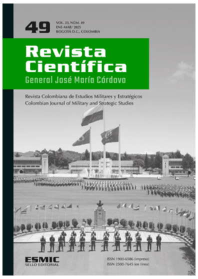

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El futuro del campo de batalla: predicciones basadas en la tecnología en el ámbito terrestre

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The future of the battlefield: Technology-driven predictions in the land domain

El futuro del campo de batalla: predicciones basadas en la tecnología en el ámbito terrestre

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ABSTRACT. The assertion that current and future available technologies are changing and will likely continue to change, as well as the nature of the operating environment, is undeniable. The more challenging task, however, is to identify the technologies that, if available to one side of a conflict, will provide a decisive advantage over a technologically weaker adversary, particularly the extent to which these technologies will affect the inherently conservative nature of land operations. Emerging technologies in current conflicts already indicate trends and predict the possible shape of the future "algorithmized" battlefield. This paper explores perspectives on the possible shape of the future battlefield over a two-decade horizon and articulates the challenges of employing a land component on a technology-saturated battlefield in a high-intensity conflict.

Keywords: future battlefield, land domain, military operations, predictions, technology

RESUMEN. Es innegable que las tecnologías actuales y futuras, así como el entorno operativo, están en constante evolución. Sin embargo, el verdadero desafío es identificar las tecnologías que, si están disponibles para una de las partes en un conflicto, proporcionarán una ventaja decisiva sobre un adversario tecnológicamente más débil, especialmente considerando su impacto en la naturaleza tradicional de las operaciones terrestres. Las tecnologías emergentes en los conflictos actuales ya indican tendencias y predicen la posible forma del futuro campo de batalla "algoritmizado". Este articulo explora las perspectivas sobre la posible forma del futuro campo de batalla en un horizonte de dos décadas y articula los desafíos de emplear un componente terrestre en un campo de batalla saturado de tecnología en un conflicto de alta intensidad.

Palabras clave: campo de batalla futuro, dominio terrestre, operaciones militares, predicciones, tecnología

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Introduction

How military operations will be conducted in future conflicts will differ from traditional approaches (Turaj & Bučka, 2020). Some changes due to innovative technologies, which have been spectacularly demonstrated on the battlefields of Nagorno-Karabakh (Petrosyan, 2023), Ukraine (Hrnčiar & Kompan, 2023; Zahradníček et al., 2023), or the Gaza Strip, are already visible today. These conflicts are characterized by the massive use of older-generation military equipment, supported to some extent by modern technology. It is a combination of existing weapons and equipment, whose genesis goes back several decades, with elements of the modern battlefield (Gibradze et al., 2022). It is, therefore, inappropriate to speak of next-generation conflicts. At the same time, at least in the case of the conflict in Ukraine, the applied military art of the Armed Forces of the Russian Federation, especially in the initial phases of the conflict, bore a high degree of conservatism and traditionalism, characterized, among other things, by the mass deployment of land forces in the form of battalion battle groups, whose composition and armament, and especially their tactical employment, did not always meet the requirements of the modern battlefield (Grau & Bartles, 2022).

However, an unmistakable feature of these conflicts is the growing trend toward integrating advanced military and commercial technologies, such as Unmanned Aerial Systems (UAS), even at the lowest levels of Command and Control (C2). This trend is driven by both technological maturity and availability. The effectiveness of such systems can be significantly increased through multiple platforms interacting with each other or through appropriate architecture and cooperation with other airborne, space-based, or ground-based sensors and effectors (Turaj, 2019). The potential for their use can only be expected to increase.

These considerations lead the broad "military community," represented by military experts, commanders, theorists, academics, researchers, and, not least, politicians, to formulate several questions, such as: Do these technologies have "disruptive" potential? Do these technologies degrade the perception of traditional operational factors? What will their capabilities be in the future? How will these capabilities manifest themselves on the ground? What changes in military art can we expect in this regard? More generally, what will the future land battlefield look like? Knowing the answers to these questions can have undeniable benefits in building and developing modern armed forces that are adequately prepared and capable of acting effectively in the foreseeable future operating environment.

Nowadays, we are offered a wide range of inspiring perspectives on the future of the military or futurology-based predictions. The works of authors Paul Scharre (2019) and Robert H. Latiff (2017) are of particular interest. Both authors almost unanimously state that future conflicts will be characterized by the autonomy of Artificial Intelligence (AI)-enabled systems, operations will be conducted mainly in cyberspace, and the land domain will be dominated by armies of "robots" either remotely controlled by soldiers or operating with a high degree of autonomy. They point to the legal and ethical issues surrounding the use of these technologies and warn that poorly thought-out deployment of technologies can have long-term devastating consequences.

Marcin Górnikiewicz (2019) also offers a very interesting excursion into the conflict of the later decades of the 21st century. He starts from the premise that humanity will, in a relatively short period of time, achieve technological advances that will radically change the traditional approach to the forms and methods of armed conflict. He predicts that many aspects, including "weapon" and "armed struggle," will be interpreted differently. In the future, combat potential will no longer be inextricably defined by the "product" of the quantifiable parameters of its physical component (Varecha, 2020a). A shift will occur, among other things, in the direction of the main effort in using military forces. While this will continue to be oriented toward the opponent's vulnerabilities, the primary objective of military forces in the future will not be to act on the physical component of combat potential and probably not even the moral component. The goal will be to degrade those components of the adversary's combat potential whose recuperation will be either significantly time-consuming or so "destructive" as to cause disruption of the adversary's cognitive functions. As AI evolves, knowledge of the mechanisms of human brain activity that will be purposefully influenced by the projection of false visual, auditory, tactile, or gustatory sensations will increase. The result will be temporary paralysis, mental and moral shock, and loss of the ability to perceive reality. Advanced high-tech prognostic methodology will become an important element in predicting the opponent's decision-making process by working on in-depth knowledge and subconscious individual and cultural codes determining decisions conditioned by specific stimuli.

This implies, among other things, that the next operational domain is likely to be a cognitive space encompassing all spheres of human perception, reasoning, and decision-making (Malick et al., 2022). However, the activities in question are still relatively in the offing. This is due to the current limitation or absence of capabilities enabling the aforementioned futuristic effects. However, this study intends to "peek" into the near future. Its ambition is to approximate the shape of the operating environment in the horizon of 20 years, primarily its land domain.

Given the current evolution of the security environment, it can be assumed that the next two decades will continue to be shaped by the same factors that have historically prompted military conflicts. Reasons for their outbreak can include, for example, resource conservation, economic, ideological, social, or religious differences, and the struggle for influence and power (Global Trends, 2021). The assumption that revolutionary change will be brought about by new technological means or new concepts of their use by which military objectives are achieved is not expected in the horizon under study. On the other hand, however, a fundamental change in the capabilities of modern and prospective assets can be expected based on the technical performance parameters of these assets, which will fundamentally change the overall understanding and approach to future military operations.

The combination of improved sensors, autonomy, process automation, and AI will contribute shortly. Technologically advanced effectors will be more accurate, better connected, faster, longer-range, and more impactful. These factors will also translate into military art. The current perception of the operating environment, the traditional “grasp” of generally understood and accepted principles, laws, and ways of employing forces, and especially the application of outdated Tactics, Techniques, and Procedures (TTPs) will no longer be appropriate to the capabilities of technologically advanced military forces.

Methods

There is a definite correlation between technological developments and changes in military art in response to implementing innovative technologies in military force structures. The study, therefore, focuses on the technological trends that are most likely to significantly impact regular armed forces on the future “algorithmized” battlefield over the next 20 years. Such predictions are never straightforward and exhibit a considerable degree of abstraction. On the other hand, however, they are essential in adequately developing military force capabilities that are adequate not only to current but especially to future threats.

The study’s aim and contribution are to outline the perspectives for the development of the future operating environment over the next two decades and formulate challenges for the use of the land component on a technologically saturated battlefield.

For this reason, the scientific efforts of the study’s authors were aimed at answering two key questions: What capabilities will new and promising technologies bring to the operational environment in the next two decades? How will these technologies affect the use of the land component on a technology-saturated battlefield?

The authors did not intend to categorize and describe “revolutionary” development projects, types, and models of modern and promising technologies of individual manufacturers nor to compare their parameters. Nor was it the intention to examine the technical solutions and clarify the principles of operation of these technologies. The technologies examined were viewed through the lens of a user-decision-maker, i.e., what will these technologies bring and how their implementation into a “battle formation” in a future operating environment may affect the shape of the land domain of the future battlefield, especially in terms of the potential impacts on the land component’s activities in such an “algorithmized” environment.

Empirical-intuitive research methods were applied in the research. The study stems from the authors’ theoretical research and analysis. It applies findings from scientific and professional publications, articles, studies, and theses, including national and international military doctrinal environments, assessing the current operating environment and its development trends. The study respects current pragmatic principles, practices, and generally accepted parameters of conventional high-intensity conflict and assesses their validity in an assumed “algorithmized” land environment.

The collected data were examined using theoretical research methods of analysis and synthesis. The findings from this analysis were formulated using a comparative approach. The formulated research questions were examined using heuristic forecasting methods. The conclusions presented are only predictive; they cannot be considered to have been proved exactly.

Digitization of the battlefield

The operating environment's current complex and dynamic nature places high demands on military forces and their development in various areas. One area is creating and maintaining situational awareness on the battlefield, which is essential for successful planning and conduct of operations. The importance of this capability will continue to grow as the volume, intensity, and dynamics of events in the operating environment increase, and future operations will be conducted simultaneously across operational domains as a part of "cross-domain" operations. Given the nature of the current operating environment, developments most influence this capability in the information environment. Therefore, the information environment is also important, especially in situational awareness of current and future operations (Fiebich, 2020).

"To see and not to be seen" has been the motto of every battlefield commander since time immemorial. Battlefield visualization has been a key requirement of the commander since the late eighteenth century when the battlefield became too vast for one person to cover visually. The consequence was introducing observer functions from which the observation results were provided to the commander to visualize the battlefield (Pong, 2022). Digitization is and will be an essential part of any battlefield in the future. It allows the commander to apply Boyd's OODA Loop (Observe, Orient, Decide, Act) decision cycle and thus supports the commander's art of determining when, where, for what purpose, what combat systems to deploy, and with what desired effect.

Intelligence, Surveillance, and Reconnaissance (ISR) capability will be achieved on future land battlefields through various sensors and systems operating in any physical environment, regardless of terrain profile, climate, and weather conditions (Rolenec et al., 2022). The digital picture of the situation in the land domain will be transmitted via broadband high-speed encrypted data transmissions, command, telemetry, and imagery information in the form of streaming high-definition video. This video will be transmitted from sensors on ground (and possibly underground), overhead, and airborne levels, at different flight altitudes, and from different viewpoints. The sensors will no longer be limited to traditional reconnaissance units, Unmanned Systems (UxS), airborne assets, and space satellites. The sensor will be for every device and every individual person on the land battlefield. All relevant information about the battlefield, including the occurrence of threats, enemy deployments, and activities, as well as friendly force tracking, will be aggregated, analyzed, evaluated, and shared in real-time. Miniaturization of communication means multi-stage data digitization, network-oriented system architecture, and automation of information processes. Reducing the information flow time will allow the acquisition of a Common Operational Picture (COP), providing real-time information about any domain in the required range down to the lowest C2 levels. Technological advances will allow the battlefield to be integrated so that, in addition to the land (and other physical) domain, the "fight" will co-occur in the information and cognitive domains. Engagement supported by augmented and virtual reality will become the standard means of operations.

More than ever, information dominance will come down to which side in a conflict can gather that data faster, analyze it accurately, and then disseminate it to the user in a safe and targeted manner, including with the help of AI. AI will self-generate action options for autonomous assets (Koch, 2022), achieving a high degree of redundancy and making action decentralized, even completely independent of the human component. The combination of affordable sensors and the ability to process large volumes of data points to a potential revolution in real-time information detection, processing, and sharing.

This capability will become a High-Value Target (HVT) for the enemy and, at the same time, will likely be a Centre of Gravity (COG) for its forces (Šlebir, 2022). The more connectivity is seen as a decisive advantage for one side, the more the other side will seek to disrupt, degrade, and turn off highly connected, information-dependent systems. The protection and resilience of information systems that provide connectivity and COP will become critical factors (Kompan, 2020). Any disruption to their functionality as a result of enemy activity can transform a combat system from a connected cohesive network to a fragmented network, unable to provide data in a complete, timely, and addressable manner, ultimately negatively impacting the COP and, thus the combat system's ability to achieve desired lethal and non-lethal effects (Global Trends, 2021). It stands to reason, therefore, that the technological evolution of information systems will be intertwined with the evolution of its "resilience."

Lethality and effectiveness on target

The future will likely focus less on firepower and more on the power of information through the concepts of Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance, and Reconnaissance (C5ISR). However, information, while it can support the effectiveness of weapon systems and increase the efficiency of decision-making processes, by itself is unlikely to be able to compel an enemy to bend to the will of an adversary (Zůna, 2021), at least not in the timeframe examined in the study.

Increasingly advanced effectors will be used to achieve the desired effects in the identified targets. One of the most significant and enduring requirements and trends in developing weapons, weapon systems, and ammunition is the increasing combination of long-range, high speed, precision, and increased potential for physical target neutralization.

The current long-range strike capabilities of modern weapon systems already foreshadow that, e.g., command posts (Rolenec et al., 2023), areas of concentration of military forces or logistics facilities, and others, which have so far been perceived as relatively safe due to their distance from the enemy's conventional assets, will become increasingly vulnerable (Spišák, 2022).

In addition to the increasing range of the weapon systems, the accuracy (Varecha, 2020b) and destructiveness (Varecha & Majchút, 2019) are also fundamentally increasing, especially indirect ones. This trend is due to the interconnection of high-precision systems (sensor-effector) with the automation of fire control processes, which are based on proper target location information, sophisticated ammunition guidance on the target, and its broad capabilities to achieve the desired lethal and non-lethal effects in that target.

Advanced ammunition and loitering munition on the future battlefield can be expected to be more destructive and more difficult to detect, mainly because of their miniaturization and their dynamics of action. Electronics are already giving advanced ammunition new capabilities, e.g., the ability for programmable airburst, proximity airburst, and guidance to meet emerging threats that could not be defeated otherwise (Breaking Defense, 2023). The increasing number, effectiveness, and relative availability of such systems will pose a significant threat not only to the most militarily critical elements of the combat system (command posts, communications facilities, high-pressure weapon systems, logistics infrastructure, and others) but to all segments in the air domain, not excluding small tactical units, and even individuals operating at the land domain of the battlefield.

Systems that can detect, track, and eliminate fast-moving projectiles and deftly maneuver miniature platforms capable of operating over long distances are and will continue to be relevant challenges. The continued development of Directed Energy Weapons (DEW), particularly laser-based weapons, may revolutionize adequate countermeasures. Their active use on the land battlefield can be expected within two decades. The rate of fire of these weapons could exceed any current and future mechanical systems.

DEW will be capable of disrupting or completely turning off the physical object and any operation of information, communication, command, control, and other electronic assets or systems. Their key asset will be their rapid effect on the targets, use regardless of weather conditions, and effect on many diverse targets. Their use on less accessible targets (e.g., underground) can be envisaged. However, their main advantage is the minimization of collateral damage, the speed of guidance on target, and, last but not least, the reduction in the number of forces necessary to meet the operation's objectives. In the future, DEW can be expected to be deployed in cooperation with all military components, services, and branches (land, air, and naval forces). Their use in space on "space-borne" vehicles or satellites is also envisaged to disrupt the enemy's satellite information and communication channels. Research is also advancing in using DEW energy against dismounted individuals (e.g., to disperse crowds) (Valouch, 2016).

Today, advanced military powers are also planning on allocating destructive laser weapons to infantry. Current firearms design capabilities appear to peak, and further development options are considered exhausted. Moreover, ballistic protection for individuals is continuously improving, and thus, the pressure to develop individual weaponry is increasing (Kulhánek, 2023). Therefore, the future may hold, for example, miniaturized lasers, which have the potential to complement small arms on the future battlefield or to replace anti-material rifles also used against dismounted troops (Extance, 2015).

DEW systems are likely to be an effective response to low-cost distributed technology threats represented by the swarms of Unmanned Aerial Vehicles (UAVs). Compared to traditional weaponry capabilities, they will be more accurate and significantly more powerful. Their key expected asset is an "infinite magazine" (Lockheed Martin, 2023).

On the other hand, a limiting factor and a significant disadvantage of these systems may be their high dependence on electricity in addition to the investment cost. The loss of a power source, for example, through damage due to combat activity, renders them unusable. A limiting factor for their introduction into land force units is their size, although the weight issue can be addressed by robotic exoskeletons and/or Unmanned Ground Vehicles (UGVs). Another limiting factor is the current international law, agreements, and constraints regulating the use of laser systems. This causes permanent damage to vision and disproportionate injury or suffering to achieve a military objective (Kulhánek, 2023).

The considerable progress in the passive protection of weapon systems is also worth noting. Technology that allows to hide the unmasking signs in the infrared spectrum emitted by combat systems, e-camouflage emitting an image behind the vehicle, a material that refracts light so perfectly that a vehicle hidden under this "smart" surface becomes almost invisible to the human eye represent a selection of Research and Development (R&D) concepts of technical camouflage of the future (Wang et al., 2013). In this context, in the timeframe examined in the study, such a method will be used with a high degree of plausibility and convincingness to camouflage combat assets and dismounted individuals across the entire spectrum of electromagnetic radiation.

Autonomy and speed

Autonomy is "a system's ability to function, within parameters established by programming and without outside intervention, by desired goals, based on acquired knowledge and an evolving situational awareness" (NATO Term, online). In the context of the presented study, external intervention must be seen without extensive human input (Rossiter, 2020).

Even though the level of autonomy and automation of both combat and support platforms and systems is advancing (Kopuletý & Palasiewicz, 2018), humans are still likely to be involved in a decision-making loop ("man-in-the-loop"), albeit only to a necessary minimum. Their role will be to exercise command (giving orders or granting permission to such a system to carry out a specific action), direction, and control over complex operations directly on the battlefield (Górnikiewicz & Szczurek, 2018). Keeping humans involved in decision-making has its advantages. The human brain remains the most advanced cognitive processing system compared to AI systems. These tend to be fragile and can make mistakes when adapting to new situations, whereas human intelligence is not only more robust but often more flexible in the face of these unfamiliar or dynamic situations. While humans do not achieve the short reaction times that machines have, they often do a better job, especially when reacting to a new situation (Foster, 2021).

There are several benefits of autonomy and automation of sub-processes, as well as the decreasing level of human interaction with military platform operators. The most important is their ability to operate continuously and for more extended periods, with higher accuracy and reliability in terms of the probability of creating the desired effect on the targets (e.g., autonomous guidance of ammunition), but also, for example, the absence of failure due to stress and fear. However, speed in terms of decision-making means speed of execution of actions or reactions.

Full autonomy of current and future military platforms is and will continue to be essential. One example is defensive, reactive systems autonomously detecting and eliminating threats (e.g., mortar shells, rockets, cruise missiles, or RPGs flying at operational bases or on ground equipment). Human involvement in the decision loop in the form of identification and confirmation of such a threat and subsequent adequate response to disarm it is impossible. This is because the reaction time is too short. With the current and expected trend in technological development of effectors and ammunition, characterized by their increasing automation of cycles, speed, lethality, accuracy, capabilities, and modes of operation (e.g., loitering munition and advanced ammunition), and saturation density on the battlefield, including the land domain, this reaction time will be even shorter. Another example of the benefits of complete autonomy of military platforms is UAS, which, if operated by an operator and this communication was disrupted by enemy activity, the operator would be unable to, for example, authorize a strike to be conducted on an identified target (Foster, 2021).

The development, advancing capabilities, and increasing autonomy of UxS are closely linked to advances in AI. AI is already being used today to enhance the performance of various existing systems, e.g., in data collection and analysis. In the second development phase, AI will be used to support decisions. C2 processes will be the same but significantly accelerated. Selected tasks, particularly the analysis, generation, and comparison of enemy courses of action, will be automated and carried out entirely "electronically." Analytical tools taking into account a range of factors and uncertainties using AI (Matiz-Rojas & Fernández-Camargo, 2023) and machine learning models will be able to interpret patterns of enemy behavior in a broader context and thus more accurately predict scenarios of the evolution of the situation. Military decision-making will be heavily dependent on AI. This will be driven not only by the exponential increase in the volume of data collected and the requirement to process and manage these data and information flows faster (Hlavizna et al., 2023) but especially by the increasing requirement to optimize the use of available combat power. Thus, the ability to prioritize and process large volumes of data will be an important milestone. In the third development phase, AI can be expected to directly "work" against sophisticated adversary systems. This capability will be key to achieving greater autonomy for platforms and entire systems.

Unmanned Systems Swarming

UAS of all types and categories are rapidly becoming more numerous, capable, and cheaper. Concentration of force at a specific time and in a decisive place has traditionally been a key factor in success or failure on the battlefield for thousands of years (Fuller, 1993). Its importance is confirmed because it is still understood as one of the principles of operations in NATO today. But will this principle continue to be crucial in the future? One confirming example in this context is swarms of UAVs, which may cause air defense systems to fail because their software will not be able to react to rapidly maneuvering numerous targets that are constantly changing flight patterns using complex algorithms. As a result, the software may be unable to process the patterns and engage these targets (Finlan, 2021).

However, the potential of micro-UAV swarms is not just about their quantity. Shortly, they could communicate, adapt their TTPs, and focus their activities on targets as circumstances change (Nohel et al., 2023). They will act as mobile jammers, mobile sensors, or UxS assemblies. These will be able to form a set of seemingly logically interconnected links that will appear as a "classical unit assembly" from the point of view of the electromagnetic spectrum. The enemy will consequently jam signals where no combat or other assets are operating, but deceptive targets create the illusion of an assembly and their communication. Taking control of UAS, jamming the communication channel between the operator and the UAV, or their positioning will be inapplicable with platforms operating with a higher level of autonomy.

UxS is expected to play an irreplaceable role on future battlefields. They will continue to replace human soldiers, which will positively affect the economy of combat operations and the economy of force. The following two decades will likely increase the prevalence of new types of UxS at all levels, including developing their capabilities. Sensors will be used in a fusion of technologies (day- and night-vision camera and thermal imager) comprising acoustic, tachypnotic, odor, seismic, and other sensors. The development of UxS will focus on their miniaturization, reduction of the electromagnetic footprint, and cooperation.

The development of sophisticated cooperative and non-cooperative collision avoidance systems providing "sense and avoid" will enable the deployment of numerous swarms of micro-UAVs on the battlefield with minimal separation distance (Višnai & Kandera, 2021). Their deployability will thus be possible in any terrain, not excluding built-up areas. In this specific rugged terrain, they will be able to operate in all its levels, including complicated multilevel constructions, i.e., inside buildings (Hrnčiar & Spilý, 2011) and also in shared air-space with human-crewed aircraft. Current concepts state that miniature UAS will soon be available to every American soldier. They will be designed to enhance the detection capability of remote threats to ensure the reliable elimination of any hidden targets (Pickrell, 2019).

Their core tasks will continue to include ISR, targeting support, search and destroy of enemy HVTs, and protection and Close Air Support (CAS) of their own forces on the land battlefield (Turaj, 2019), escorting military helicopters (Blain, 2023), or electronic warfare support.

However, their considerable potential is also in force sustainability (e.g., in the provision of materiel, ammunition, food, etc.), mobility support tasks, or counter-mobility measures (e.g., creating minefields or creating breaches in enemy minefields). UxS can also be expected to increase in detecting and removing Chemical, Biological, Radiological, and Nuclear (CBRN) material and Explosive hazards or even in decontaminating troops and vehicles.

At the same time, technological developments will bring significant advances in air defense related to Counter-UAS (C-UAS) protection and defense. UAS capable of "hunting" enemy UAVs and loitering munitions may be an advance in this area.

Manned-unmanned teaming

Semi-autonomous control of assets, equipment, and systems from a relatively safe remote place can now be considered firmly integrated on the modern battlefield. In the future, there will be a growing interest in developing the concept of troops dismounted or mounted and autonomous systems operating in joint teams, so-called Man-Unmanned Teaming (MUM-T). MUM-T represents "the synchronized employment of soldiers, manned and unmanned air and ground vehicles, robotics, and sensors to achieve enhanced situational understanding, greater lethality, and improved survivability" (BAE Systems, 2023).

The future of the land battlefield will be characterized by implementing combat UxS into unit formations, e.g., as accompanying or paired land and air platforms. Using broad-based algorithms, machine learning, and big data processing quickly will gradually enable the transition to a higher level of UxS autonomy. In the initial phases, operators will remotely control them; once the associated conceptual, technological, and operational challenges are solved, they will perform these tasks partially autonomously and, in the more distant future, possibly even fully autonomously. A significant expected benefit is not only the increase in firepower of such a combat system but, more importantly, the ability to execute a broader spectrum and wider range of tactical tasks by reducing the operational deployment of manned elements, allowing them to focus on other tasks (Aerospace Technology, 2022). At the same time, the prevalence of UxS within the MUM-T will bring a quantitative reduction in manned elements deployed and thus reduce the risk of casualties (Zahradníček et al., 2022).

However, the tactical use of UxS within MUM-T is limited by two factors. The first is the extent of the ability to process information about the micro-relief of the physical environment (Křišťálová et al., 2022; Mazal et al., 2020); the second is the lack of Positive Identification (PID) of the target. This is because the system still does not have a database of algorithms that allows it to generate a decision about the nature of the target with human-comparable accuracy. An alternative may be the already existing UxS Combat Identification (CID) capability, which allows the identification of own units on the battlefield. However, even in this case, the system cannot distinguish whether the entity (person) present on the battlefield is an enemy, a civilian, or another actor.

For the foreseeable future, the achievement of lethal and non-lethal effects will continue to be approved by human operators or decision-makers. Despite this, MUM-T is likely to become one of the key innovations on the land battlefield. Smart, connected, and modular UxS linked by a distributed intelligence network will act as force multipliers for manned platforms. The complex future operating environment will inevitably require UxS to be deployed alongside air and ground manned platforms to operate as a team. Advances in technology and AI will gradually enable greater autonomy and redundancy between future military unmanned platforms, drastically reducing MUM-T's logistical and cognitive burden in future operations (Aerospace Technology, 2022).

The increased independence of autonomous or semi-autonomous platforms will gradually make the man-in-the-loop approach obsolete, limiting the number of human operators needed to perform MUM-T. Furthermore, by removing a degree of direct control over the operations of UxS platforms, these manned elements will provide a greater degree of tactical, operational, and even strategic control over the battlefield. By removing the need for humans to operate the navigation and target identification systems of "inanimate" platforms, the operator can concentrate on more complex tasks such as intelligence dissemination and distribution or coordinating measures with other elements of the combat system formation.

Given UxS's potential, the ratio of manned to unmanned systems in the MUM-T formation will likely decrease over time as unmanned platforms become increasingly independent and reliable. Whether this trend will ever lead to the creation and deployment of exclusively unmanned formations remains to be questionable (Aerospace Technology, 2022).

Exoskeletons

When deploying MUM-T in future military operations, we can consider the most significant challenge to be the integration of "human soldiers" into such teams because, as mentioned in the previous sections of the study, unlike "machines," they suffer from fatigue and must be able to cope with dynamic changes and prevalence of lethal unmanned platforms mentally, psychologically, and physically on such a battlefield. It is the exoskeletons that can enhance the physical capabilities of the deployed "human beings," and their mass use will herald the deployment of a new military branch or specialization that can be laboriously termed "heavy dismounted infantry" (Yeadon, 2021).

A boom in the use of exoskeletons can be anticipated, especially in military branches where increased physical stress is involved in deployment, mainly due to the high weight of equipment and armament (Mudie et al., 2021), such as Explosive Ordnance Disposal (EOD) units (Wu et al., 2021) or the aforementioned infantry. Therefore, the use of exoskeletons will also be closely related to their development, which should focus on "comfortability" when worn and the possibility of integrating the weapon systems used, including the aforementioned DEWs.

The use of these "warrior suits" will reduce the soldier's metabolic expenditure, as the exoskeleton will perform mechanical work (carrying loads, walking), reducing the extent of logistical support and allowing for a wider dispersion of deployed forces on the battlefield. It will also enable the integration of the most sophisticated communication systems and C2 platforms so that the future "warrior" is explicitly "fed by data for better decision-making" (Gruss, 2022).

In the future, exoskeletons will provide a platform that enhances the survivability of deployed soldiers on the battlefield by adding additional protective equipment beyond standard personal protective equipment to provide protection against high-explosive projectiles, protect the wearer's vital body parts, and thereby reduce overall combat casualties. However, these capabilities will require changes over the next two decades in the design of the exoskeletons themselves (Bengler et al., 2023) so that they are not just another "bulk weight" for the soldier but a device that will create a "man-machine" combat complex.

Such a concept will enable the deployment of soldiers on the technology-saturated battlefield of the next two decades, with the "man-machine" representing a kind of control "node" for other advanced assets, e.g., UxS. While it may not explicitly represent the C2 element itself, it may represent a "human" backup to autonomous systems directly on the battlefield due to its increased firepower, survivability, and complex situational awareness.

Artificial Inteligence

AI can already be considered one of the Emerging and Disruptive Technologies (EDTs), i.e., a rapidly developing technology that will indeed cause breakthroughs in other fields as well (NATO, 2023). AI can be expected to explode in the next two decades, significantly impacting the requirements for overall security and defense assurance and creating challenges for operating in the land operating environment.

The application of AI, along with advanced data analytics and the use of "Big Data," will fundamentally impact the information environment where cross-domain operations are conducted. AI will be used to identify optimal influence operations aimed at confusing the adversary, diverting public opinion from supporting the resistance, or acting directly on the perceptions of deployed combatants (Lucas, 2022).

AI will also have military applications in increasing the effectiveness of the aforementioned "lethality" of modern weapon systems. In particular, its utility in "targeting," where we can foresee its total involvement in the Decide, Detect, Deliver, Assess (D3A) process, whereby its role will be crucial due to the "saving" of resources and the use of "Delivery Assets" for such targets that will not only contribute to the success of land operations but will also significantly reduce the enemy's combat potential.

Autonomous systems, or MUM-T, and "heavy dismounted infantry," will rely on the COP that AI will provide. The most important fields that AI will gradually take over in the land operating environment are those in which human intervention is not necessary, such as military hydrometeorology, military cartography, analytical support, logistics systems, and the use and protection of critical infrastructure (Jančo, 2022), or materials engineering. The second group of activities are those where human intervention is too slow to provide immediate action, such as target detection, electronic warfare, cyber protection, and explosive ordnance detection and elimination (Agarwala, 2023). Other activities and domains, such as C2 or target engagement, will continue to be in hybrid mode over the next two decades, with human intervention providing the "entry" of military art and serving to prevent the creation of moral and legal dilemmas (Morgan et al., 2020).

There is already clear direction and conceptualization of which functional areas AI should focus on, with C2, information management, logistics, and training being the main ones (Grand-Clément, 2023). The subject areas are very closely interlinked. It is reasonable to assume that AI will provide such a significant advantage to the land component in the future that it will provide superiority over an enemy that does not exploit AI capabilities.

Conclusions

The hypothetical assumption that today's military will have no chance against the technologically advanced "hypermodern" military of the mid-21st century may seem intuitive but not explicitly objective. After all, military history offers more than a few examples of refutations of such a hypothesis. In the first two decades of this century, the world's most technologically advanced military was only able to operate in a limited way against Iraqi or Afghan insurgents in irregular conflicts. On the other hand, it should be noted with certainty that the reasons for this "failure" were not solely rooted in the failure of its combat potential.

The capabilities of the most advanced armies will surely be dramatically different within two decades. A significant accelerator of their growth is the integration of innovative technologies that will cause noticeable changes on the land battlefield, especially in the areas of interconnectivity, speed, lethality, autonomy, sustainability, and other spheres. These factors will fundamentally influence the deployment concepts of the land component in future operations.

The future operating environment will be characterized by interconnectivity and operating in multiple domains simultaneously. The desire to create synergies of action is and will be evident. The information environment, volume, throughput, speed, data flow redundancy, and transmitted information processing will become decisive. The intent and direction of military force efforts will be to hack the integrity and connectivity and disable adversary system links.

It can be assumed that the land domain battle will be fought by "hybrid combat systems," but humans will occupy the dominant position. Even within two decades, C2 as a central combat function will not yet be replaced by AI-enabled machines. Humans will "play" the role of decision maker, while machines will provide overall data acquisition, processing, and analysis. UxS replaces activities that are dangerous for humans with more humans. The various platforms will be managed or, depending on the level of autonomy, at least controlled by humans from a remote, safe place.

Although the physical land operating environment to be observed, controlled, and occupied will be significantly more significant, the nature of the fight will not fundamentally change. However, the capabilities of assets will change, and the ways and means of employing them will expand. From the perspective of the physical component of the combat potential of future military forces, long-range lethal assets, such as combat UxS and UxS swarms, or long-range fires, especially rocket and barrel artillery, advanced ammunition, and loitering munitions, will be critical.

The increasing range, speed, accuracy, and lethality of effectors will affect the survivability of expensive, high-value, and hard-to-replace platforms and the performance of land forces themselves. The combination of accurate geolocation, high precision live and authentic battlefield situational awareness, continuous sensor connectivity, and instantaneous automated effector response means that, in the near future, military forces may no longer need or be able to follow the principle of "mass" in the time, space, and scale traditionally considered necessary to achieve their objectives.

One possible approach to potentially mitigate the adverse effects of fires from a technologically advanced enemy could be the further development and implementation of distribution, i.e., the dispersion of forces on the battlefield, including the distribution of operations. In this context, an increase in task, space, resource, and time-limited tactical operations can be expected. The survivability of combat systems, manned and unmanned forces on a technology-saturated battlefield will depend on their speed of deployment to the area of operations, their high degree of maneuverability in that area, and their subsequent withdrawal, regrouping, and deployment to another area. The mass deployment of combat systems in small areas, the static nature of operations, low levels of deception, cover, and concealment, linear single-domain operations, and an enumeration of other "battle-tested but outdated" traditional approaches to conducting military operations will multiply the risk of force localization and subsequent imminent neutralization.

All identified technologies will serve as the basis for overall defense capability and deterrence, as they will ensure technological dominance. Therefore, they must be developed and, of course, implemented in the development of the security sector of any state. Properly structurally integrated and procedurally implemented technologies can and probably will become determinants of qualitative advantage. However, unless the party possessing these technologies can fully perceive the capabilities and givens of the physical environment and adequately apply military art, creativity, and its own capabilities to specific conditions, the application of the potential of modern and sophisticated assets to the operating environment will be inadequate.

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