MODERN GUIDED GLIDE MUNITIONS. USE AND LESSONS FROM THE CONFLICT IN UKRAINE

MARIO V MARINOV

University of Library Studies and Information Technologies,
Bul. "Tsarigradsko shose" 119, 1784, Sofia
e-mail: m.marinov@unibit.bg

Abstract. Glide munitions have become a focal point of weapons development in the past two decades. Modern examples provide limited-cost systems with effective stand-off characteristics and the ability to inflict precision strikes. The conflict in Ukraine has showcased the effectiveness of this type of weapon, providing a case study for the examination of its effectiveness, limitations, and future vectors of development. The following paper examines contemporary such systems, as well as their historical role on the battlefield, proceeding further to extrapolate upon their use on the modern battlefield in Ukraine. Finally, the paper discusses the overarching consequences, further evolution, and lessons for the use of guided glide munitions.

Keywords: guided bomb, glide munition, FAB, UMPK, Ukraine

1. INTRODUCTION

The delivery of effective firepower in an accurate, pinpoint manner against specific targets has remained a constant goal in warfare. High-precision guided munitions usually entail high costs per unit, leading to limited usage and high target discrimination. Guided glide munitions offer a solution to this problem through their application of low-cost technologies in the conversion of existing stockpiles of unguided munitions to guided precision weapons systems. Furthermore, the application of aerodynamic gliding offers the possibility to decrease the threat to the launch platform by providing sufficient range for stand-off attack capabilities.

The following paper first introduces the concept of the guided glide munition and its historical development. Subsequently, a brief comparison is provided of modern glide munitions of Western (NATO) and Russian manufacturers based on certain core characteristics, such as range, warhead size, guidance type, and cost. The paper then provides a case study on the use of glide munitions in a high-intensity modern conflict, namely the conflict in Ukraine, and more specifically, the UMPK glide and guidance module for the Soviet/Russian FAB/RBK/ODAB bomb types. The publicly

http://doi.org/10.7546/EngSci.LXII.2025.01.09

known characteristics of Russian glide munitions are examined. The specific case of the 2024 Battle of Avdeevka is considered in further detail, and how glide munitions were used to facilitate the outcome of the battle. In turn, certain lessons are drawn from the provided case study in relation to the effectiveness, characteristics of usage, and methods of counteraction for modern air and ground-launched glide munitions. Finally, the paper provides general conclusions for the development of glide munitions and future vectors of evolution.

2. EVOLUTION OF GUIDED GLIDE MUNITIONS AND CONTEMPORARY SYSTEMS

The conceptualization of the glide munition is historically well-defined and has centred around the idea of a guided weapons system, which utilises unpowered flight and aerial gliding to increase range and provide certain stand-off capabilities. During the latter stages of the First World War, experiments were conducted with unguided air-launched torpedoes fitted with a rudimentary biplane wing structure. During the later stages of the Second World War, effective systems were developed and operationally deployed in the anti-ship and ground attack roles for the first time. In the Mediterranean, the German Luftwaffe deployed the FX 1400 and Hs 293, which were glide and boost-glide conversions of the PC-1400 and SC-500 gravity bombs, respectively, using manual command to line of sight guidance from the launch aircraft for an effective engagement range of up to 5km [1, pp. 8-15, 2, pp. 5-8]. These systems proved effective against Allied naval vessels [2, pp. 12-17]. Over Germany, the US Army Air Corps operationally deployed to limited effectiveness the GB-1 conversion for the M34 910kg general-purpose bomb in attacks on German cities from ranges of 32km [3, p. 9], beyond the effective range of flak rings. In the Pacific Theatre, the US Navy used the ASM-N-2 Bat, a conversion of the 450kg AN-M65, in attacks on both naval vessels and stationary land targets. The Bat utilized semi-active radar homing and was proven to have had limited success, suffering from shortcomings in the radar homing guidance method, but continued to see service after the war [3, p. 17]. Despite the above-listed weapons systems being early examples of the glide munition type, they were complex systems, utilizing the most advanced technologies at the time of their making, and more fundamentally, they represent the principal concepts for the role of guided glide munitions in warfare. The above-described examples represent conversions of conventional gravity bombs fitted with range-extending aerodynamic surfaces and subsystems for control and guidance. Their principal objective and role in warfare were to provide the means to accurately engage high-value targets, which possess extensive air-defence umbrellas (at the time, these were naval vessels and important land targets, such as cities, industrial centres, and large logistical nodes), in a manner where the threat to the launch platform and the ability of the target to counteract the attack were minimised to the maximum extent possible. However, despite the technologically sophisticated characteristics of these munitions, certain problems were manifested, especially in the reliability of guidance methods. Early attempts at radio guidance were easily susceptible to electronic warfare (EW), while manual command guidance was a difficult task for the launch aircraft, requiring both high levels of crew proficiency and increased exposure to threats while guiding the missile to the target. More advanced examples of glide munitions were tested by the United States during the war years, utilizing even more sophisticated guidance methods, such as heat-seeking, television guidance, image-recognition, and radar-source tracking; however, the viability in combat conditions of such weapons proved unsatisfactory and beyond the limits of technology at the time.

During the Cold War era, several factors would shape the future evolution of the glide-bomb concept. The mass proliferation of anti-aircraft surface-to-air missiles ensured the need to reliably engage ground targets protected by multi-echeloned air defense umbrellas. At the same time, improvements in electronic technologies allowed for more advanced guidance methods, such as television guidance (TGM) and, eventually, laser guidance (SALH). Sophisticated datalink channels allowed for more effective and secure communication between the launch aircraft and the munition itself during its gliding phase, allowing for greater resilience to electronic interference and higher degrees of accuracy against stationary targets, with the limited engagement potential for moving targets. Certain models of glide munitions, such as the GBU-8 and AGM-62 Walleye, were effectively employed during the Vietnam War and continued development afterward with the GBU-15 and Paveway series (GBU-10/12/16/22/58). Similarly, in the Soviet Union, the KAB-series (KAB-500 Kr/OD/S/L) were developed concurrently in the 1970s and relied on either semi-active laser or television guidance. However, it must be noted that such weapons systems were expensive and limited in ranges of up to 50km, as they relied on the control surfaces of the munitions themselves for range increases and the high altitude of launch.

The breakout phase for glide munitions into a mass-use weapon occurred with the development of satellite-based navigation, namely the US Global Positioning System, which allowed for the installation of relatively cheap, whilst simultaneously very accurate guidance modules to weapons systems. This method of guidance, along with concurrent and more recent Russian (GLONASS) and Chinese (BDS) developments, remains the primary in guided glide munitions, in combination with traditional supplementary guidance methods, such as inertial navigation (INS).

At present, there are a variety of designs and solutions for the glide munition concept, tailored to specific battlefield tasks and varying in their capabilities, as well as cost. Table 1 showcases Western NATO developments, as well as the known characteristics of the most recent Russian development of the glide bomb concept, currently used in Ukraine, and subject to further analysis in the forthcoming chapter.

The JDAM represents the simplest conversion to a precision bomb through the refitting of the nose and rear sections of the regular Mk 82 gravity bomb, with the Extended Range (ER) module providing for further conversion to a glide bomb, with limited range characteristics, but low cost. The GBU-39/B Small Diameter Bomb (SDB) represents the effort to create a low-cost stand-off munition superior to the JDAM. The ground-launched development of the SDB (GLSDB) further provides for the ability to mate the SDB with the M26 rocket booster, generally used in US-made MLRS systems such as the M270 and M142 HIMARS, allowing for the deployment of a boost-glide munition, with a superior range to the air-launched type. More expensive designs, such as the AGM-154 and GBU-53/B (SDB II), provide for more sophisticated methods of guidance and/or larger warheads. The French AASM Hammer provides an example of an air-launched guided bomb, which utilizes a rocket engine to either increase the range of the munition when fired from a high altitude or to provide for a low-altitude launch, subsequently reverting to a limited glide mode (as the munition does not possess separate aerodynamic surfaces aside from control ones) [12].

Table 1. Modern Guided Glide Munitions

System	Range	Warhead Weight	Guidance	Cost
JDAM/ Mark 82	24km	89kg	GPS, INS, SALH	21,000 USD [4]
JDAM ER/ Mark 82	72km	89kg	GPS, INS	36,000 USD [5]
AGM-154 JSOW	110km	225kg	GPS, INS, IR	540,000 USD [6, 7]
GBU-53/B	110km	48kg	ARH, SALH, IR, GPS, INS	220,000 USD [8, 9]
GBU-39/B SDB GLSDB	110km (air-launched) 150km (ground-launched/ GLSDB)	62kg	GPS, INS, SALH	40,000 USD [10]
AASM Hammer	70+km	89kg	GPS, INS, IR, SALH	163-320,000 USD [11, 12]
UMPK/ FAB500	≈60-80km (45-65km) *depending on source and observations	200kg	GLONASS, GPS, INS	≈20,000 USD

Principal trends in the development of glide munitions currently place a focus on reducing costs whilst enhancing the key characteristics of range and assortment of potential targets. Up until the beginning of the conflict in Ukraine in 2022, and more importantly after 2023, when both sides engaged in the use of glide munitions, such weapons systems had not met the test of a high-intensity conventional conflict. Thus, the case of Ukraine provides unique insights and further expands the scope of glide munitions on the modern battlefield.

The general operation of glide munitions, compared to regular gravity bombs is demonstrated in Fig. 1:

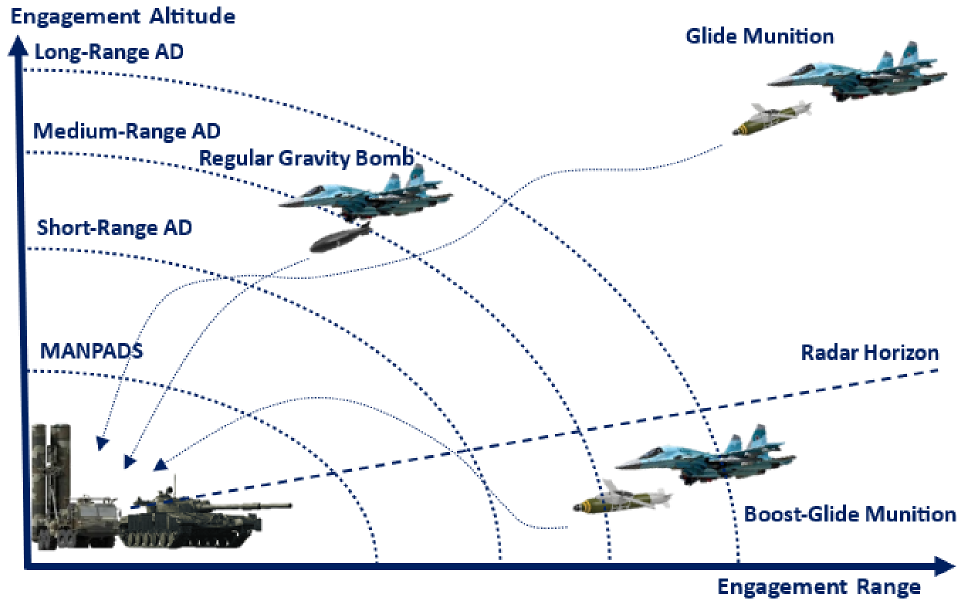

Fig. 1. Engagement profile comparison of gravity, glide, and boost-glide munitions

3. GUIDED GLIDE MUNITIONS AND THE CASE OF THE CONFLICT IN UKRAINE.

The conflict in Ukraine has brought about a general rethinking in the employment of conventional force, particularly in the ability to inflict fire upon the adversary. Traditional effective employments of air power and artillery fire, crucial to the tactical and operational defeat of the adversary, have become significantly constrained due to a variety of factors. Multi-echeloned and mobile air defense systems ensure that aircraft over or in the immediate proximity of the front operate under conditions of increased operational threats at all levels of flight operations. The combination of drone reconnaissance, counter-battery radars, and precession of artillery counter-fire ensure that conventional barrel and rocket artillery systems suffer difficulties in both concentrating and sustaining fire at any one point of the front line. Against the backdrop of such conditions, effective solutions were required for solving tasks in the tactical and operational depth of the battlefield, leading to the mass employment of aerial glide bombs, particularly by the Russian Air Force. In examining the role, employment, and effectiveness of Russian operations, certain conclusions can be extrapolated for the contemporary role of glide munitions.

The Russian Federation followed the development of the US JDAM in the 1990s with the development of the Planning and Correction Module or MPK (МПК - modul planirovannia i korrekcii) by GNPP Bazalt, showcased in 2003 for the legacy FAB-500 M62 general purpose high-explosive aerial bomb. The MPK module allowed for a 6.4-15km range from altitudes of 200-5000 meters at carrier speeds of 800-1100 km/h [13]. The MPK from Bazalt, along with a glide module for the FAB-250 from the 558th Aviation Plant, was further presented in 2009. The Bazalt MPK included four distinct configurations for the end user, with the last two including a 40–60 km range glide kit with both inertial navigation and GPS/GLONASS guidance and a final configuration, which included additional jet propulsion for an 80–100 km range [14]. None of these developments in the Russian aviation industry were visibly introduced into service before the conflict in Ukraine. Instead, Russian operations in Syria utilized the SVP-24 (specialized computational subsystem) computerised bomb sight on aircraft for traditional gravity bombs in precision strikes to great effect [15]. In Ukraine, after the initial hiatus of the early weeks of Russian operations, the Ukrainian side managed to effectively regroup and utilize its remaining air-defense complexes to contest the Russian Air Force, leading to the cessation of deep-penetration strikes and the substantial reduction of direct support strikes along the frontline. In the period from summer 2022 to summer 2023, the ground-strike component of the Russian Air Force was engaged almost in its entirety in either long-range strikes utilizing stand-off cruise and hypersonic missiles or low-flying missions close to the front line in pitch-up rocket attacks beyond the range of MANPADS and SHORAD. The situation demonstratively changed with the introduction of the UMPK in 2023.

Fig. 2. UMPK Kit (highlighted) on the FAB-500 M62.
Glide wings are folded. Source: Arma Models

The Unified Gliding and Correction Module or UMPK (Fig. 2) is an attachable glide module for Soviet and Russian gravity bombs. It has been demonstrated on the FAB-250, FAB-500, and FAB-1500 general-purpose high explosive bombs, the ODAB-500 and ODAB-1500 thermobaric bomb, and the RBK-500 cluster sub-munition bomb. The steel module includes fold-out glide wings, control surfaces, and guidance systems. Additionally, a set of stabilization (possibly control) surfaces are fitted to the rear of the bomb. When the UMPK is integrated into munitions with a ballistic-ring/anti-aerodynamic ring, such as the FAB-1500 or RBK-500/1500, an aerodynamic shroud is fitted over the nose section of the bomb (Fig. 3). The UMPK kit is currently known to include a satellite navigation module (GPS/GLONASS) and an inertial navigation system (INS) for guidance (Fig. 4) [15].

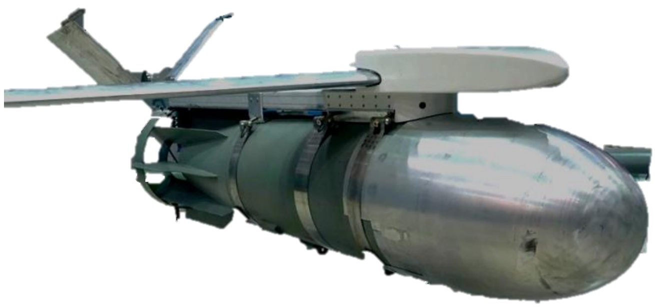

Fig. 3. UMPK on FAB-1500. Source: Army Recognition

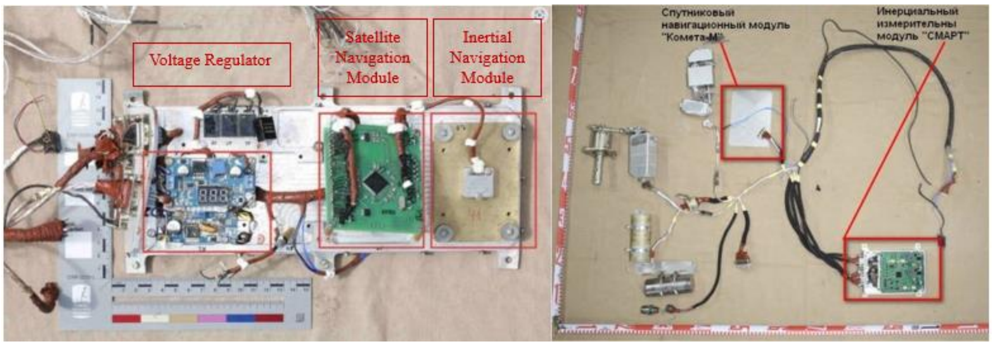

Fig. 4. UMPK guidance unit components. Source: Black Mountain Analysis

The UMPK is a rudimentary and easy-to-manufacture glide bomb kit. It does not include more sophisticated guidance methods, such as electro-optical, laser, or radar guidance, relying instead on the predetermined coordinates of stationary targets, which are inputted into the munition guidance either before take-off or from the launch aircraft. The structural characteristics of the kit are also rudimentary, as noticeable from the visible welds and method of integration with aerial munitions through a simple bolt-on procedure. The method of delivery is predominantly the Su-34 fighter-bomber and Su-35 fighter, which usually carry four FAB 250/500 with UMPK (or two FAB 1500), dropping them simultaneously in a salvo launch. After launch, the glide bomb spins 180° on its horizontal axis, subsequently deploying the glide wings. There is no concrete information on range, with certain figures placing the maximum effective range at either 45-65km or 60-80km. Considering the UMPK is not a blended body design and produces greater drag coefficients, it is logical to ascertain that the range is inferior to more refined, albeit more expensive, designs. The cost of the UMPK is placed at 20-25,000 USD [16], less than other such munitions, contributing to both the level of usage, role on the battlefield, and effectiveness. Moreover, the UMPK allows for the conversion of ready stocks of gravity bombs of the aforementioned FAB-250, 500, and 1500, amongst other types.

The intensity in the use of glide munitions has been most ostensibly demonstrated since late 2023 and into 2024 during pivotal battles in the Donbas region. During operations to take the town of Avdeevka, northwest of Donetsk, the Russian Air Force employed glide munitions massively. Dropped in salvos of 2 to 4, munitions of the FAB-250 and FAB-500 type with the UMPK module would strike targets in close proximity of one another. The density of fire was up to 100 munitions dropped in a 24-hour span over a 16 km^2 area. Such episodes of intense aerial bombardment occurred over several days between 1-7 Feb. 2024. In one documented series of strikes, 38 FABs were dropped over a 5km^2 area (Fig. 5). Principal targets included company-sized strongpoints close to the line of combat contact, the main supply route, and areas of concentration of military equipment and manpower reserves.

The employment of FABs, equipped with the UMPK, in the Battle of Avdeevka had a notable effect on the final outcome. The bombardment on the northern section of the settlement ensured the continuous advancement of Russian forces both to the south and west, eventually leading to the sectioning of the coke plant and the formation of a cauldron to the south. Progressive and continuous bombardments ensured that Ukrainian forces could not set up new strong points, whilst existing ones were destroyed along the Russian route of advance. Concurrently, the strikes against the only remaining logistics route into Avdeevka ensured that the Ukrainian garrison could neither be properly supplied nor capable of effectively counterattacking.

With an explosive filler of 200kg, the FAB-500 equipped with the UMPK module can accurately deliver devastating fire upon strong points. In the case of Avdeevka, this was proven against fortifications, as well as other hardened objects, such as multi-story apartment complexes and dense industrial zones. For comparison, a single 152mm high-explosive shell contains an explosive filler of between 8kg and 16kg – a simplified comparison in explosive mass with the FAB-500 would equate to between 25 and 12 shells, respectively; however, the instant destructive power of a FAB bomb against a single target is in the order of magnitudes larger and more accurate. Moreover, the utilization of FAB or other specialized munitions types, such as cluster (RBK-500) or thermobaric (ODAB-500) against specific vulnerable targets, not only increases the effectiveness of their neutralization but also frees up military resources in the wider operational scope.

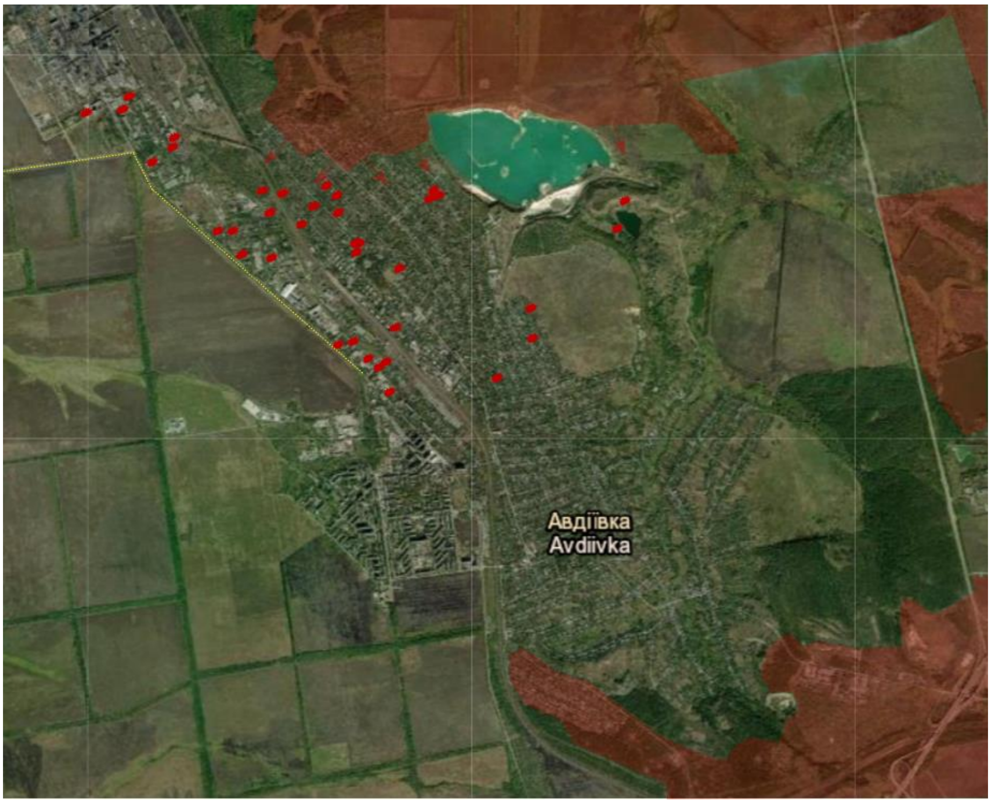

Fig. 5. FAB strikes on Avdeevka around February 7th, 2024. FAB strikes geolocated as per red icons. Russian control and movement in red. Ukrainian MSR in yellow. Source: author's library. Base satellite image from ESRI and USGS

The case of Avdeevka, and generally the broader case of the conflict in Ukraine, underline several other key aspects in the employment of glide munitions, which also include certain aspects of their effective counteraction. Key to the accuracy and effectiveness of FAB strikes is the active use of reconnaissance in recording movements, adjusting fire, and recording the results of strikes. Most commonly, reconnaissance is carried out through the use of aerial drones of varying types, especially in tactical space, where relatively cheap and less complex platforms can be utilized. However, electronic warfare measures can play a decisive role in hampering reconnaissance techniques, thus denying the ability to detect targets and direct fire missions. Complex electronic warfare systems (EW) such as the Russian R-330Zh Zhitel and Pole-21 can further degrade the operation of glide munitions themselves. As was previously described, most current generation glide munitions rely on a combined GPS and INS guidance. The conflict in Ukraine has demonstrated the ability of EW to significantly reduce the effectiveness of GPS-reliant weapons systems. Jamming and spoofing of GPS signals have, for example, degraded the performance of the Excalibur 155mm GPS-guided artillery round from 70% to 6% [17, p. 3]. Similarly, EW has noticeably reduced the use of the GLSDB, fired from the HIMARS MLRS, and the air-dropped JDAM [18]. However, even if the guidance methods are neutralized, the munition remains live and would still cause damage on impact. Other methods for counteraction through kinetic means have been demonstrated to be less reliable. As guided glide munitions are either unpowered or powered only during a boost phase of flight, they have a negligible infrared profile for locking on by MANPADs. Radar-guided air defences possess the ability to engage glide munitions, but utilizing missile interceptors can be uneconomical and would also risk placing air defense assets precariously close to the frontline in order to provide coverage. The most effective means to counteract glide munitions is to target the launch platform itself. For this purpose, and based on the range of glide munitions currently employed, long-range air defense systems (80-100+km range) possess the ability to engage launch aircraft at stand-off distances. In the Ukrainian conflict, the Ukrainian Armed Forces have, on several occasions, utilized the method of mobile air-defense groups to prepare “ambushes” for FAB carriers, destroying several aircraft. However, such groups, due to their proximity to the frontline for such a type of engagement, have also fallen victim to detection and neutralization by other long-range assets.

4. CONCLUSIONS

The development of guided glide munitions has centered on the ability to create a cost-efficient guided munition with stand-off capabilities. Most commonly, this is accomplished through the refurbishment of existing stocks of gravity bombs with a guidance kit and accompanying surfaces for aerodynamic lift. The development of satellite-based guidance has revolutionized the scale at which such types of munitions can be produced and the efficiency of their employment in warfare. The most recent conflict in Ukraine has further demonstrated the potential of glide munitions.

The UMPK kit applied to legacy Soviet-era aerial munitions have demonstrated the ability to introduce a cheap and crudely made guidance and aerodynamic module to readily available stocks of munitions, allowing for the mass use of this weapons system. Simplified manufacturing techniques and more readily obtainable electronic modules for guidance place forward the proposition of the replication of such methods for other armed forces seeking to quickly introduce a guided stand-off munition whilst recycling their existing stockpiles. Constantly evolving techniques in manufacturing and material fabrication further add to the potential of such systems becoming more widespread. However, it must be noted that such solutions suffer compared to more refined aerodynamic designs and more advanced guidance methods. Overall, even when designs use blended body shapes, a certain limit in the range of glide munitions is becoming apparent whilst the range of air defenses continues to increase, necessitating the exploration of methods for further increasing range and retaining the cost-effectiveness of the weapon. The rocket-boosted French AASM Hammer and the exploration of limited rocket or jet propulsion in variants of both the US JDAM-ER and the new iteration of the Russian UMPK concept with the UMPB D-30SN, provide the most clear-cut solution to increased range requirements, whilst also allowing for glide munitions to be released from the safety of lower altitudes (albeit with decreased ranges). Interoperability between air and land-based launch platforms is also becoming an apparent and necessary element of glide munitions with the US GLSDB configuration of the SDB for the HIMARS MLRS and the Russian D-30SN conversion for the 300mm Smerch/Tornado S MLRS. Concurrently, advancements in electronics manufacturing will provide more sophisticated guidance methods, allowing for the engagement of a larger selection of targets and greater resistance to current EW methods.

In the pure battlefield sense, the case of the conflict in Ukraine has demonstrated that the mass use of glide munitions can produce positive results and inflict significant losses upon the adversary. The explosive mass of ordinary high-explosive bombs and the specialized warheads of others provide for the ability to effectively engage hardened and fortified positions, large enemy concentrations, and specific high-value targets with precision and level of destruction, which is beyond the effective and efficient capabilities of conventional artillery, or uneconomical for other more specialized systems. Whilst the main vulnerability in the employment of glide munitions remains the threat to the launch platform itself, the required diversion and engagement of valuable mid or long-range air defense assets in such a role, close to the line of contact, can hurt the broader capabilities of the adversary. Thus, the use of glide munitions can afford results not only in the tactical and operational sense but also facilitate results in the strategic sense. Beyond the engagement of launch platforms themselves, currently, there exist limited capabilities to counteract glide munitions, especially when such systems possess guidance methods, which are difficult to interfere with through EW. Developments in cheaper and survivable low to mid-range air defenses, or even energy-based systems (although such systems are limited to line-of-sight engagement), can potentially effectively provide limited defence umbrellas against the mass use of glide munitions.

At present, glide munitions are undergoing a renaissance in their development, as they offer a unique solution for a cost-efficient mass-use precision weapon. It remains to be seen whether the conflict in Ukraine, which saw their mass employment, would also further provide the means for their effective counteraction or whether their use, proliferation, and sophistication would become a benchmark of weapons development in the coming decades.

ACKNOWLEDGMENTS

This work was supported by the NSP SD program, which has received funding from the Ministry of Education and Science of the Republic of Bulgaria under grant agreement no. Д01-74/19.05.2022.

REFERENCES

[1] W. WOLF, German Guided Missiles: Henschel Hs 293 and Ruhrstahl SD 1400X (2006) Bennignton: Merriam Press, CreateSpace Independent Publishing Platform, ISBN: 978-1475140828.

[2] S. ZALOGA, German Guided Missiles of World War 2 (2019) Oxford, Osprey Publishing ISBN: 978-1472831798.

[3] D. BLACKWELDER, The Long Road to Desert Storm and Beyond: The Development of Precision Guided Bombs (1992) School of Advanced Airpower Studies, Air University, Maxwell Air Force Base, Biblioscholar ISBN: 978-1288306206.

[4] AIR AND SPACE FORCES MAGAZINE, GBU-31/32/38 JDAM, online: https://www.airandspaceforces.com/weapons-platforms/gbu-31-32-38-jdam/ [Accessed 1 May 2024].

[5] AIR FORCE TECHNOLOGY, Joint Direct Attack Munition-Extended Range (JDAM-ER) Precision-Guided Bombs (2023) USA, Air Force Technology, online: https://www.air-force-technology.com/projects/joint-direct-attack-munition-extended-range-jdam-usa/?cf-view [Accessed 1 May 2024].

[6] US NAVY, LI 2230 - JT Standoff Weapon (JSOW), US Government, Washington, (2019).

[7] US NAVY, AGM-154 Joint Standoff Weapon (JSOW), US Navy (2021) online: https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166748/agm-154-joint-standoff-weapon-jsow/ [Accessed 2 May 2024].

[8] RAYTHEON, GBU-53/B SDB II Small Diameter Bomb Increment II (2010) *Air and Space Forces Magazine*, online: https://www.airandspace-forces.com/PDF/SiteCollectionDocuments/Reports/2010/August%202010/Day25/SDBII_factsheet_0810.pdf.

[9] S. ROBLIN, The Air Force Is Making a Big Bet on StormBreaker Bombs (2023) Popular Mechanics, online: https://www.popularmechanics.com/military/aviation/a43483654/air-force-buying-stormbreaker-smart-bombs/ [Accessed 1 May 2024].

[10] US AIR FORCE, GBU-39B Small Diameter Bomb Weapon System, US Air Force, online: https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104573/gbu-39b-small-diameter-bomb-weapon-system/ [Accessed 1 May 2024].

[11] Commission des affaires étrangères, de la défense et des forces armées (2012) Projet de loi de finances pour 2013: Défense: équipement des forces, online: https://www.senat.fr/rap/a12-150-8/a12-150-815.html#toc290 [Accessed 1 May 2024].

[12] SAFRAN, AASM HAMMER™: Smart Tactical Air-to-Surface Weapon Family Safran.

[13] AVIAPORT, Interfax-AVN, GNPP "Bazalt" predlagaet osnastit' aviatsionnye bomby svobodnogo padeniya spetsial'nym modulem planirovaniya i korrektsii (2003) online: https://www.aviaport.ru/news/45662/ [Accessed 14 April 2024].
[14] АЛЕКСАНДР, Opytnaya upravlyamaya bomba FAB-500M-62 s MPK (Rossiya, 2009–2010) (2017) online: https://raigap.livejournal.com/570890.html [Accessed 18 April 2024].
[15] M. MIHAJLOVIC, Renaissance of the Bomb - Gliding FABs, Black Mountain Analysis (2024) online: https://bmanalysis.substack.com/p/renaissance-of-the-bomb-gliding-fabs [Accessed 15 April 2024].
[16] S. ROBLIN, Just How Dumb Are Russia's Winged Smart Bombs? (2023) Popular Mechanics, online: https://www.popularmechanics.com/military/weapons/a43571893/how-dumb-are-russias-winged-smart-bombs/ [Accessed 18 April 2024].
[17] D. PATT, Too Critical to Fail: Getting Software Right in an Age of Rapid Innovation (2024) Washington DC: House Committee on Armed Services Subcommittee on Cyber, Information Technologies, and Innovation.
[18] J. PANELLA, Russia's Jamming of American Weapons in Ukraine is Showing the US What it Needs to be Ready for in a Future Fight (2024) Business Insider, online: https://www.businessinsider.com/russian-electronic-warfare-shows-us-needs-for-future-wars-2024-5 [Accessed 29 April 2024].

Received January 10, 2025