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BEYOND THE ACTIVITIES OF THE COMMAND POSTS: LOW LATENCY NATIONAL DEFENCE

A VEZETÉSI PONTOK MŰKÖDÉSÉN TÚL: ALACSONY KÉSÉSŰ HONVÉDELEM

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Abstract

In modern warfare, it is a decisive advantage if an armed force can act faster than its opponent. However, this speed - or, to use the professional term, the degree of the latency - is not just a question of the technologies used. This study examines how reducing communication system delays to milliseconds, or even to real-time data transfer, can create a tactical advantage, while also emphasizing that the real obstacles to speed are often organizational processes and outdated decision-making practices. The article presents the concept of Low Latency (National) Defence (LLD), which combines technological developments (such as C4ISR systems or artificial intelligence) with organizational culture transformation – from eliminating data silos to mission command leadership. The conclusion is that technical "zero latency" only becomes a strategic advantage if the chain of command can implement it at the speed of decision-making.

Keywords: low latency, real-time data, LLD, mission command

Absztrakt

A modern hadviselésben döntő előnyt jelent, ha egy haderő gyorsabban tud cselekedni, mint ellenfele. Ez a sebesség – vagy más szóval élve a késés mértéke – azonban nem csupán az alkalmazott technológiák kérdése. Jelen tanulmány azt vizsgálja, hogy a kommunikációs

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rendszerek milliszekundumokra vagy akár valós idejű adatátvitelre csökkentett késleltetése hogyan teremthet harcászati előnyt, de egyúttal hangsúlyozza, hogy a valódi gyorsaság akadályait gyakran a szervezeti folyamatok és az elavult döntéshozatali gyakorlatok jelentik. A publikáció bemutatja az Alacsony Késésű *Honvédelem koncepcióját, amely a technológiai fejlesztéseket (mint a C4ISR rendszerek vagy a mesterséges intelligencia) ötvözi a szervezeti kultúra átalakításával – az adatsilók felszámolásától a küldetésorientált vezetésig. A végső következtetés szerint a technikai "nulla késleltetés" csak akkor válik stratégiai előnnyé, ha a parancsnoki lánc képes azt a döntéshozatal sebességében is megvalósítani.*

Kulcsszavak: alacsony késleltetés, valós idejű adat, AKH, küldetésorientált vezetés

Introduction

My research topic, and, conversely, this article, address the application of zero- and low-latency systems and predictive data processing methods on the battlefield. As I explore this topic further, it becomes clear that there is potential to reduce the latency of individual systems.

The relevant factors clearly point in a direction that makes it obvious that, if we build from the bottom up and reduce the latency of combat equipment, this will eventually lead to delays in operational, tactical, and even strategic processes and decision-making. In addition, a reduction or even complete elimination of data transmission distances, which are directly or, in some cases, indirectly related to the tactical level. We can consider the command posts of higher units and even reachback support, including information processing and response times for all types of combat and support units, and reduce the time needed for communication among them, thereby increasing their efficiency.

Research method

In studying low-latency homeland defence, the primary research was conducted in my work environment and focused on the technical implementation aspects as discussed daily. Delay is a term I often use in my work. I frequently think about how solutions that work well at the technical level would be applicable at the organizational level. Of course, my secondary research is based on specialist books and scientific publications, including articles. I studied the various solutions, protocols, systems, and networks in the literature. What is not scientific in the classical sense, which I use as a compilation of experiences described by others. I structured the publication to cover topics from the tactical to the strategic levels, while citing only a few examples due to the broad scope of the subject. What is the latency?

Historical outlook

I want to introduce this technical definition with a frequently quoted historical example. It is a well-known historical event that in 1815, the British Empire defeated the Dutch Empire at Waterloo. There was a banker who had since become famous and who, through his news network, was able to deliver news of victory faster than the British Royal Army. He turned his advantage into great wealth. What was his advantage? The speed of information, that is, Nathan Mayer Rothschild's ability to achieve the lowest possible delay in the transmission of information from the battlefield to the strategic level, thus increasing their efficiency.[2]

Nineteenth-century armies did not have "low-latency systems" at their disposal; at that time, decision-makers were acting blindly and in the dark due to slow data availability. To put it more accurately, as the historical example shows, the lowest delay for two lines of information, depending on the distance travelled and time, was 2-3 days in 1815. Rothschild, however, skillfully exploited the technical achievements of the age and realized that whoever knows reality first controls the game. This logic still applies today, but technology has revolutionized the rules, slowing data transmission. If pigeons were the "high-tech" of the time, today it is hypersonic missiles, artificial intelligence (AI), and real-time sensor networks that provide the strategic advantage.

Technical background of the latency

The first and most important fact is that true zero latency does not exist. The most basic example of this is the speed of light, which we know can travel nearly three million meters per second in a suitable

2 Kaplan 2010: 147

medium, such as a vacuum, and this is the physical limit of every existing device.

In our case, which involves data traffic passing through military systems, we understand and examine the delay from both communication and IT perspectives. In a broader and more general sense, in this field, it means that, ideally, information is transmitted and processed between the transmitter and the receiver in zero milliseconds. We know the lower limit of the speed of light. The upper limit is very difficult to determine, but a suitable OSI reference model can serve as a benchmark. This model uses seven layers, from the physical layer upwards to the application layer, to identify factors that can increase delay. Network delay has its own causes in each layer of the OSI model.

In the lowest layer of latency, physical factors such as distance, medium, and noise cause fundamental propagation delay. This transfer of information can be influenced by weather conditions or the actual transfer material of the medium. In the second data link layer, switch processing and, most importantly, variable queuing delay play a key role, occurring between two adjacent network elements. The third network layer adds time for routing decisions and potential fragmentation delay. Here, the speed of the router and the processors of the hosts and clients is critical. In secure architectures, hardware-based encryption introduces significant, fixed processing delays. At this layer, encoding and decoding delays occur as determined by the protocol in use. The fourth transport layer determines the delay through the distribution of information protocol logic. TCP handshakes, acknowledgements, and retransmissions introduce inherent delay, unlike connectionless UDP, which provides no feedback on packet arrival, resulting in much lower latency. [3] Finally, the upper layers generate delays within the final host machines. The presentation layer handles translation and software encryption, while the application layer delay is dominated by server-side processing. At this level, beyond raw hardware performance, the application's own design, such as its algorithms, data formats, and resource management, is the decisive factor in terms of overall delay.

When examining the entire communication spectrum, it is important to mention - although this is no longer a technical requirement - the physical and physiological characteristics of operators in terms of delay, as well as the ergonomic design of their workplace. Human factors, such as biological, physiological, and communication conditions, directly

3 Rumble 2011

affect the speed of analyzing information from systems and the speed of decision-making based on that information.

Classification of latencies[4] [5]

The technical background of delays clearly shows that it is impossible to eradicate them due to physical, data transmission, and processing constraints. It is therefore essential to classify delay levels based on network size and application requirements. On closer examination, it can be concluded that the delay is application-dependent and that we do not always get a constant value, as many factors can increase it. Below, I illustrate the ideal cases.

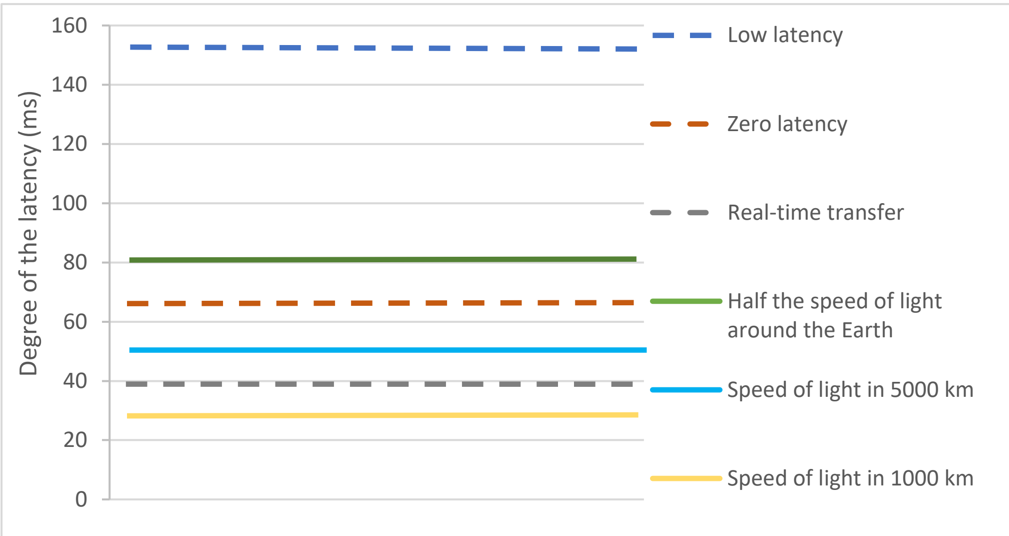

Figure 1.: Degrees of the latency compared with the speed of light in different distances.

The ideal zero-latency case must be considered in terms of machine-to-machine communication. According to ITU-T Recommendation G.114, machine-to-machine communication requires that one-way communication delay not exceed 150 milliseconds. Although this example refers to voice-based data transmission, it can be considered a reference standard in all other cases. There is already a new standard in this category, URLLC, which maximizes data transmission speed to

4 Szabó 2016
5 Attig 2017

50 milliseconds with a bandwidth of 100 Mbit.[6] Low latency generally applies to cases involving human-machine interaction. The lower limit of this class is the upper limit of ideal zero latency, while its upper limit is determined by the technology used. The resultant conclusion is precisely why its value varies from application to application, as in a video stream or a video game. It is a threshold at which the system can still compensate without significantly impairing human performance or rendering the technology unreliable. Due to physical constraints, achieving true zero latency is not possible. However, real-time data transmission systems rely on predictive algorithms that use mathematical and statistical models to create the illusion of real time. At the highest level of this method, the system can predict user actions and data flow so accurately that the user experience is perfectly continuous and immediate, virtually eliminating perceived latency.

The evolution of latency-related technology

From the beginning, IT and telecommunications systems have required low latency and sought to bridge the greatest possible distances while transferring the maximum amount of data as rapidly as possible. There are many earlier examples of the development of data transmission systems in this venue, from smoke signals to carrier pigeons. Still, the first application in history in which the physical layer was not air was the telegraph, invented by Morse in 1838. Initially, it had a 3-kilometre-long data transmission network, and its delay was considered a world record for 1-bit transmission, as sources reported it could transmit 5 bits in a single second, or 200 milliseconds. It is another question how quickly the sender and receiver were able to send and receive these signals.[7]

Not long after, at the end of the 1800s, a Hungarian, Tivadar Puskás, invented the telephone exchange, which was technically a one-way telephone. This invention is important to us, on the one hand, because it is a Hungarian invention, and on the other hand, because international standards still consider this form of telecommunication and voice data transmission as the basis for comparative delay standards. As a historical fact, the rapid and effective implementation of data transmission using Morse code and telephone services in civilian and military

6 Li 2018
7 Smith 2007

sectors to transmit intelligence information signalled a significant evolution in data transfer methods and their effective use.[8]

The next significant milestone in technological evolution was the advent of the telephone and radio, which enabled real-time, two-way communication. At this point, technology developed in two directions, resulting in two parallel but separate forms that exist to this day: wired and wireless data transmission systems. Analyzing their development history, we can see that this divergence has always had distinctive features. Thanks to technological advances, their characteristics are becoming increasingly similar, but their differences remain significant in terms of data transfer distance, data volume, and communication delay.[9]

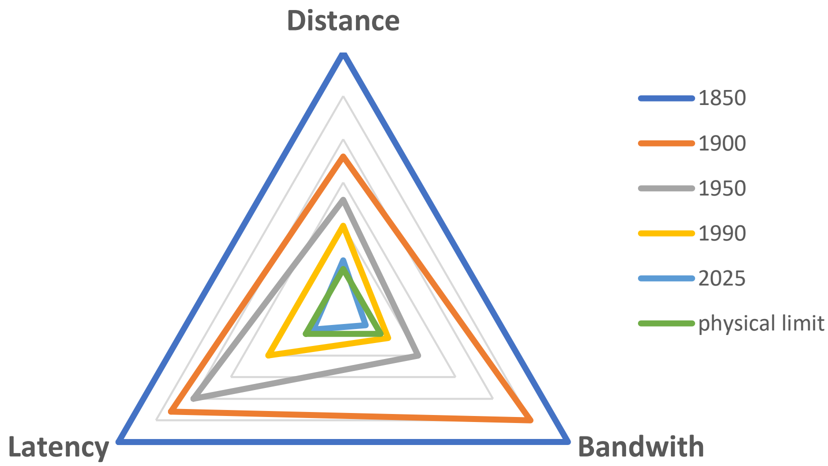

Figure 2: The historical development of the so-called distance-bandwith-latency triad.

In terms of wired connections, we have much greater bandwidth for data transfer with relatively low latency, but geographical distance and construction costs limit the network's scalability. Data transfer systems are becoming increasingly efficient in selecting the physical-layer material composition, and increasingly sophisticated protocols are also enabling this goal. In terms of latency, although laboratory values measured in milliseconds are an order of magnitude higher, this isn't very important.

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8 Bartolits 2000

9 Kópis 1996: 113-116

In wireless technology, electromagnetic waves propagate at the speed of light; thus, in theory, data transmission at the physical layer is equivalent to the speed of light. Wireless data transfer offers very low latency, i.e., near real-time data transmission, further enhanced by wireless modulation and the sophistication of network protocols already used in wired data transmission.

Long-distance purely wired or wireless systems are very rare today, so testing them in real-world environments is very difficult. Counterexamples include cables stretching across oceans between continents and satellite communications. Still, these are also almost point-to-point connections, and the statements made above are entirely true for the values measured in these cases.

Technological transfer

In the field of delay technology development, each stage of growth has been marked by three major groups with specific technological requirements for their main parameters, including delay conditions: the civil, military, and financial sectors. In terms of civil developments, residential services, communication platforms, and entertainment industry solutions are of primary importance. In the financial sector, strong integrity, an immediate feedback system, secure data transmission, and extra-low delay are important, think of the stock exchanges.

In military developments, at the end of the last century, the trend shifted. As a direct consequence of military innovations, various civilian and financial institutions benefited from the military applications. We merged several years later. Today, thanks to market demands and global trade relations, the pace of development has accelerated significantly, steadily shifting the focus toward civilian R&DI. In a multi-player market, research institute developments for armies with exclusively state-funded activities gradually fell behind due to the protracted replacement of equipment (expensive, complicated, and bureaucratic standardization procedures) and the slow return on investment. These protracted replacement factors reversed the direction of technology transfer. Today, it is completely natural for a civilian or economic innovation to appear in military equipment, which is then converted and adapted to meet military requirements. It is uncommon to find military innovation transferred into commercial use, or only in the form of solutions derived from combat or military experience being transferred to industrial modus operandi.

Application examples in the field

In line with the challenges of the 21st century, national defence and law enforcement agencies are performing increasingly complex tasks. These complex tasks require them to make greater use of digital tools across live operations and missions, including tactical and strategic decision-making and training. In these segments, achieving the lowest possible latency is crucial.

I would like to present a complex defence application and its components, where it is important to keep delays extremely low for each system element to achieve tactical superiority and strategic advantage. In my example, the C4ISR system[10], known as the brain of modern warfare, serves as a starting point for achieving this goal. This integrated system ensures that the military command has access to up-to-date information on battlefield processes, logistic support, events, troop movements, and the physiological condition of soldiers and the combat readiness of military equipment as quickly as possible.[11] In addition to data collection, this system is responsible for data display and processing. Important parts of the system are its fully independent modules, such as field-data-collection sensors, edge-network solutions, and actors that trigger responses independently or under control, most of which are located at combat positions. Another element of the system is the data transmission network, which transmits data via various wired or wireless channels, including encrypted ones.

The following is a practical illustration of the system components mentioned in the previous paragraph: Imagine a combat situation in which, based on reconnaissance reports, artillery fire is forecast, and we can continuously track the enemy's exact position using reconnaissance systems. One of the combat posts has a squad-level C-RAM radar in service, which can transmit data on any enemy fire that may be triggered to the central system, with a time-stamped offset.[12] At the main battle

[10] C4ISR: Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance System

[11] Ebbutt, 2012

[12] Balajti 2021: 9

position, operators or the automated system transmit this real-time data using the same mathematical method to a countermeasure system, usually a V-SHORAD[13] missile or laser system, which is capable of processing data on the enemy's entire trajectory and movement in real time, enabling it to fire in such a way as to destroy or deflect enemy fire while in flight as shown at the Figure 3. By specifying the range of these actors, it is easier to understand how much coordination is required and how even a delay of one millisecond in any system can affect the impact of the countermeasure triggered, which is why the magnitude of the delay plays such a huge role on the battlefield and how it indirectly contributes to the success of higher military strategic levels.

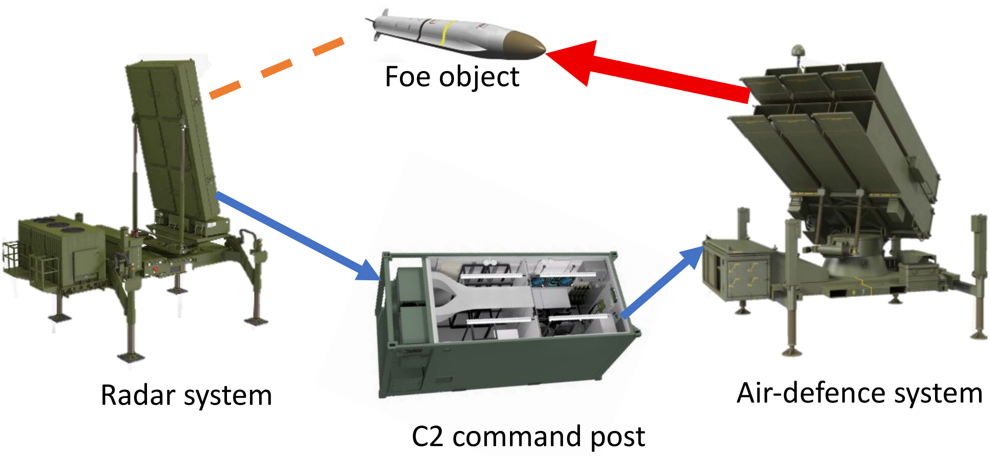

Figure 3.: Interception of a foe object by a radar system and the eleimination of it by an air-defence system' anti-missile driven by a C2 command post.

Lowering latency in the Logistical system of the army

At higher operational levels, we no longer discuss latency in terms of milliseconds. However, there are still segments where consideration can include real-time or very low-latency replenishment or maintenance. Although this statement may appear contradictory, consider how diverse, multi-segmented, and complex an organization's logistics system can be. It also depends on a combination of human and equipment factors.

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[13] V-SHORAD: Very Short Range Air Defence

In 2019, I participated in an American-Hungarian exercise in Bulgaria, during which I became familiar with the CPoF[14] system, which already included many operational-level elements that help reduce battlefield delays. The CPoF itself is a collaborative C4I system that provides for many modules to improve logistical support. One of the simplest functions of the system is fuel management. Each fuel-consuming device has a fuel gauge in its tank, which is connected to the vehicle or device's CPoF endpoint and sends fuel level data at specified intervals. Based on this, the central system can calculate consumption or issue an alert if the fuel level drops too low too soon. It then uses this data to send a logistics order for fuel at the battalion level. Of course, this is no longer the accepted practise that the vehicles must be refuelled every evening. Still, it does enable mobile logistics independent of the site, even several times a day, thereby increasing availability. We use a certain type of preventive maintenance for military combat vehicles, and its effectiveness could be enhanced with a sensor system similar to the telemetry system used in Formula 1.[15] Nowadays, IoT[16] and automotive bus systems are so advanced that there would be no financial or technological obstacles to equipping our military technology with them or even integrating them into the systems of our personal vehicles.

According to the latest news, the CPOF system will be replaced by Command Post 2025, an ongoing US Army development that is already being expanded with IoT and cloud-based integration as part of a comprehensive modernization program. The developments, including the automation of certain processes, will make future command posts more mobile and efficient, and hopefully will include the features I expect.[17]

This development would provide us with up-to-the-minute information on component wear, the condition of consumables, as well as accurate data on temperature, tire pressure, filters, and battery life. With this data, a central algorithm or AI-based solution could accurately calculate even component-level failures in combat vehicles. This method would be advantageous to us in several ways from a logistical perspective. On the one hand, it would facilitate warehousing and procurement processes. Since fewer parts would need to be kept in stock, it would also provide timely warnings about expected failures or

[14] CPoF: Command Post of the Future
[15] Furch 2018
[16] IoT: Internet of Things
[17] Németh 2021: 3

material depletion. In other words, broken parts will be replaced, or depleted lubricants will be replenished in real time. [18]

An important part of battlefield logistics is the continuous physiological examination of combat personnel to maintain their combat readiness; a rarely mentioned, underdeveloped part is the transport and classification of the wounded and the deceased to the rear. To perform this function, a system is needed that can be implemented using PAN networks (body-LAN) with organized sensors that transmit data to command centers. Although the full implementation of the concept is still pending due to technological development, preparations for future integration are already underway. After first aid, the immediate provision of ambulance and hospital care is crucial for treating battlefield injuries, provided by air rescue units (MedEvac, CasEvac). Barriers to effective care can be overcome through "remote care," which, with a reliable connection, enables remote instructions from specialists or interventions performed by robotic arms.[19]

Generally, the field of military logistics, supported by several technologies, will underpin the army's predictive logistics capabilities. Sensors in equipment, vehicles, and infrastructure will provide real-time data on condition, usage, and environmental factors. Predictive algorithms will use this data. AI and machine learning will drive the analytical engines by learning from data, identifying patterns, and making predictions. High-speed, low-latency communications will ensure real-time data transfer and processing. This low-latency, high-speed data transfer will enable rapid, informed decision-making.

Beyond the technology: the organizational level latency

In my research, I have focused on technical delays, and the results showed that modern technology successfully eliminates certain low-level delays; however, this limit exists at an organizational level. As decision-making moves beyond the tactical level, the human factor becomes increasingly crucial. In a complex organization such as the military, rapid decision-making, real-time tracking of troop movements, and timely decision-making are critical, and these capabilities are

[18] Mohan 2025

[19] Németh 2021: 4

ultimately determined not only by technology but also by the efficiency of the chain of command.

To specify the problem, in many segments of the armed forces, we find procedures that can prolong processes by hours, days, or even weeks. Due to the organization's multi-level bureaucratic nature, the momentum needed to carry out urgent tasks can be delayed by human interaction. In other cases, persons may rely on dated procedures and actions on plans that are no longer sufficiently adequate to today's challenges or to the complexity of the task responses required to individual challenges. Today, threats can emerge and escalate in a matter of hours or even minutes, impacting technical, human, and supply chain areas.

A recent event is an excellent example of the above scenario. The case involves IT and human factors: the 2021 Microsoft Exchange Server data leak. We do not know whether it affected any domestic defence actors, but it is highly likely that it did, given that 250,000 cases were reported worldwide. In general, victims only discovered the security breach after the attackers gained access to data for days or weeks. The data breach was possible because a manufacturer-provided database contained outdated information. The failure of the firewall systems created a false sense of security by failing to provide adequate alerts to decision-makers, allowing damage to occur. The breach was only discovered after the damage had already been done.[20]

In such cases, further escalation may occur, with approval levels, reporting and response chains, and "by-the-book" procedures causing dangerous delays. Similar systemic delays have been observed in defence exercises, where on-site cybersecurity incidents were not treated urgently. In those identified cases, the process followed peacetime administrative rules rather than operational urgency. In such an attack, a significant delay occurs when the response relies on approval and paperwork, as it cannot keep pace with the speed of modern threats.[21]

Change is difficult to follow or maintain, even when new technologies such as AI are available, as their application is not easy. Especially under pressure, decision-makers instinctively revert to safe, well-practiced, manual processes. When some military organizations introduced cyber defence tools early on, operators sometimes ignored or overrode automatic alerts, relying on their own judgment because they believed

[20] Microsoft Exchange Server data breach 2021
[21] Mun 2025

the systems were too new or unproven. In many cases, these delayed responses to real threats, and in at least one case, the attack was only stopped when the manual response finally aligned with what the AI had predicted hours earlier. These cases are not about technical failure, but about cultural resistance, resistance between the capabilities of the technologies and the willingness of leaders. The problem with this, however, is that it clearly increases the response time of national defence and, with it, the delay.[22]

Low Latency (National) Defence (LLD)

I emphasized in my previous paragraph how the use or non-use of AI can cause delays in a defence system. This example, which is not unusual, clearly illustrates how a popular new technology can also speed up operations. I believe that this segment is currently at the cutting edge of the tools we can use to make national defence more effective. However, it is also worth discussing simple steps, such as eliminating Excel spreadsheets and paper-based administration, treating them as data silos, or applying mission command leadership.

LLD means breaking down data silos and automating data flows, so information flows instantly between teams, systems, and military leaders, without waiting for reports or manual uploads. Unfortunately, the number of non-digital data silos is also high in this area, as paper-based orders and case files remain prevalent, tying up disproportionate amounts of human resources.[23] Mission command leadership requires commanders, or even operators, to make immediate, independent decisions during operations or combat situations without seeking approval from their superiors for actions not specified in combat orders. AI further enhances this by scanning the continuous data stream in C4ISR systems[24], identifying weak signals and emerging threats, and providing actionable information as events unfold, rather than hours or days later.[25]

In the field of military logistics, the first major task in achieving the LLD concept is digitizing the battlefield and the higher levels of command. By digitizing the battlefield and higher levels of command, the

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22 Chlad 2025
23 Németh 2023: 5
24 Department of the Army 2012
25 Czeglédi 2021

operation of the armed forces is automated and accelerated, minimizing bureaucratic burdens. The results of this in the field of logistics are increased combat readiness, reduced uncertainty in parts procurement, and a real-time, accurate picture of the force's state. This futuristic approach shortens planning cycles from months to hours, thereby helping reduce the high delays of the current system.[26] The basis of organizational development is the creation of a psychologically safe environment where information flows freely and mistakes are allowed. In this supportive atmosphere, empowered employees can experiment with new methods, thereby promoting collective learning and development grounded in a shared value system. The role of leadership in this process can be compared to that of a gardener, as it provides the appropriate space, support, and resources. In this era of technological explosion, it is vital to constantly rethink leadership approaches and warfare methodologies. The greatest risk for the Armed Forces is not the procurement of equipment but falling behind the pace of technological development in its application and the necessary organizational adaptation. This challenge is not primarily a financial one, but a question of leadership intent and a deliberate innovation strategy that accelerates both human and organizational adaptation.[27]

Advanced C4ISR operating in cyberspace provide rapid communication and real-time information, making them crucial in modern warfare. However, they also carry significant risks, as excessive information flow or incomplete data can easily lead to micromanagement and decision paralysis. To maintain mission command leadership, commanders should not deprive subordinates of their freedom of initiative but should use technology as a supportive tool. The key to success, therefore, lies in training personnel to use systems properly and in commanders having the necessary experience, confidence, and patience on an ever-changing battlefield.[28]

This line of thinking shows that a lack of resources or data does not determine the difference between successful and lagging defence organizations across countries, but rather the quality of leadership. The source of real change lies not only in new technologies but also in the leaders' conscious decision to break with outdated practices. This decision requires the courage to review traditional processes and promote digital transformation.

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[26] Sári 2024: 146-147
[27] Porkoláb 2019: 11
[28] Csíkos 2023: 89-91

Summary

My research clearly shows that technological development alone is insufficient to achieve the speed and flexibility in national defence required to meet the challenges of the 21st century. Although zero- and low-latency communication systems, real-time data processing, and artificial intelligence are indispensable tools in the struggle for tactical superiority, a real breakthrough can only come from the synergy between technology and organizational culture. One of the most important ways to achieve this is through mission command, which enables decentralized, rapid decision-making in the combat theatre. Although modern information systems can detect and signal threats in milliseconds, their value is realized at the strategic level only when the decision-making chain and organizational and bureaucratic processes operate at the same pace, and when commanders follow the principle of mission command. Therefore, my research is not only about minimizing technical delays, but also emphasizes that the philosophy of low-latency systems must be strategically combined with mission-oriented leadership to accelerate decision-making and radically reduce the time spent traversing bureaucratic layers. The greatest risk is not the lack of technology, but the failure of leadership and organizational adaptation, and thus the failure to embrace a mission-oriented leadership culture. Therefore, the key to future defence success lies not only in technological investment but also in the conscious transformation of command culture, the implementation of mission-oriented leadership, and the courageous break with outdated practices.

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