTO seeks to improve sniper effectiveness and improve own safety of the sniper by providing longer standoff range (both by day and night), better accuracy and reduced time of target engagement. This is being achieved by developing the first ever guided small-calibre manoeuvrable bullet which is guided by a real-time guidance system to track, guide and achieve bull's eye on the target. It is based on the 0.50 calibre Browning machine-gun. C–Sniper does the exact opposite of EXACTO by detecting the sniper and neutralising him. Both the programmes are trying to achieve accuracy with speed.

Counter Rocket-Propelled Grenade and Shooter System with Highly Accurate Immediate Responses (CROSSHAIRS): CROSSHAIRS is a modular, vehicle-mounted, threat detection and counter-measure system that locates and engages enemy shooters. It will take on bullets, rocket propelled grenades, ATGMs and mortars. The system will also be effective while moving. The system combines radar, the Boomerang sniper detection system, a remote weapon station and an enhanced precision locating and reporting system apart from other sub-systems to provide 360 degree "counter shooter coverage". This seems an overly defensive approach to combat.

Micro Inertial Navigation Technology (MINT): MINT attempts to develop a highly accurate navigation aid that directly measures intermediate variables, such as velocity and distance. The aim is to reduce the error which creeps in while integrating signals from accelerometers and gyroscopes. This could be placed in the sole of a shoe to help soldiers to correctly navigate through thick jungle or dense urban terrain. It could be also used by Unmanned Aerial Vehicles (UAVs) for precise flying which would be the first step for a precise strike.

Shortwave Infrared (SWIR): SWIR cameras are already in use for imaging and target recognition in starlight conditions while receiving adequate illumination from the weak natural phenomenon known as atmospheric nightglow. They are now being developed for terminal guidance systems.

Guided Small Arms Ammunition: Efforts are on to develop precision-guided small arms ammunition using a laser designator to guide an electronically fired bullet or using a laser range finder to detonate shells close to the target. Apart from the effectiveness, the cost benefits will have to be kept in mind.

Directed Energy Weapons: They are the future PGMs and development efforts are on in many countries, including India.

Conclusion

Precision guidance is affecting all aspects of warfare, from navigation to PGMs. PGMs are accurate, faster and prevent collateral damage. They reduce the size and quantity of the munitions required on the target. Cost is a stumbling block in developing countries like India which find it exorbitant. Availability of technology is another grey area as advanced countries like the US will not part with it and the Defence Research and Development Organisation (DRDO) is finding it difficult to develop an active seeker – the ultimate in precision guidance. The other aspect is the effectiveness in the mountainous terrain which India discovered by experience during the Kargil operations. Mountainous terrain and rarefied atmospheric conditions affect ballistics in unpredictable ways which the Indian Army experienced when its artillery first fired in Ladakh. The existing weapon range tables were just not applicable as they were designed for the plains. Ricochet effect in the mountains is also difficult to predict. However with time, affordable technology will be available, and the problems of atmospheric conditions and ricochet in the mountains will be resolved.

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