Norbert Daruka

OPPORTUNITIES AND RISKS OF THE TECHNOLOGICAL DEVELOPMENT OF THE HUNGARIAN DEFENCE FORCES IN THE LIGHT OF EMERGING AND DISRUPTIVE TECHNOLOGIES

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ABSTRACT: *The security environment of the 21st century is characterised by an unprecedented acceleration of scientific and technological progress. Emerging and Disruptive Technologies (EDTs) are fundamentally reshaping the nature of warfare, the structure of military capabilities, and the security landscape. For the Hungarian Defence Forces, the strategic importance of these technologies is twofold: on the one hand, they offer opportunities to enhance combat capabilities, maintain interoperability, and exploit national innovation potential; on the other hand, they pose serious challenges in terms of asymmetric threat propagation, ethical and legal dilemmas, and the risk of technological backwardness.*

The study provides a comprehensive overview of the main technology categories – artificial intelligence, autonomous systems, quantum technology, biotechnology, advanced materials, energy weapons, hypersonic systems, space technology, and new tools for cyber and information warfare – and analyses their military applications. Particular emphasis will be given to the strategic opportunities relevant to the Hungarian Defence Forces and the potential threats.

The aim of the publication is to contribute to the conscious shaping of the technological development of the Hungarian Defence Forces, their close integration into NATO and EU alliance frameworks, and the development of the Hungarian defence innovation ecosystem.

The analysis makes it clear that states that can proactively and consciously integrate EDTs into their military capabilities will retain their relevance in the security space in the future.

KEYWORDS: *emerging and disruptive technologies, quantum technology, artificial intelligence, military innovation*

ABOUT THE AUTHOR:
Norbert Daruka (PhD) is the branch head of the Scientific Research Centre of the HDF Transformation Command (ORCID: 0000-0002-7102-1787; MTMT: 10039981).

INTRODUCTION

One of the most important security policy features of the 21st century is the acceleration of scientific and technological progress. Emerging and Disruptive Technologies (EDTs) are bringing about a paradigm shift not only at the economic and societal levels, but also in the fundamental framework of warfare. Their specificity is that they are often derived from civilian developments and then become dual-use: this represents both an opportunity for

military adaptation (to find cost-effective solutions by ensuring economies of scale) and a risk for the proliferation of asymmetric threats.

Emerging technologies are based on the latest scientific advances. Although many are still at the experimental stage, they could soon have a breakthrough impact on military capabilities and societal functioning. By contrast, disruptive technologies are radical innovations that fundamentally obsolete existing systems and capabilities.

Already at its London Summit in 2019, NATO stressed that these technologies "have the potential to fundamentally transform the operational environment and define the warfare of the future".[1] This recognition led to the launch of the Defence Innovation Accelerator for the North Atlantic (DIANA)[2] program to support and connect allied innovation capabilities.[3] The EU has established the European Defence Fund (EDF) to support dual-use R&D with a similar objective.[4]

In NATO's understanding, EDTs contribute to the five main evolutionary requirements of the Basic Concept of Warfare: cognitive superiority, integrated multidimensional defence, multidisciplinary command, multi-level resilience, and broad projection of influence and power.[5]

The United States, China, and Russia play a dominant role in the global technological competition. Washington is seeking leadership in artificial intelligence (AI) and quantum technologies,[6] while Beijing is integrating its economic and military spheres through civil-military fusion,[7] but has recently devoted significant resources to AI- (and biotechnology-) based developments. Moscow, on the other hand, is building its advantage primarily on hypersonic weapons and electronic warfare.[8]

For the Hungarian Defence Forces, the integration of EDTs is not a luxury but a strategic imperative. Preserving NATO interoperability, addressing regional security challenges, and the development of the domestic defence industry all justify Hungary's emergence as a 'smart user' in the technological race.

For Hungary, as a medium-sized state, the challenge is twofold: the Hungarian Defence Forces cannot be at the forefront of all technologies, but falling behind can have serious consequences for interoperability, defence industrial development, and national security. The Zrínyi 2026 Defence and Military Development Program, as well as the National Security Strategy and the National Military Strategy, state that without the integration of modern military technology and innovative capabilities, the Hungarian Defence Forces cannot guarantee national defence and the fulfilment of alliance obligations.

The aim of this study is to provide an overview of the main EDT categories, analyse the opportunities and risks of their military application, and formulate recommendations for the technological development of the Hungarian Defence Forces.

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1 NATO 2019.

2 NATO 2022.

3 In fact, it is mostly about finding start-ups who might not otherwise be thinking about military development, but who can make their development dual-use, with financial support and economic and technological expertise – through accelerators and test centres.

4 European Commission 2021.

5 NATO 2021.

6 U.S. Department of Defense 2022.

7 Johnson 2020.

8 Biddle – Zirkle 1996.

TECHNOLOGICAL TRENDS AND MILITARY RELEVANCE

The military strategy of the 21st century is increasingly defined by emerging and disruptive technologies. Artificial intelligence, for example, offers breakthroughs by optimising logistics processes, supporting decision-making, and enabling rapid data processing in reconnaissance.[9]

Nevertheless, it poses serious ethical dilemmas for the operation of autonomous weapons systems.[10] Robotic solutions enable the machine-assisted takeover of dangerous tasks, while creating an asymmetric threat.[11]

Three fundamental dimensions of quantum technology – computation, communication, and sensing – could revolutionise encryption and navigation. While quantum communications can provide unbreakable data transmission,[12] quantum computers could compromise and render current encryption systems irrelevant.[13] NATO is therefore prioritising research and development related to quantum technologies.[14]

Biotechnology offers opportunities in military health, casualty care, and human performance enhancement,[15] but also raises bioethical and legal concerns, particularly in relation to genetic engineering and artificially enhancing human performance.

Advanced materials and nanotechnology promise lighter and stronger armour, self-repairing structures, and 3D-printed supply solutions that can significantly increase the performance and sustainability of military systems.[16] At the same time, these developments create new types of dependencies: access to and security of supply of rare earths and special alloying materials are key to long-term deployability. Although the developments are costly, they can be made available to the Hungarian Defence Forces through cooperation with NATO partner countries, provided that security of supply can be guaranteed.

Energy weapons and hypersonic systems pose new challenges: the former can provide a cost-effective alternative to drone threats, while the latter pose an almost insurmountable challenge for air defences.[17]

Space technology and next-generation communication networks have become indispensable in modern warfare, but space assets are vulnerable, and networks can be targets for cyber threats.[18]

Cyber and information warfare have become key theatres of modern conflicts. Cyberattacks and disinformation campaigns can have immediate and strategic effects that directly affect social cohesion and national resilience.[19]

The effectiveness of military logistics is as important as the development of combat capabilities in the war of the future. The digitalisation of the supply chain – through predictive analytics, digital twins, and automated warehouse management systems – will enable accurate tracking of inventories, forecasting of maintenance requirements, and optimisation

9 Cummings 2017; Horowitz 2018.
10 Scharre 2018.
11 Johnson 2020.
12 UNIDIR 2021a.
13 OECD 2020.
14 NATO 2021.
15 Payne 2021.
16 Ember 2023.
17 Sechser 2019.
18 WEF 2020a.
19 Horowitz 2018; Johnson 2020.

of supply routes. For the Hungarian Defence Forces, it is particularly important to integrate solutions that reduce dependency on external suppliers and ensure continuous supply even in theatre conditions. 3D printing and the use of self-driving transport vehicles can open up a new dimension in logistics operations.

OPPORTUNITIES FOR THE HUNGARIAN DEFENCE FORCES

The application of emerging and disruptive technologies not only serves the technical modernisation of the Hungarian Defence Forces but can also open up a new strategic path. For example, the use of artificial intelligence and autonomous systems can accelerate decision-making, enhance intelligence capabilities, and make logistical processes more efficient.[20] It is important to highlight that many of these technologies have been in use for 7–8 years already, which suggests that these solutions are not merely future possibilities, but technologies that have been known, expected, and already in practice in certain countries (e.g., Israel, South Korea) or cyber defence systems for almost a decade. AI-based predictive maintenance systems can contribute to increasing the availability of military assets while reducing operational costs. Similarly, autonomous robotic solutions can perform hazardous tasks such as mine clearance or reconnaissance, reducing the risk to personnel.[21]

New technologies also offer benefits in terms of resource efficiency. The use of digital twins[22] and simulation systems can speed up selection enormously and offer a more cost-effective and flexible training solution than traditional training. An advanced simulation system can model different battlefield situations in which soldiers – even using their digital twins and AI to find the most effective solution by trying a virtually unlimited number of possible solutions – can practice reacting without risk, while AI adaptively shapes the simulation based on the behaviour of the users.[23] This not only makes training more realistic but also speeds up the learning process.

The integration of civil innovation and defence is also a significant opportunity. As the majority of EDTs are dual-use, it is imperative for the Hungarian Defence Forces to build close links with universities, research institutes, and technology companies.[24] This not only provides access to military developments but also contributes to the strengthening of the domestic defence industry.

The European Defence Fund, the European Defence Agency, the NATO Science and Technology Organization (STO), and the NATO DIANA program offer cooperation platforms that enable the Hungarian Defence Forces to be part of the international innovation ecosystem.[25]

Strengthening alliance interoperability is another strategic advantage. Technological cooperation with NATO and EU partners allows the Hungarian Defence Forces to access the latest developments while acquiring capabilities that are essential for effective participation

[20] Horowitz 2018; Cummings 2017.

[21] Scharre 2018; Kovács – Ember 2021.

[22] A digital twin is a virtual model that continuously reflects the state of a physical system, process, or device in real time. This model is not just a static replica, but a living, dynamic representation: it is constantly updated based on sensor data, measurement results, and other information related to the real object.

[23] Payne 2021.

[24] WEF 2020a.

[25] NATO 2022; European Commission 2021.

in joint operations.[26] This improves practical cooperation and enhances Hungary's strategic weight in alliance decision-making.

Finally, new technologies can help to increase resilience. In the field of cybersecurity, defence systems supported by artificial intelligence can respond instantly to threats, thus reducing the level of damage.[27] Advanced materials and nanotechnologies can be used to develop equipment that increases the protection not only of military assets but also of critical infrastructure.[28]

The introduction of new technologies can only be successful if the personnel of the Hungarian Defence Forces are able to manage and integrate them at a high level. Strengthening digital competencies and developing targeted training modules on cyber warfare and the military application of artificial intelligence are essential. Joint educational programs with NATO partners and the involvement of domestic higher education institutions will enable the Hungarian Defence Forces to have a cadre of officers and non-commissioned officers who can not only use but also develop and evaluate new technologies. The conscious training of human resources is thus a key pillar of technological development.

RESILIENCE AND CRITICAL INFRASTRUCTURE PROTECTION

One of the most defining characteristics of the modern security environment is the rise of hybrid threats that affect the military, economic, social, and information spheres simultaneously. In addition to military operations, there is a growing emphasis on attacks against critical infrastructure, not necessarily aimed at direct destruction, but at disrupting social stability and weakening national resilience. Resilience is the ability of a nation to withstand shocks, mitigate damage, and restore its basic functioning within a short timeframe in a crisis situation, be it military aggression, cyber-attack, energy disruption, or natural disaster.[29]

Therefore, for the Hungarian Defence Forces, law enforcement organisations, and cyber defence institutions, one of the key dimensions of technological development is resilience and critical infrastructure protection.[30] At the same time, the issue cannot be limited to the security sector: maintaining technological resilience is critical for the entire public administration system – both at governmental and municipal levels –, as well as for public service networks (energy, transport, water supply, health, and communications). It is a fundamental dimension of the national instruments of power, which can only be achieved through close cooperation among the military, government, and economic and social subsystems.

Critical infrastructures, such as energy networks, communication and data transmission systems, transport hubs, water supply, and health care systems, are particularly vulnerable in the age of digitalisation. Cyber and electronic warfare tools can be used to disrupt these systems at relatively low cost and with high efficiency, with consequences for the country's overall ability to function.[31]

Consequently, the Hungarian Defence Forces have a dual role: on the one hand, they must ensure the redundant and resilient operation of their own military systems, and on

[26] NATO 2021.
[27] Johnson 2020.
[28] Emerging and Disruptive Technologies 2023.
[29] NATO 2016.
[30] Szalkai 2025.
[31] WEF 2020a.

the other hand, they must participate in the protection of civilian critical infrastructures in cooperation with cyber defence organisations, government institutions, and public service organisations.

Emerging and disruptive technologies play a key role in increasing resilience. Artificial intelligence-based monitoring and decision support systems are capable of real-time data processing and rapid detection of anomalies, enabling critical infrastructures to detect attacks or failures sooner.[32] Quantum communications can provide unbreakable data transmission in the future, fundamentally enhancing the security of government, military, and public service communications.[33] Decentralised energy solutions and the use of microsystems reduce a country's dependence on central networks, mitigating vulnerabilities. In addition, redundant communication and supply networks built at multiple levels ensure that essential public services are maintained in the event of an attack or failure.

The federal dimension is also crucial. At the NATO Warsaw Summit in 2016, NATO declared resilience as a pillar of collective defence and made it mandatory for member states to protect critical infrastructure, ensure continuity of government operations and maintain essential supply capabilities.[34] For Hungary, this means that the Defence Forces must employ interoperable solutions and work closely with NATO partners, government agencies, and civilian service systems to ensure resilience, whether in the event of a cyber-attack, energy crisis, or disinformation operation.

The specificities of the domestic security environment make Hungary particularly vulnerable to energy imports, cyber-attacks, and information operations that undermine social cohesion.[35] Therefore, the Hungarian Defence Forces, cyber defence organisations, and public administrations should jointly focus on the following key tasks in increasing resilience: developing cyber defence capabilities and supporting civil sector protection; conducting regular critical infrastructure protection exercises; strengthening public information and protection against disinformation; and involving the defence industry, public administration, and the civil sector in the development of resilience technologies.[36]

In addition, there is a need for closer cooperation among the Hungarian Defence Forces, domestic national security services, the Counter Terrorism Centre, and other dedicated security and disaster management organisations. The complexity of the threats requires a multidisciplinary and inter-institutional response, which can only be ensured through concerted action by the entire national security and law enforcement community.

In sum, resilience and critical infrastructure protection are not only strategic elements of the technological development of the Hungarian Defence Forces but also the basis for the operational capability of the entire national security and public administration system. Military capabilities alone are not sufficient: they require a coordinated civil-military response, the involvement of public administration and public service providers, ensuring federal interoperability, and the conscious use of emerging and disruptive technologies. This is the only way to increase Hungary's resilience to the complex hybrid threats of the 21st century.

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32 Johnson 2019.
33 UNIDIR 2021b.
34 NATO 2016.
35 Hungary's National Security Strategy 2020.
36 Kovács-Gurály 2023.

RISKS AND THREATS

While emerging and disruptive technologies offer significant opportunities, they also carry equally significant risks. One of the most important risks is the rise of asymmetric threats. Low-cost, commercially available drones and other autonomous devices are already capable of wreaking serious havoc, as evidenced by the experience of conflicts in the Middle East and Ukraine.[37] Also, deepfake content produced by AI and coordinated disinformation campaigns can weaken social cohesion and undermine the legitimacy of political decision-making.[38] Attacks in cyberspace also pose a serious threat: they can be launched against critical infrastructure, military communication networks, and logistics systems, even in peacetime.[39]

Ethical and legal dilemmas are another challenge. Liability issues for the operation of autonomous weapons systems remain unsettled. If an AI-controlled system mistakenly attacks civilians, who is to take responsibility? This question fundamentally affects the applicability of the law of war and international humanitarian law.[40] Biotechnological developments also carry ethical risks, particularly in relation to the genetic modification and pharmacological performance enhancement of soldiers.[41] The current framework of international law has not kept pace with technological change, so regulatory gaps may be deliberately exploited by some states or non-state actors.[42]

The risk of technological lag is also a key factor. Hungary does not have the R&D capacities of the major powers, so there is a risk that the Hungarian Defence Forces will not be able to adapt the technologies already used by their alliance partners in time. This could not only cause interoperability problems but also lead to strategic vulnerability in the long term.[43] For example, in the field of quantum technology and cybersecurity, a single decade of lagging behind can cause a lasting disadvantage that is extremely difficult to catch up from.

Rapid technological progress in itself carries significant risks, as it can not only lead to accelerated obsolescence of devices and systems but also test economic sustainability.

The continuous adaptation of doctrines and deployment procedures places a heavy burden on decision-making. Additionally, slow procurement often means that by the time a new technology enters service, it already requires modernisation. This makes long-term planning particularly difficult and increases the risk that systems in service are already partially obsolete at the moment of introduction.

Moreover, many new devices and systems are being introduced in the experimental phase, when they are not yet fully mature, and may pose reliability problems.[44] The development of energy weapons and hypersonic systems, while promising, is costly and will take time to become widely deployed.[45]

37 Biddle – Zirkle 1996.
38 Johnson 2019.
39 Horowitz 2018.
40 Scharre 2018.
41 Payne 2021.
42 UNIDIR 2021b.
43 Sechser 2019.
44 WEF 2020b.
45 U.S. Department of Defense 2022.

In addition to autonomous weapons systems, quantum technology and biotechnology raise serious ethical and legal issues. The use of genetic modification for military purposes, military performance enhancement through pharmacological means,[46] and the role of artificial intelligence in decision-making are all areas where international regulation lags behind the pace of technological progress. A key issue for the Hungarian Defence Forces is to support the clarification of legislation in a federal framework and develop clear ethical guidelines for military applications.

Overall, the risks of EDTs for the Hungarian Defence Forces can be summarised in three main dimensions:

– the proliferation of asymmetric threats;
– the escalation of ethical and legal dilemmas;
– and the technological backlog and the difficulties of economic-organisational adaptation.

Together, these factors justify a conscious and forward-looking strategy for the Defence Forces to address the integration of new technologies, seeking both to exploit opportunities and mitigate risks.

STRATEGIC PROPOSALS, POSSIBLE DIRECTIONS FOR DEVELOPMENT

The integration of emerging and disruptive technologies can be successful for the Hungarian Defence Forces if it is implemented within a conscious strategic framework. One of the pillars of this is the institutionalisation of regular technology foresight and long-term trend monitoring, which allows for the timely identification and assessment of relevant trends.[47] However, proactive adaptation can only be successful if the Ministry of Defence works in close cooperation with the civilian sector, universities, and technology companies, as most dual-use technologies are originally developed by civilians. The European Defence Fund and NATO's DIANA program provide platforms for the Hungarian innovation ecosystem to engage in international collaborations, thus strengthening the long-term technological resilience and federal embeddedness of the Hungarian Defence Forces.

Another priority is to strengthen innovation partnerships with civil society. Cooperation with universities, research institutes, and technology companies is essential, as the majority of EDTs are initially civilian developments that later become dual-use.[48] The long-term development of the Hungarian defence industry depends on the ability of civilian digital, automation and robotics developments to be applied at the military level.

Pilot programs and pilot projects also play an important role. Field trials of new technologies on a small scale provide an opportunity for the Hungarian Defence Forces to test tools and systems in a real environment before they are widely deployed. This reduces risk while contributing to an innovation-friendly approach to military culture.[49]

[46] Payne 2021.
[47] OECD 2020.
[48] WEF 2020b.
[49] Payne 2021.

However, none of the strategic goals can be achieved without the development of human resources. The Hungarian Defence Forces must make military careers attractive to STEM-trained professionals and provide continuous training for existing personnel.[50] Of particular importance in this respect is the conscious development of the reserve system, which provides an opportunity to make researchers and engineers from the civilian sector available to the Defence Forces, albeit for a limited period of time.

This model ensures that professionals can keep their scientific and technological skills up to date in a civilian environment, while allowing their knowledge to be integrated into military systems and applied in a targeted way when needed.

Understanding the basics of digital competencies, cybersecurity skills, and artificial intelligence is key, as even the most advanced technology cannot be exploited without the right professionals.[51]

The Hungarian Defence Forces should adopt a 'smart user' approach, which means that they do not strive to be at the forefront of development in all areas, but consciously select technology segments where available resources can be most effectively utilised or which are essential for federal interoperability.[52] This selective but targeted strategy ensures that Hungary does not fall behind in key technologies, while realistically mitigating excessive resource strain.

SUMMARY

Emerging and disruptive technologies are the defining factors of 21st-century warfare and security policy. Artificial intelligence, quantum technology, robotics, biotechnology, advanced materials, energy weapons, space technology, and cyber warfare are all areas that have the potential to transform military capabilities in the short term.[53] At the same time, these technologies bring with them both opportunities and threats.

For the Hungarian Defence Forces, the greatest opportunities for integrating technological capabilities are to increase combat capability, enhance resilience, and ensure alliance interoperability. By adapting these innovations, the Defence Forces can acquire capabilities that will enable them to remain a relevant player in NATO and EU defence structures even as a small country force.[54]

At the same time, asymmetric threats, ethical and legal dilemmas, and the threat of technological backwardness pose a constant challenge.[55] These factors can only be addressed through a conscious, forward-looking strategy that draws on both the alliance framework and domestic innovation potential.

The key to success lies in proactive adaptation. Hungary needs to develop a strategy that integrates the benefits of international cooperation while strengthening the domestic defence industry and ensuring human resource readiness. States that are able to integrate EDTs into their military capabilities in a timely and deliberate manner will retain their

[50] Johnson 2019.
[51] Cummings 2017.
[52] Horowitz 2018.
[53] NATO 2021; UNIDIR 2021b.
[54] European Commission 2021; NATO 2022.
[55] Scharre 2018.

strategic relevance in the international security space in the long term.[56] For the Hungarian Defence Forces, therefore, the use of EDTs is not an option, but a key prerequisite for future-proof defence.

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