PRECISE AIR STRIKE TO LOWER RISK TO CIVILIANS

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Capabilities of the modern fixed- and rotary-wing aircraft give an advantage in many aspects of warfare, however the same aircraft can bring about unintended damage and casualties. The unwanted effects of air operations attract more attention from the public opinion comparing to other means of military services. The real problem in military conflicts is to keep the risk to civilian population at the lowest level possible. Modern weapon systems can help to lower the level of collateral damage.

K e y w o r d s: collateral damage, risk to civilians, precision strike, non-lethal weapons

1. INTRODUCTION

Despite the number of operational advantages from the use of military aviation in conflict, there is inherent threat to innocent civilians from the air operations, much higher comparing to other military actions taken. The risk to civilian population takes on various forms of damage to person and property. Such unwanted effects related to military engagement are commonly known as *collateral damage*. The suffering of civilians during every military conflict is a very important part of wartime planning, basically from humanitarian reasons. It plays a significant role not only for military personnel, but for political leaders, as well. The problem of exploitation by enemy of any collateral damage occurrence can both hamper own military operations, as well as even make a government collapse.

The easiest way to protect people is to obey the international law that refers to military conflicts. As the numerous conflicts all over the world showed, the international legal regulations sometimes occur to be not enough to prevent hostilities and effectively protect civilians. This is when the technology can make a profit to spare lives of innocent people, making military attacks, especially air strikes, more precise and less lethal.

2. WEAPON SYSTEMS

The air rides during the First World War were indiscriminate in their nature because of primitive avionics and weapon systems onboard. The situation changed during Second World War, however, equipment still did not allow precision strike that is indispensable to "separate" military and civilian objects when attacked. It was quite easy to lose geographical and situational awareness. Moreover, trying to dodge ground based air defence system, the pilots were not able to spot their targets from high altitudes, especially at night and when covered with clouds, fog or smoke. Therefore, to fulfil operational requirements the number of attacking aircraft had to be increased. In these circumstances, aircrews not seeing their targets, very often, released gravity bombs away from the objectives, bringing huge risk to regular people. The level of threat to civilians grew up as the aircraft weapon loads and warhead payloads rose.

Next military conflicts, like Korean War and Vietnam War, did not change the mainstream in weaponering. Massive attack was more "popular" than surgical strike, however, there were already known "controllable" munitions. In fact, the Germans were the first to use steerable (radio-controlled) munitions in combat in 1943. Great Britain and USA also tested similar weapons. In the 1960s, Americans worked on electro-optical (so called camera bombs), as well as laser-guided bombs. The two modern, at that time, weapon systems were employed in Vietnam, that allowed to reduce the risk both to own aircrews and civilian population, by lowering the number of required sorties over hostile territory to accomplish their missions. For comparison, during WW II it took 648 bombs to destroy a point target, whereas in Vietnam - 178. It is estimated that today it would require only a few pieces of precise armament [1].

Even though more precise, the weapons were not used on a considerable scale until 1991. The Gulf War faced the beginning of the use of precision weapons that was directly intended to reduce the impact of the war on Iraqi residents, cultural and religious sites, as well as the enemy infrastructure and economy. The real breakthrough came during the hostilities in the Balkans in the 1990's. Operation ALLIED FORCE was the first to see the use of the weapon systems on a large scale. There were very few civilian victims of the operation, however it needs to be underlined that it was a conflict of relatively small scale and impetus.

Illustration 1. BOLT-117 - the world's first laser-guided bomb (750 lbs).
Source: http://www.nationalmuseum.af.mil

The type of bomb with capacity of guiding to a target is called Precision Guided Munition (PGM). A PGM bomb, contrary to a gravity bomb (in other words *iron* or *dumb bomb*), contains electronic equipment that has the capability to direct towards the target using emitted or reflected electromagnetic radiation (EMR) in the last phase before impact , but in contrast to missiles, it does not have its own propulsion.

The electronic kit of the weapons consists of seeker and tracker. The seeker distinguishes changes of the level of energy received by its sensors. Below the threshold contrast level the unit will not activate. For protection from destruction, the unit has the maximum energy level set. The tracker controls the flight to the target. There are two types of trackers: edge tracker, that recognises areas of more intense contrast between target and its background, and centroid tracker, that guides to maximum or minimum of the energy reflected or emitted by the object. Using electro-optical sensors the unit may calculate flight towards brighter or duller areas, whereas using forward-looking infra-red (FLIR) sensors - hot or cold spots.

This type of weapons to be employed requires target acquisition systems. The simplest one is the human eye, however, though the most commonly used it is not effective, especially at night, in adverse conditions and at high speed. Apart from the human eye, there have been developed several technical systems to guide bombs to the objectives, basing on:

- radio control;
- electro-optical guidance;
- infrared guidance;
- infrared imagery;
- laser beam guidance;
- radar beam guidance;
- inertial navigation;
- satellite navigation.

Implementation of infrared imagery in target acquisition allowed to eliminate the deficiency of the human eye and TV-camera systems not being capable of spotting targets in darkness or covered with smoke, etc. The laser-based control proved to have the significant disadvantage of not being effective in poor weather conditions (illumination not possible or not seen illumination of a target). The problem can be solved with the radar guidance or satellite navigation. The former allows to track targets in all weather conditions, providing pilots with fire-and-forget guidance luxury, whereas the latter actually does not require any target acquisition systems onboard as the GPS system is used for control. The drawback of GPS-based approach is that the signal from the satellites can be jammed. The inertial navigation system (INS) does not have the disadvantage, since it does not need any external input data or steering beam, besides geographic coordinates of the objective. The precision of both the satellite and inertial navigation show the dependency on the precision of measurement systems and, what is crucial, on the precision of the target geographic coordinates itself. The latter critically relies on intelligence, reconnaissance and surveillance (ISR) input!

The experiences from Iraq and the Balkans as well as contemporary operational requirements influenced the military industry products. There have been introduced multiple guidance capabilities, like:

- Joint Direct Attack Munition (JDAM) – a INS/GPS guidance kit for a range of gravity bombs;

- Laser JDAM (LJDAM) – “laser-supported” JDAM – uses Imaging Infrared (IIR) seeker for laser guidance;
- AGM-154 Joint Stand-Off Weapon (JSOW) - an adverse-weather, short-range, standoff anti-armour / Suppression of Enemy Air Defence (SEAD) dispenser weapon that uses INS / GPS for midcourse navigation and infrared imaging for terminal homing;
- Armement Air-Sol Modulaire (Air-to-Ground Modular Weapon) (AASM) – features a guidance/hybrid navigation (Kalman filtering) system which combines the position supplied by a GPS receiver and INS data. For terminal homing the weapon can rely on IIR or laser seeker, too.

These kinds of advanced guidance concepts allow to reduce and even eliminate the impact of environmental conditions and jamming of GPS signal, improving the accuracy of the air strike. The great advantage of satellite guidance is the capability to send modified target geographic coordinates to the bomb after the release. It allows to avoid undesired fatalities and damage, unless it is not too late to redirect the weapon.

Experiences from the use of heavy precision bombs in Afghanistan and Iraq proved that these weapons are not as useful for fighting in urban areas as expected, especially for mobile targets. The main reason for that is the blast-fragmentation effect. To control the impact of blast, new kinds of fuses have been developed. The fuse lights with delay after a bomb hits an object and gets inside. It reduces the impact of a bomb outside a target, but there is still a danger that ceilings and walls of targeted building collapse, bringing collateral deaths, injuries and damage. While delivering bombs over point targets, like homes or vehicles, there was usually too much “power” in a warhead just to destroy the target. Complete destruction does not have to be a *conditio sine qua non* of success during a mission. Sometimes it is enough just to disable, to prevent from the use or to disrupt the target. It was not a single case to ruin adjacent buildings, vehicles or killing and wounding innocent people while hitting legitimate objectives.

The concept of Low Collateral Damage Bomb (LCDB) was the answer to the new requirements of the asymmetric warfare. The idea emerged during Gulf War, when United States Air Force (USAF) personnel replaced all explosives in 1000-lb laser-guided bombs with concrete and used it against Iraqi anti-aircraft missiles and guns, that were placed inside dense urban areas. Limited amount of explosives dropped on a specific target considerably reduces the radius of destruction and possibility of harm to civilians.

The growing demand for minimizing risk to civilians on the one hand, and capability to engage as many as possible targets in one mission on the other, pushed the weapon systems development towards precision increase along with reduction of explosives and dimensions.

The Small Diameter Bomb (SDB) is a low-cost means of low collateral damage capability. Boeing has been chosen as a winner of the contract for SDB. Its GBU-39/B is a multipurpose, insensitive munition designed for stationary targets, equipped with flip-out wings for extended standoff range more than 110 km (60NM) (Illustration 2). For guidance it uses INS aided by Advanced Anti-Jam Global Positioning System with anti-spoofing capability. The penetrating, blast-fragmentation warhead (206 lbs / 93 kg) is coupled with a cockpit selectable functions of an electronic safe/arm fuse (ESAF), including air or delayed burst options.

Illustration 2. GBU-39/B Small Diameter Bomb I
Source: www.aviationnews.eu

This is the first 250-lb class precision guided munition that is intended to limit collateral damage and to allow to attack more objectives per sortie. Four of the bombs can be carried as a replacement for 2000-lb GBU-109 bomb, using the same pylon, giving carrying platforms more flexibility. GBU-39/B has the advantage of being carried by classic air platforms, Unmanned Combat Aerial

Vehicles (UCAV), as well as stealth aircraft (in internal bays) [2]. Its interface fits eg F-16, F-15E, F-22A, F-35, B-1, B-2, B-52 aircraft. The Focused Lethality Munition (FLM) - GBU-39A/B - is an ultra low collateral damage version of its predecessor. The steel casing of GBU-39/B has been replaced with a composite casing combined with Dense Inert Metal Explosive (DIME) fill. The new explosives technology produces lower pressure but increased impulse in the near field, whereas there is no projectiles while detonated as carbon composite case is non-fragmenting material. This kind of air delivered weapon systems represents another huge step to spare innocent lives, while providing the military with a new capability to reach the sensitive targets so far inaccessible.

Illustration 3. GBU-53/B Small Diameter Bomb II
Source: www.defenseindustrydaily.com

SDB II constitutes the next stage of the SDB I development, as USAF required a precision tool to hit moving targets in all weather conditions from stand-off. Raytheon, with its GBU-53/B (Illustration 3), occurred to win the contract, however, the seeker is a joint Raytheon/Boeing technology. SDB II has the standoff range more than 72 km (40 NM) with INS/GPS guidance capabilities similar to SDB I, but its seeker features 3 modes of operation: semi-active laser, millimetre-wave radar, and uncooled imaging infrared. Combined with a warhead that delivers shaped charge, blast and fragmentation all at once, it enables GBU-53/B to have an excellent performance against a variety of targets in all weather conditions, making the bomb resistant to countermeasures and decoys, as well. The accuracy of INS/GPS system is increased by semi-active laser guidance. The insufficient performance of laser systems in heavy fog, clouds, sandstorms, etc. is balanced by the other two functions of the tri-mode seeker. The first of the two fire-and-forget modes uses millimetre-wave radar, ideal for movement detection, especially of metal objects. The second of the fire-and-forget capability is an uncooled IIR seeker that uses high-resolution thermal scans. These solutions make the bomb highly usable under any weather conditions. Moreover, the weapon system has an interface (the Universal Armament Interface - UAI) for aircraft-bomb communication that may be used for post-release re-targeting, sending data from a ground stations (using encrypted UHF radio frequencies) or an aircraft (using secure Link-16). Link-16 makes SDB II have the ability to be dropped by one aircraft and then targeted, re-targeted or even to be send an abort command by another platform. In case of the loss of the link, the bomb continues flight with its internal seeker. Sensor fusion grants the weapon system capacity to classify targets. SDB II can be “told” to prioritize certain types of targets, eg it can distinguish between tracked and wheeled vehicles [3]. Although the bomb itself has been tested, it needs to go through a series of tests in flight with a carrying platform. It is scheduled to begin in 2011 and last until 2018, as the fielding is sometimes tied to service introduction of a specific aircraft. Likely carriers of the weapon systems are F-15E, F-35B/C Block 4, F/A-18 E/F, A-10C, F-16, F-22A, F-35A, B-1B, B-2A, B-52 and MQ-9 UCAV.

GBU-44/B Viper Strike from Northrop Grumman is an air-delivered weapons of small size that can be dedicated to UCAVs. AC-130, MC-130 and AC-27J are “the manned aircraft” to be likely carriers of the bombs. GBU-44/B is an adaptation of BAT (Brilliant Anti-Tank), ground-launched anti-tank submunition. To gain capabilities for operations in urban terrain, the accustic/IIR guidance has been replaced with semi-active laser seeker for terminal homing. The midcourse guidance is based on GPS. Its tiny size entail small amount of explosives in warhead – 1 kg only – which means lower risk of collateral damage occurrence during attack [4].

Besides the “smart” bombs there are other systems - air-to-ground missiles - which can be used to precisely engage surface targets. Unlike bombs, missiles are self-propelled, what helps to home in on target and allows pilots to strike from standoff distance. The common terminal guidance systems include IR, laser or radar beam. Missiles, like smart bombs, can take advantage of implementation of a mixture of different guiding systems, eg:

- AGM-158 Joint Air to Surface Standoff Attack Missile (JASSM) – midcourse guidance of the cruise missile is provided by a GPS-aided INS protected by an anti-jam GPS system. In the terminal phase, JASSM may be guided by an IIR seeker and a general pattern match-autonomous target recognition system,
- Standoff Land Attack Missile – Expanded Range (SLAM-ER) - uses GPS/INS midcourse and IR terminal guidance. The missile can also receive in-flight target position updates on its midcourse flight.

Aircraft, especially rotary-wing and UCAV, can be equipped with comparatively smaller air-to-ground missiles, which inherently have smaller warheads, resulting in reduced scale of destruction. Within the class we can distinguish AGM-114 Hellfire / AGM-114R Hellfire II, as one of the most popular and reliable missiles. The new version has a semi-active laser seeker. The U.S. Advanced Precision Kill Weapons System (APKWS) program aimed at precision laser-guided weapon smaller than Hellfire. BAE Systems has finally been awarded the contract for WGU-59/B within APKWS II, being modified 70-mm Hydra rocket (unguided), equipped with Distributed Aperture Semi-Active Laser Seeker (DASALS) for terminal guidance. The reliability of Hellfire and 70-mm diameter have been combined in Lockheed Martin's Direct Attack Guided Rocket (DAGR), as well. It has the same propulsion as Hydra rocket, supported by semi-active laser seeker. What is worth noticing, its feature of delayed fusing allows to reduce collateral damage. The third of the APKWS competitors, beside BAE Systems and Lockheed Martin, was Raytheon. In cooperation with Emirates Advanced Investments (EAI) of the United Arab Emirates, Raytheon has also been working on advanced semi-active laser-guided Hydra rocket, named Laser Guided Rocket (LGR). The another low-cost precision strike weapon system, Lightweight Multi-role Missile (LMM), has been developed by Thales. The laser guided weapon system of low collateral damage has emerged on the basis of the surface-to-air Starstreak system.

In accordance to follow the need for lowering the probability of causing unintended damage or casualties, there are also developed new concepts of weapons that are intended not to be a kinetic weapons. The literature of the subject contains different names of this kind of systems, like *non-lethal*, *less-than-lethal*, *less-lethal*, *pre-lethal*, *sub-lethal*, *limited destructive capability*, however, the term "non-lethal weapon" (NLW) is usually used. The technology is generally based on chemicals, sound waves, as well as directed electromagnetic energy. The systems are designed to temporarily incapacitate personnel and/or material, while minimizing probability of fatalities and permanent injuries to people, as well as undesired damage to their property or the environment, comparing to traditional weapons utilizing kinetic effect. Amongst the effects of the employment of the devices against personnel there are:

- a sensation of intense heat in targeted individuals, as a result of millimetre-wave radiation,
- disorientation, bowel spasm, nausea and vomiting, caused by infrasound waves.

Employment of high power microwave energy is capable of disabling or destroying electronic devices. It can be wide-band or narrow-band radiation, that is devoted to specific targets. The use of different chemicals can have an impact both on people and material, like sticky or slippery liquids. NLW can be also rubber or flash bang munitions, as well as tear or pepper gas used to control a crowd. The examples of the implementation of NLW concept comprise:

- Active Denial System (ADS) - a millimetre-wave transmitter that produces a sensation of intense heat in targeted individuals,
- High-Power Microwave (HPM) devices that have the capacity to destroy electronic components without affecting individuals, [5]
- Thermobaric technology that causes extended flash, sound, temperature, and pressure to disorient and/or incapacitate individuals,

- Non-lethal airburst munitions, designed to emplace liquids, aerosols, powders and other objects at a precise location,
- Anti-traction material (ATM) – a kind of very slippery, gel-like substance put on surfaces to prevent access by people and vehicles,
- The advanced tactical laser (ATL) – a concept with an infrared laser carried in an aircraft for precise air-to-ground strike missions,
- A pulsed-energy projectile (PEP) based on chemical laser to produce a large flash, bang, and shock wave to temporarily disorient and incapacitate individuals in a crowd, [6]

Another means of future technology is the Airborne Laser (ABL) – a weapon system that uses chemical oxygen iodine laser (COIL) onboard a modified Boeing 747 aircraft. Sine originally ABL has been developed to counter theatre ballistic missiles in their boost phase, nowadays it only indirectly refers to lowering collateral. However, we cannot rule out the use of similar technology in future against surface targets.

4. CONCLUSION

Since the losses in civilian population, proved to be very important factor for strategic and operational planning, the risk to innocent people is the main concern in modern warfare. The huge effort has been devoted to develop new technologies, weapon systems, tactics, techniques and procedures to spare civilians, not saying about the law. Having sophisticated means of air warfare it is much easier to spare civilians' lives during air operations.

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