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Precision Weapons in Aerial Warfare

Vivek Kapur

Gp. Capt. Vivek Kapur is Research Fellow at the Institute for Defence Studies & Analyses (IDSA), New Delhi

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Summary

Precision weapon delivery has come into the general public's mind space especially in the past two decades. While technology did not permit the achievement of great precision in earlier years, today technology has delivered the ability to place weapons at desired locations with great accuracy, currently measured in a few metres. Precision in aerial warfare, which initially lay in the individual skills of combatants, has shifted to machines through the incorporation of advanced technology. Today precision is more widespread on the battlefield that at any time in history. Indications are that in the coming years, the development of Directed Energy Weapons (DEW) will give greater magnitudes of precision than are available today.

Precision in warfare has been a much sought after capability that was realised when modern technology matured adequately. Precision has changed the very nature of aerial warfare in particular. Today modern air forces have the ability to put a bomb through a chosen window with confidence. However, trends indicate that in future precision weaponry could migrate towards directed energy weapons that have the potential to deliver a degree of precision that lies in the realm of science fiction today. It is important for all aspirants towards viable military power to work towards operationalising these energy weapons in the near future.

Introduction

Precision in aerial warfare came into prominence and entered the common man's mind-space during and after the First Gulf War of 1991 when the electronic media brought live images of modern precision targeting into our homes through coverage of the US led air-campaign against Iraq. However, precision has remained a central desire in war fighting since times immemorial. In ancient times the wielder of a sword and spear required to apply the business end of his weapon at specific parts of the opponent's body for the desired effect. If the application was precise enough, too much force would not be required to achieve the desired end of incapacitating or killing the enemy combatant. With advancements in the technology of war fighting, longer range weapons such as the bow and arrow came into use. The bow and arrow likewise required the projectile, the arrow, to impact the intended target at very specific parts for maximum effect. Still later, advancements in the technology of war required weapons to defeat body armour worn by combatants through impacting on the known or presumed weak points of the armour.

In the naval arena ships initially fought primarily through launching projectiles at each other. In the early era of muzzle loading cannon when technology did not allow the path of the projectile to be accurately predicted ships resorted to "shot gun" style attacks. Cannons were arrayed in large numbers along the side of warships. Through turning the side of their ship towards the enemy the cannons were fired in full side firing together salvos, using the "shotgun" principle, with the aim that out of a full broadside of cannons fired an adequate number of cannonballs may hit the opponent and cause catastrophic damage. In later years, when the trajectories of shells fired from more modern ship cannons became more predictable, broadsides were dispensed with and guns were now fired for the impact of individual shells on the enemy vessel. This led to the path towards precision in weapon delivery at sea, finally progressing towards guided ship-to-ship missiles.

The discussion above makes clear that far from being a new military desire, precision in weapon delivery has always been a human endeavour. What was different in earlier times was that the technology then available did not allow the degree of precision available to modern military forces.

Precision in the Air

Precision in Air-to-Air Engagements. Soon after the induction of aircraft for war fighting, military commanders saw the utility in being able to use the third dimension to gain intelligence on enemy dispositions and movement while denying the enemy similar information. Aircraft proved so effective that denying the enemy the use of his aircraft soon became a military necessity. The arming of aircraft to shoot down other aircraft commenced during World War-I with pilots carrying personal firearms aloft and using these to shoot at opposing aircraft. This, predictably, gave fairly poor results as the pilot had to fly at the same time as using his handheld firearm. The next step was the fitting of guns and machine guns to the aircraft itself. The development of interrupter gears enabled these guns to fire forwards through the propeller disk without causing catastrophic self damage. In the years between the two Word Wars, advances in sighting techniques led to the development of basic "ring and bead" sights for aircraft guns along with the theory of deflection shooting. During the Second World War "reflector" gun sights were developed as were basic gyro gun sights. Both these new devices made the firing of aircraft guns more accurate. The results obtained however were greatly dependent upon the pilot's skills. A few gifted pilots were able to put the bulk of their bullets fired from a moving platform into the small manoeuvring targets. The majority, however, found this an unachievable task. Technology finally came to the rescue with the development of air-to-air guided weapons. The first of these was the Luftwaffe's X-4 wire guided air-to-air missile, developed and inducted in the last few months of World War-II.[1]

The wire guided German X-4 was found impractical beyond fairly short ranges due to wire length (just four miles) limitations. An alternate means of guidance was sought in the 1950s and 1960s. This alternate guidance method was achieved through the use of radar. This guidance system required the guided missile carrying aircraft to illuminate the intended target with its airborne radar. The missile incorporated a radar receiver tuned to the same frequency. On picking up radar energy reflected from the target a relatively simple electromechanical autopilot onboard the missile controlled its control surface deflections to guide the missile on an interception path towards the target. Such missiles required launch aircraft support throughout their flight path as guidance depended upon the launch aircraft continuously illuminating the target on radar, for getting the required radar reflections, till missile impact. This guidance was dubbed Semi-Active radar homing (SARH) and the first US missile of this type to enter service was the Air Intercept Missile (AIM)-7 "Sparrow", more advanced variants of which can still be found in the inventories of a few air forces.

An alternate technology utilised infra red (IR) emissions from target aircraft engines. In this technique the missile carried a suitable IR seeker that detected and locked onto the

1 "Ruhrstahl X-4 Air-To-Air Missile," http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=1050, accessed 04 May 2012.

enemy aircraft's IR emissions and then guided the missile through the generation of control surface deflections to impact the target. This guidance system had the advantage of requiring no launch aircraft support post missile launch and swiftly became very popular. The first such missile to enter service was the AIM-9A/B "Sidewinder" of which the AIM-9L and later variants continue in front line service today. Advances in sensor and guidance technology have made the more modern variants of such missiles extremely accurate and difficult to evade. Radar guidance has evolved towards active radar homing missiles. These missiles carry their own radar transmitter and receiver and after approaching within their onboard radar's range from the target are totally independent much like IR guided passive missiles are.

Traditionally IR guided missiles were close combat or Within Visual Range (WVR) weapons while radar guided missiles were Beyond Visual Range (BVR) weapons. However, a few modern IR missiles such as the Israeli Python5 and Russian R-73E IR missiles boast maximum launch ranges tending towards BVR. The initial missiles exemplified by the US IR WVR AIM-9A and B Sidewinder variants and BVR radar semi-active AIM-7 Sparrow had limited capabilities and quite poor "in use" results. More recent missiles such as the AIM-9L and AIM-9X, Russian R-73, Israeli Python-4 and 5 in WVR and US AIM-120 **A**dvanced **M**edium **R**ange **A**ir-to-**A**ir **M**issile (AMRAAM), French **M**issile d'**I**nterception et de **C**ombat **A**érien (MICA), Russian R-77, Israeli Derby in the BVR radar guided category field much better capabilities. The trend is towards the increasing ability of these modern missiles to operate in a dense Electronic Warfare (EW) environment, and to increase their engagement envelopes. The trend towards higher precision in air-to-air warfare continues still.

The change in the recent past has been that while in earlier years earlier precision lay in the skills of individual aircrew, today this has been transferred to the equipment itself. Even a relatively inexperienced and unskilled pilot firing a modern air-to-air missile has a very good chance of hitting his target very precisely. This transfer of precision from man to machine makes precision much more ubiquitous in the battle-space. Great strides have been made in air-to-air precision weapons. These are broadly classified in terms of their ranges (BVR) and (WVR) and also by the kind of guidance utilised, Infra Red (IR) homing, active Radar homing or SARH. The *Astra* missile being developed indigenously by DRDO is an active radar homing BVR missile.

Precision in Ground-to-Air Weapon Delivery. As aircraft became more effective in shaping the battlefield their destruction by ground forces became more sought after. Initially simple guns already in use in land battles were adapted for this task. Shortcomings led to multiple barrel guns for higher rates of fire etc. Despite this, in World War-II it required hundreds of rounds to be fired for each aircraft kill.[2] Radar guided guns were developed to increase the

2 "Antiaircraft Action Summary World War II," http://www.ibiblio.org/hyperwar/USN/rep/Kamikaze/AAA-Summary-1045/index.html#II, accessed 30 April 2012.

success rates, but, this development coincided with rapid increases in aircraft speeds brought about by the jet engine and the round to hits ratio stayed stagnant and even at times worsened in the 1950s and 1960s. Further searches for an effective solution led to the development of surface to air guided weapons (SAGW). Early models of these also suffered from low success rates. In Vietnam dozens of Soviet Surface to Air Missile (SAM)-2s had to be fired per aircraft kill.[3] More modern missiles such as the KBP 2K22/2K22M/M1 Tunguska SA-19 "Grison", S-300 PMU1/2 SA-10 "Grumble", Akash, Osa AK SA-8 "Gecko", Patriot PAC-3, reportedly have much better success rates and have become so lethal[4] that most air forces have been forced to add a new mission, that of Suppression of Enemy Air Defence (SEAD), as an essential component of all air attacks against targets known to be defended by SAMs.

Precision in Air-to-Ground Weapon Delivery. The development of attack on ground forces from aircraft followed a similar story to that of air-to-air. The first air-to-ground air attack took the form of four 4.5 pound (lb) grenades dropped manually by Italian pilot Lt. Giulio Gavotti on Turkish ground forces on 01 November 1911.[5] Later bombs were fixed on the aircraft and dropped through the utilisation of rudimentary sighting devices leading progressively to better sighting techniques, which all shared the characteristic of the individual pilots' handling of the sighting system having a major effect on weapon delivery accuracy. A few gifted pilots achieved surprisingly accurate results which evaded the bulk of pilots. Once again precision vested in individuals and so was not easily replicable or widespread.

Precision weapon delivery has had a much greater impact in the air-to-ground domain. During World War-II, bombers carried a specialist bombardier tasked to operate intricate bombsights designed to achieve accurate delivery of the weapon load on target. Despite this the technology then available did not give particularly encouraging results. For instance, in 1944, 47 US B-29 bombers raided the Japanese Yawata steelworks and only one aircraft hit the target with just one of its 500 lb bombs and that too in a relatively less important part of the target; this single bomb hit represented just 0.25 per cent of all bombs dropped on that mission.[6] In World War-II, to hit a 60 foot by 100 foot target with a 90 per cent

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3 "Surface to Air Missile Effectiveness in Past Conflicts," http://www.ausairpower.net/APA-SAM-Effectiveness.html, accessed 30 April 2012.

4 In the 1973 Yom Kippur War, the Israeli Air Force faced a comprehensive array of the then new SAM-III and other anti-aircraft weapons on the Golan Heights and on 7 October 1973 suffered such heavy losses to SAMs that air operations were suspended until technical and tactical means to counter these SAMs could be devised.

5 Raul Colon, "The first bomb attack," http://www.century-of-flight.net/Aviation%20history/up%20to%20WW%201/first_bomb.htm, accessed 30 April 2012.

6 Richard P. Hallion, "Precision Guided Munitions And The New Era Of Warfare," http://www.fas.org/man/dod-101/sys/smart/docs/paper53.htm, accessed 03 May 2012.

probability of success with dumb (unguided) bombs required 9070 bombs carried on 3024 aircraft. These figures reduced to 1100 bombs from 550 aircraft in Korea and further reduced to 176 bombs from 44 aircraft in Vietnam[7] illustrating not only the advances in sighting systems, but also bringing out the immense effort needed to hit small targets from the air.[8] These figures highlight the very heavy effort required to destroy a ground target through aerial attack using unguided bombs.

Technology was pursued to give viable solutions to this problem. Once again, the Germans showed great innovation in developing the world's first air-to-surface precision weapon in form of the Fritz-X or PC-1400X. This was a 3450-lb glide bomb intended for use against ships and was designed with the ability to penetrate up to 28 inches of armour. The bomb featured a flare on its tail through visual sighting of which the operator on the bomb's launch aircraft sent radio commands to the bomb to make relatively minor corrections to its trajectory towards the intended target. This precision guided bomb was used on 9 September 1943 to sink the Italian battleship *Roma* off Sardinia to prevent its surrender to the Allies.[9] The first in-service modern air-to-ground precision weapon was the US Air to Ground Munition (AGM)-12 "Bullpup". This weapon used radio command guidance wherein the launch aircraft crew tracked the weapon through sighting a flare on its rear and through small joystick generated radio command signals to make the weapon manoeuvre towards its target.[10] Other guidance means included the AGM-62 "Walleye"'s optical guidance using a camera in the bomb's nose to pick up the target and lock it on to self guidance towards the subject in the centre of the camera screen. The Guided Bomb Unit (GBU)-8 had a similar guidance principle as the Walleye. The first laser guided bomb was the Texas Instruments developed Bomb, Laser, and Terminal Guidance (BOLT) -117, later re-designated as GBU-1[11]. Here the launch aircraft illuminated the target with a laser beam. The bomb incorporated a laser energy receiver that picked up laser energy reflected by the target and homed onto it. Its successors are today's Paveway-I, II, III and IV laser guided bombs.[12] The later Paveway variants also incorporate a GPS receiver to supplement

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7 The bomb vs. aircraft numbers indicates the bomb carrying capability of the bombers of these periods. It is seen that bomb loads in numbers of bombs carried have slowly reduced in parallel with increases in the accuracy of bomb delivery. Or bomb load is inversely proportional to the delivery accuracy of the aircraft weapon delivery system.

8 Ibid.

9 "German "Fritz X" Guided Bomb," http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=15564, accessed 07 May 2012.

10 Paul G. Gillespie *Weapons of Choice: The Development of Precision Guided Munitions* (Tuscaloosa: University of Alabama Press, 2006), p.106.

11 "Texas Instruments Paveway I & Pave Storm," http://www.designation-systems.net/dusrm/app5/paveway-1.html, accessed 30 April 2012.

12 "Getting Closer: Precision Guided Weapons In The Southeast Asia War," http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=18095, accessed 03 May 2012.

the laser guidance, which is especially useful in conditions of low atmospheric transparency caused by dust, smoke or moisture.

While, as is evident, several different guidance methods have been tried out in the electromagnetic spectrum, the most popular remain electro-optical, laser, and IR for their benefits of desired accuracy combined with ease of use in acquiring and engaging targets especially from single seat aircraft where the pilot has other pressing tasks to perform as well.

An Assessment

Precision weapons especially in air-to-ground delivery derive several benefits that are pertinent to look at especially as there is often an acrimonious debate about the high cost of such weapons and thus the question of their affordability. It is true that precision weapons cost a great deal. A single US Paveway-II GBU-10 weapon reportedly costs US $23,700 in a large production batch. But this weapon gives a circular error probable (CEP)[13] of just nine meters.[14] Bombers are expected to be challenged by the enemy's air defence fighters as well as ground based anti-aircraft defences. In such a situation, a few bomber aircraft are likely to be lost to enemy action. It is reasonable to expect that the more bombers one sends across the border the more aircraft may potentially be lost. We have seen that historically a very large number of aircraft were required to get even a small number of unguided bombs close to the target. With precision weapons, even a single aircraft carrying just one bomb may be able to destroy the target, thus removing the need to send large numbers of aircraft. Given that even with high precision weapon costs of upwards of $23,000 modern fighter-bombers cost more than $50-60 million, precision weapons actually work out much more cost effective.[15] This is without considering the human factor, of loss of highly trained aircrew killed or captured, which consideration would tilt the balance even more in favour of the widespread use of precision weapons.

Precision weapons have shifted the assessment of military action from counting the number of bombs or tonnage delivered in earlier years to assessments of the politico-military effect or result achieved. This has led to offshoots in military thought such as Effect Based Operations (EBO) etc.

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13 CEP is a figure obtained through extensive trials. A CEP figure indicates a 50 per cent probability that weapons dropped under similar conditions will drop within a circle of the given CEP radius from the centre of the aim point used.

14 "Guided Bomb Unit-10 (GBU-10) Paveway II," http://www.fas.org/man/dod-101/sys/smart/gbu-10.htm, accessed 02 May 2012.

15 "Weapon Costs," http://www.caat.org.uk/resources/facts-figures/weapon-costs.php, accessed 03 May 2012.

Future Trends

Given the great change that precision weapons have brought to aerial warfare, it is projected that efforts will continue towards the development of even more effective precision weapons in future. Considerable research effort is now being directed towards the development of directed energy weapons (DEW).[16] These weapons comprise means of directing energy precisely towards a target. As these weapons direct electromagnetic (EM) energy of different wavelengths towards targets, they have characteristics of very fast impact on target as EM radiation travels at the speed of light and can be focussed into very narrow beams (read precision). Lasers, microwave radiation, particle beams etc. are part of this category.[17] The US and Russia lead in these new weapons technologies.[18] China is believed to be putting in an appreciable research and development effort into this field as well. It behoves any nation aspiring to field modern military power in the 21st century to carry out focussed research and development into DEW, as these are likely to cause a change in the character of warfare as major as that brought about by gunpowder. DEW have the potential to be very precise as they mainly comprise very tightly focussed beams of electromagnetic energy, thus bringing a new level of high precision in aerial and other warfare.

Impact of DEW on Aerial Warfare. DEW developments are likely to have a great affect on the conduct of aerial warfare. Currently aircraft are limited in their effectiveness by the weapon load carried on board. Developments aimed towards producing more compact DEW could lead to incorporation of these on board aircraft. DEW armed aircraft would be limited only by the ability to generate the power required for multiple firings of their DEWs. As aircraft engines develop considerable power and also drive on-board alternating current and direct current electricity generators, the firepower carried on aircraft could see an exponential increase. DEW have the potential to be employed against multiple types of targets unlike today's specialisation of weapons into air-to-air and air-to-ground categories. For instance, a MiG-29 could today carry two air-to-ground 250 kg bombs and four air-to-air missiles. Thus, its weapons load is split between air-to-air and air-to-ground use. If it encounters targets in a particular domain exceeding its weapons carriage tailored towards that domain, it would be forced to forego engaging it. With DEW on board, this limitation is unlikely to exist as, for instance, a microwave- or laser-based DEW is likely to be as effective against an aircraft as against a tank or against a ship. Thus, the incorporation of DEW is likely to make aerial warfare more lethal and aircraft more capable against multiple target types.

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16 Leonard David, "E-Weapons: Directed Energy Warfare In The 21st Century," http://www.space.com/1934-weapons-directed-energy-warfare-21st-century.html, accessed 04 May 2012.

17 "U.S. microwave-weapon tests revealed," http://phys.org/news5382.html, accessed 04 May 2012.

18 "Airborne Laser Test Bed (ALTB)," http://www.boeing.com/defense-space/military/abl/, accessed 04 May 2012.

Precision by Cyber Means. It bears considering that cyber warfare can also offer great precision if utilised properly. Against an opponent who has a very information-enabled war fighting structure, a carefully executed cyber attack can be devastating as it could potentially cut the higher command organisation off from the fighting forces while at the same time denying the field forces information required for their effective action. If utilised against a highly networked Air Force like that of the US, cyber attacks could potentially sever the communication links between higher command and fighting forces. The latter would be ineffective in the absence of inputs on the commander's plans and task inputs. Likewise, the field forces could be deprived of intelligence and situational awareness inputs through cyber attacks on their data networks. Such deprivation could make these aircraft very vulnerable to enemy action. The fact that most modern air forces including the Indian Air Force (IAF) and the People's Liberation Army Air Force (PLAAF) are moving towards becoming network-enabled in a big way makes addition of this aspect to the study of precision in aerial warfare vital. The earlier requirement was to target the enemy's command and control structure through delivery of bombs on their physical locations. Through intelligent use of cyber warfare, these physical attacks could be replaced with a very precise cyber weapon that is inserted into the enemy's cyber network where it effectively disables the enemy's higher command and control. Aircraft could form the carrier of such cyber weapons as the enemy's cyber network; however protected it may be on the ground through physical protection, encryption and use of buried and secure fibre-optic cables, it would still require operating in wireless modes for networking with the airborne elements. This wireless part of the adversary's cyber network could be penetrated by cyber weapons carried on friendly fighters that fly within the footprint of the enemy's wireless cyber transmission and reception space. The cyber weapons could be inserted into the enemy's computer network through his wireless network where and when required.

The potential of cyber weapons as precision weapons in aerial warfare is probably at the heart of the US Air Force forming and running the Cyber warfare Command. In view of the PLAAF's rapid "informationaslisation", it is prudent for the IAF as well to seriously examine the potential of cyber warfare techniques in aerial warfare.