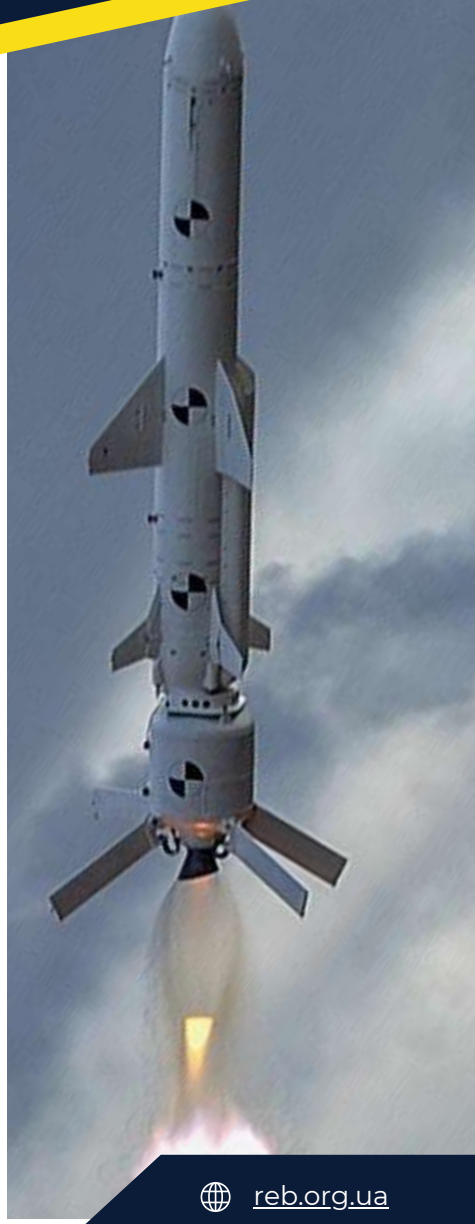
REPORT

on the Role of Western CNC Machines in the Russian Defense Industry and Consequences for Russia of their Loss

Economic Security Council of Ukraine
September, 2023



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Introduction

This policy brief focuses on the role of CNC machines in Russia's military-industrial complex and the potential consequences of their loss for Russian customers. The brief includes an analysis of the Russian machine tool market, the state of the Russian domestic machine tool industry, the use of CNC machines in the ongoing rearmament of the Russian military and other critical factors. This brief also examines the practical steps needed to deprive Russia from accessing such tools and outlines both the benefits and risks of this approach.

This brief is structured as follows:

Section 1 is devoted to the general characteristics of CNC machines, their applications (including by the military-industrial complex) and the specifics of export control regimes governing this equipment.

Section 2 assesses the importance of CNC machines for the Russian military-industrial complex as their main consumer. The use of CNC machines is considered in the context of Russian military reforms over the past two decades, as well as the large-scale rearmament of the Russian military underway amid the war in Ukraine.

Section 3 provides a general description of the machine tool market in Russia, its main players and import-export dynamics. The market analysis serves as a starting point to demonstrate the critical importance of imported machine tools for the Russian military-industrial complex and provides the groundwork for the discussion of the Russian machine tool industry.

Section 4 examines the state of the Russian machine tool industry, particularly CNC machine tools, the development of this industry, and the main problems that have led to a situation whereimported machine tools are critical for the functioning of Russian industry.

Section 5 hypothesizes, based on the preliminary findings, about the losses incurred by the Russian Federation in the event of a complete withdrawal of Western manufacturers from the Russian market. It also critically assesses the results of the Russian industrial "turn to the east",the place of Chinese CNC machines and the potential replacement of Western machines by Asianmade ones

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Section 1. General characteristics of CNC machines

1.1. General characteristics and areas of application

CNC (computer numerical control) machines are automated robotic machines that can perform operations according to a given program without direct human intervention. Such machines are an essential part of modern automation, required for ensuring the quality, speed and profit margins of production.

A variety of CNC machines are used in the medical, aviation, transportation, electronics, oil and gas industries, and almost all branches of heavy industry, including metalworking.

The **key industries** in which CNC machines are used include:

- **Metalworking**: supplies many secondary industries. To cut large metal sheets, the industry relies on CNC processes such as electrical discharge cutting, laser cutting, waterjet cutting and plasma cutting. Other applications include 2D and 3D milling of parts, threading, holemaking, manufacturing of three-dimensional parts with complex shapes, blow mold for casting, turning, cutting metal, and engraving serial numbers and barcodes.
- **Automotive**: manufacturing of engine parts, gearboxes, drive axles and other parts, surface treatment, cylinder honing, threading, etc.
- **Aerospace:** most equipment in this industry is critically dependent on the quality and precision of the machining. Aerospace parts manufactured using CNC technology include aerodynamic profiles, landing gear, manifolds, bushings, RF suppression materials, electrical connectors, engine and wing parts, gearbox and connector components, and titanium cladding.
- **Shipbuilding**: CNC mills, lathes, EDM and other processes involved in the production of almost all components for shipbuilding – from hull to interior – including deck and hull structures, trim, etc.
- **Electronics**: fine machining and production of microscopic parts. CNC is applied not only to the outer casing but also to internal components: electronic components, printed circuit boards, cases, front panels, cooling radiators, milling of technological holes, manufacturing of semiconductors and heat sinks.
- **Other sectors.**

1.2. Precision levels of CNC machines and their place in export control

Certain types of CNC machines, depending on the level of precision, are classified as dual-use goods.

According to Russian standards, the geometric accuracy of a CNC machine can be determined by its class: N (normal), P (increased), H (high), A (extra high) and C (ultra-high).

To ensure that the quality of processing does not fall below the permissible level during operation, the equipment is manufactured with a wear reserve of around 40%.

According to Western standards, CNC machines are divided into three types according to their level of accuracy: advanced type, universal type and economic type, however, there are many such classifications. At the same time, the level of precision and technological complexity directly affects the qualification of certain machines as dual-use goods.

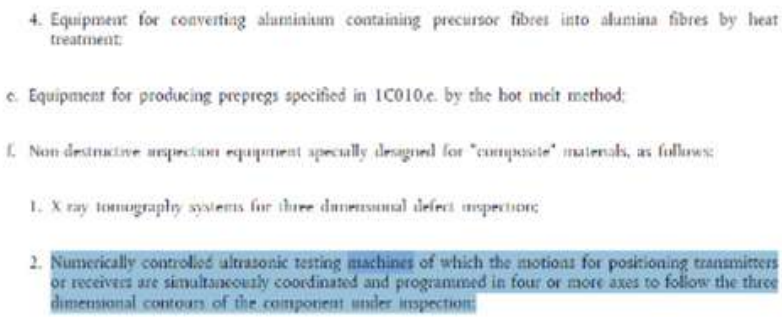
In international relations, the transfer of such technological products falls under the **Wassenaar Arrangement of 1996** on the export control of conventional arms and high technology (dual use) goods, as well as the export control rules of individual countries.

The issue of strict export controls on CNC machines first emerged in 1987, during the so-called Toshiba-Kongsberg scandal. Japanese company Toshiba, in cooperation with Norwegian company Kongsberg and several front companies, sold machine tools to the then USSR in violation of an agreement between the members of the Coordinating Committee on Multilateral Export Controls (CoCom), a Cold War-era organization that prohibited the export of dual-use and other sensitive technologies to Eastern Bloc countries. The equipment was used by the Soviet Union in the nuclear and heavy industries, as well as for the manufacture of very high-precision screws for submarines. Today, Russia is just as actively engaged in the gray import and smuggling of high-precision machine tools that currently fall under strict sanctions.

This scandal served as a precedent and foundation for the modern export control regime at both the international and national levels. For example, following this incident, Japan's export control legislation was brought into strict adherence with international norms. This included imposing special obligations on the transparency of such transactions in terms of information about the end user as well as strict controls on the technological features of the machines themselves. The latter includes requirements for trackers and tools that allow the manufacturer to control the operation of the machine in case it is moved without permission. German law also requires the mandatory practice of obtaining export licenses and documenting each delivery of dual-use goods. For example, we have already learned of court verdicts against several German citizens who were involved in the supply of high-tech machine tools to Russia before the full-scale aggression in 2022.

Despite many precedents for the use of these machines for military purposes and numerous violations of the export control regime, it remains incomplete and has many gaps that Russia actively exploits. First, the regime is not universal. Each country independently establishes rules according to which certain technologies qualify as dual-use goods within the general framework of the Wassenaar Arrangement. Second, the rules are unclear, contradictory and contain manyexceptions. These clauses make it possible to avoid punishment for supplying dual-use goods to states that violate international law, such as Iran or Russia. Third, the current export control regimes do not account for the huge amount of dual-use goods that Russia uses for military purposes. In CNC vernacular, three-axis machines are an example of this.

For example, EU legislation includes Regulation 2009/428, a regime for controlling the export, transfer, brokering and transit of dual-use goods. In 2020, this regulation was amended by the European Commission through Commission Delegated Regulation (EU) 2020/1749 dated 7 October 2020 and amending Council Regulation (EC) No 428/2009, establishing a regime for the control of exports, transfer, brokering and transit of dual-use goods.



4. Equipment for converting aluminium containing precursor fibres into alumina fibres by heat treatment;

e. Equipment for producing prepregs specified in 1C010.e. by the hot melt method;

f. Non-destructive inspection equipment specially designed for "composite" materials, as follows:

1. X-ray tomography systems for three dimensional defect inspection;

2. Numerically controlled ultrasonic testing machines of which the motions for positioning transmitters or receivers are simultaneously coordinated and programmed in four or more axes to follow the three dimensional contours of the component under inspection;

Extract from the EU Export Control Regulation

According to this regulation, machine tools with four or more axes are subject to EU export controls. However, the core of the machine tool fleet and the market, in general, is made up of three-axis machines, which can have a high level of precision, are widely used in the military-industrial complex and are relatively less expensive than state-of-the-art four- and five-axis CNCs. In addition, three-axis machines perform the vast majority of routine operations that are inevitable in the production of even the most advanced metallurgical equipment or medical devices. For the military-industrial complex, CNC machines are indispensable.

1.3. Application of CNC machines in military-industrial complex

The military-industrial complex is one of the primary consumers of CNC machines. The applications of CNC systems in this area are vast: from complex, customized weapons hulls tothe internal components of missiles. Some of the parts that are manufactured using the CNC production process are main rotor hubs, couplings, seat frames for ground and air transportation, flanges, transmission parts, missile components, helicopter components, retaining rings and ammunition lifting components.

Among **the sectors of the military-industrial complex** where CNC machines are used, the most notable include:

- **Missile production.** High precision, versatility and compatibility with a wide range of materials make CNC machines ideal for manufacturing missiles and weapons. Raytheon, one of the world's largest manufacturers of guided missiles, relies on multi-axis CNC machines to produce its 20-foot cruise missiles.
- **Aircraft parts.** Modern military aircraft need precision parts to achieve VLO (very low observability), which means they are difficult to detect with radar or other sensor technologies. Airplanes could not achieve VLO in the past because their parts were usually smoothed with epoxy resin. The epoxy would harden and separate in the field, forming sharp edges that made them easy targets. Five-axis CNC milling and drilling machines allow composite airplane skins to be manufactured to such precise tolerances that adjacent parts will match accurately without the need for epoxy.
- **Fairings and radar technology.** Radar antenna streamlined fairings are important components of military installations. They facilitate satellite communications while protecting the antenna assembly from environmental threats. They come in a variety of complex shapes that require precise measurements and fine surface finishes. Since CNC machines can achieve minimum values as low as 4 microns, fairings and other radar dish components can be manufactured to precise specifications. Moreover, the compatibility of CNC machines with fiberglass and polytetrafluoroethylene (PTFE) – the two main materials used in fairing construction – makes them the preferred machining technology in the military industry.
- **Submarines.** Underwater military equipment usually requires lightweight and corrosion-resistant specialty plastics. Although these plastics are more readily available than they were a few decades ago, they are still extremely difficult to process using conventional machining methods. The military-industrial complex relies heavily on CNC machines to manufacture support structures, fasteners and other submarine parts. This machining technology also allows engineers to create customized replacement parts for ships.

The use of CNC machines in the defense industry is not limited to these areas. In every sector where precision machining of parts is essential, CNC machines and control and measuring devices of this type are used. Notably, CNC technologies in the manufacturing industry and the military-industrial complex are actually developing in parallel: the demand for improvements toexisting machines and equipment to create modern weapons stimulates CNC machine toolmakers to constantly update and improve their products, and vice versa. In today's world, no country or company can stay in the market and be competitive in the absence of CNC machines.

Conclusions: *In summary, CNC machines are an integral part of modern automation and production process optimization. They are used in a wide range of industries, including metalworking, automotive, aviation, microelectronics and other areas. Depending on the level of precision, CNC machines can be classified as dual-use goods subject to export controls because of the potential military applications, although the current export control regime has several problems and is far from perfect. At the same time, CNC machines are critically valuable for the military-industrial complex, as the example of the Russian Federation confirms.*

Section 2. Use of CNC machines in Russian military-industrial complex

2.1. Reform and rearmament of Russian Army indicates importance of CNC machines

The full-scale Russian invasion of Ukraine in 2022 cannot be imagined outside the context of the military reforms that began when President Vladimir Putin came to power more than 20 years earlier. In turn, in addition to administrative and legal issues, a key aspect of these reforms was the rearmament of the Russian military, which meant abandoning outdated Soviet models and producing the new weapons necessary to fulfill foreign policy tasks. CNC machines, as demonstrated above, play an exceptional role in such processes. Still, for a long period of time, Russian precision engineering was on the margins of state policy and dependence on imported technologies was only growing (see sections 3 and 4 for more details).

The Russian machine tool building industry, which was virtually destroyed in the 1990s, received new importance following huge demand from the military-industrial complex in the late 2000s. As the Russian military began a systemic rearmament, there was also a renewed focus on CNC technology. According to Russian CNC manufacturers, companies in the Russian military-industrial complex account for at least 80% of their orders. Therefore, the military industry appears to be the main consumer of CNC machines in the country. The increased scale of production required the optimization of manufacturing facilities because the state defense order book was far ahead of the technological capabilities of the outdated Russian machine tool fleet. In the late 2000s, the Russian machine tool industry was in its infancy and its products were inferior to Western machine tools in many respects, while only covering only a small part of domestic demand (see sections 3 and 4 for more details). As a result, Russian military manufacturers, as well as other manufacturing companies, had no choice but to import Western CNC machines.

Notably, the Russian military-industrial complex has been forced by Russian regulations to work with Russian producers. In 2011, Resolution No. 56 was adopted, which prohibited defense enterprises from purchasing imported machine tools if their analogues were produced in Russia. This resolution has been renewed with minor changes every year since. Foreign manufacturers were forced to establish joint ventures and build machine tool plants in Russia in order not to lose customers. In practice, the needs of the military-industrial complex became the main priorityfor the state authorities. Therefore, with demonstrative and cosmetic import substitution, Western CNC machines, which at different times occupied 70 to 90% of the Russian market, became the basis for the military transformation of the past two decades.

2.2. First wave of rearmament under Putin's reforms of Russia's armed forces

The current appearance of the Russian armed forces emerged under the last two defense ministers, Anatoly Serdyukov and Sergei Shoigu. While Serdyukov tried to simplify the organizational structure and reduce the number of personnel in favor of rapid troop mobility, Shoigu focused on intensifying combat training, modernizing weapons and reversing the unsuccessful Serdyukov reforms. Serdyukov failed to organize the **rearmament of the Army**, although, from the end of 2008, the state began to spend far greater amounts of money on the Russian Army and its reform. In this process, the Minister of Defense was supposed to be the link between the real needs of the Army, the demands of the troops, budget constraints and the capabilities of the military-industrial complex. However, Serdyukov proved to be insufficiently capable in these matters.4 Instead, the defense ministry found itself in a situation of constant disruption of defense orders, infighting between Army customers and representatives of the defense industry, and unclear purchases of foreign military equipment. Due to the accumulation of failures, Serdyukov resigned in 2012.

On November 6, 2012, Shoigu became the Minister of Defense. It was during his tenure that the Russian Army became more mobile, a system of operational and tactical commands was created, and the number of troops was expanded through contract recruitment. However, in the context of CNC machines, the main achievement was the military-technical re-equipment of the Russian military. During this period, new weaponry was developed and/or adopted, such as the Armatauniversal combat platform, the fifth-generation **Su-57** fighter jet, the Kalibr cruise missile, the Sarmat intercontinental ballistic missile, the **Kinzhal** hypervelocity air-to-ship missile, and the Avangard and Zircon hypersonic systems. The share of these new models of military equipment has risen dramatically: from **15-52%** in 2012 to almost **70-90%** in 2018. The military rearmament was made possible, among other things, by the expansion of the Russian machine-tool fleet, of which imported machines have continued to account for more than 70%.

Non-nuclear deterrence is carried out by long-range precision weapons, for which the armed forces have established a serial supply of **Iskander-M** tactical missile systems, as well as submarines and surface ships with **Kalibr** missile systems. Since 2012, the number of land-, sea-and air-based carriers has **increased tenfold**, allowing for the creation of full-fledged groups of precision weapons carriers capable of firing missiles at targets at ranges of up to 4,000kilometers. Consequently, Shoigu was able to establish a process of procurement from the military-industrial complex for state needs. Proof of this was the liquidation of the Federal Service for Defense Orders, which was partly responsible for supporting the implementation of defense orders but had turned out to be highly bureaucratic. At the same time, the speed and efficiency of the rearmament process is explained not only by the priority placed on the military-industrial complex in the overall Russian industry, but also by the widespread integration of Western CNC machines into production processes.

2.3. Role of CNC in rearmament of Russian Army from 2022

Currently, the Russian leadership is launching the next phase of rearmament against the backdrop of the full-scale war in Ukraine. Thus, at the end of 2022, Shoigu announced an increase in the number of troops to 1.5 million, including 695,000 contract soldiers. It is also planned to create new military units on the territory of the temporarily occupied Ukrainian regions, as well as to increase the number of air and space forces. These ambitious plans once again require the intensification of production processes and technological innovations to ensure both the quality and quantity of weapons. In this context, CNC machines are once again indispensable, and in 2022 they continued to be actively used.

As a result, in 2022, a large number of new weapons models were delivered to the Russian Army. In the Strategic Nuclear Forces, the military-technical upgrade reached 91.3% and the rearmament of two missile regiments with Yars land-based mobile missile systems (solid fuel intercontinental ballistic missile) was completed.

Yars missile system

Another missile regiment, equipped with the Avangard missile system, was deployed, carrying an intercontinental ballistic missile armed with a hypersonic cruise missile warhead. According to Shoigu, in 2022, the Strategic Nuclear Air Force was replenished with a Tu-160M strategic missile carrier and a Tu-95M bomber. So far, the Teikovsky, Nizhniy Tagil, Novosibirsk, Barnaul, Irkutsk and Yoshkar-Ola missile divisions have been rearmed. In 2023, 22 launchers with Yars, Avangard and Sarmat intercontinental ballistic missiles will be put into operation in the Strategic Missile Forces.

Meanwhile, Uralvagonzavod, the only tank manufacturer in Russia, delivered the latest T-90M Proryv tanks to the Russian Army. The troops also received a batch of T-80BVM tanks.

T-90M tank

Another fourth-generation nuclear-powered submarine of the Borey-A project armed with Bulava ballistic missiles, the Generalissimus Suvorov, was commissioned by the Russian Navy. One of the features of the Borey is its ability to launch a Bulava missile directly from under the Arctic ice.

According to the Rostec state corporation, in 2022, the Motovilikhinskiye Zavody enterprise sent another batch of Tornado-G and Tornado-S MLRS (MLRS that can fire the cluster munitionsused in July 2022 in Kryvyi Rih) to the troops. In 2022, the Omsk Plant of Transport Engineering, part of Rostec's Uralvagonzavod concern, delivered TOS-1A Solntsepek heavy flamethrower systems to the Ministry of Defense.

At the end of November, Aviastar, a branch of the IL company, manufactured and delivered another serial heavy military transport aircraft, the IL-76MD-90A, to the United Aircraft Corporation (UAC). In 2022, the UAC also began supplying modernized Su-30SM2 fighters to the Navy. The aircraft received enhanced combat capabilities and retained the main advantages of the Su-30SM: ultra-maneuverability, long range, airborne radar with phased-array antenna, and a two-person crew that allows for simultaneous air combat and ground target engagement. In 2022, Russian combat aviation was also replenished with Mi-28NM Night Hunter attack helicopters.

Even larger-scale rearmament deliveries are planned for 2023. For example, the Russian military faces the critical issue of increasing the number of UAVs (unmanned aerial vehicles) in its inventory. In 2023, the armed forces will receive new equipment for the nuclear triad, including Sarmat intercontinental ballistic missiles. The frigate Admiral of the Soviet Union Fleet Gorshkov with Zircon sea-based hypersonic missiles is due to enter combat service in the Navy.

T-90M tank

Large-scale deliveries are also planned for long-range aviation of the Russian Aerospace Forces, including Tu-160M bombers. The updated aircraft received new onboard electronic equipment and NK-32-02 engines.

The basic version of the aircraft with four engines and a swept wing can carry up to 45 tons of payload, including X-101 and X-555 missiles. The helicopter division is also expected to expand; the first Ka-52M reconnaissance and attack helicopters entered service with the Russian Army in mid-January 2023. The helicopters are equipped with high-precisionIzdeliye 305 missiles.

The nuclear triad is planned to be reinforced by the Project 955A Borey-A nuclear-powered submarine Emperor Alexander III. The Emperor Alexander III can carry 16 Bulava solid-fuel ballistic missiles. These ICBMs can maneuver on the acceleration stage, reducing the likelihood of interception by missile defense systems. The nuclear-powered submarine also received six 533-millimeter torpedo tubes.

The Russian Army is awaiting launchers carrying Avangard intercontinental ballistic missiles equipped with hypersonic warheads. The speed of the planned Avangard warheads is about 7.5 kilometers per second. This makes them virtually invulnerable to missile defense systems.

The production of these types of weapons depends directly on the provision of manufacturing enterprises with appropriate funding and technological capabilities. A list of the main enterprises involved in the current stage of Russian rearmament has been compiled from open sources and includes:

Avangard missile system

- **The Moscow Institute of Heat Engineering and the Votkinsk Plant, both owned by Roscosmos**, develop and manufacture Yars and Avangard missiles and R-30 Bulavarockets
- **Tupolev and the Kazan Aviation Plant named after S.P. Gorbunov**, which produces the Tu-160
- **Uralvagonzavod is Russia's only tank manufacturer**, with products including T-90, T-80 and TOS-1A Solntsepek
- **Motovilikhinskiye Zavody** is owned by Rostec and produces Tornado-G and Tornado-S MLRS
- **Sevmash** is part of the United Shipbuilding Corporation
- **Aviastar** is a subsidiary of IL, a member of the United Aircraft Corporation, and produces the IL76MD90-A
- **PJSC Yuri A. Gagarin Kyiv Aviation Plant** (Komsomolsk-on-Amur) and **Irkut Corporation**, owned by Sukhoi, are part of the United Aircraft Corporation and produce the Su-30SM2
- **Rostvertol** (Rostov Helicopter Production Complex Public Joint Stock Company Rostvertol) and **JSC Sazykin Arsenyev Aviation Company Progress** are part of the Russian Helicopters holding company, which is part of the state-owned Rostec corporation, and produce the Mi 28 and Ka 52
- **Academician V. P. Makeev State Rocket Center** (part of the Roscosmos state space agency, produces the RS-28 Sarmat)

All these companies are under various sanctions imposed by the international community, most of them since the 2022 invasion. However, prior to that, numerous manufacturers of CNC machines made a large number of deliveries to these plants, which in turn made it possible for the Russian military to rearm and launch a full-scale invasion of Ukraine in 2022. This information has been confirmed both through open public procurement records and circumstantial evidence.

Based on open sources, it has been established that high-precision CNC machines of foreign origin are being used by the Tupolev Corporation, Gagarin KNAZ PJSC, Irkut Corporation, JSC Arsenyev Aviation Company Progress named after N.I. Sazykin and other enterprises. A full list of machines, models and major customers is available using the link below.

At the same time, this list is far from exhaustive, as only those plants that are involved in the current stage of rearmament in one way or another have been identified. We should not ignore the fact that the development of the Russian Army has lasted for decades, and it required weapons of varying levels of technology and complexity on a vast scale. Therefore, it is impossible to cover absolutely all those supplies.

The verification of the purchase or use of CNC machines is difficult given that Russian public procurement records in the defense sector have been closed to the public since 2021. In addition, despite the formal transparency of public procurement that is enshrined as a requirement in Russian law, there is reason to believe that most of the CNC machine tool purchases were made on the gray market, without following proper procedures.

The Russian military-industrial complex is a complex system of intertwined horizontal and vertical links, while no Russian plant has a complete production cycle and is dependent on suppliers of components that it does not usually produce itself. Accordingly, the list compiled above of enterprises participating in the current rearmament phase includes only the tip of a wide network of plants, each of which requires CNC machines. Accordingly, the Russian military-industrial complex appears critically dependent on CNC machines. At the same time, even in a quasi-capitalist economy like Russia's, the basic principle of supply and demand still applies.Therefore, it is appropriate to analyze the Russian machine tool market, including the CNC segment.

***Conclusions**: Over the past two decades, the Russian military has undergone several stages of reform and rearmament, which would not have been possible on such a scale without the use of CNC machines. Russia's military needs and relies on the development of innovative weapons systems and this has only intensified the country's reliance on CNC machines. The current phase of rearmament in the Russian Federation amplifies the demand for these technologies, making it crucial to urgently analyze the Russian machine tool market and assess its capability to satisfy the requirements of the domestic military-industrial complex.*

Section 3. Russian machine tool market import-export balance, key players and challenges

3.1. Russian machine tool market

An analysis of the Russian machine tool and precision engineering market is the starting point for assessing the importance of foreign CNC machine tools for the Russian defense industry. First, this **market is small**. According to the Stankoinstrument Association, the current volume of the Russian machine tool market is about RUB100-110 billion (approximately US$ 1.4 billion). For comparison, the European machine tool market is estimated at US$ 21.4 billion as of 2021. Another indicator of market development is the number of machine tools (expressed in terms of value) per capita. As of 2022, it amounted to US $2,177 million with a population of 143.8 million people. Thus, Russia is currently not among the top 10 machine tool manufacturing countries, ranking only 33rd in the world by this indicator. These figures not only highlight the true state of Russian technological development but also illustrate the dependence of domestic manufacturers on imported products.

The operating environment for the machine tool market is determined by the quasi-market nature of the Russian economy, characterized by active government intervention in economic processes contrary to market mechanisms. This includes restrictions on the purchase of foreign machine tools by military-industrial enterprises or subsidies to unprofitable machine tool companies, as well as support for the monopoly of certain machine tool plants (see Section 5 for more details).

The Russian machine tool market is also characterized by a lack of institutional and legal mechanisms to protect the rights of and monitor the performance of the main players, both Russian and foreign, amid the absence of the rule of law and independent courts. This means that both producers and consumers have limited opportunities to protect their rights and hold each other accountable for violations. Legal anarchy also discourages investment in the market. Finally, an important factor is the lack of adequate production capacity and financial capabilities for the development of domestic machine tool building and the small size of the market itself.

The small size of the market is one of the key characteristics, as it creates specific conditions under which the **development of national machine tool production is irrational**, as the total cost of such a project is extremely high and has a long payback cycle. The real profits and results of the machine tool industry development will be realized only after decades. In addition, the funds invested in this process are disproportionate to the potential profits from meeting domestic demand, which, given its low level due to the size of the market and the availability of Western analogues that are of high quality and relatively affordable, makes any plan for full autarky in the industry unprofitable.

Real import substitution means creating a full-fledged machine tool industry infrastructure, with the production of components as its primary purpose. This requires not just developing the most advanced machines, but also building the entire pyramid of industry enterprises, from bearing plants to machine tool manufacturers, working as a single complex. It is necessary to create a full-fledged machine-building production base, equipped with the precision machines that have recently been banned from being supplied to Russia. In addition, complete autarky and isolation of the economy is impossible in the modern world and carries enormous financial risks.

3.2. Key players in Russian machine tool market

The key actors in the Russian machine tool market include **Russian and foreign manufacturers of CNC machine tools, as well as the Russian government**, which artificially stimulates the development of national machine tool production using non-market methods. The Russian government is the key market actor: first, because it is the main customer as a consumer of military-industrial complex products; and second, because of the specifics of the operating environment, which is determined mainly by political and administrative factors.

The Russian government is actively using non-market methods in the Russian machine tool industry. In 2011, it adopted Resolution No. 56, which prohibited defense enterprises from purchasing imported machine tools if their analogues are produced in Russia. This measure has been renewed regularly since.

On the other hand, several programs for the development of the domestic machine tool building industry have been adopted at the federal level, providing substantial government subsidies and tax preferences. The government has also restricted private initiative, created state-owned corporations and formed machine tool associations (see Section 4 for more details).

Thus, the Russian government is acutely aware of its dependence on imported CNC machines and is therefore doing everything it can to limit it and encourage domestic producers. Currently, 80 manufacturing enterprises are involved in the Russian machine tool industry (56 manufacturers of metal cutting machines and 24 manufacturers of forging and pressing equipment). There are 29 companies involved in tool production.

Among the largest Russian manufacturers of CNC machines, as of 2022, are:

- StankoMashComplex (Tver)
- Ulyanovsk Machine Tool Plant (Ulyanovsk)
- Sasta (Sasovo)
- NPK Delta-Test (Fryazino)
- Stankomashstroy (Penza)

At the same time, all major Russian machine tool manufacturers are integrated into the Stankoinstrument Association, a national industry trade organization founded in 1999, followingreform of the industry.

Today, the association unites enterprises, research institutes and engineering companies that collectively produce more than 90% of machine tools, presses and tools in Russia.

Nonetheless, the Russian machine tool industry is still in a fragile state. According to official statistics, in 2021, the share of Russian machine tools in the domestic market was 30%. As of the end of 2021, Russia reported that it had produced 4,877 metalworking machines, a figure questioned by experts. According to the Ministry of Industry and Trade, the share of Russian machine tool production increased from 15% to 30% between 2017 and 2021.

However, such positive trends have been significantly undermined: first, by doubts about the validity of Russian statistics; and second, by the reality that, even for the production of its own machine tools, Russia is forced to import 80-90% of components. At the same time, the goal of the Ministry of Industry and Trade is to increase the share of domestic sales of machine tools in Russia from 30% to 50% by 2050. Currently, demand is being stimulated by the exit of foreign companies from the market and government programs to support the domestic machine tool industry. However, Russia remains a net importer of CNC machine tools and is not yet ready to develop a full-fledged machine tool industry.

It is illustrative that, despite the Russian government's decree restricting all Russian state-owned enterprises from purchasing foreign goods in the machine-tool industry if there are Russian analogues, Russian companies still prefer to purchase foreign equipment and find ways to circumvent the ban. For example, according to the Russian Federal Anti-Monopoly Service (FAS), Russian companies purchase foreign equipment and paste Russian labels on it without making any significant modifications. Another method used to circumvent the ban on foreign purchases is the crafting of technical specifications for open tenders in a way that favors imported equipment, even when the task can be carried out using Russian machines that do not differ significantly in their characteristics.

As a result, **foreign CNC manufacturers** are the main players on the market. They have an advantage in the element base, production capacities, established supply chains, technological expertise, financing and a well-established market model. Given the ambiguous transitional period after the collapse of the USSR, when the machine tool industry was virtually lost, foreign manufacturers quickly filled this niche and are in no hurry to give it up completely.

Traditionally, the world's largest manufacturers of CNC machines are China, the United States, Germany and Japan. However, China is still far behind the other three leaders in terms of technology. Among the most popular Western brands of high-precision CNC machines in Russia are Siemens (Germany), Fanuc (South Korea), Okuma (Japan), DMG Mori (Japan, Germany), Heidenhain (Germany) and Haas Automation (US). At the same time, Chinese-made machines dominate the niche of low- and medium-precision machines (see Section 5 for more details).

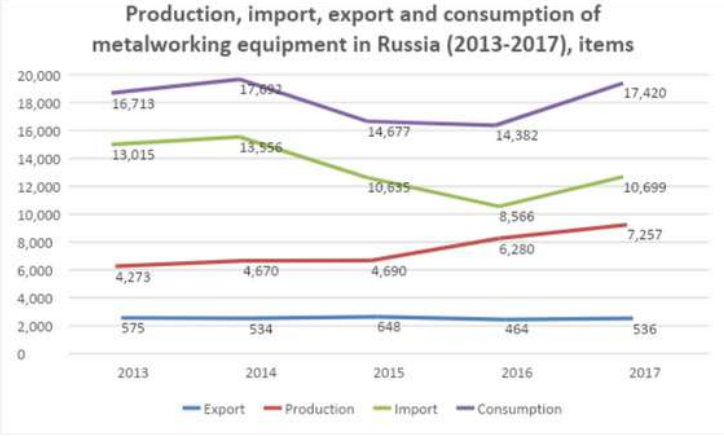
3.3 Machine tools market import-export balance and development trends in 2014-2022

A look at the import statistics for 2013 (before the annexation of Crimea and the outbreak of the war in Donbas) demonstrates import-export balance trends for the Russian machine tool market.The Stankoinstrument Association reported that in 2013, prior to the first wave of sanctions, Russia received 2,700-2,900 machine tools from Germany, 2,000 from Italy, and 600 from China and Taiwan.

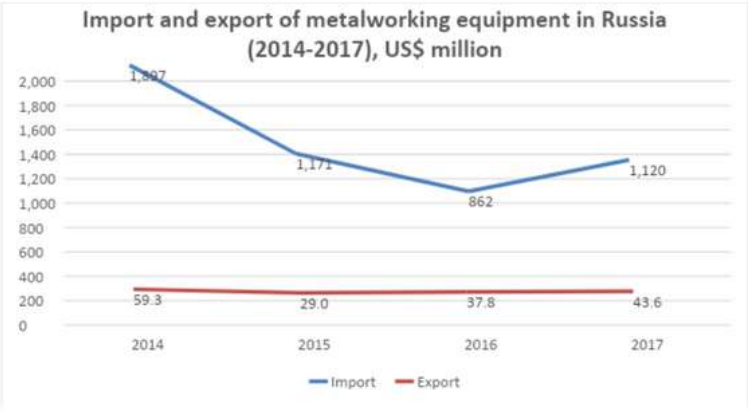
After the first wave of restrictions, there was a sharp decline. In 2014, Russia imported 1,100 units from Germany, fewer than 1,000 units from Italy, and 4,500 units from China and Taiwan. Comparing 2016 with 2014, imports decreased by 54.5% in monetary terms and by 37% in physical terms.

Thus, since 2014, there has been a gradual decline in imports due to international sanctions and import substitution programs. At the same time, some foreign manufacturers have accepted the Russian government's conditions to increase the localization of production, such as DMG Mori, a Japanese-German concern that operated at the Ulyanovsk Machine Tool Plant until March 2022.

Meanwhile, after 2016, when the Donbas conflict entered a frozen phase and political confrontation lessened, imports of foreign CNC machines began to rise, likely to boost the production capacity of the military-industrial complex.



Production, import, export and consumption of metalworking equipment (including CNC)



Import and export of metalworking equipment in Russia

At the same time, the Russian government has resorted to subsidies and preferential programs to support the domestic machine tool industry. One indicator of its revival is the growing export of products abroad. Kazakhstan was and still is the main buyer of Russian machine tools (over 60%), and about a quarter is purchased by the Navoi Mining and Metallurgical Plant. However, there was no radically positive export sales trend over the period.

Notably, Russian statistics should be viewed critically. For example, the above table states that Russian exports of metalworking equipment of various profiles jumped from 4,000 pieces in 2012 to 210,000 in 2013.

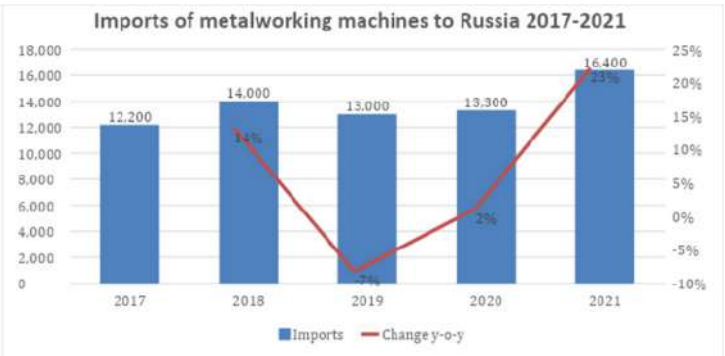
The table suggests that the sum of Russian exported machine tools for six years exceeded the entire EU machine tool fleet as of 2015, which appears absurd in context. Experts have expressed reasonable doubts about the validity of these statistics.

Exports and imports of metal cutting machines according to Rosstat						
	2010	2011	2012	2013	2014	2015
Export	2,600	3,400	4,400	210,000	150,000	6,500
Import	562,000	727,000	673,000	845,000	788,000	406,000

Another factor behind the decline in CNC machine imports in 2014-2016 was unfavorable conditions on the global energy market, which saw a sharp drop in foreign exchange earnings for the Russian budget. At the same time, as the war in Donbas entered a frozen stage in 2016, Russia and the West increased economic interaction, particularly in the technology sector.

The next important year was 2018. According to the BusinesStat 2022 report "Analysis of the market of metalworking machines in Russia," the dynamic of imports to the country in 2017-2021 was ambiguous. The growth in imports observed in 2018 was caused by the gradual recovery of the Russian economy after the earlier crisis, the stabilization of the exchange rate, increased corporate revenues and, as a result, modernization of machine tool consumer companies, which automatically increased the demand for high-tech imported products. However, by 2019, there was a 7% decline in the volume of imports of machine tools to Russia due to the exhaustion of the pent-up demand effect.

In 2020, despite the pandemic, imports did not fall but rather edged up by 2.4% year-on-year. This was primarily because the main consumers of metalworking equipment are large industrial enterprises, whose work did not stop during pandemic lockdowns. The lifting of some COVID restrictions, as well as the revival of business activity in Russia and elsewhere in the world in 2021, had a positive impact on the import of metalworking machines: the figure increased by 23.4% to 16,400 units, which is a record high for the five-year period.



Source: RBC

In other words, five years before the full-scale invasion, Russia increased its imports of CNC machines, which can be directly linked to the active military reforms and rearmament that took place during this period. The geographical distribution of machine tool suppliers is also interesting.

If we look at imports by country, we can conclude that the top 10 countries account for more than 90% of imports in value terms, while China accounts for 88% in physical terms.

Section 4. Development of Russian machine tool industry in 1991-2022

4.1 Russian machine tool industry after collapse of USSR

In the previous sections, it was repeatedly emphasized that the dominance of imported machine tools on the Russian machine tool market and in the military-industrial complex is due, not least, to the poor state of development of the Russian machine tool industry, including the CNC industry. The origins of this problem lie in the 1990s.

The Soviet Union failed to develop high-precision CNC machine tool building, despite being a major exporter of mechanical machine tools. After the collapse of the USSR, Russian mechanical machine tool building suffered a decline. This was attributable to the general economic crisis and stagnation of the planned system; chaotic attempts to quickly transition to a market economy; the loss of a leading position in the economy by the military-industrial complex and heavy industry; an unprofitable production base; and the economic inexpediency of creating a technologically complex and financially costly CNC machine tool industry in the face of open markets and wide import opportunities. While in 1990, 16,700 thousand CNC machines were produced in the Russian Soviet Federative Socialist Republic (RSFSR), their annual output dropped by a factor of 167 to 100 in 1996-1999.

In the 1990s, the Russian leadership's stance was that without domestic precision machine tool building capabilities, no funds should be allocated to its development. Instead, the necessary machine tools should be purchased abroad. As shown above, given the specifics of the operational environment and market size, this policy was not without logic. But in retrospect, the radical interpretation of the free market led to the Russian market for engineering services and machine tool building being occupied by foreign companies that maintained almost unshakable leadership until the end of the 2000s. Large-scale reforms of the Russian military became an incentive to revise the state of the Russian machine tool industry.

4.2 Restoration of Russian machine tool industry in context of military reform

As already noted, the revival of attention to Russian machine tool building occurred against the backdrop of Putin's military reforms in the late 2000s. First, the state increased the number of integrating and controlling mechanisms, uniting the main machine tool manufacturers under the auspices of state corporations. For example, in 2009, the state-owned RT Mashinostroitelstvo was created. Four years later, using it as a base, Rostec created Stankoprom, a system integrator for the Russian machine tool industry. It united research institutes, machine tool companies, tool plants, commercial entities and engineering enterprises.

In 2012, private investors created the STAN holding based on the Sterlitamatsky Machine Tool Plant, which included several other companies in the industry.

The Russian government has also begun to actively finance and subsidize Russian machine tool building. In 2011-2016, the program "Development of Machine Tool Building and Tool Industry" was in effect, under which the state funded R&D aimed at creating modern, high-performance machine tools and equipment. The same program enabled the construction of two new machine tool manufacturing plants in Lipetsk and Perm under public-private partnerships. Another such plant was launched in the city of Sasovo, Ryazan region.

Experts believe that huge demand from the military-industrial complex has been the impetus the revival of the Russian machine tool industry. According to Russian manufacturers of modern industrial equipment, military-industrial complex enterprises account for at least 80% of the orders they receive. The abovementioned resolution adopted in 2011, which prohibited defense companies from purchasing imported machine tools if their equivalents are produced in Russia, signaled that the Russian government was aware of the military-industrial complex's dependence on imported tools. It is difficult to circumvent these restrictions: a group has been set up under the Military Industrial Commission to conduct a thorough analysis of future purchases and give or deny approvals for an applicant company. Foreign manufacturers were forced to create joint ventures and build machine tool plants in Russia to avoid losing customers due to this resolution.

4.3. Russian machine tool industry after 2014 sanctions

The issue of Russian machine tool building grew critical after the first wave of sanctions was imposed in 2014. At the time of the annexation of Crimea and the beginning of the war in Donbas, Russia imported an average of 80-90% of high-precision CNC machines. Putin demanded that the country launch its own production of strategic products within two to three years.

However, the industry's growth was very slow: for example, the production of the same CNC machines from 2016 to 2017 showed an increase of only 270 units (according to the Stankoinstrument Association).

Dynamics of metalworking equipment production in Russia (including CNC)

Nevertheless, Russian experts claim that the share of imported machines has fallen to 75-80% and, according to some estimates, even down to 70%. In 2016, the amount of state support for the industry was about RUB2.7 billion. In January-October 2017, more than RUB1.5 billion was allocated through the Federal Regional Development Fund alone.

At the same time, industry representatives openly acknowledged how important imported CNC machines are for the Russian industry. For example, Pavel Shatskikh, general director of the Kazan plant Elektropribor OJSC, stated:

"There are things that can stop the Russian industry altogether. For example, everything related to metalworking equipment is imported: spare parts, spindles and tools (although this point has been improved a bit). If you don't do maintenance once, the machine won't work until you replace the original component: the program includes identification by originality and expiration date. That's why a country cannot be called a superpower or even a developed industrial country unless it produces its own equipment. And we don't make full-fledged CNCs, we just make tags for Chinese equipment. In short, it's no exaggeration to say that equipment can stop functioning at any minute."

The data on machine tool imports in 2017-2021 presented in Section 3 demonstrates the mediocre results of the Russian machine tool industry's development. In addition, numerous examples of successful import substitution in the Russian machine tool industry have proven to be fakes. For example, in May 2019, Putin visited the Kazan Aviation Plant named after S.P. Gorbunov, where he was shown a new machine tool made by domestic industry leader STAN Group in Kolomna. Specialists noted that the Russian machine precisely resembled an Italian one from Camozzi.

Information has also been found pointing to Chinese machines being represented as Russian, along with corruption scandals in the industry. For example, at the end of 2021, the head of Baltic Industrial Company, Diana Kaledina, was detained in Moscow on suspicion of supplying a foreign machine tool under the guise of a Russian one. The company's website states that the company currently has 42 customers for its products and 110 government contracts worth more than RUB7 billion. Several more contracts are in the pipeline for about RUB3 billion.

Not least, the mediocre results were due to the lack of a strategic approach to the industry. For example, over the past decade, the Russian government has adopted three programs for the development of machine tool building in Russia (the latest one in 2020) and twice took on an action plan for import substitution in the machine tool industry (the second was adopted in 2021). All these documents were cosmetic in nature. They provided subsidies for research and development and preferential treatment for machine tool plants, while ignoring the fact that import substitution is a more profound phenomenon by its very nature. The process requires the development of enterprises throughout the entire machine tool production cycle (for more details on the specifics of this process in the Russian context, see Section 3).

The "Strategy for the Development of the Machine Tool Industry for the period up to 2035" can rightly be called the guiding document for the industry. The strategy noted that the current production of metalworking equipment covers only 17% of domestic demand. The machine tool industry contributes 0.02% of gross domestic product, a fraction of the contribution in leading machine tool manufacturing countries like China (0.15%), Japan (0.23%) and Germany (0.32%).

The strategy aims to increase the production of machine tool products at an average annual rate of 5.7% to RUB79.5 billion by 2035.

The industry aims to increase the localization of Russian products to 70% by developing domestic production of key high-tech components, and raise machine tools exports to RUB16.5 billion. Again, despite the strategic intent, the content of the document itself reflects a superficial understanding of import substitution processes. It has done little to reduce the Russian industry's vulnerability from its dependence on imported machine tools.

4.4. Russian machine tool industry after full-scale invasion of Ukraine in 202

Attention to the Russian machine tool industry intensified further amid the imposition of sanctions following the full-scale invasion of Ukraine on February 24, 2022. Foreign CNC machine tool manufacturers withdrew from the market (such as DMG Mori's exit from the Ulyanovsk Machine Tool Plant). The end of new machine tool deliveries and maintenance of previously delivered machine tools has once again brought Russian national heavy and precision engineering to the forefront.

First, the failure of previous import substitution programs was recognized at the highest level, as stated by Andrey Klishas, chairman of the Federation Council Committee on Constitutional Legislation and State Building:

"The import substitution program has failed completely. There is nothing but bravura reports from sectoral departments. Our people see this in consumer goods and in many other areas."

Russian machine tool building also became a public topic as a strategic industry. For example, in March 2022, Russian Minister of Industry and Trade Denis Manturov emphasized the critical importance of state support for machine tool building:

"It is important to unify components for machine tool products and to actualize cooperation ties between Russian companies. We already have all the necessary competencies, and now we need to emphasize the production of unified, high-volume products."

The Russian Ministry of Industry and Trade has reported that domestic machine tool manufacturers occupy 33% of the local market. However, the import share of key components in Russian machine tools still ranges from 80 to 95%.

At the St Petersburg International Economic Forum (SPIEF) in June 2022, machine tool sharing was being proposed to solve the problem of foreign manufacturers leaving the Russian market. This concept aims to use the ability to quickly connect to the machine tool fleet or service of a friendly Russian company as part of industrial cooperation. This is both a means of utilizing idle equipment and an option to fill market deficits after the departure of foreign suppliers.

As expected, the Russian production of milling, drilling and grinding machines has increased. According to Rosstat, 4,947 metalworking machines were produced in Russia in the first 10 months of 2022 (up 3.3% year-on-year). However, the share of CNC machines among them fell. Currently, the state-owned Rostec corporation is planning to establish a machine tool holding company to develop and produce heavy machining equipment and tools for industry. The government is demanding that the share of Russian machine tools on the market be increased to 50% in the near future.

The prospects for the development of the Russian machine tool industry amid existing problems look ambiguous at best. Sanctions restrictions are becoming increasingly nuanced, and the toxicity of Russian assets and operations for foreign companies is growing. At the same time, the war in Ukraine is highly routinized and supply chain diversion schemes are increasing, so the fight against the supply of CNC machines remains relevant. On the other hand, it is difficult to purchase high-precision machines in small quantities, even to produce machine tools themselves. In other words, Russia's very production of machine tools still depends on Western products.

In addition, there are already fresh **signs of dissatisfaction on the part of the Russian military-industrial complex with domestic products.** Employees of the United Engine Corporation (UEC) sent a letter to the State Duma in which they described the current problems of Russian machine tool building. The letter refers to the activities of the STAN Group, which occupies about 50% of the machine tool market in Russia.

The letter's authors cite delays in STAN Group's product deliveries under contracts that have been paid for by 90% of the country's largest manufacturing enterprises. They call for accountability from both the group's owners and the officials who instructed them to continue to place large orders and participate in programs to support the domestic industry.

In 2018, Russia's Accounting Chamber, the primary watchdog for public spending, audited the use of funds allocated by the Industrial Development Fund (IDF) for 2014-2017. The auditors determined that STAN Group systematically delays the delivery of equipment, while five STAN Group organizations that received more than RUB2.23 billion from the IDF did not meet their targets. According to the auditors, the lag in the creation of new production facilities exceeded 2.5 years. At the same time, STAN Group is the market leader and includes the vast majority of Russian manufacturers of CNC machines, so this situation can be considered illustrative for the entire industry.

4.5. Technological obstacles for Russian machine tool industry

In addition to objective, non-technical barriers, the development of Russian machine tool building faces industry-specific problems. Primary among these is the production of critical components, which Russia must also import.

Antifriction linear guideways are crucial for CNC machines. Manufacturing precision guides requires not only high-end specialized equipment (a class above the guide itself) but also precision-engineered facilities. These must include clean, thermally controlled workshops with vibration protection, as well as highly advanced control and measurement tools to select guides manufactured with the necessary accuracy. Currently, there are no other enterprises of this class in Russia.

Linear rolling elements

Cartridge spindle

Precision bearings and ball-and-screw units are vital, as the type of spindle greatly influences a machine tool's classification and technical characteristics. The spindle wears out faster than the machine and therefore must be replaced with considerable regularity, depending on the intensity of the machine's operation. However, no factories in Russia manufacture replaceable cartridge spindles. While the Russian manufacturing industry can produce housings, shafts and other parts, it cannot make precision machine tool spindle bearings, which determine spindle properties .

Ultra-precision antifriction bearings can only be produced within a sample of conventional bearings, comprising only a few percent of the entire batch. This is due to the heightened accuracy requirements for machining rings for precision bearings, which exceed the capabilities of existing machining equipment. A similar situation occurs in the production of **ball screws.**

Another problem is **casting**. In the Soviet Union, there were so-called centralized foundries that worked for many customers. This helped to reduce costs because it was unprofitable for the plants to maintain their own foundry, even with a program of producing 1,000 machines a year. For this same reason, machine tool plants currently prefer to order their casting beds from China. Despite the logistics, it turns out to be more profitable.

The **metrological support of machine tools**, meaning the adequate supply of control and measurement instruments, is a separate concern. Special measuring devices are needed for alignment when assembling machine tools, especially precision ones, even from off-the-shelf components. Machine tools also require measuring probes to bind to the parts that come with the machine. These high-tech devices were previously imported but are now subject to sanctions. Even if machine tool plants currently have a set of this metrological equipment, expanding production and replacing failed devices will soon be a problem.

Finally, Russia also lacks the control system for the machine tool itself, as well as the programs for machining parts: the CNC system. The issue with spindles is connected to that with the **CNC system**, which includes a top-level computer and control units for drives – including spindles – called spindle servo converters. While Russia has servo converters capable of operating at 3,000-4,000 revolutions per minute, it does not manufacture servo converters with a rotation speed of 20,000-40,000 revolutions per minute, such as those used in precision machine tools.

Precision bearings

Ball screw transmission

Servo Converter

Technological functionality is another key characteristic of a system, growing more advanced with longer development and larger production volumes. Replicating the technological functionality of popular CNC systems like Fanuc and Siemens would require years of complex software development. According to our respondents, the limited technological functionality is considered the Achilles' heel of all Russian-made CNC systems, as the companies producing them lack the resources for large-scale development.

Similar problems exist with **feedback sensors, angle transmitter, linear array sensor, high-torque and linear engines.**

***Conclusions**: Russia is heavily reliant on imports of foreign CNC machines due to a lack of development in its precision and technological machine tool industry. This is a result of economic stagnation, outdated industrial potential, and poor funding for scientific and technological progress. The industry also faces issues with knowledge intensity and economic irrationality. Machine tool building has a long payback cycle and was unprofitable in the early years of the Russian Federation. The absence of essential components and means of production is a technological disaster, as Russia must import not only components (such as bearings, spindles, software and ball-and-screw units) but also parts for the machine tools themselves. Failures in import substitution programs and the lack of confidence in Russian products among domestic customers are becoming increasingly noticeable.*

Section 5. Potential losses from complete withdrawal of Western CNC manufacturers from Russian market and their alternatives

5.1. Assessment of Russia's losses from potential market withdrawal of Western companies

The previous sections demonstrate that Russian industry – and especially the military-industrial complex as the main consumer – is critically dependent on Western-made CNC machines. By direct and indirect indications, the strategic nature of this problem is clear. However, the following factors should be taken into account when assessing its potential consequences:

- It is impossible for Western manufacturers to completely withdraw from the Russian machine tool market. This is not only and not so much about new supplies, but also about maintenance and service, spare parts and advice on machines purchased before the sanctions were imposed. In addition, there are always opportunities for parallel imports and workarounds that objectively cannot be stopped completely.
- Western CNC machines are highly precise and manufacturers exert substantial control over the product, regardless of the customer's position. From requirements for regular software updates, genuine manufacturer spare parts and specific specially formulated lubricants to the need to contact the manufacturer for a code in case of a lockout, these characteristics make Western CNC machines an extremely vulnerable target for sabotage.
- A financial, quantitative assessment of the potential consequences of the complete withdrawal of Western manufacturers is not possible, as a large portion of Russian statistics are unavailable or unreliable. Since the 1990s, there has never been a survey of the Russian machine tool fleet. Its volume of 1.0-1.5 million machines is only hypothetical. The fate of CNC machines and their gradation in terms of precision is also unknown, as is the extent of public procurement of imported machine tools in relation to Resolution 56. All of this allows us to draw only cautious conclusions, although they do not make them any more optimistic.

Thus, if Western CNC companies leave the Russian machine tool market, we should expect the following:

- **A slowdown in Russian machine tool building.** Western firms are still the suppliers of components for Russian machine tools. As shown in Section 4, Russia is not able to produce key components of CNC machine tools.
- **Massive breakdowns**, failure of existing precision machines. Without regular updates, service, spare parts and contact with the manufacturer, machines will quickly break down and lose their production advantages.

- **Reduction or complete cessation of imports.** With unchanged goals to fulfill the state defense order and a critical drop in imports, Russia's military-industrial complex will have to squeeze out everything possible. The increased operational intensity of the existing machine tool fleet will shorten their service life.
- **Forced transition to Russian and Chinese machine tools.** In the absence of Western machine tools, Russian military-industrial enterprises will be forced to switch to domestic and Asian products. At the same time, the Russian machine-tool industry is unable to substantially meet domestic demand. In the absence of foreign components, it will continue to fail to meet government contracts, potentially leading to an increasing conflict between the defense industry and the monopolists of the machine-tool market. Although the machine tool shortage can be solved partly through equipment sharing, the increased frequency of operation will reduce service life. Switching to Chinese machine tools is not a panacea for the Russian military-industrial complex, as China can only provide Russia with low- or medium-precision machines. In addition, the quality and efficiency of Chinese machine tools is lower than that of Western models.
- **General technological degradation, loss of connection with technological progress.** Not only will Russia be deprived of access to the most advanced manufacturing technologies, it will also live in this state for a rather long time, making any attempts at catch-up modernization even more difficult. In addition, CNC machine operators will gradually lose their skills, while the technological training of engineers, designers, CNC programmers and other industry professionals will deteriorate.
- **Slowdown in the pace and quality of the military-industrial complex.** A complete shutdown of the Russian military machine is unlikely. However, a complete withdrawal of Western CNC manufacturers from the market could create a multitude of immediate problems. These could take months or even years to solve and, in retrospect, weaken and undermine the potential and capabilities of the Russian military-industrial complex.

In this context, special attention should be paid to alternative manufacturers of CNC machines, namely Chinese companies.

5.2. Asian CNC machines as alternative to Western products

Since the first sanctions were imposed in 2014, Russia has begun an intense pivot eastward in its foreign policy and trade relations. Although China has been eager to assist, it also brings its own complexities and nuances to the relationship.

As discussed above, China stands as the global leader in the production of low- and medium-precision CNC machine tools.

The Chinese leadership's decision to develop machine tool manufacturing in the country started with the construction of factories that would make simple, mass-produced machines. In fact, repeating the Soviet path, they started with manual lathes of the 16A20 type, a design developed by the Chervony Proletar plant that had been manufactured in the USSR since 1973. Although technological advancements have propelled the industry to new heights, Chinese manufacturers maintain a strong focus on making products that meet mass demand, and the continue to do so with remarkable success.

In terms of the quality-price ratio, while Chinese machines perform well, the spindle – the most expensive element of the machine – often breaks down. In general, the quality, efficiency and accuracy of the machines are lower than Western models. At the same time, the price is quite reasonable, which allows customers to regularly update their machine tool fleet without investing a lot of money to purchase and regularly maintain basic machine tools.

In addition, Chinese machines do not always cost significantly less than their counterparts; the difference in sticker price is due to several factors. While Western competitors offer amenities in the form of graphics, tips, animations and help, the Chinese prefer to provide a basic version, with everything else as an option. Although an extended version can be purchased as a separate order, the base price is usually lower than the Western equivalent.

The most popular Chinese machine tool manufacturers include:

- China CNC - milling and laser machines for wood and stone, vertical milling machines for metal
- Shenyang Machine Tool Group Co., Ltd
- Dalian Machine Tool Group Corporation (DMTG)
- Second Beijing Machine Tool Plant (Beyer)
- Suzhou Kingred Electrical and Mechanical Technology Co., Ltd.

Currently, China is virtually a monopolist in supplying Russia with machine tools that lack high precision. Precision Chinese brands, on the other hand, are mostly produced in collaboration with Taiwan, and they are relatively scarce on the market. Taiwan has a highly developed machine tool industry, and Taiwanese companies expanded into China through government policy during the infrequent periods of relative stability in the Taiwan Strait. Since Taiwanese-made machine tools are also grounded in Western technology, export control issues arise again.

In every instance, it must be verified whether the machine tool is genuinely of Chinese design and not a Taiwanese design derived from a European or American license, which might be restricted for delivery to Russia. As this information is classified, it becomes virtually impossible to gauge how many Chinese manufacturers are utilizing technology they have developed independently.

Chinese machine tools have quickly become indispensable under import substitution. Chinese manufacturers with a more flexible attitude towards their brands than Western companies have re-labelled their machine tools to pass through customs as purportedly Russian-made goods. If it is profitable for them to sell their equipment under someone else's brand, they can easily do so. In this context, the case of the Baltic Industrial Company mentioned in Section 4 is interesting.

In late 2021, the founder and beneficial owner of Baltic Industrial Company, Diana Kaledina, faced charges in a criminal case of large-scale fraud (Part 4 of Article 159 of the Criminal Code of the Russian Federation). The case originated from the supply of a milling machine, valued at nearly RUB15 million, to the company Signal in 2016. The investigation found that Signal was furnished with a Chinese-made machine, misrepresented as a domestic one. Subsequently, it was reported that new cases had been initiated against Kaledina for supplying machine tools under state contracts concluded in accordance with Law No. 223.

Generally, Chinese machine tools are inferior to Western ones in terms of precision, functional range and overall quality. They can fulfil the requirements for standard production operations, but not for high-precision machining of parts. In addition, a complete transition to Chinese machines would require a period of adaptation and an almost complete abandonment of the existing machine tool fleet, as machines from different manufacturers tend to be poorly compatible.

Overall, the substantial market share of Chinese imports in the Russian machine tool industry is already beginning to alarm many industrialists. Vladimir Serebrenny, the rector of the Stankin Moscow State Technical University, has warned:

"The determination to buy machine tools massively from China is fraught with great danger. At this stage, it is important not to fall into one dependency and it will be even more difficult to get out of it, as a monopoly is always dangerous."

***Conclusions**: Despite the limited amount of data available and the likely impossibility of a complete withdrawal of Western manufacturers from the Russian market, such a step could cause a slowdown in Russian machine tool building, a sharp reduction in imports and machine tool breakdowns in the absence of service. This would likely lead to a forced transition to low-quality Russian and Chinese machine tools, a subsequent reduction in the pace and quality of military-industrial complex products, and a fundamental technological lag. While Chinese machine tools are already readily found on the Russian market, they primarily dominate the low-precision segment and generally fall short in terms of quality and efficiency when compared with Western models.*

Conclusions

- CNC machines are an integral part of modern automation and production process optimization. They are used in a wide range of industries, including metalworking, automotive, aviation, microelectronics and other areas. Depending on the level of precision, CNC machines can be classified as dual-use goods subject to export controls because of the potential military applications, although the current export control regime has several problems. Regardless, the important role that CNC machines play in the military-industrial complex cannot be overstated, as the example of the Russian Federation illustrates.

- In recent decades, the Russian military has undergone several stages of reform and rearmament, which would not have been possible on such a scale without the use of CNC machines. Meeting the needs of state military procurement in the Russian Federation has drawn significant attention to CNC machines, ensuring the optimization and efficiency of production as well as fostering the development of innovative weapons. The current phase of rearmament in the Russian Federation amplifies the demand for these technologies, making it crucial to urgently analyze the Russian machine tool market and assess its capability to satisfy the requirements the domestic military-industrial complex.

- The Russian machine tool market is characterized by small volumes, active government intervention, quasi-market regulatory instruments, and a lack of adequate legal mechanisms and freedom of action for agents. The state determines the status and direction of the market, while subordinating it to the needs of defense procurement. The Russian government is also actively investing to develop the domestic machine tool industry and support Russian producers, although the dominance of imported technologies is almost unshakable. Despite reporting on the success of import substitution, in recent years, Russia has steadily increased imports of foreign CNC machines, as domestic producers are unable to meet the needs of state defense procurement. This requires an analysis of the Russian machine tool industry's development and the factors causing Russia's critical dependence on imported CNC machines.

- Russia is heavily reliant on imports of foreign CNC machines due to a lack of development in its precision and technological machine tool industry. This is a result of economic stagnation, outdated industrial potential, and poor funding for scientific and technological progress. The industry also faces issues with knowledge intensity and economic irrationality. Machine tool building has a long payback cycle and was unprofitable as an industry for state support and investment in the early years of the Russian Federation. The absence of essential components and means of production is a technological disaster, as Russia must import not only components (such as bearings, spindles, software and ball-and-screw units) but also parts for the machine tools themselves. Failures in import substitution programs and the lack of confidence in Russian products among domestic customers are becoming increasingly noticeable.

- Despite the limited amount of data available and the objective impossibility of a complete withdrawal of Western manufacturers from the Russian market, such a step could cause a slowdown in Russian machine tool building, a sharp reduction in imports and machine tool breakdowns in the absence of service. This would likely lead to a forced transition to low-quality Russian and Chinese machine tools, a subsequent reduction in the pace and quality of military-industrial complex products, and a systemic and fundamental technological lag. While Chinese machine tools are already readily found on the Russian market, they primarily dominate the low-precision segment and generally fall short in terms of quality and efficiency when compared with Western models.

The importance of Western CNC machines in Russian military production has been established. It is vital for sanctions authorities and relevant agencies to leverage this to weaken Russia as much as possible and prevent a repeat of its full-scale attack on Ukraine.