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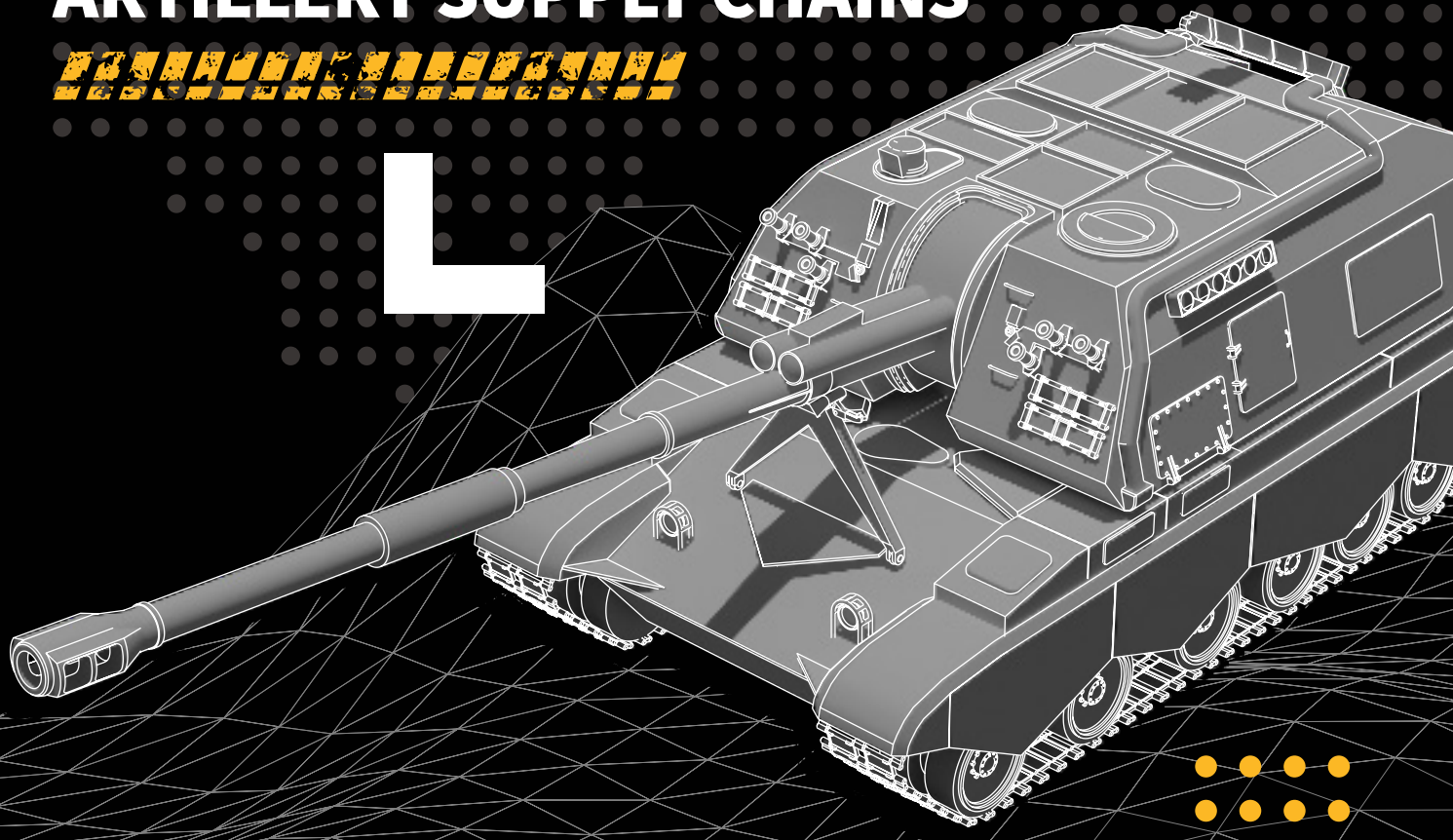
ORE TO ORDNANCE:

DISRUPTING RUSSIA'S ARTILLERY SUPPLY CHAINS



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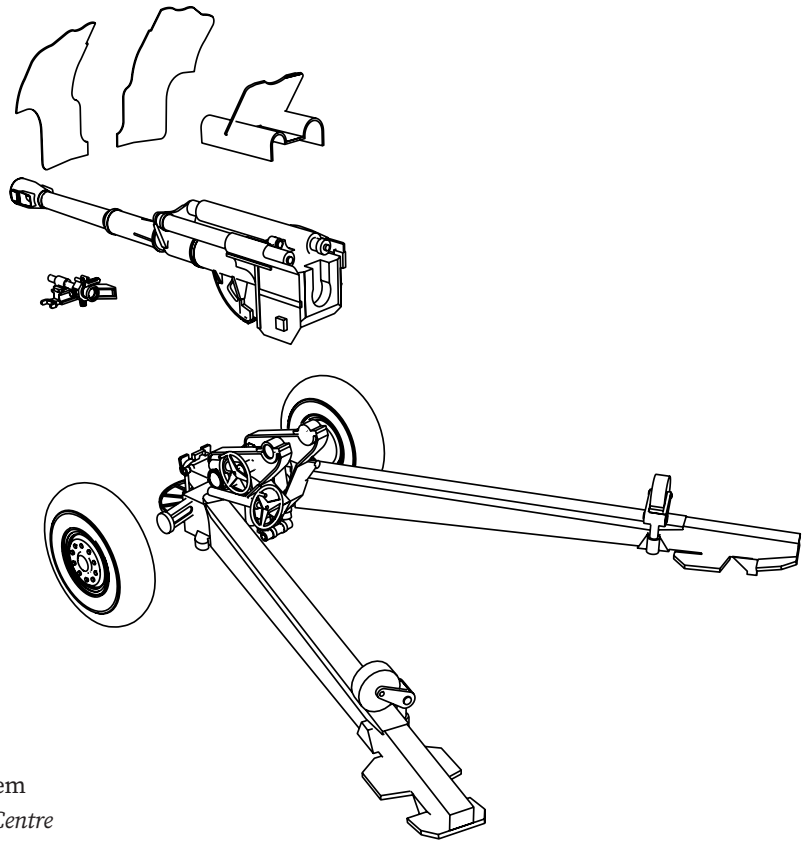

A D-20 artillery system
Source: Open Source Centre

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Executive Summary

This report focuses on Russia's artillery supply chain, as artillery is central to the invasion of Ukraine and has inflicted more than 70% of Ukraine's casualties.[1] Disrupting Russia's access to ammunition and new artillery barrels should therefore be a central focus for Ukraine's supporters. The findings within this paper will empower Ukraine's Western partners to coordinate sanctions, diplomatic pressure and civil society efforts to exploit the vulnerabilities of Russia's artillery supply chain and reduce its access to ammunition and barrels.

So far, attempts to disrupt Russia's military supply chains have achieved some successes, with thousands of Russian entities and individuals sanctioned, and evidence of raw materials being diverted from the Russian supply chain. By and large, however, they have targeted components or high-priority items that are difficult to disrupt, such as microchips, and have not taken a view as to which supply chains should be disrupted. Instead, the current approach has been to try and restrict the access of the entire Russian defence industry to key materials and equipment like machine tools. While this approach is admirable in its ambition and has produced many sanctions and even some effects, it has struggled to measurably restrict the growth of Russia's defence industry and its ability to fuel the war. This paper's findings indicate that a more effective approach is to focus on a single supply chain and identify the raw materials, products and machinery that sit outside Russia and must be imported. These elements of the supply chain may be open to Western interventions from a variety of angles, and their limited nature, combined with the overall importance of artillery, could empower governments to focus disruption efforts on these elements, to meaningfully degrade and disrupt Russia's artillery supply chain.

To evidence this, this paper provides a comprehensive analysis of Russia's artillery supply chain – from raw iron ore, cotton and sulphuric acid to the 2S19 Msta-S howitzers – to identify vulnerabilities that could be disrupted by Ukraine's Western partners. It also provides an indication of the expansion of Russia's defence industry that is currently underway. The objective of this research is to show the ways in which Russia's supply chains are truly vulnerable, and to inform future policy decisions that are taken towards supply chain disruption.

This has led to three key conclusions:

1. Russia's artillery supply chain is complex, but exposed in procurement of key raw materials and components from abroad. More than 70% of Russia's computer numerical control machines come from China, 55% of its chromium is imported, and its imports of nitrocellulose have increased by 70% since 2022, for example.

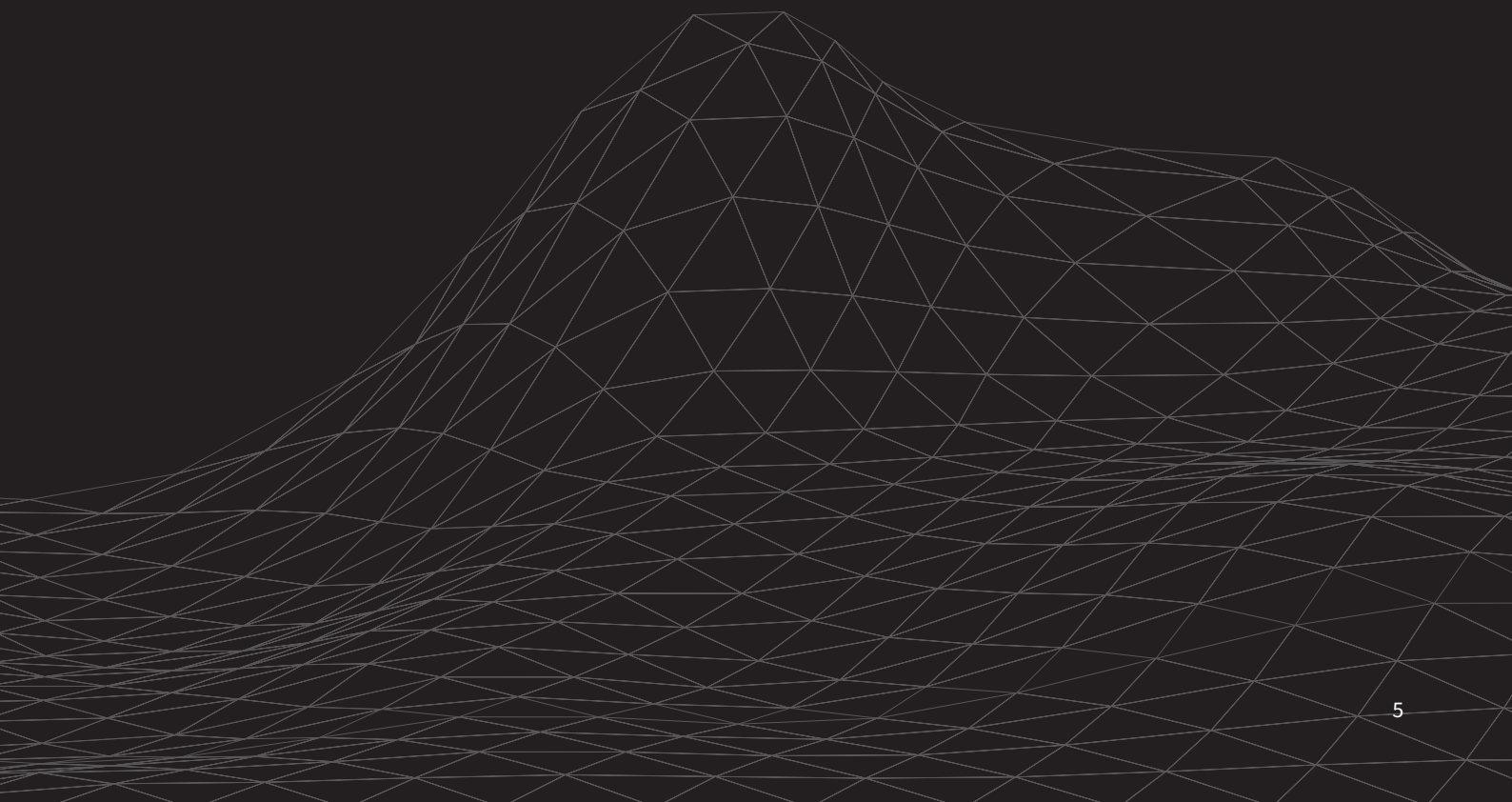
2. There is redundancy within the supply chain, and even a complete disruption of the Plastmass ammunition plant – a major producer – would not lead to a collapse in Russia's ammunition supply. It could remove 300,000 rounds from Russia's artillery ammunition production capacity, but there are alternative sources. This necessitates a comprehensive and focused approach to disruption, with intra- and inter-governmental coordination.

3. Russia's defence industry is expanding, with major works identified at the Perm and Kazan Gunpowder plants, Izhevsk Unmanned Systems Research and Production Association, several armoured-machine repair plants and Kurganpribor. However, the industry faces challenges such as a lack of personnel and a crumbling rail infrastructure that is struggling to meet the demands of the war, as well as the need for imported machinery to meet its aggressive expansion goals. There is a window of opportunity for Western governments to slow this expansion; otherwise, they risk facing a rejuvenated and more capable Russian defence industry when the invasion of Ukraine is over.

1 *Aaron Epstein et al., 'Putting Medical Boots on the Ground: Lessons from the War in Ukraine and Applications for Future Conflict with Near-Peer Adversaries', Journal of the American College of Surgeons (Vol. 237, No. 2, August 2023), pp. 364–373.*

At the same time, elements of Russia's artillery supply chain are relatively robust and contained within its borders. This led to the conclusion and key recommendation from the paper, which is that Ukraine's Western partners can achieve the greatest impact by focusing on Russia's import of key materials before they reach the country. These parts of the supply chain are the most vulnerable to external influence, whereas the elements that sit inside Russia, or can be smuggled with relative ease, are difficult to regulate without coordinated corporate compliance, and often have established networks for sanctions evasion. Disruption should, of course, focus on vulnerabilities rather than taking a broad-spectrum approach, and within the gamut of vulnerabilities, Western governments are most likely to have success against those outside Russia's borders. For example, it is apparent that Russia is facing recruitment challenges in its expansion: this is a vulnerability, but it may prove difficult to disrupt recruitment from Washington or London. Another vulnerability is that many companies in the artillery supply chain rely on Western machinery and/or Western businesses, or still have European subsidiaries that keep them supplied with key materials and components. This report shows the role that these companies play in the supply of howitzers and ammunition to the frontlines and indicates that targeted efforts to disrupt these elements of the supply chain are more likely to lead to success than a broad spectrum approach, and may create the disruption that policy makers are hoping for.

Ukraine has demonstrated determination and bravery from day one of the invasion and has upset Russia's military plans time and again. However, Russia's greater economic and industrial capacity is likely to be a determining factor in the ultimate outcome of the war. This need not be the case: Russia's industrial might can and should be disrupted with a focused effort on the artillery supply chain. Doing so will save Ukrainian lives, degrade Russia's offensive and defensive capabilities, and weaken its overall ability to fight the war in the way that its units have grown accustomed to. The Russian threat will not disappear, regardless of what happens in Ukraine – the expansion of its defence industry and armed forces makes this clear. However, there is a window of opportunity for Western powers to disrupt this expansion and slow production to prevent further Russian successes in 2025. That window is small, but Ukraine and its Western partners have the tools and knowledge to make the most of it and reduce the threat posed by Russia.



Introduction

This paper provides a comprehensive overview of Russia's artillery supply chain. It set out with the ambitious goal of mapping the supply chain, from the extraction and processing of raw materials needed for producing howitzers and ammunition, to their delivery to the frontline in Ukraine. The goal of the paper is to inform a cross-government, and ideally inter-governmental, approach to disrupting this specific supply chain.

The research has been conducted through the layering of different datasets and the expertise of a research team built specifically for this type of task. The data used includes: records from commercial providers of trade data; trade data from the UN; and publicly available information released either by the companies and enterprises involved, or through leaked financial records seen by the report authors that reveal the nature of contracts between Russian manufacturers. Extensive analysis has been conducted of Russia's internal railway data, which was obtained via a commercial trade platform, to provide additional granularity on the nature of supply between manufacturers. Many online sources are no longer available, as Russian websites relating to defence are frequently changed or removed, and company websites may have been altered to obscure their involvement in Russia's defence industry. The Wayback Machine (https://web.archive.org/) and other internet archives have been used to locate and interrogate past iterations of websites.

That data has been collated and organised to detail the process required to get from iron ore to a finished howitzer, or from cotton to a propellant charge for an artillery projectile. The research is focused on Russia's manufacturers of 122 mm, 152 mm and 203 mm howitzer ammunition, and 82 mm and 120 mm mortar ammunition. However, many of the companies involved in this supply chain also produce components for rocket ammunition and anti-tank guided missiles. The paper sets out to establish which elements of the supply chain might prove vulnerable to the policy levers available to a Western government, such as the application of sanctions, diplomatic pressure, preclusive purchases, or the disruption of financial transactions.

The paper gives a brief explanation of the role that artillery plays in Russia's invasion of Ukraine, and why it is important to focus disruption efforts on that supply chain. It sets out the component parts of a typical howitzer before exploring the supply chain for Russian howitzers in detail. The same process is repeated for artillery ammunition, taking raw materials as the starting point. The key companies involved in each step of the process are profiled, and where possible, the volume of their transactions with the Russian Ministry of Defence (Russian MoD) are indicated. The final element of the artillery supply chain – the delivery of howitzers and ammunition to the frontlines – is briefly covered to provide an overall picture of the Russian artillery lifecycle.

Since the start of Russia's invasion of Ukraine in 2014, Western countries have brought hundreds of sanctions into force against Russian companies and individuals. They have applied tools such as diplomatic pressure and public shaming of companies in a bid to limit Russia's access to key Western technology. This approach has enjoyed some success, but has failed to prevent the growth of Russia's domestic defence industry, or to alter the balance of power in the invasion. If Ukraine is to win, Russia's artillery supply chain must be disrupted; no theory of victory for Ukraine will be viable as long as Russia's supply of artillery systems and ammunition remains intact. This paper aims to help address this challenge by providing an assessment of where this supply chain is vulnerable to external action by Western governments, and showing that Russia's defence industry is far from the Soviet behemoth of the 1980s.

Chapter 1: Why Artillery?

The balance of artillery between Russia and Ukraine is the single greatest determinant of the distribution of casualties and equipment loss, the balance of military initiative, the calculus of what is operationally possible, and thus the political perception of the trajectory of Russia's full-scale invasion of Ukraine.

The initial Russian invasion force that entered Ukraine on 24 February 2022 fielded 2,214 artillery systems, of which 1,635 were howitzers and 579 were multiple rocket launchers (MRLs).[2] Russia originally viewed the invasion as a 'Special Military Operation' in which the military component was to conduct a coup de main to capitalise on the destabilisation of the Ukrainian state by Russia's special services.[3] When this failed, the Russian military found itself fighting the Armed Forces of Ukraine (AFU), which fielded 1,176 tube artillery systems and 1,680 MRLs, in a conventional war.[4] Alongside Ukraine's resolve, and Russian disorganisation, this imbalance in artillery in Ukraine's favour was a key factor in the defeat of Russian forces north of Kyiv and near Kharkiv, Sumy and Chernihiv, and Ukraine's successful retention of Donbas.

Ukraine, however, only had ammunition to support its artillery park until mid-May 2022. The result was that when Russia regrouped and launched an offensive on Donbas, it was able to achieve an indirect fires superiority of up to 20:1 in some areas,[5] as Ukraine's artillery was starved of munitions.[6] It is also important to note that this disparity in artillery gave the Kremlin the confidence that they could defeat the AFU without mobilising additional troops, despite being outnumbered by Ukraine at this time.[7] Artillery is the centre of gravity for Russia's ground forces. It is seen as the most efficient means to defeat an opponent's forces, either through destruction or by weakening them to such an extent that an offensive is certain to succeed.[8] Recognising the central and foundational role of artillery in Russia's armed forces is key to understanding the priorities for disrupting Russia's war machine. Whereas NATO forces broadly see artillery as a supporting element that is designed to set the conditions for manoeuvre forces to engage an enemy, the Russians see manoeuvre forces as responsible for both getting the enemy into a position where artillery can defeat them, and then exploit the destruction achieved by artillery. This was what Russia was doing to the AFU in Donbas in May to June 2022. It is also why, when the AFU received the Guided Multiple Launch Rocket System (GMLRS) from its international partners and began to unpick Russian artillery logistics, this brought Russian forces to a standstill, ceding the initiative to Ukraine, until Russia began the process of military mobilisation over the winter of 2022 to 2023.[9]

2 *Ukrainian Ground Forces G2 Assessment as of February 2022, presented to one of the authors in Ukraine in February 2022.*

3 *Jack Watling, Oleksandr V. Danylyuk and Nick Reynolds, 'Preliminary Lessons from Russia's Unconventional Operations During the Russo-Ukrainian War, February 2022–February 2023', RUSI, 2023, <https://www.rusi.org/explore-our-research/publications/special-resources/preliminary-lessons-russias-unconventional-operations-during-russo-ukrainian-war-february-2022>, accessed 16 September 2024.*

4 *Mykhaylo Zabrodskyi, Jack Watling, Oleksandr V. Danylyuk and Nick Reynolds, 'Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February–July 2022', RUSI, 2022, p. 16.*

5 *Author interviews with Ukrainian commanders, Ukraine, June 2022.*

6 *The Economist, "Ukraine will hold if it gets the arms it needs, says a top general.," 10 May 2024.*

7 *Michael Kofman and Rob Lee, 'Not Built for Purpose: The Russian Military's Ill-Fated Force Design', War on the Rocks, 2 June 2022.*

8 *Sam Cranny-Evans, 'Russia's Artillery War in Ukraine: Challenges and Innovations', RUSI Commentary, 9 August 2023, <https://rusi.org/explore-our-research/publications/commentary/russias-artillery-war-ukraine-challenges-and-innovations>,accessed 16 September 2024.*

9 *Reuters, 'Ukrainian Military Strikes with Western Arms Disrupt Russian Supply Lines – General', 14 July 2022.*

01

Since Russian mobilisation, the artillery advantage has consistently sat with Russia. Russia reached a high point in its rate of fire at around 38,000 rounds per day in June 2022.[10] For the remainder of the war, the rate of Russian fire has been fairly consistent, at between 7,000 and 16,000 rounds per day, averaging at around 10,000 rounds per day. Ukrainian artillery fire, meanwhile, peaked at around 9,000 rounds per day, and has rarely exceeded 6,000 rounds per day, while in early 2024, Ukraine was firing fewer than 1,800 rounds per day.[11] This disparity is largely a product of Russia's deep stockpiles and industrial mobilisation.

In addition to its fielded artillery park, Russia entered the war with approximately 13,985 artillery systems and 2,700 MRLs in storage, though not all of them were suitable for restoration. Ukraine has succeeded in inflicting sustained losses on Russia's artillery park, but Russia's defence industry has mobilised for war and is working to replace those losses. Many of the enterprises involved in Russia's artillery supply chain are working triple shifts. As a consequence, the Ukrainian General Staff assessed in February 2024 that the Russian Operational Group of Forces inside Ukraine was fielding 4,780 tube artillery systems, as well as 1,130 MRLs.[12] Despite the losses inflicted by Ukraine, Russia has managed to increase the number of artillery systems available to its forces over the opening invasion force.

Russia has also succeeded in stabilising the supply of ammunition to support its rate of fire. Russian ammunition production for 152 mm howitzers quadrupled in the first year of the war to one million rounds.[13] By the end of 2023, Russia had increased the totality of its ammunition production and is expected to produce 1.325 million new 152 mm rounds in 2024, as well as 800,000 122 mm rounds, and to refurbish an even larger number of rounds from remaining stockpiles.[14] It is procuring millions more from North Korea, Iran, Syria and Belarus.[15] By comparison, the AFU has received more than 600 155 mm howitzers from Ukraine's international partners, but a significant proportion of these have been destroyed, and ammunition supplies have been limited.

This disparity has had a range of tangible effects on the course of the fighting. The considerable attention paid to first-person view (FPV) drones conceals the reality that artillery continues to be the biggest cause of death and injury among Ukrainian troops. The actual percentage varies along the length of the frontline and is not uniform, but a paper written by the Global Medical and Surgical Support Group in 2023 observed that 70% of all Ukrainian combat casualties had been caused by Russian artillery.[16] The casualties often suffered severe wounds, including polytrauma to multiple organ systems, which, if not fatal, would likely prevent them from returning to service. Russian artillery has also inflicted widespread concussion among Ukrainian troops subjected to barrage, with multiple concussions over time leading to personnel having to be withdrawn from the front.[17]

The continued disparity in fire is one reason why the Kremlin believes it can still win the war. With approximately 1,200 km of active frontline, Ukraine must maintain enough combat-capable personnel to both hold defensive positions across this area and have enough reserves to rotate its units. The rate of rotation is increased in those sectors where units are under pressure. The accumulation of killed and wounded, with artillery injuries often causing wounds that prevent troops from returning to service even if they survive, is a strategic threat to Ukraine's ability to sustain the war effort. As of August 2024, the Russian theory of victory does not centre on major breakthroughs, but rather on the destruction of the AFU as a

10 *Author interviews with Ukrainian commanders, Ukraine, June 2022.*
11 *Data provided by the Ukrainian General Staff.*
12 *Ukrainian General Staff J2 Assessment as of February 2024.*
13 *Sam Cranny-Evans, 'Russia's Defence Industry Gears up for a Long War', EDR On-line, 9 January 2024, <https://www.edrmagazine.eu/russias-defence-industry-gears-up-for-a-long-war>, accessed 16 September 2024.*
14 *Production figures reported to the Russian Ministry of Defence by Russian defence industries, seen by the authors in February 2024.*
15 *Ibid.*
16 *Aaron Epstein et al., 'Putting Medical Boots on the Ground: Lessons from the War in Ukraine and Applications for Future Conflict with Near-Peer Adversaries', Journal of the American College of Surgeons (Vol. 237, No. 2, August 2023), pp. 364–373.*
17 *Author observations of personnel being rehabilitated from successive concussions, mainly caused by artillery, Ukraine, July 2023.*

force capable of defending the breadth of front through attrition, and it is artillery that is primarily inflicting the constant attrition of Ukrainian troops.[18] The Russian leadership likely believes it can kill its way out of the war, and artillery will be key to doing that.

Furthermore, so long as Russia maintains a substantial advantage in artillery systems, it can use tactics that will, over time, deplete the AFU of reserves – a critical vulnerability for Ukraine. For example, fixing the AFU into defending terrain can allow Russian artillery to inflict significant casualties on Ukrainian forces as they rotate and are resupplied. In other cases, Russia has used its artillery to destroy Ukrainian towns that come into range. This has fixed the AFU politically into defending unfavourable terrain to delay the widespread depopulation of nearby population centres.

Russia's artillery advantage also constrains Ukraine's tactical options, thereby limiting the risk to Russian forces. For example, during the Ukrainian offensive of 2023, Ukraine managed to concentrate 55 155 mm howitzers on its main axis of advance, as well as a variety of Soviet calibre guns along the front.[19] The total number of Ukrainian guns in action is sensitive and therefore remains undisclosed, but suffice to say that it was unable to properly resource the artillery fight in support of its offensive. Russia fielded 720 guns and 230 MRLs across the southern front, and was able to concentrate a significant proportion of those around priority areas.[20] This meant that the Ukrainian artillery concentration struggled to be brought forward because of strikes from Lancet-3M loitering munitions and counter-battery fire on what was a limited frontage. Thus, Ukrainian forces advanced into a fire pocket where they could not suppress Russian artillery, and so accepted disproportionate risk if they rose from their trenches. Given Ukraine's need to husband limited artillery and ammunition stockpiles, this situation meant that any advance had to be carefully planned and executed, both reducing the number of points at which Ukraine could dynamically threaten Russian units and slowing the tempo of Ukrainian operations. If the conditions for successful offensive action were not obtained with sufficient quantities of howitzers and munitions, this would also increase the cost to the AFU as they were unable to counter the Russian fires superiority.

Effectively constraining Russian artillery – even to achieve parity with the AFU as regards the availability at any given point in the front – would therefore have a transformative effect on the character of the war. It would achieve three things. First, it would reduce the rate of Ukraine's casualties, alleviating the pressure of rotation, and thereby allowing the AFU to preserve the fighting power of its units in defence. Second, it would reduce Russia's ability to punish Ukrainian attempts to conduct localised attacks, thereby increasing the proportion of Russian forces that must be held across the front to defend each sector, and so reducing the felt effect of Russia's advantage in personnel along the front. Third, a consequence of the preceding effects would be to stabilise the front. Between the reduced attrition of the AFU and the reduced offensive combat power of Russian forces, limiting Russia's access to artillery would likely undermine Russia's theory of victory and make the conflict sustainable for Ukraine in the long term. This would protract the war, increasing the risk to the Russian economy. It would therefore reverse the current trajectory of the conflict, where Russian leverage in potential negotiations is gaining as the AFU becomes weaker, and would instead leave Russia with the prospect of accumulating damage to its critical national infrastructure, the depletion of its stockpiles, and the growing vulnerability of its domestic economy, without any confidence that it would achieve its objectives militarily. Even if negotiations end the intensity of the fighting, limiting Russia's ability to regenerate its artillery stockpiles is critical to reducing the threat of renewed hostilities against Ukraine or a conventional threat emerging against Georgia, Moldova or European NATO.

The reduction in casualty rates and equipment loss for the AFU, were the volume of Russian artillery fire to be curtailed, could also allow new recruits to

18 *Jack Watling, 'In Ukraine, Russia is Beginning to Compound Advantages', RUSI Commentary, 14 May 2024, <https://rusi.org/explore-our-research/publications/commentary/ukraine-russia-beginning-compound-advantages>, accessed 16 September 2024.*

19 *Jack Watling, Oleksandr V Danylyuk and Nick Reynolds, 'Preliminary Lessons from Ukraine's Offensive Operations, 2022–23', RUSI, 2024, p. 17.*

20 *Ukrainian General Staff J2 Assessment.*

be kept in training for longer and formed into new units, rather than pushed to units on the front as battlefield replacements. Given that the West has a limited supply of artillery systems and armoured vehicles and is not yet producing equipment in sufficient quantities to replace losses, the reduction in the rate of equipment destruction at the front is also important if the AFU is to build new units for future operations. The reduction of Russia's artillery park is therefore a prerequisite for Ukraine rebuilding its capacity to achieve the liberation of its occupied territories. The prospect of Ukraine regaining such a capability must necessarily increase the risk of Russia continuing the conflict, building Ukrainian leverage to terminate the conflict on favourable terms. The disruption of Russia's artillery supply chains should consequently be of the highest priority for Ukraine's international partners.

Chapter 2: What Makes a Russian Howitzer?

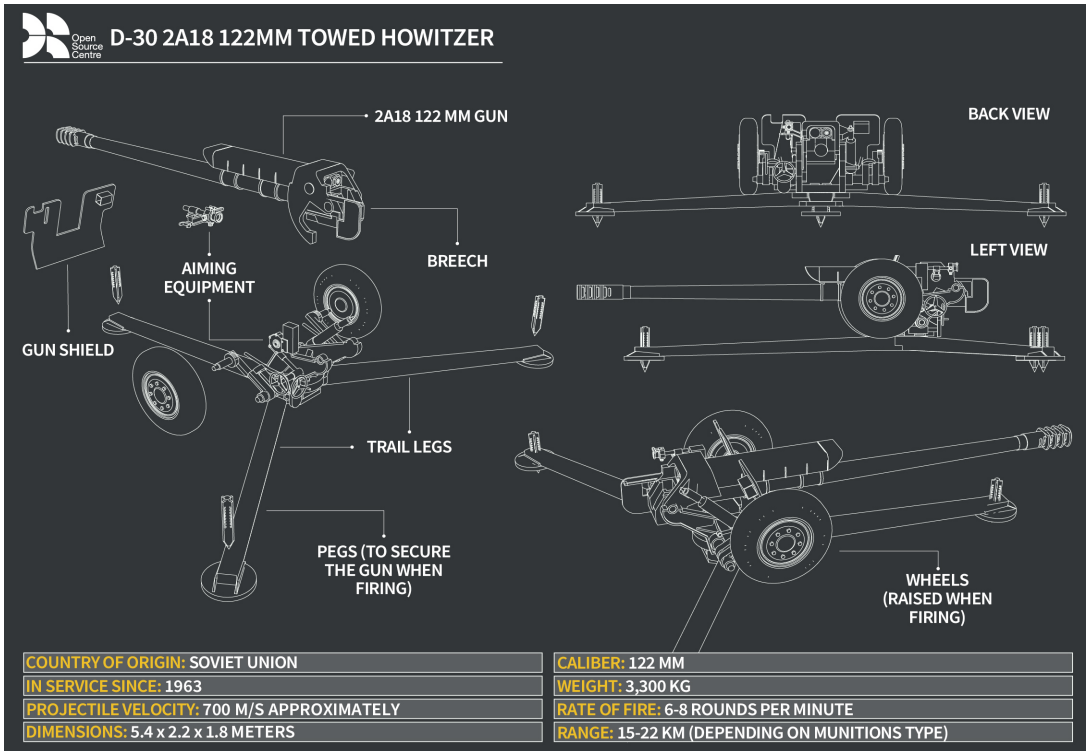
A howitzer is a large-calibre gun, over 100 mm in diameter, designed to fire large shells filled with high explosives. It can be self-propelled or towed. In Russian service, most self-propelled howitzers are based on tracked armoured vehicles designed during the Cold War.

The vehicle protects the crew from small arms fire and other howitzers, and carries the system's ammunition. Towed howitzers are moved around by the crew, which operates out in the open, exposed to enemy fire. Ammunition is typically carried in the truck that tows the howitzer, or pre-positioned so that the gun can be moved between different areas.

The core component of a howitzer is its gun assembly, which includes the barrel, breech, a bore evacuator (on a self-propelled howitzer), and a muzzle brake. The gun assembly is installed into an armoured hull with electric servos that elevate the barrel, and recuperators that absorb the recoil generated by firing the gun. The vehicle that carries the barrel in a self-propelled howitzer is built from armoured steel that is rolled to the correct thickness, often while heated, and welded into shape. This becomes the hull, which is then fitted with an engine and transmission. A drive sprocket is attached to the transmission through final drives to provide the vehicle's motion. The weight of the vehicle is supported through road wheels attached to torsion bar suspension, which all rest upon the track. The track is built using segments connected with pins, and helps disperse the vehicle's weight over a wider area, which in turn improves its ability to cross weak terrain.

02

Figure 1 : D-30 2A18 Russian towed artillery



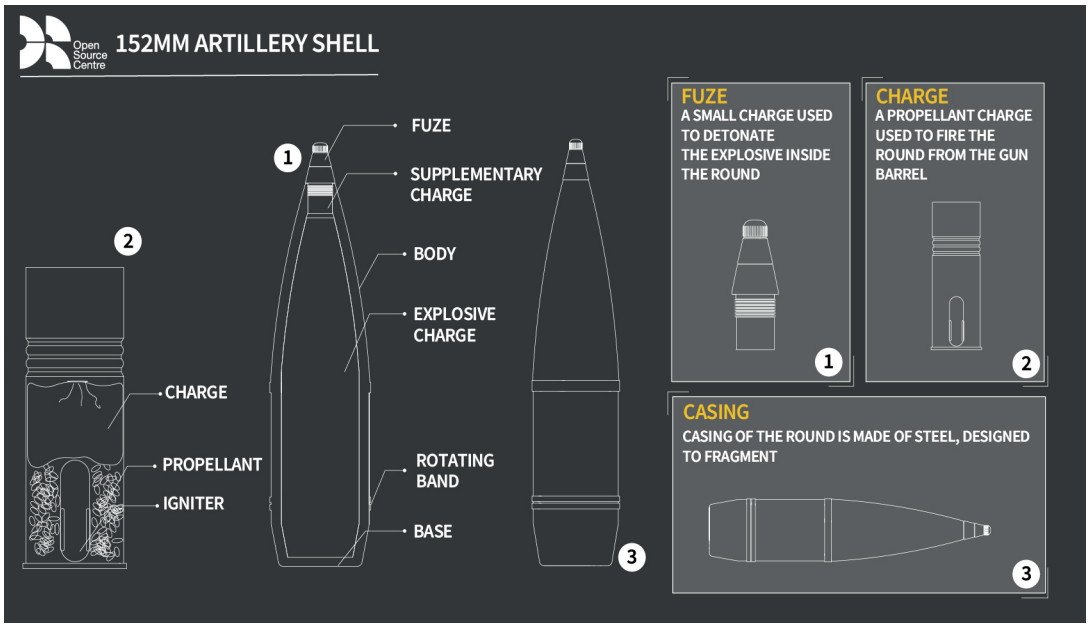
Source: Open Source Centre.

Once the gun assembly, drive train and running gear have been added to the hull, the howitzer is fitted with a fire control system. The fire control system is a computer that is used to enter coordinates and meteorological data to support the firing of the howitzer. It generates ballistic calculations that, in an ideal setting, will account for air pressure, wind and the temperature of the ammunition. The ballistic calculation generates the elevation for the gun that will give the greatest chance of successfully delivering rounds against a target. A howitzer will typically carry a radio that allows the crew to communicate with other howitzers, its battery commander or the force that it is supporting.

The final element that makes a howitzer is the ammunition. There are three components to an artillery round: the charge, the projectile and the fuse. The charge is built from nitrocellulose and propels the projectile out of the barrel at very high speeds in a ballistic arc towards the target. The projectile is made of steel with thick walls that may be pre-fragmented. The shell is filled with an explosive material that is detonated by the fuse. The fuse is a cone-shaped object that is screwed into the nose of the projectile before it is loaded into the gun; it detonates the explosive filling inside the projectile either when it hits the ground, or just above it.

Russia employs different calibre artillery systems to the West, including howitzers that are towed and self-propelled with 122 mm, 152 mm and 203 mm barrels. They are accompanied by mortars, which can also be towed or self-propelled and are used with 82 mm, 120 mm and 240 mm barrels.

Figure 2: Russian 122mm artillery shell

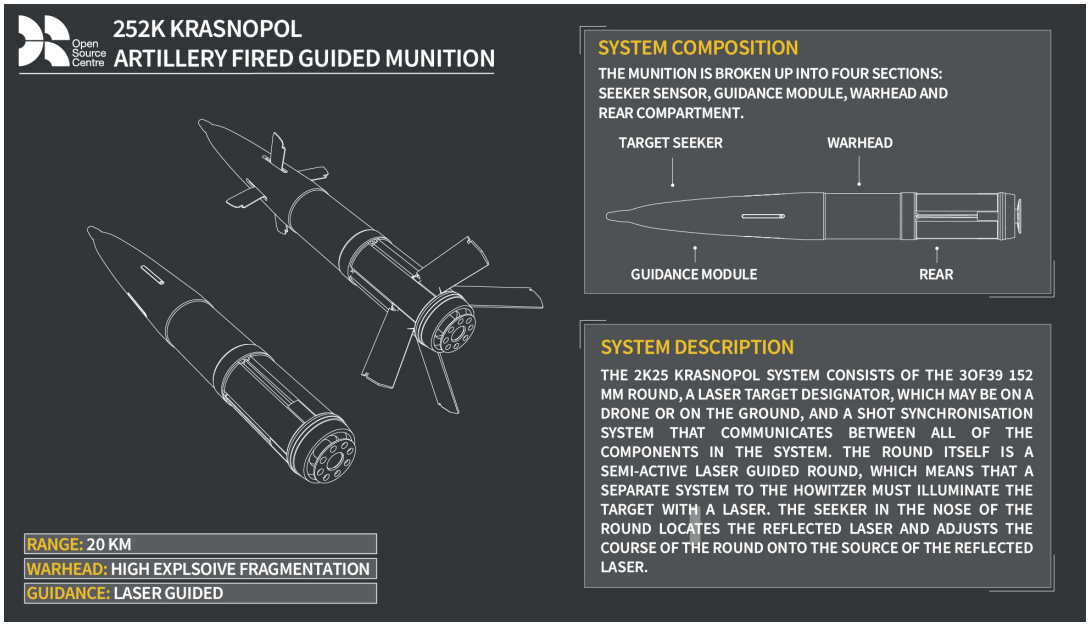


Source: Open Source Centre.

The range of the smallest howitzers is greater than the range of the biggest mortars. A mortar uses less propellant to fire its projectiles at a high angle. As a result, mortars have a shorter range and may take longer to reach their target. A howitzer has a longer and stronger barrel, which enables more propellent and heavier projectiles to be used.

Howitzer projectiles typically deliver more explosive energy; however, the lower weight and size of mortars and their ammunition means that they can be carried and used by infantry, with howitzers typically held further back.

Figure 3: 252 Krasnopol Artillery Fired Guided Munition



Source: Open Source Centre.

Chapter 3: Howitzer Supply Chains

Modern military supply chains are deeply complex, often requiring inputs from a variety of entities and culminating with a systems integrator, where the component parts are assembled into a finished vehicle or weapon. This can make it difficult to understand supply chains – and where they are vulnerable. This chapter attempts to set out the primary elements in Russia's howitzer supply chain through an in-depth look at the production of howitzer barrels. Barrels are a consumable product that must be replaced regularly or their accuracy and efficacy declines – unlike items such as armoured plates or engines, which are rarely required unless new systems are being built. At present, Russia is modernising or refurbishing many of its armoured vehicles and maintaining a large arsenal of howitzers in Ukraine.[21] This indicates that barrel production may be a bottleneck in Russia's ability to sustain its artillery forces in Ukraine.

03

21 *Jack Watling and Nick Reynolds, RUSI, 'Russian Military Objectives and Capacity in Ukraine Through 2024'.*

Manufacturers

Figure 4: Cannon units for Msta-S, made by Volgograd-based Titan-Barrikady Plant,[22] ready for assembly at Uraltransmash in Yekaterinburg, April 2023

Source: Russian military correspondent.

Artillery system production in Russia is a centralised network of interconnected manufacturers, contractors, subcontractors, suppliers and research and development (R&D) partners, managed mainly by Rostec, the state-governed defence holding, in direct cooperation with the Main Missile and Artillery Directorate of the General Staff of the Russian Army. In 2023,

Rostec announced an internal reorganisation on the 'gun-to-shot' principle, which aimed to streamline production of tanks and artillery by separating them and allowing each group to specialise. It transferred companies in the artillery supply chain from UralVagonZavod, Russia's main tank manufacturer, to Tekhmash, which had previously focused on ammunition production.[23]

22 *JSC Federal Scientific and Production Centre Titan-Barrikady, 'Образцы военной техники и продукции гражданского назначения, спроектированные и изготовленные в АО 'ФНПЦ "Титан-Баррикады"' ['Samples of Military Equipment and Civilian Products Designed and Manufactured by JSC FSPC Titan-Barrikady'], <http://web.archive.org/web/20240418080214/https:/cdbtitan.ru/product>, archived at the Wayback Machine 18 April 2024, accessed 16 September 2024.*

23 *Artem Filipenok, '"Ростех" консолидирует артиллерийские заводы по системе "пушка — выстрел"' ['Rostec Consolidates Artillery Factories on a Cannon-Shot System'], RBC, 18 April 2023, <https://www.rbc.ru/business/18/04/2023/643d41d39a7947b208aeab58>, accessed 16 September 2024.*

Key artillery production facilities are as follows:

- **Uraltransmash:** The main assembly facility for Russian artillery systems is a 143-hectare plant in Yekaterinburg which also produces trams and oil pumps for the civilian market. The plant has its own engineering and design centre for artillery, SKB Transmash-Spetstekhnika, and tests howitzers on a 15,000-hectare artillery range 17 km north of the plant. Uraltransmash developed and manufactured the main artillery systems used by the Russian army, such as the 2S3 Akatsiya, which entered service in the 1970s, and the 2S19 Msta-S, which was produced from 1989. According to Russian brand registers, the plant now owns the Msta-S, Koalitsiya-SV, Akatsiya, Tyulpan and Giatsint howitzer brands, which make up the majority of self-propelled howitzers (SPH) in Russian service.[24]

- **Motovilikha Plant:** Earlier towed versions of the Msta-S howitzers and other self-propelled machines – such as the 2S23 Nona, a 120 mm mortar based on the wheeled chassis of a BTR-80 armoured fighting vehicle – have been assembled at the SKB Motovilikha Plant. The plant went into bankruptcy in 2018 and stopped delivery to the Russian army in 2022.[25] To preserve its manufacturing processes in 2023 it was transferred to Remdizel, a Rostec-affiliated company, before being fully acquired by Rostec subsidiary Tekhnodinamika in 2024.[26]

- **Zavod No. 9:** This is a former production unit of Uralmashzavod and specialises in barrel manufacturing, being one of the four main artillery suppliers. It produces D-30 towed howitzers and various tank guns, including the 2A20 U-5TS Molot for the modernised T-62 and 2A46 for the T-72, T-64A and T-90. The plant is also the manufacturer of the Soviet-era 125-mm 2A45 Sprut-A and 2A45M Sprut-B anti-tank guns.[27]

- **Titan-Barrikady:** The Volgograd-based plant has specialised in a diverse range of artillery and missile systems and its portfolio includes Msta-B and Msta-S howitzers (the latter's assembly has been recently moved to Uraltransmash).[28]

- **Krasny Oktyabr:** Titan-Barrikady has been vertically integrated with the nearby Krasny Oktyabr metallurgy plant, which specialises in the production of special steel, and the two plants share energy and forging infrastructure. Krasny Oktyabr does not list military uses for its products, but Russian archives have records of the plant casting 152 mm barrels.[29]

The hull of a howitzer is built from high-hardness steel that is hot- or cold-rolled until it forms a material called rolled homogeneous armour (RHA). After the collapse of the USSR, Russia developed its own production of RHA, having previously relied on plants in Dnipropetrovsk, Zaporizhzhia and Mariupol in Ukraine.[30] According to the armour steel Institute Stali, the three main steel suppliers for tanks and artillery are Krasny Oktyabr iron & steel plant, Magnitogorsk Iron & Steel Works (MMK) and OMZ-Spetstal.[31] Establishing these production capabilities required a serious re-adjustment and investment in specialised production facilities with little to no civilian application, which suggests they are reliant upon the Russian defence industry.[32]

24 *All-Russian Public Organisation 'Union of Machine Builders of Russia, 'Название "Мста-С" стало брендом' ['The Name "Msta-S" has Become a Brand'], 29 March 2018, <https://soyuzmash.ru/news/companies-news/nazvanie-msta-s-stalo-brendom/>, accessed 16 September 2024.*

25 *Kommersant, '"Мотовилихинские заводы" признаны банкротом' ['Motovilikha Plants Declared Bankrupt'], 26 March 2018, <https://www.kommersant.ru/doc/3585406>, accessed 16 September 2024.*

26 *Kommersant, '"Мотовилиха" вышла с передержки' ['Motovilikha Takeover is Finished'], 26 March 2018, <https://www.kommersant.ru/doc/6834462>, accessed 5 September 2024.*

27 *Military Factory, '2A45 Sprut (Kraken): Towed Anti-Tank (AT) Gun System', <https://www.militaryfactory.com/armor/detail.php?armor_id=880>, accessed 16 September 2024.*

28 *SC Federal Scientific and Production Centre Titan-Barrikady, 'История' [History'], <http://web.archive.org/web/20240418075131/https://cdbtitan.ru/history>, archived at the Wayback Machine 18 April 2024, accessed 16 September 2024.*

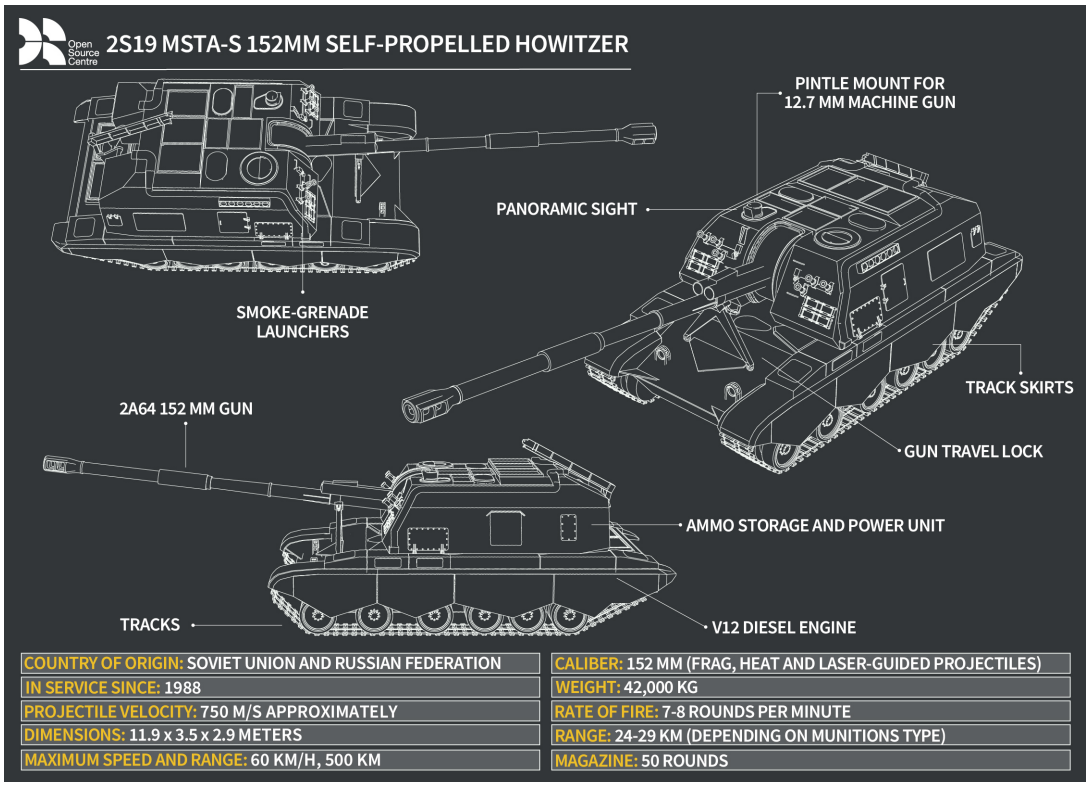
29 *Vesti, '"Красный Октябрь" впереди' ['Krasny Oktyabr ahead'], 10 April 2010, <https://www.vesti.ru/article/2032129>, accessed 16 September 2024.*

30 *Author interview with Ukrainian metallurgy experts from Azovstal Plant, 26 June 2024.*

31 *M O Alekseev, E N Chistyakov and D G Kupryunin, 'Броневые материалы. Современное состояние' ['Armour Materials. Current State'], JSC NII Stali, <https://www.niistali.ru/about-company/stati-nashikh-avtorov/bronevye-materialy/>, accessed 16 September 2024.*

32 *Author interview with Ukrainian metallurgy experts from Azovstal Plant, 26 June 2024.*

Figure 5: The MSTA System



Source: Open Source Centre.

The primary supplier of diesel engines for Russian tanks and self-propelled howitzers is the Chelyabinsk Tractor Plant (Uraltrak) , while some newer models - such as the wheeled 2S34 Malva - use engines from the Yaroslavl Motor Plant. Engine production requires heat-resistant high-alloy steel for elements such as valves and fasteners, and high-precision computer numerical control (CNC) machines.[33] Tracks for tanks and self-propelled artillery have similar requirements, and are forged by Rostec-owned Omsktransmash[34] and Kalashnikov Concern's Lipetsk Mechanical Plant.[35]

In addition to its physical structure and gun, a howitzer carries a fire control system. The traditional supplier of automated fire guidance and navigation systems for Russian howitzers is the Signal Research Institute, based in Kovrov. Like most other strategic enterprises, it is part of Rostec, and is held within the group's missile-manufacturing arm. It supplies the newest version of Russia's automated fire control system ASUNO, which has been in development since 2019 and was first shown at the Ukrainian frontline in June 2024.[36]

Each of these companies will have their own supply chains, from raw materials through to finished products that are delivered to Uraltransmash for assembly into a howitzer.

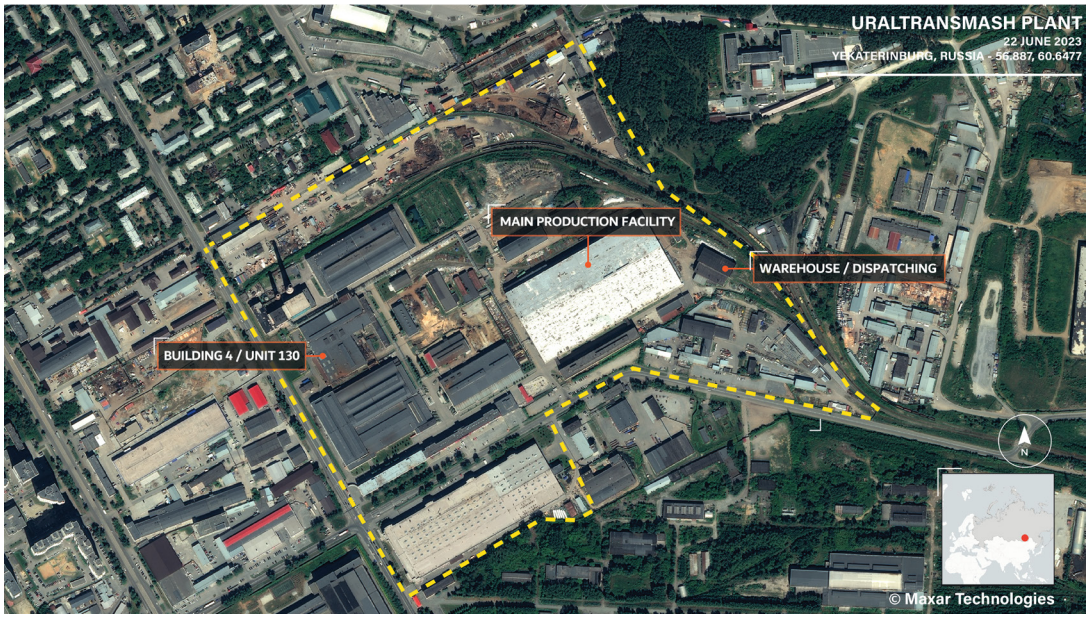
33 *CNC is a manufacturing process that automates the operation, movement and precision of machine tools using preprogrammed computer software integrated directly into the machines.*

34 *Military Informant, ' "Омсктрансмаш" объявил об открытии нового цеха по производству гусеничных лент для танков Т-80, САУ «Мста-С» и ЗРС С-300В' ['Omsktransmash Announced the Opening of a New Workshop for the Production of Tracks for T-80 tanks, Msta-S Self-Propelled Guns and S-300V Air Defence Systems'], Telegram, 2 February 2024, <https://t.me/milinfolive/112232>, accessed 16 September 2024.*

35 *Lipetsk Mechanical Plant, 'Выпускаемая продукция' ['Manufactured products'], <https://www.lmz48.ru/production/products-1/>, accessed 16 September 2024.*

36 *Rostec, 'Ростех досрочно поставил в войска "Планшет-А" на колесном шасси для управления артиллерией' ['Rostec Delivers Planshet-A to Troops on Wheeled Chassis for Artillery Control Ahead of Schedule'], 18 June 2024, <https://rostec.ru/news/rostekh-dosrochno-postavil-v-voyska-planshet-a-na-kolesnom-shassi-dlya-upravleniya-artilleriey/>, accessed 16 September 2024.*

Figure 6: The Uraltransmash Plant



Source: Maxar Technologies, RUSI, Open Source Centre.

Barrel Production

Unlike armour or engine production, barrel production is a constant requirement for any military. This is because barrels are a consumable component of a howitzer or tank. Even when steels that are resistant to high heat and pressure are used, and a chrome lining is added to the bore interior, the use of a barrel will degrade its structural integrity to the point where it must be replaced.[37] This means that a country's ability to meet its needs for barrel replacement in a high-intensity war is critical to its ability to continue the fight.

The impact of failing to replace barrels is demonstrated by a report from an operator of a 203 mm 2S7 howitzer in Ukraine: 'The gun was fired a lot in one day and overheated. It was performing poorly, and we weren't sure where the shells landed. There are no replacement barrels, so we might be transferred to the 2S1 [a Soviet-era howitzer]'.[38] This indicates not only that the gun was less accurate and effective because of barrel wear, but that the crew could be transferred to a shorter-range and less lethal system if a replacement could not be found. This is why disrupting barrel production is likely to have a greater impact on the battlefield than disrupting the production of armour or refurbishment of engines.

Russian artillery barrel manufacturers are under state control because of their strategic importance. Historically there were many barrel manufacturers in Russia, but there are now just four: Zavod No. 9 in Yekaterinburg; Titan-Barrikady in Volgograd; MZ/SKB in Perm; and the Burevestnik Research Institute in Nizhny Novgorod. The latter is the country's main artillery research and development facility; its research and production facilities are responsible for developing artillery systems and their production processes, so these facilities are equipped with trial production capacity. There is also the main assembly plant, Uraltransmash, which has its own casting and forging facility, but this is primarily the systems integrator in Russia's artillery supply chain, and reports deliveries from Zavod No. 9 and Titan-Barrikady, indicating that it is not currently a significant source of barrel production.[39]

37 *Richard G Hasenbein, 'Wear and Erosion in Large Caliber Gun Barrels', US Army Armament Research, Development & Engineering Center, 2016.*

38 *Author interview with an individual operating this system, June 2024.*

39 *According to company records for 2023 seen by the paper's research team.*

RAW MATERIALS

Metallurgy plants manufacture the steel for artillery barrels in dedicated production runs, allocating resources specifically for producing barrel moulds. The output ranges from 20 to 10 tonnes per mould, depending on the order size and forge capacity. The process begins with casting a steel bar – known as ingots – that will eventually become a barrel. The base materials needed to make the alloy – iron ore, scrap metal and small amounts of molybdenum, chromium or nickel – are melted in a blast furnace for up to 12 hours.[40] An alternate process uses an electric arc furnace, which primarily relies on electricity and scrap metal, as well as ferroalloys, which are created by reducing metal elements in a submerged electric arc furnace.[41]

The molten steel is treated to remove excess carbon before it is poured into moulds. The ingots may be subject to further treatments such as annealing, which removes impurities, and acid baths to remove forge scale from the surface.[42] The steel will be rolled into its final shape before being cut to size and transported to the customer by rail.[43]

Several metallurgy plants have been identified as suppliers to the UralVagonZavod group of companies. Most of the sources are pre-2022 registers of public procurement and contracts, as this information is no longer disclosed.

40 *BorTec Group, 'The Production of Steel – How is It Made?', <https://bortec-group.com/glossary/steelmaking/>, accessed 16 September 2024.*

41 *Total Materia, 'Ferro-alloy Production: Part Two', July 2016, <https://www.totalmateria.com/en-us/articles/ferro-alloy-production-2/>, accessed 16 September 2024.*

42 *Vesti,'"Красный Октябрь" впереди' ['Krasny Oktyabr Ahead'], 10 April 2010, <https://www.vesti.ru/article/2032129>, accessed 16 September 2024.*

43 *Unified Alloys, 'Stainless Steel 101; What is Stainless Steel and How is It Made?', <https://www.unifiedalloys.com/blog/what-is-stainless-steel>, accessed 16 September 2024.*

Table 1: Suppliers of Raw Materials Into the Barrel Production Supply Chain in Russia			
Company Name	**Products**	**Customers**	**Volume in 2023**
Krasny Oktyabr	Steel blanks for artillery and tank barrel production.	Zavod No. 9, Titan-Barrikady,[44] UralVagonZavod[45]	9,161 tonnes[46]
Magnitogorsk Iron & Steel Works	Covers the full ferrous metals production cycle, from preparation of raw materials to final metal processing.	SKB, UralVagonZavod,[47] Uraltransmash[48]	57,328 tonnes[49]
Chelyabinsk Electrometallurgical Combine (ChEMK)	More than 120 types of ferroalloys and alloys	MMK,[50] UralVagonZavod[51]	668 tonnes[52]
Aktobe Ferroalloy Plant	Ferrochrome	Krasny Oktyabr[53]	Unknown
Polema	Pure chromium, vanadium and molybdenum compounds in powder and plate form	JSC Votkinsk Plant[54]	Unknown
EK Resources LLC	Chromium ore, chromites, ferroalloys.	UralVagonZavod[55]	Unknown
CTK Euro JSC	Chrome compounds.	UralVagonZavod[56]	Unknown
Industrial Systems	Cast iron, steel, ferroalloys and ferro-chromium.	Omsktransmash[57]	Unknown
Vladmettsentr LLC	Alloy steel in ingots or other primary forms	Uraltransmash, JSC NPP Start named after AI Yaskin'[58]	Unknown
Lebedinsky Ore Mining and Processing Plant	Iron ore.	MMK[59]	Unknown
Sokolov-Sarbai Ore Mining and Processing Plant	Iron ore.	MMK[60]	Unknown

Source: Russian internal railway data, Trade data supplied by third-party commercial provider, Russian legal databases, Krasny Oktyabr Volgograd Steel Work, 74.ru, Kursiv.

44 *Krasny Oktyabr Volgograd Steel Work, 'ВМЗ "Красный Октябрь" приступил к изготовлению заготовок для танковых стволов' ['VMZ Krasny Oktyabr Began Manufacturing Blanks for Tank Barrels'], 26 December 2019, <https://web.archive.org/web/20201204135625/https://www.vmzko.ru/page/index/3901>, archived at the Wayback Machine 4 December 2020, accessed 16 September 2024.*

45 *Railway transportation records on UralVagonZavod reveal that it regularly received shipments from Krasny Oktyabr throughout 2023 and up to April 2024.*

46 *The amount is sourced from the railway transportation records of UralVagonZavod for 2023 and only includes cargo deliveries to the former.*

47 *Railway transportation records for UralVagonZavod reveal that it regularly received shipments from MMK throughout 2023 and up to April 2024.*

48 *Russian legal databases.*

49 *The amount is sourced from the railway transportation records of UralVagonZavod and SKB for 2023 and only includes cargo deliveries to the former.*

50 *Alla Skripova, 'Незаконная приватизация и поставки в США: читаем иск Генпрокуратуры к владельцу ЧЭМК о возврате заводов' ['Illegal Privatisation and Supplies to the United States: We Read the Claim of the Prosecutor General's Office Against the Owner of ChEMK to Return the Factories'], 74.ru, 13 February 2024, <https://74.ru/text/business/2024/02/13/73222901/>, accessed 16 September 2024.*

51 *Railway transportation records for UralVagonZavod reveal that it regularly received shipments from ChEMK throughout 2023 and up to April 2024.*

52 *The amount is sourced from the railway transportation records of UralVagonZavod for 2023 and only includes cargo deliveries to the former.*

53 *The steel plant received 4,039 tonnes of ferrochrome worth nearly $9 million between March and May 2024, based on trade data supplied by third-party commercial provider.*

54 *Checko.ru, 'АО "Полема" – Контракты' ['JSC Polema – Contracts'], <https://checko.ru/company/polema-1027100684050?extra=contracts&law=223&role=supplier>, accessed 16 September 2024.*

55 *Checko.ru, 'ООО "ЕК-Ресурсес" – Контракты' ['EK Resources LLC- Contracts'], <https://checko.ru/company/ek-resurses-1107746420088?extra=contracts&law=223&role=supplier>, accessed 16 September 2024.*

56 *Checko.ru, 'АО "ЦТК-Евро" – Контракты' ['CTK Euro JSC – Contracts'], <https://checko.ru/company/ctk-evro-1027700579500?extra=contracts&law=223&role=supplier>, accessed 16 September 2024.*

57 *Checko.ru, 'ООО "Промышленные Системы" – Контракты' ['Industrial Systems LLC – Contracts'], <https://checko.ru/company/promyshlennye-sistemy-1136686011626?extra=contracts&law=223&role=supplier>, accessed 16 September 2024.*

58 *Checko.ru, 'ООО "Владметцентр" – Контракты' ['Vladmettsentr LLC – Contracts'], <https://checko.ru/company/vladmetcentr-1123328005789?extra=contracts&law=223&role=supplier>, accessed 16 September 2024.*

59 *Russian legal databases.*

60 *Zhanel Zhazetova, 'Структура ERG отсудила у российского комбината более 1 млрд тенге' ['The ERG Group Sued a Russian Plant for More than KZT 1 Billion'], Kursiv, 29 March 2024, <https://kz.kursiv.media/2024-03-29/zhzh-ergsud/>, accessed 9 July 2024.*

Raw Materials In-Depth: Chromium

Our research indicates that Russia's artillery supply chain is exposed and vulnerable in its need for foreign sources of high-quality chrome ore to sustain its barrel production. Much of this material is sourced from outside Russia, and so it should be feasible to disrupt its delivery through the focused use of sanctions and by adjusting existing sanctions legislation and export control regulations.

Russia is self-sufficient to a significant degree in the raw materials required for barrel production. There is, however, evidence to suggest that Russia requires substantial imports of chromium ore to produce pure chromium, which is used for chrome-plating barrels. This is a process whereby the interior of the barrel bore is coated with a layer of chrome between 50 and 180 microns thick.[61] This thin layer of chrome protects the bore from the corrosive effects of firing. Shooting can damage the barrel. Regular maintenance, such as cleaning and lubrication, helps manage this wear. The chrome coating makes maintenance easier and reduces the harmful effects of shooting. Chromium is also used to alloy the steel used to produce artillery barrels, which makes it an important raw material for the overall barrel supply chain.

Chromium is valued for its high corrosion resistance and hardness.[62] It can be processed into different types of compounds, such as oxides and ferrochromium, which are used to harden steel, manufacture stainless steel or make anti-corrosion coatings.[63] Chrome ore (chromite) tends to be quite accessible and is primarily extracted using open-pit mining.[64] The extracted ore is mainly used to produce an alloy of iron and chromium called ferrochromium, or to process the ore into pure chromium.

Russia produces between 1.5 and 2 million tonnes of chrome ore per year from the Saranovo Rudnaya mine and in the Yamalo-Nenets Autonomous District.[65] Russia's demand for chromium is around 1.47 million tonnes per year, with a growth trend to 1.6 million tonnes by 2025 and 1.73 million tonnes by 2030.[66] About 55.2% of this consumption is covered by imports, despite Russia technically producing enough by weight to meet its needs, because Russian ore has a lower chromium content.[67] For example, deposits in the Polar Urals or the Perm region are characterised by a chromium content of 38% and 37% respectively.[68] Typically, ore with a chromium content in excess of 45%, along with a low ratio of impurities like

61 *Eliseev E. A. et, al., 'Материалы и развитие технологий, обеспечивающих ресурс стволов артиллерийских, танковых и стрелковых систем вооружения (обзор)' ['Materials and Development of the Technologies Providing the Resource Trunks of Artillery, Tank and Shooting Systems of Arms (Review)'], Proceedings of VIAM (Vol. 57, No. 9, 2017): p. 23, <https://doi.org/10.18577/2307-6046-2017-0-9-3-3>, accessed 16 September 2024. Before the plating process, the barrel blank is polished, treated with acid (etching), degreased, and then placed in an electroplating bath. An electric current and specific temperatures are applied for a set period, resulting in a chromium layer of the required thickness being deposited on the inner surfaces of the barrel. GunsClub, 'Хромирование ствола – что это и зачем нужно' ['Chromium Plating of Barrels: What It is and Why It's Needed'], <https://guns.club/lib/oruzhie/khromirovanie-stvola-chto-eto-i-zachem-nuzhno/>, accessed 16 September 2024.*

62 *American Elements: The Materials Science Company, 'Chromium', <https://www.americanelements.com/cr.html>, accessed 16 September 2024.*

63 *Britannica, 'Chromium', <https://www.britannica.com/science/chromium>, accessed 16 September 2024; Royal Society of Chemistry, 'Chromium', <https://www.rsc.org/periodic-table/element/24/chromium>, accessed 16 September 2024; SferoLit LLC, 'Феррохром ФХ 100А, 850А, ФХ025' ['Ferrochrome FKh 100A, 850A, FKh025'], <https://sferolit.ru/catalog.php?p=217>, accessed 16 September 2024.*

64 *Minerals Education Coalition, 'Chromium', <https://mineralseducationcoalition.org/minerals-database/chromium/>, accessed 16 September 2024; Заводы.рф [Factories.rf], 'Хром: свойства, способы добычи и применение' ['Chromium: Properties, Extraction Methods, and Applications'], 13 November 2020, <https://заводы.рф/publication/hrom-svoystva-sposoby-dobychi-i-primenenie - :~:text=Самым распространённым и популярным является открытый, карьерный способ. Это объясняется доступностью залежей и возможностью быстрой организации широкого фронта работ с привлечением максимума тяжёлой техники.>, accessed 16 September 2024.*

65 *Mines of the Urals, 'Сарановская шахта "Рудная" ' [Saranovsk Mine Rudnaya'], 22 August 2019, <https://uralmines.ru/saranovskaya-shahta-rudnaya/#google_vignette>, accessed 16 September 2024; Kommersant, 'ЧЭМК наладил экспорт хромовых руд' ['ChEMK Has Established the Export of Chromium Ores'], 24 December 2019, <https://www.kommersant.ru/doc/4206351>, accessed 16 September 2024.*

66 *Russtrat: Institute of International Political and Economic Strategies, 'Структура и характер зависимости РФ от импорта стратегического сырья' ['Structure and Nature of Russia's Dependence on Strategic Raw Material Imports'], 18 July 2021, <https://russtrat.ru/reports/18-iyulya-2021-0010-5096>, accessed 16 September 2024.*

67 *Ibid.*

68 *G A Mashkovtsev and T V Bakanova, 'On Mineral Resources for Ferroalloy Production', KnE Materials Science, 17 March 2019, pp. 29–45.*

aluminium and silicon, is required for metallurgic uses.[69] Russia is also understood to have a state reserve system that may include chromium as a strategic raw material, which means that a disruption to chromium supply could lead it to rely on this reserve.

In addition to Russia's ore being generally of insufficient quality for gun barrels and pure chromium, the country's reserves are underdeveloped. Russia technically sits on 52.4 million tonnes of chrome ore, around 2% of the world's global reserves, however it has only initiated development of 13% of those reserves. As a result, it is forced to import large quantities of raw materials to meet its chromium needs – for pure chromium in particular.[70] Krasny Oktyabr's relationship with the Aktobe Ferroalloy Plant in Kazakhstan, which manufactures artillery barrels, reinforces this conclusion. The two entities have no public relationship, but commercial trade data reveals that the Aktobe Ferroalloy Plant delivered more than 4,000 tonnes of high carbon ferrochrome, worth approximately $9 million, to Krasny Oktyabr between March and May 2024. As transactions between Russia and Kazakhstan are not normally recorded, it is possible that this relationship has existed for much longer.

Chromite has the harmonised system (HS) code of 2610, which is used to monitor trade between countries. Data for 2023 indicates that Russia imported around $36.7 million worth of products under this HS code.[71] Russia's imports for 2023 and January to May 2024 show that most chromium-containing goods – $29.9 million – originated from South Africa, but that the majority of South African ore was exported to Russia via European countries, including $17.9 million from the Netherlands.[72] Export data for Kazakhstan is not included in this analysis, as Kazakhstan and Russia are both members of the Eurasian Customs Union, which lacks detailed records on their mutual trade. In 2021, Kazakhstan was the primary supplier of chromium to Russia, accounting for 86.8% of imports.[73] Although supplies from Kazakhstan have significantly decreased since 2022, it is likely that Kazakhstan remains a major supplier of chromium-containing goods to Russia. Information on other countries of interest, along with the dollar value of those supplies, are provided in Table 2 below. The available data for 2024 paints a markedly different picture, with less than $1 million in chromium-containing imports between January and May. This may indicate that Russia's imports have reduced because of sanctions, or that Russia has limited the data made available on its imports.

69 *Forui Mining, 'What Are the Types and Purification Methods of Chrome Ore?', 25 July 2021, <https://www.foruimining.com/solutions/what-are-the-types-and-purification-methods-of-chrome-ore/>, accessed 16 September 2024.*

70 *Russtrat: Institute of International Political and Economic Strategies, 'Structure and Nature of Russia's Dependence on Strategic Raw Material Imports'.*

71 *Trade data supplied by third-party commercial provider.*

72 *Ibid.*

73 *FSUE All-Russian Scientific-Research Institute of Mineral Resources named after N.M. Fedorovsky, FSUE Central Research Institute of Geological Prospecting for Base and Precious Metals, FSUE All-Russian Research Institute of Oil Geology and FSUE Gidrospetsgeologiya, Государственный доклад о состоянии и использовании минерально-сырьевых ресурсов Российской Федерации в 2021 году. Хромовые руды [State Report on the Condition and Utilisation of Mineral Raw Material Resources in the Russian Federation for 2021. Chromium Ores], ed. D. D. Tetenkin et al. (Moscow: Ministry of Natural Resources and the Environment of the Russian Federation, and Federal Agency for Mineral Resources, 2022), <https://gd2021.data-geo.ru/fm/cr/>, accessed 16 September 2024.*

Table 2: Countries of Interest (the US and EU Members) Involved in Supply of Chromium-Containing Goods to Russia in 2023			
Origin Country	**Value (USD)**	**Departure Country**	**Value (USD)**
Germany	$233,749.32	Netherlands	$18,358,151.05
Italy	$72,335.74	Bulgaria	$1,732,550.00
US	$62,095.13	Lithuania	$204,505.25
Netherlands	$46,996.70	Finland	$167,954.76
Spain	$44,291.94	Germany	$136,117.12
France	$25,616.19	Poland	$56,141.89
Slovenia	$15,891.30	Estonia	$34132.40
		France	$10,104.91

Source: Trade data supplied by third-party commercial provider.

The companies involved in extracting and processing chromite and exporting it to Russia, along with the dollar value of those exports in 2023, are provided in Table 3. The top three are mining companies which both extracted and exported chromium ore to Russia. The others are mainly involved either in processing chromium ore into various chromium compounds[74] or reselling raw material.[75] Of course, not all these imports are destined for Russia's artillery supply chain; its oil and gas industry are significant consumers of chromite, too. However, there are five chromite importers in Russia with historical ties to the defence industry: Polema; Vladmettsentr; Industrial Systems; CTK Euro; and EK Resources.[76] These companies imported $6,758,000 worth of chrome products across five different HS codes in 2023. EK Resources was responsible for importing $3,485,000 worth of products under HS code 2610 (through EK-Company AG 'EKC.AG' as a supplier), indicating that it is potentially a key link in the supply of chromite imported to be processed into pure chromium for the lining of barrels.

Table 3: The 10 Largest Suppliers Involved in the Chromite Supply Chain	
Company Name	**Value (USD)**
EK-Company AG EKC.AG *	$18,311,154
Rand York Minerals (Pty), Ltd	$10,655,146
Hongfei New Materials Technology (Lianyungang) Co., Ltd	$1,552,515
Henan Sicheng Abrasives Tech Co., Ltd	$2,108,811
Lianyungang Fengbang Technology New Material Co., Ltd	$596,193
Turkiye Sise ve Cam Fabrikalari A.S.	$539,042
African Pegmatite (Pty), Ltd	$490,879
Hengsichen Abrasive Technology Co., Ltd	$290,027
Sky Naz General Trading LLC	$288,790

* Supplied to a third company that in turn supplied Russia's defence industry

Source: Trade data supplied by third-party commercial provider.

74 *Sisecam, 'Наши компании' ['Sisecam – Our Companies'], <https://www.sisecam.com.tr/ru/about-us/companies>, accessed 16 September 2024.*

75 *African Pegmatite, 'Chrome Sand: Foundry Casting Application', <https://mineralmilling.com/foundry/chrome-sand>, accessed 16 September 2024.*

76 *'JSC Polema – Contracts'; 'Vladmettsentr LLC – Contracts'; 'Industrial Systems LLC – Contracts'; 'CTK Euro JSC – Contracts'; 'EK Resources LLC- Contracts'.*

There are many methods of processing chromite to produce pure chromium. The most common is the aluminothermic method, which produces metals and alloys by reducing their oxides through a chemical reaction with aluminium. The largest producer of pure chromium in Russia is the powder chemicals plant Polema.[77] Between 2015 and 2018, Polema made 100 deliveries of pure chromium compounds and other components to Russian military plants worth $6.4 million.[78] In the first half of 2023, Polema had $928,000 in transactions with the Imperial Tula Arms Plant alone, which makes components for the 152 mm 2K25 Krasnopol guided munitions, as well as many other defence-related components. Polema also registered $134,000 in transactions with the Perm Machine Building Plant, as well as small orders with other Russian defence manufacturers.

Overall, while disruptions to imports of chromite may be difficult, they are not impossible, especially given the increasing scrutiny on supply chains and continued sanctions pressure by the US, particularly via banks. Though Russia's access to alternative suppliers like Turkey and India is a potential safeguard, the logistical complexities and the potential for sanctions to extend to those channels should not be underestimated. Thus, while chromium supply may not pose an immediate crisis, it remains a point of strategic vulnerability, especially in prolonged conflict scenarios where access to diverse and stable sources of critical materials becomes increasingly important. As with the majority of sanctions, the initial impact is likely to be indirect, and manifest itself in logistics and time costs, which does not defeat the purpose.

Manufacturing Process

The raw materials for an artillery barrel are cast, rolled, and forged in several steel plants traditionally specialising in artillery-grade alloys. Further processing involves cutting, drilling the bore, polishing, and assembly with other elements (such as the breech and recuperator) into a barrel module ready for the assembly plant. The first stage is done by plants with special steel processing capacity, such as Krasny Oktyabr and MMK. The barrel module manufacturers buy steel blanks from these suppliers and process them into finished barrels and fully assembled artillery parts ready to be installed onto the appropriate system. There are two primary methodologies for producing large-calibre artillery barrels.

The first primary methodology is radial or rotary forging. In this method, a steel blank that is shorter than the total length required is drilled and heated, before being inserted into a radial forging machine. The machine inserts a mandrel inside the blank, which can carry the rifling in the case of howitzer barrels, and the blank is passed through four hammers that operate at a very high speed and pressure to shape the steel around the mandrel. This process hardens and stretches the steel and forms it into shape in a matter of minutes.

The result will be precise, and close to the profile of the finished part. Machine tools can either be manually operated – that is, without a CNC – or automated with a CNC. Automated radial forging machines are much more precise, as they allow for the selection of the forging angle, forging diameter, and pressure.[79] It is noteworthy that the Soviet Union also imported its barrel-forging equipment from the West: a CIA report from 1982 covers the procurement of 26 automated rotary forges from Austrian company Gesellschaft fuer Fertigungstechnik und Maschinenbau (GFM).[80] One machine, an SXP 55, was installed at a Perm factory in 1975 and provided the capacity to produce artillery barrels up to 203 mm in calibre. The CIA estimated that a large-calibre barrel could be forged using this technology in two to 10 minutes, and that the USSR had procured sufficient spares for 15 years of operations.[81] The same report estimated that the Soviets could produce 14,000 barrels per year, although this only relates to the production of

77 *JSC Polema, 'Добро пожаловать на сайт АО "Полема" ' ['Welcome to the Website of JSC Polema'], <https://www.polema.net/>, accessed 16 September 2024.*

78 *'JSC Polema – Contracts'.*

79 *Requip.tech, 'Продано: Радиально-ковочная машина с ЧПУ GFM SX-40' ['Sold: GFM SX-40 CNC Radial Forging Machine'], <https://requip.tech/ru/gfm-sx-40-radial-forging-machine/>, accessed 16 September 2024.*

80 *CIA, 'Transfer of Austrian Gun-Barrel Forging Technology to the USSR', March 1982, pp. 1–6.*

81 *Ibid.*

unfinished barrels. Rotary forging machines have a number of civil applications as well as military outputs, and it is possible that many of these GFM machines were imported for civil production, although Russia's mobilisation laws do allow for the transfer of capacity and machinery from civil to military production.

The second primary methodology of barrel production is for the blank to be shaped externally before the bore is drilled using a type of machine tool that holds the blank in place as a channel is drilled through the blank from one end to the other. The drill is fed a constant supply of a lubricant that is designed to remove debris and cool the metal and drill.[82] This process may take place in two stages, with course drilling followed by fine drilling. It can take 24 hours.[83] Once the barrel is shaped and complete, it is heat treated in a shaft furnace with as many as three barrels that are brought up to temperatures of around 500°C before being cooled in oil. This regularises the grain structure within the barrel and is designed to ensure it is suitably hardened against the stresses of firing.[84] To increase the service life of barrels, the interior of the barrel bore is then coated with chrome between 50 and 180 microns thick, which increases the service life by 2.5–3 times.[85] There are separate processes for the breech and block, which are forged from similar steel to the barrel. Additional components such as a muzzle brake and recuperators are also produced, all using high-quality alloy steels. These components are combined to create a complete barrel that is then painted, tested and inspected before being shipped to one of the manufacturers, which adds the barrel to a howitzer.[86]

Altogether, the production process for a batch of artillery barrels using this methodology can take up to four months, according to the CEO of SKB, which sits within the Motovilikha Plant in Perm. The full process can also include the production of steel blanks, which may take up to five months.[87] This equates to a potential nine-month delivery schedule for batch orders made by the Russian MoD. This provides a fuller indication of barrel production capacity at many of Russia's plants. Furthermore, barrel-forging machines are shared between calibres, so a rotary forging machine that is used to make a 152 mm howitzer barrel may also be used in the production of 125 mm tank barrels. Only one manufacturer, Zavod No. 9, is understood to have distinct production lines for different calibres.[88] In addition, Russian manufacturers report recycling worn and damaged barrels from the frontline, as well as old Soviet-era barrels.[89] A rotary forge can also be used for this process by reducing a larger calibre barrel to a smaller one. Furthermore, some models, like the 2S5 Giatsint 152 mm howitzers, do not need new barrel production, as a large stock of barrels has been retained from the Soviet era, according to Vyacheslav Tsybulin, the production director at SKB.[90]

82 *'Глава 2. Технология изготовления артиллерийских стволов' ['Chapter 2. Technology of Manufacturing Artillery Barrels'], in I. F. Zvontsov et al., Технология и производство артиллерийского вооружения [The Technology and Production of Artillery Weapons] (St. Petersburg: LAN, 2016), pp. 86-236.*

83 *Russian military correspondent.*

84 *'Глава 2.3. Технология термической обработки заготовок стволов' ['Chapter 2. Technology of Heat Treatment of Barrel Blanks'], in I. F. Zvontsov et al., Технология и производство артиллерийского вооружения [The Technology and Production of Artillery Weapons] (St. Petersburg: LAN, 2016), pp. 145-151.*

85 *E. A. Eliseev et, al., 'Materials and Development of the Technologies Providing the Resource Trunks of Artillery, Tank and Shooting Systems of Arms (Review)', 23.*

86 *'Глава 11.7. Специальные требования к деталям и сборочным единицам артиллерийских систем' ['Chapter 11.7. Special Requirements for Parts and Assemblies of Artillery Systems'], in I. F. Zvontsov et al., Технология и производство артиллерийского вооружения [The Technology and Production of Artillery Weapons] (St. Petersburg: LAN, 2016), pp. 406-417.*

87 *Russian military correspondent.*

88 *MrGurKhan, 'Артиллерийский завод №9.flv' ['Artillery Plant No. 9.flv'], YouTube, 12 September 2011, <https://youtu.be/UCJ14Lk0YRY?si=Xi4e5_2BpQGV8Ps>, accessed 16 September 2024; and A-group, '9 Завод' ['9 Plant'], YouTube, 5 July 2017, <https://youtu.be/V-8I5aaxb8M?si=Ju4bzHHaK4XapbyE>, accessed 23 August 2024.*

89 *Russian military correspondent.*

90 *Ibid.*

As barrel production is key to maintaining an effective fighting force, it is useful to assess Russia's capacity to produce barrels. This is naturally challenging, but there are some data points that provide an indication of Russia's ability to meet these needs. UralVagonZavod reported the capacity to manufacture 328 armoured vehicles of all types in its 2019 annual report.[91] This was stated to be 64% of the company's total production capacity, indicating a theoretical maximum of 512 armoured vehicles per year, which in turn suggests the ability to produce 500 barrels of all calibres per year. This would not be sufficient to meet the needs of the war in Ukraine, either those generated by losses of howitzers, or those arising from wear and tear. However, by April 2024, production of self-propelled and towed howitzers had increased by 10 and 14 times respectively, compared with 2022, Bekhan Ozdoev, an industrial director at Rostec, claimed.[92] Given the above, this figure is likely reached through a combination of refurbishing old barrels, matching existing stocks to new howitzers, and new production. If 30% of UralVagonZavod's production in 2019 was focused on artillery systems, these figures indicate an approximate theoretical production maximum of 1,000 howitzers of all types per year. Within this, it is reasonable to conclude that the focus of forging may have shifted away from tank barrels and towards artillery barrels, which may mean that Russia is able to produce hundreds of new barrels per year.

Table 4: Russia's Barrel Manufacturers and the Entities They Supply

Company Name	Products	Customers
Motovilikha Plant	120 mm mortars for towed and self-propelled systems, 152 mm barrels for the towed Msta-B.	Russian MoD, Splav
Zavod No. 9	122 mm gun for 2S1 Gvozdika howitzer, 152 mm barrels for D-20 towed howitzer and 152 mm barrels for 2S3 Akatsiya SPH.	Russian MoD, Uraltransmash
Titan-Barrikady Plant	152 mm barrels for towed Msta-B and self-propelled Msta-S amongst other products.	Russian MoD, Uraltransmash
Burevestnik Research Institute	Primarily R&D for 82 mm and 120 mm mortar barrels for towed and self-propelled systems as well as the 2S34 Malva wheeled SPH.	Russian MoD, Uraltransmash
Uraltransmash	Involved in the production or assembly of almost every Russian howitzer.	Russian MoD

Source: Financial data seen by authors.

91 *JSC Research and Production Corporation Uralvagonzavod named after F E Dzerzhinsky, 'ГОДОВОЙ ОТЧЕТ Акционерное общество "Научно-производственная корпорация "Уралвагонзавод" имени Ф.Э. Дзержинского" за 2019' ['Annual Report Joint Stock Company "Research and Production Corporation "Uralvagonzavod" named after F E Dzerzhinsky for 2019'], 4 August 2020, <https://disclosure.1prime.ru/Portal/GetDocument.aspx?emId=6623029538&docId=38d08b2cd3bc4a8a9fc8f63a997e4b58>, accessed 16 September 2024.*

92 *Georgy Sultanov, 'Индустриальный директор Ростеха: новые боеприпасы учитывают защиту трофейной бронетехники' ['Industrial Director of Rostec: New Ammunition Takes Into Account the Protection of Captured Armoured Vehicles'], interview by TASS, 8 April 2024, <https://tass.ru/interviews/20453549>, accessed 16 September 2024.*

PRODUCTION IN-DEPTH: MACHINE TOOLS

Artillery barrels are complex metal structures that require large, precise machinery throughout the production process. In this respect, the question of existing production capabilities looms large. Russia is thought to have access to legacy Soviet barrel-manufacturing machines. Also, Russia relies on metalworking machine tools, including CNC machines, offering higher degree of automation and precision that support many parts of the artillery supply chain; they are used in the production of engines, in shaping the shell casings of artillery ammunition, in barrel production and in the production of many other weapons.[93] Russian internal demand for machine tools is partially met by local producers, particularly manufacturers within the military-industrial complex like Kalashnikov and Rostec, which specialize in machinery for military production. Efforts to expand domestic production capabilities are also underway.[94] Still, as of 2024, Russia has limited production capacities for machine tools manufacturing and imported many of its systems from Europe prior to 2022. For example, the Motovilikha Plant announced a contract in 2011 to procure a new radial forging machine from GFM in Austria.[95] The machine was expected to replace the legacy equipment operating at the plant, which indicates that it may have been designed to replace the SPX 55 referenced in the CIA report from the previous section. China became Russia's main supplier of machine tools after 2022, and was the primary source of CNC radial forging machines that were imported in 2023.[96] It is unclear how all of these machines will be used; however, Russia's defence industry uses around 70% of all machine tools in Russia.[97] And there is evidence that a portion of them have been used to expand artillery production capacity. At the same time, import was the primary source for meeting the machine tools consumption demands, with 70% of machine tools and 80–90% of spare parts and components coming from abroad.[98]

Russian companies have historically preferred Western machine tools over Chinese equivalents, as they are more precise and higher quality.[99] Russia's longstanding preference for Western machines and components provided Ukraine's Western partners with a critical lever of influence on the Russian war machine that was overlooked until late 2023, when a raft of sanctions came into force. Russia had accelerated its imports of machine tools and their control systems from $29.46 million in January 2022,[100] a month before the full-scale invasion, to $120.86 million in July 2023, with most coming from China.[101] As the sanctions came into effect, supplies from nation-states in the Sanctions Coalition Against Russia (the Sanctions Coalition) decreased dramatically.[102]

93 *Economic Security Council of Ukraine (ESCU), 'CNC Machinery 2.0.: Curtailing Russia's Military Production', 22 November 2023, <https://reb.org.ua/en/reporting/cnc-machinery-20-curtailing-russias-military-production-62ggk2>, accessed 16 September 2024.*

94 *Julian Cooper, 'The Machine Tool Industry of Russia at a Time of War and Sanctions', Post-Communist Economies (Vol. 36, No. 5, July 2024), pp. 527–61.*

95 *Maxim Strugov, 'Машхолдинг приобретет радиально-ковочную машину за 1,5 млрд. руб.' ['Mashholding Will Purchase a Radial Forging Machine for 1.5 Billion Rubles'], Kommersant, 17 October 2011, <https://www.kommersant.ru/doc/1797078>, accessed 16 September 2024.*

96 *Trade data supplied by third-party commercial provider.*

97 *Government of the Russian Federation, 'Стратегия развития станкоинструментальной промышленности на период до 2035 года' ['Strategy for the Development of the Machine Tool Industry Until 2035'], 5 November 2020, <http://static.government.ru/media/files/NyeLKqLhrJrydnGRBm39nHl0hJNOzHzQ.pdf>, accessed 16 September 2024.*

98 *ESCU, 'CNC Machinery 2.0. | Curtailing Russia's Military Production.'*

99 *For example, a typical Western machine can achieve a horizontal positioning accuracy of 0.015/1,000 mm and a repeat positioning accuracy of 0.003–0.007 mm. Chinese machines lag by comparison, with a positioning accuracy of 0.025/1,000mm and a repeat positioning accuracy of 0.01–0.015mm. Additionally, the mean time between failures for Western CNC machines exceeds 5,000 hours, compared to 2,000 hours for Chinese machines, which suffer from issues like leaks of oil, liquid and gas.*

100 *Joe Leahy et al., 'China's Advanced Machine Tool Exports to Russia Soar after Ukraine Invasion', Financial Times, 2 January 2024.*

101 *Ibid.*

102 *Heli Simola, 'Latest Developments in Russian Imports of Sanctioned Technology Products', Bank of Finland Institute for Emerging Economies, 29 November 2023, <https://publications.bof.fi/bitstream/handle/10024/53179/bpb1523.pdf>, accessed 16 September 2024.*

At the same time, Russia's demand for machine tools, including with CNC, is increasing. This is due to many different factors. Part of the increase is driven by Russia's struggle to recruit enough personnel to meet its production needs. The Russian media outlet Izvestia estimated that Russia was short of 4.8 million workers in 2023, and recruitment adverts on the websites of many Russian defence companies point to challenges in expanding production.[103] Machine tools, especially those with CNC, allow fewer personnel to perform a given role – albeit personnel with a higher level of training. Moreover, as of 2023, 63–65% of capital equipment in the defence and related industries was worn out or approaching the end of its service life.[104] Finally, Russia is expanding its ammunition and artillery production capacity, as well as its production of drones and all the materials of war, which drives the need for additional machine tools. Russia's domestic machine tool-building industry cannot meet this demand; it produced 9,269 machine tools in 2023, up from 7,221 in 2022.[105] At the same time, imports of processing machine tools for various materials, including metal, for the same period are understood to have exceeded 60,000 units[106], indicating the extent of Russia's import dependency.[107] To meet this need, Russia has turned to China, which is becoming a key supplier of goods and technologies critical to Russia's military-industrial complex using the following three mechanisms, explored in more detail below:

- Re-export of machine tools manufactured by countries from the Sanctions Coalition.
- Supply of machine tools manufactured at Western subsidiary factories located in China.
- Supply of Chinese machine tools that rely upon Western components, technologies, and expertise.

According to an analysis of Chinese customs data by the Carnegie Endowment, Beijing exports over $300 million worth of dual-use items to Russia every month.[108] In 2023, China was responsible for approximately 90% of Russia's imports of goods on the G7's high-priority export control list.[109] Machine tools exports from China to Russia grew 10-fold from $6.5 million in February 2022 to $68 million in July 2023,[110] representing 57% of Russia's imports of machine tools, up from 12% before the invasion.[111] Pavel Luzin, an expert on the Russian defence industry, has assessed that China's share of Russian imports of machine tool parts grew to 32% in 2022, compared to pre-invasion period, and to at least 80–90% in 2023.[112]

103 *Izvestia, 'Как же без рук: дефицит работников в 2023 году составил 4,8 млн' ['How Could It Be Without Hands: The Worker Shortage in 2023 Reached 4.8 Million'], 24 December 2023, <https://iz.ru/1624816/mariia-stroiteleva/kak-zhe-bez-ruk-defitcit-rabotnikov-v-2023-godu-sostavil-48-mln>, accessed 16 September 2024.*

104 *Technologies Localization Center, 'Россия перезапускает федеральный проект по развитию станкоинструментальной отрасли' ['Russia Relaunches Federal Project for the Development of the Machine Tool Industry'], 11 May 2023, <https://loc-tech.ru/novosti/rossiya-perezapuskaet-federalnyj-proekt-po-razvitiyu-stankoinstrumentalnoj-otrasli/>, accessed 16 September 2024.*

105 *Dzen, 'Выставка Металлообработка 2024. Прочь от технологической зависимости. Фотогалерея и впечатления' ['Metalworking Exhibition 2024: Breaking Free from Technological Dependence. Photo Gallery and Impressions'], 29 May 2024, <https://dzen.ru/a/ZlYijjBBSlv5Qn1W>, accessed 16 September 2024.*

106 *In this context, the count includes all material processing machines, including those for metal, wood and so on. The metalworking machines usually dominate: in 2022, they accounted for 50–60% of imports by material – see Dzen, 'Metalworking Exhibition 2024: Breaking Free from Technological Dependence. Photo Gallery and Impressions'.*

107 *BusinessStat, 'В 2023 г импорт станков для обработки материалов в Россию вырос на 61% и достиг 60 тыс шт.' ['In 2023, Imports of Material Processing Machines to Russia Increased by 61% to Reach 60 Thousand Pcs.'], RBC, 22 March 2024, <https://marketing.rbc.ru/articles/14705/>, accessed 5 September 2024.*

108 *Nathaniel Sher, 'Behind the Scenes: China's Increasing Role in Russia's Defense Industry', 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>, accessed 16 September 2024.*

109 *Ibid.*

110 *Leahy et al., 'China's Advanced Machine Tool Exports to Russia Soar after Ukraine Invasion'.*

111 *Ibid.*

112 *Pavel Luzin, 'Chinese Machine Tools Serve as Russia's Safety Net', The Jamestown Foundation, 22 January 2024, <https://jamestown.org/program/chinese-machine-tools-serve-as-russias-safety-net/>, accessed 16 September 2024.*

This analysis indicates that there are avenues for disrupting Russia's artillery supply chain through targeted sanctions and diplomatic pressure to restrict the supply of quality machine tools. As of August 2024, a minority of the Chinese machine tool manufacturers that are among Russia's critical suppliers were sanctioned by any member of the Sanctions Coalition. This gap in the international sanctions regime allows Chinese companies to export and re-export machine tools, including with CNC, to Russia without consequences, to manufacture Western machine tools under licence and to build critical Western technology into machines that would be far less capable without them. Many of these machines are then used to build weapons to fight Ukraine and threaten the West with nuclear war.

China as a Re-Export Hub

China serves as a re-export hub for machine tools (including with CNC) manufactured in Western countries and Sanctions Coalition states. The following supply chain assessment is based on Russia's imports under 18 HS codes corresponding to machine tool products,[113] and originating from 10 Western countries with active machine tools production.[114]

The data indicates that at least 2,113 companies supplied machine tools manufactured in Western countries to Russia during 2023 and the first quarter of 2024.[115] Among these suppliers, Chinese entities rank second (340 companies, or 17.5%), behind only Turkey (508 companies, or 26.16%). The rest of the suppliers originate from Germany (8.50%), South Korea (6.75%), Taiwan (6.08%), Italy (5.92%), the UAE (4.63%), Lithuania (2.47%) and Serbia (2.21%).[116] The total value of Russia's machine imports over the same time period was $4.5 billion. Chinese companies accounted for $568.6 million or 12.6% of the total during 2023 and the first quarter of 2024.[117]Chinese entities are increasingly facilitating the re-export of machine tools and equipment to Russia from neighbouring countries. For instance, Chinese entities account for 41% of entities re-exporting Japanese machine tools products to Russia, 26% of those re-exporting Taiwanese machine tools, and 19% of those re-exporting South Korean machine tools.[118] There are 36 Chinese companies among the top suppliers of Western machines to Russia for 2023 and the first quarter of 2024.[119] Only five of those companies have been sanctioned by members of the Sanctions Coalition – one by the US, the EU and Switzerland (Shenzhen Biguang Trading Co. LTD[120]), three just by the US (Silver Technology LTD[121], Most Development LTD[122], Agu Information Technology Co. LTD[123]), and one just by the EU (Afox Corporation LTD[124]).

For example, the Chinese companies Agu Information Technology (AIT) and Yinuo Supply Chain Management (YSCM) were established in April and August 2022, respectively, shortly after the full-scale invasion. From the start of 2023 to the end of the first quarter of 2024, they exported $75 million worth of US and Taiwanese machines, including with CNC, to Russia, and both supplied

113 *HS codes 8207, 8482, 8456-8466, 8471, 8485, 8501, 8502, and 8537 and their subgroups.*

114 *The countries included in the analysis are Austria, the Czech Republic, Germany, Italy, Japan, South Korea, Switzerland, Taiwan, the UK and the US.*

115 *Trade data supplied by third-party commercial provider.*

116 *Ibid.*

117 *A smaller share of the total number of suppliers than the share of the volume of supplies may indicate that Chinese suppliers supply CNC products to Russia at lower prices than exporters from other countries.*

118 *Trade data supplied by third-party commercial provider.*

119 *Ibid.*

120 *"Shenzhen Biguang Trading Co. Ltd," OpenSanctions.org, December 1, 2020, <https://www.opensanctions.org/entities/NK-Cpekqk9rXJr2GbBqqBpsGW/>, accessed September 18, 2024.*

121 *"Silver Technology Limited," OpenSanctions.org, June 28, 2016, <https://www.opensanctions.org/entities/NK-D7yFYwS4wRJ7XYw7GKZB7T/>, accessed September 18, 2024.*

122 *"Most Development Limited," OpenSanctions.org, May 15, 2018, <https://www.opensanctions.org/entities/ofac-50137/>, accessed September 18, 2024.*

123 *"AGU Information Technology Co Limited," OpenSanctions.org, August 23, 2024, <https://www.opensanctions.org/entities/ofac-50358/>, accessed September 18, 2024.*

124 *Council of the European Union, 'Council Decision (CFSP) 2024/1744 of 24 June 2024 Amending Decision 2014/512/CFSP Concerning Restrictive Measures in View of Russia's Actions Destabilising the Situation in Ukraine,' <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ%3AL_202401744>, accessed September 18, 2024.*

machines to importers close to the Russian defence industry.[125] AIT's largest client was the Russian company Vneshekostil, which has been under US blocking sanctions since September 2023.[126] YSCM became a supplier to the Russian company known as LLC Energy Industries. According to public procurement registers and financial data available to the authors, the latter has cooperated with Russian defence enterprises including Admiralty Shipyards, the largest Russian manufacturer of diesel-electric submarines, and Elektrokhimpribor Combine, a nuclear weapons company, among many others.

Table 5: Chinese Subsidiaries of Western Companies with Sales to Russia Exceeding $800,000 for 2023 – Q1 2024

Brand	Country of Origin	Chinese Subsidiary	Value of Deliveries (2023 – Q1 of 2024) (USD)	Quantity of Products Delivered
DN Solutions	South Korea	DN Solutions China Co., Ltd.[127]	$11,359,242	64 items
Doosan Machine Tools	South Korea	Doosan Machine Tools (China) Co., Ltd	$7,816,567	29 items
Delta Electronics	Taiwan	Delta Electronics (Jiangsu) Ltd	$6,788,456	60 items
Leadwell Machinery LTD	Taiwan	Ningbo Leadwell Trading Co., Ltd	$3,630,418	16 items
Goodway Machine Corp.	Taiwan	Goodway Machine (Wujiang) Co. Ltd	$12,136,901	99 items
Mazak	Japan	Yamazaki Mazak Machine Tool (Liaoning) Co., Ltd	$955,644	4 items
Siemens AG[128]	Germany	Siemens Standard Motors Ltd	$1,070,657	337 items
TRUMPF	Germany	Jiangsu Jinfangyuan CNC Machine Co., Ltd	$971,363	26 items
Hardinge	US	Hardinge Precision Machinery (Jiaxing) Company Limited	$701,065	3 items
	US	Hardinge Machine (Shanghai) Co., LTD	$137,873	One item

Source: Trade data supplied by third-party commercial provider.

Western Subsidiaries

Another dimension of Chinese support for Russia's need for critical equipment is the supply of products manufactured at Western companies' subsidiaries in China. An analysis of 30 Western brands that make up the main machine tools manufacturers indicates that 22 of them have direct subsidiaries registered in China (see Table 5)[129]. This study only examined subsidiaries that have their production facilities in China; it excludes those that only provide technical support, training or sales functions.

125 *Trade data supplied by third-party commercial provider.*

126 *US Department of the Treasury, 'Russia-Related Designations, Designations Updates, and Designations Removals; Issuance of Russia-Related General Licenses | Office of Foreign Assets Control', 14 September 2023, <https://ofac.treasury.gov/recent-actions/20230914>, accessed 16 August, 2024.*

127 *DN Solutions, ['DN Solutions China - Главная' ['DN Solutions China - Main Page'], <http://www.dn-solutions-china.ru/>, accessed 16 August 2024.*

128 *Siemens is a renowned producer of control panels for CNC machine tools. The shipments considered thus refer to control panels supplies.*

129 *Olena Yurchenko et al., 'Third-Best Option: China's Rising Role in Russian Access to Critical Industrial Equipment', Kyiv: Economic Security Council of Ukraine, August 12, 2024, <https://reb.org.ua/en/reporting/zapasnii-variant-dlya-agresora-novii-zvit-reb-pro-rol-kitayu-u-zberezenni-dostupu-rosiyi-do-kriticno-vazlivogo-promislovogo-obladnannya-v2qm62>, accessed September 18, 2024.*

Most of these machines are not exported to Russia directly by the Chinese subsidiaries, but via Chinese intermediaries. The case of the US company Hardinge illustrates a typical supply chain. In 1996, the company established a wholly owned subsidiary in Shanghai, Hardinge Machine Tool (Shanghai), which also serves as its demonstration, training and maintenance centre in China.[130] The company's largest production site in China is the Hardinge Jiaxing factory, established in 2010.[131] This factory manufactured three vertical CNC machines worth $701,000 in 2023 that were delivered to Russia via Chinese distributor Beijing Zhuangguan International Import & Export Trade Co.[132]

The Russian importer of Hardinge's equipment was Technoproekt, a research and production company specialising in development and production of pipeline valves for the gas, oil, and nuclear industries.[133] Technoproekt is not subject to international sanctions despite having open state contracts to supply machine tools and fittings to Russian military-industrial enterprises such as the Electrokhimpribor Combine, which manufactures components for nuclear warheads.[134] While Technoproekt could be using Hardinge's machinery to produce valves for the gas industry, it could also be shipping those machines onwards to a key entity in Russia's nuclear deterrent. There are at least 12 other Chinese entities that supplied CNC machine tools produced by Western subsidiaries to Russia in 2023.[135]

Chinese Machine Tools

There is also evidence to suggest that the expansion of Russia's defence industry is enabled by Chinese machine tools, including with CNC. For example, the Russian Izhevsk Unmanned Systems Research and Production Association, which manufactures Granat and Takhion reconnaissance drones that are used in Ukraine, recently announced that it had increased its production output.[136] Russian media reported that the company had commissioned a new 5,800 m2 production shop complete with newly installed CNC machines and an increased number of machining centres.[137] Then, in March 2024, a CNC machine produced by Chinese Dalian Machine Tool Group was observed at the new facility.[138] Another Russian defence plant, NPO Kurganpribor – which manufactures components for land and naval artillery, as well as fuzes for tank rounds and rocket launchers, among many other products – opened a new 1,500 m^2 production site with dozens of new CNC machines in August 2024.[139] The manufacturers that can be identified include Zhe Jiang Headman Machinery and Shandong Weida Heavy Industries.

The supply of Chinese machine tools with CNC to Russian defence plants is not straightforward, because Western states are critical suppliers of hardware that is essential for their production and use. For example, vital control instruments such as programmable logic controllers (PLCs) and distributed control systems (DCSs) usually come from non-Chinese companies, which hold nearly 100% of the small and medium/large PLC markets and 65% of the DCS market.[140] This means that

130 *Hardinge, 'Our History', <https://europe.hardinge.com/about-us/our-history/>, accessed 16 September 2024.*

131 *Hardinge Inc, 'Jiaxing Factory' , YouTube, uploaded 15 June 2021, <https://www.youtube.com/watch?v=FT8iNEpf90s> , accessed 16 September 2024.*

132 *Trade data supplied by third-party commercial provider.*

133 *Solenoid, 'ООО НПП "Технопроект". Передовая техника для управления потоками' ['LLC NPP TekhnoProekt. Advanced Technology for Stream Management'], <https://solenoid.ru/>, accessed 16 September 2024.*

134 *Checko.ru, 'ООО НПП "Технопроект" – Контракты' ['LLC NPP Tekhnoproekt – Contracts'], <https://checko.ru/company/npp-tekhnoproekt-1025801209334?extra=contracts&law=223&role=supplier>, accessed 16 September 2024.*

135 *Trade data supplied by third-party commercial provider.*

136 *Tass, 'Производитель БПЛА "Куб" в 10 раз увеличит выпуск продукции в 2024 году', ['Kub UAV Manufacturer to Increase Production Output Tenfold in 2024', 15 February 2024, <https://tass.ru/ekonomika/19995283>, accessed 16 September 2024.*

137 *Rostec, ' "Ижевские беспилотные системы" увеличат выпуск беспилотников в десять раз' ['Izhevsk Unmanned Systems Will Increase Drone Production Tenfold'], 15 February 2024, <https://rostec.ru/news/izhevskie-bespilotnye-sistemy-uvelichat-vypusk-bespilotnikov-v-desyat-raz/>, accessed 16 September 2024.*

138 *Allen Maggard [@zerkzal], tweet, X, 30 March 2024, <https://x.com/zerkzal/status/1773885903657730493>, accessed 16 September 2024.*

139 *Dzen, 'На курганском оборонном заводе открыто новое производство' ['A New Production Facility Has Been Opened at the Kurgan Defence Plant'], 1 August 2024, <https://dzen.ru/a/ZqsqhSMaR2FxAN-m>, accessed 16 September 2024.*

140 *Bernstein, 'The Robot Renaissance – China Investment, Global Implications', April 2022, <https://www.bernsteinresearch.com/CMSObjectBR/Files/Recruiting/The%20Robot%20Renaissance%20-%20China%20Investment%20Global%20Implications%202022.pdf>, accessed August 16 2024.*

Russia is dependent on Western technology for its machine tools, and China is too. China's reliance upon Western companies is further evidenced by the fact that of 10–16 Chinese manufacturers supplying the Russian market, at least 13 have confirmed connections with Western markets.

Refurbishment

Russia launched an extensive modernisation of its armed forces leading up to the invasion of Ukraine, concentrating much of its newest equipment in its better-trained and professionalised units. However, the losses incurred during the invasion, as well as the need to stand up additional units to fight the war, has exhausted Russia's stocks of new systems. There was a huge effort to refurbish old howitzers that had been kept in storage from the Soviet era, with the result that up to 80% of Russia's armoured fighting vehicles are now refurbished.[141] The degree of refurbishment required depends upon the conditions that the vehicles have been stored in, and for how long.[142]

It is understood that as of 2024, all new model production and repair is concentrated in Uraltransmash, while most repair and refurbishment of legacy models is conducted at Russia's armoured vehicle repair plants and the Motovilikha Plant.[143] The number of these facilities is unknown: they received their numbered names during the Second World War and some, if not most, were transferred to Rostec in the 2000s, which closed many that were not solvent.[144] Below, six of the main armoured-vehicle plants are examined in more detail.

No. 103: One of the main armoured-vehicle repair plants is No. 103 in Atamanovka (Transbaikal region).[145] This plant is the key military facility in the easternmost regions of Russia and is directly on the Trans-Siberian railway linking the European part of Russia and the Pacific coast, with a rail connection allowing the plant to load vehicles directly onto freight carriages. Satellite images reveal the plant has parking space for more than 1,000 vehicles.

141 *Watling and Reynolds, 'Russian Military Objectives and Capacity in Ukraine Through 2024'.*

142 *The Russian MoD has four types of storage: (1) Light – a heated room; (2) Medium – a closed unheated room; (3) Hard – outside, under a canopy; and (4) Very hard – in the open air or under a canopy in a maritime environment. This, plus the length of time that equipment is stored, dictates the amount of work required to bring it up to a serviceable standard. See Sam Cranny-Evans, 'Understanding Russia's Mobilisation', RUSI Commentary, 28 September 2022, <https://rusi.org/explore-our-research/publications/commentary/understanding-russias-mobilisation>, accessed 16 September 2024.*

143 *Rostec, '"Мотовилихинские заводы" выполнили обязательства по поставкам артиллерии для Минобороны РФ' ['Motovillikha Plants Fulfilled Obligations for the Supply of Artillery for the Ministry of Defence of the Russian Federation#], 25 February 2021, <https://rostec.ru/news/motovilikhinskie-zavody-vypolnili-obyazatelstva-po-postavkam-artillerii-dlya-minoborony-rf/?sphrase_id=5047180>, accessed 16 September 2024.*

144 *Roman Skomorokhov, 'Ремонтные заводы будут работать, а не пойдут с молотка' ['Repair Plants Will Work, Not go with a Hammer'], Военное обозрение [Military Review], 21 October 2022, <https://topwar.ru/203570-remontnye-zavody-budut-rabotat-a-ne-pojdut-s-molotka.html>, accessed 16 September 2024.*

145 *RIA Novosti, 'Белоусов проинспектировал Центр управления сухопутных войск' [Belousov Inspects the Command Centre of the Land Forces], 17 June 2024, <https://ria.ru/20240617/tsentr-1953330784.html>, accessed 16 September 2024. Full video: Russian Ministry of Defence, video, Telegram, 17 June 2024, <https://t.me/mod_russia/39849>, accessed 16 September 2024.*

Figure 7: Armoured-vehicle Repair Plant No. 103 in Atamanovka (Left) and its Main Parking for More Than 400 Heavy Machines (Right)

Source: Airbus Defence and Space, RUSI, Open Source Centre.

- No. 560: There is at least one more armoured-machine repair plant operating in Siberia – the Vozhaevka-based armoured-vehicle repair plant No. 560,[146] which is visibly smaller than No. 103.

- No. 81: Much closer to the frontline is Armoured Vehicle Repair Plant No. 81 in Armavir, some 200 km from the official Russian-Ukrainian border, in the Donbas area.

- No. 61: Armoured Vehicle Repair Plant No. 61 is owned by UralVagonZavod in the St Petersburg region.

- No. 163: Armoured Vehicle Repair Plant No. 163 is located in the Krasnodar region.

- No. 144: Armoured Vehicle Repair Plant No. 144 in Yekaterinburg (close to Zavod No. 9 and Uraltransmash) has been contracted by the Russian MoD for upgrades of BMDs and 2S9 self-propelled mortars to 2S9-1.

All these plants were advertising for additional staff at the time of writing, with an emphasis on CNC operators and technical engineers, indicating the rapid expansion of these facilities.[147] The majority of identified armoured-machine repair plants are involved in repair and overhaul of direct fire armoured fighting vehicles like tanks and infantry fighting vehicles. The 39th Arsenal in Perm is believed to be one of the only armoured-machine repair plants specialised in refurbishing artillery in the country. The property, including the land and buildings, had been acquired by a private entrepreneur following asset liquidation in 2021, but the liquidation was halted in the Russian courts in 2023. The case for doing so was based on the strategic importance of the plant.[148] The current status of the plant and its equipment is unknown, but it is possible that it and its infrastructure – like the tracks that carry vehicles to and from the plant – have fallen into disrepair. It is understood that ad hoc facilities have been established closer to Ukraine for the repair of artillery systems, including regular maintenance like the replacement of barrels. However, this type of facility is unlikely to be capable of returning stored howitzers to a combat-fit state.

146 *Coordinates: 50.724195, 128.703550.*

147 *JSC 163rd Armoured-Machine Repair Plant,'Вакансии' ['Vacancies'], <https://archive.is/KaAxj>, archived 27 June 2024 at Archive.is, accessed 16 September 2024.*

148 *Kommersant, '"39 Арсенал" подвергся механическому воздействию' ['39th Arsenal was Subjected to Mechanical Impact'], 5 October 2017, <https://www.kommersant.ru/doc/3429265>, accessed 16 September 2024.*

Russia has a lot of equipment waiting for refurbishment; one assessment indicates that Russia had at least 10 storage bases, 12 artillery storage bases and 37 mixed equipment storage bases.[149] For reference, one storage base – the 591st artillery warehouse in the Novgorod Region – was home to at least 400 howitzers in 2018.[150] This indicates that Russia may have thousands of howitzers sitting in storage. The refurbishment of equipment has been accompanied by what appears to be a significant effort to stand up or restore armoured-machine and artillery repair plants closer to Ukraine. The majority of those that were functional in 2022 were in the Urals. However, Russian news outlets indicate that orders were given to establish facilities closer to Ukraine in late 2022.[151] This suggests that Russia has established or will establish facilities designed to repair vehicles and artillery damaged in Ukraine and return it to the front line as quickly as possible. However, if the facilities to refurbish howitzers are specific to those vehicles, and have been allowed to atrophy, it is logical that artillery manufacturers like Uraltransmash and Motovilikha Plant would currently be responsible for refurbishing artillery stockpiles as well as manufacturing or overhauling new, more capable systems like the Msta-SM2 and 2S35 Koalitsiya.

149 *Yohan Michel and Michael Gjerstad, 'Equipment Losses in Russia's War on Ukraine Mount', IISS, Military Balance Blog, 12 February 2024, <https://www.iiss.org/online-analysis/military-balance/2024/02/equipment-losses-in-russias-war-on-ukraine-mount/>, accessed 16 September 2024.*

150 *Alexander Anatolyevich Khramchikhin, 'На страже Северной столицы' ['On Guard of the Northern Capital'], Независимое военное обозрение [Independent Military Review], 26 October 2018, <https://nvo.ng.ru/realty/2018-10-26/1_1019_guardian.html>, accessed 16 September 2024.*

151 *Alexander Bezmenov, 'Завод по ремонту танков построят в Ростовской области' ['A Tank Repair Plant Will Be Built in the Rostov Region'], Станичные ведомости [Stanichnye Vedomosti], 6 September 2022, <https://s-vedomosti.ru/novosti/zavod-po-remontu-tankov-postroyat-v-rostovskoj-oblasti/>, accessed 16 September 2024.*

Chapter 4: Ammunition Supply Chains

Russia has an anticipated need for four million 152 mm artillery rounds and 1.6 million 122 mm rounds for offensive operations in 2025. The Russian defence industry can manufacture around 1.3 million 152 mm rounds and 800,000 122 mm rounds per year, so many of the required rounds will have to be procured from abroad or refurbished from legacy stockpiles.[152] Russia has been refurbishing artillery ammunition and missiles at least since 2018, when Putin indicated that 550,000 rounds of ammunition and missiles had been refurbished and returned to service.[153]

Manufacturers

Russia's artillery ammunition manufacturers sit on top of a supply chain that is largely domestic, but some key resources are procured from abroad. There are three primary manufacturers of artillery ammunition in Russia: NIMI Bakhirev, the Plastmass Plant and KBP Shipunov. NIMI Bakhirev appears to perform as a contractor for the Russian MoD and control deliveries from companies like Plastmass and the Kazan Gunpowder Plant.

NIMI BAKHIREV

State Scientific Research Institute of Machine Building Bakhirev (NIMI Bakhirev) is Russia's oldest and most prominent developer of artillery and tank ammunition. Like most of Russia's artillery supply chain, it sits within the Tekhmash holding, part of Rostec. The available tax data indicates that it delivered goods worth around $1.7 billion to the Russian MoD in the first half of 2023.[154] NIMI Bakhirev is Moscow-based and doesn't have any known production facilities, which leads to the conclusion that it acts as an R&D, procurement and supervising entity on behalf of the Russian MoD.

NIMI Bakhirev is understood to produce a range of 125 mm ammunition that is used by tanks, as well as 152 mm rounds for artillery. Since the invasion of Ukraine, the plant has made efforts to restart production of 122 mm ammunition and to upgrade and modernise the 100 mm ammunition used by the BMP-3 infantry fighting vehicle.[155]

152 *Watling and Reynolds, 'Russian Military Objectives and Capacity in Ukraine Through 2024'.*

153 *Kremlin, 'Заседание коллегии Министерства обороны' ['Meeting of the Board of the Ministry of Defence'], President of Russia, 18 December 2018, <http://www.kremlin.ru/events/president/news/59431>, accessed 11 July 2024.*

154 *Nikolay Staykov et al.,Beyond the Bullets: How Russia's Ammunition Supply Industry Works, pending publication.*

155 *N P Semenenko et al., 'Научно-исследовательский машиностроительный институт (НИИ-24): для великой победы, для мирной жизни' ['Research Engineering Institute [NII-24]: For a Great Victory, for a Peaceful Life'], in Ammunition and High-Energy Condensed Systems [Special Issue. 2020. No.2], (NIMI, 2020). Available at: Steel and Fire: Contemporary and Perspective Tanks, 'Материал по истории и современным достижениям НИМИ (НИИ-24)' ['Material on the History and Modern Achievements of NIMI (NII-24)'], 29 December 2020, <https://btvtinfo.blogspot.com/2020/12/24.html>, accessed 16 September 2024.*

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PLASTMASS PLANT

Plastmass Plant is also a subsidiary of Tekhmash and a producer of 76–152 mm artillery ammunition.[156] Its product portfolio includes the 3VOF58 152 mm round, which is the designation given to the 3OF45 high explosive projectile, and a variable charge, designed to be fired by the 2A65 Msta-B towed howitzer and the 2S19 Msta-S self-propelled howitzer. It also manufactures 3VOF39 152 mm rounds with 3OF29 high explosive shells and charges for the towed 2A36 Giatsint-B and 2S5 Giatsint SPH.[157] Collectively, these four howitzers represent the longest-range systems chambered to fire 152 mm shells that are available to Russian forces in Ukraine. Plastmass produces a range of other warheads that are used in missiles and rockets.

INSTRUMENT DESIGN BUREAU

Instrument Design Bureau (KBP) is the second-largest supplier to the Russian MoD by value, with more than $895 million in sales for the first quarter of 2023. Its parent company is the High Precision Systems Holding, which sits within Rostec. KBP develops precision-guided weapons and air defence systems as well as automatic cannons. This includes the Kornet ATGM and Pantsir-S short-range air defence system, with deliveries of the former reported in June 2023.[158] Additionally, KBP manufactures and develops the 2K25 Krasnopol laser-guided artillery round. In August 2023, KBP started supplying the Russian army with upgraded Krasnopol rounds that can be guided onto a target by a laser designation from an unmanned aerial vehicle (UAV).[159] The enterprise has also been working on increasing the efficiency of its laser-guided KM-8 Gran bomb for 120 mm mortars and Kitolov-2M artillery shells for D-30 and 2S1 artillery systems.[160] Laser-guided rounds are important to Russia's artillery war, as the extreme dispersion adopted by Ukrainian forces reduces the efficacy of massed artillery barrages. More precise fires are therefore used against singular targets and individual howitzers when possible.

Table 6: Companies Supplying the Russian MoD and Defence Industry with Ammunition

Company Name	Products	Customers	Volume in 2023
NIMI Bakhirev	Design and development of complete ammunition for artillery and tanks. Works with other enterprises for production.	Russian MoD, Zavod No. 9, Omsktransmash	> $1.7 billion, mostly to the Russian MoD
Shipunov Instrument Design Bureau (KBP)	Design and production of artillery shells for 152 mm howitzers, as well as for mortars.	Russian MoD, Kurganmashzavod, Amur Shipbuilding Plant	> $1 billion, mostly to the Russian MoD
Plastmass Plant	Production of artillery shells for howitzers, mortars and tanks.	Russian MoD, NIMI Bakhirev, Rosoboronexport	> $350 million, mostly to the Russian MoD

Source: Financial data seen by authors.

156 *TASS, 'Ростех в пять раз нарастил производство боеприпасов на заводе в Челябинской области' ['Tekhmash Presented Modern Ammunition in the Chelyabinsk Region'], 21 June 2024, <https://tass.ru/armiya-i-opk/21166083>, accessed 16 September 2024.*

157 *'Алфавитный указатель организаций' ['Alphabetical Index of Organizations'], in Missile-Technical and Artillery-Technical Support of the Armed Forces of the Russian Federation-2018, eds N. M. Parshin et al. (Moscow: LLC Kompaniya Informatsionny Most, 2018), p. 177.*

158 *Andrei Vladimirovich Morozov et al., 'АО "Конструкторское бюро приборостроения им. академика А.Г. Шипунова" — один из ведущих разработчиков ракетно-артиллерийского вооружения' [A.G. Shipunov Instrument Design Bureau - One of the Leading Developers of Missile and Artillery Weapons'], in Missile-Technical and Artillery-Technical Support of the Armed Forces of the Russian Federation-2018, pp. 110–113.*

159 *Lenta.ru, 'Опытную эксплуатацию боеприпаса "Краснополь" для дронов успешно завершили' ['The Pilot Operation of Krasnopol Ammunition for Drones Has Been Successfully Completed'], 22 May 2023, <https://lenta.ru/news/2023/05/22/krasnopol/>, accessed 16 September 2024.*

160 *Lenta.ru, 'В России повысят эффективность снарядов "Краснополь" и мин "Грань" ' ['Russia Will Increase the Effectiveness of Krasnopol and Gran Mine Shells'], 19 May 2023, <https://lenta.ru/news/2023/05/19/shells/>, accessed 16 September 2024.*

PRODUCTION IN-DEPTH: PLASTMASS PLANT

Figure 8: The Plastmass Plant

Source: Airbus Defence and Space, RUSI, Open Source Centre.

Plastmass is an important element of the Russian artillery supply chain, located in Kopeysk in Chelyabinsk region. The following analysis indicates that the plant is responsible for at least 15% of Russia's projected 152 mm round production in 2024.[161] The plant is owned by Rostec and has focused on ammunition for artillery, tanks and aviation.[162] It specialises in the assembly and refurbishment of shells and rounds for 120 mm and 152 mm howitzers, and has supplied the Russian army with ammunition for all of its primary indirect fire systems.[163] It produces the S-8 series of 80 mm unguided rockets that are fired from Russian helicopters in a ground attack role, as well as 125 mm explosive ammunition natures for tanks. This product suite is indicative of the plant's role in supporting Russia's war effort, and, while it is by no means the only plant producing ammunition for the armed forces, it is one of the few that only produces ammunition, and for which there is sales data to indicate volume.

A significant part of the plant's production is commissioned by ammunition developer NIMI Bakhirev, which in turn is subcontracted by the Russian MoD. The Plastmass Plant reportedly made $143 million in payments to NIMI Bakhirev and $232 million to the Russian MoD in 2023.[164] In addition, publicly available arbitration records confirm that prior to 2022, the entity was subcontracted by NIMI Bakhirev to fill artillery shells with explosive materials under contracts issued by the MoD or Rosoboronexport, Russia's defence export agency.[165] The total value of these orders is $375 million – far less than the Instrument Design Bureau, which has close to $1 billion. However, as Plastmass is primarily involved in ammunition production, while KBP has a range of business lines, the volume of production at Plastmass and

161 *Watling and Reynolds, 'Russian Military Objectives and Capacity in Ukraine Through 2024'.*

162 *Arguments and Facts AIF.RU, 'Промышленный потенциал. "Завод "Пластмасс" подвёл итоги 2016 года' ['Industrial Potential. Plastmass Plant Summed Up the Results of 2016'], 23 May 2017, <https://chel.aif.ru/society/industry/promyshlennyy_potencial_zavod_plastmass_podvyol_itogi_2016_goda>, accessed 16 September 2024.*

163 *'Алфавитный указатель организаций' [Alphabetical Index of Organizations], in Missile-Technical and Artillery-Technical Support of the Armed Forces of the Russian Federation-2018, , pp. 176-82; Special Purpose Products, 'АО "Завод "Пластмасс"' ['JSC Plastmass Plant'], <http://web.archive.org/web/20220215105845/http:/www.zavod-plastmass.ru/product/produktsiya-spetsialnogo-naznacheniya/>, archived at the Wayback Machine 15 February 2022, accessed 16 September 2024.*

164 *Financial data seen by authors for the Plastmass Plant.*

165 *Russian legal databases.*

the possible impact of disrupting its operations can be more accurately discerned. A 152 mm artillery round is thought to cost around $700, suggesting that Plastmass could be contracted to produce 535,000 rounds of 152 mm ammunition for the $375 million that it has received from the Russian MoD. While this figure is unlikely to be precise, given Plastmass' range of products, it indicates the potential impact of disrupting this manufacturer.

As of early 2022, the Plastmass Plant operated 38 production facilities, repair shops and workshops with a total area of 33,005 m2, as well as 78 warehouse facilities with a total area of 37,200 m2.[166] In 2013, it had seven main structural subdivisions, including Workshop No. 4, which focused on ammunition production, with a stated output of 50,000 units per year with a 'military' purpose – Plastmass has other business arms, including the production of explosives for industrial use.[167] In September 2021, Rostec announced plans to launch a new assembly facility for 100–152 mm ammunition, with an area of approximately 4,000 m2 by 2023. The facility was to employ automated technologies worth RUB 250 million (~$3.4 million) and increase the plant's output by 150%.[168] The most recent publicly available video showing the plant's premises is from March 2022; it includes footage of a new industrial boiler room and older-looking ammunition assembly facilities.[169] Nevertheless, Rostec announced in June 2024 that Plastmass had increased its military-use production five-fold since the start of the invasion, and planned to increase production volumes by another 20% in 2024.[170]

This growth in capacity is confirmed by the plant's recruitment of new personnel, particularly assemblers of munitions for three shifts per day.[171] The plant started posting monthly job adverts on the VK social media platform in June 2022 seeking ammunition assemblers, electricians and other technical roles. The salary offered for ammunition assemblers grew from a minimum of RUB 19,000 (~ $351) per month in June 2022 to a minimum of RUB 85,000 (~ $964) by July 2024.[172] As of 24 July 2024, the plant had 134 vacancies for ammunition assembler positions on the Federal Service for Labour and Employment vacancies website, accounting for more than 20% of the plant's active vacancies.[173] The sharp increase in salaries and large number of vacancies for this unskilled position may indicate that the plant is struggling to find enough workers to meet the demands of its expanded capacity.

166 *Единая информационная система в сфере закупок ['Unified Information System in the Field of Procurement'], '№ 32211098760', last modified 3 February 2022, <https://zakupki.gov.ru/epz/order/notice/notice223/documents.html?noticeInfoId=13678085>, accessed 16 September 2024.*

167 *E-Dossier, 'Проект организации расчетной (предварительной) санитарно-защитной зоны промзоны ФГУП "Завод "Пластмасс", 456604, Челябинская область, г. Копейск, пос. Советов. Вид деятельности: производство взрывчатых материалов для промышленных взрывных работ и продукции оборонного профиля' ['Project for the Organisation of a Calculated (Preliminary) Sanitary Protection Zone of the Industrial Zone of the Federal State Unitary Enterprise "Plastmass Plant", 456604, Chelyabinsk Region, Kopeysk, Sovetov Settlement. Type of Activity: Production of Explosives for Industrial Blasting Operations and Defence Products'], 20 February 2013, <https://e-ecolog.ru/crc/74.50.02.000.%D0%A2.000138.02.13>, accessed 16 September 2024.*

168 *Rostec, 'Ростех запустит новый автоматизированный цех по производству боеприпасов' ['Rostec to Launch New Automated Ammunition Production Facility'], 22 September 2021, <https://rostec.ru/news/rostekh-zapustit-novyy-avtomatizirovannyy-tsekh-po-proizvodstvu-boepripasov/>, accessed 7 August 2024.*

169 *Polytechnic Institute of the South Ural State University, 'АО Завод Пластмасс' ['JSC Plastmass Plant'], YouTube, 24 March 2022, <https://www.youtube.com/watch?v=DAq2sZkOCKU>, accessed 16 September 2024.*

170 *Rostec, 'Ростех в пять раз нарастил выпуск боеприпасов на Заводе 'Пластмасс'' ['Rostec has Increased Fivefold Ammunition Production at the Plastmass Plant'], 21 June 2024, <https://rostec.ru/news/rostekh-v-pyat-raz-narastil-vypusk-boepripasov-na-zavode-plastmass-/>, accessed 16 September 2024.*

171 *'Завод Пластмасс' [Plastmass Plant], VK, 23 June 2022, <https://vk.com/zavod_plastmass?w=wall-144505220_349>, accessed 16 September 2024; 'Завод Пластмасс' [Plastmass Plant], VK, 12 July 2024, <https://vk.com/zavod_plastmass>, accessed 16 September 2024.*

172 *Rabota Rossii,'Сборщик специзделий' ['Assembler of Special Products'], last modified 24 July 2024, <https://trudvsem.ru/vacancy/card/1117411001388/868fc005-1700-11ed-a7a6-791a818bdadb>, accessed 16 September 2024.*

173 *Ibid.*

It is rare for any ammunition manufacturer to reveal production figures, but it is possible to form an assessment of Plastmass' output using the available data. If, for example, the production figure for 2013 of 50,000 units is accurate and remained constant until the invasion, the increases announced by Rostec indicate that Plastmass will be able to produce 300,000 units by the end of 2024. Taken together with data seen for this report, it can be reasonably concluded that the annual production output of Plastmass is at least 300,000 units of all ammunition types per year, and may be as high as 535,000 if it focuses on 152 mm natures alone. However, the plant's activities include refurbishing old ammunition, which is likely cheaper and faster than producing new ammunition, as well as the production of munitions that are more advanced and therefore likely more expensive than a traditional 152 mm round. This could lower or increase the total output of the plant. In addition, Russia is understood to have sacrificed production capacity for many of its non-artillery ammunition natures in 2022 and 2023 to meet its need for 152 mm and 122 mm rounds.[174]

Assessing the plant's artillery ammunition output is therefore challenging, but it appears likely that the plant could produce at least 200,000 rounds of artillery ammunition per year through production and refurbishment, alongside production of tank and rocket ammunition. This figure could be increased by tens or hundreds of thousands of rounds if all other production was sacrificed to focus on artillery natures. As Russia is projected to produce 1.3 million rounds of 152 mm ammunition in 2024, Plastmass may be responsible for more than 15% of the country's output.[175]

This of course depends upon the ability of the plant's supply chain to meet its needs for raw materials and products. The available data indicates that the supply chain is heavily concentrated; the plant was reliant on six suppliers for more than 95% of its purchases in terms of value, which were in excess of $179 million in 2023.[176] More than 60% of its transactions by value were with the Selmash Plant,[177] which manufactures shell bodies for 152 mm ammunition as well as S-8 rockets.[178] This plant has been expanding production capacity by refurbishing old buildings and modernising its existing machinery, and is working '24/7 in support of the SVO [special military operation]', according to the director general.[179] Plastmass' suppliers are set out in Table 7.

174 *Sam Cranny-Evans, 'Russia's Defence Industry Gears up for a Long War', European Defence Review, EDR Analysis, 9 January 2024, <https://www.edrmagazine.eu/russias-defence-industry-gears-up-for-a-long-war>, accessed 16 September 2024.*

175 *Watling and Reynolds, 'Russian Military Objectives and Capacity in Ukraine Through 2024'.*

176 *Financial data seen by authors.*

177 *Ibid.*

178 *Newsler.ru, 'В Кирове Шойгу посетил "Сельмаш" ' ['Shoigu Visited Selmash in Kirov'], 28 March 2023, <https://www.newsler.ru/politics/2023/03/28/v-kirove-shojgu-posetil-selmash>, accessed 16 September 2024.*

179 *Alexander Churin, 'С большим удовольствием поздравил с юбилеем начальника инструментального производства Алексея Фёдоровича Ипатова' ['It was with Great Pleasure that I Congratulated the Head of the Tool Production, Alexey Fedorovich Ipatov, on his Anniversary'], Telegram, 2 February 2024, <https://t.me/alexander_churin/427>, accessed 16 September 2024; Alexander Churin, 'Предприятия Группы "Сельмаш" заплатили в бюджет Кировской области 1 млрд 300 млн рублей налогов' ['The Enterprises of the Selmash Group Paid 1.3 Billion Rubles in Taxes to the Budget of the Kirov Region'], Telegram, 24 July 2024, <https://t.me/alexander_churin/431>, accessed 16 September 2024.*

Table 7: Companies Identified in the Plastmass Plant Supply Chain in 2023		
Company Name	**Products**	**Value of Transactions with Plastmass in First Six Months of 2023**
Selmash Plant	Medium- and large-calibre artillery shells and unguided rockets.[180] Products supplied to the Plastmass Plant in the past: Components for the shells of S-8 unguided rockets.[181]	$112,949,996
Kurganpribor	V-5KP1/V-5KP fuses for S-8 unguided rockets182 and fuses in general.[183]	$47,334,964
Solikamsk Plant	Charges for artillery ammunition.[184] Products supplied to the Plastmass Plant in the past: 9-Zh-4421 charges used in S-8 unguided rockets.[185]	$8,629,100
Sverdlov Plant	Octogen, hexogen, trinitrotoluene (TNT) and other explosives.[186] Products supplied to the Plastmass Plant in the past: A-IX-I explosive,[187] TNT (from the former Biysk Oleum Plant, now a branch of the Sverdlov Plant).[188]	$5,053,664
Aluminium Sales Company	Aluminium powder.[189]	$1,558,220
Ural Pyrotechnic Factory	9-VG-4421 primer.[190] Products supplied to the Plastmass Plant in the past: 9-VG-4421 primer.[191]	$3,515,412
Communar Plant (Samara)	Artillery ammunition components manufactured: Black powder and propellant charges used in artillery ammunition, such as charges used in 120mm rounds.[192] Products supplied to the Plastmass Plant in the past: Not identified.	$328,660

Source: Financial data seen by authors, Unified Information System in the Field of Procurement, Financial data seen by authors, Unified Information System in the Field of Procurement, JSC Selmash Plant, JSC NPO Kurganpribor, JSC Solikamsk Plant, ASK, Missile-Technical and Artillery-Technical Support of the Armed Forces of the Russian Federation.

180 *JSC Selmash Plant, 'О предприятии' ['About the Enterprise'], <http://web.archive.org/web/20230203171904/https://selmash.group/company> , archived 3 February 2023 at the Wayback Machine, accessed 16 September 2024.*

181 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57411009901170001900000', last modified 11 December 2017, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=4103376>, accessed 16 September 2024.*

182 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57411009901160000680000', last modified 28 June 2016, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=1820658>, accessed 16 September 2024.*

183 *JSC NPO Kurganpribor, 'О предприятии' ['About the Enterprise'], <https://kurganpribor.ru/about/>, accessed 16 September 2024.*

184 *JSC Solikamsk Plant, 'Годовой отчет АО "Соликамский завод "Урал"' за 2017' ['Annual Report Solikamsk Plant JSC for 2017'], <https://e-disclosure.ru/portal/files.aspx?id=30663&type=2&attempt=1>, accessed 16 September 2024.*

185 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57411009901170001290000', last modified 2 November 2017, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=3930987>, accessed 16 September 2024.*

186 *Sverdlov Plant, 'Взрывчатые вещества' ['Explosives'], <http://web.archive.org/web/20211205022453/https:/sverdlova.ru/products/promyshlennye-vzryvchatye-veshchestva/>, archived 5 December 2021 at the Wayback Machine, accessed 16 September 2024.*

187 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57411009901170002220000', last modified 29 December 2017, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=4254330>, accessed 16 September 2024.*

188 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57411009901170000260000', last modified 13 March 2017, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=2979520>, accessed 16 September 2024.*

189 *ASK, 'Продукция' ['Production'], accessed 26 July 2024, <http://asc-trade.com/#prod>, accessed 16 September 2024.*

190 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57411009901170001860000,' last modified 5 December 2017, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=4074722>, accessed 16 September 2024.*

191 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57411009901170001860000', last modified 5 December 2017, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=4074722>, accessed 16 September 2024.*

192 *Marina Marsovna Galimova, 'Наша задача — крепить обороноспособность России (1942–2018)' ['Our Task is to Strengthen Russia's Defence Capability (1942–2018)'], in Ракетно-техническое и артиллерийско-техническое обеспечение Вооруженных Сил Российской Федерации-2018 [Missile-Technical and Artillery-Technical Support of the Armed Forces of the Russian Federation-2018], p. 108.*

These supply chain dependencies can become vulnerabilities. The largest dependency is Plastmass' relationship with Selmash; there are other manufacturers of shell bodies within the ammunition supply chain, but they are supplying other producers. It is not clear that an alternative to Selmash could be found if it were unable to supply Plastmass.

Additionally, the expansion of the plant and recruitment of staff may be limiting production capacity. These supply chain dependencies can become vulnerabilities. The largest dependency is Plastmass' relationship with Selmash; there are other manufacturers of shell bodies within the ammunition supply chain, but they are supplying other producers. It is not clear that an alternative to Selmash could be found if it were unable to supply Plastmass. Additionally, the expansion of the plant and recruitment of staff may be limiting production capacity.

Raw Materials

The raw materials involved in producing artillery ammunition begin with the iron ore that is used to make the shell casing. A shell casing is typically made from steel, and it is designed to be strong enough to withstand the forces of firing from a howitzer, but brittle enough to shatter into small fragments when the explosive inside detonates. In the Russian supply chain, propellent is stored and transported in brass cases that are loaded into the howitzer behind the shell and detonated to fire the round. This adds zinc and copper to the supply chain.[193] The propellent itself is produced from cotton cellulose or cotton pulp and nitric acid, as well as some alcohols. Cotton pulp is produced by harvesting cotton linter and treating it with chemicals like sodium hydroxide that break down the other fibres, leaving only the cellulose, which is then purified and refined to the appropriate length. The resultant material is dried and formed into bales for transport. The final element to consider is the explosive inside the shell, which is typically a variant of Royal Demolition Explosive (RDX), which may also be known as hexogen or cyclonite.[194] RDX is made from the nitrolysis of hexamine, which is produced by combining formaldehyde and ammonia.[195]

The raw materials needed for Russia's artillery ammunition are:

- Ammonia.
- Formaldehyde.
- Aluminium.
- Nitric acid.
- Cotton pulp.
- Sodium hydroxide.
- Iron ore.
- Alloy components.
- Copper.
- Zinc.

The companies active in the supply of raw materials into Russia's artillery ammunition supply chain are shown in Table 8.

193 *Righton Blackburns, 'Introduction to Brass', <https://www.rightonblackburns.co.uk/products/metals/brass/brass-intro>, accessed 16 September 2024.*

194 *Agency for Toxic Substances and Disease Registry, 'RDX (Cyclonite)', Centers for Disease Control and Prevention, <https://wwwn.cdc.gov/TSP/substances/ToxSubstance.aspx?toxid=72>, accessed 16 September 2024.*

195 *The Chemical Company, 'Hexamethylenetetramine', <https://thechemco.com/chemical/hexamethylenetetramine/>, accessed 16 September 2024.*

Table 8: Primary Suppliers of Raw Materials into Russia's Artillery Ammunition Supply Chain			
Company Name	**Products**	**Customers**	**Volume in 2023**
Fargona Kimyo Zavodi	Cotton cellulose.[196]	Perm and Kazan Gunpowder Plants	$2.2 million to Perm and Kazan alone.
Raw Materials Cellulose	Cotton cellulose.[197]	Tambov Gunpowder Plant	$2.6 million total to Russia
United Chemical Company (UCC) UralChem	Ammonia, nitric acid and other chemical products.[198]	Perm Gunpowder Plant, Sverdlov Plant, Tambov Gunpowder Plant	>$2.6 million
Trading House UralChem	Ammonia, nitric acid and other chemical products.[199]	Kazan Gunpowder Plant, Tambov Gunpowder Plant, Sverdlov Plant	>$3 million
Kamensk-Uralsky Non-Ferrous Metals Processing Plant (KUZOCM)	Aluminium powder.[200]	Sverdlov Plant	>$1.7 million
Bina Group	Cotton cellulose, nitric acid, acetone and other chemical products.[201]	Kazan Gunpowder Plant, Aleksin Chemical Plant, Sverdlov Plant	>$2.2 million
Sredneuralsky Copper Smelting Plant	Oleum.[202]	Perm Gunpowder Plant, Kazan Gunpowder Plant, Solikamsk Plant	>$233,000
Kredo	Oleum.[203]	Kazan Gunpowder Plant, Tambov Gunpowder Plant	>$363,000
Nadezhdinsky Metallurgical Plant	Steel bars.[204]	Serov Mechanical Plant	>$10 million
Kamensk-Uralsky Metallurgical Plant	Aluminium metal products.[205]	Serov Mechanical Plant, JSC Mechanical Plant, KBP	>$3.1 million

Source: Financial data seen by authors, Unified Information System in the Field of Procurement, Fargona Kimyo Zavodi, Jizzakh Chemical Plant, Uralchem JSC.

196 *Farg'ona Kimyo Zavodi, 'Продукция' ['Production'], <https://kimyozavodi.uz/products>, accessed 16 September 2024.*

197 *Jizzakh Chemical Plant, 'Jizzakh Chemical Plant — High-Quality Loose and Sheeted (Rolled) Cotton Linter Pulp', <https://www.jcplant.uz/eng#about>, accessed 16 September 2024.*

198 *Uralchem JSC, 'Assets', <https://www.uralchem.com/about/assets/>, accessed 16 September 2024.*

199 *Ibid.*

200 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 1524900248518000311', last modified 15 November 2018, <https://zakupki.gov.ru/epz/contract/contractCard/common-info.html?reestrNumber=1524900248518000311&source=epz>, accessed 16 September 2024.*

201 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 31604563391', last modified 18 December 2016, <https://zakupki.gov.ru/epz/order/notice/notice223/documents.html?noticeInfoId=5490496>, accessed 16 September 2024; Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57111003056170000600000', last modified 25 February 2019, <https://zakupki.gov.ru/epz/contractfz223/card/supplier-info.html?id=293724>, accessed 16 September 2024; Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 31604485597', last modified 14 December 2016, <https://zakupki.gov.ru/epz/order/notice/notice223/documents.html?noticeInfoId=5398017>, accessed 16 September 2024.*

202 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 55919015877170001860000', last modified 31 August 2018, <https://zakupki.gov.ru/epz/contractfz223/card/supplier-info.html?id=4031427>, accessed 16 September 2024.*

203 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 165602568116000296000', last modified 28 March 2017, <https://zakupki.gov.ru/epz/contractfz223/card/supplier-info.html?id=3045414>, accessed 16 September 2024.*

204 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 56680000479170000380000', last modified 28 February 2017, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=2931666>, accessed 16 September 2024.*

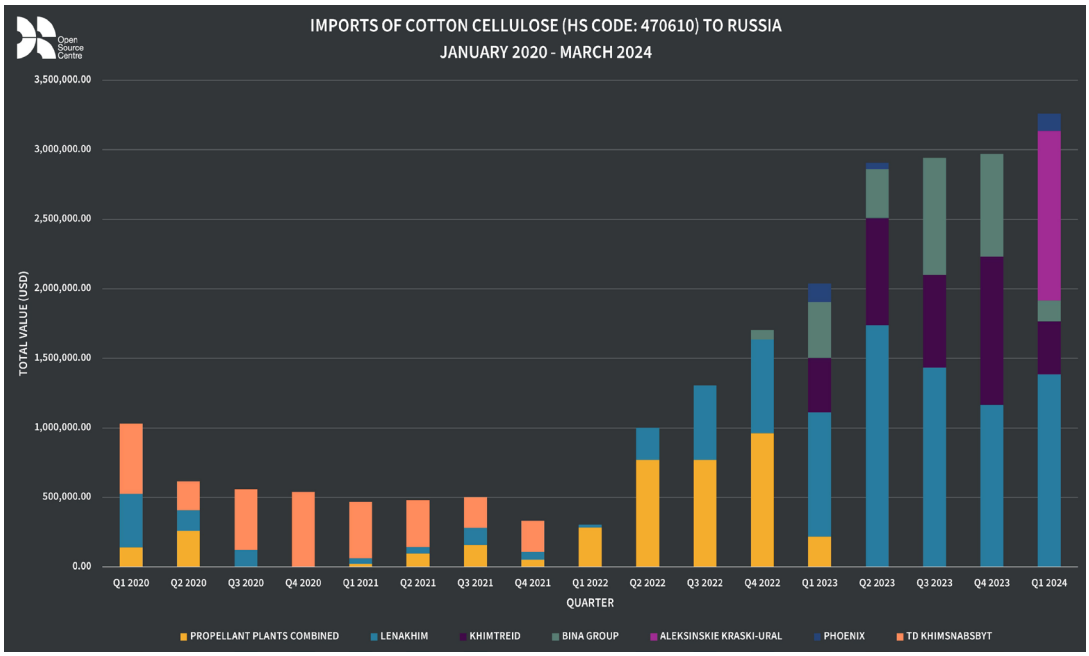
205 *Единая информационная система в сфере закупок [Unified Information System in the Field of Procurement], '№ 57105514574170011090000', last modified 1 February 2018, <https://zakupki.gov.ru/epz/contractfz223/card/contract-info.html?id=3733731>, accessed 16 September 2024.*

RAW MATERIALS IN-DEPTH: NITROCELLULOSE

The charge in an artillery round charge is made of nitrocellulose, making this a key material for artillery production. Russian propellant plants are critically dependent on imports of cotton cellulose, the base material of nitrocellulose, as Russia currently has no domestic capacity for its production. Attempts to grow cotton domestically or develop alternatives to cotton cellulose from wood or flax have so far been futile. The raw materials are often imported, leaving them open to Western interventions to disrupt Russia's access.

Uzbekistan and Kazakhstan have been the main exporters of the base material for cotton cellulose. Russia and Uzbekistan have remained particularly close following the full-scale invasion of Ukraine, as indicated by a joint statement released during Russian President Vladimir Putin's three-day state visit in Tashkent in the end of May 2024 announcing that the two countries would continue 'paying attention to cooperation in the defence sphere'.[206] Under an agreement between Uzbekistan's State Defence Industry and the Kazan Gunpowder Plant in 2020, Russia even agreed to set up licensed powder production in Uzbekistan in exchange for supplies of propellant powders in 2021.[207] Official statistics indicate that Russia's largest supplier of cotton pulp is currently Uzbekistan, whose exports of the material to Russia doubled in 2022, to $9.4 million. One report indicates that Uzbekistan sold more than 4.8 million kilograms of cotton pulp to Russia in the first nine months of 2023.[208] The majority of shipments were received by Russian entities, which appear as suppliers of all major propellant plants, including Perm, Kazan and Solikamsk. Most of these intermediaries were designated by the US Office of Foreign Assets Control (OFAC) in May 2024.

Figure 9: Russian Imports of Cotton Cellulose and Recipient Entities



Source: Trade data supplied by third-party commercial provider, Open Source Centre.

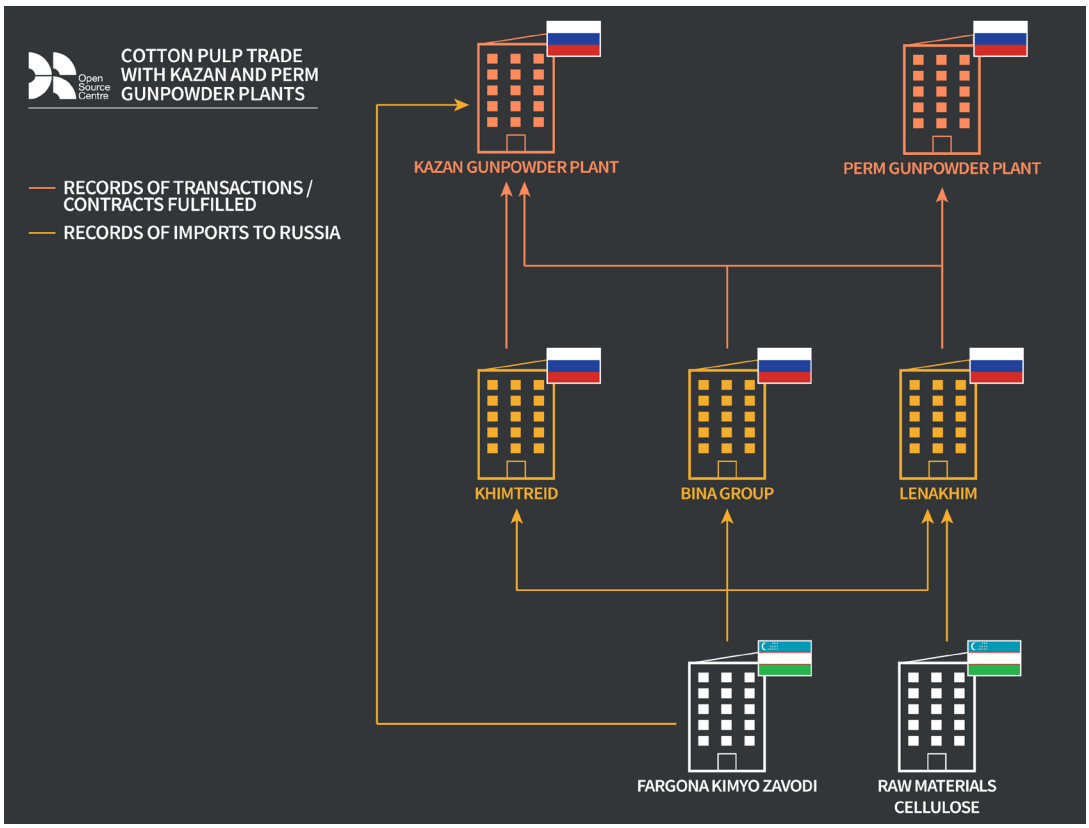
206 *Tass, 'Russia, Uzbekistan to Continue Defense Cooperation — Statement', 27 May 2024, <https://tass.com/politics/1794111>, accessed 16 September 2024.*

207 *Interfax-Russia, 'Казанский пороховой завод обсуждает с Узбекистаном проект лицензионного производства пироксилиновых порохов', 8 December 2020, <https://www.interfax-russia.ru/volga/news/kazanskiy-porohovoy-zavod-obsuzhdaet-s-uzbekistanom-proekt-licenzionnogo-proizvodstva-piroksilinovyh-porohov>, accessed 16 September 2024.*

208 *Metin Kazama, Olga Loginova and Maria Zholobova, 'Central Asian Cotton Powers Russia's Sanctioned Gunpowder Plants', OCCRP, 21 December 2023, <https://www.occrp.org/en/investigations/central-asian-cotton-powers-russias-sanctioned-gunpowder-plants>, accessed 16 September 2024.*

According to commercial trade databases, 85% of Uzbek cotton cellulose exports to Russia in 2023 came from just two manufacturers Fargona Kimyo Zavodi and Raw Materials Cellulose. The two entities are interlinked through their beneficial owners and appear to be ultimately controlled by Rustam Muminov, who has owned several companies in Russia, including LLC TD Khimsnabsbyt, which used to be a direct supplier to the Kazan Gunpowder Plant and was the largest Russian importer of cotton cellulose prior to the invasion of Ukraine.[209] Muminov is currently building a factory in Russia for hydroxypropyl methylcellulose (HPMC), a cotton cellulose derivative with civilian uses.[210] It will also have the capacity to produce cotton cellulose, and so could contribute to the defence industry.

Figure 10: Cotton Pulp Trade with Kazan and Perm Gunpowder Plants



Source: Trade data supplied by third-party commercial provider, financial data seen by authors, ClearSpending, Open Source Centre

209 *Fargona Kimyo Zavodi's beneficial shareholder, Rustam Muminov, is connected to Raw Materials Cellulose's sole shareholder, Larisa Utkina, through at least four entities with various primary activities. Muminov is a shareholder with Utkina in three active Uzbek companies, engaged in real estate, road construction and logistics services. In addition, as of July 2022, Utkina is the patent holder of the Uzbek trademark of LLC Chemistry International and Alliance Capital KS, both of which are majority-owned by Muminov.*

210 *Muminov is the sole owner of Russian entity LLC NPP Tekhnoresurs (Rus.: ООО 'НПП Техноресурс'), which has been involved in a RUB two billion ($32.5 million) project in the Shatura city district for the construction of a plant for HPMC since September 2022. The project was still under construction as of the end of 2023.*
Ministry of Property Relations of the Moscow Region, 'В Подмосковье появится новое химическое производство' ['New Chemical Production Facility to Appear in Moscow Region'], 2 September 2022, <https://mio.mosreg.ru/sobytiya/novosti-ministerstva/02-09-2022-13-20-02-v-podmoskove-poyavitsya-novoe-khimicheskoe-proizvo >, accessed 16 September 2024; Aleksey Vladimirovich Artyukhin, 'Доклад Городской округ Шатура о достигнутых значениях показателей для оценки эффективности деятельности органов местного самоуправления городских округов и муниципальных районов за 2023 и их планируемых значениях на 3-летний период' ['Report of the Shatura Urban District on the Achieved Values of Indicators for Assessing the Effectiveness of Local Government Authorities in Urban Districts and Municipal Areas for 2023 and Their Planned Values for a Three-Year Period'], Official Website of the Administration of the Shatura Urban District, 26 April 2024, <https://www.shatura.ru/files/2024/04/26/607_.pdf>, accessed 16 September 2024.

Customs records show that the Kazan Gunpowder Plant – which manufactures propellant and explosives for artillery ammunition – imported over $2.2 million of cotton pulp from Fargona Kimyo Zavodi between March 2022 and January 2023.[211] The plant also appears to have transacted with at least three other Russian companies – Lenakhim, the Bina Group, and Khimtreid – which imported significant amounts of Uzbek cotton pulp.[212] In total, the four companies imported over $3.5 million in 2022 and almost $7 million in 2023.[213] Meanwhile, the Perm Gunpowder Plant has not reported any imports, and has relied on Lenakhim and the Bina Group (with which it had contracts) to supply Uzbek cotton pulp.[214] These transactions are shown in Figure 5.

US-sanctioned[215] Lenakhim is the largest Russian importer of cotton pulp, procuring over $8 million-worth from 2019 to 2023.[216] The company received payments from the Kazan and Perm plants in early 2023[217] and has been fulfilling contracts for both since at least 2016[218] and 2013, respectively.[219] Its annual imports of cotton pulp sat below $700,000 between 2019 and 2021,[220] but in 2022 and 2023, the company imported over $7 million in cotton pulp from Fargona Kimyo Zavodi and Raw Materials Cellulose LLC, which supplied over $4.4 million.[221] Uzbek customs data shows that Fargona Kimyo Zavodi supplied a further $600,000 of cotton pulp to Lenakhim in January 2024.[222]

Other importers of cotton pulp include Kazan-based Khimtreid, a chemical products wholesaler[223] that imported just under $200,000 of cotton pulp from Fargona Kimyo Zavodi in September 2023,[224] Bina Group, a large Russian chemicals company which received payments from Kazan[225] and fulfilled contracts with Perm and other Russian defence companies.[226] Both Khimtreid and Bina Group were sanctioned by the US in May 2024.[227] The latter company has been importing large volumes of chemicals and precursors since 2020, and in 2023, it imported $1 million of cotton pulp from Fargona Kimyo Zavodi.[228]

There is some evidence that sanctions and diplomatic pressure have successfully disrupted the nitrocellulose supply chain. The Kazakhstan-based Khlopkoprom-Tsellyuloza used to be one of the largest cotton cellulose suppliers of Russian propellant plants, but as of July 2023, when the Kazan and Aleksin propellant plants were designated by OFAC, Kazakhstan has drastically decreased its total exports of cotton cellulose, sending a total of 115 tonnes, worth $232,959 to Russia, between July and October 2023, and then

211 *Trade data supplied by third-party commercial provider.*
212 *Financial data seen by authors; trade data supplied by third-party commercial provider.*
213 *Trade data supplied by third-party commercial provider.*
214 *Ibid.*
215 *U.S Department of the Treasury, 'U.S. Continues to Degrade Russia's Military-Industrial Base and Target Third-Country Support with Nearly 300 New Sanctions', press release, 1 May 2024, <https://home.treasury.gov/news/press-releases/jy2318>, accessed 16 September 2024.*
216 *Trade data supplied by third-party commercial provider.*
217 *Financial data seen by authors.*
218 *ClearSpending, 'Contract 5165602568116000054000', <https://clearspending.ru/contract/5165602568116000054000/>, accessed 16 September 2024.*
219 *ClearSpending, contract 31300390552-01, <https://clearspending.ru/contract/31300390552-01/>, accessed 16 September 2024.*
220 *Trade data supplied by third-party commercial provider.*
221 *Ibid.*
222 *Ibid.*
223 *Russian Unified State Registry of Legal Persons.*
224 *Trade data supplied by third-party commercial provider.*
225 *Financial data seen by authors.*
226 *Clearspending, 'Общество с ограниченной ответственностью "Бина Групп" ['Bina Group LLC'], <https://clearspending.ru/supplier/inn=7706725428&kpp=770601001>, accessed 16 September 2024.*
227 *US Department of the Treasury, 'U.S. Continues to Degrade Russia's Military-Industrial Base and Target Third-Country Support with Nearly 300 New Sanctions'.*
228 *Trade data supplied by third-party commercial provider.*

ostensibly ceasing its shipments altogether.[229] Instead, commercial trade data reveals that since March 2024, the entity has delivered 8,585 metric tonnes of cotton cellulose, worth nearly $17 million, to one single customer: US Department of State contractor, Bizzell Corporation.[230] Bizzell is reportedly engaged in the production of large-calibre artillery ammunition in Europe for NATO partners.[231] This is indicative of the positive effect that focused sanctions and political effort can have in denying critical materials to an opponent, while also benefiting a country's own defence industry.

Processing

The raw materials are processed into core products that are then turned into projectiles and propellant. The product that becomes the outer shell of each projectile is a steel rod that is forged and stamped into a cylinder with a cavity in the middle. The outside of the shell is shaped with a machine tool, and a thread for the fuse is cut into the cone-shaped nose of the projectile. The projectile is heat-treated and cooled. A copper band is added to the outside of the shell, which is known as a driving band; it is designed to be softer than the steel of the shell so that the metal grooves of the rifling inside the howitzer barrel bite into it. This creates a more effective seal to ensure most of the gases produced by the propellant are directed into the shell and serves to impart spin to the projectile once it leaves the barrel, which stabilises it and improves accuracy. The shell is designed to be thick and strong enough through heat treatment to withstand the pressures of being fired from a howitzer, but not so thick that it will not fragment upon detonation. Further work is carried out to remove excess metal and prepare the round to receive a fuse, and the outer surface of the shell is polished and painted before it is transferred to a filling plant.

At another plant, the explosive fill is produced, which, for Russian ammunition, is a compound called A-IX-2, an explosive made from 73% RDX, 23% aluminium and 4% wax, which is called a phlegmatizer.[232] This is added to stabilise the explosive material. RDX is produced through the nitrolysis of hexamine with nitric acid.[233] Hexamine is produced through a chemical reaction that results from formaldehyde and ammonia being mixed in gaseous states.[234] The explosive fill is added through casting or pressing through the opening left for the fuse. This takes place at the filling plant before the shells are made ready for transit. Often this is done by plugging the open nose of the shell, which is used to insert the fuse before firing.

Separately, the propellant for the shells is produced from nitrocellulose, which is produced by nitrating cotton cellulose with nitric and sulfuric acid under temperature-controlled conditions. This creates an unstable and energetic material by binding nitrate groups to the cellulose fibres found in cotton. The degree of nitration can also be controlled, leading to different nitrocellulose products. In the next stage, the nitrated cellulose is separated from the acid mixture and boiled in water to help remove unstable nitro groups. The finished mixture is then dried and cut or extruded into rods or granules. In the case of Russian ammunition, these are packed into a brass casing. The casings are filled either completely or partially, depending on the range they are designed to provide. They are they made ready for use as a propellent that is inserted behind the artillery round in the breech of the gun prior to firing.

229 *Bureau of National Statistics of Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 'Экспорт и импорт РК со странами ЕАЭС по 4, 6, 10 знакам ТН ВЭД ЕАЭС в разрезе "страна-товар" (2023 г.)' ['Export and Import of the Republic of Kazakhstan with the EAEU Countries by 4, 6, 10 Codes of the EAEU TN VED in the Context of "Country-Goods" (2023)'], 25 July 2024, <https://stat.gov.kz/api/iblock/element/60760/file/ru/>, accessed 16 September 2024.*

230 *USAspending.gov, 'Bizzell Corporation', <https://www.usaspending.gov/recipient/c6c10969-55f6-f124-92cd-30264000116a-C/latest>, accessed 16 September 2024.*

231 *Bizzell Corporation, 'Bizzell Corporation Establishes Bizzell Europe to Expand Global Footprint', LinkedIn, 3 April 2024, <https://www.linkedin.com/feed/update/urn:li:activity:7186406162395734017/>, accessed 16 September 2024.*

232 *Roly Evans and Bob Seddon, Explosive Ordnance Guide for Ukraine, Second edition, GICHD, 2022, p. 114.*

233 *H Abadin et al., 'Toxicological Profile for RDX', Atlanta Agency for Toxic Substance and Disease, January 2012, <https://www.ncbi.nlm.nih.gov/books/NBK154153/>, accessed 16 September 2024.*

234 *A Alamdari and F Tabkhi, 'Kinetics of Hexamine Crystallization in Industrial Scale', Chemical Engineering and Processing: Process Intensification, (Vol. 43, No. 7, July 2004), pp. 803-810; Department of the Army Technical Manual, Military Explosives, Head Quarters Department of the Army, Washington, September 1984.*

Russian ammunition manufacturing is not strictly specialised, and in an emergency, it is possible for companies to cover more than one stage or process. For example, one company may assemble projectiles for one calibre but deliver elements of others to a separate company working on a different calibre. There are several companies involved in this process in Russia (see Table 9); the Serov Mechanical Plant is one example. It is part of Tekhmash and is responsible for producing shells for artillery ammunition up to 152 mm. The plant was extensively refurbished in 2020 with state-of-the-art CNC machines, and has become an important element within the artillery supply chain.[235] Other companies such as Mechanical Plant in Orsk produce brass casings for propellant.[236] Charges and propellant are produced by many companies, including the Perm and Kazan Gunpowder Plants, as well as the Samara Plant, which is focused on charges for mortars.[237] The Solikamsk Plant is also responsible for manufacturing propellant for mortar and rocket ammunition. The Sverdlov Plant, which has a branch in Altai region, states that it produces Hexogen for the defence industry, and fuses are believed to be manufactured by a company called the Kazan Precision Machinery Plant and Kurganpribor.[238]

235 *RIA Novosti, 'Серовский мехзавод модернизирует производство военной продукции' ['Serov Mechanical Plant Modernises Production of Military Products'], 8 September 2015, <https://ria.ru/20150908/1238224124.html>, accessed 16 September 2024.*

236 *JSC Mechanical Plant, Company Booklet, <http://web.archive.org/web/20160502084940/http://mz-orsk.ru/upload/Buklet1.pdf>, archived 2 May 2016 at the Wayback Machine, accessed 16 September 2024.*

237 *FKP Samara Communar Plant Communar, ['Продукция завода' ['Plant Production'], <https://web.archive.org/web/20220114134814/http://fkp-kommunar.ru/products.html>, archived 14 January 2022 at the Wayback Machine, accessed 16 September 2024.*

238 *Sverdlov Plant, 'Взрывчатые вещества' ['Explosives'], <https://web.archive.org/web/20211023140331/http://www.sverdlova.ru/products/promyshlennye-vzryvchatye-veshchestva/#mark8629>, archived 23 January 2021 at the Wayback Machine, accessed 16 September 2024; 'ФКП "НПО "КЗТМ"' [FKP NPO KZTM], РБК Компании ['RBC Companies'], last modified 8 March 2024, <https://companies.rbc.ru/id/1021602829115-federalnoe-kazennoe-predpriyatie-nauchno-proizvodstvennoe-obedinenie-kazanskij-zavod-tochnogo-mashinostroeniya/>, accessed 16 September 2024.*

Table 9: Raw Material Processing Companies that Produce the Critical Goods for Ammunition Production			
Company Name	**Products**	**Customers**	**Volume in 2023**
Perm Gunpowder Plant	Propellant and explosives.[239]	Splav; Novator; Kalinin Machine Building Plant; KBP	$146 million to the companies listed
Kazan Gunpowder Plant	Propellants and charges used in ammunition for 120 mm, 122 mm and 152 mm howitzers.[240]	NIMI Bakhirev; POZiS;[241] Planta Chemical Plant; Russian MoD	$63 million to the companies listed
Solikamsk Ural Plant	Charges for mortars and tanks, rocket motors for ATGMs.	Splav; Novosibirsk Plant of Artificial Fiber; Plastmass Plant	$81 million to the companies listed
Samara Ural Plant	Charges for mortars and self-propelled artillery.[242]	NPO Bazalt; Novator	$27 million to the companies listed
Sverdlov Plant	Complete round manufacture.[243] Propellant and propellant casings for large calibre artillery. Hexogen/ RDX for explosive fill.[244]	NIMI Bakhirev; TsNIIKhM[245]	$107 million to the companies listed
Aleksin Chemical Plant	Nitrocellulose and propellant powders for large-calibre ammunition,[246] planned new production of propellant powders for artillery shells.[247]	NIMI Bakhirev, Kazan Gunpowder Plant; Tambov Gunpowder Plant	$52 million to the companies listed
Tambov Gunpowder Plant	Propellant powders used in charges for ammunition for 122 mm and 152 mm howitzers.[248]	NIMI Bakhirev; Samara Communar Plant ; Soyuz Federal Center for Dual-Use Technology; KBP	$17 million million to the companies listed
Verkhneturinsky Machine-Building Plant (VTMZ)	Shell bodies for artillery and tanks.[249]	NIMI Bakhirev	$71 million
JSC Mechanical Plant	Shell bodies for artillery and tanks. Propellant casings.[250]	NIMI Bakhirev; Splav; Kazan Gunpowder Plant	$104 million to the companies listed
Serov Mechanical Plant	Shell bodies for artillery.[251]	NIMI Bakhirev; KBP; Leningrad Mechanical Plant	$137 million, $133 million of which is to NIMI Bakhirev
Selmash Plant	Shell and rocket bodies.[252]	NIMI Bakhirev; Plastmass Plant; NPO Splav	$253 million

Source: Perm Gunpowder Plant, FKP Kazan Gunpowder Plant, FKP Samara Plant Communar, Kommersant, Sverdlov Plant, Centre for Pre-University Training of the Bauman Moscow State Technical University, Interfax-Russia, FKP Tambov Gunpowder Plant, Rostec, JSC Mechanical Plant, RIA Novosti, JSC Selmash Plant.

239 *Perm Gunpowder Plant, 'О предприятии' ['About the Enterprise'], <http://web.archive.org/web/20210206203819/http:/www.fkpppz.ru/>, archived 6 February 2021 at the Wayback Machine, accessed 16 September 2024.*

240 *FKP Kazan Gunpowder Plant, 'Пороха и заряды ко всем видам вооружения' ['Propellant Powders and Charges For All Types of Weapons'], <http://web.archive.org/web/20221208133900/https://kazanpowder.ru/products/military>, archived 8 December 2022 at the Wayback Machine, accessed 16 September 2024.*

241 *Proizvodstvennoye obyedineniye 'Zavod imeni Sergo' (Sergo Industrial Complex).*

242 *FKP Samara Plant Communar, ['Продукция завода' ['Plant Production'], <https://web.archive.org/web/20220114134814/http://fkp-kommunar.ru/products.html>, archived 14 January 2022 at the Wayback Machine, accessed 16 September 2024.*

243 *Ivan Sergeev, 'Завод имени Свердлова оштрафовали на 20 млн рублей за опоздание со снарядами' ['The Sverdlov Plant Was Fined 20 million Rubles for Being Late with Shells'], Kommersant, 15 December 2022,<https://www.kommersant.ru/doc/5721742>, accessed 26 June 2024.*

244 *Sverdlov Plant, 'Оборонная промышленность' ['Defense Industry'], <https://web.archive.org/web/20211205024058/https:/sverdlova.ru/products/oboronnaya-promyshlennost/>, archived 5 December 2021 at the Wayback Machine, accessed 16 September 2024.*

245 *Central Scientific Research Institute of Chemistry and Mechanics.*

246 *Centre for Pre-University Training of the Bauman Moscow State Technical University, 'Компании-партнеры 2019' ['Partner Companies 2019'], <https://web.archive.org/web/20200706013407/http://cendop.bmstu.ru/userfiles/docs/Компании-партнеры 2019.xlsx>, archived 6 July 2020 at the Wayback Machine, accessed 12 August 2024.*

247 *Interfax-Russia, 'Пороховое производство будет создано на Алексинском химкомбинате под Тулой' ['Propellant Powder Production Will be Created at the Aleksin Chemical Plant Near Tula'], 16 June 2020, <https://www.interfax-russia.ru/center/news/porohovoe-proizvodstvo-budet-sozdano-na-aleksinskom-himkombinate-pod-tuloy>, accessed 12 August 2024.*

248 *FKP Tambov Gunpowder Plant, 'Пироксилиновые пороха и заряды для артиллерийских выстрелов и патронов' ['Pyroxylin Powders for Cartridges of Combat Weapons'], <http://web.archive.org/web/20221204090252/https:/fkptpz.ru/>, archived 4 December 2022 at the Wayback Machine, accessed 12 August 2024.*

249 *Rostec, 'Ростех открыл на Верхнетуринском заводе новый цех по производству корпусов снарядов' ['Rostec Opens New Shell Body Production Workshop at The Verkhneturinsk Plant'], 1 July 2021, <https://rostec.ru/news/rostekh-otkryl-na-verkhneturinskim-zavode-novyy-tsekh-po-proizvodstvu-korpusov-snaryadov/>, accessed 16 September 2024.*

250 *JSC Mechanical Plant, Company Booklet, <http://web.archive.org/web/20160502084940/http://mz-orsk.ru/upload/Buklet1.pdf>, archived 2 May 2016 at the Wayback Machine, accessed 16 September 2024.*

251 *RIA Novosti, 'Серовский мехзавод модернизирует производство военной продукции' ['Serov Mechanical Plant Modernises Production of Military Products'], 8 September 2015, <https://ria.ru/20150908/1238224124.html>, accessed 16 September 2024.*

252 *JSC Selmash Plant, 'О предприятии' ['About the Enterprise'], <http://web.archive.org/web/20230203171904/https://selmash.group/company> , archived 3 February 2023 at the Wayback Machine, accessed 16 September 2024.*

PROCESSING IN-DEPTH: THE PERM AND KAZAN GUNPOWDER PLANTS

Two of Russia's most important propellant and energetics plants are the Perm Gunpowder Plant, which accounts for over 40% of Russia's propellant production based on sales, and the Kazan Gunpowder Plant, which is the country's most advanced propellant plant and has its own research and development centre as well as a dedicated nitrocellulose production facility. The Perm Gunpowder Plant is a sprawling facility that houses a TNT production plant, a ballistic missile R&D institute and an area dedicated to the testing of ballistic missile engines.[253] It also reportedly produces charges and igniters for rocket engines used in a variety of Russian weapons systems.[254] Perm is equipped with its own thermal power plant, and manufactures a range of explosives for submarine-launched, air-to-air and ground-to-air missiles and artillery systems.[255]

Following the 2022 invasion of Ukraine, both plants appear to have ramped up production. In December 2022, Perm's governor announced that the plant would receive over RUB one billion in investment for modernisation and construction of new facilities.[256] Meanwhile, the plant announced plans to add 350 workers and increase shifts for current employees after an influx of new defence orders. Similarly, the workforce at the Kazan Plant increased shifts, while the plant launched plans to upgrade production of nitrocellulose and propellant powders.[257]

Figure 11: Geographic Locations of Perm and Kazan Gunpowder Plants

Source: Open Source Centre.

253 *Fiber to Firepower: Inside Russia's Propellant Industry Supply Chain (2023), The Dekleptocracy Project (TDP)*

254 *U. S. Department of State, 'Taking Additional Sweeping Measures Against Russia', press release, 12 December 2023, https://www.state.gov/taking-additional-sweeping-measures-against-russia-3/, accessed 16 September 2024.*

255 *Rosfinprom JSC, 'Пермский пороховой завод ['Perm Gunpowder Plant'], <http://www.100rus.ru/pfo/poroh.htm>, accessed 16 September 2024.*

256 *Kommersant, 'На модернизацию Пермского порохового завода направят 1 млрд рублей ['Perm Gunpowder Plant Will Receive 1 Billion of Rubles for Modernisation'], 26 December 2022, <https://www.kommersant.ru/doc/5747766>, accessed 16 September 2024.*

257 *Real Time, 'Казанский пороховой завод нарастит мощности производства нитратов и порохов ['Kazan Gunpowder Plant Increases Production Capacity of Nitrogen-Based Compounds and Gunpowder'], 23 January 2023, https://m.realnoevremya.ru/news/271456-kazanskiy-porohovoy-zavod-narastit-moschnosti-proizvodstva-nitratov-i-porohov, accessed 16 September 2024.*

High-resolution satellite imagery confirms that, in mid-2023, both the Kazan and Perm Plants began significant expansion and renovation.[258]

Ground has been broken on a large footprint of land directly next to the Kazan Plant's nitrocellulose production facility, indicating that areas of the facility used for the production of ammunition are being expanded.[259] At least five other locations at the plant have been cleared, likely indicating plans to expand production.[260] This is shown in Figures 12 and 14.

Figure 12: Kazan Gunpowder Plant Overview

Source: Airbus Defence and Space, RUSI, Open Source Centre.

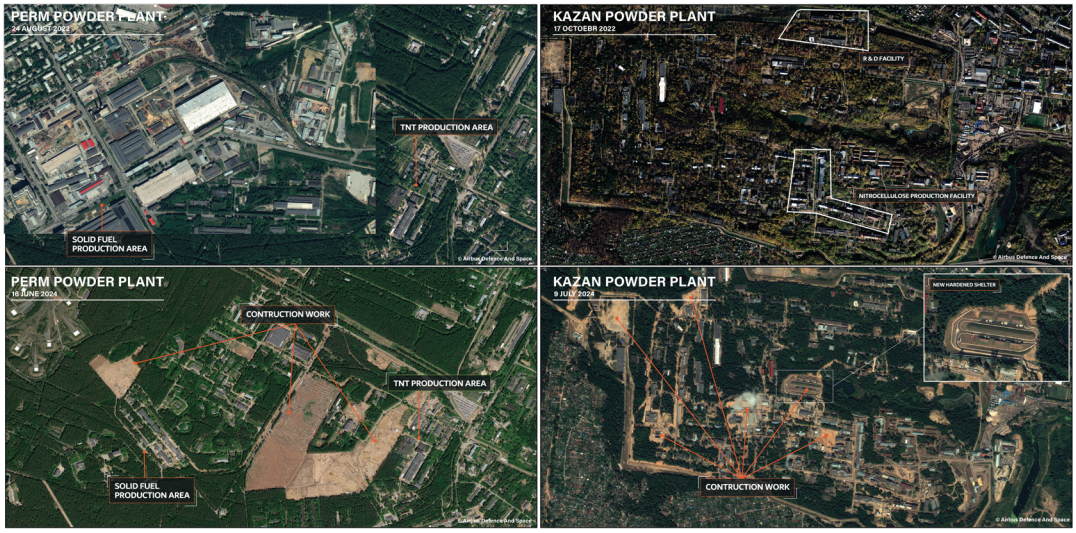
A similar expansion was observed at several locations in the Perm Gunpowder Plant, most notably alongside the TNT production facility, where large swathes of land have been deforested.[261] Similar deforestation can also be seen alongside the solid fuel production area.[262] This is shown in Figures 13 and 14.

258 *Satellite imagery provided by Airbus Defence and Space.*
259 *Ibid.*
260 *Ibid.*
261 *Ibid.*
262 *Ibid.*

Figure 13: Perm Gunpowder Plant Overview

Source: Airbus Defence and Space, RUSI, Open Source Centre.

Figure 14: New Construction Projects Underway at the Kazan and Perm Gunpowder Plant



Source: Airbus Defence and Space, RUSI, Open Source Centre.

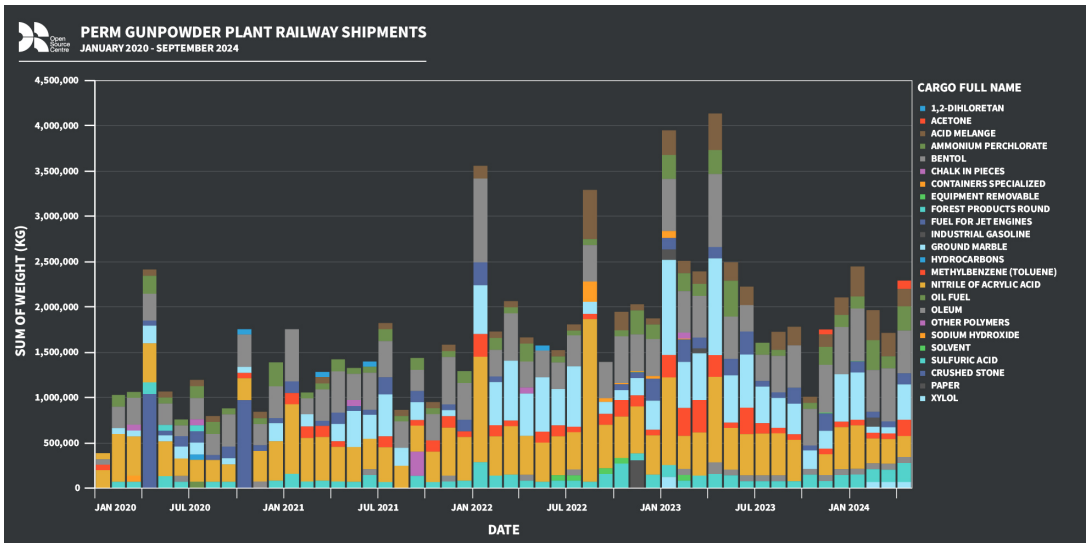
This analysis of the Perm and Kazan Gunpowder Plants further demonstrates that the vulnerabilities of Russia's artillery supply chain – specifically those that can be affected by Ukraine's Western partners – are outside Russia. There is a large and significant trade in chemicals between Russia's petrochemical industry and its defence industry, which would be difficult to disrupt. However, that same petrochemical industry has multiple intersections and relations with Western countries and companies. This means that key chemicals are linked to Western economies, providing points of exposure.

Domestic Supply Chains

Russia's sprawling petro-chemicals and mining industries are responsible for meeting much of the defence industry's needs for chemicals and

precursors. The majority are moved by rail, and analysis of Russian railway data indicates that both the Perm and the Kazan Gunpowder Plants receive large volumes of precursor materials and chemicals by rail.[263] These include monthly shipments of benthol, methylbenzene, nitric and sulphuric acid, oleum and a range of other chemicals and materials used to manufacture propellant powders, explosives and high-energetics.[264] The delivery of these materials has increased significantly since 2021.[265]

Figure 15: Railway imports to Perm and Kazan

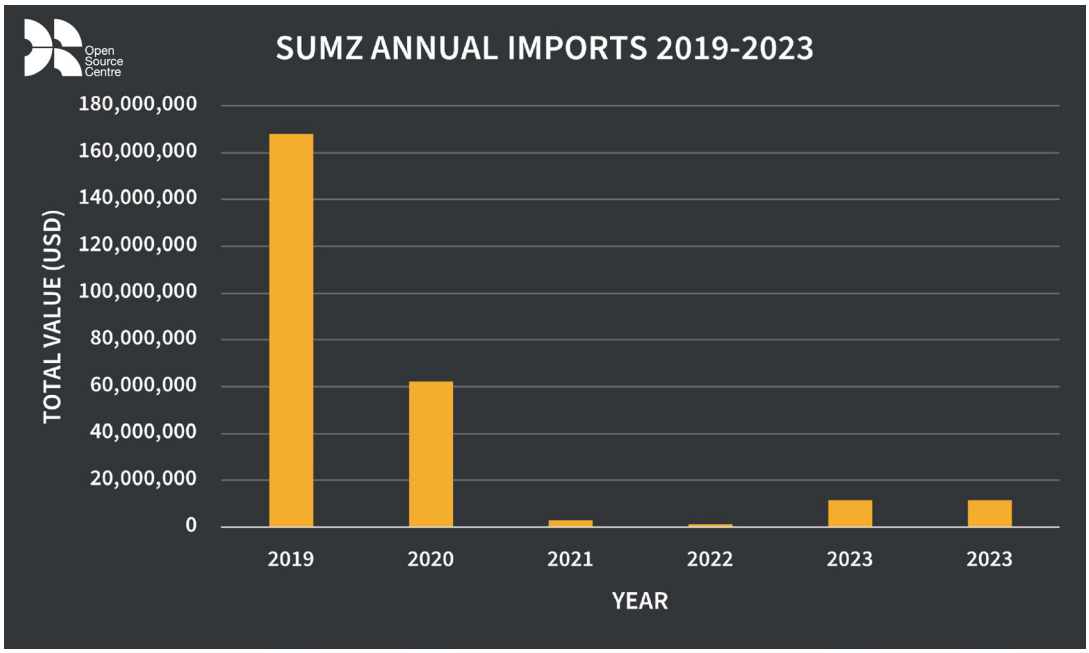


Source: Russian internal railway data, Open Source Centre.

In many cases, the chemicals are sold and shipped to the Perm and Kazan Plants by well-established Russian companies involved in the manufacture of chemicals, petrochemicals and fertilisers,[266] underscoring the intimate links between the country's defence and civilian economies. Despite acting as critical supply nodes for Russia's war effort, many of these companies continue to trade with the global economy. For example, one of the most important suppliers of precursors to both plants is Russia's Sredneuralsky Copper Smelting Plant (SUMZ).[267] Between April 2023 and April 2024, the latter shipped over 4,000 tonnes of oleum to the Kazan Gunpowder Plant and over 770 tonnes of oleum to the Perm Gunpowder Plant.[268] Oleum, otherwise known as fuming sulphuric acid, is used in the manufacture of explosives such as TNT.[269]

263 *Russian internal railway data.*
264 *Ibid.*
265 *Ibid.*
266 *Ibid.*
267 *Financial data seen by authors; Russian internal railway data.*
268 *Russian internal railway data.*
269 *US Army Materiel Command Headquarters, 'Engineering Design Handbook: Properties of Explosives of Military Interest', January 1971, https://apps.dtic.mil/sti/tr/pdf/AD0764340.pdf, accessed 16 September 2024.*

Figure 16: Annual Import Totals for Sredneuralsky Copper Smelting Plant, 2019-2023 (USD)



Source: Trade data supplied by third-party commercial provider, Open Source Centre.

Available Russian customs records show that SUMZ has been procuring machinery from overseas since 2019.[270] While its total imports have decreased since 2019, the company still imported $11.5 million of equipment and related materials in 2023.[271] Over $1 million of these shipments were spare parts for sulphuric acid blowers supplied by Herzog Hydraulik GmbH, a German company which has a history of shipping goods to SUMZ and other Russian companies.[272] An acid blower is used to move gases during the production of sulfuric acid. The majority of these acid blower spare parts, produced by Howden Turbo, were shipped via Lithuania, with the last shipment occurring in October 2023.[273]

Russia's petrochemical and refinery industry is also a critical supplier to both gunpowder plants. For example, Lukoil's refinery in Perm has been making regular deliveries of toluene by rail,[274] a critical precursor for the manufacture of TNT, to the Perm Plant.[275]

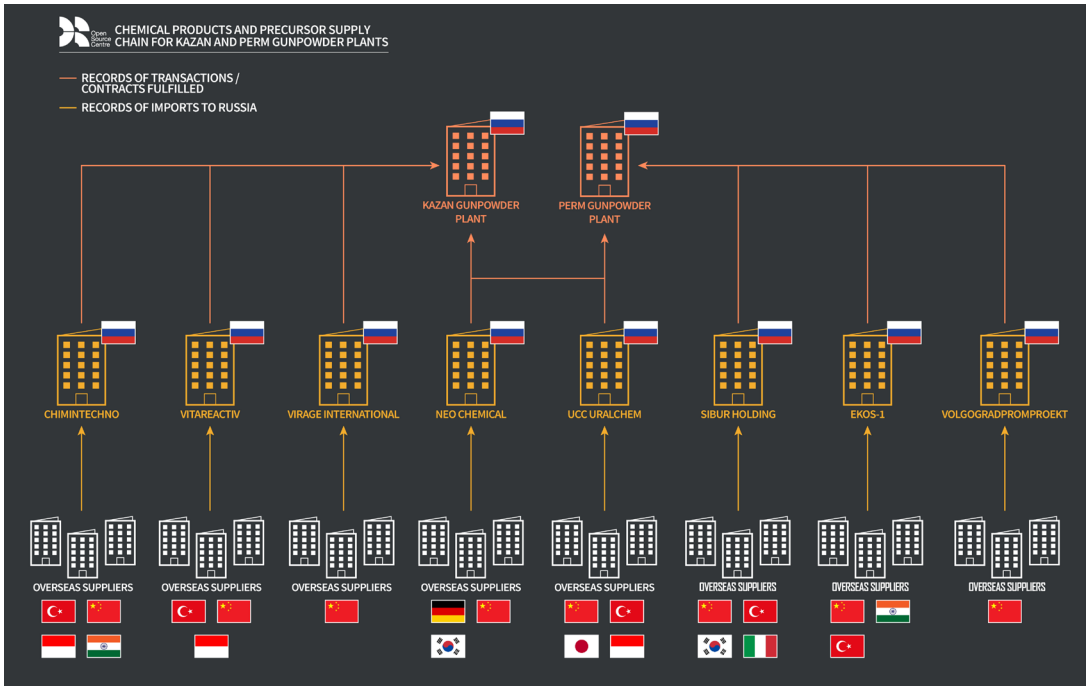
International supply chains

Internal transaction data for the first half of 2023 shows that both plants made payments to hundreds of companies in Russia,[276] including some that have imported goods.[277] Customs data reveals that dozens of these importers procured items critical to the production of propellants, explosives and shells, which can be broken down into three categories: cotton pulp; chemicals and precursors; and machinery. [278] The issue of cotton pulp supply for nitrocellulose is covered in the Raw Materials section of chapter 4 of this paper. It is sufficient to state here that the trade in cotton pulp and nitrocellulose mentioned in that section is important to the function of the Kazan and Perm Plants.

270 *Trade data supplied by third-party commercial provider.*
271 *Ibid.*
272 *Ibid.*
273 *Ibid.*
274 *AKA methylbenzene.*
275 *Russian internal railway data.*
276 *Financial data seen by authors.*
277 *Trade data supplied by third-party commercial provider.*
278 *Ibid.*

Chemicals and Precursors

Figure 17: Chemical Products and Precursor Supply Chain for the Kazan and Perm Gunpowder Plants

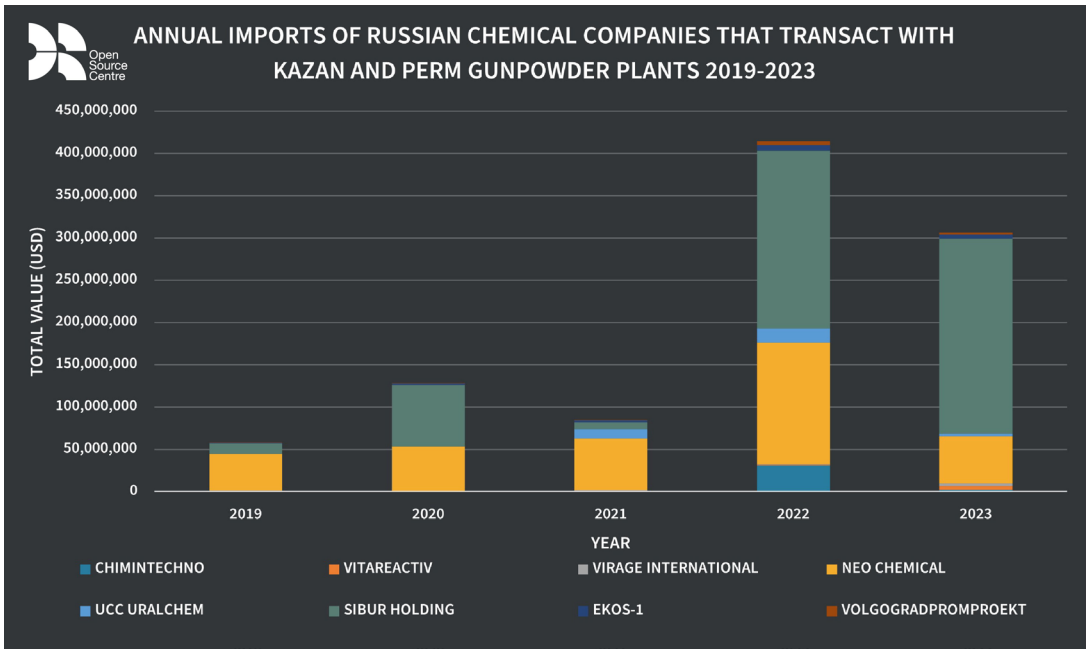


Source: Financial data seen by authors, trade data supplied by third-party commercial provider, Clearspending, Open Source Centre.

The Kazan and Perm Gunpowder Plants have also engaged with a network of large and small wholesale traders of critical chemical compounds within Russia.[279] This is shown in Figures 12 and 13. Several of these enterprises have been sanctioned by the US, UK and Ukrainian governments since February 2022. Nevertheless, some continue trading internationally and are open about their relationship with the military-industrial complex.

279 *Financial data seen by authors.*

Figure 18: Annual Imports of Russian Chemical Companies That Transact With the Kazan and Perm Gunpowder Plants, 2019-2023



Source: Trade data supplied by third-party commercial providers, Open Source Centre.

One supplier to both plants is Neo Chemical LLC, a large distributor of chemical products that states that it operates in Russia, the Commonwealth of Independent States (CIS) and Europe.[280] It has fulfilled contracts with Russia's defence industry, including with the Srednenevsky Shipbuilding Plant, the Solikamsk Plant, and the Sverdlov Plant.[281]

The company has been consistent in procuring chemicals and precursors, including epoxy resins, stearic acids, acrylic polymers and polyisobutylene - primarily from Chinese companies.[282] The last of these is a compound used for the production of explosive charges. Russian government patents demonstrate the application of polyisobutylene in the production of plastic and emulsion explosive charges,[283] including for military use.[284]

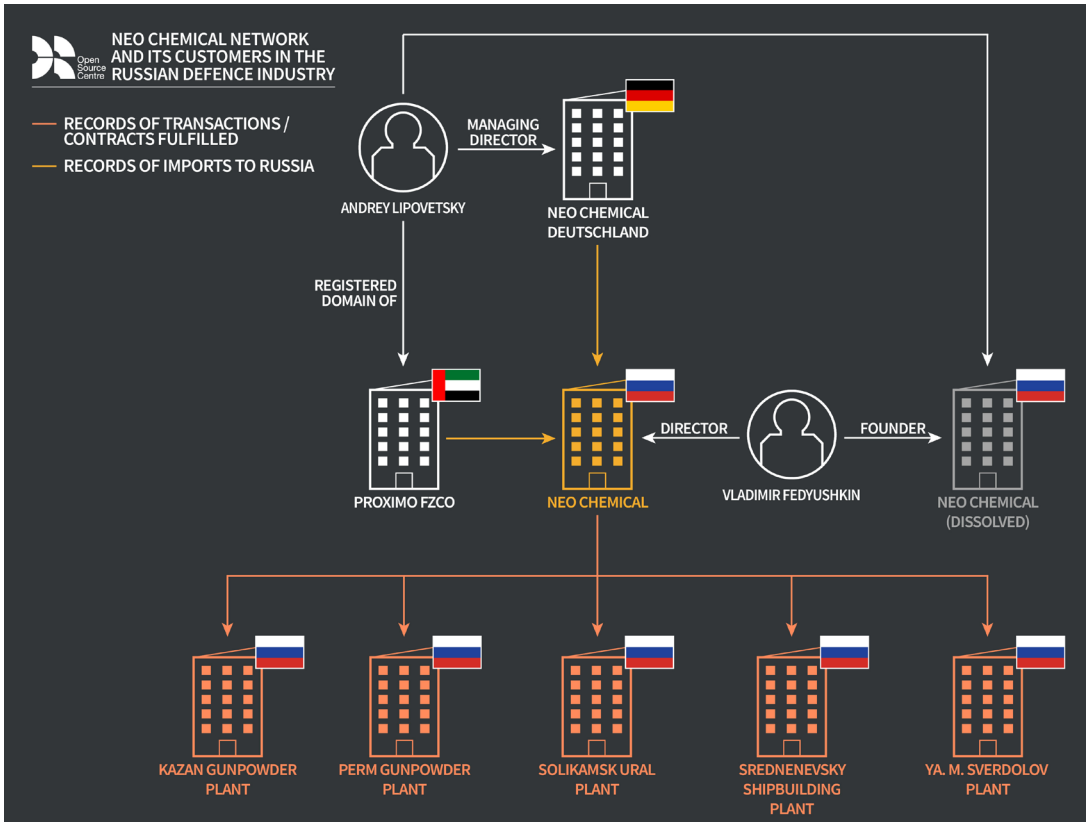
Neo Chemical is one of the largest importers of polyisobutylene into Russia, receiving over $3.4 million-worth over 2022 and 2023.[285] The largest supplier during this period was a South Korean petrochemical company named DL Chemical, which shipped over $1.6 million of polyisobutylene in that period.[286]

However, one of the company's largest foreign suppliers is Neo Chemical Deutschland, which shipped over $25 million of products – such as surfactants, epoxy resins and polyethylene produced in the EU – between March 2022 and November 2023.[287] Neo Chemical Deutschland was founded in 2004 by Russian national Andrey Lipovetsky,[288] who was the founder of a third company named Neo Chemical in Russia a year

280 *Neo Chemical, 'РАЗУМ ЭНЕРГИЯ СИЛА ['Sense, Energy, Strength']', <https://neochemical.ru/>, accessed 16 September 2024.*
281 *ClearSpending, 'ОБЩЕСТВО С ОГРАНИЧЕННОЙ ОТВЕТСТВЕННОСТЬЮ "НЕО КЕМИКАЛ" ['Neo Chemical LLC'], <https://clearspending.ru/supplier/inn=5249072845&kpp=524901001>, accessed 16 September 2024.*
282 *Trade data supplied by third-party commercial provider.*
283 *Google Patents, 'Patent RU2616729C1: Эмульсионный предохранительный взрывчатый состав и способ его получения' ['Emulsion Safety Explosive Composition and Method of its Production'], <https://patents.google.com/patent/RU2616729C1/>, accessed 16 September 2024; Google Patents, 'Patent RU2009145068A: Стабильный эмульсионный взрывчатый состав' ['Stable Emulsion Explosive Composition'], <https://patents.google.com/patent/RU2009145068A/>, accessed 16 September 2024.*
284 *Google Patents, 'Patent RU2524409C1: Устройство взрывное' ['Explosive Device'], <https://patents.google.com/patent/RU2524409C1>, accessed 16 September 2024.*
285 *Trade data supplied by third-party commercial provider.*
286 *Ibid.*
287 *Ibid*
288 *North Data, 'Neo Chemical Deutschland GmbH, Leverkusen, Germany', <https://www.northdata.com/NEO+Chemical+Deutschland+GmbH,+Leverkusen/Amtsgericht+K%C3%B6ln+HRB+54036>, accessed 16 September 2024.*

later.[289] While this iteration of Neo Chemical was dissolved in 2007, a co-founder of that company, Vladimir Fedyushkin, founded and currently operates the Neo Chemical that has been receiving shipments from Neo Chemical Deutschland.[290] Meanwhile, an individual named Andrey Lipovetsky registered the domain for a UAE-based company named Proximo FZCO,[291] which also shipped nearly $1.4 million in chemicals and acids to Neo Chemical from October 2022 to December 2023.[292]

Figure 19: The supply chain for Neo Chemical from its German and Dubai affiliates to the Russian defence industry.



Source: Financial data seen by authors, trade data supplied by third-party commercial provider, North Data, Clearspending, Open Souce Centre.

Another supplier to Kazan and Perm, UCC UralChem, has continued to import large volumes of chemicals and related materials from abroad, including lubricants, mineral fertilisers, stearic acids, catalysts, calcium nitrates and potassium nitrates,[293] the latter of which is used in production of gunpowder mixes.[294] While its imports fell from $17.5 million in 2022 to $3.3 million in 2023 the company received shipments from companies in countries such as China, Germany, Turkey, Japan, Indonesia and Malaysia.[295]

Of the Russia-based companies supplying both gunpowder plants, the largest importer is Sibur Holding, an oil and petroleum processor closely associated with Gazprom.[296] In addition to oil and

289 *Russian Unified State Registry of Legal Persons.*
290 *Ibid.*
291 *Russian domain registration service.*
292 *Trade data supplied by third-party commercial provider.*
293 *Ibid.*
294 *Charles E Munroe, 'The Nitrogen Question from the Military Standpoint', United States Naval Institute Proceedings (Vol. 35/3/131, September 1909), <https://www.usni.org/magazines/proceedings/1909/september/nitrogen-question-military-standpoint>, accessed 9 August 2024.*
295 *Trade data supplied by third-party commercial providers.*
296 *Sibur, 'О компании. История' ['About Us. History'], <https://www.sibur.ru/ru/about/history/>, accessed 16 September 2024.*

petroleum products, the company is involved in the supply of rubber and polymer products[297] and owns a large processing plant in Perm that produces polystyrene, propylene and butyl alcohol.[298] In 2022 and 2023, the company imported over $439.7 million in chemicals and precursors.[299] While many of these products were shipped by Chinese companies – including subsidiaries of Chinese state-owned enterprise SinoPec – the company also received shipments of chrome-aluminium composite catalysts and aromatic polycarboxylic acids from South Korean companies Annamoon Co Ltd and Lotte Chemical.[300]

VitaReactiv, a chemicals supplier to both Perm and Kazan,[301] imported over $5.5 million of chemicals from Chinese, Turkish and Indonesian suppliers in 2022 and 2023.[302] Contract data shows that the company has a history of supplying industrial chemicals to other Russian defence companies, including Admiralty Shipyards, Salut LLC and the Smolensk Aviation Plant.[303]

Virage International, a Kazan-based producer of chemical products,[304] has imported a curious variety of items over the years, from esters of methacrylic acids to kitchenware, primarily from Chinese companies.[305] One Chinese company that has supplied it with tert-butyl peroxybenzoate, Shanghai East Best International Business Development,[306] is ultimately a subsidiary of a Chinese state-owned enterprise.[307]

Machinery

Both the Perm and Kazan plants have also transacted with companies that have procured machine tools and industrial tooling from abroad. While it is possible that the importers are procuring such machinery to sell to Kazan or Perm, it is likely that some procure machinery for their own use while providing other related goods or services to Perm and Kazan.

297 *Ibid.*

298 *Sibur 'Сибур-Химпром', Продукция' ['Sibur-Khimprom. Products'], <https://www.sibur.ru/SiburKhimprom/products/>, accessed 16 September 2024.*

299 *Trade data supplied by third-party commercial provider.*

300 *Ibid.*

301 *Financial data seen by authors; Clearspending, 'ОБЩЕСТВО С ОГРАНИЧЕННОЙ ОТВЕТСТВЕННОСТЬЮ "ВИТАРЕАКТИВ" [VitaReactiv LLC]', <https://clearspending.ru/supplier/inn=5249093556&kpp=524901001>, accessed 16 September 2024.*

302 *Trade data supplied by third-party commercial provider.*

303 *Clearspending, 'ОБЩЕСТВО С ОГРАНИЧЕННОЙ ОТВЕТСТВЕННОСТЬЮ "ВИТАРЕАКТИВ" [VitaReactiv LLC]', <https://clearspending.ru/supplier/inn=5249093556&kpp=524901001>, accessed 16 September 2024.*

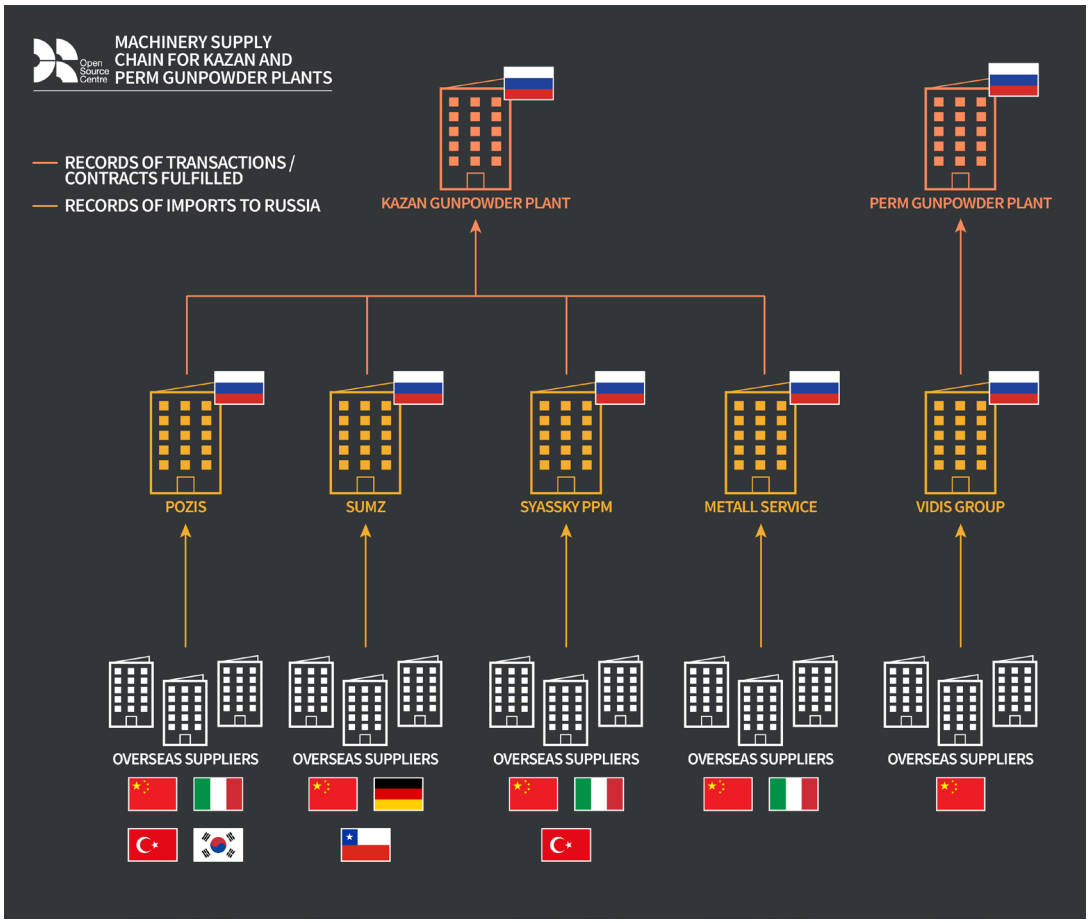
304 *Virazh, Каталог продукции ['Product Catalogue'], <https://web.archive.org/web/20220129044739/https://viragkzn.ru/catalog>, accessed 16 September 2024.*

305 *Trade data supplied by third-party commercial provider.*

306 *Third-party Chinese corporate database.*

307 *Ibid.*

Figure 20: Machinery Supply Chain for Kazan and Perm Gunpowder Plants



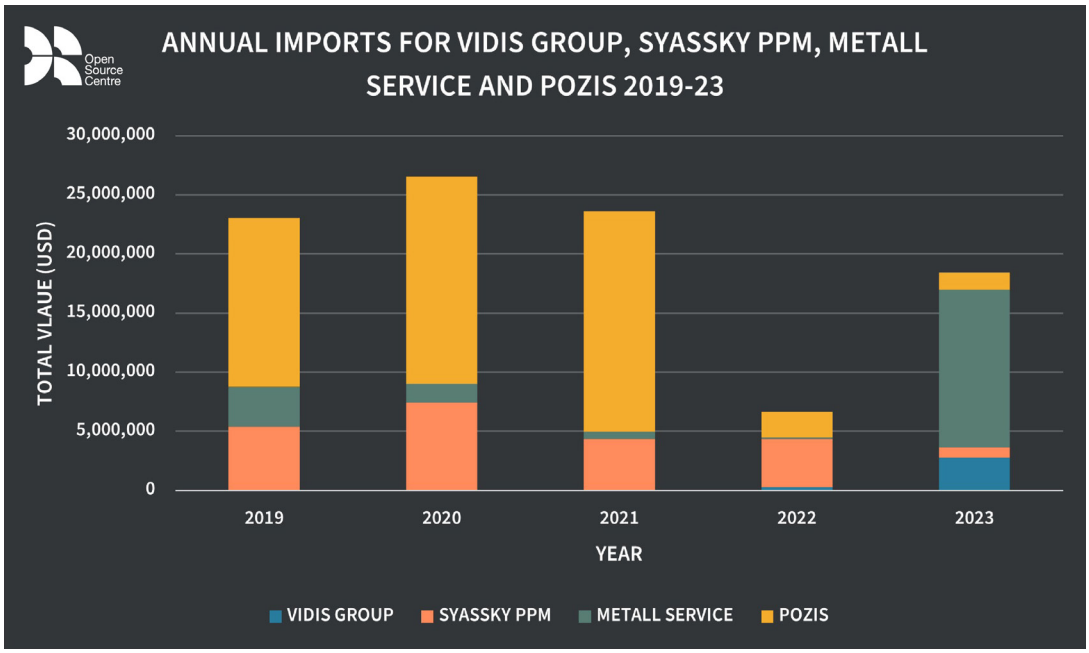
Source: Financial data seen by authors, trade data supplied by third-party commercial provider, Clearspending, Open Source Centre.

One of the most notable companies that has received large payments from Kazan is the Tambov-based Metall Service LLC, a wholesale trader of pipes, wires and rolled metals.[308] The company's website confirms that its metal production capacity has significantly expanded since 2019 with the purchase of numerous CNC machines and construction of additional manufacturing halls.[309] The website shows images of Italian, German and South Korean machine tools installed in its manufacturing halls.[310]

Import data shows that Metall Service has procured large volumes of machine tools and related components, with the total value of imports in 2023 exceeding $13.2 million, compared to $123,000 the previous year.[311] Since February 2022, the company has imported almost all of these items from Chinese suppliers, with the exception of several shipments of cutting tools acquired from Italy-based Rolm Srl in July and August 2022.[312]

308 *Metall Service, 'О компании' ['About the Company'], <https://mc24.ru/o-kompanii/>, accessed 16 September 2024.*
309 *Ibid.*
310 *Metall Service, 'Фото' ['Photos'], <https://mc24.ru/o-kompanii/foto-metall-servis/>, accessed 16 September 2024.*
311 *Trade data supplied by third-party commercial provider.*
312 *Ibid.*

Figure 21: Annual Imports for Vidis Group, Syaskky Pulp & Paper Mill, Metall Service and Pozis, 2019-23



Source: Trade data supplied by third-party commercial provider, Open Source Centre.

POZiS, which is part of Rostec, is involved in production of small-calibre munitions for artillery systems and over 20 different types of pyrotechnic ignition devices.[313] The company has imported a variety of goods, including steel alloy products and injection-moulding inserts, from Chinese, Italian, South Korean and Turkish companies.[314]

Another example, Vidis Group, is a US-sanctioned[315] metal-cutting-tool supplier[316] and was once the Russian distributor of German Widia-branded drilling and milling equipment.[317] In 2022 and 2023, the company imported a total of $3 million in metal-cutting tools and related items from Chinese companies.[318] As well as transacting with the Perm Gunpowder Plant, the company has fulfilled contracts with other defence companies, including Ulan Ude Aviation Plant, UAZ and Titan-Barrikady.[319] The latter is involved in the assembly of artillery pieces and mobile launchers for ballistic missiles.[320]

Meanwhile, Syassky Pulp & Paper Mill (Syassky PPM), a producer of wood pulp, has received payments from the Kazan Gunpowder Plant.[321] While the mill itself has not been sanctioned, it has supplied a since-sanctioned military explosives plant (Federal State Enterprise Kamensk Plant) with cellulose.[322] Customs records show that the company imported a range of industrial

313 *RIA Novosti, 'Завод в Татарстане запустил новое производство боеприпасов' ['Factory in Tatarstan Launches New Munition Production Facility'], <https://ria.ru/20180921/1529080683.html>, accessed 9 August 2024.*

314 *Trade data supplied by third-party commercial provider.*

315 *U.S. Department of the Treasury, 'Russia-related Designations, Updates and Removal; Counter Terrorism Designation Update; Issuance of Russia-related General Licenses', press release, 2 November 2023, <https://ofac.treasury.gov/recent-actions/20231102>, accessed 16 September 2024.*

316 *WIDIS Group, 'История Widia' ['History of Widia'], <https://web.archive.org/web/20200713051304/http://www.widis-group.ru/o-kompanii/istoriya-widia.html>, 13 July 2020, accessed 16 September 2024.*

317 *Widis Group, 'История Widia' ['History of Widia'], <https://web.archive.org/web/20211202223412/http://www.widis-group.ru/o-kompanii/istoriya-widia.html>, accessed 16 September.*

318 *Trade data supplied by third-party commercial provider.*

319 *Clearspending, 'Общество с ограниченной ответственностью "Видис Групп"' ['Vidis Group LLC'], <https://clearspending.ru/supplier/inn=7717683498&kpp=771701001>, accessed 16 September 2024.*

320 *TADVISER, 'Titan-Barrikady', <https://tadviser.com/index.php/Company:Titan-Barrikady>, accessed 16 September 2024.*

321 *Syas Paper Mill, 'Компания' ['Company'], <https://syas.ru/about-us/>. accessed 16 September 2024.*

322 *Clearspending, 'Открытое акционерное общество "Сясьский целлюлозно-бумажный комбинат"' ['Syas Pulp and Paper Mill OJSC'], <https://clearspending.ru/supplier/inn=4718011856&kpp=471801001>, accessed 16 September 2024.*

machinery totalling almost $5 million over 2022 and 2023 from Chinese, Turkish, German and Italian companies.[323] It is likely that Syassky PPM is procuring this machinery for its own use to produce cellulose which can then be sold to the Kazan Plant to mitigate Russia's reliance on foreign importers of cotton cellulose. If this is the case, Syassky PPM's imports may represent an opportunity for external disruption that could slow the expansion and recapitalisation of Russia's defence industry.

The supply chains of Perm and Kazan overall indicate the disruption challenges. A lot of the materials needed by both plants are produced inside Russia and transported via rail. Sanctions against the companies involved may damage their finances on the international market, but they are likely obliged to serve the Russian defence industry, and will receive government backing to continue. It stands to reason that seeking disruption of elements that could be physically stopped because they originate or transit through jurisdictions where Western powers can exercise legal or political effects is more likely to impact the supply chains of Perm and Kazan. For example, by denying access to raw materials like cotton pulp, products like polyisobutylene and key components like German and Italian industrial machinery, Western governments could be reasonably certain that both plants would have to affect a major adaptation and face disruption to their production output.

323 *Trade data supplied by third-party commercial provider.*

Delivery

After it has been filled, the ammunition is transported via rail from the factories to Russian military depots. From there, it eventually makes its way to one of three primary depots near the Ukrainian border:

- Kotluban depot, close to Volgograd. It has an area of 2.17 km2 and appears to include 67 sheds and 28 open air sites for storage of ammunition.[324]

- 68th Arsenal of the Main Missile and Artillery Directorate of the General Staff of the Russian Army, near Mozdok in North Ossetia. It has an area of 2.12 km² and appears to house 61 sheds and 35 bunker facilities dug into the ground.[325]

- The 719th Artillery Ammunition Storage Base, near Krasnodar region. It has an area of around 1 km2 and includes 13 sheds, four bunker facilities dug into the ground, and 12 open-air storage sites.[326]

It is understood that ammunition is driven from these sites to temporary storage locations inside occupied Ukraine. The routes avoid the Kerch Bridge, with less than a quarter of Russia's cargo traversing the bridge, and the majority instead driven over long distances through occupied Ukraine – even that which is destined for Kherson.[327] Once in Ukraine, the ammunition is stored in warehouse facilities that are rarely protected, but are located some distance from the frontline. It may be driven forward to the front by logistics units such as the 293rd Separate Automobile Battalion – a road-based unit located in Rostov-on-Don – or, as some accounts indicate, collected by drivers dispatched by Russian units.

Russia has recently completed a new rail route between Rostov-on-Don, Mariupol, Donetsk City and Dzhankoi in Crimea.[328] This route has a single track and has been built in a year, indicating that its primary initial purpose will be support for logistics inside occupied Ukraine. It has been reported that four engines with associated freight cars in the Russian Railways colours were observed in the Mariupol region on 5 August 2024, indicating that the rail route had been launched at that time.[329] It is possible that this rail route will become a source of supply to Russian units fighting in Ukraine, reducing reliance upon road transport.

The Russian Aerospace Forces are normally reliant on rail infrastructure and railheads for their logistic requirements. However, it appears that a lack of secure access to these facilities inside Ukraine has led to greater reliance on road transport of ammunition and supplies.[330] At certain points in the conflict, Russia has employed the rail infrastructure in occupied Ukraine to deliver directly to the front, but Ukraine has effectively severed these routes on several occasions.[331] The largest national railway carrier, owner and builder of public railway infrastructure is Russian Railways. The company is 100% owned by the government, and it is responsible for 16 railways covering the entire country. Although other companies participate in the freight sector, they operate under

324 Coordinates: 48.996392, 44.215963.

325 Coordinates: 43.739815, 44.522228.

326 Coordinates: 45.886427, 40.041599.

327 Cristian Segura, 'Russia Finalizes Train Line to Connect to the Occupied Ukrainian Territories in the Sea of Azov and Crimea', El Pais, 21 June 2024, <https://english.elpais.com/international/2024-06-21/russia-finalizes-train-line-to-connect-to-the-occupied-ukrainian-territories-in-the-sea-of-azov-and-crimea.html#>, accessed 16 September 2024.

328 Ibid.

329 Andriushchenko Time [Андрющенко Time], 'Військова складова Маріуполь [Military rundown Mariupol]' 7 August 2024, <https://t.me/andriyshTime/25581>, Telegram post, accessed 16 September 2024; Andriushchenko Time [Андрющенко Time], 'Та до недобрих новин. Росіяни запустили добудовану залізницю через з Ростову до Маріуполя через Гранітне/Маловодне [And now to the bad news. Russian launched a newly constructred railway link from Rostov to Mariupol through Granitne/Malovodne]' 4 August 2024, <https://t.me/andriyshTime/25466>, Telegram post, accessed 16 September 2024.

330 Alex Vershinin, 'Feeding The Bear: A Closer Look At Russian Army Logistics And The Fait Accompli', War on the Rocks, 23 November 2021, <https://warontherocks.com/2021/11/feeding-the-bear-a-closer-look-at-russian-army-logistics/>, accessed 16 September 2024.

331 Maria Engqvist, 'A Railhead Too Far: The Strategic Role of Railroads during Russia's Invasion of Ukraine', FOI Russia and Eurasia Studies Programme, November 2022, pp. 3-5.

Russian Railways' network, leasing access from the state-backed monopoly. For example, the Federal Freight Company JSC, delivers raw materials to the fuel and energy sector and to metallurgical industries. It is owned by Russian Railways and participates in the Russian public procurement system.[332] Among its most prominent clients is UralVagonZavod, the largest supplier of military equipment in Russia and the sole manufacturer of tanks in Russia. There are also rail companies that specifically handle military cargo, like T-Trans, which delivered military cargo to the frontline in 2022 by order of the Russian MoD.[333]

There are some signs that the rail network is struggling to cope with the pressures of sanctions and to meet the demands of the war. The Ukrainian advance into Kursk in August 2024 prompted the large-scale movement of Russian troops to the area, primarily using rail. This caused overcrowding at stations in the region and led Russian Railways to cancel freight trains coming from Belarus.[334] The Belarusian Railway Workers Association reported that a significant portion of the Moscow region locomotive fleet was used to complete the transfer. This led to a shortage of locomotives to return train carriages, which were abandoned in Smolensk.[335] Russian Railways reportedly faces a labour shortage – much like Russia's defence industry – as well as challenges in finding spares to maintain its rail fleet. According to Russian Railways, the high volume of locomotive repairs needed and the longer timeframes needed to repair them because of a lack of parts mean that Russia's ability to export cargo is decreasing. The number of trains put on hold due to a lack of maintenance more than doubled in 2023.[336] As of 2024, about 40,000 trains were out of service because the locomotives re undergoing repairs.[337] Russian Railways's own figures for 2024 indicate a year-on-year decline in freight loading of 3.5%, as well as a 6.8% reduction in freight turnover.[338] It is reasonable to conclude that the Russian railways are both a vital element in the artillery supply chain and a potential vulnerability. However, further study – of a similar nature to this paper – would be required to assess the exposure of the Russian railways to external disruption and anticipate actions that Russia might take to secure alternatives to Western components.

332 *Companium.ru, 'АО «ФЕДЕРАЛЬНАЯ ГРУЗОВАЯ КОМПАНИЯ - Екатеринбург» - ИНН 6659209750' ['JSC FEDERAL FREIGHT COMPANY - Ekaterinburg - TIN 6659209750'], <https://companium.ru/id/1106659010600-fgk>, accessed 16 September 2024.*

333 *T-Trans, 'Доставка груза для Минобороны РФ' ['Cargo Delivery for the Ministry of Defense of the Russian Federation - T-Trans'],' 18 May 2022, <https://ttrans.ru/proekty/dostavka-gruza-dlya-minoborony-rf>, accessed 16 September 2024.*

334 *Belarusian Railway Community, 'Оперативно: РЖД ограничивает направление поездов БЖД в Курскую область' ['Promptly: Russian Railways Limits the Direction of BZD Trains to the Kursk Region'], Community of Railway Workers of Belarus, 14 August 2024, <https://belzhd.info/news/operativno-rzhd-ogranichivaet-napravlenie-poezdov-bzhd-v-kurskuyu-oblast/>, accessed 16 September 2024.*

335 *Dennis van der Laan, 'Russian Rail Faces Collapse After Ukraine's Kursk Invasion', Rail Freight, 15 August 2024, https://www.railfreight.com/railfreight/2024/08/15/russian-rail-faces-collapse-after-ukraines-kursk-invasion>, accessed 16 September 2024.*

336 *Wagon-Cargo Program Complex, 'Проблема простоя вагонов требует комплексного решения' ['The Issue of Idle Railcars Requires a Comprehensive Solution | Wagon Engineering Center'], 22 March 2024, <https://wagon-cargo.ru/news/problema-prostoya-vagonov-trebuet-kompleksnogo-resheniya/>, accessed 16 September 2024.*

337 *Ekaterina Kruglova, 'Ежедневно выбывает 20 поездов. У РЖД проблемы с ремонтом локомотивов' ['Every Day 20 Trains are Out of Service. Russian Railways has Problems with Locomotive Repairs'], 17 March 2024, <https://www.dk.ru/news/237200044>, accessed 16 September 2024.*

338 *Interfax, 'Loading on Russian Railways network declines 3.5%, freight turnover 6.8% in March – RZD', 1 April 2024, <https://interfax.com/newsroom/top-stories/100941/>, accessed 16 September 2024.*

Conclusion

This paper set out to investigate Russia's artillery supply chain and identify vulnerabilities that could inform thinking around disrupting the defence industrial base. It has explored the critical role played by artillery in Russia's invasion of Ukraine, and how Russia's supply chains are set up to support the war effort. The available information indicates that Russia's defence industry is expanding, through new facilities in Kazan and Perm, supplies of CNCs from China, and mass recruitment programmes. This suggests that, if it is not interrupted, Russia will be in a better position to conduct a prolonged war in a material sense by 2030 at the latest.

From analysing Russia's artillery supply chain from end to end, it is clear that some elements are more robust than others. From the mining pits that feed the furnaces at Krasny Oktyabr to the cotton fields that are harvested throughout summer to make nitrocellulose, to the storage sheds at the Kotluban ammunition depot, Russia's artillery supply chain is a complex ecosystem of raw material suppliers, foreign machinery, trains and overworked specialists. The foundations of the artillery supply chain – namely the factories themselves – and the depots used to store ammunition close to Ukraine are hard to disrupt. These facilities sit inside Russia, in some cases thousands of kilometres from Europe, in others built to withstand a NATO aerospace assault.

Russia is self-sufficient in many of its needs, especially in raw materials like iron ore, and may have enough machine tools and stored howitzers from the Soviet era to support its war in Ukraine. However, the longer the war continues, the more Russia's dependencies on foreign suppliers will become a weakness. The examples identified here – such as chromite, cotton cellulose and CNC machines – are examples of raw materials and components that must be sourced from abroad to maintain the artillery supply chain. There have been efforts at disruption of supplies of some of these, but the expansion of Russia's artillery manufacturing capability, and its ability to continue using artillery ammunition at a high rate of expenditure, indicate that these efforts have failed to successfully limit or affect the artillery supply chain.

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However, Russia's artillery supply chain is not infallible. It can be disrupted with the help of Ukraine's international partners, through careful targeting of vulnerabilities. The evidence gathered for this paper indicates that Ukraine's Western partners would be better able to disrupt Russia's artillery supply chain by focusing efforts in a coordinated manner on raw materials and components that are procured outside Russia. This would involve sanctions and diplomatic pressure: levers that have so far been pulled only in an ad hoc and opportunistic manner. A concerted approach, with additional resources dedicated to enforcement and disruption, will have a greater chance of success. Disrupting the artillery supply chain should be a priority, and if the vulnerabilities identified in this report can be successfully disrupted for prolonged periods, Russia will struggle to meet its needs for artillery ammunition and barrels – this will be vital if Ukraine is to survive.

For example, strict sanctions against the supply of chrome ore to Russia would impact the barrel production process and likely other military outputs, as well as the oil and gas industry, which is a significant source of funding for the Russian state. Most resources are imported from countries or companies in jurisdictions that are Western partners or receptive to their concerns. It is more difficult to secretly transfer thousands of tonnes of chromium ore into a country than to smuggle in a few thousand microchips. It therefore appears likely that enforced sanctions in this field would have a better chance of successfully disrupting the chromium supply to Russia than sanctions on microchips have had of disrupting that supply chain. Russia would eventually find an alternate source of chromium, but that would take time and could present further disruption opportunities.

Other tools may include: diplomatic pressure, such as encouraging Taiwan to examine companies exporting CNC machines to Russia and China; or preclusive buying of raw materials on the open market to prevent the hostile nation from accessing them, or to drive up the price and limit access.

There is a growing alliance of authoritarian powers aligned against the West and the rules-based international order. Russia, China and Iran frequently work together to evade sanctions, degrade the authority of Western governments and counter the progress made by democracies since the end of the Second World War. The current focus is Russia, but the need to disrupt supply chains will emerge again as these autocratic regimes continue to attack the West. Western governments must develop the ability to understand and disrupt an opponent's most critical supply chains sooner rather than later. As Russia expands its defence industry, there is an opportunity to limit its ability to support the war. But there is also a necessity to do so, to help Ukraine win the war. Left on its current trajectory, Russian fire superiority will increase year-on-year and become less vulnerable to external disruption through pressure on the supply chain. It is therefore paramount that Ukraine's partners work together to find routes that will lead to the disruption of the artillery supply chain. This report provides a starting point; there are dozens of vulnerabilities that could be identified. And if each one could be acted on in concert, it would prove very challenging for Russia to adjust before the trajectory of the war had changed.

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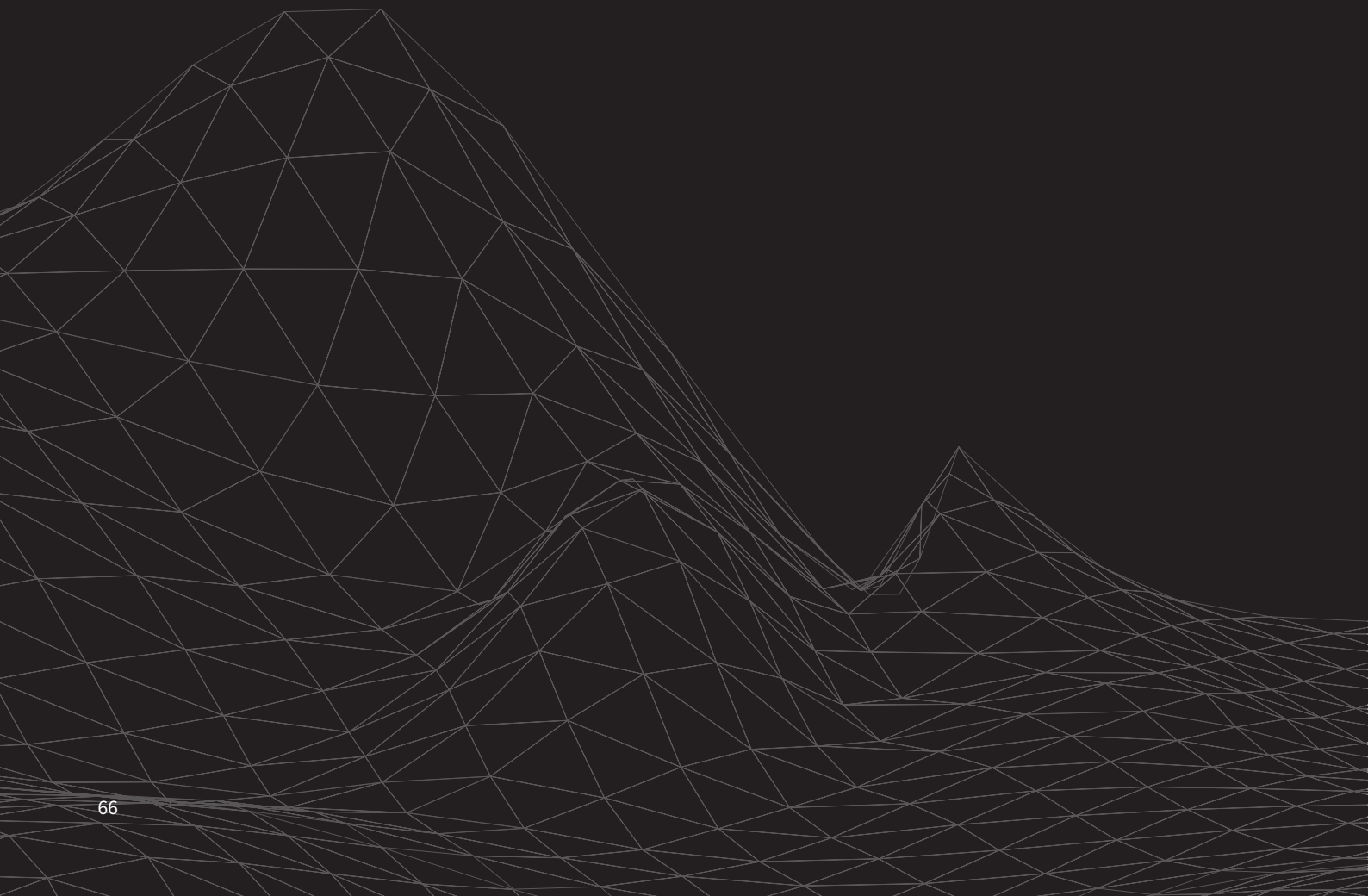

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