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TRENDS AND CHALLENGES IN TECHNOLOGY DEVELOPMENT FOR MILITARY NEEDS NEW FACES OF RMA

ABSTRACT: The article presents an analysis of the selected, considered key, technologies development affecting the military area. The authors of the analysis started from the assumption that nowadays, it is the commercial technology that should determine the development of technology used for military purposes. This is due to the fact that the biggest driver of technology development is the market game - that is, competition. The greatest market potential lies in the diversity and scale that characterizes the civilian market. Only from the set of solutions used commercially can policy-makers and military decision-makers choose the right ones for military applications. The analysis presented here drew heavily on examples of this phenomenon which can be seen in the ongoing war in Ukraine. The set of emerging tendencies is defined in 4 trends - dispersion, sharing, convergence and miniaturization. They provide timeless guidelines for the way of thinking in the light of exponentially occurring changes in the field of technology. Such a change in commanders' thinking should be the challenge of the RMA (Revolution of Military Affairs) implementation process. This means new challenges for commander education where knowledge of tactics becomes as important as understanding the capabilities of network technologies.

KEY WORDS: technology development scenarios, Revolution of Military Affairs, development tendencies, network technologies

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INTRODUCTION

The authors of the article made in their analysis the overriding assumption that technology in the phase of modern development is at such a stage of the exponential graph that it forces changes in other spheres - political, social and economic. This relationship has been evident in every previous breakthrough in the development of technology, such as the invention of the electron tube, the semiconductor (first the diode and then the transistor), the integrated circuit, microchips, etc. However, technological determinism predicted by H. Innis[1] and McLuhan[2] has gained exceptional acceleration due to virtualization and the development of the concept of programmable (SDR) and then cognitive technologies. This means that the frailties of matter are being replaced by an information space which is probably governed by different laws than the principles we know and take into account. This is accompanied by people's growing uneasiness about the not-too-distant prospect of artificial intelligence (AI) which will be able to develop and function on its own independently of human cognition and knowledge. At this point, the almost century-old thoughts of M. McLuhan can be invoked again, pointing out that he not only predicted a "global village" (the Internet), "the hammer as an extension of man" (Internet of Things, IoT) but also a discovery of revolutionary character that "media as an extension of man" is nothing other than artificial intelligence - AI.

In such settings of the current stage of technology development, in which future scenarios can in no way rely on approximations based on the past, a new credibility is acquired by the thesis that the greatest development of technology is taking place in the commercial - civilian rather than military - area. In this context, the analysis of technologies being developed for military purposes mainly comes from the commercial area. This, in turn, determines a way of forecasting the development of military solutions - especially in the sphere of information and transportation - based on previous civilian concepts. From the collection that is developed for commercial purposes - policy-makers and military decision-makers select those that can be used in the activities of the armed forces.

The consequence of such ontological and consequent epistemological assumptions is the reliance on the McLuhan and H. Innis schools of technological determinism in communication sciences, the evolutionary and competitive school in management, and liberal theories in International Relations. Network technology, which is both core and mainstream of

[1] H.A. Ignis, *The Bias of Communication*, Toronto-Buffalo-London, 1999.
[2] M. McLuhan, *Zrozumieć media. Przedłużenie człowieka*, WNT, Warszawa 1998.

current human development, is characteristic of, according to the theses of A, and H. Tofler, democratic and liberal systems[3]. This prompts to eliminate the dominant influence of the state on the development of technology ("economics undermines the state"[4]) and at the same time, it condemns totalitarianisms to inevitable failure - as exemplified by the outcome of the "Arab Spring" or the course of the war in Ukraine.

The cited assumptions make it necessary to carry out the analysis from the commercial to the military area, pointing out not only the obvious such impact but also the technological trends that are inevitable for the military area, no matter what kind of military operations the political and military leaders plan to conduct. For the purposes of the research conducted, the analysis was narrowed down to a few key technologies. This is justified not only by the limitation of this article and human attention span but the essential criterion were breakthrough technologies identified during the ongoing war in Ukraine. Such as, unquestionably, information technologies. In formulating the assumptions for the research, the authors of the article applied a rational limitation to communications technology which, along with armaments, is one of the two key ones in the sphere of conducting contemporary and probably future military operations. The study of communications technology is passionate enough as it includes an interesting phenomena related to the reversal of the influence direction between the communications technology intended for the armed forces and the commercial technologies.

Underlying such a significant change in the nature of technology development for military purposes were changes initiated during the Cold War. These changes should be considered in the dynamic comparative relationship between the two paradigms that characterized the two political-military blocs.

In the Eastern Bloc, tasks related to the development of such technologies were distributed to individual Warsaw Pact member states. They were based not on their competencies but on their geostrategic location and the resulting communications capabilities. In a way, this resulted not only in a shift of the center of gravity to the westernmost countries of the alliance (Poland, East Germany, Czechoslovakia, Hungary) but even within the Soviet republics themselves. For example, the role in various branches of space and aerospace technology was assigned to Ukraine, electronics - to Latvia (plants in Riga). The selection of some plants located east of the

[3] A. Toffler, H. Toffler, *Wojna i antywojna,* Kurpisz S.A., Poznań 2006, p. 367.
[4] Ibidem, p. 230.

Urals concerned heavy industry which in armaments is less demanding and needs less sophisticated technologies. Such specialization was also applied among the Warsaw Pact member states themselves: miniature lamps as a substitute for modern electronics in the 1970s were produced in East Germany, modern electronic sets in Hungary, radars in Poland, etc.

In the Western bloc, a completely different pattern was adopted. It was the NATO member states themselves that proposed the type and extend of their technological involvement. Thus, technological specialization resulted from the competence of individual countries. Only in the overarching-strategic layer the dictate of the US in this alliance was evident [5].

Regardless of geopolitical considerations and variations in technology development for defense and security needs, it should be noted that it was in the 1960s in the US that the foundations for modern network technologies were built. Although the research was conducted mainly in relation to nuclear weapons threats. Problems solved, related for example to the dispersion of information or packet switching, were precisely to protect as much as possible from the effects of such a conflict[6] [7]. But at the same time, the proposed solutions provided the basis for a modern network view which found its application in the incredibly fast developing technologies based on transistors and then integrated circuits. However, it is not only significant that many names familiar to Poles appear in this case (P. Baran, A.K. Cebrowski, A. Garstka, M.C. Libicki) but in building these foundations more than 50 years ago, a very modern model of cooperation of many entities from several sectors was adopted. The postulate formulated by V. Bush after the end of World War II passed the test brilliantly in this case. Besides, the US constituted the best setting for such technological breakthroughs. The reversal of the aforementioned trend in the 1970s in the US was a direct consequence of the early development of semiconductors and modern computing. It is no coincidence that this phenomenon was so significant in the US - it was the only country in the world with such potential where the development of network technology and computing in the 1960s proceeded with parallel involvement of the political, military and private sectors. This bore fruit

[5] An example of US dominance at the political level was the mechanism for building and implementing successive NATO strategies. The impetus for developing a new Alliance strategy was always a new strategy developed overseas. Even in the content of NATO strategy documents, it was very easy to see content smuggled in from documents developed a year or two earlier in the US.

[6] P. Baran, Paul Baran and the Origins of the Internet, Rand Corporation, (https://www.rand.org/about/history/baran.html, (accessed: 3.06.2022).

[7] P. Baran, *On Distributed Communications*, United States Air Project RAND Corporation, Santa Monica 1964.

in technological breakthroughs in the following decades of the 20th century that were matched only by Japan. The reverse trend is now a reality. State-of-the-art solutions in the communications area come from the commercial sphere, only to be adapted to military requirements. The success of the solution is evidenced by its replication to this day in the development of technology for military needs. The implementations of this concept are the Falcon projects using military infrastructure on the US west coast and Pacific islands and the Starlink system fulfilling military-type tasks in many aspects: as a new type of navigation, call-center of the defense industry, communication system resistant to traditional interference through the use of cognitive radio solutions, etc. Other spectacular examples of the implementation of the "Bush triangle" are the consequences of using Google for the outbreak of the "Arab Spring" and the functioning of the AWS cloud (Amazon) aimed at organizing the "escape" of databases located in the Ukrainian physical infrastructure into cyberspace in the first days of the war with the Russian Federation.

Another but no less important area exemplifying the reversal of the trend in question was the development of space technology - particularly satellite technology until the 1980s. The leading projects at the time were those aimed at the military area and national and allied security. That is why in the first decades of space technology development it was very costly, aimed at achieving a political goal rather than reducing spending. Perhaps for this reason, the "star wars" initiated by R. Regan were an important element in the outbreak of the economic crisis in the USSR. The first individual commercial space projects appeared in the late 1960s and early 1970s. However, for the most part, the philosophy of state-owned entities adopted by the companies in this industry caused a very serious crisis in the space sector at the turn of the century. Only the incredible development of electronics and miniaturization with a significant drop in production costs laid the groundwork for initiating the current wave of satellite technology development. This wave is characterized by the private sector dominance whose services are increasingly used by the military sector in the form of procurement. Another example of this migration of solutions in the purely military area into the civilian and commercial area is FH's "frequency hopping" technology. This solution initially provided transmission security by spreading it across the radio frequency spectrum. The cooperating transmitter and receiver changed their operating frequency according to the code used, making it possible to hide the transmitted content from an unauthorized party. Emerging commercial mobile networks in the 1990s subsequently adopted this technology as a very

efficient way of reusing the allocated bandwidth for transmission allowing multiple subscribers to communicate. In this case, not only enhancing transmission security but also cost considerations were of the utmost importance.

However, this is an example of a broader change that spread in the US across many areas of technology in the 1970s. Since that period, the prevalence of commercial technology has steadily increased. It was solutions from the commercial area that were becoming the primary collection to build offerings for the military area. Today, many solutions that have their main application in the commercial area are being adapted to purely military and wartime requirements. Therefore, it was considered reasonable to analyze a selection of the most important trends in the development of commercial technologies affecting their use in the military area. The commercialization of military technology is also related to its internationalization, where contractors come from many different countries. One could invoke the words of a Ukrainian government official, who said: „it was Poland that supplied Ukrainians with systems that using Soviet missiles shoot down Iranian drones launched by the Russians" [8].

This article attempts to build a set of conditions that will accompany the development of technology. They will determine the set of solutions from which those for implementation for national security needs will be selected. The war in Ukraine is a glaring example not only of a military conflict but also of a technological conflict between two concepts of developing means of communication for military needs.

TRENDS BUILDING THE FUTURE

The cognitive process implemented uses a deductive approach. It involves backward type of thinking. This is a way of qualitative forecasting. Its main advantage is the understanding of the future, its disadvantage is the difficulty of demonstrating the connection between the images of the future (*i.e.* scenarios) and the present. The second, the forward approach, requires inductive thinking, where the analysis of the present factors is made and their course in the future is plotted. The advantage of this method is the ease and accessibility of such a

[8] "Dziękujemy braciom Polakom". Ukraińcy zniszczyli irańskie drony wyrzutniami z Polski, Do rzeczy, 12 października 2022, https://dorzeczy.pl/opinie/356782/ukraincy-zniszczyli-iranskie-drony-zaluzny-dziekuje-polsce.html, (accessed: 3.08.2022).

procedure but the disadvantage is that the picture (scenario) obtained is difficult to describe or even to understand[9].

In order to build images or scenarios about the future development of technologies that may have a significant impact on the military field, solutions that exhibit an uncommon, i.e. exponential course of development have been selected. Due to the limited space for presentation and analysis, the most significant but not always noticed and taken for granted solution, in the opinion of the authors, were chosen. They relied on a collection of studies that make a broad analysis of such conditions and technologies[10]. Repeated typifications of trends in these studies made it possible to propose the following phenomena for broader analysis:

- dispersion,
- sharing,
- miniaturization,
- convergence.

DISPERSION AND SHARING

Dispersion is becoming a phenomenon accompanying human life almost commonly which is a direct result of the development of various technologies. More broadly, this phenomenon is part of the society functioning networking, technology and our daily life. Such technologies as cloud computing, blockchain, and configurations of modern satellite systems in which large geostationary satellites are giving way to systems composed of numerous (thousands), small (1 dcm^3), light (kilogram), and mobile satellites, are considered characteristic of dispersion.

Cloud computing initially had only business applications. The cloud concept was to transfer commercial networks to the Internet because of a large and growing amount of data to be stored. In this case physical warehousing found its virtual application. The concept is based on the virtualization of servers and therefore the virtualization of IT resources. Thus, it is also an example of a trend of increasing the degree of resources sharing. This sharing is most often based on the dynamic shift in the processing paradigm that is taking place, from stand-alone

[9] K. van der Heijden, *Scenarios. The Art of Strategic Conversation*, John Wiley & Sons, Ltd, Chichester. 2005

[10] P. Diamandis, S. Kotler, P*rzyszłość jest bliżej niż nam się wydaje*, Poltext, 2021. V. Dhillon, D. Metcalf, M. Hoper, *Zastosowanie technologii blockchain*, PWN, Warszawa 2018;.K. Kelly, *Nieuniknione. Jak inteligentne technologie zmienią naszą przyszłość,* Poltext Warszawa 2017; A. MCafee, E. Brynjolfsson, *Maszyna. Platforma*. *Tłum. jak ujarzmić cyfrową rewolucję*, PWN, Warszawa 2019; K. Schwab, *Czwarta rewolucja przemysłowa*, Studio Emka, 2018; W. Isaacson, *Innowatorzy*, Insignis, Kraków 2016.

units to client-server architectures to the special use of networks. This evolution, therefore, encompasses different layers of the cloud: from infrastructure as a service (IaaS or HaaS [Hardware]), platform as a service (PaaS), to software as a service (SaaS) or framework as a service (FaaS). These layers are represented in both the private and public domain[11].

Cloud technology related to the use of the Internet potential is beginning to be increasingly applied not only in the purely commercial field but also in the government and security areas. The best example of this is the planned "move out" of sensitive data and those related to the security of Ukraine to the previously prepared potential of Amazon - to Amazon Web Services (AWS) [12].

Earlier this year, as Russian troop movements were observed in Ukraine, the government began physical preparations to defend its country and its people. Prior to the Russian invasion, Ukrainian law required certain government data and selected private sector data to be stored on servers physically located in Ukraine. A week before the Russian military invasion, the Ukrainian parliament passed legislation allowing government and private sector data to be moved to the cloud. To that end, the Ukrainian leadership made inquiries and offers to several global giants in the field. Amazon was one of the first companies to meet such formulated needs very quickly using Amazon Web Services (AWS)[13].

The process initiated even before the February 2022 outbreak allowed a massive 10 petabytes of data essential for the state and its security to be sent to the cloud from all 27 ministries, 18 universities, the largest remote learning school (serving hundreds of thousands of displaced children) and many private sector companies. The use of such migrated data is interesting. Information on higher education degrees and programs from the Ministry of Education and Science allows tens of thousands of students to prove the validity of their education when applying for jobs or for their next professional or academic degree. Data from the AWS allows students to continue taking their final exams at the end of this school year, whether they are in Poland, Moldova or Romania. Researchers from many disciplines have moved their research data resulting from decades of academic work to the cloud so that their

[11] A. Mateos, J. Rosenberg, *Chmura obliczeniowa. Rozwiązania dla biznesu*, Helion, Gliwice 2011, p. 27-42.
[12] AWS employees help secure vital data so the Ukrainian government, education, and banking institutions can continue to serve Ukrainian people, Amazon, https://www.aboutamazon.com/news/aws/safeguarding-ukraines-data-to-preserve-its-present-and-build-its-future, (accessed: 3.10.2022).
[13] Ibidem

work can continue. In this way, AWS has supported research related to monitoring radiation levels around nuclear power plants near conflict zones in Ukraine [14].

A similar phenomenon is occurring in the business sphere, where, for example, Ukraine's largest private bank, PrivatBank, which serves 40% of the Ukrainian population, has moved its operations to the cloud. The bank's technical team moved nearly 270 applications and 4 petabytes of customer data from some 3,500 servers in less than 45 days. According to PrivatBank's head of IT, Polish manager Mariusz Kaczmarek, such measures were aimed at reducing dependence on equipment located in various regions of Ukraine that may have been destroyed during the war. Interestingly, once the war is over, it is planned to continue operating under a new system - independent of the physical infrastructure in Ukraine. PrivatBank customers can now access their funds and the bank's services online[15].

Another skyrocketing network technology is blockchain. This concept is likely to change a great many branches of the economy and ultimately our lives. The fact that the impetus for its development came from the very dynamic use of bitcoin, as a response to the financial crisis in 2007 and 2008, points to commercial sources. Probably the near future will indicate new areas of use of "distributed trust" technology. The philosophy of this technology, mainly its assumptions, are part of new solutions for ensuring network-centricity of command systems and warfare. It is in distributed terms that the conduct of modern defense operations (war in Ukraine) should be considered. Blockchain has a distributed register architecture technology. Distributed means that each device connected to the network participates in data transmission and monitoring. The nodes of this network are distributed around the world which means that it is impossible for one person to take over the network. The working principle of this network is consensus. Broadly and meticulously, the concept of blockchain was introduced by an anonymous author using the pseudonym Satoshi Nakamoto in 2008, immediately after the Great Financial Crisis. This makes it possible to directly tie this concept to the ongoing work to avoid similar processes in the banking system as those initiated in the 21st century. Therefore, the first implementations of blockchain were in the form of bitcoin.

In early January 2009, the bitcoin network was launched. In 2014, a second blockchain generation was created called Ethereum which offered a much wider range of uses than bitcoin. It was described earlier by Vitalik Buterin, the son of a Russian computer scientist. The

[14] Ibidem
[15] Ibidem

Ethereum Virtual Machine offered a much wider range of services than just financial. As a result, plans and concepts for the use of blockchain technology have been able to cover areas such as notary services, accounting (decentralized databases of accountants), medical records, voting, referenda land records, identity verification, vehicle sharing and rental, car owner registries, data storage and digitization of documents, records of results, grades, certificates in education. It is often pointed out that blockchain allows to replace government institutions, banks and stock exchanges in most functions. The latest generation of blockchain is Hyperledger, improving this technology especially in the area of IoT (Internet of Things) and in logistics and production of various goods[16].

When analyzing the phenomenon of dispersion which is often intertwined with dematerialization[17] carried out through the network, it is also important to pay attention to trends related to the "crowd". In the most general terms, network technologies have caused two extremely important phenomena for the development of the economy and society in the future. These are crowdfunding and crowdsourcing. They require attention as they have also appeared in the military sphere, with examples coming from the war in Ukraine.

Crowdfunding in its initial phase had a purely economic dimension. The phenomenon takes advantage of the growing Internet and the platforms created that bring together people or other entities interested in developing a specific business, service, product or technology. These platforms connect entities that aim to develop a specific business and people or entities that are interested in funding that business. Most often this involves buying a share of the future profit from such a business.

The most significant feature of this enterprise is the combination of the almost unlimited financial resources of the "crowd" and many thousands of excellent technological ideas which in the classic conditions of competitive struggle based on the power of transnational corporations would not have a chance to take off. After all, nothing accelerates the development of technology like money[18]. The money of "small" investors stands at the root of "small ideas" that in time become big. This will certainly result in the fact that crowdfunding and crowdsourcing initiatives will become the biggest competitor of powerful corporations in

[16] V. Dhillon, D. Metcalf, M. Hoper, *Zastosowanie technologii blockchain,* PWN, Warszawa 2018; M. Swan, *Blockchain. Fundament nowej gospodarki*, Helion, Gliwice 2020.
[17] K. Kelly, *Nieuniknione. Jak inteligentne technologie zmienią naszą przyszłość,* Poltext Warszawa 2017.
[18] P.H. Diamandis, S. Kotler, *Przyszłość jest bliżej...,* p. 112.

the future. Crowdfunding initiatives were born in the US, where the first such venture funding a tour by the British band Merillion was launched in 1997.

Crowdfunding platforms can support funding by various communities for scientific research, film and music productions, software development, building websites or public facilities. Recently, crowdfunding for election campaigns has become increasingly popular, giving these political ventures a new dynamic. The entry of this kind of technology into the political field has introduced a new kind of opportunity as well as a threat to the area of national security. Just as any technological concept can have both its civilian (usually at first) and military applications, so it can represent an opportunity and open up new possibilities but also generate a new kind of threat. In the military sphere, the most glaring example of the incredible development of such platforms and initiatives is the ongoing war in Ukraine. Modern armaments and equipment are being purchased based on crowdfunding. This applies not only to the world - global initiatives[19] but also to our domestic ones[20]. However, this is followed by the threat of new opportunities to finance terrorism and extremism. Combined with blockchain, darknet or cloud computing, crowdfunding will pose a very complex threat.

The most recognizable commercial platforms of this type are Kickstarter or Indiego, while the most common form of funding is the sale of shares. The convergence of several technologies - such as crowdfunding and blockchain - is very interesting. An example of this is the Initial Cost Offering (ICO) solution which originated in the cryptocurrency world and is based on blockchain technology[21].

The already mentioned other technology based on the concept of the crowd is crowdsourcing. Again, the most significant impetus for the development of this technology and related platforms was the modern Internet, which has reached many corners of the globe. A powerful crowd of contractors for outsourced services are workers - *e.g.* academics from India, China. This builds an unprecedented intellectual potential to carry out outsourced works and services. The origins of crowdsourcing can be traced to the functioning of Second Life. The way this platform worked built a new idea of creating specific values, products and services by a

[19] D. Boffey, Ukraine crowdfunding raises almost $10m in 24 hours to buy kamikaze drones, The Guardian, 12 October 2022, https://www.theguardian.com/world/2022/oct/12/ukraine-crowdfunding-kamikaze-drones-russian-attack-cities-military (accessed: 3.10.2022).
[20] M. Duszczyk, Ukraina napędza falę zbiórek nad Wisła, Rzeczpospolita, 8 września 2022, https://www.rp.pl/biznes/art37003041-ukraina-napedza-fale-zbiorek-w-sieci-nad-wisla, (accessed: 13.10.2022).
[21] P. Diamandis, S. Kotler, Śmiało, *Przyszłość jest bliżej*..., p. 116.

whole crowd of participants. The distributed execution of work also had its origins in ventures rallying the technological revolution, the forerunner of which was the Kiva platform with its subsystems Kiva US, Kiva Labs, Kiva City. The previously mentioned Kickstarter and Indiego platforms were also created using crowdsourcing[22]. The most popular crowdsourcing platforms are Duolingo, reCAPTCHA, MTURK (Amazon) [23].

It is impossible to analyze this technology without reference to war applications - if only from the conflict in Ukraine[24] [25]. It is worth recalling numerous call centers of arms and equipment manufactures that were created around the world to support Ukraine with current knowledge and resolving technical problems that Ukraine had with the new armament.

CONVERGENCE OF SPACES

Developments in technology are setting a new trend related to the merging of spheres. While a dozen years ago, looking into the future consisted of singling out new spheres - such as warfare or armed conflict in the form of land, air, water, space and the infosphere, we are now inclined to look more and more holistically at previously singled out areas. The first example of such a change is the aforementioned area of armaments and industry for the economy. In the area of information technology, there has been a blurring of the boundaries of these areas, as exemplified by the current armed conflict in Ukraine. The example proposed in this article of such a holistic approach is to pay attention to the technological merging of the space, information and airspace spheres. Such divisions cease to be valid as both technology and information recognize none of them.

Space became an area of particular interest during the Cold War, as specifically a new dimension of the global confrontation between the superpowers. The symbolism of this event was primarily due to demonstrating the great range of rockets carried by satellites. This indicated the possibility of a nuclear-armed missile strike against US territory and resonated with policy makers and the societies of the rival states. The USSR not only possessed already a significant number of nuclear payloads but could in the very near future flare US territory with

[22] P. Diamandis, S. Kotler, Śmiało, HELION, Gliwice 2017, p. 185.
[23] Ibidem, p. 198-199
[24] M. Cieślak, *Ukraine: How crowdsourcing is rescuing people from the war zone*, BBC News, 19 March 2022, https://www.bbc.com/news/technology-60785339, (accessed: 13.06.2022).
[25] V. Bergengruen, *How Ukraine Is Crowdsourcing Digital Evidence of War Crimes*, Time, 18 April 2022, Https://time.com/6166781/ukraine-crowdsourcing-war-crimes/, (accessed: 13.06.2022).
R.W. Griffin*, Podstawy zarządzania organizacjami*, PWN, Warszawa 2002.

them. In October and November 1957, the first two artificial Earth satellites were launched. This was followed a few months later by the launch of Explorer 1 that made it possible to discover radiation in the Earth's magnetic field, later called the Van Allen belts. Telstar 1 is considered to be the first communications satellite. It was designed from the ground up to transmit telephone calls and data (TV, telegraph and radio signals). It was also the first private satellite. It made the world's first transmission of moving television images possible.

The first wave of development of satellite communications was based on expensive solutions, implemented, however, at the expense of competition between powers. A revision of these assumptions was made in the US in the 1970s, where the special treatment of the military area was reduced, allowing unfettered competitive struggle. In the area of space technology, the Americans relied on cooperation of many players from several sectors - government, military, industrial and scientific. The result of this approach was the creation of NASA (National Aeronautics and Space Administration) in July 1958. Teamwork, despite the undisputed role of W. von Braun, led to success, as there was no such danger as in the Soviet team, neither the risk of one person dominating the project thanks to the dispersion of efforts. A significant level of coordination of such complex research was important. In performing such a function parallel experience acquired with network technologies under the auspices of DARPA was used. This provides an excellent example of the permeation of technological thought between the military and commercial fields, equally in both directions. Another great example of such benefits is the military's use of experience in space projects in building space shuttles by Lockheed Martin that allowed through studies to identify the optimal CEO structure in such ventures[26]. The U.S. Armed Forces used this to build a command structure at lower, middle and strategic levels. This model has been introduced in the Polish Armed Forces and is being implemented successfully.

The Soviet model, on the other hand, adopted an interesting way of functioning with several scientific teams competing with each other, which, in a way, in addition to significant disadvantages, had the advantage of making the research carried out more dynamic. In this case, several centers can be mentioned, organized around such constructors as Mikhail Yangiel, Vladimir Chelomei and Sergei Korolov. On the other hand, in S. Korolov's team itself one could see the charismatic leadership, great knowledge and organizational skills of this scientist, which

[26] R.W. Griffin*, Podstawy zarządzania organizacjami*, PWN, Warszawa 2002.

dominated the entire team. This, in turn, in the event of his death due to chronic illness led to the collapse of the project. There was simply no other person who could successfully take over the leadership of such a complex and demanding project.

The third wave of satellite-based communications development is proving to be a great success. It is difficult to forecast the scale of this success but it is already possible to speak of a technological breakthrough in this area. It would be difficult, in fact, to isolate in the multi-year history of this type of communications any spectacular achievements on a par with the current pace of building networks such as Star Link. The first sign of the current development wave of satellite communications and services was the perturbations of the mysterious IRIDIUM system and the success of Globalstar. The former system was likely to be a commercially built system functioning for military purposes. Its peculiarity of operation was to rely heavily on the operation of a constellation suspended in space around the Earth which was supposed to protect it from complete destruction by the enemy. Another unique feature was a very low orbit. Eventually (after bankruptcy in 1999) it became the first global commercial communications system - even serving the area around Earth's poles. It now operates under the supervision of the US government. The constellation of more than 60 satellites operates at an altitude of 780 km using the 20-30 Ghz band and FDMA and TDMA type access. A lot of controversy arose from the collision on February 10, 2009 between Iridium 33 and the military satellite Kosmos 2251. A lot of data pointed to a deliberate destruction of the Iridium satellite by a military device over Siberia, although the latter was supposed to be out of service [27].

The second satellite system to be a complete success was Globalstar. The system was suspended above IRIDIUM, as it was at an altitude of 1,400 km, but it was not global - it did not cover the northern part of Greenland, the islands of northern Canada nor Norway. It used modern CDMA access technology and relatively low communication bands - in the 1.6 and 2.5 Ghz and 5 and 6 GHz ranges. The system finally became fully operational in 2001 before the outbreak of the Second Gulf War and became one of the essential means of communications in the area. It raised a lot of controversy and conjecture about the main reasons for the network. The system was already operating in the form of small, very handy terminals resembling cell phones and smartphones as we know them today[28].

[27] P. Daniluk, *Radiowe systemy łączności ruchomej*, AON, Warszawa 2004, p. 125-128.
[28] Ibidem, p. 128-132.

Analyzing the convergence of space from a contemporary point of view, we propose to pay attention to the very intensive research and implementation work concerning not only space but those layers around the Earth that directly surround it.

In this regard, the Loon project can be considered an interesting solution. Although it has already been completed and has yielded a great deal of interesting conclusions and experience, it is very likely that there will be further attempts to implement such concepts until they are economically viable.

Google's project called Loon was launched in 2013. It was intended to attempt to build a system that delivers the Internet from an altitude of about 20 km above the Earth's surface to those places that current satellite systems are supposed to deliver to. The project operated on a pilot basis in New Zealand. It also had its spectacular emergency applications in Peru and Puerto Rico. In the first case, the system provided communications for areas affected by flooding. Hurricane Maria, on the other hand, wreaked havoc on much of Puerto Rico and the Virgin Islands, leaving 83% of the population without access to cell phone networks. The Loon system operated in the 900 MHz band providing not only phonic communications but also high-speed Internet access. The system even provided more than 300 days of operation in the stratosphere with a direct range of 40 km radius for one balloon. Preparing to launch the balloon took about 45 minutes. The tests also included a trek of the system between Peru and Puerto Rico and around the globe. The project was eventually shut down due to the unprofitability of the venture[29].

However, it can be assumed that further miniaturization of electronic components as well as development of material technology will force a return to this type of solution. The high mobility of the system resulting from the rapid transport of components on board of transport aircrafts and the short time of its preparation and development are of the essence. Large range from the air (stratosphere), imperceptible signal delays (less than in satellite communications) and the highest throughput resulting from the possibility of using higher operating frequencies than in space systems are also an asset. It will be of no small importance in the near future to provide better laser communications than satellite systems and to move the system according to atmospheric conditions near the Earth's surface. In the military area, such systems can

[29] Loon. *Expanding internet connectivity with stratospheric balloons*, https://x.company/projects/loon/, (accessed: 13.06.2022).

replace tropospheric networks (tropospheric radio beacons) allowing to build connections based on a much smaller number of relay stations than traditional solutions.

It should be noted that moving higher into the space where the Earth's artificial satellites orbit, one of the greatest technological revolutions in the history of mankind is taking place there. This breakthrough is being achieved primarily with Falcon rockets and the Star Link communications system (and more). This is a spectacular success for E. Musk, resulting from a different approach to the development of modern technology, and, in a way, to the management of companies in this sector presented so far. There were and are already quite a few satellite systems to provide telecommunications network and Internet access services. However, an approach based exceptionally consistently on a cost strategy has been based on synergizing the potential of several interrelated activities – individual rockets and launch platforms, Internet operations and modern power sources. Such activities in the telecommunications sphere could not be afforded by military institutions. This was due to the fact that a network that was created primarily to provide Internet access around the world, to its dynamic configuration, is quickly becoming a communication, navigation, service system used on the battlefield.

Particularly interesting was the "duel" with Russian military interference systems which were only effective for a few hours. The idea of programmable or otherwise intelligent radio applied to the Starlink network has demonstrated its superiority by determining the directions for reengineering such projects in the purely military area. The intensive reprogramming of the system made the Starlink network immune to conventional broadband jamming. In addition, it demonstrated the superiority of systems "suspended" above the ground from those typically on the ground when using very short waves.

Starlink is a satellite constellation being built by SpaceX that provides Internet access services throughout the Earth. Its goal is to cover places where network access is not possible or is severely limited. In addition, it is intended to compete with terrestrial operators due to its assumed parameters. In the long term, revenues from the provision of satellite services are expected to help SpaceX execute its Martian plans.

Ultimately, the first part of the system is to have 4408 satellites deployed in low earth orbit (LEO) at altitudes of 540 to 570 km[30].

[30] 540 km - 1584 satellites (72 planes of 22); 550 km - 1584 satellites (72 planes of 22); 560 km - 172 + 348 satellites (4 + 6 planes of 43 and 58); 570 km - 720 satellites (36 planes of 20).

Half of this number of satellites should be in place and operational by March 29, 2024, the remainder by March 29, 2027.

The essential operating range of the subsystem, due to the higher altitude of the installation, is the longer wavelength band *i.e.* Ka-band, *i.e.* 1.7 GHz - 30 GHz.

In the longer term, it is also planned to place an additional 7518 satellites in lower orbits, at an altitude of less than 400 km above the Earth[31]. Half of this number of satellites should be in place and operational by November 19, 2024, the remainder by November 19, 2027. The essential operating range of the subsystem due to the lower altitude of the constellation is the shorter-wave band - that is, V, *i.e.* 37.5 GHz - 52.4 GHz.

It is worth underlining that Star Link is being upgraded all the time. The first revolutionary solution being implemented is that satellites launched from September 2021 have communications between each other in space carried out in the laser spectrum band. The second improvement relates to the use of special coatings to reduce sunlight reflections.

At this point, it should be noted that even before the outbreak of war in Ukraine, there were debates regarding the use of the Star Link communication system as a navigation system[32]. Among the various applications of this system, several solutions and services were launched and dedicated to the needs of Ukraine. The control of UAVs, the use of geolocation by artillery, satellite communications on the move or powering terminals with on-board vehicle voltage are only some of them[33].

An important function directly related to military operations is the possibility of providing direct links with many manufacturers of armaments used by the armed forces of Ukraine[34]. The scale of these services, not only offered but carried out under such difficult circumstances, is

[31] 335,9 km - 2493 satellites; 345,6 km - 2547 satellites; 350,8 km – 2478 satellites.

[32] P. Czajkowski, *Przekształcili satelity Starlink w system nawigacji. Muskowi się to nie podoba*..., IT hardware.pl, ttps://ithardware.pl/aktualnosci/przeksztalcili_satelity_starlink_w_system_nawigacji_muskowi_sie_to_nie_podoba-24019.html, (accessed: 25.10.2022).

[33] M. Mitkow, Brytyjskie media: Siły Zbrojne Ukrainy korzystają z sieci Starlink, Space 24, 30.03.2022 https://space24.pl/satelity/komunikacja/brytyjskie-media-sily-zbrojne-ukrainy-korzystaja-z-sieci-starlink, (accessed: 25.10.2022).

[34] Ł. Michalik, Zepsułeś HIMARS-a? Zadzwoń do Polski – wyjątkowy helpdesk pomoże naprawić broń 21.09.2022, Wp technika, https://tech.wp.pl/zepsules-himars-a-zadzwon-do-polski-wyjatkowy-helpdesk-pomoze-naprawic-bron,6814786789321568a, (accessed: 25.10.2022).
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astonishing. In considering this, the several statements by official representatives of the US government and armed forces expressing thanks and praise for E. Musk should be of no surprise.

A network developed in parallel but less spectacularly and more focused on providing services to telecommunications companies, is OneWeb. The project was threatened with bankruptcy during the outbreak of the Covid pandemic. The UK government was involved in the project, not only politically but also financially. This is an example showing a very different approach to the development of modern technology in Europe than in the US. Among the 14 space missions carried out under the project - 13 were secured by Roscosmos (Baikonur and Tsiolkovsky cosmodromes) using Soyuz rockets (from February 27, 2019 to February 10, 2022). This was due to purely economic considerations guaranteeing the lowest costs associated with satellite launches. An interesting organizational and political undertaking was the last one carried out on January 10 from French Guiana but still using a Soyuz rocket. It was evidently a shift resulting from the war in Ukraine. However, the fundamental question is what was behind such a breakneck decision to launch a Russian missile from French facilities in South America. It should be noted that the whole undertaking had to be started back in the fall of 2021, including the preparation for transporting and delivering the missile to South America. It had to take place a few months before the outbreak of war in Ukraine, probably making the project much more expensive. The fourteenth mission on October 22 has already been carried out from facilities in India. The next five missions are planned mainly based on the infrastructure of the Kennedy Center in Florida using SpaceX's Falcon 9 rockets. In this case, we can see how unfavorable political conditions have a bad impact on the formation of alliances in the business sphere, making it difficult to One Web's largest competitor, the owner of Starlink, to transport satellites into space. Nevertheless, during its fourteen space missions OneWeb managed to place in Earth's orbits 462 satellites. On average, each mission allowed to launch 34 or 36 telecommunications satellites, weighing about 150 kilograms each, functioning in an orbit of about 1,200 kilometers and operating in the 12- 18 GHz band (Ku-band). Other orbits will be operating at an altitude of 800- 950 kilometers. The leadership of Russia's FSB expressed its objection to the operation of the system over the territory of the Russian Federation pointing to the espionage nature of the project.

The key trio of modern satellite communications systems already in place and providing mobile Internet access services is the mPower network O3B (Other 3 Billion). The system is an

initiative of a space and aviation giant – Boeing [35]. It operates in a higher orbit than previous examples of satellite systems, around 8063 km. Thus, it is a MEO-type system, with satellites appearing 5 times a day. Because of its higher orbit, it operates in Ka-band - at 4.3 GHz. The higher orbit also determines the weight of the satellites – around 700 kg. In 2017, an order was announced for a new generation of O3b satellites consisting of 7 satellites. SpaceX was contracted for two additional launches, that means to perform four launches for the entire O3b mPOWER constellation between 2022 and 2024[36].

The O3B system is proving to be the only one providing broadband Internet services installed in MEO orbit so far. Most of current systems, due to their signal delay and throughput (and therefore frequency of operation), operate in LEO orbits. The bandwidth needs of today's Internet and banking services have forced systems to be descended to low orbits - offering at most tens of ms of latency - which requires an orbit of less than 2,000 km. However, LEO orbits are becoming denser, with several thousand satellites. In addition, they need to move faster, they cover a smaller area and operate for a shorter period of time (several tens of minutes), so the O3B system proposal is an example of the ongoing technological discussion over the future of such communications.

Noteworthy is another project that has not been implemented yet. It is the Kuiper System. It is planned to be based on 3276 satellites at an altitude of 590 - 630 km operating at 17-30 GHz. This is an interesting venture not because of the manager of this project who turns out to be the recent deputy head of the competing Starlink network but a concept relying on 12 ground stations facilities directing the AWS network. Not having access to more detailed data does not allow us to make interesting assumptions but it does indicate very serious planning for the cloud computing "emigration" to space. This concept is somewhat reminiscent of the assumptions of "Star Wars" four decades ago that also considered the "escape" of certain data into space (independent of the destruction of infrastructure located on Earth).

MINIATURIZATION AND MULTIPLE USE

Arguably, it would be a truism at this point to analyze miniaturization that occurs in electronics, since it is a phenomenon that is not only obvious but also widespread. Therefore,

[35] P.H. Diamandis, S. Kotler, *Przyszłość jest bliżej niż się wydaje*, Poltext Warszawa 2021, p. 67.
[36] June 25, 2013 - 4 satellites, July 10, 2014 - 4 satellites, December 18, 2014 - 4 satellites, March 9, 2018 - 4 and April 4, 2019 - 4.

the authors of the article propose to look at this phenomenon occurring in airspace and space as a continuation of the space convergence in modern technological development.

In the sphere of drone use and development, miniaturization has become one of the key trends[37]. Miniaturization primarily generates cost reductions as we can see in other types of technology used for defense purposes. Particularly noteworthy are the concepts of drone swarms where miniaturization is expected to play a significant role. However, the biggest challenges and the subsequent revolutionary paradigm shift in the way engineers look at designing have been introduced by "in-space" miniaturization.

In succor of Space X's offerings are other numerous civil-military cooperation projects, such as the Millennium Space System Project. This is an example of cooperation between a tycoon from the big three "space-flight" concerns, the US Air and Space Forces and Space X[38]. Such cooperation is possible thanks to the approach that E. Musk has propagated - based on economic viability mainly resulting from miniaturization - *e.g.* of satellites and their modular design. Hence the concept of QubeSat-type satellites weighting from tens of kilograms to fractions of a kilogram, based on the experience of amateur satellites (AMSAT), have appeared. They often constitute a "fill" of free space when transporting larger satellites (*e.g.* StarLink) [39]. This has led to a cost reduction in launching such items to $200,000 [40].

The cost-effectiveness and economy initiated by the introduction of the market game rules have aroused an unprecedented development of satellite technology based on miniaturization, including telecommunications. This is why the third wave of development of this technology is so incredible. Those market phenomena introduced across the Atlantic have resulted in changes in our country. At least two examples of recent initiatives in Poland are worth citing. The first one is a nanosatellite called SatRev[41]. SatRev is a Polish startup specializing in the design, production and operation of mini-satellites for Earth observation. The company wants to be the world's first satellite manufacturer to use 100% renewable energy in the production

[37] J. Chu, *Miniaturizing the brain of a drone. Method for designing efficient computer chips may get miniature smart drones off the groun*d, "MIT News Office, July 11, 2017, https://news.mit.edu/2017/miniaturizing-brain-smart-drones-0712, (accessed: 25.10.2022).
[38] Millennium Space Systems, A Boeing Company News Room, https://www.millennium-space.com/media/u-s-space-force-tetra-1-satellite-prepared-for-launch-after-15-month-integration, (accessed: 20.10.2022).
[39] This is reminiscent of a similar phenomenon in telecommunications, where a similar "free space" but in terms of time (time slot) has been used to transmit SMS in the transmission of phonic signals in cellular networks.
[40] The innovators: build and launch your own satellite ... for £20,000, The Guardian, Business News, 5 April 2015
[41] M. Szutiak, *W Legnicy będą produkowane nanosatelity SatRev*, Telepolis, 11.05.2022, ttps://www.telepolis.pl/tech/kosmos/satrev-nanosatelity-produkcja-legnica, (accessed: 20.10.2022).

process. Up to 100 satellites a year will be manufactured in a production hall including a laboratory and clean rooms, built by the Legnica Special Economic Zone.

The second example is another Polish company - Space Forest[42]. It emphasizes its desire to pursue the same path as the aforementioned E. Musk companies, such as SpaceX, *i.e.* lowering many times the cost of launching cargo into space. Space Forest also wants to make an industry coup by offering space services much cheaper than its competitors. The way to do so also worked well for SpaceX - the idea is to build rockets that can be reused many times, with the only loss being the fuel used during the mission. Perun rocket is intended to be just that - key components of the rocket are to be recovered, making them reusable. Solutions for Perun are being tested with the Bigos series of rockets. A recent test of Bigos 6 allowed the operation of Thrust Vector Control (TVC) - motor thrust vector control - to be tried out.

CubeSats are regularly used by the US military as part of its CNCE (CubeSat Networked Communications Experiment) program, where small satellites are designed to detect and track ballistic and hypersonic missiles. On June 30, 2021, a pair of them equipped with the HBTSS (Hypersonic and Ballistic Tracking Space Sensor) module was launched into low Earth orbit on a three-month mission. The idea is to create an entire constellation of CubeSats that warn of incoming missiles and send real-time data on the missile's location to command centers, but there is still a long way to go [43] [44].

Numerous studies related to space technology indicate that the ratio of nanosatellites and traditional satellites is beginning to equalize[45]. The scientific community, not only in Europe, is trying to miniaturize devices for various applications. A preliminary step to such a process is to use modular designs first. From these miniaturization is made through continuous improvement.

[42] Space Forest, https://spaceforest.pl/rocket-technologies/, (accessed: 28.10.2022).
[43] D. Vergun, Nanosatellites Could Play Pivotal Role in Defense Against Enemy Missiles, 12 July 2021, U.S. Department of Defense. ttps://www.defense.gov/News/News-Stories/Article/Article/2685840/nanosatellites-could-play-pivotal-role-in-defense-against-enemy-missiles/, (accessed: 28.10.2022).
[44] Kieszonkowe satelity CubeSat przyszłością branży kosmicznej. Oto co potrafią, Komputer Świat, ttps://www.komputerswiat.pl/artykuly/redakcyjne/kieszonkowe-satelity-cubesat-przyszloscia-branzy-kosmicznej-oto-co-potrafia/wv5t2lg, (accessed: 28.10.2022).
[45] Nanosats Database, https://www.nanosats.eu, (accessed: 28.10.2022).

SUMMARY

It should be considered an interesting statement by many specialists in the field of modern technology that modern but mainly future-oriented solutions and accompanying trends are "inevitable"[46]. Such an assessment of the phenomenon is based on several premises. First, the scale of these changes is already unstoppable. The direction of change is also unalterable. The speed of solutions being developed and implemented was never experienced before in that part of the graph of the exponential curve.

This perhaps obvious statement about the inevitability of the key technologies development is also a message for the defense industry and the operation and equipment of the armed forces. First of all, these trends must be skillfully recognized and read. But even more important is to understand the need to adapt to them. The process of technology development presented in the paper is dictated today by commercial and civilian solutions. It is only from such a broad set that policy and military decision-makers can make choices, especially in the area of technology related to information systems. This is unquestionably demonstrated in the conducted analysis of selected state-of-the-art network and space technologies, as they represent the mainstream of forward-looking concepts for the application of currently emerging solutions. However, this does not mean that in the areas of weaponry itself, purely military solutions do not continue to dominate. Although this too becomes debatable when we cite numerous examples from the ongoing war in Ukraine. On both sides of this conflict, armaments are being retrofitted or upgraded with technology of purely commercial use - drones, vehicles, aircraft, navigation, etc.

One very practical message emerges from the analysis presented: a significant area requiring special research is emerging. The presented trends in the development of modern technologies should not be limited to engineers in technical universities to equipping them with the necessary tools to traverse their professional lives through the next technological generations.

No less important, and perhaps even more important and urgent at the same time, is the inclusion of compulsory modules on these issues in the training of future officers as well as those officers who excel their knowledge in military academies. The war in Ukraine shows how

[46] P. Diamandis, S. Kotler, *Przyszłość jest bliżej niż nam się wydaje*, Poltext, Warszawa 2021; V. Dhillon, D. Metcalf, M. Hoper, *Zastosowanie technologii blockchain*, PWN, Warszawa 2018; K. Kelly, *Nieuniknione. Jak inteligentne technologie zmienią naszą przyszłość*, Poltext Warszawa 2017.

this kind of knowledge, even among general-military commanders, artillery, etc. is becoming as indispensable as knowledge of tactics and command. Knowledge of modern technologies and the accompanying new - open-minded way of thinking is becoming crucial to succeed in such a complex and modern battlefield.

Network-centrism, postulated almost three decades ago by A. Cebrowski, has become a reality with a whole host of new challenges not only for commanders but also for politicians, economists, engineers and entrepreneurs. However, such a wide range of stakeholders of this concept Vice Admiral Cebrowski did not foresee.

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