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CERTAIN GEOPOLITICAL INSIGHTS INTO THE TECHNOLOGICAL SINGULARITY

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ABSTRACT

Due to the penetration of mobile communication solutions, the exponentially inflating cyberspace of the present epoch has connected two-thirds of the global human population to the digital blood circulation of our world. The technological and geopolitical turbulences of our present offer several novel opportunities for emerging nations with necessary technological inclinations. Nonetheless, it precipitated the emergence of new frontlines in geopolitical / geo-economical affairs. The potential inherent in AI, coupled with the fusion of massive real-time data generation technologies (IoT) and the (planned to be) omnipresent ICT ecosystem (5G/6G), brought the TS on the horizon. Certain geopolitical aspects of TS are examined in this paper by analysing the relevant literature, illustrating that the lack of expertise and implementation of TS-founding technologies may cause limitations in countries' ability to exert geopolitical leverage.

Keywords: Technological Singularity, AI, 5G/6G, IoT, Geopolitics

„If the many are in disagreement, then
they become the dinner of the lonely one."
(Obrusanszky, 2008, p. 22)

INTRODUCTION

Considering the scientific and technological Research & Development & Innovation (R&D&I) trends of our time and the known preferences and plans of the political and economic sectors, it is reasonable to assume that the evolution of our information society based on information and communication technologies (ICT) will accelerate. The Internet-based technologies that have laid the third wave of globalisation have radically transformed our world's social, scientific and economic structures. Access to information and the dissemination of new scientific results is proceeding at a level of freedom unprecedented in human history, which has allowed once large *(e.g. India, China)* and „rising" nations *(e.g. Estonia, Israel, Singapore)* to become potential beneficiaries of the third wave. It is reasonable to say that, considering the quantity/quality/complexity of data available and the dynamically growing extent of ICT networks that facilitate information circulation, our cyber-universe is expanding at an extraordinary pace. Combined with achievements in Artificial Intelligence (AI) technology, this could make it feasible in the foreseeable future to create self-evolving ecosystems (e.g. Industry 4.0), which can be considered the foundations of the singularity predicted by John von Neumann.

The above-mentioned self-evolving ecosystems are referred to as Technological Singularity (TS) in this paper that may be delivered as a symbiosis of the following three technologies even in the forthcoming years:

1. *AI* – the evaluating/analysing/managing element of the TS.
2. *Next-generation ICTs* – in particular, the "inclusive" (exploiting the planned symbiosis of mobile/fibre/satellite/WiFi/ad-hoc networks) 5G and upcoming 6G ecosystems deliver massive data circulation at an extreme transfer rate for a rapidly growing number

of network endpoints. In other words, they form the interface medium between AI and the data collection and task execution ecosystems.

3. *The Internet of Things (IoT)* – is the element of TS that ensures its operational abilities in the physical world and ensures real-time, constantly updated data for AI.

This document does not cover transhumanism (see Kurzweil, 2014) and emerging and disruptive technologies (EDTs) that are being intensively researched but have not yet been deployed for military or civilian purposes (e.g. quantum communications and computing).

The geopolitical implications of the TS triad outlined above have been examined by several authors, respectively, from both a security and a geopolitic/-economic perspective. Certain geopolitical aspects of TS are examined in this paper based on an analysis of the relevant literature, pointing out that the lack of expertise and a low-level implementation of the TS enabler technologies can fundamentally limit the geopolitical influence of countries.

1 THE TECHNOLOGICAL SINGULARITY

According to the reminiscence of his fellow scientist, in the twilight of his life, John von Neumann expressed that technological progress would inevitably reach a point where the synergy of technologies would create a paradigm shift, and after that, *"human affairs, as we know them, could not continue"* (Ulam, 1957, p.5). The notion of TS refers to the potential in the synergy of the TS triad in this paper, building on the non-transhumanist definition of TS echoing the criteria of Industry 4.0/5.0 (Fakhir et al., 2020); briefly, the AI, at a certain point, becomes capable of recursive self-improvement, creating more advanced solutions (machines/artificial entities) than itself (Seewald, 2022).

1.1 TS FOUNDER EDT TRIAD

NATO's expert group identified the dominance of Emerging and Breakthrough Technologies (EDTs) as a strategic priority for the Alliance (Siposne Kecskemethy, 2021). The scope of NATO's EDT strategy consists of nine R&D&I areas, including AI and next-generation communications networks alongside, e.g. quantum technologies, bio- and human enhancement technologies, autonomous systems, and novel materials (Reding – Eaton, 2020). The US Department of Defense's Technology Vision (2022) divided critical technologies into three groups (seed areas of emerging opportunity, effective adaptation areas, and defense-specific areas), classifying certain aspects of AI as "adaptation" and next-generation mobile communications technologies (FutureG) as "emerging" (OUSD R&E, 2022).

From a practical approach, the definition of IoT – *all devices that can form an infrastructure and communicate with each other, providing access to data generated collected by each infrastructure element and (or) act as actuators* – defines a broad category that includes the most of the IT/ICT solutions. The potential of IoT is sufficiently portrayed in the statistics of 2023 when approximately 15.14 billion active IoT solutions were operational; the industry predictions suggest a duplication by 2030 (Vailsehery, 2023). The projected 30 billion could be a low estimation considering the predicted effect of the 6G technology, which is planning with human "micro-networks", like body-worn and implanted IoT devices, enabling, e.g. the 'Digital Soldier' solutions, which could be assigned to the human-enhancement EDT segment (Rajasekaran, 2024).

The next-generation mobile communication ecosystem (5G) natively supports industrial applications, including IoT-like technologies, as per standard. Regarding architecture and design, 3G was the last traditional mobile network based on primarily specific, dedicated hardware. 4G has started exploiting IT advances more profoundly in its network functions, while deploying off-the-shelf (OTS) IT hardware in 5G became a per-standard option complemented by high-level softwareisation and virtualisation features. In 5G/6G networks, high-accuracy positioning and supporting high-speed, high-altitude moving network endpoints will be essential (Tóth 2023). The 5G capability portfolio can be grouped into three core use cases:

- mMTC - massive Machine Type Communication supporting large-scale machine-to-machine/IoT solutions,
- eMBB - enhanced Mobile Broadband ensuring high-speed data transmission,
- uRLLC - ultra Reliable Low Latency Communications for solutions demand highly reliable connection with extremely low latency (e.g. remote control of drones, vehicles, surgical equipment).

The 1. table below introduces the extent of the generational transition between 4G- 5G- 6G:

Table 1 - Comparing 4G/5G/6G by specific metrics

	4G	**5G**	**6G**
Peak data rate	1 Gbps	20 Gbps	1000 Gbps
Max. number of connected endpoints	100 000 / km^2	1 000 000 / km^2	100 / m^3 (a)
Latency	10 ms	1 ms	0.1 ms
Max. channel bandwidth	20 MHz	0.1/0.4/2 GHz (FR1/FR2-1/FR2-2) (b)	100 GHz
Max. spectral efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Vertical coverage	n/a	300 m	10 000 m

(a): 6G, considering the vertical extent of the space covered, sets the target value not area but volume basis. (b): FR1=0.41-7.125 GHz; FR2-1=24.25–52.6 / FR2-2=52.6-71 GHz

Source: contribution of the author based on 3GPP 3GPP TR 21.916 V16.1.0 (2022) and ETSI TS 138 104 V17.7.0(2022)

The near-ubiquitous coverage ability of 6G (ITU IMT-2030) will be a core requirement. The per-standard 5G network topology builds on fibre elements in its transport network, heterogenous cell ecosystem (macro/micro/pico/femto sized cells), and distributed antenna systems (Farkas, 2023). According to ITU/3GPP/ETSI recommendations and specifications, 6G will dynamically exploit the satellite and high altitude (18-22 km) platform systems (HAPS), ad-hoc and WiFi networks. Version 18 of the 3GGP standard is already examining the applicability of AI for 5G to ensure the expected quality of services, considering the deployability constraints of base stations and the scarcity of available frequency bands, radio signal propagation characteristics, and the required power efficiency of the network (Liu et al. 2024).

Based on the definition of the EU AI Regulation, which builds on the OECD specification, AI is a machine-based system designed to operate with varying degrees of autonomy and capable of generating outputs (e.g. predictions, recommendations, decisions) that affect the physical or virtual environment for explicit or implicit purposes (EU 5662/24, 2024). The NATO Foundation Defense College defines AI as the ability of machines to mimic, with a degree of autonomy, the problem-solving and decision-making processes of the human brain related to a given task by processing large amounts of information at high speeds, exploiting the capabilities of software, algorithms and deep neural networks, and using increasing amounts of data (Berger, 2021).

The researchers identify three AI stages of development:

1. Weak or narrow AI (ANI) – embraces function-specific (e.g., data analysis/processing/identification, inferential decision support algorithms) solutions used presently and trained on structured data sets.
2. Strong or general AI (AGI) – measurable to the human intelligence, capable of high-level abstraction, trained on unlabelled datasets. With the dynamic spread and evolution of multimodal large language models and their descendants, AGI might be closer than anticipated.
3. Artificial superintelligence (ASI) – that is assumed to outperform human intelligence significantly (Kovacs, 2023).

Concluding, the AI may

- possess continuously actualised inputs on its area of competence along with other relevant parameters that influence its functioning,
- the input is provided intentionally (human involvement), or the model collects them by detecting its physical and cyber-physical environment;
- transform the available inputs into information to make decisions, including its learning/self-improvement workflows;
- trigger changes in the offline and online space through its decisions, supporting and enhancing several areas of human activities at a large scale.

There are debates about whether multimodal large language models (mLLMs) or their extended descendants (e.g. LLMs' hallucinations reducer retrieval augmented generation - RAG) or other models like Liquid Neural Networks (LNN) can realise AGI (Kumar et al., 2023). Deciding this debate is out of the scope of this paper. Nonetheless, LLMs' potential applications, thanks to their semantic and sentiment analysis capabilities, may offer significant support to (e.g.) defence/law enforcement/cyber defence/scientific sectors. Over the last decade, recognising its potential, the business community has attracted the best researchers from academia and has become dominant in AI R&D&I, laying the foundations for an explosion in the global social penetration of the technology (Maslej et al., 2023). There is a growing trend towards the involvement of AI in creative research (e.g. creating new antibodies, delivering hydrogen fusion); therefore, researchers warn of the risks associated with using AI (Madeiga, 2023).

2 TS GEOPOLITICS AND GEO-ECONOMICS

Many authors have criticised the "classical" (realist) directions of geopolitics, especially after the end of the First Cold War (Topalidis et al., 2024). According to them, the realists took little account of factors such as scientific/technological advances and the enhanced weight of economic characteristics in their analyses. The expansion of cyberspace, particularly the rise of the Internet, has brought many changes to human life and undeniably impacted geopolitical processes. However, the arguments that the goal of modern geopolitics is not to optimise the capacity of a particular state to pursue its interests but to solve societal problems are questionable, especially in the context of contemporary geopolitical events, confusing the geopolitical and geo-economical soft means and collateral gain with the objectives.

The elements of the TS triad, among other EDTs, are strongly interconnected with our physical world, exerting a significant influence on its events. The TS triad's R&D&I, manufacturing and operational processes are highly resource-intensive, including the human factor. The relevant states - specifically those at the forefront of the development of AI, 5G/6G, and IoT technologies - are willing to make considerable direct and indirect efforts to control resources needed to keep or reach their positions.

Rudolf Kjellen, in line with the military science of his era, examined the dynamics of power in the world via the domains of land and sea. The work of Giulio Douhet, considering the technological developments since the turn of the century (1900) and the experiences of the First World War, has introduced airspace as the third domain of geopolitics to be analysed. Space around Earth, as the fourth element of the matrix, was added at the end of the 1950s (Szilagyi, 2018). The concept of cyberspace, as the fifth domain, was introduced after the end of the First Cold War, at the beginning of the Internet era in military and geopolitical works (Kuehl, 2009). The virtual cross-section of geopolitics and TS is in the fifth domain (cyberspace).

2.1 CERTAIN ASPECTS OF CYBERSPACE

Although several nations supra- and international organisations have created their concept, we do not have a globally accepted definition of cyberspace. The word "cyberspace" was visualised first in a collage by Danish artists Susanne Ussing and Carsten Hoff in 1969. It became known to a broader audience from popular sci-fi literature (William Gibson's Burning Chrome and Neuromancer, 1982).

Cyberspace is a virtual reality based on ICT networks in Gibson's vision; a non-space, a simulation matrix facilitating the management and exchange of humanity's data assets with visual mapping. According to the UN's definition, cyberspace is a fictional or virtual environment for electronic communication, the best-known manifestation of which is the Internet. At the same time, the UNIDIR study, based on Kuehl's 2009 formulation, emphasises the role of the electromagnetic spectrum, according to which cyberspace is a planet-wide (global) domain of the information ecosystem. Its unique characteristic is that it creates, stores, modifies, exchanges and exploits information through interdependent and interconnected networks based on ICTs, exploiting electronic infrastructure and the electromagnetic spectrum (UNIDIR, 2023). The business domain interprets cyberspace as a kind of data/information sphere, the manifestation of which is the Internet (Masuda, 1996). The EU has adopted the definition created by Committee on National Security Systems (USA) with some simplification of the content (which was also adopted by NIST SP 800-30 Rev. 1); according to that, cyberspace is an information environment, a global domain of interdependent information system infrastructures, including the Internet, telecommunications and computer networks, and integrated data processing and control/management solutions (CNSSI 4009, 2022). The NATO AJP-3.20 doctrine defines cyberspace as the domain of interconnected and insular communications, IT or other electronic systems and networks and the data stored/transmitted/processed in them. Researchers of the Cooperative Cyber Defence Centre of Excellence (CCDCOE) have defined cyberspace as a time-dependent set of interconnected information systems and the users interacting with them (Ottis – Lorents, 2010). This concept converges to the three-layer (physical/logical/cyber-personality) model defined in the doctrine (AJP-3.20), where the physical layer covers the hardware, the logical layer the software (including protocols, applications, and data components), and the cyber-personality the virtual representations of offline persons, organisations (Haig, 2022). The definition of the Tallinn Manual - IT networks consisting of physical and non-physical components, based on the use of computers and the electromagnetic spectrum, for the storage/modification/exchange of data – is more in line with Kuehl's work. The definition of cyberspace in the Hungarian National Cybersecurity Strategy (NCSS – Government Decree 1139/2013. III. 21.) leads to the next chapter of this work. According to the NCSS, cyberspace is a set of globally interconnected, decentralised, ever-growing electronic information systems and the social and economic processes that take the form of data and information that emerge through these systems. Besides the NATO/UN characteristics, the Hungarian definition incorporates the concept of time *(ever-growing, dynamically changing by the new technology additions)*, thus giving cyberspace an organic character.

2.2 THE CYBER – SPACE

The definitions cited share the common feature of emphasising cyberspace's physical network foundation. From an operational point of view, it is logical to consider the importance of satisfactory control of cyberspace's nodes—all the relevant IT and ICT devices—and the transmission routes amongst them to control the information stored/processed/transmitted in cyberspace (Adams, 2024).

“The complexity of many systems can be attributed to the interwoven web in which their constituents interact with each other... the underlying networks are not static, but continuously change through the addition and/or removal of new nodes and links.” (Bianconi - Barabasi, 2001, p. 2) Cyberspace is growing dynamically in terms of its physical extent and the number of entities using it. Broadly interpreting the observations of Bianconi and Barabási (2001), cyberspace as a complex system is changing in terms of both its physical and virtual components; new nodes are created, modified (strengthened, weakened, terminated), and the number, complexity and weight of their connections are in a constant state of flux.

The hybridisation of social interaction has led to expanding networks of relations over borders and continents (Lobastova, 2020). The evolution/changes in the quantity and quality of these connections and interactions, analogous to the volatility of the current interests, activity levels and attention of human entities in the Internet era, show a high level of variability (Bradbury, 2016). In pursuit of the boundaries of cyberspace, the question arises whether, if no sentient entity interacts with a given segment of cyberspace at a given moment in time and/or no information is created/modified/transmitted/utilised on devices assigned that cyberspace segment, then the segment under investigation is part of cyberspace at the time under consideration. In other words, is cyberspace's form and spatial structure quasi-static/mechanical, or could it be described in terms of dynamic/organic features, similar to the spatial concept of social geography (Kelemen, 2023).

From a fusionist perspective, the spatial structures studied by social geography are not restricted to the natural environment / Euclidean spatial definition, nor are they mere manifestations of the interaction ecosystem of human societies, but are the outcome of a dynamic interaction between both (Pirisi – Trocsanyi, 2019).

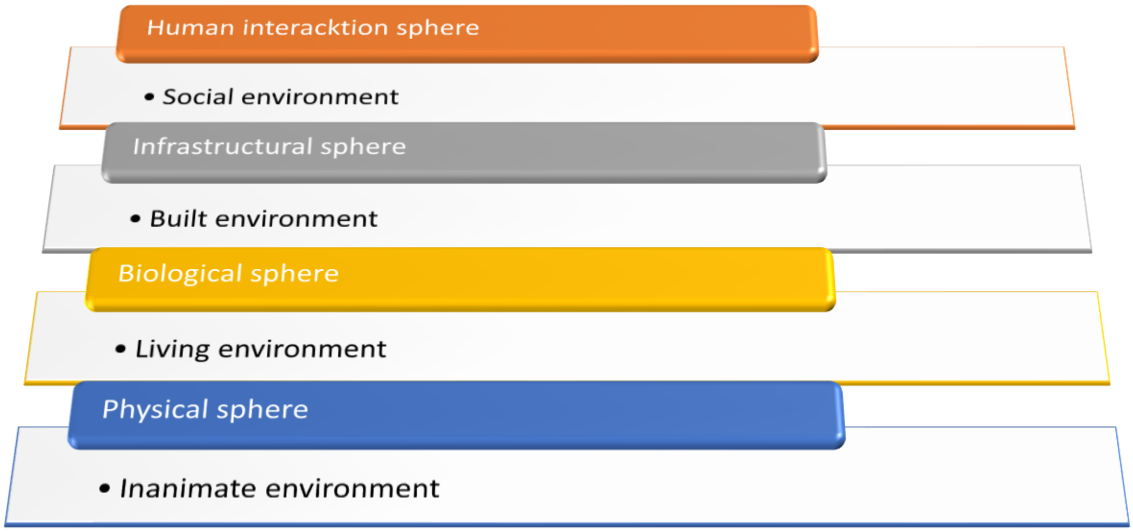

Figure 1 Layers of geographical space
Source: author's editing, based on (Pirisi – Trocsanyi, 2019)

Applying this as an analogy to cyberspace, the 'natural environment' is equivalent to the ICT ecosystem of cyberspace - which is also part of the infrastructural sphere of geographic space and influences the physical/biological/human interaction spheres - while the most illustrative example of the cyberspace-shaping influence of community/social relations/interactions is the world of social media.

Cyberspace's structure is multidimensional, amorphic, and dynamically changing in response to momentary requests and interactions; from the perspective of space-time, it is simultaneously point-like and infinite. From a humancentric interpretation of geographic space organization, cyberspace's structure is multidimensional, amorphic, and dynamically changing. As Pirisi-Trocsanyi (2019) suggests, it is a virtual twin of the human interaction sphere. Its liquid-natured morphology transforms moment to moment in response to requests and interactions of active participants (humans, virtual entities). From the perspective of space-time, cyberspace is simultaneously point-like and infinite.

Accepting the definitions of cyberspace based on Kuehl's work and the Pirisi-Trócsányi human-centered spatial analysis model, in an operational approach, I suggest to accept its description as a dual quality sphere.

- Focusing on the possibilities of physical access that may ensure the control, acquire information and/or utilize the physical features of cyberspace's sub-systems (e.g. exploit 5G/GPS radio waves for passive radar purposes), it presents a quasi "static" character, its perimeter could be defined with high accuracy: the outermost frontier of physical network devices those relevant to the human race.
- Regarding the quantity and quality of interactions, approaching cyberspace from the perspective of influence operations reveals that cyberspace is an ecosystem with an organic nature and high volatility.

Regarding the geopolitical/geo-economic/national security "soft" means of influence operations, it is essential to own the "moral high ground" that the targeted entities consider as such for the influencing party (Topalidis et al., 2024). It is not easy to achieve in a global virtual space, as what was yesterday a high ground can now be a valley of disinterest or a chasm of rejection. Therefore, it is remarkable to what extent the 'ancient' social Darwinian principles of geopolitics (achieving cyber superpower status, increasing vital cyber 'living space', owning cyber resources) are being applied in the community platform segment, where the largest (state) actors are doing their best to maximise their potential for influence.

2.3 GEO-ECONOMIC INSIGHTS

To found/maintain geopolitical/geo-economical advocacy based on technological development - as an objective - is based on limited resources of a closed system (the Earth), so the contest for control resources ensures the creation and apply technologies depicted emerging and disruptive, both overt and covert, is becoming increasingly severe. This competition has been a core feature of human history and one of the main drivers of technological development (innovation). Since the beginning of human history, influence-creating/supporting means – described as soft methods and procedures – have played a fundamental role in competition for resources. The emergence of geo-economics as a stand-alone discipline has been supported by a historical framework in which the major players in the global space have imposed relatively significant constraints on the active use of their military power to defend their national interests. More emphasis has been placed on "soft" (including economic) means of geopolitical advocacy. Although the adjective "soft" refers to advocacy without "hard" means, some argue that geo-economics is a fusion of the logic of war (conflict) with the methods of trade (Luttwak, 1990). Others describe geo-economics as pursuing and protecting national interests and acquiring geopolitical advantage through economic means (Blackwill – Harris, 2016). As can be seen from the definitions quoted, the assertive approach (based on the logic of war) was not made obsolete by the end of the First Cold War. In a paper based on the work of Blackwill and Harris (2016), the author argues that deliverance of a state's geopolitical objectives requires economic power, practical usage of the geo-economic toolbox - trade/investment/financial and monetary/assistance (aid)/energy and raw materials/sanctions policies - and a proper foreign economic strategy, complemented by the art of well-guided, economically focused governance of the state, including other means of ensuring economic prosperity e.g. international co-operations frameworks and capable military forces (Troxell, 2018).

Mackinder's defined sea powers typically gained a strategic advantage (e.g., control of natural resources, knowledge/information) over land powers. To overcome the former was hampered by the fact that the technologies possessed/applied by the land powers, regardless of how advanced they were in their time, could not negate the determinants of geography that caused handicaps for land powers (Csizmadia, 2017). Although the 'power of geography' remains inevitable in terms of kinetic (military) power projection and production/trade value chains, cyberspace (primarily the internet) has had a profound impact on the last 30+ years of our world by changing the distribution of information, supporting the rise of such significant players as India and China (Friedman 2005). The model outlined by Thomas Friedman, ensuring a proper geopolitical approach, analyses globalisation in the context of the emergence (and changes) of global 'networks', resources and data flows. According to Friedman, the first wave of globalisation can be dated from the end of the 15th century (the great geographical discoveries), the second wave from the turn of the 18th and 19th centuries (the first industrial revolution), and from the turn of the millennium the global availability of the Internet laid the foundations for Globalisation 3.0. By transforming economic value chains, digitalisation and Internet have ensured the basement of China's present position, placed India and Brazil into emerging status, and helped Russia to re-emerge, providing these countries with a significant influence on global economic processes. The technological innovations of the last three decades in digitalisation (e.g. internet, mobile communications, AI) have provided an opportunity (for those prepared) to reshape geopolitical and geo-economic power trajectories radically (Csizmadia, 2017).

The increasing use of AI anticipates the likelihood that, in contrast to the business/technology-knowledge concentration dynamics of the first decade of the 21st century, that can be described as oligopoly dominance of technology giants (e.g. IBM, Microsoft), the significance of technology SME entities with a sizeable global presence will increase. The immense increase in digitalisation at a global scale, with a specific focus on mobile communications, will support both the development and application of AI-based technologies and the increasing penetration of the global market by the entities developing them (Bankuty-Balogh, 2022). At this moment, the reduction in business/technology capabilities concentration is at best at an early stage, since the cost of next-generation chip development is far beyond the K+F+I budget of the average SME. Furthermore, developing LLMs is not quite a budget-friendly process for an SME. Around 30,000 NVIDIA A100 GPUs (approx. 10,000 USD /pc) are used to train ChatGPT. A 12 Billion USD capital injection allowed OpenAI to begin the upgrade process of its GPU fleet with NVIDIA H100s (approx. 30 000 USD /pc) in 2023 (Sims, 2023). However, the R&D&I cost of derivative products (e.g. based on OpenAI solutions) could be down to the "garage technology" level.

Regarding the chip (semiconductor) industry, technological concentration is still a reality and is even strengthening. IBM invested USD 6.77bn in R&D in 2023, while the Taiwanese chip giant (TSMC) invested USD 5.85bn in R&D. By comparison, these sums are close to the total R&D expenditure (including all research strands) of the business sphere in Finland, which ranked 7th in the EU.

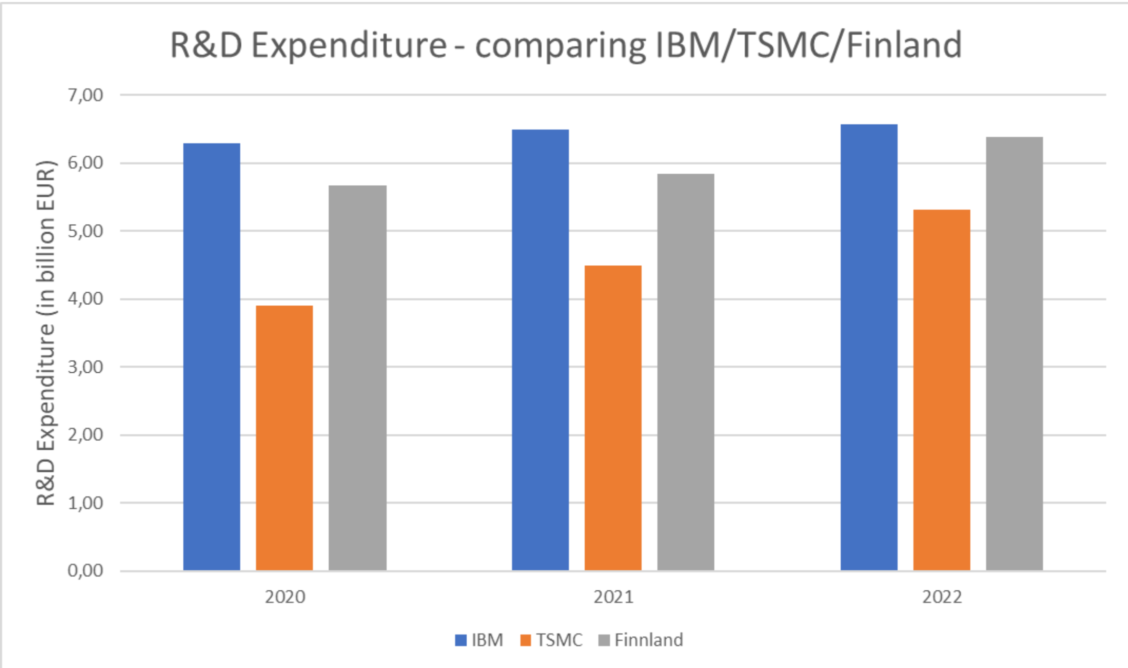

Figure 2 R&D Expenditure - comparing IBM/TSMC/Finland
Source: https://www.macrotrends.net/stocks/charts/IBM/ibm/research-development-expenses, https://www.macrotrends.net/stocks/charts/TSM/taiwan-semiconductor-manufacturing/research-development-expenses, The EU industrial R&D investment scoreboard

Concerning the whole R&D vertical spent by the business sphere, the EU (combined expenditure) and China are closely tied to second place in the global arena, with a 60% capacity of the US ranked first.

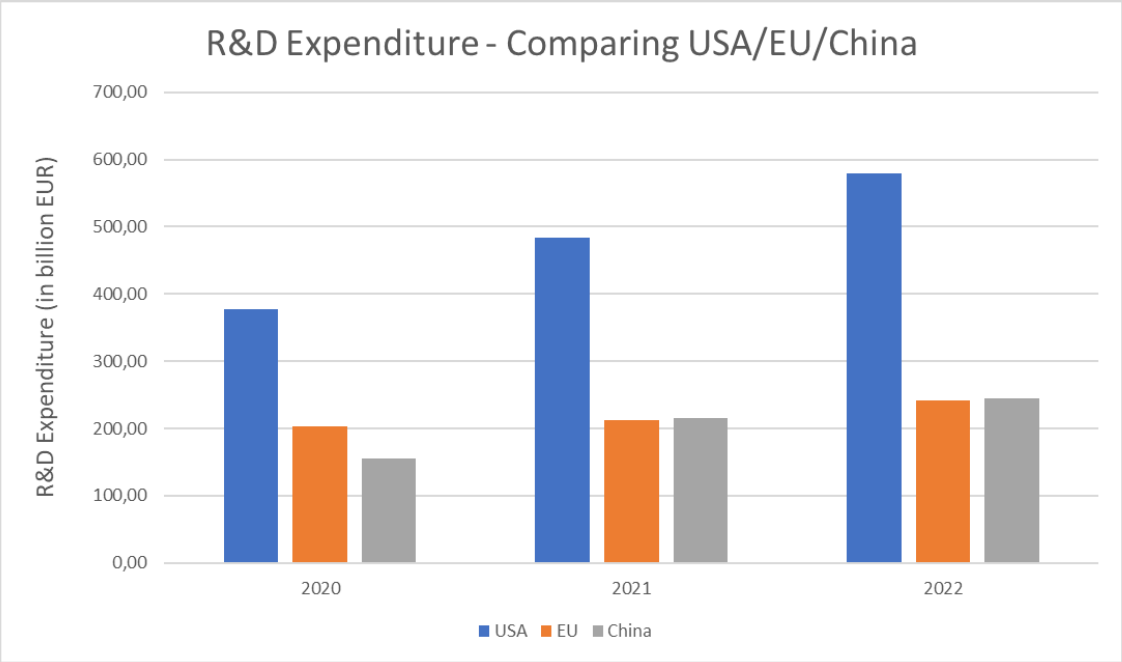

Figure 3 R&D Expenditure - Comparing USA/EU/China
Source: The EU industrial R&D investment scoreboard

The EU Cybersecurity Strategy and the Digital Compass 2030 highlight the importance of domestic manufacturing capabilities and semiconductor production. The Commission's STEP (Strategic Technologies for European Unity) initiative builds on 11 EU funding programmes and increases the Defence Fund budget by 1.5bn EUR for "chip sovereignty" (16.12.2020 JOIN(2020) 18 final, 9.3.2021 COM(2021) 118 final). The EU Chips Act (EU 2024/795), which complements the Horizon Europe Regulation, foresees 3.3Bn EUR of Community (EU) funding and 40Bn EUR of private capital allocation for EU chip R&D&I and manufacturing development.

Meanwhile, the US has dedicated approximately 53bn USD (~48.5bn EUR) of its federal budget for such purposes (expanded with ~ 250bn EUR through other resources and financial instruments); 73.6% (35.7bn EUR) of federal funding is planned to be spent on manufacturing capacity development by 2027 (Zimmermann, 2022). Theoretically, in both scenarios (EU/US), the baseline is the 10-10 per cent global chip market share in 2020, dominated by the parties, which the EU aims to double; the US has yet to set strict goals. The difference in the sizes of the two funding portfolios would lead to the dubious conclusion that the US aims to attract at least 80% of global manufacturing output to its territory. Of course, this would be a questionable goal even if the entire manufacturing capacity in Taiwan (which currently provides 50% of global chip output) were to be relocated to the US.

The 2020 report of the expert group mandated by NATO's Secretary General to assess the Alliance's position and future role (NATO 2030: United for a New Era) highlighted the importance of NATO addressing the challenges of China's increasing geopolitical position in a volatile geopolitical environment and the growing importance of the EDTs (Siposne Kecskemethy, 2022).

China, departing from the policy of Deng Xiaoping ("silent progress"), has embarked on assertive geopolitical activity, exploiting its technological and commercial capacities built up during the second half of Globalization 2.0 and the third wave of it. The Chinese influence portfolio, in contrast to the US practice – which relies heavily on traditional instruments of geopolitical assertiveness, e.g. projection of military power, alliance systems (Troxell, 2018) – builds primarily on its vital position in a networked interdependent global economy, on its technological advancement, and the export of its accumulated capital surplus (Csenger-Eszterhai, 2021). Without further in-depth discussion of China's national security advocacy 'portfolio', the country's leadership primarily uses the geo-economy as a toolbox for its political advocacy. In a peculiarly Chinese way (state capitalism: combining state economic engagement with a market economy in a state-controlled internal market), China has taken advantage of the post-Cold War international economic system and its sources of innovation to peak its geo-economic advocacy processes (Batson, 2021). In several cases, it uses even stronger state incentives to mobilise Chinese entities involved in geo-economic promotion activities in the economy, industry, and science.

A country's innovation capacity is a crucial marker in our technology-intensive economic era (Bankuty-Balogh 2022). The strategic importance of innovation is highlighted in the NATO 2030 Agenda Proposal 4, the EU Digital Decade 2030 policy agenda, and the New European Agenda for Innovation (EU 2022/2481). Drawing lessons from the 2008 economic crisis, China has accelerated its shift from labour-intensive production to a higher technology and knowledge-based one (Kocsis-Komjathy-Peti, 2017).

The US and China dominate in terms of scientific/technological achievements. An analysis by the Australian Institute for Strategic Studies shows that China has built up significant scientific potential over the past decades in critical/emerging technologies as defined by NATO, the EU, the US, and Australia. Researchers identify a significant Chinese lead for technologies relevant to this paper, primarily 5G, 6G and AI (Gaida-Wong-Leung-Robin, 2023).

According to the World Intellectual Property Organization (WIPO), an EU member state (Sweden) is among the top three most innovative countries globally, with 5 EU members in the top 10.

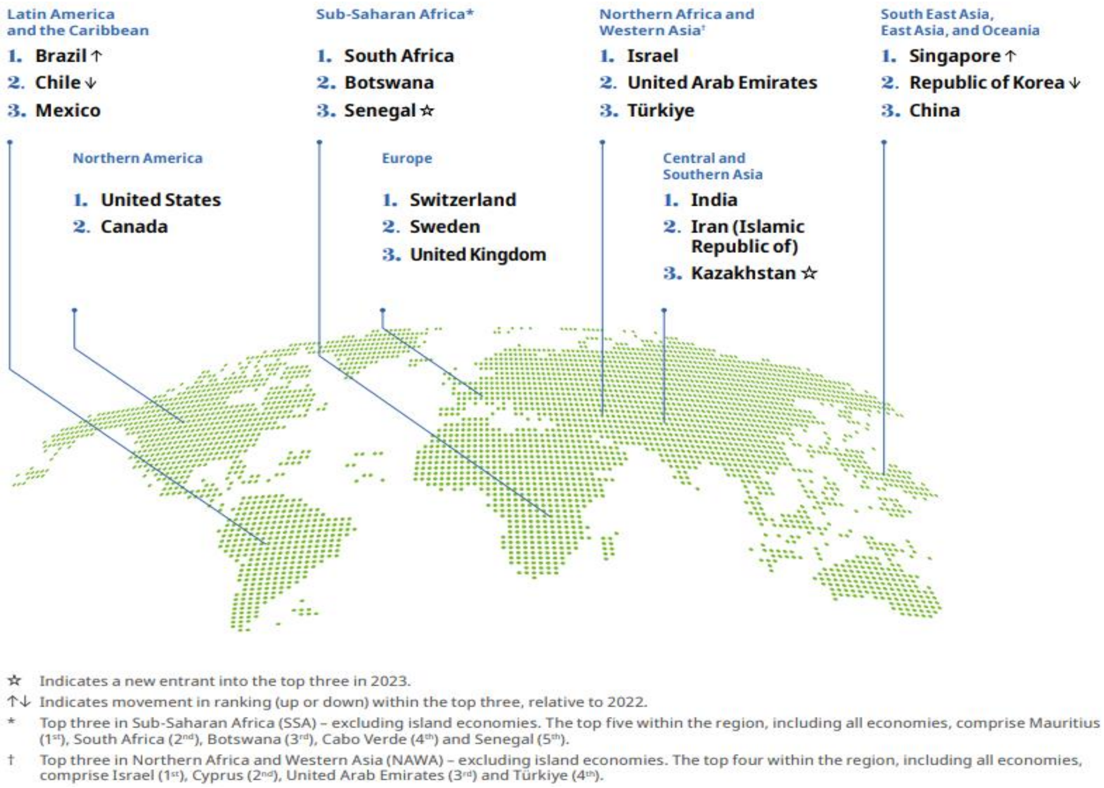

Figure 4 Top three innovation economies by region
Sorurce: WIPO 2023. Global Innovation Index. p.18. Online: https://doi.org/10.34667/tind.48220

The EU is, in a quasi-tie, in first place in the TOP100 in terms of the number of S&T100 clusters; while in quantitative terms, there are 25 S&T100 clusters active in the EU territory, one of them is a "cross-border" (French/German/Swiss) initiative. Analyzing at a nation-state level, by 2023, China already had 24 S&T100 clusters, overtaking the US (21 clusters). Germany is third in the nation-state ranking with 9 S&T100 clusters. Focusing on the EU context, France is also in the top ten) with 3 S&T100 clusters. The S&T100 clusters are also interlinked with the most innovative and, therefore, most attractive industrial clusters in the country. As a salient and significant example, Chinese investment in Germany is predominantly concentrated in the most valuable industrial clusters of the "engine of Europe" (WIPO, 2023).

According to the WIPO's preliminary S&T100 2024 report, China took the lead with 26 S&T100 clusters, the US drew back to 20, and the EU, since one German cluster fell out of the top 100, has 24. The clusters of China (4), the USA (3), Japan (2), and South Korea (1) share the top 10 places of the clusters (Bergquist – Slee, 2024). Focusing on the cooperation between the leading S&T100 clusters on publications and patents, examining the partnering countries of a given cluster, the US is usually within the first three, and China can be found within the first five. As the WIPO study points out, the TS triad, under aliases, plays a leading role in the patent application activity of the S&T100 clusters. Consequently, the TS triad (a.k.a. computer technology, digital communication, semiconductors, electrical machinery, measurement) will be an immanent part of the R&D&I processes of our future globally.

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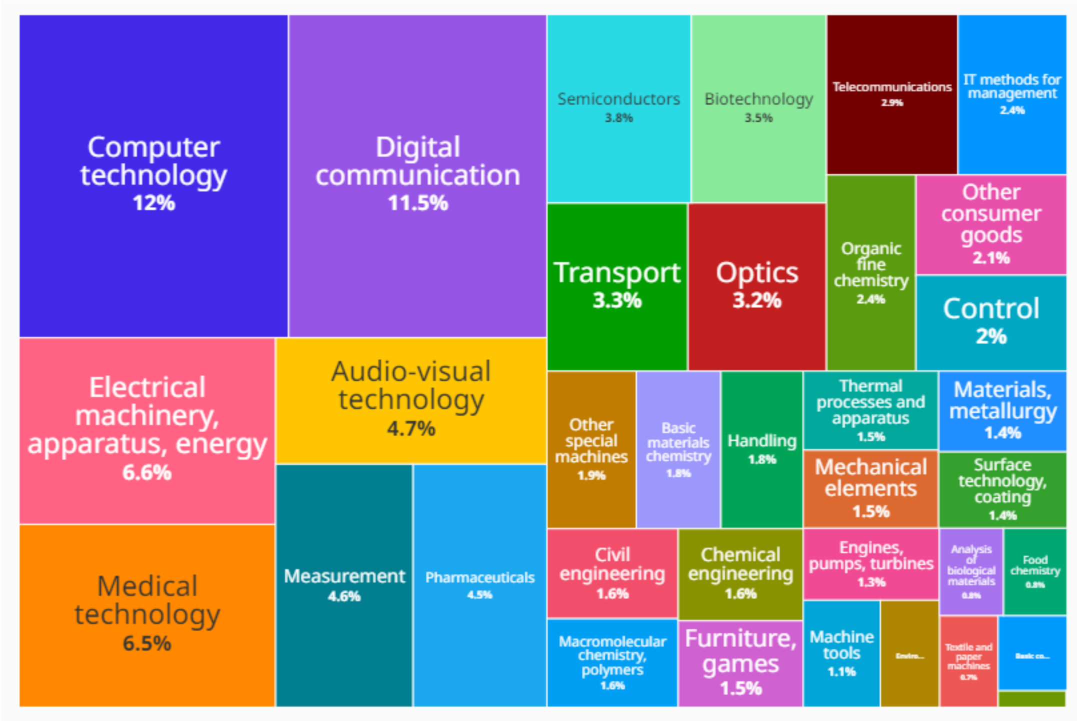

Figure 5 Share of PCT technology fields in top 100 clusters
Source: (Bergquist – Slee, 2024)

CONCLUSION

This paper presented some possible geopolitical insights of TS and its enabling technologies, pointing out that knowledge and extensive use of enabling technologies are essential for countries wishing to maintain their geopolitical status. For almost five years, the 5G/6G and MI elements of the TS triad have been the focus of severe conflicts between the technology superpowers (Bradford, 2023). The strategic importance of MI, described as the 'brain' of TS, is highlighted by the fact that the two leading powers in the industry (the US and China) have initiated discussions at the highest political level to develop control mechanisms for the technology (Depp, 2024). Perhaps one of Henry Kissinger's last, *possibly belated*, exhortations is behind the regulatory initiative of the two great powers (Kissinger – Allison, 2023). In assessing the complex geopolitical impact of TS, it is necessary to point out that those cannot be separated from the geopolitical implications of the TS triad and cyberspace. Their complex impact moderately generates new specific challenges and risks, although reinforcing existing ones and accelerating their processes. The TS's yet unexplored ("black box" type) geopolitical/security challenges are primarily due to the specificities of AI technology and cyberspace (Vinge, 1993).

Although neither the development of enabling technologies (semiconductor manufacturing and R&D&I) nor the creation and training of MIs and LLMs are part of the SME-level budgets, Globalisation 3.0 has shown that it is possible—with the right development vision and strategy—for countries and enterprises alike to move forward from the follower status. The internet, which has paved the way for Globalisation 3.0, has created the possibility for the emergence of parties that suffered backlashes in the previous waves of globalisation by "democratising" access to information that supports development. Taking the positive examples of China, India, Singapore, and Estonia as a case in point, it is clear that nations that allocate sufficient resources to the application and research of EDTs/critical technologies and can set their R&D strategic directions with sufficient foresight may lay a solid foundation to address the challenges of the forthcoming decade effectively.

Geopolitics and geoeconomics have also preserved their conventional scope in the era of Globalisation 3.0. Given the strong links between TS and the physical world (resource and raw material requirements), the pressure to develop/apply the underlying technologies suggests the emergence and escalation of further conflicts. The volatile geopolitical and geo-economic environment of our era makes it challenging to assess and predict even our medium-term horizon effectively. However, it is necessary to consider the limitations of geo-economic and, within this, technology-based advocacy. For example, in the case of the existence of effective interdependencies, which cannot be or are hard to replace, as mentioned in the context of China, it is also a basic assumption that the parties involved in the process of asserting interests accept the rules of the given international order and act accordingly. Unless this prerequisite is met, the hard elements of the geopolitical toolbox (e.g. force projection) might come into effect. In addition, the awareness of the cultural specificities of the parties involved and the ability to correctly assess the drivers that spawned them is essential. Any assumption suggesting that a particular technology-based solution/service portfolio is as meaningful in the UK as in Buthan leads to geo-economic advocacy misconceptions. If even one of the previously noted is not fulfilled, the resulting outputs of the (meant-to-be) advocacy processes will not be in coherence with the scheduled/estimated values.

Presuming that humanity's evolution will continue according to the ongoing technology trends, it is inevitable to intensify scientific research on the technological, security, and geopolitical aspects of the TS triad and its components (MI-5G/6G-IoT) for all states willing to maintain/develop their geopolitical status.

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