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Russia's struggle to modernize its military industry

How sanctions, war and 'innovation stagnation' are weakening Moscow's capabilities

Mathieu Boulègue

CHATHAM HOUSE

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Summary

— Russia has spent record amounts on defence over recent years, with its spending set to exceed 6 per cent of GDP in 2025. Despite this, the country's military-industrial complex (OPK) has been degraded by a decade of international targeted sanctions and by the Ukraine war effort. Russia's ability to produce military hardware has been severely impacted, and its ability to innovate and adopt modern military technology constrained as a result of these challenges, as well as pre-existing weaknesses. The OPK is currently struggling to build *genuinely* new and technologically advanced systems. Instead, it is relying on Soviet-era legacy systems and research.

— The current state of the OPK is one of regression, rather than the evolution that the Kremlin would have the world believe. In the new round of its state armament programme (from 2025–34), Russia will likely have to simplify and slow its military production, accept reduced quality of outputs and manage a form of 'innovation stagnation' in its research and development (R&D). The OPK is also unlikely to expand into new production schemes, focusing instead on existing, proven and battle-tested systems.

— Yet these problems are not insurmountable for Russia. It still has the military-industrial and -scientific bases necessary to prosecute the Ukraine war, and could recapitalize its military hardware and modernize its armed forces in the right conditions. In the short term at least, the OPK will likely continue to produce systems that are 'good enough' to sustain a clear and constant threat to Ukraine, NATO and the West in general.

— Aside from the effects of the war on Ukraine and sanctions, the OPK suffers from a series of pre-existing weaknesses. These include financial and economic struggles, workforce and labour market deficiencies, industrial over-concentration, a lack of industrial coherence, and major systemic problems such as corruption and deficient quality control.

— The OPK is well practised at adapting to difficult circumstances. But its efforts to adapt to the various constraints it currently faces remain incomplete and inefficient. There are clear limits to what imports from the small number of partners Russia still has can do to replace high-quality, Western-made components and systems. Meanwhile, domestic production is unable to meet Russia's needs in full. Tightening of the current sanctions regime would degrade the OPK further, with the technological gaps between Russia and the West (and China) becoming wider and eventually too great to overcome.

— The West's goal must ultimately be to encourage these developments, seeking to reduce the overall threat from Russia by limiting the modernization of the latter's increasingly outmoded military industry. In such a scenario, the Kremlin would be forced to review its intention to confront Western/NATO countries symmetrically in conventional and strategic competition. Such a policy would not prevent Moscow from waging low-intensity warfare entirely, but could render the Russian threat more manageable, as a restricted military industry and shortages of advanced weapons systems would leave Russia unable to compete militarily in the long term.

Introduction

Since the full-scale invasion in Ukraine began in 2022, a significant part of the Russian federal budget has been directed towards the war effort. By 2023, almost one-third of total spending was allocated to defence and security.[1] Russia's defence expenditure is projected to reach 6.3 per cent of GDP in 2025,[2] representing a new high point since the end of the Cold War. The military budget is also bolstered by additional expenditures in civilian and dual-use sectors.

Yet, despite these additional resources, the Russian military-industrial complex (OPK) has been damaged by over a decade of targeted international sanctions and the consequences of Russia's 2022 invasion of Ukraine. Pre-existing weaknesses – notably including industry bottlenecks, financial issues, and workforce and labour market deficiencies – have been put under greater stress and other inherent, systemic factors have become more prominent.

Although the OPK has been able to adapt to such difficult circumstances to an extent, the situation has severe consequences for Russia's overall approach to modern military technology and military innovation. The pressure of meeting battlefield requirements and the constraints of sanctions have damaged Russia's military-scientific base, which in turn determines how Moscow will prosecute war in the future.

Understanding the impact of the 2022 invasion of Ukraine and international sanctions on Russia's military-industrial and military-scientific bases is key to assessing the ability of the Kremlin to continue prosecuting the war and maintain its threat to the rest of Europe and beyond. The evidence gathered during our research makes it clear that Russia's military industry can still muddle through and threaten Ukraine and Western nations with systems that, although not perfect, are 'good enough'. But it is also apparent that a degraded OPK will struggle to keep up with Western (and Chinese) advances in military technology over the longer term.

The following sections of this research paper assess the weaknesses – both internal and external – afflicting the OPK, and explain how its ability to sustain the war effort has been affected by these and other factors such as sanctions. The paper looks at how the industry is adapting to the constraints imposed by international sanctions and explores the associated challenges for Russia's continued procurement of military-grade and dual-use components. It then details Russia's approach to military R&D and innovation in the current context, before concluding with discussion of the short- and long-term implications of the state of Russia's OPK for the war on Ukraine and for Western/NATO countries.

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1 Ukrainska Pravda (2023), 'Russia's military-industrial complex is gaining momentum. Where does the money come from, and who helps Russia produce missiles?', 29 May 2023, https://www.pravda.com.ua/eng/articles/2023/05/29/7404294; Bloomberg News (2023), 'Russia Plans Huge Defense Spending Hike in 2024 as War Drags', 22 September 2023, https://www.bloomberg.com/news/articles/2023-09-22/russia-plans-huge-defense-spending-hike-in-2024-aswar-drags-on; Kantchev. G., Malenko, A. and Galkina, E. (2024), 'Here's How the Russian and Ukrainian War Efforts Compare, in 10 Charts', *Wall Street Journal*, 6 January 2024, https://www.wsj.com/world/russia/heres-how-therussian-and-ukrainian-war-efforts-compare-in-10-charts-1cf9a74f.

2 Korsunskaya, D. and Bryanski, G. (2024), 'Russia hikes 2025 defence spending by 25% to a new post-Soviet high', Reuters, 30 September 2024, https://www.reuters.com/world/europe/russia-hikes-national-defence-spending-by-23-2025-2024-09-30; Meduza (2024), 'Russia's State Duma approves 2025 federal budget, allocating 6.31 percent of GDP to military spending', 21 November 2024, https://meduza.io/en/news/2024/11/21/russia-s-state-duma-approves-2025-federal-budget-allocating-6-31-percent-of-gdp-to-military-spending.

Identifying the weaknesses in Russia's military-industrial complex

The ongoing war on Ukraine and the impact of international sanctions have deepened existing weaknesses, failings, industry bottlenecks and other issues in Russia's military-industrial complex. In this context, it is important to assess the push and pull factors affecting the OPK along the production value chain – especially how they affect the ability to sustain the war effort.

Although increased efficiency of OPK production remains an official goal of the Russian state, there are several constraining factors to contend with, including financial and economic struggles, workforce and labour market deficiencies, industrial over-concentration, and systemic problems such as corruption and poor quality control.

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This reality is in sharp contrast to the regular optimistic statements published by the Kremlin that depict the OPK as the 'most powerful in the world in terms of production volumes'[3] and state that the military has 'become even stronger' despite sanctions.[4]

Financial and economic struggles

Defence procurement and military priorities for the armed forces are enshrined in the State Armament Programme (GPV), initially scheduled until 2027.[5] In the context of the war, the next round of GPV will be earmarked for the period 2025–34, with discussions over its content already under way between the Ministry of Defence and the Ministry of Industry and Trade.[6] The formation of the new GPV will undoubtedly fuel debate between those prosecuting the war in Ukraine, those enabling it from an industrial perspective and those financing it.

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3 *Izvestia* (2024), 'Мантуров назвал российский ОПК самым мощным в мире' [Manturov calls Russia's defence industry the most powerful in the world], 14 May 2025, https://vpk.name/news/862639_manturov_nazval_rossiiskii_opk_samym_moshnym_v_mire.html.
4 RIA Novosti (2024), 'Санкции сделали российский ОПК еще сильнее, заявил Алиханов' [Sanctions have made the Russian defence industry even stronger, Alikhanov said], 13 August 2025, https://vpk.name/news/901254_sankcii_sdelali_rossiiskii_opk_eshe_silnee_zayavil_alihanov.html.
5 Connolly, R. and Boulègue, M. (2018), *Russia's New State Armament Programme: Implications for the Russian Armed Forces and Military Capabilities to 2027*, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/sites/default/files/publications/research/2018-05-10-russia-state-armament-programme-connolly-boulegue-final.pdf.
6 Vedomosti (2024), 'Мантуров: формирование новой госпрограммы вооружений уже идет' [Manturov: formation of a new state arms programme is already underway], 24 March 2024, https://www.vedomosti.ru/politics/news/2024/05/24/1039326-manturov-zayavil.

The OPK is in bad economic shape, and several structural factors are to blame. Even before the 2022 invasion of Ukraine, the OPK was struggling under international sanctions following the first invasion in 2014 and with the effects of the COVID-19 pandemic. Russia's shift towards a war economy since 2022 has led to a so-called 'military Keynesianism',[7] whereby the national economy is turned towards military spending, production and transfers.

The Kremlin argues this situation is only temporary and under control – President Vladimir Putin has himself warned that the Russian economy should not be 'distorted' overly towards the defence sector.[8] The reality, however, is different: the war economy brings 'good' macroeconomic results, but is causing real-world problems such as increased inflation, decreasing wages and purchasing power, and a liquidity crisis in the banking sector.

Regarding the latter, OPK companies are suffering from a debt management issue. Because of the structure of state defence orders (GOZ), the government does not allow for pre-payment in advance of military production, which forces OPK producers to request loans. Over recent decades, many unprofitable producers were artificially propped up by the state to avoid disruptions in the production chain. Companies (mostly owned by Rostec, the largest state-owned defence conglomerate in Russia) on the verge of bankruptcy were therefore able to borrow money from banks through facilitated loans.

But unpaid loans and the emergence of 'toxic' assets led Russian banks to limit lending to OPK companies, which in turn were not able to meet the demands of GOZ production, import substitution and the conversion of the industry towards civilian and dual-use production.[9] In the 2010s, relations between OPK producers and financial institutions soured rapidly as a result – so much so that the government intervened to streamline the process with banks involved in OPK loans (including Sberbank, VTB and others).

Before COVID-19, the government made the financial stabilization and recovery – or 'normalization' – of the OPK a priority.[10] Several solutions were identified, such as the recapitalization of certain companies to pay off their debts or attempts at preferential restructuring of long-term debt through major Russian banks. But the full-scale invasion of Ukraine dashed hopes of achieving this goal. OPK companies are also complaining that government payments remain insufficient to cover production expenses in addition to interest and loan repayments.[11]

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7 Ishchenko, V., Matveev, I. and Zhuravlev, O. (2023), 'Russian Military Keynesianism: Who Benefits from the War in Ukraine?', policy memo, Washington, DC: PONARS Eurasia, https://www.ponarseurasia.org/russian-military-keynesianism-who-benefits-from-the-war-in-ukraine; Bluhm, K. (2024), 'Where is Russia's 'Military Keynesianism' Headed?', policy memo, Washington, DC: PONARS Eurasia, https://www.ponarseurasia.org/where-is-russias-military-keynesianism-headed.
8 *Izvestia* (2024), 'Путин потребовал не допускать перекосов в экономике РФ в сторону обороны' [Putin demanded that Russia's economy should not be skewed towards defence], 15 May 2024, https://iz.ru/1696911/2024-05-15/putin-potreboval-ne-dopuskat-perekosov-v-ekonomike-rf-v-storonu-oborony.
9 Connolly and Boulègue (2018), *Russia's New State Armament Programme*; Boulègue, M. et al. (2024), *Assessing Russian plans for military regeneration: Modernization and reconstitution challenges for Moscow's war machine*, Research Paper, London: Royal Institute of International Affairs, https://doi.org/10.55317/9781784136178.
10 Päiväläinen, A. and Rajala, K. (2020), *Competitiveness of Russia's Defence Industry: Weak but Steady – Analysis of Economic Indicators*, working paper, Helsinki: Finland National Defence University, https://www.doria.fi/handle/10024/177052.
11 Snegovaya, M. et al. (2024), *Back in Stock? The State of Russia's Defense Industry after Two Years of the War*, report, Washington, DC: Center for Strategic and International Studies, https://www.csis.org/analysis/back-stock-state-russias-defense-industry-after-two-years-war.

The existing debt burden compounds the general lack of profitability among OPK companies. Russian military industrial producers are not profitable in the same way as their Western counterparts. Rather, they are supposed to be operating in a sustainable way, making only small, 'manageable' losses. Even major state corporations are suffering from significant losses and decry a lack of revenue.[12] The absence of profit has long been a point of contention between producer companies and the Russian Ministry of Defence, with the latter pressing manufacturers to lower prices as much as possible while maintaining quality.

Unprofitability is further compounded by issues related to price fixation between the OPK and the Ministry of Defence. Traditionally a source of friction, price fixation within GOZ was usually discussed over weeks of negotiations, with a complicated formula used for profit calculation,[13] and no flexibility or adaptability for producers – especially in the context of the demands of the war. The government recognized the difficulties this system caused and forced the creation of a new price fixation mechanism in 2018 to reduce production costs.[14]

Based on an 'incentive model' to improve production efficiency and an 'extended index' approach to limit price inflation,[15] the 2018 price regulation mechanism was, however, largely a failure. The government requested another round of discussion to address pricing issues in 2023.[16] Meanwhile, OPK companies have complained that price fixation mechanisms offer no incentive to reduce production costs.[17]

Under the continued stress of the war against Ukraine, the above factors have worsened the ongoing 'military industry overheating',[18] with more than a third of Russia's GDP now coming from the OPK but being immediately swallowed by the war effort.[19] In the context of the shift to a war economy, OPK companies are paid more but are expected to expand their output to match the relentless demands of the war – a situation that does not significantly change their overall financial position for the better.

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12 Luzin, P. (2023), 'The Russian army in 2023: military districts, money and the military-industrial complex', Riddle, 17 February 2023, https://ridl.io/the-russian-army-in-2023-military-districts-money-and-the-military-industrial-complex.
13 Oxenstierna, S. (2013), 'Defence spending', in Hedenskog, J. and Vendil Pallin, C. (eds) (2013), *Russia's Military Capability in a Ten-Year Perspective – 2013*, Stockholm: Swedish Defence Research Agency, https://www.foi.se/en/foi/reports/report-summary.html?reportNo=FOI-R--3734--SE.
14 Rosinformbureau via *Novosti VPK* (2017), 'Закупки в ОПК-2017: стандартизация, мотивация, кооперация' [Purchases in the 2017 OPK: standardisation, motivation, cooperation], 24 November 2017, https://vpk.name/news/199237_zakupki_v_opk2017_standartizaciya_motivaciya_kooperaciya.html.
15 Päiväläinen and Rajala (2020), *Competitiveness of Russia's Defence Industry*.
16 Larina, A. (2023), 'Правительство поручило создать группу ВПК по решению споров о ценах на продукцию гособоронзаказа' [The government has ordered the creation of a VPK group to resolve disputes over prices for state defence procurement products], *Kommersant*, 22 March 2023, https://www.kommersant.ru/doc/5888279.
17 Rostec via *Novosti VPK* (2024), 'Сергей Чемезов: Уже сегодня мы формируем заделы для постпобедного периода' [Sergei Chemezov: Today we are already laying the groundwork for the post-victory period], 20 June 2024, https://vpk.name/news/878808_sergei_chemezov_uzhe_segodnya_my_formiruem_zadely_dlya_postpobednogo_perioda.html.
18 Sapozhkov, O. (2023), 'Военно-промышленный перегрев' [Military-industrial overheating], *Kommersant*, 15 December 2023, https://www.kommersant.ru/doc/6397842.
19 Luzin (2023), 'The Russian army in 2023: military districts, money and the military-industrial complex'.

Since the war, the government has sought to solve this problem by increasing its oversight of the OPK. Previous talk of 'privatizing' some elements of the military industry to incentivize competition have now been overtaken by state-led efforts to regulate the sector by law.[20] Furthermore, direct state control over OPK companies is increasing, with some enterprises deemed to have been 'illegally privatized' brought back under public ownership by force.[21]

As production costs continue to rise, it will be harder for companies to reduce costs and boost production – especially with decreased input under current circumstances.

These ailments will continue to afflict the OPK. As production costs continue to rise, it will be harder for companies to reduce costs and boost production – especially with decreased input under current circumstances. Any efforts to meet the demands of the next GPV for 2025–34 will come at the expense of quality. It remains to be seen whether decisions by Andrey Belousov, who was appointed as defence minister in May 2024, will be able to reform or transform the state of Russia's military industry.

Workforce and labour market deficiencies

Labour market issues have always affected the OPK and have been compounded by the international sanctions placed on Russia since 2014, as well as the COVID-19 pandemic. The OPK is not missing a workforce *per se*, but it is critically lacking in qualified and trained workers. The government acknowledges that it has a problem in the sector: official estimates of the workforce gap range from around 140,000 employees[22] (including 50,000 highly skilled personnel)[23] to 400,000 workers (roughly 20 per cent of all OPK employees).[24]

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20 TSAMTO via *Novosti VPK* (2024), 'Предприятия ОПК с выручкой более 10 млрд. в год будут вносить в перечень экономически значимых организаций' [Defence industry enterprises with revenues of over 10 billion per year will be included in the list of economically significant organizations], 1 August 2024, https://vpk.name/news/896237_predpriyatiya_opk_s_vyruchkoi_bolee_10_mlrd_v_god_budut_vnosit_v_perechen_ekonomicheski_znachimyh_organizacii.html.
21 Interfax (2023), 'Президент РФ заявил, что возврат государству активов не означает деприватизации' [President of the Russian Federation stated that the return of assets to the state does not mean de-privatization], 12 September 2023, https://www.interfax.ru/russia/920320.
22 Interfax AVN via *Novosti VPK* (2024), 'В Минпромторге заявили о необходимости 140 тыс. специалистов в сфере ОПК' [The Ministry of Industry and Trade announced the need for 140 thousand specialists in the defence industry], 12 July 2024, https://vpk.name/news/888665_v_minpromtorge_zayavili_o_neobhodimosti_140_tys_specialistov_v_sfere_opk.html.
23 Charter 97 (2023), 'Russian Defense Plants Face Record Shortage Of Qualified Personnel', 18 January 2023, https://charter97.org/en/news/2023/1/18/532745.
24 Luzin, P. (2022), 'Russia's Defense Industry Growing Increasingly Turbulent', *Eurasia Daily Monitor*, 19(173), 17 November 2022, https://jamestown.org/program/russias-defense-industry-growing-increasingly-turbulent; Gorenburg, D. et al. (2024), *Crafting the Russian War Economy: The Effects of Export Controls on Russia's Defense Industrial Production*, report, Arlington, VA: CNA, https://www.cna.org/reports/2024/10/crafting-the-russian-war-economy.

Since 2022, recruitment has been further complicated by military conscription and mobilization for the war in Ukraine, the use of temporary contractors and the 'brain drain' (see below), as well as trade-offs within the economy, with other industries requiring an increased workforce.[25] OPK companies are also competing against each other, offering incentives to attract recruits.

The personnel gap is compounded by an age gap in the industry. OPK workers are generally older than those in most other sectors. The disparity is particularly stark in design bureaus and research centers, where the average age is over 70.[26] Younger workers are generally not incentivized to work for the OPK, as they favour other parts of the private sector or migration.[27] Indeed, young people generally no longer perceive the OPK as a source of prestige or career development. To remedy the situation, the government is trying to incentivize college and university students to enroll in OPK companies.[28] For example, the Ministry of Education and Science has created several programmes to entice young workers.[29] Rostec has also been recruiting directly from universities.[30]

In the context of COVID-19, the OPK also introduced more stringent working conditions to keep ever-increasing production quotas on track and boost labour productivity. These measures include cutting paid holidays, lengthening work shifts and mandating overtime, as well as the introduction of six-day working weeks or round-the-clock production.[31] However, official claims that the OPK is working 'almost around the clock'[32] must be tempered by reality. In most cases, companies cannot pay their staff for the extra shifts required, lack the necessary qualified workers or both. Sustained higher production rates are also putting pressure on production tools and machinery (see below).

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25 Gorenburg et al. (2024), *Crafting the Russian War Economy*; *Noviye Izvestia* (2023), 'В бой идут старики: оборонные заводы страны не могут набрать рабочих' [Old men go into battle: the country's defence plants can't recruit workers], 19 January 2023, https://newizv.ru/news/2023-01-19/v-boy-idut-stariki-oboronnye-zavody-strany-ne-mogut-nabrat-rabochih-394312; Ismailov, A. (2023), "Everything for the Front!' How War Is Changing Russia's Labor Market', The Moscow Times, 4 December 2023, www.themoscowtimes.com/2023/12/04/everything-for-the-front-how-war-is-changing-russias-labor-market-a83311.
26 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.
27 Engvall, J. (2021), *Russia's Military R&D Infrastructure – A Primer*, report, Stockholm: Swedish Defence Research Agency, https://www.foi.se/rapporter/rapportsammanfattning.html?reportNo=FOI-R--5124--SE.
28 *Izvestia* (2024), 'Кравцов сообщил о работе более 90 тыс. студентов колледжей на предприятиях ОПК' [Kravtsov reported more than 90,000 college students working at OPK companies], https://iz.ru/1768561/2024-10-02/kravtcov-soobshchil-o-rabote-bolee-90-tys-studentov-kolledzhei-na-predpriiatiiakh-opk.
29 Rostec via *Novosti VPK* (2024), 'Сергей Чемезов: Уже сегодня мы формируем заделы для постпобедного периода' [Sergei Chemezov: Today we are already laying the groundwork for the post-victory period], 20 June 2024, https://vpk.name/news/878808_sergei_chemezov_uzhe_segodnya_my_formiruem_zadely_dlya_postpobednogo_perioda.html.
30 TASS via *Novosti VPK* (2024), 'Ростех запустит два новых трека подготовки специалистов для предприятий ОПК' [Rostec to launch two new tracks for training specialists for defence industry enterprises], 15 August 2024, https://vpk.name/news/902516_rosteh_zapustit_dva_novyh_treka_podgotovki_specialistov_dlya_predpriyatii_opk.html.
31 Boulègue, M. (2020), 'How is the Russian Military Responding to COVID-19?', War on the Rocks, 4 May 2020, https://warontherocks.com/2020/05/how-is-the-russian-military-responding-to-covid-19; Kazakova, D. (2023), 'Главный танковый завод РФ придумал, как решить проблему с кадрами' [Russia's main tank plant has figured out how to solve its personnel problem], URA, 1 March 2023, https://ura.news/news/1052630070; The Moscow Times (2023), 'Russian Defense Chief Says Military Factories Working 'Around the Clock", 2 January 2023, https://www.themoscowtimes.com/2023/01/02/russian-defense-chief-says-military-factories-working-around-the-clock-a79864; Gorenburg et al. (2024), *Crafting the Russian War Economy*.
32 TASS (2023), 'Чемезов: задействованные в выполнении ГОЗ заводы Ростеха работают в новогодние праздники' [Chemezov: Rostec plants involved in fulfilment of the state defence order are working on New Year holidays], 2 January 2023, https://tass.ru/ekonomika/16732727.

More fundamentally, workforce productivity in the military industry has never been strong and remains generally low. Beside the initial boost from state-sponsored propaganda encouraging support for the war, OPK workers are given no genuine incentives to improve their productivity, motivation or skills. Instead, there are many disincentives such as non-competitive salaries, bad working conditions, an absence of strong management, secrecy around military-industrial production and corruption.

Finally, the OPK labour market is affected by the ongoing 'brain drain' of young workers from Russia.[33] An exodus of young talent started before the 2014 invasion of Ukraine and a decade of war has only encouraged it further. The 'brain drain' affects many economic sectors in Russia, but particularly the IT industry and applied sciences. An estimated 70,000 Russian IT specialists have left the country since 2022.[34] This situation is compounded by the general decline in the quality of higher and scientific education since the 1990s[35] – a larger issue often referred to as 'degraded science' (see below).

These workforce deficiencies are a reminder that the OPK has a crucial social responsibility in Russia, as well as economic and military roles. In many cities across the country, the OPK remains a major (and sometimes the only) source of employment. Regardless of the war, OPK companies *must* stay operational – if just to guarantee social stability.

Industrial over-concentration

Partly to address the problems of pricing and OPK unprofitability discussed above, the post-Soviet military industry was restructured in the 2000s and consolidated around major state-owned consortiums and corporations.[36] The main player to this day remains Rostec, which concentrates about 75 per cent of all military-industrial companies under its control.[37] The initial goal of this restructuring was to boost Russian domestic and international competitiveness, decrease production costs, reduce duplication of effort and consolidate the industry at large.[38]

However, in practice, the integration of companies within larger 'industry champions' did not meet expectations. Indeed, consolidation failed to address pre-existing industrial production bottlenecks, while companies in bad financial shape were absorbed by others without their problems being addressed (as, for instance, with the Almaz-Antey merger or the integration of Ilyushin with Sukhoi and Irkut with United Aircraft Corporation).

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33 Herbst, J. E. and Erofeev, S. (2019), *The Putin exodus: The new Russian brain drain*, Washington, DC: The Atlantic Council Eurasia Center, https://www.atlanticcouncil.org/in-depth-research-reports/report/the-putin-exodus-the-new-russian-brain-drain-3; Talanova, D. (2023), 'The great Russian brain drain', *Novaya Gazeta*, 19 August 2023, https://novayagazeta.eu/articles/2023/08/19/the-great-russian-brain-drain-en.
34 Lehtinen, S., Saari, S. and Suominen, A. (2022), *Russia's technological policy and knowhow in a competitive global context*, Helsinki: Prime Minister's Office of Finland, https://www.fiia.fi/wp-content/uploads/2022/06/russias-technological-policy-and-knowhow-in-a-competitive-global-context.pdf.
35 Persson, G. et al. (2016), *Russian Military Capability in a Ten-Year Perspective – 2016*, report, Stockholm: Swedish Defence Research Agency, https://www.foi.se/en/foi/reports/report-summary.html?reportNo=FOI-R--4326--SE.
36 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.
37 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
38 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.

Industrial consolidation tends to diminish competition, as it reduces the pool of available manufacturers,[39] especially small and medium-sized private companies.[40] Furthermore, concentration often leads to hidden structural deficiencies, bureaucracy and corruption further away from official scrutiny.

Consolidation of the OPK has also led to the emergence of Rostec as a de facto monopoly within segments of Russia's military-industrial production. This over-concentration started with the takeover of bankrupt UralVagonZavod and KurganMashZavod in late 2016[41] and continued with the acquisition of United Aircraft Corporation in 2018[42] to cement Rostec's dominance in the aeronautical sector. Before the 2022 invasion of Ukraine, Rostec was also linked with the absorption of United Shipbuilding Corporation. Yet the emergence of Rostec as an industrial monopoly has arguably stifled not only competition in the OPK, but also its R&D capacity and innovation more generally.

The VPK gives President Putin a form of 'manual control' over major defence-industrial decisions by putting him in the powerful role of conflict mediator and arbiter between the main industry players and their grievances.

To help streamline decisions between key players of the military-industrial complex, the Russian government recentralized the decision-making process under the Military-Industrial Commission (VPK). The constant infighting between OPK leaders, the Ministry of Defence, and the Ministry of Industry and Trade over budget, price formation and lobbying forced the Kremlin's hand in 2013, and the VPK was created to help defuse tensions. The commission also gives President Putin a form of 'manual control' over major defence-industrial decisions by putting him in the powerful role of conflict mediator and arbiter between the main industry players and their grievances.

The VPK serves several other functions, including reporting on the outcomes of key decisions, a discussion and lobbying platform between stakeholders and a decision-making function for anything linked to the GPV and the GOZ. The role of the VPK was strengthened in May 2023 with the nomination of new board members,[43] including deputy prime minister Yury Trutnev, head of the Chief Directorate for Special Programs of the President Alexander Linets, Colonel General

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39 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
40 Päiväläinen and Rajala (2020), *Competitiveness of Russia's Defence Industry*.
41 Bodner, M. (2017), 'Rostec to swallow Russia's premier battletank maker', Defense News, 25 April 2017, https://www.defensenews.com/land/2017/04/25/rostec-to-swallow-russias-premier-battletank-maker.
42 Russian Aviation Insider (2018), 'Rostec gains control over Russia's United Aircraft Corporation', 25 October 2018, https://www.rusaviainsider.com/rostec-gains-control-russia-united-aircraft-corporation.
43 President of the Russian Federation (2023), 'Указ Президента Российской Федерации от 29.05.2023 № 390 "О некоторых вопросах деятельности Военно-промышленной комиссии Российской Федерации и полномочных представителей Президента Российской Федерации в федеральных округах"' [Decree of the President of the Russian Federation of 29.05.2023 No 390 "On Certain Issues of the Activities of the Military-Industrial Commission of the Russian Federation and Plenipotentiary Representatives of the President of the Russian Federation in the Federal Districts"], presidential decree, 29 May 2023, http://publication.pravo.gov.ru/document/0001202305290027?index=1.

Vasily Tonkoshkurov as first deputy chairman, and head of the FSB scientific and technical service Mikhail Mikhailov. The presence of Security Council secretary (and former defence minister) Sergey Shoigu, Security Council deputy chairman (and former president of the federation) Dmitry Medvedev and Putin aide Alexei Dyumin further strengthens the Kremlin's influence over the OPK.

Lack of industrial coherence and structural flaws

Before the 2022 war, the strategic imperative of the OPK was to realize a 'conversion' of the industry. Considering the above economic and financial factors, as well as the impact of the 2014 sanctions, the government had pushed the OPK to adopt a dual policy of 'civilianization' and diversification of production. The official pre-war objectives were to pivot towards civilian and dual-use production to generate more revenue for OPK companies – especially in the face of reduced state orders under GPV 2027. Initial targets from 2016 sought to increase the share of civilian and dual-use production to 30 per cent of the total OPK output by 2025 and 50 per cent by 2030.[44]

Unsurprisingly, the 'conversion' of the OPK has so far been a failure.[45] The onset of war and the subsequent shift to a war economy broke all hopes of achieving official targets. OPK companies do not have production chains adapted to the serial production of civilian goods, especially without initial capital investment or state subsidies.

Another structural deficiency relates to the OPK's inability to fulfil the production surge to meet the demands of the armed forces in the context of the war. A key priority of GPV 2027 was already to prepare for surges in 'serial and uninterrupted production of military hardware'.[46] Yet the absence of investment to finance the expansion of production lines severely constrained manufacturers. Since 2022, the OPK has been struggling to match requests for ever-increasing production volumes and to modernize their production lines.[47] Indeed, surge production has been degrading production tools faster than they can be upgraded, although certain segments of the OPK have been faring better than others – for instance, drones and armoured vehicles.[48]

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44 TASS via *Novosti VPK* (2024), 'Мантуров сообщил о росте доли высокотехнологичной продукции гражданского назначения в ОПК' [Manturov announced an increase in the share of high-tech civilian products in the defense industry], 2 July 2024, https://vpk.name/news/883703_manturov_soobshil_o_roste_doli_vysokotehnologichnoi_produkcii_grazhdanskogo_naznacheniya_v_opk.html.
45 *Nezavisimoye voyennoye obozreniye* via *Novosti VPK* (2020), 'Оздоровление предприятий ОПК – приоритет власти' [Recovery of defence industry enterprises is a priority of the authorities], 17 February 2020, https://vpk.name/news/375160_ozdorovlenie_predpriyatii_opk_prioritet_vlasti.html; Bolshakova, E. (2020), 'Рынок с ароматом ГОЗ' [Market with the aroma of GOZ], *Kommersant*, 18 March 2020, https://www.kommersant.ru/doc/4290231.
46 President of the Russian Federation (2017), 'Совещание с руководством Минобороны, оборонно-промышленного комплекса, главами министерств и регионов' [Session with the leadership of the Defence Ministry, military-industrial complex, and heads of ministries and regions], 22 November 2017, http://kremlin.ru/events/president/news/56150.
47 Boulègue, M. (2017), 'Russia's New State Armament Programme Offers a Glimpse at Military Priorities', Chatham House Expert Comment, 27 November 2017, https://www.chathamhouse.org/expert/comment/russia-s-new-state-armament-programme-offers-glimpse-military-priorities.
48 Ovsyaniy, K. (2023), 'Satellite Images Suggest Russia Is Ramping Up Production Capacity For Its War Against Ukraine', Radio Free Europe/Radio Liberty, 1 November 2023, https://www.rferl.org/a/russia-ramping-up-war-production/32658857.html; TASS via *Nezavisimoye voyennoye obozreniye* (2023), 'В этом году производство бронетанкового вооружения в РФ выросло втрое – Мишустин' [This year, the production of armored weapons in the Russian Federation has tripled – Mishustin], 5 December 2023, https://nvo.ng.ru/news/782793.html.

The current situation is compounded by the challenges of modernizing military hardware. Pre-2022, the OPK was busy carrying out the 'modernization' of the majority of Russian military systems in service in the armed forces. Modernization in the Russian context entails a combination of procuring genuinely new systems and upgrading existing and legacy platforms to make them look 'modern'.[49] In truth, modernization represents a 'gap filler'[50] to compensate for the absence of new hardware.[51] The modernization effort largely rests on upgrading Soviet-era systems in targeted increments and maximizing the active service life of legacy systems. This is in line with the current war effort against Ukraine, where mass is necessary to overcome existing deficiencies.

Due to the impact of sanctions and the war in Ukraine, the OPK is currently struggling to build *genuinely* new and technologically advanced systems.[52] Instead, it is relying on Soviet legacy systems and research.[53] Despite top–down pressure to build 'new' systems, the armed forces have less incentive to try out such systems than to rely on combat-proven hardware already employed in the war. This situation is discouraging military innovation and leading instead to a simplification of OPK production based on 'proven', basic and cheap systems.

The modernization effort largely rests on upgrading Soviet-era systems in targeted increments and maximizing the active service life of legacy systems.

The OPK is also fragilized by corruption. Endemic corruption is a defining feature of the OPK and, more widely, of the Russian military.[54] Corruption facilitates the inner workings of the military establishment.[55] The shift to the war economy since 2022 and the subsequent increase in defence spending have brought about more opportunities for corrupt business practices, therefore inevitably leading to spiraling production costs, delays and unmet quotas.[56]

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49 Russian Defense Policy blog (2017), 'What Does Modern Mean?', 18 November 2017, https://russiandefpolicy.blog/2017/11/18/what-does-modern-mean.
50 Oxenstierna, S. (2019), *Russian Military Capability in a Ten-Year Perspective – 2019*, report, Stockholm: Swedish Defence Research Agency, https://www.foi.se/report-summary?reportNo=FOI-R%E2%80%934758%E2%80%93SE.
51 Bendett, S. et al. (2021), *Advanced military technology in Russia*, Research Paper, London: Royal Institute of International Affairs, https://www.chathamhouse.org/2021/09/advanced-military-technology-russia.
52 Boulègue et al. (2024), *Assessing Russian plans for military regeneration*.
53 James Martin Center for Nonproliferation Studies (2023), 'Forecasting Russian Military Innovation: The Role of Soviet "Zombie Weapons"', Monterey, CA: Middlebury Institute of International Studies, https://nonproliferation.org/forecasting-russian-military-innovation-the-role-of-soviet-zombie-weapons.
54 Outhwaite, R. (2023), *A Corrosion of Corruption: The Parlous state of the Russian military*, report, London: Action on Armed Violence, https://aoav.org.uk/2023/the-corrosion-of-corruption-the-state-of-the-russian-military.
55 Beliakova, P. and Perlo-Freeman, S. (2018), *Corruption in the Russian Defense Sector*, Somerville, MA: World Peace Foundation, https://worldpeacefoundation.org/wp-content/uploads/2024/03/Russian-Defense-Corruption-Report-Beliakova-Perlo-Freeman-20180502-final.pdf; Gorenburg et al. (2024), *Crafting the Russian War Economy*.
56 Snegovaya et al. (2024), *Back in Stock? The State of Russia's Defense Industry after Two Years of the War*.

There is no genuine oversight or willingness in government to tackle this problem, with the exception of several 'corruption cases' affecting minor consultants and subcontractors to the OPK.[57] Rather than acting as a deterrent, such cases – which invariably target small-scale operators and not the most influential ones – only serve as useful reminders for industry players to avoid being too greedy and to play by established rules. Recent high-profile cases must be seen as examples of political infighting, rather than genuine anti-corruption measures.[58]

Finally, the OPK remains afflicted by quality control issues. Quality control standards were severely degraded after the end of the Cold War. The reintroduction of embedded agents of the Military Representation Bureau directly inside OPK companies does not seem to have solved the problem.[59] Furthermore, the presence of military inspectors conducting random audits does not solve the wider issues of decrepit production tools, low workforce motivation and productivity, or the use of sub-standard components. The armed forces are now regularly experiencing faulty systems, resulting in accidents and misfires.[60]

Quality control issues also extend to subcontractors, with coordination among them lacking.[61] If subcontractors fail to meet production deadlines, there are few alternative inputs available to systems integrators, thereby provoking bottlenecks along the production value chain and delays in order fulfilment.

Outdated production chains and procurement difficulties

The existing weaknesses discussed above are compounded by inherent flaws in specific sectors of the Russian military industry. These sectoral 'Achilles' heels'[62] have been further fragilized by war and sanctions, and especially limited internal and external procurement alternatives. They are also a testament to the OPK's general state of technological backwardness, outdated production chains and aging equipment along the industrial value chain.[63] These failings are due largely to the inability of the OPK to meet the technological challenges of local production of materiel that were previously imported, to enhance domestic manufacturing capabilities, and to adapt and scale-up production lines.[64]

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57 Sentorov, Y. (2024), 'В модернизации вооружений нашлось место для хищений' [There was room for theft in the modernization of weapons], *Kommersant*, 18 March 2024, https://www.kommersant.ru/doc/6578618; Sergeyev, N. (2024), 'Деньги «Роскосмоса» исчезли в барокамере' [Roscosmos money disappeared in a hyperbaric chamber], *Kommersant*, 18 March 2024, https://www.kommersant.ru/doc/6633738.
58 Cooney, C. (2024), 'Russian deputy defence minister Timur Ivanov accused of taking bribes', BBC News, 24 April 2024, https://www.bbc.com/news/world-europe-68886406; Papachristou, L. (2024), 'Russia detains former deputy defence minister for suspected fraud as corruption probe deepens', Reuters, 29 August 2024, https://www.reuters.com/world/europe/russia-opens-fraud-case-against-former-deputy-defence-minister-2024-08-29.
59 *Nezavisimoye voyennoye obozreniye* via Novosti VPK (2011), 'Военные представительства опять режут по живому' [Military representatives prove to be harsh once again], 15 June 2011, http://vpk.name/news/53830_voennyie_predstavitelstva_opyat_rezhut_po_zhivomu.html.
60 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
61 Frolov, A. (2018), *Russian Defense Procurement in 2017*, Moscow Defense Brief No. 4, Moscow: CAST.
62 Connolly and Boulègue (2018), *Russia's New State Armament Programme.*
63 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
64 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.

Constant requirements for the war effort and cumulative rounds of sanctions have created shortages of specific components that the OPK often has to swap for lower-quality and less sophisticated alternatives.[65] The list of industrial bottlenecks and critical dependencies have so far been recorded in the following sectors:[66]

- Microelectronic components, especially optical systems and microchips;
- Metalworking machine tools and precision machine-building tools;
- Aircraft, helicopter and naval propulsion systems;
- Space-grade technologies and components;
- Special steels and reinforced metallurgical products for armored vehicles; and
- Bearings for armored vehicles.

Microelectronic components

Microelectronics are paramount to the production of military hardware. But Russia's access to quality dual-use electronic components, microchips and microprocessors, advanced optical systems and space-grade components has been severely constrained by sanctions.[67] The war in Ukraine has exposed Russia's critical dependency on Western components for the 'silicon lifeline'[68] of dual-use computer chips, semiconductors and electronics used in advanced systems.[69]

Post-2014, the OPK failed to stockpile enough components to support continued warfare against Ukraine. Indigenous import substitution efforts failed to achieve the intended effects, not least because the national tech manufacturing industry remains underdeveloped. Western standards for the production of semiconductors and military-grade electronic components are higher.[70] Components bought 'off the shelf' through third-party imports – the vast majority from China – also do not fully meet integration requirements for Russian hardware.[71] The most advanced components remain, for now, Western-made.

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65 Bergmann, M. et al. (2023), *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry*, Washington, DC: Center for Strategic and International Studies, https://www.csis.org/analysis/out-stock-assessing-impact-sanctions-russias-defense-industry; Connolly, R. (2023), 'Russia's Defense Industry', in Kendall-Taylor, A. et al. (2023), *Identifying Russian Vulnerabilities and How to Leverage Them*, report, Washington, DC: Center for a New American Security, https://www.cnas.org/publications/reports/identifying-russian-vulnerabilities-and-how-to-leverage-them.
66 Connolly and Boulègue (2018), *Russia's New State Armament Programme*; Bergmann et al. (2023), *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry*.
67 Petrova, V. and Galieva, D. (2022), 'Чипонезависимость со скидкой' [Chip independence with a discount], *Kommersant*, 15 November 2022, https://www.kommersant.ru/doc/5667792.
68 Byrne, J. et al. (2022), *Silicon Lifeline: Western Electronics at the Heart of Russia's War Machine*, London: Royal United Services Institute, https://www.rusi.org/explore-our-research/publications/special-resources/silicon-lifeline-western-electronics-heart-russias-war-machine.
69 Rácz, A., Spillner, O. and Wolff, G. (2023), *Russia's War Economy: How Sanctions Reduce Military Capacity*, policy brief, Berlin: Forschungsinstitut der Deutschen Gesellschaft für Auswärtige Politik, https://www.ssoar.info/ssoar/bitstream/handle/document/86644/ssoar-2023-racz_et_al-Russias_War_Economy_How_Sanctions.pdf; Bilousova, O. et al. (2023), *Russia's Military Capacity And The Role Of Imported Components*, Kyiv: Kyiv School of Economics Institute, https://kse.ua/wp-content/uploads/2023/06/Russian-import-of-critical-components.pdf.
70 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
71 Komrakov, A. (2023), 'Китай не хочет делиться с Россией всеми технологическими секретами' [China Does Not Want to Share All Its Technological Secrets with Russia], *Nezavisimaia Gazeta*, 15 January 2023, https://www.ng.ru/economics/2023-01-24/1_8642_china.html.

As a result, the OPK is often left with no choice other than to reduce standards by retrofitting systems with less advanced electronic or optical technology. All these adaptations and workarounds lead to systems that are cheaper and more numerous, but less reliable, which causes errors, ammunition misfires and accidents – a particularly problematic feature in kill chains for target acquisition and precision strikes, as well as ammunition maintenance.[72]

Machine-building tools

Machine-building tools are another critical 'Achilles heel' of the OPK. These include metalworking machine tools, such as laser-cutting tools and lathes, and other computer numerical control machine tools employed in military hardware manufacturing.[73] Expert estimates vary somewhat, but between 70 and 90 per cent of machine tools and associated spare parts used in Russia across all sectors are imported from abroad (mostly from Germany, Italy and other European countries, Japan and the US).[74] Furthermore, the OPK uses between 70 and 80 per cent of all machine tools available in Russia.

Expert estimates vary somewhat, but between 70 and 90 per cent of machine tools and associated spare parts used in Russia across all sectors are imported from abroad.

Under the impact of sanctions since 2014, the OPK has had to adapt by cannibalizing existing machine tools from the civilian industry, while timidly increasing domestic manufacturing.[75] Mitigation policies started in 2014, with several programmes aimed at limiting foreign imports to reduce dependency in favour of internal manufacturing.[76] These policies have mostly failed so far, and recent updates continue to set unrealistic short-term goals – such as internally producing over half of the machine tools used.[77] Reverse engineering foreign-made machine tools also did not provide a solid alternative, not least because of the inability to produce components and parts to high standards.

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72 Martin, B., Barnett, D. S. and Mccarthy, D. (2023), *Russian Logistics and Sustainment Failures in the Ukraine Conflict*, research report, Santa Monica, CA: RAND Corporation, https://www.rand.org/pubs/research_reports/RRA2033-1.html.
73 Malmlöf, T. (2019), *Russian Machine Tool Industry – Prospects for a Turnaround?*, Stockholm: Swedish Defence Research Agency, https://www.foi.se/rapportsammanfattning?reportNo=FOI-R--4635--SE.
74 Bergmann et al. (2023), *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry*; Luzin, P. (2023), 'Lagging Production of Machine Tools and Parts Plagues Russian Military-Industrial Complex', *Eurasia Daily Monitor*, 20(184), https://jamestown.org/program/lagging-production-of-machine-tools-and-parts-plagues-russian-military-industrial-complex; Borovikov, O. (2024), *Ore to Ordnance: Disrupting Russia's Artillery Supply Chains*, RUSI and Open Source Centre, https://static.opensourcecentre.org/assets/osc_ore_to_ordnance.pdf; Cooper, J. (2024), 'The machine tool industry of Russia at a time of war and sanctions', *Post-Communist Economies*, 36(5), pp. 527–61, https://doi.org/10.1080/14631377.2024.2325787; Mashnews (2023), 'Ростех: доля импорта станков в РФ сократится менее чем до 50%' [Rostec: the share of machine tool imports to Russia will decrease to less than 50%], 23 August 2023, https://mashnews.ru/rostex-dolya-importa-stankov-v-rf-sokratitsya-menee-chem-do-50.html.
75 Cooper (2024), 'The machine tool industry of Russia at a time of war and sanctions'.
76 Ibid.
77 Ibid.; Government of the Russian Federation (2020), 'Стратегия развития станкоинструментальной промышленности на период до 2035 года' [Strategy for the Development of the Machine Tool Industry Until 2035], Government Decree, 5 November 2020, http://static.government.ru/media/files/NyeLKqLhrJrydnGRBm39nHl0hJNOzHzQ.pdf.

The main solution has therefore been to acquire machine tools from abroad, mainly from China. But this approach has resulted in Russia replacing one foreign dependency with another: the share of imported tools from China grew from 13 per cent to almost 90 per cent in 2023.[78] Russia is now seeking to diversify third-party imports to other sources.[79] However, imported machine tools are generally of lesser quality than their Western counterparts and fail to meet OPK precision requirements and standards.

Another issue relates to the life cycle of Western-made machine tools.[80] As the OPK stretches the operational life of existing imported machines, it needs to balance overuse with lack of access to spare parts and additional components required to keep machinery running.[81] As high-standard machines wear out, production of existing designs will undoubtedly slow down.

The situation may force certain companies to scale down industrial production, which risks GOZ requirements not being met. Finally, as well as machine-building tools themselves, Russia is missing special steels and metallurgic products necessary to machine into military hardware – especially rail bearings.[82]

The conflict against Ukraine has created a form of 'bubble', in which the OPK is evolving beyond economic rationality or industrial logic to meet the constant demands of the war machine,[83] as well as provide a form of socio-economic stability for the Russian Federation. For the time being, the OPK will therefore regress in terms of quality of output but endure – although without addressing any of the chronic weaknesses affecting it.

The question of whether the government plans to address these long-term issues will have to wait until after the end of the war – although the OPK expects that the 'volumes of military production will remain high for a long time'.[84] Meanwhile, the OPK is adapting internally, and with the help of other partners and foreign countries, to sustain the war and cushion the impact of sanctions.

The impact of sanctions and war, and how the OPK is adapting

International sanctions and the breakdown of cooperation with the Ukrainian military industry as a result of the war have posed a 'serious challenge' for the OPK.[85] It has been unable to regenerate and maintain stocks of critical components, as well as remaining dependent on imported Western components and industrial

78 Luzin, P. (2024), 'Chinese Machine Tools Serve as Russia's Safety Net', *Eurasia Daily Monitor*, 21(9), https://jamestown.org/program/chinese-machine-tools-serve-as-russias-safety-net.
79 Cooper (2024), 'The machine tool industry of Russia at a time of war and sanctions'.
80 Boulègue et al. (2024), *Assessing Russian plans for military regeneration*.
81 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
82 Bergmann et al. (2023), *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry*.
83 Luzin, P. (2023), *Russia's Military Industry Forecast 2023–2025*, Philadelphia: Foreign Policy Research Institute, https://www.fpri.org/article/2023/04/russias-military-industry-forecast-2023-2025.
84 Potapov, I. (2024), 'Чемезов рассказал об ОПК после завершения СВО' [Chemezov spoke about the defense industry after the completion of the NWO], Lenta.ru, 22 August 2024, https://lenta.ru/news/2024/08/22/chemezov-rasskazal-ob-opk-posle-zaversheniya-svo.
85 Regiony Online (2016), 'Importozameshchenie – "blesk I nishcheta" rossiiskogo oboronno-promyshlennogo kompleksa' [Import sanctions – the "rise and fall" of the Russian military-industrial complex], 18 January 2016, http://www.gosrf.ru/news/21738.

equipment.[86] Indeed, a general rule of thumb is that the more advanced a Russian weapons system is, the more dependent its production is on foreign imports.[87]

Russia has continued to have access to sanctioned Western dual-use and military-grade components and technology, especially after the imposition of sanctions in 2014.[88] There are also many examples of alternative procurement structures, third-party imports and networks aimed at bypassing current restrictions.[89]

The OPK – and the Russian government more generally – have learned to adapt to these challenges in many ways, including through domestic changes (such as internal production, import substitution programs), with external partners (such as third-party imports, co-production and foreign partnerships), as well as through other methods (including black-market acquisitions and other illegal procurement networks). The Kremlin still benefits from insufficient enforcement of international sanctions, loose secondary sanctions regimes and gaps in export control regulations.[90]

Domestic adaptations

Stockpile (mis)management

Since 2014, the OPK has had to find a balance between depleting existing stocks of components and hardware to prosecute the war, procuring ammunition and platforms from already stretched production chains, and retrofitting and cannibalizing Soviet legacy platforms.

Depleting existing stocks of materials, components and ammunition became the default, short-term solution at the onset of the 2022 invasion of Ukraine.[91] But depletion of existing stockpiles without proper replacement strategies quickly led to shortages of components, especially for expensive parts such as precision-guided munitions.

This situation affected successive equipment deliveries in the following years as part of GOZ.[92] Furthermore, attempts to stockpile certain components did not meet the requirements of the war, as stocks quickly depleted.[93] Moreover, when stocks were available, they did not always meet quality requirements – especially for ammunition – and were unusable as a result.[94]

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86 Boulègue et al. (2024), *Assessing Russian plans for military regeneration*; Bilousova et al. (2023), *Russia's Military Capacity And The Role Of Imported Components*.
87 Luzin (2023), 'Lagging Production of Machine Tools and Parts Plagues Russian Military-Industrial Complex'.
88 Baker, S. and Krasnolutska, D. (2024), 'Russian Weapons, American chips: How a weapon packed with US technology killed a 6-year-old girl in Ukraine', Bloomberg, 2 October 2024, https://www.bloomberg.com/features/2024-russian-missiles-us-tech-ukraine.
89 Bilousova et al. (2023), *Russia's Military Capacity And The Role Of Imported Components*; Watling, J. and Somerville, G. (2024), *A Methodology for Degrading the Arms of the Russian Federation*, occasional paper, London: Royal United Services Institute, https://www.rusi.org/explore-our-research/publications/occasional-papers/methodology-degrading-arms-russian-federation; Ukrainska Pravda (2023), 'Russia's military-industrial complex is gaining momentum. Where does the money come from, and who helps Russia produce missiles?'.
90 Boulègue et al. (2024), *Assessing Russian plans for military regeneration*; Bilousova, O. et al. (2023), *Russia's Military Capacity And The Role Of Imported Components*.
91 Stewart, P. and Ali, I. (2022), 'Burning through ammo, Russia using 40-year-old rounds, U.S. official says', Reuters, 12 December 2022, https://www.reuters.com/world/europe/burning-through-ammo-russia-using-40-year-old-rounds-us-official-says-2022-12-12; Luzin (2023), *Russia's Military Industry Forecast 2023–2025*; Malmlöf, T. (2023), *Russia's defence industry at war: Can it live up to expectations?*, Stockholm: Swedish Defence Research Agency, September 2023, https://www.foi.se/rest-api/report/FOI%20Memo%208231.
92 Malmlöf (2023), *Russia's defence industry at war*.
93 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
94 Martin, Barnett and McCarthy (2023), *Russian Logistics and Sustainment Failures in the Ukraine Conflict*.

As part of its stockpile management, the OPK was forced to reuse and retrofit Soviet legacy equipment.[95] Outdated and lower-quality hardware therefore increasingly entered the battlefield in Ukraine – going back as far as T-54 and T-55 main battle tanks, for instance.[96] The OPK also learned to cannibalize civilian equipment for military purposes, from household appliances[97] to passenger aircraft.[98] The industry also chose to limit exports of military equipment to meet domestic requirements for the war effort.[99]

Using existing stockpiles in different shapes and forms is not a panacea for the OPK's problems, but remains a valuable adaptation in the short term.

Using existing stockpiles in different shapes and forms is not a panacea for the OPK's problems, but remains a valuable adaptation in the short term. Indeed, low-quality equipment and ammunition have not prevented Russia from prosecuting its war on Ukraine – especially since attritional, mass warfare strategies do not necessarily require advanced systems and high-end technology.[100]

Domestic production and import substitution

Attempts to ramp up domestic production have had varying results, as surge production capabilities are affected by the chronic weaknesses in the OPK discussed above. Some manufacturing facilities and production chains have been adapted to increase the output,[101] but various attempts at reverse engineering have proved unsuccessful.[102]

A key feature of Russian attempts to adapt to the war and sanctions was the creation of import-substitution programmes. Two such programmes (one for supplies sourced from Western countries and one for Ukraine) were set up in 2014.[103] The initial target required 85 per cent of imported military components to be replaced with local production by 2025[104] – an ambitious goal that even the Kremlin recognized would be impossible to meet.[105]

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95 The Moscow Times (2023), 'Russia Pulls Thousands of Soviet-Era Military Vehicles From Major Storage Facility', 8 August 2023, https://www.themoscowtimes.com/2023/08/08/russia-pulls-thousands-of-soviet-era-military-vehicles-from-major-storage-facility-a82088.
96 Cotovio, V., Sebastian, C. and Bourke, M. (2023), 'Russia is sending museum pieces into war, but experts say they may still be effective', CNN, 8 May 2023, https://www.cnn.com/2023/05/08/europe/russia-t-55-tanks-ukraine-intl-cmd/index.html.
97 Whalen, J. (2022), 'Sanctions forcing Russia to use appliance parts in military gear, U.S. says', *Washington Post*, 11 May 2022, https://www.washingtonpost.com/technology/2022/05/11/russia-sanctions-effect-military.
98 Bergmann et al. (2023), *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry*.
99 Mosolova, D. and Stognei, A. (2024), 'Russian arms group warns it may halt exports as Ukraine war demands surge', *Financial Times*, 23 October 2024, https://www.ft.com/content/b81b340d-3b24-4c90-81d3-e29e281f85f7.
100 Snegovaya et al. (2024), *Back in Stock? The State of Russia's Defense Industry after Two Years of the War*.
101 Connolly (2023), 'Russia's Defense Industry'.
102 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
103 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.
104 TASS (2017), 'Путин поставил задачу сохранить темпы перевооружения армии и флота РФ' [Putin is aiming to maintain the rearmament rate for the Russian Navy], 12 April 2017, http://tass.ru/armiya-i-opk/4176307.
105 Government of the Russian Federation (2020), 'Стратегия: развития станкоинструментальной промышленности на период до 2035 года' [Strategy: development of the machine tool industry for the period up to 2035].

Unsurprisingly, import substitution has so far been a failure in most of the sectors impacted by the war – except for a small number of areas, including uncrewed aerial vehicles (UAVs) and certain artillery munitions. Many issues are yet to be addressed. These include, among others: inefficient state regulations; an inability to adapt production lines and cope with demand; an absence of facilitated loans or capital investment by OPK companies to implement the programmes; a lack of skilled workers; and increased component costs.

The main issue, however, is linked to cost controls for substituted production. Import substitution is simply not a cost-effective solution for OPK producers,[106] as it creates a 'securitization of the economy'[107] without actual economic rationality.

Attempts at adapting to sanctions have also been largely inefficient. The OPK simply cannot cope with demand and rising production costs – a situation that is even more critical in the more technologically advanced sectors of the industry.[108]

With time, the OPK will be forced to simplify its offer and limit production cycles both in terms of quantity and quality. Indeed, the OPK will rely on less advanced military-grade components and more on dual-use (and sometimes purely civilian) technology.[109] It also means that, in the short term at least, Russia must adapt with and through partners abroad.

Adaptation *with* and *through* external partners

In light of the OPK's inability to adapt internally, Russia was forced to quickly replace its critical dependency on Western-made dual-use and military components by another dependency on alternative foreign suppliers. Moscow has been evading sanctions for over a decade by directly importing Western and non-Western military and dual-use components and hardware from regional partners that have not joined the international sanctions regime.

To do so, Russia is using two distinct strategies:

- Parallel imports of sanctioned Western dual-use and military technology through third countries and other sanctions evasion schemes; and
- Assistance from partners such as Iran and North Korea to directly import finished systems, spare parts and components, in addition to joint projects and co-production.

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106 Malmlöf, T. (2016), 'A Case Study of Russo-Ukrainian Defense Industrial Cooperation: Russian Dilemmas', *The Journal of Slavic Military Studies*, 29(1), pp. 1–22, https://doi.org/10.1080/13518046.2015.1094941.
107 Lehtinen, Saari and Suominen (2022), *Russia's technological policy and knowhow in a competitive global context*.
108 *News.ru* (2023) 'Стало известно, в каких отраслях экономики Россия добилась импортозамещения' [It became known in which sectors of the economy Russia has achieved import substitution], 19 October 2023, https://news.ru/moskva/stalo-izvestno-v-kakih-otraslyah-ekonomiki-rossiya-dobilas-importozamesheniya.
109 Snegovaya et al. (2024), *Back in Stock? The State of Russia's Defense Industry after Two Years of the War*.

Parallel imports

Parallel imports allow the OPK to keep acquiring sanctioned Western-made items through countries that are not following the sanctions regime – mainly from Belarus, China, Iran, North Korea, South Caucasus and Central Asian countries or the United Arab Emirates (UAE).[110] Despite the problems described previously, these partnerships allow the OPK to bypass international sanctions in many sectors.

To do so, Russia relies on several semi-legal and illegal procurement and re-export tracks,[111] including:

- Black market acquisitions and smuggling networks;[112]
- Networks of non-sanctioned, non-Western intermediaries, suppliers and individual agents; and[113]
- Shell and front companies, and falsification of names, manifests and certificates in countries under sanction.[114]

Complex, and often untraceable, schemes now cover the globe. Several transshipment hubs exist, such as China and Hong Kong (for microelectronic components),[115] the UAE,[116] Iran, India, Central Asia (mostly Kazakhstan and Kyrgyzstan) plus the Russia-led Eurasian Economic Union,[117] Türkiye, Vietnam and Balkan states.

Direct external assistance

Non-Western third-party imports of off-the-shelf military hardware have increased exponentially since 2022. This increase is particularly pronounced the cases of Iran (for instance, attack drones and missiles), North Korea (ammunition and artillery rounds via the so-called 'Orient Express' rail and maritime supply routes),[118] and Belarus (armored vehicles).

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110 Gorenburg et al. (2024), *Crafting the Russian War Economy*; Rácz, Spillner and Wolff (2023), *Russia's War Economy*.
111 Ukrainska Pravda (2023), 'Russia's military-industrial complex is gaining momentum. Where does the money come from, and who helps Russia produce missiles?'; Bilousova et al. (2023), *Russia's Military Capacity And The Role Of Imported Components*.
112 Miroshnychenko, B. (2022), 'Контрабандна пухлина. Як Росія краде воєнні технології та що з цим робити' [Contraband tumor. How Russia steals military technology and what to do about it], *Ekonomichna Pravda*, 17 May 2022, https://www.epravda.com.ua/publications/2022/05/17/687111; Barnes, J. E., Schmitt, E. and Gibbons-Neff, T. (2023), 'Russia Overcomes Sanctions to Expand Missile Production, Officials Say', *New York Times*, 13 September 2023, https://www.nytimes.com/2023/09/13/us/politics/russia-sanctions-missile-production.html.
113 Miroshnychenko (2022), 'Контрабандна пухлина. Як Росія краде воєнні технології та що з цим робити' [Contraband tumor. How Russia steals military technology and what to do about it].
114 Snegovaya et al. (2024), *Back in Stock? The State of Russia's Defense Industry after Two Years of the War*.
115 Krollik, A. and Mozur, P. (2024), 'The Illicit Flow of Technology to Russia Goes Through This Hong Kong Address', *New York Times*, 25 July 2024, https://www.nytimes.com/2024/07/25/technology/russia-sanctions-chips.html.
116 Snegovaya et al. (2024), *Back in Stock? The State of Russia's Defense Industry after Two Years of the War*.
117 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
118 Byrne, J., Byrne, J. and Somerville, G. (2023), *The Orient Express: North Korea's Clandestine Supply Route to Russia*, report, London: Royal United Services Institute, https://rusi.org/explore-our-research/publications/commentary/report-orient-express-north-koreas-clandestine-supply-route-russia; Bermudez Jr., J. S., Cha, V. and Jun, J. (2023), 'Dramatic Increase in DPRK-Russia Border Rail Traffic After Kim-Putin Summit', Beyond Parallel, 6 October 2023, https://beyondparallel.csis.org/dramatic-increase-in-dprk-russia-border-rail-traffic-after-kim-putin-summit; DeYoung, K. (2023), 'North Korea provided Russia with Weapons, White House says', *Washington Post*, 13 October 2023, https://www.washingtonpost.com/national-security/2023/10/13/north-korea-russia-weapons-ukraine.

China is providing non-lethal assistance to Russia and facilitates exports of dual-use technology and components.[119] China has become the largest supplier of high-tech imports[120] (such as semiconductors and microelectronic components), machine-building tools (see above), telecommunications equipment, military-grade and dual-use spare parts, and vehicles. Although Chinese components are generally of lesser quality than the Western-made components they replace, the war and associated sanctions have created a form of overreliance on Chinese imports.[121]

In addition to direct and indirect military assistance from non-Western partners, Russia has been able to create and consolidate parallel import schemes, black market ventures, smuggling networks and complex semi-legal supplier deals.

However, all these adaptations together do not amount to a complete solution for the OPK. There are clear limits to third-party imports and sanctions evasion schemes such as additional costs, lower-quality components and substitutes, unpredictable deliveries, and delays in supplies.[122]

The situation is therefore not fully sustainable in the long term. The OPK will need to address domestic production challenges as a priority, as third-party imports can only ever be a stop-gap measure.[123] Furthermore, import gaps will likely force Russian companies to compete for access to components, which may lead to gradual production stagnation in several sectors (notably advanced weaponry)[124] as critical components become harder to source.

Assessing Russia's approach to military technology and innovation

Beyond military-industrial production and procurement, the Ukraine war and international sanctions have also damaged Russia's military-scientific base. This damage, in turn, affects the rate of military innovation and R&D. More importantly, it determines how the Kremlin will wage war in the future.

Russia's OPK never truly broke free from the Soviet legacy in its approach to military R&D and scientific innovation. The military-scientific base in fact carried over most of the negative traits and weaknesses that used to afflict Soviet research. These attributes still define the OPK's approach to military technology and innovation today.

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119 Sher, N. (2024), 'Behind the Scenes: China's Increasing Role in Russia's Defense Industry', commentary, Carnegie Politika, 6 May 2024, https://carnegieendowment.org/russia-eurasia/politika/2024/05/behind-the-scenes-chinas-increasing-role-in-russias-defense-industry?lang=en.
120 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
121 Snegovaya et al. (2024), *Back in Stock? The State of Russia's Defense Industry after Two Years of the War*.
122 Rácz, Spillner and Wolff (2023), *Russia's War Economy*; Bergmann et al. (2023), *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry*.
123 Popova, A. (2023), 'How to exploit Russia's addiction to Western technology', *Foreign Affairs*, 3 November 2023, https://www.foreignaffairs.com/china/how-exploit-russias-addiction-western-technology.
124 Exchange during a Chatham House online workshop organized in December 2024.

The Russian scientific and innovation base is highly securitized.[125] Officials depict modern military technology in existential terms[126] – military-scientific and -industrial innovation, R&D and the procurement of advanced technology are all understood as essential for 'great power' status and prestige, economic growth and sustained strategic competitiveness.[127] Military innovation is therefore informed by the Kremlin's worldview depicting Russia as a 'besieged fortress' and the need to protect national security interests from perceived Western encroachment on Russia's 'sphere of influence'.[128]

Military technology applications must respond to Russia's way of war – limited action, pre-emptive neutralization of threats, surprise and deception, asymmetric means and decisiveness.[129] However, these concepts come with the caveat that the Russian leadership is acutely aware that it cannot sustain technological competition with either the West or, increasingly, China.

Military technology applications must respond to Russia's way of war – limited action, pre-emptive neutralization of threats, surprise and deception, asymmetric means and decisiveness.

Russia simply does not have the military-scientific and innovation base able to catch up with the advances made elsewhere in the world. Nor does the Kremlin want to. Indeed, it has chosen to compete, often asymmetrically, in specific sectors as a way of leveraging what is left of Russia's military R&D capacity.[130]

Moscow has to employ such asymmetric methods because of the loss of conventional superiority in the context of the war and the 'growing capability gap' with the West.[131] Such asymmetric advantages are therefore not a total replacement. Russia will not be able to keep up the pace by deploying these methods, but merely 'narrow existing gaps' in targeted sectors.[132]

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125 Grisé, M. et al. (2025), *Russia's Military After Ukraine: Potential Pathways for the Postwar Reconstitution of the Russian Armed Forces*, Santa Monica, CA: RAND Corporation, January 2025, https://www.rand.org/pubs/research_reports/RRA2713-1.html.
126 Zysk, K. (2023), 'Struggling, Not Crumbling: Russian Defence AI in a Time of War', commentary, Royal United Services Institute, 20 November 2023, https://www.rusi.org/explore-our-research/publications/commentary/struggling-not-crumbling-russian-defence-ai-time-war.
127 Lehtinen, Saari and Suominen (2022), *Russia's technological policy and knowhow in a competitive global context*.
128 Renz, B. (2019), 'Russian responses to the changing character of war', *International Affairs*, 95(4), pp. 817–34, https://doi.org/10.1093/ia/iiz100.
129 *Voyenno-promyshlennyy kur'yer* via Novosti VPK (2019), 'Герасимов рассказал об ответе на американскую стратегию "Троянского коня"' [Gerasimov spoke about the response to the American Trojan horse strategy], 4 March 2019, https://vpk.name/news/255804_gerasimov_rasskazal_ob_otvete_na_amerikanskuyu_strategiyu_troyanskogo_konya.html; http://redstar.ru/vektory-razvitiya-voennoj-strategii.
130 Bendett et al. (2021), *Advanced military technology in Russia*.
131 Zysk (2023), 'Struggling, Not Crumbling: Russian Defence AI in a Time of War'.
132 Schwartz, P. (2019), 'Russian Science And Technology: Current State And Implications For Defense', in Blank, S. J. (ed.) (2019), *The Russian Military In Contemporary Perspective*, Strategic Studies Institute, US Army War College Press, https://www.jstor.org/stable/resrep20098.8?seq=1.

In this context, sanctions are weighing heavily on the OPK in terms of innovation and approach to military R&D. Furthermore, the war has revealed many shortcomings in Russia's military-scientific base and innovation capacity. Accordingly, Russia can only ever hope to be 'good enough' in terms of competing with its rivals.[133]

Russia's military-scientific base

The OPK's military-scientific base is overcentralized, which prevents it from achieving the flexibility and responsiveness required for genuine innovation. Despite several adaptations since the end of the Cold War, the present-day OPK has largely remained stuck in the state-centralized, top–down approach to innovation that characterized it during the Soviet era.[134]

Military innovation in Russia mostly relies on traditional state-centric structures, divided between the myriad Soviet-legacy research institutes, design bureaus and scientific-production associations.[135] The main coordinating and supervising body for military R&D is the Main Directorate for Innovative Development in the Ministry of Defence, while the Commission for Innovative Projects and Technologies supervises implementation.

Because research is heavily centralized, the scope for collaboration, synergies and spin-offs between civilian R&D and the OPK is limited.[136] By contrast, civil–military conversion is a major driver of military innovation in Western countries. Furthermore, except for in a few technology sectors such as UAVs, Russia lacks vibrant small- and medium-size enterprises in the technology sector that could be absorbed by the OPK to foster greater innovation. Interaction with the civilian world rarely happens in the OPK, not least because of over-classification and mutual lack of trust.[137]

The state-centric approach to military innovation goes against current worldwide trends: the Russian OPK is largely uncompetitive in the face of Western private sector start-ups and venture capitalism-based approaches to innovation. Russia's scientific business model is simply not fit for technological competition.

In recent years, however, Moscow has tried to develop a network of platforms to foster greater innovation capabilities and better links with the civilian world.[138] Following the 'Skolkovo' innovation model (which itself takes after the Soviet model

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133 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.
134 Dear, K. (2019), 'Will Russia Rule the World Through AI? Assessing Putin's Rhetoric Against Russia's Reality', *The RUSI Journal*, 164(5–6), pp. 36–60, https://doi.org/10.1080/03071847.2019.1694227; Sidorkova, I. (2018), 'Военное «Сколково»: зачем Шойгу строит технополис в Анапе' [Military Skolkovo: why Shoigu is building a technopolis in Anapa], RBC News, 13 March 2018, https://www.rbc.ru/politics/13/03/2018/5a9e82869a7947860d0516ca; Kania, E. B. (2019), 'Innovation in the New Era of Chinese Military Power', *The Diplomat*, 25 July 2019, https://thediplomat.com/2019/07/innovation-in-the-new-era-of-chinese-military-power; Zysk, K. (2021), 'Military R&D, innovation and breakthrough technologies', in Bendett et al. (2021), *Advanced military technology in Russia*.
135 For a comprehensive account, see Engvall (2021), *Russia's Military R&D Infrastructure – A Primer*.
136 Bukkvoll, T., Malmlöf, T. and Makienko, K. (2017), 'The defence industry as a locomotive for technological renewal in Russia: are the conditions in place?', *Post Communist Economies*, 29(2), pp. 232–49, https://doi.org/10.1080/14631377.2016.1267967.
137 Ibid. See also Adamsky, D. (2014), 'Defense Innovation in Russia: The Current State and Prospects for Revival', *IGCC Defense Innovation Briefs*, 2014(5), https://escholarship.org/uc/item/0s99052x.
138 Zysk (2021), 'Military R&D, innovation and breakthrough technologies'.

of 'technoparks', closed cities and other Soviet *monogorodie*), Russia established the Foundation for Advanced Research in 2012 and the ERA Military Innovation Technopolis in 2018.

Both the foundation and ERA are intended to bridge the gap between R&D concepts and real-world military applications,[139] as well as increase the technological feasibility of future military hardware. Both structures carry out fundamental research and application in priority fields such as AI, autonomous systems and military robotics, machine learning, quantum computing and nanotechnology.[140]

ERA is tasked with facilitating civilian–military cooperation, and has been recruiting staff from universities and civilian research institutes.[141] Its R&D capacity is directly supervised by the Main Directorate of Research and Technological Support of Advanced Technologies in the Ministry of Defence.[142] Furthermore, the ministry transferred several of its special military-scientific units to ERA. These units were created in 2013 to boost direct military innovation applications for the armed forces.[143] The main OPK companies and producers also maintain a presence in ERA through joint projects – which could potentially bring administrative hurdles and bureaucracy.

Much of the success or failure of the foundation and ERA rests on funding, however. Both are likely to be uncompetitive in this area: the foundation's initial annual budget was only around $70 million, with about 40 to 50 projects requiring funding.[144]

Innovation pathways

As the foundation's meagre budget shows, military innovation remains relatively underfunded in Russia. Capital investment from the state is lacking and foreign direct investment is limited by sanctions.[145] Meanwhile, the funding that is available is diverted because of well-known issues such as systemic corruption, ill-adapted legal and regulatory frameworks and unnecessary bureaucracy.[146]

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139 Russian Ministry of Defence (undated), 'About Technopolis', https://mil.ru/activity/innovation/era/about.
140 Zysk (2021), 'Military R&D, innovation and breakthrough technologies'; *Izvestia* (2024) 'В технополисе «Эра» обсудили расширение применения робототехники в войсках' [The Era Technopolis Discussed the Expanded Use of Robotics in the Troops], 4 October 2024, https://iz.ru/1769720/2024-10-04/v-tekhnopolise-era-obsudili-rasshirenie-primeneniia-robototekhniki-v-voiskakh.
141 *Izvestia* (2024), 'Студенты рассказали о работе в технополисе «ЭРА» над передовыми новинками для МО' [Students spoke about their work in the ERA technopolis on advanced innovations for the Ministry of Education], 20 September 2024, https://iz.ru/1762169/2024-09-20/studenty-rasskazali-o-rabote-v-tekhnopolise-era-nad-peredovymi-novinkami-dlia-mo; Stepovoi, B. (2024), '«Эра» усердия: военный технополис отбирает лучших студентов вузов' ["Era" of Diligence: Military Technopolis Selects the Best University Students], *Izvestia*, 20 September 2024, https://iz.ru/1761667/bogdan-stepovoi/era-userdiia-voennyi-tekhnopolis-otbiraet-luchshikh-studentov-vuzov.
142 Russian Ministry of Defence (undated), 'About Technopolis'; Zysk (2021), 'Military R&D, innovation and breakthrough technologies'.
143 Boltenkov, D. (2017), *Russian MoD's "Science Companies"*, Moscow Defense Brief, Moscow: CAST, No. 6; Russian Ministry of Defence (undated), 'Nauchnye roty' [Scientific companies], https://recrut.mil.ru/for_recruits/research_company/companies.htm.
144 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.
145 Connolly (2023), 'Russia's Defense Industry'.
146 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.

Overall, the OPK's pathway to military innovation is, and will remain, incremental:[147] a series of gradual, small-step evolutions rather than big, sudden breakthroughs.[148] Innovation generally takes the form of integrating technological solutions directly into proven, older-generation systems – which in turn makes them 'modern' (see above).

Russia's military sector has been forced to adopt a 'retain-and-adapt'[149] approach, as military production is no longer innovation-led. In other words, Russia 'innovates' through 'smart adaptation' under technical and economical constraints that have a negative, cumulative effect at the tactical level.[150]

Some limited 'high-risk/high reward'[151] experiments have been conducted in targeted sectors (for instance, those focusing on hypersonic glide vehicles), which display some willingness to take risks for the sake of innovation.[152] But, under sanctions, Russia must rely on lesser-quality components. This reliance limits the ability for the OPK to carry out innovative projects like these. This will eventually translate into a form of 'gradual stagnation'[153] of the OPK's ability to manufacture advanced hardware, as well as a qualitative degradation of its industrial outputs.[154]

Weapons systems also remain beset by failures affecting development cycles and their operational life span – for instance, the Losharik submersible tragedy in 2019[155] and the August 2019 explosion at the Nyonoksa range during weapons testing[156] that released radionuclides into the atmosphere.

'Degraded science'

Considering the factors weighing on Russia's approach to military innovation, continued shortened production cycles necessary to sustain the war and the impact of international sanctions are gradually leading to a form of innovation stagnation of the OPK.

Russia's military R&D and innovation base is in a state of 'degraded science'[157] – a phrase that refers to the continued deterioration of the quality and quantity of military science undertaken in Russia since the collapse of the Soviet Union.

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147 Bendett et al. (2021), *Advanced military technology in Russia*; Zysk, K. (2021), 'Defence innovation and the 4th industrial revolution in Russia', *Journal of Strategic Studies*, 44(4), pp. 543–71, https://doi.org/10.1080/01402390.2020.1856090.
148 Zysk (2021), 'Defence innovation and the 4th industrial revolution in Russia'.
149 Radin, A. et al. (2019), *The future of Russian military: Russia's Ground Combat Capabilities and Implications for U.S.-Russia Competition*, Santa Monica, CA: RAND Corporation, https://www.rand.org/content/dam/rand/pubs/research_reports/RR3000/RR3099/RAND_RR3099.pdf.
150 The author credits and thanks Aleksi Päiväläinen for this idea and quote.
151 Lehtinen, Saari and Suominen (2022), *Russia's technological policy and knowhow in a competitive global context*.
152 Zysk (2021), 'Defence innovation and the 4th industrial revolution in Russia'.
153 Gorenburg et al. (2024), *Crafting the Russian War Economy*.
154 Connolly (2023), 'Russia's Defense Industry'.
155 Glantz, J. and Nilsen, T. (2020), 'A Deep-Diving Sub. A Deadly Fire. And Russia's Secret Undersea Agenda', *New York Times*, 20 April 2020, https://www.nytimes.com/2020/04/20/world/europe/russian-submarine-fire-losharik.html.
156 Kryzyzaniak, J. (2019), 'The Nenoksa accident: A timeline of confusing and conflicting reports', Bulletin of the Atomic Scientists, 23 August 2019, https://thebulletin.org/2019/08/the-nenoksa-accident-a-timeline-of-confusing-and-conflicting-reports.
157 Rakhmanov, A. (2017), 'Razzhalovannaia nauka' [Degraded science], *Voyenno-Promyshlennyy Kur'yer*, 29 May 2017, http://vpk-news.ru/articles/37000.

Several explanations for this situation stand out, primarily linked to the shortage of qualified scientists and young engineers and the continued exodus of capable individuals from Russia.

This loss of intellectual capital is compounded by the decrease in the overall quality of higher scientific and technical education.[158] Although Russia had an excellent inheritance from Soviet science, R&D remains focused more on theoretical research and less on practical application.[159] Finally, the high average age of scientists in most design bureaus hinders the development of a culture of innovation and modernity.[160]

Russia's standing in the Global Innovation Index has steadily declined since 2017, with the country ranking 59th out of 133 countries in 2024.

This state of degradation can be seen in international measurements of innovation potential and capabilities. For instance, Russia's standing in the Global Innovation Index has steadily declined since 2017, with the country ranking 59th out of 133 countries in 2024.[161] The number of military-related R&D patents filed by Russia and scientific publications has also collapsed since the 1990s (although many remain classified),[162] as have Russia's overall advances in critical technologies such as advanced materials or AI-enabled systems.[163]

The OPK is not yet facing an existential crisis in terms of military innovation, but remains unable to project the Russian armed forces into genuine technological modernity.[164] Indeed, innovation in weapons design will continue, although the capacity of the OPK to bring its designs to serial production levels remains in doubt.[165] Russia's multiple R&D structures generally have no difficulty in thinking innovatively and creating blueprints, but there remains a wide gap to bridge in the ability of the OPK to develop those ideas into actual systems.

External partnerships will not solve the OPK's systemic issues. Russia will have to bridge the technological gap on its own – especially when considering the implications of a growing dependence on China. The industry will also have to rethink its approach to human capital to better support military R&D, since current solutions to the 'brain drain' are far from sufficient.[166]

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158 Persson et al. (2016), *Russian Military Capability in a Ten-Year Perspective – 2016*.
159 Lehtinen, Saari and Suominen (2022), *Russia's technological policy and knowhow in a competitive global context*.
160 Connolly and Boulègue (2018), *Russia's New State Armament Programme*.
161 World Intellectual Property Organization (undated), 'Russian Federation ranking in the Global Innovation Index 2024', https://www.wipo.int/gii-ranking/en/russian-federation.
162 Connolly and Boulègue (2018), *Russia's New State Armament Programme*; Rakhmanov (2017), 'Razzhalovannaia nauka' [Degraded science].
163 Australian Strategic Policy Institute (undated), 'Who is Leading the Critical Technology Race?', https://techtracker.aspi.org.au.
164 Boulègue et al. (2024), *Assessing Russian plans for military regeneration*.
165 Exchange during a Chatham House online workshop organized in December 2024.
166 Kendall-Taylor et al. (2023), *Identifying Russian Vulnerabilities and How to Leverage Them*.

The state of innovation in key sectors

Despite the state of general decrepitude of the OPK and to the gradual degradation of innovation, the Russian military industry should not be completely underestimated in its ability to continue producing weapons systems and hardware able to hold Western forces at risk of destruction.

Innovative systems and hardware do still find their way into practical use. Indeed, Ukraine has become something of a testing ground for the Russian military innovation that does exist. It remains to be seen, however, whether the OPK will be able to design, engineer and produce the next generation of weapons systems capable of sustaining strategic and technological competition in key sectors.

Space technology

Space is hardly a place where 'good enough' is good enough, especially in light of the strong Soviet scientific legacy in this field. The Russian military relies on space operations for many of its activities, including ICBM technology, military navigation, positioning and intelligence, surveillance and reconnaissance (GLONASS constellation),[167] remote sensing,[168] ballistic missile early warning systems, communications, signal intelligence and reconnaissance, and sub-threshold warfare (such as inspector satellites and counter-space capabilities).[169]

Russia continues to suffer from the breakdown of space cooperation with Western partners. The industry is struggling financially as a result: in July 2024, Russia adopted a law on public–private partnerships to reduce the amount of state financing in the space industry, which will potentially restrict options further.[170] The state-owned space agency Roscosmos no longer focuses on scientific space exploration, but rather on sustaining Russia's comparative advantages in space – particularly those in communications satellites and launch vehicles.

However, the Russian satellite industry is not in good shape. Sanctions are constraining Russia's access to space-grade components and equipment, and particularly electronics, onboard equipment, and optical and radar imaging systems.[171] Non-Western supplies do not fully match Russian requirements and standards. Roscosmos will therefore likely be forced to either prolong the service life of existing space platforms to the point of failure or create newer, but simpler satellites with shorter life cycles and, potentially, reduced capabilities.[172] Meanwhile, the future of modern *Soyuz* and new *Angara* launchers remains unknown. If the availability of launch vehicles is reduced, the number of satellites placed into orbit

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167 Lavrov, A. (2017), Russia's GLONASS Satellite Constellation, *Moscow Defense Brief*, CAST, 4-2017, https://bmpd.livejournal.com/2845443.html.
168 The Space Review (undated), 'Dancing in the dark redux: Recent Russian rendezvous and proximity operations in space', https://www.thespacereview.com/article/2839/2.
169 Unal, B. and Boulègue, M. (2020), 'Russia's Behaviour Risks Weaponizing Outer Space', Chatham House Expert Comment, 27 July 2020, https://www.chathamhouse.org/2020/07/russias-behaviour-risks-weaponizing-outer-space; Samson, V. and Cesari, L. (2024), *Global Counterspace Capabilities Report: An Open Source Assessment*, Secure World Foundation, https://swfound.org/media/208099/swf_global_counterspace_capabilities_2025.pdf.
170 TASS via *Novosti VPK* (2024), 'Принятие закона о ГЧП положительнейшим образом повлияет на развитие космической отрасли' [The adoption of the PPP law will have a positive impact on the development of the space industry], 18 July 2024, https://vpk.name/news/890968_prinyatie_zakona_o_gchp_polozhitelneishim_obrazom_povliyaet_na_razvitie_kosmicheskoi_otrasli.html.
171 Luzin, P. (2024), *Russia's Space Program After 2024*, report, Philadelphia, PA: Foreign Policy Research Institute, July 2024, https://www.fpri.org/article/2024/07/russias-space-program-after-2024.
172 Ibid.

will reduce and related support missions will become less viable, especially since commercial launches are not currently an option for Russia due to the constraints of sanctions and the low quality of Russian-made equipment.

Military robotics and autonomous systems

Since its invasion of Georgia in 2008, Russia has made tremendous progress in its approach to uncrewed technology and military robotics. The 2008 war was a wake-up call to the need for drone support for intelligence, surveillance, target acquisition and reconnaissance (ISTAR) operations. Since then, the OPK has structured an indigenous military-industrial base for ISTAR and loitering drones. The use of UAVs is now an integral part of Russian warfare, and drones have demonstrated their effectiveness during both wars against Ukraine and in Syria.

Russia's approach to drones is focused more on the robotization of the armed forces than on genuine autonomy through AI-enabled systems. Indeed, systems currently deployed are not designed to be autonomous, but remain remote-controlled by a human operator.[173] Discussions around autonomy, for now, retain a 'human-in-the-loop' approach to military robotics[174] – not least because autonomous systems require a technological leap Russia is unlikely to make under current conditions.

Continued developments in the robotization of the armed forces and in the autonomous regime depend heavily on the continued procurement of advanced microelectronics, semiconductors, microchips and computing power, as well as drone engines – access to which is restricted by international sanctions.

Advanced military-industrial partnerships with external partners and *Shahed* drone supplies from Iran[175] will not solve all of Russia's problems in this area. Indeed, continued developments in the robotization of the armed forces and in the autonomous regime depend heavily on the continued procurement of advanced microelectronics, semiconductors, microchips and computing power, as well as drone engines – access to which is restricted by international sanctions.

AI-enabled systems

Further to the autonomous regime, military innovation is putting considerable effort into developing AI-enabled systems, as well as related projects such as advanced machine-learning and computing, big data analytics and supercomputers. In each

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173 Bendett, S. (2021), 'Military robotics development', in Bendett et al. (2021), *Advanced military technology in Russia*.
174 RIA Novosti (2020), 'Виталий Давыдов: живых бойцов заменят терминаторы' [Vitaly Davydov: terminators will replace human soldiers], 21 April 2020, https://ria.ru/20200421/1570298909.html.
175 Bennett, D. and Ilyushina, M. (2023), 'Inside the Russian effort to build 6,000 attack drones with Iran's help', *Washington Post*, 17 August 2023, https://www.washingtonpost.com/investigations/2023/08/17/russia-iran-drone-shahed-alabuga.

of these areas, Russia depends on access to Western-made technologies,[176] and therefore the availability of critical components is heavily restricted. Nevertheless, the development of AI capabilities is a source of prestige for the Kremlin.[177]

Military R&D focuses – mainly via ERA – on the development of AI-enabled solutions in the field of electronic warfare, robotics and uncrewed systems, command and control and cyberwarfare.[178] As elsewhere in the world, AI technologies are understood as incremental enablers aimed at 'augmenting and amplifying existing capabilities', rather than replacing them altogether.[179]

These stated goals, however, are impeded by the impact of sanctions in parallel sectors. Indeed, AI cannot exist without advanced microelectronics, semiconductors and microchips, or the IT specialists and scientists the OPK is lacking. Furthermore, the sector is severely underfunded,[180] with few state resources available and private investments devoted to AI-related R&D – although the war against Ukraine is offering valuable operational experience that could feed into the latter.

Other priority areas

Russia's so-called 'super weapons' and other 'doomsday' systems unveiled in 2018[181] are also impacted by both sanctions and the demands of the Ukraine war. Despite these problems, Russia has deployed several hypersonic systems against Ukraine, notably the aero-ballistic *Zircon* missile and the air-launched semi-ballistic *Kinzhal* missile.[182]

However, the novelty of these systems must not be overstated. They should generally be understood as 'upgraded versions of existing technologies',[183] rather than battlefield or strategic 'game-changers'. As often with official Russian communications, the message that these 'super weapons' convey is the most potent capability. These systems must also be placed into the reality of procurement cycles under the next round of GPV and caveated by the impact of sanctions.

In electronic warfare (EW), lessons learned from Russian operations in Syria and Ukraine have demonstrated the continued ability of Russian forces to degrade the operating environment and disrupt adversarial C4ISR capabilities.[184] Designated

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176 Nadibaidze, A. (2023), *Russian Perceptions Of Military AI, Automation, And Autonomy*, Washington, DC: Foreign Policy Research Institute, https://www.fpri.org/wp-content/uploads/2022/01/012622-russia-ai-.pdf.
177 Associated Press (2017), 'Putin: Leader in artificial intelligence will rule world', 1 September 2017, https://apnews.com/article/bb5628f2a7424a10b3e38b07f4eb90d4.
178 Engvall (2021), *Russia's Military R&D Infrastructure – A Primer*; Konaev, M. (2023), 'Military innovation and emerging technologies', in *Understanding Russia's military vulnerabilities*, Project Summary, London: Royal Institute of International Affairs, https://chathamhouse.soutron.net/Portal/Public/en-GB/DownloadImageFile.ashx?objectId=7398&ownerType=0&ownerId=203677.
179 Kerr, J. (2024), 'Russia's asymmetric enablers', in Boulègue et al. (2024), *Assessing Russian plans for military regeneration*.
180 Polyakova, A. (2018), 'Weapons of the weak: Russia and AI-driven asymmetric warfare', Brookings Institution, 15 November 2018, https://www.brookings.edu/research/weapons-of-the-weak-russia-and-ai-driven-asymmetric-warfare.
181 Connolly (2021), 'Putin's 'super weapons'', in Bendett et al. (2021), *Advanced military technology in Russia*.
182 Reuters (2024), 'Russia uses Zircon hypersonic missile in Ukraine for the first time, researchers say', 12 February 2024, https://www.reuters.com/world/europe/russia-uses-zircon-hypersonic-missile-ukraine-first-time-researchers-say-2024-02-12; Garanich, G. and Karazy, S. (2023), 'Kyiv says it shoots down volley of Russian hypersonic missiles, Reuters, 17 May 2023, https://www.reuters.com/world/europe/air-defence-systems-repelling-attacks-ukraine-early-tuesday-officials-2023-05-16.
183 Connolly (2023), 'Russia's Defense Industry'.
184 Scott, R. (2022), 'From the JED Archives: Tuning In, Turning On: Russia Brings Radio Electronic Combat to the Fore', *Journal of Electromagnetic Dominance*, 22 March 2022, https://www.jedonline.com/2022/03/22/from-the-jed-archives-tuning-in-turning-on-russia-brings-radio-electronic-combat-to-the-fore.

EW troops have been instrumental in the second invasion of Ukraine, and several systems have proven effective for proximity jamming, radio and GSM isolation and anti-drone warfare.

Yet like other systems, EW relies on access to high-quality microelectronic components, computers and microchips, receivers and advanced circuitry that is severely restricted by sanctions.[185] In the short term, therefore, Russian EW operations might decrease in quality due to shorter life cycles for EW equipment, lower operational tempo and reduced mobility for mobile systems.

Through ERA and other structures, the OPK continues to invest where possible in the development of breakthrough technologies such as quantum computing, sensing and cryptography,[186] nanotechnology and composite materials, human enhancements and neural networks. In these fields, as in others, Russia trails other countries in the number of patents, and actual military applications remain undetermined.[187] Other key areas of focus for the Russian armed forces are the development of advanced computing, data storage capabilities and encrypted cloud-based services for sensitive communications, for all of which quality microelectronic components are also required.

Conclusion

The Russian military-industrial complex suffers from many limitations. In light of the challenges highlighted in this paper, the OPK is likely to go through a steady period of decline marked by:

- The simplification of military production and procurement – particularly for hardware;
- Lower production rates due to stretched production chains and reduced availability of machine-building tools and components;
- Reduced quality of outputs owing to a less skilled workforce and industrial capacity; and
- 'Innovation stagnation' in military R&D, scientific research and advanced technologies.

All these factors point to a regression, or at least a gradual stagnation, of the OPK. Since the full-scale invasion of Ukraine in 2022 and the imposition of sanctions in 2014, there has been little change in terms of Russia's military-industrial output. What has changed, however, is the *capacity* of the OPK to support the ongoing demands of the war.[188] For instance, components are increasingly produced with lesser quality, and high-quality machine-building tools are being replaced with inferior ones.

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185 Bergmann et al. (2023), *Out of Stock? Assessing the Impact of Sanctions on Russia's Defense Industry*.
186 Krelina, M. (2021), 'Quantum technology for military applications', *EPJ Quantum Technology*, 8(24), https://doi.org/10.1140/epjqt/s40507-021-00113-y.
187 Lehtinen, Saari and Suominen (2022), *Russia's technological policy and knowhow in a competitive global context*.
188 Exchange during a Chatham House online workshop organized in December 2024.

This situation may lead the OPK to adopt more 'primitive' production cycles and methods, and to a simplification of Russian military production towards well-known, easier-to-produce systems. Such a shift is already visible, for instance, in the refurbishment of Soviet-era equipment and the procurement of low-tech hardware. In this context, the Russian armed forces will increasingly depend on modified Soviet platforms, boosted by limited modern and advanced technological add-ons.

Yet these problems are not insurmountable for Russia. Russia's military industry demonstrated its resilience in the years following the Soviet Union's collapse and recovered from the decay of the 1990s. The OPK is equally resilient today. It remains able to sustain the minimum military-industrial and -scientific bases necessary to prosecute the war against Ukraine, provide weaponry for the war effort and ultimately recapitalize the country's military hardware and modernize the armed forces in line with the next state armament programme for 2025–34.

The OPK will continue to muddle through and keep producing systems that are 'good enough' to pose a sustained threat to Ukraine. But being 'good enough' to sustain a war against Ukraine is not the same as being able to compete against NATO forces or China into the future.

The Russian military-industrial and the military-scientific bases will likely remain 'good enough' for the time being. In the long term, the technological gaps with Western/NATO countries (and China) will widen. This situation will make it harder for Russia to sustain competition with its adversaries.

It is hard to assess for how long the high rate of defence spending and military production will be kept up – especially if the war moves further towards diplomatic negotiations and/or if international sanctions against Russia are lowered or even removed. The OPK might be pressured to maintain production rates as an economic and political imperative by the Kremlin, in order to ensure a swift rearmament and regeneration of Russia's military force.[189] In any case, it will be some time before Russia's defence spending drops to pre-2022 levels.

The same caveat applies to third-country imports of finished systems – it cannot be reliably predicted whether the OPK will seek to increase domestic production or continue to rely on imports from Iran, North Korea and others for entire segments of military procurement. But for now, Russia must maintain good relations with the trading partners it still has – particularly China, Iran and North Korea – to keep the latter option open.

As the reorientation of the OPK towards the production of civilian goods is not an option, a form of 'demilitarization' of military production towards dual-use products may be a viable post-war option. In any case, the OPK will require a 'soft landing' after the war ends – whenever that may be.[190]

Sanctions will continue to have an impact on Russia's military-industrial and -scientific bases. Researchers and policymakers in the West are starting to understand

189 Boulègue et al. (2024), *Assessing Russian plans for military regeneration*.
190 Exchange during a private roundtable with military experts organized in December 2024.

the dependencies and weaknesses of the OPK,[191] and are even discussing the need to degrade entire parallel industrial segments to the military industry in the civilian world.[192]

Western sanctions must be targeted equally at the short-term objective of degrading Russia's ability to keep fighting and, in the longer term, at the complete decline of the OPK and associated civilian sectors. The overall goal would be to force Russia to 'go cheap' in areas where quality cannot be compromised and where being 'good enough' is not enough.[193]

Efforts to accelerate the OPK's decline could focus on strengthening the sanctions regime by applying tighter export control mechanisms (including closing existing loopholes), punishing external partners enabling Russia's war, identifying and closing evasion mechanisms, and encouraging the 'brain drain' of potential workers and innovators.

There are, however, many unknowns surrounding the continuation of sanctions against Russia. At the time of writing, diplomatic uncertainty still remains between Moscow and Kyiv, with talks underway aimed at securing a potential ceasefire and a wider agreement on terms to end the war.[194] The likelihood of sanctions relief for Russia is currently unclear. But if sanctions were to be loosened or even lifted, Russia's ability to recapitalize military hardware and modernize its armed forces would be given a significant boost.

If Russia chose to maintain defence spending at its current high level for the foreseeable future, a ceasefire would also mean that the Kremlin obtains more 'bang for its buck' – a quicker pace of military procurement and modernization, alongside reduced battlefield demands and lower rates of attrition.

More research is necessary to understand which specific sectors of the OPK are worst hit by sanctions and the demands of the war, and which ones are doing comparatively better. In the context of the new state armament programme for 2025–34, it will be equally important to assess which sectors will fare better than others, especially if quality critical components or machine-building tools become sought-after commodities.

All of this suggests that the West's ultimate goal must be to encourage the degradation of Russia's military industry, reducing the overall threat from Russia by creating the conditions for further decline. In such a scenario, the Kremlin would eventually have to review its intentions to confront Western/NATO countries symmetrically in conventional and strategic competition. Such a policy would not prevent Moscow from waging low-intensity warfare entirely, but might render the Russian threat much more manageable, as a blunted military industry and shortages of advanced weapons systems would leave Russia unable to compete militarily in the long term.

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191 Borovikov (2024), *Ore to Ordnance: Disrupting Russia's Artillery Supply Chains*.
192 Watling and Somerville (2024), *A Methodology for Degrading the Arms of the Russian Federation*.
193 Boulègue et al. (2024), *Assessing Russian plans for military regeneration*.
194 Holland, S., Faulconbridge, G. and Harmash, O. (2025), 'Trump says Russia, Ukraine agree to immediate ceasefire talks, Kremlin offers no timeframe', Reuters, 20 May 2025, https://www.reuters.com/world/europe/china/trump-speak-putin-end-war-ukraine-europeans-demand-ceasefire-2025-05-19.

About the author

Mathieu Boulègue is a consulting fellow in the Russia and Eurasia Programme at Chatham House. He specializes in Eurasian security and defence issues, with a focus on Russian foreign policy and military affairs. His research portfolio includes Russian warfare and military industry, Ukraine, Russia-NATO relations, and Russia-China defence and security relations.

In his previous role as a research fellow at Chatham House, Mathieu led the institute's work on the Arctic region, focusing particularly military/security issues and Russia's polar power projection. He graduated from Sciences Po Toulouse in France and holds an MA in international conflict studies from King's College London.

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Cover image: Workers manufacture military vehicles at a factory owned by Russian missile producer Almaz-Antey in St Petersburg, 18 January 2023.
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The Royal Institute of International Affairs
Chatham House
10 St James's Square, London SW1Y 4LE
T +44 (0)20 7957 5700
contact@chathamhouse.org | chathamhouse.org

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