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ARTICLE

Defence innovation and the 4th industrial revolution in Russia

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ABSTRACT

Russia is pursuing select 4th Industrial Revolution (4IR) technologies in a drive to rapidly close the capability gaps with rivals. The transformation of warfare these technologies portend could also make Russia more vulnerable. Joining the 'technological race' seems therefore less of a choice than an existential necessity. Constrained by structural problems and lacking the resources of the US and China, however, Russia has so far struggled to leverage its ambitions within the 4IR. Yet it has also shown the ability to experiment with 4IR technologies, including hypersonics and AI, to amplify existing symmetric and asymmetric capabilities, and create interconnected systems that may provide critical advantages.

KEYWORDS Russia; defence innovation; emerging technologies; hypersonics; military strategy; artificial intelligence

Introduction

Ahead of the vote in the Russian parliament in July 2012 on a new agency that would be tasked with pursuing breakthrough technologies, Deputy Prime Minister Dmitrii Rogozin said that 'After 20 years of stagnation it will be hard [for Russia] to catch up with the West's weapons development the ordinary way,' given the long post-Cold War inertia and decay in the defence sector.[1] Breakthrough technologies, conversely, could not only narrow the defence gap but potentially provide Russia with much-needed critical advantages in a relatively short period of time. Therefore, Rogozin argued, Russia had to establish 'a radical organisation' to aggressively pursue risky innovation projects in the most promising areas. The result, later that year, was the creation of the Advanced Research Foundation (*Fond perspektivnykh issledovanii* – FPI), which was intended to become

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[1]Rogozin quoted in 'Predator on the prowl: Multi-billion DARPA rival set up in Russia', *RT*, 5 July 2012, https://www.rt.com/news/darpa-rogozin-army-future-technologies-529/.

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a 'real predator'[2] in the effort to place Russia among global leaders in new technologies.

In addition to the expected rapid modernisation of the defence sector, Russia's intent to push forward the development of breakthrough military technologies has been driven by another central factor of defence innovation, as identified by Stephen Rosen,[3] that is its potential ability to change the character of future warfare. The reasoning is well embedded in Soviet strategic thinking about the 'military-technical revolution' and the impact of new technologies on a fundamental discontinuity in the character of warfare.[4] Likewise, contemporary Russian authorities are concerned that new, possibly disruptive technologies may alter the ways and means of achieving victory, potentially in radical ways, thus generating vulnerabilities that Russia's enemies could take advantage of.[5] Leaving the development of such technologies to adversaries threatens therefore to further widen the asymmetry of power between Russia and its perceived adversaries. This in turn could undermine strategic balance, the maintenance of which has been given top priority in Russia's foreign and defence policy in the post-Cold War era.[6] Seen from Moscow, joining the 'technological race' seems therefore less a choice than an existential inevitability. As President Putin put it bluntly: 'Those who manage to ride this technological wave will surge far ahead. Those who fail to do this will be submerged and drown.'[7]

Furthermore, the Russian government has consistently expressed an expectation that innovation in the defence sector and the massive defence acquisition programmes could generate a wave of progress that would lift not only the Russian armed forces, but also the economy by driving a nationwide technological innovation.[8] Innovation centres that Russia has been setting up are to become generators of ideas and dual-use technologies intended to fuel economic growth by creating new jobs and high-tech products to be commercialised for both domestic and foreign markets.[9] Indeed, in September 2016, Putin ordered the domestic defence industry to increase its share of civilian and dual-

[2]Federal'nii zakon ot 16 oktyabrya 2012 g. N 174-FZ 'O Fonde perspektivnykh issledovanii', *Rossiiskaya gazeta*, 19 October 2012, https://rg.ru/2012/10/19/fond-dok.html; 'Predator on the prowl'.

[3]Stephen Rosen, *Winning the Next War. Innovation and the Modern Military* (London: Cornell University Press, 1991), 18–21.

[4]Dima Adamsky, 'Through the Looking Glass: The Soviet Military-Technical Revolution and the American Revolution in Military Affairs', *Journal of Strategic Studies*, 31/2 (2008), 257–294; Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel* (Palo Alto, CA: Stanford University Press, 2010).

[5]'Shoigu prizval voennykh i grazhdanskikh uchionykh ob'edinit'sya dlya raboty nad iskusstvennym intellektom', *Voennoe obozrenie*, 14 March 2018, https://topwar.ru/137827-shoygu-prizval-voennyh-i-grazhdanskih-uchenyh-obedinitsya-dlya-raboty-nad-iskusstvennym-intellektom.html.

[6]Ivan Cheberko, 'Pochemu v Rossii ne poluchilsya analog DARPA', *RBK Daily*, 12 April 2018.

[7]Vladimir Putin, *Poslanie Prezidenta Federal'nomu Sobraniyu*, President of Russia, Moscow, 1 March 2018, http://kremlin.ru/events/president/news/56957.

[8]Interview with Dmitrii Rogozin, *Life.ru*, 30 January 2018.

[9]Vladimir Putin, *Poslanie Prezidenta Federal'nomu Sobraniyu*, President of Russia, Moscow, 12 December 2013, http://kremlin.ru/events/president/news/19825; Vladimir Putin, *Poslanie Prezidenta Federal'nomu Sobraniyu*, President of Russia, Moscow, 12 December 2012, http://kremlin.ru/events/president/news/17118.

purpose products from 16.8% to 30% by 2025, and up to 50% by 2030.[10] The development of breakthrough technologies is therefore seen not only as critically important to national security, but also to Russia's economic future and international standing at large.

Consequently, and since 2010 in particular, Russia has systematically increased its focus on new and potentially disruptive technologies in all major 4IR fields, including artificial intelligence (AI) and quantum computing, big data, automated decision-making, and human-machine hybrid intelligence as well as autonomous and AI-enabled unmanned systems, intelligent robotics, hypersonics, additive technology, and so-called 'weapons based on new physical principles' (*oruzhie na novykh fizicheskikh printsipakh*),[11] i.e. directed energy, radiological, genetic, electromagnetic and geophysical weapons – to name a few examples. While the effort is expected to produce new types of weapon systems, the new technologies are also being applied to strengthen the traditional pillars of Russian defence, deterrence and coercive options. i.e. nuclear capabilities, non-nuclear strategic weapons and general purpose forces, as well as asymmetric non-military methods and means.

This development has potentially far-reaching implications for the Russian armed forces and the country's international standing. Yet, Russia's pursuit of 4IR technologies has received fairly limited scholarly attention, with some notable exceptions.[12] There remains a lacuna of scholarly analysis of Russian 4IR development programmes at large, not least in the context of their military-strategic and operational implications.

This analysis aims to help fill the knowledge gap by raising and answering the following research questions: (1) what strategies does Russia apply to pursue breakthrough technologies and stimulate defence innovation, and to what extent does the research into and development of 4IR technologies have an impact on Russia's traditional state-driven, top-down innovation model; (2) to what extent do emerging technologies amplify Russian symmetric and asymmetric warfare capabilities; and (3) how do they impact Russia's position in and the key ramifications of the ongoing strategic competition?

[10]Denis Zhurenkov, Anton Savel'ev, 'Gosudarstvenno-chastnoe partnerstvo v nauchnoi sfere', *Oboronno-promyshlennyi kompleks*, No.1 (33) 2018.

[11]'Oruzhie na novykh fizicheskikh printsipakh', *Military Encyclopaedic Dictionary*, The Ministry of Defence of the Russian Federation, http://encyclopedia.mil.ru/encyclopedia/dictionary/details_rvsn.htm?id=13770@morfDictionary; 'Piervyi Voennyi innograd', Era technopolis, https://www.era-tehnopolis.ru/.

[12]See in particular excellent work done by Samuel Bendett (CNA) published in *Defense One, National Interest* and other outlets, e.g. 'Putin Seeks to Plug Gaps in Russia's State-Driven Tech Efforts', *Defense One*, 18 January 2020, https://www.defenseone.com/technology/2020/01/putin-calls-more-hi-tech-breakthroughs/162496/; Vasily Kashin, 'Russian perspectives on the Third Offset strategy and its implications for Russian-Chinese Defence technological cooperation', in Tai Ming Cheung and Thomas Mahnken (eds) *The Gathering Pacific Storm. Emerging US-China Strategic Competition in Defence Technological and Industrial Development*, (Amherst, New York: Cambria Press, 2018), 211–238; Keith Dear, 'Will Russia Rule the World Through AI? Assessing Putin's Rhetoric Against Russia's Reality', *The RUSI Journal*, Volume 164, 2019, Issue 5–6, 36–60.

This paper argues that despite grand ambitions, new initiatives, and modifications of the traditional defence innovation model to incorporate civilian and private-sector innovation, Russia struggles to leverage 4IR technologies due to structural and circumstantial constraints and a lack of resources relative to near-peer competitors, the US and China. Still, although an unlikely global 4IR leader, Russia has shown the ability to experiment with and exploit 4IR technologies that are being incrementally added to amplify symmetric responses and asymmetric capabilities, for instance hypersonic weapons and AI in grey-zone operations, respectively. The interconnected systems may in the future provide Russia a critical advantage on the battlefield, provided it finds the right relationship between technology and hardware on the one hand, and concepts, doctrine, and organisations on the other.

The paper is organised in two main parts. The first examines the Russian defence innovation model and strategies applied to foster innovation, including attempts to combine the traditional Russian state-dominated approach with progress being made in the civilian and private sectors, where many of the sought-after 4IR technologies are developed. The second part analyses a) the main effects of Russian defence innovation on the ongoing strategic competition, and b) selected examples of Russian 4IR technologies with their expected strategic and battlefield advantage: hypersonics (representing a continuation of missile development technology at which Russia has traditionally excelled), and the country's novel AI technology.

This study is based on primary sources, such as Russian government documents and materials, published interviews with Russian civilian officials and military brass, and discussions presented in military and civilian journals and newspapers, both government-affiliated and independent, as well as other media outlets that shed light on the context and the nature of defence innovation in Russia. The challenge of studying defence development in Russia in general, and the development of breakthrough military technologies in particular, is sensitivity of the topic. Many projects in the planning, development, and experimentation phase remain highly classified and are kept out of public view. Occasional leaks provide some information about the direction of development, the interest level of Russian authorities, and the possible impact of defence innovation on Russian military strategy and warfare. Some programmes presented by the Russian authorities are designed to produce a particular signal effect, though the reality in such cases does not always match the overambitious rhetoric that is employed. To overcome the limitations inherent in open-source research, this article aims to base its assertions on a critical assessment of a variety of unrelated sources from within and outside the government. Unless otherwise stated, all translations from Russian to English are by the author.

The Russian 4IR defence innovation model

Theo Farrell and Terry Terriff have identified three key drivers of military change: pressure from the senior leadership that could induce changes in culture; emulation of other professional militaries; and an external shock.[13] While in the case of Russia the latter is less evident, there is little doubt that the Russian state's top political and military leadership has been a key driver behind the effort to accelerate the development of 4IR technologies.

The trend has been strengthened under the rule of Vladimir Putin, with the expansion of the state and centralisation of many Russian industries and companies (e.g. United Shipbuilding Corporation, United Aircraft Corporation) causing the public sector's share of the economy to reach approximately 70%. As all central schools of military innovation argue, military organisations, being extensive bureaucracies, are not only tough to change but are designed not to change and therefore have to be strong-armed to accept change and innovation[14] – a dynamic evident in the Russian approach. Furthermore, Russian emulation of innovation processes adopted by other militaries is also evident, not only in the priorities identified, but in the very innovation model Russia seeks to adapt to its own environment.

Strategies

The basic Russian innovation model for developing breakthrough technologies consists of creating state-driven 'radical innovation centres' or 'technoparks' (also called technopolises, futuropolises, or innopolises) aimed at fostering conditions seen as necessary to enable innovation. Russia has established several such centres in the civilian and defence sectors since 2011. In order to draw on breakthrough technologies being developed also in the civilian and private sectors, the Russian government creates military-civilian collaborative platforms to maximise the generation and exchange of ideas and expertise, and to increase the state's access to talent. As the Russian authorities argue, the foundation for Russia's potential to become one of the global leaders in the development and use of AI[15] is based on its strong intellectual tradition and high level of education in science, technology, engineering and mathematics (STEM) across the population – strengths broadly considered to be conducive to high-tech development.[16]

The use of emulation processes, i.e. imitating the methods and means of warfare[17]and the innovation paths taken by other militaries, is another

[13]Theo G. Farrell and Terry Terriff, *The Sources of Military Change: Culture, Politics, Technology* (Boulder, CO: Lynne Rienner, 2002).
[14]Adam Grissom, 'The future of military innovation studies', *Journal of Strategic Studies* (2006) 29:5, 919; Rosen, *Winning the Next War*.
[15]Ukaz Prezidenta Rossiiskoi Federatsii ot 10.10.2019 g. № 490: O razvitii iskusstvennogo intellekta v Rossiiskoi Federatsii, President of Russia, http://www.kremlin.ru/acts/bank/44731.
[16]Ukaz Prezidenta Rossiiskoi Federatsii ot 10.10.2019 g.
[17]Farrell and Terriff, *The Sources of Military* Change, 5.

important feature of Russian defence innovation. One of the flagship innovation centres, the Advances Research Foundation (FPI),[18] has been broadly compared in Russia, including by then President Dmitrii Medvedev, to the US DARPA,[19] and preceded by the Skolkovo Innovation Centre referred to as the Russian Silicon Valley.[20] The stated purpose of the FPI is to pursue R&D of cutting-edge technologies, primarily for the needs of the defence sector.[21] While it is too early to make a conclusive assessment of the FPI's performance, its record of achievement is mixed.

The establishment of the FPI did not immediately lead to new ideas. Some of the FPI's most widely publicised projects were in fact developed by others earlier, including the Fedor robot (developed by the Russian State Corporation for Space Activities – Roskosmos); liquid breathing technology (experimented with in the Soviet Union since the 1980s); and robots for energy resource exploration on the continental shelf (developed by the Rubin Central Design Bureau for Marine Engineering). However, the programmes pursued by the FPI have gradually expanded. In addition to AI, unmanned autonomous systems and automated decision-making, researchers are working on quantum computing and technology for processing information based on superconducting qubits ('Liman'), 3D printing of polymetallic products ('Matrix'), and additive technology in the aircraft industry ('Tantal'). FPI R&D programmes also focus on a means of monitoring near-earth space ('Horizon'), a detonation ramjet/engine for high-speed aircraft, a reusable rocket, a means of individual camouflage and protection ('Tavloga'), intelligent robotics, and exoskeletons. The scope and developmental stage of these programmes vary significantly. The Marker unmanned ground combat vehicle (UGV),[22] which among other functions is set to combine the ability of autonomous navigation with interaction with other unnamed systems, has been under development since March 2018 and has already been tested in a range of conditions, including in 2020.[23]

While the FPI pursues civilian and dual-use programmes, in 2018 Russia created a 'military Skolkovo': an innovation technopolis called Era that explicitly seeks to develop technology for the Russian armed forces.[24] According

[18]Fond perspektivnykh issledovanii, https://fpi.gov.ru.
[19]'Medvedev rasschityvaet, chto fond proryvnykh issledovanii ispol'zuet opyt DARPA', homepage of the United Russia party, 1 October 2012, https://er.ru/news/91312/.
[20]Interview with Andrei Grigorev in *Natsional'naya oborona*, No. 6, 2020, https://oborona.ru/includes/periodics/maintheme/2015/0126/164814981/detail.shtml.
[21]Ibid.; FPI, https://fpi.gov.ru.
[22]FPI Projects, https://fpi.gov.ru/projects/; see also 'FPI ne sostyazaetsya s amerikanskim DARPA, zayavil zamgendirektora', *Ria novosti*, 5 February 2020; FPI, https://fpi.gov.ru; 'V Rossii nachalis' raboty po sozdaniyu pervoi mnogorazovoi rakety', *Ria novosti*, 28 February 2020; 'FPI: Rossiya mozhet voiti v pyaterku liderov po kvantovym vychisleniyam', *Ria novosi*, 29 November 2019.
[23]'Kak chelovek: v Rossii ispytyvayut boevogo robota', *Gazeta.ru*, 29 June 2020, https://www.gazeta.ru/army/2020/06/29/13135063.shtml.
[24]Ukaz Prezidenta Rossiiskoi Federatsii ot 25.06.2018 g. № 364: O sozdanii Voennogo innovatsionnogo tekhnopolisa 'Yera' Ministerstva oborony Rossiiskoi Federatsii, President of Russia, 25 June 2018, http://

to the Russian MoD, Era was created to reduce the time from scientific discovery to implementation in the form of military weapons and equipment as well as to provide advanced training of personnel for defence industry enterprises and military research institutes.[25]

Era is to become 'a base for the development and pioneering of a model of the interaction of scientific, educational, and industrial organisations', with an objective of assembling some 2,000 military scientists.[26] Its priority R&D fields include AI, small spacecraft, robotics, automated control and IT systems, computer science and computer engineering, pattern recognition, information security, hydrometeorological (meteorological) and geophysical support, energy sufficiency, nanotechnology, and bioengineering. Other priorities are weapons based on new physical principles, meaning electromagnetic, radiological, genetic, geophysical and directed energy weapons such as the Peresvet land-based mobile combat laser system, which some believe may be used for air and missile defence.[27]

Officially, the weapon system has been on combat duty in five missile divisions of the Strategic Missile Forces since December 2019, though it is being further developed to enhance its qualities and strength.[28] Russia is also working on completing the design and development of other directed energy systems, such as tactical laser weapons for destroying unmanned aerial vehicles (UAVs) and lightly protected surface targets.[29] Other laser systems are already in use to protect airborne defence systems of Russia's strategic, tactical and army aviation forces from ground-to-air and air-to-air missiles with optical homing heads.[30]

The Era technopolis model is a combination of laboratories, engineering centres, and 'open spaces' equipped with the most advanced equipment specifically designed for promising military scholars and members of

kremlin.ru/acts/bank/43213; 'Strel'bovye ispytaniya boevogo robota "Marker" proidut v 2020 godu', *Voenno-promyshlennyi kurer*, 21 November 2019; Zhurenkov, Savel'ev, 'Gosudarstvenno-chastnoe partnerstvo v nauchnoi sfere'.

[25]'Voennyi innovatsionnyi tekhnopolis "Yera"', Ministry of Defence of the Russian Federation, 5 March 2020, http://mil.ru/era/about.htm; Inna Sidorkova, 'Voennoe "Skolkovo": zachem Shoigu stroit tekhnopolis v Anape', *RBC News*, 13 March 2018, https://www.rbc.ru/politics/13/03/2018/5a9e82869a7947860d0516ca.

[26]*Vladimir Putin posetil Voenno-innovatsionnyi tekhnopark YeRA*, President of Russia, 22 November 2018, http://kremlin.ru/events/president/news/59179.

[27]While its missions are shrouded in secrecy, the Russian MoD describe its task as providing cover for operations of the Russian mobile ground missile systems. 'Prezident RF: Boevyye lazery uzhe postupayut na vooruzhenie voisk', *Rossiiskaya gazeta*, 1 March 2018; 'Piervyi Voennyi innograd'; *Vladimir Putin posetil Voenno-innovatsionnyi tekhnopark*.

[28]'Verkhovnyi Glavnokomanduyushchii Vooruzhennymi Silami Rossii Vladimir Putin prinyal uchastie v rasshirennom zasedanii Kollegii Minoborony', Russian Ministry of Defence, 24 December 2019, https://function.mil.ru/news_page/country/more.htm?id=12268217@egNews; 'Nachal'nik General'nogo shtaba Vooruzhennykh Sil Rossiiskoi Federatsii general armii Valerii Gerasimov vstretilsya s predstavitelyami Voenno-diplomaticheskogo korpusa, akkreditovannymi v Rossii', Russian Ministry of Defence, 18 December 2019, https://function.mil.ru/news_page/country/more.htm?id=12267331@egNews; 'Vooruzhennye sily Rossiiskoi Federatsii osnashchayutsya innovatsionnymi vidami oruzhiya osnovannymi na novykh fizicheskikh printsipakh', Ministry of Defence of the Russian Federation, 8 January 2020, https://function.mil.ru/news_page/country/more.htm?id=12270004@egNews.

[29]'Vooruzhennye sily Rossiiskoi Federatsii osnashchayutsya innovatsionnymi vidami'.

[30]Ibid.

academia.[31] The objective is to create a strong link between theory and practice in order to integrate all stages of the product generation cycle: from idea to limited-scale testing.[32] Hence, according to Deputy Defence Minister General Pavel Popov, representatives of Russia's top arms manufacturers, including branches of major corporations such as Kalashnikov and Sukhoi, will co-locate with private companies and research teams.[33] Era partners, for instance, with a range of military and civilian actors, including the Sozvezdie concern, which is the leading developer and manufacturer of electronic warfare, communication and electronic countermeasures systems and equipment, and the renowned Kurchatov Institute, the largest interdisciplinary laboratory in Russia. It hosts a substantial share of Russia's nuclear physics facilities and pursues cutting-edge technologies such as nanotechnology, biotechnology, IT, cognitive technology, next-generation nuclear power systems, plasma physics and tokamaks, as well as information and communication technologies and systems.[34] According to official data, 257 organisations cooperate with the Era technopolis, 80% of which are enterprises of the Russian military-industrial complex, while 18% are scientific institutions and two per cent are non-profit organisations.[35]

'Science cities' with a high concentration of scientists and an R&D infrastructure are not a new phenomenon in Russia. In the Soviet Union, such *'naukograd'* were numerous and some have survived to the present day. However, the current model, while building on that experience, introduces a novel element: cooperation of the state military and civilian branches with the private sector. Traditionally, military research communities have been separate from the business sector. This relatively new development appears in part to emulate the US model of public-private and business-academic research as well as government/military-private sector cooperation, while maintaining state control.[36] Other experts discern possible inspiration from the Chinese model of innovation, with science and technology parks linked to the campuses of large military universities.[37]

Russia has applied a similar innovation model to create the intellectual and physical infrastructure needed to facilitate development of 'the crown jewel' of 4IR technology: artificial intelligence. In addition to the AI-focused R&D taking place at the FPI and Era (which has been tasked with developing 'smart weaponry' equipped with AI systems),[38] Russia also aims to exploit AI developed in the

[31]'Voennyi innovatsionnyi tekhnopolis 'Yera' sozdan v sootvetstvii s Ukazom Prezidenta Rossiiskii Federatsii ot 25 iyunya 2018 g. № 364', Russian Ministry of Defence, http://mil.ru/era/about.htm.
[32]Ibid.
[33]'Sovet po razvitiyu Voennogo tekhnopolisa "YeRA" obsudil proekt strategii, predlozhennyi Kurchatovskim institutom', Russian Ministry of Defence, 25 May 2019, https://function.mil.ru/news_page/organizations/more.htm?id=12232894@egNews.
[34]The partners of Era, https://www.era-tehnopolis.ru/partners/.
[35]'Voennyi innovatsionnyi tekhnopolis "Yera"'.
[36]Poslanie Prezidenta Federal'nomu Sobraniyu, 2018.
[37]Dear, 'Will Russia Rule the World Through AI?'; Sidorkova, 'Voennoe "Skolkovo"'.
[38]'Oruzhie razuma: rossiiskii put' k Voennomu iskusstvennomu intellektu', *Izvestiya*, 22 November 2018.

civilian sector. Indeed, several private Russian AI developers have received a degree of international recognition, including VisionLabs: founded in 2012 and located at the Skolkovo Innovation Centre, it specialises in facial recognition for banking and retail.[39] The FaceN algorithm, focused on neural networks and developed by NTechLab, won first place in a 2015 world championship for facial recognition technologies.[40] Another example is the Neural Networks and Deep Learning Lab at the Moscow Institute of Physics and Technology, which was selected to compete in the Amazon Alexa Prize 'Socialbot Grand Challenge' in 2019.[41]

Hence, the Russian authorities are creating public-private consortiums to facilitate collaboration between the private high-technology sector and civilian academic institutions on the one hand and military and security institutions on the other.[42] Participants include AI labs at Russia's leading universities, such as Moscow State University, the Higher School of Economics, the Russian Academy of Sciences, the iPavlov Conversational Intelligence and Dialog Agents project, the above-mentioned Moscow Neural Networks and Deep Learning Lab,[43] the National Centre for Cognitive Technologies at the Information Technologies, Mechanics and Optics University in Saint Petersburg.[44] The National Research Nuclear University has been working on an AI programme called Virtual Actor, developed to be capable of situational and emotional intelligence and of adapting to human psychology, behaviour and emotions.[45]

The Russian MoD has shown an interest in developing both theoretical AI research and AI implementation as well as war games with a broad spectrum of scenarios to determine the impact of AI models on the changing character of warfare at the tactical, operational and strategic level.[46] One expression of the state's focus on AI development is the 'National Strategy for the Development of Artificial Intelligence for the period until 2030'.[47] Signed by President Putin in October 2019, the strategy announces key objectives in investment, R&D,

[39]'VisionLabs unveils Russia's first smart home face recognition system', *Skolkovo News*, 5 April 2018, https://sk.ru/news/b/news/archive/2018/04/05/visionlabs-unveils-russia_1920_s-first-smart-home-face-recognition-system.aspx.

[40]'Russian Startup N-Tech.Lab Upstaged Google in Face Recognition', *Prnewswire*, 16 December 2015, https://www.prnewswire.com/news-releases/russian-startup-n-techlab-upstaged-google-in-face-recognition-562635061.html.

[41]'Dream Team', the Neural Networks and Deep Learning Lab at Moscow Institute of Physics and Technology, http://deeppavlov.ai/dream_alexa.

[42]'Shoigu prizval Voennykh i grazhdanskikh uchenykh sovmestno razrabatyvat' robotov i bespilotniki', Russian MoD, 14 March 2018, https://tass.ru/armiya-i-opk/5028777.

[43]'Dialogs with conversational AI', iPavlov project's home page, https://ipavlov.ai.

[44]'AI Is for Active Involvement … of Russian Students in Artificial Intelligence Research', *Russian Academic Excellence Project*, Ministry of Science and Higher Education of the Russian Federation, 20 December 2019, https://5top100.ru/en/news/115622/?sphrase_id=16842.

[45]'Kak razvivaetsya iskusstvennyi intellekt v Rossii', *Agit Polk*, 18 December 2018, https://agitpolk.ru/3918-kak-razvivaetsya-iskusstvennyj-intellekt-v-rossii/.

[46]'Konferentsiya "Iskusstvennyi intellekt: problemy i puti ikh resheniya – 2018"', Russian Ministry of Defence, 14–15 March 2018, http://mil.ru/conferences/is-intellekt.htm.

[47]Ukaz Prezidenta Rossiiskoi Federatsii ot 10.10.2019.

education and training, and seeks to improve the coherence of the state's approach to implementing AI programmes across a range of sectors.[48]

To satisfy the growing need for AI specialists and foster conditions needed to attract talented youth, Russia is testing various strategies to train and retain new generations of specialists.[49] A large number of higher education institutions offer not only professional AI training but also participation in actual development projects commissioned by the universities' corporate partners, including Gazprom Neft, MTS (a telecoms operator) and Sberbank (a banking and finance giant), Russian Railways, Rosseti (a power grid operator), the Skolkovo Institute of Science and Technology, and others.[50] Another example of this trend is a cooperation agreement signed by the FPI and the Russian Ministry of Science and Higher Education aimed at facilitating the creation of new scientific schools and centres of competence focused on breakthrough R&D.[51]

Limitations

While in most cases the development of Russian 4IR technologies is relatively new and still a work in progress, several aspects of Russian defence innovation strategies may constrain further advancement. These include a preference for domestic rather than foreign supply chains; a low level of innovation across the economy; insufficient and unpredictable project funding; long-standing structural problems in the defence industry; and worrying trends in the educational base. The Russian economic model as a whole and spill-over effects from the country's foreign policies generate additional impediments.

As Russia was entering its rapid period of sweeping modernisation in the early 2000s, former Defence Minister Anatolii Serdyukov and former Chief of the General Staff Nikolai Makarov (both 2007–12) attempted to offset some of Russia's technological backwardness by purchasing selected capabilities abroad, such as Israeli drones, Italian infantry vehicles and small arms, German combat training centres for brigades and smaller units, and French Mistral amphibious assault ships.[52] The purchases were important not only to rapidly provide capabilities that were lacking, but to partake in the latest Western technological achievements in ways that would expedite the modernisation of Russia's domestic defence industry, thus saving years of home-grown development.[53]

[48]Ibid.
[49]'AI Is for Active Involvement . . . '; 'Konferentsiya "Iskusstvennyi intellekt'.
[50]Ibid.
[51]'Minobrnauki i FPI podpisali soglashenie o sotrudnichestve po proryvnym razrabotkam', *Tass*, 9 July 2019, https://nauka.tass.ru/nauka/6645611.
[52]Katarzyna Zysk, 'Managing Military Change in Russia', in J. I. Bekkevold, I. Bowers, M. Raska (eds), *Security, Strategy and Military Change in the 21st Century: Cross-Regional Perspectives* (London: Routledge, 2015).
[53]Interview with Vladimir Vysotskii, *Moscow Defence Brief*, 2010/1; see also the same topic discussed in *RIA Novosti*, 31 July 2011.

This policy, however, was largely reversed in 2013 when the new military leadership, including Defence Minister Shoigu and Chief of the General Staff Valerii Gerasimov promised to favour domestic production over foreign manufacturers. Apart from pressure from the defence industry lobby, the move was driven by the concern that Russia could become excessively dependent on advanced foreign technology.[54] To accelerate modernisation of the defence industry, the government has assisted with such incentives as tax relief, low-interest loans, and help in obtaining key components of major weapons systems.

Prospects for defence innovation have also been undermined by spill-over from the consequences of Russia's foreign policy, such as Western sanctions and freezes in defence cooperation imposed in response to Russia's annexation of Crimea in 2014. This has further limited Russia's access to Western technology and slowed military modernisation in several strategically important fields, exposing areas in which Russia has remained dependent on foreign components, including Ukrainian gas turbine engines, German diesel power units, and dual-use technology and electronic components for Russian weapons and satellites purchased from the United States, France and Germany.[55] While Russia has launched a programme to support the development of domestic import substitutes, and has found some components in China, it takes time and resources to develop them. Higher prices and lower quality may be the result, along with a number of accidents that have occurred during testing.[56]

Progress, therefore, has been uneven, notwithstanding the full weight of the government's political and financial support. The low level of innovation in Russia's overall economy has not helped. The country does have several innovative sectors, including the space industry, parts of the defence sector, and IT services, and there are a range of successful firms (NtechLab, Kaspersky Lab, Yandex and Sberbank to name a few). Yet in 2019 Russia ranked 46th in the Global Innovation Index, down from 43rd in 2016 and 45th in 2017.[57] Russia's effort to spur innovation by expanding the governmental sector does not constitute a solid foundation for innovation. Labour productivity in state-owned Russian industries and companies is estimated to be much lower than

[54]Zysk, 'Managing Military Change in Russia'.

[55]'The strengths and weaknesses of Russia's military', *Deutsche Welle*, 7 April 2018, https://www.dw.com/en/the-strengths-and-weaknesses-of-russias-military/a-43293017. The sanctions have not been 'waterproof', however, as some material from Germany was delivered to the Russian defence industry even after the sanctions were imposed; see Yuri Lobunov, 'Germany – a partner of the Russian military?', *Intersection*, 13 July 2016, http://intersectionproject.eu/article/security/germany-partner-russian-military.

[56]'Skorbnaya zhivuchest', *Kommersant*, 23 July 2019, https://www.kommersant.ru/doc/4039718; cf. Gustav Gressel, 'The sanctions straitjacket on Russia's defence sector', Commentary, The European Council on Foreign Relations, 13 February 2020, https://www.ecfr.eu/article/commentary_the_sanctions_straitjacket_on_russias_defence_sector.

[57]*Global Innovation Index 2018*, https://www.globalinnovationindex.org/gii-2018-report#; *Global Innovation Index 2019* https://www.globalinnovationindex.org/analysis-indicator.

in the private sector and is more than 30% below the national average.[58] As state industries rely on preferential state funding, they have limited incentive to invest in innovation and create a competitive environment. Crucial decisions are also more likely to have political rather than commercial objectives.[59]

Despite the state's large-scale effort to improve the future pool of specialists in new technologies, some data suggest the Russian educational system is no longer the solid basis for high-tech development that it was in the Soviet era. While Russia is ranked fourth in the OECD's 2019 global index of education, less than one per cent of Russia's graduates earned a degree in IT, communication or other forms of technology. The Moscow State University – considered Russia's highest ranked computer science research institution – was listed 43rd globally in 2017, 60th in 2018, and 78th in 2019.[60]

This challenge is exacerbated by another central problem affecting the Russian military-industrial complex, namely a decline in professional expertise and the human resources available to it. Highly qualified employees are on average more than 50 years of age; 70% of research personnel with a doctoral degree are over 60, and about half of those are actually over 70.[61] The share of specialists under 30 is less than four per cent.[62] According to Andrei Ilnitskii, adviser to the Russian MoD, more than half of the 1300 enterprises of the Russian military-industrial complex are experiencing personnel shortages.[63] A worsening of the economic situation increases the risk of further brain drain, as shown by a public opinion survey conducted by the Levada Centre in December 2019: as living standards continue to fall and economic opportunities decrease, more than half of Russians between the ages 18 and 24 consider moving abroad permanently.[64]

The Russian innovation programmes struggle, furthermore, with insufficient and unpredictable funding. The protracted economic crisis in Russia, including periods of stagnation and low-level recession since 2014, has put R&D funding under further pressure, limiting the scope and pace of the development programmes. The annual budget of the FPI, for example, has amounted to USD 50–60 million per year, compared to the USD 3.4 billion allocated for

[58] Martin Russell, *Seven economic challenges for Russia. Breaking out of stagnation?* European Parliamentary Research Service, July 2018, 4.
[59] Ibid.
[60] Dear, 43–44.
[61] Andrei Ilnitskii, adviser to the Russian MoD, presentation at international scientific conference 'Human capital in digital economy', Russian New University, 18 February 2018, https://www.rosnou.ru/pub/diec/assets/files/IlnitskiyAM.pdf.
[62] Prof. V.A. Tsvetkov, *Oboronno-promyshlennyi kompleks Rossii: problemy i perspektivy razvitya*, lecture at the second conference 'The Economic Potential of Industry in the Service of the Military-Industrial Complex', Moscow, 9–10 November 2016, Financial University Under the Government of the Russian Federation, http://www.ipr-ras.ru/appearances/tsvetkov-opcconf-2016.pdf.
[63] Ilnitskii, 'Human capital in digital economy'.
[64] 'Emigratsionnye nastroieniya', Levada Center, 26 November 2019, https://www.levada.ru/2019/11/26/emigratsionnye-nastroeniya-4/.

DARPA in 2019.[65] In 2017 the FPI budget actually decreased from RUB 3.8 billion to RUB 3.4 billion RUB. Ambitions to boost FPI spending significantly in the coming years have not been matched with funding.[66] Indeed, the presidential decree establishing the Era technopolis stipulated that its key innovation projects are to be financed not only from the MoD budget, but also the FPI budget.[67] Additionally, the Russian defence industry continues to struggle with the spectre of long-standing structural problems such as pervasive corruption.

Other factors behind Russia's poor economic performance include excessive dependence on natural resources, an unfavourable business environment and low levels of foreign investment, all aggravated by the weak rule of law and deficient intellectual property rights. The Russian political system is additional constraint on economic development. On the one hand it permits relatively rapid decision-making, so that grand initiatives like the creation of a military technopolis require only a stroke of the presidential pen. The system's procedural efficiency, however, is undermined by pervasive corruption, red tape and heavy-handed bureaucratic control, all of which obstruct the generation and implementation of innovative projects. Sergey Guriyev, chief economist at the European Bank for Reconstruction and Development, argues that economic recovery will be impossible unless Russia radically reduces the state's role in the economy and protects property rights.[68]

An assessment by the International Monetary Fund dated August 2019 concluded that the Russian authorities have put in place a relatively strong macroeconomic policy that has reduced uncertainty and helped to minimise the consequences of external shocks such as Western sanctions and low energy prices.[69] The World Bank points out that unemployment remains at a historically low level (4.5%), and the Russian banking sector has remained largely stable. A typical Russian citizen was 1.8 times richer in 2017 than in 2000. Russia has also continued to diversify exports, albeit slowly; it remains dominated by energy exports, which accounted for 65% of total exports in 2018 (compared to 59% in 2017).[70]

[65] DARPA, Budget, https://www.darpa.mil/about-us/budget.

[66] Aleksei Nikol'skii, Svetlana Bocharova, 'Novoe litso Voennykh innovatsii', *Vedomosti*, 26 February 2018; 'Byudzhet Fonda perspektivnykh issledovanii na 2018 godu ostanetsya prezhnim', *Ria Novosti*, 6 July 2016, https://ria.ru/20160706/1459588542.html; DARPA, Budget, https://www.darpa.mil/about-us/budget.

[67] Ukaz Prezidenta Rossiiskoi Federatsii ot 25.06.2018 g.

[68] Sergey Guriyev, *Only radical reforms can stop Russian economic stagnation*, RaamopRusland/Window to Russia, 26 August 2019, https://www.raamoprusland.nl/mission-statement-window-to-russia/188-mission-statement-window-to-russia.

[69] *Russian Federation: 2019 Article IV Consultation-Press Release; Staff Report*, IMF, 2 August 2019, https://www.imf.org/en/Publications/CR/Issues/2019/08/01/Russian-Federation-2019-Article-IV-Consultation-Press-Release-Staff-Report-48549.

[70] *Weaker Global Outlook Sharpens Focus on Domestic Reforms*, 42nd issue of the Russia Economic Report, World Bank, 4 December 2019, http://documents.worldbank.org/curated/en/782731577724536539/Weaker-Global-Outlook-Sharpens-Focus-on-Domestic-Reforms.

However, long-term growth prospects are expected to be modest due to structural constraints and sanctions. Domestic investment has remained low, at 20–22% of GPD, while foreign investment has fallen substantially and capital flight has accelerated. From 2014 to 2018, foreign investment declines in Russia reached USD 320 billion, or about 4% of GDP per year.[71] Structural reforms are needed to increase long-term growth and reduce the risk of stagnation. This means reducing the state's role in the economy, reducing regulations, and strengthening institutions, to name but a few key actions.[72] Yet structural reforms are not on the government's agenda to any sufficient degree. It is unknown how long Russia can pay for and sustain its defence innovation efforts, military modernisation, and high level of military activity at home and abroad, and without risking domestic political stability. The economic impact of the Covid-19 pandemic, combined with a further fall in energy prices, has sent shockwaves across the Russian state,[73] heightening uncertainty about the future of the defence innovation programmes.

Strategic context and battlefield advantages of 4IR capabilities

Overall, Russia does not appear to have a strong foundation in terms of factors considered to be enablers of R&D, including favourable economic, business, educational, industrial and legal environment that are conducive to stimulating innovation.[74] Does that mean the Russian defence innovation model is doomed to failure? And to what extent may Russia's advantages and driving forces help it to achieve success in selected, high-priority fields seen as key to a successful strategic competition? The section below places Russia's pursuit of 4IR development in the broader strategic context, then examines two examples of high-priority Russian R&D programmes: hypersonics and AI.

Strategic context of Russian 4IR development

The Russian authorities view the technological race as a central element in the ongoing great power competition, one that could potentially produce a game-changing, war-winning advantage. Given its long-standing perceived vulnerability to US/NATO military-technological superiority, Russia has sought to match some existing Western military capabilities symmetrically. Initially, in the 1990s and early 2000s, Russia had to compete from a position

[71]Sergey Guriyev, Only radical reforms can stop Russian economic stagnation.
[72]Russian Federation, IMF; *Weaker Global Outlook*.
[73]Heli Simola, 'Russian economy hit by COVID-19 and oil market turmoil', *Bank of Finland Bulletin*, Blog, 15 May 2020, https://www.bofbulletin.fi/en/blogs/2020/russian-economy-hit-by-covid-19-and-oil-market-turmoil/.
[74]Dear, 'Will Russia Rule the World Through AI?', 36–60.

of dramatic inferiority in conventional forces and a widening gap between the capabilities of its domestic military-industrial complex and those of its Western rivals. The Russian defence sector went through an extensive physical decline, suffering the dwindling attention of top political leadership, a national economic crisis, and insufficient material and human resources.[75]

As a result, the Russian leadership focused initially on stake-raising strategies based on the only significant capability available at the time – nuclear weapons. The idea was to ramp up the risks to competitors, so that any action to threaten Russia would be rejected in advance as prohibitively costly and likely ineffective. Russia's subsequent renewal and fielding of an increasingly diverse nuclear arsenal, its delivery systems and supporting infrastructure, were accompanied by doctrinal revisions that have elevated the role of nuclear weapons. Military doctrines (including from 2000, 2010 and 2014) have maintained clauses permitting Russia the first use of nuclear weapons in a conventional conflict.[76]

However, the advances of the sweeping military modernisation programme launched in 2008 have increasingly enabled Russia to invest in strategies of denial, aimed to convince competitors that it would be impossible to translate military means into political ends at an acceptable cost.[77] Russia has managed to level out its military decline and partially rebuild innovation capability by constructing the foundations of advanced new technological development programmes. It has gradually increased the role and significance of non-nuclear defence and deterrence in its military doctrine and strategy. Its well-established missile technology, including the development of hypersonics, is at the heart of this change. Long-range high-precision ballistic and cruise missiles, followed by hypersonic boost-glide vehicles and cruise missiles that are under development, constitute the backbone of Russia's non-nuclear defence and deterrence, as highlighted in the 2010 military doctrine, subsequently elevated to the strategic level in its update from 2014.[78]

Despite the largely successful military modernisation programme, Russia has been unable to engage in full-spectrum symmetrical competition. Its military technology remains inferior to that of the US and NATO, and China is likely to be an increasing challenge in the long run. Hence, Russia has simultaneously pursued both symmetrical and asymmetrical means and

[75]Zoltan Barany, *Democratic Breakdown and the Decline of the Russian Military* (Princeton University Press, 2007); Anne C. Aldis, Roger N. McDermott, eds, *Russian military reform 1992–2002*, (London: Frank Cass, 2003); Dale R. Herspring, 'Undermining Combat Readiness in the Russian Military, 1992–2005 , *Armed Forces & Society*, Vol. 32 (2006), 513–531.

[76]Voennaya doktrina Rossiiskoi Federatsii, Nezavisimoe Voennoe Obozrenie, 22 April 2000; Voennaya doktrina Rossiiskoi Federatsii, President of Russia, 5 February 2010, http://kremlin.ru/supplement/461; Voennaya doktrina Rossiiskoi Federatsii, Security Council of the Russian Federation, 26 December 2014, http://www.scrf.gov.ru/security/military/document129.

[77]Thomas Mahnken, A Framework for Examining Long-Term Strategic Competition Between Major Power, SITC Research Brief, January 2017, 2.

[78]Voennaya doktrina 2010; Voennaya doktrina, 2014.

methods of warfare. The objective has been to undermine or circumvent the opponent's military-technological superiority and exploit its vulnerabilities, preferably in a cost-effective manner politically and economically. This means, among other efforts, experimenting with selected 4IR technologies that are seen as both force enablers and force multipliers for Russia's traditional military (nuclear and non-nuclear) as well as non-military defence, deterrence and coercive options.

The case of hypersonics and AI: Strategic and battlefield advantages

One of key 4IR fields in which Russia has made significant progress and which is exerting an impact on the strategic environment, strengthening Russia's overall ability to compete, has been hypersonic technology.[79] Progress on that front stands in contrast to Russian AI development. Although the strategic importance of AI is appreciated, Russia is far from being a global AI leader, a fact the Russian authorities themselves acknowledge.[80] Still, AI technology has been a major preoccupation of the top political and military leadership inasmuch as so many other key 4IR technologies rely on it, including autonomous weapon systems, automated decision-making, human-machine hybrid intelligence, intelligent robotics, and harvesting and exploiting big data. Like hypersonics, AI is already having an operational impact as a force enabler and multiplier in all three main pillars of Russian defence and military strategy (nuclear, non-nuclear, non-military) discussed below.

Hypersonic technology

Russia has succeeded in following a consistent missile development pathway since the 1980s, making the country a global leader in two cutting-edge 4IR technologies: hypersonic boost-glide vehicles and hypersonic cruise missiles. This distinction was preceded by the development of a substantial arsenal of long-range land-, sea- and air-launched precision strike cruise and ballistic missiles (e.g. Kh-555/Kh-55SM, Kh-101/Kh-102, Kalibr, Iskander-K, Iskander-M and SSC-8/9M729) that allow Russia to engage land targets across Europe and large parts of Asia from international waters or Russian airspace, in addition to delivering them as anti-ship cruise missiles. The missiles' ranges, stealth capability, high subsonic speed and low-altitude flight profile are intended to strain the enemy's ability to defend effectively.[81] The ground-launched missiles, able

[79]Dean Wilkening, 'Hypersonic Weapons and Strategic Stability', *Survival*, 61:5, 2019, 129–148; Robert O. Work and Greg Grant, *Beating the Americans at Their Own Game: An Offset Strategy with Chinese Characteristics*, CNAS Report, June 2019.
[80]Ukaz Prezidenta Rossiiskoi Federatsii ot 10.10.2019 g.
[81]Robert Dalsjö, Christofer Berglund, Michael Jonsson, Bursting the Bubble. Russian A2/AD in the Baltic Sea Region: Capabilities, Countermeasures, and Implications (Stockhold: FOI, March 2019).

to reach European cities with little warning, are mobile and thus harder to detect and destroy.[82]

As a result, the growing role of non-nuclear deterrence in Russian strategic thinking has fuelled long-standing speculation among Russian and Western experts about the imminent shift in the major share of missions of the Russian strategic deterrence from the nuclear to the non-nuclear domain. Indeed, the Russian General Staff assumes that the production and deployment of long-range high-precision weapons, in particular hypersonics, 'will make it possible to transfer a major part of missions of strategic deterrence from the nuclear to the non-nuclear sphere'.[83] Defence Minister Shoigu has promised that Russia will have 'full non-nuclear deterrence' by means of a fourfold expansion of the number of non-nuclear strategic weapons by 2021.[84]

However, any such transition is still in the future and depends on when and if Russia's economy will allow the acquisition of a large number of such weapons along with a credible intelligence support system – i.e. an improved C2ISTAR infrastructure (command and control plus intelligence, surveillance, target acquisition and reconnaissance) that can effectively locate targets from longer distances, not least mobile targets.[85]

The development of hypersonic technology highlights the continued critical importance of nuclear forces and strategic stability in Russia's military doctrine and strategy. The Russian authorities' – and President Putin's – *idée fixe* has been to render useless any Western strategic air and ballistic missile defences that may reduce the vulnerability of the US strategic nuclear forces and thus undermine the strategic balance.[86] While some experts claim the development of hypersonics for this reason would be a solution to a non-existent problem,[87] the Russian authorities have, nonetheless, consistently pointed to it as one of the main reasons for the high priority attached by Russia to the development of hypersonic technologies.[88]

[82]Interview with NATO Secretary General Jens Stoltenberg, *Spiegel International*, 2 April 2019, https://www.spiegel.de/international/world/interview-with-nato-secretary-general-stoltenberg-u-s-100-percent-behind-us-a-1260690.html.

[83]'Vystuplniye nachal'nika General'nogo shtaba Vooruzhennykh Sil Rossiiskoi Federatsii generala armii Valeriya Gerasimova na otkrytom zasedanii Kollegii Minoborony Rossii', Moscow, 7 November 2017, Russian Ministry of Defence, http://function.mil.ru/news_page/country/more.htm?id=12149743@egNews.

[84]'Ministr oborony Rossii provel ustanovochnuyu lektsiyu kursa "Armiya i obshchestvo"', Russian Ministry of Defence, 12 January 2017, https://function.mil.ru/news_page/world/more.htm?id=12108199@egNews&_print=true.

[85]Dalsjö, Berglund, Jonsson, *Bursting the Bubble*.

[86]Putin's statement on US missile defences at the International Economic Forum, St. Petersburg, June 2016: 'Putin's warning', https://www.youtube.com/watch?v=kqD8lldlMRo.

[87]Andrew W. Reddie, 'Hypersonic missiles: Why the new "arms race" is going nowhere fast', *Bulletin of the Atomic Scientists*, 13 January 2020, https://thebulletin.org/2020/01/hypersonic-missiles-new-arms-race-going-nowhere-fast/.

[88]Russia's preoccupation with extending range has also been behind projects such as the nuclear-powered nuclear cruise missile Burevestnik, which is to have an 'unlimited range'; *Poslanie Prezidenta Federal'nomu Sobraniyu*, 2018; official channel of the Russian Ministry of Defence, published on 19 July 2018, https://www.youtube.com/watch?v=okS76WHh6FI.

These weapons systems aim to provide an innovative solution by evading missile defences with advanced speed and manoeuvrability, thus being inherently difficult to shoot down. Apart from their speed in excess of five times the speed of sound, dramatically reducing warning time, one of the key advantages of hypersonic boost glide vehicles and cruise missiles is the difficulty of accurate attack assessment by the adversary until late in the vehicles' trajectories. This is due to their significant manoeuvrability that allows them to divert to targets that may be 'hundreds of kilometres to either side of their initial trajectory'.[89] These new strike systems, developed to reach heavily defended, high-priority targets, have qualities that also make them a demanding target for US battle networks because they are moving through 'near space' – an operational domain that is not well covered by US sensors.[90]

In December 2019, Russia announced deployment of the first hypersonic boost-glide vehicles: the Avangard intercontinental ballistic missile system.[91] Two other hypersonic missile systems appear to be in advanced development phases: the sea and ground-launched high supersonic to hypersonic cruise missile 3K22 Tsirkon[92] (range approximately 500–1,000 km, Mach 4.5–6) and Kh-47 M2 Kinzhal air-launched ballistic missile (range over 2,000 km, Mach 10).[93] The introduction of hypersonic boost-glide vehicles and cruise missiles, especially when conventionally armed, could have a profound effect on strategic stability. As defence against them may be prohibitively high, it may increase the likelihood of offence dominance in a conventional strike. This, in turn, may create problems of crisis instability and arms-race instability with profound implications for the global strategic environment.[94] The head start Russia has in development, with China not far behind (followed by India and France), has therefore been a source of a concern in US policy circles, where symmetric and asymmetric responses are being considered.[95]

Artificial intelligence

AI development has been a top priority on Russia's 4IR development list and is being pursued with an increasing sense of urgency.[96] Defined in the

[89]This is also a major difference between ballistic missiles (which are inherently hypersonic) and non-ballistic hypersonic weapons, Wilkening, 'Hypersonic Weapons and Strategic Stability', 131, 137.
[90]Work and Grant, Beating the Americans at Their Own Game.
[91]'Russia proceeds with Avangard hypersonic missile production according to schedule', *Tass*, 2 July 2019; '"Okazalis" v "Avangarde": kak i gde budut razvorachivat' novuyu sistemu', *Izvestiya*, 4 November 2018; 'Shoigu zayavil, chto rossiiskie voennye skoro poluchat novoe giperzvukovoe i lazernoe oruzhie', *Tass*, 18 June 2019.
[92]'Vladimir Putin raskryl kharakteristiki rakety "Tsirkon"', *Rossiiskaya gazeta*, 20 February 2019.
[93]'Perspektivy robotizatsii rossiiskih vooruzhenii', *Ria novosti*, 9 February 2016.
[94]Wilkening, 'Hypersonic Weapons and Strategic Stability'.
[95]Rebecca Kheel, 'Russia, China eclipse US in hypersonic missiles, prompting fears', *The Hill*, 27 March 2018, https://thehill.com/policy/defense/380364-china-russia-eclipse-us-in-hypersonic-missiles-prompting-fears.
[96]'Putin rasskazal, kto mozhet stat' vlastelinom mira', *TV Zvezda*, 1 September 2017, Russian Ministry of Defence, https://tvzvezda.ru/news/vstrane_i_mire/content/201709011425-qb2f.htm.

Russian AI strategy as 'technological solutions capable of mimicking human cognition and performing intellectual tasks similarly to, or better than, humans',[97] the technology is expected to have possibly game-changing impact on both the military and civilian sectors.

Russia views AI development in terms of a long-term strategic competition and a potentially winning solution in several fundamental ways. First, AI systems may strengthen the socio-economic foundation of Russian power by massively transforming the national economy. Putin has argued that in the coming decades additional global GDP growth due to the introduction of AI could be 1.2% annually, i.e. twice the economic impact of information technology at the beginning of the 21st century.[98] Similarly, Minister for Economic Development Maksim Oreshkin sees the integration of AI as possibly leading to a significant increase in labour productivity by 2030.[99] German Gref, former Minister of Natural Resources and subsequently CEO of the thriving Sberbank, also anticipates positive nationwide effects from the integration of new economic or financial solutions based on AI.[100] Such development would be highly welcome given the poor long-term economic projections for Russia issued by the IMF and the World Bank.[101]

Second, the urge to push ahead with AI development stems from its possible impact on the trajectory of future warfare and the ways and means of victory, broadly considered one of the main drivers of defence innovation in general.[102] AI-enabled systems could create a more effective, less expensive strategy to compete asymmetrically with the United States when symmetrical competition, outside a few selected fields, is not within Russia's reach.[103]

Third, the Russian authorities see AI development not only in terms of the potentially immense opportunities, but also as a source of new vulnerabilities in national, technological and economic security.[104] Putin and other influential leaders, such as Gennadii Osipov, director for the AI programme at the Institute of Artificial Intelligence at the Russian Academy of Sciences, argue that employing AI in information systems and to link non-military and military technologies may give an adversary critical superiority, providing victory in any conflict even before its official eruption. AI could therefore have a destabilising effect by undermining the strategic balance.[105]

[97]Ukaz Prezidenta Rossiiskoi Federatsii ot 10.10.2019 g.
[98]Quoted in 'Oreshkin: iskusstvennyi intellekt pomozhet povysit' proizvoditel'nost' truda', *Ria novosti*, 4 September 2019.
[99]Ibid.
[100]'Gref schitaet, chto razvitie iskusstvennogo intellekta sposobno sil'no izmenit' Rossiyu', *Tass*, 17 October 2019.
[101]Russian Federation: 2019 Article IV Consultation-Press Release; Weaker Global Outlook.
[102]Rosen, Winning the Next War.
[103]Bytev Aleksei, Smirnova Lyudmila, 'Udarnye intellekty. Chelovek ukhodit s polya boya', *Voenno-promyshlennyi kuryer*, 24 September 2019.
[104]'Shoigu prizval Voennykh i grazhdanskikh uchenykh'.
[105]Cheberko, 'Pochemu v Rossii ne poluchilsya analog DARPA'.

Despite the possible game-changing qualities of AI and its potential to radically alter future warfare, its development and application in Russia to date appears more incremental than revolutionary. Notably, AI is being tested and applied as a force enabler and force multiplier for traditional symmetric and asymmetric military and non-military methods and means, such as the nuclear capability, non-nuclear strategic and general purpose forces, and non-military measures.

For instance, Russia is experimenting with turning AI technology into a battlefield advantage in several fields, including unmanned aerial vehicles (UAV), unmanned underwater vehicles (UUV), ground-based robotic systems, unmanned boats and other innovative combat systems.[106] Such exploitation of AI extends to nuclear missions, as demonstrated by the development of the nuclear-powered and nuclear-armed UUV Poseidon, likely tasked with destroying infrastructure, carrier groups and other high-value targets.[107] Some sources indicate that other projects are underway, including the application of AI to control various air defence systems, including S-300, S-400, and Pantsir.[108]

Likewise, AI is being applied to enhance the combat effectiveness of other traditional weapons to minimise personnel losses.[109] Russian drone development, though progressing at a slower pace than the authorities initially hoped for? is one example.[110] In 2013, the General Staff promised domestically produced drones by 2020, investing more than USD 900 million (about RUB 5 billion) for the purpose.[111] Although the domestic industry has been struggling to attain the objective, it has advanced in developing Israeli-licenced surveillance drones and manufacturing unmanned vehicles for surveillance, reconnaissance and target acquisition, though with limited range and endurance (e.g. Forpost-M, Forpost-R',[112] or Orlan-10[113]). As of May 2020, however, Russia still lacked assault drone capability, considered a major vulnerability.[114] However, the development appears to be moving forward (e.g. Al'tius/Al'tair heavy UAV, Okhotnik attack

[106]'Rossiiskie bespilotniki vedut kruglosutochnyi kontrol' v Sirii, zayavil Shoigu', *Ria novosti*, 27 September 2017.
[107]'Istochnik: zavodskie khodovye ispytaniya "Poseidona" nachnutsya letom 2019 goda', *Tass*, 10 February 2018.
[108]Aleksandr Kruglov, Aleksei Ramm, Yevgenii Dmitriev, 'Sredstva PVO ob'yedinyat iskusstvennym intellektom', *Izvestiya*, 2 May 2018.
[109]'Vooruzhennye sily Rossiiskoi Federatsii osnashchayutsya innovatsionnymi vidami oruzhiya'.
[110]'MO potratilo 5 mlrd rub. na bespilotniki, no rezul'tata net – Popovkin', *Ria novosti*, 7 April 2010.
[111]Vladimir Popovkin, quoted in: Mikhail Sergeyev, 'Nebesnyi dolgostroi', *Rossiiskaya gazeta*, 25 February 2013; 'Genshtab dolozhil o real'nykh rezul'tatakh Voennoi reformy', *Odnako.org*, 14 February 2013.
[112]'Minoborony RF poluchit 10 novyh bespilotnikov "Forpost-R"', *TV Zvezda*, 5 February 2020, https://tvzvezda.ru/news/opk/content/2020251520-QDjSI.html.
[113]'Bespilotniki "Orlan-10" nachali razvedku nad Voennym skladom pod Achinskom', *Ria novosti*, 3 March 2020; 'Dron – v stroi: "Orlan-30" naidet tseli dlya artillerii', *Izvetsiya*, 2 October 2019; 'Do kontsa goda v VVO postupit partiya bespilotnykh letatel'nykh apparatov "Orlan-10"', Ministry of Defence of the Russian Federation, 16 December 2019, https://function.mil.ru/news_page/country/more.htm?id=12267088@egNews.
[114]'Top 10 military innovations novelties Russian defense industry Army-2018 Moscow Region Russia', *DefenceWebTV*, published on 28 August 2018, https://www.youtube.com/watch?v=nvT_sKTD7p0.

UAV).[115] Russia has also shown an interest in swarm technology, which, if successfully developed, could provide Russia with a significant edge on the battlefield.[116]

Russian AI-enabled technologies also aim to strengthen the basis for asymmetric competition in both the military and non-military domains. In the view of the Russian MoD, the position of leading states in today's information society is largely determined by their level of development in information technologies, primarily those of cognitive analysis and decision support at various levels of management.[117]

The Russian General Staff attaches critical importance to winning and holding information superiority and influencing the cognitive-psychological domain, seen as key in any contemporary conflict. Influence operations and other forms of AI-enabled and AI-augmented 'information confrontation' (*informatsionnoe protivoborstvo*)[118] exploiting new forms and roles of information and social interaction are set to play an increasingly prominent role in Russia's military strategy.[119] Sergei Chvarkov, professor at the Russian Academy of Military Sciences, points that cyber weapons have several critical advantages and in some cases may be many times more effective than physical destruction by conventional weapons; moreover, threats and attacks in the information sphere are hard to retaliate against.[120]

The exploitation of big data is likely to play a significant role in enhancing existing and creating new means of confrontation. It requires creating an infrastructure and conditions for big data harvesting, considered by the Russian authorities? a key factor in AI development. To this end, the Russian national AI strategy clearly states that priority in accessing big data will be given to state actors.[121]

Russia has also demonstrated interest in combining new technologies, such as AI and drones, in order to augment traditional methods of influence operations such as disinformation, demoralisation and propaganda. Specially developed Russian drones and cell site simulators have been able to impersonate cell phone towers with the objective of intercepting, jamming, spoofing or broadcasting tailored content on civilian mobile phones belonging to the opposing side. Russia has tested such systems in operations in Eastern

[115]'Istochnik soobshchil ob ispytaniyakh prototipa BLA "Al'tius" so sputnikom', *Ria novosti*, 20 January 2020; Oleg Falichev, 'Smozhet li okhotit'sya "Okhotnik"?' *Voenno-promyshlennyi kuryer*, 14 April 2020.

[116]'Vysshii bespilotazh: Voennye vpervye otrabotali deistviya udarnykh grup dronov', *Izvestiya*, 7 November 2019. See also Jörgen Elfving, 'Ryska obemannade farkoster – Det västliga försprånget inhämtat?', KrVA Handlingar och Tidskrift nr 2–2020.

[117]'Shoigu prizval voennykh i grazhdanskikh uchenykh ob"edinit'sya dlya raboty nad iskusstvennym intellektom', *Voennoe obozrenie*, 14 March 2018, https://topwar.ru/137827-shoygu-prizval-voennyh-i-grazhdanskih-uchenyh-obedinitsya-dlya-raboty-nad-iskusstvennym-intellektom.html.

[118]'Informatsionnoe protivoborstvo', *Military Encyclopaedic Dictionary*, The Ministry of Defence of the Russian Federation, http://encyclopedia.mil.ru/encyclopedia/dictionary/details.htm?id=5221@morfDictionary.

[119]See also Sergei Chvarkov, professor at the Russian Academy of Military Sciences, 'Nauka o voine – neobkhodimost' ili dan' mode?', *Nezavisimoe voennoe obozrenie*, 20 February 2020.

[120]Chvarkov, 'Nauka o voine'.

[121]Ukaz Prezidenta Rossiiskoi Federatsii ot 10.10.2019 g.

Ukraine and Syria by delivering content to cell phones of opposing fighters. Based on information harvested from the smartphones, the projected content was intended to harass, intimidate and undermine morale, for instance by revealing seemingly compromising details about the adversary's commanders or divulging knowledge about soldiers' own families. Such methods have also been used against NATO soldiers deployed in the Baltic republics as a part of NATO's Enhanced Forward Presence, apparently for similar influence operation purposes.[122]

Furthermore, Russia has been investing in counter-network capabilities that could disrupt or degrade the backbone of the US and NATO information technology-enabled warfare, critical infrastructures (C4ISR), including space-based systems, command and operational networks, and other complex technological warfare enablers that developed countries depend on. The Russian Aerospace Forces, created in 2015, integrate the previously separated offensive and defensive capabilities, including air defence, missile defence, offensive electronic warfare, anti-space capabilities (such as anti-satellite missiles and manoeuvring space robots),[123]and directed energy weapons, such as the abovementioned Peresvet.[124] They are likely to play key role in crisis and conflict, including regional war scenarios.

Conclusions

Driven by the top political and military leadership and partly emulating other militaries, Russia has systematically increased its focus on 4IR technologies. The pace of development has been mixed, with advancement in selected key areas. The achievements appear to have strengthened the basic foundations of Russian defence and military strategy, providing a broader spectrum of options in defence, deterrence and escalation management. To date, 4IR development has not produced a fundamental change in the character of

[122]'"We are watching you": Russia accused of sending threatening texts to British troops', *The Telegraph*, 15 October 2019; 'Electronic warfare by drone and sms', *Digital Forensic Research Lab*, Atlantic Council, 18 May 2017, https://medium.com/dfrlab/electronic-warfare-by-drone-and-sms-7fec6aa7d696; 'Reports suggest Russia engages in psychological warfare in Avdiyivka – media', UNIAN Information Agency, 1 February 2017, https://www.unian.info/war/1754086-reports-suggest-russia-engages-in-psychological-warfare-in-avdiyivka-media.html; Thomas Grove, Julian E. Barnes, Drew Hinshaw, 'Russia Targets NATO Soldier Smartphones, Western Officials Say', *The Wall Street Journal*, 4 October 2017; Keir Giles, 'Time to Shed More Light on Russian Harassment of NATO Forces' Families', *Expert Comment*, Chatham House, 14 August 2019, https://www.chathamhouse.org/expert/comment/time-shed-more-light-russian-harassment-nato-forces-families; 'Russian Harassment of NATO Personnel, Families: The Next Chapter in Information Warfare?', *Military.com*, 3 September 2019, https://www.military.com/daily-news/2019/09/03/russian-harassment-nato-personnel-families-next-chapter-information-warfare.html.

[123]According to several sources, including the US Space Command, Russia tested such missiles in mid-April 2020, 'Russia tests direct-ascent anti-satellite missile', US Space Command, Department of Defence, 16 April 2020, https://www.spacecom.mil/MEDIA/NEWS-ARTICLES/Article/2151611/russia-tests-direct-ascent-anti-satellite-missile/.

[124]'Minoborony RF razmestilo boevyye lazery v mestakh dislokatsii', *Nezavisimaya gazeta*, 19 July 2018; 'Na boevoe dezhurstvo zastupili "Peresvety"', *Krasnaya zvezda*, 5 December 2018.

Russian warfare. Rather, it has been a process of an incremental evolution, with gradual improvements in symmetrical and asymmetrical methods and means of warfare. That said, the development of 4IR technologies may be non-linear, and the occurrence a breakthrough that could revolutionise Russia's warfighting capability and its ability to compete cannot be excluded.

Russia has made attempts to modify its traditional top-down, state-driven innovation model by building a bridge to the civilian and private sectors. It remains to be seen whether the state will provide sufficient support for 4IR development through all stages of the product generation cycle: from idea to limited-scale testing and production. Structural and circumstantial constraints on this process have been numerous, and Russia lags behind the United States and China in particular. While Russia has emulated elements of US and possibly Chinese technological innovation pathways, the idiosyncrasies of the Russian defence innovation model and the broader political, economic and legal ramifications, have produced different outcomes. Problems such as centralised and inefficient bureaucracies, weak intellectual property rights and rule of law, poor investment climate, pervasive corruption, and insufficient funding are among the problems that hinder swift progress in fields that are particularly dependent on creating a breeding ground for creativity and the free exchange of ideas.

Furthermore, Russia's slow economic growth, discouraging long-term socioeconomic prospects and spill-over effects from its own foreign policy have limited access to foreign technology, knowhow, supplies, and investments. Domestic policies, such as the state's tightening of control over the Internet and its tendency to take over, punish or ban companies for non-compliance (e.g. Telegram, VKontakte, LinkedIn) may have a further dissuasive effect on Russian and foreign investors.[125]

Given the current set of circumstances, Russia appears an unlikely global leader in 4IR technologies. The question, however, is to what extent such technologies are necessary to satisfy the needs and objectives of Russian defence policy and military strategy as well as the country's ability to successfully compete with other great powers. Despite the relatively limited scope and modest progress of its 4IR programmes, Russia has demonstrated a willingness and an ability to rapidly exploit some of the new technological gains as they emerge, by integrating AI, for example, to enhance nuclear, non-nuclear and non-military capabilities and missions. The interconnected systems that Russia is creating – combining advanced pre-4IR technologies with such features as artificial intelligence, autonomous systems, and

[125]Alena Epifanova, *Deciphering Russia's 'Sovereign Internet Law'*, DGAP Analysis No. 2, 2020, German Council on Foreign Relations, https://dgap.org/en/research/publications/deciphering-russias-sovereign-internet-law; Justin Sherman, Samuel Bendett, 'Putin Takes Another Step in Bid to Control Russia's Internet', *Defense One*, 8 April 2020, https://www.defenseone.com/ideas/2020/04/putins-latest-step-his-bid-control-russias-internet/164467/.

quantum computing – may provide a sharpened edge on the battlefield, if not the critical advantage that the Russian top leadership is ultimately pursuing.

One notable Russian advantage is that ethical and moral considerations related to military applications of AI and autonomous weapons systems will likely not emerge as a major factor constraining further development. While the Russian authorities promise to develop ethical norms covering the interaction between humans and AI, they simultaneously argue that excessive regulation can hamper the pace of AI development and implementation in Russia, thus undermining the country's chances in the ongoing technological competition.[126] In Russia's pursuit of AI technology, therefore, the national interest is likely to remain a higher priority than privacy and human rights. In this context, state-controlled and state-driven innovation in Russia can provide an advantage as limitations on harvesting large amounts of data are unlikely to get in the way of creating the infrastructure and conditions conducive to AI development. Similar logic applies to Russia's stance on Lethal Autonomous Weapons Systems: although Russia argues for inserting humans in the decision-making process, the country has rejected a proposition to create an international body capable of limiting the sovereign rights of states in the process of building and testing such technologies.[127]

Even if successful in generating some breakthroughs, the Russian military organisation's ability to translate newly achieved technological prowess into battlefield advantage will remain in question. For innovation to occur, it has to be significant in scope and impact, and it must alter how the armed forces operate while substantially increasing their battlefield effectiveness.[128] As Robert Work argues, having 'the best technology is not enough' in a successful political-military-technology competition. The key is the relationship between technology and hardware on the one hand, and concepts, doctrine, and organisations on the other,[129] i.e. a change in operational praxis. In other words, a successful military modernisation is not defined by technology and hardware alone, but requires changes in organisation and force deployment while anticipating the implications of new technologies for future warfare. Following the development of 4IR in Russia and tracking what Russia can invent, develop and successfully deploy is an issue requiring further research. As Russia continues to field existing and emerging 4IR technologies, another important topic on the future research agenda should be the extent to which Russia can take advantage of the new technologies by

[126]Ukaz Prezidenta Rossiiskoi Federatsii ot 10.10.2019 g.
[127]Justin Haner, Denise Garcia, 'The Artificial Intelligence Arms Race: Trends and World Leaders in Autonomous Weapons Development', *Global Policy*, Vol. 10, Issue 3, September 2019, 331–337.
[128]Grissom, 'The future of military innovation studies', 907.
[129]Work and Grant, Beating the Americans at Their Own Game.

creating the optimal relationship between technology and operational concepts.

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