EMERGING AND DISRUPTIVE TECHNOLOGY TRENDS IN DEFENSE AND SECURITY

Daniel DOICARIU

"Carol I" National Defence University, Bucharest Romania

In order to be able to identify technological trends in the field of defense and security, different scenarios are carried out, analyzes over certain time horizons, in-depth analyzes of ongoing research, but also estimates that are based on the opinions of experts in the field. In this endeavor, I had as the objective of the scientific research to obtain an overview of the trends of emerging and disruptive technologies relevant in the fields of defense and security, considering the current regional context. The effort was focused on the assessment of emerging and disruptive technologies, based on research and analysis of recent available literature in the field. I have come up with clarifications on defining the emerging, disruptive technologies and their convergence, the trends in the context of hybrid warfare, as well as the most promising and relevant technologies that can be applied on a large scale and are going to influence the fields of defense and security.

Key words: emerging technologies, disruptive technologies; hybrid warfare; defense and security.

1.   DEFINITIONS AND CLARIFICATIONS

Emerging and disruptive technologies are a topic of recent debate, both in the field of academic research and at the political-military level and in the business environment, which aims at their development and implementation. The proof of the importance of the phenomenon represented by emerging and disruptive technologies is found in the mediatization of the concept, the increased number of debates, articles, scientific conference, etc.

In the reference work *What is an emerging technology?* the authors identified five key attributes that qualify a technology as emerging: radical novelty, relatively rapid growth, coherence, prominent impact, and uncertainty and ambiguity (Rotolo et al., 2015). From the authors' perspective, they agreed that emerging technologies represent: *"a radically novel and*

relatively fast growing technology characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions and patterns of interactions among those, along with the associated knowledge production processes. Its most prominent impact, however, lies in the future and so in the emergence phase is still somewhat uncertain and ambiguous" (Rotolo et al., 2015, p.4). At different points in time, each technology seemed to bring something radically new to its field of applicability, even though the idea (theoretical concept) itself already existed.

The search for newer and newer innovations can also lead to disillusionment Any new technology, from discovery to maturity, is characterized by a lot of uncertainty. Figure 1 depicts 3 "S" curves for the life cycles of 3 types of technologies. "S" curves illustrate that uncertainty arises because: the technology is radical, the technology is early in its life cycle, or because of the increasingly unclear nature of security threats.
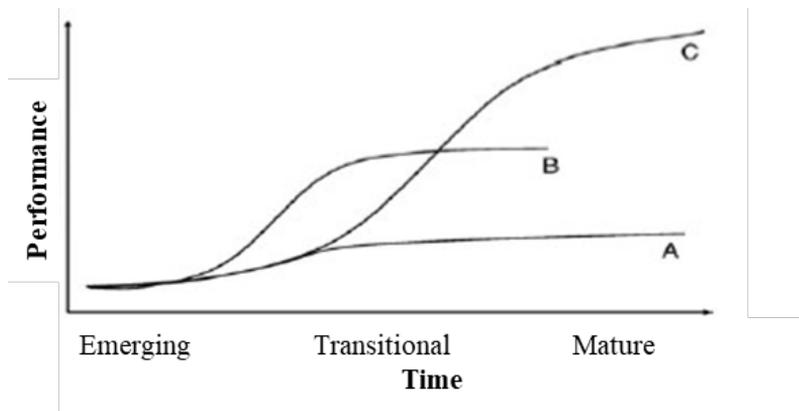

Fig. 1 Emerging technologies and the nature of technological innovation (James: 2016, p.14)

Curve A highlights that some technologies may fail to deliver the performance requirements expected by developers because technological or engineering issues may arise that are difficult to overcome in a short time or without additional resources.

Curve B illustrates a situation where a technology is being replaced by other technologies that are better, cheaper, or benefiting from a faster rate of development. The longer it takes for a technology to be validated and certified, the more

likely it is that new ones will emerge.

Curve C highlights that only some technologies will reach the stage where they will be mature enough to be considered for the transition to new military capabilities. But here comes the question of the cost of designing the emerging technology versus the benefits and effects produced.

A clarification of the meaning of emerging technology is found in the report *Emerging technology trends for defense and security*, where emerging technologies are considered *"technologies with low maturity or technology readiness level (TRL), currently in development"* (Andas: 2020, p.9). In other words, these technologies exist, but not on a large scale, being still in the stage of validation and recognition of potential. Also, this report presents the meaning of the terms convergent and disruptive technology, which may cause effects as a result of emerging technologies, as follows:

– *"Technology convergence involves merging of existing technologies in order to create new and better possibilities and allows development and maturation"* (Andas: 2020, p.9). It can be understood that by joining emerging technologies with already validated technologies, these improved technologies will result in superior effects.

– *"Disruptive technologies in the context of defence and security are technological developments that change the conduct of conflict and the rules of engagement"* (Andas: 2020, p.9). These technologies are mature and can make a difference on the battlefield.

The relationship of emerging - convergent - disruptive technologies can be found in the example of the *tank* (Andas: 2020, p.9). The emergence of armored vehicles took place at the beginning of the 20th century. The advances achieved in the First World War were due to the convergence with some technologies, such as tracks, armor, motorization, etc. which had a significant impact on the battlefield, which practically ensured the transition to the maturation of what the tank was to represent. The maturation of the tank occurred in the period between the two world wars, with the convergence of combat platforms and the command-control that was achieved by equipping it with radio stations. This combination as well as the doctrinal updates produced a disruptive effect at the beginning of World War II materialized by the blitzkrieg attacks carried out by the German army.

2. EMERGING AND DISRUPTIVE TECHNOLOGY TRENDS IN HYBRID WARFARE

Hybrid warfare is a topical notion in military science research and international studies of modern warfare and threats, and refers to the use of unconventional methods, as part of a multi-domain conflict-based approach, to disrupt and shape the actions of an adversary.

This is not an anomaly in the conduct of wars, but rather a transition, combining elements of the old and new generations of warfare. Hybrid warfare is preferred for various reasons: the adversary force is superior, to avoid international sanctions or to maintain a *"hot zone"* for a long time in a region, etc. As a rule, hybrid operations do not ensure a final victory. If an army is not able to also sustain classic military operations when the situation requires it, it cannot win the war. The transition from irregular hostile actions to classic combat operations and vice versa is actually characterized by the combination of the two, i.e. hybrid warfare.

In time, hybrid warfare will become a normality in the military actions, and the planning and decision-making process will pay more attention to the unconventional elements present in a classical war.

Hybrid warfare can provide the element of surprise in an operational environment, and disruptive technologies will help surprise and breaking an enemy's rhythm.

New technologies also bring new threats, both militarily and to civil society. *"We are increasingly confronted by cyber, hybrid, and other asymmetric threats, including disinformation campaigns, and by the malicious use of ever-more sophisticated emerging and disruptive technologies"* (Brussels Summit Communique: 2021), it was mentioned in the press release of the Brussels NATO summit of June 14, 2021. NATO leaders determined the *Emerging and Disruptive Technology Implementation Roadmap,* as early as 2019 at the London summit and the approval by the defense ministers of the NATO member states of the *NATO Coherent Implementation Strategy on Emerging and Disruptive Technologies* in 2021. Also, in 2021, *Defense Innovation Accelerator for the North Atlantic – DIANA* was launched. NATO's innovation activities focus on the following priority areas: artificial intelligence, autonomy, quantum, biotechnologies, hypersonic systems, space, novel materials and manufacturing, energy and propulsion, next-generation communications networks

(Emerging and disruptive technologies: 2023).

Simona R. Soare, expert in defense and military analysis at IISS (International Institute for Strategic Studies), proposes five steps that could transform NATO in an innovator at a strategic level through *"establishing a NATO civil-military technology assessment capability; prioritizing systemic innovation targets; setting ambitious benchmarks linking innovation to capability development, deterrence, defense, and resilience; doubling down on collaborative innovation so that no ally gets left behind in the innovation competition; and committing to more ambitious NATO-EU cooperation"* (Soare: 2021, pp. 2-3). Technological progress will change the way future wars go, given the actors that are involved, the place where these new types of conflicts unfold, and especially the speed at which they are carried out and their hybrid character.

The challenge for NATO member states is the *"step forward"* that must exist in the face of state or non-state actors that could create instability by using such high-impact technologies. The cooperation in the field of civil-military research, the management of problems at NATO or EU level through specialized agencies, the creation of response mechanisms and procedures, etc. can

ensure the necessary advance in front of the opponents. The rush to discover new possible emerging and disruptive technologies is a different Cold War of nowadays, even if this time at global level. The great economic and military powers are caught up in this research, innovation and arms race. The international context, with a conflict of aggression by the Russian Federation on Ukraine, with many unstable regions or on the verge of becoming potential outbreaks of insecurity should exercise the greatest caution in the implementation of technological innovations with disruptive ramifications. The UN High Representative for Disarmament Affairs highlighted several major trends in the risk of conflict in the context of emerging and disruptive technologies. One of the trends that he drew attention to is related to *„the emerging nature of warfare enabled by networked militaries, autonomy, uncrewed vehicles, advanced sensors, and weapons that can attack at hypersonic speeds''* (Nakamitsu: 2019, p. 1).

A 2020 US report discussed how emerging technologies are integrated into military forces and concepts of operation, the interactions between emerging technologies, and the extent to which national policies and international law enable or inhibit their development, integration and

use (Sayler:2020, pp. 23-24). This report provides an overview and military implications of emerging military technologies from the US, China, and Russia, the three major military competitors, on artificial intelligence, lethal autonomous weapons, hypersonic weapons, directed energy weapons, biotechnology, and quantum technology.

Perhaps more than ever, the promotion of these emerging and disruptive technologies on the battlefield will have decisive implications for future hybrid military conflicts. Even if the physical presence of the military will decrease on the battlefield, efficiency in battle, the rhythm of defense/offensive, the ability to analyze the real situation may have destabilizing consequences.

In the National Defence Strategy for 2020-2024, a series of risks and threats are identified in the area of emerging technologies, to which Romania must respond: *"The exponential trend towards development of emerging technologies (5G, artificial intelligence, big data, the Internet of Things, cloud and smart computing) generates both the need to increase and improve communications that will support innovative digital services designed to assist citizens and business environment, and the need to collect and secure all data and information circulating in those systems"* (National Defence Strategy: 2020, p.19). As a benchmark regarding the future directions of research, development and implementation of emerging and disruptive technologies at the national level will be *"hypersonic vectors, 5G, quantum communication infrastructures, laser and electromagnetic applications, air and underwater monitoring equipment, artificial intelligence, autonomous platforms"* (National Defence Strategy: 2020, p.21). The Defense White Paper mentions the fact that among the main directions for the development of defense capabilities, the Romanian Army will also have as its direction of action *"capitalizing on the potential of emerging and disruptive technologies on the development and use of the armed forces"* (Defense White Paper: 2021, p.24). Moreover, Romania's Military Strategy specifies that the endowment of the Romanian Army will follow, among other things: *"the acquisition of weapons systems and equipment for military use using innovative, emerging and disruptive technologies"* (Military Strategy of Romania: 2021, p.25).

3. THE IMPACT OF EMERGING AND DISRUPTIVE TECHNOLOGIES ON DEFENSE AND SECURITY

The development of emerging and disruptive technologies will be able to ensure opponents' deterrence instead of needing effective defense. These technologies know no limits, nor is their strategic value fully known, but the idea that some of them could have an effect equivalent to that of a nuclear weapon should not be ruled out. The comparison does not refer to physical or destructive effects, but to the long effects on humanity In this reality, there is a need to adopt new mechanisms, not only in the field of production, possession and use of new technologies, but also in the control of their exports, mechanisms based on comprehensive legislation and regulations applicable to current trends (Popescu: 2021).

NATO updated the Strategic Concept at the Madrid summit (2022), noting that *"Emerging and disruptive technologies bring both opportunities and risks. They are altering the character of conflict, acquiring greater strategic importance and becoming key arenas of global competition. Technological primacy increasingly influences success on the battlefield"* (NATO 2022 Strategic Concept: 2022, p.5). In the *NATO Science & Technology Trends 2023-2043 Report*, emerging, disruptive and converging technologies are mentioned with a perspective on the next 20 years (figure 2).
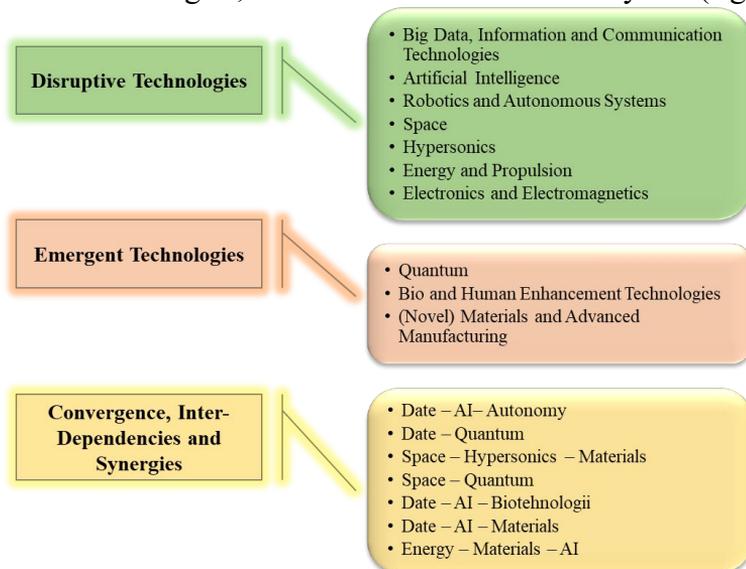
Disruptive Technologies
- Big Data, Information and Communication Technologies
- Artificial Intelligence
- Robotics and Autonomous Systems
- Space
- Hypersonics
- Energy and Propulsion
- Electronics and Electromagnetics

Emergent Technologies
- Quantum
- Bio and Human Enhancement Technologies
- (Novel) Materials and Advanced Manufacturing

Convergence, Inter-Dependencies and Synergies
- Date – AI– Autonomy
- Date – Quantum
- Space – Hypersonics – Materials
- Space – Quantum
- Date – AI – Biotehnologii
- Date – AI – Materials
- Energy – Materials – AI

Fig. 2 Emerging, disruptive technologies and their convergence (Reding et al., 2023) - extract

An analysis of the current state of the technologies mentioned in figure 2 helps us to understand the importance given by NATO member countries to the convergence, interdependence and synergy between emerging and disruptive technologies.

Military art is influenced and must be adapted to what new technologies represent in the military field. In the article *Impact of new technologies on military art - specialist study*, attention is paid to the convergence of two or more emerging technologies in influencing military art and leading military actions. The author argues that *"As far as the command-control function is concerned, artificial intelligence is a focal point, in the sense that, once matured, it can be the core that coagulates the advantages offered by many of the analyzed technologies, but also by others, when they might be operationalized. Big data, which aims to manage large volumes of data, can facilitate fast and efficient "learning" that allows the system to quickly adapt to new situations. Quantum technology, through the characteristics it promises, can give it a significantly higher data processing speed, given the enormous computing capacity, secure transmission of data in the network, as well as detection capabilities that exceed the laws of classical physics. Unmanned vehicle systems on board add the ability to*

project force in an unprecedented way to the command-and-control system equipped with artificial intelligence, by making them autonomous, both from the point of view of movement and from the point of view of generating effects on the target (detection - selection - employment; monitoring - surveillance; jamming, etc.)" (Cîrciumaru: 2021, p.9).

The superior capacity of convergence between emerging and disruptive technologies will help achieve effects (Defence Technology Framework: 2019), such as:

– *enhanced lethality and mass effects* – projected hard power meant to defeat opponents in multiple areas;

– *improved protection* – an adequate capability that is agile, robust, maneuverable and able to provide persistent effects;

– *superiority in decision-making* – collecting, analyzing and understanding data more efficiently and at increased speeds to quickly identify threats, opportunities and options;

– *operational tempo* – it process and share information more efficiently to act quickly, collaboratively, and at a rate that adversaries cannot match, in complex and unpredictable ways;

– *resilience enablers* – increased support for the future force through

logistics, medical treatment, and better information;

– *sub threshold activities* – increased availability of legal and ethical opportunities to react, detect and respond to adversarial actions below the threshold of conventional war.

Some of the emerging or disruptive technologies may be within the reach of many states, especially those with low costs. Drones are proving to be weapons that have not yet reached their full potential, and yet they can penetrate enemy defenses, gather information about the adversary, supplement the activities of the military, etc. The convergence of technologies can create imbalances in the conduct of battle, with surprising effects. For example, a technology such as artificial intelligence could be associated with quantum computing to produce more powerful autonomous learning methods, leading to improvements in image recognition and target identification, or the development of more complexed autonomous weapons (Sayler: 2020). Technological innovations have been capitalized on in the way conflicts are conducted, influencing military tactics and doctrines over time. Military strategists that embraced the new technologies gained supremacy on the battlefield over those who were conservative or complacent with out-of-date ideas.

Figure 3 (a, b, c, d) shows 4 graphs with information for the period 2018-2021 regarding the leading states in the field for some of the essential disruptive technologies: Data, Artificial Intelligence, Space and Electronics and Electromagnetics.
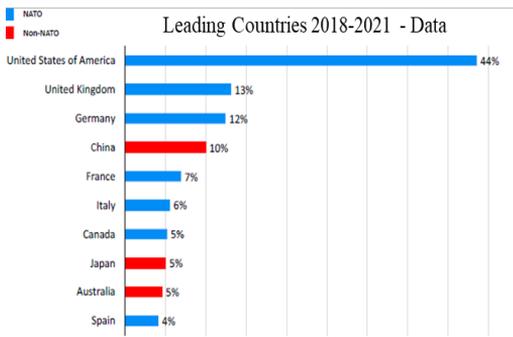
Figura a. Big Data, Advanced Analytics and Information Communication Technologies (Data)
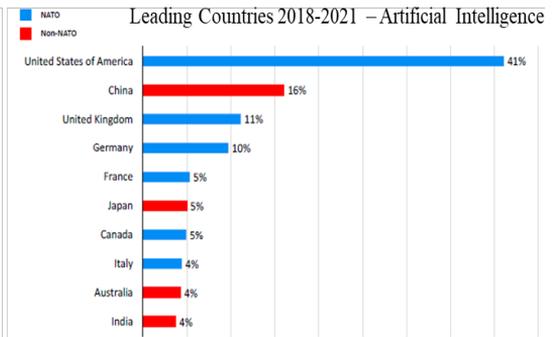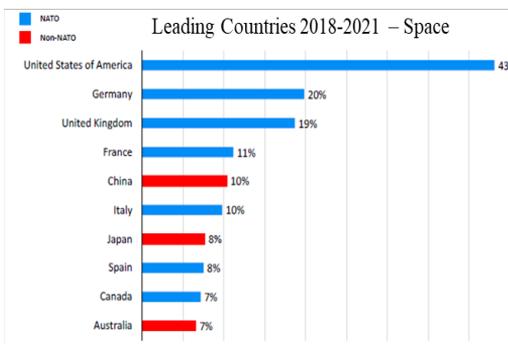
Figura b. Artificial Intelligence

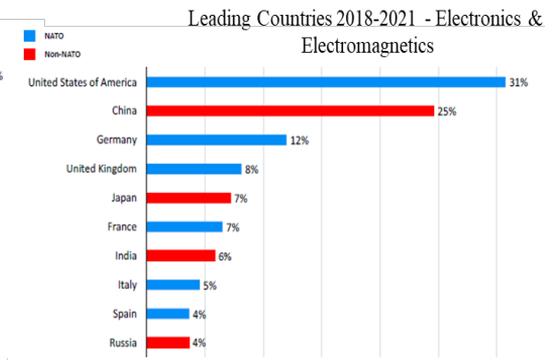**Figura c.** Space Technologies

Figura d. Electronics & Electromagnetics (E&EM)

Fig. 3 Leading States in Key Disruptive Technologies (Reding et al., 2023) - extract

The analysis of the graphs reveals that the United States of America is the leader in the field on all 4 analyzed components, with percentages of over 30%. Another observation is that of the top 10 leading countries in the field, most are NATO members, which indicates the increased interest in the military field in the area of disruptive technologies. These analyzes were determined by the concerns of top institutions regarding scientific and technological research in NATO states, on the fields mentioned in figure 3.

4. CONCLUSIONS

Emerging technologies in the field of defense and security have a major influence on military operations, and the convergence of new technologies with existing ones have disruptive effects, being capable of generating effects of

optimization and effectiveness of some combat systems, of amplifying performances in time-limited situations or decision-making under conditions of uncertainty.

Any war with new generation technologies will not completely replace previous generations. The nature of war will not change because of this change. The methods and techniques of warfare are adapted according to the performance of the equipment; the implementation of new concepts is determined by previous experiences and the way of action of the enemy. The current conflict in Ukraine is proof that infantry fighting vehicles, tanks, artillery, aircraft, etc. are combined with new technologies such as UAVs, satellites, HIMARS systems (High Mobility Artillery Rocket System), etc., in other words, the classic generation of warfare will not disappear due to the appearance of a new one, but will actually merge with it.

Emerging and disruptive technologies have the potential to change the balance of power and create new forms of insecurity. Military doctrines and strategies should be revised much more frequently to meet new challenges that may have profound military implications. The convergence of two or more technologies can replace the supremacy of established equipment.

Coincidence or not, the last decade has seen a lot of regional and global security and defense events such as the competition for scarce resources, the withdrawal from Afghanistan (2021), the COVID 19 pandemic and the resulting instability, the aggression of the Russian Federation on Ukraine (2014, 2022), China's intention to control Taiwan, etc. What could happen next? There will certainly be consequences, as a result of the multiple events of the last 10 years. Emerging and disruptive technologies will be able to solve some problems of the past, in the future, with a major impact on security and defense, by countering hybrid risks and threats.

I believe that the current emulation around emerging and disruptive technologies so often voiced is actually another kind of *arms race.*

REFERENCES

1. Andas H. (2020). *Emerging tehnology trends for defence and security.* Norwegian Defence Research Establishment. 20/01050
2. Andrew D. J. (2016). Emerging Technologies and Military Capability. *Emerging Critical Technologies and Security in the Asia-Pacific*. Palgrave Macmillan London, 6-21
3. Brussels Summit Communique. (2021). Accesat pe 01.08.2023 la https://www.nato.int/cps/en/natohq/news_185000.htm

4. Carta Albă a Apărării. (2021). Ministerul Apărării Naționale. Bucharest

5. Cîrciumaru F. (2021). *Impactul noilor tehnologii asupra artei militare – studiu de specialitate*. Editura UNAp „CAROL I"

6. Defence Tehnology Framework. *Defence Science and Technology*. (2019). Ministry of Defence. London

7. *Emerging and distuptive technologies*. (2023). Accesat pe 01.08.2023 la https://www.nato.int/cps/en/natohq/topics_184303.htm?selectedLocale=en

8. Military Strategy of Romania. (2021). Ministry of National Defence. Bucharest

9. Nakamitsu I. (2019). *The Role of Emerging Technologies in Military Conflicts*. Inter Press Service. Accesat pe 01.08.2023 la https://cs.brown.edu/people/jsavage/sources/2019_10_10_IPS_TheRoleOfEmergingTechnologiesInMilitaryConflicts.pdf

10. National Defence Strategy 2020-2024 (2020). Presidential Administration. Bucharest

11. NATO 2022 Strategic Concept. (2022). Summit NATO in Madrid

12. Popescu S. (2021). Impactul tehnologiilor emergente și distruptive asupra domeniului militar. *Conferință Științifică Internațională Gândirea Militară Românească*. Statul Major al Apărării. Ediția a III-a. 218-228

13. Reding D.F., De Lucia A. M., Blanco A. M., Regan L. A. & Bayliss D. (2023). *Science & Technology Trends 2023-2043 across the Physical, Biological, and Information Domains.* 1. NATO Science & Technology Organization

14. Rotolo D., Hicks D. & Martin B. (2015). *What Is an Emerging Technology?*.SPRU Working Paper Series (SWPS), 2015-06: 1-40

15. Sayler K.M., (2020). *Emerging Military Technologies: Background and Issues for Congress*. Congressional Research Service – CRS. R46458

16. Soare S.R. (2021). *Innovation as Adaptation: NATO and Emerging Technologies.* Policy Brief. The German Marshall Fund of the United States - GMF. Accesat pe 01.08.2023 la https://www.gmfus.org/sites/default/files/Soare%2520-%2520NATO%2520emerging%2520tech.pdf