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Innovation in Defense and Artificial Intelligence: A Comparative Study of Approaches to the United States, China, and Brazil

Innovación en defensa e Inteligencia Artificial: un estudio comparativo de los enfoques en Estados Unidos, China y Brasil

Abstract: This study analyzed the application of science and technology in Brazilian defense, focusing on the evolution and impact of technological innovations—particularly artificial intelligence (AI)—in the military sector. This research compared the long-term strategies of the United States and China (which invest heavily in AI, data governance, and civil-military fusion) with the Brazilian' trajectory in disruptive technologies. Based on a literature review and analysis of official documents, this study detailed the approaches of these powers, highlighting their implications for Brazil. The results showed that, despite the Brazilian infrastructure for AI and other defense innovations, its Defense Sector Innovation System faces significant limitations due to economic, political, and management challenges and vulnerability to technological restrictions and internal fragmentation. This study emphasizes the need for civil-military integration, strategic partnerships, and the overcoming of cultural and structural barriers to ensure national autonomy and competitiveness.

Keywords: Technological innovation; Science and technology; Artificial Intelligence; Technological sovereignty; National defense.

Resumen: Este artículo analiza la aplicación de la ciencia y la tecnología (C&T) en la defensa brasileña, centrándose en la evolución y el impacto de las innovaciones tecnológicas, especialmente la inteligencia artificial (IA), en el sector militar. El estudio comparó las estrategias a largo plazo de Estados Unidos y China —que invierten masivamente en IA, gobernanza de datos y fusión civil-militar— con la trayectoria de Brasil en el ámbito de las tecnologías disruptivas. Basándose en una revisión bibliográfica y en el análisis de documentos oficiales, el estudio detalló los enfoques de estas potencias, destacando sus implicaciones para Brasil. Los resultados mostraron que, a pesar de la infraestructura brasileña en materia de IA y otras innovaciones en el ámbito de la defensa, el Sistema de Innovación del Sector de la Defensa (SIS-Def) se enfrenta a importantes limitaciones debido a retos económicos, políticos y de gestión, además de a la vulnerabilidad ante las restricciones tecnológicas y la falta de coordinación interna. El estudio subrayaba la necesidad de la integración civil-militar, las alianzas estratégicas y la superación de las barreras culturales y estructurales para garantizar la autonomía y la competitividad nacional.

Palabras clave: Innovación tecnológica; Ciencia y tecnología; Inteligencia Artificial; Soberanía tecnológica; Defensa nacional.

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1 INTRODUCTION

In the contemporary geopolitical landscape, artificial intelligence (AI) has emerged as the main vector of technological innovation in the defense sector, redefining military capabilities and national security strategies on a global scale. Its ability to process vast volumes of data, automate decisions, and optimize operations gives it a central role in the pursuit of technological superiority and the guarantee of national sovereignty (Cheung, 2021; Kulahin *et al*., 2024). This technological transformation reflects the rapid pace of modern science and responds to the new threats and challenges from an ever-changing international landscape.

The race for leadership in defense AI has driven massive investments and long-term strategies in developed nations. Powers such as the United States and China stand at the forefront of this movement, seeking to improve their own military capabilities and to influence the global geopolitical theater via technological dominance (Bogdanov; Yevtodyeva, 2021; Cai; Zhang, 2024). However, this accelerated advance also manifests itself in technological curtailment since more developed nations seek to preserve their supremacy, making it difficult for emerging countries to access critical and sensitive technologies (Galdino, 2022).

For developing countries such as Brazil, building autonomous defense AI capabilities configures an imperative strategy to ensure their autonomy and competitiveness. However, the country faces multifaceted challenges in its journey, including overcoming technological constraints and addressing internal limitations, such as budget predictability and the effective articulation of its Defense Sector Innovation System (SIS-Def) (Azevedo, 2018; Girardi Moreira; Galdino, 2024).

Thus, this study seeks to answer the following guiding question: how do the AI-focused defense innovation strategies of the United States and China differ from each other, and what implications these approaches entail for the development and autonomy of AI in the Brazilian defense sector?

For this, this study analyzed and compared the AI-focused defense innovation strategies from the United States and China and discussed their implications and challenges for the development and autonomy of AI in the Brazilian defense sector.

This study aims to:

a. Characterize the main AI development and integration strategies and initiatives in the United States defense sector;

b. Describe the Chinese approaches and investments in applying AI in its defense capability;

c. To examine the current Brazilian SIS-Def AI development and adoption structure and challenges;

d. Compare the AI strategies in defense of the United States and China, finding their similarities and differences and the impact of technological curtailment for Brazil; and

e. Discuss the implications of the approaches of the global powers above and of Brazilian internal factors (such as budget predictability) for the construction of AI autonomy and competitiveness in Brazilian defense.

This study has five sections. After this introduction, the methodological procedures section details the qualitative approach and literature review in this research. Then, the theoretical framework section discusses the concepts of technological capabilities, sovereignty, and technological constraint in AI in defense. The analysis and discussion section describes the results of comparing the AI strategies in the United States, China, and Brazil and their implications. The final section reports the main conclusions.

2 METHODOLOGICAL PROCEDURES

A qualitative analysis was carried out to investigate defense AI innovation strategies in the United States, China, and Brazil. This qualitative methodology was chosen for its ability to deeply explore the complexities and nuances of the development and application of AI in defense, enabling a rich and contextualized understanding of the approaches of several nations (Creswell, 2014).

This research was based on a narrative and documentary bibliographic review that sought to find and analyze the pertinent scientific literature and official documents. The sources were selected by a non-systematized search method, using academic repositories such as Google Scholar, Web of Science, Scopus, and SciELO. Combinations of terms such as "Inteligência Artificial," "IA," "Artificial Intelligence," "defesa," "militar," "estratégia," "inovação tecnológica," "EUA," "China," and "Brasil" were used as keywords in this search. The results were analyzed from the perspective of the theme of this study and selected due to their attested adherence to the proposed objectives.

Official reports and documents from governments and research institutions that contributed to a comprehensive and detailed view of AI strategies in defense and the structure of SIS-Def were also considered. These documents proved essential to the understanding of the current process of construction of the organizational culture and the culture of national innovation in AI, being duly incorporated into the references of this study.

The AI defense strategies of the studied countries were comparatively analyzed by finding patterns, similarities, and differences in approaches, investments, challenges, and results in the bibliographic and documentary sources.

Although this research benefited from diverse sources, a narrative review approach that focused on synthesizing and interpreting the literature was adopted to build its comparative analysis.

3 THEORETICAL FRAMEWORK

This section establishes the conceptual and theoretical foundations in this study that underpinned its analysis of the defense AI innovation strategies in the United States, China, and Brazil. It will address key concepts (such as technological innovation, sovereignty,

and technological curtailment) and detail the approaches of each nation to develop and apply AI in their military sectors.

3.1 Innovation, technology, and defense: fundamental concepts

3.1.1 Innovation as a driver of progress in defense

Technological innovation in defense has consolidated itself as a strategic imperative in a global scenario of rapid transformations and interconnection between nations. The ability of a country to develop sophisticated military technologies enhances its security and sovereignty while also positioning it in the complex global power game (Cheung, 2021). Such technological evolution reflects the rapid pace of modern science, the need to respond to emerging threats, and the challenges of the international environment (O'Hanlon, 2000).

In this context, innovation constitutes the engine of progress, an essential component for the ability of military forces to keep up with contemporary technological dynamics. Robert Leach (2024) reinforces that the multifaceted challenge of military innovation requires understanding emerging threats, taking advantage of cutting-edge technologies, and overcoming doctrinal paradigms. Doctrinal innovation, in particular, must be driven by practitioners in the field. It is based on four main pillars: grassroots ideation, rapid prototyping, deliberate fusion of technology and tactics, and the emergence of new concepts (Leach, 2024). The pursuit of technological superiority constitutes a constant goal, driving progress and competitiveness in the industry (Lake, 2019).

The Information Age increased the strategic importance of science and technology (S&T) as such research activities and innovations constitute essential components to ensure the active and autonomous presence of nations, adding value to their products and processes and directly impacting their competitiveness in the global market (Pellanda, 2013). To ensure national security, all Expressions of National Power must exercise Defense (which is not exclusive to the Armed Forces), with emphasis on military expression (Azevedo, 2018). This systemic perspective of technology and innovation is essential for the defense sector (Longo; Moreira, 2013).

The speed of the recent technological evolution has driven "defense transformation" in several nations. This process obtained success in environments that favored constant innovation and continuous adaptation (Murray, 1997; Murray; Knox, 2001; United States of America, 2004). Achieving this goal and preparing and equipping military forces to face what is known as new threats requires establishing a robust defense industrial base. A strong defense industrial base strengthens the deterrent power of a nation and generates significant economic, social, and scientific-technological impacts, contributing to its development (Ambros, 2017; Sandler; Hartley, 1995).

3.1.2 Technological sovereignty and curtailment in the global scenario

The search for technological sovereignty has become a central pillar in national defense strategies, especially in global scenario marked by intense competition and technological

curtailment. March and Schieferdecker (2023) deem technological sovereignty not as total independence or autarky but as the ability of a nation to develop, control, and use critical technologies to ensure its strategic and security interests, reducing external dependence in sensitive areas. This capacity is fundamental for national autonomy and competitiveness on the geopolitical theater (Galdino, 2022; March; Schieferdecker, 2023).

In turn, technological curtailment represents the antithesis of technological sovereignty, manifesting itself as a set of practices nations develop to maintain their political and technological supremacy (Galdino, 2022). Such practices can include the ban of technology transfer, the acquisition of promising startups by large international corporations, brain drain from late-industrializing countries, and the imposition of fiscal, customs, health, or human rights barriers. Moreover, military or intelligence operations can neutralize, hinder, or impede the innovation capacity of peripheral countries to preserve technological inequalities (Galdino, 2022).

Meeting such challenges and developing authentic, national military capabilities that integrate sophisticated, innovative, and reliable technologies require several factors, including high doctrinal competence, efficient long-term planning, advanced maturity in drafting operational and technical specifications, effective financial engineering to ensure constant resources, and a dynamic innovation environment. The latter depends on the availability of sophisticated infrastructure for research, development, testing, and evaluation, highly skilled human resources, and a robust defense industrial base (Cronin, 2024; Galdino, 2022). Thus, enhancing technological sovereignty demands a robust legal framework, continuous scientific and technological advances, constantly updated critical technologies, and a great focus on the development of science and education (Faykov; Baydarov, 2023). Thus, institutional support, strategic partnerships, and prioritization of critical technologies are essential for long-term technological independence (Dementiev, 2024).

3.2 Artificial intelligence in the defense sector: a strategic imperative

AI has recently emerged as one of the most disruptive and transformative technologies, globally redefining military capabilities and defense strategies. The application of AI in the military sector configures a technological evolution and a strategic imperative to achieve technological superiority in modern warfare (Kulahin *et al*., 2024). The AI-driven strategic deployment of technological innovation has become an indispensable facet of military power projection, altering hardware, operational protocols, and strategic doctrines (Szeleczki, 2020).

The quest for technological dominance in AI has sparked intense competition between major powers, reshaping strategic capabilities and the global defense architecture. The convergence of civilian and military technology has blurred traditional boundaries, creating an environment in which advances in one domain rapidly influence the other, especially regarding dual-use technologies (Xiao; Xun, 2020). This posture has remodeled strategic capabilities and defense architecture, aiming to combat curtailment and expand technological autonomy and

maturity (Cai; Zhang, 2024). In general, countries such as the United States and China engage themselves in a military technological race, significantly investing in areas such as hypersonic weapons and advanced systems of command, control, communications, computers, intelligence, surveillance, and reconnaissance, which are increasingly impacted by AI (Bogdanov; Yevtodyeva, 2021; Kulahin *et al*., 2024).

However, the rapid integration of AI into military contexts raises complex and urgent ethical questions. The need to balance the benefits of AI with the protection of human rights in military operations configures a central challenge. The ethical use of in the military AI requires transparency, accountability, and human oversight, addressing the importance of dealing with biases and ensuring compliance with international humanitarian law (Islam; Wasi, 2024). Proposals for responsible innovation frameworks are crucial to ensure that the implementation of AI in warfare complies with humanitarian laws and moral standards, guiding the mitigation of ethical risks and promoting ethical and responsible deployment (Kazmi, 2024).

3.2.1 The United States strategy

The United States, seeing AI as a key pillar for maintaining its military superiority, has developed and implemented robust strategies to integrate and advance AI in its Department of Defense (DoD). The "Data, Analytics, and Artificial Intelligence Adoption Strategy" the DoD published in 2023 represents the evolution of previous efforts (such as the 2018 AI strategy and the 2020 data strategy review). This integrated approach emphasizes robust data governance and the agile, responsible implementation of emerging technologies, with annual reviews to ensure alignment and continued progress. A general in the United States DoD, for example, stated that AI will provide significant advantages on the battlefield (Bergun, 2019).

The key strategies of United States DoD include the rapid and staggered adoption of AI technologies. The United States defense industry focuses on accelerating the acquisition of technologies to gain a decision-making advantage, integrating AI into military and business operations to enable fast, informed decisions. The United States armed forces remain at the forefront due to its well-structured defense innovation system and substantial investment in military research and development (Gholz; Sapolsky, 2021).

The United States strategy for applying AI in the military sector includes several critical dimensions. It acknowledges the pressing need for robust data governance as it ensures clear resource allocation and AI initiative optimization. Such effective governance is essential to define appropriate funding levels, avoid unnecessary overlaps between autonomy and AI research, and ensure that basic AI research receives appropriate financial support (Konaev *et al*., 2020). The strategy also emphasizes the integration of AI with advanced data analysis to improve strategic decision-making. Advances in areas such as high-fidelity sensing, machine learning, and computer vision are crucial for enabling military systems to efficiently collect, organize, and analyze

large volumes of data, providing superior situational awareness and helping leaders at all levels of command to make more informed decisions (Konaev *et al*., 2020).

The United States actively seeks international partnerships to boost its military AI, especially initiatives such as the AI Partnership for Defense and the AUKUS agreement. However, these collaborations face substantial ethical challenges, including the need to balance the sharing of sensitive data with the protection of transparency and the prevention of adversarial attacks. Harmonization of policies between partners (especially regarding AI ethics standards) poses another significant obstacle (Trabucco; Maas, 2023). For the DoD, investing in education and training to develop a skilled AI workforce constitutes a priority. Its capacity-building programs aim to offer the proper technical skills in the effective use and management of AI technologies. Its strategy also includes significant investments in technological infrastructure to support the development and implementation of AI (ranging from the modernization of systems to the creation of technological platforms that facilitate experimentation and the use of technology).

3.2.2 The Chinese project in S&T and AI

China has shown remarkable strategic ambition in science, technology, and innovation (with a particular focus on AI), aiming to consolidate its position as a global leader and reduce its dependence on foreign technologies. Analyzing the science, technology, and innovation policies in China since the end of the 20th century evinces a continuous process of transformation due to the co-evolution between the phases of its development strategy and the changes in its productive structure and institutional and economic apparatus (Hiratuka; Diegues, 2021). This co-evolution follows long-term planning that adapts to change but still focuses on structural transformation, which is essential for developing and maintaining national sovereignty in the international geopolitical system (Cheung *et al*., 2016).

The Chinese strategy prioritizes endogenous innovation, which translates into large investments in research and development to foster local technological capacity, especially in critical areas such as artificial intelligence and semiconductors (Hiratuka; Diegues 2021). Moreover, one of its central initiatives is the integration between the civilian and military sectors (known as civil-military fusion) to maximize AI innovation and application. This means that military use can quickly adapt technological advances in the civilian sector; synergy that strengthens both sectors. The 2006 Medium and Long-Term Plan for Science and Technology was complemented by the Medium and Long-Term Plan for the Development of Science and Technology in Defense to reduce the technological military gap in China and strengthen the deterrent power and asymmetric capacity of its security systems and weapons. The Medium and Long-Term Plan for Science and Technology megaprojects reflected the concern with the development of dual-use technologies, with a focus on the military area (Cheung, 2018; Zhou; Liu, 2016). The International Institute for Strategic Studies has also explored how the Chinese have focused on reducing their dependence on foreign technology and investing in domestic production and dual-use technologies (International Institute for Strategic Studies, 2024).

China is developing a robust infrastructure to support the growth of AI, including the creation of innovation zones and specialized research centers. However, it recognizes the gap between it and developed countries in basic research, algorithm development, key equipment, semiconductors, software, skilled labor, and a well-structured ecosystem (Ding, 2018). This highlights the need for coordinated actions to foster the private sector, provide basic infrastructure, and improve regulatory and standardization aspects. China is directing investments to cutting-edge strategic technologies (focusing on AI fields), which can cause disruptive changes, such as big data, cross-media, hybrid augmented (human-machine), and swarm intelligence; advanced machine learning; and brain-inspired and intelligent quantum computing (Webster *et al*., 2017).

The Chinese government is also establishing policies and regulations to ethically and safely guide AI development and use. Its strategy foresees three stages with ambitious goals by 2050: to transform China into an innovative country by 2020; match advanced countries in innovation in certain areas by 2030; and position itself as a global leader in innovative capacity by 2050, with one of the most advanced scientific frameworks in the world (Hiratuka; Diegues, 2021).

3.3 The AI scenario in Brazilian defense

This sub-item will address the situation in Brazil, articulating it with the concepts and strategies of the powers discussed above.

3.3.1 The Brazilian Defense Sector Innovation System (SIS-Def) and AI

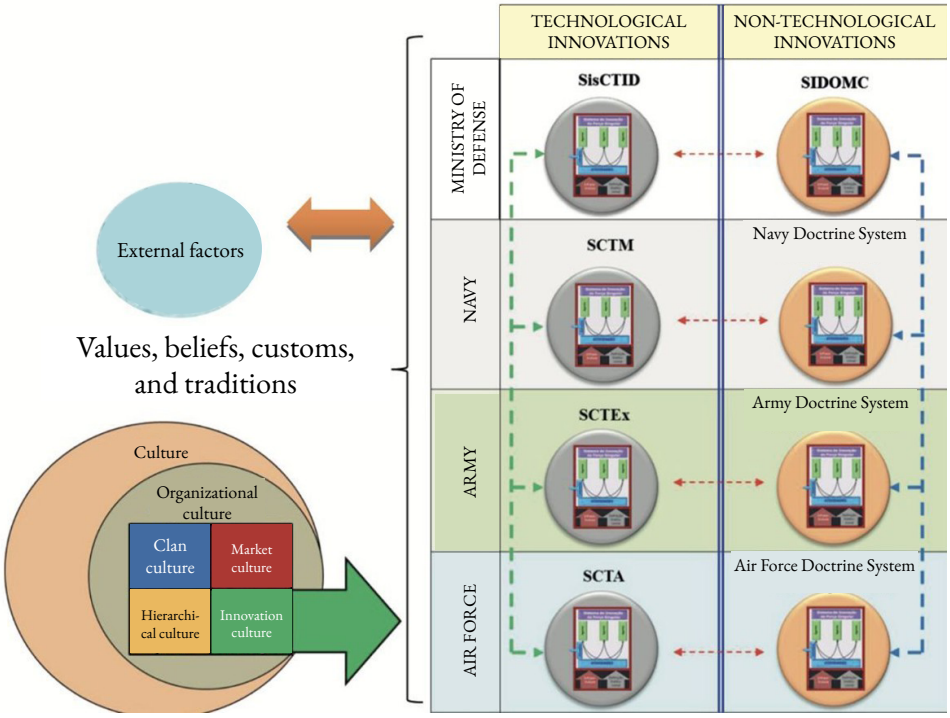
In the global evolution of S&T, it is essential to understand the dynamics of the process in Brazil, especially regarding the application of AI in defense. Its well-structured National Science and Technology System includes a strong core in graduate education *stricto sensu*. Moreover, agencies such as the Ministry of Education and the Ministry of Science, Technology, and Innovation have been working on training human resources and encouraging research, development, and innovation in areas aimed at industrial development (Salerno; Daher, 2006).

The interaction between defense actors is formalized in what the literature defines as SIS-Def (Azevedo, 2018). In its broadest sense, an innovation system consists of a set of distinct institutions that jointly and individually contribute to the development and dissemination of technologies (Cassiolato; Lastres, 2003). SIS-Def (Figure 1) mainly aims to encourage innovation in the sector, promoting interactions between its components for the development of products, processes, or organizational methods (Azevedo, 2018). This system consists of government agencies (especially the Armed and Auxiliary Forces), the defense industrial base, research institutes, higher education institutions, development agencies, and the legal and normative framework governing it (Cunha; Amarante, 2011).

The implementation of models such as the Defense, Industry, and Academy System by the Brazilian Army—inspired by the triple helix model (government-industry-academia)—exemplifies the search to boost innovation in the sector, taking advantage of the capillarity of the Armed Forces in the national territory. The creation of innovation governance centers in

technology parks facilitates interactions between triple helix actors, strengthening scientific and technological expression and promoting regional socioeconomic development (Silva; Quandt, 2019). This system often adopts the open innovation process—coined by Henry Chesbrough (2003)—which values relationships with partners as distinguishing factors in the innovative process (Lindegaard, 2010).

Figure 1 – Sis-Def schematic representation



Source: Azevedo (2018).

However, Brazilian SIS-Def innovations, despite the existing infrastructure, are yet to achieve the expected results for the sector, especially regarding AI and other defense innovations. Azevedo (2018) points out that this scenario reflects several factors (including economic, political, management aspects) and the macroeconomic trend of Brazil. Interactions between SIS-Def agents remain scarce. Similarly, SIS-Def interactions with other innovation systems outside the defense sector are lower than expected, characterized by initiatives that follow no formalized system (Azevedo, 2018; Cunha; Amarante, 2011).

3.3.2 Challenges and opportunities for AI in Brazilian defense

Despite its efforts and infrastructure, the AI scenario in Brazilian defense faces significant challenges that limit the full development and application of innovations. SIS-Def innovations remaining below expectations reflect a complex interaction of economic, political, cultural, and management factors (Azevedo, 2018). One of the most prominent obstacles

refers to vulnerability to technological curtailment. The Brazilian technological duality offers the country the chance to attract investments for defense, but exposes it to the risk of being the target of curtailment practices from developed nations that seek to maintain their supremacy (Girardi Moreira; Galdino, 2024). To mitigate this vulnerability and ensure its sovereignty, Brazil must invest in critical technologies and autonomous knowledge, reducing its external dependence (Girardi Moreira; Galdino, 2024). Moreover, the innovation policy in Brazilian defense faces obstacles and cultural and structural barriers that need to be overcome (Azevedo; Borba; Araújo, 2021).

To address these challenges, Brazil has adopted important initiatives, such as the creation of strategic projects and the implementation of capacity-based planning in its Ministry of Defense. Notable examples of these efforts include the Submarine Development Program, which aims to build conventional and nuclear-powered submarines, representing a technological and strategic leap forward for the Brazilian Navy. Another success story is the development and production of the KC-390 Millennium multi-mission freighter by Embraer, which shows the capacity of the Brazilian defense industrial base to generate highly complex and internationally competitive products. The Geostationary Defense and Strategic Communications Satellite also illustrates investment in space capabilities to ensure communications sovereignty and national security. Capacity-based planning, defined as "the ability to achieve a desired effect under specific standards and conditions by combinations of means and procedures to perform a set of tasks" (JCS J-8, 2009, p. 6), seeks to optimize management and planning. Although Brazil is implementing capacity-based planning, countries such as the United States, Australia, and New Zealand have already adopted it (Silva *et al*., 2019).

However, important gaps remain. The Brazilian Ministry of Defense and the Armed Forces have disjointed subsystems of technological innovations (inovatec) and non-technological innovations (inovadout). Azevedo (2018) finds neither a system that integrates the management of innovations in a comprehensive and strategic way within the scope of Defense nor the interconnection between the systems of technological and doctrinal innovations. Moreover, a critical observation refers to the absence of defense-related aspects in the Brazilian Strategy for Artificial Intelligence, regulated by MCTI Ordinance no. 4,979, of July 13, 2021 (Brasil, 2021).

4 ANALYSIS AND DISCUSSION

In the contemporary geopolitical scenario, technological innovation, particularly in AI, has emerged as the main vector of competition between the great powers. The pursuit of technological superiority configures a military objective and a strategic imperative that shapes international relations and power projection.

4.1 The technological competition between the United States and China in the age of AI

The analysis of the technological innovation strategies in the military expression of power shows how major international actors, such as the United States and China, adopt robust policies and massive investments to maintain and expand their technological capabilities, especially in

AI. This competition directly reflects global power dynamics, in which technological dominance translates into strategic advantage and deterrence.

The United States has positioned itself at the forefront of defense innovation, driven by a well-structured system and substantial investment in research and development (Gholz; Sapolsky, 2021). The DoD "Data, Analytics, and Artificial Intelligence Adoption Strategy" clearly exemplifies this commitment, aiming to enhance data governance, accelerate the adoption of AI technologies, and ensure a decision-making advantage (Konaev *et al*., 2020). The United States strategy emphasizes the agile integration of AI into military and business operations (enabling quick and informed decisions) and actively seeks international partnerships (such as the AI Partnership for Defense and the AUKUS agreement) to boost military AI (Trabucco; Maas, 2023). The view of military leaders, such as that of the DoD general above, reinforces that AI will provide significant advantages on the battlefield (Bergun, 2019).

On the other hand, China has shown an equally remarkable ambition, focusing on endogenous innovation and on the reduction of its dependence on foreign technologies. Its strategy follows long-term planning, such as its Medium and Long-Term Science and Technology Plan, which aims to reduce the technological gap in its military and strengthen the deterrence power and asymmetric capacity of its security systems and weapons (Cheung, 2018; Hiratuka; Diegues, 2021; Zhou; Liu, 2016). China intensively integrates its civilian and military sectors, enabling military use to quickly adapt civilian technological advances, a synergy that strengthens both sectors (International Institute for Strategic Studies, 2024). Despite its gaps in areas such as basic research and semiconductors (Ding, 2018), China invests in cutting-edge strategic technologies, including various aspects of AI and quantum computing (Webster *et al*., 2017), to become a global leader in innovative capacity by 2050 (Hiratuka; Diegues, 2021).

These two powers engage in multifaceted competition. While the United States commits itself more to hypersonic weapons, China aims to improve its command, control, and communication systems (Bogdanov; Yevtodyeva, 2021). This technological race follows the relentless pursuit of technological superiority in modern warfare (Kulahin *et al*., 2024) and the projection of military power (Szeleczki, 2020). Both countries face the challenge of ethically and safely integrating AI, with discussions on transparency, accountability, and human oversight in military operations (Islam; Wasi, 2024; Kazmi, 2024). Technological curtailment, a practice developed nations use to maintain their supremacy, also constitutes a constant factor in this scenario, influencing the strategies of both sides and those of nations that aim to obtain some freedom of action to develop their science, technology, and innovation projects (Galdino, 2022).

4.2 The Brazilian scenario in global technological competition

In contrast to the long-term strategies and massive investments of powers such as the United States and China, Brazil faces a scenario of technological innovation in defense with peculiar challenges and opportunities. As detailed in the Theoretical Framework (Section 3.4.1), Brazil has a structured National Science and Technology System with a strong graduate core (Salerno; Daher, 2006) and a SIS-Def that seeks to promote interactions between government agencies, its defense industrial base,

research institutes, and higher education institutions (Azevedo, 2018; Cunha; Amarante, 2011). The adoption of models such as the Defense, Industry, and Academy System, inspired by the triple helix, and the practice of open innovation (Chesbrough, 2003; Lindegaard, 2010; Silva; Quandt, 2019;) show an understanding of the importance of collaboration for technological development.

However, the analysis shows that the Brazilian SIS-Def innovations, including in AI, have failed to achieve the expected results (Azevedo, 2018). This multifactorial limitation includes economic, political, and management aspects. One of the main obstacles refers to technological curtailment since, although technological duality can attract investments, it also exposes Brazil to the risk of having its innovation capacity neutralized by nations that seek to maintain their supremacy (Girardi Moreira; Galdino, 2024). The innovation policy in the Brazilian defense sector also faces obstacles and cultural and structural barriers that hinder its advancement (Azevedo; Borba; Araújo, 2021).

In this context, the lack of budget predictability significantly contributes to the discontinuity of strategic projects of the Armed Forces, particularly those involving S&T. In Brazil, the principle of yearly federal budget leads to inefficiencies in long-term defense contracts as the absence of a multi-year financial structure extend project schedules and increase costs (Araújo Costa, 2024).

Despite these challenges, Brazil has implemented initiatives to improve its planning and management. The adoption of capacity-based planning in its Ministry of Defense (Joint Chiefs of Staff, 2009; Silva *et al*., 2019) constitutes an important step toward resource allocation optimization and skills development. However, the disarticulation between the subsystems of technological and doctrinal innovations in the Ministry of Defense and the Armed Forces (Azevedo, 2018) prevents a comprehensive and strategic management of innovation. A critical point that highlights this disarticulation is the absence of defense-related aspects in the Brazilian Strategy for Artificial Intelligence, regulated by MCTI Ordinance no. 4,979, of July 13, 2021 (Brasil, 2021).

Overcoming these gaps and strengthening the Brazilian position in the global technological competition requires it investing in critical technologies and autonomous knowledge, reducing its external dependence (Girardi Moreira; Galdino, 2024). The integration between its Navy and Air Force S&T systems and strategic partnerships with teaching and research institutions, such as Instituto Tecnológico de Aeronáutica (Pellanda, 2013), are crucial to explore complementarities and foster innovation. Such measures, continuous investment in well-trained human resources, and innovation policies are essential for Brazil to consolidate its technological sovereignty and competitiveness in the global defense scenario.

5 CONCLUSIONS

The analysis of the technological innovation strategies in defense, with a particular focus on AI, shows a global scenario of intense competitiveness and a strategic imperative to maintain sovereignty and power projection. The ability to develop and apply disruptive technologies has become a key differentiator in the contemporary era, redefining military capabilities and geopolitical relations.

The study of the approaches adopted by the United States and China highlights the importance of robust and integrated policies. The United States shows a consolidated strategy focused on data governance, the rapid adoption of AI, and the search for international partnerships to maintain its decision-making and operational advantage. For its part, China pursues an ambitious trajectory of endogenous innovation, with massive investments in research and development and strong civil-military integration, seeking global leadership in AI by the middle of this century. Despite its different approaches, both nations share the goal of achieving and maintaining technological superiority by driving an arms race in areas such as AI and cutting-edge weaponry.

This research points to a challenging scenario with latent opportunities in Brazil. Its Defense Sector Innovation System has a formal structure and important initiatives, such as capacity-based planning and the search for open and collaborative innovation models. However, the innovations it generated remain below expectations and are limited by economic, political, cultural, and management factors and vulnerability to technological curtailment. The disarticulation between innovation subsystems and the absence of an explicit approach to defense in the Brazilian Strategy for Artificial Intelligence are significant gaps that prevent the full use of the national potential.

So Brazil can strengthen its capacity for technological innovation in defense and ensure greater autonomy and competitiveness on the global stage, it must overcome cultural and structural obstacles, which requires continuous investment in critical technologies and autonomous knowledge, essential to reduce external dependence and mitigate its vulnerability to technological constraints. Effective integration between the various SIS-Def actors; the promotion of strategic partnerships between military, academic, and industrial institutions; and the explicit inclusion of defense needs in its national AI policies are essential steps to optimize resource allocation and foster a more resilient innovation environment. Only with a coordinated approach and long-term planning in line with international best practices will Brazil be able to consolidate its technological sovereignty and secure its strategic position in a world increasingly driven by innovation. Future studies could further the analysis of effective mechanisms for budget predictability in defense and investigate the impact of policies to foster AI in civil-military innovation ecosystems.

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