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MILITARY LOGISTICS DRONES: THE INNOVATIVE SOLUTION FOR TRANSPORTATION CHALLENGES ON THE BATTLEFIELD

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ABSTRACT

Military logistics drones play a crucial role in optimizing the supply and support processes of troops in the field. These unmanned aerial vehicles are used to quickly deliver essential supplies, ammunition and equipment to conflict zones or remote locations where access by conventional means is difficult or impossible. At the tactical level, logistics transport drones are capable of executing precise delivery missions, streamlining reaction times and reducing the risks of exposure to ground forces. In addition, they can operate autonomously or semi-autonomously, allowing logistics teams to focus their resources on other operational priorities.

These drones can be used both in support of combat units, providing them with essential equipment in real time, and to support operations to reconstruct critical infrastructure after a military action. Their flexibility and speed make them indispensable in the dynamic context of a modern theater of war, where short delivery times can make the difference between the success and failure of a mission.

KEYWORDS: joint operations, tactical operations, military logistics drones, ground transport drones, air transport drones, innovative solutions, speed and efficiency

1. Introduction

Currently, based on the lessons identified and learned from the high-intensity armed conflict in Ukraine, armies around the world are facing complex challenges that require rapid and effective adaptation of the theory and practice of operational logistics. In this regard, tactical combat forces must be prepared to respond rapidly to various threats, from asymmetric conflicts to hybrid wars. One of the main obstacles in this context is continuous logistical support, which becomes increasingly difficult as theaters of operations expand. Rapid mobilization of resources, management of stocks and ensuring an efficient supply chain are essential for the success of the missions of NATO combatant forces engaged in joint and tactical operations with national and/or multinational status. Therefore, the new challenges of operational logistical support are amplified by the unpredictable nature of adversary actions, which requires rapid adaptation to continuous changes on the battlefield (Ashbridge, 2023).

On the battlefield, efficient and resilient transport is a very important element for the success of any offensive and/or defensive operation. Proactive management of the military supply chain allows the identification and avoidance of potential vulnerabilities, such as enemy attacks on transport-resupply convoys. In

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these conditions, the use of drones (land and aerial unmanned) suitable for carrying out logistical transports represents an innovative solution for current operational challenges. These unmanned aerial transport systems already exist, with capabilities for moving limited loads (ammunition, food, lubricants, medicines, etc.) over distances appropriate to the tactical level necessary for the accomplishment of missions by units and/or subunits operating in the first echelon or isolated within the large unit or units of which they are part (NATO's ACT, 2023).

To ensure easy maneuverability, air transport drones can be equipped with advanced navigation systems and communication technologies, enabling them to operate autonomously or semi-autonomously. This provides them with enhanced flexibility in tactical operations. However, the use of logistics drones also introduces security and regulatory challenges that must be addressed to fully realize their potential. In the modern operational environment, logistics drones offer a promising solution to meet the challenges of Just-in-Time replenishment for troops to carry out their missions and achieve the desired objectives. As a result, there is a growing need for logistics drones that provide timely and efficient transport, continuously driving innovation and improving performance (Minculete, 2024).

Drones have also been assigned essential logistical support tasks, improving the efficiency of military operations. A conclusive example is the use of drones by the US military in Afghanistan. They were used to quickly transport equipment, ammunition and medical supplies to troops on the front lines. By using drones, the military was able to reduce the delivery times of resources, which was essential in critical situations. Drones were also used to monitor the status of logistics and assess the needs of troops in the field. This information allowed commanders to make quick decisions about the resources needed, thus improving the efficiency of support operations. In the conflict in Ukraine, drones were used not only for attacks, but also to transport medical equipment and essential supplies to units in conflict zones. Through drones, the Ukrainian military was able to maintain a constant flow of resources, even in conditions of intensive fighting (Watling & Reynolds, 2025).

To develop the scientific content of this material, I conducted an analytical and comparative study of several sources identified in the field. At the same time, I evaluated, processed, and correlated the information and data obtained with others regarding the effective use of these logistical transport systems, which have been beneficial to the forces that fought in Iraq, Afghanistan, and Ukraine.

2. Essential Elements regarding Military Logistics Drones

Military logistics drones are unmanned ground (UGV) and aerial (UAV) vehicles specifically designed to perform various logistical support tasks, such as transporting materials or performing research and surveillance missions during logistical support actions. They are used especially in difficult or inaccessible environments for traditional vehicles, thus providing an innovative solution to operational logistical challenges (Uppal, 2024; Sander, 2024).

Given a general classification option, these unmanned aircraft, of different sizes (which can deliver a range of critical supplies in quantities of up to 10 kg, from 10 to 20 kg, from 20 kg to 500 kg and above) are functionally configured with fixed wings, rotary wings, gyrocopter, quadrocopter (with 4 engines and 4 support arms), hexacopter (with 6 arms, each with one engine or with 3 arms with 2 engines) and hybrids, to operate coordinated in networks with supply-distribution lines of different lengths, so as to transport and deliver absolutely necessary

materials to multinational operational structures, as well as to civilians trapped in confrontation zones, without loss of human and logistical resources (Garbett, 2022; Santos, 2023).

The payload capacity of drones varies significantly from one model to another. Light logistics drones can carry a few kilograms, while larger models can carry loads of over 100 kg. This capacity is very important for the efficient use of these systems in operational logistics, allowing the rapid delivery of necessary goods in conflict zones or in emergency situations (Garbett, 2022).

The technology behind logistics drones is complex and relies on several essential components. These include sensors, which are: a) optical – used to capture images and videos in real time, essential for surveillance or delivery missions; b) proximity – helps avoid obstacles during flight; and environmental – measures atmospheric conditions, such as temperature and humidity, to adjust flight parameters (Singh, 2024).

Logistics drones are equipped with advanced navigation systems that allow them to plan their routes autonomously. They can use GPS as well as real-time mapping technology to navigate complex environments. The range of drones varies depending on the model and application, but many are capable of flying between 20 and 100 kilometers on a single charge (Rajeb, 2024).

It follows that logistical drones represent an innovative and efficient solution to the challenges of operational military logistics support. With the continuous development of technology, their use will continue to expand and diversify. By using drones to achieve the objectives of operational logistics, in accordance with the requirements of combat forces, appropriate factors supporting Just-in-Time logistics are implemented, such as: *speed and efficiency; accessibility; reducing risks to personnel; lower costs; flexibility* (Lucic, 2023). These criteria will be briefly discussed in sections 3 and 4.

3. Current Challenges of Logistical Support in the Tactical Field

The transportation of equipments and materials and is an essential component in the conduct of tactical and joint military operations with national and/or multinational status within NATO. However, this process is often hampered by numerous difficulties, which can affect the efficiency and success of missions. One of the greatest obstacles in the transportation of equipment and materials is the accessibility of the terrain. Many areas where military or humanitarian operations are carried out are characterized by rugged terrain, poorly maintained roads or a complete lack of road infrastructure. These conditions make the transportation of heavy equipment and essential resources extremely complicated and often impossible. For example, in mountainous areas or in regions with frequent flooding, motor transport vehicles can become stuck or be subject to significant damage. In addition, accessibility is also influenced by climatic conditions. Extreme weather phenomena, such as torrential rains or heavy snowfalls, can make transportation difficult or even completely blocked. Thus, in operational logistics planning, logisticians must consider not only distances, but also the type of terrain and weather conditions, which adds an additional degree of complexity to the organization of transport (Andronic, 2019).

In addition to the difficulties related to terrain and accessibility, the transport of resources is often exposed to security risks. In conflict zones, transport convoys are frequent targets for enemy attacks. These attacks can include ambushes, mine explosions or air strikes, which makes transport not only a logistical challenge, but

also an extremely dangerous activity. Security risks require additional protective measures, such as military escort of convoys or the use of alternative routes, which can be longer and more expensive. These measures, although necessary to ensure the security of personnel and resources, can delay deliveries and complicate mission planning.

In the context of military and humanitarian operations, the speed and efficiency of transport of equipment and materials needed by combat and support forces are major objectives. The success of a mission often depends on the ability to deliver the necessary resources in the shortest possible time. In the case of humanitarian interventions, delays in the delivery of aid can lead to loss of life and a worsening of the situation.

Speed is often compromised by the aforementioned challenges, such as difficult terrain and security risks. Logistics efficiency is also influenced by coordination between the various agencies involved in transportation, which may have different processes and protocols. Thus, effective collaboration between these entities is essential to ensure a constant flow of resources.

To meet urgent needs, military organizations with research capabilities must invest in technological solutions that facilitate the monitoring and management of tactical combatant formations' transportation. The use of delivery drones, advanced GPS systems, and logistics management software can significantly improve the speed and efficiency of deliveries (Minculete, 2024).

The *logistics costs* associated with transporting equipment and materials are another important factor that can influence mission performance. These costs can include actual transportation, security, vehicle and infrastructure maintenance, as well as potential losses due to enemy attacks or damage. In many situations, mission budgets are limited, and logistics costs can consume a significant proportion of available resources. This can lead to restrictions on the type and quantity of equipment and resources that can be transported, thus affecting the response capacity and effectiveness of missions. For example, in the case of a humanitarian intervention, a limited logistics budget can limit the number of rescue teams that can be sent to an affected area, which can lead to a delayed response and reduced impact on the affected population (Minculete, 2023).

The challenges in transporting resources and equipment are therefore varied and complex, with direct implications for the efficiency and speed of missions. Land accessibility, security risks, logistics costs and the need to respond quickly to critical situations are just some of the challenges that organizations face in this field. A strategic approach, integrating modern technologies and promoting collaboration between the different entities involved, is essential to overcome these obstacles and ensure the success of operations.

4. The Advantages of Logistics Drones in a Military Operational Context

In recent decades, drone technology has evolved rapidly, having a significant impact on many areas, including operational military logistics. Logistic drones have demonstrated that they can transform the way resources are delivered to the battlefield, offering a number of advantages that contribute to the effectiveness of tactical military operations (in particular). These advantages include speed, efficiency, risk reduction, flexibility in adapting to different combat scenarios, and reduced long-term logistical support costs (Nurgaliev, 2023).

One of the most obvious advantages of logistics drones is the speed and efficiency with which they can deliver needed resources to the battlefield. Logistics drones are capable of transporting

ammunition, food, medicine, and other essential materials directly to combat and support structures, significantly reducing the waiting time for supply-resupply. In conditions of armed conflict, every minute counts, and logistics drones can make rapid deliveries, eliminating the need to transport resources by traditional methods, which can be slower and more exposed to risks from opposing forces (Eskandaripour & Enkhsaikhan, 2023).

Furthermore, logistics drones can operate in difficult weather conditions or in hard-to-reach areas where ground vehicles would have difficulty. They can navigate direct routes, avoiding bottlenecks and obstacles that could delay delivery. This speed of response is essential in crisis situations, where resources must reach soldiers quickly to support operations (Lucic, 2023).

Ground drones, or unmanned ground vehicles (UGVs; ground robots), could mark a new era in military innovation. In Ukraine, these vehicles have already been actively used on the front lines for more than a year, performing essential functions such as transporting weapons and explosives, mining and remote demining, as well as evacuating wounded soldiers. The main purpose of the UGVs was to reduce the direct involvement of Ukrainian troops in combat and save the lives of soldiers. These vehicles are used to carry out mining operations at strategic points and blockade areas, to protect sensitive areas with automatic weapons, and to intervene against armored vehicles using anti-tank equipment, which have proven vulnerable to UAV drones. In addition to these tasks, the development of UGVs has also focused on logistical applications and the evacuation of the wounded. A relevant example in this regard is the multifunctional robot Vepr (KNLR-E), which has shown excellent performance since 2023 and complies with NATO standards (Syngaivska, 2024) (Figure no. 1).

Figure no. 1: *UGV Vepr (KNLR-E) on a mission to evacuate a wounded combat casualty*
(Source: Adapted from Syngaivska, 2024)

Considering the need to use UGVs in future joint multinational operations, in the USA, specialized bodies proposed a few years ago the use of an unmanned vehicle, called a "robotic mule", which has the capacity to perform various logistical support operations, such as: transporting troops in the combat devices in which it operates; transporting materials from classes I-V (Meal Ready to Eat – MRE, ammunition, fuel, etc.) from Combat Supply (Service) Points (CSPs) to the firing positions of soldiers and their combat equipment (from the component platoons of combat companies); evacuating wounded soldiers from combat positions to Casualties Collections Points (CCPs) or from

them to medical treatment formations Role I (Medical Treatment Facility Role I – MTF Role I); providing (non-standard) services, such as recharging the electric batteries of vehicles, equipment, etc. (Michalski & Nowakowski, 2020).

Given the imperatives of minimizing losses in logistical resources (human and material), especially during the transportation of materials (day and night) to tactical combat structures engaged in joint multinational operations (especially over large areas), Alliance specialists are studying, analyzing and identifying several options for efficient material support of troops by establishing and safely moving fully autonomous ground vehicles (UGVs) – singly or in columns (convoys) – supported by aerial drones (UAVs) (Ashbridge, 2023), as can be seen in Figure no. 2.

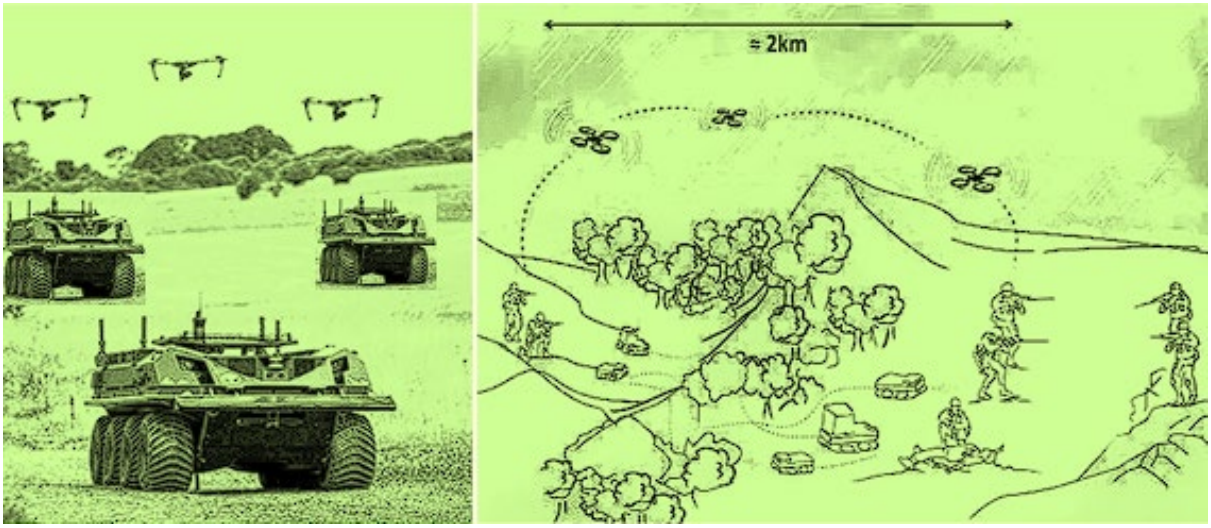

Figure no. 2: *UGVs (AtlasPro) on the move, supported by drones, to carry out the resupply with essential materials of the offensive operation executed by a mechanized infantry battalion*
(Source: Adapted from Ashbridge, 2023; Konak, 2020)

Another important aspect of using logistics drones in a military context is the potential to reduce long-term costs. While the initial investment in drone technology can be significant, the savings generated by operational efficiency and reduced risks to personnel often offset these costs. Logistics drones can reduce the need for expensive ground vehicles and additional personnel required to transport resources, which leads to savings in their maintenance and operation. In addition, the efficiency of deliveries and the reduction of waiting time for supply-resupply can contribute to improving the effectiveness and performance obtained in the conduct of tactical operations, which can have a positive economic impact in the long term. More efficient logistics support means better equipped units and subunits, but also better prepared, which translates into the success of operations by achieving the end state and, implicitly, in saving resources (Konak, 2020).

The first three images in Figure no. 3, show the use of a logistics drone (quadrocopter type), which, in order to resupply a CSP of a mechanized infantry company, transports a box with 12 pieces of MRE or medicines and sanitary materials packed in a support (of about 10 kg) resistant to disconnection and falling from a low height from the ground. In the same figure, the following three images depict, the drone transporting to the same recipient either two containers (of 5 liters each) of

fuel or lubricant or a box with steel core cartridges, caliber 5.56 mm (800 pieces), with disconnection after the device lands on the ground (Mecharithm – Robotics and Mechatronics, 2022).

Figure no. 3: *Use of a logistic drone (quadrocopter) for the emergency transport of essential materials, necessary for the first-echelon tactical combat structures*
(Source: Adapted from Autonomous Unmanned Aerial Vehicle for Logistics Resupply, 2022)

Logistics drones offer remarkable flexibility in adapting to different combat scenarios. Whether it is a defensive mission, an offensive operation or a humanitarian intervention, logistics drones can be adjusted to meet the specific needs of each situation. For example, in the case of an urban conflict, logistics drones can deliver resources quickly to hard-to-reach areas without requiring complex transportation infrastructure. In addition, logistics drones can be equipped with various types of sensors and equipment, which allows them to collect terrain information, monitor enemy movements and assess environmental conditions. Thus, they not only improve logistics delivery, but also contribute to the overall strategy of military operations (Cornell et al, 2023).

One of the most compelling advantages of employing logistics drones in a military context is the significant reduction in risks to human personnel. Traditional supply and resupply missions often require soldiers to action into hostile sites, exposing them to enemy fire, mines, and various other threats. In contrast, drones can carry out these tasks from a safe distance, operating behind enemy lines or in hazardous areas, all while safeguarding the lives of soldiers. While drones are not entirely free from risks, they drastically minimize the danger to military personnel compared to conventional methods. Furthermore, by using drones, logistics teams can direct their focus toward other critical operational aspects, secure in the knowledge that resupply missions can be executed safely and effectively (Nurgaliev, 2023).

In joint multinational operations, autonomous drones are especially valuable for enabling low-risk resupply between Forward Operating Bases (FOB) and Forward Operating Sites (FOS), as well as other advanced logistical locations. These include Combat Supply (Service) Points (CSP), from which materials are delivered to the combat or firing positions of platoons within operational companies (such as mechanized infantry, tanks, mountain infantry, etc.) of the combat battalions.

In Figure no. 4 (a generic presentation of the battlefield), quadcopter drones are

shown performing logistical transport of ammunition, in the process of decoupling loads – ranging between 20 and 50 kg – to the CSP of a tank company engaged in offensive actions within a mechanized infantry battalion involved in a joint multinational operation. To highlight the CSP (where surveillance and reconnaissance drones are also present), the boundary color is different from the rest of the image.

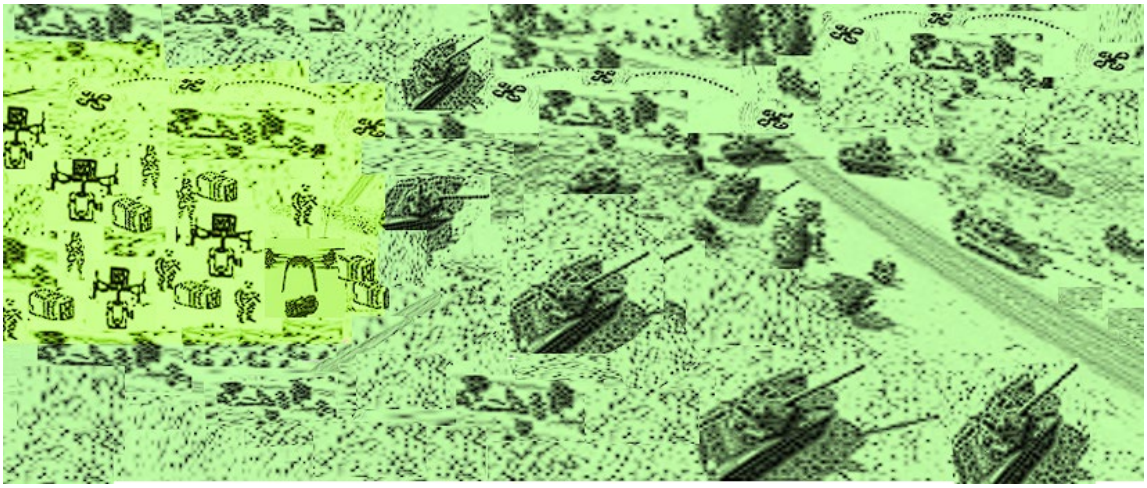

Figure no. 4: *Logistics transport drones on a mission to resupply the CSP of an armored company*
(Source: Adapted from Narendra, 2023; Minculete, 2024)

As drone technology continues to evolve, it is expected that they will play an increasingly important role in military operations, transforming the way militaries around the world plan and execute their logistical support activities for their operational forces.

5. Challenges and Limitations of Military Logistics Drones

Currently and in the future, military logistics drones are and will become increasingly important in modernizing and streamlining the delivery and transportation processes of goods according to the requirements of operational forces. However, the use of these innovative technologies is not without challenges and limitations. In this section, we will explore the main aspects related to the technology, the legal and ethical considerations, as well as the vulnerabilities to enemy countermeasures to destroy drones intended for military logistics operations.

One of the most important aspects of logistics drones is their *reliability*. Drones need to function smoothly to ensure efficient and safe deliveries. However, certain technical problems can occur, including software errors, sensor failures, or physical damage to the devices. These failures can lead to delivery delays, loss of goods, or, in the worst case, accidents, which can threaten public safety (Çıkmak, 2023).

Drone autonomy is another critical consideration. Many logistics drones are limited by their battery capacity, which restricts their range and operating time. In addition, supplementary payloads can further reduce autonomy, forcing operators to plan shorter routes or make more deliveries, which can impact the overall efficiency of the delivery system. Also, fast-charging solutions or advanced battery technologies are still in development, and their widespread implementation may take time (Benarbia, 2021).

Weather conditions pose another significant challenge for logistics drone operations. High winds, rain, snow, and other adverse weather conditions can affect the stability and control of drones. Additionally, certain conditions, such as fog or low visibility, can limit the ability of drones to navigate safely. This raises questions about the reliability of air transport in adverse conditions and the need to develop technological solutions that allow drones to operate safely in such circumstances (Konert, 2021).

Besides the mentioned criteria, logistical drones still have limited efficiency considering their reduced payload, which limits the sufficient transport of certain types of materials that are requested in large quantities by combat and support forces (such as, for example, ammunition with a decisive role).

Currently, the use of logistics drones is governed by *national and international legislation*, which varies significantly from country to country. Commercial flight regulations, registration and licensing requirements, and flight restrictions in certain areas (e.g. near airports or densely populated areas) are just a few of the legal issues that need to be considered. These regulations can significantly influence the adoption of logistics drones and create obstacles for operators looking to implement innovative delivery solutions (Benarbia, 2021).

In addition to legal regulations, the use of drones for logistics also raises *ethical questions*. For example, there are privacy concerns, as drones may collect data about people or places during operations. Similarly, the use of drones in medical deliveries or disaster areas may be seen as an opportunity to save lives, but it also raises questions about accessibility and equity. It is essential that drone operators develop clear and transparent policies regarding the use of these technologies to address these ethical concerns (Konert, 2021).

Logistics drones can become targets of attacks by enemy reconnaissance, diversion and attack groups or teams or terrorist elements. There are significant risks in terms of interception, jamming or even physical attacks on drones. These vulnerabilities can compromise not only deliveries but also the safety of personnel involved in operations, as well as civilians. For example, the use of attack drones to shoot down logistics drones is a tactic that can be used by enemies (Thornton, 2018).

As military logistics drone technology advances, so too does the development of effective ways to annihilate them. Sophisticated solutions are available to intercept or neutralize drones, such as jamming systems and disintegration technologies. These countermeasures can drastically limit the effectiveness of logistics operations and create a climate of insecurity for drone operators. It is therefore essential that the industry invests in robust security solutions to protect logistics drones against these threats (Molloy, 2024).

In conclusion, logistics drones have a particularly important role to play in modernizing delivery processes, but the challenges and limitations related to technology, legal and ethical considerations, as well as vulnerabilities to enemy countermeasures must be carefully managed. Only by addressing these issues can a safe and effective use of drones integrated into military operational logistics be ensured, thus contributing to innovation, efficiency and connectivity in the field.

6. The Future of Logistics Drones in Multinational Operations

Logistics drones represent a key aspect of the evolution of military technology, having a significant impact on the way supply (resupply) and transport operations are carried out in theaters of war.

In the future, technological innovations will transform these devices into even more efficient and versatile tools. Among the most important directions of development are those briefly highlighted below. Future military logistics drones will benefit from advanced artificial intelligence algorithms, allowing them to operate completely autonomously. They will be able to navigate complex environments, adapting to changing weather conditions and unforeseen obstacles, without human intervention. This will reduce risks to military personnel and increase the efficiency of operations (Ryan, 2022).

Innovations in materials and design will enable the creation of logistics drones with greater payload capacities and extended ranges. These drones will be able to transport heavy equipment, ammunition or essential medical supplies over long distances, thus ensuring logistical continuity in conflict zones (Intimedia, 2023).

The use of 5G technologies and satellite communication networks will allow logistics drones to transmit data in real time, facilitating coordination between different combat units and subunits, for a rapid and coordinated response to emerging threats. This also reveals the possibility of integrating logistics drones into existing defense ecosystems by connecting with other autonomous platforms, such as attack drones or unmanned ground vehicles. This interoperability will allow for a more efficient use of resources and a rapid response to battlefield challenges (Uppal, 2024).

As logistics drone technology advances, their integration into the military art of NATO and beyond will become increasingly important. Armies around the world are beginning to recognize the advantages that logistics drones offer, and this is influencing military doctrines and operational planning (Syngaivska, 2024).

Logistics drones will allow NATO member states' operational forces to adapt quickly to changing situations and respond effectively to supply-resupply needs. This flexibility is essential in modern conflicts, where speed of reaction can make the difference between success and failure.

The use of drones for logistics can significantly reduce the costs of military operations by minimizing the need for traditional ground or air transport, which often involves high risks and costs. This allows financial resources to be allocated to other essential areas, such as the development of advanced technology or the training of personnel (Ryan, 2022).

In an interconnected world, cooperation between nations becomes essential (especially between NATO members), which will make the integration of logistical drones into the concept of action of operational forces require the sharing of technologies and information between allies, contributing to the creation of more efficient and secure operational logistical networks (NATO Allied Command Transformation, 2024).

7. Conclusions

The impact of logistical drones on the effectiveness of multinational military operations is profound and far-reaching. By integrating these technologies into supply chains, combat and support forces will be able to respond quickly to changes on the battlefield. Drones will be used to transport both consumable and non-consumable materials, as well as to gather critical intelligence, thereby providing an overview of the operational situation. This ability to combine logistics with combat intelligence will enable the generation of more efficient and well-founded operational concepts at the joint and tactical levels.

Another important aspect is the reduction of response time in critical situations. In the context of military conflicts, every second counts, and drones can quickly deliver the necessary resources,

ensuring the continuity of operations. For example, during a confrontation, a drone can deliver medicines, water, or ammunition to soldiers, providing immediate support and helping to save lives and maintain troop morale. Furthermore, drones can be used to assess and monitor the terrain, facilitating better-documented and consolidated logistic support decisions for combat forces.

Looking ahead, the vision for operational military logistics within NATO is one in which drones (both ground and aerial) will become an integral part of supply and delivery operations, particularly. As technology advances, logistical drones are expected to become increasingly autonomous, capable of performing complex missions without the intervention of military logistic personnel. This autonomy will allow operational forces to optimize their resources and reduce the risks associated with engaging logistical personnel in specific tasks. Additionally, the integration of artificial intelligence in drone operations will enable more efficient mission planning and execution, improving coordination between different units and large combat formations.

Another aspect of the future of military logistics concerns the integration of drones with other emerging technologies, such as autonomous vehicles and artificial intelligence systems. This synergy will enable the creation of intelligent logistics networks, capable of quickly adapting to battlefield conditions and optimizing real-time deliveries. Moreover, the development of heavy-lift transport drones is expected to allow the delivery of larger quantities of equipment and resources, thereby enhancing the effectiveness and efficiency of military operations.

In conclusion, logistical drones represent an exceptionally valuable tool for operational forces, driving the transformation of how resupply, transportation, maintenance, and medical support will be conducted.

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