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Loitering Munition: Impact, Response and Approach to its Integration into Smaller Armed Forces

Vyčkávací munice: dopad, reakce a přístup k její integraci do menších ozbrojených sil

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Abstract: The article analyzes loitering munition as a distinct category separate from traditional UAVs and examines its role in recent armed conflicts. Drawing on qualitative and quantitative analysis, it finds that these systems have become a persistent feature of modern warfare, which is also reflected in the rapid expansion of acquisition efforts within NATO countries after years of stagnation. Building on these findings, the article introduces four functional criteria defining loitering munition and provides a targeted DOTMLPFI mapping that outlines the key requirements and indicative metrics needed to achieve full operational capability. The study shows that progress across all DOTMLPFI domains is essential for effective and sustainable integration, particularly in smaller armed forces.

Abstrakt: Článek analyzuje vyčkávací munici jako samostatnou kategorii odlišnou od tradičních UAV a zkoumá její roli v nedávných ozbrojených konfliktech. Na základě kvalitativní a kvantitativní analýzy dochází k závěru, že se tyto systémy staly trvalou součástí soudobých konfliktů, což se odráží i v rychlé expanzi akvizičních snah v rámci států NATO po letech stagnace. S využitím těchto poznatků článek představuje čtyři funkční kritéria vymezující vyčkávací munici a nabízí cílené mapování DOTMLPFI, které shrnuje požadavky a orientační metriky potřebné k dosažení plné operační schopnosti. Studie ukazuje, že pokrok ve všech oblastech DOTMLPFI je nezbytný pro účinnou a udržitelnou integraci, zejména u menších ozbrojených sil.

Keywords: Armed Conflicts; Autonomous Systems; Drones; Loitering Munition; UAS.

Klíčová slova: ozbrojené konflikty; autonomní systémy; drony; vyčkávací munice; bezpilotní vzdušné systémy.

INTRODUCTION

Loitering munition (LM) represents a relatively new and rapidly evolving category of military technology that has emerged prominently in modern conflicts. These systems combine the characteristics of unmanned aerial systems (UAS) and precision-guided munitions, offering a unique capability to loiter over a target area before engaging. Their increasing use on contemporary battlefields highlights their growing relevance in both conventional and asymmetric warfare.

The primary aim of this paper is to analyze the role of LMs in current armed conflicts as a new military capability. The authors focus particularly on their potential implementation within smaller military (like Czech Armed forces are), which often face limitations in resources and personnel. By examining the doctrinal, organizational, and technical aspects of LMs, this study seeks to provide practical recommendations for their effective integration into the force structure of such militaries.

1 METHODOLOGY

Using quantitative and qualitative analysis and synthesis, the article aims to discuss the following three research questions:

1. What is the role of LMs in current armed conflicts?
2. What is the attitude of certain members of NATO regarding LMs?
3. How to implement LMs into armed forces currently lacking it?

To achieve those goals, authors analyze up-to-date literature available on the topic and observe contemporary armed conflicts, focusing exclusively on the impact LM has in those struggles. For the purposes of the third question, the article derives four functional criteria that characterize loitering munition based on the identified operational patterns. These criteria form the foundation for a targeted DOTMLPFI mapping, which structures the capability's requirements and enables the development of an indicative metrics framework for assessing its implementation level.

2 CHARACTERISTIC

While almost every article or publication agrees that Israeli IAI Harpy was the first LM used (Gilli and Gilli 2016) the assessment of some current assets could be divisive and ambiguous. For instance, some authors called Russian long-range air asset Shahed-136/Geran 2 LM, others not because of limited or missing autonomy (Galba 2023). Some publications also merge LMs into a broader UAS category, which makes it difficult to assess their performance in the given conflict. As an illustration, there is a claim that 75 % of Armenian military hardware was destroyed by drones (Hecht 2022). Although Azerbaijani forces used LM extensively, without further data it's impossible to gain a full picture on the effectiveness of LM versus conventional UAS.

Definition

There are many definitions describing LM, for example, within NATO, LM was originally defined as follows: "A munition able to remain in position over a target area following an aborted target and to be reassigned a target whilst in flight" (De Zitter 2024, 9). A new definition is currently being discussed within NATO, which more accurately describes LM: "An Aerial LM is a munition following an operator influenced flight path (which can include to remain over a certain position) and is capable of non/beyond line of-sight target verification and precision attack, has the ability to abandon an attack, can be re-assigned and is destroyed by functioning of its payload," (ibid.) Accordingly, it reflects a more precise conceptualization of LM. Additionally, the authors consider the following definitions to broaden their understanding of the topic:

- "LM is expendable uncrewed aircraft that can integrate sensor-based analysis to hover over, detect, and crash into targets" (Bode and Watts 2023).
- "LM is a type of unmanned aerial vehicle designed to engage beyond-line-of-sight ground targets with an explosive warhead" (Gettinger and Michel 2017).

3 LOITERING MUNITION IN CURRENT ARMED CONFLICTS

Living in an unstable world, we are witnessing a significant number of armed conflicts that reveal glimpses of new technological and tactical implications for how current and future wars may be waged. While the nature of war remains constant, its character can change (Spišák 2023). Through the lens of this analysis, the authors conclude that one constant persists: the use of LMs.

3.1 Nagorno-Karabakh (2020)

While LMs were likely first used in combat between Azerbaijan and Armenia as early as in 2016 (Bode and Watts 2023), it was during their 2020 war that they achieved significant success on the battlefield, dramatically helping Azerbaijan achieve its operational goals. The conflict is particularly significant from a technological perspective, as it marked the first time LMs were deployed on a large scale against conventional armed forces (Nasereddine 2021).

As previously stated, it is difficult to distinguish between UAS and LMs in this conflict. Still, it can be said that Azerbaijan entered the conflict with at least 200 pieces of LMs, primarily of Israeli origin (such as the Harop and SkyStriker). The primary target for those (semi-)autonomous systems were located at the frontlines – artillery units, logistic centers, and reinforcements. LMs proved effective against conventional Armenian Ground-Based air defence systems, such as the S-300, which were unable to intercept them (Jones 2022). This created a paradox: advanced air defense systems were routinely destroyed by significantly cheaper aerial assets. Following the conflict, several Azerbaijani officials publicly expressed satisfaction with the performance of LMs, particularly highlighting the role of the Harop system (Bode and Watts 2023).

Amirkhanyan says that Armenia's failure should not be attributed solely to technological limitations, but also to flawed doctrine and a lack of mobility (Amirkhanyan 2022). On the other hand, Orsini describes LMs as an "emerging centerpiece" on the modern battlefield, stating that despite Armenia's shortcomings, no current military employs sufficient countermeasures to stop them. According to him, lethality in today's paradigm comes predominantly in unmanned and aerial-to-surface form (Galba 2023). Although technological superiority plays a key role on the battlefield, and loitering munitions currently appear to have the potential to transform the nature of warfare, the authors also agree with the assumption that technology alone does not win conflicts, and that the development of defensive capabilities can always be expected. It is the quality of personnel and the effective operational use of available assets that enable the full realization of their technological potential. The same applies to LMs.

3.2 Ukraine (2022 – present)

The three-year-long Russian invasion of Ukraine has proven to be a large scale, high-intensity conflict, marked by a constant technological race and a strong drive for innovation on both sides. LMs have been deployed in the theatre since the very beginning of the conflict, with both Russian and Ukrainian Armed Forces using domestically manufactured systems (such as Ukraine's ST-35 and Russia's KUB-BLA) as well as imported types (such as Poland's WARMATE and Turkey's Kargu - Orisini 2022; Galba and Procházka 2023; Frackiewicz 2025). The capability, sophistication, and impact of these weapons vary depending on the type of LMs and the quality of countermeasures in the area of deployment.

The use of UAS is extensive, with estimates suggesting that 25 to 50 UAS operate within every 10 square kilometers of battlefield in Ukraine (Petráš et al. 2024). The deployment of LMs in conflict represents a significant milestone in both the development and operational application of this category of weapon systems. According to Petráš, the rise of UAS, including LM, constitutes a direct response to the limited capability of conventional towed and rocket artillery (ibid.) to strike strategically or operationally significant targets with the required precision. Throughout the war, the Russian Armed Forces have employed various types of LMs, including systems such as the ZALA Kub (KUB-BLA) and ZALA Lancet. With a 12 kg payload and 40 minutes of endurance, the Lancet represents a typical "medium" type of LM designed to destroy vehicles and other military hardware (Galba 2023). it is effective mainly as a counter-battery asset against conventional artillery. An analysis of strike activity throughout the Ukraine conflict shows a clear increase in the employment of LM compared to conventional PGM (see Figure 1 below).

It is commonly stated that the majority of deployed LMs operate under the human-in-the-loop model - that is, a human operator must visually confirm the target before a strike. However, it has been claimed that at least some LMs in the Ukraine conflict were deployed to attack pre-programmed targets (King 2023). Bode and Watts (2023) express concern that there is a clear trend in the war toward increasing autonomy, aimed at accelerating decision making process.

Particular attention should be paid to the Iranian-origin LM Shahed-131/136 (designated Geran-1/2 in Russian service), which have been employed extensively for the strategic bombardment of Ukraine's energy, transportation, and industrial infrastructure. The war in Ukraine has also showed how LM can be integrated into efforts to achieve strategic-level effects.

While the strategy of using aerial devices as tools to instill fear and impose one's will on the adversary is nearly as old as aerial warfare itself (Spankaran 2024). The war in Ukraine is the first in which this has been attempted primarily through substitutes for conventional aerial platforms - namely, LM used *en masse,* such as the Iranian-supplied Shahed-131 and Shahed-136. These systems, designed for very long-range missions (up to 2, 000 km) and equipped with an above-average warhead capacity (approximately 40 kg of explosives) have formed the backbone of Russian aerial strike packages aimed at conducting deep strikes.
According to observations, their operational use is characterized by low unit costs – estimated at approximately USD 35,000 per unit (Hollenbeck et al. 2025) – which, when contrasted with the multimillion-dollar price tags of cruise missiles such as the Kalibr or Kh-101[1] (ranging from USD 6.5 to 13 million - Shulzhenko 2024), renders them exceptionally cost-effective.

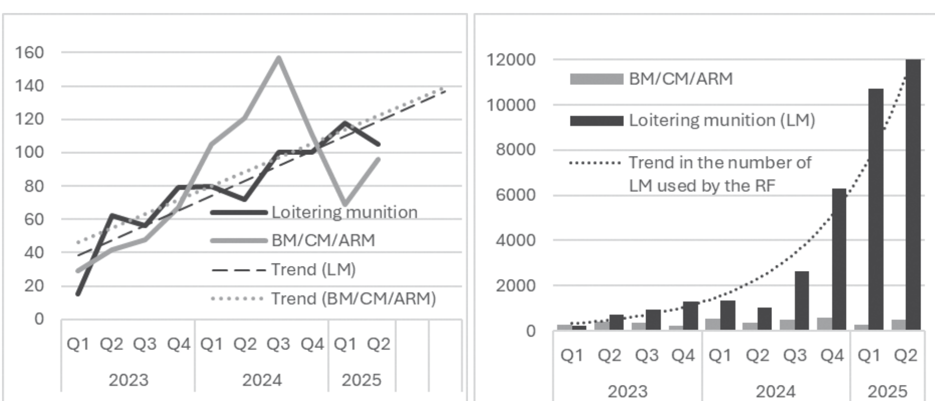

Figure 1: Analysis of the number of munitions used by the RF in the conflict in Ukraine by type of munition[2]

1 Used in the war at least in some cases for similar purposes

2 Based on Ivaniuk 2025; Zhuhan and Degtyarev 2024

The economic dimension of LM deployment was further reinforced by the localization of Geran-2 production in the second half of 2024 at the Alabuga Special Economic Zone in Tatarstan. This marked a shift by the Russian Federation from importing complete systems from Iran to fully autonomous domestic manufacturing, facilitated by an unofficial transfer of technology. According to Ukrainian estimates, current production capacity has reached approximately 300 Geran-2 units per day (Kulish 2025), with indicators suggesting continued expansion.

As a result, the Geran-2 has become a central instrument in a systematic, long-term sustainable, and economically advantageous aerial offensive—enabling Russia to conduct extensive and repeated strikes against strategic targets deep within enemy territory without relying on costly air force assets or highly sophisticated precision-guided munitions. Since the summer of 2024, this development has led to a marked intensification of Russia's deep-strike campaign, with certain days in June and July 2025 (CSIS n.d.) witnessing the deployment of over 600 Russian unmanned aerial systems within a single 24-hour period.

Despite the scale and recurrence of Russian strikes, primarily directed against Ukraine's energy infrastructure, these attacks have not achieved a sustained degradation of the targeted systems. This outcome is partly attributable to the comparatively limited destructive effect of LM relative to conventional PGMs (King 2023). According to official Ukrainian statements, the interception rate of launched systems reaches up to 90% (Hollenbeck et al. 2025). In terms of payload, a single Shahed-type loitering munition carries approximately the same mass of explosive material as three standard 155 mm artillery shells, a comparison that reflects payload equivalence rather than overall lethality or fragmentation effects (Ivaniuk 2025, Zhuhan and Dektyarev 2024).

3.3 Other Conflicts

The ongoing war in Gaza (2023–present) is another large-scale conflict in which technological advancements play a major role. While Israel is pioneer in the development of LM, it was Hamas that deployed multiple UAS and rockets during its attack on 7th October 2023. Page claims that one of the assets used in the surprise assault was a modified version of the al-Zouari drone, effectively transforming it into LM (Page 2025, 6). Hamas itself released video footage of these weapons, but based on that material, it is not possible to determine whether they were true LMs or simply kamikadze drones.

Nonetheless, reports continue to claim that at least 35 of these assets were indeed LMs, capable of loitering before striking (Rassler and Veilleux-Lepage 2025). This makes the current war in Gaza another conflict in which both sides employ LM. Israel has used its UAS arsenal in Gaza, including the Harop LM, which has demonstrated operational efficiency in detecting and engaging enemy targets (Düz and Koçakoğlu 2025, 40).

One of the main lessons from the war in Gaza is that organic UAS capabilities, likely including LM, at lower echelons have proven highly effective, enabling forces to maintain operational tempo even in dense and challenging terrain (Watling and Reynolds 2024, 29). Despite their precision-strike capabilities, the conflict has caused massive collateral damage to Gaza's infrastructure (Stojar et al. 2024, 115).

Looking briefly at other significant armed conflicts in the past few years, there is a striking similarity in the presence of LM. That include the red sea crisis with attacks on ships waged by Houthis (since 2023) as well as mutual bombardment between Israel and Iran. Even in most recent example, 4 days long air domain clash between India and Pakistan in May 2025, both actors used large amount of UAS and LMs to strike the other side, effectively multiplying their own force posture while not risking valuable aircraft and life of their combatants. Despite the limited effect those assets created (Ghostal, Shahid and Patel 2025), the tactic and means chosen to wage this limited escalation further confirms the shift in warfare towards uncrewed lethality.

To conclude, the most remarkable observation of current armed conflicts is that – with exemption of Armenia in 2020 (probably – Oryx 2023) - both sides were able to deploy and engage LM against enemy in all these clashes. At least to some degree. The trend of increasing use of LM is particularly evident in the war in Ukraine.

3.4 Advantages and Strengths oOf Loitering Munition

Contemporary wars reveal much about how LM shapes the character of these conflicts. Among various considerations, it can be concluded that LM provides the following advantages to the Armed forces that employ them:

- **Precision** – As a guided weapon with a short identification-to-attack cycle, LM offers the capability to strike moving or concealed targets with greater precision and effectiveness than conventional towed or rocket artillery (Foss 2024). This precision also presents an opportunity to reduce collateral damage during conflict. Another advantage of LM lies in its aerial mobility, which enables it to attack targets from above, exploiting weaker armor. Orsini (2022) claims that a battery of LM can replace a howitzer battery in "each active-duty field artillery battalion", which would provide dispersed mass and higher mobility on battlefield while achieving similar fire effect. However, this claim is highly dependent on the type of LM, as larger variants offer greater firepower. To date, traditional towed artillery remains a crucial asset on the Ukrainian battlefield (Axe 2025).
- **High reactivity and agility** – Due to their ability to loiter, LM can remain in operational space for extended periods, providing armed forces with a means to respond swiftly to changing battlefield conditions. The endurance of LM varies by type: smaller models can stay airborne for less than 20 minutes, while larger variants are capable of remaining aloft for several hours.
- **Easy Deployability** – While this depends on the specific type of LM, their general design often allows for quick and straightforward launch and dispersal, which is an essential factor for survival on the modern battlefield. Several small systems report launch times of less than two minutes (Avinc n. d.)
- **Affordable Cost** – Although this aspect was partially addressed in the context of the Russian invasion of Ukraine, it bears repeating. LM is arguably the most cost-effective

beyond-line-of-sight precision weapons in contemporary warfare, enabling armed forces to acquire them in greater quantities compared to other sophisticated weapon systems (Bode and Watts 2023, 24). This development has also significant implications for anti-UAS warfare, as the economics of conflict now come into play, compelling adversaries to deploy expensive anti-air assets to defend against relatively inexpensive LM.

- **Increased Survivability** – As with other guided or autonomous systems, LM can be operated from a relatively safe distance, reducing the risk to personnel. Deploying LM on the battlefield may also have a psychological impact on adversaries, as constant threat surveillance and rapid strikes can deter offensive actions. This awareness could make enemy forces less inclined to continue their advancement.
- **Strategic Value** - It could be said that LM offers a distinct capability for cost which could be much more acceptable for many medium and small armed forces, while providing utility even for significant players. Still, the LM does not represent a miraculous tool to solve everything and could be used to achieve every operational goal. On contrary, its synergy coming from combined arms warfare and multi-domain operations which provides the biggest advantage against enemy and should be desired by commanders (Petráš 2024).

3.5 Disadvantages and Weaknesses of Loitering Munition

While LM offers notable tactical benefits, it is equally important to recognize the inherent limitations associated with their operational deployment. These drawbacks can substantially influence the effectiveness of the system in complex operational environments while simultaneously raising questions related to accountability and the legitimacy of their employment.

- **Low Destructive Effect –** One of the primary limitations of LM is their relatively low destructive capability, which stems from the restricted weight of the warhead. This constraint significantly reduces their effectiveness against fortified positions or heavily armored targets, limiting their operational role to engagements against lightly protected assets or personnel.
- **Low Speed and High Vulnerability -** LMs typically operate at relatively low speeds compared to conventional missiles, making them highly susceptible to interception. Their slow flight profile and limited maneuverability expose them to a wide range of defensive measures, including small arms fire, short-range air defense systems, and even other unmanned platforms.
- **Susceptibility to Detection and Neutralization –** Despite their compact size, LM is increasingly vulnerable to detection and counteraction due to advancements in counter-unmanned aerial systems (C-UAS) in recent years, conclusion drawn primarily from the evolution of warfare in Ukraine.
- **Ethical Considerations –** Beyond technical and tactical constraints, ethical and legal risks associated with LM must be considered. Autonomous functionalities in certain systems raise concerns regarding accountability for strike decisions and the potential violation of international humanitarian law, particularly the principles of distinction and proportionality.

4 NATO AND LOITERING MUNITION

Table 1 summarizes NATO member states that have incorporated LMs into their arsenals. It is based exclusively on opensource information; therefore, the authors emphasize that the actual situation may differ if certain countries have chosen not to disclose such data.[3] If a country is not stated in the table, it did not signed contract for LMs until summer 2025.

While this article does not claim a direct causal link between those conflicts and the acquisition of LMs, the observed correlation is nonetheless valuable. It illustrates the growing diffusion of this technology into the armaments of NATO forces.

Table 1: Overview of LM Capabilities in NATO Countries possessing the capability

State	LM operated before 2022	**LM until July 2025[4]**	**Use of domestically produced LM**	**Type of LM**
Albania	No	Yes	No	YIHA-III (donated by Turkey)
Canada	No	Yes	No	Contract signed for Switchblade 300 & 600
France	No	Yes	Yes	Switchblade, MV-100 Veloce 330 for testing
Germany	No	Yes	Yes	Contract signed for HX-2
Greece	No	Yes	No	Contract signed for Switchblade
Hungary	No	Yes	No	HERO 30, some already delivered
Italy	No	Yes	No	HERO 30
Lithuania	No	Yes	No	Contract signed for Switchblade
Netherlands	No	?	No	Procuring vessels which should carry LM, but not enough info
Poland	Yes	Yes	Yes	Warmate
Romania	No	Yes	No	Contract signed for Switchblade

3 It's also possible that source referring about acquisition of LM doesn't call it like that, labelling it as classical UAS instead. In that case, its possible that it was missed.

4 Both operated equipment and contract signed.

Sweden	No	Yes	No	Contract signed for Switchblade
Turkey	Yes	Yes	Yes	Kargu, YIHA-III etc.
USA	Yes	Yes	Yes	Many, (discussed below)

It is evident from the number of states shown above that NATO member states are still in the process of catching up with the growing trend of adopting LM. Prior to 2022, only the USA and Turkey were significantly engaged in this segment. Today, however, many allied states are either negotiating with LM providers or referencing LM in their strategic defense documents.

In February 2025, the European Defence Agency (EDA) announced that 17 EU member states had expressed interest in acquiring LM, prompting the agency to take preliminary steps toward joint procurement, such as the market mapping (EDA 2025). Other countries are also investing independently; for instance, Estonia announced a tender in 2024 to procure LM worth 400 million euros (ERR 2024). Additionally, the private sector in several European countries has begun designing and offering domestically developed LM systems, indicating a growing manufacturing potential across the continent.

The following section examines two NATO powers with distinctly different approaches to LM, as well as the case of the Czech Republic.

4.1 The United States

Possessing unparallel resources within NATO, the USA military has extensive and continuous experience with LM, along with significant manufacturing capabilities to produce them. The USA military operates several distinct types of LM across different branches, including primarily American-manufactured systems such as the small tactical Switchblades 300 (and its bigger variant, the 600), Phoenix Ghost, and Altius-600M etc. Still, the war in Ukraine significantly accelerated both production and demand. Notably, Aevex Aerospace expanded its manufacturing capacity in 2024, claiming it could produce up to 1,000 Phoenix Ghosts LMs per month at full capacity (Arabia et al. 2024).

Nevertheless, the intensity of combat and the high “consumption rate” of UAS in Ukraine has demonstrated that even highly capable industrial base may struggle to sustain wartime production levels under standard peacetime conditions over the long term. Currently, the U.S. Army and Marine Corps[5] have concrete short-term plans to expand the deployment of LM assets at the lowest tactical echelons (Harper 2025).

Nevertheless, it can be argued that operational concepts for employing LM, as well as measures for defending against them, are not yet fully developed as desired. For example, the Fire Support and Field Artillery Operations of the U.S. Army Manual (2024)

5 Organic Precision Fire light program

does not mention LM even once, while UAS are discussed throughout the document (Department of the Army 2024). Similarly, LM is mentioned only once, and only briefly as a rising trend among "threats to surface targets", in the key Field Manual on U.S. Army Air and Missile Defense Operations ((Department of the Army 2020).

Nasereddine (2021) views the lack of a dedicated solution for countering LM as a significant problem, comparing it to the mistake made by both Russian and Armenian forces, who treated LM as just another airborne threat rather than addressing them with tailored countermeasures.

4.2 France

France serves as an example of a military power that did not possess LM for an extended period. In fact, the decision to procure them was made only after the outbreak of the conflict in Ukraine, alongside a broader increase in defense spending. In 2023, France ordered American Switchblade systems to "establish an urgent initial capability for the benefit of French forces," indicating that decision-makers in Paris recognized a significant capability gap after observing early lessons from the war in Ukraine (Machi 2022).

In alignment with its strategic autonomy objectives, France promptly initiated a domestic development program for a family of LM with varying categories involved an unconventional approach, including collaboration with the automotive industry (Overell 2025). Despite the somewhat accelerated and the interdisciplinary nature of the development process, meaningful progress has been achieved. By 2025, France has acquired its first sets of domestically produced LM, although currently only for training and testing within the French Armed Forces. These systems, predominantly part of the MATARIS family, encompass a broad spectrum of operational ranges and capabilities (Mackenzie 2025).

Interestingly, France does not explicitly mention LM in its most recent National Strategic Review (2025), instead referring to "drones and remotely operated munitions" for its Armed Forces. The document also expresses an intention to simultaneously manage major armament programs alongside short, low-cost development cycles with civilian support (France 2025). The authors therefore conclude that this language reflects France's commitment to the planned development and integration of LM into its Armed Forces.

4.3 Czech Republic

The Czech Republic currently does not possess or have contracted weapon systems that could be classified as LM. LM is mentioned only briefly in the current Czech Armed Forces Development Concept 2035, which states that both Ground and Special Forces should introduce this capability (Department of Defense of the Czech Republic 2024a).

While some other documents (such as Vision of future warfare beyond 2040) do not mention LM explicitly, the capabilities they emphasize (e.g. the ability to "engage the enemy at a greater distance than the enemy can respond" at the tactical level - Department of Defense of the Czech Republic 2024b) align closely with advantages offered by LM.

Doctrinally, the Czech Armed Forces are still in the early stages of development regarding LM. However, there is no doubt that they are interested in acquiring such weapons. In 2023, the newly appointed commander of the 43rd Airborne Battalion described the introduction of LM to his unit as a "great challenge" (Pojman 2023) and in the same year, the Army declared its intent to procure 10 LM sets for the Land Forces. This marked a clear shift from the original vision of acquiring only a small number of conventional UAS, reflecting lessons learned from the war in Ukraine.

As of July 2025, however, no official update on the potential procurement has been published by the Czech Ministry of Defence or the Armed Forces (Grontová 2025). From an industrial perspective, the potential in the Czech Republic is relatively high, with domestic manufacturers already offering their own LM systems.

5 IMPLEMENTING LOITERING MUNITION

As discussed in previous chapters, LM is a military phenomenon of the 21st century, and none of contemporary armed conflict has been waged without their involvement. It is therefore necessary to at least theoretically consider the potential integration of these weapons into the Czech Armed Forces, as Czech military is the main subject of authors' interests and it currently do not possess any type of LM or UAS with offensive capabilities. However, similar modest Armed Forces could also benefit from this approach. The process of fielding a new category of weaponry requires a precise functional delineation grounded in empirical evidence. As noted in the introduction, no universally accepted or explicit definition of LM has yet been established, and the conceptual boundaries of this category continue to evolve across both academic and military discourse. The preceding chapters analyzed the deployment of LM in recent conflicts and the growing trend of their procurement among NATO member states, illustrating the changing perception and operational relevance of this capability.

Building on these findings, a semi-empirical definitional framework has been developed to support the assessment of LM capability and its prospective implementation within Armed forces. Derived from open-source analyses, the framework abstracts dominant operational features observed across multiple conflicts where LM is demonstrably employed. While OSINT data allow for the reconstruction of functional behavior, they do not enable full verification of control processes; the criteria therefore represent empirically grounded generalisations rather than detailed technical descriptions.

Accordingly, LM can be characterised through four functional criteria that define their core attributes and provide the foundation for subsequent capability analysis within the DOTMLPFI structure:

- **Remote or autonomous operation -** LM is designed for remote or autonomous employment, with no onboard crew. This attribute defines their operational autonomy and differentiates them from conventionally manned or directly piloted systems.
- **Sensor-driven target engagement –** The system employs onboard sensors, typically electro-optical or infrared, to detect, identify, and prioritise targets. Engagement decisions are conditioned by sensor evaluation, whether executed autonomously or under human supervision, which distinguishes LM from pre-programmed or purely ballistic weapons.
- **Enduring presence in the target area –** LM possesses the capability to remain within the target area for an extended period, conducting surveillance, target confirmation, and timing optimization prior to strike execution. This enduring presence provides tactical flexibility and persistent situational awareness. This is what distinguishes "loitering" from "cruising," which is primarily intended for movement and is typically found in other types of weapon systems.
- **Expendable employment concept –** LM is intended for one-time use. Upon mission completion, typically through target impact, the system is not recovered. This expendable design has direct implications for logistics, life-cycle management and cost-effectiveness.

5.1 Introduction to DOTMLPFI Mapping of the Loitering Munition Capability

Based on the four functional criteria for LM a targeted mapping has been conducted to determine the implications for each element of the DOTMLPFI construct of the LM capability. The mapping identifies, for each criterion, the doctrinal, organisational, training, materiel, leadership/education, personnel, facilities, and interoperability requirements, along with the associated indicative metrics that form framework for readiness assessment and capability trade-offs.

Table 2: Criteria X DOTMLPFI mapping

F. areas	K1	K2	K3	K4
	Remote/autonomous operation	Sensor-driven target engagement	Enduring presence in the target area	Expendable employment concept

D	Rules for employment of unmanned weapon systems Allocation of decision-making authority and the chain of responsibility (ROE applicable to UAS/LM employment)	Protocols for target validation and pre-strike verification Requirements for auditability and post-strike accountability	Tactical concepts and procedures for leveraging loitering (holding patterns, priority target queues, retasking authority)	Criteria governing the employment of expendable effects (cost-per-effect considerations, loss-acceptance thresholds).
O	Establishment of dedicated operational cells/staff for tasking, command & control and sustainment (O&S).	Integration of ISR (intelligence, surveillance, reconnaissance) and target-management functions within planning units	Planning capacity for extended mission timelines and flexible tasking workflows.	Logistic flows for munitions, replenishment cycles and stock management (procurement and sustainment planning)
T	Training in remote operation, C2 procedures, contingency and emergency protocols	Operator and analyst proficiency in signature recognition, exploitation of sensor feeds, and human-in-the-loop decision processes	Training focused on prolonged surveillance, dynamic retasking, and energy/endurance management.	Handling, storage and safety procedures for expendable munitions Tactical planning for attrition rates.
M	Secure C2 links, protected telemetry, redundant command channels and anti-jamming/anti-spoofing measures.	Performance requirements for EO/IR (and other) sensors Data-fusion software, on-board/edge processing capability and secure data links	Requirements for endurance (flight time), power management, navigation accuracy and geofencing capabilities.	Design emphasis on cost-efficient mass production, safe packaging and compatibility with existing logistics containers.
L	Senior leadership briefed on limits of remote control, legal and ethical responsibilities.	Command awareness of sensor limitations, false-positive risks and evidentiary standards.	Tactical education on seizing fleeting opportunities during loitering and operational risk management.	Analytical capability for cost-effectiveness assessments and strategic decisions regarding force posture and stockpile levels.
P	C2 operators, cyber/communication specialists and mission planners.	Imagery analysts, target-validation operators and software engineers.	Mission planners and retasking operators with expertise in dynamic targeting.	Logisticians, munition specialists and ordnance handlers.

F	Hardened and secure control stations; redundant communications infrastructure.	Analytical workspaces and sensor-feed simulators for operator training and verification.	Test ranges capable of long-duration loitering scenarios Infrastructure for recharging and maintenance	Storage facilities meeting safety, security and environmental controls appropriate for munitions.
I	Standardised C2 interfaces for integration with allied systems and tactical networks.	Standardised data formats, IFF integration and de-confliction tools for shared battlespace awareness.	Rapid sharing of target updates and retask commands across allied C2 and ISR networks.	Standardised containerisation and transport procedures to enable transfer between units and allied partners

5.2 Metrics Framework of the Loitering Munition Capability Attainment for Smaller Armed Forces

The assessment of the current state of LM capability attainment is referenced to the concept of Full Operational Capability (FOC), which marks the point at which the capability is considered fully achieved. At this stage, it meets all DOTMLPFI requirements for sustained and authorized employment.

The following framework operationalizes the structure of capability requirements derived from the Criteria X DOTMLPFI mapping (see Tab. 2), providing a basis for evaluating how these interrelated requirements, which collectively constitute the LM capability, are being fulfilled and embedded within the institutional structures of small armed forces. Each of the function area section specifies the corresponding metrics for assessing progress in the respective area, considering the constraints typical of smaller defence establishments, such as limited manpower, constrained budgets, and reliance on allied cooperation and shared infrastructure.

The inclusion of the Logistics & Expendability area at the end of the DOTMLPFI structure reflects the inherently consumable nature of LM, where sustainment planning and supply resilience directly determine operational persistence and strategic viability. Within the DOTMLPFI construct, logistics thus represents not merely a support function but a defining determinant of capability, linking materiel characteristics, cost-per-effect considerations, and replenishment cycles to the long-term usability of the system in sustained operations.

Doctrine. Doctrinal attainment requires explicit incorporation of LM employment into national and service-level doctrine, with particular emphasis on live fire safety, airspace deconfliction and rules for human oversight. Metrics of progress therefore include the formal publication and age of doctrine or policy documents referencing LM employment, codified live-fire procedures and approved training corridors, and logged occurrences of doctrinally mandated legal or command reviews prior to engagement. For small armed forces, an additional marker is the degree of doctrinal harmonisation with allied standards, which enables cooperative training and combined operations. These indicators are primarily documentary (regulation texts, signed orders, range approvals) and audit based (after action review records).

Organisation. Organisational attainment addresses how the capability is embedded within a limited force structure and where tasking authority is placed in practice. Relevant indicators capture the establishment of C2 elements at appropriate tactical echelons (e.g. company/battalion/brigade as relevant), the proportion of manoeuvre units authorised to task LM, median tasking turnaround time, and operational readiness rates for organic detachments. Given small state constraints, analysis should distinguish light, infantry scale systems, suitable for decentralised employment, from heavier, longer endurance platforms that require centralised oversight, and should monitor the practical distribution of kits and delegated authorities across units.

Training. Training attainment must be aligned to a system taxonomy that reflects mass, lethality and mission role. Metrics include average annual operator training hours per system class, frequency of simulator or live fire scenarios, certification pass rates, and the extent of participation in allied training exercises. Because sensor driven engagement and verification procedures are central, training indicators should specifically capture imagery-analysis proficiency and human-in-the-loop decision drills.

Materiel. Materiel metrics combine empirical performance with integration and practical deployability. Key indicators comprise mean operational loiter time under representative conditions, C2 link resilience (link loss rate), sensor detection/classification performance (operational ROC measures), and strike precision metrics where applicable. Equally important are integration measures such as the share of systems delivered in transportable or vehicle mounted kits, availability of complete training packages, and compatibility with national logistic and C2 infrastructures. For expendable systems, materiel attainment must also track the rate at which planned endurance and expendability profiles are met in operational or exercise contexts.

Leadership and Education. The extent to which the commander corps understands operational, legal and ethical dimensions is a critical institutional variable. Metrics for leadership attainment include the percentage of relevant commanders completing accredited briefings or courses on LM employment, documented inclusion of human oversight protocols in operational orders, and assessments of decision quality from after action reviews. In small state settings, the presence of clear legal review procedures and documented command accountability for targeting decisions is an important marker of doctrinal and ethical consolidation.

Personnel. Personnel indicators reflect the human structure that sustains LM employment. For smaller armies, pragmatic staffing models typically rely on crossqualification rather than creation of large, dedicated units. Metrics therefore include specialist staffing ratios per operational unit (operators, imagery analysts, communications/cyber specialists), crossqualification rates (for example, mortar or UAS crews certified for LM roles), and median fill or surge times for specialist vacancies. These measures indicate whether the force can sustain LM tasks without disproportionate personnel churn or capability gaps.

Facilities. Facilities attainment evaluates whether available infrastructure supports realistic training, testing and sustainment. Indicators consist of annual available range hours for loitering scenarios, counts of secured control stations meeting minimum standards, and ordnance storage capacity expressed in "days of supply". For small states, evidence of facility adequacy often hinges on successful bilateral or multinational access arrangements to allied ranges and training resources.

Interoperability. Interoperability measures must capture the force's ability to operate LM within national and allied C2/ISR frameworks. Metrics include conformity with established C2/ISR interface profiles (national or STANAG equivalent), median latency for target and retask data exchange in joint exercises, and the proportion of missions employing multi-source ISR verification. Additionally, because LM represent both an offensive capability and an airspace hazard, interoperability with counter UAS and deconfliction systems, measured by integration scores and functional tests, is a critical indicator.

Logistics and Expendability. Logistics metrics address the sustainability of deployable, consumable effects. Key indicators include replenishment lead time (days), unit procurement cost and cost per effect estimates from exercise BDA, and stock levels measured in "days of supply" against projected consumption rates. For small armed forces, attainment is signalled both by predictable procurement pipelines and by the ability to maintain reserve stocks through surge periods, often facilitated by pre-negotiated supplier arrangements or allied support.

Collectively, these area specific indicators operationalise the Criteria × DOTMLPFI mapping for a smaller armed forces. They specify how each defining attribute of LM translates into measurable organisational, doctrinal and technical milestones and enable monitoring of the degree to which the capability is being realised, embedded and operationally sustained within a constrained defence ecosystem. The metric set supports phased assessment (e.g. Not Ready → Initial Operational Capability (IOC) → FOC) and is intended to inform acquisition choices, training investments and interoperability planning.

Given the limited availability of quantitative and classified data on LM employment, the metric framework presented in this study is conceived as a conceptual construct rather than a numerical evaluation tool. The indicators proposed within each DOTMLPFI domain are designed to capture the qualitative dimensions of capability attainment, reflecting adaptation processes without prescribing fixed thresholds or quantitative benchmarks. This approach preserves analytical validity while remaining adaptable to varying data environments and national conditions.

CONCLUSION

Through both quantitative and qualitative analysis, this study has demonstrated the increasingly vital role of LMs on the modern battlefield. Their unique combination of surveillance and strike capabilities, along with their adaptability across various operational environments, positions LMs as a transformative asset in contemporary military operations. The findings confirm that LMs are not merely supplementary tools but are becoming central from tactical to strategic planning.

Selected case studies have illustrated the diverse approaches taken by different armed forces in implementing LMs. These examples highlight variations in doctrine, organizational structure, and operational integration, reflecting each nation's specific strategic priorities and resource constraints. The comparative analysis underscores the importance of tailoring LMs deployment strategies to the unique needs and capacities of individual military organizations.

Finally, the study has outlined a general framework for the implementation of LMs within smaller armed forces as are the Czech Armed forces. By addressing key areas such as doctrine, training, organizational integration, and interoperability, the authors have proposed practical recommendations that support the effective adoption of LM technology. These insights aim to assist defense planners and decision-makers in leveraging the potential of LM to enhance operational effectiveness while maintaining flexibility and cost-efficiency.

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