Expertise

Great Powers' Military Robotics

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Résumé Alors que les technologies évoluent, la compétition entre les grandes puissances s'intensifie. C'est particulièrement le cas des trois puissances militaires principales : les Etats-Unis, la Chine et la Russie. Les trois acteurs ont des conceptions très différentes de l'innovation. Ces trois acteurs ont des conceptions très différentes de l'innovation. Il en va de même pour leurs cadres institutionnels et gouvernmentaux en matière d'innovation dans le domaine de la défense, leurs doctrines militaires et leurs investissements dans les nouvelles technologies à des fins militaires, qui diffèrent largement. Cet article présente les trajectoires divergentes empruntées par ces trois grandes puissances et place la robotique militaire dans le cadre de leur compétition stratégique globale. Avec les transformations technologiques telles que l'intelligence artificielle, l'informatique quantique ou encore les essaims de drone, les forces armées du monde entier délèguent de plus en plus de tâches aux systèmes robotiques. Sur terre, dans les airs et dans l'espace maritime, les systèmes inhabités (unmanned or uncrewed vehicles) deviennent progressivement des éléments centraux de la puissance stratégique.

Schlüsselbegriffe military robotics; emerging disruptive technologies (EDTs); defence innovation; military doctrine; strategic competition
Keywords robotique militaire ; technologies émergentes disruptives ; innovation de défense ; doctrine militaire ; compétition stratégique

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Introduction

Military robotics is a core technology of modern and future warfare. Advances in the field are closely tied to evolutions in emerging and disruptive technologies (EDTs) such as artificial intelligence (AI), quantum computing, and big data, as well as breakthroughs in the civilian domain.[1] Military robots are systems that can perform automated, automatic, or autonomous actions based on algorithms.[2] In the military domain, robotics is expected to be a force multiplier, to lessen human risks and costs of armed forces, and to significantly impact strategic competition in the 21st century.[3]

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With advances in technology and decreasing production costs, military robotics is becoming more accessible to a wider range of actors.[4] In the domain of unmanned aerial vehicles (UAVs), which is military robotics' most developed area, recent findings show that 95 states currently operate UAVs, 20 of them possess armed drones and another 20 are seeking to acquire this capability.[5] The development of unmanned ground vehicles (UGVs) and unmanned maritime systems (UMSs) is also evolving rapidly. Notably for UGVs, the similarity of the technology involved to that of certain civilian industries – the automotive industry, for instance – makes the development and production of these systems easier and less costly.[6] UMSs are more difficult to design because the maritime environment remains challenging for unmanned systems.

Great powers are expected to lead the future development, deployment, and use of military robotics, notably due to their large defence budgets and research and development (R&D) technical capabilities. In addition, the revived competition between great powers has incentivised their investment in this field. The great powers' policies, doctrines, and capabilities regarding military robotics represent the basis for understanding global trends and the potential futures of military robotics. Accordingly, this article analyses and compares the developments in the United States, China, and Russia regarding their (1) defence-related innovation policies; (2) doctrinal evolutions regarding the integration of military robotics in the armed forces; and (3) investments in and the capabilities of different types of military robotics.

The United States' objective to maintain its technological lead

The US defence-related innovation policy still relies on the Cold War era "Offset Strategy", which aims at maintaining a technological advantage over competitors to ensure strategic primacy. The United States invests more intensively than any other state, with annual spending on defence innovation consistently above USD 55 billion since 1983.[7] Nevertheless, the budget of the US Department of Defense (DoD) is not entirely sufficient to sustain long-term developments, because R&D of EDTs are very costly. Collaboration between government agencies, such as the Defense Advanced Research Projects Agency (DARPA) and the Defense Innovation Unit (DIU), and access to Silicon Valley and the world's best network of private scientific institutions and universities allow the United States to continue to lead in the R&D of military robotics. Scientific progress also benefits from the liberal and market-oriented US economic system.

In terms of doctrine, the United States considers the use of military robotics as providing strategic, operational, and tactical advantages. Robotic capabilities are intended to deter competitors and reduce the involvement of personnel in the "three Ds" (dull, dangerous, and dirty) of field missions.[8] In the absence of a proper doctrine, the US Army has published a guiding document entitled *The U.S. Army Robotic and Autonomous Systems Strategy* that details four primary tactical tasks for unmanned systems: (1) increase situational awareness; (2) supply logistics to diminish the physical burden on soldiers; (3) facilitate movement and the ability to manoeuvre; and (4) protect human forces on the front lines.[9] Published in 2017, this document illustrates the US lead over its competitors in doctrinal thinking on the integration of military robotics into its armed forces.

Regarding capabilities, the US robotics arsenal remains unmatched. The US military currently operates

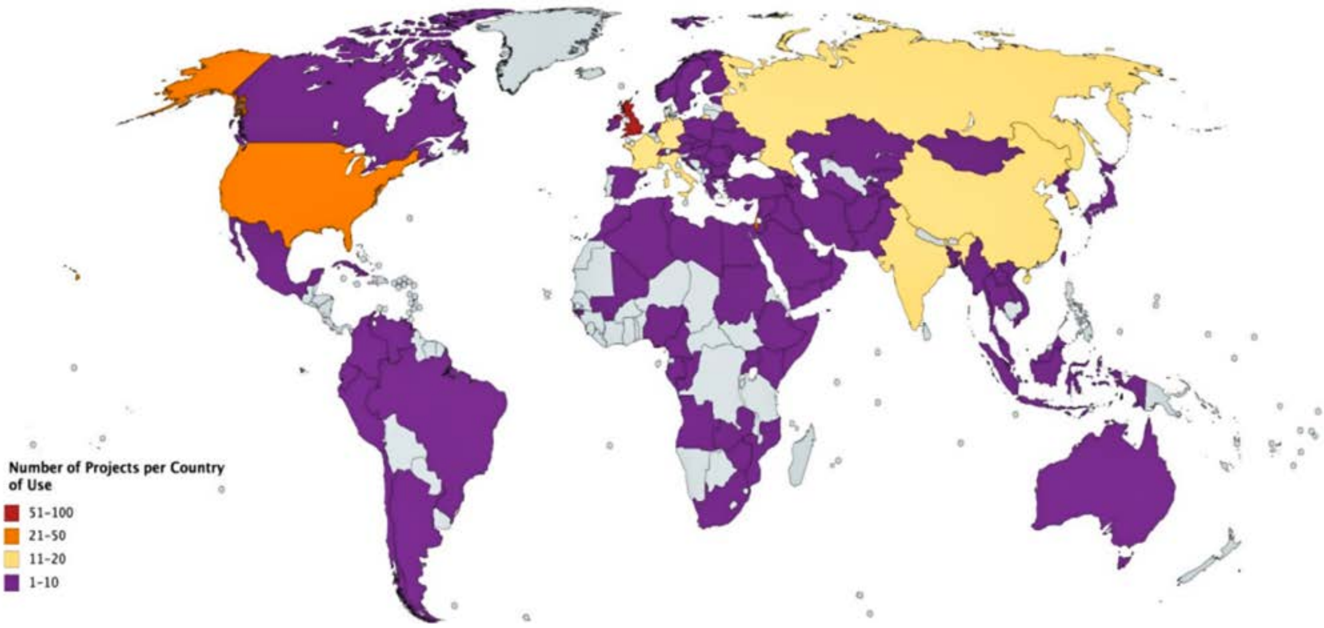

Figure 1: Number of RAS projects per country. (Source: B. Torossian et al., "The military applicability of robotic and autonomous systems", The Hague Centre for Security Studies, February 2020: 20).

26 types of UAVs, ranging from micro-drones to large unmanned stealth UAVs. The United States also benefits from decades of experience in this domain, strong institutional support, and the largest acquisition market (expected to reach USD 9.48 billion by 2025).[10] Regarding UGVs, the United States is gradually fielding more systems with a focus on manned-unmanned teaming between robots and soldiers. The Marine Corps and US Army are supplied with Milrem Robotics' THeMIS UGVs, and the overall UGV acquisition market is expected to triple by 2025 to reach USD 384.5 million.[11] The UMSs acquisition market will likely witness the most significant increase in both quality and quantity and is expected to reach USD 1.126 billion by 2025.[12] This covers the entire spectrum of naval capabilities, ranging from the man-portable Battlespace UUV to XLUUV unmanned submarines.[13] The DoD has also developed swarming technology that allows groups of drones to behave collectively, as shown by the Perdix tests in 2017.[14]

Overall, the United States' performance in defence innovation, doctrinal evolutions, and fielding of military robotics suggests that it has the ability to remain the dominant player in this field. The size of its military budget, the intensity of its dual-use and military-related R&D, and the collaboration between branches of the DoD and leading technological universities position the United States to dominate the competition in military robotics. In addition, the United States can rely on a large network of partnerships and alliances with some of the world's most economically and technologically advanced nations, such as Japan, South Korea, and NATO members. International cooperation such as the AUKUS trilateral pact between Australia, the United Kingdom, and the United States is primarily focused on sharing dual-use technologies, thereby acting as a force multiplier for the US defence innovation effort. This is a noteworthy difference from Russia and China.[15] Figure 1 shows the number of civilian and military robotics and autonomous systems (RAS) projects worldwide and highlights the dominance of the United States (together with the United Kingdom) in this domain.[16]

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Technology	Top 5 countries					Technology monopoly risk
Advanced aircraft engines (incl. hypersonics)	🇨🇳 48.49%	🇺🇸 11.69%	🇮🇳 6.96%	🇬🇧 3.93%	🇮🇷 3.60%	7/10 4.15 **medium**
Drones, swarming and collaborative robots	🇨🇳 36.07%	🇺🇸 10.30%	🇮🇹 6.13%	🇮🇳 5.15%	🇬🇧 4.53%	5/10 3.50 **medium**
Small satellites	🇺🇸 24.49%	🇨🇳 17.32%	🇮🇹 7.82%	🇩🇪 4.36%	🇬🇧 4.11%	5/10 1.41 **low**
Autonomous systems operation technology	🇨🇳 26.20%	🇺🇸 21.01%	🇬🇧 5.28%	🇩🇪 5.11%	🇰🇷 3.55%	3/10 1.25 **low**
Advanced robotics	🇨🇳 27.89%	🇺🇸 24.64%	🇬🇧 5.49%	🇮🇹 4.81%	🇰🇷 3.79%	4/10 1.13 **low**

Figure 2: Top 5 country rankings in the areas of defence, space, robotics, and transportation. (Source: J. Gaida et al., "ASPI's Critical Technology Tracker – The global race for future power", Australian Strategic Policy Institute, 2023: 17).

China's significant catch-up in innovation and military robotics

Since 2012 China has implemented a defence-related innovation policy called the Military-Civil Fusion (MCF). The MCF policy aims to foster a fusion between the country's civilian technology players and armed forces under the supervision of the Chinese Communist Party (CCP).[17] MCF has become one of China's main strategic efforts, seeking to catch up with more technologically advanced states and surpass the United States as the leading global power by 2049.[18] By reforming the Chinese Academy of Science and placing research institutes, private corporations, and defence conglomerates directly under the CCP's control, China has reached a remarkable level of sophistication in developing innovative technologies. However, experts have also highlighted that the aspiration to develop an entrepreneurial defence innovation base clashes with the CCP's desire to exercise full control over all defence-related undertakings.[19] It has also been claimed that China is still far from securing an entire supply chain of advanced electronics or semiconductors on its own.[20] Figure 2 shows the top 5 country rankings in defence, space, robotics, and transportation.[21] This highlights China's leading role in the development of emerging technologies that include robotics-related defence applications.[22]

China is also making progress in doctrine on the integration of military robotics into its armed forces. As one observer points out, this is a direct mark of the overall *"evolution of the PLA [People's Liberation Army] away from its historical preoccupation with internal security and China's continental defense to an emerging doctrine of deploying military power beyond China's shores"*.[23] Through its Forward Defence (FD) concept, China intends to apply asymmetric means of warfare to defeat a more powerful opponent off its coast.[24] In this regard, EDTs are fundamental to China's defence posture, since automation and robotisation are two components of FD. They allow the PLA to make faster and more informed decisions and deal with a wider spectrum of threats.[25] China is reportedly considering the possibility of using autonomous weapons to achieve tactical and operational advantages on the battlefield.[26] The fielding and integration of unmanned systems are also seen as a symbolic benchmark in China's quest for strategic primacy.

China is significantly investing in AI and robotic capabilities: in 2018, AI-related defence spending reached USD 2.7 billion, and the acquisition market of military robotics accounted for USD 1.44 billion in 2019.[27] China's military robotics-related development is notable in the field of UAVs. Having started by producing low-cost models copied from US drones in the 1990s, China has become a *"driving force of the horizontal and vertical proliferation of UAVs."*[28] China can now produce cutting-edge systems such as the GJ-11 that are comparable to US products. Illustrative of this success is its exports of UAVs to at least 16 states.[29] While Chinese UGVs used to not be particularly sophisticated, it has made notable progress, such as with the Sharp Claw I, which carries a light machine gun. The UGVs acquisition market is expected to grow at an average of 64% per year between 2019 and 2025, reaching USD 465.6 million.[30] Regarding UMSs, China is seeking to challenge the United States' maritime dominance with un-

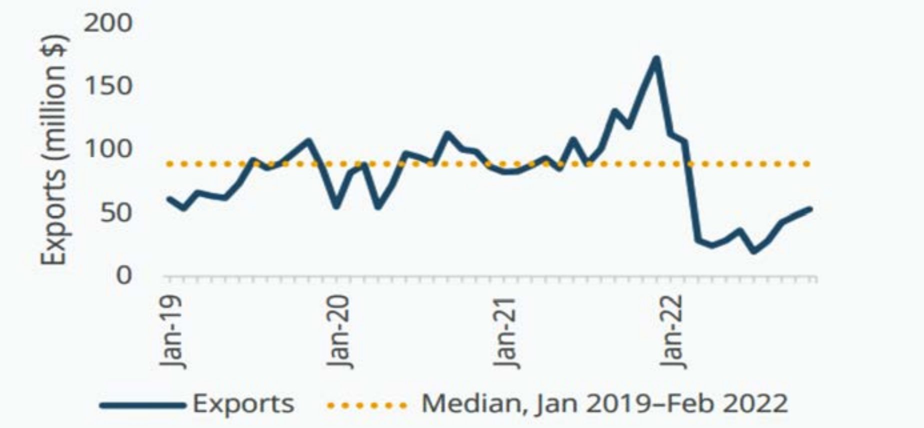

Figure 3: Integrated circuit exports to Russia, by value, Jan. 2019-Nov. 2022. (Source: D. Andrew et al., "Russia shifting import sources amid U.S. and Allied export restrictions – China feeding Russia's technology demands", Washington International Trade Association, January 2023: 13).

manned systems such as the HS001.[31] The Chinese UMS acquisition market is expected to grow sevenfold to reach USD 800 million by 2025.[32]

Overall, China has become a leader in developing EDTs, surpassing the United States in certain key dual-use technologies such as collaborative robots and hypersonic vehicles.[33] China's technological progress over the last few years has indeed been remarkable. Yet the slow reform of the country's economic system, cumbersome bureaucracy, and demographic and economic challenges may pose certain limits in the foreseeable future.[34] In the context of defence innovation, China is struggling to outperform Western systems and to form independent supply chains for key technologies. China's catch-up is thus evident and substantial, notably considering the significant expected growth of its acquisition market. But it is unclear whether China will have the capacity to surpass the United States in the field of military robotics.

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Russia's struggle to remain in the technology competition

Russia revised its defence-related innovation policy in the past decade. This included the creation of the Advanced Research Foundation (ARF), an institution similar to the US DARPA.[35] In 2008 Russia also founded the Technopolis Era complex in Anapa, a sort of "military Silicon Valley", to develop and test EDTs. The establishment of Technopolis Era illustrates the Russian government's effort to *"develop an extensive – and still growing – defense R&D network of collaborating platforms, involving the armed forces and civilian state and private actors"*.[36] So far, these initiatives do not seem to have been successful, largely due to Russia's poor innovation performance and the small size of the ARF budget. Russia ranks 45th on the Global Innovation Index and it is not a leader in AI and other EDTs.[37] Moreover, with the ARF's budget of USD 63 million per year, Russia's investments are far below those of the United States and China.[38] Russia's defence industry is also overly dependent on foreign-made electronics and semiconductors, since domestic production capacity in this area is practically non-existent. Problems have been exacerbated by Western sanctions against Russia following its invasion of Ukraine in 2022. Figure 3 shows the variation in semiconductor exports to Russia since January 2019.[39]

At the doctrinal level, most observers thought that a reformed Russian military under the New Generation Warfare (NGW) paradigm would enable Russia to conduct modern joint and hybrid warfare, including the use of military robotics.[40] One objective of this paradigm was notably to replace approximately 30% of human forces with robots.[41] Similarly, Russia's 2019 Active Defence (AD) operational concept relies on the logic of pre-emptively neutralising an enemy that seeks to attack the country, including through the extensive use of EDTs.[42] Russia continues to seek to replace certain human tasks in its armed forces with robots, and reportedly seeks to allocate them direct combat tasks. It has invested in the development of humanoid robots, such as FEDOR, that would be able to carry weapons and perform basic infantry tasks.[43] Yet it appears that Russia has not integrated robotic systems into its armed forces doctrines to the extent that most experts thought before the Russian-Ukrainian war. This indicates that Russia lags behind the United States and China in this area.

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Russia has invested heavily in R&D and the integration of robotic systems over recent years. UAVs have been integrated at almost every military level and are increasingly used. Russia has focused its efforts on tactical drones that are inexpensive to produce, such as the S-70 Okhotnik or the Grom. The UAV acquisition market is expected to reach USD 1 billion in 2025.[44] Given its historical orientation as a land power, Russia is investing significant efforts in the development of UGVs. The UGV acquisition market is expected to grow from USD 90 million in 2019 to USD 300 million in 2025.[45] The Russian armed forces have reportedly used various types of UGVs during their operations in Syria and Ukraine, thereby gaining battlefield experience. However, most of these systems, such as the Uran-9, have not performed well.[46] Russia has not prioritised the development of UMSs, mainly because it lacks the technical expertise and funding. Aside from Poseidon – a nuclear-powered and nuclear-capable system reportedly under development – Russian UMSs are unlikely to perform at the level of those of the United States or China.[47] The Russian UMSs acquisition market is expected to reach USD 81.8 million by 2025.[48]

Overall, Russia was struggling to develop EDTs even before the war with Ukraine in 2022. This included unsuccessful reforms of its defence-related innovation policy and investments in robotics and performance levels far below those of the United States and China.[49] Western sanctions on most industrial products and technologies have reduced Russia's ability to develop and produce military robotics. The country's blacklisting by integrated circuit industry leaders, such as the Taiwan Semiconductor Manufacturing Company and Intel, and China's refusal to supply it with advanced technologies are significant constraints.[50] Yet Russia may still be able to acquire sensitive Western-made advanced technologies through countries such as Belarus, Turkey, and China, albeit at a much lower rate and at higher costs. Moreover, while Russia's doctrinal development under the NGW paradigm seemed to have improved its military capabilities, the performance of its armed forces in Ukraine suggests otherwise. Indeed, it appears that 20th-century military doctrinal concepts remain predominant.[51]

Conclusion

The three major military powers – the United States, China, and (to a lesser extent) Russia – are leading the way in the strategic competition to develop military robotics. Three indicators can be used to assess and compare the advances they have made in this field.

Regarding defence-related innovation, the United States is in the lead. It can exploit the benefits of its comparative advantages, such as its large military budget, Silicon Valley's link to military technology development, and its strong network of academic and research institutions. Yet China is catching up with its Military-Civil Fusion policy and is closing the gap with the United States in terms of innovation capacity. China is already leading in some key areas. Russia's inability to coherently reform its defence innovation system and the limited funding it invests in innovation mean that it will struggle to remain competitive.

The analysis of doctrines shows that all three states aim at increasingly delegating military tasks to robotic systems. The United States and China are at the forefront of the conceptual development of their plans to integrate military robotics into their armed forces. More specifically, these two countries have made significant progress in thinking about when and how to use unmanned vehicles for military applications, whereas Russia has not been able to do so, as suggested by the minimal appearance of robotic systems in the war against Ukraine.[52]

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In terms of capabilities, the scale of the US investment in military robotics remains unmatched. It is also the only state developing and procuring the full spectrum of air, land, and sea capabilities. China's developments have been considerable over the past decade, and it is conceivable that it will challenge US military dominance in several fields. Russia's spending on military robotic systems is only a fraction of those of the United States and China, although it has advanced in the area of UGVs. In the future, Russia will likely be able to compete in some niche markets, such as low-tech tactical drones, but overall it will most likely continue to lag behind the two other major military powers.

Ultimately, a comparison of these countries across the three indicators reveals that the United States is likely to remain the leading power in the development and fielding of military robotics, while China is becoming a serious competitor. Russia is practically out of the high-level competition for the near future, notably following the defence-related and economic consequences of its war with Ukraine. Therefore, the great power competition in military robotics has become a binary one between the United States and China.

Regional powers will also compete in certain segments, however. Technologically advanced states, such as Israel, the United Kingdom, Australia, and members of the European Union, are increasing their R&D projects in military robotics (see Figure 1). As such, it can be expected that in the future the two major powers – the United States and China – will dominate the field of military robotics, while medium and small powers may lead in certain niche sub-fields. ◆

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